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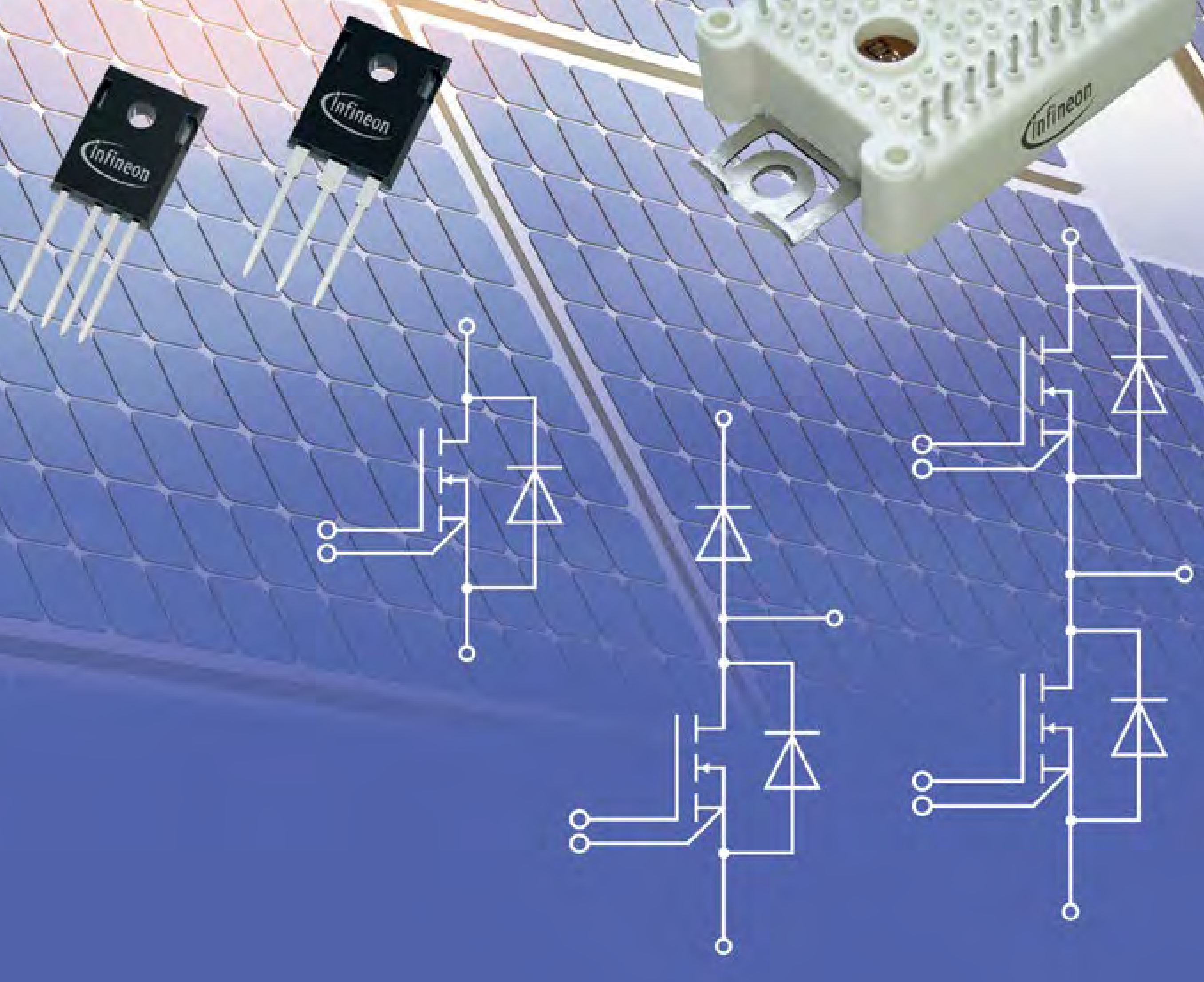
Electronics in Motion and Conversion

May 2017

Infineon CoolSiC™ – Revolution to rely on.

› 1200V CoolSiC™ MOSFET – High Performance Complemented by High Reliability, **page 34-38**

› Tipping Point for Wide Band Gap Technology Signals Start of Mainstream SiC Adoption, **page 20**



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Events

SMT Hybrid 2017
Nuremberg, Germany, May 16-18
http://www.mesago.de/en/SMT/home.htm

PCIM Europe 2017
Nuremberg, Germany, May 16-18
http://www.mesago.de/en/PCIM/home.htm

IWBGPEAW 2017
Stockholm, Sweden, May 21-23
mietek.bakowski@acreo.se

Sensor + Test 2017
Nuremberg, Germany, May 30 June1
http://www.sensor-test.com/press

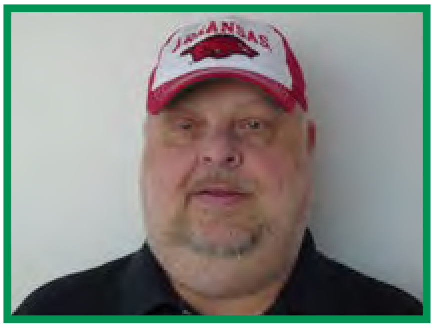
Intersolar 2017
Munich, Germany, May 31 June 2
www.intersolar.de/de/intersolar-europe.html

White Asparagus, Once Again

I can't remember how many years that I've been coming to PCIM, but I always remember the delicious asparagus from the Nuremberg region. A lot of important things had already happened when I began urging GE Solid State in the late 80's to consider the PCIM Conference. IGBTs had been invented and were about to change the world of power electronics - mainly in variable speed motion and in ignition for combustion engines. It was my pleasure to do application work to initialize some of these designs and help make them successful. The first variable speed motor application controlled by an IGBT (called a "COMFET" by RCA) was launched in 1987 by Braun in Kronenberg. I remember visiting Mr. Bauer, an engineer who first trusted his food mixer product to an IGBT. After that, the IGBT became the workhorse for power applications, often in a multiple die package for three phase applications, ubiquitous in the industry.

The world is constantly in flux, and now wide-band gap devices have become mature and continue to grow in volume. Silicon Carbide and Gallium Nitride are successful. Their benefits are smaller system designs with the same or better performance than silicon. In the early days we had the impression that these materials would be exclusive to premium applications. Reduced losses, higher speeds, and smaller associated components requirements now make them a first choice for many applications.

It is nice to see General Electric back together with Danfoss Silicon Power, manufacturing SIC Modules in Utica, NY. About two decades ago, GE left power semiconductors, and sold GE solid state (and its RCA Solid State acquisitions) to Harris. Harris management misunderstood the important role of power semiconductors, so sold off discrete power products (which became part of Fairchild, and more recently On Semiconductor), with the rest, Intersil, having been sold to Renasas. It certainly is interesting to follow how the power semiconductor industry continually develops, as demonstrated for example by how Semikron and Rohm are now working together. The important thing is seeing progress, growing markets, and applications in wind and solar.



I invite you to my annual podium discussion at PCIM Europe! Wide-band gap devices are taking over more and more designs that have historically been served by silicon. We see higher switching frequencies and higher operating temperatures. The reduced size in high performance systems is both a benefit and a challenge. Improved measurement equipment is needed to analyze the design correctly.

Leading wide-band and test and measurement gap companies will join us to provide insights into designing with GaN and SiC.

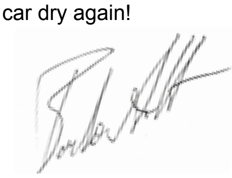
Wednesday, May 17th at the PCIM in Hall 6, Booth 143
From 13:30 to 14:30
"SIC – Design, EMC and Measurement"
From 14:30 to 15:30
"GaN – Design, EMC and Measurement"

I look forward to seeing you there, and to an active exchange that will benefit all participants.

Bodo's Power Systems reaches readers across the globe. If you are using any kind of tablet or smart phone, you will now find all of our content on the new 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 May:
If you drive a convertible watch out for thunder storms and don't forget to close the top while dining in a restaurant. We just watched people in Florida who did, and it takes a lot of energy to get the car dry again!

Best Regards



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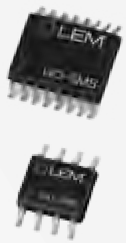

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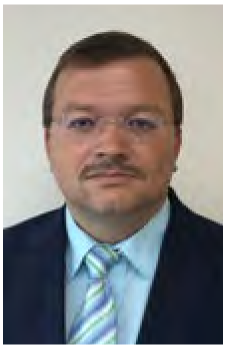
Widening the performance/cost gap with equivalent silicon power transistors, the EPC2045, cuts the die size in half compared to the prior-generation EPC2001C eGaN FET. The EPC2047 eGaN FET also cuts the size in half so that it is now about 15 times smaller than equivalently rated silicon MOSFETs.

Applications for the EPC2045 include single stage 48 V to load Open Rack server architectures, point-of-load converters, USB-C, and LiDAR. Wireless charging, multi-level AC-DC power supplies, robotics, and solar micro inverters are example applications for the 200 V EPC2047.

Designers no longer have to choose between size and performance - they can have both! The chip-scale packaging of eGaN products handles thermal conditions far better than the plastic packaged MOSFETs since the heat is dissipated directly to the environment with chip-scale devices, whereas the heat from the MOSFET die is held within a plastic package.

http://epc-co.com/epc

Expert to Present at PCIM and SMT Hybrid Packaging 2017



Indium Corporation's Andreas Karch, Regional Technical Manager for Germany, Austria and Switzerland, will present at PCIM Europe 2017 and SMT Hybrid Packaging on May 16 in Nuremberg.

Karch will present Performance of Current Flux Systems in Solder Pastes to Increase the Electrical Reliability of Assemblies. He will discuss solder paste flux systems, solder paste performance, and the addition of solder volume for pin-in-paste using Solder Fortification® preforms.

Karch provides support, including sharing process knowledge and making technical recommendations for the use of Indium Corporation's materials, including solder paste, solder preforms, fluxes, and thermal management materials. Karch has more than 20 years of automotive industry experience, including the advanced development of customized electronics. He is an ECQA-certified integrated design engineer and has a Six Sigma Yellow Belt. The Austrian Patent Office also selected him as one of the 2014 recipients of the Top 10 Inventum Awards for an automotive LED assembly. Karch maintains a thorough understanding of process technologies and project management skills.

www.indium.com

Acquiring a Disruptive Power Conversion Technologies

Peregrine Semiconductor Corp., a Murata company and the founder of RF SOI (silicon on insulator), announced the acquisition of Arctic Sand Technologies. An MIT spin-off, Arctic Sand designs and manufactures low-power semiconductors for use in DC-DC power conversion applications. This strategic acquisition will accelerate Murata's vision to revolutionize power electronics with the world's smallest, most efficient power solutions.

Through this acquisition, Arctic Sand's low-power semiconductors will be added to Murata's existing product lineup in order to enhance and expand its power module business in not just the telecommunications market, but also the data communications and industrial electrical markets. Furthermore, Murata will be able to accelerate Arctic Sand's existing business targeting applications in mobile computing, smartphones and LCD display panels.

In certain applications, Arctic Sand's technology reduces the space occupied by power components by 50 percent, reduces the height of component by 3x, reduces losses in power management by up to one half and increases platform run time by more than one hour. Combining this technology with Murata's modular technologies will make it possible to provide solutions with high integration and excellent conversion efficiency in a wide range of low-power fields. Demand for these technologies is expected to grow even further as electrical and electronic components become smaller and thinner.

Peregrine, a subsidiary of Murata, originally identified Arctic Sand's technology as a key component for successful development of disruptive power management solutions.

www.arcticsand.com

www.psemi.com

www.murata.com

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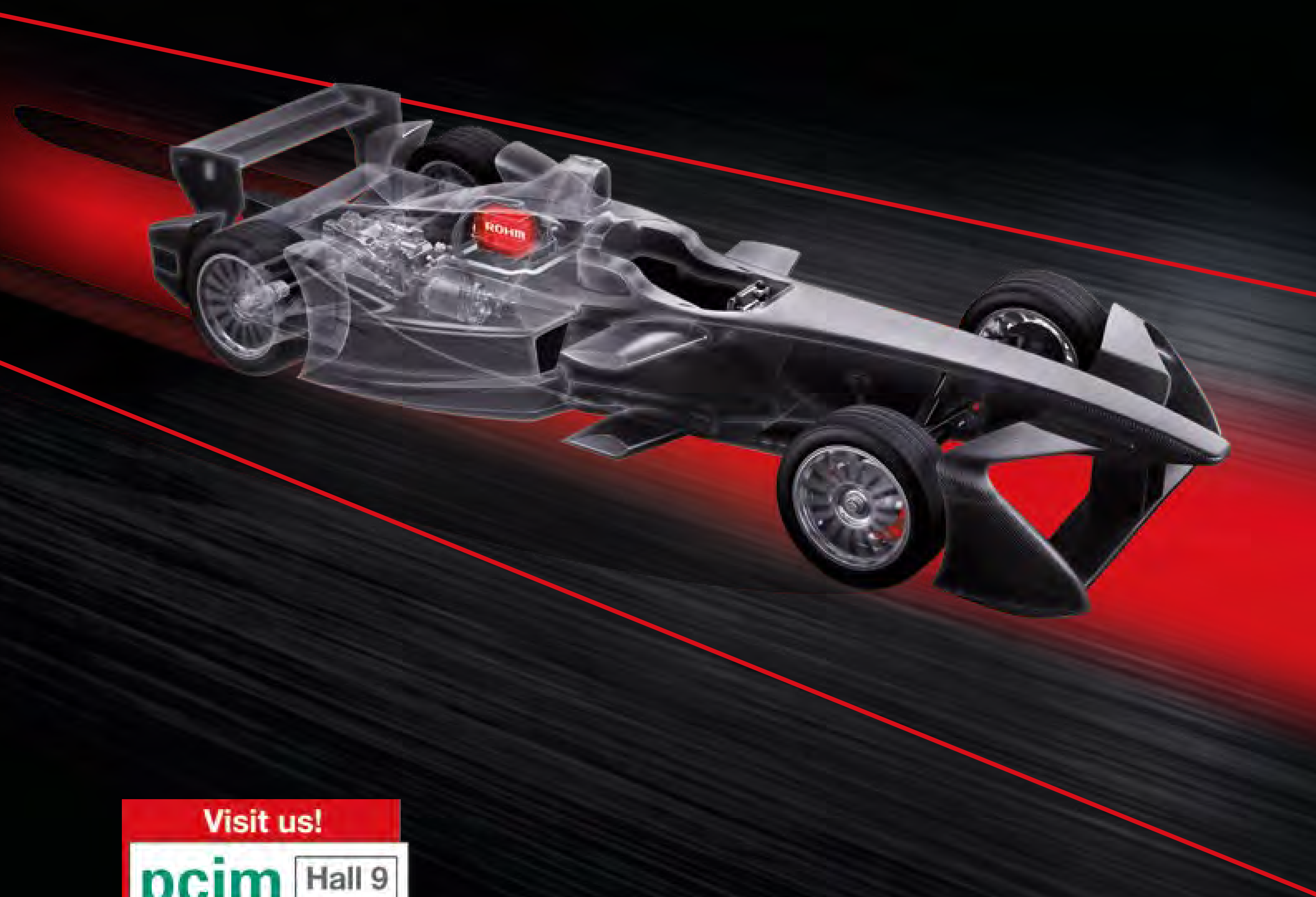

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2017 Innovation Award and Young Engineer Award

Semikron Innovation Award 2017 goes to team of engineers from the Karlsruhe Institute of Technology for their new power electronic circuit for increased solar power output, while the 2017 Young Engineer Award goes to two deserving winners in recognition of their work on the development of a new digital IC for PC power supply systems, as well as a new design tool for automotive power systems.
This year's Semikron Innovation Award went to a team of three engineers: Mario Gommeringer and Alexander Schmitt from KIT Karlsruhe, and Johannes Kolb from Schaeffler Technologies, SHARE at KIT, Karlsruhe. The award-winning team has developed a new innovative power electronic circuit that will help maximize power output in solar power generators. The circuit known as the HILEM circuit or "High Efficiency Low Effort MPP Tracking Circuit" was developed as part of a cooperation project between the Karlsruhe Institute of Technology and the Schaeffler Hub for Advanced Research (SHARE) and can be connected between any number of photovoltaic strings and a common inverter. The circuit maximizes the energy yield of solar generators by enabling individual maximum power point (MPP) tracking for each cell string.
This year's Young Engineer Award has gone to two young researchers. The first award winner Pierrick Ausseresse from Infineon Technologies was selected for his work on the development of a new digital IC for use in PC power supplies. This innovation is very much in line with the trend towards developing firmware for a digital CPU based controller specifically for switch mode power supplies (SMPS). At the heart of this innovation is a digital LLC control featuring a low-cost controller that meets the tight dynamic load step requirements. The digital approach also allows for the integration of flexible protection features that make the power supply system more robust than with

Photo: (f.l.t.r) Prof. Leo Lorenz (ECPE), Johannes Kolb (Schaeffler Technologies), Mario Gommeringer (Karlsruhe Institute of Technology), Alexander Schmitt (Karlsruhe Institute of Technology), Pierrick Ausseresse (Infineon Technologies), Marco Schilling (Ilmenau Technical University), Bettina Martin (SEMIKRON-Stiftung)

analog systems. What's more, this approach eliminates the need for auxiliary power supply for standby operation.
The other joint winner of the Young Engineer Award is Marco Schilling from Ilmenau Technical University. Mr Schilling's award-winning development Opti-PAC is a versatile tool for optimum active and passive component selection in automotive power systems such as electric drivetrains or DC/DC converters.

www.semikron-stiftung.com

Key Account Manager for Lite-On Group

As of now, Maximilian Leppig assumes responsibility for the Lite-One Group as Key Account Manager at SMT. "Direct customer contact is very important. In the case of globally operating companies such as Lite-On, it is all the more important to offer a direct contact. Due to my new position, we will facilitate and intensify the communication with Lite-On. I am looking forward to getting to know the responsible contacts personally," said Mr. Leppig about his new area of responsibility.
The Lite-On electronics group headquartered in Taiwan is one of the market leaders in optical drives and employs around 80,000 people worldwide.
SMT already supplied several vacuum soldering systems to the Lite-On factories in Guangzhou, China and Jalisco, Mexico. Since 2009, SMT has been producing inline vacuum reflow soldering systems for voidfree soldering in Wertheim and is one of the leading specialists in this segment with more than 110 systems sold.

www.smt-wertheim.de

Teaming up to Enhance Online Design Environment for Power-Supply Applications

STMicroelectronics is extending the focus of its eDesignSuite online design environment with the addition of complementing components from Wurth Elektronik, a major transformer manufacturer, to help customers complete their new projects more quickly and cost-effectively.
More and more electronic product design is done online using manufacturer-published tools that are often free to use and provide templates to jump-start circuit design, product selectors, simulators to help evaluate performance, and access to technical support and component purchasing. ST's eDesignSuite can help accelerate design of many circuits and systems including Switched-Mode Power Supplies (SMPS), LED lighting, filters, motor drives, and others.
ST has now linked its eDesignSuite with the web-based Smart Transformer Selector published by Wurth Elektronik, enabling power-supply designers to automate selection of a suitable off-the-shelf transformer while still working in the eDesignSuite environment. Other online design tools generate the transformer specification, and leave the designer to figure out the best way to satisfy it: often by ordering a custom component – which can add cost and turnaround time to the project -- rather than searching manually through complex transformer specification sheets.

www.st.com/eDesignSuite

www.we-online.com/sts

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New Member of CharIN to Contribute to High Power Charging System with SiC Technology

Rohm becomes a regular member of the CharIN (Charging Interface Initiative) , an association to develop and establish the Combined Charging System (CCS) as the standard for charging battery-powered electric vehicles of all kinds.

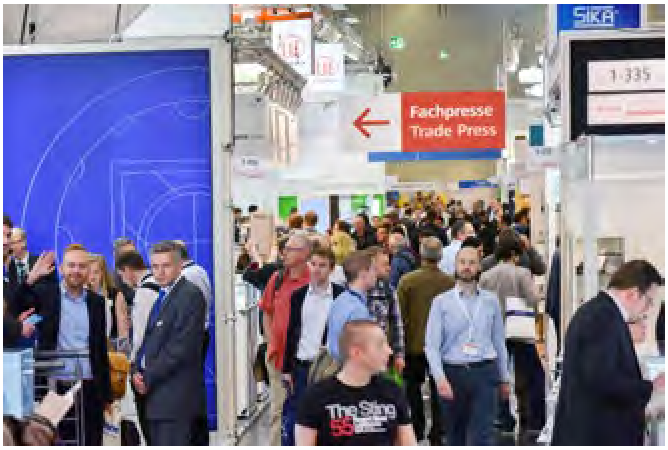
Rohm assures the help to shape up and evolve the e-mobility market by providing Analog-Power solutions of Power management ICs, resistors, and discrete devices especially cutting-edge SiC (Silicon Carbide) Technologies which will eventually contribute to the significant size and weight reduction of the system together with the improvement on total cost ownership.

The president of ROHM Semiconductor GmbH Mr. Christian André commented: 'We are delighted to be a member of expertise in the efforts of creating global standard of automotive charging system. As a pioneer in Silicon Carbide Technologies, ROHM has a clear vision to contribute to the evolution of e-mobility. In this context, CharIN is a perfect organization to share our extended experiences in the field to accelerate the expansion of e-mobility by providing cutting-edge technologies to on/off board chargers for rapid charging, high power DC/DC converters and traction inverters.'

www.rohm.com/eu

Europe's Biggest Measurement Fair – End of May in Nürnberg

The 24th international measurement fair, the SENSOR+TEST, will be held from the 30th of May to the 1st of June, 2017, on the fair grounds



of the Nürnberg Exhibition Center. This is the communication platform across all branches of industry for developers, design engineers, and users in the area of sensor, measuring, and testing technology. It is also a must for students of natural sciences and engineering. State-of-the-art sensors and measurement technology are crucial for future advances in technical devices, machines, systems, and processes. And without the latest testing equipment, the continuously increasing requirements for reliability of products and processes cannot be met. Particularly, the digital world of Industry 4.0, the Industrial Internet, and the Internet of Things requires more and more precise data from real processes to derive added value from this information.

Please note: This press release contains a clearly structured compilation of all product news which the SENSOR+TEST exhibitors will show at the fair (as at mid February 2017). It is classified by exhibiting topics and contains links to full texts as well as pictures of the innovations.

www.sensor-test.de

Benchmark in Customer-First Web Offerings

Vincotech, a supplier of module-based solutions for power electronics, is proud to announce that its state-of-the-art new website is up and running. Featuring a revamped look, feel and functions, this new Internet showcase was built to make the retooled brand even stronger.

Vincotech's offering at www.vincotech.com raises the bar for websites in this industry. Its forward-looking design is sure to appeal to visitors and serve customers for many tomorrows to come. It affords effortless access to in-depth info on every product. Everything customers need - descriptions of potential applications, details on Vincotech's topology and housing portfolio, and comprehensive technical support - is just a few clicks away.

Key features include: Precise pin-out and topology specs, interactive 3D object files; Comprehensive database; Ultra fast, compound search capability; Effortless comparison of products on wish-lists Live chat – a fast, convenient way to get in touch with a Vincotech engineer and Responsive design

For more about Vincotech's range of power modules, visit:

www.vincotech.com/products/product-search.html

Ludger Trockel President of TDK Europe

TDK Corporation announces that effective April 1, 2017, Ludger

Trockel (53) has been named President of TDK Europe GmbH, the company's European sales organization. He thus succeeds Rudolf Strasser (64), who has retired on March 31, 2017.

TDK Europe's management team also includes Andreas Keller (47) and Josef Vissing (53). Keller, Senior Executive Vice President, will serve as the TDK Europe Managing Director alongside Trockel. Vissing, Executive Vice President, will serve as Deputy Head of Sales.

The three are in full agreement: "TDK Europe's already established set-up enables us to offer the best support for our European customers with a unique product portfolio centered on TDK's three key markets, Automotive, Industrial & Energy and Communications. We aim to continue to grow the business together with our customers and support the growth strategies of TDK Corporation, among others, by promoting our expanded product range for sensors."

www.tdk.com/

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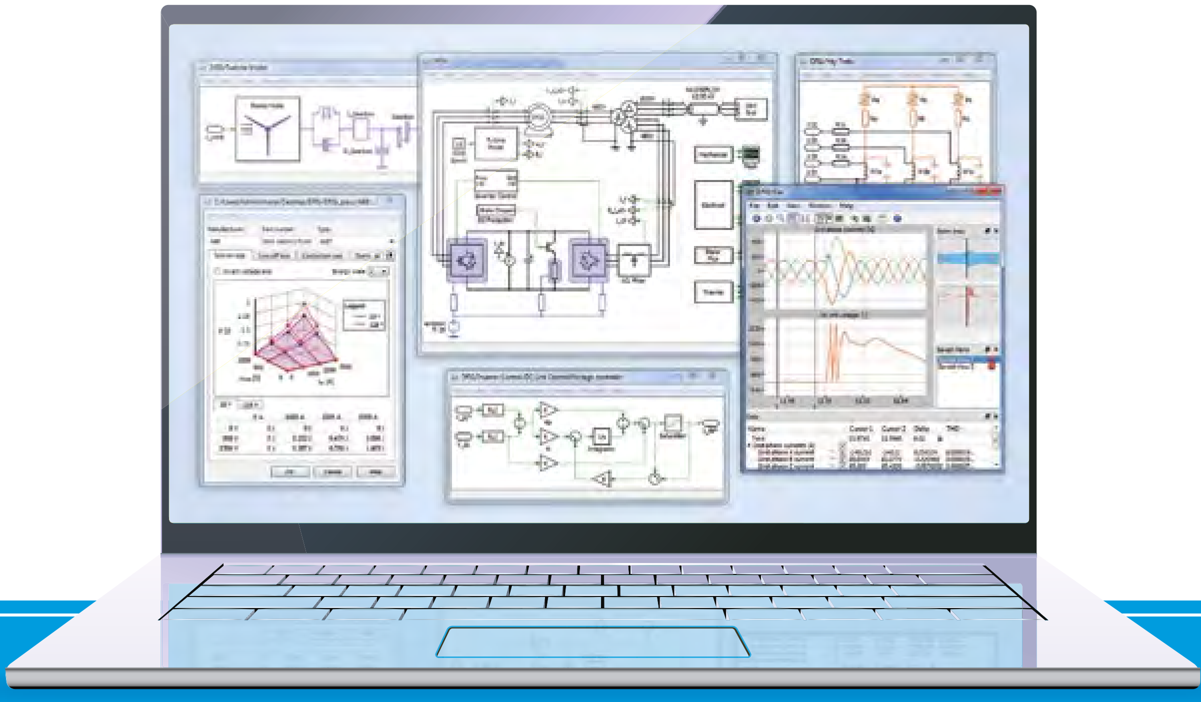

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Intersolar Europe Munich, May 31–June 2, 2017

Intersolar Europe is once again set to serve as the most important industry meeting point for the solar industry and its partners. Manufacturers, distributors, service providers and suppliers will gather in Munich to discuss the latest trends, technologies and products. The exhibition also boasts an extensive accompanying program: Among this year's highlights are the special exhibit Smart Renewable Energy, a French-German networking event and the Intersolar AWARD, which is celebrating its 10th anniversary. In addition, the Intersolar Europe Conference, led for the first time by new chairman Dr. Pierre-Jean Alet, will address a broad range of topics on May 30 and 31.
Solar power is hot. In January, the German Solar Association announced that another milestone had been reached with 300 gigawatt peak (GWp) of PV capacity installed worldwide. According to the association, solar power systems with a nominal capacity of 75 gigawatts were added in 2016 – approximately 30 percent more than in 2015. 2016 also brought good news from Germany: According to data from the Germany Federal Network Agency, around 51,900 new solar power plants with a capacity of approximately 1.52 GWp were installed last year, as compared to 1.46 GWp the previous year. Experts believe that more than 2 GWp could be deployed this year – an outstanding market environment for Intersolar Europe 2017.

www.intersolar.de/en

Joining the U.N. Global Compact Initiative

Powerbox has become a signatory of the United Nations Global Compact, the world's largest corporate responsibility initiative. As such, Powerbox pledges to support and promote the Compact's 10 principles in the areas of human rights, labor, the environment and anti-corruption.
Powerbox's environment, social and governance (ESG) commitment begins with the company's value system and a principled approach to doing business. This means operating in ways that at a minimum, meet fundamental responsibilities in the areas of human rights, labor, the environment and anti-corruption. By incorporating the Global Compact principles into Powerbox strategies, policies and procedures, and establishing a culture of integrity, it not only upholds its basic responsibilities to people and the planet, but is also sewing the seeds for long-term, sustainable success.
Powerbox places the environment and sustainable development at the forefront of everything that it does. In its product development, manufacturing, supply, sourcing and operations it is constantly implementing technologies and processes that reduce energy consumption and other environmental impacts. The UN Global Compact's Ten Principles are derived from: the Universal Declaration of Human Rights, the International Labor Organization's Declaration on Fundamental Principles and Rights at Work, the Rio Declaration on Environment and Development, and the United Nations Convention Against Corruption.

www.unglobalcompact.org/

Joining Forces in Strategic Collaboration

Danfoss Silicon Power is establishing production in the US and entering into a collaboration with industrial giant General Electric (GE). The collaboration means that Danfoss Silicon Power will become the world's leading provider of silicon-carbide (SiC) power modules.
The SiC power modules will create smaller, faster, and more effective electronic devices, and are expected to revolutionize the technology within solar and wind energy as well as the future generations of electric and hybrid cars.

The transatlantic collaboration between Danfoss and GE will be part of New York Power Electronics Manufacturing Consortium (NY-PEMC) in Utica, upstate New York. The private-public consortium and other similar programs were established in 2014 by the state of New York with a total investment of more than USD 20 billion for the creation of high-tech jobs.
By early 2018, DSP will establish SiC power modules packaging operations in Utica, and is expected to create hundreds of jobs in the coming years. GE will provide SiC chips for the modules.
The news has been announced today, Friday, March 24, by Andrew M. Cuomo, Governor of New York State, which is financing all startup costs as well as production facilities. Danfoss will lease both the facility and equipment from New York State and occupy the entire facility in Utica, which includes two cleanrooms, labs, offices and logistics space.
"This is a very important step for Danfoss, as the US is our biggest market and essential to our business. The cooperation with GE has great strategic impact for Danfoss – it is important for our future growth plans in the US, and we have big expectations for the further developments in this highly-specialized area," says Executive Vice President and COO in Danfoss, Kim Fausing.
With 330,000 employees, GE is one of the world's leading industrial companies. It has spent millions of dollars in developing the ultra-thin SiC chips, which will be used in the power modules from Danfoss.
"Danfoss Silicon Power is gaining a unique position as the only independent SiC module manufacturer in the US and GE has been a customer from day one. Similarly, it has opened the door to the US market, where demand for the power modules manufactured by Danfoss Silicon Power is expected to grow explosively," says Claus A. Petersen, General Manager and Vice President of Danfoss Silicon Power.

www.siliconpower.danfoss.com

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DC/DC Book of Knowledge - Now with New Magnetics Chapter

The new edition of the Recom DC/DC Book of Knowledge has been released, with an additional chapter on magnetics. More than 1,000 online copies have been downloaded by engineers worldwide, in the first few weeks. This shows how valuable this source of in-depth practical power design information is to the power supply community.

The author, Steve Roberts, says: "I am overwhelmed to hear that the new book of knowledge has been so well accepted in the industrial and educational communities. This makes all the hard work in writing the additional chapter worthwhile."

The new edition features an additional chapter on magnetics to cover the fundamentals of inductors and transformers. The chapter begins with terminology, core saturation, air-gapped inductors, core geometry, core losses, the skin effect and proximity effect. Worked examples of buck and boost DC/DC converter designs show how to correctly dimension the magnetic components and how to calculate the losses in the magnetic core and switching elements. The section continues with DC/DC transformer design, showing how to specify Royer push-pull, forward and flyback transformers - again with worked examples to demonstrate how to calculate the dimensions, turn ratios, losses and duty cycle limits for these topologies. For flyback transformers, the gap length and bobbin dimension calculations are also explained. Free PDF versions are available in English, German, Chinese and Japanese at:

www.recom-power.com/bok

Featuring InFORMS® Reinforced Solder Preforms at PCIM Europe 2017

Indium Corporation will feature its reinforced solder alloy fabrications, InFORMS®, at PCIM Europe 2017, booth 7-315, May 16-18, in Nuremberg, Germany.

Indium Corporation is redefining solder with its InFORMS solder preforms. InFORMS are a composite preform consisting of solder and a reinforcing matrix that, together, increase lateral strength and bondline co-planarity while improving thermal cycling reliability.

When InFORMS were used to solder a DBC to the baseplate of an IGBT, one study showed:

4x improved thermal cycling reliability compared to a solder preform-only approach

2x improved thermal cycling reliability compared to a solder preform + Al wirebond stitch approach

Reduced voiding (<1%)

Lower cost of ownership – as a drop-in replacement for a standard preform or solder paste, InFORMS require no additional process steps or equipment

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ECPE Workshops

ECPE Workshop: Condition and Health Monitoring in Power Electronics
4 - 5 July 2017, Aalborg, Denmark
Chairmen: Prof. F. Blaabjerg (Aalborg University), Dr. S. Mollov (Mitsubishi Electric R&D Centre Europe), Dr. A. Rojko (ECPE)

ECPE Tutorial 'Power Semiconductor Devices & Technologies'
26 - 27 April 2017, Berlin, Germany
Chairmen: Dr. A. Mauder (Infineon), Prof. D. Silber (Univ. of Bremen)

ECPE Workshop 'EMC in Power Electronics: From Harmonics to MHz - Design for EMC and Fast Switching'
3 - 4 May 2017, Berlin, Germany
Chairmen: Prof. E. Hoene (Fraunhofer IZM), Dr. L. Dalessandro (Schaffner Group)

European PhD School on 'Power Electronics, Electrical Machines, Energy Control and Power Systems'
22 - 26 May 2017, Gaeta, Italy
Chairman: Prof. G. Tomasso (University of Cassino)

ECPE Tutorial 'Power Electronics Packaging'
21 - 22 June 2017, Würzburg, Germany
Chairmen: Prof. U. Scheuermann (Semikron), Dr. J. Popvic-Gerber (TU Delft)

ECPE Tutorial 'Thermal Engineering of Power Electronic Systems - Part I (Thermal Design and Verification)'
18 - 19 July 2017, Erlangen, Germany
Chairmen: Prof. U. Scheuermann (Semikron), D. Malipaard (Fraunhofer IISB)

ECPE Tutorial 'Thermal Engineering of Power Electronic Systems - Part II (Thermal Management and Reliability)'
10 - 11 October 2017, Nuremberg, Germany
Chairmen: Prof. E. Wolfgang (ECPE), Prof. U. Scheuermann (Semikron)

ECPE Tutorial 'Power Circuits for Clean Switching and Low Losses'
9 November 2017, Aalborg, Denmark
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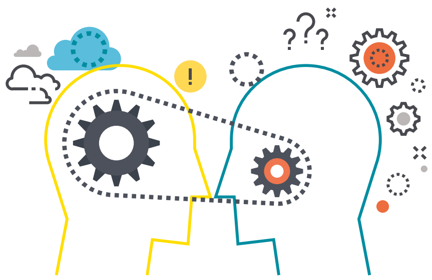

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Collaboration Sales in Japan

Photo: (left to right) Erwin Ysewijn, Managing Directror Semikron Japan; Mr. Kazuhide Ino (Ph.Doctor), General Manager Power Device Division, Rohm Co.,Ltd.

Rohm and Semikron will kick-off collaboration sales of SiC power devices and modules, to contribute to the innovative evolution of the Japanese power electronics market.
Rohm has been a leading developer of advanced Silicon Carbide (SiC) products and SiC power devices in particular. It was the first company in the world to manufacture the SiC MOSFET in 2010 and offers SiC Schottky diodes as well. The wide range of Rohm SiC chips is suitable for an easy module integration.
Semikron is one of the market leaders in power modules, covering a wide range of packages for all applications. It is well known for its cutting edge packaging technology that has set standards in power electronics. Semikron offers SiC modules in six different packages covering 20A to 600A, which are widely used in the world-wide power electronics market, enabling energy savings in various applications. Both companies together will synergize their joint knowledge (about Device, Control and Module technology) in the approach to the Japanese power electronics market, offering the perfect power solution. Both companies will collaborate to widen the SiC power module lineup and contribute to energy saving and miniaturization.

www.semikron.com

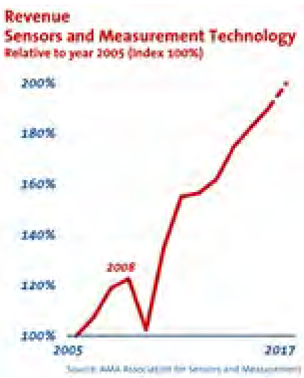
Revolutionizing the Semiconductor Purchasing Process

Microchip Technology Inc. debuted its updated, feature-rich and mobile-optimized e-commerce platform for purchasing microcontrollers, mixed-signal, analog, Flash-IP solutions and more. microchipDIRECT, which sells Microchip parts directly to customers, has been updated with several new mobile-accessible features that are now available for the first time in the semiconductor industry. The new mobile website includes high-volume quotes, custom programming, ordering flexibility, numerous languages, worldwide currency options and global support.

"Consumers expect a certain look, feel and ease-of-use on any e-commerce site they visit whether purchasing consumer goods or semiconductors," said Sean Strickler, director of corporate sales at Microchip. "microchipDIRECT is meeting those consumer expectations by providing a B2C-like experience that allows our clients to check product stock quantities, see pricing, track orders or download a data sheet directly from their mobile device. We are proud to be the industry leader in this area with unique key features that are easily accessible on our new mobile-optimized website."
The key features of the new mobile-optimized website include:
Volume pricing: Users can now easily request a quote for high-volume pricing via a smartphone, tablet or desktop device. No other website in the industry offers this feature.
Custom programming: Customers are able to add custom code to a microcontroller or memory device via the microchipDIRECT Programming Center. This service offers fast and low-cost programming. Customers can also easily apply their approved pricing quote to a programmed part.
Ordering flexibility: Customers are able to check when their order will arrive before they commit to placing an order. In addition, customers are now able to schedule their orders up to 12 months in advance and dropship to most global locations using their smartphone or tablet.

www.microchipdirect.com

Sensors and Measurement: Turnover, Investments, and Exports Are Up



AMA Association for Sensors and Measurement (AMA) polled its members on the economic development during 2016. The sensor and measuring industry was able to maintain its successful growth in all segments. The AMA members anticipate a further growth in revenue of five percent and plan to invest another five percent, compared to the results of the previous year. Last year, the sensor and measurement industry generated a cumulated growth in turnover of four percent. With this result, the sensor and measurement industry was able positively stand out from the development of the producing industry as a whole, which nearly stagnated last year.
This development is also confirmed by the willingness of the sensor industry to invest. In fact, the AMA members invested two percent more last year than in the previous year. The representatives of the sensor and measurement industry propose to further increase their investment by an additional five percent. At the same time, they also plan to expand their workforce by a further three percent.

www.ama-sensorik.de

Networking Application Development with RZ/N Series of Microprocessors

Renesas Electronics announced the new RZ/N Series of industrial networking communication microprocessors (MPUs) that simplifies network-based application development. The RZ/N Series is ideal for use in industrial network devices such as network switches, gateways, programmable logic controllers (PLCs), operator terminals, and remote I/O units. The RZ/N brings together multiple industrial networking technologies within a single chip, enabling system manufacturers to develop systems supporting a variety of industrial network protocols and network redundancy protocols in less time. Renesas also delivers broad ecosystem support to facilitate system manufacturers' software development by offering a general application programmable interface (API) that provides a unified support for network protocol stacks implemented by industry-leading Renesas partners, in addition to compiler and OS environments. The RZ/N lineup comprises three product groups for scalability: the RZ/N1D Group for high-end applications, the RZ/N1S Group for mid-range applications, and the RZ/N1L Group for low-end applications.

www.renesas.com

CTO Alexander Gerfer appointed to the Executive Board

Alexander Gerfer (51), CTO of the Würth Elektronik eiSos Group, has been appointed to the company's Executive Board. With immediate effect, together with the CEOs of the Würth Elektronik eiSos Group, Oliver Konz and Thomas Schrott, he would be co-responsible for the future strategies of one of Europe's largest suppliers of electronic and electromechanical components. Alexander Gerfer's appointment is an acknowledgment of his excellent services on behalf of the company. At the same time, this reflects the relevance of the areas under his responsibility, namely research and development, product management, and quality and supply-chain management, for the success of the group as a whole. Besides being appointed to the Executive Board, Alexander Gerfer this year is also celebrating the twentieth anniversary of his employment with the company. Since taking up his job in April 1997, he has been working at the Würth Elektronik eiSos facility in Waldenburg. As is so typical at Würth, the graduate engineer started out on his career as a technical sales representative, soon moving on to the area of product management, where he was employed as departmental director, authorized signatory, managing director, and most recently as CTO.

"Alexander Gerfer has played a major part in the success of Würth Elektronik eiSos, and now it's time for the company to show its appreciation for his efforts and the enormous positive impact that he's made on the development of our product portfolio over the past years," says CEO Oliver Konz. Thomas Schrott, his CEO colleague, goes on to say: "We warmly welcome our CTO Alexander Gerfer as an Executive Director and wish him every success and continued good luck in his decisions."

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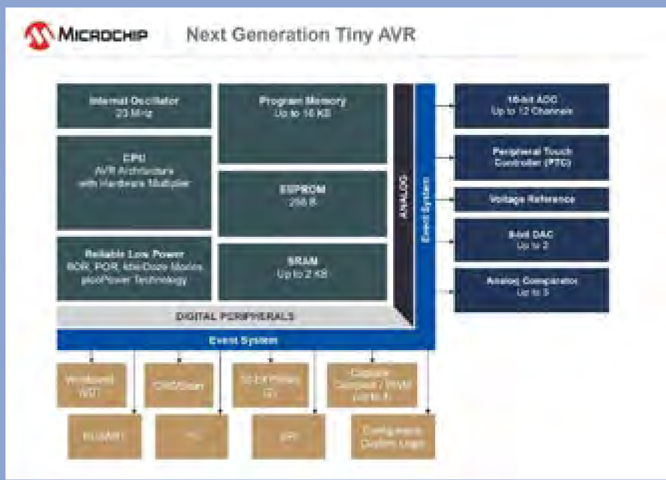
tinyAVR® MCUs Increase System Throughput While Lowering Power Consumption in Embedded Applications

Microchip continues the expansion of the AVR product line with three new ATtiny MCUs that were introduced at the embedded world show in Nuremberg. The MCUs combine Core Independent Peripherals (CIPs) with larger 16 KB Flash memory. They allow intuitive graphical configuration of embedded software via the online Atmel START tool. The ne ATtiny1617 series offers pin- and code-compatibility with ATtiny817 series and support peripheral communication without CPU overhead and capacitive touch.

Microchip announces further expansion of its AVR microcontroller (MCU) portfolio with the addition of three new devices to the tinyAVR MCU family. The new ATtiny1617 series of MCUs expands the range of AVR devices that feature Core Independent Peripherals (CIPs), which help to increase system throughput while lowering overall power consumption. The new devices extend the memory offering for these next-generation tinyAVR MCUs with new 16 KB Flash options, while remaining pin- and code-compatible with the recently released ATtiny817 series devices. Furthermore, all members of the family are supported by Atmel START, an online tool for intuitive graphical configuration of embedded software projects.

The new MCUs offer 16 KB Flash, 256 B EEPROM, and 2 KB RAM in 14-, 20-, and 24-pin packages. The devices contain key features of other tinyAVR MCUs including the Event System Controller, which allows peripherals to communicate without using the Central Processing Unit (CPU) and enables designers to customise the configuration of the MCU for their specific application. The on-chip Peripheral Touch Controller (PTC) simplifies the development of capacitive touch systems. Other integrated features include: a 20 MHz internal oscillator, high-speed serial communication with USART, SPI, and I2C, configurable custom logic blocks, a 10-bit Analogue-to-Digital Converter (ADC) with internal voltage references, operating voltages ranging from 1.8 V to 5.5 V, and picoPower® technology for sleep currents as low as 100 nA.



The new devices are fully supported by the Atmel Studio 7 Integrated Development Environment (IDE), the STK600 platform and Atmel START, a free online tool to configure peripherals and software for easy development.

The three new tinyAVR MCUs are available today for sampling and in volume production.

- ATtiny1617 is available in a QFN24 package
- ATtiny1616 is available in a QFN20 and SOIC20 package
- ATtiny1614 is available in a SOIC14 package.

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Tipping Point for Wide Band Gap Technology Signals Start of Mainstream SiC Adoption

By Dr. Peter Wawer, Division President Industrial Power Control at Infineon Technologies AG

The past few years have been notable for the increased rate of investment in developing alternative semiconductor materials such as silicon carbide (SiC) and gallium nitride (GaN). Further improvements in SiC transistor manufacturing costs in recent times signaled a watershed moment – the turning point for SiC power semiconductors to be successfully mass-produced and implemented in electronic designs for a wide range of applications. The lower price and increased availability of SiC has resulted in renewed demand from power designers who are under pressure – pressure to address legislative and commercial requirements for improved energy efficiency and to keep up with the never-ending expectations for system cost reduction that have been set.

High power and high voltage power converters are still relatively difficult to miniaturize compared to other circuit elements. This is largely because heat needs to be properly dissipated, and smaller circuits with increased thermal density are more challenging in this respect. The arrival of SiC in power electronics, offering better power density and efficiency, has opened up many more possibilities, making silicon carbide-based devices genuine contenders to supersede the limitations of silicon-based MOSFETs, IGBTs and diodes.

Efficiency, power density and the reduction of system cost are all key drivers behind the use of alternative semiconductor materials such as SiC and GaN for power diodes and transistors. Certain application sectors will always be early adopters of any new technology if the benefits outweigh the risks. Depending on a number of factors, others will follow when the cost-to-performance ratio is attractive enough to migrate to a new technology. As an example, hybrid power modules using silicon IGBTs and SiC Schottky diodes have already become mainstream in solar power converters with high switching frequencies some time ago.

The fact that SiC is not just a drop-in replacement for silicon is seen as one of the major factors inhibiting uptake in recent years. Doubts over material and hence product quality also prevented designers from stepping into ‘here be dragons’ territory.
Solar inverters and boost circuits are already gaining from the benefits offered by SiC MOSFET technology, quickly followed by Uninterruptible Power Supplies (UPS) and chargers. Segments currently seen as more ‘wedded’ to silicon such as motor drives, traction and automotive applications are subsequently expected to make the leap over to widespread acceptance and use of the new materials.

But as with every emerging trend, the resultant boom in production comes with its pros and cons. Multiple suppliers have entered the SiC substrate wafer supply market, meaning increased production and competition has driven down costs. And more investment in R&D has led to tangible improvements in quality and reliability. The move from 4-inch to 6-inch, and eventually 8-inch SiC wafers is predicted to reduce costs significantly in the coming years, and SiC wafer quality is generally improving. The knock-on effect of this is increasing yield, which should in turn lead to the tipping point for the implementation of SiC even in more cost-sensitive applications.

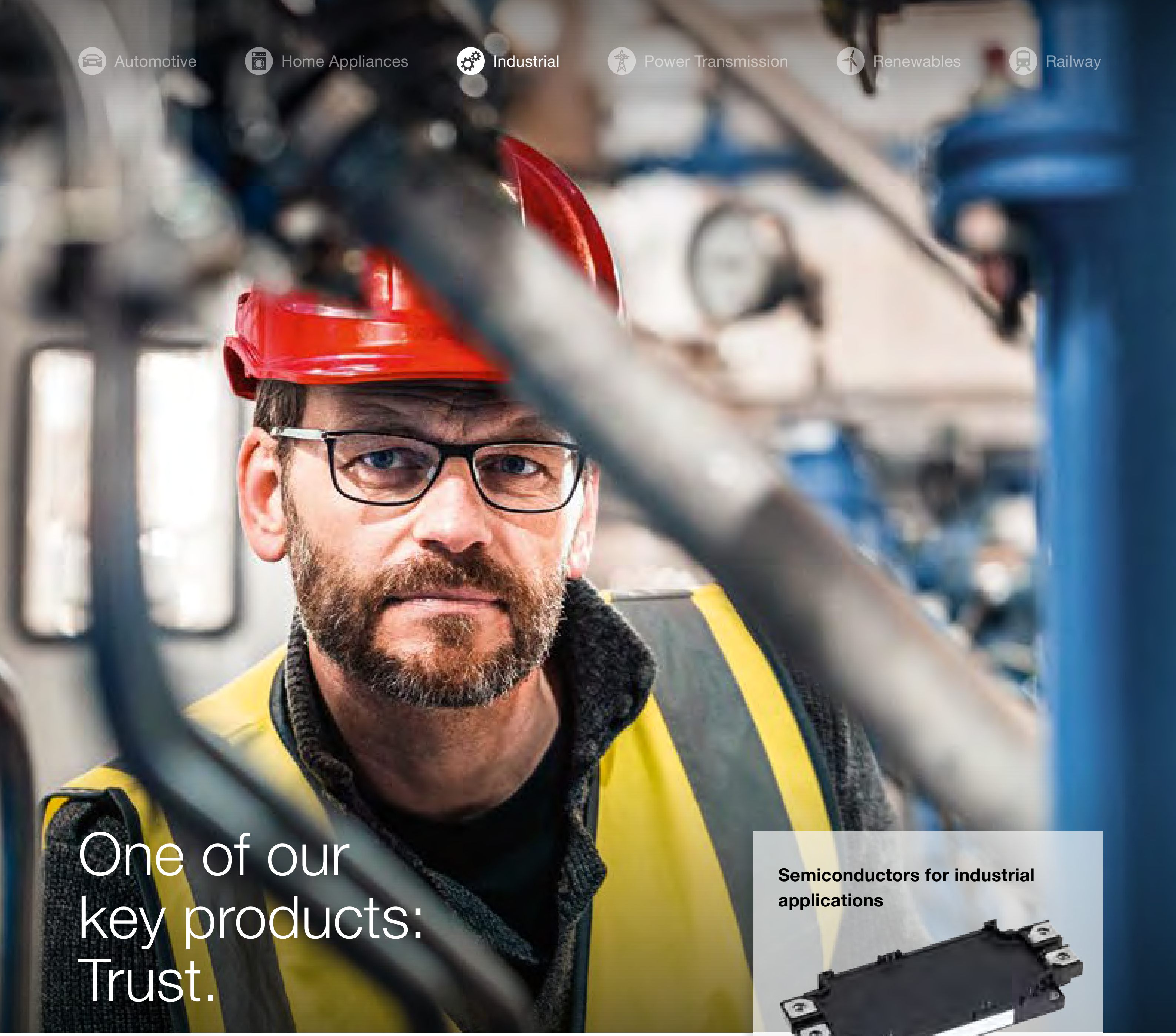
However, SiC device manufacturers are unevenly matched in terms of product quality and pricing. Some are new and untested “niche” players on the market, many of which will probably need to consolidate to survive. Others are well-established semiconductor companies with the capability to produce large volumes in-house under strictly controlled manufacturing processes and quality conditions. Before widespread adoption can take place, customers will need to be sure that their chosen semiconductor supplier will be able to provide a consistent supply of high-quality products and continues to deliver this as demand increases.

It’s clear that manufacturers of SiC power semiconductors will need to generate unshakeable confidence in the reliability of their products to gain credibility in the market, from tried and tested specifications to heat-resistant package material and reliable production bases. If this can be achieved, SiC devices will become truly mainstream.
Early adopters wishing to incorporate SiC into their designs and make the next essential step towards an energy-smart world will need to partner with a supplier with dedicated products for the right applications and a proven track record in both innovation and reliability. They will be looking for assured high-volume production capability as well as manufacturing standards of outstanding quality.

As a pioneer in the commercial use of SiC technology, Infineon was the first company worldwide to introduce SiC-based diodes to the market back in 2001. This was followed by the introduction of commercial power modules containing SiC components in 2006. Infineon now offers 5th-generation SiC technology as diodes and is preparing to ramp its first wide band gap products based on SiC MOSFET technologies in the near future. However, unlike other suppliers, Infineon’s strong roots in silicon enables the company to offer customers a comprehensive variety of optimized power products – from silicon through hybrids to dedicated wide band gap solutions.

(Visitors to PCIM in May this year will find Infineon its full range of GaN and SiC technologies, including dies, diodes, discretes and power modules.)

www.infineon.com/CoolSiC



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Applied Power Electronics Conference and Exposition - APEC 2017

APEC, the premier annual event in applied power electronics enables power electronics professionals to meet, exchange the latest technical knowledge and develop valuable industry connections.

By Gary M. Dolny, Bodo's Power Systems, gary.dolny.us@ieee.org

The 2017 Applied Power Electronics Conference and Exhibition (APEC-2017) was held from March 26-March 30 at the Tampa Convention Center, Tampa, Florida, USA. The conference, which is jointly sponsored by the IEEE Power Electronics Society (PELS), the IEEE Industry Applications Society (IAS) and the Power Sources Manufacturers Association (PSMA) brings together professionals from all sectors of the power electronics industry for in-depth technical presentations and discussions that combine theory with practical applications.

Attendees stroll the exhibit hall at APEC 2017

This year's technical program was organized into technical sessions, industry sessions, exhibitor seminars and an evening of rap sessions. Over 500 papers were presented covering all aspects of applied power electronics. The papers for the technical sessions were chosen through a rigorous peer review process to ensure high-quality presentations. For the industry sessions, the speakers were invited to make a presentation only, without submitting a formal manuscript for the APEC Proceedings. This allows for information on current topics that would not otherwise be publically presented at a professional conference. While many of these are technically oriented, some also address business related issues. The exhibitor seminars were a series of half-hour presentations that provided more in-depth discussion of exhibitor's products and services than could be obtained by a vist to their booth.

A series Professional Education Seminars were held prior to the start of the technical program. The Professional Education Seminars address the need for in depth discussion of important and complex power electronics topics. Each seminar combined practical applications with theory designed to further educate the working professional in power electronics and related fields. The Professional Education Seminars at APEC are three and one half hours (including breaks) in length, range from broad to narrow in scope, and can vary from introductory to advanced in technical level. The 18 seminars covered a wide range of topics including design, control, EMI and reliability, components and systems, SiC devices, and wireless charging and magnetics.

In addition to the technical sessions, 269 exhibitors were on hand to provide attendees the opportunity to examine product offerings, design tools and services from the leading suppliers in the power electronics industry. The conference also offered numerous opportunities for professional networking, including an Exhibit Hall Welcome Reception and a social event themed "Little Havana" featuring food, entertainment, games and antique automobiles.

Wide-bandgap materials and devices were once again a major focus of the conference program as numerous presentations discussed the commercialization of both GaN and SiC devices. Significant attention was devoted to the reliability and robustness of these devices in applications such as electric and hybrid electric vehicles, industrial power converters and consumer applications.

A plenary presentation by L. Stevanovic described General Electric's approach to developing a silicon carbide based MW-scale converter. The 2.5 MW utility scale converter uses a new generation of high-performance SiC MOSFETs with voltage rating from 1.2-3.3 kV and current ratings up to 100A per die. Extensive stress testing was described that verified device safe operating area, avalanche capability, short-circuit ruggedness and body diode surge capability.

A number of presentations from Wolfspeed addressed performance, reliability and life testing issues of SiC. J.Casaday described quantitative reliability measurements and accelerated life data for 900V,10mohm, 32mm^2 SiC MOSFETS being developed for automotive and industrial applications. The devices passed die level qualification tests at a T_j of 175C including HTRB, H3TRB, and HTGB. SiC MOSFET performance was compared to commercial Si-IGBT technology in a 90kW converter and was shown to reduce drive-train inverter losses by 78%. A second presentation from Wolfspeed by M. Das discussed their all SiC standard modules in both half-bridge and six pack configurations. In addition to passing the standard JEDEC/IEC qualification tests, the power cycling lifetime exceed 1997LESIT standards and now approaches the capability of modern IGBTs in standard packages. J. Palmour described Wolfspeeed's SiC MOSFETs for Industrial applications. He stressed the idea that "not all amps are created equal" and that the traditional cost-per-amp metric doesn't properly capture the benefits of SiC solutions since the reduced switching losses of SiC are not accounted for. He suggested cost-per-kW-delivered as a better metric. He also showed the improved performance at switching frequencies >10kHz achieved with all SiC modules compared to Si-IGBTs, demonstrated Wolfspeed's 1kV 3rd generation SiC MOSFETs in a fast EV charging system and presented performance data from 3.3 kV devices and modules with switching frequencies >50kHz.

A presentation by G. Sheh of Monolith Semiconductor argued that standard reliability testing does not adequately represent the stresses seen in actual circuit operation of SiC devices and that development of in-circuit reliability testing is an important criterion for reliability verification. He proposed a pump-back converter topology that stresses devices at their rated current and voltage during continuous switching that emulates real-life conditions and demonstrated reliable operation of test units over a 100 hour test cycle. Monolith also presented rugged 1.2kV SiC MOSFETs fabricated in a high-volume 150mm CMOS fab. The process flow allows both Si and SiC devices to be run in parallel in a commercial production line through the reuse of established CMOS unit process steps and the minimization of special process tools to the extent possible. The resulting devices passed 175C HTRB and HTGB testing and demonstrated <300uJ switching losses with R_g=5 ohm.

R. Radharkrishnan of Global Power Technologies Group described Advanced SiC Technologies for Power Circuit Applications. He discussed device advances including monolithic integration of a Schottky diode with a SiC MOSFET for improved 3rd quadrant operation and step graded epitaxy for optimal specific-on-resistance. He showed 1200V SiC MOSFETS with specific resistance less than <3.5mohm-cm² and threshold voltage of 3.8V.

A number of presentations addressed the use of wide-bandgap devices for high frequency topologies. S. Watts Butler of Texas Instruments described the GaN Standards for Power Electronic Conversion Devices Working Group. This is an independent working group consisting of GaN producers, users, researchers and non-profit agencies with multiple sponsorship including IEEE and JEDEC. The mission of the group is to accelerate the maturity of the GaN industry by creating standards and guidelines for testing, reliability qualification and data sheet parameters for GaN-based power conversion devices early in the product lifecycle.

A. Lidow, of Efficient Power Conversion (EPC) described how a new version of "Moore's Law" applies to GaN technology. He noted that current generation GaN devices exhibit 2X R_{sp} improvement over the previous generation while both exhibit superior performance compared to the best available Si MOSFETs in a converter application with 48V in and 5V out operating at 500kHz. This improved technology will accelerate adoption of GaN in traditional end markets while enabling new applications such as LIDAR and wireless power to be efficiently addressed. He concluded that a potential 250X further improvement with GaN is still possible.

D. Kinzer of Navitas discussed the company's proprietary AllGaN™ technology that is capable of monolithic integration of 650V e-mode GaN FETS along with GaN logic and driver circuits to provide solutions for switching frequencies of 1MHz and above. He demonstrated AllGaN™ performance in a variety of high-frequency applications addressed by the new technology including a 45W active clamp flyback converter with 94.5% efficiency and a 1MHz, 3.2kW server supply with 70W/in^3 power density.

R. Singh of Genesic Corp. described recent progress in medium voltage (3.3kV-15kV) SiC devices. Key applications in this space include solar and wind power inverters, traction and power grid. For this voltage range Singh advocated a SiC bipolar transistor dubbed the SJT. This class of devices offers low R_{dson}, temperature independent switching and positive temperature coefficient for easy paralleling. A 10kV SiC-BJT with 4.2mJ Eoff and 1.6 mJ Eon was demonstrated.

G. Miller of Sarda Technologies described a heterogeneous integrated power stage. The so-called HIPS technology integrates GaAs switches with silicon drivers and passive components. Miller argued that GaAs is the ideal material for high-frequency switching applications due to its very high electron mobility. In addition, the costs can be low since the Sarda approach leverages an existing $8B US GaAs industry.

APEC 2018 will be held from March 4-8 2018, in San Antonio, Texas, USA at the Henry B. Gonzalez Convention Center. Additional information is available at the conference URL.
http://www.ieee.org/conferences_events/conferences/conferencedetails/index.html?Conf_ID=34780

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7th ECPE SiC & GaN User Forum

Potential of Wide Bandgap Semiconductors in Power Electronic Applications

By Andreas Lindemann, Otto-von-Guericke-University Magdeburg, Chair for Power Electronics, and ECPE European Center for Power Electronics e.V.

Overview Report of Conclusions from Nuremberg, 8.-9. March 2017
ECPE wide bandgap user forum recently celebrated a decadal anniversary: As premier event of this kind it has accompanied the development of Silicon Carbide (SiC), Gallium Nitride (GaN) and other wide bandgap power semiconductor devices and their design-in into circuits and systems for more than ten years. Following several other European venues the seventh event took place in March at Nuremberg. The highest number of registrations ever showed the great interest of power electronics community in this actual subject. Main technical focus has been on new developments with SiC and GaN transistors including system and circuit design, related aspects like packaging and parasitics, and an outlook on future prospects. Renowned experts from industry and research institutes all over the world have been invited to explain state of the art and trends, to foster physical understanding, to in depth explain their research and development work in technical presentations and to share their knowledge in discussions. The wide bandgap user forum this way has established a valuable platform to exchange experience and ideas, to show best practice of power electronic systems with SiC or GaN, to discuss and find out how to appropriately design-in those almost ideal but also challenging components, and which open issues need to be addressed. It aimed at pointing out approaches to fully exploit the high potential of wide bandgap devices for the benefit of modern electric and electronic systems in a variety of applications. Presentations of results of relevant European research projects impressively complemented this aspect. Some main topics of this year's ECPE wide bandgap user forum are summarized in the following:

State of the Art and Trends
SiC power electronics is well established in the voltage range 600V, 1200V and 1700V. Circuits make use of diodes and increasingly transistors where the diversity of types observed in recent years today converges to MOSFETs. Devices and their base material have reached a considerable level of maturity, also permitting to understand and implement useful device properties like avalanche ruggedness. Packaging still is a issue with some novel approaches, usually without wire bonds, demonstrated by research institutes and industry. Package related parasitics will inuence electromagnetic compatibility (EMC) as they tend to foster current or voltage oscillations respectively in conjunction with switching actions. Besides optimized packages dedicated gate drivers promise to counteract this undesirable effect. As appropriate for a user forum, related practical aspects of lab work like suitable current sensing have also been addressed. Research and development with regard to SiC devices aim at exploiting higher power ranges using devices with higher voltage or current ratings, the latter also being achievable through parallel connection.

Obviously devices used in durable goods such as photovoltaic inverters in the Megawatt range, wind converters or traction converters of railway rolling stock, serving as application examples, will need to prove an appropriately high level of reliability. The experience already gained thus significantly fosters the pursued evolution towards higher power levels of compact and highly e_cient SiC converters.

GaN devices | mostly transistors with blocking voltages up to 600V | and circuits employing them have been realized and concurrently are subject to considerable research and development: On device level, main interest is dedicated to parameter stability, reliability and ruggedness. Intermediate results have shown actual achievements in particular of optimised stability, and unveiled approaches for a deeper understanding of underlying mechanisms. GaN devices are mainly used in switched mode power supplies with moderate nominal power. As such, automotive on board chargers in electric or hybrid vehicles might become a lead application.

Accepting the challenge of holistic system design permits to create innovative solutions, together optimizing semiconductor devices, passives - i. e., capacitors and inductors or transformers - and assembly, for example permitting to integrate the transformer into the printed circuit board. While miniaturization may be limited by the application - e. g. single phase inverters requiring a certain capacity to compensate the ripple of instantaneous power - experience has been gained that resonant switching is advantageous when employing frequencies above 100...150kHz. Below, hard switching with fast GaN devices would still be efficient. The aforementioned considerations related to packaging, drivers and EMC of course apply for GaN devices and circuits as well.

The user forum's review intendedly hasn't been restricted to SiC and GaN: In their particular field of application both kinds of devices compete with Silicon (Si) power semiconductors.

While the latters still are produced in the highest volume, the formers increasingly replace and complement them in circuits and applications their particular properties | in many cases especially switching speed - are advantageous for. Two alternatives have been presented as well, promising extraordinary characteristics at moderate cost: 3C SiC exhibits a different structure of the atomic lattice, enabling the use of different production technology being currently under development, especially with the aim to avoid wafer bow and stress. Tentatively Schottky diodes, MOSFETs and IGBTs up to 1200V seem feasible. It is further suggested to assemble such MOSFETs in a lead frame based surface mount package, thus constituting a compact phase-leg circuit. As a different approach, vertical Gallium Oxide (Ga_2O_3) Schottky diodes are proposed as a potential cost efficient solution for the voltage range between 600V and 1200V, competing with SiC and GaN.

Conclusion and Outlook
Power electronics is an enabling technology for a multitude of rapidly growing applications:

It permits to increase energy efficiency, to feed electrical energy from renewable sources intothe grid, to control drives and power supplies in electric vehicles or also to control machineryand robots in any modern production environment. Wide bandgap devices and the relatedcircuits and systems are a fascinating and rapidly evolving part of power electronics as theaforementioned up-to-date contributions to ECPE wide bandgap user forum have impressivelyunderlined. This important subject is continuously followed up by the ECPE wide bandgapworking group; an update about further progress in this area will be available on the occasionof the next ECPE SiC & GaN User Forum.

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13th Battery Experts' Forum

International Setting of the Battery World Addressed Li-Ion Technology and E-Mobility

By Roland Ackermann, correspondent editor Bodo's Power Systems

The 13th Battery Experts' Forum again was the meeting point for the 750 participants of the international battery world and took place in Aschaffenburg town hall from 14 to 16 March 2017. The organiser was Batteryuniversity GmbH in Karlstein (Bavaria). More than 50 leading experts, developers and researchers reported on the latest trends in lithium ion battery technologies; and 40 specialist exhibitors complemented the experts´ meeting.

The Forum offered participants the rare opportunity to get comprehensive information in direct dialogue with the experts on all major trends and new developments in a comparatively short time. The main topics:

- World market analysis: Market – Trends – Prices
- Next generation cell chemistry
- Cell production in Germany
- E-Mobility

The event was moderated by Dr. Jochen Maehliss, manager of Batteryuniversity GmbH, Dr Kyriakos Georgiadis, manager of BMZ GmbH research projects, and Dipl.-Ing. David Flaschentraeger, senior project manager for storage vehicle application at BMZ. The participants had the opportunity to visit BMZ GmbH in Karlstein by e-bus. In the production halls of BMZ, they could experience automated production with industrial robots live with plant manager Daniel Fabbiano.

On 14 March, several training courses were offered. Participants could use the unique opportunity to find out about the principal fundamentals of lithium ion battery technology, battery management systems, the latest standards and legislation as well as the transport of lithium batteries on the road.

Roundtable Discussion

Picture: BEF Roundtable

The separate roundtable with leading experts of the lithium ion battery technology discussed the question "Does Germany need a cell production?" As the market researchers predict a ten-fold increase of lithium ion cells for electromobility, energy storage, healthcare and consumer products, it would be disadvantageous for German companies to remain dependent on foreign, predominantly Asian manufacturers of battery cells.

The technology of the total battery and thus the traction battery cells, too, is a key element for individual electromobility. Today, the traction battery is one of the most important components of the electric vehicle (value added share 30 to 40%). With a share of around 60 to 70% the traction battery cell determines the added value of the battery pack.

Prerequisite of future plans is the improvement of the know-how, an increased fundamental research in the universities plus the decision, whether to stay with the lithium ion or to switch to lithium sulphur or lithium air technologies respectively. The answer: In parallel with the growing success of electric vehicles operation of a sustainable volume cell production in Germany would be economically feasible. The national platform for electromobility (NPE) has published a roadmap and recommends the start of production in 2021 and a gradual expansion to 13 GWh/year in 2025, requiring investments of around 3 billion Euros.

Selected members of the competence network lithium ion batteries (KLiB), including Manz AG, M+W Group, thyssenkrupp AG, BMZ Group, Litarion and StreetScooter, have founded an initiative to form a "neutral" nucleus that is open for companies of all industries. Sven Bauer, founder and CEO of BMZ, commented: "Objective of this nucleus is the installation of a team planning series production of cells in Germany – prismatic, pouch and cylindrical 21700.

Technology Location Germany

With high-quality products, services and solutions, German industry is one of the leading suppliers worldwide. In Germany, new registrations of electric vehicles are developing very dynamically. For Germany, electromobility means the chance and the challenge to secure and expand its top position as an industry, science and technology location. The federal government is pursuing the aim of registering a million electric cars by 2020. To this end, it agreed a promotion in 2016 in the form of buyers' premiums, tax incentives and expansion of the charging infrastructure.

Energy Storage Systems as a Future Trend

In addition to electromobility, experts see the area of electricity storage in private households and for commercial purposes as one of the largest future markets for lithium ion battery technologies. Energy storage systems (ESS) are an innovative and forward-looking energy storage technology with great market potential. Using these stationary energy storage systems, the energy generated by photovoltaic systems or other renewable energy sources such as wind and hydropower can be temporarily stored locally. As required, the stored electricity can be either fed into the mains grid or used by the producer.

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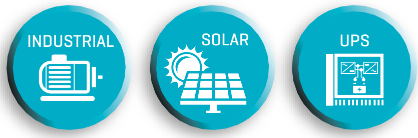

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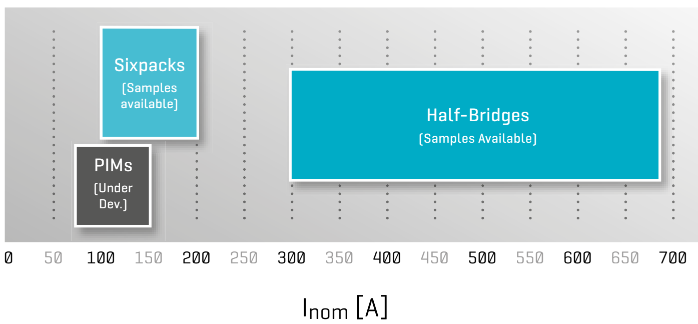

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Lithium Ion Battery Technologies on the Rise
Lithium ion accumulators are generally used where long-lasting and energy-rich storage systems with high energy density are required. The electronics industry in particular uses the advantages of the lithium ion accumulator technology, such as light weight, long standby time and high capacity. In future, this demand will be increased further with the development of new application areas, such as power and garden tools. The predicted trend towards increased use of electromobility in the area of electric vehicles such as cars, buses, forklifts or delivery vehicles, e-bikes and electric scooters as well as towards high-performance energy storage systems will generate increasing demand.

Li-Ion batteries – a Cornerstone for the Breakthrough of Electromobility and Renewable Energies
Battery research is running at full pelt and it is an important element for the breakthrough of electromobility and renewable energies. Electromobility protects the climate and the environment, promotes technological innovation and makes new business models possible. Globally, electromobility is the key to the climate-friendly transformation of mobility. It is a task for the whole of society and comprises many more elements than just the electric vehicle: the electromobility system is formed of many components together, from drive technologies to the charging infrastructure. Between 2020 and 2030, the experts from the German national platform for electromobility (NPE) are expecting a significant breakthrough in electromobility.

Three Highly Interesting Sessions
In the sessions of the Battery Experts´ Forum, the top topics of this year's industry meeting point on 15 and 16 March 2017 included the "Global Market for Llithium Ion Battery Technologies" and "Cell Manufacturers and Users". The topics of "Electromobility" and "New Materials and Technologies" were discussed in two parallel sessions. The keynotes included:

- Global market analysis, trends and future visions: Sven Bauer, Managing Director, BMZ GmbH
- The future of German cell production: Dr Michael Krausa, Managing Director, Lithium Ion Battery Competence Network (KLIB)
- Status of electromobility in Germany: Kurt Sigl, President of the German federal association for e-mobility (Bundesverband eMobilität e.V.)
- Commercial e-mobility – realised economically: Prof Achim Kampker, StreetScooter GmbH
- The rechargeable battery market and main trends in 2016 – 2025: Christophe Pillot, AVICENNE Développement
- Lithium ion cells for power tools and e-bikes: Martin Donnert, Sony Europe Limited


Picture: Sven Bauer Battery Experts Forum 2017

Main Session
After the above-mentioned profound keynote of Sven Bauer the program in the main hall "World Market, Cell Manufacturers and Users" covered the following presentations:

- Li-ion cells for power tools and e-bikes by Yoshihito Inoue from Sony Europe Ltd.
- Battery longevity and its optimization on the example of a Li-NMC cell by Adrian Heuer and others, Fraunhofer ISE
- Qualification activities for selection of cells at STIHL, by Henrik Gaul, Andreas Stihl AG
- Methods for non-destructive aging detection by Peter Keil, Technical University Munich
- Simulation-supported diagnosis of lithium-ion batteries, by Fridolin Roeder, TU Braunschweig Institute of Energy and Process Systems Engineering
- Samsung Note 7 case battery safety issues impact on business by Samuel De-Leon, Shmuel De-Leon Energy, Ltd.
- Challenges and milestones for building up a cell production, by Anis Koubaa, ESCAD Automation GmbH
- Battery module production by wire and laser bonding by Paul Gruber, F&K Delvotek Bondtechnik GmbH
- LG Chem Li-ion cell technology by Dong Wook Chun, LG Chemical Ltd, and
- Next generation cylindrical LiB and new market outlook by Tkyun Lee, Samsung SDI.


Picture: BEF Exhibition

Session "E-Mobility":
More than the above-mentioned keynotes of Prof. Achim Kampker and Kurt Sigl, the following topics were presented:

- Batteries in high-performance vehicle applications, by Mate Rimac, Rimac Automobili d.o.o.
- Pioneers of electromobility – what can we learn from them? By Roger Knecht, Kamoo AG
- Integrating different battery technologies for the electromobility by Andreas Gronarz, Foreseepower SAS
- Electric buses charging at night, by Harald Ludescher, Ziehl-Abegg Automotive GmbH
- 100 V interchangeable batteries in practice by Franz Huber, Mattro Mobility Revolutions GmbH and
- Gauss electric motorcycle – experiences during aunching and testing on test stands and on race tracks by Prof. Hans-Peter Bauer, Hochschule Darmstadt.

Session "New Material and Technologies"

- Solid-state batteries by Dr. Martin Finsterbusch, Forschungszentrum Juelich,
- Lithium sulphur batteries by Paul Haertel, Fraunhofer IWS

- Solid electrolytes by Dr. Andreas Hofmann, Karlsruher Institut für Technologie,
- Lithium-plating prediction in Li-ion batteries, by Dr. Hennning Lorrmann, Fraunhofer ISC,
- Safety and emission tests on lithium-ion cell by Dr. Michael Abert, Fraunhofer ICT,
- Advanced battery test solutions, by Martie Janssen, Chroma ATE Europe BV,
- Dangerous good lithium batteries – violations and consequences by Uwe Wunderlich, hazardous freight consultant,
- ADR-compliant transport and storage of not transport-safe lithium-ion batteries, by Michael Knobloch, Genius Technologie GmbH, and
- Lithium batteries in the working environment, by Jens Erbstoesser, Erbstoesser GmbH.

Picture: Enery Storage System BMZ ESS 9.0

Specialist Exhibition

At an accompanying specialist exhibition, international experts offered advice and first-hand information about their products and innovations. At the forum, companies such as Stihl AG & Co. KG, Panasonic Industrial Devices Europa GmbH, Samsung SDI, Shmuel De-Leon Energy, Sony Europe Limited and Texas Instruments Inc. displayed their products, solution concepts and services. Visitors took the opportunity to discuss with experts and to make new contacts.

E-mobility Test Track

In the palace square in front of Aschaffenburg town hall, participants at the forum tested devices from Stihl in an outdoor pavilion. Interested parties tried out e-bikes with the BMZ drive system. Furthermore, there was an e-Porsche Speedster to test as well as a BMW i8. The electric bus from Ziehl-Abegg Automotive GmbH was also a highlight. The StreetScooter from the familiar DHL fleet could be tested, too.

BMZ Launches Energy Storage System with Higher Capacity

With the new lithium ion energy storage option – the BMZ Energy Storage Systems (ESS) – both private and commercial solar system operators have the ability to inexpensively store solar energy during the day, then use it in their own homes or businesses as needed. The new storage system, designated ESS 9.0, has a rated capacity of 85 kWh and a lower specific price than its little brother, the ESS 7.0. Otherwise, it retains all the features typical for a BMZ energy storage system. Features:

- Very powerful, up to 300 A discharge current
- Flexible and expandable. Up to twelve units can be switched in parallel
- Safe and robust with a multi-level safety concept
- Emergency power supply and off-grid option.

www.battery-experts-forum.com

embedded world 2017 Consolidates its Role as Leading International Exhibition

By Roland Ackermann, correspondent editor Bodo's Power Systems

In its 15th round, embedded world in Nuremberg, Germany, has once again impressively reinforced its status as the number one international gathering for the embedded system technology experts. In 2017 it again reported significant increases in all important exhibition-specific KPIs and broke new records after three action-packed days of trade fair and congresses.

More than 30,000 trade visitors – including an international contingent of 38% – came to Nuremberg for an event that reached new heights with more than 1,000 exhibitors (+8%) from 40 countries. The professional community was equally impressed by the concurrent embedded world and electronic displays conferences: 1,796 embedded and display experts from all over the world (+8%) travelled to Nuremberg to enjoy professional dialogue and knowledge-sharing.

Highly Satisfied Exhibitors

This year too, the mood in the halls was excellent and both exhibitors and trade visitors were very satisfied with the event they call their own. Both groups benefited from the professional dialogue with one another and a number of new projects were instigated. All of this is also confirmed by the exhibitor poll, in which nine out of ten participating companies rated the event a success. Based on this upbeat mood and the results at their stands, equally as many companies said that they would be exhibiting again in 2018. Around nine out of ten expect follow-on business from the event and 94% were able to forge new business contacts. In addition, 95% confirmed that they managed to reach their target groups.

Almost without exception, trade visitors were satisfied with the content of the event and range of products on display. Nine out of ten of the 30,017 trade visitors are involved in the procurement decisions of their companies. This is further evidence of the great importance of the fair for the embedded community. No less than 86% would recommend visiting embedded world to their business contacts and colleagues, while 97% stated that they would be visiting embedded world again in 2018.

Successful Conference

For years now the embedded world Conference has been the equivalent of a transfer of knowledge par excellence, as the meeting place of the most innovative embedded systems developers from all over the world, and at the same time the biggest European conference devoted to embedded systems development. Here, all the major topics and themes in and around embedded systems development are presented in papers, enlarged upon and discussed in classes. Everything heard was solution-oriented throughout, directly supporting the activities and focus of embedded systems developers.

The success of the embedded world Conference bases on direct participation by a whole community — hardware and software designers of a segment that's virtually unequalled in creating innovative ideas for countless applications. Conference content, solicitously selected by an international jury, guarantees the necessary balance of knowledge and annual unfolding and analysis of the latest developments and trends. But what's special about the embedded world Conference is that contributions are consistently solution-oriented, of great value and directly aiding both single participants and in fact the whole segment in what confronts them daily.

Riccardo Mariani, Chief Functional Safety Technologist, Intel

The embedded world Conference was always on the spot when new ideas and solutions were forged and emerged: the introduction of multicore processors in embedded applications for instance, the triumphant advance of new microcomputer architectures, new wireless communication standards, the introduction of new programming languages and technologies, plus the new test and verification methods that subsequently resulted.

The theme of the embedded world conference was "Securely Connecting the Embedded World". As well as the two main thematic focus areas "Internet of Things" and "Security & Safety", the programme included another four conference clusters: "Software & Systems


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Engineering", "Hardware Engineering", "Embedded OS" and "Management Focus". The keynotes were held by Mathias Wagner, Chief Security Officer, NXP as well as Riccardo Mariani, Intel Fellow and Chief Functional Safety Technologist for the Intel IoT Group in Pisa, Italy, who described what's needed to usher in a new age of autonomous things in a diversity of industries, encompassing Automotive, Robotics and Retail. The individual conference clusters were made up of sessions and classes and so allowed participants to choose between highly topical, practice-based content or technically sophisticated tutorials devoted to exploring an issue in greater depth.

Session "Low Power"

In session 12 "Low Power", the first presenter Dr. Christoph Budelmann in his paper "Bringing IoT into Harsh Environments: Security and Reliability with Optical Power and Data Transmission for Ultra-Low Power Sensor Nodes" described the development and realization of new ultra-low power sensor nodes, fully powered by a single photodiode. The presented concept offers secure and reliable optical power supply and communication for small electronic sensor nodes. This makes the system suitable among others for IoT applications especially in harsh environments such as vibration analysis and ice detection on rotor blades of wind power stations.

Very interesting, too, was the presentation "Intelligent Power Management for Textile Energy Harvesters Supplying Wearable Sensors" by Daniel Ladua of Technical University Ilmenau: During motion the extremities and the body produce unexploited mechanical energy. That usually lost energy expands the lifetime of non-rechargeable batteries or recharges accumulators and capacitors. New textile energy harvesters can be integrated into common clothing and worn during normal activities to produce energy in everyday situations. Within this scenario it is hard to claim a continuous energy input, e.g. if the breaks between power input are too long or the motion is properly too small. This is the reason why conventional continuous energy harvesting concepts can't work reliably. The solution described uses a complex generation concept. The generator is composed of a tribo-electric and piezoelectric part. Both parts are implemented in textiles. The presented energy harvesting concept enables recovering unused energy to supply a sensor circuit autonomously from finite power sources like non-rechargeable batteries.

Øivind Loe of Silicon Labs covered "Running Your Embedded System at 0 MIPS - The Power of Autonomy": Over the last few years, reducing current consumption specs has been a major focus in the MCU market. Active current consumption and deep sleep current consumption have been reduced greatly. The effect of this change is obvious, with greatly improved battery life in our everyday embedded applications, and a promise of energy harvesting in the future. However, in order to properly leverage these current consumption specifications of modern MCUs, developers must take many considerations into account. Øivind Loe explored how autonomous operation of peripherals in modern MCUs can be leveraged to achieve the low-power promises conveyed in datasheets by getting closer to operating at '0 MIPS.'

Gary Straker from ON Semiconductors in his paper "Advanced Wireless & Smart Passive Sensor Technology Enables More Effective Use of Sense Data in IoT Implementations" looked at the main dynamics affecting sensor based IoT implementation and outlined what attributes the supporting electronics need to possess. He showed how a highly integrated solution – featuring multiple sensor mechanisms and cloud-based connectivity – will have significant benefits over more conventional solutions made up of discrete sensors accompanied by power hungry, costly processor ICs. Finally, some of the key application scenarios where this type of solution offers real value were detailed. The electronics engineering community, he stated, is developing more suitable hardware that optimizes sensing functions that operate at the "edge" of the IoT and provides the data required for software analytics to process.

And Andreas Riedenauer from Ineltec Mitte gave some realistic views to "Ultra Low Power Design - Practical Hints and Pitfalls". There is a marketing hype in terms of low and ultra-low power consumption of electronic devices, especially microcontrollers. What is true? What should a developer have to consider? What are the pitfalls when optimizing the power consumption? How much reduction of power consumption makes sense? What are the side effects of low power design? What about batteries, super caps and lifetime? ...and temperature? 24 bit ADC with 2.5 µA? RTC with 60 nA? Radio receivers with 2,4 µA continuous current consumption?

IoT, wearables, data loggers and new radio applications are creating a growing demand for low power and ultra-low power electronic circuits. Andreas Riedenauer explained some power saving methods and components as well as some pitfalls one should be aware of when trying to eliminate microamps of current consumption. Last, but not least, he commented some marketing influenced statements from a practical point of view.

BTW: The next embedded world exhibition and conference will take place from 27 February to 1 March 2018 in the Nuremberg Exhibition Centre.

www.embedded-world.de/en

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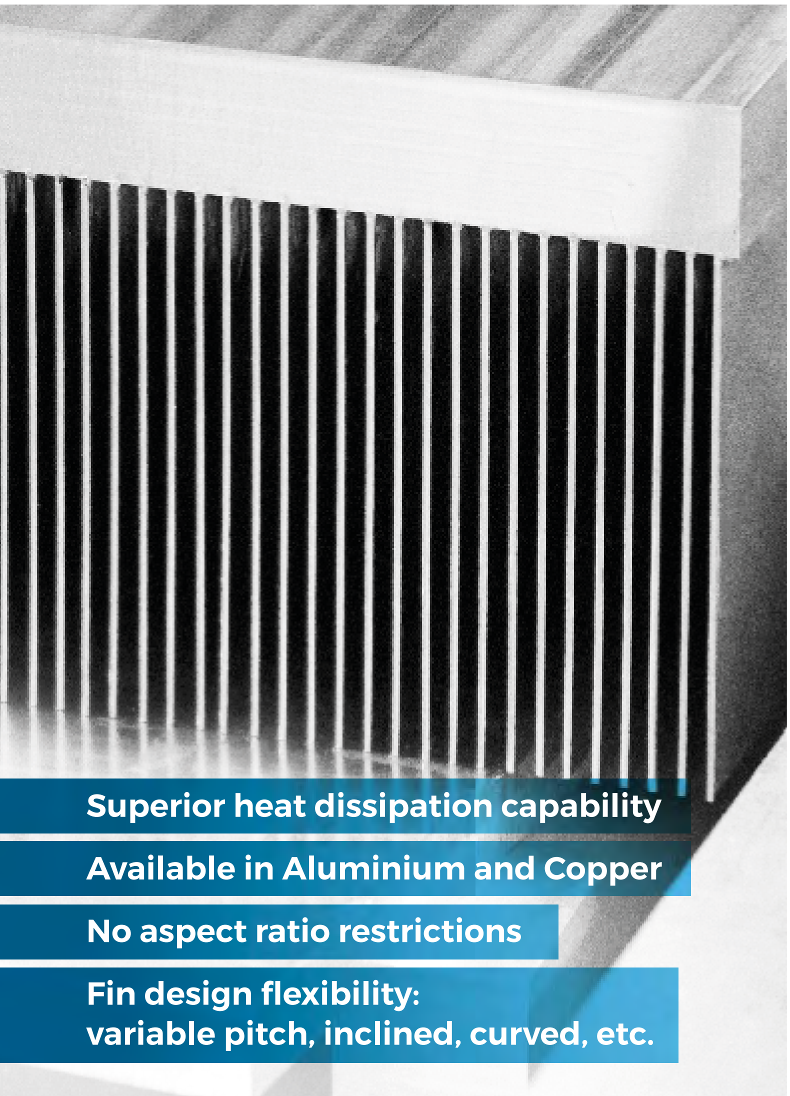

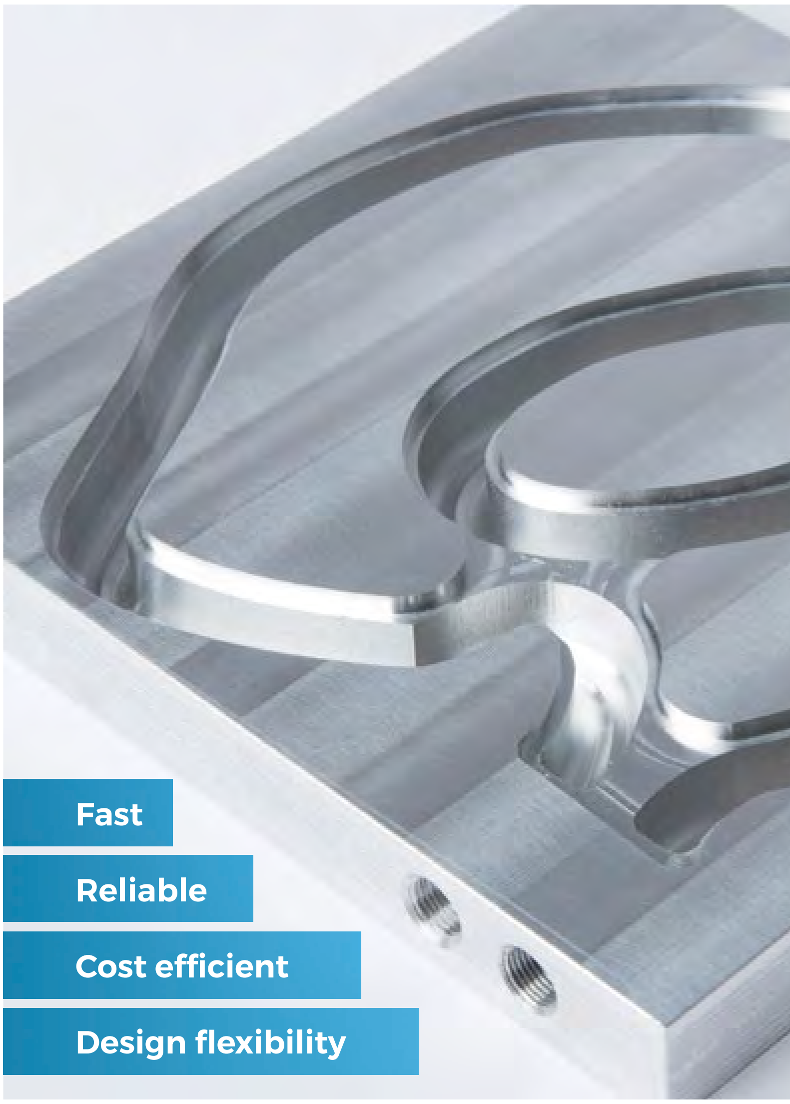

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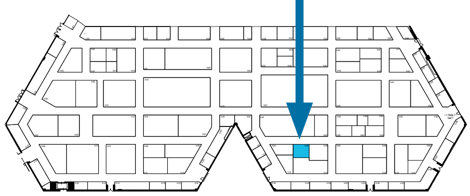

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Silicon Carbide (SiC) switches become increasingly more important for differentiation of power converters in size, weight and/or efficiency. The dedicated material properties of SiC enable the design of minority carrier free unipolar devices instead of the charge modulated IGBT devices. As such, they deliver highest efficiency, higher switching frequencies, reduced heat dissipation and space savings – benefits that, in turn, also lead to overall lower cost.

By Marc Buschkühle, Infineon Technologies AG, Warstein,

In addition to the static and dynamic performance, further topics need to be addressed to be ready for higher volume inverter use. Proper reliability is mandatory as well as sufficient threshold voltage and applications oriented short-circuit robustness. IGBT compatible driving with VGS= 15 V for turn-on will simplify the change from IGBT to SiC MOSFET solutions. These topics were adressed with the new 1200V CoolSiC™ MOSFET from Infineon.

Introduction

SiC MOSFETs with blocking voltages of 1200V are interesting in application fields such as solar converters, UPS, battery chargers as well as industrial drives. These applications benefit from the reduction of switching and conduction losses; the thermal budget can be utilized to achieve higher switching frequencies to reduce the physical size of passive components and minimize the cooling effort, weight and cost.

The CoolSiC™ complemented by T- MOSFET design was developed to limit the electric field in the gate oxide in on-state as well as in off-state. An attractive specific on-resistance for the 1200V class is provided, achievable even in mass production in a stable and reproducible way. The low on-resistance is already achieved at driving voltage levels of only VGS= 15 V combined with a gate-source-threshold voltage of more than 4V being a benchmark in the landscape of SiC transistors. These boundary conditions are the baseline for transferring quality assurance methodologies established in the silicon power semiconductor world in order to guarantee FIT rates expected in industrial and even automotive applications.

Lead products

Schematic	Type	R_{DSON}	V_{DS}	Package
Single switch (Drain, Gate, Source)	IMW120R045M1	45 mOhm	1200 V	TO247-3pin
Single switch (Drain, Gate, Driver Source, Power Source)	IMZ120R045M1	45 mOhm	1200 V	TO247-4pin
Half bridge with NTC	FF11mR12W1M1_B11	11 mOhm	1200 V	Easy1B PressFIT
	FF23mR12W1M1_B11	23 mOhm	1200 V	
Booster with NTC	DF11mR12W1M1_B11	11 mOhm	1200 V	
	DF23mR12W1M1_B11	23 mOhm	1200 V	

Selectively sampling on request.

Figure 1: CoolSiC™ MOSFET lead product overview

For fast switching IGBTs and SiC transistors, the design of the package is equally important.

With a look to the available power module platforms, some packages are extremely advantageous towards fast switching SiC devices. The stray inductances need to be as low as possible, but in addition a highly symmetric design is needed as well.

The Easy-Module platform for example is predestined for this use. In contrast to well-known standard packages with baseplate, the Easy-Module platform allows building a highly symmetric, low inductive design. For this reason the popular and flexible Easy1B power module is used to implement a first SiC half bridge and booster solutions optimized for photovoltaic, off board electric vehicle charging and uninterruptable power supplies.

The flexible pin grid of Easy modules simplifies PCB layout and offers a stray inductance below 10 nH. This is a huge improvement, a step down by 70-80% compared to existing solutions like EconoDUAL™, or standard SIXPACK designs. It represents a significant innovation in power module design.

Figure 1 depicts an overview about the lead products. The listed products are just the first step getting the broadly optimized portfolio of CoolSiC™ MOSFET products with further devices currently under development.

Device design philosophy

Switching losses of SiC-MOSFETs are usually quite low and especially almost temperature independent. Advanced design activities focus on the area specific on-resistance as the major benchmark parameter for a given technology. For 4H-SiC based planar MOSFETs an extraordinary high interface trap density close to the conduction band has to be overcome. This ends up at very low channel mobilities and therefore high contributions of the channel to the total on-resistance. The high defect density is reflected in various peculiarities of SiC-MOSFET based devices. An observed way to overcome this dilemma is to increase the electric field applied across the oxide in on-state, exceeding values usually being used in silicon based MOSFET-devices. Such high fields in the oxide in the on-state can potentially accelerate the wear out. This can be seen as a long term reliability risk, in particular with respect to the high defect density of SiC-substrates.

Production code generation

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Based on those considerations, it is obvious that planar MOSFET-devices in SiC have actually two sensitive areas with respect to oxide field stress, as sketched in the left part of figure 2

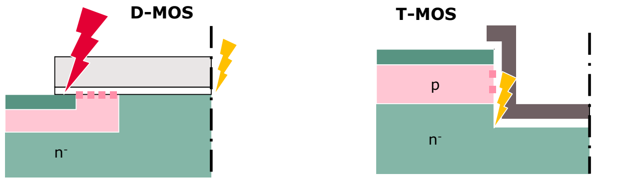

Figure 2: Left part: Typical structure of a planar MOSFET revealing two sensitive areas with respect to oxide field stress. Right part: Typical structure of a Trench-MOSFET, critical issue is the oxide field stress at the trench's corners.

First, the usually discussed stress in reverse mode in the area of highest electric field close to the interface between drift region and gate oxide and second the overlap between gate and source which is stressed in on-state.

A high electric field in on-state is seen as more dangerous since no device design measures are in place which could reduce the field stress during on-state. Thus, the overall goal is to combine the low RDSon potentially offered by SiC with an operation mode where the part remains in the well investigated safe oxide field-strength conditions. In the on-state, this can be achieved today by moving away from the planar surface with its high defect density towards other, more favorable surface orientations.

Gate Oxide Reliability

The challenge regarding the gate oxide reliability of SiC MOS devices is to ensure a low enough failure rate, including extrinsic defects, throughout a desired life time under given operation conditions. The typical industrial requirement targets of << 100 ppm in 20 years of operation. The root cause for extrinsic defects in the gate oxide of SiC MOS devices is mainly ruled by defects within the substrate material, epitaxial process and, to a less significant contribution, by the remaining process chain. Tests of commercial MOSFET products reveal that this issue is still a serious concern for the use in industrial systems.

Therefore, long time tests with a larger number of devices were performed to investigate extrinsic gate oxide failure rates for Infineon's CoolSiC™ MOSFET. An experiment was done in two groups of 1000

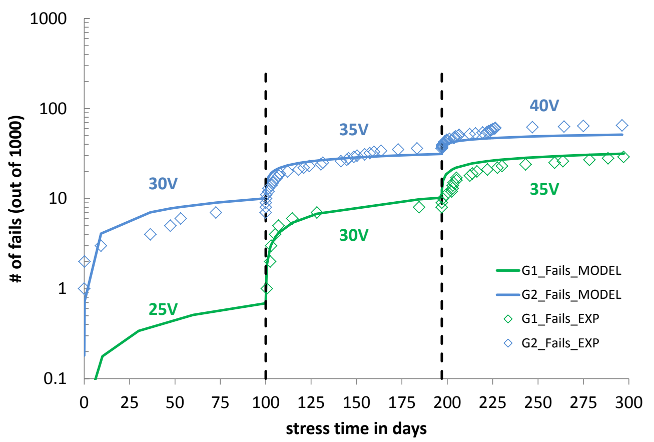

Figure 3: Long term test: the number of fails is plotted over stress days. In total 2 groups of 1000 devices where tested at 150°C with constant gate voltage VGS which is indicated. VGS is increased by 5 V every 100 days. Each dot represents a fail. Solid lines represent the prediction by linear E model

discrete devices each, performed at 150°C under constant gate bias stress for three sequences of100 days. Figure 3 summarizes the test results. After 100 days, the gate source voltage was increased by +5 V.

These statistics fit well to the linear E-Model. An acceleration factor was determined for best fit corresponding to the solid lines in figure 3.

By extrapolating this result to an operation life time of the device of 20 years using the recommended voltage levels, the model predicts a failure rate of 0.2 ppm. Hence, there is evidence to have a reliability of the gate oxide similar to the one known from IGBTs, which fits perfectly to the typical industrial requirement.

Dynamic Performance

Being a unipolar device, the dynamic performance of the SiC-MOSFET is mainly ruled by its capacitances. The device was designed to have a small Gate-Drain reverse capacity Crss compared to the input capacity Ciss. This is beneficial to prevent the MOSFET from parasitic turn-on and sophisticated gate driver circuitry when operated in a half bridge configuration.

Figure 4 displays the typical switching losses of a half bridge with single devices mounted in a 4-pin TO-247 housing as function of drain current. The turn-off energy Eoff is nearly independent of the load current since it is dominated by capacities, whereas the turn-on energy Eon increases linearly with current.

At an application current of 20 A, the total losses Etot sum up to 0.43 mJ which enables switching frequencies in the range of 50-150 kHz.

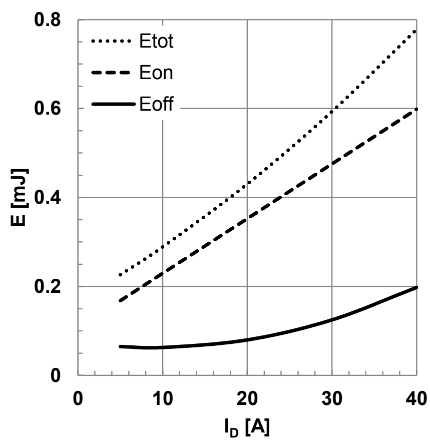

Figure 4: Typical switching energies as a function of drain current ID.

Conditions:
VGS = 15 / -5 V,
RGext = 4.5 Ω,
VDS = 800 V,
Tvj =175° C, 4 leg TO-247 in half bridge configuration

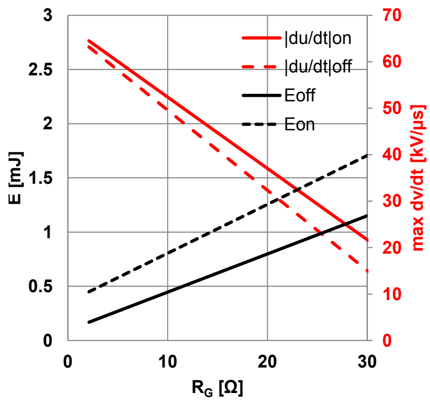

Figure 5: Typical switching losses (left axis, black curves) and maximum dv/dt values (right axis, red curves) vs. RGext. Conditions: VDS=800 V, ID = 40A, VGS = 15 / -5 V, Tvj=175°C, 3 leg TO-247 in half bridge configuration

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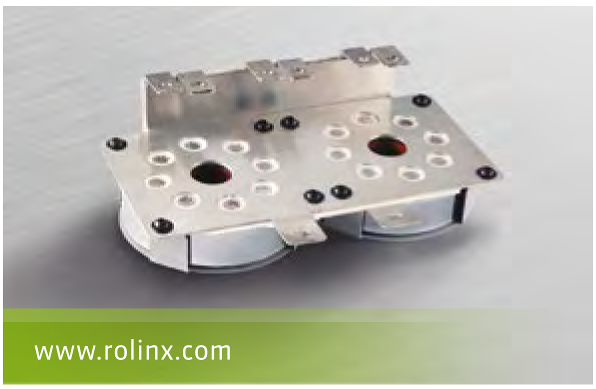

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The 4th pin of the TO-247 package is to connect the gate driver directly to the source pin, avoiding the negative feedback from the load current due to source stray inductances. Thus, in comparison to a 3-leg TO247 half bridge configuration, about 100 µJ total switching energy can be saved at a current of 20 A. This is a reduction of about 30% based only on the optimization of the package using the same die.

Figure 5 provides an insight to the MOSFET's ability to easily control the voltage slope dv/dt by adapting the gate resistor RG. This is particularly of interest for drives applications. However, the reduced voltage slope dv/dt is paid for by increased switching losses.

Obviously, the loss reduction will be more prominent in applications where there is no dv/dt limitation and grows with the switching frequency. This is common in DC-DC boost or buck/boost topologies, providing the benefit of smaller, lighter and lower cost magnetic components. Various studies have already proven that – even with more expensive power switches – the cost of material can be reduced for a wide spectrum of applications. This number of applications will increase over the mid-term time frame based on the anticipated cost reduction over time for SiC based components.

Static Performance

The key parameter of the static output characteristic of a MOSFET is the total resistance RDS(ON).The newly introduced die features a typical on-resistance of 45 mΩ at room temperature at VGS = 15 V. A positive temperature coefficient of the on-resistance makes the devices predestined to be used for paralleling. In Figure 6 the output characteristic is given in direct comparison to the state of the art 1200 V HighSpeed 3 IGBT. Due to the knee voltage on state characteristic the conduction losses especially under partial load can be reduced enormously. At system level, the feature of knee voltage free conduction behavior offers a significant potential for loss reduction. Many systems are operated under partial load conditions for a large portion of their life and conduction losses are considerably lower compared to the competing standard IGBT technologies. Even at very low switching frequencies of less than 5 kHz and unchanged dv/dt slopes it can be seen that a knee voltage-free switch with integrated body diode, in synchronous rectification mode, offers a potential of 50 % total loss reduction compared to a commercial IGBT solution available today.

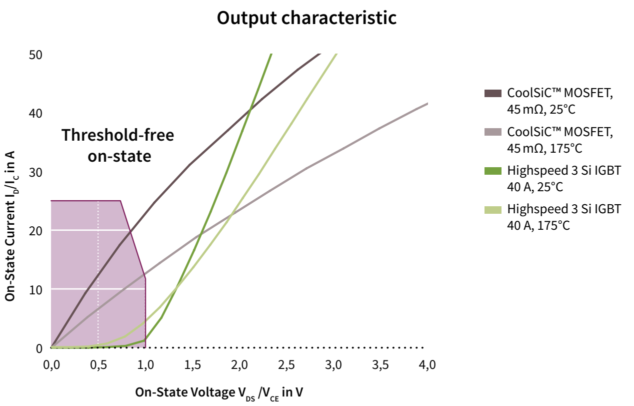

Figure 6: Typical SiC-MOSFET output characteristic in comparison to IGBT solutions

In contrast to booster-stages, typical inverter applications require a well-defined short circuit capability especially in case of failure events in the field. Reflecting this important need, the CoolSiC™ MOSFET is the first SiC-MOSFET on the market with a specification of short circuit robustness.

In contrast to typical DMOS behavior the transfer characteristics (25°C /175°C) reveal a crossing point already at VGS = 12 V. Above 12 V, the current decreases with temperature which is beneficial to limit the saturation current in a short circuit event.

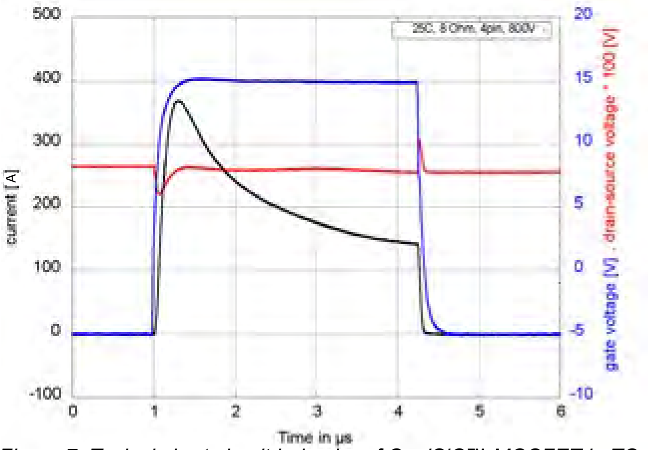

Figure 7: Typical short circuit behavior of CoolSiC™ MOSFET in TO-247-4

Figure 7 denotes the most critical, so called hard short circuit event. The behavior and robustness under this special condition was analyzed in detail. The CoolSiC™ MOSFET is the first SiC MOSFET with short circuit specification.

In contrast to standard IGBTs the short circuit current rises to factor of 10 compared to the nominal current of the device. After the first peak the saturation current decline to a much lower level due to the temperature depending characteristics described above.

Summary

Infineon is a pioneer in the commercial use of the SiC technology. As the first company worldwide, SiC based diodes were introduced in the market as early as 2001. Meanwhile the 5th generation of such parts is available as discrete devices. The product design was always carefully oriented on a beneficial cost-performance evaluation.

The concept of Infineon's SiC-Trench-MOSFET combines a low on-resistance with an optimized design preventing too high gate oxide field stress, providing IGBT like gate oxide reliability. The SiC-Trench-MOSFET features superior performance in terms of switching behavior and losses. The analysis done confirms a full controllability of the voltage slopes in booth, turn-on and turn-off transients. The current slopes for turn-on as well can be controlled by the gate resistor. In turn-off, the di/dt is determined by parasitic capacitive effects.

Furthermore the device is the best available mix of electrical performance and robustness features like the short circuit reliability.

With the CoolSiC™ MOSFET technology, the beginning of a new era of power electronics in terms of power conversion efficiency and power density has begun.

Acknowledgment

I would like to thank all Infineon colleagues for their contribution which made this CoolSiC™ MOSFET technology possible, in particular the members of the concept-, technology- and module- development team at the Infineon sites: Erlangen, Villach and Warstein.

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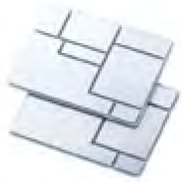

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Configurable Gate Drives for nHPD^2

The nHPD2 package targeted at traction applications offers a number of advantages for the power stack designer, but also adds complexity in designing a gate drive that can be used to target the different options offered by the nHPD2 package. The article describes a flexible approach to the gate drive design.

By Bryn Parry, Amantys Power Electronics Limited & Chris White, Hitachi Europe Limited

Introduction

The nHPD^2 package from Hitachi offers a number of advantages for the power stack designer, but some of these advantages provide challenges for the design of the associated gate drive. A flexible approach to the design of the gate driver will enable the power stack designer to optimize the design quickly.

The nHPD2 Package

The nHPD^2 module is designed to meet the future challenges and requirements of power converter design. An enabler for scalable, optimized converter designs, it offers reduced losses, enhanced monitoring and a simple route to oscillation-free Silicon Carbide (SiC) adoption.

The product range offers a standardised package throughout the industrial voltage classes (1700 V to 6500 V) with simple paralleling for high currents. This allows a modular, scalable converter design with a high level of design re-use across platforms to keep client system costs low.

The very low stray inductance, offering a 75% reduction compared to IHM modules, permits optimized converter design. Paired with the latest generation Hitachi IGBT silicon, nHPD^2 offers low losses and high power density, while future adoption of SiC is straightforward and available today.

Protection and monitoring is enhanced through the inclusion of an NTC temperature sensor and current measurement via auxiliary terminals.

Figure 1: LV and HV nHPD2

Challenges for the Gate Drive Design

The nHPD^2 package is a very compact design, which is highly challenging for a complete gate drive to be fitted on top of the package. The situation becomes easier if multiple nHPD^2 packages are placed in parallel, as the additional space can be used to mount the whole gate drive close to the IGBT module package. Customers, who prefer to mount the gate drive away from the IGBT module, for reasons of reliability or survivability in the event of a major failure, or to keep gate drive electronics cooler, can split the gate drive design, with protection circuits mounted on top of the IGBT module package and the core gate drive mounted away from the package.

The nHPD^2 is designed to be paralleled, but the difficulty for the gate drive designer is that that the spacing between IGBT modules may be different for each power stack design. A flexible approach would be to use cables to connect the paralleled IGBT modules together, but this would require using many connectors; in high reliability applications this may not always be acceptable. The alternative is to use a fixed printed circuit board as a distribution board. This has the advantage of robustness and simplicity, but does mean that each parallel design would require a new design of distribution board.

Parallel connection of IGBT modules brings its own challenges. The layout of the bus bars and the gate inductance can have a large effect on the current sharing between the individual IGBT modules. There is no substitute for good design practice. Nevertheless, the nHPD^2 package minimizes the impact of parallel imbalance.

The nHPD^2 package is also designed to support SiC devices, given that it has a very low stray inductance. In this way, the faster switching speed of SiC MOSFETs, which significantly reduces switching losses, is not impeded by having to limit voltage overshoots to such an extent at turn-off. The gate drive can be designed to be compatible, but the high dV/dt of the SiC power devices requires that the power supply for the gate drive will also need updating.

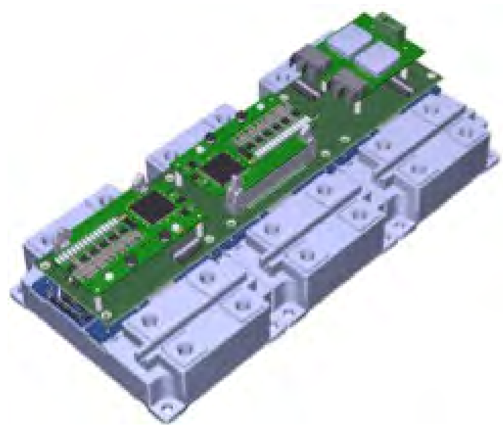

Figure 2: Modular Gate Drive Concept

Modular Gate Drive for Fast Evaluation

The flexibility of the nHPD^2 package design dictates a flexible gate driver for initial evaluation and power stack design testing. Amantys Power Electronics has split up the main functions of the gate drive to make it easier to customize the design for a particular power stack.

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6A		ISL8203M
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The concept is shown in Figure 2 for three nHPD^2 modules in parallel. The core gate drive contains all of the standard features of the gate drive, such as the gate resistors and control of the gate drive protection features.
The module interface card (MIC) is mounted directly on top of the nHPD^2 module. This contains the desaturation detection circuit and the measurement circuits used by Amantys. Care needs to be taken to ensure that creepage and clearance distances between adjacent nHPD^2 modules will meet the specified standards even if the nHPD^2 modules are mounted very close to each other.
Amantys has used a simple distribution card to connect the paralleled nHPD^2 modules together. This does mean that the design has to be changed if the module spacing changes. However, by keeping the distribution card simple, this task will be relatively straightforward.
Finally, the interfaces and power supplies are mounted on a separate card above the distribution board. The power supply and the interfaces to the central controller are very dependent on the layout of the converter and the voltage. The option of using an electrical or fibre optic interface is easily accommodated.

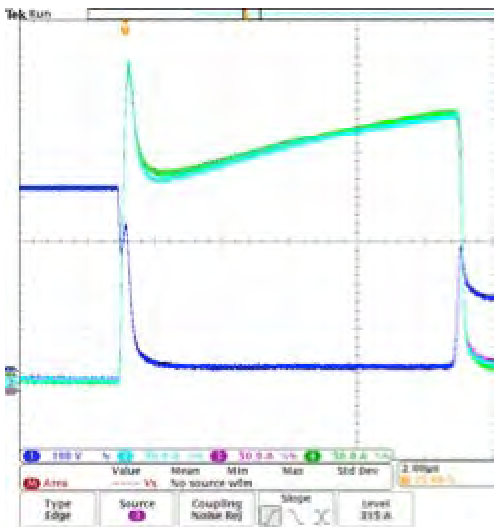

Figure 3: Parallel Performance of three nHPD2 Modules

Parallel Switching Performance

The nHPD2 is designed to be paralleled easily. Nevertheless, good layout design rules for the bus bars and the DC link capacitors still need to be followed. The impedance of each current path through the paralleled IGBTs must be as closely matched as possible. This is sometimes difficult to achieve and the addition of a common mode choke on the emitter and the gate can help to match the current flow through the IGBT modules. Figure 3 below shows excellent results using Amantys' nHPD2 gate drive with three nHPD2 modules in parallel.

Gate Drive Optimization

Amantys' gate drives feature Power Insight, which is a two way communications protocol between the central controller and the gate drive. Data is superimposed on top of the PWM switching command and feedback/acknowledge signal. This allows online configurability of the gate drive; for example, the power stack designer can modify gate resistor vales (Rg_on, Rg_off and Rg_soft_off) and gate-emitter capacitances (Cge) without removing the gate drives from the power stack or interrupting device switching. This opens the door to selection of gate resistances appropriate to different converter operating conditions, see Figure 4. This is of potential use in applications with varying DC link voltage, such as DC-fed rail traction applications (750 V, 1500 V, 3000 V) and solar inverter applications; it is also useful in renewable energy applications in allowing wider variation in DC link voltage under grid fault conditions, simplifying controller design.
The Amantys core architecture provides the power stack designer with the ability to modify voltage detection levels and timings for desaturation detection. The interaction between the power stack and the gate drives can be fully optimized for maximum performance.

SiC Compatibility

Since the nHPD2 package is offered with full SiC options, Amantys has included a feature on the gate drive to enable -5 V off-state and +20 V on-state gate drive output voltages for evaluation of future full-SiC modules, such as the full SiC module from Hitachi, MSM600F-S33A. Additional future-proofing of the Amantys gate driver includes superior fast short circuit protection within 5 µs which is highly desirable for wide-band gap device operation.

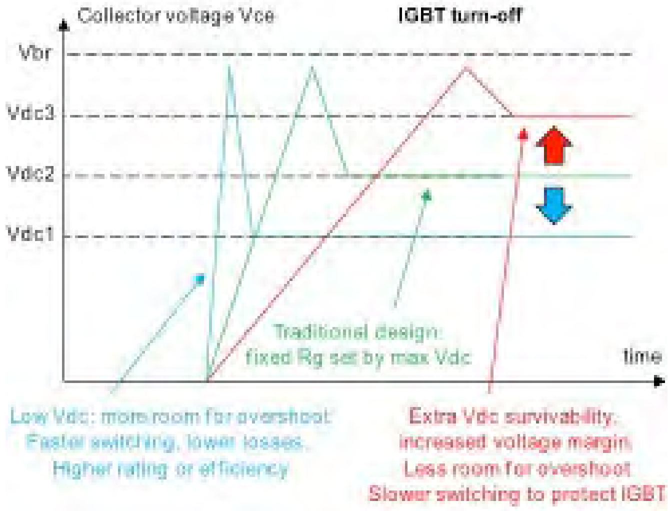

Figure 4: Using selectable gate resistance to tune device switching to converter operating conditions

Vce(on) Measurement

The on-state voltage drop between the collector and emitter of the IGBT, Vce(on), is an important measurement for assessing the IGBT module operation and can be an input into algorithms for detecting degradation. The gate drive includes a high resolution Vce(on) measurement circuit on the module interface card that can be read from the gate drive over the Power Insight link using a Power Insight Adapter.

Conclusion

The nHPD2 module offers a significant step forward in improving the performance of the power stack. The ease of paralleling the nHPD2 module makes it simple to build a flexible power stack to target a wide range of applications. Supporting this new generation package technology, Amantys has designed a flexible, configurable gate drive, providing outstanding current sharing across multiple nHPD2 modules that enables the power stack designer to evaluate quickly and then optimize the performance of the power stack.

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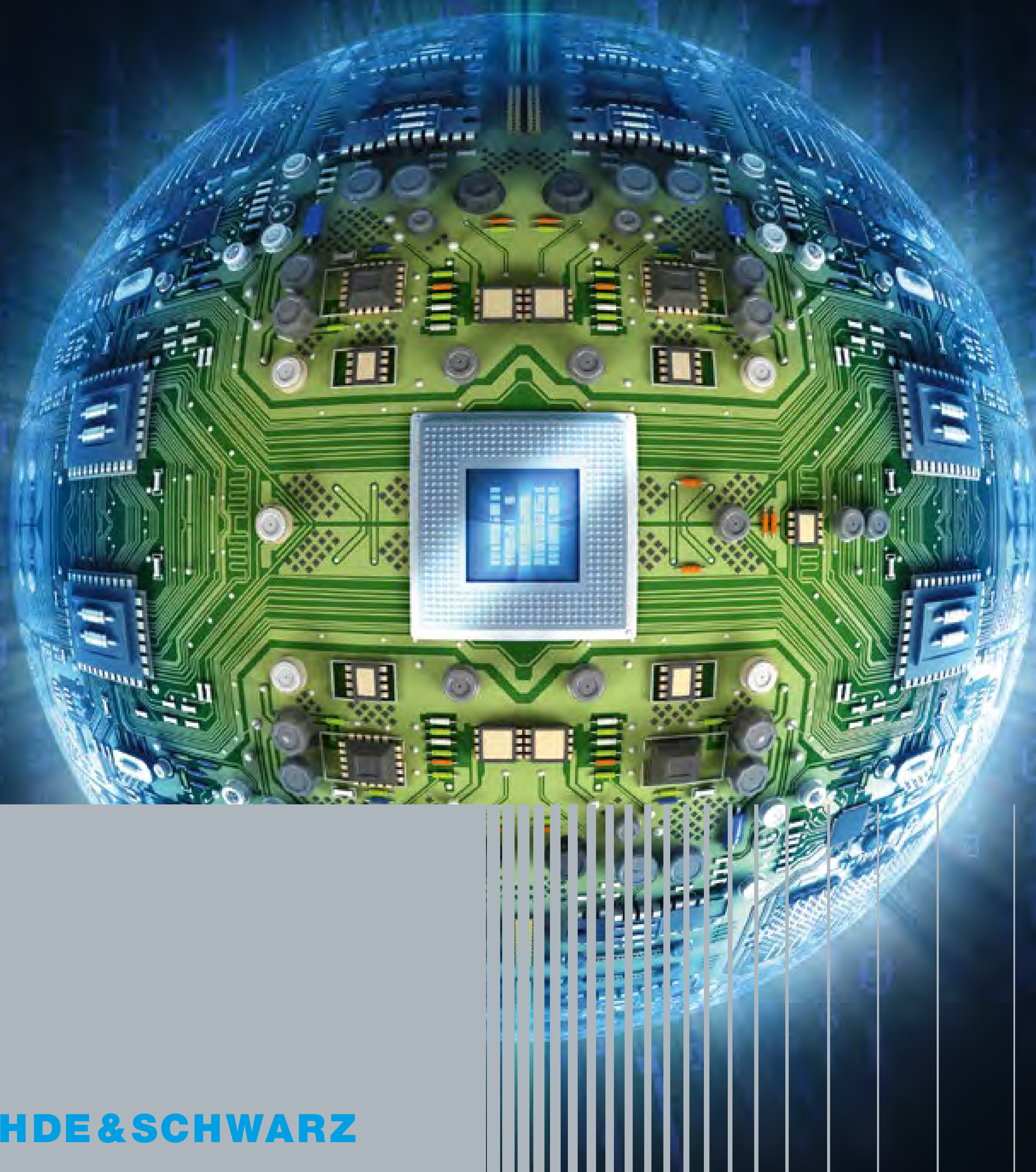

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High Humidity Robustness of ABB's IGBTs and Diodes

HV- IGBT modules employed in high power applications are subject to harsh environmental conditions. This article provides a brief insight into the latest generation of 6.5kV HiPak modules with reliable performance under extreme conditions, as demonstrated in the new THB-HVDC test.

By Charalampos Papadopoulos, Munaf Rahimo, Chiara Corvasce, Daniel Schneider, Rachid Jabrany, Neungho Shin, Karen Ruef, Claudia Widmer, Gontran Pâques, Maria Amongero, Chantal Toker-Bieri, Patric Strasser and Raffael Schnell, ABB

Introduction:

High voltage IGBT modules are used in high power applications including traction (tramways/trains), heavy duty drives, transmission and distribution and renewables such as in wind-power generation and conversion. Many of these applications are subject to harsh environmental conditions and in most cases the inverter cabinets do not shield the power electronics, including the IGBT modules from such conditions. As an example, IGBT modules can be for instance subject to increased humidity levels. Also the inverter is not always running under full load conditions and can be in idle or running in partial load which means that the temperature can rise or drop relatively fast. Due to that, moisture can penetrate into the IGBT modules while the train is stopped for longer periods of time and there is no higher temperature levels to drive out moisture from the modules. Another aspect is that condensation can appear while having a temperature drop during operation, which can lead to drastic changes in the material properties (e.g. dielectric properties of chip passivation and module encapsulation materials such as Si-gel). These undesirable modifications can have a negative impact on the electric field at the periphery of the semiconductor device and therefore cause an increased localized stress at the chip junction termination region. Therefore, it is crucial that the materials used for the IGBT module and the design of the power semiconductor including chip termination and passivation can cope with the increased stress levels, posed by the application during commissioning as well as for the foreseen lifetime up to 30 years.

Testing for environmental impact:

Predicting the robustness of various power semiconductor designs for a planned lifetime of up to 30 years is very challenging, even more so since the conditions of the environmental impact are mostly not well understood.

THB, the classic test:

In the past, the standard THB (temperature humidity biased) test with 85% r.h. and 85°C was used with a reverse bias of 80V, with a typical test time requirement of 1000 hours. This test promotes charge or ion movements due to increased moisture levels combined with relatively higher temperatures and voltages, which allows detection of instabilities caused by process variations or insufficient design margins. With such a standard test, decades of experience have been accumulated. However, for high power semiconductors, the 80V applied reverse bias remains at a much lower level from typical voltages used in real power electronics converters.

Improved testing: It was shown that by increasing the applied voltage to more realistic values [1], this will cause an acceleration of electrochemical mechanisms which could play a more dominant role when compared to the classical impact of charge or ion movement. The new condition can promote electrochemical corrosion, which causes several materials like aluminum, nitride and even oxides compositions to change structure and lose their main protective functionalities. This electrochemical corrosion takes place normally when high moisture levels are present on the surface of the chip, so that enough reactant moisture ions are available. This can only be triggered when both moisture and high voltage are present together. This also means that the well-known HTRB test under high temperature and high voltage, BUT without moisture, would also not serve this purpose. Therefore, a new test is required to fully quantify the device performance in such harsh environment.

We have come to learn that not only humidity and temperature accelerate the ageing of power semiconductors. Voltage is also a significant acceleration factor and thus it is important that the voltage is reflecting the real application conditions. The most critical test to stress the chip termination and its passivation material is the THB test with an increased collector emitter voltage also referred to as THB-HVDC or H3TRB (i.e. High Voltage, High Humidity, High Temperature reverse biased).

This tests is being performed with the same standards applied in a THB test while increasing the collector emitter voltage dependent on the device voltage class from 60 – 80%. This test can be performed in a standard controlled climatic environment well known from the past.

Evolution of device reliability in harsh environments

Power semiconductor manufacturers including ABB have learned in the recent years that HV devices are vulnerable to environmental impact, especially humidity. Beside of the material selection and the design, impurities such as particles and scratches can influence the electrical fields or promote corrosion, which can both result in accelerating component ageing. Particles for instance could be generated in the whole process chain, starting from wafer sawing to wire-bonding, soldering, ultrasonic welding … etc. Furthermore, they can also be introduced due to wear and tear of automated handlers or carriers [2]. ABB has taken these aspects very seriously by the relentless elimination of particle sources through design and processes adaptations, optimized cleaning steps, a rigid automated optical inspection and screening to root out possible defects or impurities early in the production chain.

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As a result and since 2013, ABB gradually introduced an improved HiPak platform [3] which practically shows no field returns for several hundred thousand delivered modules. Furthermore, we have currently improved the passivation of HV IGBTs and Diodes even further and verified their high levels of robustness by using the new THB-HVDC test. The THB-HVDC test has been performed on the newest generation of 6.5kV IGBTs [4] and Diode chips assembled in the improved HiPak2 module of ABB. The conditions in the test were 85°C, 85% rel. humidity and 4.5kV (70%) collector emitter voltage for 1000h while using the ramp up and ramp down within the typical THB specification. In order to increase the stress on the device, the ramp down of temperature and moisture in the chamber was kept short and performed within 3h. After the ramp down a final measurement of the blocking capability has been performed. By measuring the weight of the modules, it was proven that there is still a high amount of moisture present in the module.

In Figure 1, the monitoring of the THB-HVDC test is shown with the above mentioned applied voltage of 4.5kV on the left axis and the leakage current monitoring on the right axis. The curves need to be noise free during the complete test time to ensure that any possible leakage variations are representing an actual change in the device behavior.

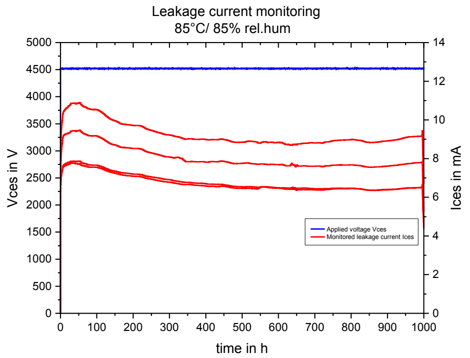

Figure 1: 6.5kV HiPak 2 leakage current monitoring during THB-HVDC 1000 hour test at 4500V

After the test, the reverse bias I-V characteristic is measured and compared to the initial measurement before the THB-HVDC test. A good design will demonstrate similar I-V characteristics before and after the THB-HVDC test as shown in Figure 2. However, a parallel shift, like a slight increase in leakage current is allowed due to different reasons like remaining moisture in the module, temperature … etc.

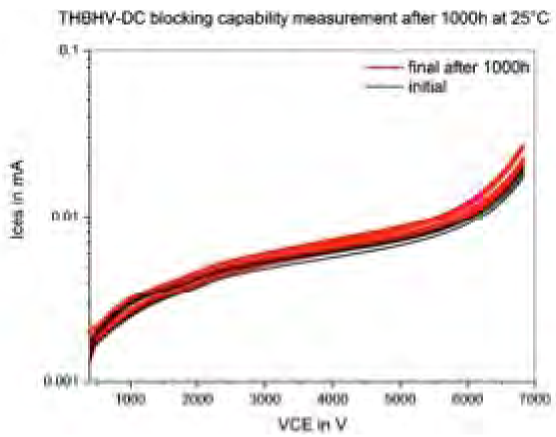

Figure 2: Reverse bias I-V characteristics of a 6.5kV HiPak 2 before and after THB-HVDC 1000 hours test

To finalize the analysis of the modules, a further criterion is to show that no significant corrosion is visible on the chips after the 1000h THB-HVDC as illustrated in Figure 3. Both IGBTs and Diodes were analysed after having disassembled the module and removed the gel with no corrosion or defects observed after this harsh test.

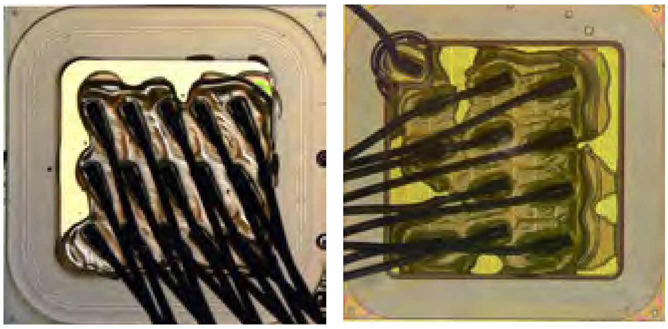

Figure 3: Optically inspected 6.5kV representative Diode (left) and IGBT (right) chips after THB-HVDC 1000 hours test

Conclusion

The THB-HVDC represents a much better application relevant reliability test than the commonly used standard THB test [5]. Nevertheless, for harsh environmental application conditions, especially in relation to absolute humidity levels, it is still difficult to properly translate results of the THB-HVDC test to effective field reliability performance. For instance, it is yet undefined how much test time is required to reflect a 30 years life expectancy. At this stage, 500h can be sufficient, but as well it could be 1000h or even more. The newest power semiconductor developments and new technologies allow the devices to operate and sustain such harsh conditions which will help to improve for the lifetime predictions.

Acknowledgement:

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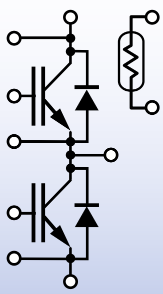
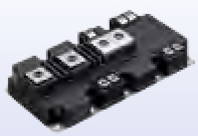
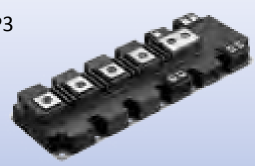
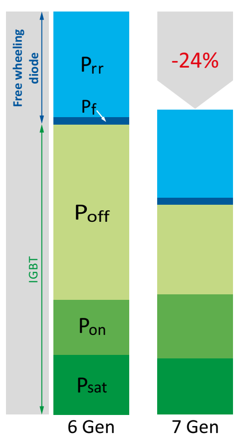
Line-up



	1200V	1700V
PP2 	900A	1200A
	1200A	
PP3 	1400A	1400A
	1800A	1800A



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New Horizons in Thermal Cycling Capability Realized with the 7th gen. IGBT Module Based on SLC-Technology

In various power electronic applications, the lifetime of the converter is a key factor for consideration for estimating the total cost. Particularly at intermittent load profiles the lifetime of a power converter is limited by the temperature cycling capability of the power module packages due to the interconnection of materials with different CTEs (Coefficient of Thermal Expansion). The 7th gen. IGBT modules are based on the new SLC packaging technology with a material composition based on matching CTEs which result in the highest thermal cycling capability.

By Thomas Radke, Narender Lakshmanan, Mitsubishi Electric Europe B.V

Introduction

The 7th gen. NX-type IGBT modules in the 650V, the 1200V and the 1700V categories have been developed in a comprehensive line-up to provide the best solution for different power classes. The new CIB (Converter Inverter Brake) modules which have been recently developed and the 800A / 1200V half bride module will further extend the line-up. The 7th gen. NX-type IGBT modules and the G1-series IPMs are based on the SLC package technology offering a remarkable advancement in the level of the thermal cycling capability. This improved thermal cycling capability can be exploited to extend the inverter lifetime. A lifetime extension essentially reduces the total cost, because the system can operate longer and new investments can be postponed.

SLC-Technology

SLC (SoLid Cover) -Technology is a newly developed package technology for realizing power semiconductor modules with high reliability and high thermal conductivity [3]. The comparison of the SLC package structure with a conventional module structure is shown in Figure 1. As it can be noticed from Figure 1, the SLC-Technology possess a significantly altered package design in comparison to the conventional module structure.

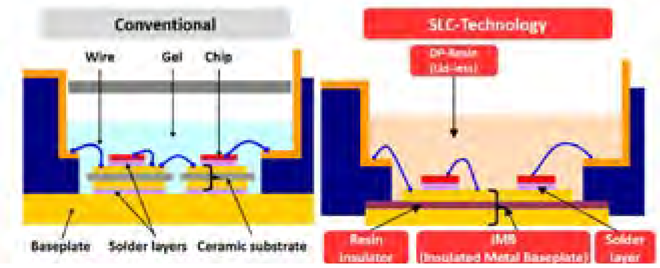


Figure 1: Comparison of SLC and conventional package structures

The soft silicone gel of the conventional structure is replaced by the hard DP-resin (direct potting resin). This hard encapsulation with DP-resin, which has an optimized CTE (Coefficient of Thermal Expansion), prevents the degradation of the chip solder [3].

The conventionally used ceramic insulation layer is replaced by a resin insulation material in the SLC-Technology. This resin insulation material has a CTE value matching with that of copper. Both copper as well the resin insulator have a CTE of about 17ppm/K as shown in Table 1. Therefore, in case of temperature cycling, there is no mechanical stress caused by the mismatch in the CTE values between the copper baseplate and the insulation layer. Furthermore, the baseplate solder layer is completely eliminated because the top and bottom side copper layers are directly bonded to the insulating resin layer. Employing this IMB (Insulated Metal Baseplate) in combination with the hard encapsulation (DP-resin), the thermal cycling capability is substantially improved. The status of the ongoing thermal cycle test is presented in Figure 2. Currently, a level of 70k cycles has been already achieved. The test was conducted for a temperature swing of ΔT_c=80K at the case and ΔT_j=100K at the IGBT junction. This result is about 10 times higher than the conventional capability, and this test

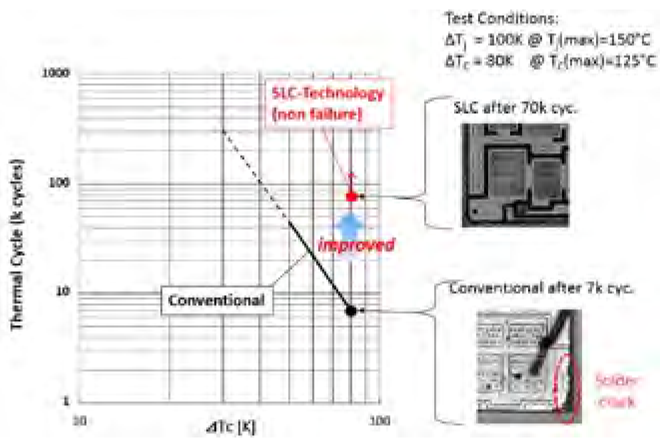


Figure 2: Thermal cycle test status

is still ongoing since the module's failure point has not yet been encountered. Furthermore, as shown on the right side of Figure 2, even after 70k cycles no delamination at all could be observed and therefore, an even higher thermal cycling capability is expected.

In the conventional module packaging structure, the metallized ceramic substrates are utilized to realize the electrical insulation between the electrical circuit (consisting of the semiconductor chips) and the module's base plate. The substrate layer is fixed to the copper base plate by a solder layer. The drawback of this arrangement is evident from the nature of the resulting material combination - the mismatch of CTE between ceramic, solder and copper. Depending on the ceramic material employed, the insulator CTE is in range of 4.5~7 ppm/K as shown in Table 1. This mismatch causes solder cracks during temperature swings and limits the lifetime of the power modules. As shown in Figure 2, after 7k cycles (with a swing of ΔTc=80K), the solder layer begins to crack.

Material	CTE [ppm/K]
Ceramic	4.5 ~ 7.0
Cu	≈17
Insulating resin layer	≈17

Table 1: Table with Coefficient of Thermal Expansion

Load Cycles in Power Applications

Load cycles have to be considered in almost all power electronic applications. The load profile depends on the individual application conditions. tions requiring significant load cycling for its normal operation, is usually limited by the inverter design (for eg –limited to about 30K) to offer an acceptable power cycle lifetime. Also, higher temperature swings and thermal cycles have to be considered in case the system temporarily pauses operation based on a discontinuous operating sessions wherein the entire heatsink may cool down to the ambient temperature. For air-cooled heat sinks, this cooling down takes a couple of minutes due to the nature of the heatsink thermal time constant. For a liquid cooled inverter, the cooling down process is faster since just some tens of seconds are sufficient to cool down the total system. That means if an inverter is used in a production process which is discontinuous, either due to tuning/adjustment requirements, breaks taken by the machine operator or due to interrupted flow of materials - thermal cycling also has to be taken into consideration. Similar considerations have to be taken also for certain other application like cranes or elevators where the power converters do not operate continuously. If we consider typical operational IGBT junction temperature of 125°C and an ambient temperature of 25°C, the junction temperature swing(ΔTj) will be in the range of 100K in case of such intermittent inverter operation. The temperature cycling capability has approximately an inverse exponential dependency with the temperature swing. Therefore, considering the power cycling capability curve of a conventional IGBT module, the ΔTj=100K swing causes dramatically higher relative aging compared to the ΔTj=30K swing. Due to that fact that the total system pauses the operation for several minutes, we can assume that also the IGBT case temperature will also experience a temperature swing of about ΔTc=80K.

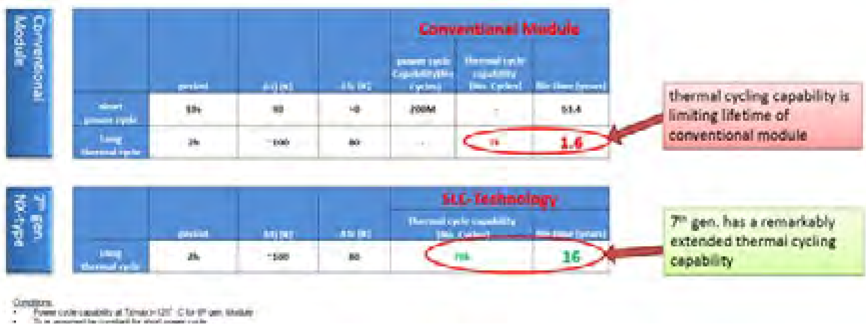
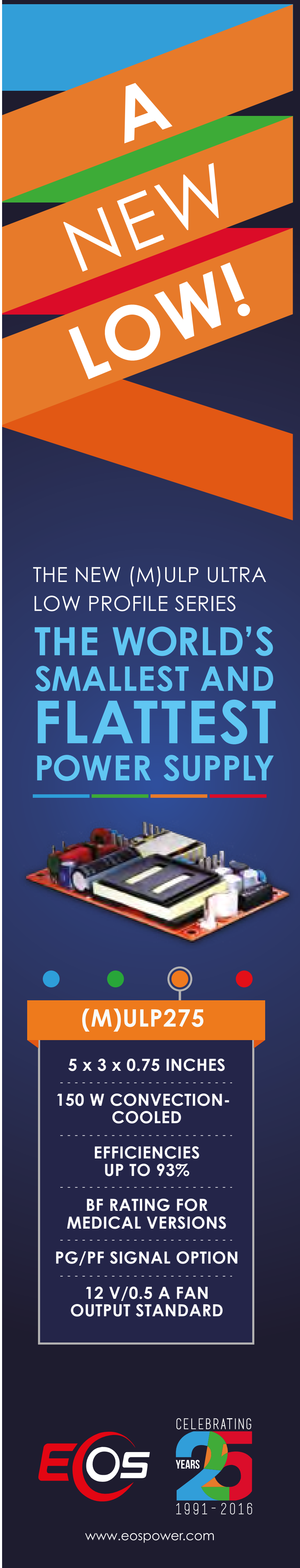


Figure 3: Application example for load cycling

In applications such as machine tools or servo drives, the occurrence of a high number of load cycles within a relatively short duration has to be considered. Load cycles typically occur in the form of short pulses possessing a time duration in the range of a few seconds. Since the thermal time constant of the heatsink is in the range of a few minutes, it can be assumed that the heatsink temperature remains constant between successive load cycle pulses. The number of maximum allowable junction temperature swing (ΔTj) for applica-

In figure 3, an example of an application is provided. If we consider a process where one load cycle occurs every 10 seconds, and the temperature rise of about 30K the power cycle capability for ΔTj=30K is about 200 million cycles which means the inverter lifetime can be estimated to reach a total operational lifetime of about 63 years which is acceptable. But if we have to consider an interrupted process chain and assume that the inverter operation is interrupted every 2 hours for a couple of minutes, the thermal cycling capability of the



power module has to be taken into consideration. For a case temperature swing of about 80K (ΔTc=80K) the thermal cycling capability of a conventional module is limited to about 7000 cycles which, under the assumed operation conditions, would be equivalent to about 1.6 years of total operational lifetime. Considering that the 7th gen with the SLC technology has a thermal cycling test result of more than 70k cycles we can expect a remarkable extension of operational lifetime, in this example, will be extended to more than 16 year of operation.

In conclusion, it can be stated that for various applications where non continuous operation has to be considered, the lifetime of power converters can be significantly improved by utilization the of 7th gen. NX-type IGBT Module based on SLC-Technology.

Line-up Expansion

As a first step, the 7th gen. NX-Type IGBT modules are developed in the blocking voltage classes : 650V and 1200V. The 6in1 and 7in1 topology modules are developed covering current ratings from 100A to 200A. The 2in1 modules in the M-size (62x152mm²) package cover the current ratings from 225A~600A. To realize a further expansion of the current ratings toward higher blocking voltages and higher rated currents, an improved resin insulation layer material - the IMB-technology was developed. The new resin material provides a higher thermal conductivity while simultaneously maintaining the high electrical insulation capability [2]. The utilization of this improved material enables a reduction in the thermal impedance that enables the development of modules with higher rated currents. This technology has now been applied and an 800A/1200V 2in1 module is under development in the M-size package. On the other hand, the improved thermal conductivity enables an increase in the insulation layer thickness without a negative impact on the resulting thermal resistance. By this approach, an insulation capability of 4kV has been achieved and this is utilized to realize to modules with a blocking voltage of 1700V [4].

Figure 4: Line-up of 7th gen NX-type IGBT modules

In addition to the expansion towards higher current levels and higher voltage levels, the development of modules with CIB-topology for the current ratings between 35A and 150A has been initiated. These CIB configuration modules consist of a three-phase input rectifier bridge, a brake chopper and a three-phase output inverter. For the smaller current ratings, a 45x107.5mm S-size package is under development. To be compatible to the de-facto standards as much as possible, the IGBT housing for this CIB module is now available in the market with two different pin terminal configurations. Furthermore, all CIB modules will be made available in the market with both the solder pin terminal version and the press-fit pin terminal version.

New 1700V Modules - Optimized for High Efficiencies

IGBT modules with 1700V blocking capability are mainly used for inverters with 690Vac output voltage. The applied dc-link voltage "V_{CC}" is in the range of 1000V~1200V and essentially higher than that required by inverters intended to deliver 400Vac (which require 1200V category IGBT modules). The higher applied voltage results in higher switching losses due to the higher voltage at the transition of collector emitter voltage. This is the reason why inverters utilizing the 1700V IGBT modules are usually operated at lower switching frequencies compared to an inverter using the 1200V IGBT modules. As a result, in conventional 1700V IGBT modules, the switching losses become the dominant part even at low switching frequencies. Therefore, the switching losses have been identified as the bottleneck for the IGBT module performance in industrial inverter mode applications. For the chip design of the 1700V, the 7th gen IGBT and the diode chipset, this has been considered and counter measures have been taken. In Figure 5 the E_{off} vs V_{CEsat} tradeoff is shown and it represents the IGBT chip performance. During the chip design, the IGBT characteristics can be tuned to achieve lower conduction losses or lower switching losses. If, for example - an IGBT chip design is optimized for very low V_{CEsat} , the switching losses tend to be high and vice versa - an IGBT chip design which is optimized for low switching losses tend to have a high V_{CEsat}. As shown in Figure 5, the 7th gen 1700V device offers both lower switching and lower conduction losses. This means that the overall chip performance is improved and is better than the conventional chip. The conduction losses are slightly better but the switching losses are essentially improved by about 40%. Apart from the IGBT chip, the 7th gen. 1700V diode which based on the RFC structure (relaxed field of cathode) has an improved overall performance and is tuned for operations at high switching frequencies.

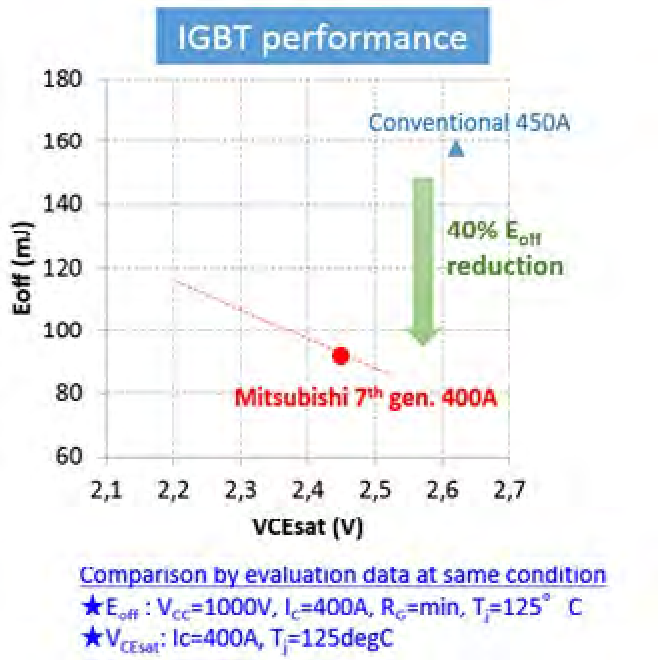


Figure 5: Eoff vs. VCEsat trade-off comparison of 7th gen. 1700V IGBT chip

In Figure 6, the loss comparison (which was prepared by using the Melcosim software [1]) of a 600A/1200V module (CM600DX-34T) versus a conventional 600A/1700V IGBT module under a typical inverter mode operation condition is shown. The improved chip characteristics result in a loss reduction of 7.4% at a switching frequency of 0.5 kHz. For higher carrier frequencies, the improvement becomes more significant. Therefore, with 1 kHz the loss reduction is 16.4%, with 2.0

kHz the reduction is 25.8%, and with 4 kHz 33.6% of the losses can be saved. This loss saving will improve the power converter efficiency, and in-turn contribute to the energy savings and eco-friendly operation. Apart from the energy, enabling loss reduction will lead to lower operation temperatures and therefore facilitate increasing the load of the inverter. Therefore by utilizing this new 7th gen. 1700V chipset enables designing the inverter with higher power density and cost optimization.

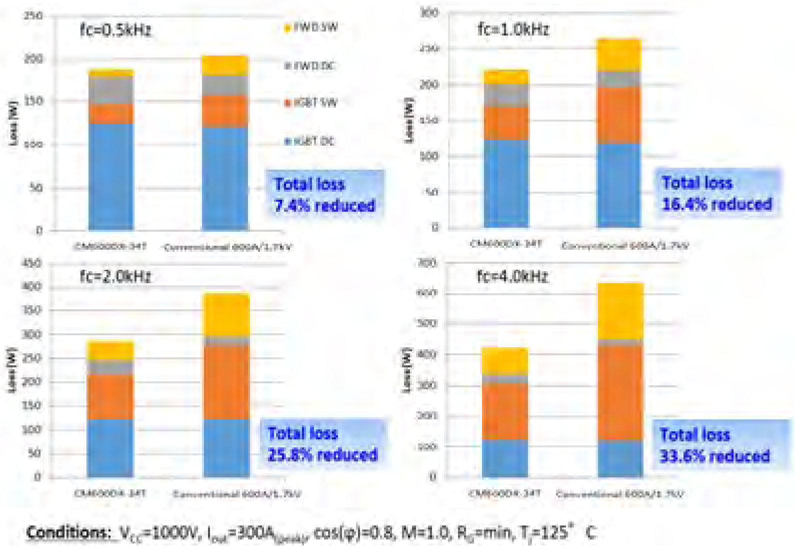


Figure 6: Loss comparison of 1700V IGBT modules

Summary

The 7th gen NX-type IGBT module offers an enormously improved life time by utilization of the SLC-Technology. Matching and optimizing the CTEs of the SLC package Technology opens-up this new horizon in thermal cycling capability. An example application has demonstrated that a significantly higher lifetime can be achieved. This technology is now available in a comprehensive line-up, which has been expanded to include CIB modules and the 1700V category modules. The new 1700V IGBTs and the diode chip sets have a trade-off optimization of the switching characteristics and the conduction characteristics which result in a significantly higher efficiency and overall module performance.

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By Abdus Sattar Ph.D., and Leonid Neyman Ph.D., IXYS Corporation

The IXIDM1401 is a high-voltage isolated gate driver module based on the IX6610/IX6611 chipset, which allows creation of an isolated IGBT driver with a high voltage isolation barrier between the primary and secondary sides as well as between secondary side drivers. This creates a very flexible architecture, which can be used for 3-phase motor drivers, half-bridge switches, push-pull converters, or other applications in UPS, renewable energy, and transportation, which require isolation between primary and secondary side and/or between secondary side drivers.

An internal power supply provides up to 2 W per channel of isolated power to drive both upper and lower IGBTs, effectively isolating the MCU from the high power circuitry. Operating from a single polarity 15 V power source, it provides +20 V/-5 V to drive the IGBT gates and +3.3 V to drive the MCU, maintaining up to 4 kV isolation voltage between the MCU and gate drivers and between gate drivers as well.

Built-in under-voltage and over-voltage protection prevents the IGBTs from operating at gate voltages outside of the optimal window and informs the MCU about such conditions without regard to the source of the problems, which may come from either the low/high side IGBT behind the isolation barrier or the primary side before the isolation barrier.

An over-current protection with a 300 mV threshold can be implemented by utilizing either a current-sense resistor or IGBT de-saturation event. It turns the IGBT off immediately after the collector current exceeds a value set by the user and informs the MCU to make an appropriate decision.

An Active Clamping Comparator with a 3.1 V threshold (with respect to the negative IGBT gate voltage) disables the driver when the collector voltage exceeds level set by the user, preventing excessive power dissipation in the IGBTs.

TTL level compatible input signals from an external MCU are used to operate secondary side drivers. The IXIDM1401 implements a dual-channel bidirectional transformer interface, which transmits the primary side input commands from the MCU to the secondary side and information from the secondary side to the MCU. Asynchronous data transmission is implemented by narrow pulses to prevent the transformer's core saturation.

A narrow pulse detector is also implemented to prevent transmission of very narrow false PWM input signals to the drivers. Input signal pulses with width narrower than 100 ns are suppressed and pulses with width greater than 350 ns are transferred to the drivers.

To avoid limitations to the input pulse maximum width, only short pulses representing rising/falling edges of the input signals are transmitted from the primary side, while the secondary side restores the original pulse width.

The secondary side gate drivers convert the incoming PWM logic signals into +20 V/-5 V (in respect to COMMON) bipolar gate drive signal with a typical 10 A peak drive current capability. Separate positive and negative gate driver outputs allow optimization of IGBT turn on/off time without an external diode by selecting serial gate resistors of different values.

The built-in dead time delay circuitry, with channel A priority, prevents the IGBTs from turning on simultaneously. If channel B is active and channel A is forced into on-state, channel B becomes disabled immediately and the channel A IGBT turns on with a preset delay time. After channel A becomes inactive, channel B, if active, turns on with the same delay time. If channel A is active and channel B is forced into on-state, this command will be ignored as long as channel A remains active. If channel A becomes inactive before the command activating channel B expires, channel B becomes active with a preset delay time after channel A becomes inactive.

It allows using a single input signal source to create a complementary switching pair of IGBTs in a half-bridge configuration by setting channel B to permanently enabled and operating channel A only.

Dead time between pulses at Gate A and Gate B outputs is hardware programmed to ~420 ns. If the dead time required to operate specific IGBTs is greater than implemented in IXIDM1401, it should be programmed by the MCU or factory-adjusted to the required value.

The over-temperature protection function disables the IGBTs if the internal chip's temperature exceeds 150° C, and resumes normal operations when the temperature falls below 125° C. If the IGBT assembly is equipped with a temperature sensor, the IXIDM1401 is able to translate its signal to the MCU.

A dual-channel bidirectional transformer interface allows transmission of information to the MCU about secondary side power supply faults and IGBT over-current conditions.

All fault conditions at the primary side stop execution of the PWM cycle at both drivers, while all fault conditions at the secondary side stop the PWM cycle at the affected driver only. If fault conditions appear before the start of the PWM cycle, the PWM cycle will be ignored as long as fault conditions exist.

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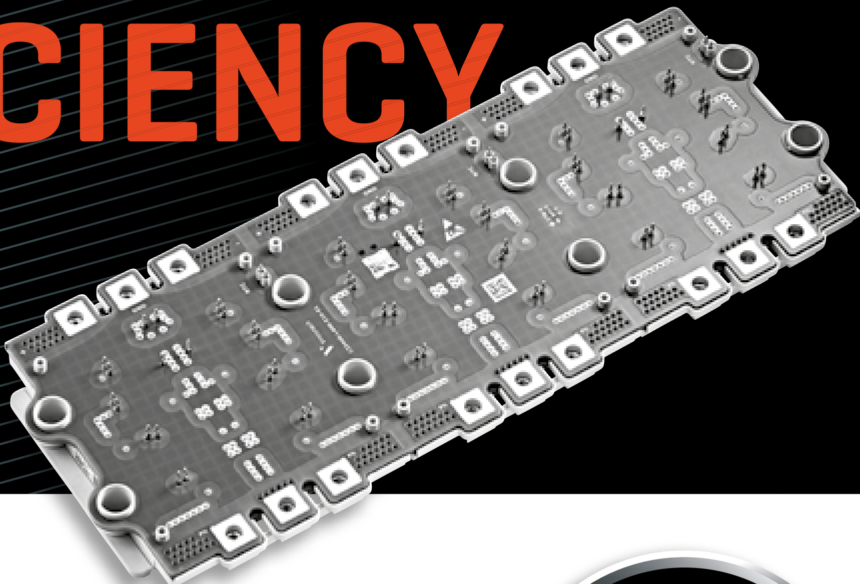

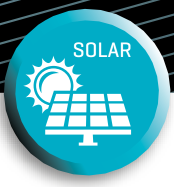

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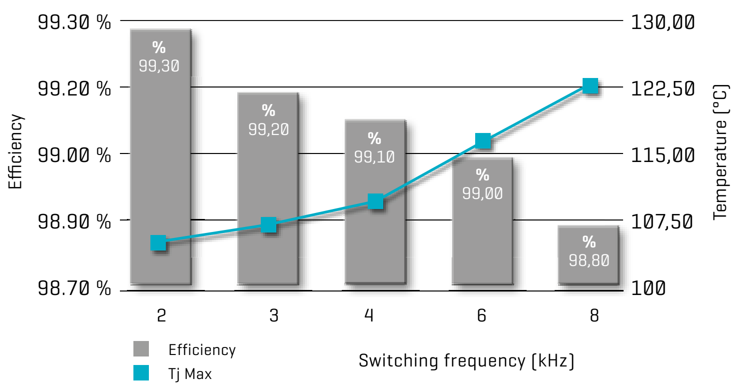

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The IXIDM1401 power block is designed to provide up to 2 W of power. It has a start-up mode and a run mode. In the start-up mode, the converter operates from the internal oscillator and activates only a portion of the power switches to reduce the dynamic current consumption/power dissipation. After start-up, the converter activates the entire power switches and goes into run mode. The run mode is held off ~1.28 ms. Transmit operation is disabled during start-up mode to minimize current draw in the secondary. After run mode begins, it will continue until a restart occurs, which returns the power block to start-up mode.

In the run mode, the power block operates either from an internal or external clock. Use of an external clock from the MCU enables minimizing noise interference between IXIDM1401 devices in case of multi-phase applications like motor drivers.

The power block's push-pull converter duty cycle depends on the external clock duty cycle as DCPL = 0.5 – DCEXT/2.015 that allows for adjustment of secondary output voltage by varying the duty cycle in case of over/under-voltage.

A converter's watchdog timer prevents potential damage due to absence of an external clock. Whenever the external clock period exceeds the watchdog timeout of 40 µs, the converter switches to the internal clock.

Active Clamping protection implemented in IXIDM1401 enables prevention of IGBT damage in case of an inductive load turned off with high inductive current. In such situations, the IGBT collector voltage may easily exceed the breakdown limit and destroy the IGBT. One of the ways to prevent this condition is to keep the IGBT conducting until the energy stored in the inductor is not enough to create a collector over-voltage condition. The IXIDM1401 utilizes ACL comparators with 3.1 V thresholds in respect to negative voltage source that may be used for implementing an advanced active clamping technique.

Triggering the ACL comparator forces the gate driver output to a tri-state condition and the IGBT starts to turn on due to the breakdown diode current charging the IGBT gate. After the IGBT turns on, its collector voltage falls, the diode recovers from breakdown, and the ACL comparator turns on the OUTN output, which forces the IGBT gate low. This sequence may repeat several times until the energy in the external inductance is dissipated. The ACL comparator is active only when the driver's output OUTP is OFF.

Each of the IXIDM1401 IGBT drivers also contains an over-current (OC) comparator with a
300 mV threshold in respect to the COMMON pin. Over-current protection can be implemented either by using a low value current sense resistor, an IGBT with a secondary current sense output, or utilizing a de-saturation event.

If an over-current fault occurs, the driver's output is forced low for the rest of the cycle. Normal operation resumes at the beginning of the next PWM gate drive cycle.

A noise filter at the current sense input may be required due to low sense voltage. The OC comparator has an internal 100 pF capacitor connected in parallel to the input; therefore, only a serial resistor can be added to create such a filter. The OC comparator's input is grounded during the off time of the IGBT and remains grounded for 3.5 µs immediately after the IGBT turns on to prevent false tripping. When an over-current event occurs, the Output Faults Pulse Generator creates a narrow 200 ns pulse that is used by the Fault Control Logic to communicate the fault condition to the MCU.

The IXIDM1401 is available in a 50 x 50 x 25 mm package with a 12-pin, 1 mm-pitch FFC connector to communicate with an MCU, two 5-pin, 2.54 mm-pitch headers to provide signals to/from the IGBTs, and one 2pin, 2.54 mm-pitch header to translate signals from an external temperature sensor to the MCU.

One of the possible applications, shown in Figure 1, represents IXIDM1401, which operates IXYS Corporation's phase leg IGBT module MIXA225PF1200TSF.

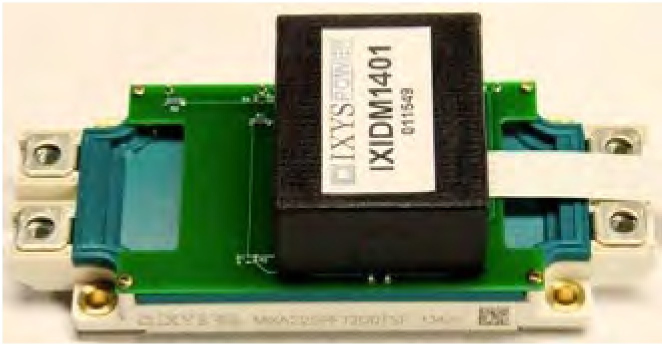

Figure1: IXIDM1401/ MIXA225PF1200TSF Modules Assembly

Powered from a single polarity 15 V power supply, IXIDM1401 operates two 1200 V IGBT devices with a maximum collector current of 360 A. This design allows the MCU to alert customers about under/over-voltage conditions on the primary and secondary sides, and overload conditions when the IGBT goes into de-saturation mode. The MCU can be powered from this module and does not require a separate power source. If a user prefers to drive the MCU from an external power source, this can be accomplished as well. Internal IXIDM1401 logic can be also powered from the same external source, minimizing power consumption from the 15 V power supply.

Typical applications for this design are shown in Figures 2 and 3.

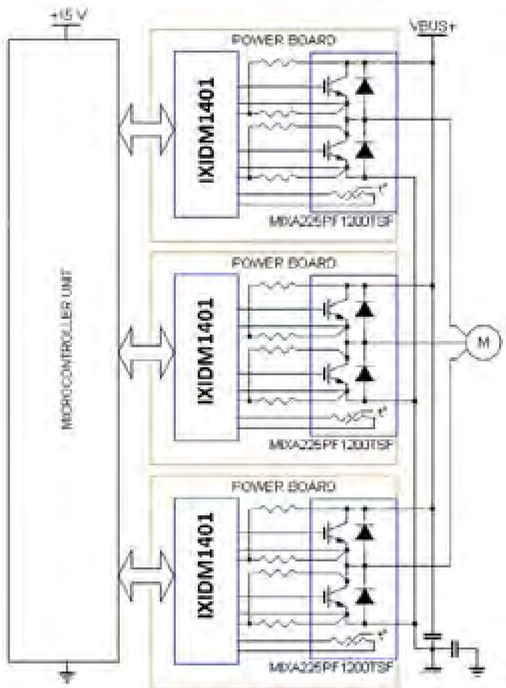

Figure 2: Typical Application Circuit of a Three-phase Motor Driver

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Highlights

- Variety of module package offerings (small to large, fit to application)
- High power density with integrated magnetic and passive components
- Performance (efficiency, thermal, transient response)
- Reliable (power and thermal stress tested)
- Low EMI (CISPR 22 Class B ratings on modules)

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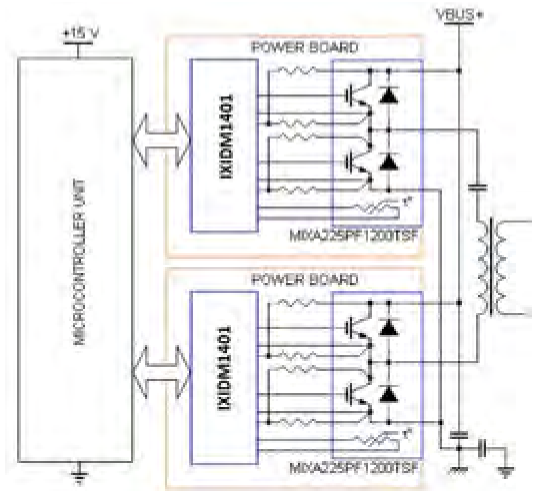

Figure 3: Typical Application Circuit of a Full-bridge Inverter

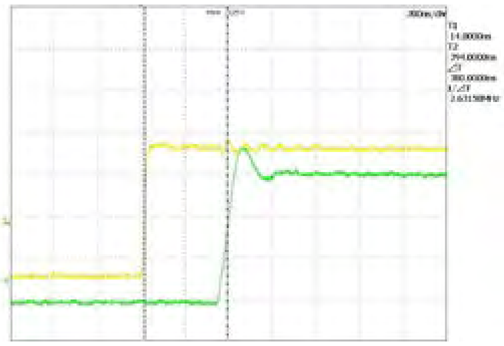

Figure 4: Input to Output Propagation Delay Channel: A Rising Edge (10 nF load)

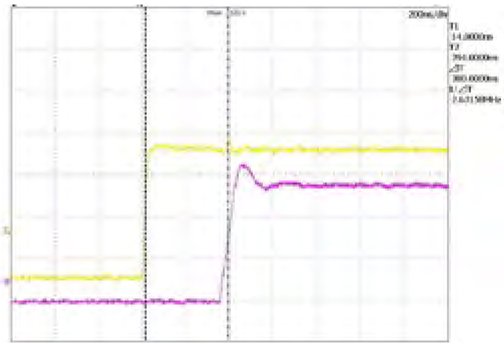

Figure 5: Input to Output Propagation Delay: Channel B Rising Edge (10 nF load)

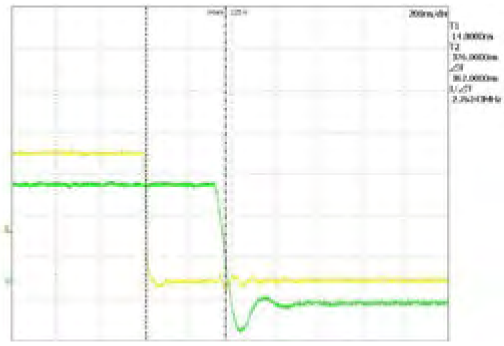

Figure 6: Input to Output Propagation Delay: Channel A Falling Edge (10 nF load)

Figures 4 – 7 display IXIDM1401 performance with the 10 nF gate load capacitance, while figures 8 – 13 display IXIDM1401 performance with MIXA225PF1200TSF module as a load. In each of the figures below, the yellow curve represents an input signal, while the green and magenta curves represent output signals.

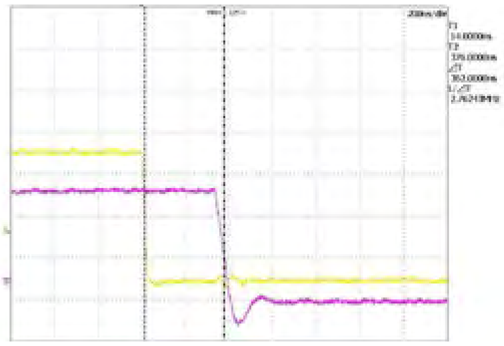

Figure 7: Input to Output Propagation Dela:y Channel B Falling Edge (10 nF load)

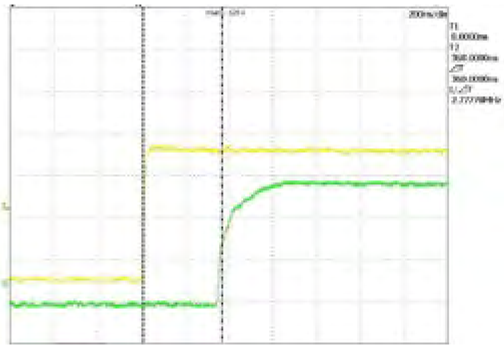

Figure 8: Input to Output Propagation Delay Channel A Rising Edge (MIXA225PF1200TSF load)

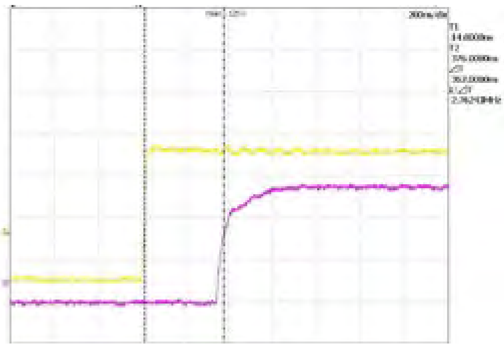

Figure 9: Input to Output Propagation Delay Channel B Rising Edge (MIXA225PF1200TSF load)

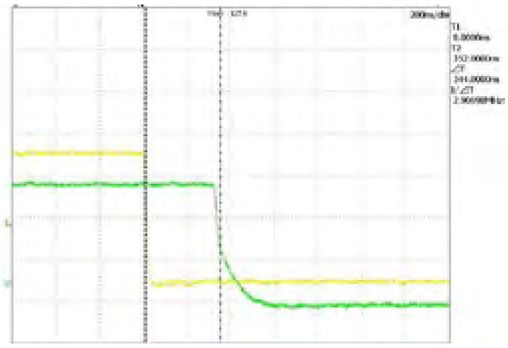

Figure 10: Input to Output Propagation Delay Channel A Falling Edge (MIXA225PF1200TSF load)

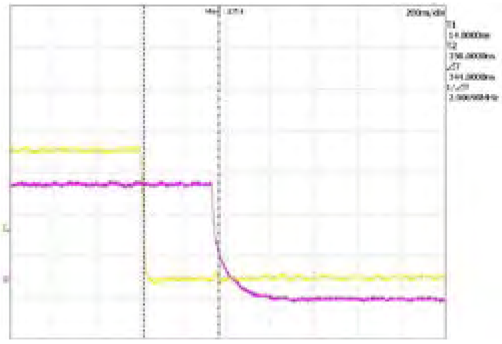

Figure 11: Input to Output Propagation Delay Channel B Falling Edge (MIXA225PF1200TSF load

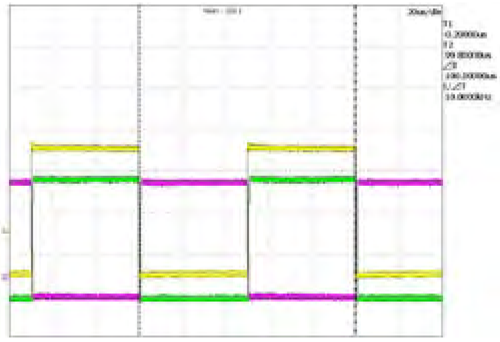

Figure 12: MIXA225PF1200TSF operating in complimentary mode with a single signal source at channel A and channel B permanently enabled

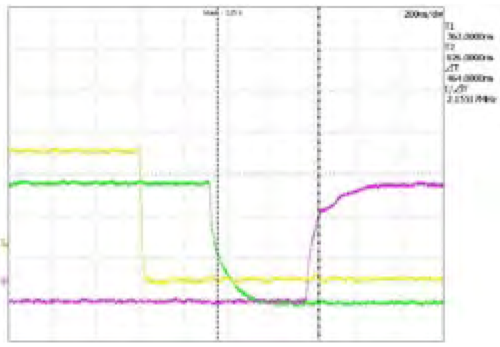

Figure 13: Dead time generated by IXIDM1401 in complementary mode

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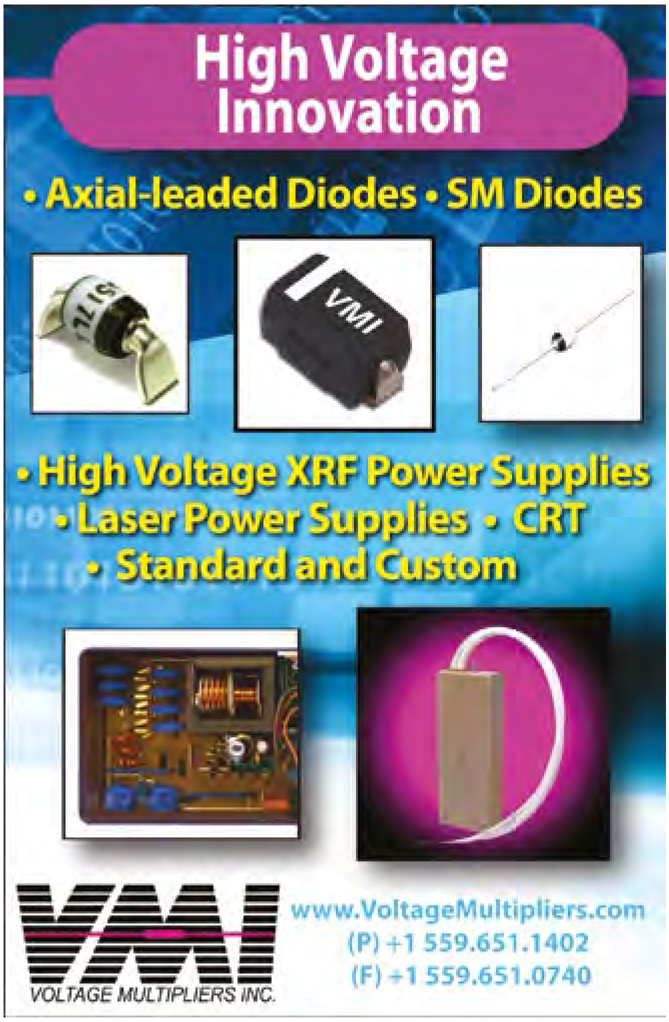

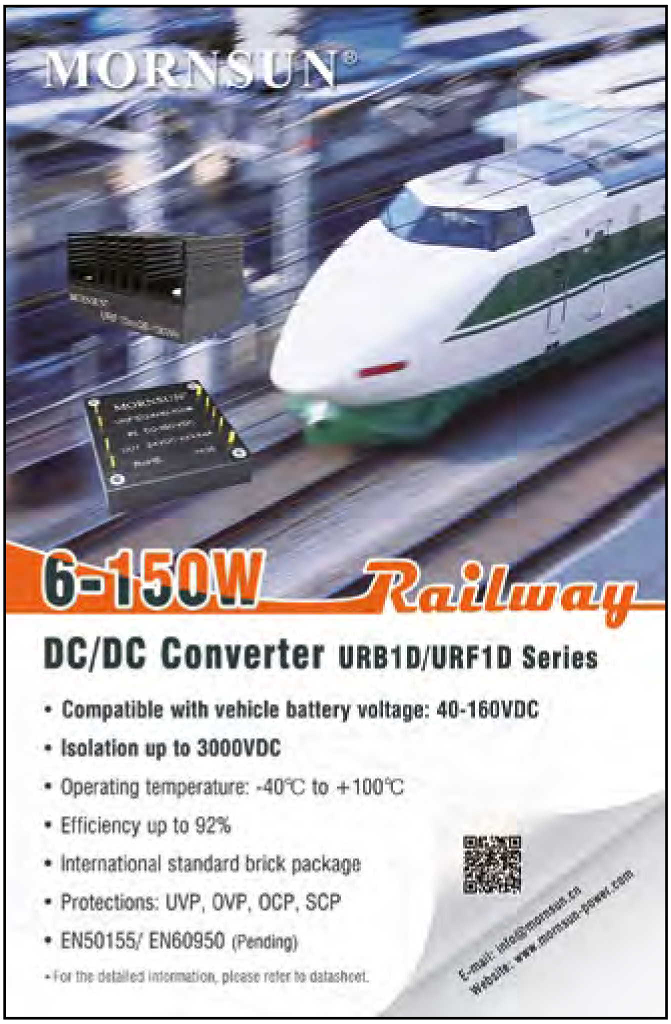

Low-inductive three-level Modules for 1+ MW 1500 VDC Solar PV Central Inverters

With multi-string inverters gaining ground in the utility-scale PV market, new solutions for Central Inverters are needed. This article presents the benefits of combining the low-inductiveVINco X12 package and the new Mitsubishi gen 7, achieving an outstanding efficiency and power density to meet the highly demanding requirements of the solar PV inverter market.

By Guillem Gargallo, Product Marketing Manager, Vincotech GmbH, Unterhaching

Rising cost pressure is driving demand for solar energy systems rated beyond 1000 VDC. The industry has responded with standards and components enabling up to 1500 VDC. Multi-string inverters are evolving fast to adapt to these new requirements. The latest devices are able to handle 80+ kVA. This is why the price gap between multi-string and central inverters is closing and the competition between these solutions is heating up for utility-scale applications. With string inverters gaining market share in these application, engineers are hard-pressed to act fast and respond with innovative answers. Two-level solutions are no longer competitive; more advanced topologies are needed to stay in the game.

VINco X – the three-level package for central inverters
Simply adapting two-level housings to three-level topologies is certainly not the right answer. This would limit the maximum frequency and negate some of the advantages of NPC configurations. With this in mind, Vincotech tapped its deep well of experience with three-level modules to come up with high-power solutions. Low inductive VIN housings are built to handle higher switching frequencies, thereby enabling engineers to reduce overhead in passive components and achieve outstanding efficiencies.

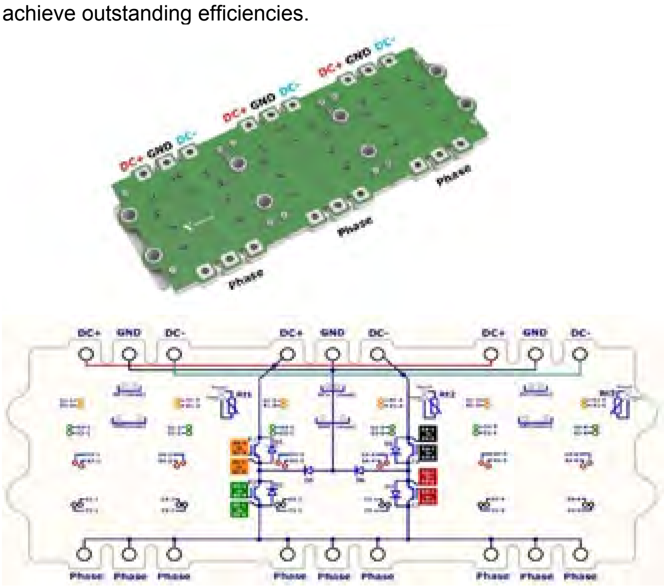

Figure 1: The VINcoNPC X12 diagrammed

The VINcoNPC X12 family meets the challenging requirements for central inverters, while retaining the string inverter's speed and flexibility. The terminal connection allows DC and AC stages to be split, which makes busbar design that much easier.
Circuits are meticulously laid out to distribute current evenly and prevent individual components from overloading.

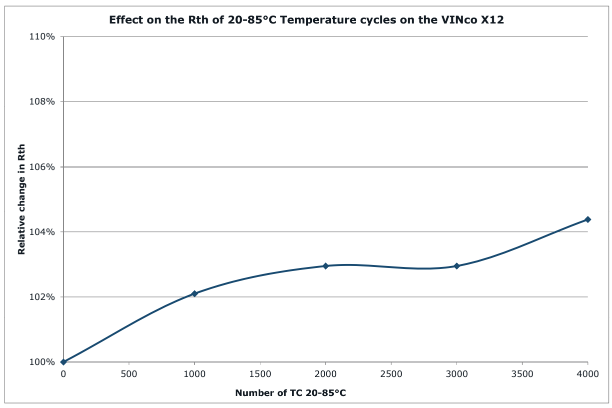

Figure 2: 20-85°c temperature cycles' effect on the VINcoNPC X12 Rth

The baseplate used in this modular design lacks large copper surfaces, so thermal interface material does not bleed out. With the benefit of this 'pump-out' prevention and Vincotech's phase change material, reliable thermal performance is assured over the module's lifetime.

Features

- Optimized connections for three-level topologies
- Low internal inductance (5 nH for low inductive commutation loop; 9 nH for the high inductive loop) enables higher frequencies
- Fully symmetrical layouts for uniform current sharing
- Modular constructions for better thermal performance

Benefits

- Easier busbar design
- Smaller passive components needed
- Individual dies are not overloaded
- Proper thermal performance
- Cost-competitive solution for central inverters

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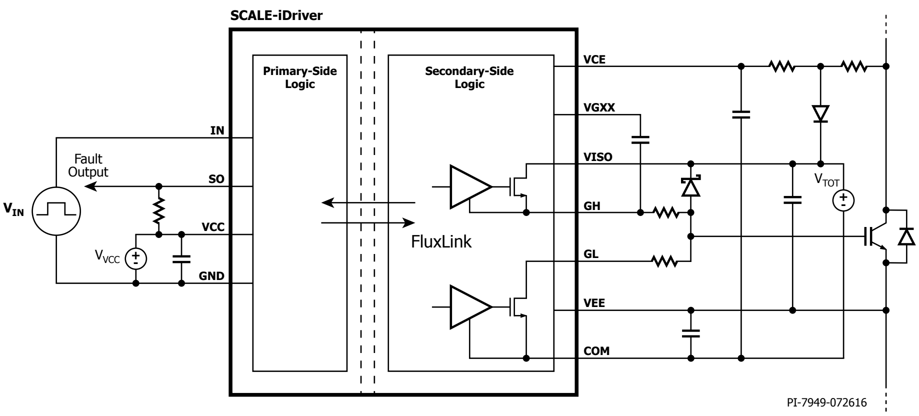

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New VINco X12 with Mitsubishi 7th Gen

Mitsubishi's new 7th generation (M7) of IGBTs and diodes is a perfect match for the VINcoNPC X12 family. M7 dies are up to 25% smaller than those used in the current VINcoNPC X12 for the same current rating, so the nominal current may be stepped up from 1200 A to 1800 A. On top of that, conduction losses are up to 20% lower and the switching characteristics result in superior EMC.

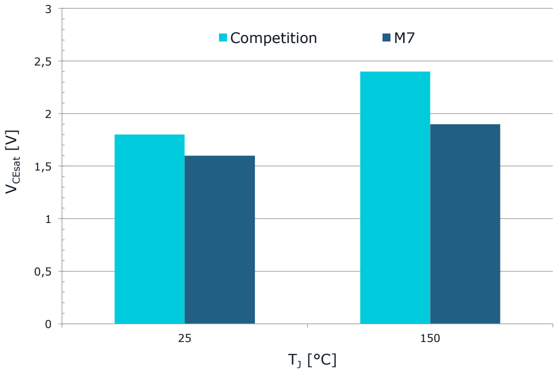

Figure 3: IGBT VCEsat at 100A and VGE = 15 V

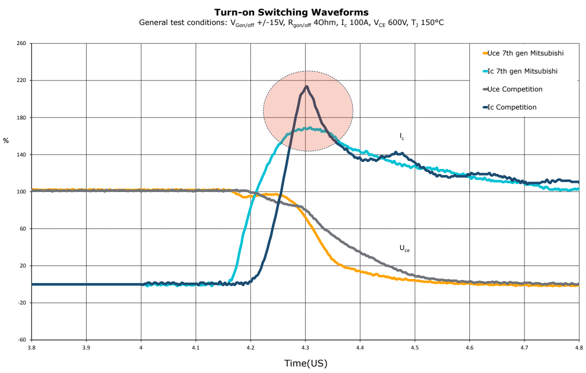

Figure 4: Turn-on switching waveforms; test conditions: VGon/off +/-15V, Rgon/off 4Ohm, Ic 100A, VCE 600V, TJ 150°C

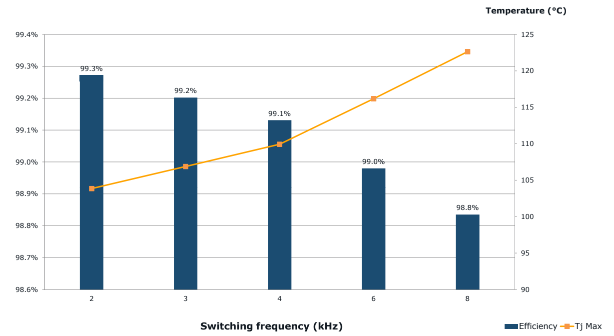

Figure 6: LD00FP70 efficiency and maximum junction temperature vs. switching frequency for 1 MW Conditions: VIN = 1300 VDC; VOUT= 400 VAC; IOUT = 833 A/phase ; fSW = 50 Hz; Rg_ON/OFF = 0,5 Ω; TSINK = 85°C

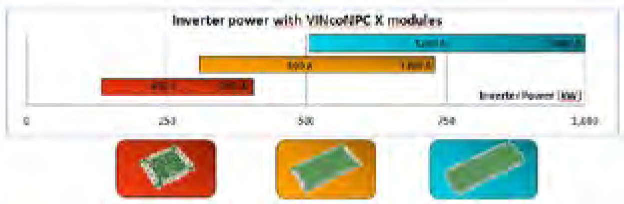

Figure 7: VINcoNPC X module lineup

Thanks to this module type's greater power density and efficiency, **one MW can be achieved without paralleling modules** or having to use two-level modules in a highly inductive design to achieve the three-level configuration. This option of using one module per phase to reach 1 MW is remarkably efficient, achieving a 99% rating at 6 kHz and even higher efficiencies at lower switching frequencies. The maximum junction temperature of all components under these conditions remains below 120°C, thereby leaving ample margin for safety in the event for overload conditions.

Conclusion

String inverters are making inroads into utility-scale installations, so manufacturers of central inverters will have to adapt if they want their products to remain viable. However, the demands of the highly competitive PV market cannot be met by simply modifying packages designed for other industries.

Vincotech, a leader in the PV industry, has a lot to offer to these manufacturers. Built on innovative ideas and the insight comes with experience, Vincotech solutions meet this market's exacting demands for efficiency, power density and reliability at competitive costs.

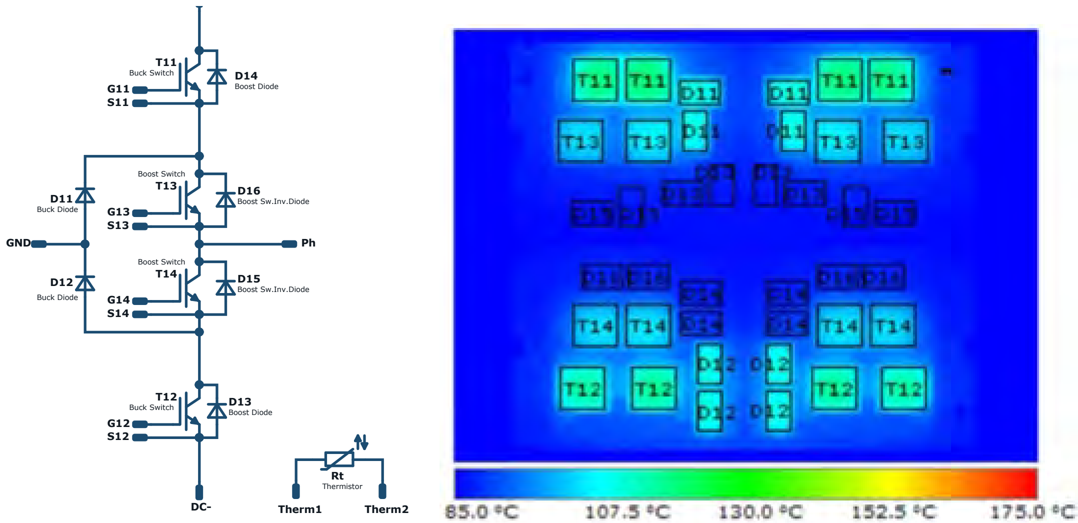

Figure 5: Thermal distribution of one unit of the 70-W624NIA1K8M701-LD00FP70 for 1 MW output power. Conditions: VIN = 1300 VDC; VOUT= 400 VAC; IOUT = 833 A/phase; fSW = 6kHz; fSW = 50 Hz; Rg_ON/OFF = 0,5 Ω; TSINK = 85°C

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Closed Loop Current Transducers with Excellent Performance are also Cost-Effective

Isolated current transducers use many different magnetic technologies varying from simple open-loop devices based on Hall cells to complex closed-loop transducers using fluxgates as the magnetically sensitive element[1]. The higher accuracy of the more complicated types comes with an increased cost. Within each technology family the challenge of new developments is to attain the performance of transducers in the family above while maintaining the cost advantages inherent to its design. In this article we describe new closed-loop transducers using the Hall Effect in a custom ASIC for low currents from 1.5 A to 50 A nominal for PCB mounting. Their performance is similar to that of transducers using fluxgates. Advanced manufacturing techniques have also been introduced, and the new transducers achieve the highest levels of quality and traceability.

By Steve Moureaux, R&D Program Manager and Diego Gutierrez, Senior R&D Design Engineer, LEM

New transducer concept

The simplest current transducers are open-loop devices in which the magnetic field from the primary current is sensed and amplified; they suffer from the drawbacks of any open-loop system, especially that of not having a stable feedback network to define their sensitivity.

Closed loop devices are more complex but they cancel the primary magnetic field with a secondary current in a coil of N turns and so have improved performance: the sensitivity is set by the value of N so it is precise and stable; above a few kiloHertz the transformer effect takes over from the feedback loop so the effective bandwidth is much higher than the noise bandwidth, and by always operating at zero magnetic field the linearity is intrinsically good. The response time, driven by the transformer effect, is very fast.

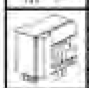
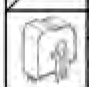
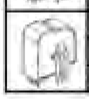
Old design	Old reference	New design	New reference	Secondary connection	Creepage Clearance (mm)	Temperature range
	CAS 6-NP		LES 6-NP	+5V GND V_{out}	dcl 7.7 dcp 7.7	-40 to 85°C
	CAS 15-NP		LES 15-NP			-40 to 85°C
	CAS 25-NP		LES 25-NP			-40 to 85°C
	CAS 50-NP		LES 50-NP			-40 to 85°C
	CASR 6-NP		LESR 6-NP	+5V GND V_{out} V_{ref}	dcl 7.55 dcp 7.55	-40 to 85°C
	CASR 15-NP		LESR 15-NP			-40 to 85°C
	CASR 25-NP		LESR 25-NP			-40 to 85°C
	CASR 50-NP		LESR 50-NP			-40 to 85°C
	CKSR 6-NP		LKSR 6-NP	+5V GND V_{out} V_{ref}	dcl 9.9 dcp 9.9	-40 to 105°C
	CKSR 15-NP		LKSR 15-NP			-40 to 105°C
	CKSR 25-NP		LKSR 25-NP			-40 to 105°C
	CKSR 50-NP		LKSR 50-NP			-40 to 105°C
	None		LPSR 6-NP	+5V GND V_{out} V_{ref} OCD	dcl 9.5 dcp 9.5	-40 to 105°C
	None		LPSR 15-NP			-40 to 105°C
	None		LPSR 25-NP			-40 to 105°C
	None		LPSR 50-NP			-40 to 105°C
	LTS 6-NP		LXS 6-NPS	+5V GND V_{out}	dcl 7.7 dcp 7.7	-40 to 85°C
	LTS 15-NP		LXS 15-NPS			-40 to 85°C
	LTS 25-NP		LXS 25-NPS			-40 to 85°C
	LTSR 6-NP		LXSR 6-NPS	+5V GND V_{out} V_{ref}	dcl 7.55 dcp 7.55	-40 to 85°C
	LTR 15-NP		LXSR 15-NPS			-40 to 85°C
	LTSR 25-NP		LXSR 25-NPS			-40 to 85°C

Table 1: Correlation of the new transducers' references with their equivalents from earlier families

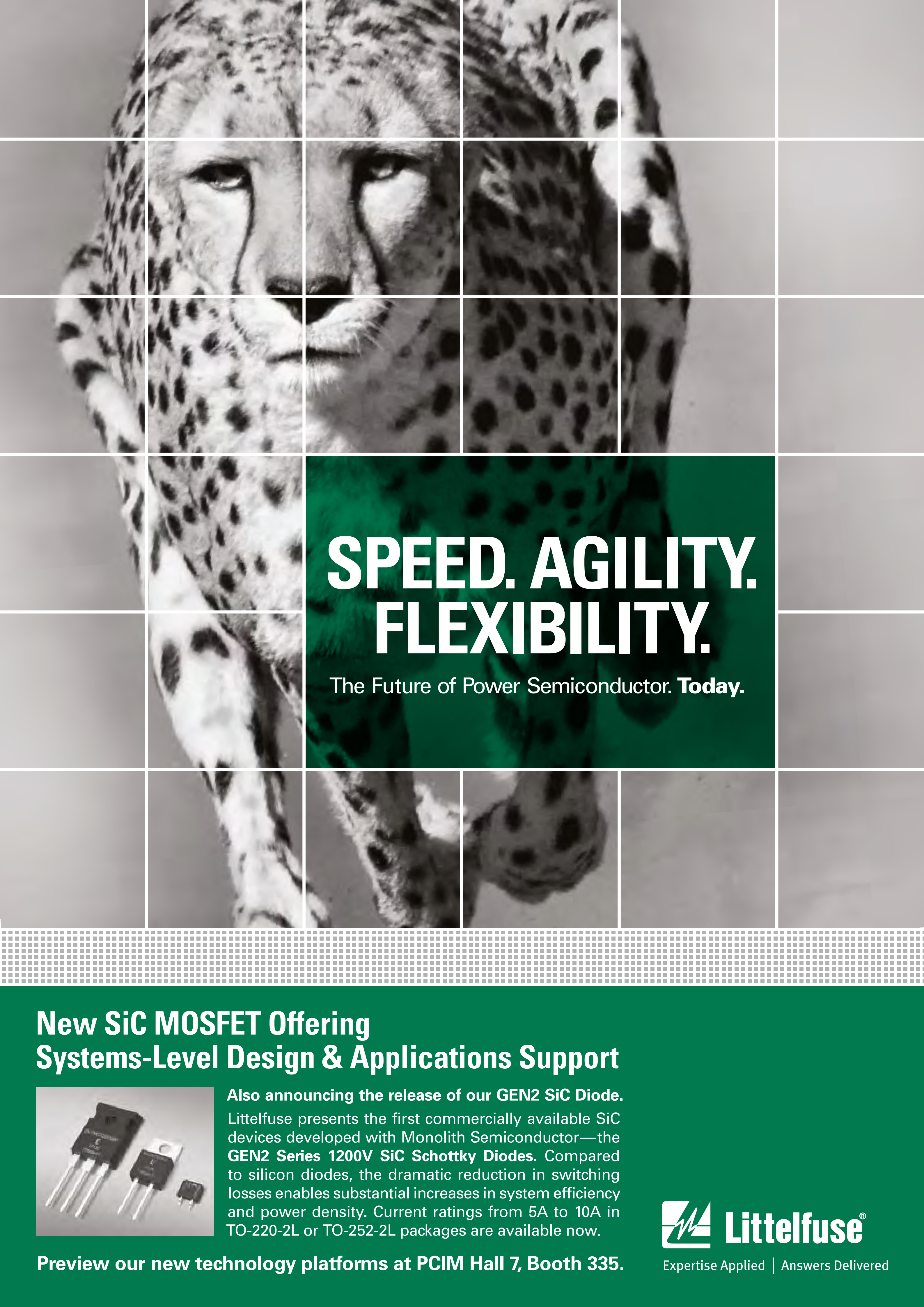
For convenience in the most recent sensor generations, the secondary current is converted back to a voltage V_{OUT} using a precise, stable measurement resistor followed by an amplifier referenced to a voltage V_{REF}.

The simplest closed loop transducers use Hall cells as the magnetically sensitive element: they have the advantages listed above but the Hall cells cause one weakness: the offset voltage ($V_{OUT} - V_{REF}$ with zero primary current), and its drift. Users requiring good offset performance tend to use transducers based on fluxgates – but fluxgate transducers have more components and are more costly.

This article describes a new family of LEM compact closed-loop current transducers in which the shortcoming of Hall cells has been addressed and most performance parameters equal those of small fluxgate transducers.

The heart of the new transducers is a custom designed and exclusively owned ASIC into which the Hall cells are integrated and whose features include:

- a new patented arrangement of multiple Hall cells in a very symmetrical layout merged with the first amplifier stages;
- use of sophisticated offset cancelling techniques in all of the electronics blocks in the control loop which generates the secondary current as well as in the amplifier which generates V_{OUT};
- an on-chip memory so that during production of each transducer any residual offset – or other imperfection - can be measured and a correction stored.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The result is a family of transducers whose offset drift is in the range of 4 – 14 ppm/°C, depending on the transducer sensitivity[2].

This is over four times smaller than the previous generation of closed-loop transducers based on Hall cells, and very similar to those using fluxgates.

In the new ASIC the opportunity was taken to add a very fast Over-Current Detection feature to give an indication that a measured current is exceeding its expected value or switch power off in the event of a short circuit.

The transducer family

Table 1 gives a complete overview of the new family of LEM transducers.
Among the earlier references the CAS, CASR and CKSR families use fluxgates and the LTS(R) families use Hall cells. The new references all use Hall cells.
Table 2 summarizes electrical performance of 25 Amp sensors.

Table 2 clearly shows that the performance of the new LKSR 25-NP is similar to that of the fluxgate based CKSR 25-NP and considerably improved compared to LTSR 25-NP, the earlier Hall based design. The most impressive improvement is in the drift of $V_{OUT} – V_{REF}$ when $I_P = 0$ (the offset drift). For 25 Amp transducers the improvement is almost 10x.

Manufacturing

From the outset the philosophy of manufacturing process of the new family was planned with full automotive qualification in mind. It has been designed to be autonomous, with an "Industry 4.0" approach.

As an example of the design for quality: two secondary coils wound in series are used to give best high frequency performance: a special winding technique, economical in production time, is used to avoid any soldered connections between them. Equally there are no soldered joints between the coil and the internal PCB; only press-fit connections.

Each transducer is individually calibrated and sensitive adjustments are stored in a One-Time-Programmable memory in the ASIC. Also a unique ID number is written in the memory: each individual ASIC and its history can be individually traced. The passive components are traceable at the lot level.

	LTSR 25-NP Earlier Hall	CKSR 25-NP Fluxgate	LKSR 25-NP New Hall
Sensitivity error (%)	± 0.6	± 0.7	± 0.2
Temperature coefficient of sensitivity [ppm/°C]	± 50	± 40	± 40
Electrical offset voltage (mV)	25.0	1.4	1.0
Magnetic offset current (mA) after overload 10x I_{PN} (Referred to primary)	80	100	90
Reference Voltage V_{REF} @ I_P=0	2.475 - 2.525	2.495 - 2.505	2.485 - 2.515
Temperature coefficient of V_{REF} @ I_P=0 (ppm/°C of 2.5 V)	± 100	± 50	± 100
Temperature coefficient of V_{OUT} - V_{REF} @ I_P=0 (ppm/°C of 2.5 V)	± 37.5	± 4	± 4
Linearity (%)	± 0.1	± 0.1	± 0.1
Reaction time @ 10% of I_{PN} (ns)	100	300	300
Response time to 90% of I_{PN} step (ns)	400	300	400
Overall accuracy (% of I_{PN}) @ 25°C	0.7	1	0.6
Overall accuracy @ T_A=85°C (% of I_{PN})	1.9	1.35	1.0
Overall accuracy @ T_A=105°C (% of I_{PN})	NA	1.45	1.2

Table 2: Electrical performance examples showing excellent performance of a new transducer (LKSR 25-NP model)[3]. I_{PN} is the nominal current range of the transducer; 25 Amps in this example.

Characterization

Full characterization of the new transducer family has been carried out over all the extremes of operating conditions. As an example, in figure 1 the characterization of offset voltage over temperature for a LKSR 25-NP transducer is shown. The offset drift is calculated as is less than 4 µV/°C, equivalent to less than 1.6 ppm/°C for these transducers (the specification limit is 4 ppm/°C).

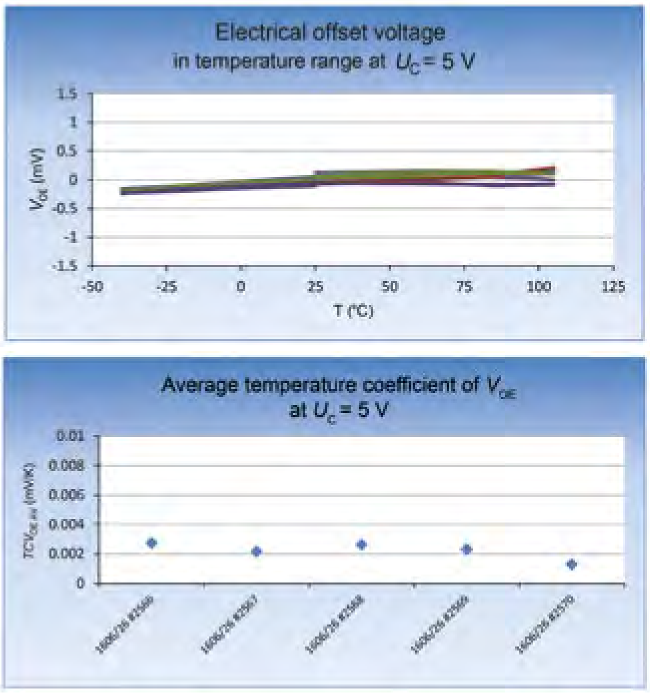


Figure 1: Characterization example: offset drift - LKSR 25-NP model.

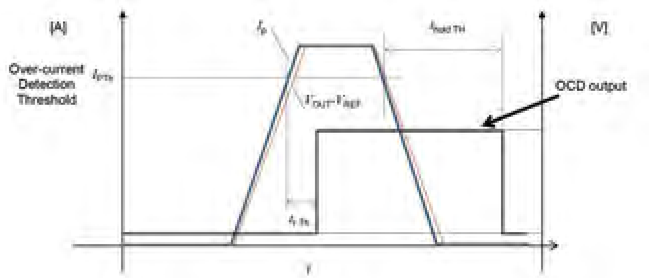


Figure 2: The OCD response time tr is 2.2 µs maximum and the hold time t_{hold} is 1 ms.

Over-Current Detection system

The OCD system monitors the transducer secondary current. This allows a faster response time than at the transducer output and, since the control loop which generates the secondary current is not limited by the 5V supply voltage, it allows the OCD trigger level to be set outside the transducer measurement range. The OCD threshold can be set between 1.25x and 5x I_{PN}. It is triggered by both positive and negative over-currents. The default value is 2.9x I_{PN}.

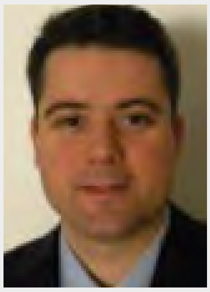
Figure 2 shows the OCD timing.

Figure 3 shows a photograph of examples of the new transducers.

Figure 3: Different transducers from the new families: LES, LESR, LXS, LXSR, LKSR, LPSR series

Conclusion

This article has introduced new closed-loop Hall cell transducers which give the extra performance of fluxgate transducers without the extra cost. They will be particularly well suited to applications where low offset drift is important such as in the AC output of solar power installations where standards require a very low DC component in the output current. Low offset drift also opens up more servo drive applications. The strong performance of these transducers comes from an ASIC which was specifically designed for them combined with an advanced high quality manufacturing process.



Diego Gutierrez –
LEM Senior Research & Development Design Engineer

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Steve Moureaux – LEM Research & Development Program manager

Steve Moureaux holds a B.S. in Microengineering and in Quality Management, Six Sigma Black Belt graduated. He joined LEM in 2001 as Automotive Quality Manager and continued to project management in 2010. He is head of the LEM R&D Industry Drives and Renewable Energy team since 2014.

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1 see http://www.lem.com/images/stories/files/products/1-3applications/CH24101.pdf for example
2 In this article "ppm" is referenced to 2.5V, the center point of the measuring range with SV supply.
3 Latest results are shown: the characterization of the new transducers is finishing at the time of writing.

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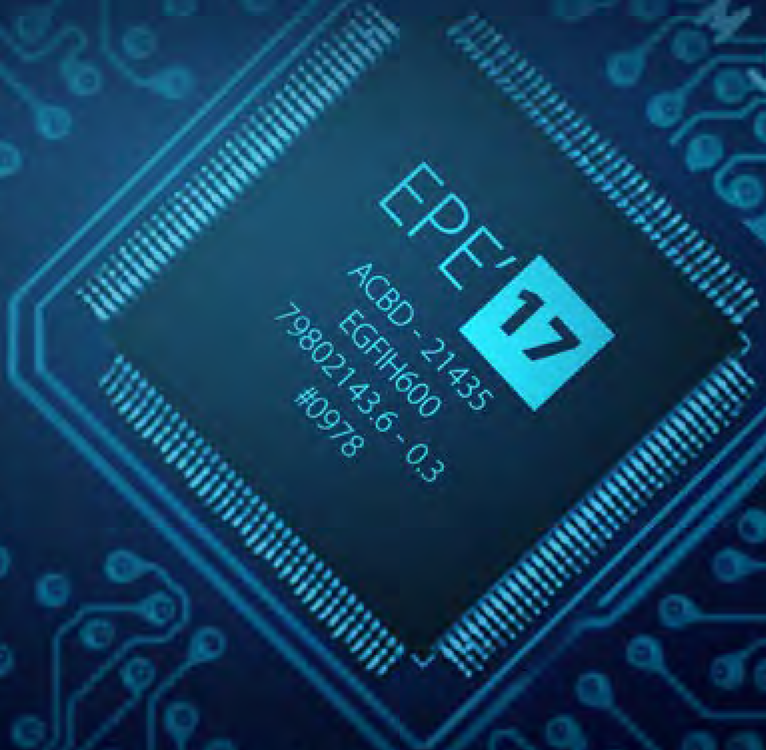

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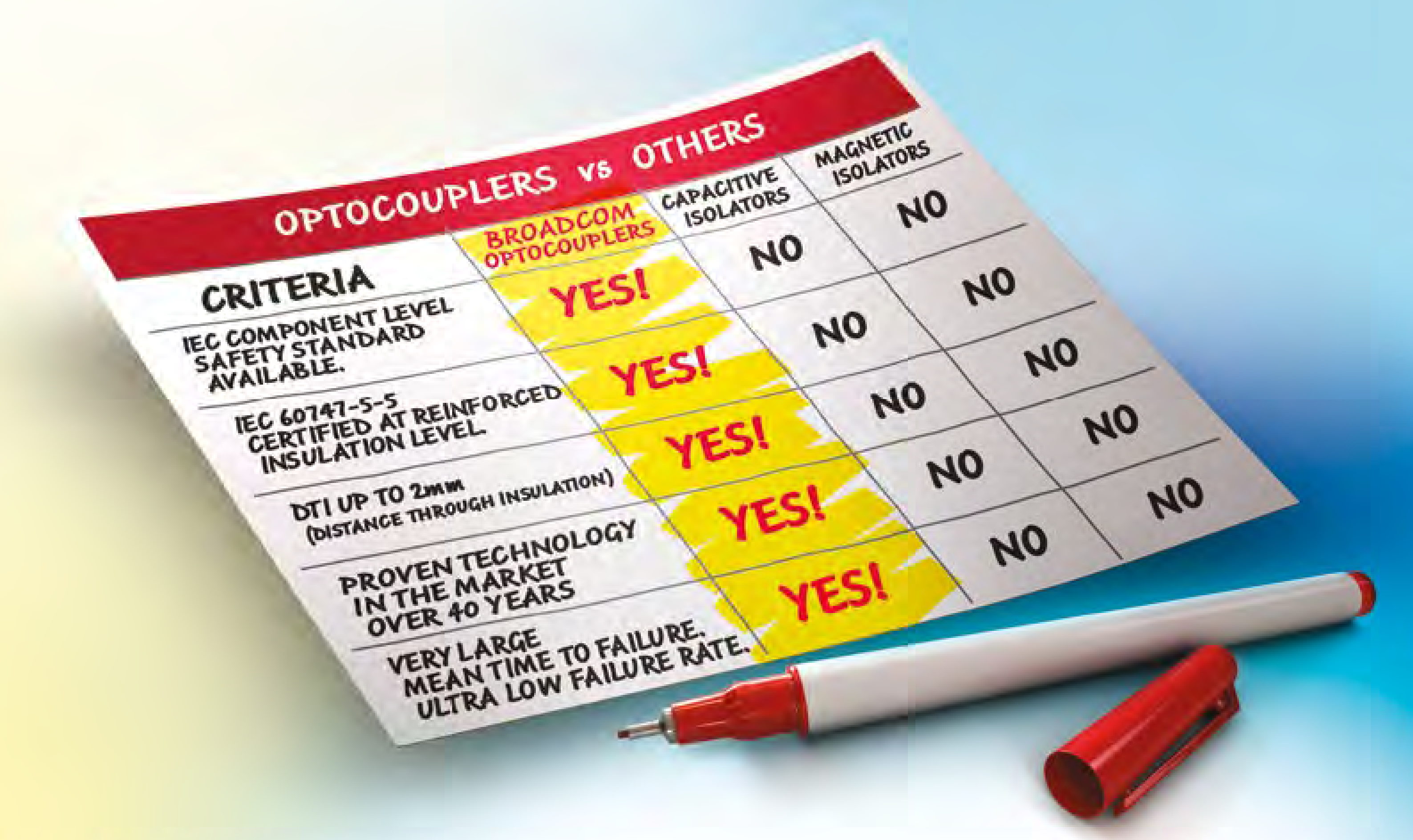

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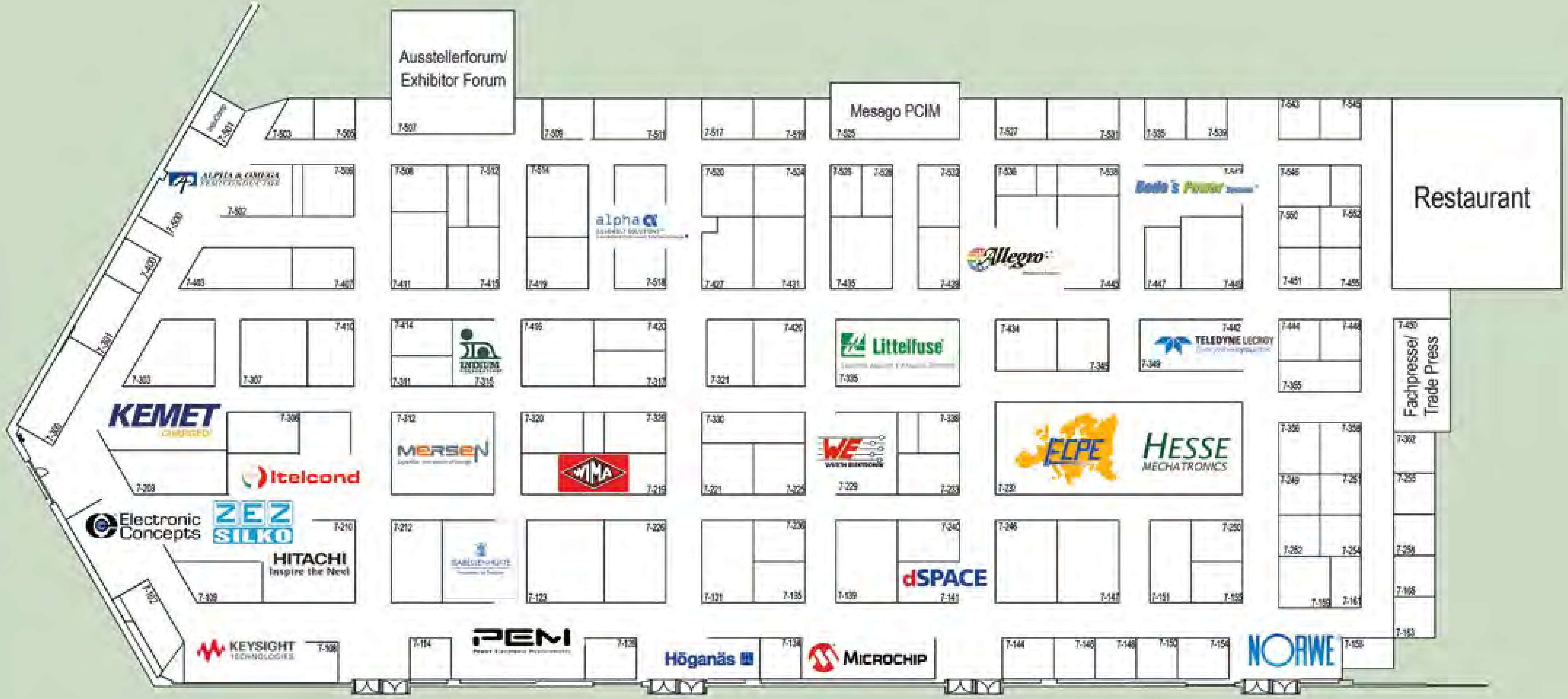

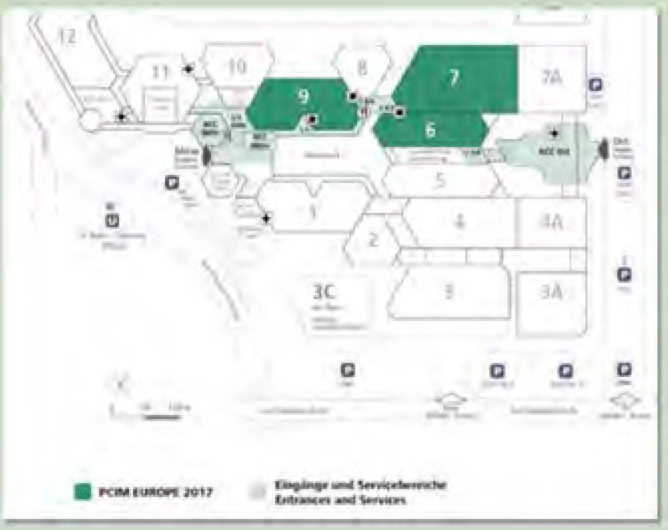

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Maximum Efficiency for Inverters

TDK has joined forces with Infineon Technologies to develop a design for xEV inverters that achieves a very high efficiency of over 98 percent over a power range of 10 kW to 150 kW. This success has been achieved by matching of the Infineon IGBT module and the EPCOS and TDK passive components.

By Tomas Reiter, Infineon AG and Wolfgang Rambow, EPCOS AG

The new Infineon HybridPACK™ Drive IGBT module is characterized by its compact design and high efficiency – essential criteria for e-mobility applications. The FS820R08A6P2B model is designed for a current of up to 820 A and a blocking voltage of 750 V and features a pin-fin heatsink for the coolant. These modules enable the realization of drives with output powers of up to 150 kW. The FS660R08A6P2FB with a flat baseplate can be used as an alternative, if less power is required. This IGBT module offers identical electrical behavior, but is designed for a maximum current of 660 A. The HybridPACK™ Drive family concept enables excellent scaling for a variety of power classes for both xEV and industrial applications.

Different module frames are already available in the product series and include those for weld contacting of load terminals (FS820R08A6P2) and frames with long motor terminals (FS820R08A6P2LB) for simple implementation of current sensors.

All modules of the R08A6P2 series are based on the latest generation of EDT2-IGBT chips from Infineon, designed for barrier-layer temperatures of up to 175 °C in the switching mode. The rugged chipset is resistant to short circuits and, even under the harshest environmental conditions, offers a very high level of reliability. Under realistic conditions of use, the R08A6P2 series achieves an efficiency of up to 98 percent (Figure 1). The module is optimized for switching frequencies in the range from 6 kHz to 10 kHz.

Thanks to the wide spacing between the connections, excellent insulation and minimal leakage currents are achieved, which means that the module is also suitable for high voltages, as is intended in future. Figure 2 shows a complete inverter, consisting of HybridPACK module with cooling plate, controller and driver board, as well as the EPCOS PCC capacitor for the DC link.

Figure 2: Complete motor inverter for a power output of up to 150 kW. The most important passive component is the EPCOS PCC as DC link capacitor. The complete design is available as an evaluation kit.

Compact solutions for the DC link

For this design, two EPCOS PCC capacitors come into consideration, which are also available for other HybridPACK modules. The B25655P5507K051 type features a stacked winding design, is designed for 500 V DC and, with a capacitance of 500 µF, can withstand continuous currents of up to 160 A. If the cooling of the capacitor is sufficient, the maximum current can be considerably higher for a short time. The great advantage of the stacked winding technology is its high volume fill-factor of nearly 1. The dimensions are 154 mm x 72 mm x 50 mm.

The second type (B25655P5407K1512) is based on the low-cost flat winding design and, due to its somewhat lower volume fill-factor, offers a capacitance of 400 µF for continuous currents of up to 140 A within the same dimensions. During design-in it is essential to ensure that the DC link capacitor is sufficiently cooled under maximum current load.

Low ESL and ESR values of the DC link capacitors are critical for a successful inverter design. Only with sufficiently low ESL values, is it possible to eliminate, or at least minimize, voltage peaks and oscillations when switching the IGBTs. The listed PCCs feature an ESL of just 15 nH. Their ESR values, responsible for the losses, are only 0.5 mΩ or 0.7 mΩ, respectively. These low values are achieved thanks to a large busbar with six terminals that are matched perfectly with those of the HybridPACK module (Figure 3). With modified busbar designs, values of

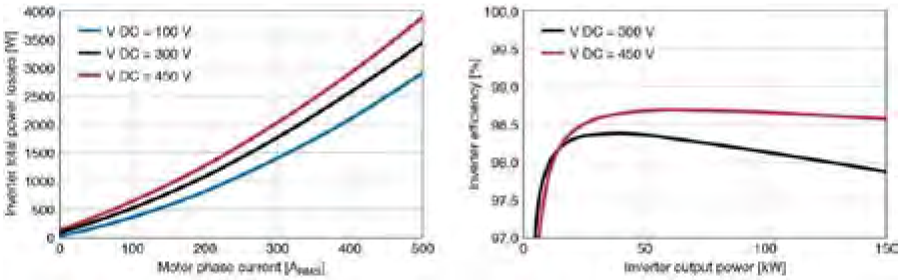
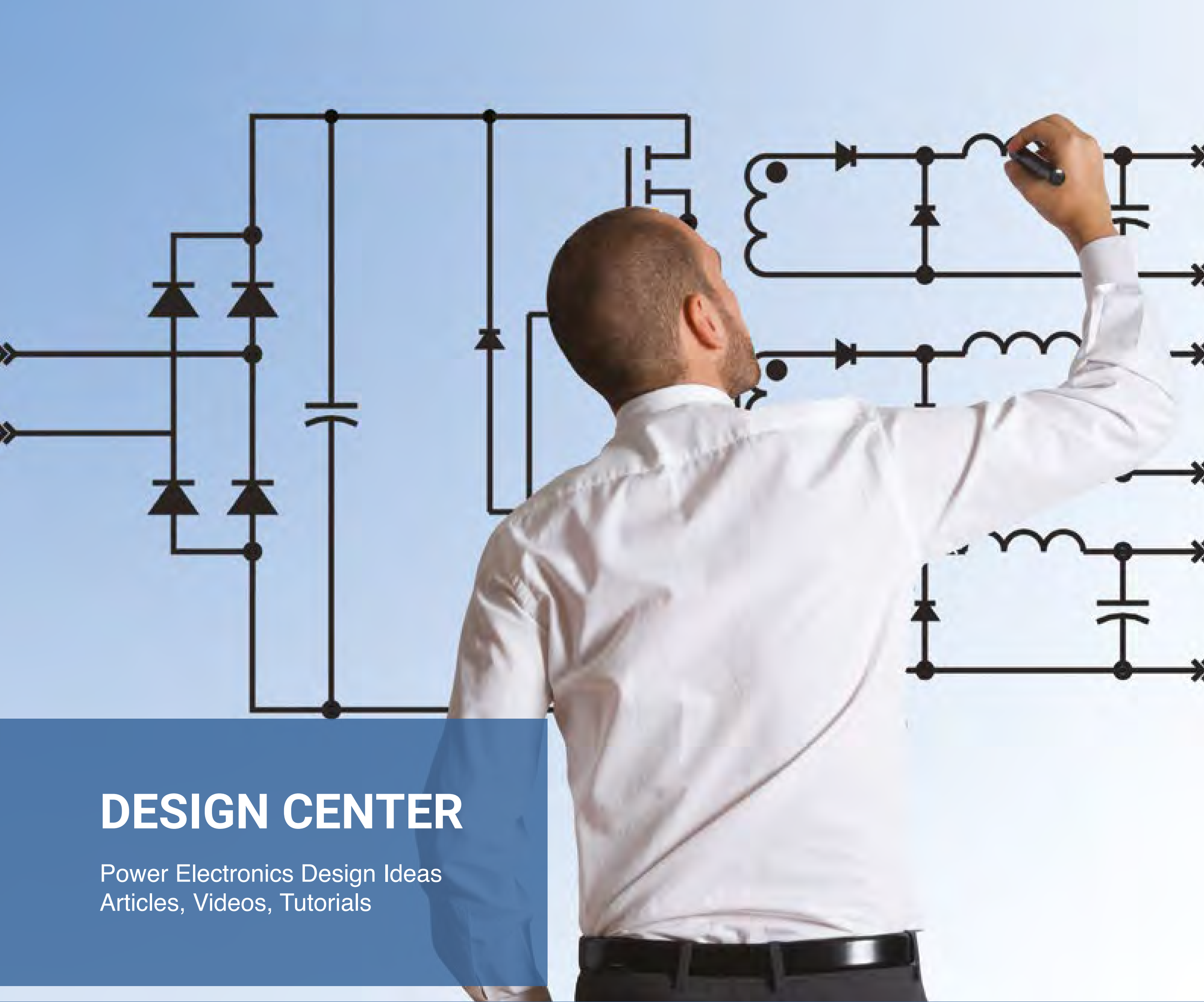


Figure 1: Measured converter losses using the evaluation kit at a switching frequency of 8 kHz. The efficiency in the power range of 10 kW to 150 kW exceeds 98 percent (450 V operating voltage, cos φ=0.85). This results in improved ranges for plug-in and hybrid electric vehicles.

Figure 3: The busbar of the EPCOS PCCs has six large terminals and ensures that the ESL and ESR are minimized.



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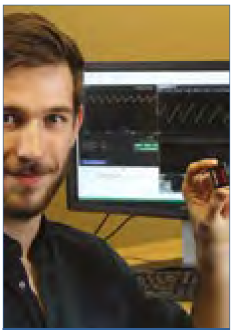

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less than 10 nH and less than 0.5 mΩ will be achieved in future.

The production lines of the capacitors mentioned above comply with the requirements for automotive products, in order to achieve the greatest reliability. One particularly important factor here is the welding of the internal busbar, as its quality essentially decides the current-carrying capacity and the power loss. Apart from their high reliability, the EPCOS PCCs also offer excellent EMC performance, ensuring excellent noise suppression in the FM band around 100 MHz.

(1 minute, 50 Hz). Their turns ratio is 1:1.08 and the inductance is 100 µH. Despite the high dielectric strength, the dimensions of the transformer are only 11.7 mm x 13.5 mm x 11.35 mm. The leakage current path between primary and secondary side is 6 mm, making it suitable for converters with a continuous operating voltage of 500 V.

Interference-free logic

The controller board assumes the control of the entire inverter. Its heart is an Infineon 32-bit TC277 microcontroller from the AURIX™ automotive series. To ensure that the logic

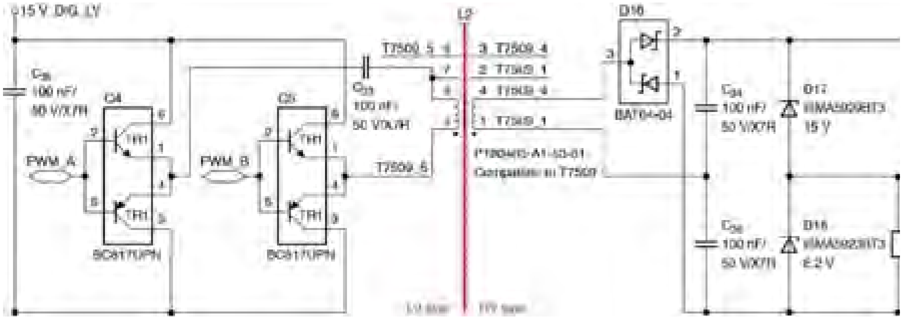

Figure 4: The task of the gate driver transformer is to ensure galvanic isolation between the high-voltage and low-voltage sides.

Galvanic isolation – an essential feature in automotive electronics

The driver board has the task of supplying three high-side and three low-side IGBTs with the necessary switching signals at their gates. It is essential to ensure sufficient galvanic isolation between the driver circuit and the IGBTs to prevent dielectric breakdown of the supply voltage to the driver board in the event of a fault. The crucial component for this purpose is the gate driver transformer. Figure 4 shows the circuit used for supplying the insulated IGBT drivers.

This reference design uses six B78307A2276A003 (P100403) EPCOS gate drive transformers. These ensure the necessary high insulation voltage of 2.5 kV

operates faultlessly, TDK ACT45B-101-2P-TL003 CAN-bus common-mode chokes are designed into the interfaces. At a frequency of 10 MHz these chokes exhibit a common-mode impedance of 5.8 kΩ, thereby ensuring interference-free data traffic. The chokes, which are qualified according to AEC-Q200, have dimensions of just 4.5 mm x 3.2 mm x 2.8 mm, making them among the smallest of their type in the world. TDK MMZ-1608R600AT chip beads provide additional noise suppression in the signal cables.

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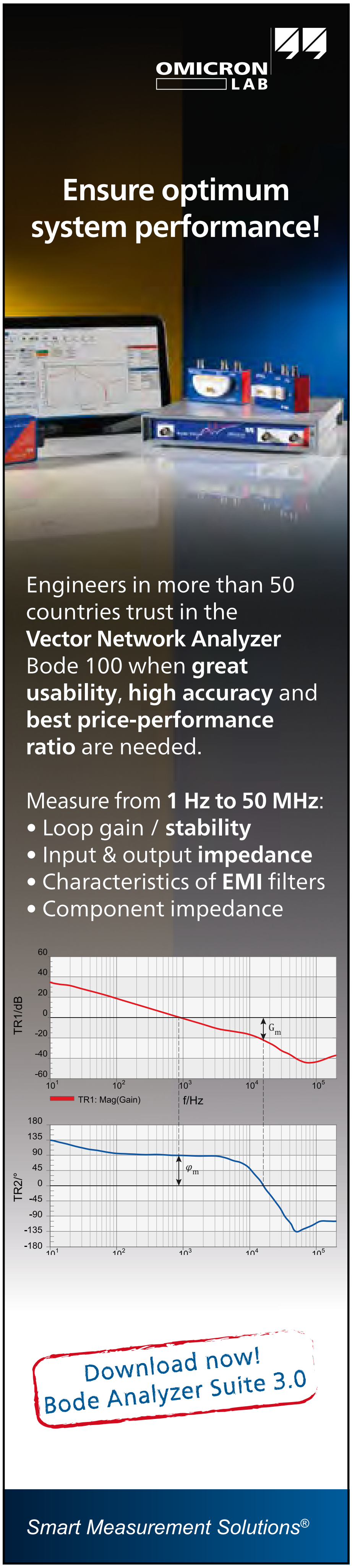

The Benefits of Bi-Directional Power Design

The power system designer of just a few years ago might have wished for the means of simply transforming one DC voltage to another; today, that wish is fulfilled and the "DC transformer" is a reality. Even more design freedom follows on the realisation that power flow through selected families of such devices can be fully reversible – they are bi-directional.

By Arthur Jordan, Principal Field Applications Engineer, Vicor

Before looking at some of the new ways that the abilities of these components can be put to work, it's worth taking a moment to consider how a small shift in perspective may inspire novel product concepts and circuit configurations. We are accustomed to a left-to-right paradigm: we habitually see, and draw, diagrams in which signals progress from source to destination, sensor to output transducer, across the page in that direction. Power, too, commonly makes its way from source to load, left to right across the sheet. It is natural to think of power conversion components and sub-systems as conforming to this convention, and being uni-directional. For most of the history of power electronics, this has been broadly true. An obvious exception being the conventional AC transformer.

The SAC; a symmetrical converter

Modular components now available to the designer provide two key attributes; they are available as effective and efficient "DC transformers" - that is, they provide a fixed-ratio DC-DC conversion: and, they are inherently bi-directional. A detailed description of how bi-directional operation is achieved is beyond the scope of this short article; but a "broad-brush" understanding can be gained by looking at the main elements of the Sine Amplitude Converter, which is the core enabling technology. As we have abandoned left-to-right thinking, start in the centre, where there is a transformer, and a series capacitor that is maintained in resonance with the transformer's leakage inductance. To one side there is a switching bridge that (conventionally) would be viewed as an input stage chopping a DC bus, and to the other, an essentially identical arrangement that might be termed a synchronous rectifier. As long as those two paths switch synchronously with the resonant waveform in the central "tank", the whole device is symmetrical, and acts exactly as a DC transformer; voltage is stepped up according to the turns ratio of the magnetics, and current stepped down – or vice-versa. Changes in impedance presented at one port are reflected (by the square of the turns ratio, as expected) at the other, and power will flow accordingly. Resonant, zero-voltage and zero-current switching ensures low losses: minimal stored energy in the resonant tank yields good transient response through the converter: MHz switching means small and light inductors and capacitors.

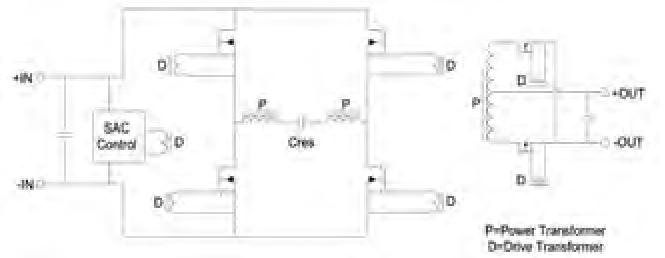

Figure 1: Sine Amplitude Converter

Although the SAC topology in inherently bi-directional, two families of power components are particularly useful for bi-directional applications. One is the Bus Converter Module, or BCM, that offers isolated fixed ratio conversion between two voltage rails. The other is a non-isolated version (known as NBM) that is otherwise similar. The latter part is slightly easier to use in a bi-directional setting, as it will "start" (establish and stabilise resonant switching) from power applied to either port. If isolation is necessary, using the BCM necessitates a small amount of additional circuitry to provide the bias to start it from power applied to the "secondary".

Bi-directional use cases

Efficient bi-directional power conversion can be applied to a range of different scenarios, that can be grouped together in a number of general divisions, as shown in Figure 2. The converter (isolated or not) can operate in its forward direction – conventionally a step-down, such as 48 V to 12 V: or in reverse, as a step-up. It can at different instants operate in either direction; or, in the fourth case, twin units can act as a mirror pair; two identical units connected back-to-back.

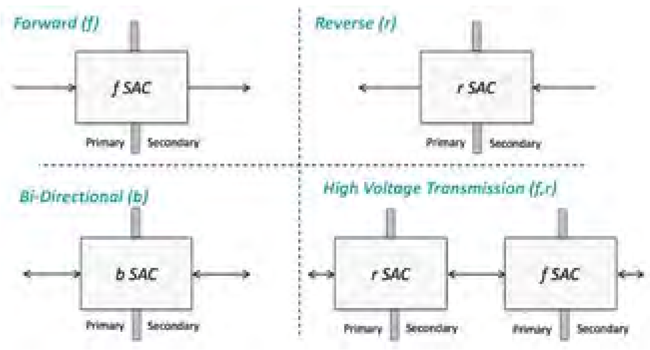

Figure 2: Four modes associated with SAC power processing

Renewable energy is providing the stimulus for development of many potential applications. Until recently, the default use of photovoltaic panels has been as grid-connected arrays, feeding power via an inverter, back to the electricity supply utility to offset or even reverse the flow of power to (from) a property or installation. Rapidly gaining ground is the notion of isolated (that is, not grid-connected) solar-power arrays feeding local storage for consumption on the local "micro grid". Hand-in-hand with that is the resurgence in the concept of DC power distribution on a building-wide (or even wider) scale. 380 V is commonly proposed for such a bus and, as the high-side voltage, this is a level that can be accommodated today by modules from the BCM/NBM families.

Figure 3 shows the generic case of such an installation, in which multiple DC loads are supplied from a range of renewable sources, using a battery bank as a back-up. The back-up battery, and the electro-mechanical flywheel, would be examples where bi-directional power flow would be required. Differing voltage rails on both the supply (or storage) side can be accommodated simply by selecting the appropriate conversion-ratio module from the range available. On the consumer side of this picture, it might be that LED lighting would operate from a lower voltage than the main DC distribution. Once again, a suitable step-down ("reverse") converter module could take care of the transition. An experimental configuration documented by Vicor has applied such a structure with device-by-device power distribution implemented through a 24V bus using intelligent USB-C connectors which, in the latest specification, are capable of supporting 100W.

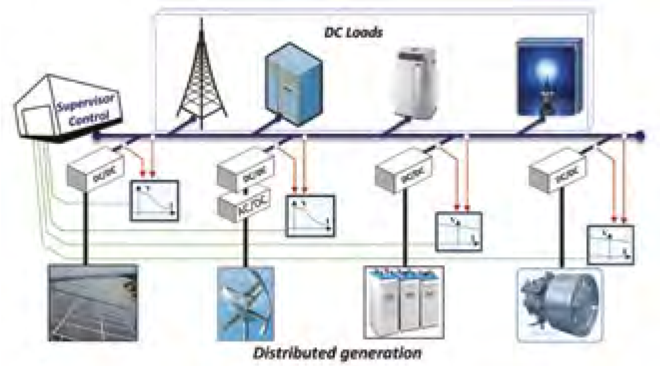

Figure 3: Subsystems based on 24Vdc bus with intelligent 100W USB C connectors

Bi-directional flow with regulation

The block diagram in Figure 4 shows what is, in effect, a special case of energy storage at a different potential (e.g. 12V) to the equipment being powered (48V). A 5:1 conversion takes place through the NBM module; regulation is always at the high side. The battery voltage is stepped up, then regulated to the required level; or for charging, the higher bus voltage is regulated such that the 5:1 down conversion yields correct charging level. Figure 4 in fact depicts a new piece of test equipment for power supply labs that can provide both a regulated test voltage to a product and provide a regulated load, recycling the energy so that only a small fraction used for test is provided by the grid. The traditional approach to this problem would be to provide twin power paths; step-down (and regulation) to charge the battery, step-up to return power to the 48 V bus when primary power fails. In addition to the power conversion functions, this would also entail some element of control, with safety lock-outs, to switch from one state to the other. Using the bi-directional system components makes for a simpler, more compact solution. However, as noted above, regulation is not presently available in bi-directional modules, so some power-path re-routing is required to make use of the single regulator in both directions.

An exact analogy of power utility grid and super-grid practice is found in the fourth case in Figure 2. In this, a converter is connected in the step-up direction to transmit power at a higher voltage over some distance, followed by an identical unit connected to step-down, at the far end. The objective being, of course, to reduce I^2R losses in the intervening cabling. Just as the utilities transform their AC to hundreds of kV for transmission, the engineer designing DC distribution can use the DC-transformer to the same end. While this employs the reversibility of the NBM modules, power flow in such a scenario might or might not be bi-directional.

One unusual case where this strategy has been employed is that of the tethered drone or UAV (unmanned aerial vehicle). Not all drones need to free-fly, but may need extended operation (to conduct site surveys, or architectural photography, for example). Power can be fed to such machines along an umbilical, or tether. Clearly, it is desirable that the weight saved in on-board batteries should not be cancelled by weight of cabling – therefore, a thin gauge power feed is indicated. A case study modelled at Vicor used a 50 V on-board motor supply, but stepped this up to 400V with an 8:1 converter so that thin wire with a 2 Ω loop resistance was tolerable.

Vehicle electrification

The rapidly-developing field of electric vehicles and hybrids looks set to provide many more applications where bi-directional power flows between disparate DC buses will prove useful. Dual-voltage vehicle architectures at the low level (12 V and 48 V) call for, depending on whether they are mild-, medium- or full-hybrids, a range of interconnections of buses, and power flows between battery and units such as integrated starter/generators. To which the hundreds-of-Volts traction power rails of the full EV only adds further complexity, and brings the technology into the sphere of regenerative braking and energy recovery.

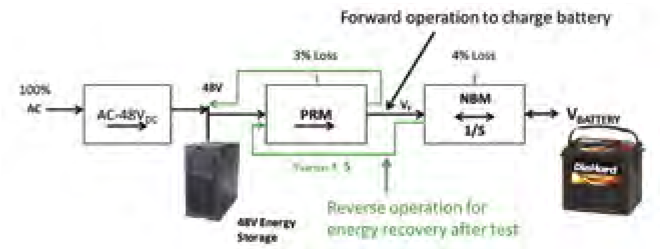

Figure 4: Bi-Directional DC in Battery Test

All of these cases can be modelled using Vicor's online PowerBench Whiteboard tool. This has comprehensive "black-box" behavioural models of NBM converter modules at its disposal. The parameters of a real-world application can be quickly entered, and the software is fully prepared for forward or reverse converter operation. An accurate prediction of real-world voltages, currents and losses both within the converters and eternally, is immediately available. Parallel connection of modules is supported, and works equally well in the bi-directional case. Power handling from 200 W up to as much as 20 kW is feasible using modules with bi-directional capability, with voltage ratings that extend to over 400 V.

Conclusion

On learning of the availability of bi-directional power conversion components, many engineers will immediately think of straightforward applications such as the back-up battery/reserve power cases outlined above. But, just as setting aside left-to-right thinking might help understanding of some of the principles, engineers can look further afield for opportunities to use this approach. Study a system diagram; is there energy storage and energy recovery? If so, that is an opportunity for these bi-directional products. It's not just electrical energy: it could be kinetic energy (as with an electric or hybrid-electric car), potential energy, or any other form of energy that can be converted to electricity. Power designers need to look beyond power chains and ask how they can use this approach to improve their system.

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Small Heat Loads

Big Challenge to enhance Heat Sink Performance?

Within the thermal industry there is a common belief, that small heat loads are easily dissipated with conventional heat sinks. To a degree, this belief is true, however, when it comes to the optimisation of low power heat sinks, the challenges are as prominent as they are with multi- Kilowatt heatsinks. When dealing with low power heat sinks, performance gains are very hard to achieve and even harder to quantify as they are often only a fraction of a degree.

By Andreas Engelhardt, Business Development Manager, Columbia-Staver Ltd.

Columbia-Staver have recently been studying the optimisation of a heat sink to be used in handheld devices. As expected all of these issues were seen first-hand together with some additional project specific challenges such as maximum skin temperature on the heat sink.

In order to achieve the best possible performance, an approach with multiple prongs was chosen:

1. A new heat sink similar to the current design was selected and a number of physical prototypes were produced. This enabled the customer to progress with his prototype development on a system level.
2. The new heat sink was subjected to a detailed thermal evaluation using CFD. A simple unenhanced aluminium heat sink was the benchmark to be compared with a number of enhancements:
   - The application of three L-Shaped heat pipes.
   - A combination of two heat pipes and a copper insert
   - A novel method which involved the “cold bonding” of a copper bases to an Aluminium cold forging

   Comparison of these different heat sink enhancement methods showed improvements against the benchmark heat sink, but the improvement increments when compared with the cost implications were seen as not large enough to justify the cost increase.
3. The optimisation tool within Ansys ICEPAK was used to optimise both, the fin pitch and the fin thickness on an equal surface area heat sink. This was necessary due to the complex geometry of the device heat sink, which could not be parametrised. These finding were then manually transferred into the customer heat sink with its more complex geometry and individual features for final verification.

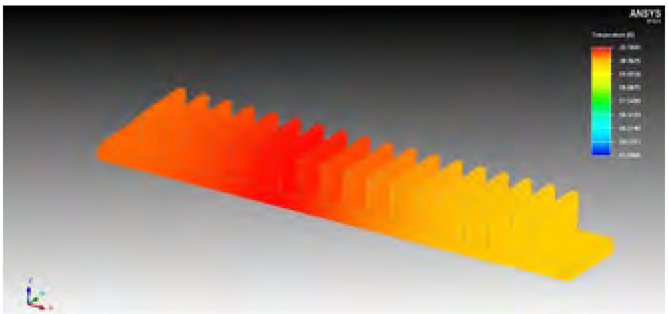

Figure 1: Heat Sink Layout – Equal Surface Area Heat Sink

For this project, and in order to mitigate customer concerns as well as determine the power level the heat sink has to dissipate, the modelling strategy was applied to the existing product and compared against empirically gathered data. This was necessary due to the fact that the heat sink is to dissipate heat loads from a collector, which connects to a number of components within the device.

For a known temperature on top of the collector, which was achieve during testing, it was determined that the heat sink is dissipating 1.2 Watts. Once that power level was obtained, the model was run in fixed power mode, and a comparison of the experimental data with the predicted data was made. For that location on top of the internal heat collector, very good correlations within 0.1°C between simulation results and measurements were achieved. Therefore the model was seen as accurate enough and used for the investigation of the new heat sink.

The new geometry was then benchmarked as just a plain heat sink to ensure that the CFD model is working as intended and producing stable results. Once that was found, different enhancement technologies, such as heat pipes, a combination of heat pipes and copper inserts in the heat input are of the heat sink, and also a novel technology, where Aluminium and Copper were diffusion bonded within the cold forging tool were investigated. Results from this investigation can be found within Figure 2. The figure is reporting the heat sink performance in the form of thermal resistance, to allow the direct comparison between all results and is to be understood that the lower the value, the better the heat sink performance.

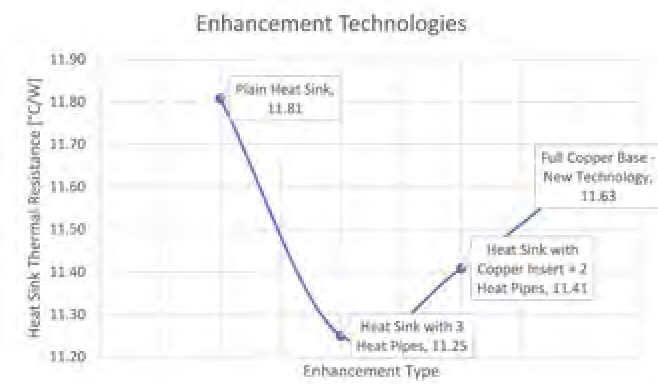

Figure 2: Heat Sink Enhancements Comparison

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Package	1U Rack-mount	2U Rack-mount	3U to 9U Rack-mount	Floor Standing	Floor Standing
No. of Models	54	70	80	80	65
Voltage Range	0-5 Vdc to 0-1,000 Vdc	0-5 Vdc to 0-10,000 Vdc	0-5 Vdc to 0-4,000 Vdc	0-5 Vdc to 0-4,000 Vdc	0-16 Vdc to 0-4,000 Vdc
Current Range	0-1.5 Adc to 0-250 Adc	0-0.2 Adc to 0-600 Adc	0-1.2 Adc to 0-2,700 Adc	0-7.2 Adc to 0-4,500 Adc	0-24 Adc to 0-24,000 Adc

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It can be seen from Figure 2, that all results are reasonably close to each other, but, the version with three L-Shaped heat pipes offers the greatest performance gains. However, when the thermal resistance difference is translated back to a temperature difference, for the power level of 1.2Watts, it would only result in a 0.67°C difference in component temperature between the best enhanced version and the plain Aluminium heat sink. It has also to be concluded, that in this instance, the novel direct diffusion bonding of Aluminium and copper in the cold forging tool does not offer any significant advantages.

Based on the above findings, further investigations towards optimising the conventional heat sink were undertaken. With the heat transfer mode being natural convection, the first area to investigate was the fin spacing. The initial fin spacing was 5mm, and two different avenues were pursued, first a manual attempt, where the heat sink geometry was changed in CAD and then re-imported into ICEPAK and investigated. This lead to one curve, however, it was also seen as beneficial to use a more automated optimisation approach through the parametric solver within ICEPAK. In order to be able to use this tool, the heat sink had to be simplified into an equal surface area native ICEPAK smart part. For this the width and depth of the heat sink were maintained, and the fin height of the rectangular fins was determined by the surface area of the previous heat sink. The collector heat source was applied off-centre directly under the base of the heat sink, and not on a non-finned wing. This simplification has led towards an approximately 1°C difference in component temperature between both models, which needs to be considered when looking at the results. Overall, a range of fin spacings starting at 4mm and ending at 6mm was investigated, and where possible, the results of the analysis of the full heat sink were overlaid onto the graph of the parametric optimisation.

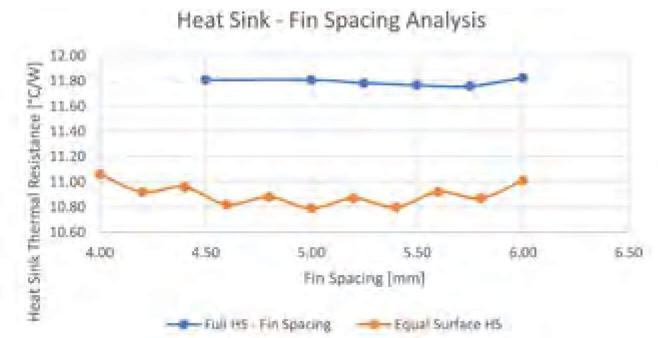

Figure 3: Fin Spacing Comparison

When looking at the above results in Figure 3, a number of factors have to be considered, which contributed to the odd looking curve being returned from the parametric optimisation. The first one is that the geometric food print was maintained at all time, meaning that when the fins outgrew the foot print available on the heat sink base, a fin was dropped. Therefore, the results are a combination between the benefits of an increased fin spacing and a reduction in available fin area, which directly counter act each other. The second factor is that the real heat sink has a number of cut-outs and different fin geometries, which also counteract the trend that a larger fin spacing can show significant benefits.

After it was found that a change in fin spacing alone would not offer a significant performance change, the fin thickness became the next candidate for investigation. Fin thicknesses from 1mm to 3mm were investigated in 0.25mm steps and the results can be seen in Figure 4 below.

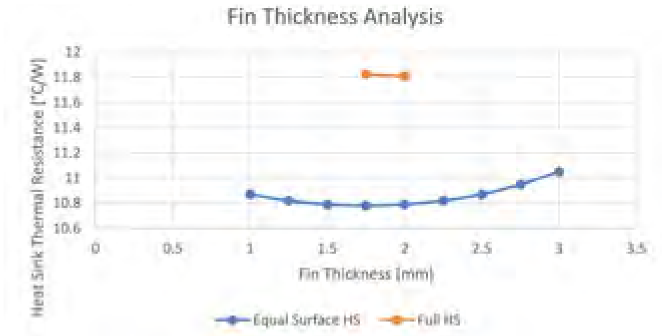

Figure 4: Fin Thickness Comparison

Figure 4 shows that a sweet spot in fin thickness was around the 1.5 – 2mm mark, where the fins are thick enough to conduct the heat away from the base, but not too thick to prevent effective dissipation into the air by acting as a thermal damper. Again, it can be seen that the results are very close together, and the potential performance gains are fairly small. Once the reduced fin thickness was transferred into the CAD geometry of the full heat sink, and investigated in the full model, it was seen that the component temperature was maintained, and a 4% weight saving could be achieved, but no additional performance gains realised.

Overall, it has to be concluded that the optimisation of a low power heat sink has proven quite challenging, and performance gains were hard to achieve and not easy to quantify due to their minute nature. Based on these findings, other factors such as component costs had to be taken into account as well, and carefully be weighted up against any potential gain in thermal performance. With that in mind, any changes to the initial fin geometry are seen as very beneficial as it comes without any cost penalty. With a conventional optimisation, the component temperature could be maintained but with a weight reduction of 4%. This offers the customer an advantage to his device, but it also again proved the usefulness of CFD as a tool to quickly and cost effectively evaluate multiple concepts for cooling solutions prior to committing resources to test multiple prototypes. Once all the results are available and evaluated, and combined with the customer's changed geometry, a final round of prototypes will be produced and then undergo approval testing prior to the official device launch later this year.

For Columbia-Staver, this project was an important milestone to showcase the increased in-house simulation capabilities for the first time and also penetrate an exciting new market, which is for handheld medical devices.

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New Contender for the Power Transistor Throne

How GaN is threatening the MOSFET's crown

For more than 35 years, power MOSFETs have dominated the field of power converter design in the low to medium power range. This has been supported by continuous innovation in the components structure and related semiconductor technology. Fast switching characteristics and low losses, as well as ease of use in various circuit topologies also contributed to their success.

By Francois Perraud, Team leader - Power and Automotive Solutions Semiconductors, Panasonic

At the dawn of a new millennium, however, silicon power MOSFETs are reaching their theoretical performance limits, which means that further progress in power supplies and power management systems will no longer be as easy to achieve with these switching elements. Current trends in power supply unit design are focusing on higher efficiencies and power densities, that go beyond the capabilities of the silicon MOSFET technology. Development engineers need new switching devices that are able to meet these requirements. And so begins the conception of gallium nitride transistors (GaN).

The characteristics of GaN

The first GaN power transistors were introduced in the early 2000s, after being used over a decade as a standard fixture in high-frequency technology. The favourable combination of chemical-physical characteristics offered by GaN - such as ten times the dielectric strength of silicon, high electron mobility and carrier density, very fast carrier recombinations, and last but not least a high maximum junction temperature of over 400°C –open up additional prospects for this material.

Applied to power transistors, these characteristics enable the manufacturing of high-switching frequency capable transistors. These in turn improve the power density of power conversion systems, thanks to lower conduction losses, and thanks to a reduction of the typical system size and weight – for example by reducing the size of passive components under fast switching conditions.

Gallium Nitride transistors are therefore becoming a realistic and attractive alternative to silicon transistors and start conquering the field of power electronics.

Overview and advantages of the Hybrid Drain Gate Injection Transistor (HD-GiT) structure from Panasonic

Many GaN switches in the 600 V range presented up to now had the disadvantage of being self-conducting (normally on). Unlike MOSFETs, this means that they conduct current when no gate voltage is applied. As a countermeasure, some manufacturers have implemented cascode structures to obtain normally off switches. Cascode structures have major drawbacks as compared with single normally off transistors though, such as the impossibility to directly control the switching speed of the GaN element, the increased manufacturing complexity, and increased parasitic elements due to the nature of the circuit.

Panasonic X-GaN™ transistors in contrast are a normally-off enhancement of the High Electron Mobility Transistor structure (HEMT). Like in HEMTs a very mobile 2D electron gas is generated at the boundary between two materials with different band gaps. An added p-doped gate structure gives to the X-GaN transistors their normally off characteristic (see Figure 1). The proposed transistor structure is called Hybrid-Drain Gate Injection Transistor (HD-GiT).

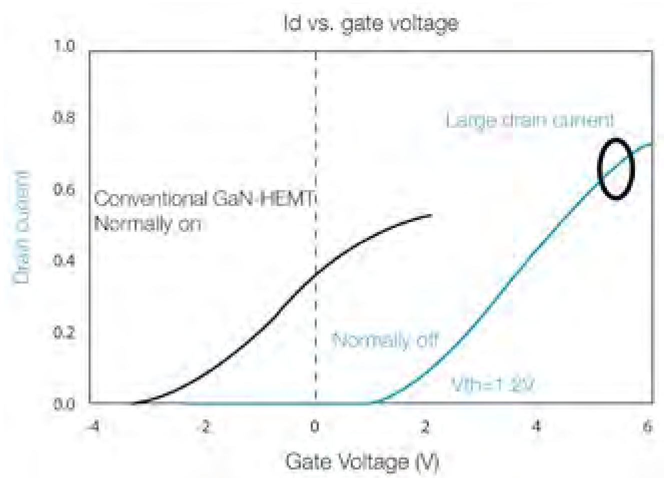

Figure 1: Hybrid-Drain Gate Injection Transistor (HD-GiT)

Since the HD-GiT gate can be accessed directly, the gate circuit can be design to control and adjust the transistor's du/dt and di/dt – a major advantage as compared with the cascade.

The lateral structure of the GiT is also advantageous for fast switching, since its parasitic capacitances are typically lower than those of vertical structures, such as for example silicon-based super-junction MOSFETs (see Figure 2).

The Figure-of-Merit (RDS(on) · QG) of a 600V/70nOhm GiT is therefore ~350 mΩ · nC, in other words around one tenth the value of modern silicon components.

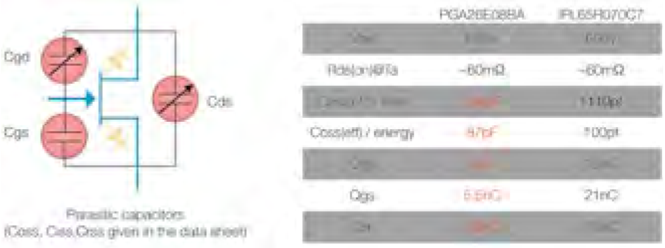

Figure 2: Parasitic capacitances are typically lower

Gate driving principle

The GiT transistor is controlled as mix of a field effect transistor and (bi)polar transistor. As with FETs, a positive threshold voltage needs to be applied between the source and gate to open a conductive channel. At the same time, a small on-time current needs to flow into the gate to increase the conductivity of the conductive layer and to keep the switch-on resistance as low as possible in the useful operating area. The transistor is switched off by removing the voltage from the gate; the gate current stops, the channel closes, the transistor is blocking again. Unlike with IGBTs however, the charge recombinations at switch off do not result in measurable delays or power losses due to tail currents (see Figure 3).

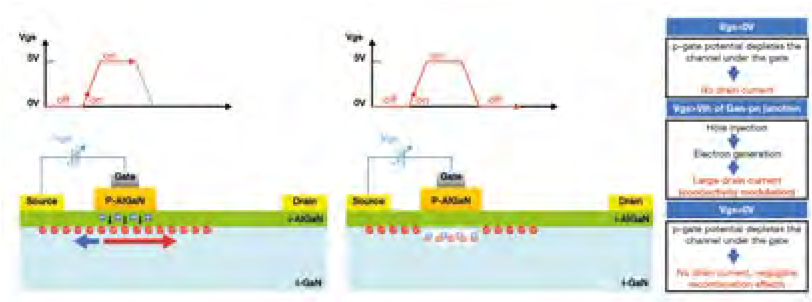

Figure 3: Charge recombinations at switch off do not result in measurable delays or power losses due to tail currents

X-GaN™ GiT transistors allow current to flow in the reverse direction once the source, gate, and drain potential are set in a way that current is fed in at the gate. Unlike with MOSFETs the reverse current does not flow through a parasitic body here, instead is it conducted through the channel. Even though they are reminiscent of a diode, the thresholds in the third quadrant of the static IV curve are not dictated by junction's behaviour, but are simply the threshold voltage of the transistor plus any negative bias voltage that is applied to the gate.

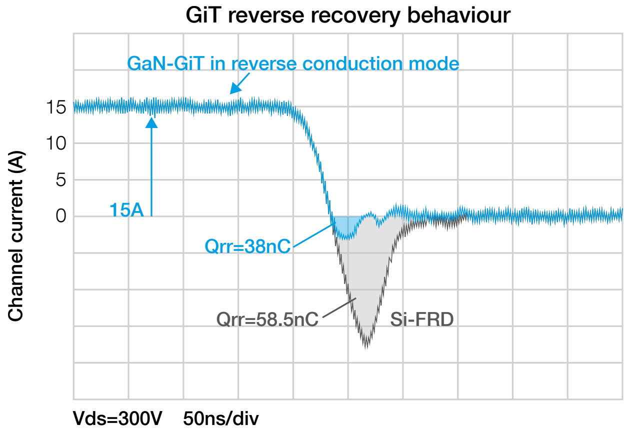

Figure 4: Conduction and recovery performances of the GiT in the reverse mode are the same as those of an SiC Schottky diode

In the same way as a MOSFET, the GiT can be switched on in the reverse direction in order to further reduce the losses by operating under 0V-offset condition. The GiT recovers extremely quickly from reverse conduction. The recovery energy practically just corresponds to the energy required to charge the output capacitance. The conduction and recovery performances of the GiT in the reverse mode are the same as those of an SiC Schottky diode (see Figure 4).

Panasonic's HD-GiT structure eliminates the problem of current collapse

Developers of gallium nitrite components have to deal with the phenomenon of current collapse., When the

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transistor is under high voltage stress, conduction electrons can become trapped in defects in the crystal, at interfaces between layers etc., which can leads to a rapid increase of the RDS(on) (on-resistance), leading to a rapid increase in losses and the destruction of the components. This effect can be especially critical for hard switched topologies.

So far Panasonic has been the only provider of GaN components to publicly announce the complete elimination of the problem of current collapse. The figure 5 shows Panasonic's unique approach for solving the issue. An additional p-doped structure, similar to the gate, is grown near the drain and electrically connected to it. That structure injects holes into the GaN components, that recombine with the trapped electrons.

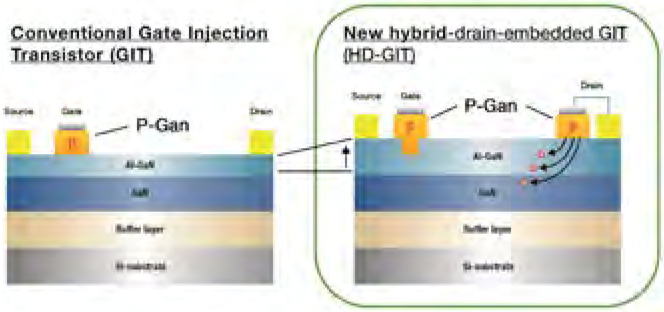
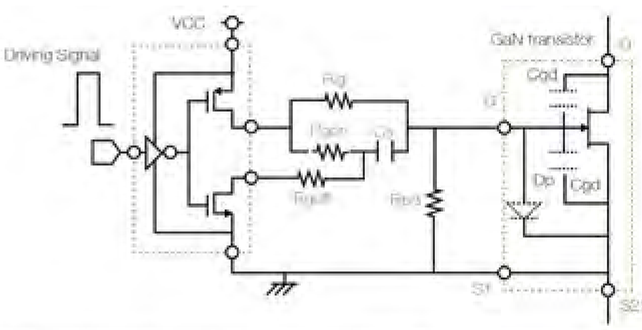


Figure 5: An additional p-doped structure, similar to the gate, is grown near the drain

The HD-GiT uses a recessed gate so that the thickness of the AlGaN layer is increased in order to avoid depletion of the charge carriers under the p-doped area close to the drain. The HD-GiT was proven to have the same excellent switching characteristics as the conventional GiT structure.



Rgon	Controls the dv/dt, limits gate current at turn on
Cs	Speed up capacitor - allows spike at t on/t-off
Rig	Controls the constant gate current during on-time
Rgoff	Controls the dv/dt, limits gate current at turn-off
Rpd	Gate pull down-avoids a floating gate when driver IC is off

Figure 6: Using available high-performance MOSFET gate drivers

Reliability

In order to guarantee the reliability of the HD-GiT transistors in mass production, Panasonic not only tests against the usual JEDEC standards for Si components, but also developed its own additional GaN-specific tests to guarantee the long-term stability of the transistors, for example with regard to current collapse. Accelerated life tests have showed a worst case FiT rate of ~10 FIT can already be achieved.

Applications of GiT transistors

Gate driving

In addition to selecting the right topology and gate control scheme, the choice of the gate driver circuit is especially important. Fortunately, a simple and common push-pull gate triggering circuit with separate switch-on and switch-off resistors can be used. Figure 6 shows a typical gate circuit for GiTs that can be realised using available high-performance MOSFET gate drivers.

The designer can easily control the switching behaviour of the transistor, as shown on Figure 7 (example of dv/dt control at turn on).

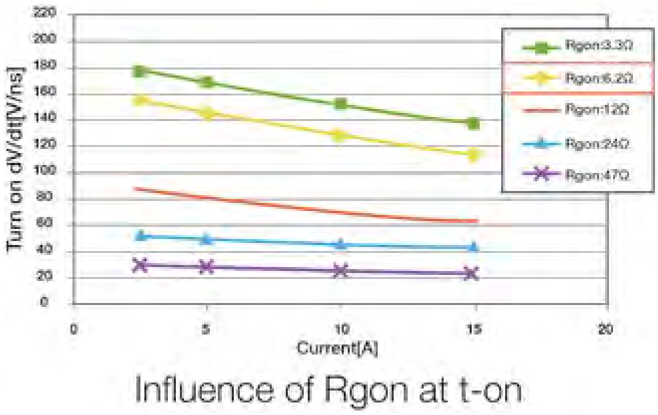


Figure 7: Control the switching behaviour of the transistor

As well as providing the necessary dynamic power during the switching transition, the gate driver must also reliably keep the transistor turned on. The gate input characteristic of the GaN GiT corresponds to a diode (see Figure 2). The constant gate current flow through this internal gate diode Dgs during the on-time is controlled by Rig during the on interval (Figure 5).

Finally, keeping the transistor reliably switched off requires attention, because the threshold voltage of GiTs is significantly lower than the typical level in MOSFETs. Even though the small Crss/Ciss ratio of the X-GaN transistors protects against Miller capacitance coupling effects, a negative voltage can be optionally applied to the gate during the off time to increase the safety margin.

Panasonic gate driver IC

Panasonic brought out its own X-GaN™ gate driver at the end of 2016 for developers who want to quickly deploy a solution using GiTs. The X-GaN driver IC is optimized for high switching frequencies up to 2 MHz and provides an easy way to unlock the full performance of the transistors. Besides optimized gate control terminals, additional integrated functions are provided - such as a charge pump for (option-

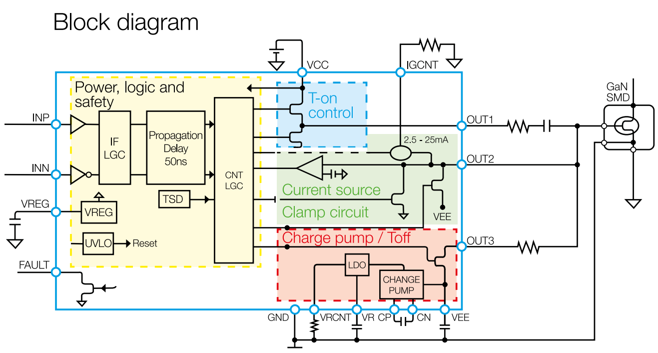


Figure 8: X-GaN driver IC is optimized for high switching frequencies

ally) generating negative gate voltages, or safety features against under-voltage and gate oscillations (Figure 8).

Advantages in applications

Panasonic's GiT transistors are aimed at power converters in the ~100 W to ~5-6 kW range, where MOSFETs with 600 V to 650 V are typically used today.

Depending on the requirements of the application, developers can target maximum efficiency, maximum power density, or a compromise between the two.

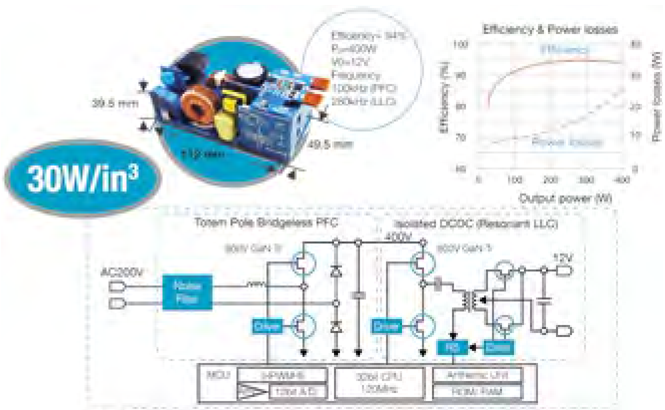


Figure 9: Compact and efficient AC-DC demo unit

Thanks to their "0 reverse recovery" behaviour, GaN transistors make some topologies practically usable, such as for example totem-pole PFCs, which require fewer parts as conventional designs and exhibit state-of-the-art efficiency performance.

Increased switching frequency enables passive components to be miniaturized – in particular magnetic components – whereas the power density of circuits such as resonant DC-DC converters can be increased. Last but not least, GaN bring significant efficiency improvements under partial load operation in resonant circuits of this type. Panasonic has used and demonstrated these capabilities in a highly compact and efficient AC-DC demo unit (Figure 9)

Applications like power supplies for IT, telecoms servers and AC adapters should benefit most from these in the short term. The automotive industry has also demonstrated significant interest in being able to use such components in on-board chargers or DCDCs in the medium term.

After the start of the mass production starts at the end of 2016, Panasonic will further extend its offer of GaN-on-Silicon transistors. After the successful introduction of the 600 V versions with on- resistances of 70mOhm and 190mOhm, the line-up is now to be extended with new variants between 40mOhm and 350mOhm. The 600 V switches in series production will also guarantee a Vds pulse rating of up to 750 V.

http://eu.industrial.panasonic.com/

SiC MOSFETs in Optimized Packaging Deliver a 3× Reduction in Switching Losses, Enabling Affordable High-Efficiency EV Battery Chargers.

Advances in wide bandgap semiconductor designs are enabling SiC MOSFET die capable of increasingly faster switching speeds and lower switching losses. Improved low-inductance packages are essential in allowing circuit designers to take full advantage of this fast switching capability to improve power converter system efficiency and ultimately deliver energy savings to the customer. Simple and practical improvements to commercially available discrete packages can significantly extend the performance of SiC MOSFETs without introducing proprietary packages that are difficult and costly to incorporate into a practical converter design. This article describes the fundamental switching speed limitations of conventional discrete MOSFET packaging technology, presents and quantifies two new Wolfspeed packaging options, and shows how these new products can be used to cut losses and simplify the design of a 20kW active front end targeted for off-board, EV fast charging.

By Edgar Ayerbe, Dr. Adam Barkley and Dr. John Mookken, Wolfspeed

Introduction

With the introduction of Wolfspeed's latest C3M™ silicon carbide MOSFETs, package inductance and printed circuit board layout are becoming critical factors in achieving the best system performance. C3M MOSFET die have been engineered to switch hundreds of volts and tens of amps per nanosecond. However, the large common source inductance of the conventional TO-247-3 package (due to source wirebonds and package source pin) causes a negative feedback mechanism that limits achievable di/dt and imposes associated switching losses. As shown in the upper switch position of Figure 1, Q1's source inductance (LS1) and corresponding voltage drop are shared by the power switching loop and the gate drive loop. During a fast di/dt switching transition, this common source voltage opposes the applied gate driver voltage (VDRV1). As a result, the gate-source voltage at the MOSFET die is reduced, significantly slowing switching transition speed and increasing switching losses. One solution to overcome this problem is to introduce new packaging options that include a dedicated Kelvin source pin to be used for the gate driver return connection, the KS pin shown in the lower switch position (Q2) of Figure 1. When used with an isolated gate driver (VDRV2), the gate drive loop is no longer affected by the voltage appearing on the power switching loop source inductance. This breaks the negative feedback mechanism and enables significantly faster switching speed and lower switching losses.

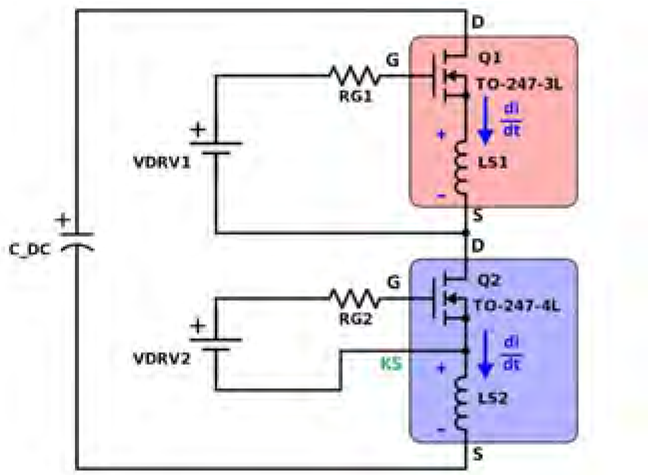


Figure 1: Hypothetical MOSFET bridge leg with TO-247-3L upper device (Q1) and TO-247-4L lower device. The achievable di/dt in the TO-247-3L is limited because the voltage drop across common source inductance LS1 opposes the applied gate driver voltage VDRV1. The addition of a Kelvin source pin in the TO-247-4L combined with an isolated gate driver VDRV2 effectively removes this di/dt limitation, thereby drastically reducing switching losses.

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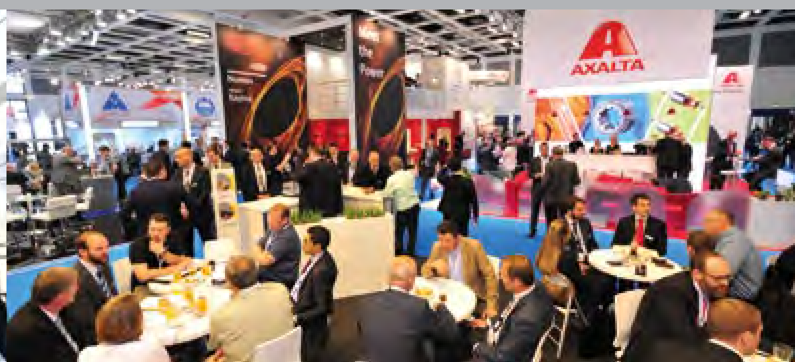

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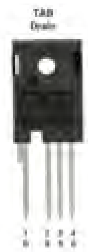
Wolfspeed has introduced two new SiC MOSFET package options with a dedicated Kelvin source pin; see Table 1 for the present product offerings. The first is a surface mount TO-263-7 package specifically designed for MOSFETs rated up to 1700V, while still having a 52 percent smaller footprint than D3PAKs commonly used for 1200 – 1700 V devices. Its five paralleled power source pins drastically reduce the power loop source inductance as compared to other surface mount packages. The second package option is a through-hole TO-247-4L featuring 8mm of creepage distance between the drain and source.

Part Number	Rds(on) (mΩ)	Voltage (V)	Package Picture
C3M0065090J	65	900	
C3M0120090J	120	900	
C3M0280090J	280	900	
C3M0065100J	65	1000	
C3M0120100J	120	1000	
C3M0075120J *	75	1200	
C2M1000170J	1000	1700	
C3M0010090K *	10	900	
C3M0065100K	65	1000	
C3M0120100K	120	1000	
C3M0075120K	75	1200	

* Available Soon

Table 1: Wolfspeed SiC MOSFET with Kelvin source pin

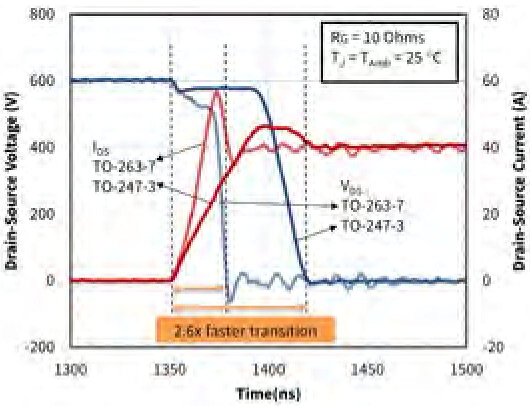


Figure 2: Measured turn-on switching transition for the same SiC MOSFET die product in two package options. The TO-263-7L package (using Kelvin source pin for gate return) switches 2,6× faster than the TO-247-3 (no KS pin).

Measured Results: Validating Improved Switching Performance

The improved switching performance of the new package types has been validated using clamped inductive switching tests performed on the family of die products in Table 1. Figure 2 compares a 600V/ 40A turn-on switching transition for the 1000V, 65mΩ MOSFET die in a TO-263-7L package (with Kelvin source pin) vs. a TO-247-3L with no Kelvin source pin. Even for this moderately-sized MOSFET die with a conservative 10 Ω external gate resistor, the switching transition time is reduced from 72ns to 27ns resulting in a 2.6x faster transition.

Because this phenomenon is driven by MOSFET di/dt, the greatest opportunity for switching loss reduction is expected in the case of a large area MOSFET die switching high current levels and driven aggressively with low external gate resistance. A second clamped inductive switching test was performed using the 10mΩ, 900V die driven with VGS = -4 / +15 V, RG = 5 Ω, and VDD = 600 V. Figure 3 shows the switching loss vs. drain current when packaged in a standard TO-247-3L package (left) vs. TO-247-4L package with Kelvin source pin (right). In both cases, the measured losses include the losses of the upper MOSFET's intrinsic body diode being used as a freewheeling diode. The results demonstrate a potential 3.5× reduction in switching losses when measured near rated current. SiC MOSFETs also enable higher frequency operation in soft-switched or resonant circuits commonly found in the DC/DC converter section of on-board and off-board DC fast chargers [2]

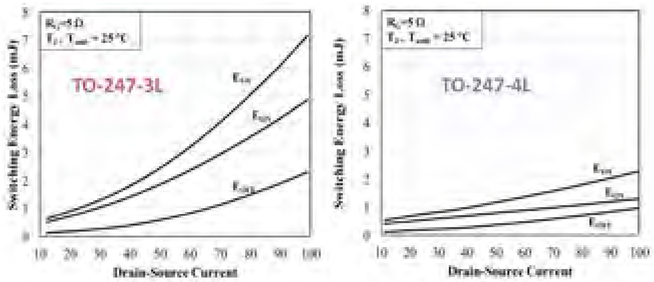


Figure 3: Switching energy losses vs. drain current for the 10mΩ 900V SiC MOSFET in a TO-247-3L vs. TO-247-4L package. For this large area die driven with a 5Ω external gate resistor, a 3.5× switching loss reduction is observed near rated current.

Application: Cost-Optimized 20kW AFE for Fast Off-board EV Charger

The surge in demand for EVs has created new opportunities for SiC MOSFETs both on and off the vehicle. Half-bridge hard-switched circuits are used in drive-train DC/DC converters, traction drives, and PFC front end converters of battery chargers. SiC MOSFETs also enable higher frequency operation in soft-switched or resonant circuits commonly found in the DC/DC converter section of on-board and off-board DC fast chargers.

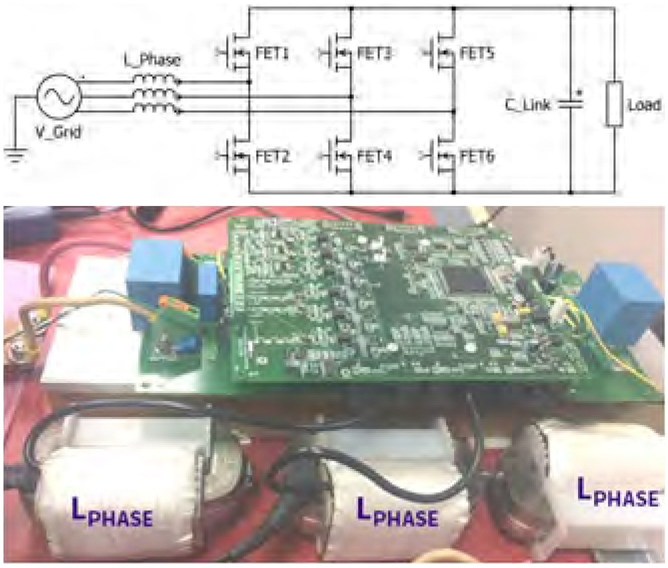


Figure 4: High-level technical specifications, 2L six-switch AFE power stage circuit topology, and realized 20kW AFE hardware prototype based on 2× C3M0065100K per switch position.

We have shown that these new packaging options and proper use of the Kelvin source pin offer dramatic reduction in switching losses for hard switching applications. Combining this switching performance with the 1000V C3M SiC MOSFETs' low conduction losses over temperature, low QRR body diode, and more linear output capacitance allows circuit designers to breathe new life into a number of well-known, simple two-level circuit topologies. To demonstrate how these benefits can be monetized at the system level, Wolfspeed has developed and tested the 20kW two-level SiC-based active front end (AFE) shown in Figure 4, targeting the first stage of an off-board EV fast charger.

This two-level 20kW SiC-based AFE prototype is designed with 2× C3M0065100K MOSFETs per switch position with no additional anti-parallel freewheeling diodes. A switching frequency of 48 kHz has been selected to strike a good balance of phase-inductor cost-reduction, phase-current THD, and ease of EMI filter design (third harmonic below 150 kHz). Each phase inductance of 400 µH is constructed using a gapped AMCC 50 Metglass 2605SA1 core and copper foil windings. A standard voltage-oriented control approach with space vector PWM is implemented digitally in a TMS320F28335-based control board. Dead-time has been reduced to ~100 ns in order to limit distortion near phase voltage crossings. The resulting measured

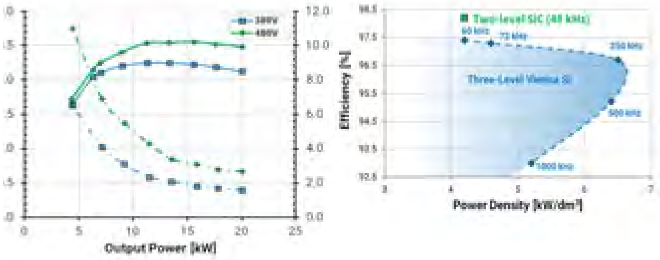


Figure 5. Measured 2L SiC AFE efficiency and THD vs. power level (left) demonstrates that this simple topology and control approach can meet all targets. Measured efficiency and estimated power density for the 2L SiC AFE vs. several state-of-the-art published Si Vienna Rectifiers (right) demonstrates an approximate 1% improvement in efficiency via a 30% reduction in power losses.

efficiency and THD are shown in Figure 5, where all technical targets have been met.

Compared to the popular three-level silicon-based Vienna Rectifier topology, this approach offers a ≥ 30% reduction in power loss (kWh savings), circuit simplification, parts count reduction, easy control implementation, native support for bidirectional power flow (V2G), and similar net system BOM. Further details of the AFE prototype and comparisons to the Vienna Rectifier can be found in Reference [1].

Summary and Conclusion

The global market for power semiconductors deployed into cars is expected to grow by more than 3 billion dollars in the next five years due to increased electrification of vehicles [3]. Fast, highly-efficient on-board and off-board charging is becoming a key enabler to wide-spread adoption of EVs. Here, discrete SiC MOSFETs in intelligent economical packaging offer circuit designers new tools to improve power conversion efficiency, power density, and ultimately energy savings for the consumer. An example two-level active front-end prototype has shown that Wolfspeed's C3M SiC MOSFETs offer state-of-the-art system performance and a 30% reduction in power losses affordably while using a simple circuit topology and control approach.

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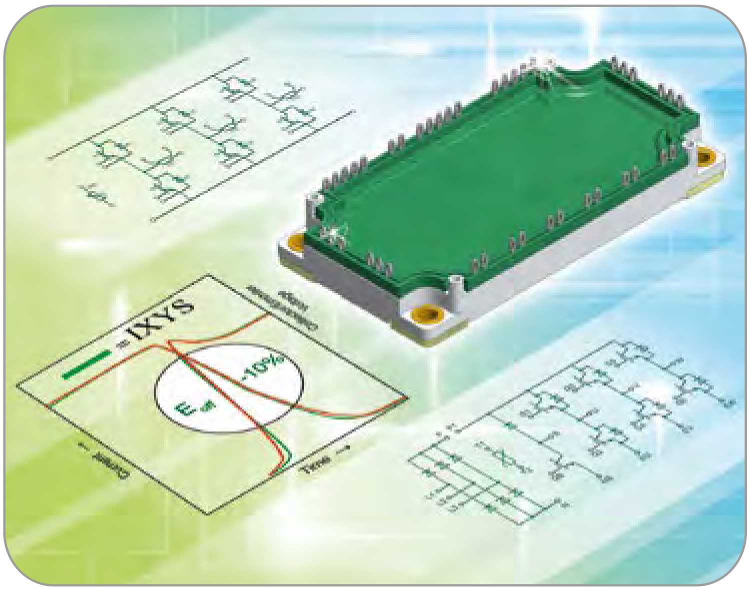

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MIXG 180W1200TEH	1200V	6-pack	E3
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Water-Cooled Capacitor with Integration Technology

DC-link film capacitors always work in a challenging ambient temperature up to 115°C for new energy vehicle controllers. Integrated water-cooled film capacitor is a good solution for these high ambient temperature applications, in addition it contributes to higher energy density, higher thermal conductivity and better mechanical strength.

By David Ting, CTO and Eric Wong, CAE, EAGTOP, CHINA

Introduction

Film capacitor has been widely used in new energy vehicle controller, but it also faces the challenge of high ambient temperature in its application. DC- link film capacitors always work in a challenging ambient temperature up to 115oC, especially for HEV/PHEV, due to the impact of internal combustion engine. As for film capacitor, its maximum working temperature is only 105oC, which becomes the main restriction of thermal design for new energy vehicle controller.

An effective way to solve working temperature restriction is to enhance the cooling capacity of film capacitor in order to decrease the capacitor temperature. The EAGTOP integrated water-cooled film capacitor is an innovative solution for this application in high ambient temperatures, meanwhile contributes to higher energy density, higher thermal conductivity and better mechanical strength.

Application of DC-Link capacitors

Film capacitors are always utilized in the intermediate circuits (DC-link) of converters. For new energy vehicles, this integrated water-cooled film capacitor has the following main functions:
(a) smoothing the ripple of DC voltage,
(b) to provide energy for the inverter and acts
(c) as the snubber component for IGBTs circuit.

Figure 1 shows a typical new energy vehicle DC-link application of this film capacitor.

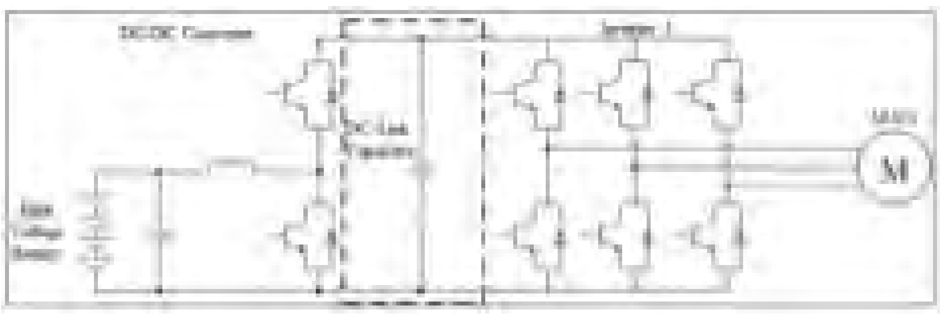

Figure 1: Example of converter with a DC-link

Water-cooled capacitor's structure

The water-cooled film capacitor design is based on Infineon's HP Driver IGBT. Additional passive power electronics are integrated in this hard-ware components, such as film capacitors, laminated bus bar and liquid cooling plate for IGBTs.

Figure 2: structure of water-cooled capacitor

Figure 2 shows the structure of the integrated water-cooled capacitor.

Water-cooled capacitor verification

Film capacitors generally use epoxy resin as the potting material, with the thermal conductivity coefficient within the range of 0.6-1.5 W/m*K. Capacitor housings are usually made of metal or plastic. The thermal conductivity of metal (15-400W/m*K) is much higher than that of plastic (0.2-0.3 W/m*K). EAGTOP water cooled capacitor housings use aluminum alloy (approximately 180W/m*K) instead of PPS (Polyphenylene Sulfide) (approximately 0.2 W/m*K), in order to improve the cooling capacity of the capacitor.

We use ANSYS to establish steady-state thermal simulation model for water-cooled capacitor in order to verify the influence of the potting and housing material thermal conductivity on the core temperature rise.

Our input conditions for the simulation are as follows:

1) Bus Bar and capacitor core bear the ripple current of 170 Arms, with ESR (Equivalent Series Resistance) about 0.28 mΩ
2) IGBT heating power is 1500 W
3) System is cooled directly with standard 50% water / 50% ethylene glycol coolant at a rate of 8L/min with an inlet temperature of 70oC

4) The other surfaces which are exposed to the air are cooled with method of air natural convection and radiation, the ambient temperature amounts +115oC.

Simulation verification of the influence of potting and housing material thermal conductivity on the core temperature rise

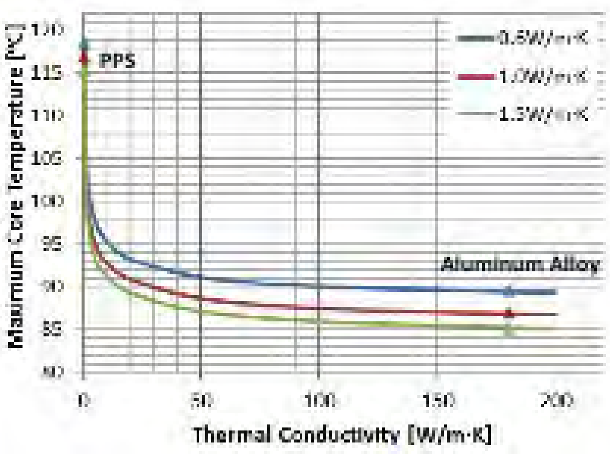

*Figure 3: curves of maximum core temperature with thermal conductivity of housing material at potting materials thermal conductivity coefficient of 0.6 W/m*K, 1.0 W/m*K, and 1.5 W/m*K.*

In order to verify the influence of potting and housing material thermal conductivity on the core temperature rise, we just calculate the maximum core temperature with different thermal conductivity of potting and housing material. Figure 3 shows curves of maximum core temperature with thermal conductivity of housing material at potting materials thermal conductivity coefficient of 0.6 W/m*K, 1.0 W/m*K, and 1.5 W/m*K. We can see that the maximum core temperature decreases with the increase of housing material thermal conductivity with the other factors remaining unchanged. The decline trend of maximum core temperature is obvious when the housing material thermal conductivity coefficient is within the range of 0.2-50 W/m*K. But, the maximum core temperature decline trend is going to be

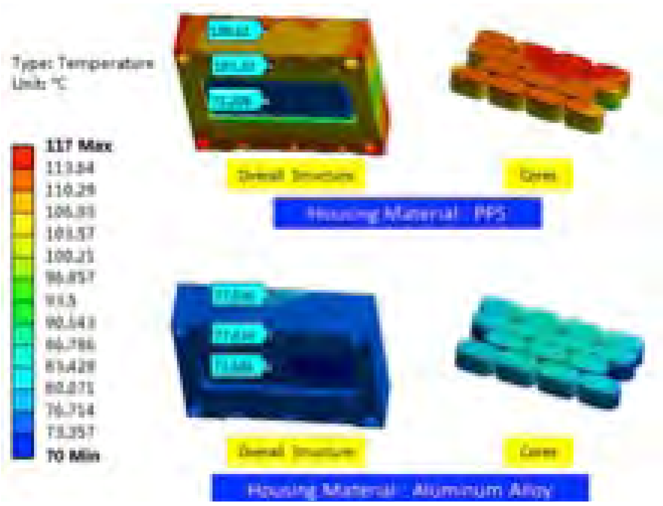

*Figure 4: temperature distribution of overall structure and the cores of the film capacitor when we respectively use PPS and aluminum alloy as the housing material, maintaining the potting material thermal conductivity coefficient as 1.0 W/m*K.*

gentle when the housing material thermal conductivity coefficient is above 50 W/m*K. We keep potting material thermal conductivity coefficient of 1.0 W/m*K. When using PPS as the housing material, the maximum core temperature is about 117oC, and this is beyond the maximum tolerance temperature (105oC) of the capacitor core. When using an aluminum alloy material as housing, the maximum core temperature is reduced to 87oC.

In addition, figure 3 also shows that the maximum core temperature decreases with the increase of potting material thermal conductivity with the other factors remaining unchanged. Therefore, the influence of thermal conductivity of potting material on the core temperature rise cannot be ignored.

Simulation verification of aluminum alloy's cooling capacity
Figure 4 shows the temperature distribution of overall structure and the cores of the film capacitor when we respectively use PPS and aluminum alloy as the housing material, maintaining the potting material thermal conductivity coefficient as 1.0 W/m*K. Obviously, we can see that the uniform temperature effect of aluminum alloy is far larger than that of PPS.

The core temperature is greatly reduced with this uniform temperature effect.

According to the simulation results, the aluminum alloy housing cooling capacity is much larger than of PPS housing. With the other factors remaining unchanged, the maximum core temperature has reduced by 30oC using aluminum alloy as the housing material when compare to PPS. Considering the maximum working temperature of the capacitor core is 105oC, the film capacitor has a redundancy of about 18oC to accommodate up to a higher ambient temperature of the electric vehicle controller.

Summary
As for EAGTOP water-cooled capacitor, the thermal conductivity and mechanical strength are enhanced by aluminum alloy housing and its cooling capacity was improved by water cooling system accordingly. Simulation results show that the integrated water-cooled capacitor not only can accommodate up to 115oC car controller ambient temperature, but also, the 18oC design redundancy will adapt to a harsh ambient temperature. In short, water-cooled capacitor with integration technology will extend the life of the capacitor and the new energy vehicle drive.

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Power Path Management in Charger ICs

A commonly used power path management scheme, dynamic power path management (DPPM), is discussed in this article. The DPPM control loop adjusts the charge current dynamically based on the input source current capability and load current level to achieve a minimum charge time for a given source and system load. With DPPM, the system can obtain power immediately once the input source is applied, even with a deeply discharged battery. The system voltage regulation method is also discussed.

By Aaron Xu, MPS

In mobile devices with a rechargeable battery, a charger IC is needed to charge the battery when an external power source is applied. The system load inside the mobile device could be provided by the battery, the input source, or both, depending on the connection of the battery and system load. A power path management scheme is needed to handle this kind of power source selection.

Dynamic power path management (DPPM) is the most popular scheme for power path management in mobile applications. The basic power stage structure for DPPM is shown in Figure 1.

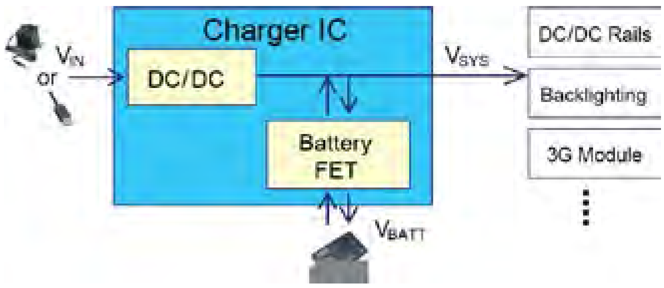

Figure 1: NVDC Power Path Management Structure

In the DPPM system, the system load is connected to the system bus (VSYS). VSYS can be powered from the battery through the battery FET, or from the input source through a DC/DC convertor or LDO. When the input source is not available, the battery FET is fully on, so the battery provides power to the system load.

When the input source is applied, VSYS is regulated by the input DC/DC converter or LDO. Simultaneously, VSYS provides a charge current to the battery through the battery FET. In this charging mode, priority is given to the system load, and the remaining power is used for charging. The charge current is adjusted dynamically based on input source capability and system load level, achieving a minimum charge time.

During the above charging process, if the system load is over the power capability of the input source, VSYS will drop. Once VSYS drops to a DPPM threshold, the DPPM control loop activates and reduces the charge current automatically to prevent VSYS from dropping further. This process is also called DPPM mode.

In DPPM mode, if the charge current is reduced to zero, and the system load is still over the input power capability, VSYS continues dropping. Once VSYS drops below the battery voltage (VBAT) level, the battery provides power to VSYS through the battery FET. This is called supplement mode. In supplement mode, the input source and battery provide power to the system simultaneously.

Before entering supplement mode, if the battery FET is in linear mode (not fully on, for example when VBAT < VSYS_MIN + DV, or during a start-up transient), to ensure a smooth transition in and out of supplement mode, an ideal diode mode is preferred to control the battery FET, such as the one in the MP2624A.

During the ideal diode mode, the battery FET operates as an ideal diode. When the system voltage is 40mV below the battery voltage, the battery FET turns on and regulates the gate driver of the battery FET. The voltage drop (VDS) of the battery FET is about 20mV. As the discharge current increases, the battery FET obtains a stronger gate drive and smaller on-state resistance (RDS) until the battery FET is completely turned on. When the discharge current goes lower, the ideal diode loop generates a weaker gate drive and larger RDS(ON) to keep a 20mV difference between the battery and system until the battery FET is turned off.

VSYS regulation in DPPM mode can be flexible depending on the system requirement. If the front-end converter from the input to the system is an LDO, VSYS can be set at a level to specially benefit the system requirement. For example, VSYS is 4.65V for the MP2661 and 5.0V for the MP2660.

If the front-end converter from the input to the system is a DC/DC converter, VSYS is usually set to follow the battery voltage to improve efficiency. This is commonly referred to as a narrow voltage DC (NVDC).

There are several advantages for DPPM control. First, the system gains power immediately once the input source is applied, regardless of whether the battery is depleted or not. Second, the charge current is adjusted dynamically based on the input source and system load to achieve a minimum charge time.

The limitation for DPPM control lies on the fact that it is complicated but ensures a smooth transition between the different operation modes. Usually, a VSYS loop, ideal diode loop, charge voltage, and charge current loop are required for battery FET control.

Conclusion

With DPPM control, the system can obtain power as soon as the input source is applied, even if the battery is depleted. The charger IC with DPPM control can also optimize the charge current to fully utilize the input source current capability. Although the control for DPPM is complicated, DPPM is widely used in charger ICs that require power source selection, such as in MPS's MP2624A, MP2660, and so on.

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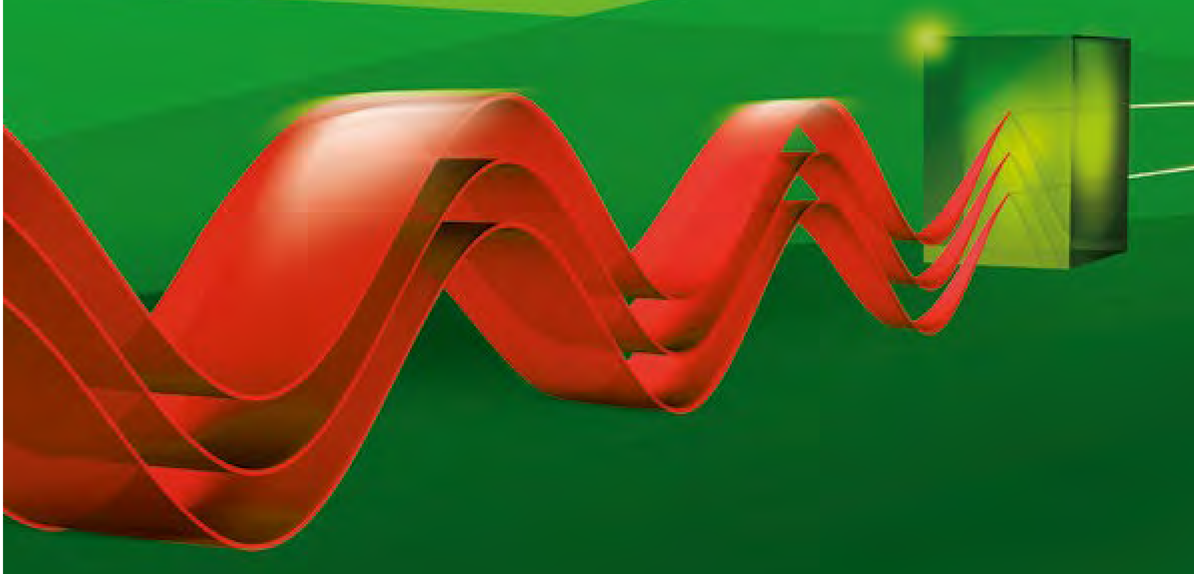

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Novel Technique to Reduce Substrate Tilt & Improve Bondline Control between AlN Substrate and AlSiC Baseplate in IGBT Modules

Large area solder joints in multi-chip power semiconductor packages experience fatigue caused by the periodic straining of the interconnection layers during thermal excursions as the device is operational. These stresses lead to delamination and cracks within the solder layer after many thermal cycles which increase the junction-to-case thermal resistance and ultimately lead to early device failure [2].

By James Booth, Dynex Semiconductor Ltd and Karthik Vijay, Indium Corporation

Introduction

Cracking and solder layer delamination occurs earlier in inhomogeneous solder joints due to stress concentration at thinner areas of the joint, Figure 1.0 shows how crack length within the solder joint increases greatly with solder layers thinner than 200 µm. This figure illustrates how tilted samples, where part of the joint is <200 µm, are more susceptible to cracking and delamination.

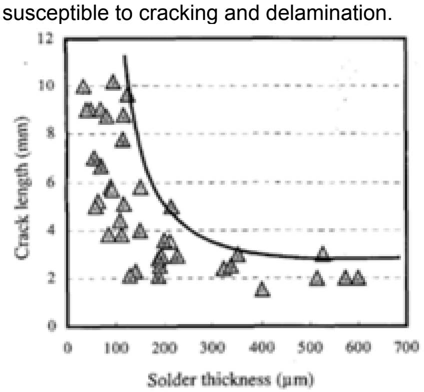

Figure 1.0: Correlation between solder joint thickness and induced crack length after thermal cycling [1]

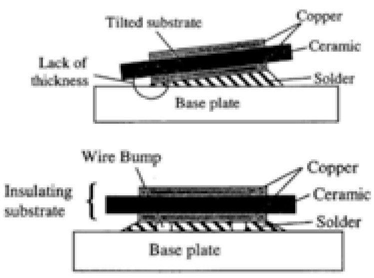

Figure 1.1: Substrate tilt example (top) and solution using wire bonds to achieve bondline uniformity (bottom) [1]

The advent of spacer technology allows control of the solder joint thickness for a given solder volume by reducing substrate tilt to achieve a homogenous solder layer, as Figure 1.1 demonstrates. This is most commonly done in power semiconductor modules by stitch bonding aluminium wire of a desired diameter to an AlSiC baseplate: for copper baseplate modules, copper 'bumps' can be stamped in the component (Figure 1.2).

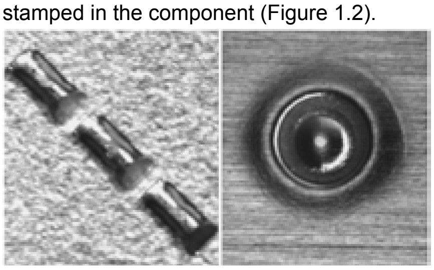

Figure 1.2: Traditional bondline control methods, aluminium wirebonds on AlSiC baseplate (left) and stamped 'bump' in copper baseplate (right)

The use of spacers in large area solder joints increases the joint lifetime by allowing for homogenous delamination. This occurs at a much slower rate than inhomogeneous delamination caused by substrate tilt [1-2]. This technology is well documented and employed today in power module assembly, but this technique results in a high cost of ownership due to extra process steps and capital equipment costs.

InFORMS® are reinforced solder preforms with an embedded mesh, offer an alternative solution to achieve a homogenous solder layer. When the solder melts during reflow, the reinforced matrix remains intact and serves to maintain uniform bondline thickness. InFORMS® offer a drop-in solution to standard preforms and eliminates the additional process steps associated with the traditional aluminium stitch bond method. This study evaluates the lifetime of InFORMS® against the traditional aluminium stitch bond method.

Sample Preparation

The same soldering profile and identical process steps were used to assemble modules with InFORMS® as well as modules with the traditional wirebond method, for achieving a homogenous solder layer. These samples were also compared to reference modules with no bondline control; four of each variant were tested. The samples were then temperature cycled chamber to chamber with a ΔT of 200 K; cracking and delamination of the solder layer were monitored by scanning acoustic microscopy every 200 cycles. Module assembly consisted of soldering ceramic AlN substrates (with Cu metalisation) to 140x70 mm AlSiC baseplates using 200 µm SnSb5 solder preforms. The samples with the InFORMS® consisted of a 200 µm mesh with a 225 µm net solder thickness. The samples with aluminium stitch bonds used 180 µm diameter wire. These were compared to 200 µm thick preforms with no bondline control. 200 µm is the targeted bondline thickness as this offers the lowest thermal resistance without suffering from increased strain.

Following the assembly of the samples, one of each sample type underwent a laser surface profiling scan to determine the substrate tilt prior to thermal cycling tests. This was

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determined as the mean height variation across the top of the substrate at four points; maximum deflection was also measured. The InFORMS® sample shows the least co-planarity deviation (smallest ΔZ) at 52.5 µm and a maximum deflection of ~60 µm (Figure 3), followed by the wirebonded sample at 56.5µm with a maximum deflection at ~70 µm, and finally the sample without bondline control at 67.5 µm and a maximum deflection of ~90 µm. It is noticed that on all samples the substrates are tilted inward toward the baseplate, owing to the concave shape of the baseplate.

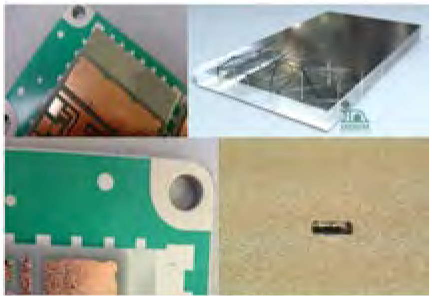

Figure 2: Assembly images showing sample soldered with InFORMS® (top) and sample with wirebond spacer (bottom).

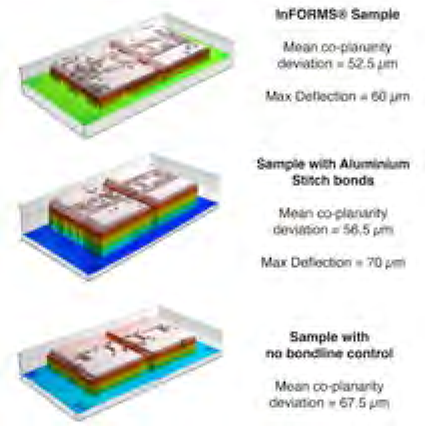

Figure 3: Each sample type underwent a laser surface profiling scan to determine the substrate tilt prior to thermal cycling tests.

Thermal Cycling

Samples were thermal cycled using a Vötsch VT 7012 S3 chamber to chamber thermal cycler. The samples were cycled from -50°C to 150°C under the following conditions.

t_{dwell} = 1 hour $\quad T_{s(max)}$ = 150°C

$t_{transition}$ = 30 seconds $\quad T_{s(min)}$ = -50°C

ΔT = 200K

Results

Figure 4 shows the SAM images at zero, 600 800 cycles of the baseplate/solder interface for all three techniques. Delamination of the solder layer is witnessed as bright reflections emanating from the edges of the solder layer. No delamination was witnessed at 200 and 400 cycles for all bondline variants. At 600 thermal cycles for the samples with no bondline control, delamination was observed. Cracking was witnessed in the secondary SAM gate, reflecting the substrate/solder layer by showing bright reflections indicating cracking. No delamination or solder cracking was seen for the InFORMS® samples or wirebonded samples at 600 cycles.

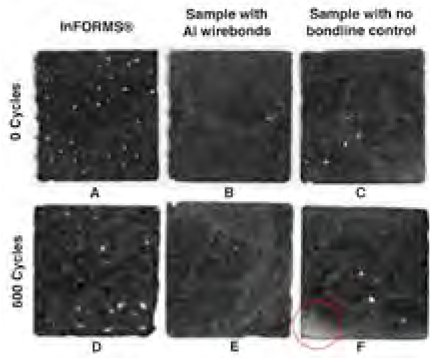

Figure 4: SAM results at zero, 600, and 800 cycles

At 800 cycles, solder cracking was observed with the samples made with Al wirebonds (Figure 5). These appear at the same location where the solder layer is at its thinnest due to the concave nature of the baseplate. The InFORMS® samples showed no signs of cracking or delamination at 800 cycles (Figure 5).

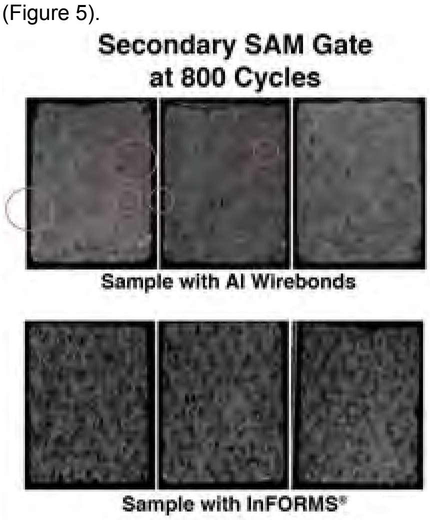

Figure 5: 800 cycles; Secondary SAM gate highlighting cracks in the solder layer for samples with Al wirebonds. No signs of cracking/delamination for the InFORMS® samples.

At 1000 cycles, the InFORMS® samples still showed no signs of cracking or delamination (Figure 6). Some solder cracking/delamination was observed with the samples made with Al wirebonds. Severe cracking was observed on the samples with no bondline control.

Summary and Conclusion

A novel technique to prevent substrate tilt and maintain a homogenous 200µm solder layer using InFORMS® with an embedded metal mesh was evaluated and compared to the traditional aluminium stitch bond technique for AlSiC baseplate modules. These

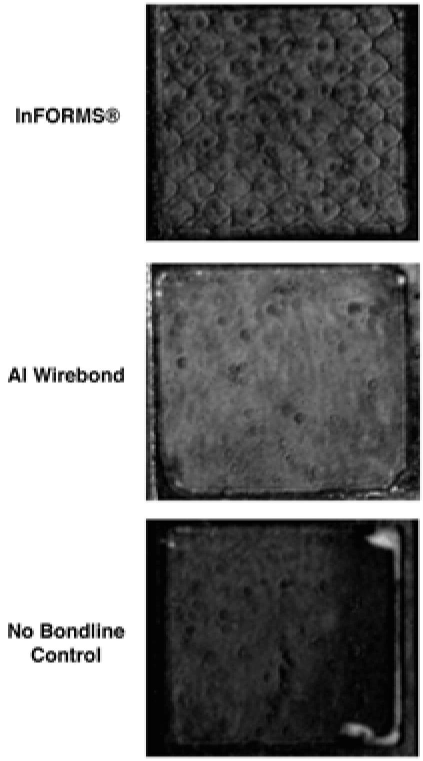

Figure 6: 1000 cycles; InFORMS® No delamination/solder cracking observed in InFORMS®; Some delamination/solder cracking observed in Al wirebond samples; Sever cracking observed in samples with no bondline control.

were also compared to samples with no bondline control.

Surface profile scan to determine substrate tilt showed that InFORMS® samples had the lowest co-planarity deviation of 52.5 µm. The samples were subject to temperature cycling (-50/+150C) to observe solder layer delamination/cracking of the solder joint. At 600 thermal cycles, the samples with no bondline control first showed cracking at the tilted side with a difference of ~90 µm – the lowest side of which emanated cracking and delamination. At 800 thermal cycles, the samples with Al wirebonds showed signs of cracking with some, but not all samples; again with cracks appearing at the thinner end of the solder joint, i.e., the centre of the baseplate. No cracks or solder delamination were seen for the InFORMS® samples at 600 or 800 thermal cycles. Even at 1000 thermal cycles, the InFORMS® samples did not show solder cracking/delamination.

While the effect of bondline control has already been studied and shown to improve joint lifetime in power modules, using InFORMS® presents a more reliable method as opposed to the aluminum stitch bonding method. The reinforced matrix in the InFORMS® supressed solder fatigue by resisting creep and showed improved reliability compared to the traditional wirebond method.
InFORMS® also offer a drop-in replacement to achieving bondline homogeneity, without additional process steps of wirebonding and associated capital equipment costs, thereby providing the lowest cost of ownership.

Application Note

Application note can be found at www.indium.com/informs

Acknowledgments

The authors would like to thank Dr. Steve Jones for his contribution to this research.

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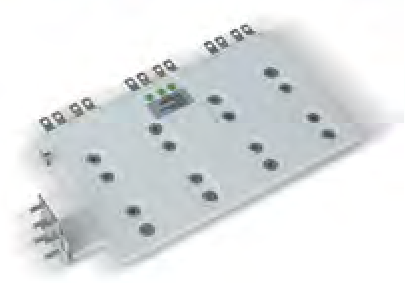

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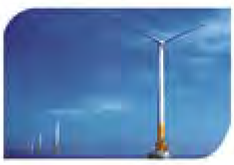


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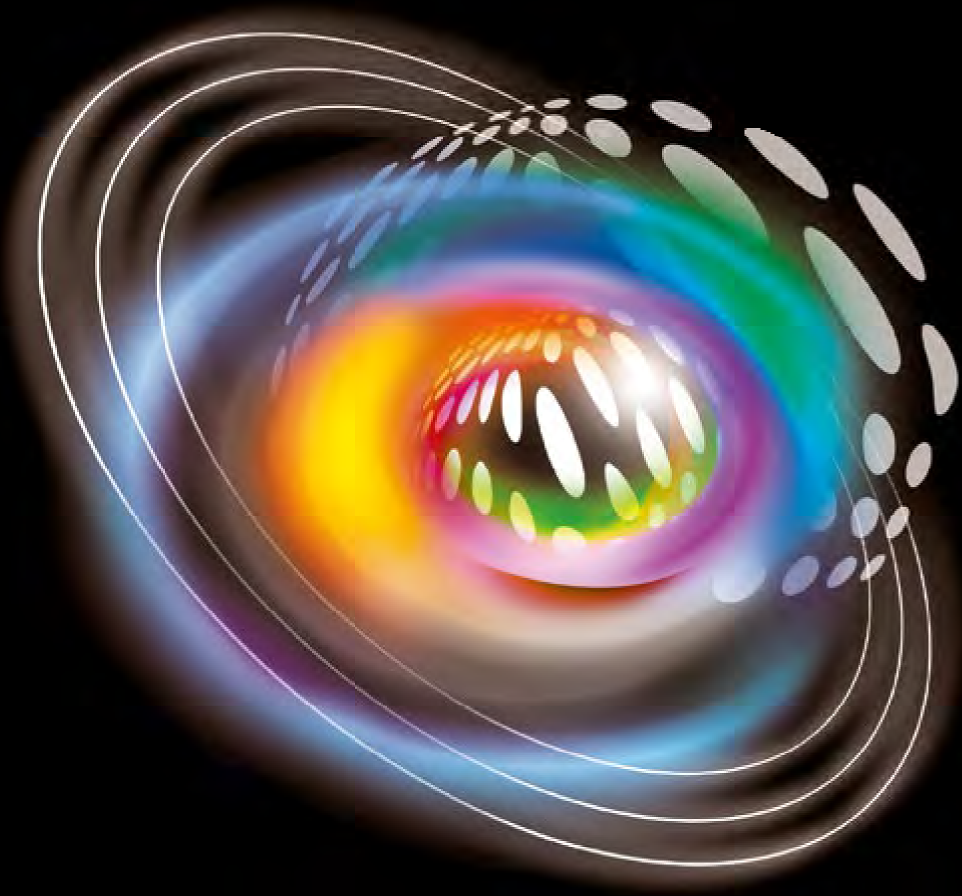

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Tiny 2.6A Brushed DC Motor Driver for Portable, Battery-Powered IoT Devices

The STSPIN250 single-chip 2.6A driver for brushed DC motors extends STMicroelectronics' family of miniature, low-voltage, energy-efficient drivers for battery-powered portable and wearable applications. The driver integrates a full power-MOSFET bridge and fixed off-time PWM current controller in a tiny 3mm x 3mm package that saves space in portable equipment. The low on-resistance of the power stage (200mΩ total, high-side + low-side) and the best-in-the market current-sipping standby mode -- below 80nA -- help maximize battery runtime and keep equipment-case temperatures down. Its supply-voltage range of 10V to 1.8V allows designers to specify a power source as small as a single Li-ion cell.

Brushed DC motors offer a strong combination of performance, cost-effectiveness, and reliability, and are a popular choice of designers in a wide variety of applications. STSPIN250's high output-current capability allows use in low-to-medium-power applications such as portable printers, POS terminals, consumer devices, electronic valves or door lockers, toys, and medical or wellness devices ranging from electric toothbrushes to syringe pumps. It also has comprehensive built-in protection features including Under-Voltage lockout (UVLO), non-dissipative over-current protection, short-circuit protection, and thermal shutdown.

www.st.com/STSPIN

Low-Cost Regulated SIP8 DC/DC Converters

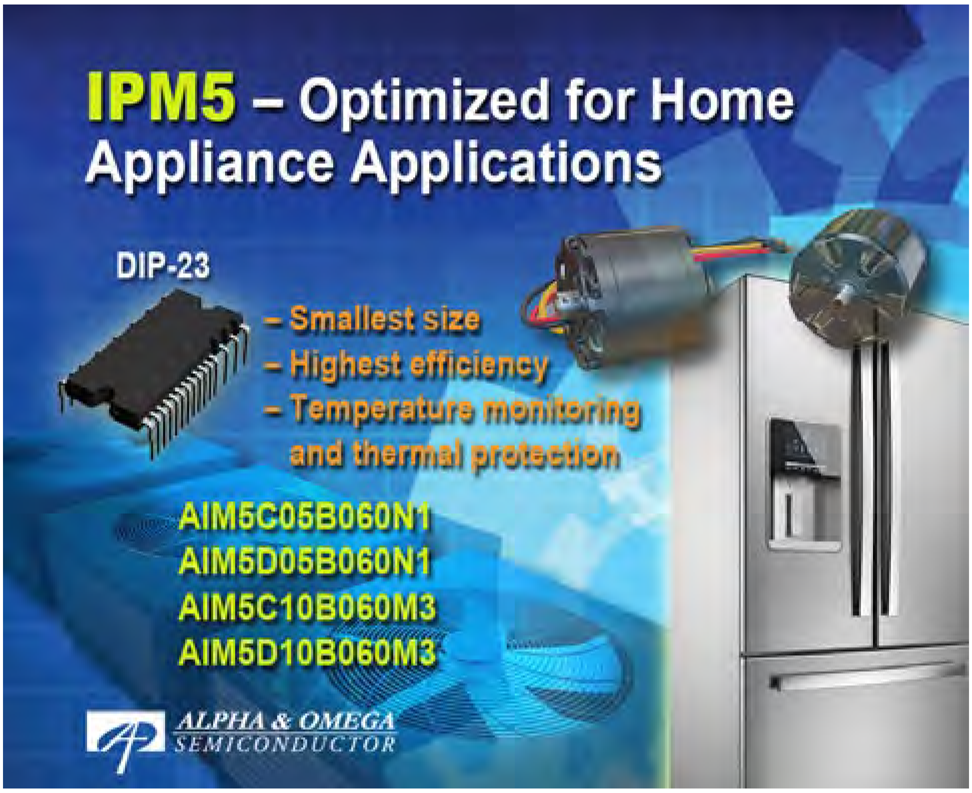
Recom's regulated DC/DC converters RSE (2 Watt) and RSOE (1 Watt) series were developed for a variety of industrial, transport, test & measurement which require on-board 5V power supplies; the cost-effective converters operate at extreme temperatures from -40°C up to +80°C at full load.

The fully upgraded DC/DC converters are offered with nominal 2:1 input voltages of 5V and 24V and with 5V output voltage. Tight output regulation protects against any sudden change in input voltage and keeps interference levels low and output voltage stable. They are pin-compatible with the RSO, RS, RS3 and RS6 series for an easy upgrade on existing circuit boards. The converters are packaged in an industry standard SIP8 housing measuring a compact 21.8 x 9.2 x 11.1 mm and have an I/O isolation of 2 kVDC. The converters reach efficiencies up to 80% at full load. At low loads common converters fail to produce high efficiency rates; however, the RSE and RSOE series converters still reach 70% efficiency at 30% load and can even maintain full functionality down to 0% load. They are overcurrent as well as short-circuit protected with rapid start-up times less than 500µs. Industrial Class A EMC levels are met with a pi-filter. All modules are certified to UL62368-1 with a CB report and come with a full three-year warranty. Samples are now available at our authorized distributors.

www.recom-power.com

600V Intelligent IGBT Power Module IPM5 Series

Alpha and Omega Semiconductor Limited announced the release of its intelligent power module, IPM5 series. Its compact size is optimized to deliver excellent efficiency and ruggedness. The IPM5 is a reliable module system designed with AlphaIGBT™ technology integrated with high functional gate driver ICs, and high-density package technology for applications such as refrigerators, washing machines, and fan motors.



The IPM5 series is built upon the latest patent-pending package technology platform and features an industry-leading IGBT technology with fast turn-off and low VCE(SAT) that reduces the power losses incurred during conduction and switching. It is integrated with multi-function gate driver ICs with features such as wide-input voltage interface, over-current protection, and over-temperature protection and monitoring.

"IPM-driven inverters have been widely used in home appliances and 3-phase-motor-drive applications due to global energy saving regulations. IPM5 was developed to meet these requirements while offering the ideal combination of higher efficiency, high ruggedness and better EMI performance," said Dr. Brian Suh, Vice President of IGBT/IPM product line at AOS.

www.aosmd.com

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Based in Munich, Germany, ITPR Information-Travels Public Relations is a full-service consultancy with over a decade of experience in the electronics sector.
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3300V Gate Drive Enables Rapid Power Stack Optimization

Amantys Power Electronics Limited has launched a fully configurable version of it's 3300V gate drive. The 3300V gate drive contains Amantys' Power Insight technology that enables two way communications between the gate drive and a central controller for configuring the gate drive and communicating fault information.

The 3300V gate drive is designed to comply with international standards for railway applications and motor drives such as EN 50155 for railway applications and IEC 61800-5-1 for variable speed drives. Supported by Amantys' Power Insight Adapter and Power Insight Configurator software tool, the power stack designer can optimise the settings of gate resistors, gate-emitter capacitor, fault detection thresholds and timings (eg: fault lockout times and dead times) without removing the gate drives from the power stack. This enables rapid testing and optimisation of the power stack.

The robust design can operate over -40ºC to +85ºC and has protection features for short circuit faults, collector-emitter over voltage and gate drive power supply failure. The gate drive stores fault counter information on board the gate drive which can be downloaded at a later date for fault diagnosis. The gate drive also provides LED indication for operational status and faults.

The 3300V gate drive will be used in applications such as traction converters, HVDC infrastructure, wind energy and medium voltage converters.

www.amantys.com

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Ceramic Technology Offer 10nF Safety Certified MLCCs

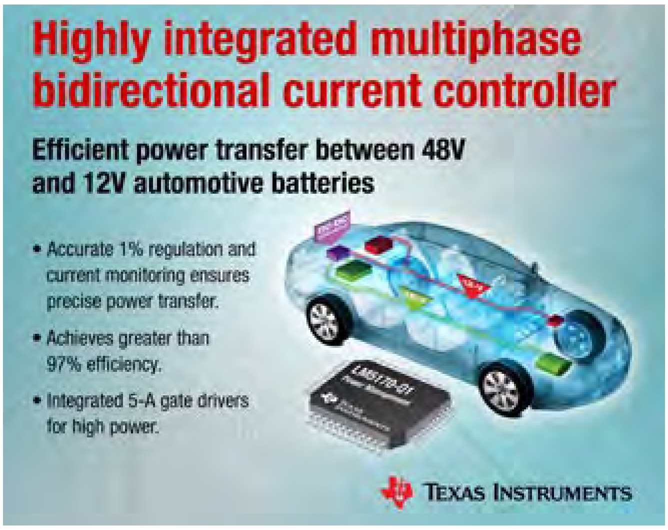
Knowles brand Syfer has responded to demands by increasing its range of 250V ac X1/Y2 Safety Certified capacitors to 10nF. MLCC's have been used in automotive applications for years, but the big change being seen is the voltage rating and size of components now being used. This revolution in MLCC technology, used in control electronics, is being driven by modern on-board charging systems - PHEV & EV where mains ac is involved.

Available in a 2220 case size, these X7R dielectric capacitors offer the user the option of greater total capacitance on the board, or piece part count reduction. For example, they can take the place of 2 x 4.7nF X1/Y2 capacitors connected in parallel to reduce component count, size and weight - leading to a significant reduction in cost. Knowles high voltage capacitor expertise means this range offers the highest capacitance / widest range available for a class X1/Y2 250Vac surface mount MLCC. All Knowles Safety Certified capacitors comply with international UL and TÜV (UL ongoing) specifications to offer designers the option of using a surface mount ceramic multilayer capacitor to replace leaded film types. Offering the benefits of simple pick-and-place assembly, reduced board space and lower profile - they are also available in a FlexiCap™ version to reduce the risk of mechanical cracking. REACH, RoHS and ELV compliant.

www.knowlescapacitors.com

Multiphase Bidirectional Current Controller

Texas Instruments introduced the industry's first fully integrated multiphase bidirectional DC/DC current controller, which efficiently



transfers electric power greater than 500 W per phase between dual 48-V and 12-V automotive battery systems. The highly integrated LM5170-Q1 analog controller features an innovative average current-mode control method that overcomes the challenges of today's high-component-count, full digital control schemes. For more information, samples and an evaluation module, see www.ti.com/lm5170q1-pr-eu.

Hybrid electric vehicles use both a high-voltage 48-V battery and the standard 12-V automotive battery. Design engineers typically manage these dual battery systems using a digital control scheme, which includes multiple discrete components such as current-sense amplifiers, gate drivers and protection circuits. These full digital control schemes are bulky and expensive. To solve this challenge while improving performance and system reliability, TI offers a mixed architecture in which the microcontroller handles higher-level intelligent management, and the highly integrated LM5170-Q1 analog controller provides the power conversion. Read the blog post, "Interconnecting automotive 48V and 12V rails in dual battery systems," to learn how to overcome the challenges of designing a power supply for hybrid electric vehicles.

www.ti.com

New Reflow Generation at the SMT/Hybrid/Packaging

Under the motto "SMT - Innovation creates future", SMT Thermal Discoveries presents as an absolute highlight its newly developed reflow soldering system SMT QuattroPeak ® 3.6. In modern design with new options in the operating software, SMT points the way to the Smart SMT Factory from the standpoint of Industry 4.0 and impresses with the usual extremely low energy consumption.

There are further innovations at the award-winning SMT vacuum reflow soldering system. SMT puts its longtime know-how, as a leading manufacturer with more than 110 vacuum soldering systems sold, into the progress of the system. The optimized transport transfer, the cycle time improvement and the heavy load transport with optimized

profile coating are presented at the system. SMT demonstrates a high degree of flexibility in transport with its curing system SMT HTT. With 1-track to x-tracks, up to two transport levels, heavy-load transport (up to 50 kg / m) and bi-directional conveyor (Lean concept), the system can be customized to customer requirements.

With the SMT Cube, SMT is showing another facility that is awarded the "Global Technology Award". The temperature control system is designed for the temperature pre-treatment of the electronic components and modules for function tests. The highlights of the system are the small footprint and the Lean concept, which allows loading and unloading at one place.

SMT Hybrid Packaging, booth 4-149

www.smt-wertheim.de

Three-Phase BLDC Controller and MOSFET Driver IC

Allegro MicroSystems Europe has announced a three-phase brushless BLDC motor controller for use with N-channel external power MOSFETs. Allegro's AMT49413 incorporates much of the circuitry required to design a cost-effective, three-phase motor drive system with maximum supply voltages up to 50 V.

This device is targeted at high current BLDC motor applications for speed, position, or torque control requirements. It has been designed for battery powered power tools, lawn and garden equipment and factory automation, pumps, fans, blowers and appliance applications within the consumer and industrial markets.

The AMT49413 provides functionality over a wide input supply range. A unique charge pump regulator provides adequate (>10 V) gate drive for battery voltages down to 7 V, and allows the device to operate with a reduced gate drive at supply voltages down to 5.5 V. A bootstrap capacitor is used to provide the above-battery supply voltage required for N-channel MOSFETs. An internal charge pump for the high-side drive allows for DC (100% duty cycle) operation.

Internal fixed-frequency PWM current control circuitry can be used to regulate the maximum load current. The peak load current limit is set by the selection of an input reference voltage and external sensing resistor. The PWM frequency is set by a user-selected external RC timing network. For added flexibility, the PWM input can be used to provide speed and torque control, allowing the internal current control circuit to set the maximum current limit. Efficiency is enhanced by using synchronous rectification.

A full suite of protection features is provided including MOSFET shoot-through, undervoltage, overvoltage, HALL logic fault, low motor current and short to ground, supply and across motor winding. The dead time can be set by a single external resistor.

www.allegromicro.com

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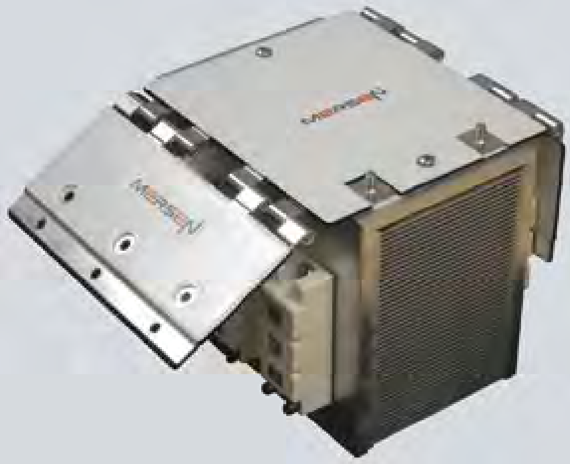

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WIMA DC-Link Capacitors

WIMA DC-LINK capacitors are designed for the high power converter technology. At high frequencies they show a higher current carrying capability compared to electrolytic capacitors. Further outstanding features are e.g.:

- Very high capacitance/volume ratio
- High voltage rating per component
- Very low dissipation factor (ESR)
- Very high insulation resistance
- Excellent self-healing properties
- Long life expectancy
- Dry construction without electrolyte or oil
- Particularly reliable contact configurations
- Customer-specific contacts, capacitances or voltages

WIMA DC-LINK capacitors are available with capacitances from 2 µF through 8250 µF and with rated voltages from 400 VDC through 1500 VDC. The components are environmentally compatible with the RoHS 2011/65/EU regulations.

www.wima.com

Ruggedized Axial-Leaded Aluminum Electrolytic Capacitor Meets Specs from -40 ° to +150 °C

Cornell Dubilier Electronics, Inc. (CDE) has introduced a line of axial-lead aluminum electrolytic capacitors for applications which require very high-performance under all operating

conditions. The AXLH is a uniquely-designed axial-lead electrolytic that has the performance characteristics required for mission-critical circuitry. Continuous ripple current is rated at up to 28 amps RMS. With a load life rating of 2,000 hours at full-rated voltage and 150 °C, and a shelf life of 10 years, the AXLH will stand the test of time.

Targeted application fields include military, aerospace, off-road vehicles, infrastructure system electronics. Nine values are available, from 470 µF to 4,700 µF, with ratings from 25 Vdc to 63 Vdc. Maximum ESR ranges from 13 to 32 mΩ at100 kHz.

Where other electrolytics may lose performance under very hot conditions, a hallmark of the AXLH is its ability to handle high ripple current at elevated temperature. Like other CDE capacitors, the AXLH Series is subject to the industry's most rigorous dynamic testing. Procedures outlined in MIL-STD-202, method 204 are used to record the 20g vibration tests. AXLH case diameter is a low-profile 20 mm for all values. Depending on values, lengths vary from 26.5 to 42.5 mm. The axial-lead wires are a substantial 1 mm. The devices are RoHS compliant and free of conflict materials.

www.cde.com/AXLH/AXLH.htm

Highly Integrated Multi-Cell Battery Pack Monitor

Intersil, a subsidiary of Renesas Electronics Corporation announced the ISL94202 3-to-8 cell battery pack monitor that supports lithium-ion (Li-ion) and other battery chemistries used in applications such as vacuum cleaners, lawn equipment, handheld power tools, e-bikes, scooters, toys, and energy storage systems. Li-ion batteries are smaller, weigh less, and deliver longer battery life than other battery chemistries, but require monitoring and protection for safe use. The highly integrated ISL94202 battery pack monitor enables ultra-small 2-terminal designs, and accurately monitors, protects and cell balances rechargeable battery packs to ensure safe operation and charging.

The ISL94202 operates as a stand-alone battery protection system using an internal state machine with five pre-programmed modes for accurately balancing and controlling each battery cell. It monitors and protects the battery pack from catastrophic events such as hardware faults, short circuit conditions, and cell voltage overcharge/over-discharge and meets the UL2054, UL2271/72 and IEC62133 specified pack safety requirements. Designers can program the ISL94202 battery monitor's protection settings to enable the industry's smallest, low-cost battery packs without requiring an external microcontroller. If required, the ISL94202 can also communicate with an external microcontroller via I2C serial bus to provide additional fuel gauge measurements, including state of charge and state of health information. Precise fuel gauge status is provided by the device's high-side current measurement feature.

www.intersil.com/products/isl94202

eGaN® Technology Takes a Quantum Leap in Both Performance and Cost

silicon (eGaN®) power FETs and ICs advances the performance capability while lowering the cost of off-the-shelf gallium nitride transistors with the introduction of the EPC2045 (7 mΩ, 100 V) and the EPC2047 (10 mΩ, 200 V) eGaN FETs. Applications for the EPC2045 include single stage 48 V to load Open Rack server architectures, point-of-load converters, USB-C, and LiDAR. Wireless charging, multi-level AC-DC power supplies, robotics, and solar micro inverters are example applications for the 200 V EPC2047.

Widening the performance/cost gap with equivalent silicon power transistors, the 100 V, 7 mΩ EPC2045, cuts the die size in half compared to the prior-generation EPC2001C eGaN FET. The 200 V, 10 mΩ EPC2047 eGaN FET also cuts the size in half so that it is now about 15 times smaller than equivalently rated silicon MOSFETs.

Designers no longer have to choose between size and performance – they can have both! The chip-scale packaging of eGaN products handles thermal conditions far better than the plastic packaged MOSFETs since the heat is dissipated directly to the environment with chip-scale devices, whereas the heat from the MOSFET die is held within a plastic package.

There are three development boards available to support easy in-circuit performance evaluation of the EPC2045 and the EPC2047 respectively. The EPC9078 and EPC9080 support the 100 V EPC2045, whereas the EPC9081 features the 200 V EPC2047.

www.epc-co.com

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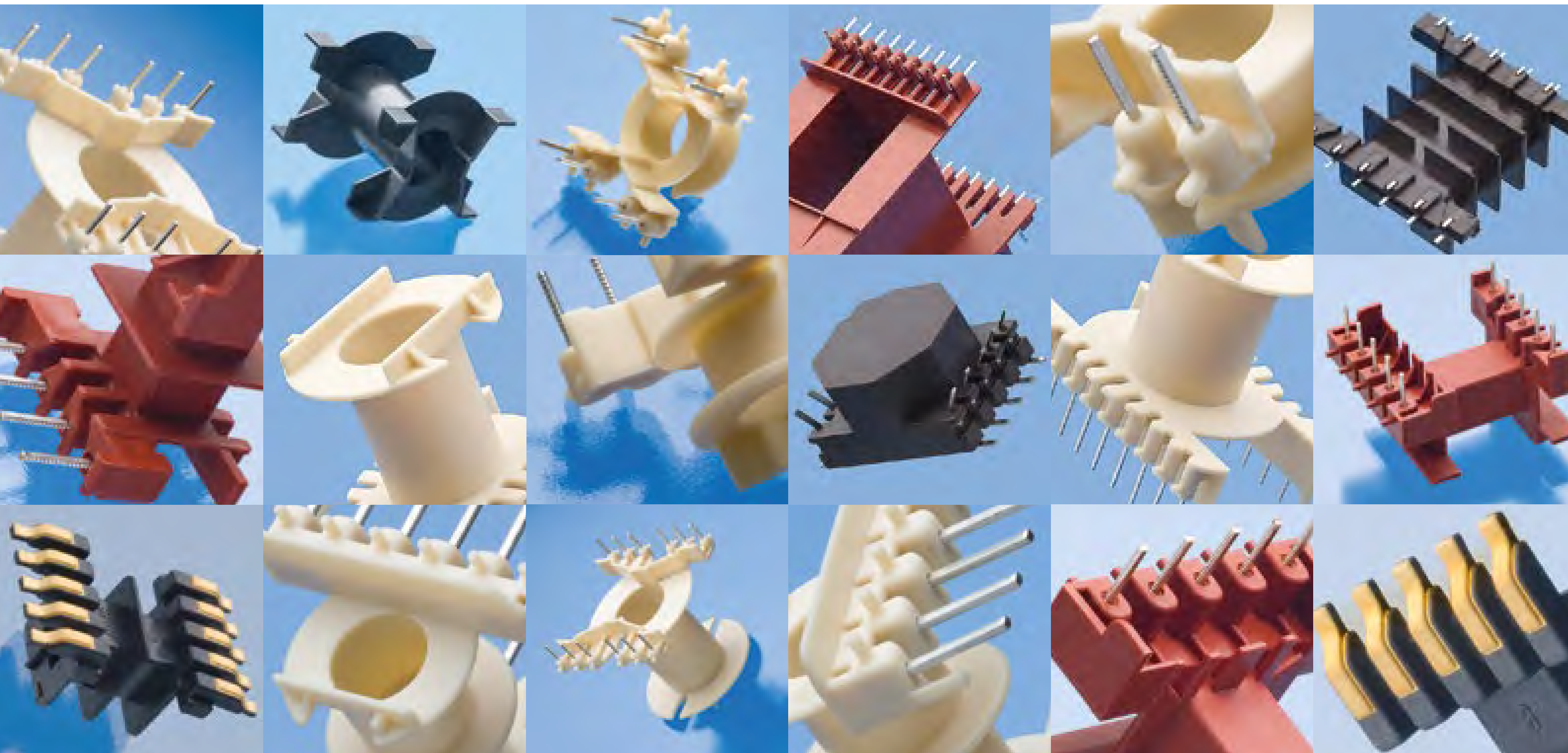


www.norwe.com | www.norwe.eu

Digitally Controlled Surge Voltage, Inrush, and Short-Circuit Protection

IXYS Corporation (NASDAQ: IXYS), a global manufacturer of power semiconductors and ICs for energy efficiency, power management, transportation, medical, and motor control applications, today announced a digital power design that demonstrates surge voltage protection as well as inrush current and short-circuit protection for battery powered devices based on the Zilog MCU.

This reference design demonstrates the cost effective use of proven Zilog MCU for digital power control, integrating IXYS power and digital control software in one ready to use design.

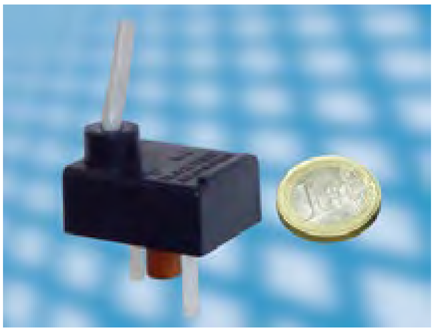
Compared to hardware only solutions, digital control ones help simplify the system and provide power designers with a greater flexibility at the same time. This design makes use of the Z8F3281 microcontroller (MCU) from Zilog, Inc. for digital control. It protects the load from transient voltage spikes emanating from the battery and also safeguards the battery from inrush current and short-circuit conditions at the load.

The load current can range from 0 to 20A, and the output voltage is programmable from 12V to 48V, using the MCU or an external resistor divider. The inrush current limit is set at 30A, and the surge voltage protection is up to 150V. At a load current of 20A, the efficiency is at 99 percent in the idle state. When the output voltage is at 24V, it becomes 99.5 and 98 percent at 48V and 12V, respectively.

www.ixys.com

Compact Calibrated 2000A Current Sensing Busbar Probe

The Raztec RAZP-2000 sensor is a compact, high current, open loop current sensor, capable of operating under high overload and ambient temperature conditions. It is specifically designed for use in applications where small size is critical and current is to be measured economically. It mounts through a 6.5 or 7.5mm diameter hole in the current carrying bus bar. The RAZP-2000 incorporates hybrid technology to assure excellent speed of response for the fast detection of fault current transients. The sensor is optimized for linearity over the entire current range. There is also negligible hysteresis which makes



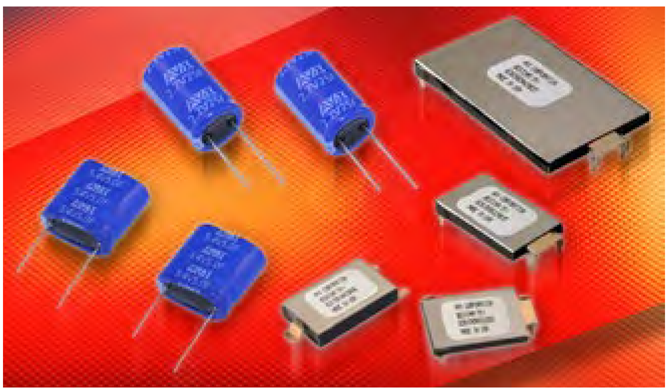
current sensing over a wide dynamic range practical. It is rated for common automotive temperature ranges with very stable performance parameters that set a new benchmark for open-loop current sensors. The RAZP-2000 is configurable for a wide range of busbar sizes and current ratings and is adapted every time to the specific project application for an optimal result. Please contact us with your technical requirements.

Pewatron AG, with Headquarter in Zurich and branch office in Munich – Germany is the official European distributor of Raztec products since 2009.

www.pewatron.com

Supercapacitor Technology Delivers Ultra-High Pulse Power and Capacitance Densities

AVX Supercapacitors or Double Layer Capacitors provide a unique combination of characteristics recognised as delivering an excellent



compromise between electronic and dielectric capacitors. Available now in Europe through TTI, Inc., a world leading specialist distributor of electronic components, the technologies developed by AVX in its BestCap, SCC Series Cylindrical and SCM Series Module capacitors enable very high pulse power and capacitance density, providing reliability in multiple applications.

The BestCap Series offers capacitance of 4.7mF to 1000mF and Voltage of 3.6V to 20V. Designed for high reliability and long life, the devices are low profile, only 2mm to 6mm in height. They feature minimum capacitance loss for short duration pulses, low ESR and low leakage. Available mounting options include surface mount, though hole and wires. Applications include RFID, GSM / GPRS / WIFI Modules, gas and water meters, IoT applications, portable devices, security devices and others.

www.ttieurope.com

Best-in-Class 900V MOSFETs Enhance Power and Efficiency of Flyback Converters

Power-supply designers can satisfy system demands for higher power and greater efficiency using the latest 900V MDmesh™ K5 super-junction MOSFETs from STMicroelectronics, which deliver best-in-class on-resistance (RDS(ON)) and dynamic characteristics.

A 900V breakdown voltage assures extra safety margin in systems with high bus voltages. The new series contains the first 900V MOSFETs with RDS(ON) below 100mΩ, and gives the industry's best RDS(ON) among DPAK devices. Also, with the industry's lowest gate charge (Qg), they ensure faster switching for greater flexibility where a wide input-voltage range is required. These characteristics ensure high efficiency and reliability in all types of flyback converters including standard, quasi-resonant, and active-clamp designs covering power ratings as low as 35W up to 230W or higher. In addition, low input and output capacitances (Ciss, Coss) enable zero-voltage switching with minimal energy loss in half-bridge LLC resonant converters.

The increased safety margin and superior static and dynamic behavior of the new devices enable designers to improve the performance of a wide variety of products such as server power supplies, 3-phase switched-mode power supplies (SMPS), LED lighting supplies, electric-vehicle (EV) chargers, solar generators, welders, industrial drives, and factory automation.

ST's family of MDmesh K5 super-junction transistors now offers numerous choices at voltage ratings of 800V, 850V, 900V, 950V, 1050V, 1200V, and 1500V. Together with versatile package options including TO-220AB, TO-220FP, TO-247, TO-247 Long Lead, IPAK and I2PAK, as well as D2PAK and DPAK surface-mount power packages, ST's super-junction devices present designers with a comprehensive portfolio.

www.st.com/mdmeshk5

Versatile, Stable, Low-Voiding Indium8.9HF Solder Paste at SMT Hybrid Packaging 2017

Indium Corporation will feature its void-reducing Indium8.9HF Solder Paste to help customers Avoid the Void® at SMT Hybrid Packaging May 16-18, in Nuremberg, Germany.

Indium8.9HF is a no-clean, halogen-free solder paste that delivers versatility and stability in the printing process. Under optimal process conditions, Indium8.9HF: Demonstrates consistent printing performance for up to 12 months when refrigerated; Maintains excellent printing and reflow performance after remaining at room temperature for one month and Delivers excellent response-to-pause even after being left on the stencil for 60 hours. See Indium Corporation at SMT booth 4-321.

www.indium.com

LinPak

New standard for fast high-power switching.

The innovative LinPak concept answers the market's request for a new package that offers exceptionally low-stray inductance and, due to separated phase and DC connections, allows for simpler inverter designs. The LinPak low-inductive phase leg IGBT module is available in 1700 V and 3300 V with current ratings of 2 × 1000 A and 2 × 450 A, respectively.

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AEC-Q100 Qualified Family of 40V PoL Regulators

Exar Corporation announced a new AEC-Q100 qualified family of 40V switching regulators for automotive applications such as infotainment head units and Advanced Driver Assistance Systems (ADAS). The XR76203-Q, XR76205-Q and XR76208-Q are 3A/5A/8A synchronous step-down regulators designed to provide a wide 5.5V to 40V input voltage range and an adjustable output voltage down to 0.6V while providing excellent transient response and output accuracy over the entire voltage range. In addition, the XR76208-Q is the highest current (8A), fully synchronous, 40V regulator on the market that offers AEC-Q100 qualification.

The XR76203/5/8-Q family features Exar's proprietary emulated current mode Constant On-Time (COT) control loop. It provides fast transient response with ceramic output capacitors and excellent line and load regulation while simplifying system design. The family also offers a host of supervisory and protection features for proper sequencing, safe operation under abnormal operating conditions and light load operation.

This 40V regulator family has met the AEC-Q100 qualification requirements for Temperature Grade 1 (-40°C to 125°C), HBM ESD Class Level 2 and CDM ESD Class Level C4B. In addition, the automotive grade DC/DC buck regulators are offered in a 5mm x 5mm QFN with wettable flanks allowing for 100% automatic optical inspection of solder wetting post-assembly.

www.exar.com/xr76205-q

Superjunction +FETs™ Push Performance Envelope

D3 Semiconductor, a company bringing together affiliated semiconductor companies and top-talent experts, announces its inaugural entry into the power semiconductor market with the launch of its +FET™ line of 650V-rated superjunction MOSFETs.

+FET MOSFETs enable high-efficiency solutions for a range of hard-switched applications, including PFC boost and inverters used in telecom, enterprise computing, UPS and solar.

The +FET product roll-out includes over 50 devices with 13 different RDS(ON) ratings ranging from 1000 mOhms to 32 mOhms. Packages types include: traditional thru-hole (TO-220/TO-220FP), surface-mount (DPAK/D2PAK) and advanced surface-mount (5x6/8x8) devices.

For all package sizes and ratings, D3 Semiconductor's +FET devices exhibit a Qg RDS(ON) FOM (Figure of Merit) that is among the highest available.

The high efficiency of the new +FET MOSFETs, gained by lowering switching and conduction losses, helps to simplify thermal management. The devices' smooth switching behavior reduces switching noise and drives faster design cycles by lowering the need for snubber circuits. Their advantage of higher ampacity per package type improves power supply density, which in turn enables the use of advanced surface-mount packages in higher power designs.

www.d3semi.com/MOSFET-Overview

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»Bandwith DC to 350 kHz

Series RAZCi
»From 0...±12 A to ±60 A configurable
»Linearity up to 0.1...0.2 %

Series SWL-DC
»From 0...±5 A to ±500 A
»Accuracy ±1 % FS

Series KIFHY-1
»From 0...±6 A to ±50 A
»Rise time 0.3 μs
»Bandwith DC to 300 kHz

Series YW-THX
»0...±100 A to ±1000 A
»Accuracy ±1 %

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HiperPFS-4 Power Factor Correction ICs Enable 98% Efficient PFC Designs Up to 550 W

Power Integrations announced its HiperPFSTM-4 family of power factor correction (PFC) ICs. The device family serves applications targeting excellent efficiency and power factor performance at both full load and light load conditions. HiperPFS-4 devices incorporate a 600 V MOSFET suitable for 305 VAC input and a high efficiency, variable frequency, CCM PFC controller in a single, compact, electrically isolated, heatsinkable package. The IC family delivers high power factor, low THD and uniformly high efficiency across a wide output load range, allowing OEMs to meet the demanding 80 PLUS® Platinum and Titanium power supply standards.

HiperPFS-4 ICs achieve a high power factor of above 0.95 and low THD even at 20% of rated load. The devices also meet the stringent surge requirements of major computer and entertainment equipment providers, such as the 1 second 410 VAC input test, which ensures field reliability and robustness against voltage swells and surges.

The new HiperPFS-4 ICs suit enclosed designs up to 300 W, open frame power supplies of up to 400 W and highline applications up to 550 W. Protection features include UVLO, UV, OV, OTP, brown-in/out, cycle-by-cycle current limit and power limit. HiperPFS-4 ICs consume less than 60 mW at 230 VAC while regulating output at no-load and less than 20 mW in sleep mode.

Comments Edward Ong, product marketing manager at Power Integrations: “The HiperPFS-4 product family offers very high efficiency and power factor plus low THD across a wide load range. The benefits afforded by the unique frequency-sliding control technology enable HiperPFS-4 designs to deliver very high efficiency down to very light load – important when targeting EU CoC requirements that include a 10% load efficiency measurement. The 600 V integrated power MOSFET and sophisticated protection features make the IC family ideal for use in regions where input voltage fluctuations can be severe. HiperPFS-4 devices provide safe PFC operation with a good margin at 305 VAC input for data centers and commercial LED lighting. Other applications include refrigerators (which increasingly contain high PFC specification requirements), cordless tool chargers and eBike battery chargers.”

Available for high and low line applications, HiperPFS-4 ICs are available in thermally-efficient eeSIP packaging, which simplifies heatsink mounting. Devices cost $1.46 in 10,000-piece quantities

www.power.com/products/hiperpfs-4/

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Former manager of R & D / managing director in D, USA, NL,A.
Consultant and owner of an electronics design lab since 23 yrs.
140 publications resp. patent applications, inventor of
the current-mode control in SMPS (US Patent 3,742,371).
Names and business affairs of clients are kept strictly confidential.

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Light Pipes for Status Display

SCHURTER improves upon a classic product: the new 6600-5 series IEC outlets are available with integrated light pipes. An intelligent, space and cost-saving solution for PDUs used in data centers and other multi-distributed power applications.

PDUs often use LEDs mounted in between outlets to display a current status. The high packing density of servers in modern data centers demands the same of power distribution units. With SCHURTER's appliance outlet, the integrated light pipes provide space and assembly cost savings over conventional strip designs. Service technicians are able to clearly see which systems are working properly, or respond to required maintenance adjustments. The triggering of the LEDs is freely configurable, wherein each state can be clearly and independently represented. An outlet could, for example, signal an outage with a red LED, or a critical power consumption pattern with a yellow LED.

www.schurter.com

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Electronics in Motion and Conversion

May 2017

High humidity robustness of ABB's IGBTs and Diodes

ABB's high-power thyristors

Even the device was designed decades ago, the thyristor maintains its unique position in the high-power semiconductor market. This is because of its attractive price performance ratio and due to the lowest on-state value, high reliability and outstanding performance.
ABB has developed a new range of thyristors offering very low loss design, low leakage current and high blocking stability. The safe operation temperature is up to T_{jmax} = 125 °C assuring a reliable operation in demanding applications like HVDC, FACTS, hydro-electric or industrial applications.

ABB's Poster Sessions and Conferences at PCIM Europe 2017

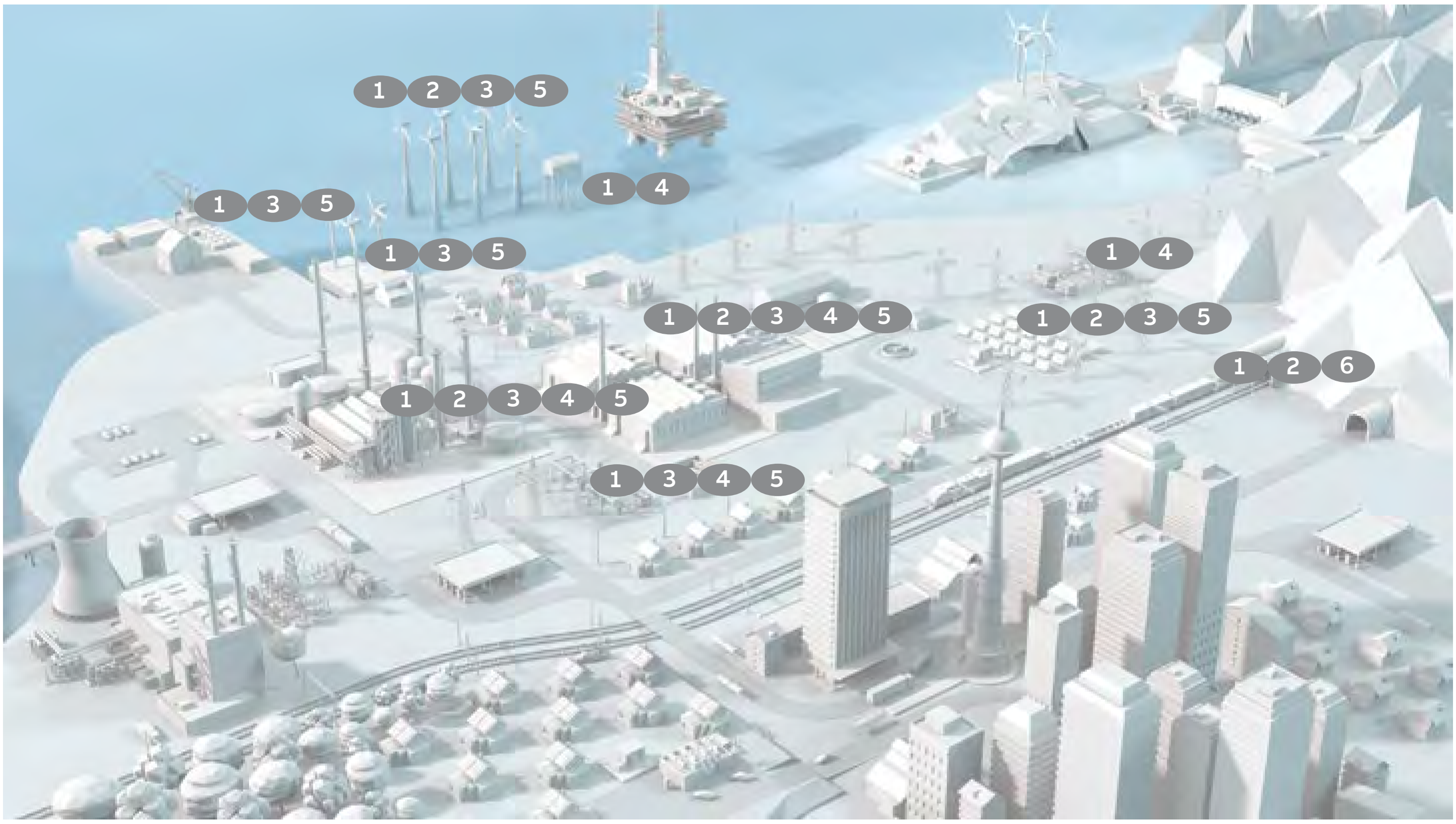
Poster Sessions

- “New Generation Large Area Thyristor for UHVDC Transmission”
  Jan Vobecky, Karlheinz Stiegler, Marco Bellini, Urban Meier, ABB Switzerland
  Tue, 16 May 2017, 15:30, Foyer Ground Floor Entrance NCC Mitte
- “The Next Generation of 4500 V / 3000 A BIGT StakPak Modules”
  Franc Dugal, Andreas Baschnagel, Munaf Rahimo, Arnost Kopta, ABB Switzerland
  Tue, 16 May 2017, 15:30, Foyer Ground Floor Entrance NCC Mitte
- “Optimized Layout of 1700 V LoPak1 IGBT Power Module by Holistic Design Approach”
  Sven Matthias, Samuel Hartmann, Athanasios Mesemanolis, Raffael Schnell, ABB Switzerland
  Tue, 16 May 2017, 15:30, Foyer Ground Floor Entrance NCC Mitte
- “Paralleling of LinPak Power Modules”
  Andreas Baschnagel, Daniel Prindle, Silvan Geissmann, Fabian Fischer, Samuel Hartmann, Raffael Schnell, Gontran Pâques, Arnost Kopta, ABB Switzerland
  Tue, 16 May 2017, 15:30, Foyer Ground Floor Entrance NCC Mitte
- “A Technology Platform for Reverse Conducting IGCT with 94 mm device diameter”
  Maria Alexandrova, ABB Switzerland
  Tue, 16 May 2017, 15:30, Foyer Ground Floor Entrance NCC Mitte

Conferences

- " IGCT based Modular Multilevel Converter for an AC-AC Rail Power Supply"
  David Weiss, Michail Vasiladiotis, Noemi Drack, ABB Switzerland; Andrea Grondona, ABB Sweden
  Tue, 16 May 2017, 12:00, Room Mailand
- “An Optimized Plug-In BIGT with No Requirements for Gate Control Adaptations”
  Munaf Rahimo, Charalampos Papadopoulos, Chiara Corvasce, Arnost Kopta, ABB Switzerland
  Wed, 17 May 2017, 10:30, Room Brüssel 2
- “The Next Generation of High Power Modules with Enhanced Trench BIGT Technology ” Charalampos Papadopoulos, Munaf Rahimo, Chiara Corvasce, Maxi Andenna, Arnost Kopta, ABB Switzerland
  Wed, 17 May 2017, 11:30, Room Brüssel 2
- “1.7 kV High-Current SiC Power Module Based on Multi- Level Substrate Concept and Exploiting MOSFET Body Diode during Operation”
  Slavo Kicin, Enea Bianda, Francisco Canales, ABB Corporate Research, Switzerland; Samuel Hartmann, Fabian Fischer, ABB Switzerland
  Thur, 18 May 2017, 14:30, Room Brüssel 1

ABB Semiconductors' portfolio and applications



1. High-power IGBT modules (LinPak, HiPak and StakPak)
2. Medium-power IGBT modules (62Pak and LoPak)
3. Fast recovery, rectifier and welding diodes
4. Thyristors
5. IGCTs
6. GTOs

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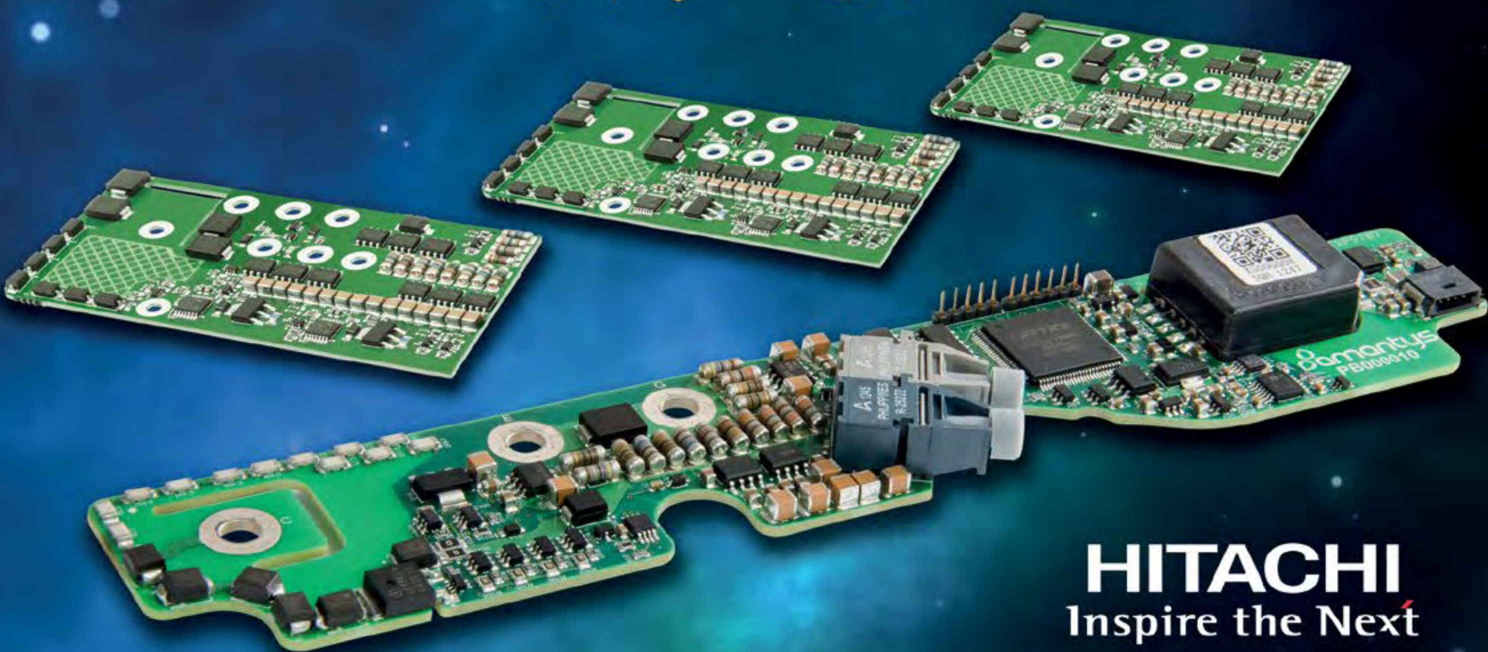

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