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Bodo´s Power Systems®

Electronics in Motion and Conversion

March 2016

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The Gallery

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Events

CIPS 2016, Nuremberg, March 8-10
https://conference.vde.com/cips/2016/Pages/welcome.aspx

Smartsystemsintegration,
Munich Germany, March 9-10
http://www.smartsystemsintegration.com

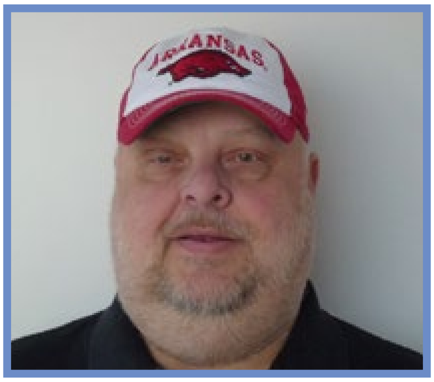
APEC 2016,
Long Beach, CA, March 20-24
http://www.apec-conf.org/

New Energy Husum 2016,
Husum Germany, March 17-20
http://www.new-energy.de/new_energy/de/

ExpoElectronica 2016,
Moscow Russia, March 15-17
http://expoelectronica.primexpo.ru/en/

battery university 2016,
Aschaffenburg, Germany, April 5-7
http://www.batteryuniversity.eu

What a Wonderful World,



We live in a world that has great resources - manmade disasters are not necessary. Nature always teaches us to stay together to overcome natural disasters. War continues in too many places, is destroying the life of millions of people, and the shortsighted seek to fence themselves off from refugees believing that will solve the problem. While countries such as Turkey are currently hosting 2.5 million refugees, mainly from Syria, the whole of Europe is holding back from accepting far fewer. Thanks to Chancellor Merkel, Germany showed great humanitarianism by welcoming refugees into the country last year. What are a million refugees in a wealthy country of 80 million? "Bavarian-Beer-Tent" politicians are beyond having a human understanding of the issue. Integrating the refugees in our country will only strengthen our economy as they become consumers and workers.

The combatants and the world must find ways to end the warfare and allow refugees to get back to their countries and their homes in a just society. With such little progress, world leaders seem so weak, or seem influenced by some other agenda. In free countries we vote for our leaders. Do we always get good judgement, or do we only get what the most simple-minded or outspoken in the population vote for?

In contrast, some natural disasters, like global warming, can be slowed down or solved with an adequate technical course. Modern life demands the use of electric power. But we must reduce our consumption of electrical power that is generated by natural resources like oil, coal, and by nuclear power. We have seen the risks and still face contaminated places in Chernobyl and Fukushima. We still miss the learning curve of politicians on this issue. Decision-makers who are pro nuclear energy should be required to clean up the next disaster.

It is good to see that renewable electric power is moving ahead in many places around the world. Water power generation is well established as the historic renewable, wind and solar power continue to expand the base developed just in the last decades. Renewable energy is now a significant part of the supply. In some areas more green power is produced than is consumed, so storage and a robust smart grid will be a solution. Intelligent electronics and suitable high power switches are doing the job to get there. A really smart grid will only function with advanced power semiconductors. Key elements will be wide-band-gap semiconductors, based on SiC or GaN.

Conferences and shows are great forums for discussing progress in technology. APEC is again in Long Beach, California, and provides a traditional assembly of engineers and academia discussing future progress in electronics. A main subject is efficiency, minimizing losses in electronic designs. A large portion of the discussions will be on wide-band-gap semiconductors. The CIPS conference in Nuremberg in early March will also focus on wide-band-gap semiconductors. I look forward to meeting my friends at these events and to chatting about future designs.

This is the third issue for 2016. All technical articles are archived on my website.

Bodo's Power Systems reaches readers across the globe. If you speak the language, or just want to have a look, don't miss our Chinese version: www.bodoschina.com

My Green Power Tip for March:
Do not open your fridge too frequently. Think of what you need and get your food in and out in one fast action. Avoid opening the door for each item.

See you at APEC in Long Beach

Best Regards

KEEP UP WITH THE TIMES

LF xx10

Current transducer range
Pushing Hall effect technology to new limits

To save energy, you first need to measure it! To maximise energy savings, you need to measure the current used accurately!
By using the most advanced materials available, LEM's new LF xx10 transducer range breaks new ground in accuracy for Closed Loop Hall effect transducer performance.
LEM ASIC technology brings Closed Loop Hall effect transducer performance to the level of Fluxgate transducers and provides better control and increased system efficiency, but at a significantly lower price.
Available in 5 different sizes to work with nominal currents from 100A to 2000A, the LF xx10 range provides up to 5 times better global accuracy over their operating temperature range compared to the previous generation of Closed Loop Hall effect current transducers.
Quite simply, the LF xx10 range goes beyond what were previously thought of as the limits of Hall effect technology.

- Overall accuracy over temperature range from 0.2 to 0.6% of I_{PN}
- Exceptional offset drift of 0.1% of I_{PN}
- Fast response time less than 0.5μs
- Higher measuring range
- 5 compact sizes in a variety of mounting topologies (flat or vertical)
- Immunity from external fields for your compact design
- 100% fully compatible vs LEM previous generation
- -40 to +85°C operation

www.lem.com

At the heart of power electronics.

LEM®

Exar Corporation Appoints Robert Pfister as VP of EMEA Sales

Exar Corporation announced the appointment of Robert Pfister to the position of Vice President, EMEA Sales. Mr. Pfister brings 25 years of professional experience in sales and management for technology companies and will be responsible for driving all aspects of Exar's success in Europe, including strengthening key customer relationships, growing and increasing market penetration.

"Robert's extensive experience as a sales executive in Europe will be very valuable to Exar as we continue to grow our business in this region of the world," said James Lougheed, Exar's Vice President, Sales and Marketing. "He will play a key role in driving sustainable revenue growth extending our recent progress in this important market."

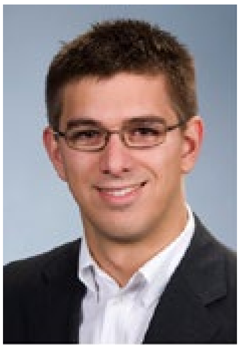
Prior to joining Exar, Mr. Pfister served as Vice President of Sales of Intersil and Managing Director for

Intersil Germany. Before his tenure at Intersil, Mr. Pfister held sales positions at Harris Semiconductor

and General Electric. Located at Exar's corporate office in Germany, Mr. Pfister will be Exar's top sales executive in Germany. He holds an engineering degree in electronics from University of Applied Sciences in Regensburg, Germany.

www.exar.com

European Director of Sales



Christopher Rocneanu joins United SiC incorporated as European Director of Sales. Since the start of his career he has been focused on wide bandgap products in the industrial and automotive market. Being driven by the idea to convert the power electronic world into using SiC and being strongly customer oriented he will be a welcome addition to USCI team of technical experts.

Prior to joining USCi he was a Field Application Engineer at MEV Elektronik GmbH and afterwards Business Development Manager, Europe at ROHM Semiconductor GmbH. He was responsible for SiC devices and related products and increased the sales revenue and reputation in the market significantly by executing on-time, on site customer support, market and product analysis and competitor analysis studies.

www.unitedsic.com

PEMD 2016 Conference Program Announced

Join over 400 power electronics, machines and drives specialists at one of the biggest power electronics confere ences in the UK. PEMD 2016 will be attended by both industry and academia and attracts some of the most prominent industry names to our conference exhibition.

The program spans 3 full days with 5 different conference streams. You will hear over 200 oral presentations and over 100 poster presentations – this year's conference program is bigger and better than ever offering high quality, peer reviewed papers in all aspects of power electronics, machines and drives.

The Conference sessions include:

- Aerospace and marine machines
- Converters for grid connection and power distribution
- Electric fuel cell / hybrid vehicles
- HVDC and converters
- Machine drive control
- Multi-level converters
- Permanent magnet machines
- Solar PV, tidal, wave, sea, river and hydro power systems

PEMD 2016 takes place in Glasgow on 19-21 April 2016. See the full program and register your place.

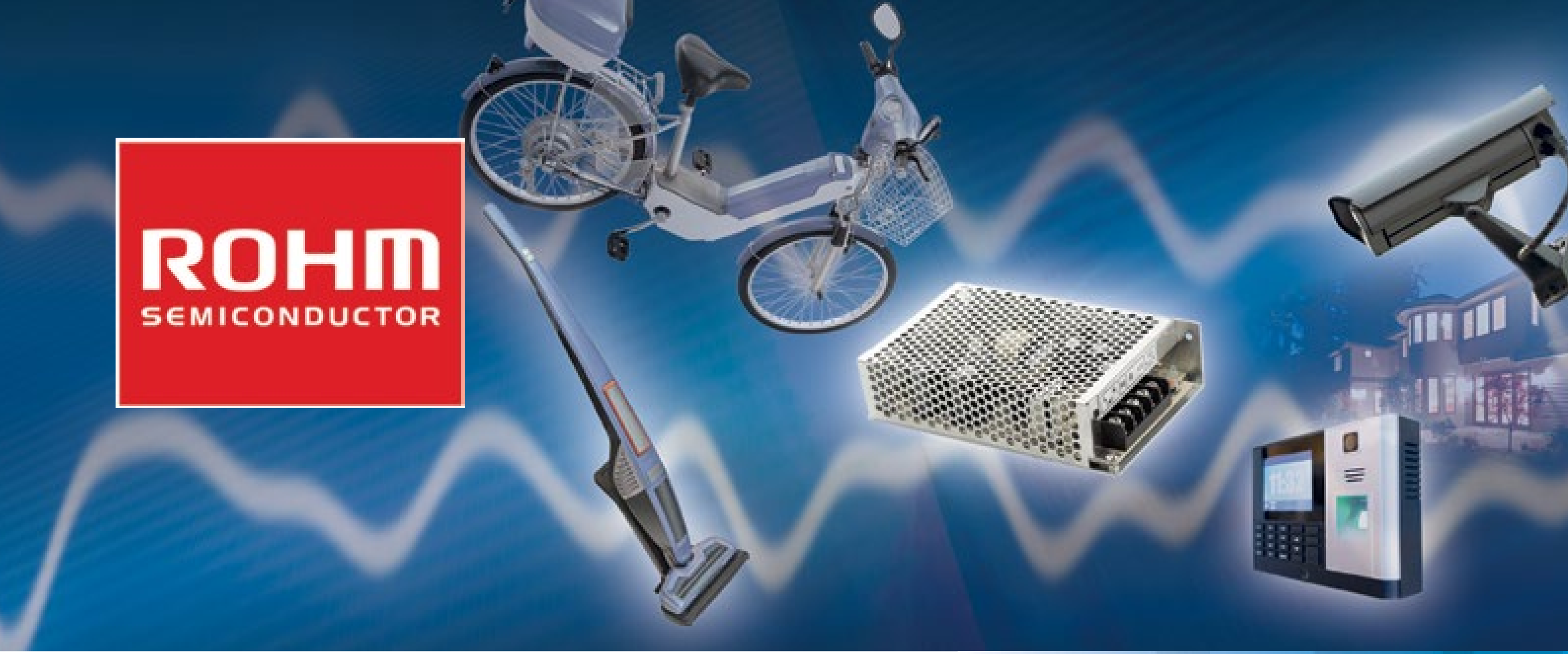
www.theiet.org/pemd

Strengthening the Sales Team in Germany

Starpower Europe continues to expand. "With Rickmer Heubeck-Wex, we were able to add an experienced expert to the sales team. He will henceforth mainly support the German and Central European customer base and be the contact person for key accounts", explains Peter Frey, Managing Director of StarPower Europe. By developing the sales force, customers are able to receive a greater degree of support for technical issues. The technical sales department works hand in hand with the European R&D Center, in which StarPower recently invested close to a million euros. Additionally, a network of international distributors and local authorised dealers ensures a comprehensive coverage for medium to small-sized customers.

Mr Heubeck-Wex has been working within the power semiconductor market for many years and will be joining the sales team in Nuremberg. The engineer for energy and system automation was previously employed as the Product Manager, Key Account Manager and Head of National Sales at the company Semikron for 16 years in the division of semiconductor modules and systems, and brings with him many years of application experience with a focus on drive technology, power supplies and renewable energies.

www.starpowereurope.com



HIGH VOLTAGE DC/DC CONVERTER ICs

- High Voltage
- High Reliability
- Ultra-High Efficiency

ROHM provides a complete line-up of High Voltage DC/DC-Converter ICs. In addition to the just released BD9G341, ROHM offers other solutions like BD9G101, with internal high-side 42V Power MOSFET, providing 0,5A DC output with small SOT23 package.

BD9G341 Features

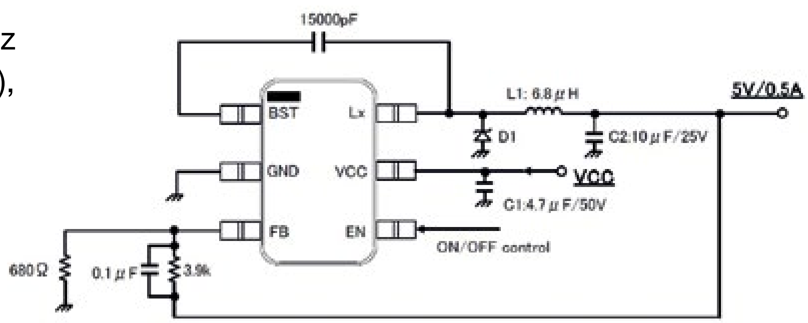
- Wide input voltage range: 12V to 76V (80V max.)
- Output current: up to 3A
- High efficiency under light and heavy load conditions

BD9G101 Features

Tiny 6-pin SOT23 SSOP6 package!

- V_{IN} = 6V to 42V
- V_{OUT} = 1V to 0,7* V_{CC}
- I_{OUT} = 500mA
- Switching Frequency = 1,5MHz
- Under Voltage Lockout (UVLO), Thermal Shutdown (TSP), Over Current (OCP) Protection
- ENABLE pin
- Operating Temperature of -40 ˚C to +105 ˚C

Typical Application Circuit



ROHM‘s DC/DC-Converter-ICs are built for Power supplies, Industrial Distributed applications, Automotive, Battery Powered Equipment

Website and Centralized Product Database Launch

Dean Technology, Inc. announced the launch of its new website at www.deantechnology.com. This release marks the first step in a multi phased effort that the company is taking to streamline customer communications and the management of product data.

At the heart of the new site is a custom built product database that is integrated with other IT systems as well as internal workflows and processes. This ensures the consistency and accuracy of all product and technical information provided, and helps to keep staff focused primarily on customers' needs. The website aims to keep all navigation and display as simple as possible, while allowing for maximum expansion and growth.

"Our new website is really just the first step in efforts we are taking to transform how we interact with our customers and market," said Griffin Caruolo Director of Marketing and Business Development for Dean Technology. "In order to keep up with a world that demands more information, faster, and to ensure the accuracy and consistency of the information we give out required us to take a holistic look at how we run our business. The results of that review, and a multiple year development process, are exceptionally exciting, and this new site is just the beginning of what we intend to offer. Look for even more great things from us in the coming months!"

www.deantechnology.com

Licence for SKEDD-Technology to Diehl Metal Applications

With SKEDD-technology, Würth Elektronik ICS has developed a simple and dependable alternative to solder and press-fit technology. SKEDD realizes an innovative connection concept: components or connectors that use SKEDD to attach directly to a circuit board – without an adapter – can also be connected and disconnected over the course of many cycles.

Diehl Metal Applications develops and manufactures customized solutions across the entire value-added chain: prematerial, tool manufacturing, stamping technology, S+D press-fit zones, plating technology, and metal-plastic compaind systems. By using SKEDD, the company will expand its portfolio of connection technologies between contact systems and circuit boards. "For DMA, SKEDD represents an ideal addition to our S+D press-fit zone product family and a future-oriented further development of our innovative solutions for our customers across the world," explains Frank Uibel, Managing Director of DMA GmbH in Berlin.

"We're glad we could attract Diehl Metal Applications, one of the leading manufacturers of press-fit zones and metal-plastic composite systems, as a SKEDD-licence partner. This is another important milestone in establishing SKEDD-technologies in the market", says Dr. Klaus Wittig, Managing Director of Würth Elektronik ICS.

http://www.we-online.com

Preforms Sintering Technology at APEC 2016

Alpha Assembly Solutions, the world leader in the production of electronic soldering materials, plans to feature the ALPHA® Argomax® Ag sinter product range at the 2016 APEC show, Booth #1561, to be held in Long Beach, California from March 20th – 24th.

Alpha will demonstrate its new Argomax® 9000 Silver Sintering Preforms which is a world first for the Power Semiconductor Industry. These innovative preforms deliver superior thermal conductivity, ultra-high reliability and excellent electrical conductivity. They have shown excellent performance in large area attachment and can help to simplify the manufacturing process.

Argomax® 9000 preforms are proving to the most reliable die attach materials on the market. It can be used in a range of applications from power modules to Automotive applications, in areas in which thermal and electrical conductivity and joint strength is crucial. The preforms are available for sampling in tape and reel format and waffle pack for standard pick and place equipment.

www.AlphaAssembly.com

The Global Shift Towards 100% Renewables

The World Wind Energy Association (WWEA) and New Energy Husum are pleased to invite all small and medium wind stakeholders to participate in the 7th World Summit for Small Wind (WSSW2016), taking place in Husum/Germany on 17 and 18 March 2016, in parallel with the New Energy Husum Trade Fair 2015 (17- 20 March 2016). The main theme of the 7th WSSW is New opportunites for small wind – the global shift towards 100% renewables. The summit is aimed at jointly exploring new markets and potential applications for small wind turbines. Also, to present new innovative business models that could exploit the competitiveness of the technology in developed and developing countries.

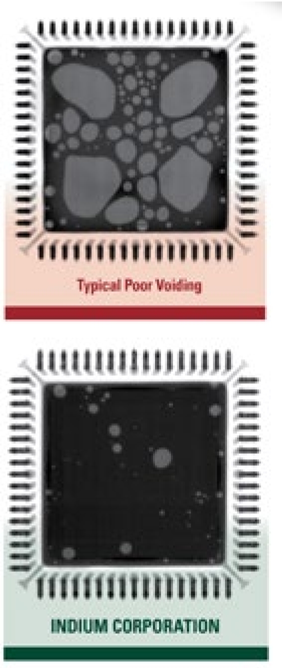
new energy

HUSUM · 17–20 MARCH 2016

www.small-wind.org

www.new-energy.de

Feature Low-Voiding Solder Paste at IPC APEX 2016



Indium Corporation will feature its void-reducing no-clean solder pastes to help customers Avoid the Void™ at IPC APEX Expo, which will be held on March 15-17 in Las Vegas, Nevada.
Indium Corporation, the industry-leading source of void-reducing materials and results, has specifically formulated Indium10.1 solder paste to reduce voiding significantly below the industry average – for improved finished goods reliability. Indium10.1 delivers robust reflow capabilities and a wide processing window, which accommodates various board sizes and throughput requirements, and minimizes defects.
For a halogen-free option, Indium8.9HF solder paste delivers very low voiding. Its unique oxidation barrier technology makes it perfectly suited for a variety of applications, especially automotive assembly.
In addition to outstanding print transfer and excellent response-to-pause, Indium10.1 and Indium8.9HF both provide excellent pin-in-paste solderability and hole-fill, while remaining stable at room temperature for up to 30 days.

Avoid the Void means manufacturers no longer have to settle for unacceptable levels of voiding when soldering QFNs, CSPs, or BGAs. Indium10.1 and Indium8.9HF are part of Indium Corporation's family of high-performance, lead-free, low-voiding, no-clean solder pastes.
For more information about Indium Corporation's low voiding solder paste.

www.indium.com/avoidthevoid

Intersolar AWARD 2016

Innovations form the basis for progress and are an important cornerstone of every industry. In order to shine a spotlight on the innovative power of companies in the solar industry and to publicly recognize their achievements, the Intersolar AWARD 2016 is honoring pioneering solutions in the solar industry for the ninth year in a row. The award will be presented at Intersolar Europe, the world's leading exhibition for the solar industry and its partners, which takes place from June 22–24, 2016 in Munich. Companies that exhibit at one of the global Intersolar or electrical energy storage (ees) events can now register in advance and submit their projects for the AWARD beginning February 1, 2016.
All applications must be submitted by March 24, 2016. Technologies and products in the solar industry are not only paving the way for the energy transition in Germany – photovoltaics is booming worldwide. In Asia and the USA in particular, newly installed output continues to grow. In 2014, Germany fed more solar power into the grid than ever before and drew approximately six percent of its power from solar sources. Solar sources already account for eight percent of power in Italy, while in Greece they account for seven percent. More than 177 gigawatts (GW) of photovoltaic power is installed worldwide, and SolarPower Europe predicts that the total capacity will triple, reaching 550 GW within five years.

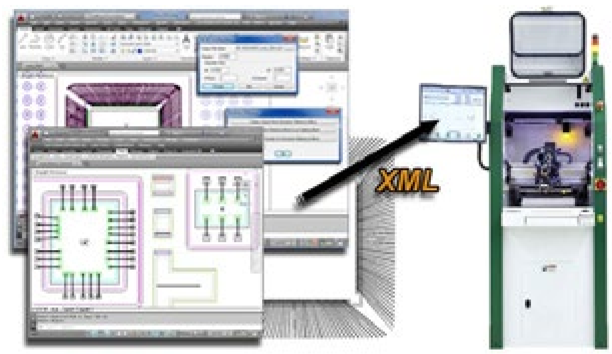
www.intersolarglobal.com/award

www.intersolar.de

Hesse Mechatronics Partners with CAD Design Software

Hesse Mechatronics, Inc., the Americas subsidiary of Hesse GmbH, world leader in wedge wire bonding technology for power, automotive, medical, aerospace, RF, microwave, opto, military and consumer electronics, announces that the company recently partnered with CAD Design Software.
The Hesse Mechatronics Utility Module creates an XML data file that contains wire bond information of polylines in a DXF/DWG file. This XML data file can be used with Hesse Mechatronics wire bonding machines that accept XML data format. This can be done on the Hesse Mechatronics Wire Bonders BJ820, BJ935 and BJ939.

- Multiple bond wire groups can be set with unique References.
- Sequence numbers and direction arrows will be visible in the drawing.
- Create individual bond wire reference blocks.
- Update existing blocked entities such as the dies or chips with Reference points that will be included in the XML output.



www.hesse-mechatronics.com

http://www.cad-design.com/

More than 40 Speakers for Technology Trends at 10th Battery Experts Forum

Participants at the 10th Battery Experts Forum, organized by Batteryuniversity, can look forward to an even more comprehensive program than in the previous years. The forum, formerly known to the international expert audience as 'Developer Forum Battery Technologies', with accompanying exhibition takes place from April 5 to 7, 2016 in the Stadthalle Aschaffenburg, Germany. This year for the first time, among other things, five additional parallel sessions are being offered, where topics regarding cell design and new materials, cell and battery tests, lifetime and safety, high-voltage systems, and electromobility will be examined particularly closely in successive specialist presentations given by different experts.

The scope of the basic training seminar, which takes place on April 5, has also been expanded. In addition to the seminars "Lithium-ion Battery Technologies" and "Battery Management Systems" offered in German language, two courses on the topics of "Battery Safety" and Battery Chargers" in English language are also now offered. Dr. Jochen Mähliß, head of Batteryuniversity, explains: "The number of persons having to deal with lithium-ion batteries in any way in their work has rapidly increased in the past years, and thus also the demand for adequate training programs that as closely as possible support the requirements. By expanding the range of courses, we hope to better address individual information needs of course participants in the future." There has always been lots of positive feedback on the trainings provided by Batteryuniversity. Over the past years, significantly more than 1,200 course participants attended the basic and further training seminars of Batteryuniversity, in order to get a quick and thorough overview of, for example, the latest technologies, standards and shipping regulations.

www.batteryuniversity.eu

Design Support on Power and Thermal Management

Rogers Corporation's Power Electronics Solutions (PES) group provides some of the world's leading high-power and thermal management materials solutions with its ROLINX® and curamik® product lines.

To assist engineers in achieving optimum performance and cost-effective results with these materials, Rogers PES hosts an information-packed Design Support Hub at www.rogerscorp.com/designhub. This free design and application technology center is available 24 hours a day, 7 days a week for visitors to the Rogers Corp. website.

The PES Design Support Hub helps design engineers increase the power-handling capabilities, improve thermal management, and enhance the quality and reliability of their circuit designs via highly focused technical guidance and information. The PES Design Hub includes technical papers, product data sheets and brochures, instructional videos, and the unique PES University training program. These educational opportunities are based on PES' various advanced power-handling and thermal-management materials and extend across all areas of electronics, from analog to digital devices and circuits, from audio through microwave frequencies, and from DC converters and batteries to microprocessors.

Technical literature available at the PES Design Support Hub includes reports on silicon nitride (Si_3N_4) substrates for power electronics and lifetime testing of laser diode coolers. Additional downloadable literature features data sheets and brochures on Rogers ROLINX and curamik material solutions for power handling and thermal management as well as design rules for the optimum use of specific material solutions, such as curamik ceramic substrates and DBC coolers and ROLINX busbars.

www.rogerscorp.com/designhub

InnoSwitch-CP ICs Dramatically Improve Charging Performance of Smart Mobile Devices

InnoSwitch-CP family I NN2214-2215 off-line CV/CC Flyback Switcher IC with Integrated 650 V MOSFET and Sync-Rect and Feedback.

By Power Integrations

Faster Charging: The Innoswitch-CP devices incorporate a constant power output profile which, when paired with an adaptive-voltage protocol such as Qualcomm Quick Charge 3.0 or USB-PD, permits smart mobile device makers to optimize charging time across a range of products. Developers employing adaptive charging technology achieve dramatically faster charge times, improved charging efficiency and backward compatibility with the popular 5 V USB BC 1.2 specification, all while minimizing overall thermal management and battery charging system cost.

InnoSwitch-CP ICs use Power Integrations' innovative FluxLink technology (Fig. 1) which enables high-performance secondary-side control to be implemented with the simplicity and low component count usually associated with primary-side regulation. It also optimizes the effectiveness of output synchronous rectification, resulting in extremely high efficiency across the full load range. For example, no-load consumption at 230 VAC is less than 10 mW, while full-load efficiency exceeds 90%. InnoSwitch-CP devices easily meet all global energy efficiency regulations.

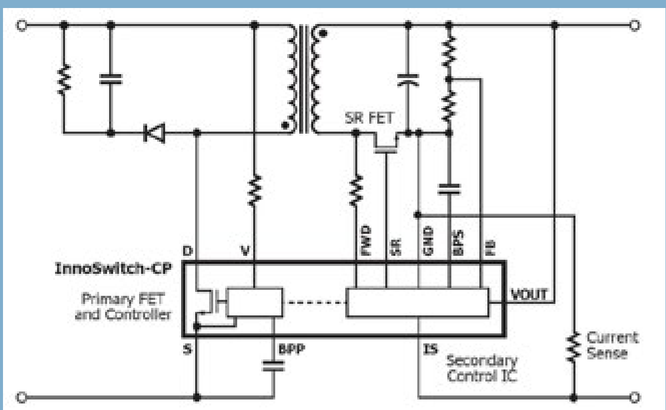


Figure 1: FluxLink: Magneto-Inductive Coupling

InnoSwitch-CP ICs incorporate a comprehensive suite of advanced protection features including: OVP; output OCP with 3 V auto restart; hysteretic thermal shutdown and line input overvoltage protection with accurate brown-in/brown-out thresholds. Devices are fully compliant with safety and regulatory standards, including: 100% production HIPOT compliance testing equivalent to 6 kV DC/1 sec; reinforced insulation; and isolation voltage testing to above 3,500 VAC. They are UL1577 and TUV (EN60950) safety approved and EN61000-4-8 (100 A/m) and EN61000-4-9 (1000 A/m) compliant.

The InnoSwitch™-CP family of ICs dramatically simplify the development and manufacturing of low-voltage, high current power supplies, particularly those in compact enclosures or with high efficiency requirements. The InnoSwitch-CP architecture is revolutionary in that the devices incorporate both primary and secondary controllers, with sense elements and a safety-rated feedback mechanism into a single IC.

InnoSwitch-CP Operation

InnoSwitch-CP devices operate in the current limit mode. When enabled, the oscillator turns the power MOSFET on at the beginning of each cycle. The MOSFET is turned off when the current ramps up to the current limit or when the DCMAX limit is reached. Since the highest current limit level and frequency of a InnoSwitch-CP design are constant, the power delivered to the load is proportional to the primary inductance of the transformer and peak primary current squared. Hence, designing the supply involves calculating the primary inductance of the transformer for the maximum output power required. If the InnoSwitch-CP is appropriately chosen for the power level, the current in the calculated inductance will ramp up to current limit before the DCMAX limit is reached.

InnoSwitch-CP senses the output voltage on the FEEDBACK pin using a resistive voltage divider to determine whether or not to proceed with the next switching cycle. The sequence of cycles is used to determine the current limit. Once a cycle is started, it always completes the cycle. This operation results in a power supply in which the output

voltage ripple is determined by the output capacitor, and the amount of energy per switch cycle.

ON/OFF Operation with Current Limit State Machine

The response time of the ON/OFF control scheme is very fast compared to PWM control. This provides accurate regulation and excellent transient response. The internal clock of the InnoSwitch-CP runs all the time. At the beginning of each clock cycle, the voltage comparator on the FEEDBACK pin decides whether or not to implement a switch cycle, and based on the sequence of samples over multiple cycles, it determines the appropriate current limit. At high loads, the state machine sets the current limit to its highest value. At lighter loads, the state machine sets the current limit to reduced values.

At near maximum load, InnoSwitch-CP will conduct during nearly all of its clock cycles. At slightly lower load, it will “skip” additional cycles in order to maintain voltage regulation at the power supply output. At medium loads, cycles will be skipped and the current limit will be reduced. At very light loads, the current limit will be reduced even further. Only a small percentage of cycles will occur to satisfy the power consumption of the power supply.

Availability and Price

The INN2214K IC delivers 15 W output power for universal voltage chargers and adapters, while the larger INN2215K part delivers up to 22 W for similar applications. InnoSwitch-CP samples are available now. Devices are priced at $0.90 in 10,000-piece quantities.

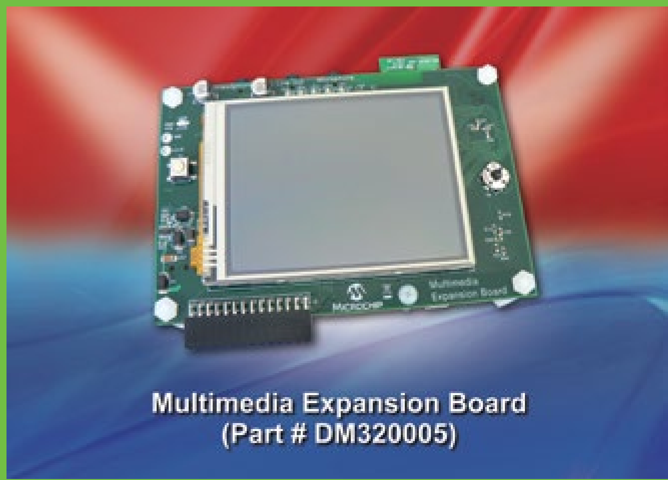
https://ac-dc.power.com/products/innoswitch-family/innoswitch-cp/

Win a Multimedia Expansion Board along with a PIC32 Starter Kit from Microchip

Bodo's Power is giving you the chance to win a Multimedia Expansion Board (DM320005) along with a PIC32 Starter Kit (DM320001) from Microchip.

The Multimedia Expansion Board (MEB) with the PIC32 Starter Kit provides users with an integrated-yet flexible-solution for the development of high-impact user interfaces. The board comes with a 3.2 color TFT touch-screen QVGA display, an onboard FCC-certified WiFi® module, a 24-bit stereo audio code, a three-axis accelerometer, a joystick and a microSD®™ memory card slot. Simply connect any DM320001, DM320003-2, DM320004, DM330012 and DM240012 Starter Kit to the MEB and you´re ready to develop, program and debug code for the user interface features. Demo software for the MEB can be downloaded from the Microchip Application Library, including software for the joystick, accelerometer, CPLD and more.

The PIC32 Starter Kit provides the easiest and lowest cost method to experience the PIC32 microcontroller for the first time. From the over 35 source code examples to the getting started project, users quickly learn Microchip's 32-bit family of microcontrollers and development tools. The kit includes everything needed to write, program, debug, and execute code on a high performance PIC32 microcontroller.



For your chance to win a Multimedia Expansion Board along with a PIC32 Starter Kit please visit and enter your details onto the online entry form:

www.microchip-comps.com/bodo-multimedia

"Higher, Faster, Further": How Innovations and Innovative Spirit Are Changing Our Daily Lives

By Petra Haarburger, President, Mesago Messe Frankfurt GmbH (Stuttgart)

On route to a short-notice business appointment, I yet again got caught in congested traffic. As I watched exhaust fume levels in the air rise practically before my eyes, I thought: Taking the train might have been smarter.

Suddenly, I got a call from a colleague on my hands-free system. It made me realize again how quickly our means of communication have changed – especially how we can be reached anytime and anywhere. Having grown up in an era before cell phones, tablets, computers, and Bluetooth connections, I probably notice this more than others. And another thought also struck me:

Thanks to the Internet, the 21st century has witnessed the development of all-new communication channels. Whether it's e-mail, SMS, chats, blogs, or social media, Generation Y in particular makes constant use of them. We can now disseminate everything from simple information and new ideas, to innovative approaches to a wide array of viewpoints. When it comes to the uncensored generation and circulation of knowledge, this sets a powerful precedent. We are amidst the Information Age, which connects our world in seconds and has fundamentally changed our professional and private lives. It would now be hard to imagine life without that worldwide phenomenon, the smartphone. A phone, music player, online library, memo board, and calculator all in one, it's with us wherever we go. Meanwhile, manufacturers are constantly launching newer, "smarter" models, subjecting users to a never-ending flood of information. Some find the ubiquity of the smartphone aggravating, but others consider it a source of knowledge and inspiration. But where are these changes taking us? What innovations lie ahead? Which of them will change our society, and more importantly, how? Here, sustainability is the operative word. Back in the 19th century, Werner von Siemens made an observation that has since proven prescient: "We succeed not in the advantages we take, but in the benefits we provide." Right now, we're at a crossroads regarding the ecological, economic, and social challenges we face.

The light turned green, and off I went. Just a few minutes later, I stopped again as another light turned red. Countless vehicles waited in line. The image of particulate and nitrogen oxide values climbing higher and higher kept appearing in my mind. We should have developed a new mindset and a particular innovative spirit long ago. "Innovative spirit" – what exactly does that mean? One glance at my smartphone, and Google knows what I'm looking for. The online definition is just a tap away: It's the human faculty for creating something new or solving [practical] problems innovatively. That's precisely what we need – forward-thinking ideas, and the courage to venture down unknown and sometimes rocky roads. Roads that open up new, unforeseen perspectives. In a world driven by superlatives like "higher", "faster", and "further", we're fond of speaking of major revolutions that lie ahead.

Looking back on history, however, humankind has consistently taken small steps to adapt its environment in line with Darwin's theory of evolution. Only those who have embraced change with open arms have survived. Fundamental transformations don't take place overnight, but in a long, drawn-out process. So if you try to withstand the latest developments and the progress they bring, you won't evolve. This applies to people, companies, and society. But what approaches make the difference? For those looking to succeed, the pressure is considerable.

Factors such as climate change and scarcity of global resources – especially energy and water – are increasingly forcing us to take action. Virtually every sector is exploring intelligent ways to integrate and use new technologies.

Although it plays a key role, the electronics industry is not the only field constantly reinventing itself as a result. With mobility a defining subject of our time, the automotive industry is also facing greater demands than ever. This expression of freedom comes with the obligation to take responsibility for future generations.

Vehicle manufacturers around the world are already diligently fine-tuning prototypes with intelligent drive systems and minimal emissions, including models that run on electricity. Engines with no CO2 emissions or other forms of pollution are no longer a dream – some of these modern developments are already a reality. While electrical drive systems have yet to see widespread use in our vehicles, this too is only a matter of time – and the clock is ticking.

Engineers are already working tirelessly to find solutions to pressing future issues. The world's oil and gas resources are finite, and our energy consumption needs to be reduced. We also have to reduce the environmentally lethal emissions we produce – because our world can't tolerate endless levels of pollution. This is why we need innovations and innovative spirit to advance our current and future society.

So what point am I making? I believe that by organizing exhibitions, conventions, and seminars focused on technology, we, as an event organizer, can help to advance society. Our events offer an ideal platform for presenting latest trends and developments and ensuring the transfer of cutting-edge knowledge and information among exhibitors and attendees. I'd like to take this opportunity to invite you to two of our events in Nuremberg this year: SMT Hybrid Packaging in April, and PCIM Europe in May.

I'll also be attending these exhibitions and I'm already excited about the innovative and inspirational product developments that will be unveiled. Many of them could go on to shape the future. I look forward to seeing you in Nuremberg!

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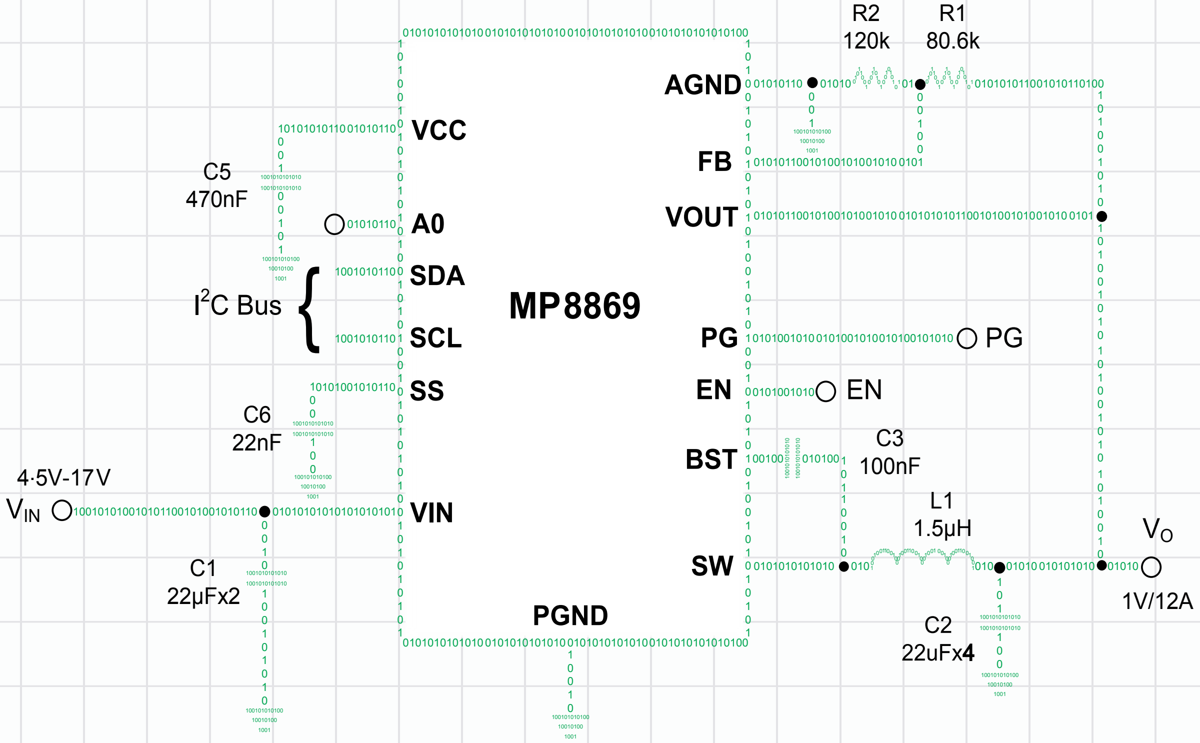

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System Solution: "SiC-Inverter for Industrial Motor Drive".

In many power electronics-based applications such as industrial motor control units, requirements like space, weight and efficiency play an increasing role. Product development and manufacturing expenses should remain low while the design effort should result in more compact systems and, at the same time, product quality and reliability should be guaranteed.

By Aly Mashaly and Fabrice Gringore, Rohm Semiconductor GmbH

This leads to more demanding design requirements on the system and component level and ultimately affects the overall consistence of power devices, passive components, cooling technologies and PCBs.

In order to achieve the required enhanced system properties, semiconductor devices have to cope with higher power density, higher efficiency and reliability. In consequence, silicon carbide (SiC) has become of higher interest in recent years, because it sets new standards in terms of temperature resistance and performance, leading to improved switching voltage and frequency, switching losses and size and in some applications leading to the reduction of total system costs.

Compared to silicon (Si), the electric breakdown field of SiC is higher by almost a factor of ten (2.8 MV / cm vs. 0.3 MV / cm). The higher dielectric field strength of the extremely hard substrate allows for a thinner layer structure and reduces the surface resistance. In combination with the high carrier mobility shorter switching times can be generated, which causes the energy loss in the switching to diminish significantly and to remain almost constant even at considerably higher ambient temperatures, compared with conventional Si semiconductors, as shown in Figure 1.

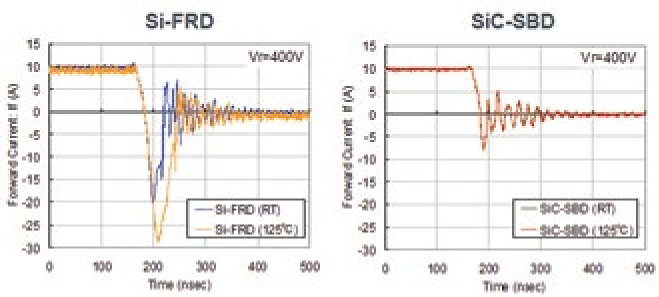

Figure 1: SiC shows better switching performance at higher temperature than Si Devices

Total power losses in switching applications consist of static and switching losses. Switching losses result from turning on and turning off the device and demand to be taken into particular consideration if high switching frequencies are required. The switching frequency in power electronic systems is often defined by application- and system-specific limits. For example, in motor drive application the switching frequency is determined by the required output frequency to the AC motor, resonance performance of the entire system, EMC requirements and thermal management.

Turn-off velocity is confined by the permissible switching over voltage and also EMC requirements such as common mode effects, however the turn-on velocity is confined by the permissible peak current and electromagnetic immunity (EMI), both setting the frame for the feasible switching speed.

Power semiconductors are taking on various static and dynamic states during switching operation. In any of these states, energy is dissipated, heating up the device and accumulating to the overall power loss of the switch. Therefore, suitable thermal management concepts have to be taken into account to avoid over-heating and to ensure the reliability of the device and the entire system as well.

The most popular power device for high-voltage, high-current applications used to be IGBT. Contrary to IGBTs, MOSFET do not have a threshold voltage for the on-state characteristic. IGBTs achieve lower on-resistance by injecting minority carriers into the drift region but these generate tail current when transistors are turned off. SiC devices do not need conductivity modulation to achieve low on-resistance due to their much lower drift-layer resistance and in consequence, do not generate tail current. Compared to silicon-based fast recovery diodes, SiC SBDs have much lower recovery loss and noise emission, at similar threshold voltage, and unlike silicon FRDs, these characteristics do not change significantly over current ranges (Figure 2).

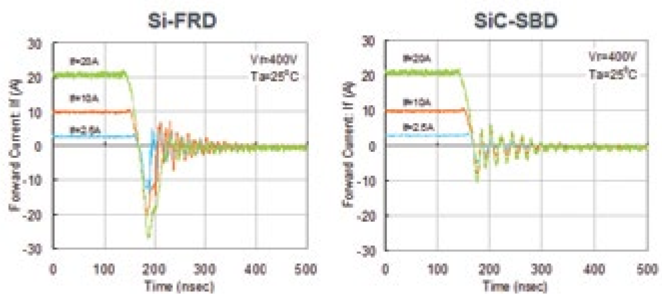

Figure 2: SiC has overall better switching properties at higher currents comparing to Si Devices

A Myriad of Possibilities - Application Examples

The greater switching speed allows for a higher switching frequency and makes SiC devices particularly suitable for use in many industrial applications, e.g. DC/ DC Converters, active front ends, energy recovery systems, solar inverters and UPS.

For motor drive applications the insulation materials of AC motors are a challenge when using high speed switches like IGBTs and even more when using SiC. For industrial motors with standard insulation, the switching speed is limited from 1 kV/µs up to 5 kV/µsin order to minimize stress on the insulating materials. By using SiC, switching speed in a range higher than 15 kV/µs is possible. This value is dependent on factors such as output signal of the inverter, coupling effects, cable length as well as the type of cable. The high dv/dt can lead to damage the motor insulation and thus to premature aging of the motors. Depending on the application and the length of the motor cable, an output filter like dv/dt filter or sinusoidal filter is needed in order to prevent this scenario (as shown in figure 3). By using this kind of output filters, cables without shielding can be used which leads to reduce costs dramatically. Another benefit of such filters is that the high frequency currents in the motor windings decrease which leads to reduced losses, heating and noise in the engine. As a result, the life time and the reliability of the entire system improve.

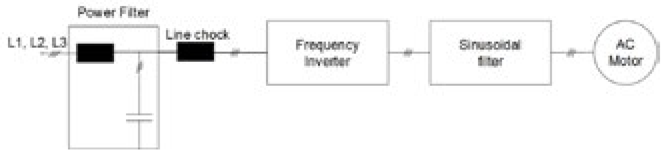

Figure 3: Industrial motor drive application with sinusoidal filter

The benefit of SiC can be well seen in industrial applications where sinusoidal filters on the output of the inverter are needed, e.g. motor drives where power up to the double-digit Kilowatt range with cable length of 100 m between motor and inverter is required. These applications are commonly featuring motor frequencies in a range of 50 Hz and switching frequencies in a range of 10 kHz and are mainly solved with IGBT technology. Using IGBTs for these applications with higher switching frequencies is not feasible due to the high thermal stress on IGBTs which occurs when the switching frequency exceeds these values.

Considering the parasitic elements in this system, like commutation parts of the DC link, motor windings and cables and conceiving this system as a resonant circuit, the main and common challenge in this application remains that the resonant frequency is normally close to the low switching frequency. This means that the resonant circuit could be excited by the switching frequency of the IGBT, leading to high oscillation on the system and subsequently extremely thermal stress on the passive components and motor as well. To prevent this phenomenon, Power engineers have to make a trade-off between thermal stress and resonance behaviour of the system. To overcome this technical challenge engineers commonly used to connect a sinusoidal filter to the output of the inverter in order to reduce such stress.

SiC opens new doors in this market by giving engineers the possibility to define a higher switching frequency for such an application (>16kHz), which is not possible with IGBT. Using SiC leads to minimized thermal stress, shift the switching frequency away from the resonant frequency, ripple current becomes smaller, the output filter can be downsized and the reliability of the entire system increases.

With the new full SiC modules from ROHM, the switching losses can be reduced by 75%.

To illustrate the difference between Si-IGBT technology and 3rd Generation of SiC technology from ROHM, a simulation of an inverter has been performed.

Simulation parameters are as follows: Vdc= 600V, Imotor=200Arms, Fsw.=10 KHz.

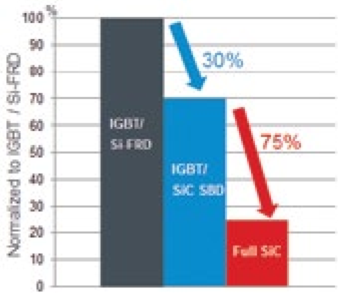

Figure 4: Comparison between IGBT, hybrid module and full SiC technology

As shown in Figure 4, switching losses in inverter applications can be dramatically reduced by using 3rd generation SiC MOSFETs from ROHM. This excellent step allows the engineers to increase the switching frequency without dealing with thermal stress like when using IGBTs. This also results in significantly smaller and lighter inductors and capacitors. Smaller and lighter coils mean fewer required components e.g. for noise reduction, as well as smaller heat sinks. All in all, SiC helps to downsizing the system.

With its Powers Systems Application group located in the Headquarter near Düsseldorf ROHM can now support customers by thoroughly examining the application and customer requirements, investigating the advantages of the SiC technology on a system level and by finally identifying the best and most cost efficient solution. For example, in most of the industrial motor drive applications AC motors are driven with an output frequency of only 50 Hz. High switching frequency is normally not needed for this kind of applications. Therefore, for these applications a reduction of 30% of power losses is absolutely sufficient to find a perfect cost/benefit compromise. This can be achieved by using a hybrid configuration combining Si-IGBT and SiC Schottky Barrier Diode in the circuit instead of a Si-IGBT/Si FRD (Figure 4) – which results in significantly improved thermal management. Reverse recovery behaviour of the SiC SBD is almost completely eliminated even at high operating temperatures, see figure 1.

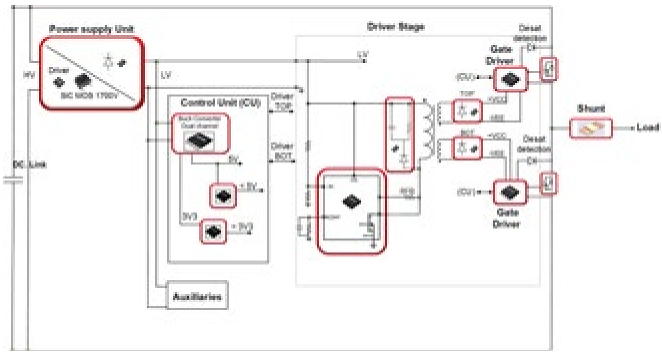

Figure 5: Solutions from ROHM for high power density inverter applications (highlighted in red)

ROHM solutions for inverter applications

In the development phase of their commercial Silicon Carbide switches, ROHM always had in mind to deliver not only SiC MOSFETs and SiC Diodes on their own but an effective system solution, (Figure 5) ROHM offers many ways to reduce the BOM and production costs, i.e. a multitude of semiconductor devices on Si and SiC basis for tailor-made solutions of all kinds of power electronic requirements, from the DC/DC Converter and control units to the driver stage. Schottky diodes, Super Junction MOSFETs, hybrid MOS, IGBTs and FRDs cover voltage ranges from 300 to 1200V, SiC MOSFETs and SBDs cover voltage ranges up to 1700V.

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In the case of a DC/DC converter for an auxiliary power supply, the use of the new 1700V SiC MOS (SCT2H12NY) in a TO268 package resulted in significantly improved Rdson (1.15 Ω instead of 9Ω by Si-MOS) as well as in higher current capability in the same package are a compared to Si-MOS. With its very low input capacitance (Ciss) the switching frequency can be higher than 100kHz, which leads to distinct volume reduction of magnetics and space on the PCB. By using a TO268package the possibility of automatic assembly is given now, which means a significant reduction of production costs and ultimately, the reduction of total costs. To get the best performance of this device ROHM developed a special driver (BD768xFJ-LB) with dedicated controller in a SOP-J8S package.

Further advantages become evident when examining the example of an optocoupler-less isolated flyback converter for DC voltage conversion (BD7F100HFN-LB): In the market there are two conventional solutions. One solution is by using a third winding on the primary side. Disadvantage is that it leads to enlarge the transformer, increase the power consumption and it is inaccurate to control the output voltage. The other solution is to getthe feedback signal from the secondary side by usingan adjunct optocoupler. The disadvantage here is, that this concept requires a voltage divider, increases the power consumption and because of a coupling capacitance between the primary and secondary side the EMC performance is critical which makes an extra filter necessary to minimize EMC noises.

Compared to these conventional solutions, the new (BD7F100HFN-LB) does not require signal feedback from the secondary side, which means that an optocoupler or transformer with third winding becomes unnecessary. The module contains a 60-V MOS for currents up to 1.25 A andit operates with a constant switching frequency of 400 kHz. To ensure reliable operation, the flyback converter is protected against low input voltage, over-current, output short circuit and over-temperature. With this integrated solution, not only the design becomes smaller -the response times are faster as well.

Also, as ROHM proposes, closely associating the isolated gate driver to the power stage component choice and design consolidates this approach of a system solution. Indeed, driving Silicon carbide switches requires significantly higher performance than legacy drivers, and this in many areas.

The first key feature to bear in mind is the immunity to common mode transients (CMTI). As mentioned before the switching speed of SiC can be higher than 15 kV/µs, it could go well above 50 kV/µs.

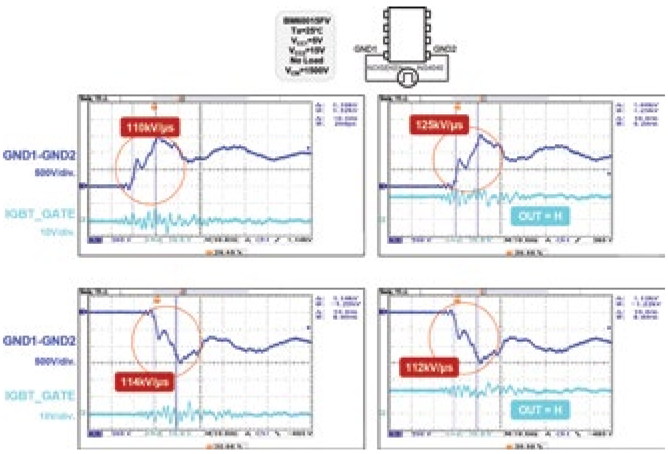

Figure 6: Common mode transient immunity performance test beyond the 100kV/µs limit

Commonly, as featured in all ROHM's isolated gate drivers (see figure 6), 100 kV/µs is the safest and minimum immunity that shall be guaranteed for a safe system drive.

Still related to safely supporting significantly higher frequencies, the propagation delay, and particularly the matching of single channel isolated gate drivers, is critical. As such, a general rule of thumb for the propagation delay and device to device matching is to be kept respectively below 100ns and 50ns. For the latter, some applications are even tending to require around 20ns in the very next future. This tight timing reliability, over the whole temperature range, is enabled by the coreless transformer technology of isolation, unlike with conventionally-used optocouplers for legacy IGBT or MOSFET switches (Figure 7).

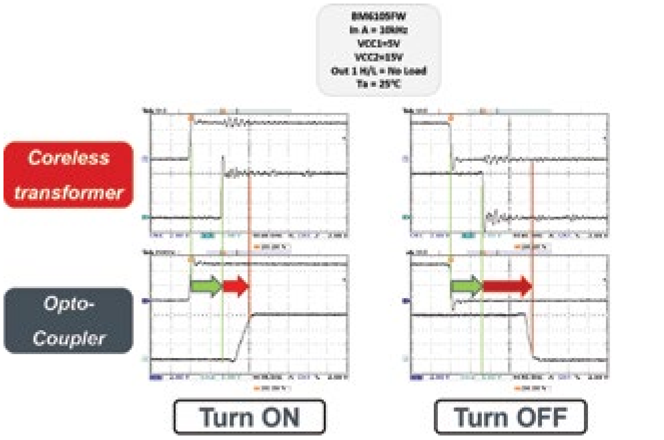

Figure 7: Benchmark of propagation delay performance and reproducibility

Since the gate capacitor needs to be chargedmore frequently, having a sufficient gate current capability may allow pushing out the limit where you need to add an external push-pull buffer, enabling few tens of cents savings as well as some propagation delay. A 3 Amp minimum gate current drive is already significantly higher than the majority of conventional solutions, particularly optocoupler-based solutions.

Last, since Silicon-Carbide switches do require higher drive voltage than IGBTs, a gate output voltage range of operation above 22V is available by the ROHM driver. It enables to drive agnostically any generation of Silicon Carbide switches.

Combining all of these drastic specification improvements in an isolated gate driver enables the Silicon Carbide-enabled system to reliably reach its optimal performance.

Summary

At first glance, the SiC technology is in fact somewhat complicated and - lacking larger numbers - currently more expensive than that of silicon. However, the use of SiC power semiconductors on a system level enables significant improvements in terms of efficiency, circuit complexity, size and weight as well as extended lifetime, particularly at high voltages and currents. The overall system efficiency is noticeably improved, the operation is possible in higher temperature ranges and it requires less passive circuit elements; not to forget the considerable benefits that can be leveraged not only in the design phase, but in the medium and long term.

All in all, ROHM is currently the sole Silicon carbide MOSFET supplier able to provide this complete and efficient power stage.

Finally, ROHM started to establish a power lab in its facility in Germany in order to support the European customer technically and strongly on system level, circuit level as well as on device level.

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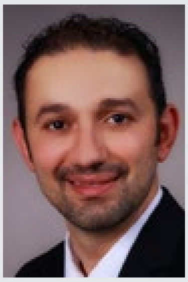
Authors:



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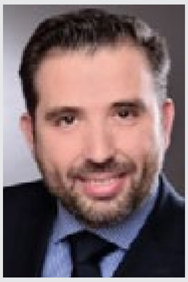

LinPak – the new Standard Phase-Leg Module with Exceptional Low Inductance

One year ago ABB presented the LinPak, a new IGBT module generation that is the enabler for lowest overall stray inductance. In the meantime the LinPak module with a footprint of 100 x 140 mm² has established itself as a new standard.
The ABB lineup of LinPak modules starts with a module rating of 1700V and 2x1000A. This spring ABB will complement the LinPak family with a 3300V and 2x450A rated module.

By Raffael Schnell, Fabian Fischer, Samuel Hartmann, Dominik Trüssel and Andreas Baschnagel, ABB Switzerland Ltd. – Semiconductors

The LinPak IGBT module features an exceptionally low stray inductance enabling the full utilization of advanced low switching loss IGBT chipsets and even future full silicon carbide switch solutions.
In addition the LinPak is ideally suited for parallel connection with negligible derating, thus allows for a large range of inverter powers with just one module type. Together with the open standard concept this module fulfills a long wish of the industry in nearly all high-power segments such as traction & CAV (commercial, construction and agricultural vehicles), wind & solar and industrial drives to name a few.

Present IGBT module solutions are at its limit when it comes to advanced and faster IGBT/diode chipsets since the overall stray inductance per switched ampere is too large and high over-voltage will occur. In addition, the available electrical contact area of today's modules is limited and dates back to times when the packages were rated with 50% less current than now. Due to today's modules' lack of scalability, a large variation of outlines exists to match various inverter ratings. The presented LinPak module concept solves all these issues and is published as an open standard. Several module manufacturers have adopted the outline and customers benefit from a standard solution. The LinPak offers as well exceptional low package stray inductance of 10nH and an easy customer interface enabling the construction of a very low-inductive DC-connection with sufficient contact area for the high current densities. This is the ideal fit for the full utilization of the advanced fast IGBT/diode chipsets such as the latest 1700V SPT^{++} technology. It also makes the package fit for future hybrid and full SiC solutions that come with much higher switching speeds.

Figure 1: ABB's low-inductive LinPak IGBT module for reliable high-power converters

Beside the very advanced and novel package concept, the LinPak features ultra-sonic welded terminals and an advanced high reliability solder joint between the unrivaled AIN substrate and AlSiC base-plate material combination. In addition, the well-established high temperature cycling capable bonding technique and the gate-print to substrate aluminum bond interconnect from the improved HiPak are incorporated in the new LinPak design.

Application benefits

Module scalability and record current density

The LinPak module type offers the benefit that just one module type is needed per voltage rating. Thanks to a homogenous current path concept, the module enables parallel connection of more than four modules without any significant derating (Figure 2).

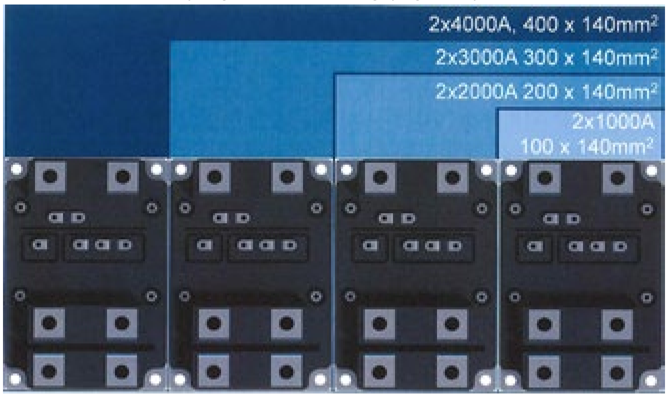

Figure 2: LinPak scalability

The current density of LinPak modules offers a solid improvement of more than 10% compared to older module types on the market as shown in Table 1.

Module Type	Current Rating	Foot-print	Current / Area
LinPak	2 x 1000A	100 x $140mm^2$	$14.3Acm^{-2}$
HiPak	3600A	140 x $190mm^2$	$13.5Acm^{-2}$
PrimePACK	2 x 1400A	89 x $250mm^2$	$12.6Acm^{-2}$

Table 1: Current density of LinPak compared to other module types

Mechanical concept and connections

The gate-unit connection for the LinPak is realized with a simple adapter-board (PCB) directly mounted onto the module between AC and DC terminals. The connection to the auxiliary terminals for gate, emitter, collector and thermistor are realized with M3 screws. In addition, four molded M3 nuts are positioned in the corners to mechanically fix the adapter board for harsh environmental applications like traction or CAV. The adapter-board connects the modules' gates and

auxilliary emitters in parallel. Thus, many modules can be connected in parallel with just one gate-unit.

The NTC thermistor is located in the center of the module and thus allows a fast monitoring of the module base-plate temperature. Optionally auxiliary emitters that tap the potential of the power emitter connection on the Minus-DC and Phase-Terminal can be equipped. Those 2nd auxilliary emitters can be used to sense the inductive internal voltage drop during fault conditions. This allows the gate-drive unit to react faster to short-circuit events and trigger protective functions.

The power connections are designed to enable an absolute symmetrical DC-connection, which is crucial for excellent current sharing. The creepage and clearance distances are designed according to IEC 60664-1 and EN 50124-1 for functional insulation up to a device rating of 3300V.

Power connections

The LinPak offers the highest contact area per rated current. Table 2 compares the current per M8 screw for various packages. To compare the various package types, the phase current is calculated by dividing the device's nominal current by √2.

Module Type	Nominal current	Phase current	Amp / M8 screw (phase terminals)	Amp / M8 screw (DC terminals)
LinPak	1000A	707A	354A	250A
PrimePACK	1400A	989A	495A	350A
HiPak	3600A	2546A	600A	600A

Table 2: Current per M8 screw connection

Because of the large contact area offered by the LinPak, heating of the contact interface and the terminal itself is much reduced compared to HiPak or PrimePACK modules.
For future chip generations with even further increased current densities, the LinPak offers space between the existing phase-connections to accommodate a third AC-connection which reduces the contact resistance from bus-bar to module even further.

Record low stray inductance

Present module designs have rather high stray inductance values causing high over-voltages. This makes the use of advanced fast chipsets – such as the ABB 1700V SPT++ chipset – difficult and the use very fast future SiC solutions close to impossible.

The LinPak is designed to offer the lowest internal stray inductance current thus enabling low inductive bus bars. Figure 3 compares the LinPak with a HiPak including a bus bar and an assumed DC-capacitor inductance of 1.5nH. Still when including the bus bar and

	HiPak (1.7kV / 3600A)	4 LinPak (1.7kV / 4000A)
Module inductance	16nH	2.5nH (10nH for a single module)
Bus-bar inductance	10nH	1.5nH
Capacitor inductance	1.5nH	1.5nH
Total (module including DC-link)	27.5nH	5.5nH (22nH for a single module)
$L_\sigma \cdot I_{nom}$ (3600A)	99µVs	19.8µVs
Over-voltage @ t_f = 0.12µs (1700V SPT++)	**825V** ***100%***	**165V** ***20%***

Figure 3: Stray inductance including bus bar

capacitor, the over-voltage is below critical levels compared to the HiPak solution – even with fast chipsets. This makes the LinPak the ideal candidate for parallel connection up to high current applications without compromising the switching losses.

Electrical results

The 1700V, 2x1000A rated LinPak modules have been tested in a real application environment with laminated bus bars. The achieved stray inductance is below 25nH. As a result the measured waveforms figure 5 to 7 show exceptional smooth switching characteristics and very low voltage overshoots, this despite the very fast and low-switching losses SPT++ chipset.
This renders obsolete the need for sophisticated gate-units with active clamp circuits that are always critical for gate-driver reliability. As a prove figure 6 shows the IGBT safe operating area (SOA) with double nominal current turn-off to a high DC-link voltage of 1300V without active clamp. Thanks to the low inductive design of the LinPak the over-voltage even under this extreme conditions stays below 1700V!

Conclusions & Outlook

The LinPak is a new open standard module that satisfies the requirements posed by both new advanced fast and high current density chipsets as well as customer wishes for a flexible and scalable IGBT module that is, in addition, ready for future technologies such as SiC devices. The benefits of the novel low stray inductance LinPak IGBT module are clearly demonstrated and measurements confirmed the expectations from the new module.
Today, the benefits of the new package enable customers to profit from the latest chip technologies with low-inductance for achieving the highest current density. Furthermore, particle free ultrasonic welding of the main terminals, advanced wire bonding including the well-established and unrivaled AIN / AlSiC substrate / baseplate material combination for high temperature cycling capability are incorporated. At PCIM 2016 in Nuremberg ABB will present the 3300V LinPak version including results from the electrical verification.

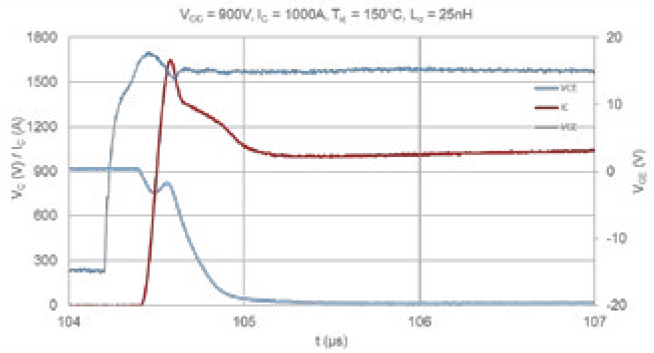

Figure 4a: Nominal IGBT turn-on

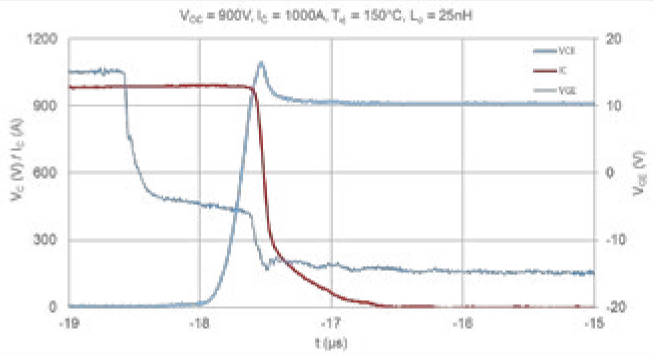

Figure 4b: Nominal IGBT turn-off

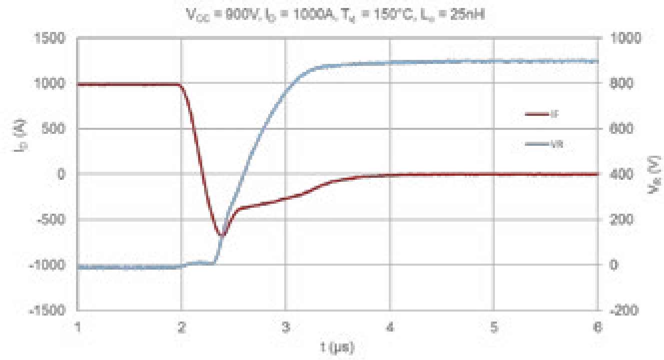

Figure 5: Nominal Diode recovery

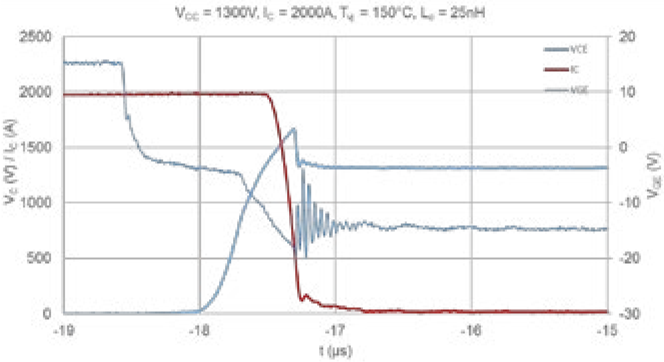

Figure 6: IGBT SOA at double nominal current

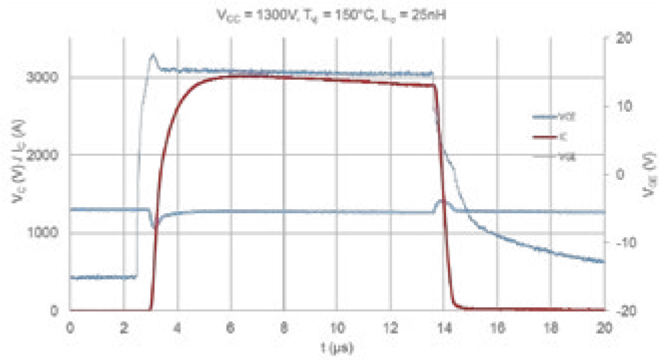

Figure 7: IGBT short-circuit ruggedness

Literature

1. Raffael Schnell, Samuel Hartmann, Dominik Trüssel, Fabian Fischer, Andreas Baschnagel, Munaf Rahimo, “LinPak, a new low inductive phase-leg IGBT module with easy paralleling for high power density converter designs” Proc.PCIM’15 Nuremberg, 2015
2. Raffael Schnell, Munaf Rahimo “The Quest for Higher Switching Frequency and its Implications on Semiconductor Switches” Proc. PCIM’11 Nuremberg, 2011
3. Corvasce C., Kopta A., Rahimo M.T., Schnell R, Geissmann S., Vobecky J.; “New 1700V SPT+ IGBT and Diode Chip Set with 175°C Operating Junction Temperature” EPE’2011, BIRMING-HAM, UK, Aug. 2011
4. R. Schnell, U. Schlapbach, K. Haas, G. Debled, “Parallel Operation of LoPak Modules” Proc. PCIM’03 Nuremberg, 2003.
5. G. Borghof “Implementation of low inductive strip line concept for symmetric switching in a new high power module”, PCIM’13 Nuremberg, 2013

Temperature Limits for Power Modules - Part 2 Lifetime

In part 1 the limit of maximum junction temperature was discussed. Here in part 2, a second thermal limit, due to wear out caused by temperature cycling will be illustrated using an example from a real life application.

By Jeremy Howes and Greg Shendel, Parker Hannifin Automation Group NC. USA; with David Levett and Tim Frank, Infineon Technologies North America

Introduction

The effects of wear out in power modules due to temperature cycling should be carefully considered in any power electronics design, especially in applications with high cyclical loading and long life requirements. Semiconductor packages are constructed using different materials, which have different rates of thermal expansion, expressed as coefficients of thermal expansion, CTE. Temperature cycles induce stress in the dissimilar materials, eventually causing degradation of the joints between these materials. In a typical power module with baseplate this degradation occurs in three places: at the chip level, on the top side where the bond wires attach to the top metallization surface of the chip; on the bottom side where the chip is soldered to the Direct Copper Bonded (DCB) ceramic and in the system solder joint between the DCB ceramic and the baseplate. Long term temperature cycling testing at the chip level is achieved through active power cycling tests where a typical temperature cycle lasts several seconds, referred to as Power Cycling seconds (PCsec) testing.

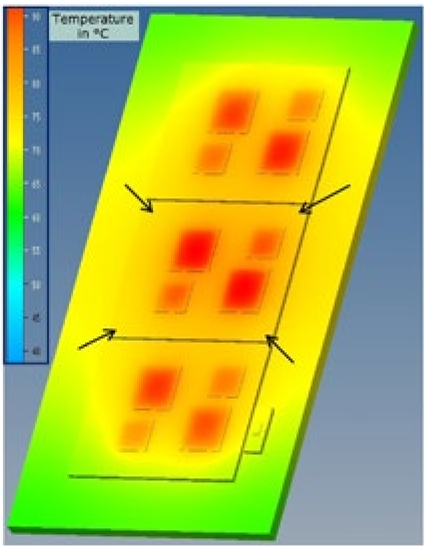

Figure 1: Four corners of center DCB used for temperature variation simulations.

For the system solder the test temperature cycle lasts several minutes and is referred to as Power Cycling minutes (PCmin) testing.

Converter Design Requirements

The application example shown here is for a three phase grid tie converter. The lifetime specification for the converter was to meet a 12 year life operating 24/7. The design was based on a 300A 1200V EconoDUAL™ 3 module from Infineon Technologies mounted on an air cooled heat sink. The end user provided a mission profile of the application by measuring the load over a typical 5 day time period sampled at 1 second intervals.

Methodology

The estimation of lifetime was sub-divided into the following five steps.

1) Mission profile. This describes the actual operating conditions in the end application over a typical time period. This can be the hardest part of any calculation as real data is often not available. If no real data is available, it is recommended to perform analysis with a best estimate of the mission profile.
2) Loss calculation. Calculate the semiconductor losses as they change over the time period of the mission profile. A simple calculation can often be used to decide if PCsec or PCmin is the limiting life factor for a given profile to reduce the number of required calculations.
3) Temperature variation. Using a thermal model of the module, the temperature changes of the chips and the system solder layer during the mission profile can be calculated. If PCsec is the limiting factor, the temperature changes of both IGBT and Diode chips should be calculated.
4) Rain flow quantization. Using a rain flow method algorithm the delta T excursions can be extracted from the temperature profile and then quantized or binned into their different delta T ranges. For example all the delta T excursions between 27.5°C and 32.5°C can be grouped together in the same bin with a delta T of 30°C
5) Lifetime estimation from supplier data. The % of lifetime consumed for each bin of delta T events can be estimated using graphs showing the statistical degradation at specific delta T levels provided by the module supplier. The % lifetime of all the bins can then be summed to provide total percentage of the design life used over the complete mission profile. Note this does assume that all degradation will sum linearly.

Worked Example

Mission Profile and Loss Calculator

With the end user providing more than 400,000 data points for the load mission profile the first step was to somehow reduce the number of data points for analysis; but how does one decide which time periods are typical or worst case? To assist with the initial evaluation the data was divided up into 135 blocks consisting of 3200 samples each (approx. 53 minutes' worth of data). The load values of each block were integrated and the blocks with the highest levels plotted. One block was selected for analysis, which, using engineering judgement, had significant load peaks and troughs which produce large delta T's. Using the Infineon on-line tool, Iposim, the losses at several load points were calculated for both the IGBT and the diode chips. A curve fit was applied to these losses vs. load points to enable a simple interpolation of losses at any load point. Note the task here was simplified as both the fundamental frequency (of the grid) and switching frequency of the IGBT's are fixed. When more variables are involved this loss estimation becomes more complex. After performing an initial estimate calculation on the changes in temperature it was clear that the PCmin would be the limiting factor as at a grid fundamental frequency there is a low temperature ripple on the chips.

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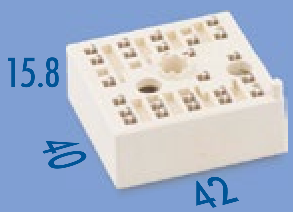
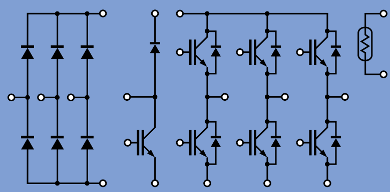
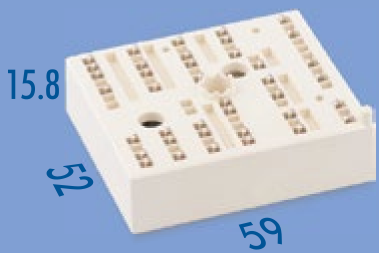
MiniSKiiP® 1

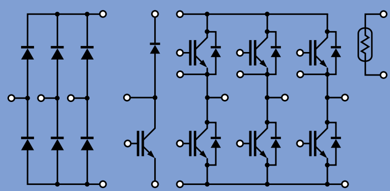




I_C	1200V
8A	●
15A	●

MiniSKiiP® 2





I_C	1200V
25A	●
35A	●

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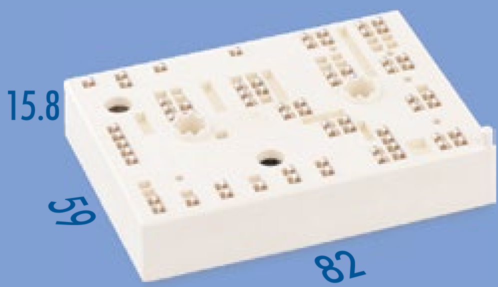
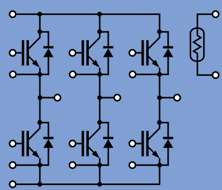
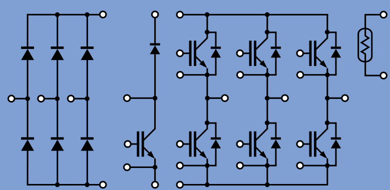




I_C	1200V
100A	●
150A	●

Under development



I_C	1200V
50A	●
75A	●
100A	●

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Temperature Variation and Rain Flow Quantization

The next step in the calculation was to estimate the change in temperature of the solder layer between the DCB and the baseplate over the loss profile, as any degradation of this solder layer, and it's resultant increase in chip thermal resistance is dependent primarily on changes in temperature, delta T. Using a validated Finite Element Model (FEA) of the module the temperature of the system solder layer at the corners of the DCB could be simulated see Figure1. The corners are used as this is where the stress is the highest and where the degradation or delamination starts (1).

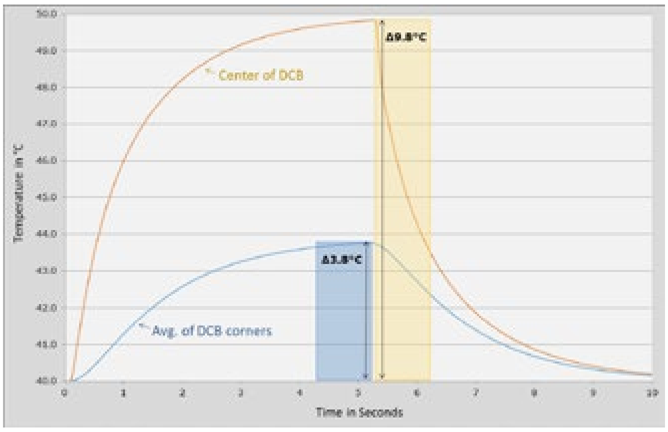

Figure 2: Temperature variation in DCB temperatures with a 5 second power pulse.

Figure 2 shows the temperature variation during a 10 second load cycle. Running a full FEA model for a 53 minute transient loss profile is not practical. A much simpler method is to use the FEA model to derive an electrical equivalent circuit Foster model that describes the transient thermal characteristics of the solder layer with respect to dynamic power loss. The model can be derived by applying a constant power, in the FEA model, to both the IGBT and diode chips. Once the steady state temperature was reached, the power was removed, and the cooling curve of the average temperature of the corners of the system solder layer was recorded, see Figure 3.

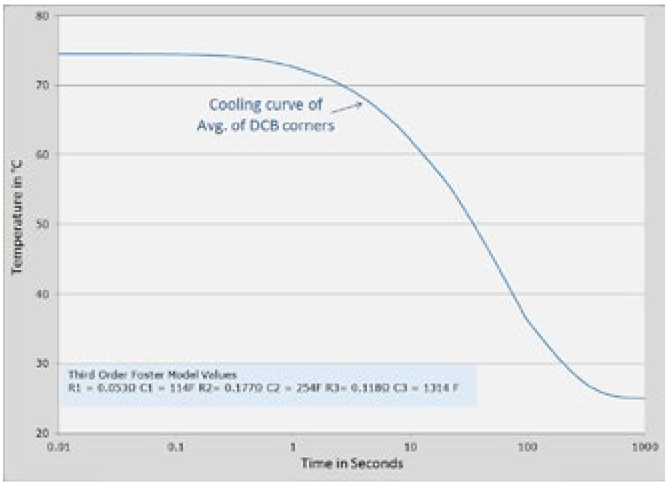

Figure 3: Cooling curve of corners of the DCB derived from the FEA model.

From this cooling curve a third order Foster model was derived as shown in Figure 3. The block of 3200 power loss values from step 1 were then fed into the 3rd order Foster model and the temperature profil obtained as shown in Figure 4.

From this temperature profile the delta T values were extracted and binned using a rainflow algorithm. In this application, the ambient temperature changes could be ignored as the converter was operating in a climate controlled environment, however, ambient changes typically need to be considered in the mission profile.

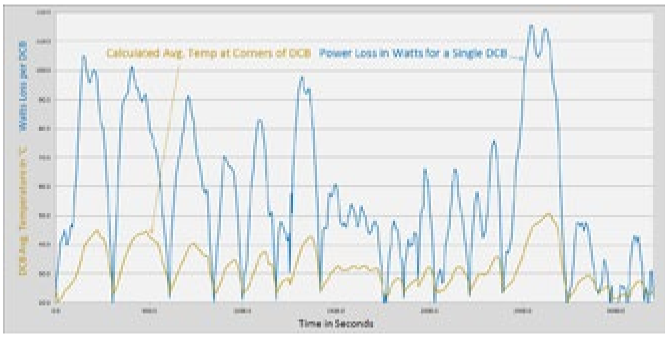

Figure 4: Center DCB power loss in Watts and calculated Avg. DCB corner temperature vs. time.

Lifetime estimation

The % of design lifetime used by each bin could then be calculated using data provided by Infineon. This data, provided in graphical form, shows how many cycles it will take at any given delta T for the module to reach the end of its defined design life, (the definition of life being a 20% increase in thermal resistance junction to case). For example, from the rain flow analysis of the data shown in Fig 4 there is a single delta T event in the Δ30°C bin. For a 12 year life, that equates to ≈120,000 temperature cycles at a delta of 30°C. The defined design life for a delta T of 30°C is ≈ 500,000 cycles, so ≈24% of the life time is used by this bin. Summing all the bins the estimated percentage of total life used in 12 years is 54%. Expressed another way the end of design life is estimated to be 22 years.

The Next Level

In this estimation engineering judgement was used together with assumptions and omissions to reduce the work and arrive at 90% of the answer with 10% of the work. The calculations shown here, took 1-2 days of work once the FEA model was available. Note a close collaboration with the module vendor is strongly recommended to fully understand the correlation between the actual mission cycle and the supplier test data provided (2), also to assess the possible effect of any assumptions made in the calculation. Some possible options that could be considered to help provide a more accurate result:

- Running a full rain flow on all 135 data blocks and considering design life for min, max and average time blocks.
- Including changes in ambient temperature and changes in lifetime due to the temperature cycle starting temperature.
- Considering the increase in thermal resistance due to delamination of solder layers and degradation of any Thermal Interface Material (TIM).
- Calculating the variation in the Foster model with different IGBT chip loss to Diode loss ratios.

If these and other second order effects are taken into account and failure modes of other components such as capacitors and fans are included then any lifetime reliability estimations of the converter can be very time consuming. It should be remembered that all these calculations are based on a statistical analysis and are only as good as the input data. So how much is enough? Some questions that might help frame the answer to that difficult question are: what is the cost of a converter failure, how often do the worst case conditions really occur, how accurate is the mission profile and base loss and temperature calculations, what is the actual realistic lifetime requirement and finally, as a design engineer, how well do you want to sleep at night? It is also possible to implement in the system controls an on-line life time estimator, and so be able to act preemptively with preventive maintenance if the customer has subjected the converter to an especially severe mission profile.

Conclusion

In these two articles we have considered two different corner points in the thermal design of IGBT based power modules. In part 1, the focus was keeping the semiconductor itself below the maximum operating temperature; in part 2, the focus was on calculating if the module internal interconnects could withstand the temperature swings and meet the design life time specification of the product. These two corner points can be mutually exclusive and it is recommended that both these thermal constraints be considered as key components of any design review process.

Reference:

1. Comparison between active and passive thermal cycling stress with respect to substrate solder reliability in IGBT modules with Cu baseplates. Marc Schafer. PCIM Europe 2014.
2. Impact of Test Control Strategy on Power Cycling Lifetime. S. Schuler. PCIM Europe 2010

Contact details:
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By Dr. Christian Rod and Mr. Pierre Goumaz, LEMSYS SA

With the LEMSYS PRO-AC test equipment, both manufacturers and users have now access to a performant and economical solution for dynamic parameters measurement.

Motivations

In a world where energy becomes more and more valuable, efficient power electronics devices are bound to increase their market share. The necessary increase in the production capability implies a specific and adapted solution for testing these new and efficient devices, characterized by fast commutations and a high sensitivity to parasitic elements, such as inductance. In order to provide the market with such an adapted solution, LEMSYS has designed the PRO-AC test equipment, which is presented in this article.

The LEMSYS PRO-AC

The test equipment is presented on Figure 1. Restrained in a single compact cabinet.The PRO-AC will fit as easily inside a fully automatic production line as in a qualification laboratory. In the later situation especially, the dedicated electrical output will allow you to change the adaptor in no more than a few minutes, allowing you to easily use the same test equipment with a multitude of different devices and packages.

The mechanical adaptor is included in a specifically designed test frame that comprises a heating system for tests at devices rated temperature. This test frame can be used in a semi-automatic way (the user start the test sequence through the graphical user interface) or in a full-automatic way (the test sequence is started by the closure of the device-under-test drawer). Depending on the application, the choice between these two modes can be done easily through a dedicated user interface directly on the test frame.

Figure 1: Lemsys New Pro-AC Test Equipment

Regarding the inner conception, it follows the goal of maximum simplicity. The repetitive and modular design leads to maintenance down-times as low as possible, increasing as much the production capability and decreasing the need for spare parts stock.

The graphical user interface of the in-house developed control software (Figure 2) has been conceived to limit to its minimum the time required by the edition of a test sequence. Moreover, this control software includes a lot of useful functionalities such as the possibility to run a test equipment auto-diagnostic, the possibility to save both plot images and measurement points in case of a failed test for analysis and reporting purposes and the real time statistics (Figure 3) allowing the user to easily keep an eye on the production quality.

Figure 2: Main Control Software GUI for test edition

Figure 3: Display of Real Time Statistics in the Main Control Software

Key Points

Fast switching devices require a test equipment with dynamic parasitic values (inductance and capacitance) as low as possible. The new LEMSYS PRO-AC has been designed with the primary goal to provide the lowest parasitic inductance on the market. LEMSYS is proud to announce that this goal has been successfully reached ! Indeed, measurements taken directly on the device under test, and therefore including both the test equipment and the adaptor, show a value as low as 37.12 nH, as can be observed on Figure 4.

Such a low parasitic inductance value enables the PRO-AC to perform tests on very sensitive devices, such as the GaN transistor GS66508P, in conditions that create damaging oscillations if performed on other testers available on the market.

Figure 4: Effect of the parasitic inductance on the DC-link voltage during a turn-off

Key Dynamic features	
Collector Current	Up to 600A and up to 2500A for short-circuit test
Collector Voltage	Up to 1500V
Parasitic inductance	Ab. 35 nH
Maximum di/dt	Ab. 3000 A/µs
Maximum dv/dt	Ab. 250 kV/µs

Table 1: The Key Dynamic Features

All common switching values, such as turn-on delay, rise-time or switching losses can be measured through different tests using standard single and double-pulse waveforms. Figure 5 illustrates a turn-on test at the LEMSYS PRO-AC rated voltage and current, respectively 1500V and 600A.

Figure 5: 1500V-600A Double Pulse Waveform on a FZ1200R33KF2 IGBT module

Figure 6 illustrates the turn-on behavior of a C3M0065090D SiC device measured on the new LEMSYS PRO-AC. It can be seen the fast switching capability of the test equipment since the measured rise-time corresponds to the typical value indicated by the manufacturer datasheet, confirming the adequacy of the LEMSYS PRO-AC with the test of wide-bandgap devices.

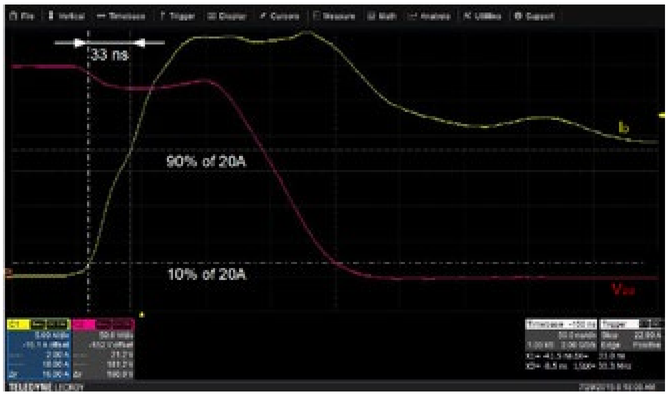

Figure 6: Turn-on behavior of a SiC device (C3M0065090D)

Integration of static tests

The last key advantage of the new LEMSYS PRO-AC is its ability to be easily upgraded to a full AC and DC test system. Including all the standard static tests, such as leakage current and breakdown voltage up to 3kV, RDSon and/or forward voltage drop up to 2000A and gate leakage current measurements down to only a few nA, this test equipment will be the perfect solution for both production and qualification tests. Moreover, such an upgrade can be done without the need to upgrade the adaptor since they are already fully compatible with LEMSYS full range of tests.

Summary

With the release of the new PRO AC-DC product family, LEMSYS confirms its status of a key player in the power semiconductor test equipment market. With this new product range which addresses both high performance requested by engineers and economical imperatives imposed by the market and technical issues faced by test engineers. Developed with the goal to gather both high technical performances and the simplest possible use, the PRO AC-DC product family will integrate a production line as easily as a qualification laboratory. Indeed, according to the previously presented results, users can expect:

1. The lowest stray inductance on the market.
2. A solution specifically designed for the devices generation.
3. A use as simple as possible, regarding both the graphical user interface and the change of mechanical adaptor, that allows quick test sequences design and reduced idle time.
4. The possibility to add an option including all the standard static tests.

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Radiation Action on I-V Characteristics of Power Semiconductor Devices Based on Silicon

Results of theoretical research of influence of cumulative dose on I-V characteristics (I-VC) of power semiconductor devices based on silicon are presented. It is shown that unlike low-power devices at which the radiation leads to falling of threshold voltage and building up of differential resistance, the threshold voltage of power devices under the radiation influence, as a rule, grows, and differential resistance practically doesn't change.

By A.V. Stavtsev, D.O. Malyi, A.A. Pisarev, D.A. Titushkin; Proton-Electrotex, Russia, Orel and S.I. Matyukhin, V.O. Turin, State University ESPC, Russia, Orel, e-mail: sim1@mail.ru

Nowadays power electronics applications based on powerful semiconductor devices are used in various areas of human activity: household (vacuum cleaners, refrigerators, air conditioners, washing machines, etc.), electric-power industry (frequency and voltage converters in power stations, technical process capacity regulators residential sector (elevators and lighting), automotive industry (robotic assembly lines, welders, conventional and hybrid engine management systems), aerospace industry (power-supply systems and electric drives). Major part of power semiconductor devices (PSD) is used in metal manufacture and communications (induction furnaces, high-performance power supplies, converters and control devices). Computer and power electronics responsible for the work of "mind" and "muscle" of modern technics accordingly, become the primary technology of the 21-st century. And at the same time, large-scale usage of PSDs leads to constant expansion of the range of conditions in which these devices have to operate.

Part of these conditions is connected with the effect penetrating radiation produces on PSD. This, in particular, happens due to the implementation of the latest electronic developments in atomic energetics, altitude aircrafts, and also by the increasing usage of power electronics in space research including interplanetary flights. All this, together with the current safety and failure-free operation requirements makes research in radiation effects on various PSD characteristics extremely relevant.

One of the most important characteristics of PSD is the I-VC, since their output capacity and performance factor greatly depend on it. The reviews of the research works on the radiation effects on I-VC and other PSD characteristics are presented fairly wide in today's literature [1-12]. However in these works the main attention is usually given to the area of comparatively low current density (up to 50 A/cm2) where the major physical effect determining I-VC is the interaction of injected carriers with deep impurity levels that act as recombination and trapping centers. In this research we present the theoretical study of the influence of the cumulative dose on powerful high-voltage devices which, unlike low-power devices, generally operate at high current density (over 50 A/cm2) and high injection levels and in which the following effects of the carriers interaction become significant: loss of emitter junction injection rates, electron-hole recombination (EHR) and Auger recombination.

I-VC of power electronic devices

As it is known [13; 14], at high injection levels, p-n-p-n-structures I-VC correspond to p-i-n-diodes I-VC which, in case of on-state, can be presented as follows [14-20]

$$V_F \approx \frac{\eta kT}{e}\ln\left(\frac{I_F}{I_{Si}}\right)+\frac{1{,}5kT}{e}\exp\left(\frac{W_n}{2L_p}\right)+$$

$$+\frac{W_n I_F}{GS\left(\frac{T}{300}\right)^{\beta}}+\frac{(C_n+C_p)\,\tau_p^2}{e^2(\mu_n+\mu_p)}\left(\frac{I_F}{S}\right)^2, \qquad (1)$$

where I_F - direct current; V_F - forward voltage drop in the device; η - ideality factor which in this research equates η ≈ 1,6; e – electron charge; k - the Boltzmann constant; G ≈ 16 (Ohm·cm)$^{-1}$; T – absolute temperature of the element; S – it's surface; W_n - low-doped n-base thickness; μ_n and μ_p- electron and hole mobility accordingly; τ_p - lifetime of minority carriers (holes) in the base; C_n и C_p – Auger recombination constants; β – exponent of power: ß ≈ 1 .

Ambipolar length of hole diffusion in the base L_p, which is included in the formula, is determined by the expression [14-18]

$$L_p = \sqrt{\frac{2b}{b+1}D_p\tau_p}\ , \qquad (2)$$

where $D_p=kT\mu_p/e$ - hole diffusion rate and $b=\mu_n/\mu_p$ - electron and hole mobility ratio, which is b ≈ 2,7 for silicon.

Value I_{Si} is presented as follows [14-18]

$$I_{Si} \approx \frac{2eD_p n_i S}{L_p} \frac{b\,\mathrm{sh}(W_n / L_p)}{b\,\mathrm{ch}(W_n / L_p)+1}, \qquad (3)$$

where n_i - concentration of intrinsic carriers in the base.

Comparison of calculations, performed by formula (1) with the results of experimental measurements is presented in figure 1.

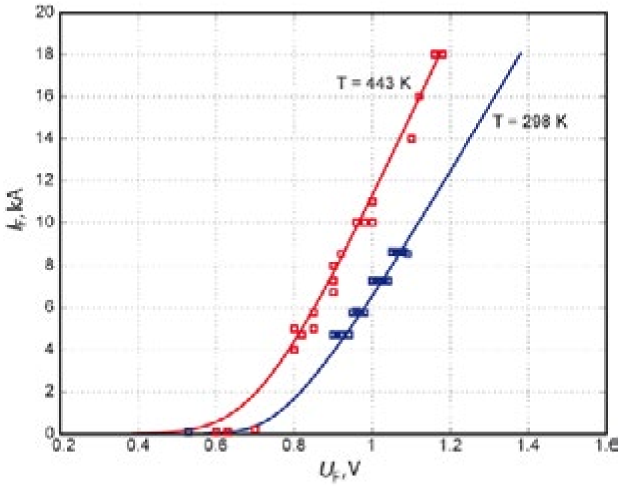

Figure 1: I-VC of the high-power diode D053-7100-4-N (Proton-Electrotex): markers – measurement results; block curves – the results of the theoretical calculations by Formula (1)

As the figure shows, Formula (1) is in the satisfactory fit with the experimental data. The first item in the formula is direct voltage drop in p-n-junction, the second item is voltage drop with allowance for base conductance modulation by injected carriers, the third one registers voltage drop, conditioned by EHD, and the decrease of emitter injection coefficient, and finally, the forth – voltage drop, conditioned by the Auger-recombination.

As it is shown in figure 1, under high current the curve of PSD I-VC becomes practically linear and can be approximated by the following expression

$$V_F \approx V_{T0} + rI_F, \qquad (4)$$

where V_{T0}- threshold voltage; r – differential resistance of the device.

Reverse current of silicon PSD is mostly generated and is determined by the expression [17]

$$I_R \approx \frac{en_i d_n S}{2\sqrt{\tau_p \tau_n}}, \qquad (5)$$

where τ_n- lifetime of the electrons in the p-emitter and d_n- thickness of layer of space charge in the n-base.

Being represented in micrometers, this thickness (in µm) can be expressed [17]

$$d_n \approx 0,52\sqrt{\rho_n V_R}, \qquad (6)$$

where ρ_n- specific resistivity of silicon in the n-base (Ohm·cm); V_R- reverse voltage (V).

Changes in silicon properties under the action of radiation
Radiation action leads to [1-12] the atomic ionization of the semiconductor and produces radiation defects and new atomic energy level defects in the band gap of the semiconductor, and as a consequence, leads to:

- decreasing of lifetime of the charge carriers:

$$\frac{1}{\tau(\Phi)} = \frac{1}{\tau_0} + K_\tau \Phi; \qquad (7)$$

- decreasing of charge carrier concentration:

$$n(\Phi) = n_0 \exp(-K_n \Phi); \qquad (8)$$

- change in mobility:

$$\frac{1}{\mu(\Phi)} = \frac{1}{\mu_0} + K_\mu \Phi. \qquad (9)$$

In turn, the change in concentration and mobility leads to the change in specific resistance of silicon:

$$\rho(\Phi) \approx \rho_0 \exp(K_\rho \Phi). \qquad (10)$$

In the proportions (7)-(10), values with Index 0 refer to silicon characteristics before irradiation and the letter Φ denotes the cumulative radiation flux (fluence). Constants K_τ, K_n, K_μ and K_ρ are radiation constants which depend on the manufacturing technique and the specific resistance of the basic material, nature of the radiation, and the type of radiation defects. In the further calculations we used values of these constants which are given in Research [21] for CZ-silicon, irradiated with fast neutrons (with energy of about 1-1,5 MeV). In particular, we considered that WK_τ is specified by the following empirical relations:

For n-silicon:

$$\frac{\text{ñ}}{K_\tau^{(n)}} = 4 \cdot 10^4 + 5,76 \cdot 10^6 \left(\frac{p}{n}\right)^{0,534}, \quad \left[\frac{}{\text{ñì}^{2}}\right];$$

For p-silicon:

$$\frac{\text{ñ}}{K_\tau^{(p)}} = 2,5 \cdot 10^5 + 5,55 \cdot 10^6 \left(\frac{p}{n}\right)^{0,395}, \quad \left[\frac{}{\text{ñì}^{2}}\right],$$

Where p- and n- - hole and electron concentration in silicon accordingly

Results of mathematical simulation of radiation action on I-VC of PSDs and discussion
Formulas (1)-(10) allow to perform mathematical simulation of radiation action on I-VC of PSDs. In particular, figure 2 shows the results of the simulation of neutron radiation action on I-VC of PSDs.

As the results show, uniform irradiation of PSD leads to the change in the threshold voltage of the devices but almost does not alter their differential resistance. Thereat, as our calculations show, change in PSD characteristics is mostly connected with the decreasing lifetime of the charge carriers (7), and the decrease of carrier concentration (8) and mobility (9) has almost no effect on I-VC of PSD.

Inconsiderable dependency of PSD differential resistance on radiation can be explained by the fact that under major current density it is mostly defined, as it is seen from the comparison of (1) and (4), by electron-hole recombination processes [the third item in (1)], and consequently does not directly depend on the lifetime of the charge carriers. Under the radiation action, PSD resistance can change considerably only due to the change of the Auger-recombination speed [the fourth item in (1)].

Total change in threshold voltage of PSD is conditioned by the voltage drop in p-n-junction [the first item in Formula (1)] and the increase of voltage in the base [the second item in (1)]. Speed of the threshold voltage change equals

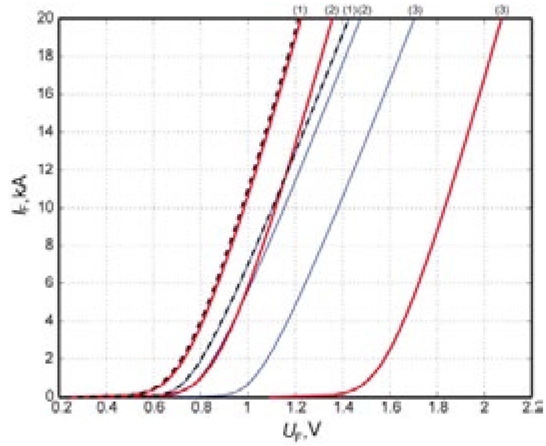

Figure 2: Theoretical I-VC of power diode D053-7100-4-N, irradiated by neutrons (block curves): 1 - Φ = 3·10^12 cm^−2; 2 – Φ = 10^13 cm^−2; 3 – Φ = 3·10^13 cm^−2. Thin curves – T = 298 K; thick curves – T = 443 K; dotted line – I-VC of the unirradiated diode.

$$\frac{dV_{T0}}{d\Phi} \approx \frac{kT}{e} \times$$
$$\times \left\{ \begin{array}{c} 0,75 \dfrac{W_n}{L_p(\Phi)} \exp\left(\dfrac{W_n}{2L_p(\Phi)}\right) - \\ -\eta f\left(\dfrac{W_n}{L_p(\Phi)}\right) \end{array} \right\} \times$$
$$\times \frac{K_\tau^{(n)} \tau_p(\Phi)}{2}, \qquad (11)$$

where $1 \le f(x) \le 2$:

$$f(x) = 1 + x \coth(x) - x \frac{b \operatorname{sh}(x)}{b \operatorname{ch}(x) + 1}.$$

Dependency $\tau_p(\Phi)$ in Formula (11) is defined by the Expression (7) and $L_p(\Phi)$ - by Formula (2), where $\tau_p = \tau_p(\Phi)$

High dependence of voltage change speed (11) on relation W_n/L_p is quite noticeable. This dependence causes threshold voltage in the devices with thin base $W_n < 2L_p$ to reduce at small values of cumulative radiation flux. However with the increase of the cumulative dose and in case of $W_n \ge 2L_p$ threshold voltage of PSD increases rather quickly due to the leading voltage rise in the base as compared to the voltage drop in p-n-junction. At that, charge carrier lifetime degradation (7) leads to the increase of the reverse current (5) at any values of cumulative radiation flux:

$$\frac{dI_R}{d\Phi} \approx \frac{e n_i d_n S}{4\sqrt{\tau_p(\Phi)\tau_n(\Phi)}} \left(K_\tau^{(n)} \tau_p(\Phi) + K_\tau^{(p)} \tau_n(\Phi)\right).$$

Conclusion

The results we have got show that the emerging effects, connected with the interaction of charge carriers with each other - decreasing constants of emitter junction injection, electron-hole recombination, additional Auger-recombination channel – cause sufficient difference in I-VC of powerful high-voltage devices and low-voltage devices, which lack the mentioned effects. Particularly, unlike low-voltage devices that show threshold voltage drop and rise of differential resistance, resistance of high-voltage devices conditioned by EHD processes remains almost unchanged, and threshold voltage generally rises.

The latter circumstance is connected with the fact that at high current density the change in threshold voltage under irradiation is conditioned mostly by the voltage change in the low-doped n-base, which greatly depends on the relation between the base thickness and the length of the minority carrier free path W_n/L_p and increases due to the reduction of minority carrier lifetime under the action of irradiation. At the same time, power devices with thin base $W_n<2L_p$, as it is shown in Formula (11), can show threshold voltage drop at values of cumulative radiation flux (i.e. as long as the inequation $W_n<2L_p$ is fulfilled), which can be used (and is being used) for purposeful modification of device characteristics by means of irradiation methods

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Achieving very low or zero standby power for AC/DC power supplies

In the future the average household will have more than 60 devices plugged in and on standby 24 hours a day. From coffee machines and TVs, to chargers and smart plugs, these devices can cost households hundreds, even if inactive. But while consumer demand for electrical goods increases, global energy standards are driving the need for reduced standby loss.

By Florian Mueller, Texas Instruments, Freising, Germany

For example, the European Commission Code of Conduct (COC) and the US Department of Energy (DOE) define standby power standards for power supplies when they are on, but disconnected from a load. The COC limits the no-load power consumption for 1W to 49W output power rating to 75mW (Tier 2) and the DOE to 100mW. The Energy Star program, developed in the US and expanded to the EU, for cell phone charger limits the no-load power to 30mW for the highest 5 star. However, the industry is pushing even for less than 5mW standby power which is called zero standby power.

At low power levels, the flyback topology is probably the best choice for an offline design. It is one of the least expensive isolated topologies because it uses a very low number of components. In the past, an optocoupler was usually used to regulate the secondary side output but modern quasi-resonant (QR) flyback controllers provide primary side regulation, enabling designers to bypass the optocoupler altogether.

Primary side regulation uses the magnetic feedback via the bias winding to close the feedback loop. This makes it among the most cost-effective isolated offline topologies, because a simple resistor divider connected to the bias winding is sufficient to regulate the output voltage. This article focuses on achieving low standby power for a primary-side regulated QR flyback.

Primary-Side Regulated Flyback

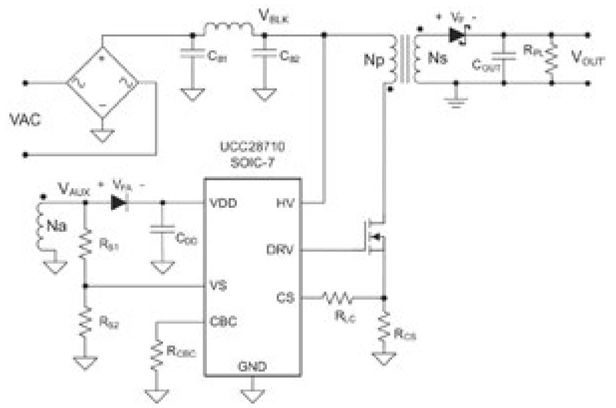

Figure 1: Primary-Side Regulated Flyback

Figure 1 shows the schematic of a PS QR flyback controller (UCC28710) from Texas Instruments. Quasi Resonant operation uses the resonance ringing, caused by the circuit parasitics and the primary inductance, to lower the switching losses (see Figure 2: Switchnode Voltage).

After the core of the transformer is completely demagnetized (secondary side current has ramped down to zero) there will be a resonant ringing, caused by the primary inductance and the energy stored in the parasitic switch node capacitance. The controller detects the valley of the resonant ringing and turns on the MOSFET. The switching frequency varies in order to have the switching event happen on a valley. The lower switchnode voltage at the valley reduces switching losses.

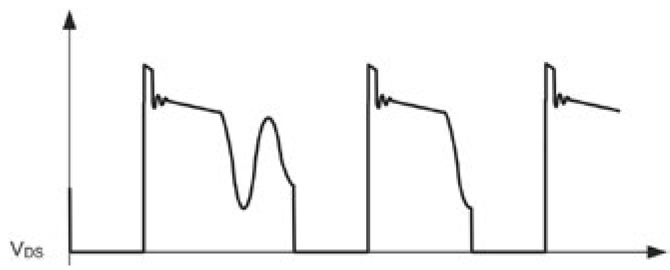

Figure 2: Switchnode Voltage (drain-to-source voltage of the primary MOSFET)

Standby power

The total standby power consists of two main components. The first main component is the energy, which is taken every switching cycle from the input, and the second main component is the loss of the startup circuit.

The leakage losses of the input bridge rectifier and the bulk capacitors have also a contribution to the total loss, but they are very small (usually below 1mW even for an input voltage of 230VAC) and must only be considered for achieving zero standby power.

The parasitic switchnode capacitance and the snubber network also add additional losses to standby power.

Cycle Energy

The controller takes a minimum amount of energy from the input each switching cycle, called the minimum cycle energy. The two limiting factors for the lowest possible minimum cycle energy are the minimum controllable on-time t_{on_min} and the minimum switching frequency f_{sw_min}. t_{on_min} cannot be affected by the designer. This time is mainly determined by the leading edge blanking time and is given in the datasheet. On the contrary f_{sw_min} can be chosen by the designer.

Usually the minimum possible switching frequency of the controller or the required transient response defines f_{sw_min}. Unfortunately there is a trade-off between low standby power and fast transient response. The lower the f_{sw_min}, the lower the standby power, but this has a negative impact on the transient response.

Why is this the case? A primary side regulator does not monitor the output voltage constantly. The controller samples the auxiliary voltage just one time per switching cycle to control the output voltage. During the rest of the period time the controller is blind. It can take up to the period time to detect a load transient, meaning the transient response is worse for longer period times, and respectively for lower switching frequencies.

Startup Circuit

There is a resistive startup method which results in a high increase in standby power because the startup resistor is permanently connected to the very high bulk voltage V_{BLK}, allowing power to dissipate in the resistor. For low standby power applications an active start up method must be used, like the controller UCC28710 (see Figure 1). The principle is simple, a normally on device, usually a depletion mode FET, replaces the startup resistor. Once the output voltage ramped up, the controller can turn off the startup FET. This reduces the losses in the startup circuit significantly.

Snubber Network

For a low standby power application it is better to use a TVS snubber instead of an RCD (resistor, capacitor, diode) snubber. While the TVS snubber is more expensive, it achieves higher efficiency because the power is not dissipated before the TVS cathode voltage reaches $V_{in}+V_{clamp}$.

The choice of the correct diode is also very important - an ultra-fast diode is important if a TVS snubber is used for a valley switching topology. In some low power applications it is possible to disclaim the snubber network. This will decrease the standby power further.

Parasitic Switchnode Capacitance

The parasitic switchnode capacitance C_{SN} has also an impact on the standby power. C_{SN} is the sum of the parasitic capacitances of the MOSFET (C_{oss}), the transformer, snubber diode, output diode and the layout. The dominant part is the MOSFET output capacitance C_{oss}. Each switching cycle the energy E_{IN_PAR} ($E_{IN\_PAR} = C_{SN} * V_{BnlK}^2$)is stored in CSN. A portion of this energy is dissipated in the switch and in the snubber. The remaining energy is delivered to the auxiliary and secondary outputs. Decreasing CSN is helpful to achieve very low standby power.

Minimum Load Requirement

If the cycle energy is not absorbed then the output voltage loses regulation and increases if the output is unloaded. This is prevented by applying a minimum load on the output, usually in form of a resistor. In fact a bigger pre-load improves the transient response but increases the standby power. If the secondary sideparts withstand a higher output voltage then a very low minimum load can be used which lowers the standby power.

Zero Standby Power

Achieving zero standby power is very tough. The losses without an active load must be less than 5mW across the input voltage range. The switching frequency must be reduced dramatically to achieve this low power level. Unfortunately reducing the switching frequency has a big tradeoff. The transient response gets very bad, because it can take up to the period time, before the controller detects an output voltage drop. Texas Instruments found a solution for this problem. There is a zero standby power chipset, consisting of a primary side regulated flyback controller (UCC28730) and a wake-up controller (UCC24650). The UCC28730 operates with a very low switching frequency of only 32Hz under no output load conditions. The UCC24650 monitors the output voltage V_{out} constantly. If V_{out} drops more than 3% due to a load step, the wake-up controller sends a wake-up signal to the primary side through the transformer (across the isolation barrier). There is no need for an additional isolation component. The primary side controller (UCC28730) detects the wake-up signal and increases the switching frequency immediately by delivering three transition-mode pulses. This approach enables a fast transient response and a very low standby power at the same time.

Conclusion

It needs some effort to achieve very low standby power. Many components make up the final result- from an active start-up circuit and a small switchnode capacitance to low switching frequency. Fortunately a primary side controlled topology does not have to deal with losses of an optocoupler and an external error amplifier. Nevertheless achieving zero standby power is difficult, even for a primary side regulated controller. A smart method, like a wake up controller, is needed to limit the standby losses to less than 5mW for high-power AC/DC power supplies – minimizing energy and financial waste for example when your phone charger is left plugged in all day.

About the author

Florian Mueller was born in Rosenheim, Germany, in 1976. He received a degree in electrical engineering from the University of Haag. After working for several years as freelancer in the field of electrical engineering, he joined TI in 2008 and is working in the European Power Design Services Group, based in Freising, Germany. His design activity includes isolated and non-isolated DC/DC and AC/DC converters for all application segments.

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20 MHz Bandwidth Envelope Tracking Power Supply Using eGaN® FETs

This article, we will present an ET power supply using EPC8004 high frequency eGaN FETs for 4G LTE wireless base station infrastructure. The ET power supply is based on a multi-phase, zero-voltage switching (ZVS) synchronous buck converter. It offers 20 MHz large signal bandwidth, delivering over 60 W average load power sourced from 30 V. 92% average total efficiency is achieved when tracking a 20 MHz LTE envelope with 7 dB peak-to-average power ratio (PAPR).

By Yuanzhe Zhang, Ph.D. and Michael de Rooij, Ph.D.
Efficient Power Conversion Corporation

Multi-Phase Topology with Soft-Switching

A four-phase synchronous buck pulse-width modulated (PWM) topology is selected, as shown in figure 1. The power switches are EPC8004 eGAN FETs. The PWM control signals for adjacent phases are phase-shifted by 90 degrees. Switching at 25 MHz in each phase gives the full converter an effective output switching frequency of 100 MHz. A resistive load is used to represent the radio-frequency power amplifier (RFPA), and a fourth-order filter with 20 MHz bandwidth that supports zero-voltage switching is designed, allowing high efficiency operation and automatic phase current balancing [2]. The printed circuit board (PCB) layout is optimized according to the design practices in [3].

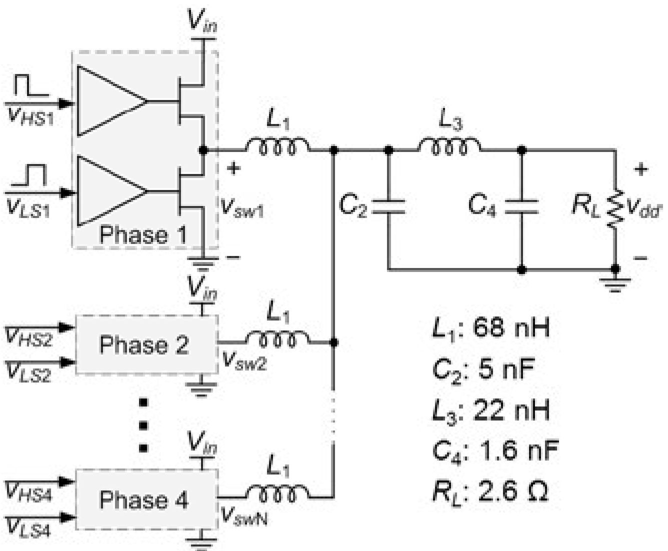

Figure 1: Diagram of a four-phase synchronous Buck converter with fourth-order output filter

Low loss High Speed Gate Driver

Design of the gate driver that supports switching at high frequency is very challenging, particularly for the high-side FET in the half-bridge configuration. Traditional bootstrap half-bridge gate drivers (LM5113 [4], for instance), designed for higher current, lower frequency applications, generally have high loss due to the reverse recovery charge of the bootstrap diode. As a result, the maximum switching frequency is limited. In order to achieve 25 MHz switching frequency while maintaining high efficiency, a synchronous FET bootstrap supply [5] is used.

In [5], a way to use LM5113 at high frequency is introduced, with proper circuity to disable its internal bootstrap diode. In this application, however, a different approach is implemented. As shown in figure 2, digital isolators ISO721MD [6] and ultra-high speed logic gates SN74LVC2G14 [7] are used instead of the LM5113.
The EPC2038, with the smallest electrical and physical footprint is selected as the synchronous bootstrap FET (Q_{BTST}) for minimal parasitics and associated losses. The low side FET driver consists of the same component as the high side for matched propagation delay.

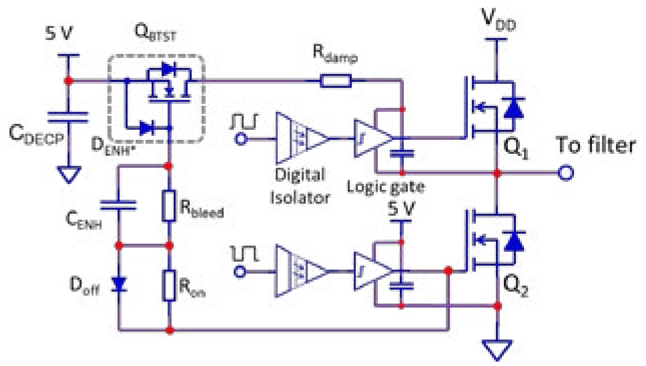

Figure 2: Schematic diagram of the gate drive circuit with synchronous FET bootstrap supply, for one phase of the system converter

Static Efficiency Measurement

The ET supply is evaluated at steady-state operating points. Figure 3 shows the measured power-stage efficiency, and total efficiency that includes the losses in the gate driver, for a range of duty cycles (output voltages). The peak efficiencies are greater than 94% and 93% for power-stage and total, respectively, at around D = 0.5, or 15 V output. The static measurement was not performed for output voltages higher than 17 V due to thermal limit as no heat sink is mounted on the eGaN FETs.

The probability distribution function (PDF) of a 20 MHz 7 dB PAPR LTE envelope signal is also shown in figure 3. Even though the output voltage range is from 5 V to 28 V, voltages around 9 V to 15 V occur with significantly higher probability. Nevertheless, the power stage efficiency is greater than 90% over the whole range.

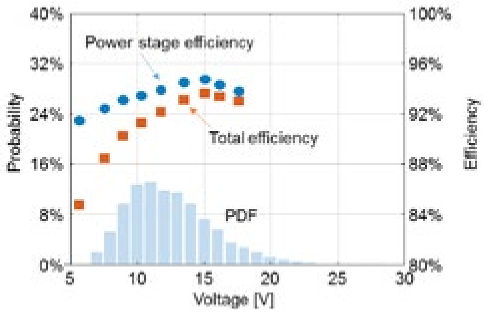

Figure 3: Measured steady-state power-stage efficiency and total efficiency; and probability distribution function (PDF) of the 20 MHz LTE envelope signal

Dynamic ET Measurement

The 20 MHz LTE envelope signal is converted into eight PWM signals, for controlling the high side and low side FETs in four phases. Appropriate dead times to achieve ZVS operation are also implemented at this stage. The PWM signals are stored in the memories of an Altera® Arria® V FPGA [8] and transmitted to the gate drivers. The resolution of the pulse width is around 0.2 ns, allowing fine adjustment of duty cycles and dead times for high fidelity ET performance. The block diagram of the LTE signal generator system is shown in figure 4.

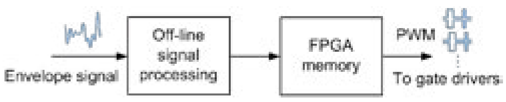

Figure 4: Simplified diagram of ET signal generation

The output of the ET supply is measured with a 1 GHz differential probe (TDP1000). A sample of the measured output voltage is compared to the reference in figure 5. The average output power is 67 W and the peak value is 346 W, corresponding to 7 dB PAPR. Average power-stage efficiency and total efficiency are 93% and 92%, respectively. Accurate

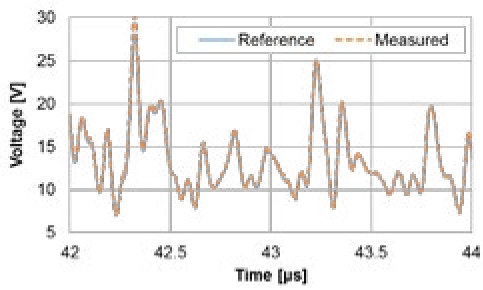

Figure 5: Reference and measured LTE envelope signal

tracking is achieved with the normalized root-mean-square error (NRMSE) of only 1.2%. The measured maximum current slew rate is 180 A/µs.

Summary

eGaN FETs and integrated circuits are helping to achieve very high switching frequency in switched-mode power supplies, leading to breakthroughs in a large number of applications where bandwidth, slew rate and efficiency are critical. ET is one of them.

Due to lower input and output capacitances (C_{ISS} and C_{OSS}) and lower gate charge (Q_G) [9], GaN based switching converters are able to operate at tens of megahertz switching frequency with high efficiency. With topologies such as multi-phase and multi-level, GaN switching converters can achieve high bandwidth that meets the requirement of modern wireless communication standards, such as 4G LTE.

An ET power supply with four-phase soft-switching buck converter using EPC8004 is able to accurately track a 20 MHz 7 dB PAPR LTE envelope signal with greater than 92% total efficiency, delivering 60 W average power. The design is also scalable to satisfy different power levels by choosing different EPC parts.

eGaN® FET is a registered trademark of Efficient Power Conversion Corporation.

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E Mobility for Components and EMC – Simulation and Measurement

The objects of simulation are a motor drive with frequency/voltage converter, DC/DC voltage converter and a battery with a battery management system (BMS). The purpose of the study is to make a simulation model that is as close as possible to the real device and to propose different methods to lower or isolate the disturbance effects.

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For the current simulation are taken into account only conducted emissions. Radiated emissions can be implemented in the future in a three dimensional model. The created simulation models are designed in order to be connected with other PSpice models in order to make a complete model of the test E-car.

The depletion of fossil fuels and the rising of the fuel prices in the recent years have led to an increased interest of the car manufacturers in the construction of hybrid and electrical cars. On the other hand the requirements that are set for EMC of the elements of such new machines are very strict and hard to accomplish. Having in mind the high price of the car elements for these new types of cars it was found more acceptable and cost effective to simulate the behaviour of the machine in software applications and to test the EMC effects on the simulation model until good results are achieved.

Data for the simulation / Technical parameters

The schematic of the test electrical car is presented on figure 1. The elements of the car with highest EMC emissions are used for this study.

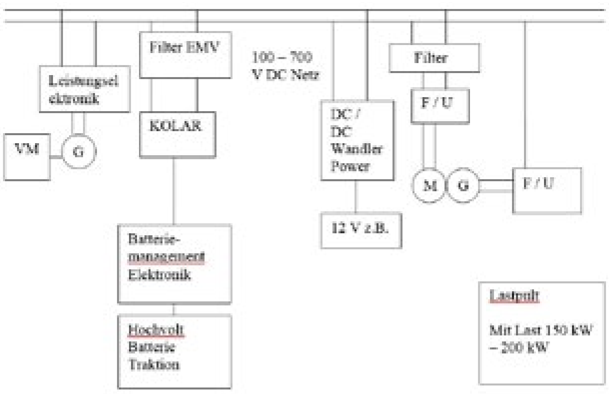


Figure 1: Schematic of the test E-car

For the simulation is used data from the technical parameters of the corresponding real devices in the test E-car, namely:

- Motor drive
- Frequency-voltage converter,
- DC/DC voltage converter,
- Battery with BMS.

EMC Simulations results

The frequency of the PWM control signal is 50 KHz. The duty cycle depends on the form of the required sinusoid. The selected frequency of the sinusoid is 660 Hz, which corresponds to the maximum load of the electrical motor and it is the heaviest operational mode.

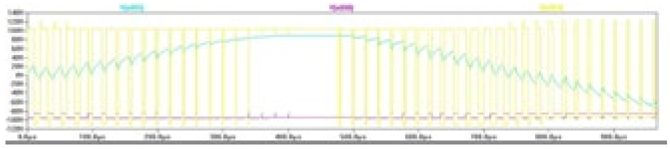


Figure 2: Wave forms of phase A signal and PWM control signal

The red line (Vn005) in the graphics represents the form of the sinusoid measured between phases A and B. In the current simulation model are used no additional filtering capacitors. That's why the sinusoid on the graphic has some fluctuations from the ideal sinusoid form. The green line (Vn008) is the control signal of the upper transistor from the bridge and the blue line (Vn004) shows the control signal for the lower transistor.

On figure 3 is presented the Fast Fourier Transformation (FFT) of the output sinusoid.

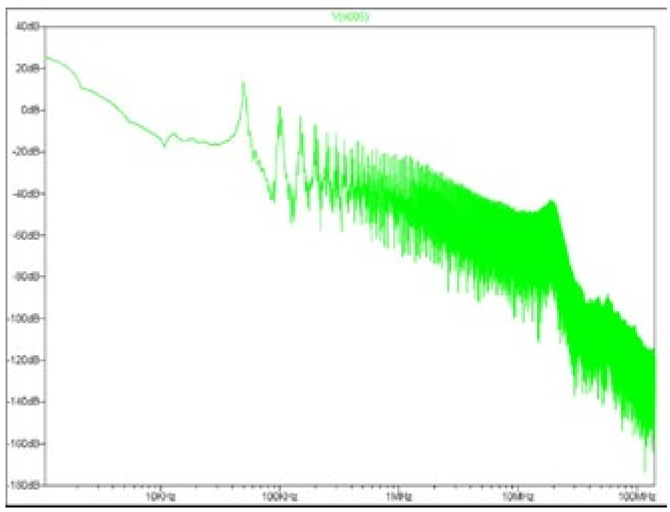


Figure 3: FFT of the output sinusoid

On the figure can be seen that there is one main harmonic at 50 kHz, followed by higher harmonics. There is one peak at around 20 MHz, which has the highest negative effect on the signal and has to be eliminated.

EMC Measurement results

At the following measurement figures 4 and 5 the very high disturb EMC voltage is at the grafics.

Figure 4: EMC voltage measurement at the battery line

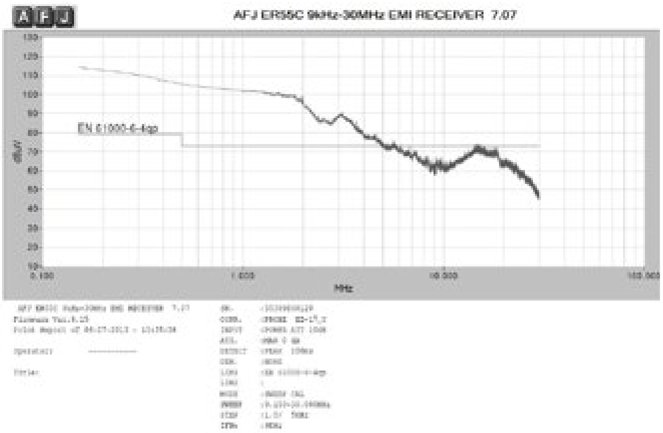


Figure 5: EMC voltage measurement at the frequency/ voltage transducer

The result of the practical measurement is, that the EMC test at the standard EN 61000-6-4 is NOT PASSED.
We have many very high disturb effects. The simulation result have the same characteristic of the measurement grafics, but the simulation result is not full the same characteristic like the practical measurement.
The reason is, that the EMC model have only the galvanic coupling effect and not all EMC coupling effects.
But the simulation and the measurement result is, that the EMI is very high and not pass the test.

Conclusions

The simulation models of the e-car components were made based on default parameters. The technical characteristics of the real experimental device can be different from the simulation ones and thus the simulation results might differ from the experimental results. Based on the result from the simulation can be concluded that an external input filter have to be used in order to improve the EMC characteristics of the device. The simulation results invoke the conclusion that the operating frequency of the filter has to be DC up to 60 Hz and the current should be rated according to the batteries used.

For output filter we recommend that a sine wave filter for motor drives with motor frequency 0- 1000 Hz and motor power up to 35 kW should be used. Such filters are easily available on the market.

References:

1) Napierala T., E. Hoene, Systemmodellierung für Komponenten von Hybridfahrzeugen unter Berücksichtigung von EMV-Aspekten, 11. Jun 2009, pp. 26 – 58
2) Palme R., EMV eines Batteriemanagementsystems in der Elektromobilität, Betrachtung und ganzheitliche Analyse mittels Elektrofahrzeugnachbildung am Motorprüfstand, Fachhochschule Nordhausen, 2012
3) Won-Sik Oh*, Sang-Kyoo Han, A Three Phase Three-level PWM Switched Voltage Source Inverter with Zero Neutral Point Potential, Journal of Power Electronics, Vol. 5, No. 3, July 2005, pp. 9
4) A. F. Petrie, C. Hymowitz, A SPICE MODEL FOR IGBTs, Intusoft, 222 West 6th St. Suite 1070, San Pedro, CA 90731, pp. 6

http://www.img-nordhausen.de

Digital SupIRBuck™ Reduces Time-to-Market

Infineon Technologies AG introduced the PMBus SupIRBuck voltage regulator family. The devices are easy-to-use, fully integrated and highly efficient DC-DC regulators with I²C/PMBus interface. The integrated PWM controller, MOSFETs and Bootstrap diode make them space-efficient solutions, providing accurate power delivery for low output voltage and high current applications. Due to the programmable digital interface with remote testing using telemetry, customers will benefit on up to 90 percent reduced design and test times – allowing significantly shorter time-to-market. Additionally, the highly integrated devices further reduce the board space in the range of 50 percent compared to conventional 2-chip solutions.

The new SupIRBuck voltage regulators are ideal for applications in data centers, network storage, wireless infrastructure, mass computing or industrial automation. The devices can be comprehensively configured via PMBus and the configuration stored in internal memory. In addition, 75 PMBus commands allow precise run-time control, fault status monitoring and telemetry of parameters like V in, V out, I out, T or P out. The new synchronous buck regulators can also operate as a standard analog regulator without any programming and can provide current and temperature telemetry in analog format.

http://www.infineon.com/supirbuck

Low Pulse Width Distortion (PWD) High Speed Photocouplers

Toshiba Electronics Europe has launched two high speed photocouplers, TLP2745 and TLP2748. The new IC output photocouplers feature low Pulse Width Distortion (PWD) and low power consumption for high speed, high temperature operation. The new photocouplers have been designed for applications such as high-speed digital interfaces for measurement or control devices, intelligent power module (IPM) drives and programmable logic controllers for use in industrial settings.

The TLP2745 is a buffer logic type (high input → high output) photocoupler, while the TLP2748 is an inverter logic type (high input → low output) coupler, both provide an isolation voltage of min. 5000 Vrms.

Demand in recent years for energy-saving products has brought about a need for increasingly efficient power systems. Featuring a high speed propagation delay time of 120 ns (max) for higher operational efficiency while guaranteeing 40 ns (max) pulse width distortion and 70 ns (max) propagation delay skew, these new ICs allow the reduction of inverter dead time, contributing to an overall improvement in power efficiency. In addition, by guaranteeing a threshold input current of 1.6mA (max), they allow bufferless direct drive from microcomputers, and as such a reduction in energy consumption and cost.

http://www.toshiba.semicon-storage.com

Fast Switching Four-Channel Transistor Photocouplers

Toshiba Electronics Europe has expanded the line-up of its low input current transistor photocouplers with a pair of 4-channel versions, the TLP292-4 and TLP293-4. They are suitable for operation in a wide temperature range from -55 to +125˚C and can be used for a variety of high-density surface mount applications including programmable logic controllers (PLC), switching power supplies and simplex or multiplex data transmissions.

These photocouplers are housed in SO16 packages measuring just 10.3mm x 7.0mm x 2.1mm, that provide the space saving requirements needed for ever thinner and more compact finished products. Both are comprised of phototransistors optically coupled to Toshiba's latest long life InGaAs infrared light emitting diodes. The TLP292-4 can operate directly by AC input current, while TLP293-4 is the DC input version.

www.toshiba.semicon-storage.com

High-Voltage Batteries with First 100-V High-Side FET Driver

Texas Instruments introduced the first single-chip 100-V high-side FET driver for high-power lithium-ion battery applications, delivering advanced power protection and control. The bq76200 high-voltage solution efficiently drives high-side N-channel charge and discharge FETs in batteries commonly used in energy storage systems and motor-driven applications, including drones, power tools, e-bikes and more. For more details, see www.ti.com/bq76200-pr.

Key features and benefits of the bq76200:

- Versatile supply voltage range: Compatible with a variety of battery architectures, capacities and voltage ranges from 8-V to 75-V, with an absolute maximum of 100-V.
- Advanced-protection FET control: The fast-switching feature minimizes fault response time and disables the discharge FET if a battery has been severely discharged.
- Quick development time and reduced overhead: The adaptable driver works with small to large power FET arrays by simply scaling the charge-pump capacitor, reducing engineering overhead and speeding development time.
- High integration and small package size: The bq76200 integrates a high-voltage charge pump and dual FET drivers into one 5-mm by 4.4-mm by 1-mm thin shrink small outline package (TSSOP).

www.ti.com

High Vibration Surface Mount Aluminum Electrolytic Capacitors Handle 30g

Cornell Dubilier Electronics, Inc. (CDE) has introduced a ruggedized SMT Aluminum Electrolytic Capacitor series, able to withstand continuous vibrations of up to 30g of stress. This durability makes the new AFK_V Series especially well-suited to military and transportation applications, as well as in robotics.

The AFK_V Series offers low impedance and up to 5,000 hours life @ 105 ºC, at rated voltage. Available capacitance values range from 10 µF to 6,800 µF, with voltage ratings of 6.3 Vdc to 100 Vdc.
Packaged in a metal V-chip, SMT case, the new capacitors use a combination of three mechanical enhancements that provide greater vibration resistance as compared with the standard SMT package.
A support terminal was added to suppress vibration of the molded support base to the PCB, and therefore reduce contact stress. The support base was extended to create a high retention wall structure to better support the capacitor body. In an effort to reduce internal vibration of the capacitor winding, a larger diameter lead wire is used, which is very effective at eliminating internal lead breakage at critical stress points.
"By offering SMT aluminum electrolytics that are able to withstand high vibration, we give engineers a great solution to improve end-product durability," said Bill Haddad, Product Manager. "Circuitry that is on-board rough terrain vehicles or in factory automation can reach high vibration levels." Other applications include industrial power conversion, lighting control and automotive applications.

http://www.cde.com/HV/AFKLanding.htm

Low Loss Switch Mode Regulators with up to 95 % Efficiency

A family of highly efficient switch mode regulators from Mornsum had been displayed by Special Electronic (SE) at the embedded world in Nuremberg. Efficiency is up to 95 percent together with a low standby consumption of 54 mW. Based on the low losses the cost efficient devices do not need a heatsink. That helps for compact system design. The Input voltage range is from 6,5 bis 36 VDC and operating temperature is from -40°C bis +85°C. The short circuit proofed device can be ordered in open frame or SIP package. More detailed information of the Mornsun K78(L)xx-500R3 can be requested from power@spezial.de.

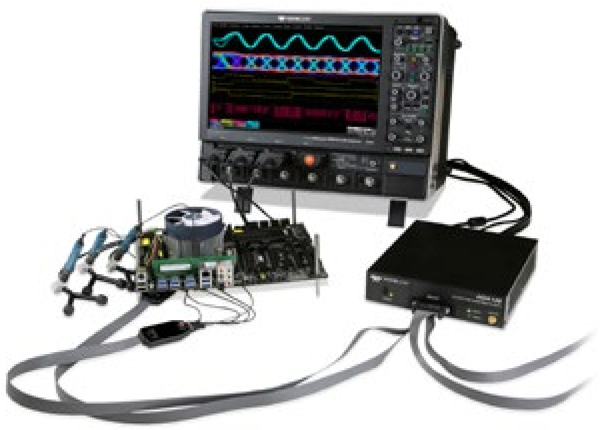
www.spezial.com

High-speed Digital Analyzer and Probing System Complete Mixed-Signal Solution

Teledyne LeCroy significantly expands the capabilities of its industry-leading oscilloscopes with the introduction of the HDA125 High-speed Digital Analyzer. The HDA125 digital acquisition system captures 18 channels of digital data at 12.5 GS/s. Adding it to Teledyne LeCroy oscilloscopes by means of the LBUS interface architecture results in the most flexible, highest-performance mixed-signal solution available. Also announced is the QuickLink probing system, featuring low-cost, high-fidelity probe tips that work with both the HDA125 and Teledyne LeCroy WaveLink probes using the new Dxx30-QL QuickLink adapter.

HDA125 High-speed Digital Analyzer:
The HDA125 samples 18 input signals at 80 ps intervals (12.5 GS/s) for accurate characterization of the fastest signals. However, sample rate is only half the story□high-speed embedded systems testing often poses challenging signal amplitude conditions. The High-speed Digital Analyzer meets these challenges with a 3-GHz digital leadset, ultra-low probe loading, and industry-leading sensitivity (150 mV minimum signal swing). The system ensures the most precise digital signal interpretation with a unique hysteresis adjustment capability, and three times better threshold accuracy than competing mixed-signal instruments.

QuickLink Probing System:
The QuickLink probe tip system is designed from the ground up to be compatible with both the HDA125 High-speed Digital Analyzer and with Teledyne LeCroy's WaveLink series of differential analog probes. This cross-connection capability allows a device under test (DUT) to be equipped with QuickLink Solder-In (QL-SI) tips at all desired test points, enabling swapping of connections between digital and analog acquisition systems as needed.



http://teledynelecroy.com/ddr/

T-Series Power Modules with 7th Generation IGBT and NX-Type Package

Mitsubishi Electric Corporation announced the introduction and commercialization of its T-Series power semiconductor modules. The modules realize improved power loss and reliability for general-purpose inverters, elevators, uninterruptible power supplies (UPS), wind- and solar-power equipment, servos and other industrial equipment.

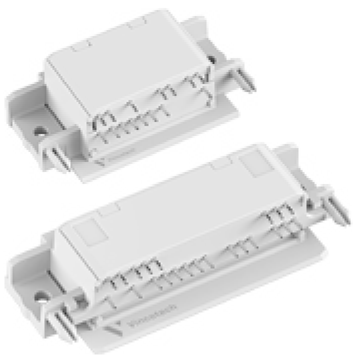
The T-Series, featuring 7th Generation CSTBTTM chip and 7th Generation diode, achieve low power loss and low EMI noise.
The cell design of the IGBT chip is optimized to have an improved controllability of the dv/dt by the gate resistor. The Relaxed Field of Cathode (RFC) diode chip is incorporating a new backside diffusion process leading to suppression of recovery-voltage surge.
New T-series is based on the well-established NX-Type package featuring the market standard 62mm low profile outline. The line-up covers various circuit topologies such as 2in1, 6in1 and 7in1 and a comprehensive range of current ratings at 650V, 1200V and 1700V to suit a wide scope of applications.

The newly developed SLC (SoLid Cover)-Technology enables the design of inverters with higher output current, higher power density and improved reliability in both power and temperature cycling. The SLC-Technology is combining a resin-Insulated Metal Baseplate (IMB) and hard direct potting resin.
The IMB consists of an electrically insulating resin layer with a top and bottom side copper layer by direct bonding, thus eliminating the conventional metal baseplate and the substrate solder layer. Less layers and matched thermal expansion coefficients lead to high thermal cycling capability, exceeding several times the conventional capability. At the same time, the thermal resistance is reduced by 30% compared to conventional modules having aluminum oxide insulation. The SLC concept utilizes one common substrate instead of multiple ceramic substrates. This approach eliminates wire bond interconnections between different substrates, thus increasing the effective area available for chip-mounting and reducing the internal wiring inductance by 30%.
The T-Series NX-Type package is using direct potting resin instead of silicone gel. This hard mold wraps around the interconnections on the chip surface and spreads the mechanical stress more homogeneously since the specially controlled epoxy resin is matched to the thermal expansion rates of other materials and featuring improved adhesion. IGBT modules with such direct potting resin achieve a significantly improved power cycling capability.

www.mitsubishichips.eu

flow90 Modules Save Space on the PCB

Vincotech, a supplier of module-based solutions for power electronics, announced the release of the extension of its housing family flow90, with the new flow90 0. The flow90 housings are used for standard products with CON, PIM, and PACK configurations and make the most of the PCB to minimize the application's footprint. Vincotech's flow90 1 as well as the new flow90 0 housings feature a space-saving package enabling a 90-degree angle between heat sink and PCB. These modules allow the installation of the power module on the same side of the PCB as other through-hole components. Featuring pins arrayed at a 90-degree angle, there is no need for a flexible PCB.



The flow90 modules eliminate costly L-shaped heat sinks and enables easy mounting by clipping the module right in to the PCB. The flow90 housing comes in 2 sizes: flow90 1 with 35 x 84 x 21 mm and the new flow90 0 with 38 x 66 x 21 mm.

www.vincotech.com/flow90

Battery Chargers Enabling Faster Charge

Wolfspeed SiC MOSFETs provide innovative power solutions for industrial battery chargers, enabling a 40 percent reduction in size and a 20 percent reduction in system cost.

Wolfspeed, A Cree Company, announced that Gruppo PBM, a leader in industrial battery chargers, is using Wolfspeed™ SiC MOSFETs in its new HF9 battery charger family to enable higher efficiency and power density at a lower overall system cost.

Demand for safe, efficient, and fast-charging industrial batteries has increased exponentially along with the proliferation of power electronics. The HF9 product family is designed to provide the highest possible efficiency while achieving easy scalability for power ranging from six to 16 kilowatts. These benefits are made possible in part by Wolfspeed 1200V SiC MOSFET technology.

"We selected Wolfspeed SiC Planar MOSFETs for our new HF9 battery charger family because they enabled us to improve our battery chargers while achieving operational savings, increased productivity and increased safety. This was not possible with the best IGBTs in the market," said both Marco Mazzanti and Giancarlo Ceo, who respectively serve as CTO and R&D engineer at Gruppo PBM.

Based in Italy, Gruppo PBM specializes in rugged high-frequency battery chargers, dischargers, and testers. By using Wolfspeed SiC MOSFETs in its latest HF9 family, Gruppo PBM not only achieves improved efficiency, but also a reduction in component count, improving the overall reliability in the system by lowering the operating temperatures and—most importantly—reducing overall system cost.

www.wolfspeed.com

Enabling Superior Resolution in Augmented Reality and Autonomous Vehicle Applications

Efficient Power Conversion announces the EPC2040 power transistor, an extremely small, fast switching gallium nitride power transistor that enables superior resolution, faster response time, and greater accuracy for high speed end-use applications. This product is ideal for pulsed laser drivers used in LiDAR technology, the technology at the heart of autonomous vehicle guidance systems and augmented reality platforms.

Benefits of using eGaN FETs in augmented reality systems include lower laser diode heat resulting from narrower pulse widths, high efficiency due to lower laser diode driver heat, more compact systems because of the small eGaN FET footprint, and consistent operation because of the EPC2040 is stable with temperature.

www.epc-co.com

SiC Schottky Diodes AMP Plus Certified Products

Global Power Technologies Group, Inc. a maker of SiC Diodes, SiC MOSFETs, SiC modules and SiC hybrid modules is proud to announce their SiC Schottky Diodes AMP Plus Certified Products. Global Power Technologies Group's SiC Diode assortment is the largest in the Industry, starting with 600V, 650V, 1200V, 1700V and 3,300V in SMD and thru hole package styles.
The AMP Plus Trademark guarantees their SiC Diodes are all rated at 175°C junction temperature, which certifies that the current you are getting is the full forward current when utilizing our product in your applications.
Many of the industry's SiC Schottky Diodes Data Sheets are engineered to make the design and purchasing departments think that they are getting a higher current rating.
For example, you may see the following spec:

V_{RRM} = 1200 V

I_F (T_C=135°C) = 25.5 A

$_C$ = 99 nC

It appears that the rating is 25.5A; however, at a Junction Temperature of 150°C, the current rating falls to 20 A.

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Example of our 20A AMP Plus part spec175°C:

VDC	1200 V
Q_C	86 nC
I_F	20 A

In addition, because we have our own in-house epitaxial wafer fab at our Southern California facility, we are able to pass on a much lower cost to our customers. Please visit Digikey's website for pricing and complete information.

http://www.gptechgroup.com

Hybrid Polymer-Aluminum Electrolytics Handle 30g with Very Low ESR, High Ripple Currents

Cornell Dubilier Electronics, Inc. (CDE) has announced ruggedized versions of their SMT Hybrid Polymer-Aluminum Electrolytic Capacitors, now able to withstand continuous vibrations of up to 30g of stress. This rating has been accomplished through electrical and mechanical redesign. Hybrid polymer-aluminum electrolytic capacitors combine the very low ESR and high ripple currents of conductive aluminum polymer capacitors with the higher voltage and capacitance ratings of aluminum electrolytic technology.
Packaged in a compact V-chip, SMT case, the new capacitors are available in two series, the 125 °C HZC_V and the 105 °C HZA_V. Both series have capacitance values up to 330 µF and ripple current values of 2 amps RMS or greater, in larger chip sizes. At maximum ratings, HZA_V capacitors have an exceedingly long life of 10,000 hours, with the HZC_V rated at 4,000 hours. The HZA _V is rated at 25 to 63 Vdc and 25 to 80 Vdc on the HZC_V.

CDE incorporated three important upgrades for vibration resistance. A support terminal was added to suppress vibration of the molded support base to the PCB, and therefore reduce contact stress. The support base was extended to create a high retention wall structure to better support the capacitor body. In effort to reduce internal vibration of the capacitor winding, a larger diameter lead wire is used, which is very effective at eliminating internal lead breakage at critical stress points.
"The high vibration rating allows designers of ruggedized products to access the benefits of the hybrid polymer-aluminum electrolytic technology," said Bill Haddad, Product Manager. "They are a particularly good fit where circuitry mounts to mechanical systems or for military transportation." Other applications include industrial power conversion, lighting control and automotive applications.
Since its founding in 1909, Cornell Dubilier has been dedicated to advancing capacitor technology for applications.

http://www.cde.com/HV/smthv.htm

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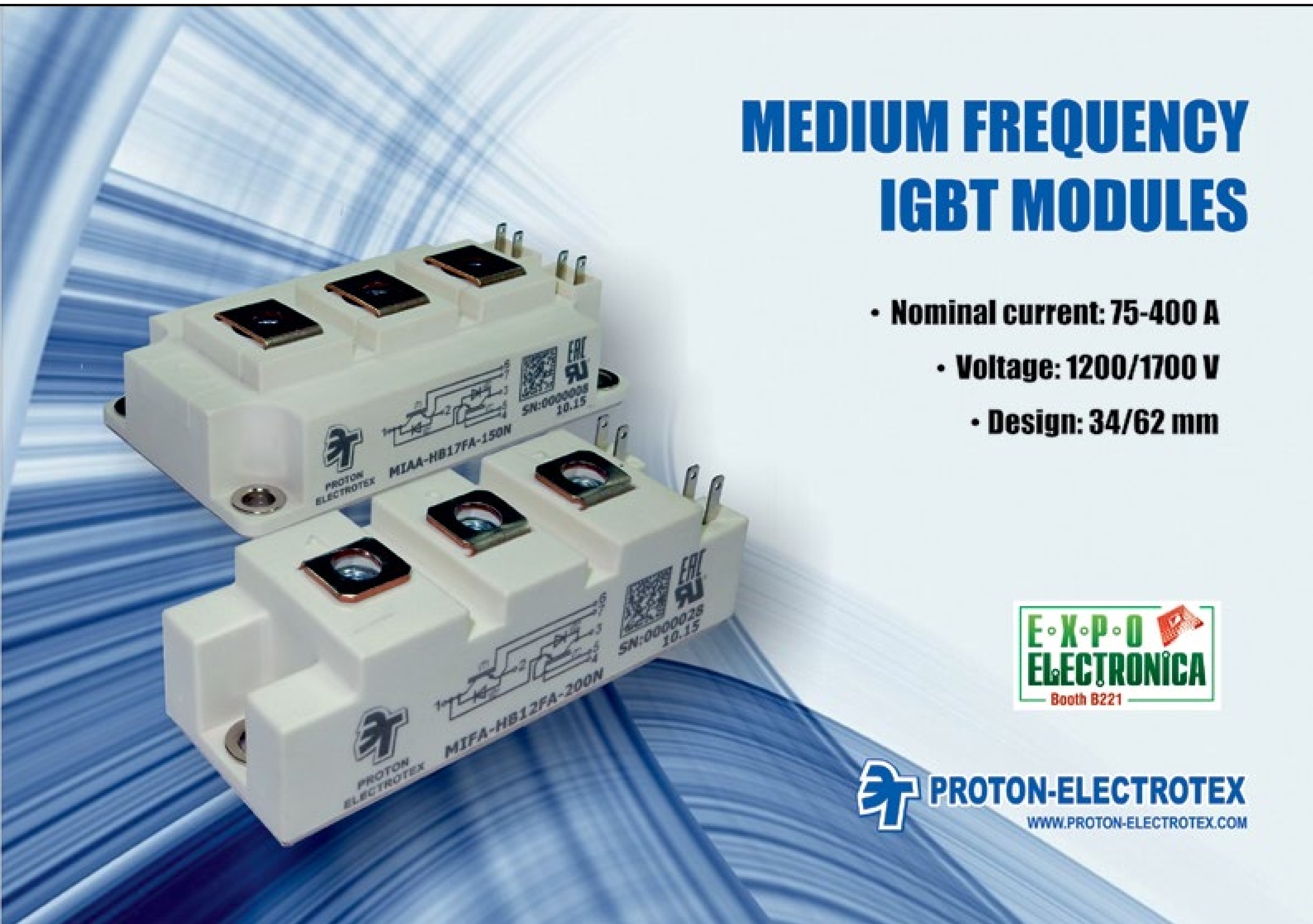

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Steve Jones, R&D Technology Manager, DYNEX Semiconductor Ltd, United Kingdom

»PCIM is an excellent event to interchange technical information, find partners to develop your projects and socialize with colleagues.«
Francisco Javier Azcondo, Professor, University of Cantabria, Spain

»PCIM is a good possibility to inform about the actual state of the art of power electronics and possibilities to use them in an optimal configuration.«
Hans Krischer, Concept Engineer, Bombardier Transportation, Germany

»Coming to PCIM this year allowed me to keep in touch with the present know how in power electronics and to share my experience with peers.«
Gilles Lanfranchi, Senior Designer, Adetel, France

»Thanks for making this kind of outstanding chance to look at the latest technology and information. It was a really good chance to be close to that kind of things.«
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New Developments in Power-Factor Correction
Richard Redl, Redl Consulting, Switzerland

Electromagnetic Design of High Frequency Converters and Drives
Jacques Laeuffer, Dtalents, France

High Performance Control of Power Converters
Christian Peter Dick, Jens Onno Krah, Cologne University of Applied Sciences, Germany

Advanced Design with MOSFET and IGBT Power Modules
Tobias Reimann, ISLE Steuerungstechnik und Leistungselektronik Germany; Thomas Basler, Infineon Technologies, Germany

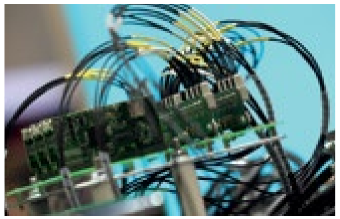
SMPS Topology Selection and Circuit Design Tricks
Bruce Carsten, Bruce Carsten Associates, USA

Reliability of IGBT Power Modules
Josef Lutz, Chemnitz University of Technology, Germany

IGBT Gate Drive Technologies
Reinhard Herzer, Arendt Wintrich, Semikron Elektronik, Germany

Design Challenges for High Frequency Magnetic Circuit Design for Power Conversion
William Gerard Hurley, Werner Hugo Wölfle, National University of Ireland, Ireland

Reliability Engineering in Power Electronics – from Components to Systems
Frede Blaabjerg, Francesco Iannuzzo, Huai Wang, Aalborg University, Denmark



Conference

Tuesday, 10 May 2016

Conference Opening and Award Ceremony				
KEYNOTE »Welcome to the Post-Silicon World: Wide Band Gap Powers Ahead«				
Coffee Break				
SiC Devices	Module Materials	Magnetics & Inductors	DC/AC and AC/DC Converters	**SPECIAL SESSION** Passive Components
Lunch Break				
SiC Reliability	DC/DC Converters I	Control Converters	Control Techniques in Intelligent Motion Systems I	DC/AC Converters
Poster/Dialogue Session				
Exhibition Party				

Wednesday, 11 May 2016

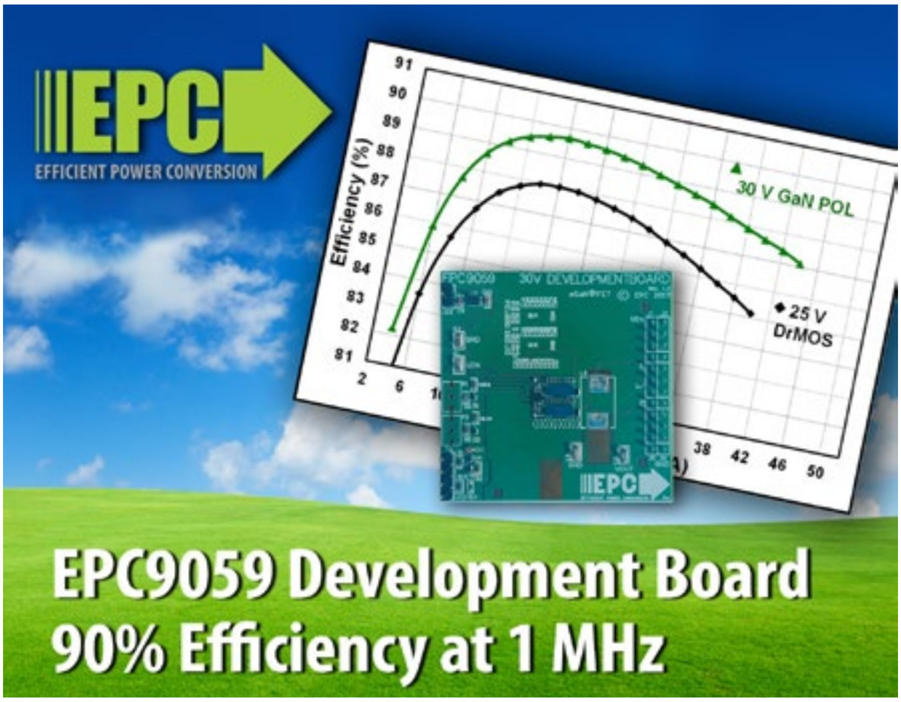
KEYNOTE »Smart Transformers – Concepts/Challenges/Applications«				
Coffee Break				
GaN Converters	Module Design	Power Electronics in Transmission Systems in Smart Grids	**SPECIAL SESSION** E-Mobility	High Power Semiconductor
Lunch Break				
Multi Level Converters	DC/DC Converters II	Lamp Ballasts Lighting Systems	Sensorless Motor Control	Software Tools and Applications
Poster/Dialogue Session (15:30 hrs – 17:30 hrs)				
PANEL DISCUSSION The Smart Future of Power Electronics (16:30 hrs – 18:30 hrs)				

Thursday, 12 May 2016

KEYNOTE »Trends of Solar System Integration Electricity Networks«			
Coffee Break			
Cosmic Ray & Ruggedness	**SPECIAL SESSION** Smart Lighting	New and Renewable Energy Systems	Power Electronics in Automotive
Lunch Break			
Module Technology	Drive Strategies in Power Converters	Energy Storage	Control Techniques in Intelligent Motion Systems II

Development Board with 50 A, 1 MHz to Reduce Size in Point-of-Load

Efficient Power Conversion Corporation (EPC) introduces the EPC9059 half-bridge development board for high current, high frequency point-of-load (POL) applications using eGaN ICs to reduce power conversion size.



The EPC9059 development board has a 30 V maximum device voltage with a 50 A maximum output current. In this application two 30 V EPC2100 eGaN IC's operating in parallel with a single onboard gate driver to achieve higher output currents. GaN devices have superior current sharing capability compared to silicon MOSFETs, making them more attractive for parallel operation.

The total system efficiency of this board operating with 12 V input to 1 V output with a switching frequency of 1 MHz peaks near 90%. It runs with natural convection and no heatsink up to 32 A, and at heavy load condition of 40 A showed a 2.5% efficiency advantage over silicon based DrMOS solutions, which translates to an almost 20% reduction in total system power loss.

This board demonstrates how eGaN technology enables smaller size, higher efficiency, and higher power density at the higher frequencies and higher currents required in next generation point-of-load converters

http://www.epc-co.com

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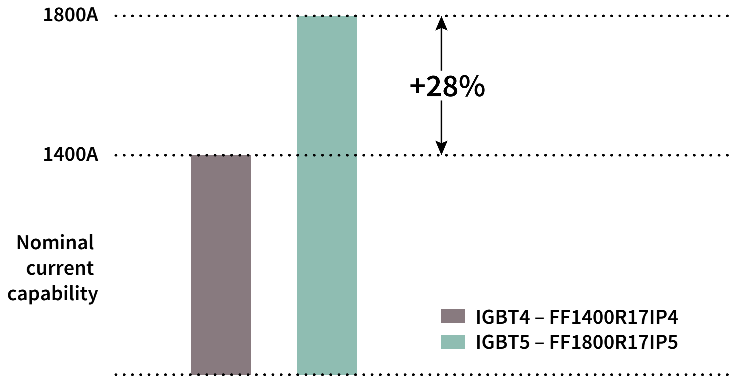

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