ISSN: 1863-5598

ZKZ 64717
03-21

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Electronics in Motion and Conversion

March 2021

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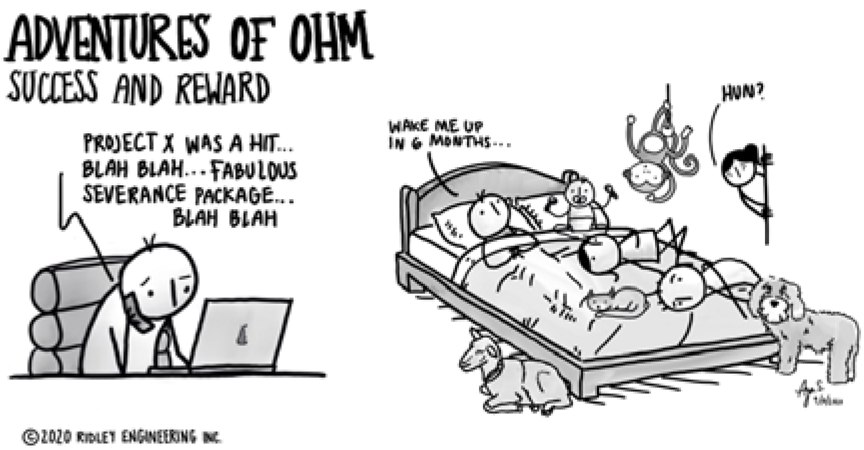
GvA Power Electronics

CONTENT


ADVENTURES OF OHM
SUCCESS AND REWARD
PROJECT X WAS A HIT... BLAH BLAH... FABULOUS SEVERANCE PACKAGE... BLAH BLAH
WAKE ME UP IN 6 MONTHS...
HUH?
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The Gallery

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

Printing by:
Brühlsche Universitätsdruckerei GmbH
& Co KG; 35396 Gießen, Germany

www.bodospower.com

Introducing Bodo's Wide Bandgap Expert Talk

Wide bandgap power semiconductors continue to gain ground. The number of applications that allow the use of this technology is steadily increasing. Silicon carbide and gallium nitride, each for its own area, have a variety of advantages. Higher switching frequencies, better temperature resistance and compact size are just some of them, but the most important is the higher efficiency that these materials allow due to their physical properties. The potential that rests in this technology is huge and we want to meet it with a new format: Bodo's WBG Expert Talk.

I would like to take the opportunity to introduce this new initiative to you. Our idea is to continue the knowledge exchange and information flow, to create a regular platform that encourages dialogue outside the rigid calendar of trade fairs. The goal is to present innovations quickly, at first hand and to provide in-depth information. We plan to run these regular virtual live sessions quarterly. Each session will focus on technical articles that have been published in the magazine and, at the same time, offer our readers the opportunity to ask the authors questions, who will then answer them live. We believe this will directly lead to lively discussions between the experts. Questions from participants should reach us in advance or can be submitted live via chat during the talk. These talk sessions will be very focused on Wide Bandgap topics.

I am excited to confirm that the first event will take place on March 31. We plan to discuss GaN from 3 to 4 pm cet and SiC from 4:30 to 5:30 pm cet. The articles being covered will be made available in advance online. At the same page you can also register for the event and forward your questions by email to

us in advance. The recorded conversations will of course be made available afterwards. We will be using the Zoom platform for this event and we will continue to share all further information on our website and in the e-Newsletters.

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:
Support your local stores and save the environment from unnecessary transportation. The shop around the corner might be offering click and collect. If we want to enjoy their offering in the future we need to help them now!

Kind regards

Holger Moschek

Events

IPC APEX 2021
Online March 8-12
www.ipcapexexpo.org

SEMICON CHINA 2021
Shanghai, China March 17-19
www.semiconchina.org

SEMI THERM 2021
Online March 22-26
www.semi-therm.org

emv 2021
Online March 22-26
www.e-emc.com

Hannover Messe 2021
Online April 12-16
www.hannovermesse.de

electronica China 2021
Shanghai, China April 16-16
www.electronica-china.com

IEEE-PEMC 2021
Gliwice, Poland April 25-29
www.ieee-pemc2020.org

Smart Systems Integration 2021
Online April 27-29
www.smartsystemsintegration.com

PCIM Europe digital days 2021
Online May 3-7
www.pcim.mesago.com

PCIM Europe 2021 to be Held Exclusively in Digital Form

At the beginning of February, the decision was made to postpone the PCIM Europe to late summer following talks with exhibitors and partners. In light of the ongoing pandemic and challenging situation, numerous industry players have been hesitant to commit to an on-site event. For this reason, Mesago Messe Frankfurt has decided to hold a digital event only. With the "PCIM Europe digital days", an online format will be offered to the power electronics community enabling networking and knowledge transfer from 3 – 7 May 2021. Over five days, suppliers and users in the industry can receive information on key developments and connect in a variety of ways. In addition to extensive exhibitor profiles, the conference program will consist of outstanding presentations as a mix of live and video-on-demand presentations, followed by discussions with the speakers.

www.pcim.mesago.com

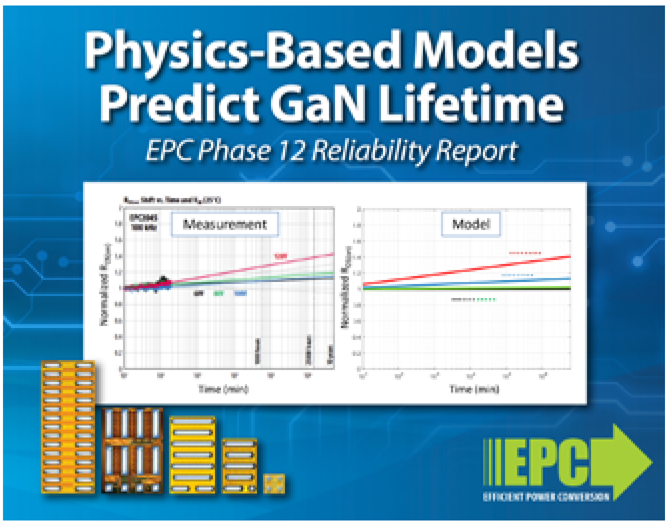
Improving the Reliability of Electronic Components

The Europe-wide research initiative Intelligent Reliability 4.0 (iRel40) aims to improve the reliability of electronic systems and microelectronic components. Coordinated by Infineon Technologies, 75 science and industry partners from 13 countries are pooling their forces to achieve this goal.
"Enhancing electronics performance through miniaturization and integrating more and more functions is progressing steadily. Performance and complexity are increasing, as the costs per function go down," says Dr. Reinhard Ploss, CEO of Infineon Technologies AG. "Powerful electronics form the basis for forward-looking technologies such as electro-mobility, autonomous driving, renewable energies and energy-efficient connected solutions. However, they will only be successful if users can depend on reliable functionality, quality and lifetime. Reliability is a key differentiating factor in international competition."
iRel40 adopts a holistic approach to optimizing the reliability of microelectronic systems along the entire value chain – from the wafer to the chip and the packaging and finally to the system and hence the actual application. The aim is to significantly reduce failure rates and thus improve product quality and lifetime. This approach also contributes to more sustainable management of our natural resources. Experts from science and industry in Europe are working together to achieve this. They are relying on the latest insights and methods in material research and failure analysis, including modeling and simulation, as well as artificial intelligence. The project is divided into eight work packages that deal with aspects such as requirements, theoretical principles, materials, test methods, and pilot applications. Infineon will, in particular, contribute its expertise and skills in chip and packaging technology. https://www.irel40.eu

www.infineon.com

Reliability Report Shows Field Experience of GaN-Devices

EPC announces its 'Phase-12 Reliability Report', documenting the strategy used to achieve a remarkable field reliability record. eGaN devices have been in volume production for more than eleven years and have demonstrated very high reliability in over 226 billion hours of operation, most of which are in vehicles, LTE base stations, and satellites, to name just a few applications with rigorous operating conditions. This report presents the results of testing eGaN devices to the point of failure, which provides the information to identify intrinsic failure mechanisms of the devices. By identifying these intrinsic failure mechanisms, deep knowledge of the behavior of a device over time, temperature, electrical or mechanical stress can be developed and used to create physics-based models that accurately project the safe operating life of a product over a more general set of operating conditions. According to Dr. Alex Lidow, CEO and co-founder of EPC, "The release of EPC's 12th reliability report represents the cumulative experience of millions of devices and five generations of technology. These reliability tests have been undertaken to continue our understanding of the behavior of GaN devices over a wide range of stress conditions."
Dr. Lidow continues, "Standard power semiconductor qualification testing is inadequate since it only reports parts that pass a very specific test condition. By employing our test-to-fail methodology we have consistently produced more robust, higher performance, and lower cost products for power conversion applications and have amassed a reliability track record beyond what is achievable with traditional silicon MOSFET technology."



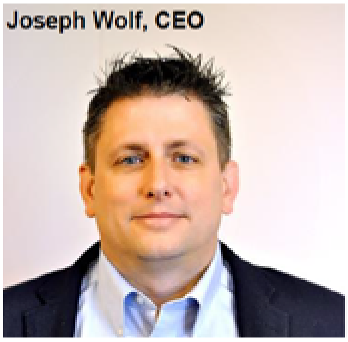
www.epc-co.com

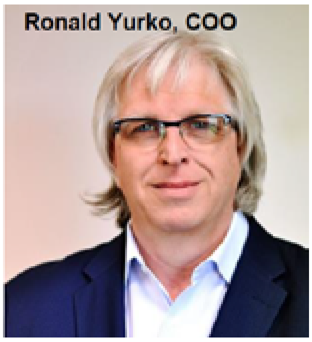
Expanding Production Capacity of SiC Power Devices

ROHM has recently held an opening ceremony announcing the completion of a new building at ROHM Apollo's Chikugo plant to enhance the production capacity of SiC power devices. The building is a state-of-the-art environmentally friendly factory that introduces a number of energy-saving technologies to its production facilities, with 100% of its electricity coming from renewable energy sources. ROHM continues to lead the industry in technological development, such as by introducing the industry's first full SiC power modules and SiC trench MOSFETs. At the same time, boasting an integrated production system, ROHM is working to improve production efficiency by increasing wafer diameter and utilizing the latest equipment while also reducing the environmental impact of manufacturing. In addition to this new building, SiCrystal GmbH, a ROHM Group company that manufactures SiC wafers, is scheduled to start operating with 100% renewable energy from the next fiscal year, reducing CO2 emissions from purchased power at the plant to zero. As a result, all major production processes for SiC wafers will use environmentally friendly renewable energy.
In response to the urgent need to address global energy issues, the ROHM Group will continue to improve SiC power device performance – expected to be key to achieving energy saving in electric vehicles and industrial equipment – contributing to reducing environmental impact by promoting the use of eco-friendly equipment and renewable energy in the production process.

www.rohm.com

Appointment of CEO and COO





Powerex is pleased to announce the appointments of Joseph Wolf as President and Chief Executive Officer and Ronald Yurko as Chief Operating Officer, in connection with the retirement of John Hall from the company. Joseph has been with Powerex since 2008, most recently serving the role of Vice President and CFO. Ronald has been at Powerex since 2007, most recently in the role of Vice President of Value-Added Products. Powerex is a joint venture between General Electric and Mitsubishi Electric with corporate headquarters and manufacturing located in Youngwood, Pennsylvania. The company was founded in 1986 and can trace its origins back to Westinghouse Electric, which established the facility at the current location in 1956. The 90,000 square feet of manufacturing space includes silicon wafer processing, diffusion, assembly, test,and high reliability screening. Powerex also features a semi-automated manufacturing power module line in a Class 10,000 cleanroom. Powerex is a leading domestic manufacturer of high-power semiconductor solutions. Its broad product line includes SiC MOSFETs (SiliconCarbide Metal-Oxide-Semiconductor Field-Effect Transistor), IGBTs (Insulated Gate Bipolar Transistors), HVIGBTs, rectifiers, thyristors, custom power modules and assemblies. These highly reliable electronic component solutions are designed for the Defense, Aviation, Traction, Mining, Medical, and Renewable Energy markets.

www.pwrx.com

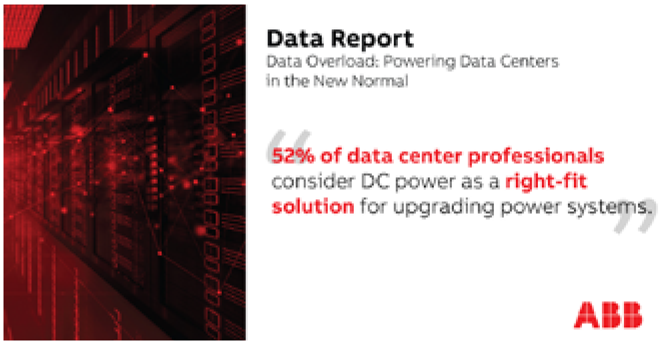
Certified Components for Automotive Electronics

Würth Elektronik has published a catalog of AEC-Q200 certified components for automotive electronics. Product highlights include ferrites, inductors and particularly robust electromechanical components. Design kits from many product groups are available for developers—as sample sets with free refill service. With WE-TEMA, Würth Elektronik offers an innovative series of ferrites for cable assembly, some variants of which use new, innovative materials like nanocrystalline and manganese-zinc. The range of high-frequency inductors is now complemented with the WE-MCI product family. With their inductance ranging from 1 nH up to 470 nH, the multilayer ceramic inductors cover a wide variety of application areas. The WE-MAIA SMT series of storage chokes has been extended with package sizes 1610, 5020, 5030, 4020HT. Würth Elektronik presents its new WE-SCFA contact fingers, certified for the special requirements in automotive applications and with WE-SMSA SMT spacer bolts. Besides detailed product information in several chapters, the new automotive catalog also provides extensive background and design knowledge as well as a series of practical application examples. The Würth Elektronik Automotive Components Catalog is now available in English at http://www.we-online.de/aspcatalogue21.

www.we-online.com

Data Center Professionals are Considering Power System Upgrades

The events of 2020 rapidly accelerated a global, cross-industry digital transformation, underscoring the mission criticality of data centers as the backbone of the world's virtual economy. In fact, the data center market is expected to grow by nearly 14% in 2021. ABB Power Conversion issued a data report, "Data Overload: Powering Data Centers in the New Normal," that explores the unprecedented demand on data centers in 2020 as well as long-term impacts that will shape data center operations for years to come. Not surprisingly, 96% of data center professionals surveyed reported that demand on their data center increased in 2020, which could indicate why 53% of those surveyed are likely to consider power system upgrades to meet increased demand in the future. "The impact of COVID-19 fundamentally accelerated the concept of mission critical. Overnight, businesses became even more reliant on the cloud to enable operations, processes and remote collaboration. This immediate transition would not have been possible without data centers backed by efficient and reliable power systems," said Jeff Schnitzer, president, ABB Power Conversion. "Power is the ultimate enabler. Not only for rapidly scaling data center operations to meet exponential demand, but for energizing the ongoing digital transformation that's the beating heart of technology and smart societies of the future. And data center power architectures are core components of this."



www.electrification.us.abb.com

Stefan Schaffhauser Takes Over as CEO

In keeping with a long-term succession plan, the previous CEO, Markus Dalla Monta, will retire as of July 2021, following a 35-year career at Traco Power. Stefan Schaffhauser will assume the CEO position with the beginning of the business year on April 1, 2021. As of this date, he will lead the Traco Power Group together with the CFO, Adrian Berger. As before, Rolf Caspar – company owner and Chairman of the Board – will continue to concentrate his efforts on strategic issues in the firm, in conjunction with the board of director members, Jennifer Caspar and Ueli Wampfler.

During the past three years, Stefan Schaffhauser managed the international business team at Traco Power as their managing director, effectively contributing to a positive corporate development. Prior to his career at Traco Power, Schaffhauser was employed at various industrial enterprises in management positions and as a business consultant.

Stefan Schaffhauser obtained a Master's degree in Engineering and Management at the ETH (Confederated Technical University of Switzerland) in Zurich. "It is a great honor for me to assume the management of this outstanding company," says Stefan Schaffhauser. "Traco Power is situated extremely well financially, and we can build on innovative products, a strong brand, and an excellent company culture. I look forward to further advancing Traco Power together with my management team and our staff members."

www.tracopower.com

Acquisition of Magnetic Component Manufactorer

Bourns announced that its newly-formed subsidiary has acquired all shares and interests of the various entities comprising the Kaschke Group with its headquarters in Göttingen, Germany. Kaschke was founded by Kurt Kaschke in 1955 and became known for its high competence in the development and production of application specific magnetic products. The Kaschke mission to use their ferrite core knowledge base for the development of solutions tailored to specific customer requirements matches Bourns' culture of innovative design. "As one of the few companies that has the capability to design and build ferrite core materials as well as manufacture complex inductive components, Kaschke will bring to Bourns the experience and creativity needed to solve customers' complex application challenges," said Gordon Bourns, Chairman and CEO of Bourns. "We are excited to welcome Kaschke to the Bourns organization to combine our capabilities and build stronger customer relationships." Al Yost, President and Chief Operating Officer at Bourns, said "This acquisition is an important element in Bourns' strategy to strengthen our inductive technology capability and broaden our portfolio of innovative magnetic products."

"The combination of Kaschke and Bourns will enable the development of a full portfolio of products that will help our customers meet the challenging EMI filtering requirements of the next generation power supplies in the automotive, industrial and new energy markets," said Silke Baumgartner, President of Kaschke Components. "I'm delighted to form an alliance with Bourns, a company with a history and core values that are fully aligned with Kaschke's."

www.bourns.com

Joining Forces to Advance Global Leadership in Embedded Solutions

Renesas Electronics and Dialog Semiconductor announced they have reached an agreement on the terms of a recommended all-cash acquisition by Renesas of the entire issued and to be issued share capital of Dialog (the “Acquisition”) for EUR 67.50 per share, representing a total equity value of approximately EUR 4.9 billion (approximately 615.7 billion yen).

Dialog is an innovative provider of highly-integrated and power-efficient mixed-signal ICs for a broad array of customers within IoT, consumer electronics and high-growth segments of automotive and industrial end-markets. Centered around its low-power and mixed-signal expertise, Dialog brings a wide range of product offerings including battery and power management, power conversion, configurable mixed-signal (CMIC), LED drivers, custom mixed-signal ICs (ASICs), and automotive power management ICs (PMICs), wireless charging technology, and more.

Dialog also offers broad and differentiated BLE, WiFi and audio system-on-chips (SoCs) that deliver advanced connectivity for a wide range of applications; from smart home/

building automation, wearables, to connected medical. All these systems complement and expand Renesas’ leadership portfolio in delivering comprehensive solutions to improve performance and efficiency in high-computing electronic systems.

“The transaction we announced today represents our next important step in catapulting Renesas’ growth plan to achieve substantial strategic and financial benefits, following our previous acquisitions,” said Hidetoshi Shibata, President and CEO of Renesas. “Dialog has a strong culture of innovation along with excellent customer relationships and serves fast growing areas including IoT, industrial and automotive. By bringing Dialog’s talented team and expertise into Renesas, together, we will accelerate innovation for customers and create sustainable value for our shareholders.”

www.renesas.com

PCIM Asia Celebrates its 20th Anniversary and Relocates to Shenzhen

2021 marks the 20th anniversary of PCIM Asia which will move to the brand new Shenzhen World Exhibition & Convention Center, from 9 – 11 September. The fair’s relocation will create greater business opportunities for the power electronics industry within the South China region and beyond. Despite challenges resulting from the pandemic, the 2020 edition received positive feedback from both exhibitors and visitors, reconfirming the fair’s position as one of the industry’s leading trade platforms.

The three-day show will showcase products and solutions applied in the areas of frequency conversion, electrified transportation, energy storage technologies and silicon carbide materials. Buyers can look forward to seeing a diverse range of products including power semiconductor components and modules, integrated circuits, passive components, magnetics & core materials, thermal management, sensors, assemblies and subsystems, electrical drives, power converters, power quality & energy storage, test & measurement, development software as well as information and services.

Call for Papers now Open

Industry experts and academics are invited to submit their papers on the latest solutions and trends in the power electronics field for the PCIM Asia Conference 2021. Held alongside the PCIM Asia exhibition, the conference is a leading platform for knowledge sharing for the power electronics, intelligent motion technology, renewable energy and energy management sectors. Interested parties are encouraged to submit their abstracts by 15 March.

www.pcimasia-expo.cn

ECPE Award Cooperation - EPCIA Student Award

The EPCIA Student Award is jointly presented by the European Passive Component Industry Association (EPCIA), the European Center for Power Electronics (ECPE), and the European Passive Components Institute (EPCI). Passive components, such as capacitors, resistors, inductors or filters, are crucial to make the (electronics) world “go round”. There is no semiconductor component and no electronic circuitry which can work properly without passive components. It has been decided to offer an Award to all students, graduate students and PhD candidates who participate in an ECPE event and / or Passive Components Networking Symposium (PCNS) and have addressed issues related to passive components in their respective thesis or paper subject (see conditions on the website www.ecpe.org/infocentre/awards/epcia-student-award/). The EPCIA Student Award program grants maximum six Awards per year and will run for 3 years (starting from 1 January 2021). Each Award is granted with € 1,000, subject to the provision that it may be split amongst more than one applicant.

www.ecpe.org

RELIABILITY MEETS FLEXIBILITY

Vincotech

MiniSKiiP®DUAL – now featuring advanced NEW die-attach technology for longer life

Manufacturers expect more from power modules these days. Extended operating time at high temperatures is a top priority. VIN's advanced new die-attach technology strengthens the bond between chips and DCBs to live up to those expectations all across the MiniSKiiP® product line.

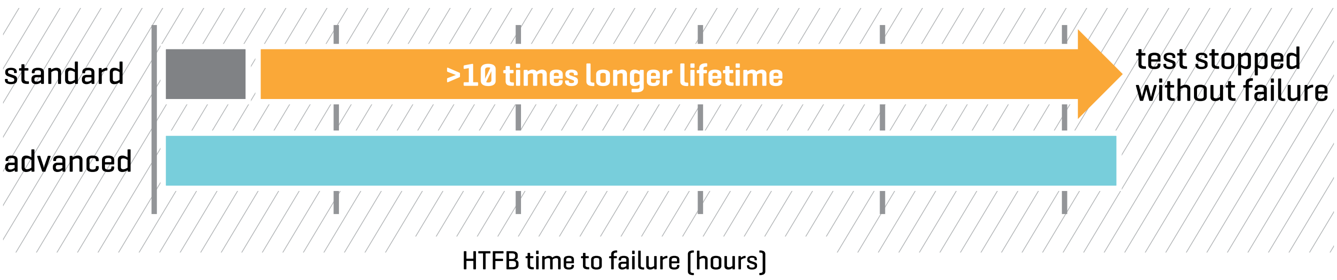
Featuring latest-generation **IGBT M7** and **IGBT7** chips, Vincotech MiniSKiiP® DUAL products deliver the triple-play benefits of **superior performance, multiple sourcing** and **longer life** for flexible and scalable inverter designs with nominal currents up to 400 A.

Main benefits

- More than ten times longer life at high operating temperatures
- Latest-gen chips up efficiency and power density to help drive down system costs
- Less material usage (rather than copper bus bars) plus easy, solder-free assembly equals even greater savings

INDUSTRIAL SOLAR UPS

MiniSKiiP®: with advanced die-attach technology shows superior lifetime at T_{vj}=150°C



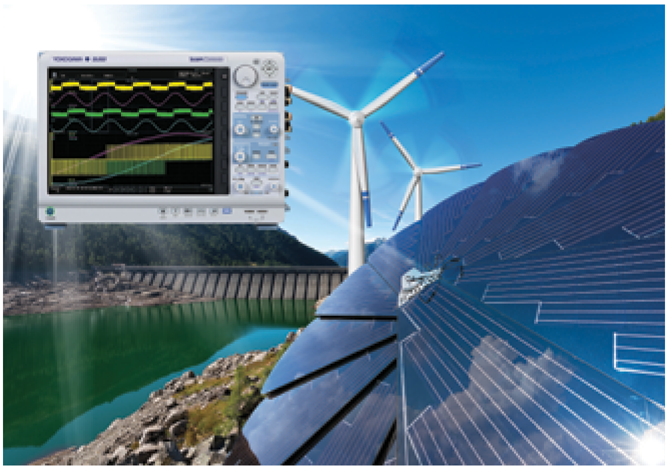
www.vincotech.com/miniskiip-dual

EMPOWERING **YOUR IDEAS**

ScopeCorder for Manufacturers Developing Renewable and Energy Efficient Technologies

Yokogawa Test & Measurement has added another instrument to its ScopeCorder family of portable multi-channel data-acquisition recorders, extending and improving their speed, channel count and data acquisition features.

As society increasingly looks to cut energy wastage and improve the energy efficiency of facilities such as data centres, manufacturers are looking to develop more energy efficient and renewable energy sources. Yokogawa's DL950 is designed to offer manufacturers a highly detailed view of an application's electrical behaviour.



Providing a combination of the high-speed sampling and signal fidelity of an oscilloscope and the long-term data recording capabilities of a recorder, the DL950 measures signals at a high bit resolution while securing data in the harshest of environments. Building on the capabilities of the well-established DL850E, the DL950 ScopeCorder can handle larger amounts of data at a faster sample rate and with a longer recording time. It has a large acquisition memory up to 8 Gpoint, and a 200 MS/s sample rate at 14-bit, compared to the DL850E's 100 MS/s at 12-bit. This is twice the sample rate but with much more detail. The DL950 can run up to 32 isolated analog channels with 10 MS/s at 16-bit or up to 128 digital channels.

The DL950 ScopeCorder provides developers in electric power markets with a high degree of insight into the behaviour of these systems by capturing and analyzing a wide variety of electrical signals, mechanical performance parameters indicated by sensors and decoded serial bus signals. The dual capture feature offers both data acquisition recorder functionality and the sample speed and trigger features of an oscilloscope. This allows developers to analyze the finest waveform details while observing multi-channel measurements over longer periods. The DL950 offers five options for acquiring data, allowing users to choose the best method for their application. They can opt for normal acquisition into the fast internal acquisition memory, recording to flash memory, recording to the internal hard disk (SSD) or directly to the PC via normal Ethernet or opt for 10 Gigabit Ethernet.

Data can be captured to a PC streaming over a very long time at up to 160 MB/s, with data volumes limited only by the PC's storage size. Using 10 Gigabit Ethernet, data can be transferred from the DL950 to a PC at 50 times the speed of its predecessor. A fiber optic cord and the Yokogawa's IS8000 PC software are used for transmission.

The DL950 will also feature Flash Acquisition, used to store data when a PC cannot be used, for example when capturing data from, power plant or other similar application. In these applications the unit would usually need to be switched off before moving it to an office to save data on a PC. Using Flash Acquisition, data can be captured over a long time with a high-speed sample rate of 20 MS/s (8CH) and 10 MS/s (16CH).

The 512GB internal SSD can record up to 50 days. Depending on the sample rate it can record for five hours on one channel at up to 2 MS/s, or record at 200 kS/s for 20 hours with 16 channels. Waveforms from dual capture can also be recorded, useful for capturing rare spontaneous events. The DL950 provides ultimate versatility, as it can be connected to 21 types of input modules. These include 12-, 14- and 16-bit isolation modules, universal voltage/temperature modules, acceleration/voltage modules, strain modules and frequency modules. Up to five DL950s can also be synchronized to allow the use of up to 160 voltage channels. Alternatively, up to 640 temperature channels can be used, employing 16 channels with eight slots for each of five DL950 units. The subunits can be synchronized to start and stop their measurements via signals from the main unit.

The DL950 is also easy to use via a large 12.1 inch touch screen, providing convenient access to its wealth of features. Yokogawa's power analyzers and a selection of other instruments can be time synchronized through the device's integrated IEEE1588 PTP master function and the IS8000 Integrated Software Platform. The units can also be controlled remotely, allowing home workers to continue conducting tests while working away from the test laboratory.

Dedicated application menus simplify the setup. Touching an application icon brings up the graphical setup screen for the application, while users can also register frequently used applications as favourites.

"With the DL950, the already excellent ScopeCorder family attains new levels of data acquisition speed and greatly improved usability", says Terry Marrinan, Yokogawa Test & Measurement's Vice President for Europe & South East Asia: "Offering the versatility to discover more from a large number of input types, the insight available from a high bit resolution and a high level usability from easy set-up, the DL950 gives developers the tools they need to gain detailed information on the behaviour of energy efficient and new renewable energy technologies and devices."

https://tmi.yokogawa.com/eu/

Dual Component 700A Thyristor Modules with Minimized Static and Heat Losses

Currently one of the most pressing issues of low-frequency power semiconductor thyristors and diodes is modifying the design of discrete semiconductors to prolong their service life, reduce electrical and heat losses, and increase operating power [3-4]. This is mostly caused by the constantly growing production, transmission, transformation and consumption of energy, as well as the need to keep improving the technical and economic parameters of converting technology [1].

By Titushkin Dmitry, Surma Alexey, and Antonov Sergey, Proton Electrotex

However, the use of traditional (for modern IGBT modules) approaches to increase the parameters of power thyristors and diodes is not always advisable, since these approaches are based on a rather long and expensive rework, including the use of cheaper and more advanced composite materials, reduction in the amount of structural elements, as well as changing individual structural elements to reduce the cost of mass production. Applying these approaches brings the term for releasing the upgraded product to the market to 2-3 years (which is often unacceptable for the customer), and the costs of developing this product increase to the range of 300,000 - 400,000 EUR, nullifying the economic effect of the implemented improvements. In addition, even more risks arise for example in terms of long-term field trials by the end user or difficulties in carrying out product certification [2]. In this regard, it is still important to use the approach of optimizing the parameters and features of power semiconductor elements with a minimum amount of reworking other structural elements, and the use of modern modeling tools makes it possible to reduce the iteration of upgrading, to reduce development costs and the time to bring the upgraded product to the market down to 1 year or less.

Reduction of static and thermal parameters in a dual-component module with a baseplate width of 60 mm

A dual-component A2-type power thyristor module with a baseplate width of 60 mm rated for a voltage of 1800 V and an average current of 540 A was upgraded at a customer's request (appearance of the module is shown in Figure 1). The current product line of A2 modules is shown in Figure 2.

Figure 1: Appearance of a A2 module with baseplate width of 60 mm

In this version of the design, the electrical and thermal contact of the semiconductor elements is provided with a clamping structure providing an increased cycle resistance and resistance to surge currents.

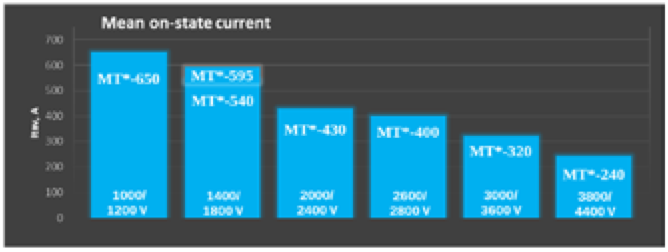


Figure 2: Existing lineup of A2 modules

The process of modeling the main electrical parameters and characteristics resulted in the following solutions to achieve the required thermal and electrical losses of the module:

- Increasing the diameter of the semiconductor element and optimizing the topology to increase the active cathode area by 10%;

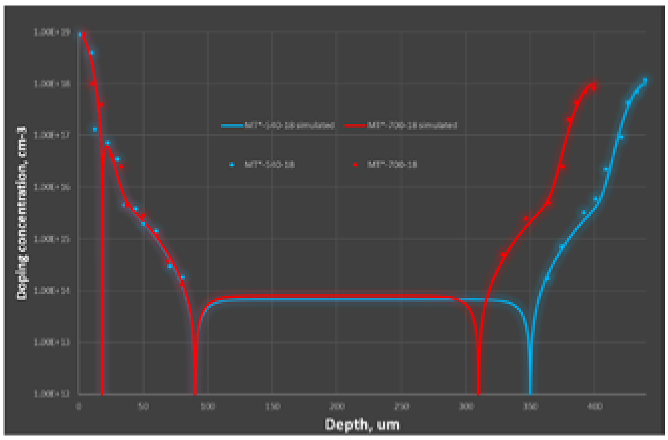


Figure 3: Calculated diffusion profiles of a standard MT-540-18-A2 and an optimized MT*-700-18-A2 thyristor module in comparison with experimental data*

- Reducing the specific electrical resistance of the original silicon wafer;
- Reducing the thickness of the diffusion element and optimizing the diffusion profile (Figure 3 shows data on the calculated and experimental values).

After a pilot batch was produced qualification tests confirmed main results of the modeling:

1. Static losses – threshold voltage (VT(TO)) decreased by 5%, dynamic resistance (rT) by 10%. Figure 4 shows data on the calculated and experimental values of static losses in the open state for a standard MT*-540-18-A2 and an optimized MT*-700-18-A2 thyristor module in comparison with the measured values for alternatives from other manufacturers.
2. Heat loss – junction-case thermal resistance (Rthjc) reduced by 10%. Figure 5 shows the experimental values of the thermal resistance of a standard MT*-540-18-A2 and an optimized MT*-700-18-A2 thyristor module in comparison with the measured values for alternatives from other manufacturers.
3. The surge current in the open state – increased by 20% at the maximum temperature of the pn junction Tjmax = 130°C. Figure 6 shows the experimental values of the surge current in the open state for the standard MT*-540-18-A2 and the optimized MT*-700-18-A2 thyristor module in comparison with the measured values for alternatives from other manufacturers.

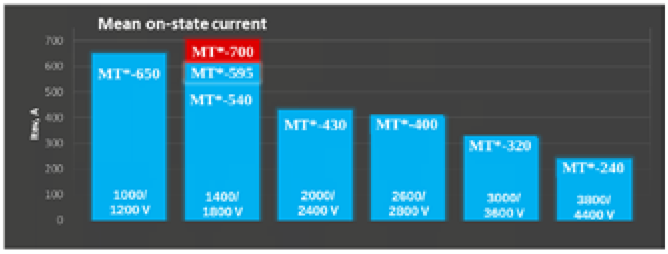


Figure 7: Updated lineup of the A2 modules

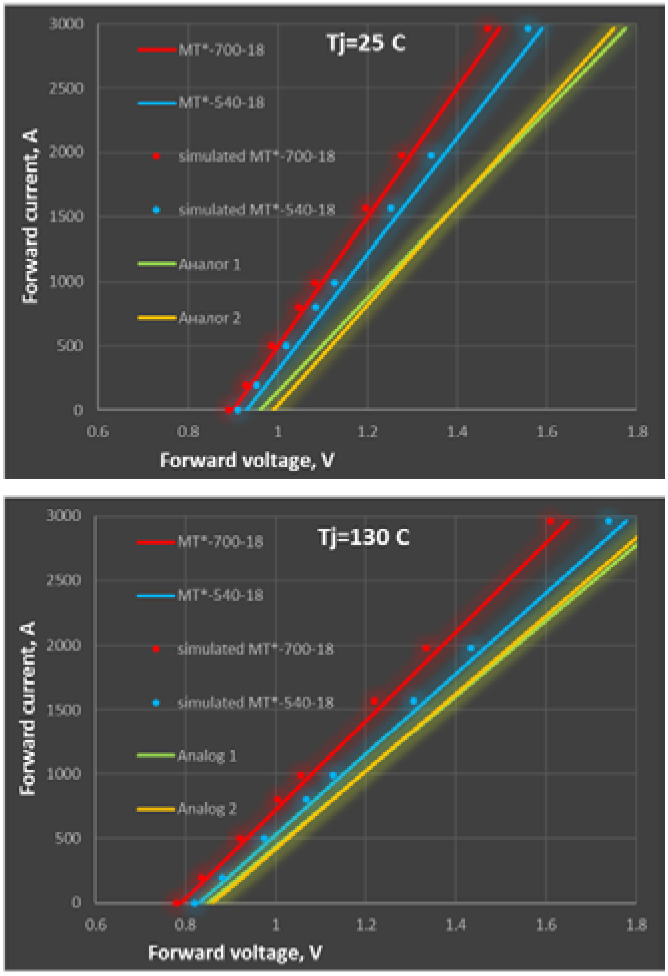


Figure 4: Static losses of a standard MT*-540-18-A2 and optimized MT*-700-18-A2 thyristor modules

Interview with Alexander Semenov, General Director, Proton-Electrotex

By Bodo Arlt, Publisher Bodo's Power Systems

Bodo Arlt: The company Proton-Electrotex exists since 1996. Where did it all start and what has been achieved over the past years?

Alexander Semenov: In February 2021, the company celebrated its twenty-fifth anniversary, a landmark event for both the power electronics industry and the company itself.

The first projects of Proton-Electrotex were related to the development and production of power thyristors for a number of projects in Russia. From the beginning the company set a goal of providing high-quality solutions, which served as the key to further success. Within a few years we managed to enter the European market where competitors from Germany, Great Britain, the Czech Republic and Japan have been developing their business for decades.

Twenty years ago the global market was new and unexplored for us, the mentality and approach to doing business were very different from Russian. But this did not prevent Proton-Electrotex from adapting to requirements of foreign customers for power semiconductors. Within a few years our company has earned trust of both major industry-forming customers and the respect of competitors. Now Proton-Electrotex is a well-known and respected brand not only in Europe but also in the global market of power semiconductor devices.

Bodo Arlt: The company was involved in many large, critical projects of strategic importance in various industries and countries. Why it was you and how did you manage to achieve this? Could you highlight the main competitive advantage of Proton-Electrotex?

Alexander Semenov: The company has accumulated a lot of achievements over this quarter of a century. Every year we developed new products and improved existing portfolio so they could find their application in various industries. Every day employees of the company work to reach new heights.

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DPG10-1500B/E	1 to 1500A	2750J
DPG10-3000B/E	3 to 3000A	2750J
DPG10-4000B/F	4 to 4000A	7700J
DPG20-10000B/G	10 to 10000A	15000J

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For example, one of the most significant international projects is participation in the upgrade project of the Vyborg DC link. This is the only DC link in Russia that was built to export electricity from Russia to Finland. Our company also participated in the restoration of the Sayano-Shushenskaya hydroelectric power station. We provided our semiconductors for the repair of hydroelectric power equipment after the accident in 2009.

Among the recent achievements, I would like to mention entering the prestigious Techup-2019 rating. This is a national ranking of fastest-growing technology companies. Proton-Electrotex took the first place in the category “Export potential” among all Russian enterprises.

The company has a full production cycle, extensive infrastructure, modern production lines, measuring equipment and “clean areas”. In 2010 the company founded its R&D Center in Moscow to work on development of fundamentally new devices for modern industry, and to carry out tests for reliability and maximum service life of devices.

Production of power semiconductor devices at Proton-Electrotex is adapted for customization according to the customers’ requirements. The company has an ability to group devices by parameters, to make specific wire connections, and produce products with a unique set of parameters that are ideally suited for various industries. All production processes of the company are organized in strict accordance with the requirements of the quality management system (ISO 9001) and environmental management (ISO 14001).

Bodo Arlt: What is your opinion about the current state of the semiconductor market?

Alexander Semenov: Right now the power electronics market is characterized by restructuring and consolidation of the main players, as seen in a series of mergers and acquisitions. Besides, new large high-tech companies are entering the global market, mainly new players from the Chinese market.

Despite the rapid growth of the global power electronics industry, the Russian market segment is stagnating due to the decline in economic activity in the country, sanctions as a barrier to attracting international investors, and general lack of government policy for the development of industries consuming power semiconductor devices. In this regard, truly successful companies need to be focused on global presence and strengthening their positions in important economic centers of the world from the point of view of power electronics.

Bodo Arlt: What areas of the company's activities do you consider the most groundbreaking and promising? Why?

Alexander Semenov: In 2016 the company launched production of IGBT modules in MIAA and MIFA housings. Before that 95% of IGBTs were supplied to Russia from abroad. Now we continue to expand the range of IGBT modules and work on a number of promising projects. From the point of view of substitute products, there is currently no alternative to IGBT devices, moreover, there is no fundamental knowledge that can lead to the replacement of these devices. This direction is at the stage of growth, both in terms of volume and in terms of technical improvement.

At the same time, SiC-based devices continue to storm the industry and may compete in the IGBT market in future. Wide-band gap semiconductors allow to build reliable high-frequency converters, replacing conventional high-voltage power transformers and significantly exceeding the latter in terms of technical and economic indicators.

Bodo Arlt: What in your opinion is the most important thing for success of any company?

Alexander Semenov: The most important thing in business is smart quality management, competent staff, being customer-oriented (customization), technical support and overall well-coordinated work of all departments of the company.

I define the quality management as the company management based on a clear knowledge of the system parameters, the ability to control these parameters using various techniques, rapid response to any deviations, the use of corrective measures to reduce negative impact of emerging factors in the external and internal environment of the company. In this area we have made great progress from the point of view of both the development of company's management system and from the point of view of its automation.

Bodo Arlt: Dear Alexander thank you for the time and let us look forward to more challenging innovations in power electronics

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Immediately after graduating from the Leningrad Polytechnic Institute of M. I. Kalinin with a degree in Semiconductors and Dielectrics in 1984 Alexander Semenov got a job at the Experimental Design Bureau “PROTON” as an engineer. From the very beginning of his career, he wanted to put into practice the knowledge he received at the institute and had a strong desire to create something new and really useful. In 1996, a group of former employees left Proton that was going through hard times then and founded the Proton-Electrotex company. By that time, they already had a small business producing solar cells for solar panels. That project allowed them to earn enough money to start a new business. The company bought a license from Russian Electrotechnical Institute to produce fast thyristors. Within a year, they perfected all the processes and received the first products. As soon as in 1998 they became the leaders of the domestic electrical industry in the area of manufacturing power semiconductor devices. Since then, working on the development of domestic power electronics has become Alexander’s life's work.

Thus, the upgrade allowed to create a dual-component module MT*-700-18 with an average on-state current (ITAV) increased by ~30% up to 700A at a case temperature Tc = 80°C and a maximum temperature of the pn junction Tjmax = 130°C. At the same time, other electrical parameters and characteristics of the module have not changed. Figure 7 shows the current line of dual-component A2 modules with a baseplate width of 60 mm manufactured by Proton-Electrotex, including the new 700 A module.
Main differences in normal parameters between the standard MT*-540-18-A2 and optimized MT*-700-18-A2 are represented in Table 1:

Conclusion
This article demonstrates the results of upgrading dual-component thyristor and thyristor-diode modules including modifications MT3, MT4, MT5, MT/D3, MT/D4 and MT/D5 with a baseplate width of 60 mm designed for a voltage of 1800 V with reduced heat and electrical losses. This upgrade allowed to increase average current in the open state to 700 A, reduce thermal resistance p-n junction-case, threshold voltage and dynamic resistance, and increase surge current without compromising the reliability and service life of the product.

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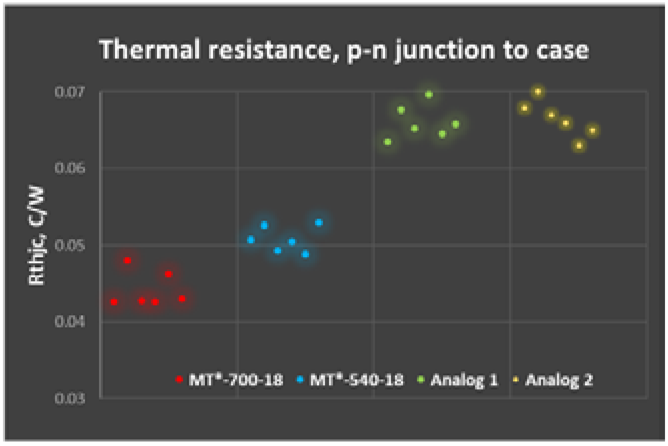


Figure 5: Heat resistance junction-case for a standard MT-540-18-A2 and optimized MT*-700-18-A2 module*

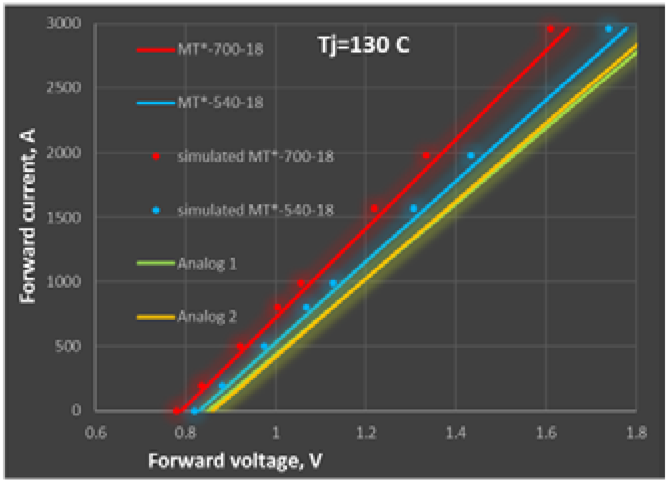


Figure 6: Surge current for a standard MT-540-18-A2 and optimized MT*-700-18-A2*

Name and designation of the parameter			MT*-540-18-A2 МТ/Д*-540-18-A2	MT*-700-18-A2 MT/D*-700-18-A2	Measurement conditions
I_{TAV}	Mean on-state current	A	540 (T_C=85 °C)	700 (T_C=80 °C)	180 sine el. deg.; 50 Hz
I_{TRMS}	RMS on-state current	A	845 (T_C=85 °C)	1099 (T_C=80 °C)	180 sine el. deg.; 50 Hz
I_{TSM}	Surge on-state current	kA	15,5 (T_j=T_{jmax}) 18 (T_j=25 °C)	20 (T_j=T_{jmax}) 23 (T_j=25 °C)	180 sine el. deg.; tp=10 ms; single pulse; V_D=V_R=0 B;
V_{DRM}, V_{RRM}	Repetitive peak off-state and reverse voltage	V	1400...1800	1400...1800	Tj min< Tj <Tj max; 180 sine el. deg.; 50 Hz;
I_{DRM}, I_{RRM}	Repetitive peak reverse and off-state current, max	mA	70 (T_j=T_{jmax}) 3 (T_j=25 °C)	70 (T_j=T_{jmax}) 3 (T_j=25 °C)	V_D=V_{DRM}; V_R=V_{RRM}
V_{TM}	Peak on-state voltage, max	V	1.50 (I_{TM}= 1570 A)	1.65 (I_{TM}= 2198 A)	T_j=25 °C
R_{thjc}	Thermal resistance p-n junction-case, max	°C /W	0.0325 (per module) 0.0650 (per component)	0.0255 (per module) 0.0510 (per component)	180 sine el. deg.; 50 Hz
T_j	Temperature of p-n junction	°C	–40...+130	–40...+130	

Table 1: Comparison of normal parameters

Minimizing Thermo-Mechanical Stress in Chipscale eGaN Devices

Enhancement-mode gallium nitride (eGaN) FETs have demonstrated excellent thermo-mechanical reliability in actual operation in the field or when tested according to AEC or JEDEC standards. This is because of the inherent simplicity of the "package," the lack of wire bonds, dissimilar materials, or mold compound [1].

By Robert Strittmatter, Alejandro Pozo, Shengke Zhang, and Alex Lidow, Efficient Power Conversion

In addition to the component-level reliability, there are other industry specific standards like IPC-9592, or OEM environmental requirements that impose system or board-level tests for components mounted on a PCB. Among these, there is always a subset that induces severe thermo-mechanical stress on surface-mounted parts such as eGaN FETs, and especially on the solder joints between the parts and the board. For instance, the most stringent temperature cycling requirement (Class II Category 2) from the IPC-9592 standard calls for 700 cycles at −40°C to 125°C without failure in a sample size of 30 units. The reliability of the solder attachments depends on several factors that are independent of the device, including the PCB layout, design and material, the assembly process, the heatsinking solution in operation, and the nature of the application. Therefore, providing a precise model to predict time to failure in a particular application becomes infeasible and impractical. Nevertheless, in the past, EPC published a model to predict time to failure of solder joints based on the correlation between strain energy density and fatigue lifetime [2,3]. In this article, more Temperature Cycling, and Intermittent Operating Life (also known as Power Temperature Cycling) results will be presented under different conditions. In addition, data and analysis on how to improve solder joint reliability with the use of underfill materials will be provided. Underfills are commonly used in applications that may expose surface mount devices to the harshest environmental conditions. It is important to emphasize that underfill is not required to ensure proper operation of eGaN FETs. In fact, EPC conducts most of the reliability tests during product qualification with the devices under test mounted on FR4 boards with no underfill. The list of tests includes HTRB, HTGB, H3TRB, uHAST, MSL1, IOL, HTOL, ELFR, HTS and in many cases TC. That being said, underfill may be used for improved board-level reliability since it reduces the stress on the solder joints resulting from coefficient of thermal expansion (CTE) mismatches between the die and PCB. Moreover, underfill provides pollution protection and additional electrical isolation in those cases with strict creepage and clearance requirements. Finally, underfill also helps in reducing the junction-to-board thermal impedance since the materials used have higher thermal conductivity than air, although lower than typical thermal interface materials. Note that the incorrect choice of an underfill material could also worsen solder joint reliability. Therefore, guidelines based on simulation and experimental results will be provided.

Criteria for Choosing a Suitable Underfill

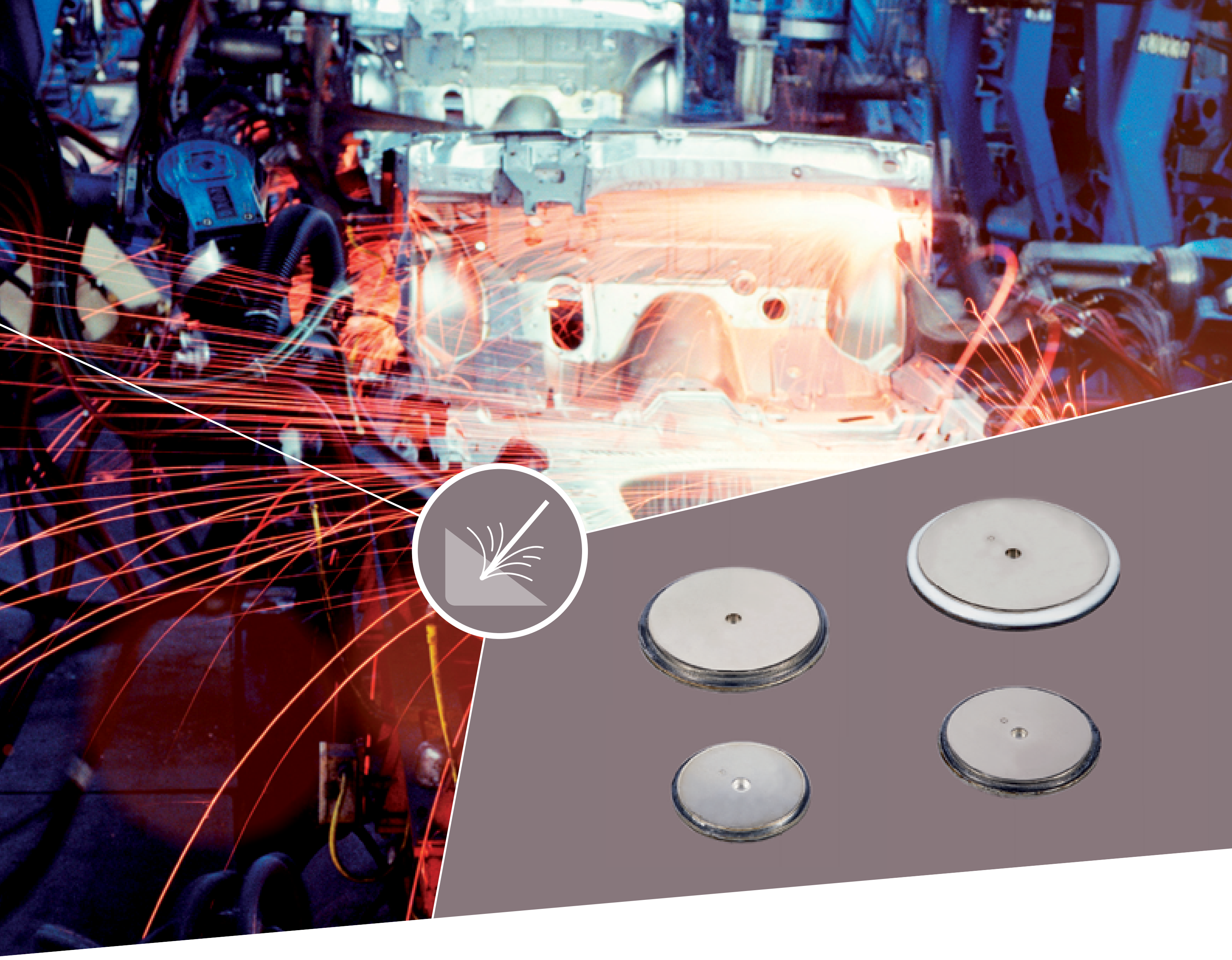
The selection of underfill material should consider a few key properties of the material as well as the die and solder interconnections. Firstly, the glass transition temperature of the underfill material should be higher than the maximum operating temperature in application. Also, the CTE of the underfill needs to be as close as possible to that of the solder since both will need to expand/contract at the same rate to avoid additional tensile/compressive stress in the solder joints. As a reference, typical lead-free SAC305 and Sn63/ Pb37 have CTEs of approximately 23 ppm/°C. Note that when operating above the glass transition temperature (Tg), the CTE increases drastically. Besides Tg, and CTE, the Young Modulus – a gauge of material "stiffness" - is also important. A very stiff underfill can help reduce the shear stress in the solder bump, but it increases the stress at the corner of the device, as will be shown later in this section. Low viscosity (to improve underfill flow under the die) and high thermal conductivity are also desirable properties. Table 1 compares the key material properties of the underfills tested in this study.

Underfill Study under Temperature Cycling

Temperature Cycling (TC) results of various eGaN FETs under two different conditions, with and without the underfill materials listed earlier will now be explored. Two temperature cycle ranges were tested: (i) −40°C to 125°C; and (ii) −55°C to 150°C. For all cases, the parts were mounted on DUT cards or coupons consisting of a 2-layer, 1.6 mm thick, FR4 board. SAC305 solder paste and water-soluble

Manufacturer	Part Number		CTE (ppm/C)		Storage Modulus (DMA) @ 25°C (N/mm²)	Viscosity @ 25°C	Poisson's Ratio	Volume Resistivity	Thermal Conductivity	Dielectric Strength
		Tg (TMA)	Below Tg	Above Tg						
HENKELS LOCTITE	ECCOBOND UF 1173	160	26	103	6000	7.5 Pa*S				
NAMICS	U8437-2	137	32	*100*	8500	40 Pa*S	0.33	>1E15 Ω-cm	0.67 W/mK	
NAMCIS	XS8410-406	138	19	*70*	13000	30 Pa*S				
MASTERBOND	EP3UF	70	25-30	75-120	3400	10-40 Pa*S	0.3	>1E14 Ω-cm	1.4 W/mK	450 V/mil
AI TECHNOLOGY	MC7885-UF	236	20		7500	10 Pa*S		>1E14 Ω-cm	1 W/mK	750 V/mil
AI TECHNOLOGY	MC7885-UFS	175	25		7500	10 Pa*S		>1E14 Ω-cm	2 W/mK	1000 V/mil

Table 1: Underfill Material Properties



flux was used, followed by a flux clean process prior to the underfill. Temperature Cycling data for EPC2001C and EPC2053 are provided in Tables 2 through 5 and results for EPC2206 are provided in the Weibull plot in Figure 1. For both temperature ranges, the Namics underfills (U8437-2_N and 8410-406B) provide a large lifetime advantage compared to no underfill. The same applies to the Henkels (UF1137_H). On the other hand, Masterbond EP3UF was found to degrade the reliability. It is thought that this was primarily the result of the low Tg, which meant that the underfill was exercised well beyond its glass transition temperature in all our studies. However, based on material properties, it is suspected that Masterbond EP3UF may be a suitable candidate for applications staying below 70°C.

Product/DOE	EPC2701C										
Stress condition: -40°C to 125°C	Status	300 cycles	550 cycles	850 cycles	1000 cycles	1250 cycles	1550 cycles	1750 cycles	1950 cycles	2150 cycles	2450 cycles
No Underfill	Completed	0/32 fail	0/32 fail	0/32 fail	0/32 fail	2/32 fails	5/32 fails	8/32 fails	15/32 fails	20/32 fails	26/32 fails
	On-going	0/32 fail	0/32 fail	0/32 fail	0/32 fail						
Henkels UF1137_H	On-going	0/40 fail	0/40 fail	0/40 fail	0/40 fail	0/40 fail					
Masterbond EP3UF_M	On-going	0/40 fail	0/40 fail	14/40 fails	31/40 fails						
MC7685-UFS	Completed	0/32 fail	0/32 fail	0/32 fail	0/32 fail	1/32 fails	2/32 fails	2/32 fails	3/32 fails	6/32 fails	14/32 fails
MC7885-UF	Completed	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	1/32 fails	4/32 fails
Namics 8410-406B	Completed	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail
Namics U8437-2_N	Completed	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail
	On-going	0/80 fail	0/80 fail	0/80 fail	0/80 fail	0/80 fail					

Table 2: -40°C to 125°C Temperature Cycling results for EPC2001C

Product/DOE	EPC2053										
Stress condition: -40°C to 125°C	Status	300 cycles	550 cycles	850 cycles	1000 cycles	1250 cycles	1550 cycles	1750 cycles	1950 cycles	2150 cycles	2450 cycles
No Underfill	Completed	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	2/32 fails	3/32 fails	3/32 fails	3/32 fails
Henkels UF1137_H	On-going	0/40 fail	0/40 fail	0/40 fail	0/40 fail	0/40 fail					
Masterbond EP3UF_M	On-going	1/40 fails	7/40 fails	15/40 fails	25/40 fails	39/40 fails					
MC7685-UFS	Completed	0/32 fail	0/32 fail	0/32 fail	1/32 fails	17/32 fails	32/32 fails	32/32 fails			
MC7885-UF	Completed	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	1/32 fails	1/32 fails	1/32 fails
Namics 8410-406B	Completed	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail
Namics U8437-2_N	Completed	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail	0/32 fail
	On-going	0/40 fail	0/40 fail	0/40 fail	0/40 fail	0/40 fail					

Table 3: -40°C to 125°C Temperature Cycling results for EPC2053

Product/DOE	EPC2701C					
Stress condition: -55°C to 150°C	Status	300 cycles	600 cycles	900 cycles	1100 cycles	1300 cycles
No Underfill	Completed	0/16 fail	0/16 fail	1/16 fails	1/16 fails	2/16 fails
Henkels UF1137_H	On-going	0/20 fail	0/20 fail	0/20 fail	1/20 fails	
Masterbond EP3UF_M	On-going	0/20 fail	0/20 fail	4/20 fails	6/20 fails	
MC7685-UFS	Completed	0/16 fail	0/16 fail	0/16 fail	1/16 fails	1/16 fails
MC7885-UF	Completed	0/16 fail	0/16 fail	0/16 fail	0/16 fail	0/16 fail
Namics 8410-406B	Completed	0/16 fail	0/16 fail	0/16 fail	0/16 fail	0/16 fail
Namics U8437-2_N	Completed	0/16 fail	0/16 fail	0/16 fail	0/16 fail	0/16 fail
	On-going	0/20 fail	0/20 fail	0/20 fail	0/20 fail	

Table 4: -55°C to 150°C Temperature Cycling results for EPC2001C

Product/DOE	EPC2053					
Stress condition: -55°C to 150°C	Status	300 cycles	600 cycles	900 cycles	1100 cycles	1300 cycles
No Underfill	Completed	0/16 fail	0/16 fail	0/16 fail	0/16 fail	1/16 fails
Henkels UF1137_H	On-going	0/20 fail	0/20 fail	0/20 fail	0/20 fail	
Masterbond EP3UF_M	On-going	5/20 fails	15/20 fails			
MC7685-UFS	Completed	1/16 fails	9/16 fails	13/16 fails		
MC7885-UF	Completed	2/16 fails	1/16 fails	7/16 fails		
Namics 8410-406B	Completed	0/16 fail	0/16 fail	0/16 fail	0/16 fail	0/16 fail
Namics U8437-2_N	Completed	0/16 fail	0/16 fail	0/16 fail	0/16 fail	0/16 fail

Table 5: -55°C to 150°C Temperature Cycling results for EPC2053

Intermittent Operating Life Study

In Temperature Cycling, both the device and PCB are placed inside a chamber that cycles the ambient temperature, leading to an iso-thermal temperature change across the assembly. In Intermittent Operating Life (IOL), temperature rise is realized by dissipating power inside the device. Therefore, in IOL only the device and the PCB in the vicinity of the die change in temperature. As a result, the stresses on the solder joints resulting from the CTE mismatch between the eGaN FETs and PCB are not as high as in Temperature Cycling. However, the time to complete a full cycle is much faster than in TC (Note that IOL may also be known as Power Temperature Cycling). Figure 2 shows the results of a group of 32 samples of EPC2206 tested to failure under two different conditions. In all cases, each cycle consisted of a heating period of 30 seconds, followed by a cooling period of another 30 seconds. In Figure 2, information in blue shows the devices that were cycled between 40°C and 100°C, and in orange, the devices cycled between 40°C and 150°C. In both cases, solder fatigue is the only failure mechanism, so the slopes of the Weibull fits were almost the same. However, the Mean Time to Failure was strongly accelerated by the ΔT and Tmax reached during each cycle.

In addition, a third cohort of parts using underfill Namics U8437-2 was started cycling between 40°C and 150°C.

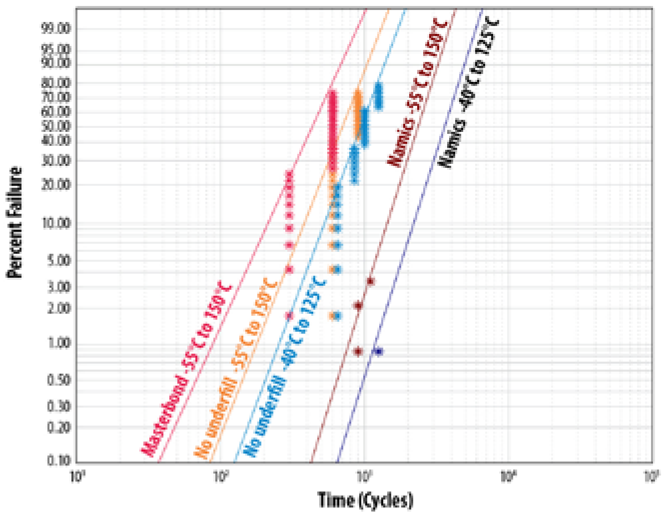


Figure 1: Weibull plots of Temperature Cycling results of EPC2206

After 53,000 cycles no failures were observed. The green line in Figure 2 assumes one failure after 53,001 cycles, and therefore can be viewed as a lower bound on the performance of this underfill. Clearly, as was found in the TC studies, the Namics underfill was found to affect a significant improvement (> 100x) in lifetime under cyclic temperature stress.

Finite Element Analysis

To better understand the key factors influencing thermo-mechanical reliability when using underfills, finite element simulations of EPC2206 under temperature cycling stress were conducted. Figure 3 shows the simulation deck used for this analysis. The die is placed on a 1.6 mm FR4 PCB, and the temperature change is ΔT = +100°C above the neutral (stress free) state. Two key underfill parameters were varied: Young's modulus and CTE. As shown in the figure, stress is analyzed along the cut line shown, providing visibility into the stress within the solder bars, die, and underfill.

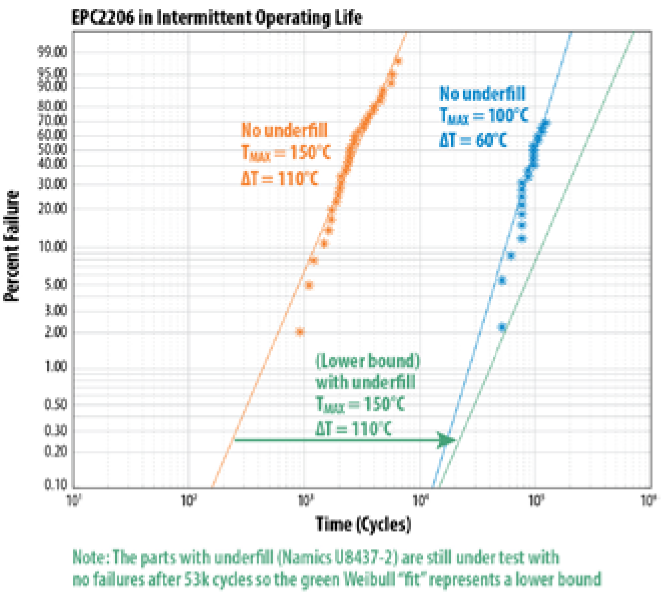


Figure 2: Weibull plots of Intermittent Operating Life results of EPC2206

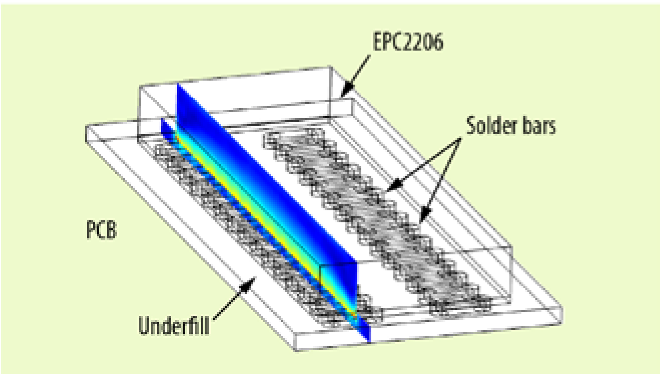


Figure 3: Simulation deck for finite element analysis of stresses inside EPC2206 under temperature cycling stress. Die with underfill mounted on a 1.6 mm FR4 PCB. Stress is analyzed along the cut line shown.

Figure 4 shows the Von Mises [4], or peak shear stress, in the edge-most solder bar along the cutline. For clarity, only stress in the solder bar is shown. In addition, mechanical deformations are exaggerated by 20 times in order to illustrate the shear displacement in the joint. Four distinct underfill conditions are simulated by changing the Young's modulus (E) or the CTE of the underfill. As can be seen, the solder bar in the no underfill case has by far the most extreme shear stress and deformation. The addition of underfill significantly alleviates stress from the joint, with the higher the E, the less stress in the joint. For underfills with poor CTE matching to the solder joint, stresses can also build up in the joint.

Figure 5 shows the same four conditions, but this time the Von Mises stress is shown in the die and underfill as well. As can be seen, the high Young's modulus cases show low stress in the solder joint, but high stress inside the die and underfill near the die edge. These high stresses can lead to cracking and ultimate failure inside the device. FEA analysis shows that there is an optimal Young's modulus in the range of ~6 to 13 GPa, providing a good compromise between protecting the solder joint and protecting the die edge. With regard to CTE, the analysis shows that high underfill CTE (> 32) should be avoided.

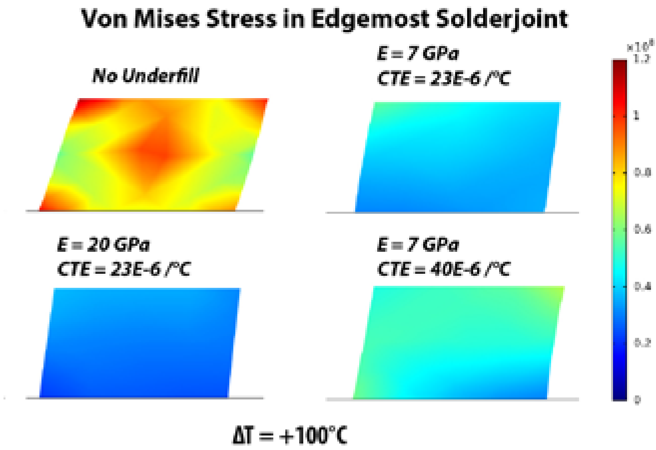


Figure 4: Von Mises (peak shear stress) in the edge-most solder bar under a temperature cycle change of ΔT = +100C. Four different underfill conditions are simulated, with changing Youngs modulus (E) of the underfill, and different CTE as well. Note that mechanical deformation has been exaggerated by 20x in all cases.

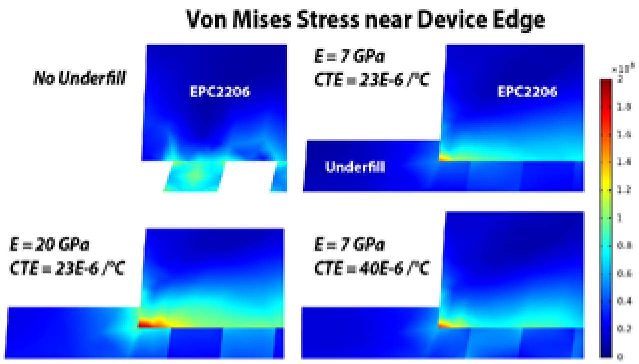


Figure 5: Von Mises (peak shear stress) in the edge-most solder bar under a temperature cycle change of ΔT = +100C. Four different underfill conditions are simulated, with changing Youngs modulus (E) of the underfill and different CTE as well. Note that deformation has been exaggerated by the same scale in each picture.

Guidelines for Choosing Underfill

The main guidelines for choosing an underfill for use with eGaN FETs are listed below:

- Underfill CTE should be in the range of 16 to 32 ppm/°C, centered around the CTE of the solder joint (24 ppm/°C). Lower values within this range are preferred because they provide better matching to the die and PCB.
- Glass transition temperature (Tg) should be comfortably above the maximum operating temperature. When operated above Tg, the underfill loses its stiffness and increases its CTE, which may compromise solder joint reliability.

• Young's (or Storage) modulus in the range of 6−13 GPa. If the modulus is too low, the underfill is compliant and does not relieve stress from the solder joints. If it is too high, the high stresses begin to concentrate at the die edges. From the experimental results in this study, Henkels UF1137_H and Namics 8410-406B and U8437-2_N underfills provide excellent boost in thermomechanical reliability when used with eGaN FETs.

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How SiC MOSFETs Are Made and How They Work Best

A story about to make them and not to break them

Semiconductors came a long way since the early beginning of the minute man project and the traitorous eight puzzling about if better office air filtering would increase the yield of their production. In the more recent years there has been a big push into energy efficient conversion.

By Thomas Hauer, Avnet Silica

With this push, silicon MOSFET's with R_{DSon} values in the low mΩ range became a familiar thing for low voltage devices, but the higher the blocking voltage of MOSFET's go, the higher the R_{DSon} gets. With such high R_{DSon}, these devices were still unsuitable for high voltage and high power applications and the only way to handle such applications were the use of IGBT devices. Silicon Carbide or in short SiC has proven to be a material with which it is possible to build MOSFET like components that enable circuits with even more efficiency than it has ever been possible with IGBT's before. SiC gains a lot attention these days, not only because of its properties but also because the devices get more and more price competitive to IGBT's and manufacturers bring in a long term investment strategy, at system level, to secure supplies. One of the manufacturers that made its way on to the top of SiC suppliers is without a doubt STMicroelectronics. STMicroelectronics invested a lot in research and development in past years to get a comprehensive STPOWER portfolio for the market, but there were also significant invests in the supply of the material. In 2019 STMicroelectronics acquired the Swedish SiC manufacturer Norstel AB, also did a multi-year agreement with CREE and later in early 2020 with SiCrystal, a Rohm subsidiary, too on SiC wafer supply just to name some strategic movements that have been made.This strategy proves itself very well for STMicroelectronics and so they became a key player in the very fast growing SiC market. To not just water your mouth, now lets discuss SiC devices.

Silicon Carbide, The Not So New Material

The very first documented experiments with SiC material were around 1849 and the material is already widely in use in bullet proof vests or as abrasive. One of the inventors of the IGBT discussed in [1] back in 1993 the superior behaviour of different SiC material compared to Silicon (Si) devices. Table 1 shows values of the different materials that have been discussed in [1] and [2]. These values make some interesting statements about SiC materials. The breakdown electric field strength E_c is more than a magnitude better than Si at a doping level of $4{:}8x10^{16}cm^{-3}$. The higher saturation drift velocity v_{SAT} as well as the higher bandgap voltage E_g also stand out. An interesting figure is λ which states the thermal conductivity. Here SiC materials are more than twice as good as Si, which brings new possibilities to packaging and packaging density as well as current handling capability. However, [1] is from 1993 and just in the last few years SiC was gaining traction in the market, so there must have been some roadblocks that had to be solved. On of the roadblocks was an appropriate bulk growing process. With Si the bulk growth according to the Czochralski process is well understood and established. The usual growth rate of such a bulk is several meters per hour. This process however is not suitable for SiC bulk growth. For SiC production a process called physical vapour transport (PVT) has to be used. This process uses a crystal seed on top of a chamber and beneath it there is SiC source material that gets heaten up to around 2000 - 2500°C. This high temperature causes vapour to rise from the source material to the crystal seed and so the bulk grows. This process unfortunately is not as fast as the Czochralski process and so the resulting growth speed is several millimeters per hour which is a lot slower than Si growing. Unfortunately the process still is far from perfect and there is a relatively high density of defects within the material which is described in detail in [2].

	Si	6H-SiC	4H-SiC	GaN
$E_g[eV]$	1.1	2.86	3.26	3.45
$v_{SAT}[\frac{cm}{s}]$	10^7	$2x10^7$	$2.2x10^7$	$2.2x10^7$
$E_c[\frac{V}{cm}]$	$2x10^5$	~$4x10^6$	~$3.2x10^6$	~$3x10^6$
$\lambda[\frac{W}{cmdegC}]$	1.5	4.9	4.9	1.3

Table 1: Comparison of Si to 6H-SiC, 4H-SiC and GaN.

In table 1 there is also GaN referenced with its material properties. This material and its resulting products are also causing some stir in the market at the moment, but at the moment the market traction is not as big as it is for SiC and the focus is more on devices around and below 600V in high frequency applications. There is certainly a place for such products but the product variety as it is there for SiC isn't there at the time this article is written and semiconductor vendors focus more on SiC than they do for GaN. This is also due to the reason that the process of SiC is in lots of points very similar to Si process and machines can be used for both materials which is clearly an advantage.

Device Properties And Their Gate Driving

Now that we have elaborated on the SiC material properties and learned, that it is superior in its parameters compared to Si in high energy applications it is time to look closer into the devices and applications. As introduced above, STMicroelectronics is one of the top players in the SiC market, so lets have a look at their product portfolio in figure 1.

When looking at the voltage range the portfolio addresses it is clear that there is a range where SiC MOSFETs compete with Si MOSFETs and there is a range where they compete with IGBT's. In the lower voltage range Si MOSFETs do come quite close with the SiC devices but, SiC devices can offer a lower gate charge and a better thermal specification. The other end of the spectrum are the IGBT devices. Here it is clear that due to the low R_{DSon} of a SiC MOSFET these devices are unquestionable superior to IGBT's, not mentioning the, again, lower gate charge.

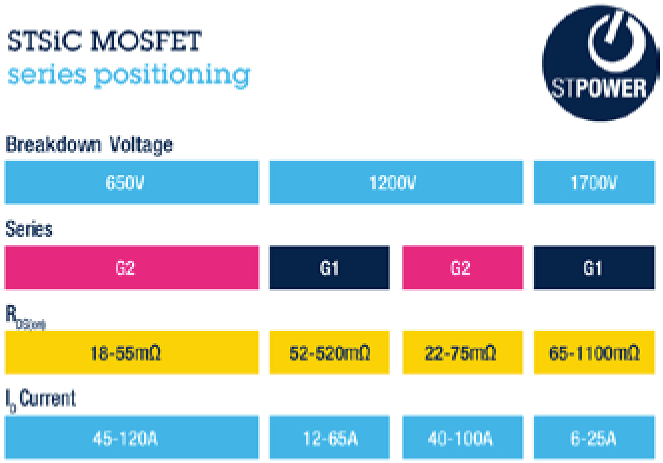

Figure 1: Product placement of SiC Power MOSFETs in the ST portfolio, STPOWER

How to Drive SiC MOSFETS

With the superior material properties in mind the question poses how these parts have to be controlled on to work at their very best. Starting from things we know, Si MOSFETs need a positive gate voltage, which is recommended around 12V or even less and the negative gate voltage should be ground potential. IGBT's have an asymmetrical gate driving voltage, that means that the positive gate voltage is around 15V and the negative voltage is around -5V .

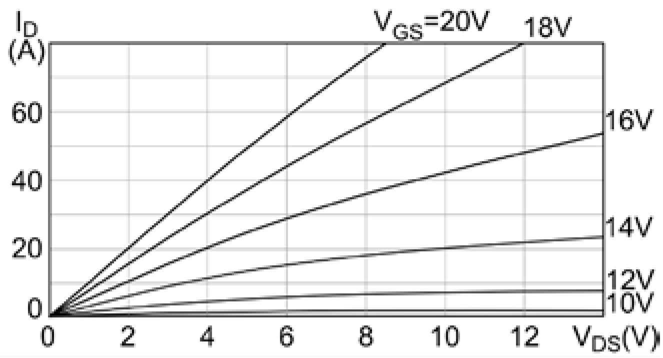

Figure 2: SCT30N120 output characteristics (Tj = 25 °C)

A SiC MOSFET basically works with the voltage levels of a Si MOSFET or IGBT, but not at its best parameters. Ideally a SiC MOSFET gets at its gate 20V for being switched on at the minimum R_{DSon}.

When switching off SiC MOSFET's with 0V, one effect has to be considered, the Miller effect which is already known from Si MOSFET's. This effect can be problematic when the device is used in a bridge configuration, especially when one SiC MOSFET is switched on and the second experiences a surge on its Drain and switches on accidental due to parasitics. This turn on creates a short circuit from high voltage to ground and consequently damages the circuit.

However SiC devices can be operated at lower gate voltages than the 20V named earlier, but the output characteristics change a lot, as it can be seen in figure 2. It can be concluded that a lower gate voltage results in a lower overall system efficiency. Optimizing the SiC MOSFET gate driving circuit for low R_{DSon} with high enough gate voltage is just half of the work that can be done to optimize for losses. Switching losses are the other part that can be optimized, like showcased in [3]. For driving the SiC MOSFETs in [3] STGAPxx MOSFET drivers have been used. STGAPxx MOSFET drivers do come in two different flavours as can be seen in figure 3 and figure 4. In figure 3 the schematic shows how gate driving of SiC MOSFETs can be done when using a bipolar gate driver supply. This bipolar gate driving voltage is not mandatory as described above but it helps to minimize the Miller effect and creates a better controllable on and off switching. Figure 4 therefore shows a schematic with an active Miller clamp. This enables the designer to have a unipolar gate driver supply.

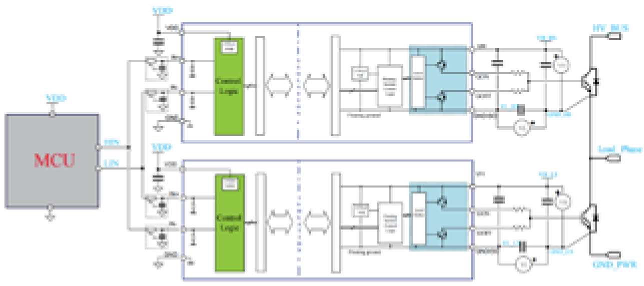

Figure 3: STGAP2SICS with a half bridge configuration and separate gate driving paths.

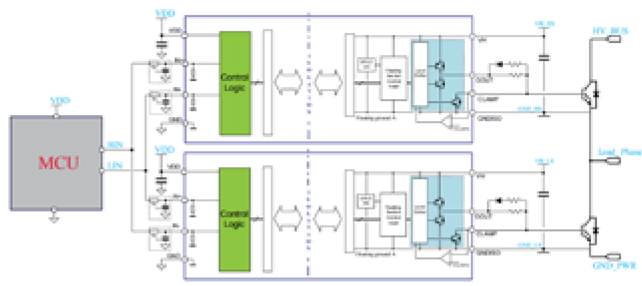

Figure 4: STGAP2SICS with a half bridge configuration and a combined gate driving path with additional miller clamp.

Taken out of [3] figure 5 and 6 show the difference it makes when optimizing the resistors in the gate driving circuit in terms of energy losses. The difference between having a 10Ω or a 1Ω is 250µJ in losses that can be eliminated. It also points out that the switching losses are not symmetrical that means for switching on losses are different to switching off. Also worth noting that in case a longer switch off time is needed for better EMI performance it does not hit the efficiency as hard as it does for switching on because the slope is lower.

And there is one more thing to point out when comparing IGBT with SiC. A major difference from SiC MOSFET's to IGBT's is, when the devices are switched off. To be completely switched off, the IGBT needs to sweep out its minority carriers completely. This last transport happens when the IGBT is already switched off and the voltage across the collector and the emitter is at its maximum and so it has a huge contribution to the switching losses of an IGBT. This effect, called tail current, does not exist with SiC MOSFETs and switching off can be done with less energy losses.

Conclusion

The parameters and properties that have been discussed in this article shine a light on certain aspects when doing power electronic designs. Current and future electronic designs such as battery charger, motor and solar inverter can hugely benefit from these new devices not only in efficiency but also in size enabling high-power, high-temperature operation. But it is not only the device's properties that make curious for new designs and the future its also the strategy of STMicroelectronics. Silicon Carbide (SiC) technology is part of strategy at STMicroelectronics, STPOWER, to invest in wide bandgap (WBG) technologies, which also include Gallium Nitride (GaN). The company dedicated a huge amount of resources to this technology, which promises a bright future and even better performing SiC devices which we all can be curious about and looking forward to.

Figure 5: Eoff vs. Rg at VDD=800 V, ID=20 A, VGS=-2 V to 20 V, Tj=25 °C as been tested and calculated in [3]

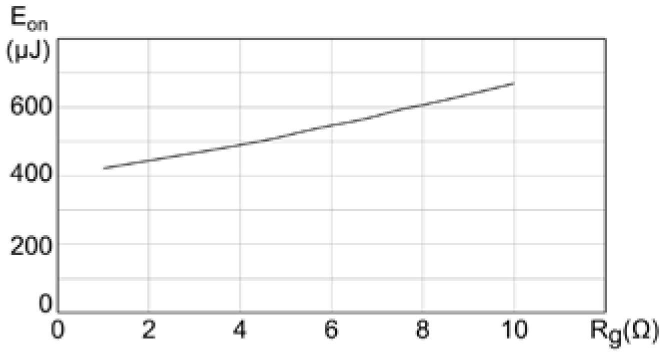

Figure 6: Eon vs. Rg at VDD=800 V, ID=20 A, VGS=-2 V to 20 V, Tj=25 °C as been tested and calculated in [3]

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Towards Future-Proofed Battery Solutions

A group of quality and certification managers at power supply and battery charger manufacturer Mascot, examines some current advances in battery technology.

Lithium-ion batteries have in the past few years become the preferred choice in a broad spectrum of applications. It is easy to see why. They tick the eight key requirements of the ideal battery, namely: high specific energy, high specific power, affordability, long life, safety, wide operating range, low toxicity and the ability to be charged rapidly.

By Dag Pedersen, Mascot AS

On top of that, lithium-ion batteries are highly versatile, boast high energy density and low self-discharge – below half of that of nickel-based batteries – and require little maintenance. They also fulfil the key requirement of any battery, which is the ability to provide instant start-up when needed.

But they have their limitations too: issues around transportation have become well-documented and lithium-ion batteries are also subject to aging, even when they are not in use, while a protection circuit is invariably needed to maintain voltage and current within safe limits.

Figure 1: The search for the 'perfect' battery solution continues unabated

Developments continue apace in lithium-ion batteries, specifically through the employment of single crystal cathode material instead of graphite. This is set to to deliver major benefits in the rapidly developing electric vehicle sector which is striving for the twin aims of ever greater battery capacities as well as longer service life, with 15 years a widely quoted industry target. However, the longevity of the most common Li-ion battery types in consumer applications such as mobiles, where they are typically charged to the maximum allowable voltage, is set to continue to be limited.

To help improve the specific energy of li-ion products, silicon nanowire anodes are being used which deliver enhanced watthours per kg (Wh/kg) – typically up to twice that of commercial Li-ion cells. However, like all Si nanowire-based structures, their cycle life is limited. Microscale Si islands can develop under the nanowire arrays, with cycling that results not only in stress and cracking, but also in capacity loss emanating from reduced contact with current collectors.

Unsurprisingly, the search for the 'perfect' battery solution continues unabated. With almost all battery types, development time is typically extended – 10 years is commonplace – with many concepts abandoned in the laboratory, and others having their initial launch dates put back, often multiple times, when these are found to be unrealistic. This extended development time makes battery manufacture an unattractive proposition for investors – meaning it takes real commitment and patient, understanding benefactors to bring a new type of battery to market. It is hardly surprising, therefore, that the successful launch of a new battery is not only a rarity but a major event – and that some proven technologies that were previously put aside for commercial reasons are enjoying renewed focus and investment.

One of these is sodium ion batteries. Advances in this technology area kept pace with lithium ion products in the 1970s and 1980s, but the spotlight turned to lithium from that point. However, with concerns over remaining global supplies of lithium, and associated higher costs, the search for more available and cost-effective alternatives has intensified. Sodium is the sixth most abundant element in the Earth's crust and can also be extracted from seawater, meaning that supplies are potentially almost infinite.

While not boasting the same energy density as lithium-ion batteries, there are notable advantages in the areas of safety and cost, with sodium able to operate across a broader range of temperatures.

Sodium ions have similar intercalation (charging) chemistry to lithium ions meaning many of the materials being tested for sodium batteries are similar to those used for lithium. However, graphite cannot be employed as the anode in sodium-ion batteries, as it is not energetically favourable to put sodium in between the individual layers. Some companies are using hard carbon anodes, with an $NaPF_6$ electrolyte.

The most widely seen design for sodium ion batteries is similar to the most common lithium counterparts: a sodium oxide cathode, a carbon-based anode and a non-aqueous solvent electrolyte. The manufacturing processes are also similar, so any factories producing lithium-ion batteries will be fully adaptable towards sodium-ion technology.

This is key given that one recent analysis by Bloomberg New Energy Finance forecast that demand for lithium will grow 1500 times by 2030. This has the potential to push prices for lithium higher, and making alternative battery types could then be an economic necessity rather than a novelty.

Performance is not an issue either. Indeed, in June last year it was revealed that one particular solution developed by a team from Washington State University (WSU) and Pacific Northwest National Laboratory (PNNL) was able to deliver a capacity similar to some lithium-ion batteries and to recharge successfully, keeping more than 80 percent of its charge after 1,000 cycles.

Transport is another possible application for the higher energy density types of sodium-ion batteries, typically those using non-aqueous electrolytes – in effect any application currently served by lithium-ion batteries. Power tools, drones, low speed electric vehicles, e-bikes, e-scooters and e-buses would all potentially benefit from the lower costs of sodium-ion batteries with respect to those of lithium-ion batteries at similar performance levels.

In the longer term, continued rapid development will see sodium-ion batteries deployed in very high-density applications, such as long-range electric vehicles and consumer electronics such as mobile phones and laptops, which are currently served by higher-cost lithium-ion batteries.

A number of companies have identified the potential of sodium-ion batteries and are committed to developments in this area,

Figure 2: The Blueline 3743 LA charger is one of an extensive range from Mascot which are suitable for charging sodium ion batteries as well as other battery types

Sodium ions are larger than lithium ions, meaning the energy density of batteries containing them is naturally lower, making sodium particularly well suited to stationary applications where battery size is less important.

Many of the first applications are likely to be as replacements for lead-acid batteries where sodium-ion technology can deliver much higher energy density and performance at similar cost. Such applications include smart grids, grid-storage for renewable power plants, car SLI batteries, UPS, telecoms, home storage and other stationary energy storage applications.

Any applications in extreme temperature locations – high or low – such as weather stations, field work, pipeline inspections equipment, communication links or the likes, are also suitable for sodium-ion batteries.

notably Faradion, Tiamat, Aquion Energy, Novasis, Nitron and Altris.

Any battery of course is only effective as how rapidly and safely as it can be charged. During charging of sodium ion batteries, positive sodium ions are extracted from the cathode and transferred to the anode, while the electrons travel through the external circuit; for discharging, the process is reversed.

The good thing seems to be that charging time is comparable with alternative battery types and that there is no need for specialist charging equipment – meaning that, depending on the application, a switch to sodium ion products can be made without significant cost or inconvenience in this area.

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Cascode GaN FET Dynamic Characterization

As we've discussed in a previous article, dynamic characterization of Gallium Nitride (GaN) power semiconductor field effect transistors (FET) present very difficult challenges because of their higher frequency operation and multiple variations of technology. One of the popular GaN device types is Cascode GaN FET, which provides even more difficult challenges with its oscillation prone device behavior. In this article, we specifically discuss how we overcome the challenges associated with Cascode GaN FET measurements.

By Ryo Takeda, Takamasa Arai, Bernhard Holzinger, Michael Zimmermann and Mike Hawes at Keysight Technologies

Challenges for Cascode GaN FET dynamic testing

Cascode GaN FET came into marketplace earlier than the other types of GaN power devices because it can provide normally off operation and has a wider gate drive voltage range. However, circuit designers found the device is not so easy to use in an actual circuit, because it is prone to oscillate and its device characterization is very difficult to measure and get repeatable extractions. Many designers must slow down the device operation with a large gate resistor when using it in their circuit, which reduces the benefit of using a fast speed GaN power device.

Figure 1 shows divergent oscillation at turn off. Figure 2 shows large gate voltage ringing at turn on. Both are related to the unique structure of the Cascode GaN device (cascode of a low voltage Si MOSFET and a high voltage GaN HEMT) shown in Figure 3.

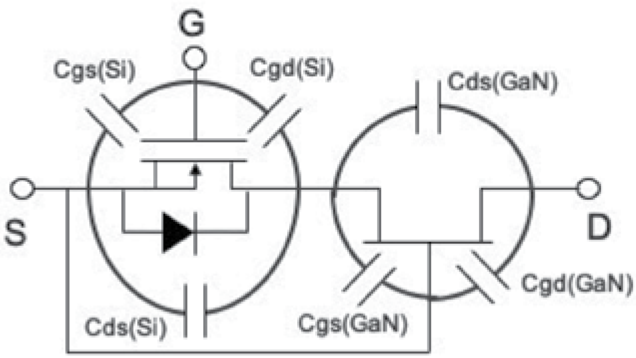

Figure 3: Cascode structure for high voltage depletion mode GaN device.

The divergent oscillation seen in Figure 1 is caused by the avalanche breakdown of the low voltage Si MOSFET in the structure. [1] The oscillation of V_{gs} seen in Figure 2 is related to V_{gs} unbalance due to the inductance between the MOSFET source and the GaN HEMT gate. The Cascode GaN FET dynamic characteristic measurements are important for both device manufacturers and device users (i.e. power circuit designers), because it is hard to use the device without knowing the condition to avoid oscillation.

Figure 1: Oscillation at turn off can destroy device and peripheral circuit.

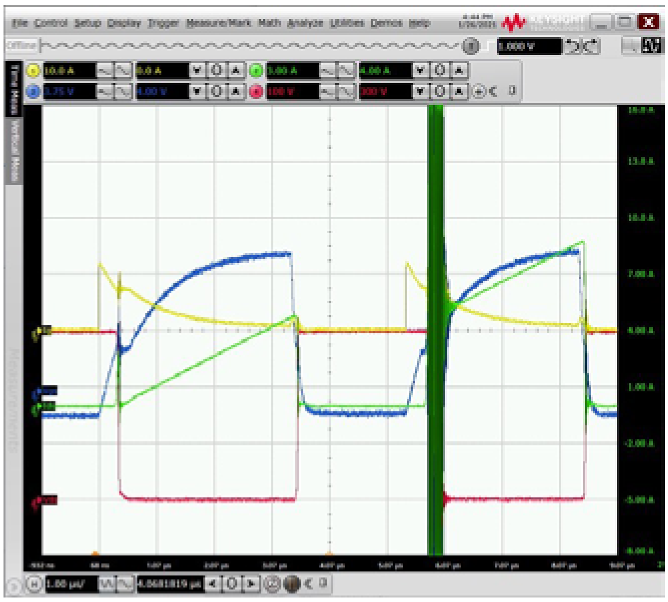

Figure 2: Large oscillation at turn on.

Key considerations when evaluating Cascode GaN devices
There are three important components to avoid oscillation when using Cascode GaN devices. One is a snubber circuit, the second is a ferrite bead and the third is the gate resistor (R_g) dependency. The RC snubber circuit consists of a resistor and a capacitor connected in series (i.e. a simple low pass filter). If it is attached between the drain and the source of the power FET, it can reduce or eliminate the sharp voltage rise when the FET turns off. It is important to use the RC snubber circuit to avoid oscillation. It is also important to find the right combination of resistor and capacitor by performing the double pulse test as it will be used in the actual application.

The Ferrite bead reflects and dampens high-frequency noise with its inductive behavior. If an appropriately sized ferrite bead is used, based on the noise frequency on V_{gs} during the double pulse test, the noise is cleanly removed. There is a chip type ferrite bead that has a spiral structure in the horizontal direction which minimizes stray capacitance and therefore, works effectively to suppress oscillation. Application notes published from Cascode GaN FET manufacturers recommend and describe the use of ferrite beads.

Another key characteristic to evaluate is the R_g dependency. R_g limits the current flowing into gate and therefore, controls the ramp speed of V_{gs}. The dependency is important when designing power circuits. However, exchanging R_g is not convenient, because the gate resistor for GaN power circuits is usually a SMD type to minimize stray inductance. Therefore, R_g should be soldered and unsoldered to measure the gate resistor dependency.

All three of the considerations described are very important for power electronics circuit design. It is desirable to have a double pulse test system that allows characterization of a device, including the ability to see effects of different RC snubber circuits, ferrite beads and R_{gs}.

Keysight's Cascode GaN FET dynamic characterization solution
Keysight's PD1500A Dynamic Power Device Analyzer/Double Pulse Tester has a modular architecture that accepts customized GaN test boards. As discussed in an earlier article, the customized GaN test boards have key enabling technologies such as a low inductance current sensor, a non-solder DUT contact, and AUTOCAL implementation for repeatable and reliable measurements.

For Cascode GaN devices, additional capabilities are provided to make its characterization easy and effective.

The customized test board for Cascode GaN FET is shown in Figure 4. The test board has ferrite bead terminals and a solderless contact for RC snubbers. An appropriate ferrite bead which suppresses high frequency energy is selected. For the RC snubber, you can attach or detach it using a through hole type connector on the board. You can find best RC snubber by measuring characteristics with various combinations. Figure 6 shows measurement results on a Cascode GaN FET with this board. The RC snubber used was a combination of a 15 Ohm resistor and a 33pF capacitor.

A solderless replaceable gate resistor mechanism is also implemented. The same board and the same DUT can be evaluated easily using different gate resistors. Figure 7 shows example results using the solderless replaceable gate resistor mechanism. The board shown in Figure 5 is for a TO-220 package device. If the DUT is a SMD package, a board tailored for the SMD Cascode GaN device can be made with solderless DUT contact technology.

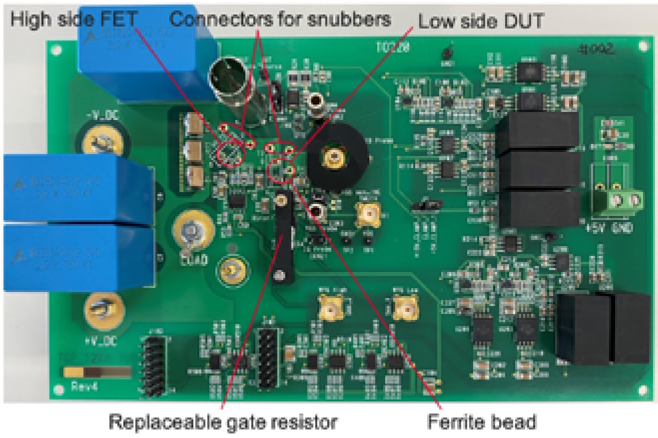

Figure 4: Test board for TO-220 Cascode GaN FET.

The board is plugged on to the PD1500A test fixture and is controlled using the PD1500A software user interface.

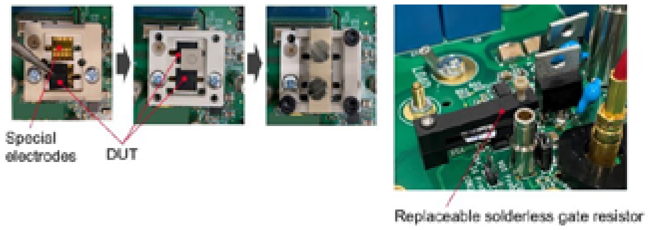

Figure 5: Solderless DUT contact & replaceable gate resistor.

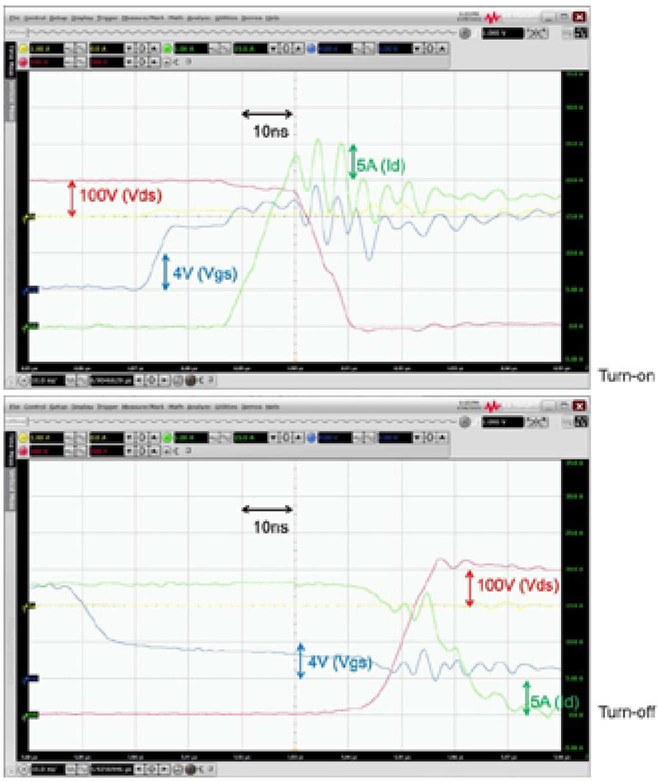

Figure 6: Test results for Cascode GaN FET (TPH3212PS) R_g=15Ohm

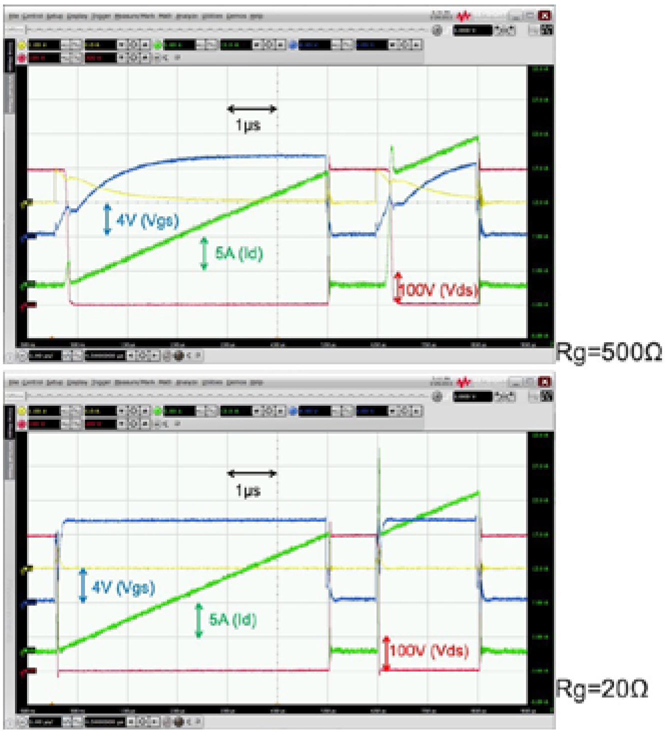

Figure 7: Test results with replaceable gate resistors (500 Ohm & 20 Ohm)

Summary

Cascode GaN FET dynamic characterization is challenging due to oscillation prone device structure. Finding a good operation condition is important for circuit design to take advantage of its superior performance. The PD1500A Dynamic Power Device Analyzer/Double Pulse Tester provides convenient ways to accurately characterize Cascode GaN FETs, using a customized test board to simulate operating conditions with the required peripheral circuitry. For more information, please follow this link or contact your local Keysight representative. https://www.keysight.com/find/pd1500a

References

1. Avoiding Divergent Oscillation of a Cascode GaN Device Under High-Current Turn-Off Condition, X. Huang, et. al, IEEE Trans. Power Electronics, Vol.32, January 2017.

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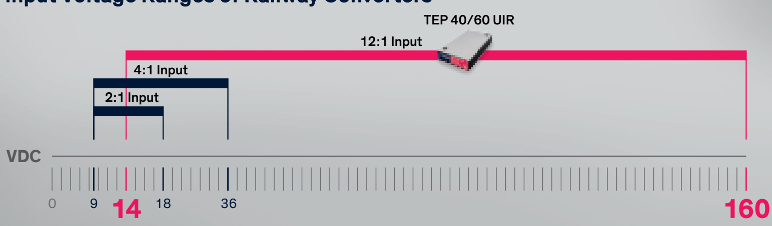
Input Voltage Ranges of Railway Converters



How Does Flyback Synchronous Rectification Affect EMI?

Due to the rapid development of mobile devices in the last decade, cell phone applications have expanded into every aspect of society. In day-to-day life, few people leave their cell phone, even for a few minutes. As a result, high battery capacity and fast charging speed has become one of the most critical features for cell phones, and the demand for adapters with higher power ratings and higher power density has increased exponentially.

By Siran Wang, Technical Marketing and Application Engineering Manager, Monolithic Power Systems

The old 5V/1A output specification has become obsolete. New designs are generally above 2A, with up to a 20V output. Most of the cell phone market leaders (e.g. Huawei, Oppo, and Vivo) have been promoting their high-power adapters as standard in-box accessories for years, and the market feedback has been very positive. In Apple's 2020 autumn press release, they abandoned their standard 5V/1A in-box adapter, which has stimulated another boom for the demand of aftermarket high-power adapters.

Flyback topologies are still the most popular solution for these high-power mobile phone adapters. However, synchronous rectification (SR), which can be accomplished through SR MOSFETs, is one of the major evolutions in adapter design due to this new market trend. Synchronous rectification has become the mainstream solution on the secondary side of adapters, replacing the conventional Schottky diode.

Synchronous Rectification Basics

Synchronous rectification solutions utilize a MOSFET for output current rectification. Compared to the relatively fixed forward voltage drop of a diode, a MOSFET's voltage drop is proportional to the current and turn-on resistance (see Figure 1). A MOSFET significantly impacts the conduction power loss of the rectification. In other words, by selecting an SR MOSFET with an ideal turn-on resistance, an SR solution can achieve better efficiency and thermal performance than a conventional diode solution, which is the most critical requirement for high-power adapter designs.

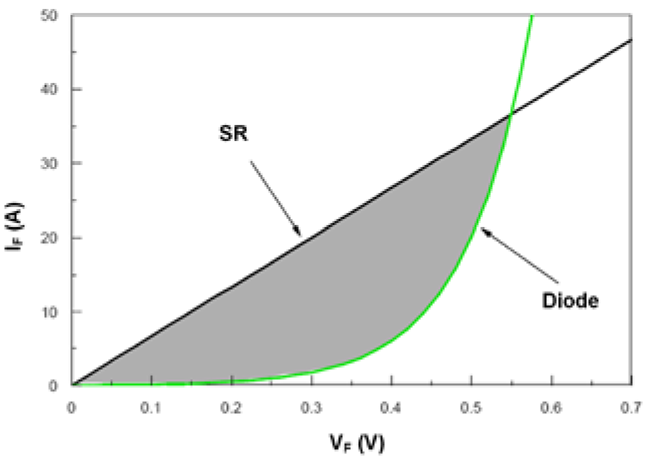


Figure 1: Difference in I-V Characteristics Between MOSFET and Diode

In a conventional flyback converter application with a Schottky diode on the secondary side, it is well known that the switching characteristic of the diode (especially the reverse recovery current) has a significant effect on the EMI performance. Therefore, it must be carefully dealt with in practical applications. After replacing the diode with a synchronous rectification MOSFET, the situation is completely different, because the MOSFET does not have a theoretical reverse recovery effect.

However, this does not necessarily mean that a synchronous rectification solution has fewer EMI problems. On the contrary, designers should pay more attention to how they design flyback solutions with SR, especially in regards to EMI noise source and the coupling path.

Synchronous Rectification Impact on the EMI Noise Source Amplitude

To understand the impact on the EMI noise source, SR operation principles must be discussed in greater detail. Most controllers drive the SR MOSFET based on the direct detection of the drain-source voltage (VDS), as this does not require communication with the primary side and reduces the total BOM cost. Figure 2 shows that there are usually two thresholds to control the SR MOSFET when it turns on and off. They are both negative voltage thresholds to guarantee that the SR MOSFET is always securely turned off when it is reversely biased.

As a result, there are short periods of body diode conduction at both ends: just before the device turns on, and after the SR MOSFET turns off. The timing control is critical for SR controllers, as these two periods can introduce extra conduction loss (with longer times being

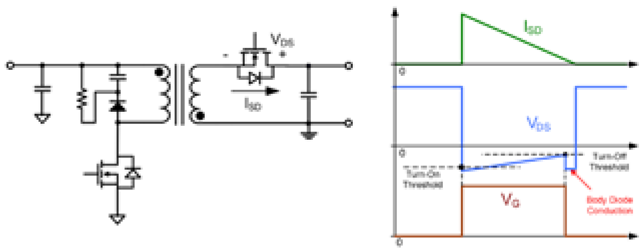


Figure 2: Basic Operation Principle of Flyback SR Solution

worse). In addition, but if the turn-off time is too long, it may lead to a severe reverse recovery current after the SR turns off, because of the poor characteristics of the MOSFET's body diode.

Figure 3 shows how the reverse recovery current of the body diode went up to 9A because of the SR's early 400ns turn-off, which then led to an 80V high-voltage spike due to the leakage inductance. It is commonly understood that EMI problems are closely related to the pulse amplitude and the slew rate of the noise source. This corresponds to a stronger EMI noise source on the secondary side of the flyback converter.

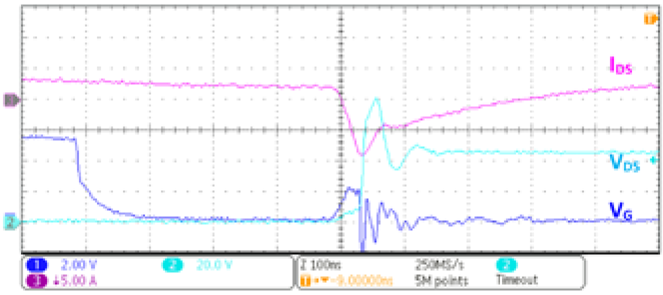


Figure 3: High-Spike Current and Voltage Caused by SR Early Turn-Off

A similar problem occurs if the SR turn-off is too late. Figure 4 shows the results if the SR is turned off after the current is reversed due to the propagation and driving delay. This leads to a short shoot-through period because the primary and the secondary MOSFET turn on at the same time. As a result, the negative current rises to a high 10A amplitude. This leads to an 87V high-voltage spike after the SR MOSFET turns off.

To mitigate these issues, it is vital that the timing of the SR turn-on and turn-off are both well-controlled. Figure 5 shows the MP6908, a, SR controller with intelligent fast turn-off from Monolithic Power Systems (MPS). As the market leader of flyback synchronous rectification controllers, the MP6908 implements the most advanced SR control scheme currently available in the industry. The precise and sophisticated signal process, proprietor gate voltage regulation, and super-fast turn-off speed enable optimized synchronous rectification timing control.

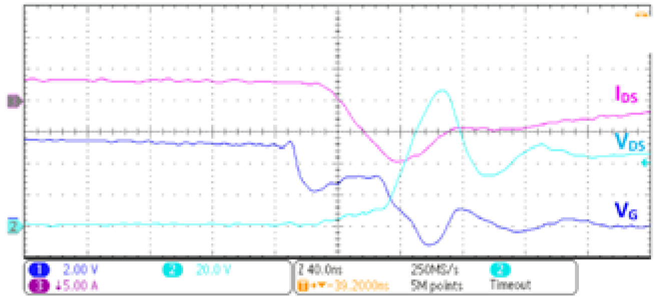


Figure 4: High-Spike Current and Voltage Caused by SR Turn-Off Delay

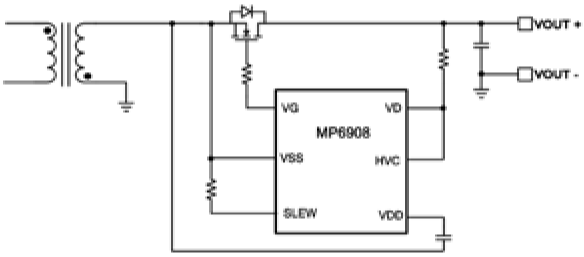


Figure 5: Typical Application of MPS's MP6908 in a Flyback Solution

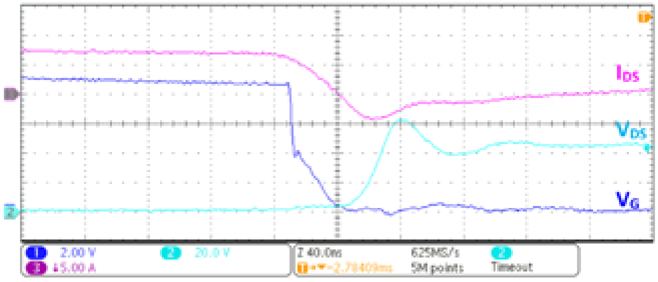
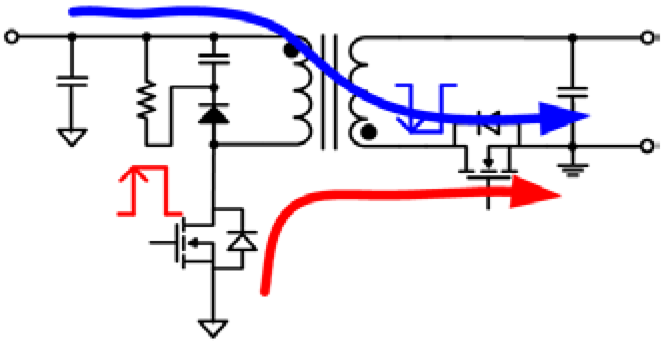
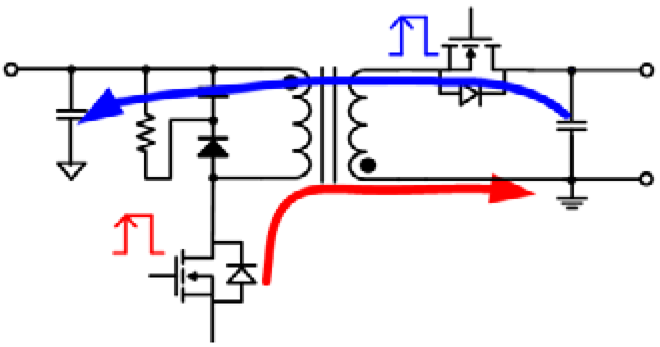


Figure 6: Low-Spike Current and Voltage with the MP6908's Optimized Timing Control



a) CM Noise Coupling Path with Low-Side SR



b) CM Noise Coupling Path with High-Side SR

Figure 7: Comparison between High-Side SR and Low-Side SR

The MP6908 demonstrates that by controlling the turn-on and turn-off timing, there is a relatively low spike in both current and voltage (4A and 62V, respectively) (see Figure 6). This results in reduced EMI noise.

SR's Impact on the CM Noise Cancellation Effect

In many flyback synchronous rectification solutions on the market, it is recommended to place the SR on the low side of the secondary side winding, because it is much simpler for the SR controller to get biased power directly from the output. However, the conventional Schottky diode is always placed on the high side, which implies there is some benefit to this location. In fact, there is a major difference between a high-side and low-side SR placement in flyback converters, regarding the common mode (CM) noise cancellation effect (see Figure 7).

Each side (primary and secondary) of the flyback converter has one main CM noise source, and that is where the switching device and the transformer winding are connected together (see Figure 7).

Figure 7a shows when the synchronous rectifier is placed at the low side. The primary CM noise source and the secondary CM noise source are on the winding ends with different magnetic polarities. As a result, the switching directions of the two noise sources are always in the opposite direction. Since the two noise sources are on opposite sides of the transformer, the CM noise each creates has an additive effect, thus making more noise.

Figure 7b shows when the SR is placed at the high side, and the two noise sources are on the winding ends with the same magnetic polarity. In this scenario, the switching directions of the two noise sources are always in the same direction, and there is a cancellation effect between them.

Based on these analyses about CM noise coupling, the high-side SR set-up has an obvious advantage over the low-side placement in terms of EMI performance. It is also very common to get a difference of 3dB or more between the high-side and low side set-ups in practical application designs.

Conclusion

Flyback adapter design with SR is different from conventional set-ups with a Schottky diode. When adopting an synchronous rectification solution, the two main expectations are improved efficiency and thermal performance. However, there are other aspects to consider, such as EMI performance.

With a well-controlled flyback synchronous rectification solution, designers can achieve better performance, a lower power device rating, higher product reliability, and minimize EMI noise. At the same time, devices like the MP6908 from MPS integrate an internal high-voltage regulator that can provide self-biased power without any external circuitry. When paired with a high-side SR set-up, these systems can also reduce BOM costs while developing more sophisticated adapter designs that are free of EMI issues.

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Self-Powered Modules for Measurement and Control in Medium Voltage Power Electronics

Future Medium Voltage Power Electronics solutions for measurement and control require a new approach that increases simplicity, reliability and safety while lowering total costs. Saker has been researching a multifaceted approach to this problem via self-powering. We call this technology TrueIsol and it means more than meets the eye.

By Enrique Ojeda, Founder, Saker Medium Voltage

Stating the problem

The main issue in dealing with MV is the electrical isolation needed to accommodate different system areas that are working at different reference voltages, and even voltages that are floating and have fast varying common modes. In practice this is a two-way problem since it affects both the supply of energy to power a module and the transmission of information, analog or digital to/from a ground referenced central control module. Figure 1 shows the traditional configuration in power electronics to power semiconductor drivers and other control/measurement modules. The isolation barrier shown will always be limited in dielectric strength and have parasitic capacitances that will show up as unwanted interferences in the control module when high slew rates are involved. Moreover most of the physical distance that separates the central control module and the measurement/control module is joined by copper cables that can pick up electric and magnetic fields in high-voltage high-current switchers.

Also the common mode voltage present in many measurements cannot be easily adapted to ground referenced control electronics. Floating measurements of voltages and currents are an ever increasing necessity with the implementation of cascaded topologies than can handle kV DC buses.

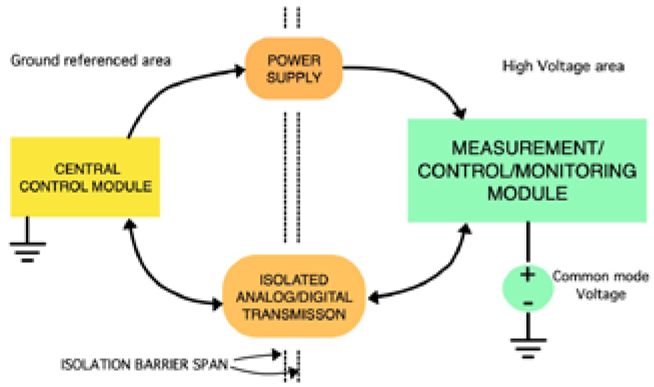

Figure 1: Traditional configuration of measurement and control modules in power electronics.

An example could be the continuous monitoring of Vce saturation voltage in an IGBT as it could provide valuable information about a bond wire lift-off event. Here two problems arise, how to power this monitoring circuit and how to transmit this floating analog measure to a control and monitoring module.

Another example is found in MVDC bus dischargers. If one is to develop a active switched discharger that draws zero current in the off-state and discharges the rail when activated then usually an isolated power supply is needed to overcome the difference in potential between a ground referenced control and the 2-pole floating MVDC rails. With a self-powered approach this isolated power supply would not be necessary.

The copper cables that connect on either side of Fig. 1 the isolated power supply and the digital/analog coupler (optical or capacitive) add weight, cost and increase the risk of ground faults. Optical communication with fibers can be used to increase the limited isolation of traditional couplers, and high voltage switching devices can eliminate the isolated power supply with the self-powering principle.

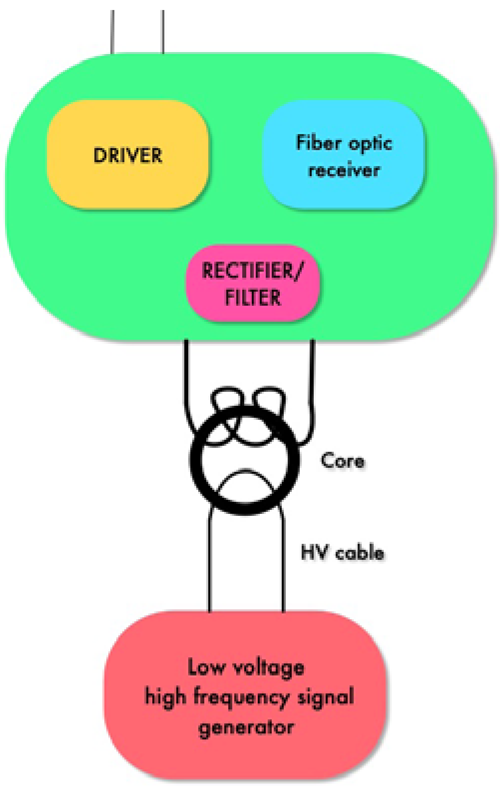

Figure 2: Long loop primary cable with multiple secondaries concept.


A better way to deliver power
for greater range
for heavier payloads
for longer run-time
for more security coverage

Current approaches to powering floating modules

Isolated power supplies. The widest available approach to providing energy to a floating module is that of the transformer. High switching frequencies are used to keep core size small and in recent years modules with high rated isolation have appeared in the market. The main drawback is that their size grows as common mode voltage grows due to isolation requirements.

High frequency primary loop. This is a particular case of transformer where a cable loop acts as a common primary to many secondaries. The primary consist of a high voltage cable that carries a low voltage high frequency signal and its wound around a magnetic core. A voltage is induced in the secondary that once rectified and filtered can be used to supply the internal electronics.

In this particular case the insulation between HV and LV parts is provided by the cable carrying the primary high frequency component. The drawbacks of this arrangement are increased complexity, especially in the case of constant current primary loop control, and radiated EMI from the HV cable loop in the primary that acts as an antenna. This approach is commonly used in drivers for thyristor stacks.

Power over fiber optic or PoF, is a technology in which a fiber optic cable carries optical power which is used as an energy source rather than carrying data. Usually more than one multimode fiber are used for this purpose. The receiver side is fitted with a photovoltaic unit that will generate electrical current to power up the necessary circuits. This system is however expensive, specially the power laser, the output power of the transmitting device degrades over time, and the output power is limited by the conversion efficiency of the photovoltaic module.

The concept of self-powering

Why transfer the energy needed for a certain module through an expensive and bulky barrier with limited isolation when there is enough energy in the MVDC bus rail or in "sub-rails" found in cascaded topologies, this is the main concept of self-powering. The name 'self-powering' may seem misleading to some, since the module is still taking the energy from outside of itself, but the main idea is that now the module becomes effectively independent from the rest of the system.

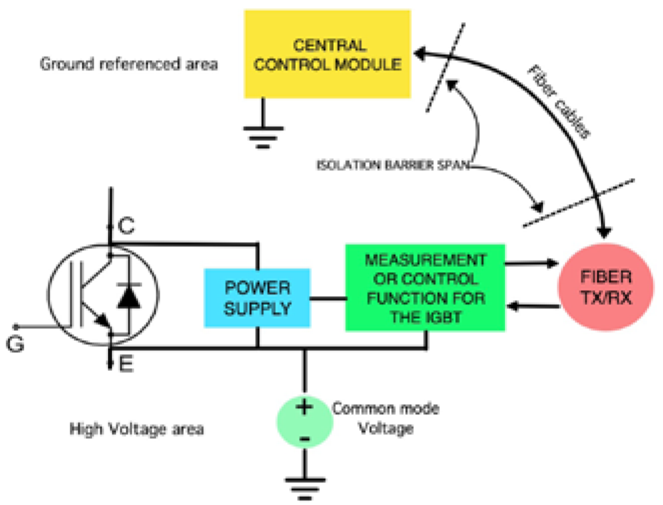

Figure 3: Block diagram of a generic self-powered module attached to an IGBT.

As mentioned not only is the main DC rail a source or energy, but also the floating "sub-rails" found in cascaded topologies, such us the anode-cathode voltage in thyristors or the collector-emitter in IGBTs. The switched nature of these "sub-rails", varying between the ON saturation voltage and the OFF blocked voltage state, only makes for a lower average effective voltage as seen from the outside. A schematic of this concept for a module that is connected to an IGBT is shown in Fig. 3. The module may have input or output fiber optic connectors to transfer analog or digital data. The main idea however is that now the module floats in the same way the IGBT does and the isolation between the ground referenced control and IGBT is provided by fiber optics with all their known benefits.

One of the first implications is that the power supply does not need to be isolated which is a great advantage and now suddenly the common mode at which the module is floating does not really matter neither how fast the common mode voltage swings.

Properties of self-powered MV modules

Future Power Electronic Systems designed with self-powered modules will enjoy advantages over traditional approaches. Some of these are:

1. Makes for an overall distributed solution. Self-powered modules can be considered independent from the rest of the system and thus distributed vs. a centralised solution. Their only interface with the rest of the system should be through fiber cables which can be considered as transparent in the electrical sense. The same characteristics of distributed systems do apply, for example the independent failure of components without cascading effects.
2. Inherent isolation, improved EMI rejection and measurement CMRR. The only interface between a module performing measurement/monitoring/control functions should be fiber optics. There are no parasitic capacitances through which fast slew rates can couple. All this allows for increased attenuation against common mode interference, improved signal integrity in high EMI environments or protection against over voltage impulses.
3. High-side and low-side solutions. Depending on how the power supply is configured respective to the rail it is connected to solutions to measure/control/monitor in high-side or low-side configuration are possible.
4. More convenient the higher the common mode voltage of the module. Traditional powering solutions based on isolated power supplies should be carefully designed based on isolation voltages and slew rate of the common mode voltage at the secondary. With a self-powered approach the concept changes and now what matters is only the maximum voltage of the bus at which the modules is connected to. Thus this approach becomes more convenient as the common mode voltage becomes higher.
5. Less copper, less weight. With self-powered solutions the amount of copper in the system is reduced creating not only cost and weight advantages but also overall safer solutions due to reduced probability of ground fault events. The weight/size advantage is readily noticeable when high dielectric strengths are required as compared to traditional approaches.

Multifaceted research area

At Saker we started exploring and experimenting with this idea some years ago. After some research and development of prototypes with inherent isolation via the self-powering principle we realized that the concept itself is more complex and ample than initially expected. From our point of view it is multifaceted and should cover at least the following areas of research:

1. Power supplies. These are non-isolated power supplies with a ratio between input and output voltage >300. Also the power should be kept very low to keep total dissipation low, to ease protection against input over-voltages and also because the lower the power the more reliable the power supply will be. In some cases these power supplies also have to withstand the same over-voltages that distribution power frequency lines do suffer. Traditionally the approach and research has focused on isolation for safety and efficiency for energy savings with large output currents. However the objectives to optimize with these power supplies are different and such are the topologies/configurations that we have found to be more apt. This area still has room for research and we have developed switched solutions not covered to our knowledge in the available literature. For one, the voltage rating of p-channel semiconductors is severely limited leaving only n-channel devices as viable switchers in power supplies with kV inputs. However the driving of high-side n-channel MOSFETs and IGBTs conveys extra difficulties, even more when a 100% working duty cycle is a necessity which makes driving transformers a no viable solution. Also, although the inductor has been used as the core energy transfer device in switchers, capacitive elements could also find room in helping with very high input-output voltage ratio power supplies. Figure 4 shows a prototype of a 2.5kV to 5V all switched approach using two 2-layer boards, shaped to be inserted inside a cylindrical insulator.

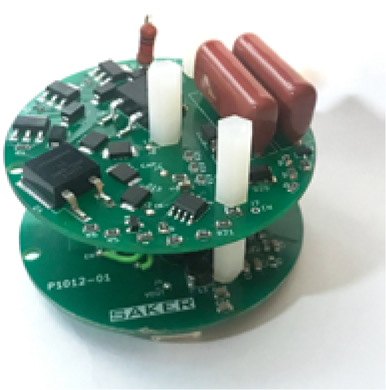

Figure 4: 2.5kV to 5V non-isolated switched power supply prototype, external inductor not shown. Input current is kept in the low mA range

2. Low power analog electronics. Having a low power power supply forces the analog measuring or control designs to run on very little current. Periodic demands in current can be smoothed out by the use of capacitors, but keeping quiescent current as low as possible should be a priority. Nowadays low power digital electronics knowledge is widespread, however very low power analog designs are not that common. Some low power analog designs even call for non-traditional solutions. For example ADCs are commonly advertised as low power, with some models consuming a few mW. However it is not mentioned that the generation of the clock and conversion signals needed to run these parts can take much more power than the ADC itself, so certain applications could enjoy another approach for analog to digital conversion, such as PWM conversion.

3. High voltage low current fuses. The power supply will be connected to a MV low impedance source, so in the event of a semiconductor failure within the power supply there is still a need to provide protection against a catastrophic event using a fuse. Power supplies used for self-powering modules do (and should) consume very little power, which in practice for a kV input means that the input current is going to be in the mA or even uA range. However low current (<30mA) and high voltage (>3kV) fuses are non existent in the market. At Saker we have been researching different approaches to this type of current limiting fuse. To this purpose we built a HV switch with a 15kV thyratron and a capacitor bank to be discharged through the tested fuse. Although it is an old element, it is easier to build and drive than a similarly rated thyristor stack if only for the lack of clamp requirement. Figure 5 shows the thyratron setup and figure 6 shows the current discharge profile for a certain experimental current limiting fuse connected between the thyratron and the capacitors charged at 6kV. The short reached a peak of 140A and did effectively cut in 1us. The event is so fast that it does not even produce any audible noise. Other approaches with lower peak currents are currently being tried although in practice fuses are tested with a certain X/R impedance ratio that limits the peak currents involved.

Figure 5: Test setup for a 15kV thyratron.

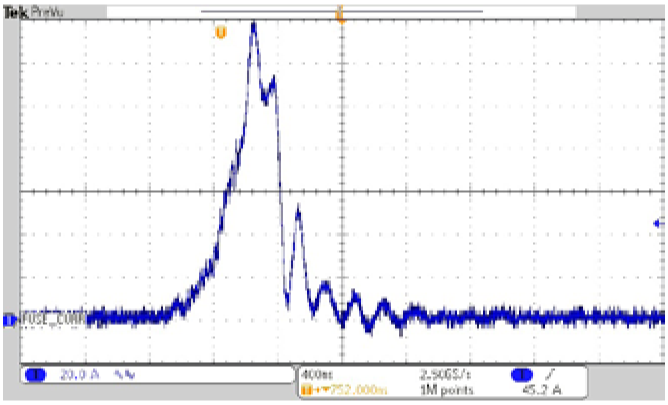

Figure 6: Current profile for an experimental fuse discharge at 6kV rail. Inductive oscillations can be seen at the cut-off tail.

4. Low power optical emitters/receivers. The current commercial offering in optical emitters/receivers does not meet the needs of low power analog designs with self-powering . At Saker we develop our own custom optical emitters/receivers and tailor them to the particular application at hand, for example receivers for simple ON/OFF control functions that run on less than 20uA quiescent current are possible. Not only current drawn by optoelectrical components should be improved but functions also. For example fiber cables are bidirectional, but mostly used in unidirectional way due to lack of commercial dual emitter/receivers in one package. Having the same fiber to transmit and receive can also have advantages from the system simplicity point of view.

We cannot stress enough how important it is to keep overall current consumed by a self-powered module low, as this will affect the size of the power supply, its reliability, the required protections needed to survive over-voltages and most importantly it affects the demands on how to obtain very high ratios (>1000) of input/output voltage.

Applications

Some possible areas of applications are:

1. Dischargers. MVDC switched bus dischargers that are optically controlled and are self-powered from the line that is to be discharged. This greatly simplifies design, cost and the optical isolation provides for virtually unlimited isolation.
2. Driving of semiconductors. Switching on and off of semiconductors could be accomplished by this approach as the blocked state provides enough voltage and energy to provide this function. The trigger signals and others such as error can be supplied by optical means. This solution would not have a practical limit in the number of stackable modules. However it would not suit continuous thyristor triggering in DC applications, unless operation above latching current is provided.
3. MV Sensors. The measurement of both AC and DC is possible with this approach and it would make for an overall cheaper and simpler installation than what is offered nowadays. The solution appeals AC networks for all the drawbacks that casted instruments transformers do have such as weight, ferroresonances and severely limited bandwidth. A direct interface to a control module via digital signals would even save ADC converters.
4. Control and monitoring functions. Various monitoring functions such as temperature or semiconductor saturation voltage monitoring or simple ON/OFF control functions are possible.
5. Power Quality solutions. Taking AC or DC measurements for PQ applications at medium voltage has never been easy due to isolation requirements and the difficulty in making floating measurements. Since self-powered solutions are inherently floating new measurements possibilities are possible in this area.

Conclusions

The development of modules for measurement, control and monitoring based on the self-powering principle for cascaded power electronics topologies brings a new horizon of research. This approach can spawn an array of new modules, lower manufacturing costs, enhance performance and ease system simplicity while increasing overall safety and reliability.

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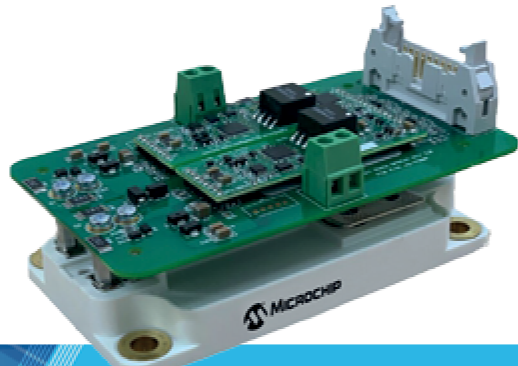

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Phase Shift Correction: It Takes Two

Phase shift correction in power analysis is like dancing a tango: it takes two – the power analyzer supporting the function as well as a suitable sensor with a known phase delay. If one of them is missing… well… just imagine that tango…

By Kai Scharrmann, HIOKI Europe

Using shunts to measure currents in power analysis might be an option for small currents, but when you look at measuring currents above 50A then typically current sensors come into play.

However, every current sensor in the world produces a gradually increasing phase error in the high-frequency region due to group delays of the circuitry. Additionally, differences in the design of various sensor models cause the magnitude of this error to vary.

A phase shift correction function allows to compensate this error. To make such a phase shift correction function work properly you need two things:

- A power analyzer making the correct calculations in its software
- A current sensor with a known phase shift

A good way to explain the calculations in the power analyzer software is by comparing it to the "deskew" function of an oscilloscope: If two different signals arrive at the oscilloscope at different times due to latencies then the "deskew" function lets you align those signals by compensating the latency with a fixed time value.

When you enter the phase shift correction value in a power analyzer like HIOKI's PW6001 then you basically do the same thing because phase shift is essentially a time delay between current and voltage.

Figure 1: HIOKI PW6001 power analyzer

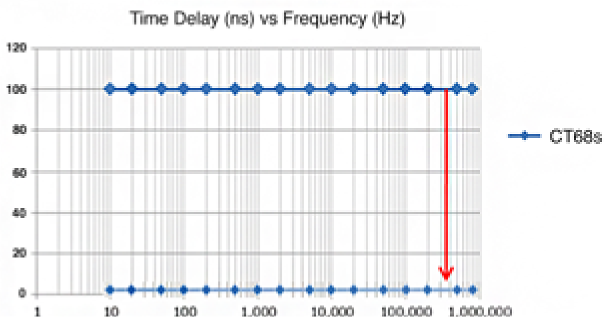

Figure 2: Time delay of HIOKI CT68 sensors

As an example, here is how this delay looks for a HIOKI CT68 series current sensor. The time delay is shown in nanoseconds against the frequency in figure 2.

100ns delay at 100Hz doesn't have the same impact as 100ns delay at 1MHz. This becomes clear when translating the above time delay into phase delay values described in degrees (see figure 3).

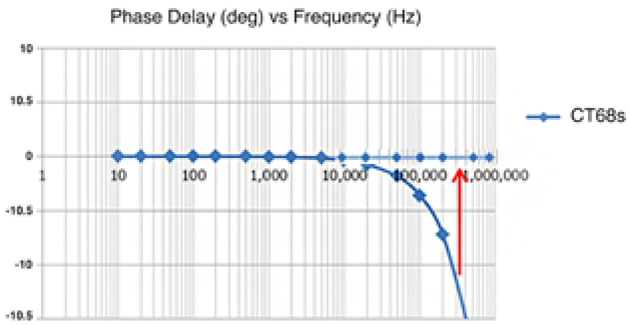

Figure 3: Phase delay vs frequency

Figure 4: HIOKI current sensors

To make things as straight forward as above of course you need a current sensor where the time delay is the same regardless of the frequency. With HIOKI current sensors like the CT68 series this is the case so coming back to the deskew function you only need one value to compensate the phase shift of the sensor.

This is one of the things that makes HIOKI sensors special – but it is not standard for current sensors currently on the market. Here is what would happen with a typical current sensor (see figure 5).

A sensor where the time delay values are different depending on the frequency will make the phase shift compensation in a power analyzer much more difficult. Because which value do you use as your "deskew" parameter?

Another thing that makes HIOKI current sensors special is that for the phase delay it is not relevant where your wire core is located within the sensor when you make the measurement (see figure 6).

The reason why you can only see one single line in the chart is because the phase delay curves for all five measurement positions are the same. Again, this is not a standard feature for current sensors on the market. Typically, the position of the wire core within the sensor does make a difference as you can see in graph 7.

As you can see there is no phase shift compensation without a power analyzer to support the feature. But as you can also see only the combination of power analyzer and suitable current sensor allows you to perform a proper phase shift compensation in your measurements.

HIOKI has been concentrating on making sensors for power measurement for many years so time delay characteristics have always been a focus point for HIOKI's engineers. At the same time sensors from other manufacturers are typically only designed for accurate (DC) current sensing where phase delay characteristics are less important.

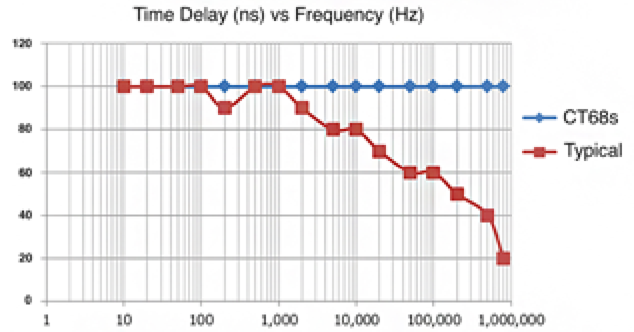

Figure 5: Typical sensors compared to HIOKI CT68 series

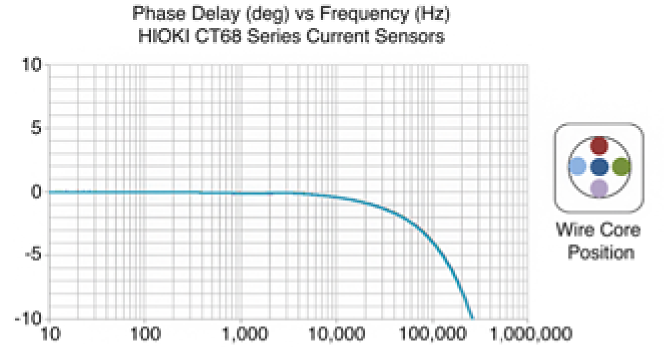

Figure 6: HIOKI CT68's phase delay and wire core position

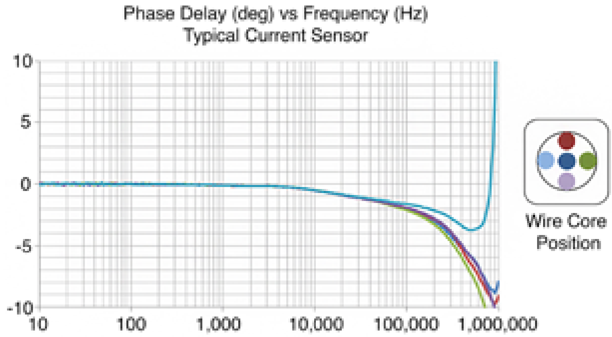

Figure 7: Typical sensor's phase delay and wire position

Figure 8: Power Analysis - it takes two...

Therefore HIOKI power analyzers together with HIOKI current sensors are the perfect combination for your wide-band power analysis applications from DC to high frequency. Because like with a tango it takes two.

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How Silicon Carbide Is Improving Switched Power Converter Designs

When it comes to designing power converters, wide bandgap (WBG) technologies such as silicon carbide (SiC) are now a realistic option during component selection. The introduction of 650 V SiC MOSFETs has made them more attractive for applications where they would not have previously been considered.

By René Mente, Senior Staff Engineer, Infineon Technologies

Their superior robustness in efficient hard-switching topologies makes them ideal for implementing the Power Factor Correction (PFC) stage of power solutions reaching into the kilowatt range. And, thanks to the higher switching frequencies supported, smaller magnetic components become an option, delivering a welcome reduction in volume to many designs.

No such thing as a free lunch

While the benefits are many, their attainment is not achieved by merely dropping a SiC MOSFET into the gap left by removing a silicon equivalent. Engineers need to take time to understand their characteristics to gain full advantage of the change while also understanding their different limitations and failure modes. The forward voltage of the body diode in a CoolSiC™ device is four times greater than that of a silicon MOSFET. As a result, an LLC converter could see a 0.5% drop in efficiency at light loads. High efficiencies in PFC topologies are also attained by boosting through the channel rather than the body diode.

On-resistance on par with silicon at operating temperature

One key comparison parameter is the on-resistance, $R_{DS(on)}$. Silicon MOSFETs look better than SiC on paper but, thanks to their lower multiplication factor (κ), an 84 mΩ CoolSiC™ device achieves the same $R_{DS(on)}$ as a 57 mΩ CoolMOS™ device at 100°C (Figure 1). CoolSiC also offers a higher breakdown voltage, $V_{(BR)DSS}$, than silicon MOSFETs, which is useful in applications that start-up in low-temperature environments.

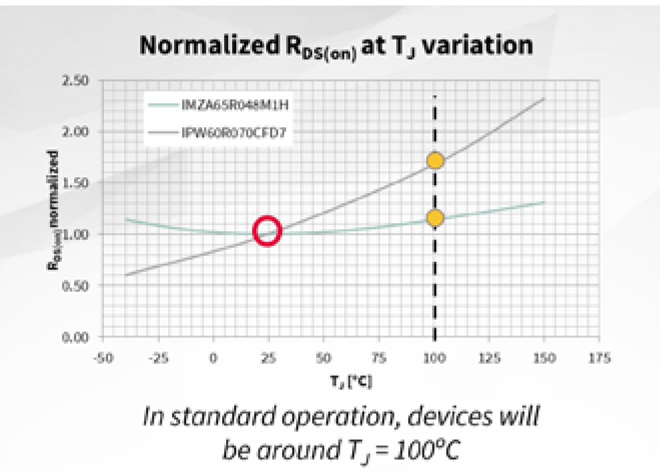

Figure 1: The influence of temperature on $R_{DS(on)}$ is lower for CoolSiC™ than CoolMOS™, resulting in a similar on-resistance at typical operational temperature.

The EiceDRIVER™ family remains the ideal companion to CoolSiC™ MOSFETs. However, to attain the low $R_{DS(on)}$ defined in the datasheet, a gate voltage (V_{GS}) of 18 V, rather than the typical 12 V for silicon MOSFETs, is needed. If a new gate driver is being chosen, it is worthwhile selecting one with a 13 V undervoltage lockout to ensure safe operation under abnormal conditions of the target application. A further benefit of SiC is the limited impact temperature has on the transfer characteristic between 25 °C and 150 °C (Figure 2).

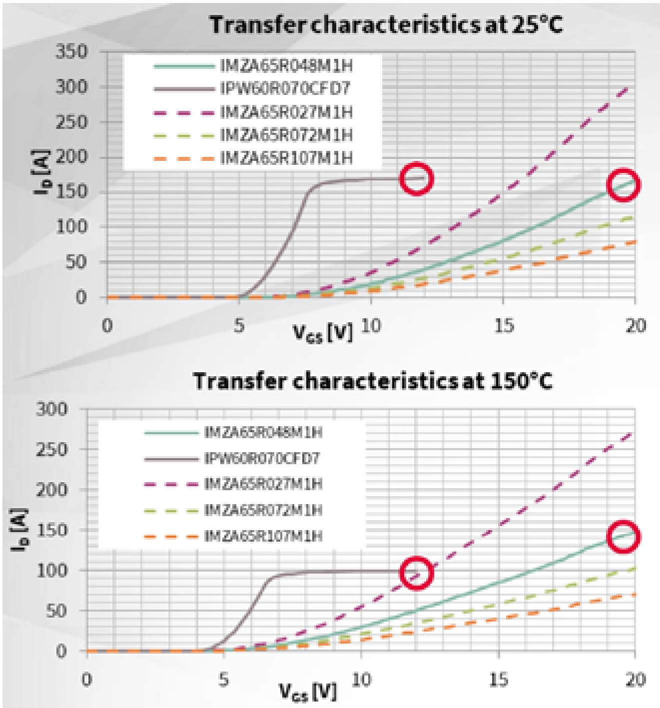

Figure 2: The transfer characteristics at 25°C (left) and 150°C (right) show a significantly lower impact for SiC devices than silicon MOSFETs.

Avoiding negative gate voltages

Negative gate voltages can result in a long-term degradation of the SiC MOSFET that can result in latent failures. Thus design engineers should ensure that V_{GS} never drops below -2 V for more than 15 ns. Should this occur, a drift of the gate threshold voltage ($V_{GS(th)}$) can result that also increases $R_{DS(on)}$ over the lifetime of the application. Ultimately this leads to a drop in the hard-won system efficiency gains, the key reason for choosing SiC in many cases.

A high-value resistor is typically used with silicon MOSFETs to combat negative V_{GS}, thereby slowing di/dt and dv/dt. However, for SiC devices, the preferred approach is to insert a diode voltage clamp between gate and source. If the negative voltage is purely an inductive issue, selecting a CoolSiC™ device with a Kelvin source is highly recommended. This can result in E_{ON} losses three-times lower than a device without it (Figure 3).

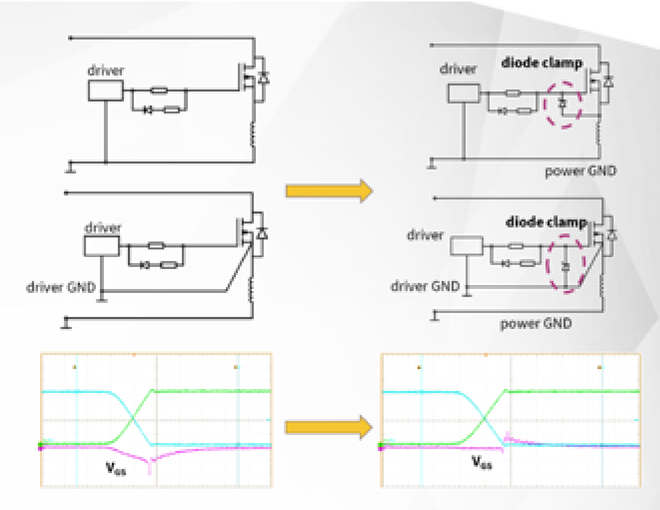

Figure 3: To avoid that the gate of a SiC MOSFET goes negative, a diode clamp, separate commons, and a Kelvin source should be considered.

Pushing beyond 99% efficiency

A further advantage of CoolSiC™ MOSFETs is their higher output capacitance, C_{OSS}, at drain-source voltages, V_{DS}, above around 50 V. This delivers reduced levels of overshoot without needing to implement a gate resistor. The Q_{OSS} behavior of SiC technology also benefits hard and resonant switching topologies as less discharging is required, something that impacts E_{on} losses in CCM totem-pole PFCs. Using 48 mΩ devices, efficiencies of over 99% for a 3.3 kW CCM totem-pole PFC can be attained (Figure 4) where the best possible efficiency using CoolMOS™ in a dual-boost PFC design peaks at 98.85%. And, despite the higher cost of the SiC MOSFETs, the SiC-based design is more cost-competitive.

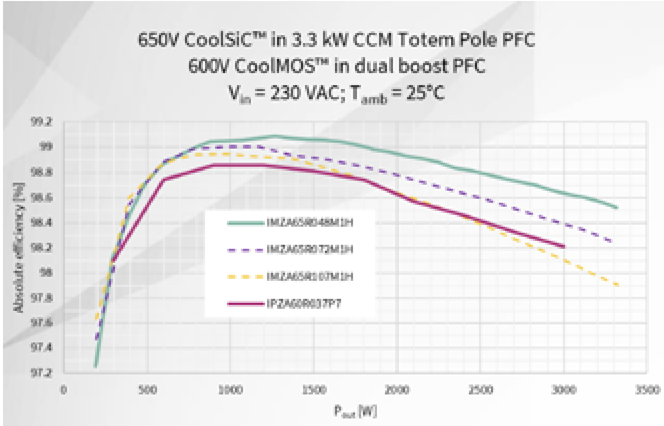

Figure 4: Even a 107 mΩ CoolSiC™ CCM totem-pole PFC comes close to 99% efficiency, mostly outperforming the best CoolMOS™ dual-boost PFC approach.

Summary

SiC MOSFETs offer a range of advantages over silicon alternatives that, coupled with its robustness in hard switching applications, make it worth considering in the most efficient power conversion applications. The 650 V CoolSiC™ family's introduction makes SiC MOSFET technology more economically viable for those pushing power conversion to its limits.

www.infineon.com/coolsic-mosfet-discretes

www.infineon.com/WBG

Industry Predictions for 2021

Vicor released its industry predictions for 2021, covering 4 areas: Automotive, High-Performance Computing, Aerospace & Defense and Robotics.

By Nicolas Richard, Lev Slutskiy, Teo DeLellis, and Henryk Dabrowski, Vicor

The accelerating speed of innovation is driven by changing habits and reset priorities due to the pandemic. Vicor's experts present examples, where existing trends will significantly accelerate and place greater stress on the use and development of efficient, compact, modular-based power delivery networks (PDNs).

Automotive – Covid has accelerated move to Electric Vehicles and Migration to 48V systems by Nicolas Richard, Vicor's Director of EMEA Automotive Business Development.

Transportation has been among the hardest hit by the global pandemic. Fewer people are commuting and traveling long distances. The Automotive industry has seen a rapid decline in sales, and forecasts show this slowdown extending well into 2021. Manufacturers have responded by placing increased focus on growth segments, specifically electric vehicles. While they have cut back development on traditional cars, they are moving ahead with EV developments focusing technology that delivers competitive advantage. While there are fewer commuters, surveys show that people feel much safer using their own cars rather than using public transportation. Consequently, we believe this will accelerate the need for cost-effective electric vehicles, so the trend to replace 12V PDNs with 48V PDNs will significantly accelerate with the increased focus on deeper investment into EV development.

2021 will see more 48V battery systems, particularly in mild hybrids, as manufacturers add active suspension, rear wheel steering or antiroll stabilization systems. Supporting this move, more 48V systems will need to convert down to 12V to support car safety, comfort, infotainment, and navigation systems. In addition to enabling lighter cabling or delivering higher power, the conversion from the high-voltage batteries in HEVs and EVs is more efficient when the step down required is reduced by increasing the voltage to 48V. Primary battery voltages used to power EVs and HEVs will also increase in voltage with 800V becoming much more common allowing faster charging time. These changes demand a new class of power components to create the power distribution network within next year's automobiles.

Figure 1: NBM6123 – Scalable 800V <-> 400V DC/DC 6.4kW

With 400V and 800V based charging stations being deployed, vehicle compatibility with any station requires simple and efficient conversion between the two voltages. The NBM6123 provides 6kW of 400V and 800V fixed-ratio conversion in a 63 x 23mm CM-ChiP package, enabling a high-efficiency and high-density scalable solution for battery-to-charger station compatibility. The bidirectional capability of the NBM6123 allows the same module to be used for either step-up or step-down conversion. In addition, the NBM6123 can also be used to provide a 400V source for air conditioning and cabin electronics during 800V charging, minimizing battery balancing circuitry.

New 48V based power delivery networks need to support legacy 12V loads with increased power requirements and new drive, steer and brake-by-wire high power systems. Providing increased power at 48V with a growing number of loads requires high-density modules versus larger and bulkier discrete solutions. Vicor offers several modules for power delivery from 48V. These devices include fixed ratio and regulated converter solutions that support both 48V and 12V loads. These converters can be contained in a single housing or be deployed throughout the vehicle leveraging a smaller and lighter 48V power distribution network. DCM and PRM modules provide 48V to 12V and 48V to 48V regulated outputs, respectively. The NBM provides either 48V to 12V or 12V to 48V bidirectional, fixed ratio conversion.

High-Performance Computing – Data Center Capacity Demand Will Exceed Physical Plant Space by Lev Slutskiy, Vicor's Regional Manager.

Data centers were already growing at a rapid pace, but the pandemic has accelerated data center demands beyond previous forecasts and will continue as a permanent increase even after the coronavirus has abated. More people are working at home, more students are attending school at home, and with fewer options for leisure time outside the home, more people are streaming videos and playing on-line games. We have experienced how critically reliant users are on the datacenter metropolitan backbones enabling todays telecommunications infrastructure. In 2021, the quest for more power efficiency in the datacentre will step up a gear where we believe not only will the datacenter industry purchase more renewable energy than in previous years, but we anticipate more datacenters moving away from Alternating Current (AC) in favor of Direct Current (DC) infrastructure solutions to better cope with the massive increases in power demands of high-performance computing.

This rapid and unanticipated acceleration in demand is outpacing the ability to expand physical capacity in data centers; therefore, data center operators will need to pack more capacity into the existing rack space. That has significant implications for power delivery. Being able to deliver power more efficiently and within the same rack footprint with excellent thermal management is more essential than ever. AI, cloud and big data are driving demand for much higher processing power resulting in far higher energy consumption and higher currents, which in turn lead to increased losses of electricity due to power conversion and transformation processes. A third area for significant

change in power innovation within the Datacenter will be in terms of power delivery and power efficiency at the cabinet and rack level to deal with the increased computing power (multiple exa-FLOPS) needed to enable the cloud, AI and big data applications.

A more efficient way to manage power is to increase the voltage within these systems and to use direct current either after alternate current rectification or directly from a source of renewable energy. The task of conversion of the high voltage (usually 260 – 410 V DC) to the values used at the input of modern computing units (12V or better 48V) could be performed by bus converters. We believe that system designers will use more of these innovative architectural solutions, such as Factorized Power Architectures (FPAs), and efficient converter modules to shorten the distances between the high current supplier module to the point of load (PoL), to lower PDN resistance which will minimize power loss in future supercomputing applications. Several major high-performance computing (HPC) manufacturers, such as Nvidia who was recently been listed in the #1, #3, #4, and #5 spots on the 'Green 500 list', have moved over to this approach in effect turning the datacenter green from the inside out.

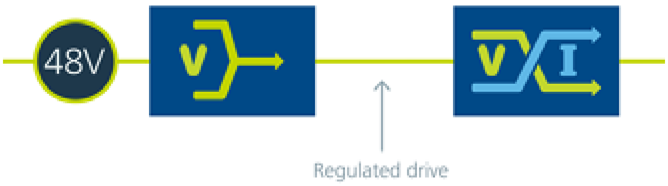

Figure 2: Factorized power regulation and transformation stages

Military and Aerospace – The big three drivers of change for 2021 will be the pandemic, hypersonic missiles, and asymmetric warfare by Teo DeLellis, Vicor's Business Development for Aerospace.

As a result of the massive investment to combat Covid 19, governments around the world have had to reprioritise and shift economic support to help communities, businesses and citizens deal with the impact of the pandemic. A recent study by Janes in June 2020 highlighted that defence spending is down among NATO's top European spenders. Consequently, as we enter 2021, there will be incredible fiscal pressure on governments to redirect funds away from traditional budget strongholds, such as defence, to shore up national economies, social welfare and other important endeavours.

This shift is in direct contradiction to the geopolitical pressures of rising nationalism on many levels. An example of this is Sweden's decision to increase military spending by 40% as tension with Russia grows.

We believe that technology and innovation will need to pick up the shortfall between these contradictory pressures enabling governments to do much more with less while maintaining military readiness with new digitally enabled technologies. In the U.S., the hypersonic missile threat from Russia and China has kicked both our missile defence and offensive missile programs into a higher gear which will result in innovation first envisaged as 5 years away to happen this coming year. Asymmetric warfare which will also be an important driver of change in 2021 as the "drone swarm" attack scenario puts high value targets at risk from low value drones, and taking out a $1,000 drone with a $100,000 missile is not sustainable. This will drive technological advances like integrating AI more into defence systems and deploying lasers to deal with the rise of drone swarms more effectively. Drone technology will continue to dominate the landscape of reconnaissance as power supply technology will help missions to go further and longer than before.

Figure 3: Vicor-DCM5614-VIA

Robotics – European Drone and robot sightings set to reach 747 Million in 2021 by Henryk Dabrowski, VP Sales for Vicor in EMEA.

By the end of 2021, for every woman, man and child in Europe there will be at least one sighting of a delivery robot or drone on its way to dropping off a package or disinfecting public spaces as a part of our fight against the pandemic. Robotics will also see significant innovation acceleration as businesses look to robotics to safely engage with customers and perform tasks without exposing people to the coronavirus. To meet demand, robotics developers will need to leverage existing designs, treating them as platforms, rather than trying to develop new robots from the ground up. Scaling platforms will require power scaling to meet different sizes and capabilities of robots. A modular, scalable approach to power delivery will be critical to meeting this challenge.

One of the key factors to expanding automated delivery services will be range and weight of the robot or drone. Vicor enables designers to lighten their drones for performance and manage power in such a way that the drones can fly further and more reliably than ever before. We predict that denser populations in Europe's cities will see many more bots than drones, while more remote areas such as Alps will see more drones help with crisis issues and delivery of vital medical supplies, while heavier deliveries will be supported by autonomous trucks. In Europe, Tescos, Amazon, DHL and UPS have all began trials with delivery drones and we see the recent pandemic as the tipping point to push retail towards a complete digital transformation. The convenience of home delivery that people have become accustomed to during lockdown will mean that in-person shopping at your favourite store or supermarket will not return to pre-pandemic levels. The use of robots rolling around the streets, and drones in the air will enable retailers to provide deliveries at even lower cost. In China, drones have already begun deliveries to remote parts of the country, and we see accelerated progress with logistics companies achieving permissions from national flight authorities to allow for retail air travel via drone.

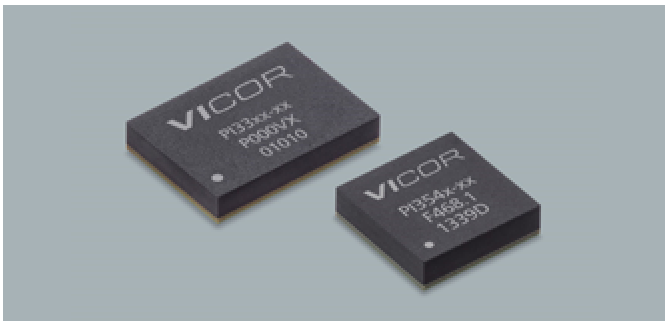

Figure 2: ZVS Buck

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Reliability Challenges of Automotive-grade Silicon Carbide Power MOSFETs

In this article, a discussion is given about testing and related results of Silicon-carbide power MOSFETs for automotive applications. It reports mainly about trends, testing for wear of components, and testing for abnormal conditions. In summary, the main challenges are related to the cost of raw material, stable high-temperature operation, and high current density. However, the scenario is very dynamic and major changes are expected in the coming 2-3 years.

By Francesco Iannuzzo, Aalborg University, Denmark

Introduction

Because of the roadmaps worldwide toward society decarbonization, Power Electronics has boomed in the last twenty years. The reason for this is that the production, storage, and consumption of green energy are typically delocalized and need many more intermediate conversions than the ones from traditional fossil fuels. An example of an application of power electronics is the electricity generation from wind. In such an application, reliability/security of supply is an intrinsic issue, along with challenges related to the efficiency, the cost of energy, the volume of converters, and their protection. Such systems are also typically more complex than the fuel-powered generators, hence they require special control efforts involving e.g. active- and reactive power management, resiliency against grid sags and condition monitoring. Wind power is an example of an intrinsically power-electronics-enabled resource: the rotor speed of a wind turbine varies depending on the wind intensity, and transferring the gathered power to the grid at constant voltage and frequency would not be possible without power electronics. Another example comes from heavy-traction applications. ABB has presented a power-electronics traction transformer (PETT) in 2014 [1], where the goal was to replace the bulky and massive line-frequency iron transformer abord trains with a lighter and more efficient version based on power electronics. Mitsubishi has presented in the same year a retrofitting project for the Odakyu 1000 series train with the main power train based on SiC MOSFET modules [2].

In automotive, high-power modules are more and more demanded because of the increasing number of energy conversions need to run a modern hybrid or full-electric vehicle. Typically, three main converters are needed, namely the battery charger, the motor drive, and the auxiliary services converter. A higher frequency is a key challenge here, driven by demand for lower volume and higher efficiency. Other very important challenges are higher operating temperature and higher robustness, i.e. longer lifetime, short-circuit- and over-current withstanding capability, which often demand highly customized and integrated solutions.

Silicon carbide (SiC) is historically known for its mechanical properties, in particular its hardness, which is the second-highest in nature after diamond. As a semiconductor, SiC exhibits outstanding properties that overtake traditional silicon in terms of bandgap, breakdown electric field, saturation velocity, and thermal conductivity, which make out of it a great candidate to compete with silicon in the power-electronics arena [3]. According to Yole/Systemplus, the SiC device market will have a compound annual growth rate of 40 % in the next 4 years [4]. Many players are present in the field, namely CREE/Wolfspeed, ROHM, ST, and Infineon, and almost all the power electronic component manufacturers have SiC devices in their portfolios. Nowadays, both discrete and module versions are available, and a 3rd generation is already available since 2017, which uses trench-gate technology. The landscape evolves very fast. For example, CREE has invested 1 billion USD in 2019 for a new production fab [5].

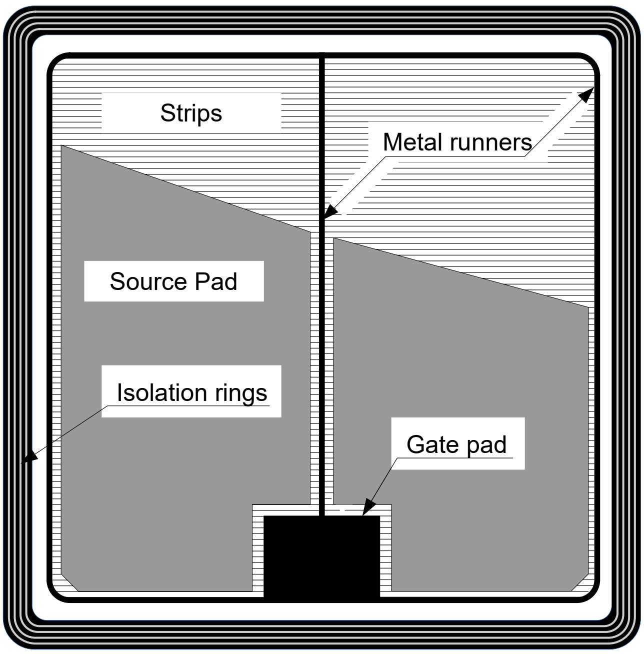

Figure 1: A typical power MOSFET chip structure. The drain contact is on the back side (not visible in the picture).

According to a recent market forecast from Yole Développement, the automotive market is to drive both the technological and market development in power electronics in the coming decade [6]. The expected operating life of automotive-grade components is around 15 years or 300,000 km, which can be translated into an expected life of 10,000 operation hours. In such a demanding scenario, it becomes crucial to test for reliability.

Power-cycling testing of SiC MOSFETs

There are two fundamental approaches for packaging of power-electronic components, i.e. discrete packaging and module packaging. The first one has no electrical isolation, hence an external isolation layer must be provided, whereas the second one has a so-called direct-bond copper (DBC), or substrate, which provides this feature. Another main difference is the isolation filler, i.e. transfer-molding resin in discrete packaging, and silicone gel in modules, although there may be found some different solutions, especially in custom designs. However, in either case, one or more semiconductor devices ("chips") are present, which are the core of the power electronic device. A chip has typically a sandwich-like structure, where a top layer made of metal is the source contact, and the bottom layer is the drain contact (see Figure 1). The bottom layer is glued on the substrate with a solder paste or, more recently, with a silver-sintered layer. The top layer is usually contacted using metal bond wires.

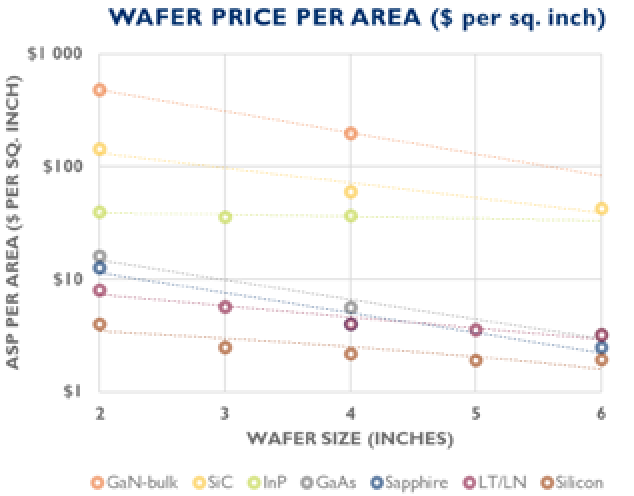

Figure 2: Wafer price per area of several semiconductor materials for power electronics [7].

Figure 2 shows the cost per square inch of modern semiconductor materials [7]. As it can be noted, the SiC price is still above 10x higher than silicon, which constrains the development of devices with this technology. Such a constraint forces component designers to reduce significantly the chip area, which, in turn, produces two other consequences: a) a smaller area for bond-wire footprints, and b) a higher power density, hence a higher temperature swing. The two above issues are related to packaging. On top of them, an issue intrinsically related to the SiC semiconductor itself needs to be mentioned, i.e. the larger bandgap requires a higher electric field at the gate oxide that can cause electrical instabilities.

Degradation in SiC MOSFETs can occur at two main levels, namely packaging- and semiconductor level.

Packaging degradation

The increase in the semiconductor current density implies an increase in the bond-wire current density. To investigate such an effect, Figure 3 displays the usage of a Kelvin-source connection for monitoring the bond-wire voltage drop during power cycling [8]. Two SiC-MOSFET modules, namely A and B, were subjected to power-cycling tests under the conditions reported in Table 1. The maximum and minimum temperature, the temperature swing, and the timing were kept the same. The only difference was the load current. The results show that the current density has an impact on the series resistance (see Table 2). The sample with the higher current has shown a larger increase in the series resistance, although all the other testing parameters were kept the same.

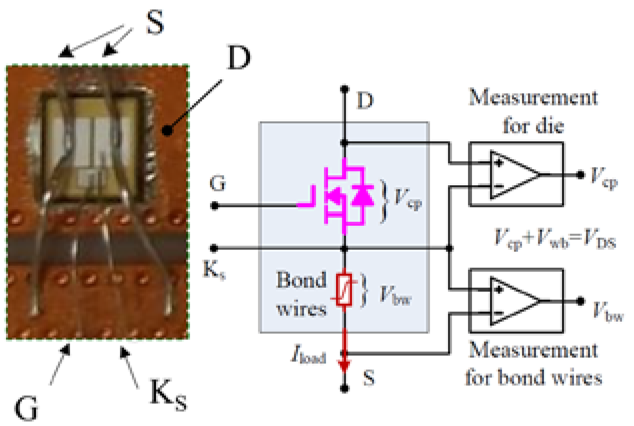

Figure 3: Photograph (left) and schematic (right) of Kelvin-source connection for testing the bond-wire voltage drop during power cycling [8].

Test parameters	Module A	Module B
$T_{j,max}$	125 °C	125 °C
$T_{j,min}$	65 °C	65 °C
ΔT_j	60 °C	60 °C
t_{ON}/t_{OFF}	2s / 4s	2s / 4s
Load current	24 A	12 A

Table 1. Conditions used for assessing the effects of current density on bond-wire liftoff failure [8]

	12 A		24 A	
mΩ	0 cycles	70k cycles	0 cycles	70k cycles
Average	3.07	4.03	2.70	4.68
Std deviation	0.51	1.13	0.34	0.87

Table 2. Series resistance of bond wires at end of life (around 70,000 cycles) in the case I_{LOAD} = 12 A and I_{LOAD} = 24 A [8]

Semiconductor degradation

Degradation at the semiconductor level happens mostly in connection with high-temperature operations. Because of the wider bandgap compared to silicon, silicon carbide would exhibit a larger threshold voltage than silicon with the same gate oxide thickness. This is not acceptable from an application point of view, as gate drivers and circuitry are nowadays widely standardized in the range 10 V to 20 V. This market constraint calls for a thinner gate oxide of SiC MOSFETs compared to silicon, which in turn makes oxide quality more critical. At high temperatures, the probability of having energetic ("hot") electrons through the oxide becomes more and more significant due to the well-known Fowler-Nordheim tunneling effect [9]. Figure 4 displays this condition, where a hot electron through the channel has energy enough to pass through the oxide and it either gets to the gate terminal or gets trapped into the gate layer. In this latter case, a permanent negative gate charge adds up to the device, which increases its threshold voltage. This phenomenon is regenerative, as the higher the threshold voltage, the higher the losses, and the higher the losses, the higher the temperature. Figure 5 displays the degradation curves obtained for both the semiconductor chip and its bond-wires during a power-cycling experiment with a maximum temperature of 175 °C. Although a bond-wire degradation is observed, the semiconductor chip fails independently of it. The degradation observed is a typical thermal-runaway phenomenon [9].

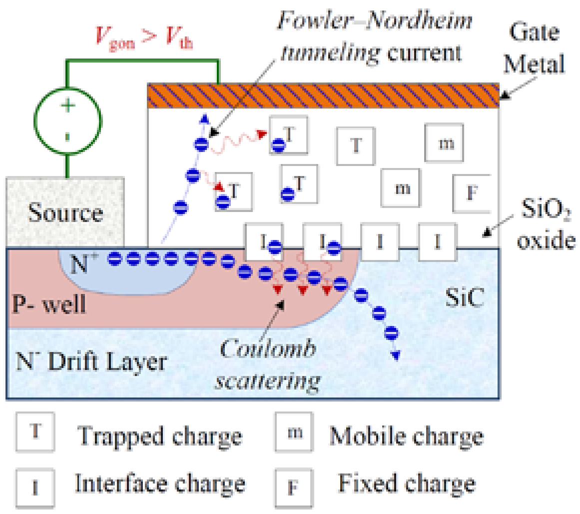

Figure 4: Effects of hot-electron trapping related to the Fowler-Nordheim tunneling mechanism [9].

Testing for abnormal conditions

Highly-reliable applications, such as energy production from renewables require an expected life of 20 or more years. In this time horizon, random failures cannot be neglected. Random failures are related to abnormal events occurring during the component's life, such as grid voltage ride-through, overloads, short-circuits, and lightnings.

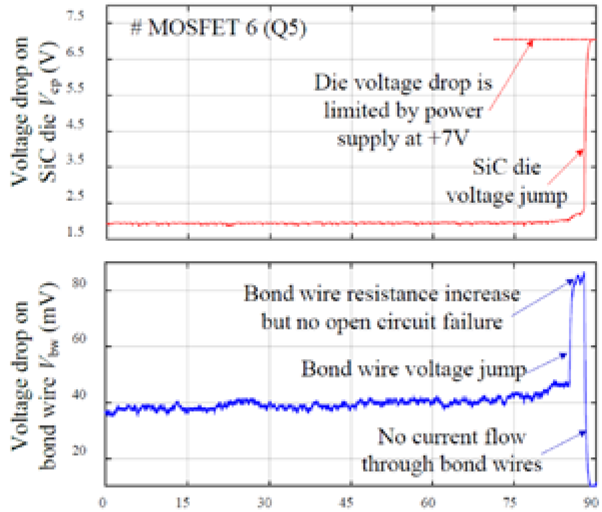

Figure 5: Degradation curves during power-cycling of a commercial SiC MOSFET module, with a maximum temperature of 175 °C. Top: voltage drop across the semiconductor chip. Bottom: voltage drop across bond-wires [9].

Short-circuit is one of the greatest challenges. Testing against short-circuit events is risky, as such events often end up in a catastrophic failure. To prevent this and to allow post-failure analysis, a protection circuit must be used. Figure 6 shows a principle schematic of a non-destructive tester for short-circuit conditions [10]. A power supply V_{DC} charges preliminary a capacitor bank C_{DC} up to the test voltage. The series protection is made up of parallel-connected IGBT power switches, which are operated simultaneously. The series protection is fired earlier than the device under test (DUT) and is turned-off right after it. In this way, in the case of failure and loss of control, the energy dissipated on the DUT is largely limited. The timing should be finely tuned in the fraction-of-microsecond scale, therefore an FPGA hardware generates the test signals. All the waveforms are sampled using an oscilloscope and collected with a personal computer.

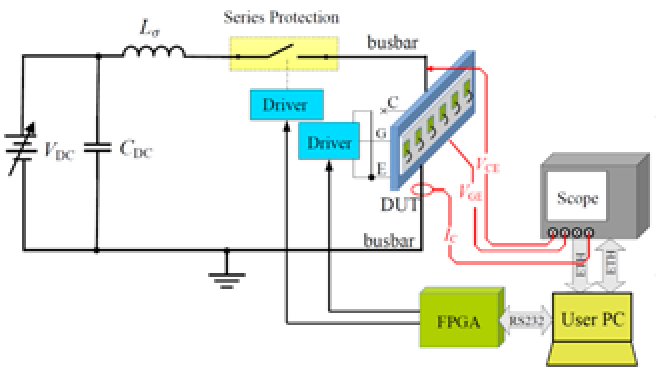

Figure 6: Principle schematic of a setup for short-circuit testing of power semiconductors.

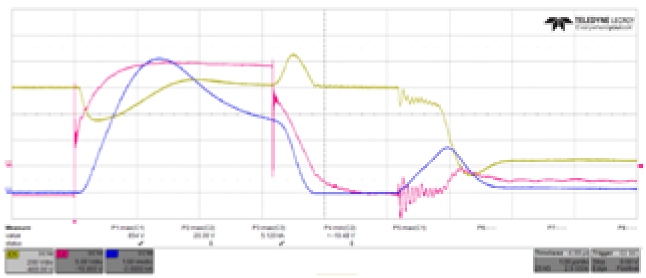

Figure 7: Short-circuit waveforms for a commercial 1.2 kV, 300 A SiC MOSFET module. Yellow: drain voltage [200 V/div]; Blue: drain current [1 kA/div]; Pink: gate voltage [5 V/div]. Time: [1 us/div]. [11]

Figure 7 displays the rupture waveforms of a commercial SiC MOSFET after a 3-microsecond short-circuit event [11]. The turn-off sequence appeared to be safe in the experiment. However, after about 2 microseconds after the turn-off, a sudden increase in the drain current occurred, evidencing that an instability took place and led the device to destruction. A post-failure analysis on the same unit demonstrated a burnt spot on one chip (see Figure 8). Another example is given by the waveforms showed in Figure 9. In this second case, a failure occurred during turn off. A possible interpretation of such phenomena is related to the dependence of the on-state characteristics on the temperature. Figure 10 shows a superimposition at two different temperatures of the characteristics taken from the datasheet of the commercial device used for the tests. At low gate voltages, e.g. V_{GS} = 10 V, SiC MOSFETs exhibit a negative-thermal-coefficient behavior, which means that the current increases when the temperature increases. Although such a so-low voltage level is unusual in normal operations, it may appear in the case that a significant current is triggered through the gate oxide because of a high temperature, ending up in an electro-thermal instability.

To prove the above hypothesis, a post-failure analysis has been done at much lower short-circuit energies, so that the device under test was not severely damaged. The observation done showed clear evidence of a crack occurring through the field oxide and possibly leading to a conductive path between the gate terminal and the source metallization [12].

Status and prospects

Cost is certainly the major hurdle for a broad diffusion of SiC MOSFETs in power-electronics applications. A lower cost would mean gaining one more design degree of freedom. The chip area could be not a constraint anymore and could allow the full exploitation of the SiC material potential, especially from a reliability standpoint.

With no doubt, the temperature is the second hurdle. Despite high expectations, operations are still limited to Tj, max = 150 °C in the greatest number of cases. To conquer the automotive market (worth 1.5 B$, CAGR 3,4% in 2017 [13]), a 200 °C stable operation is demanded.

The third hurdle is new interconnection concepts. Temperature swing has become a constraint at the solder layer, too. New and cheap concepts are demanded to enable the transition toward SiC technology.

However, the scenario is very dynamic. As mentioned above, the first world SiC wafer manufacturer Cree invested 1B$ in a new wafer fab in May 2019 [5]. Danfoss has now an enlarged portfolio with Danfoss Bond Buffer® technology (copper wire bonding) [14]. Major changes have still to be expected in the coming 2-3 years.

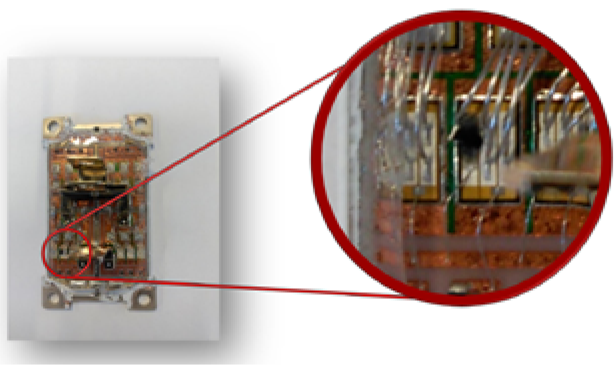

Figure 8: Post-failure analysis on a commercial SiC MOSFET module after a short circuit test, showing a burnt spot on a chip.

Conclusion

I have discussed the main reliability challenges of state-of-the-art SiC MOSFETs aimed at automotive applications. As take-home messages, I would highlight:

1) the automotive applications are expected to drive the power electronics scenario in the coming decade. This means that whatever the new technology, it has to comply with the current- and the coming automotive standards, in particular related to high-temperature operations.
2) Wear testing in Silicon Carbide components evidences two distinct failure mechanisms, i.e. bond-wire lift-off and threshold voltage shift. Current density plays a major role in bond-wire lift-off, whereas temperature mostly affects the threshold voltage shift. A technology effort is demanded at both levels.
3) Abnormal operations are as important as normal ones for SiC reliability assessment and are currently the most limiting performance.

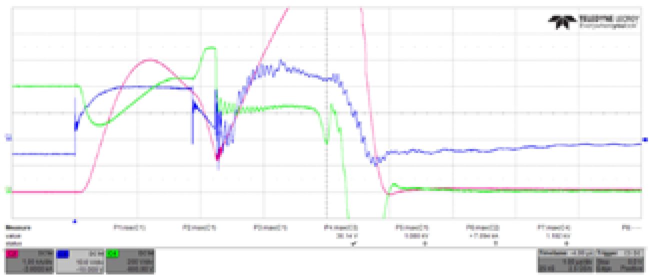

Figure 9: Short-circuit waveforms for a commercial 1.2 kV, 300 A SiC MOSFET module. Green: drain voltage [200 V/div]; Pink: drain current [1 kA/div]; Blue: gate voltage [10 V/div]. Time: [1 us/div].

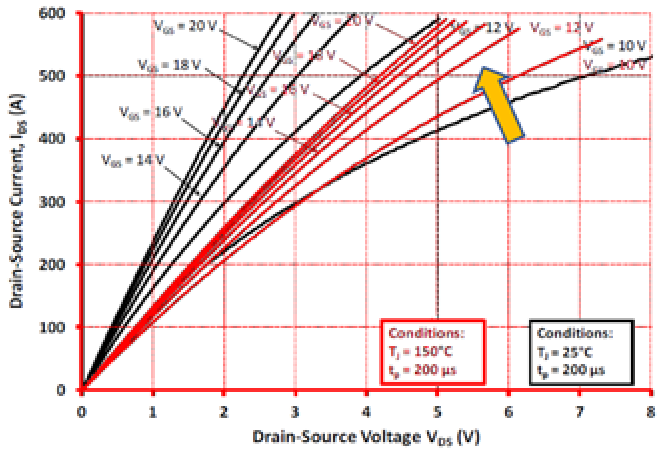

Figure 10: Dependence of on-state characteristics of a SiC commercial device on the temperature. Black: 25 °C; Red: 150 °C [11].

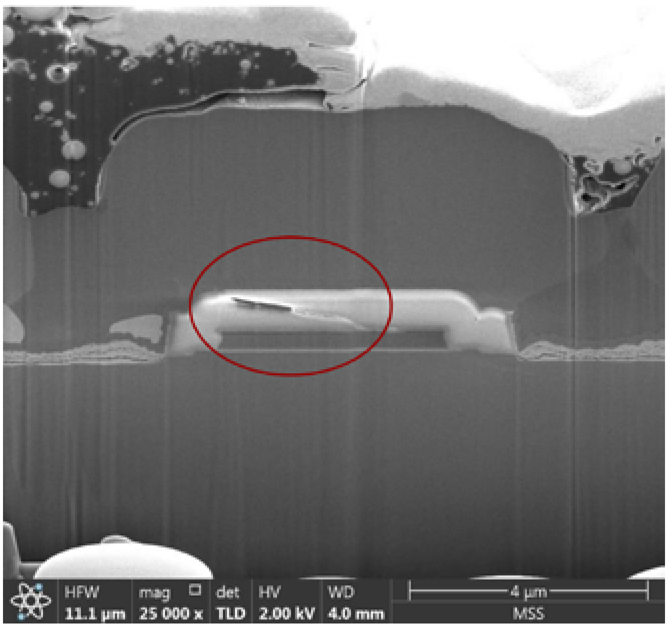

Figure 11: Post-failure analysis on a commercial discrete SiC MOSFET after a repetitive short-circuit test, showing a crack in the field oxide [12].

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www.et.aau.dk

Extending the Supply Voltage of a 600 V Input, No-Optocoupler Isolated Flyback Controller to 800 V or Higher

In traditional isolated high voltage flyback converters, tight regulation is achieved using optocouplers to transfer regulation information from the secondary-side reference circuitry to the primary side. The problem is that optocouplers add significant complexity to isolated designs: there is propagation delay, aging, and gain variation, all of which complicate power supply loop compensation and can reduce reliability.

By Yuchen Yang, Senior Applications Engineer, and William Xiong, Applications Engineer, Analog Devices

Moreover, during startup, either a bleeder resistor or a high voltage start-up circuit is required to initially power up the IC. Unless an additional high voltage MOSFET is added to the start-up components, the bleeder resistor is a source of unwelcome power loss.

The LT8316 is a micropower, high voltage flyback controller that does not require an optocoupler, complicated secondary-side reference circuitry, or additional start-up components.

Extending Supply Voltage

The LT8316 is housed in a thermally enhanced 20-lead TSSOP package with four pins removed for high voltage spacing. By sampling the isolated output voltage from the third winding, no optocoupler is required for regulation. The output voltage is programmed with two external resistors and a third optional temperature compensation resistor. Quasiresonant boundary mode operation helps to achieve excellent load regulation, small transformer size, and low switching loss, especially at high input voltage. Because the output voltage is sensed when the secondary current is almost zero, no external load

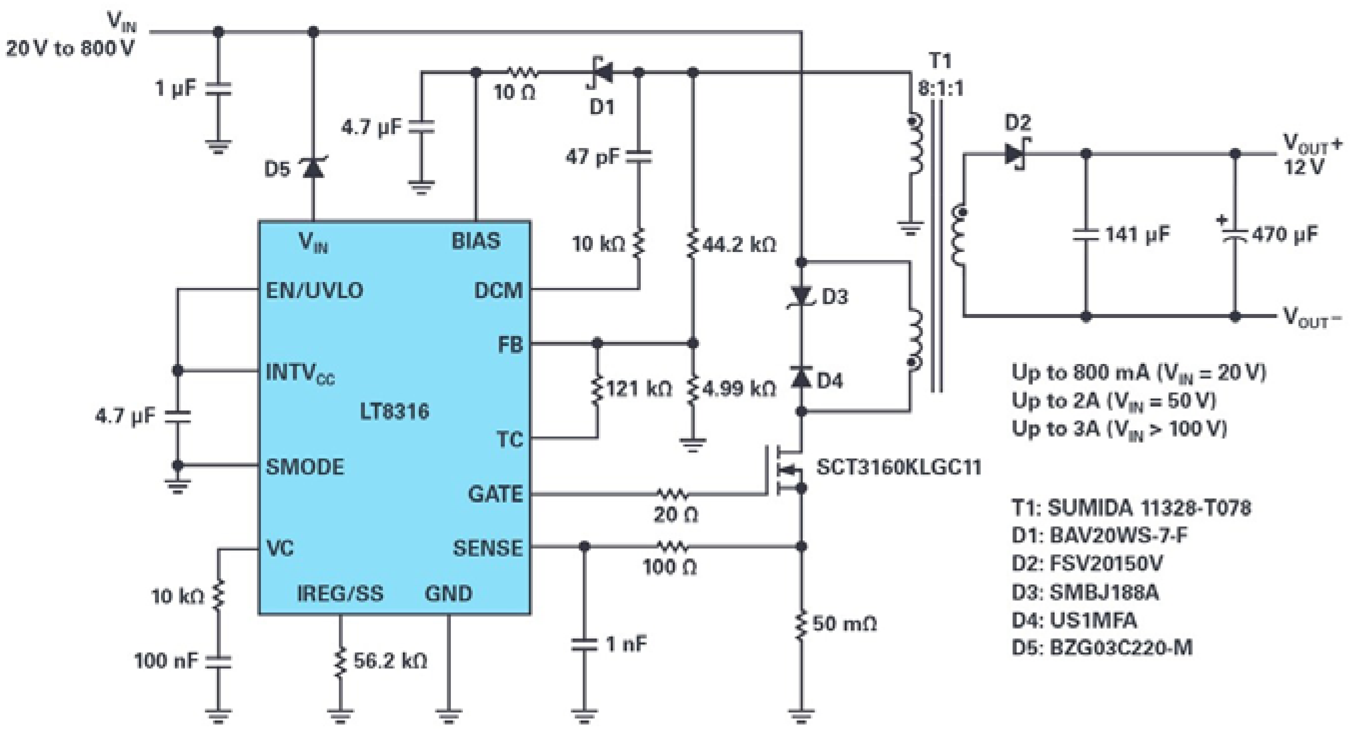


Figure 1: A complete 12 V isolated flyback converter for a wide input from 20 V to 800 V with a minimum start-up voltage of 260 V.

compensating resistors and capacitors are needed. As a result, the LT8316 solution features a low component count, greatly simplifying the design of an isolated flyback converter (see Figure 1).

The LT8316 is rated to operate from a VIN of up to 600 V, but this can be extended by placing a Zener diode in series with the VIN pin. The voltage drop across the Zener diode reduces the voltage applied to the chip, allowing the supply voltage to exceed 600 V.

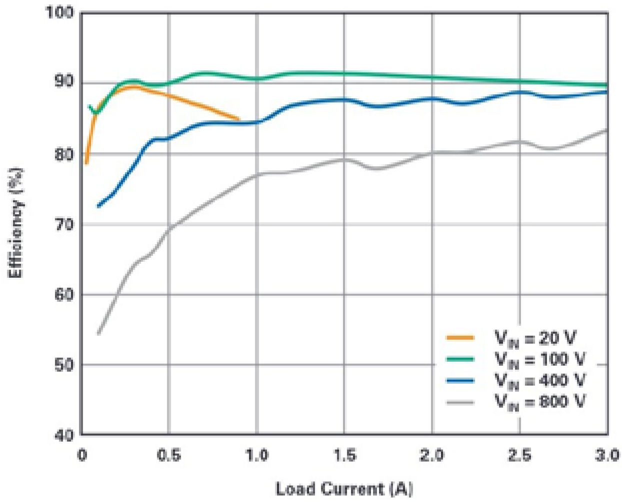


Figure 2: Efficiency of the flyback converter in Figure 1.

Figure 1 shows the complete schematic of a flyback converter with a wide input range of 18 V to 800 V. The guidelines for component selection are detailed in the LT8316 data sheet. With the 220 V Zener diode placed in series with the VIN pin, the minimum supply voltage for startup is 260 V, give or take, considering the voltage tolerance of the Zener diode. Note that after startup, the LT8316 will operate normally with a supply voltage below 260 V. Figure 2 shows efficiency at various input voltages, with the flyback converter achieving 91% peak efficiency. Even with no optocoupler, load regulation at different input voltages remains tight, as shown in Figure 3.

Low Start-Up Voltage Design

The previous solution extends the input voltage to 800 V, but the Zener diode raises the minimum start-up voltage to 260 V. The challenge is that some applications require both high input voltage and low start-up voltage. An alternative 800 V maximum input voltage solution is shown in Figure 4. This circuit uses Zener diodes and a transistor to form a voltage regulator. The input voltage can safely go to 800 V with the VIN pin regulated at around 560 V. The benefit of this circuit is that it allows the LT8316 to start up at a lower supply voltage.

Nonisolated Buck Converter

The LT8316's high voltage input capability is easily applied in a simple, nonisolated buck converter where an isolated transformer is not required. A relatively inexpensive off-the-shelf inductor is adopted as the magnetic component.

For a nonisolated buck application, the LT8316's ground pin is connected to the switch node of the buck topology, which is a varying voltage. The unique sensing scheme of LT8316 sees the output voltage only when the switch node is connected to the ground, which leads to a simple buck schematic.

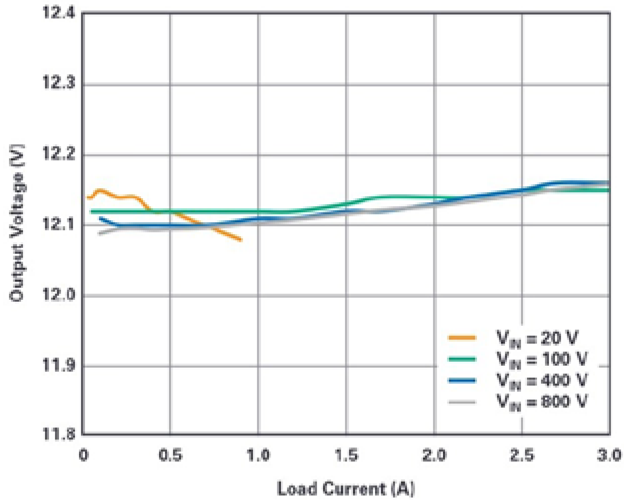


Figure 3: Load and line regulation of the flyback converter in Figure 1.

As with the flyback converter, the supply voltage of the buck converter can be extended. Figure 5 shows the schematic of a buck converter with up to 800 V input voltage. A 220 V Zener diode is placed between the supply voltage and VIN pin of LT8316. The minimum supply voltage for startup is 260 V, considering the voltage tolerance of the Zener diode. After startup, the LT8316 continues to operate normally with lower supply voltage. Figure 6 shows efficiency at various input voltages, with the buck converter achieving 91% peak efficiency. The load and line regulation is shown in Figure 7.

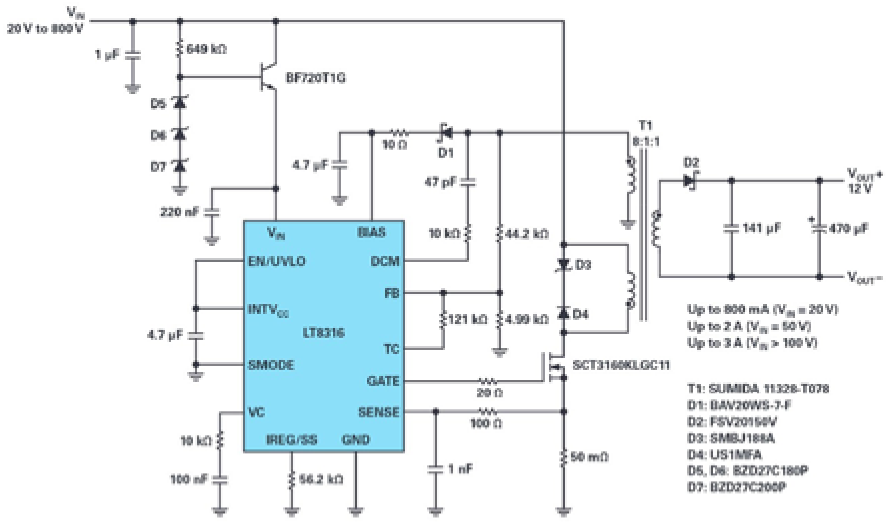


Figure 4: Schematic of an isolated flyback converter: 20 V to 800 V input to 12 V, with low start-up voltage.

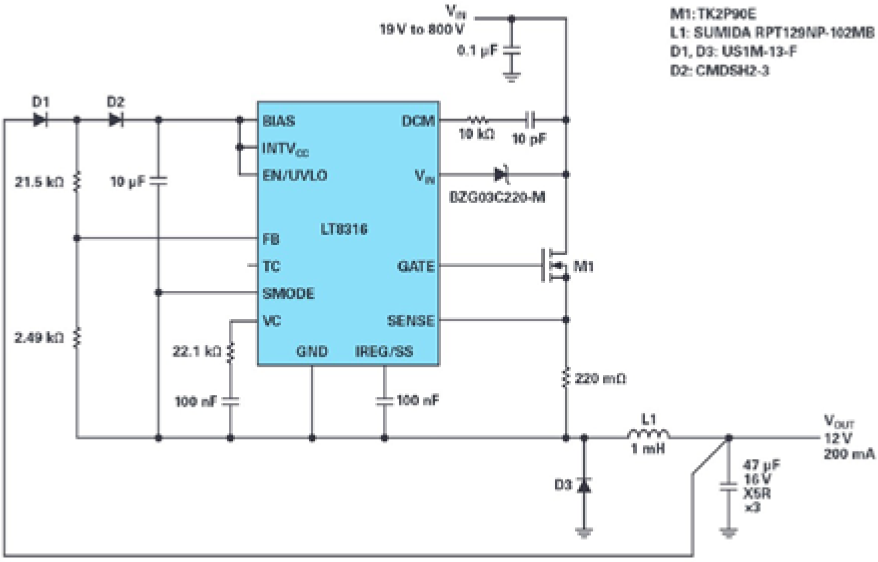


Figure 5: Schematic of a nonisolated buck converter with up to 800 V supply voltage.

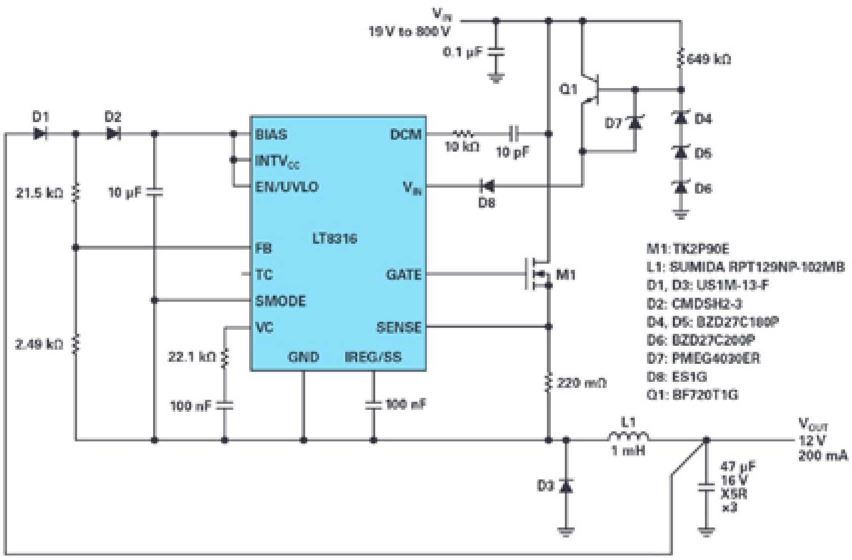


Figure 8: Schematic of 800 VIN nonisolated buck converter with low start-up voltage.

Similar to the flyback converter in Figure 4, a voltage regulator can be added between the supply voltage and the VIN pin to achieve the low start-up voltage of a buck converter. It should be noted that there is a body diode from the GND pin to the VIN pin, which raises the emitter voltage of the transistor and causes base-emitter breakdown. In order to prevent this, two diodes are added to protect the transistor. The low start-up voltage solution is shown in Figure 8.

Conclusion

The LT8316 operates in quasiresonant boundary mode and requires no optocoupler for excellent regulation. In addition, it includes rich features such as low ripple Burst Mode® operation, soft start, programmable current limit, undervoltage lockout, temperature compensation, and low quiescent current. The high level of integration simplifies the design of low component count, high efficiency solutions in a wide variety of applications ranging from battery-powered systems to automotive, industrial, medical, telecommunications power supplies, and isolated auxiliary/housekeeping power supplies.

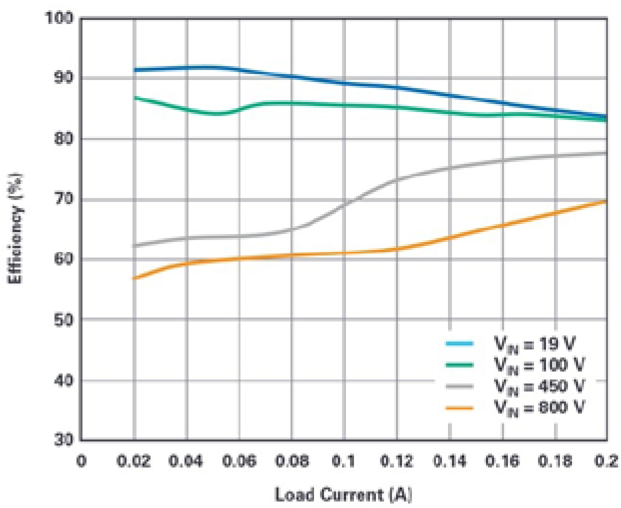


Figure 6: Efficiency of the buck converter in Figure 5.

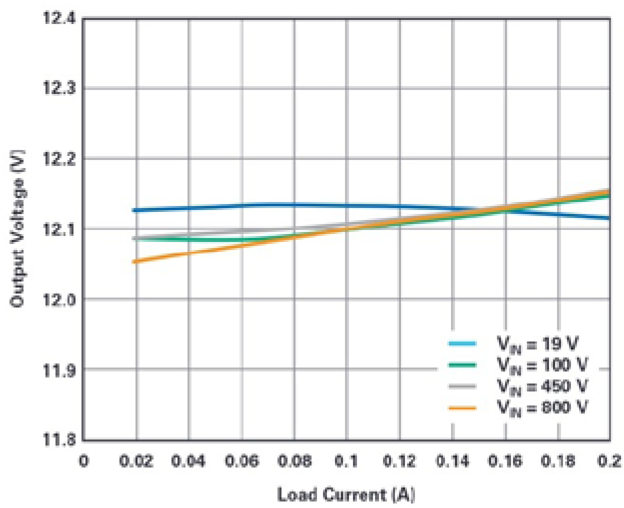


Figure 7: Load and line regulation of the buck converter in Figure 5.

External Power Supplies with Interchangeable Plugs for International Compatibility

Jasper Electronics has expanded its line of medical grade power supplies with 27 model series of external power adapters. The adapters are compliant with International Electromechanical Commission (IEC) standards for the safety and effectiveness of medical electrical equipment, including: IEC60601-3rd Edition, UL/cUL, TUV, and FCC certification. Several of the wall-mounted model series have interchangeable AC plugs for international compatibility, and all units have custom connector and cable options.

"With this significant expansion of our IEC60601-certified external medical power supply product lines, we've provided our customers in the medical electronics industry with a wide range of high efficiency, reliable power options," said Robert Nishimoto, president, Jasper Electronics. "With a selection that includes external fanless designs, a wide range of input and output power ratings, interchangeable AC plugs, and both standard and custom cable and connector options, customers will be able to select optimum specifications, performance, and price for their medical applications."

Jasper Electronics' comprehensive range of medical-grade external power supplies includes both wall-mounted and desktop configurations with output power ratings from 4.5W to 310W. All models carry safety agency certifications (UL/cUL, TUV, CE, FCC, and IEC60601 -3rd Edition), and many feature multiple sets of interchangeable AC plugs for worldwide compliance. The HEMG Series devices feature universal input harmonic power factor correction (PFC) with high efficiency.

www.jasperelectronics.com

Solid State Relay with Integrated Current Limiting and Thermal Shutdown

Littelfuse announced the CPC1561B Solid State Relay (SSR). The CPC1561B is the highest current (1 A, 60 V) normally-open SSR currently available on the market to integrate both current limiting and thermal shutdown circuits. The small, surface-mount CPC1561B SSR's dual fault protection benefit provides a rugged solution for demanding applications that is not possible when using electro-mechanical relays and standard SSRs. "The CPC1561B is ideal for markets and applications that cannot be down for long periods of time due to over current, over temperature and electrical stress," said Steve Andrezyk, Director of Marketing for Littelfuse-IXYS Integrated Circuits. "The CPC1561B output relay can survive harsh conditions and resume normal operation once the fault is removed, thus reducing product down time and potentially eliminating service call time as the SSR both protects itself and resets to resume normal operation." The CPC1561B is available in tape and reel format. Sample requests can be placed through authorized Littelfuse distributors worldwide.

www.littelfuse.com

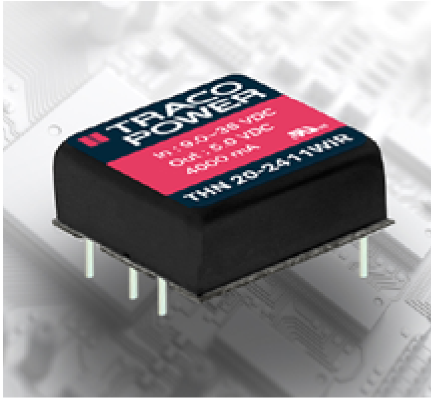
High-Temperature Capacitors Operate up to 125°C

Even if water cooling is not possible or the cooling water temperature can only up to 45°C, the HTC high-temperature capacitors from Celem (sales: Eurocomp) are used safely and reliably. Various designs are offered in the HTC series, which are available for 550V or 1000V, depending on the capacitance. Depending on the design, the capacitance values range from 0.1 µF to 0.4 µF. The picture shows the designs CSM, C-Cap mini, CMPP and CSP with the different connection options. On request, these capacitors can be manufactured with UL-certified resin. Celem uses a high-quality high-temperature film for its HTC series which makes the series ideal for e.g. wireless power transmission in automotive applications, for example, as part of inductive wireless charging for EVs.

www.eurocomp.de

20 Watt DC/DC Converter in a 1”x1” Metal Package

The TRACO THN 20WIR series is a family of ruggedized 20 Watt DC/DC converters for highest reliability in harsh environments, expanding our existing railway range in the 1” x 1” package up to 20 Watt. The THN 20WIR has a wide 4:1 input range and increased resistance against electromagnetic interference, shock/vibration and thermal shock and come in a compact six-side shielded 1” x 1” metal package. The innovative design provides high efficiencies up to 91% and thus enables an operating temperature range from -40 to +65°C without derating. The approvals according to standards EN 50155

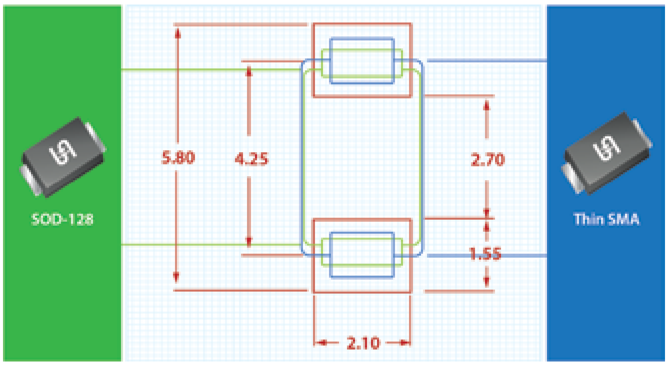


and EN 61373 qualify them for railway and transportation systems. Additional qualification for the fire behavior of components according to EN 45545-2 and the safety approval according IEC/EN 62368-1, UL62368-1 support a potential compliance test of the application. Built-in features like an internal EN 55032 class A filter, input under-voltage-lockout, short circuit protection, remote On/Off and output voltage trim make this series suitable for almost any application demands and thus facilitate the design-in process.

www.tracopower.com

Fast Recovery AEC-Q Rectifiers in Two Compatible Packages

Taiwan Semiconductor announces the availability of the RS2x family of fast recovery rectifiers. These 2A-rated diodes are available with reverse voltage ratings of 200V and 1 KV, each available in either SOD-128 or Thin SMA package. These two surface mount packages align with standard pc-board solder pads facilitating interchangeability,



with the Thin SMA offering a lower profile and the SOD-128 improved thermal dissipation.

“The RS2x Family offers industry leading forward voltage drop, switching speed, low profile and industry standard thermally-efficient packaging,” said Vice President, TSC Products, Sam Wang. “The combination of medium (200V) and high (1KV) ratings and identical performance in a pair of compatible packages enables design efficiency and manufacturing flexibility.”

Rectification, blocking and freewheeling uses for the RxBS Family include enclosed and open frame power supplies and power electronic conversion systems used in automotive, industrial, telecom-datacom-networking systems, LED lighting, battery charging systems, UPS and inverters.

Design resources include comprehensive datasheets (https://bit.ly/3jl7fPz https://bit.ly/3o7GJgh) and spice models for each component in the series.

www.taiwansemi.com

Hybrid LIC Supercapacitors

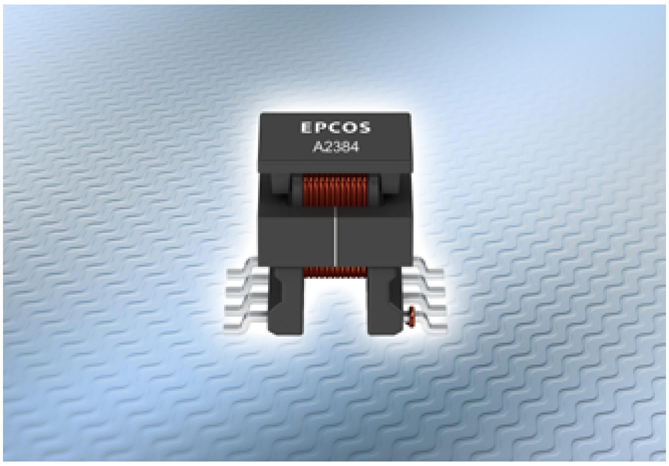
Cornell Dubilier Electronics introduces two series of Hybrid LIC Supercapacitors in response to the growing need for ultra-high capacitance values at higher operating voltages. The VMF and VPF Series operate at 3.8 WVDC with capacitance values up to 220 Farads. The higher voltage results in increased energy density. With

Cornell Dubilier Electronics VMF and VPF Series
3.8 Vdc LIC Hybrid Supercapacitors
https://cde.com/new-product/vmf-vpf

nearly eight times the energy density and a fraction of the leakage current of similar volume 2.7V supercapacitors, designers can use smaller or fewer components to achieve the desired amount of energy storage. In addition, VMF and VPF have an advantage in applications with long standby and run times. Both series can deliver quick bursts of energy that may be used to maintain voltage when power is interrupted, or they may be used to extend battery life by reducing peak repetitive current demands on the battery. Due to their high energy storage capacity, some applications can use these components in place of costly batteries. Unlike batteries, hybrid supercapacitors do not degrade with each charge/discharge cycle. They are also inherently safer than batteries, with no risk of thermal runaway. For applications requiring higher voltage or capacitance, CDE can design custom series-parallel banks of components, packaged into modules with the desired lead configuration. Standard components within the series are offered in a radial board-mount package. Sizes range from 8mm to 16mm in diameter with lengths from 16mm to 25mm. Life cycles are rated up to 500,000 charge/discharge cycles. Operating temperature ranges from -25 °C to 85 °C. Both series are fully RoHS compliant and UL recognized.

www.cde.com

Transformers for DC/DC Converters

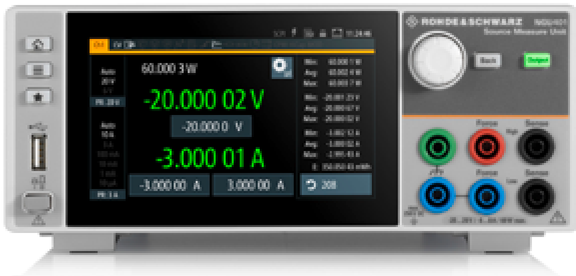


TDK Corporation presents the EPCOS E10 EM series, a range of insulated SMT transformers that are suitable for various DC/DC converter topologies and gate driver circuits in e-mobility and industrial electronics. There are four models in the series, with basic winding insulation of a working voltage of 500 V_{RMS} and reinforced insulation of 300 V_{RMS}. The turns ratio is between 1:0.76 and 4:1, depending on the model. Measuring just 11.7 x 13.15 x 11.35 mm^3, they are extremely compact. The compact design meets clearance and creepage requirements in accordance with the IEC 60664-1 standard (Np/Ns: min. 5.5 mm clearance, min. 6 mm creepage), due to the internal construction of the transformers. Outstanding reproducibility and reliability are ensured thanks to highly automated production with an AOI final inspection. The component in the EPCOS transformer series B78307A*A003 is qualified in accordance with AEC-Q200 Rev. D.

www.tdk-electronics.tdk.com

Source Measure Units Enable Simultaneous Sourcing and Measuring

The steady extension of the Rohde & Schwarz portfolio of specialty power supplies continues with the first two models in the R&S NGU series of high-precision SMUs. The instruments' innovative current feedback amplifier technology provides both maximum sensitivity and accuracy to reliably measure currents from nA to A in a single sweep. The four-quadrant R&S NGU401 is the specialist for semiconductor testing. It provides source measurements for any equipment requiring source and sink voltages in the range from –20 V to +20 V. In addition to the voltage regulation mode of power supplies, the R&S NGU includes a fast current regulation mode to avoid damaging current-sensitive devices under test, such as LEDs or other semiconductors. An external arbitrary waveform source connector turns the R&S NGU401 into an AC source and makes it possible to simulate glitches or unstable power supplies of up to 1 kHz.
The two-quadrant R&S NGU201 is optimized for battery drain analysis of any battery-powered device, including mobile phones, tablets, and the full range of IoT equipment. Design engineers can use it to simulate real-world battery characteristics.



The two-quadrant R&S NGU201 addresses wireless device battery tests and automatically switches from source mode to sink mode at a defined positive input voltage. The four-quadrant R&S NGU401 can also switch at negative voltages, supporting source measurements for a vast range of power supply types.

www.rohde-schwarz.com

650 V Hybrid IGBT Discrete Family

Infineon Technologies has launched a 650 V CoolSiC™ Hybrid IGBT portfolio in a discrete package with 650 V blocking voltage. The CoolSiC hybrid product family combines key benefits of the 650 V TRENCHSTOP™ 5 IGBT technology and the unipolar structure of co-packed Schottky barrier CoolSiC diodes. The devices are especially suited for DC-DC power converters and power factor correction (PFC). These can typically be found in applications like battery charging infrastructure, energy storage solutions, photovoltaic inverters, uninterruptable power supplies (UPS), as well as server and telecom switched-mode-power supplies (SMPS). Due to a freewheeling SiC Schottky barrier diode co-packed with an IGBT, the CoolSiC Hybrid IGBTs perform with significantly reduced switching losses at almost unchanged dv/dt and di/dt values. They offer up to 60

percent reduction of E on and 30 percent reduction of E off compared to a standard silicon diode solution. Alternatively, the switching frequency can be increased at least by 40 percent with unchanged output power requirements. A higher switching frequency will allow reducing passive components size and thus lower bill-of-material cost. The Hybrid IGBTs can be used as a drop-in replacement for TRENCHSTOP 5 IGBTs allowing an efficiency improvement of 0.1 percent for each 10 kHz switching frequency without redesign efforts. The product family creates a bridge between pure silicon solutions and high performing SiC MOSFET designs. Even more, in comparison to pure silicon designs, Hybrid IGBTs can improve electromagnetic compatibility and system reliability.

www.infineon.com

Power Supplies Address EV and Hydrogen Production Applications

TDK Corporation announces the introduction of 50V, 400V and 500V output models to the TDK-Lambda GENESYS+™ series of programmable DC power supplies. With output power levels of 5kW, 10kW and 15kW in 1U, 2U and 3U high 19" rack-mount packages, the G50, G400, G500, GSP50, GSP400 and GSP500 models are fully compatible with the current series. The additional models are targeted at testing electric vehicle (EV) powertrains and other automotive sub-systems, and proton exchange membrane (PEM) electrolysers for hydrogen production. These optimised output voltages enable the power supplies to deliver more current without needing to parallel two or more units.

All models seamlessly transition between constant voltage and constant current modes and also have constant power operation. For higher power systems, multiple power supplies can be connected in parallel with a patented advanced master/slave system that provides dynamic load response and ripple and noise characteristics comparable with that of a single power supply. The GENESYS+™ products can be ordered with three phase input ranges of 170-264Vac, 342-460Vac or 342-528Vac. The 5kW GENESYS+™ units weigh less than 7.5kg for easy movement or installation. Where user access is not required or needs to be restricted, a blank front panel option (with no metering or control functions) is available. Snap-on dust filters can also be added to limit airborne contamination.

www.emea.lambda.tdk.com

Switch Provides True Reverse Current Blocking for Type-C PD

Alpha and Omega Semiconductor announced a Type-C Power Delivery (PD) high voltage source protection switch capable up to 28V absolute maximum voltage. The AOZ1374 is a smart protection switch in a small thermally enhanced 3mm x 3mm DFN package. AOS's prowess in high-performance ICs combined with AOS's high SOA MOSFETs using advanced co-packaging techniques. AOZ1374 supports a slew of protection features, including true reverse blocking in a small solution footprint with an industry-leading on-resistance of 36mOhm. While USB ports in consumer and computing equipment can receive up to 100W of power, power typically comes from an AC-DC adaptor supporting Type-C PD. The host device itself typically provides (sources) 5V @ 3A or up to 15W. This is the most common implementation in notebook applications and also in the majority of desktops. However, Type-C PD ports are gaining popularity in more devices such as smart monitors and power banks, and for such applications, a high voltage sourcing switch is required to deliver up to 100W power. Type C high voltage sourcing switches are also increasingly common in graphics cards or game consoles to power highend virtual reality gaming goggles. Similarly, a personal computer can connect to a monitor using one single Type-C cable providing both power and data. AOZ1374 uses a design IP developed for the AOZ1375DI high voltage bi-directional source/sink Type C protection switch with added integration features to eliminate the eternal current limiting resistor. The device features 28V absolute maximum voltage with the current limit capability, and startup safe operating area (SOA) management would be the ideal protection switch for the applications mentioned above.

www.aosmd.com

Flux-Cored Wire for Robotic and Laser Soldering

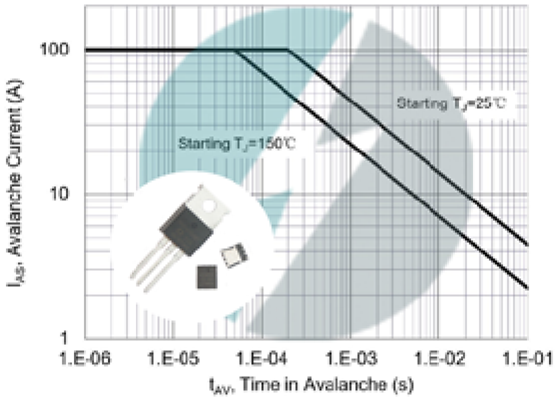
Indium Corporation announces that it is now offering CW-232, a uniquely formulated flux-cored wire that combines superior wetting speed and spread with extremely low-spatter performance.

Indium Corporation's CW-232 is a highly activated rosin flux-cored wire developed to meet the demanding requirements of robotic and laser soldering applications by delivering additional wetting power in order to achieve higher throughput. CW-232 also works exceptionally well in hand soldering applications. Due to its "no-spatter" technology, CW-232 eliminates flux spattering that can burn operators' hands, impair the vision system of the robotic soldering machines, or make finished products less aesthetically appealing.

www.indium.com

MOSFETs for Industrial Motor Control and Battery Powered Tool Applications

MaxPower Semiconductor announces the full commercial availability of its Proprietary Advanced Trench MOSFETs that are optimized for industrial motor control applications. This 30V to 150V MaxFET™ family is designed for high current capability and to increase efficiency in both motor torque and battery life, which also supports high inductive load switching with low conduction and switching losses for efficient battery operation.



These devices have a demonstrated success in motor control applications for industrial devices. The combination of low on-resistance, high avalanche rating, and advanced packaging technologies create a range of ultra-rugged parts to fit today's design requirements for this growing market.
For example, the MXP40N1P0BGL, which is ideal for battery pack, load switching, and high efficiency DC/DC converter applications, features; typical on-resistance of 0.77mW at Vgs = 10V, maximum on-resistance of 1.0mW at Vgs = 10V, and typical gate charge of 63nC at Vgs = 4.5V over an operating temperature range of -55 to 150°C. Parts are available in all of the most requested, industry standard packages, such as PQFN 5x6, D-PAK, D2-PAK, and TO-220. MaxPower also uses advanced packaging techniques, such as the implementation of Cu-clip, which helps to reduce the maximum junction temperature during operation and extend the device's operation life and reliability. The Cu-clip also helps conduct heat to the package exterior and provides the option of two-sided cooling, all benefiting efforts toward advanced thermal management for smaller form factors.

www.maxpowersemi.com

80 V RETs for 48 V Automotive and Other Higher Voltage Bus Circuits

Nexperia announced a 80 V RET (Resistor-Equipped Transistor) family. These RETs or 'digital transistors' provide enough headroom for use in 48 V automotive board net (e.g. mild hybrid and EV cars) and other higher voltage circuits which are often subject to large spikes and pulses that previous 50 V parts cannot handle. RETs save space and reduce manufacturing costs by combining the bias resistor and bias-emitter resistor in the same SOT23 (250 mW P_{tot}) or SOT323 (235 mW P_{tot}) package as the transistor. Double RETs (two transistors and two matching bias resistors and bias-emitter resistors) are also available in the SOT363 package with a P_{tot} of 350 mW for even greater integration and savings. The series (NHDTx and NHUMx) includes 42 parts with PNP / NPN combinations. These come with the same bias resistor combinations as Nexperia's 50 V parts. Devices have a 100 mA current capability and are AEC-Q101-approved. Frank Matschullat, product group manager at Nexperia comments: "Design engineers working on new EV applications can future-proof their systems with confidence by using Nexperia's new RETs to simplify circuit design, save PCB space, reduce pick and place time and increase reliability. As well as 48 V automotive circuit driver applications, general-purpose switching and amplification and other digital systems will benefit from these new high voltage devices."

www.nexperia.com

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