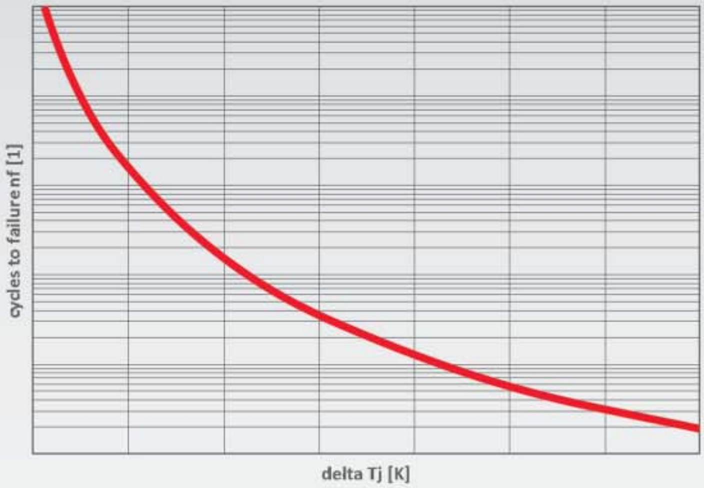
ISSN: 1863-5598

ZKZ 64717
09-14

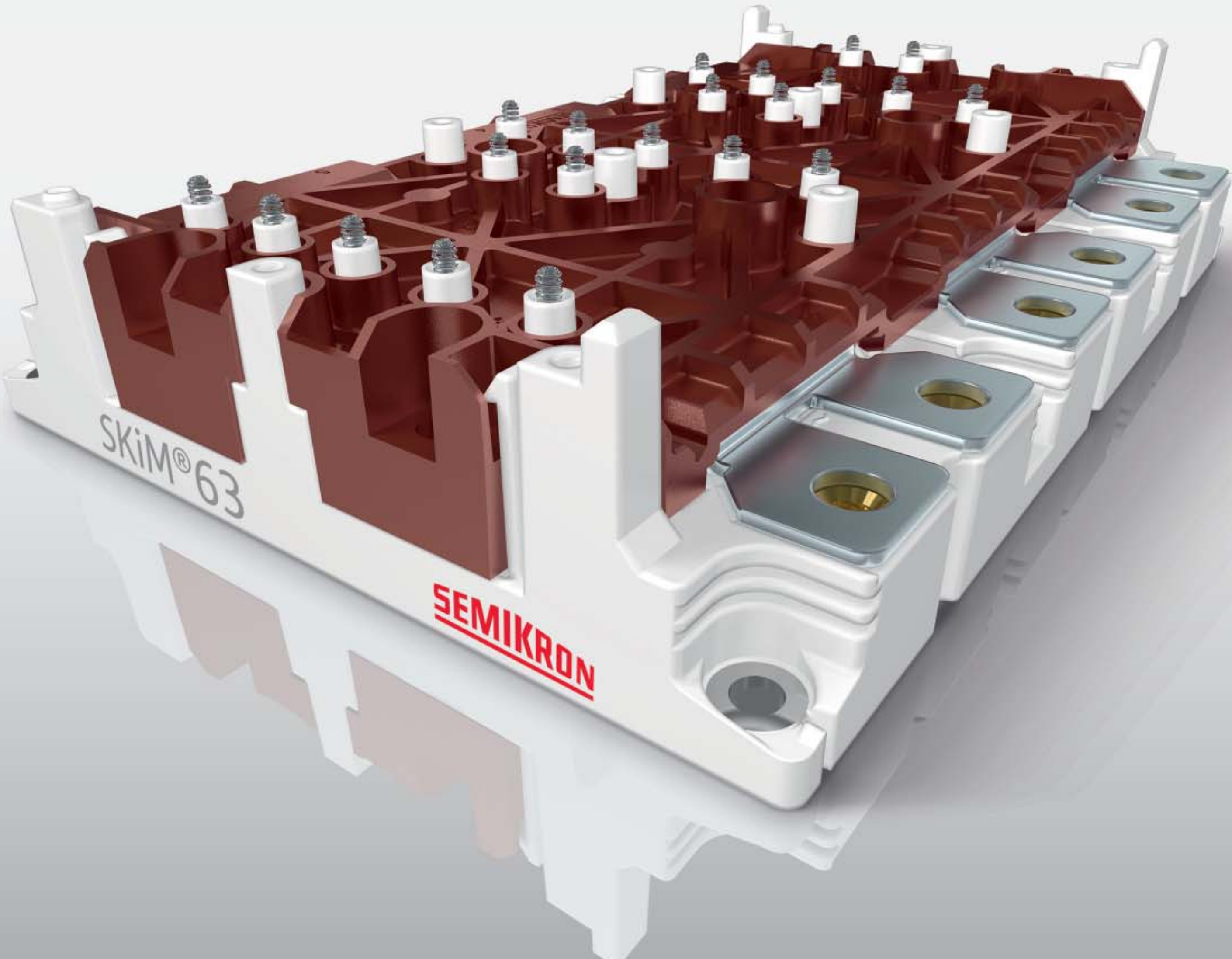
Bodo´s Power Systems®

Electronics in Motion and Conversion

September 2014



Reliability of Advanced Power Modules for Extended Maximum Junction Temperatures



Read online and search for key subjects from all articles in Bodo's Power Systems by going to Powerguru: www.powerguru.org

powerguru.org

Bodo´s Power Systems®

The Gallery

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Free Subscription to qualified readers

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

circulation ASC audit since 09/2006 print run 24 000

Printing by:
Druckhaus Main-Echo GmbH & Co KG
63741 Aschaffenburg, Germany

Events

ECCE 2014,
Pittsburg, PA, September 15-18
http://www.ieee.org/conferences_events/conferences/conferencedetails/index.html?Conf_ID=21325

Hybrid & Electric Vehicle Forum 2014,
Munich, Germany, September 17-18
http://transport.flemingeurope.com/hybrid-electric-vehicles-forum

INNOTRANS 2014, Berlin, Germany,
September 23-26 http://www.innotrans.de/

EU PVSEC 2014,
Amsterdam, Netherlands, Sept. 22-25
http://www.photovoltaic-conference.com/

INTELEC 2014, Vencouver, Canada,
Sept.28- Oct. 2 http://www.intelec.org/

EDPC 2014, Nuremberg, Germany,
Sept. 30-Oct.1 www.mesago.de/de/EDPC/

It is Show Time Again

The busiest time of the year has begun – as we observe the race to innovation in power electronics.

After spending a quarter century in design and applications, I've now been in publishing for one and a half decades. Time rushes by as I get older. It is my passion now to get important information to my colleges in research and design. This is issue number 100, as I mentioned in August, and with a record 84 pages for a September issue. In my last viewpoint I calculated the cumulated pile of all my magazines that have been printed to date. With increasing page count, we will be reaching the sky even faster!

I am returning from Lappeenranta in Finland, where I attended EPE ECCE. Soon I will start off for Pittsburg, Pennsylvania, and ECCE North America. Intelec, in Vancouver, Canada, is focused on power solutions for communication electronics. The EU PVSEC 2014 for photovoltaics will be in Amsterdam. The LED Professional Symposium returns to Bregenz at Lake Bodensee in Austria.

And September will be a very busy month for all of you planning on coming to Munich for Oktoberfest. Be aware, the party starts in September, so plan your business meetings early enough to not miss Oktoberfest this year. From the September 20th through October 5th you can see all the happy Bavarian natives in their lederhosen. Right after Oktoberfest, you can go to Grenoble in France for the SEMICON Europa.

The next big party in Munich will be for electronica, in the second week of November, this time not at the same time as Thanksgiving in the US. The Thanksgiving conflict this year will be on November 27th, the last days of sps ipc drives in Nuremberg, Germany.

Phew – with all these upcoming conferences, I am tired already! But my freelance team and I will do our best to bring you valuable

information from leaders in industry and academia. Information can be shared around the world in an instant. While creative designs develop at one location, implementation in manufacturing can happen any place in the world.

Reducing power consumption by eliminating losses is the most important goal for all of us.

Wide band-gap semiconductors are helping us achieve this. Passives in the design solution need to step up to match this performance. So we must watch for innovation in these areas.

Communication is the only way to progress. We delivered nine issues this year, and September marks 95 technical articles published year to date, amongst 660 pages. They are all archived on my web-site and also retrievable at PowerGuru. Bodo's Power Systems serves readers across the globe. If you speak the language, or just want to have a look, don't miss our Chinese version: www.bodospowerchina.com.

My Green Power Tip for September:
If you read my magazine and know of colleagues that may be interested, please circulate the magazine around to them. I hear from a lot of labs that they do this which not only increases the reach of the magazine, but also saves resources.

See you soon at ECCE, and around the world.
Best Regards

LED professional,
Bregenz, Austria, Sep. 30- Oct. 2
http://www.lps2014.com

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Infineon Technologies to Acquire International Rectifier

Infineon Technologies and International Rectifier Corporation announced that they have signed a definitive agreement under which Infineon will acquire International Rectifier for US-Dollar 40 per share in an all-cash transaction valued at approximately US-Dollar 3 billion. The acquisition combines two semiconductor companies with leadership positions in power management technology. By the integration of International Rectifier, Infineon complements its offerings and will be able to provide customers with an even broader range of innovative products and services. Infineon will also benefit significantly from greater economies of scale as well as a larger regional footprint.

Dr. Reinhard Ploss, CEO of Infineon Technologies AG, says: "The acquisition of International Rectifier is a unique opportunity. With their great knowledge of specific customer needs and their application understanding, International Rectifier employees will contribute to Infineon's strategic development from product thinking to system understanding and system solutions.

Oleg Khaykin, President and CEO of International Rectifier, says: "This transaction provides significant value to our stockholders and opens new strategic opportunities for both our customers and employees.

The International Rectifier Board of Directors and Infineon's Supervisory Board have approved the transaction. The closing of the transaction is subject to regulatory approvals in various jurisdictions and customary closing conditions, as well as approval of International Rectifier stockholders.

www.infineon.com

www.irf.com

Modular Inverter System VARIS™ in Russia

Proton-Electrotex JSC, well-known manufacturer of semiconductors and stacks, based in Orel, 380km south of Moscow, takes over the distribution of the modular inverter system VARIS™ by GvA Leistungselektronik GmbH on the Russian market.

Looking forward to serving the Russian market very well with the modular inverter system VARIS™ (from left): Zait Akcam, Head of Sales GvA, Andrey Tyukov, Sales Director Proton-Electrotex, Alexander Semenov, General Director Proton-Electrotex and GvA Marketing Manager Erik Rehmann.

GvA is responding to the increasing interest in its innovative inverter system with a strong local partner in Russia. VARIS™ scores in detail by its modular design, its flexibility but also its sustainability and profitability. The very wide power range from 300 kW to 2.8 MW and in parallel even a multiple of it covers almost all applications of power electronics – f.e. the grid connection, the renewable energies or drives of any kind. With VARIS™ R there is also a system compatible rectifier available.

VARIS™ XT, the modular IGBT inverter by GvA Leistungselektronik GmbH, in particular inspires with a lot of power of over 2 MW and also with its compact and flexible construction.

Andrey Tyukov, Sales Director at Proton-Electrotex, is impressed by his new product family: "With VARIS™ we can provide our customers from now on a very flexible inverter system. It covers a very wide power range – it is standardized but also flexible to match customer requirements. I am sure that this will be a success not only on our Russian market."

Zait Akcam, Head of Sales at GvA, is very pleased to extend the long-standing partnership: "For me it is important that with Proton-Electrotex we have gained a very competent and reliable partner for the distribution of our VARIS™ system on the important Russian market. I look forward to intensifying our long-term cooperation. "

www.gva-leistungselektronik.de

Addition to Management Board

The appointment of Christian Müller as Managing Director starting July 2014 is yet another successful step in the realignment of upper management within the SEMIKRON Group.

The 50-year-old began his professional career at Price Waterhouse Coopers in Munich. Over the past 15 years, Mr Müller held a number of management posts at the European head office of the leading US automobile supplier Federal Mogul in Wiesbaden. Before leaving the company, Mr Müller held the joint position of Head of Finance at the company's holding in Germany and Finance Director of one of four global business units with 30 sites worldwide.

Mr Müller will take over as Chief Financial Officer (Finances and Central Functions) at SEMIKRON, working alongside Harald Jäger (Operations, R&D and chief spokesman for the management board) and Peter Sontheimer (Sales, Product Management and Marketing). This appointment completes the strategic realignment of the SEMIKRON Management Board.

www.semikron.com

POWER FORTRONIC Bologna, September 18, 2014

The segment of power electronics is growing with a faster rhythm than other sectors, as a matter of fact, thanks to increasing research on intelligent, reliable, energy efficient and environmentally sustainable solutions, necessarily linked to the world of power.
In this dynamic context, Power Fortronic, promoted by Assodel (Italian Association Electronics Suppliers), on the 18th of September in Bologna, will present a meeting for the electronics community that can't be missed.
A one-day event designed to give a state-of-the-art, concise, updated and immediate accessible overview on the industry's "hot" topics.

Market trends, technologies and leading companies

The eleventh edition of the vertical forum will place particular emphasis on technologies for next generation energy supply systems and advanced power converters, which require efficiency and power density. Drivers for these applications include advanced power semiconductor devices and new materials to improve them and the system reliability.
To guarantee the topicality of the chosen themes, the big names in the industry have already confirmed their participation at Power Fortronic: Infineon Technologies, Fuji Electric, Rohm Semiconductor, Ducati Energia, Agilent Technologies, IXYS, Nippon Chemicon.

The classic format with something new

Among the novelties of the 2014 edition, the "innovation arena" is dedicated to start-ups and companies that are able to express Italian excellence. A space where university and industry can meet in order to create new partnership opportunities.

www.fortronic.it

Cooling Planar and Non Planar Magnetics

Payton Planar Magnetics is in the business of designing custom high frequency planar and non planar magnetics from a few watts to 100kWatts in a single package. Payton has been emphasizing the importance of providing cooling for all magnetics with power dissipation of over 1 Watt. Conduction cooling is used for most semiconductors and this cooling method is also ideal for magnetics. Planar cores are ideal for conduction cooling but even a non planar core, properly designed can be kept cooled. The example presented in this release is a buck inductor at 100kHz, 10uH at 60Amps. With 43 Watts of dissipation proper cooling is imperative. Mounted on a heat sink and with the inductor having 1 Cº/W hot spot to heatsink thermal impedance, proper cooling is achieved. This inductor can fully operate with no derating with a heatsink at 100 ºC.
Payton with the best engineering support in the industry can design and produce samples of any custom planar or conventional magnetic design in as little as few weeks.
Please visit our booth's at ECCE, September 15-18 in Pittsburgh, and at The Battery Show, September 16-18 in Novi, Michigan.
An APP is available at Google Play and Apple App store under "PAYTON RFQ". Along with a request form right from your smart device, educational videos on planar technology are available.

http://www.paytongroup.com

Power Integrity, Measuring, Optimizing, and Troubleshooting Power Related Parameters in Electronics Systems

A book for engineers written by Steven M. Sandler. Steven is forever grateful to the following individuals and companies and apologize profusely in the event he left anyone out.
He want to thank his editor, Michael McCabe, and all of the folks at McGraw-Hill for giving him the opportunity to write another book on a subject that has received little attention. A special thank you for allowing him luxury of presenting this book in color. Thanks to Kritika Kaushik, the project manager for the book. She had the difficult job of making this book happen.
Thanks to his long term friend and business partner, Charles Hymowitz, Vice President of Sales and Marketing for Picotest, and CEO of AEi Systems. He read every page, edited, commented, and offered many helpful suggestions to make this a better book. Thank you does not seem to cover it, but thanks. Bernhard Baumgartner, Florian Hämmerle, and Wolfgang Schenk of OMICRON Lab for their constant support, for including the noninvasive measurement in their instrument and for being great friends in addition to sales partners.
Thanks for the support and the many helpful comments and suggestions. Mark Roberts, Stacy Hoffacker, Mike Mende, Amy Higgins, and Tom Lenihan from Tektronix were always ready and willing to help, whether it was to discuss equipment, answer questions, or arrange the shipment of loaner instruments to and from his lab. They also offered some comments and suggestions. David Tanaka, Yasuhiro Mori, Eileen Meenan, and Hiroshi Kanda from Agilent Technologies for the tremendous knowledge they possess regarding their instruments and their willingness to share some of it with him. He also thank them for arranging the shipment of loaner instruments in and out of his lab.
Dan Burtraw, David Rishavy, and Mike Schnecker from Rohde-Schwarz for arranging the loan of their RTO1044 oscilloscope, for answering the many questions he asked, and for providing helpful comments and suggestions helping to make this a better book.
Bob Hahnke, Steve Murphy, Stephen Mueller, and Kathleen Woods from Teledyne Lecroy for their support of demo equipment and for the helpful comments they provided.
Hawk Shang of PICOTEST Corp for his generous support of our projects, for making excellent general purpose test equipment, and for manufacturing the Picotest signal injectors. Hawk, thank you for all that you do.
Chris Hewson of Power Electronic Measurement for providing the CWT015 probe used in this book as well as answering my questions about Rogowski current probes in general.
Paul Ho, Nazila Arefazar, Cesar Redon, Gordon Leverich, Michael Lui, Shivam Patel, Sahar Sadeghi, Josh Behdad, John Aschennbrenner and Tom Boehler of AEi Systems, and Dave Morrison of How2Power.com for all of your comments and suggestions to make this a better book. Thanks to Tim Guzman, also of AEi Systems, for his photography and image contributions.
Shawn Winchester and Artescapes for enhancing many of the oscilloscope and spectrum analyzer images to make them clearer and easier to see. Shawn also managed daily operations at Picotest, allowing him to focus on writing this book.
To all of you, "thanks" doesn't say enough, but he could not have finished this book without you.

ISBN 978-0-07-183099-7 (alk. paper) - ISBN 0-07-183099-5 (alk. paper)

http://www.mhprofessional.com

Material Solutions for Wide Range of Circuits at the PCB West 2014 Conference & Exhibition

Rogers Corporation will be showing some of its high-performance electronic printed-circuit-board (PCB) materials and offering advice on optimum ways to use them at the upcoming PCB West Exhibition (http://pcbwest.com), September 10, 2014, at the Santa Clara Convention Center (Santa Clara, CA).

At Booth #300, Rogers will display examples of its many circuit materials, including RO4835™ and RO4360G2™ circuit laminates and COOLSPAN® Thermally & Electrically Conductive Adhesive (TECA) film. As part of the technical conference, Sr. Market Development Engineer John Coonrod will review PCB material characteristics and circuit-fabrication methods and how they relate to high-frequency insertion-loss performance.

Rogers RO4835 high-frequency laminates, specially formulated with enhanced oxidation resistance, were developed for applications needing improved electrical stability over time and temperature, while maintaining the cost advantages of a thermoset, FR-4 processable material. Just as with RO4350B™ material, RO4835 laminates offer a dielectric constant of 3.48 at 10 GHz, a low loss tangent of 0.0037 at 10 GHz, and low z-axis of coefficient of thermal expansion (CTE) for excellent plated-through-hole (PTH) reliability across a wide range of processing and operating conditions.

These improved oxidation resistance circuit materials exhibit x- and y-axis expansion coefficients similar to that of copper. RO4835 laminates are RoHS-compliant, do not require special preparation, and can be processed using standard fabrication methods. Typical applications include automotive radar and sensors, point-to-point microwave backhaul units, power amplifiers and phased-array radar.

RO4360G2 laminates have a tailored high Dk of 6.15 @ 10 GHz, which allows next generation power amplifier designers to meet size and cost reduction targets. Specifically, the laminates' higher Dk allows for a significant reduction in finished circuit board size (20-30%). RO4360G2 laminates process similar to FR-4, are automated assembly compatible, and offer the same reliability and repeatability that customers have come to expect from Rogers RO4350B material. With a UL 94V-0 flame rating and fully lead-free process capable, these laminates possess excellent thermal conductivity of .81 W/m/K for improved reliability, a low Z-axis CTE for reliable plated through holes, and drill performance as good as or better than RO4350B laminates.

COOLSPAN TECA film is a thermally and electrically conductive adhesive that is designed for bonding circuit boards to heavy metal backplanes, heat sinks, and housings. The thermosetting, epoxy-based, silver-filled adhesive is a practical alternative to fusion bonding, sweat soldering, press-fit, and other mechanical approaches for attaching circuits to associated structures. COOLSPAN TECA film, which is supplied in sheet form on a PET carrier, is able to survive lead-free-solder processing and offers outstanding chemical resistance and high temperature performance, helping designers to keep things cool.

For PCB West 2014 Conference attendees, Rogers' John Coonrod will be examining why some PCB materials are better than others at achieving low insertion loss, during his presentation "Variables of PCB Fabrication and Design that Affect Insertion Loss." September 10 at 11 AM. Coonrod, who holds a bachelor's degree in Electrical Engineering from Arizona State University, is a Sr. Market Development Engineer for Rogers Advanced Circuit Materials Division. He has over 25 years of experience in the PCB industry, working with flexible, rigid, and high-frequency PCB materials.

www.rogerscorp.com.

Site Features Enhanced Utilities, Graphics, Navigation Tools and Functionality

Acopian Power Supplies launched their new website. The redesigned site provides richer online content, and a menu of user-friendly tools to help engineers quickly and easily access the power supplies that meet their precise applications. Launched in response to the continued expansion of Acopian's product offering, the website encompasses the company's full power supply portfolio, which comprises over one million distinct power supply models. The power supplies, which target the computing, aerospace, automotive, medical, telecommunications, and industrial control markets include AC-DC single, dual and triple output power supplies, AC-DC wide adjust output power supplies, DC-DC converters, high voltage AC-DC and DC-DC power supplies, redundant systems and N+1 power supplies. An Online Custom Power Supply System Builder allows viewers to customize a power supply or multiple-output power system built to their specific requirements.

The site's improved search utilities offer customers the ability to locate the appropriate power source by simply entering the required DC voltage or model number, or by selecting from the comprehensive power supply and photo array index.

www.acopian.com

Andy Mackie Named President of IMAPS Empire Chapter

Indium Corporation announces that Andy C. Mackie, Ph.D., MSc, has been named president of the Empire Chapter of the International Microelectronics Assembly and Packaging Society (IMAPS).

IMAPS is the world's largest society dedicated to the advancement and growth of microelectronics and electronics packaging technologies through professional education.

Dr. Mackie's responsibilities as president include coordinating all activities for Empire Chapter members and organizing local technical meetings, tours, and networking activities with the members, corporate members, and universities and labs in the region. The Empire Chapter hosts meetings throughout upstate N.Y., including Binghamton, Corning, Syracuse, and Rochester. Dr. Mackie will also play a key role in helping organize the Nanotechnology International Workshop.

"We're honored to have Dr. Mackie, who is a forward-thinking individual dedicated to the advancement of microelectronics, join us as an organizational leader within the IMAPS community," said Michael O'Donoghue, executive director of IMAPS. "Dr. Mackie's endless commitment to learning will, no doubt, be of great value as president of our Empire Chapter."

www.indium.com

Pioneering Power Systems for Future Aircraft

Raytheon has been selected to provide power systems expertise as part of several major aerospace industry consortia which are currently developing the More Electric Aircraft (MEA) of the future. This marks the company's formal entry into the MEA market following Raytheon's significant investment in commercial aviation power solutions.
The company's involvement spans the full range of power architecture and product collaborative initiatives under the Aerospace Growth Partnership which include: Power Off-take and Power Conversion for the More Electric Engine (SILOET II, Rolls-Royce), Electric Engine Start power delivery (POMOVAL, Labinal Power Systems), Motor Drive power delivery sub-systems (LAMPS, UTC), Dedicated HiTSiC Power Modules (R-PSM, Raytheon), and the Harsh Environment Health Monitoring Devices (HEEDS, AEC).

Central to Raytheon's strategy is leveraging its unique HiTSiC (High Temperature Silicon Carbide) produced at its UK foundry, which excels at optimal power delivery in high density, high temperature power supplies. Existing modules have a maximum operating temperature of around 150°C due to the limitations of silicon devices. As a result, large, heavy liquid cooling systems are required. Raytheon's new silicon carbide can operate at temperatures of above 300°C, allowing more compact modules and greater efficiency, which is perfect for commercial aircraft, breaking away from the traditional tradeoffs while providing great value for money.

www.raytheon.com

C2000™ F281x Microcontrollers Celebrate 12 Years of Leadership

Texas Instruments celebrates 12 years of leadership in motor control applications for its C2000™ TMS320F2812 and TMS320F2810 microcontrollers (MCUs). The F281x MCUs offer integration of high-performance digital signal processing, high-precision analog and flash memory on a single chip, which have made them customer favorites in a diverse range of applications, including drives and automation, automotive, aerospace, digital power, solar and smart grid technology. Twelve years after launch, TI has shipped tens of millions of C2000 F281x MCUs to customers around the world. TI continues to build on the success of the F281x MCUs with its Delfino™ and Piccolo™ MCU families, preparing the company for leadership in the MCU industry for many years to come.

"Delta Industrial Automation and Digital Power groups decided to use TI's C2000 F281x MCU devices 10 years ago when we needed DSP performance with integrated analog and flash on a single chip," said Dr. Jacky Chen, principal servo drives design manager, Delta Electronics. "Since that time, the compatible roadmap to new Delfino and Piccolo devices has made it easy for us to evolve our products while TI's continued commitment to this day to the F281x MCU generation makes us comfortable that our products based on C2000 microcontrollers will still be in production for many years to come."

www.ti.com

8-inch IGBT Wafer and Module Production Base in China

Dynex Semiconductor announced that on 20th June 2014 its parent company, Zhuzhou CSR Times Electric Co Ltd held a ceremony at its facility in China to mark the opening of a $240 million IGBT production base in Zhuzhou.
The production base, the first of its kind in China, and the second worldwide, will produce high power IGBT chips and modules using 8-inch silicon. Annual output of the first phase of this production line is expected to reach 120,000 wafers and 1 million pieces of IGBT modules. This IGBT line is being operated by the newly formed Semiconductor Business Unit of CSR Times Electric, of which Dynex is the European subsidiary.
The technology being used in the new facility has been developed at Lincoln in the UK by the multinational CSR Zhuzhou R&D Centre based at Dynex Semiconductor Ltd. The UK R&D centre was established in 2010 to focus on leading edge power semiconductor technology and specifically the next generation of IGBT products.
CSR began construction of the 8-inch production line in May 2012. Throughout the build, equipment installation and commissioning Dynex has played a leading role in providing technical advice, support and staff training both in Lincoln and in China.
The IGBT is the key component in today's energy efficient electric energy conversion systems used in electric locomotives, metros, electric and hybrid electric vehicles, electric power grids and renewable energy plants. Using the latest silicon wafer fabrication equipment and the latest process technologies, the new line will initially produce high power modules using the latest soft punch through field stop and trench technologies.
Dr Paul Taylor, President and CEO of Dynex Commented "Since the acquisition of Dynex by CSR Times Electric in 2008 there has been a rapid development in our IGBT capability. We began with 4 –inch wafers, then up graded to 6-inch at our plant in Lincoln. We then extended our technology to support the design of this new facility. It complements our base in the UK by giving us access to a world leading 8-inch IGBT wafer fabrication facility and a high volume module assembly line"
"Our rapid development does not stop there "continued Dr Taylor "the new line has been kitted out with the latest equipment, and the next phase of expansion is already being planned. This targets key markets such as electric automotive and renewable energy. So at our UK R&D Centre we are already working on designing the next generation of advanced silicon and silicon carbide power devices, and are busy recruiting new staff to expand our multinational research, design and development teams to meet this exciting new challenge"

www.timeselectric.cn/en

www.dynexsemi.com

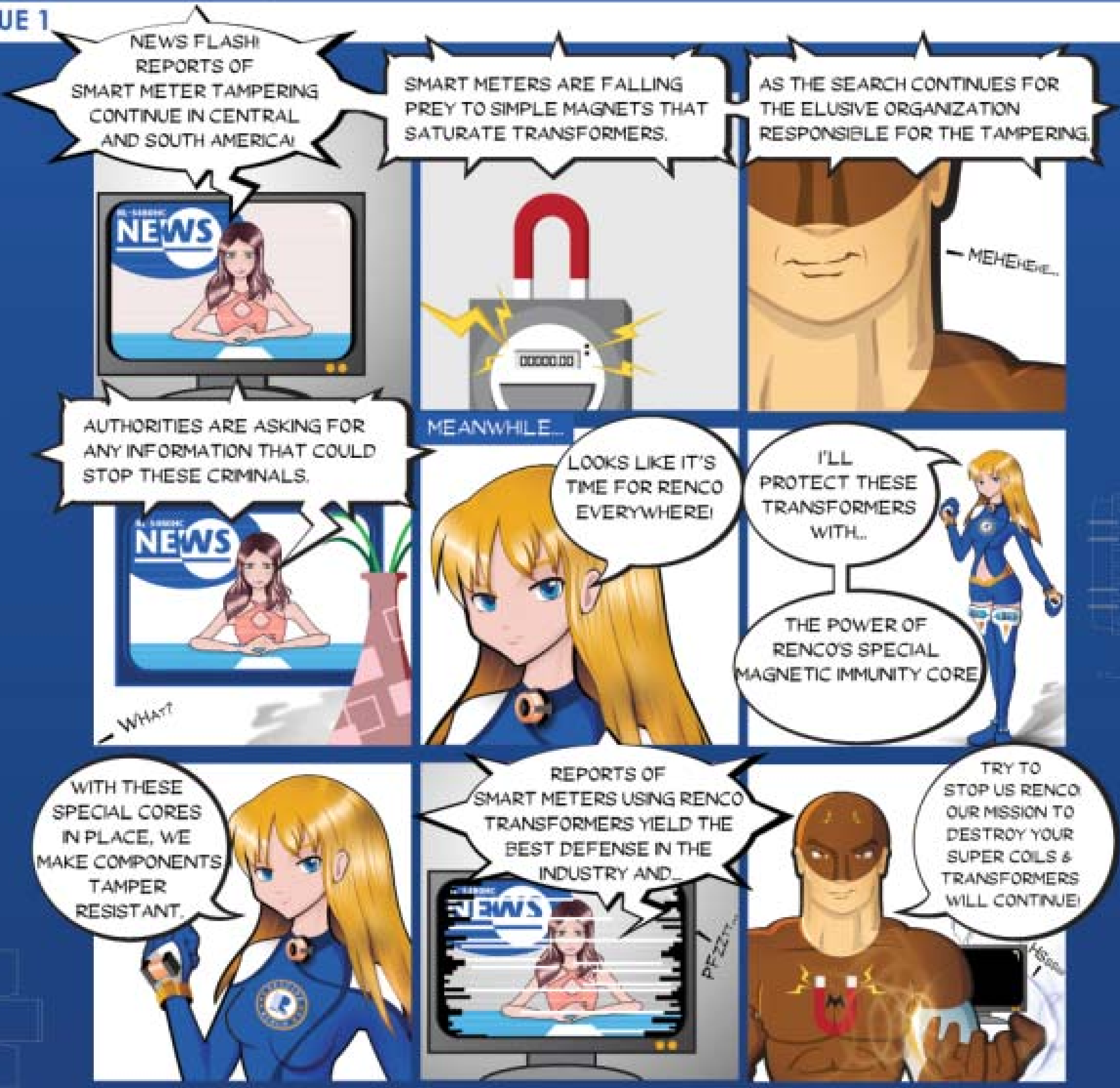
IGBT Reference Book

The Infineon IGBT Reference book is available as e-book version (to access it you just need to quickly register and then get full reading access to the complete book - it can then also be ordered as hard copy as out of the e-book you are not allowed to save or print).

http://bit.ly/IGBT-reference-book

TAMPER RESISTANCE

ISSUE 1



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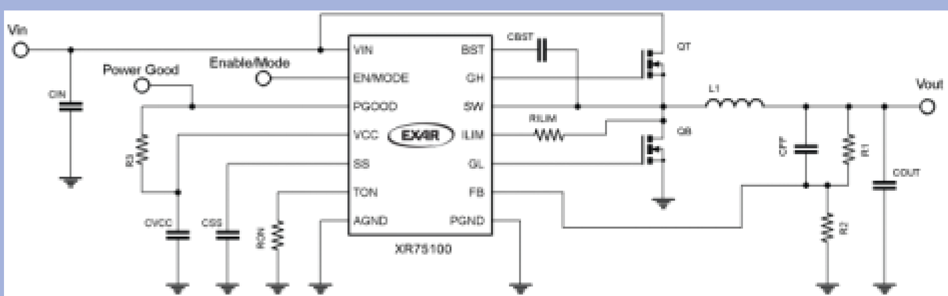
40V COT Controller Delivers 0.008%/V Line Regulation

The XR75100 Simplifies Point-of-Load Supply Designs in Industrial Applications

Exar Corporation, a leading supplier of high-performance integrated circuits and system solutions, introduced the XR75100, a new 40V capable switching controller in its line of DC-DC power conversion products. The XR75100 Synchronous Step-Down Controller supports point-of-load (POL) supplies from industrial 24VDC and 24VAC rectified sources. The patented emulated current mode Constant On-Time (COT) control scheme provides the fast transient response of conventional COT controllers without any of the compromises. This device delivers core voltage rails for ASICs, FPGAs, DSPs and other various processors in Medical, Automotive, Instrumentation and a wide range of other industrial markets.

The XR75100 with exceptional 0.008%/V line regulation across the entire input voltage range and 1% output accuracy over full temperature range provides increased headroom to engineers for easier design implementations. Exar's COT control loop enables operation with ceramic output capacitors, eliminating loop compensation and reducing overall component count for ease of system design. The XR75100 is specified with a wide input voltage range of 5V to 40V and delivers an adjustable output voltage from 0.6V to 30V. Additionally, the device offers a host of supervisory and protection features for proper sequencing, safe operation under abnormal operating conditions and light load operation.



"The XR75100 has been developed in response to our broad spectrum of industrial customers who need to power modern high power FPGAs and DSPs from traditional sources such as 24V AC and DC. The 40V operating range allows for a wide range of input fluctuations," said James Lougheed, vice president, power management products, Exar. "Hardware engineers responsible for board level power systems will appreciate Exar's patented COT control scheme, which makes the XR75100 easy to design with and keeps the component count low."

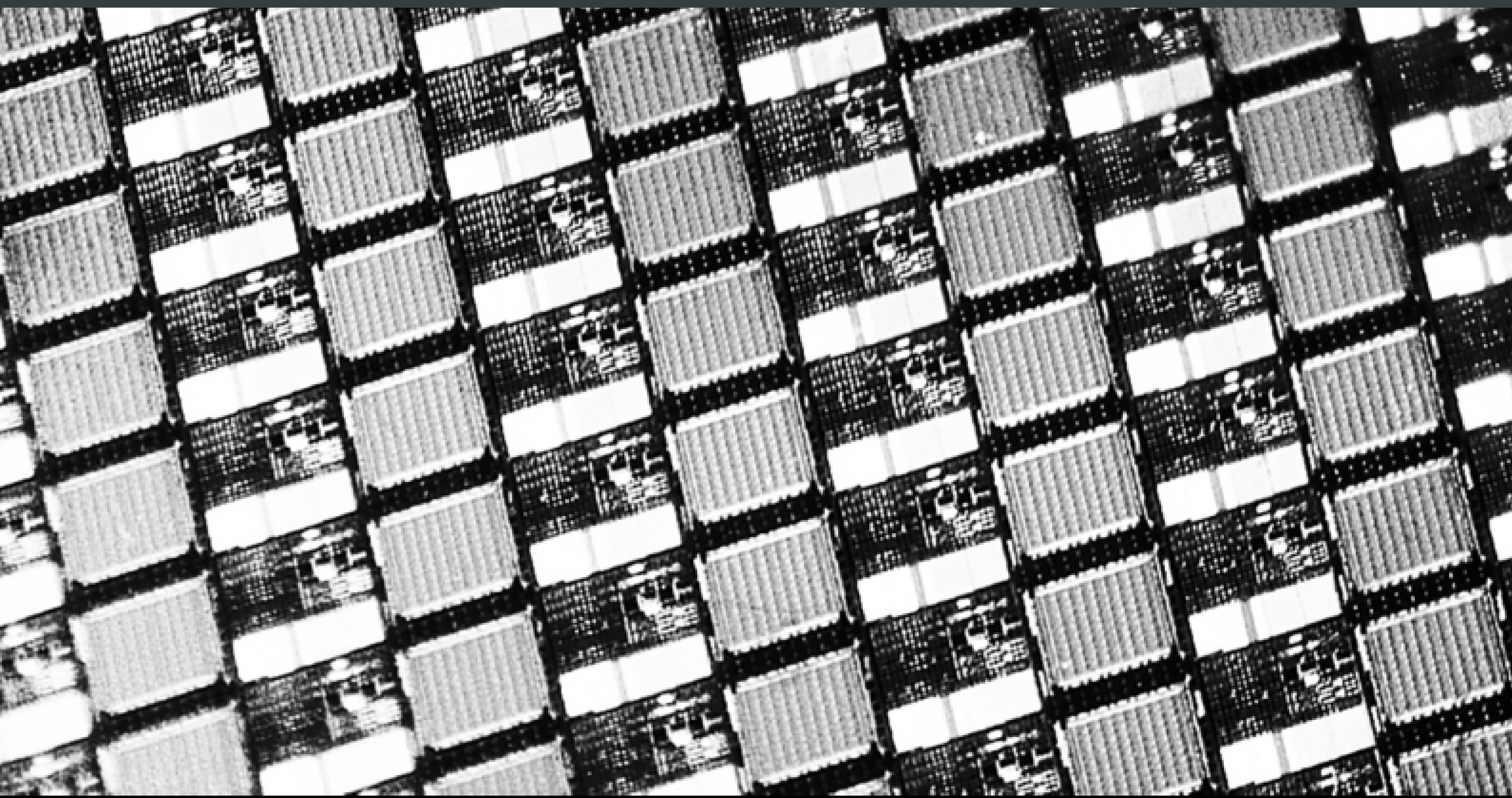
Product Availability and Pricing:
The XR75100 is available now in a RoHS compliant, green/halogen free space-saving 16-pin 3x3 QFN package and is priced from $1.59 in 1000 piece quantities.

Additional information on the XR75100 is also available at:
http://www.exar.com/XR75100

Additional information on Exar's DC-DC power conversion products is also available at:
http://www.exar.com/power-management/power-conversion

About Exar:
Exar Corporation designs, develops and markets high-performance integrated circuits and system solutions for the Communications, High-End Consumer, Industrial & Embedded Systems, and Networking & Storage markets. Exar's broad product portfolio includes analog, display, LED lighting, mixed-signal, power management, connectivity, data management, and video processing solutions. Exar has locations worldwide providing real-time customer support. For more information about Exar, visit:

http://www.exar.com



Win an MPLAB Starter Kit for Digital Power

Bodo's Power is offering you the chance to win an MPLAB Starter Kit for Digital Power (#DM330017) from Microchip. This starter kit allows the user to easily explore the capabilities and features of the dsPIC33F GS Digital Power Conversion family. It is a digitally controlled power supply board that consists of one independent DC/DC synchronous Buck converter and one independent DC/DC Boost converter. Each power stage includes a MOSFET controlled 5W resistive load. The kit features an On-Board In-Circuit Debugger / Programmer via USB, LCD display for voltage, current, temperature and fault conditions and an on-board temperature sensor.

The Digital Power Starter Kit provides closed-loop Proportional-Integral-Derivative (PID) control in the software to maintain the desired output voltage level. The dsPIC® DSC device provides the necessary memory and peripherals for A/D conversion, PWM generation, analog comparison and general purpose I/O, preventing the need to perform these functions in external circuitry.

For the chance to win an MPLAB Starter Kit for Digital Power, please visit:

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China- a Key Player in Power Electronics

From low cost production to an innovation driver -

By Prof. Dr. Leo Lorenz, ECPE

China incl. Taiwan today is the largest, most dynamic and very competitive but also challenging marketplace for power semiconductor devices and power electronics products in the world. In the last decade China was considered a low cost, high volume, production location for consumer & computing electronics incl. low - end power converters. Due to many infrastructure measures such as high speed trains, e-mobility, factory automation, etc. energy supply related technologies e.g. power quality control units, renewable energies and energy transmission lines, etc. as well as state controlled energy saving projects China elevated to an extremely attractive country for key technology player around the world. Recognized player today are SME's and big companies from Europe, USA and Japan providing their services and technologies with localized production capabilities.

Since the beginning of this decade, China is preferable accepting foreign companies setting up local R&D centers. This decade is headed by „Innovation Decade". China is moving ahead from a low cost production country to an innovative high quality production location with leading edge technologies. Regarding the application of new IP's China is leading followed by Japan, USA and Korea (this info is given in WIPO; world intellectual property organization). Europe dropped down and is occupying the number 5 position. Having a look on the most innovative companies today on a worldwide basis, ZTE is number one in terms of new patent applications followed by 2 Japanese companies Panasonic and Sharp, number 4 is already Huawei the technology leader for communications systems. Number 5 is Bosch and number 8 is Siemens. Within the umbrella of the „innovations Decades", the Chinese government initiated several projects to attract top experts from around the world to join Chinas Universities & Research centers for teaching and directing basic research topics. The "111 Foreign Senior Expert Program" is dedicated for people from outside China to spend several month on a regular basis or even years in China initiating and supervise dedicated research projects. The "Top Talent Scientist" program is pulling outstanding scientists to attract them for a University carrier and provides them freedom in basic research for future important technologies with a very generous financial support. The elite universities - for the time being 9 universities - cover all important power electronic disciplines and enjoy an outstanding financial support from the government. Of course all of them have to compete on the open market for research funding from the government and industry as well as for scientific recognition on the world market.

Due to this tremendous investment in basic and applied research, the contribution of scientific paper on international conferences in power electronics elevated from ≤1% in 2000 to more than 30% today.

Among the number of domestic and international conferences, the PCIM is competing very successfully. In 2014 the PCIM welcome already experts from industry and academia in the 13th year in series for a dedicated and highly recognized conference and exhibition in the field of Power Electronics. The PCIM in China is already a great success story and belong to the most important technical platforms for researchers, product development engineers as well as decision makers and marketing specialist to detect new attractive business opportunities. This exhibition and conference has grown continuously over the years to become the most prestigious forum to exchange information in important power electronic technologies. The conference itself is supported by a dedicated Advisory Board consisting of distinguished professors from universities and Industries from China, Japan and Europe.

The PCIM Asia this year addressed key developments in advanced power converters, future power semiconductor devices as well as renewable energy technologies. The 2 keynote presentations on "Model-Based control of E-vehicles" by Pengju Kang (GE Global Research Center Shanghai) and E-mobility including charging infrastructure a global perspective by Prof. Enrique Dede (University of Valencia) highlighted import future directions dedicated for the mega-cities in Asia. A special industrial session on "power Devices for E-vehicle and renewable technologies attracted many participants from industry, universities and research centers.

The recipients for the Best Paper Award this year where: Prof. Gaolin Wang from Harbin Institute of Technology on Sensorless Control (sponsored by Mitsubishi) and Prof. Prasad Enjeti from Texas A&M University (USA; sponsored by Semikron) on Grid for large scale PV-Plants; The Young Engineer Award was devoted to Dr. Ziwei Quyang from Technical University of Denmark on Three Port DC-DC Converters (sponsored by Mesago)

The PCIM Asia with 13 year history in China is a brilliant example of how to outperform in the high competitive Chinas Market. The PCIM 2015 is now open for setting up a comprehensive technical program for attracting experts from industry and academia around the globe.

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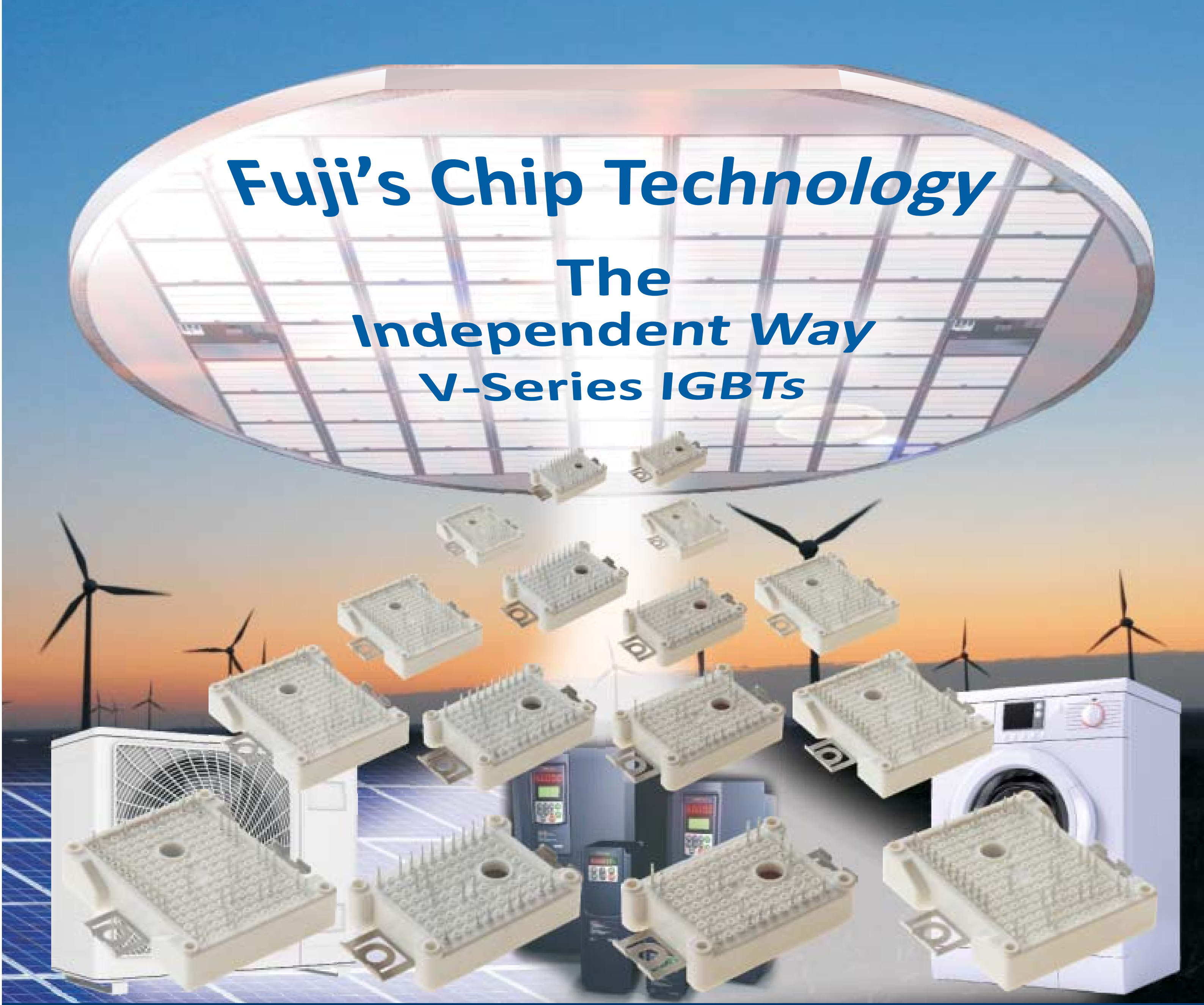

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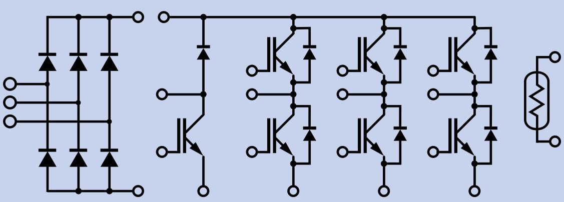

With solder pins

Package	I_C	600V	1200V
	10A	●	●
	15A	●	●
	20A	●	
	30A	●	
	15A		●
	25A		●
	35A		●
	50A	●	

With PressFit contacts

Package	I_C	600V	1200V
	10A	●	●
	15A	●	●
	20A	●	
	30A	●	
	15A		●
	25A		●
	35A		●
	50A	●	

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Electronics Industry Digest

By Aubrey Dunford, Europartners

The Graphene Flagship, one of the largest-ever European research initiatives representing an investment of € 1 billion over the next 10 years, is doubling in size. 66 new partners are being invited to join the consortium following the results of a € 9 M competitive call. This shows the growing interest of economic actors in graphene. The partnership now includes more than 140 organisations from 23 countries. The 66 new partners come from 19 countries. It is fully set to take graphene and related layered materials from academic laboratories to everyday use. Graphene is an extraordinary combination of physical and chemical properties: it is the thinnest material, it conducts electricity much better than copper, it is 100-300 times stronger than steel and it has unique optical properties. Graphene is set to become the wonder material of the 21st century, including by replacing silicon in ICT products.

SEMICONDUCTORS

X-FAB Silicon Foundries announced it will expand its MEMS manufacturing capabilities in two of its German locations, Erfurt and Itzehoe. Driven by increased customer demand for MEMS manufacturing services, the expansion includes two new dedicated MEMS fabs with cleanroom space totaling more than 2,000 m2 . MEMS devices manufactured at X-FAB include pressure sensors, micro-mirrors, microphones and microfluidic devices used in mobile, consumer, medical and automotive applications. Customers requiring CMOS and MEMS solutions also benefit from access to X-FAB's existing CMOS wafer fabrication facilities.

Worldwide semiconductor manufacturing equipment billings reached $ 10.15 billion in the first quarter of 2014, so SEMI. The billings figure is 9 percent higher than the fourth quarter of 2013 and 39 percent higher than the same quarter a year ago. In Europe, semiconductor manufacturing equipment billings reached $ 580 M; the figure is 55 percent higher than in Q113. Worldwide semiconductor equipment bookings were $ 9.89 billion in the first quarter of 2014. The figure is 27 percent higher than the same quarter a year ago and 5 percent lower than the bookings figure for the fourth quarter of 2013.

Boston Semi Equipment (BSE) has completed the acquisition of MVTS Technologies. BSE and MVTS are supplying reconfigured automated test equipment (ATE). The combination of the product lines, service offerings and global reach of both companies has created a single, comprehensive source for companies seeking ATE equipment solutions from the secondary market.

OPTOELECTRONICS

Sharp announces the development of the Free-Form Display, a device that can be shaped to meet a wide range of user needs. Conventional displays are rectangular because they require a minimal width for the bezel in order to accommodate the drive circuit, called the gate driver, around the perimeter of the screen's display area.

PASSIVE COMPONENTS

TE Connectivity, a $ 13 billion world leader in connectivity, has entered into a definitive agreement to acquire Measurement Specialties for a total transaction value of approximately $ 1.7 billion. Measurement Specialties, a global designer and manufacturer of sensors and sensor-based systems with expected revenue of $ 540 M in its current fiscal year, offers a broad portfolio of sensor technologies including pressure, vibration, force, temperature, humidity, ultrasonics, position and fluid, for a wide range of applications and industries.

Vishay, a manufacturer of discrete semiconductors and passive electronic components, announced the acquisition of Holy Stone Polytech, a Japanese manufacturer of tantalum capacitors.

DISTRIBUTION

European distribution bookings in Q114 grew by 8.3 percent compared to the previous quarter and by 5.2 percent when compared to the same period in the previous year, so the IDEA (International Distribution of Electronics Association). European distribution billings in Q114 grew by 4 percent, when compared to Q114. At 1.03:1 the Q114 overall book-to-bill ratio showed a decrease from Q413 (1.06).

In the first quarter, the German component distribution market grew by 3.7 percent to € 743 M, so the FBDi. Order input was up 7.6 percent to € 768 M. The book-tobill-rate was above one for the sixth time in a row. With a turnover of € 505 M, an uptick of 3.5 percent, and representing a 68 percent share of the total market, the dominant semiconductors remained slightly lower than the average. Passive components leapt 5.6 percent to € 111 M, and electromechanical jumped 6.1 percent to € 81 M. The rest of the market is divided between displays (2.9 percent), power supplies (2.1 percent) and sensors (0.8 percent).

Converge, an Arrow company, has expanded its European presence by opening a new office in the United Kingdom, in addition to expanding its German sales operation. Converge is a global distributor of electronic components that offers obsolete-and shortage-component sourcing, vendor reduction programs, bill-of-material management, and inventory disposition solutions. The new UK office in Harlow joins a network of European Converge locations in Nice, France; Dusseldorf, Germany; Stockholm, Sweden; Amsterdam, Netherlands; Turku, Finland; and Tel Aviv, Israel. The company retains warehousing and engineering support for Europe in Amsterdam, with a complete engineering, testing and quality inspection process on site, complementing similar setups in Asia and America.

This is the comprehensive power related extract from the «Electronics Industry Digest», the successor of The Lennox Report. For a full subscription of the report contact:
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GaN Switches, Energy Harvesting, IGBTs, and DC-DC Converters on Show in Tokyo

By Jeff Shepard, Darnell Group

This year's Techno-Frontier power electronics exhibition at the Big Site Exhibition Center in Tokyo included several important advances in technology. The one that drew the most interest was a new family of normally-off GaN transistors rated for 600V that was debuted by Sanken. In another display of advanced technology, energy harvesting systems based on electret technology were being demonstrated in several stands.

Moving to (much) higher power levels, Mitsubishi announced a new 300A/1200V IGBT module designed for use with liquid cooling in hybrid and electric drives for automobiles. In a much smaller package, Torex was revealing a new family of micro step-down dc-dc converters with an integrated coil that achieves a level of miniaturization and profile reduction that is one of the smallest in class for a load current of 2A.

The highlight of the Sanken Electric Co. Ltd. booth was the demonstration of the new normally-off GaN transistor and gate driver IC built into a single package. The initial offering consists of two products, the DGF6020 rated for 600V and 20A with an on-resistance of 50 milliOhms and the DGF6010 rated for 600V and 10A with an on-resistance of 100 milliOhms. Both are delivered in an 8mm-square by 0.85mm-high QFN package to minimize parasitic inductance and enable high-frequency power switching.

These GaN FETs are expected to find application in power supplies for servers, power conditioners, digitally-controlled power supply, wireless power supply systems, and other power supply units where small size and high-efficiency are important attributed. These switches deliver ultra-fast (5MHz) operation with the 5V logic level power supply and input signal.

Sanken also offers two half-bridge evaluation boards for these devices. Both the high-side and low-side of the half-bridge circuit is equipped with an isolator. It is designed to operate with an input voltage of 400V and can switch at up to 5MHz. High-voltage, high-current switch evaluation is possible by inputting a logic signal with a microcomputer, etc. The QFN8-HB2-1S evaluation board includes 10A switches while the QFN8-HB2-1D includes the 20A devices. The boards are made from FR4 1.6mm 2 layers, Cu Thickness 70um, and measure 40.35mm × 74.5mm.

The Electret Energy Harvester Alliance was at Techno Frontier for the second year demonstrating its progress in the development of small harvesters and systems based on electret technology. The Electret Alliance was founded by Professor Yuji Suzuki, in the Department of Mechanical Engineering at the University of Tokyo. Corporate members currently include: OMRON Corp., Asahi Glass Co., Ltd, THHINK Wireless Technologies Japan Co., Ltd., Techno Design Co., Ltd., and Konishiyasu Co., Ltd.

The efforts of the Electret Alliance have already begun to yield results. THHINK was demonstrating a series of three energy harvesters based on this technology. All are currently in sampling, with production anticipated in 2015. All three deliver an output of 5.2Vdc and operate from vibrational energy of 30Hz and 0.15G. They generate from 0.1mW up to 1.0mW. A next-generation design was being demonstrated that harvest rotational energy (for example from a micro wind turbine) and can produce several mW of output.

"We developed a novel MEMS process for Parylene high-aspect ratio structure (HARS) for soft but robust HARS spring. We also propose a passive gap-spacing control method using electret in order to avoid stiction between top and bottom substrates. Out-of-plane repulsive force is successfully demonstrated with our early prototype both in air and liquid. By using the present electret-based levitation method to keep the air gap, a MEMS electret generator has been developed for energy harvesting applications," stated Dr. Suzuki .

OMRON (a member of the Electret Energy Harvester Alliance)and Holst Centre/imec unveiled during Techno Frontier a prototype of an extremely compact vibrational energy harvesting dc power supply claiming the worlds' highest efficiency. Combining OMRON's electret energy harvester with a Holst Centre/imec power management IC, it can convert and store energy from vibrations in the µW range with high efficiency to the driving voltage of general sensors. The prototype measures 5 x 6 cm – with potential to shrink as small as 2 x 2 cm. Its small size, light weight (15.4 gram) and user-variable output voltage are ideal for a wide-range of autonomous wireless sensor node applications in the industrial and consumer domains, particularly in inaccessible locations.

"Energy harvesting – extracting unused or waste energy from the local environment – is perfect for autonomous sensor nodes. It does away with the need for cables and changing batteries, allowing true "fix-and-forget" systems. The combination of OMRON's robust electrostatic vibration harvester and our efficient power management technology enables an extremely compact design that can be installed in even the most inaccessible places – whereas today's vibrational harvester power supplies are too large and too heavy," says René Elfrink, Senior Researcher Sensors and Energy Harvesters at Holst Centre/imec.

"The vibration in the environment of customers are various and volatile. Under such an environment, our harvester can produce energy even just a little. But so far, we could not use our harvester as a stable dc power supply. Before developing this compact vibrational harvesting power supply, we benchmarked power management technologies from many potential partners and found Holst Centre/imec's offering to be the most mature. The resulting power supply meets all the requirements for small, low-power wireless sensors, particularly industrial applications such has equipment control and predictive maintenance systems," adds Daido Uchida, General Manager of Technology Produce & Start-up division of OMRON Corporation.

Mitsubishi Electric Corporation announced that it will begin shipping samples of its new 300A/1,200V and 300A/650V J1-Series power modules for electric and hybrid vehicles starting on October 31. The 300A/1,200V module is suited for high-voltage battery inverters used in hybrid buses and trucks. The 300A/650V module is designed for use in smaller-capacity inverters used in small EVs and mild hybrids.

These modules feature Mitsubishi's CSTBT (carrier-stored trench-gate bipolar transistor) IGBT technology that includes on-chip temperature sensing and on-chip current sensing for higher reliability and lower power losses. The forward voltage drops are 1.4V for the 300A/650V CT300CJ1A060 module and 1.7V for the 300A/1,200V CT300CJ1A120 module.

Mitsubishi is also offering potential customers an evaluation kit for these J1-series automotive power modules. The kit includes three elements: The Evaluation Printed Circuit Board with a custom gate-drive IC, optimized drive and protection circuits, drive signal isolations and a power supply. The DC-link capacitor assembly with two types of film capacitors optimized for use with the J1-series a board-mounted type with lower dc-line inductance and a block-type that features higher vibration withstand capability. And the kit includes a water cooling jacket to provide optimal thermal performance.

Finally, the XCL211/12 series of dc-dc converters being previewed by Torex are ultra-small (3.1 x 4.7 x 1.3mm) micro step-down dc-dc converters with an integrated coil that achieves a level of miniaturization and profile reduction that is one of the smallest in class for a load current of 2A.

With the integrated Inductor, new series of dc-dc converters from Torex is designed to minimize EMC emissions and radiated noise, while maximizing efficiency. The operating voltage is from 2.7V to 6.0V and the output voltage can be set freely from 0.9V to VIN using external resistors.

The XCL211/212 series include a 1ms (typ.) high-speed soft-start function for quick turn-on, a chip enable pin to turn the IC on and off and a CL discharge function to quickly discharge the output capacitor when the IC is turned off. A thermal shutdown circuit is also built in which shuts down the IC when the chip's temperature reaches 150 degrees C and re-starts it when the temperature drops to 130 degrees C (typ.) or less.

www.darnell.com

Datacom DC-DC, LiDAR and Radiation Hardened Devices for Satellites

By Alex Lidow Ph.D.; Efficient Power Conversation

KEY TAKE AWAYS

- In 2017, Datacom (Data storage, computing and telecommunications) power supplies revenues are forecasted to top $11.4B[1]. In that same year there will be $2.5B revenues from the MOSFETs that are the core semiconductor component in these power supplies[2]. eGaN® FETs have consistently demonstrated a 25% or more improvement in efficiency in these applications[3].
- LiDAR (Light Distancing And Ranging) is a new application that will dominate applications such as real-time motion detection for video gaming, computers that respond to hand gestures as opposed to touch screens, and fully autonomous vehicles. eGaN FETs' ultrafast switching speed enables the high resolution needed to make these applications a reality.
- Radiation hardened eGaN FETs perform 40 times better and withstand 10 times the radiation of silicon Rad Hard devices. The Satellite industry is a $196B market that greatly values the large boost in power conversion efficiency enabled by this new technology.

In past issues of Technology Driving Markets, we discussed the disruptive nature of the eGaN FET and the inevitability of it displacing the aging power MOSFET. In the last issue we discussed Envelope Tracking and Wireless Power Transmission: two amazing new applications enabled by eGaN technology with the potential to touch every consumer of wireless and portable computing and communications appliances. This issue of Fast Just Got Faster discusses three additional applications enabled by eGaN technology: Datacom DC-DC, LiDAR, and Radiation Hardened devices for satellites.

Datacom DC-DC

The hunger for more efficiency continues to be a driving factor in most electronics – especially in applications such as server farms and centralized telecommunications centers. When compared with MOSFETs, eGaN FETs are significantly more efficient. The lower power losses translate into products with higher output, improved power density, and increased efficiency. This translates into lower energy consumption and reduced electric bills for the consumer.

In figure 1 are two representative examples of popular DC-DC converters. In figure 1 (a) is a 48 V to 12 V DCDC converter, and in figure 1 (b) is a 12 V to 1.2 V DC-DC converter. These two represent the highest volume DC-DC converters used today in Datacom applications today. Efficiency is the key to competitiveness. In these two examples, as well as virtually every other example examined, eGaN FETs reduce power losses by 25% or more.

In 2017, Datacom power supplies revenues are forecasted to top $11.4B[1]. In that same year there will be $2.5B revenues from the MOSFETs that are the core semiconductor component in these power supplies[2].

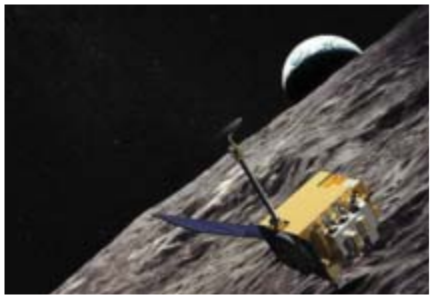
LiDAR

LiDAR uses pulsed lasers to rapidly create a three dimensional image or map of a surrounding area. One of the earliest adopters of this technology is the Google Maps "driverless" cars. Today's eGaN FETs' higher frequencies give LiDAR systems superior resolution, faster response time, and greater accuracy. These characteristics enable new and broader applications such as real-time motion detection for video gaming, computers that respond to hand gestures as opposed to touch screens, and fully autonomous vehicles. In 2018, the LiDAR market is estimated to reach $551M in 2018 with a CAGR of 16.64% 2013 through 2018[4].

Radiation Hardened

Power converters used in harsh environments, such as in space, high-altitude flight, or high-reliability military applications must be resistant to damage or malfunctions caused by radiation.

Picture of the Google car



Picture of the Moon and Satellite

Most electronic components require specialized design or manufacturing processes to reduce their susceptibility to radiation damage. For this reason, radiation-hardened devices tend to lag behind the most recent technology developments. While silicon-based power MOSFETs are no exception, eGaN FETs, however, perform 40 times better electrically while being able to withstand 10 times the radiation. This opens the door to major cost savings in communications and research satellites. It is anticipated that the $196B global space market in 2023 will drive a greater than $100M radiation hardened transistor market that will be dominated by GaN transistors such as the eGaN FET.

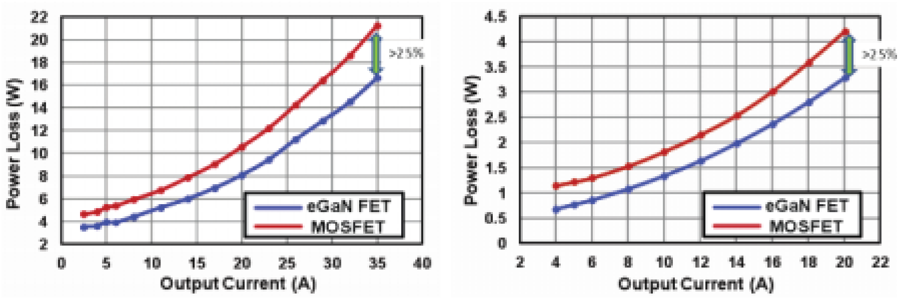


Figure 1: Power loss comparisons between MOSFET-based DC-DC converters and eGaN FET-based converters. (a) 48 V to 12 V bus converter. (b) 12 V to 1.2 V point-of-load converter. In both cases eGaN FETs reduce losses by more than 25% at rated output power.

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Reliability of Advanced Power Modules for Extended Maximum Junction Temperatures

In the early days of power electronics, lifetime assessment was restricted to maximum load conditions and generous margins. Today, application specific mission profiles, which reflect the dynamic behavior of the load and of the cooling system, are evaluated to estimate the lifetime of power electronic systems. This approach improves the prediction quality, but it requires better and more refined lifetime models. How such a lifetime model can be derived for advanced power modules will be presented.

By Uwe Scheuermann, Semikron Elektronik GmbH & Co. KG, Nuremberg, Germany

The demand for extended maximum junction temperatures above 150°C in power semiconductor components gained growing attention in the beginning of this century driven by 3 major factors: the high coolant temperatures in hybrid electrical vehicles, the potential of wide band gap devices to operate at much higher temperatures, and the enhanced current capability of silicon devices when operated at junction temperatures up to 200°C. This required a considerable increase in lifetime of the package, because a component must fulfill the same lifetime expectation at extended junction temperature to be acceptable for applications. Depending on the exact operation conditions and the lifetime model applied, an increase in lifetime of a factor of 5 is necessary for each 25°C increase of the maximum junction temperature as a rule of thumb, resulting in a required lifetime increase of a factor 25 for 200°C maximum junction temperature.

The progress in the last decade has delivered improved interconnection technologies with the potential to reach this target. Ag diffusion sintering and transfer liquid phase bonding are candidates for replacing the traditional solder die attachment. And Cu wire bonds or Al cladded Cu wire bonds are enhancing the lifetime of the top side chip contact considerably compared to the classical Al wire bonds.

When such improved technologies are introduced along with first lifetime test results to demonstrate their potential, the demand for a consistent lifetime model arises to evaluate the advantage for specific applications based on mission profiles. However, the generation of experimental data to establish a new lifetime model for improved technologies requires a test vehicle from controlled series production and years of lifetime testing.

The following discussion will present a power cycling lifetime model for an advanced power module named SKiM63. This module, which was introduced to the market in 2008, is a 100% solder-free design [1]. The silicon chips are attached to the DBC substrates by Ag diffusion sintering, thus eliminating solder fatigue. The top side contact of the chip is connected by 300µm Al wire bonds with improved bond loop geometry. Mechanical fatigue tests on heavy Al wire bonds had already shown the increase of lifetime by an enhanced aspect ratio, which is the ratio of wire bond loop height to the distance between bond stitches [2]. However, this improvement potential was limited by solder fatigue in the classical module design [3].

The SKiM63 module design is based on the pressure contact technology and thus does not contain a base plate. This feature improves the temperature cycling capability by eliminating the stress between the ceramic substrate and the base plate. Tests have proved a cycling capability beyond 1000 cycles in a two chamber temperature cycling test between -40°C and 125°C [4]. The design without base plate also eliminates potential fatigue between substrate and base plate in active power cycling. The load contacts are formed as bus bars with multiple pressure contacts to simultaneously establish the electrical contacts as well as the thermal contact between substrate and heat sink. Spring contacts are implemented to transmit the control and auxiliary signals to the substrates. An explosion view of the SKiM63 is shown in Figure 1.

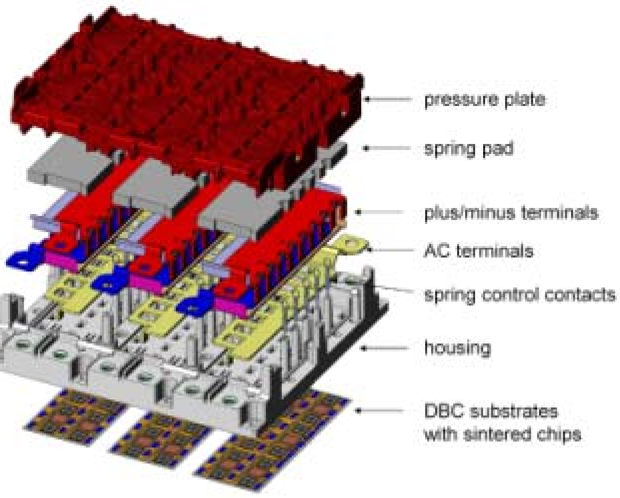

Figure 1: Explosion view of the SKiM63 module architecture

This SKiM63 module was selected as a vehicle to establish the first empirical power cycling lifetime model for sintered devices with Al wire bonded top side contacts. Since solder fatigue is completely eliminated, only wire bond heel cracks and wire bond liftoff are found as failure modes. For a consistent lifetime model, all important parameters of the power cycling tests had to be investigated. Variation of these parameters allows to model their influence on the lifetime in real applications.

It is known from the first lifetime models that the magnitude of the temperature swing has a significant impact on the component lifetime during power cycling. However, degradation of the device contacts can affect the thermal resistance and/or the electrical contact resistance and thus can lead to an increase of the temperature swing during the test. Therefore, the control strategy is important for the evaluation of the test result [5]. Some authors propose to control the test conditions to maintain constant losses or even constant temperature swings. Since these control strategies are not relevant for most application, all power cycling tests presented here were conducted with constant current pulses and constant pulse length t_{on} and pause length t_{off}. The characteristic temperature swing is always the value obtain at the beginning of the test after stationary thermal conditions are reached. In the power cycling test program the temperature swing ΔT_j varied between 64K and 113K and the number of cycles to failure n_f observed by experiment ranged between 31,000 cycles and 7.7 million cycles (Figure 2).

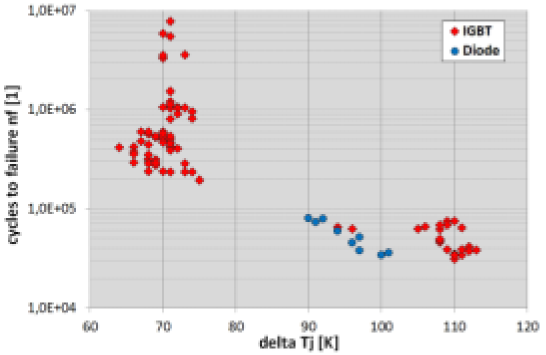

Figure 2: Number of cycles to failure n_f as a function of temperature swing for the test data set

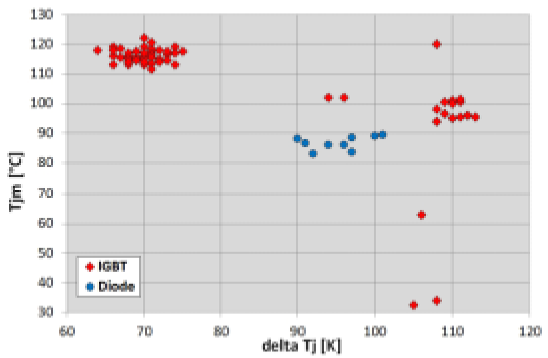

Figure 3: Medium junction temperature as a function of temperature swing for the test data set

The medium junction temperature $T_{jm}=T_{j,min}+\Delta T_j/2$ was varied between 32.5°C and 122°C to investigate the impact of the Arrhenius term (Figure 3). It should be pointed out, that some test were also performed with minimum junction temperatures below 0°C to include the effect of cold start situations. The aspect ratio of the Al wire bond was selected between 0.19 and 0.42 to analyze the potential of wire bond geometry optimization (Figure 4). It should be emphasized, that the design parameter for the SKiM63 module is an aspect ratio of 0.31. The range of power pulse duration t_{on} between 70ms and 63s is depicted in Figure 5. The variation over almost 3 orders of magnitude shows the special focus on this parameter within this investigation.

In total, 97 power cycling tests results were used as the data base for the derivation of the lifetime model for the SKiM63 module, 88 test were performed on IGBTs and 9 test were performed on diodes (marked by blue circles in Figures 2-5). The total test time to collect this data base amounted to 5 years.

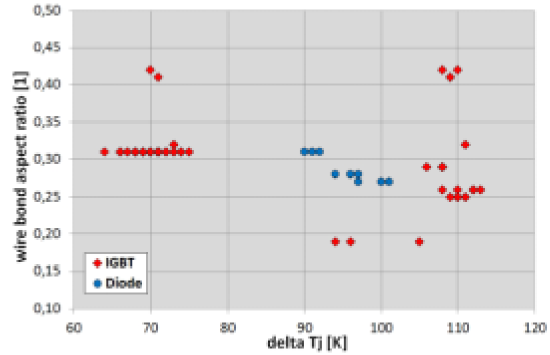

Figure 4: Wire bond aspect ratio as a function of temperature swing for the test data set

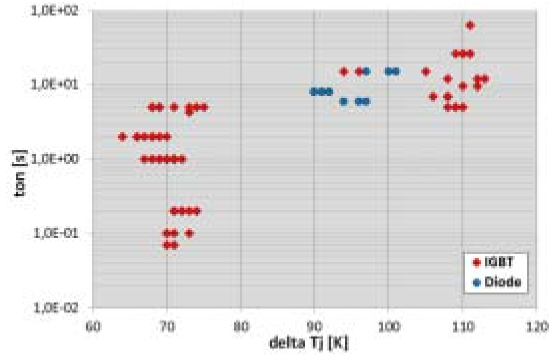

Figure 5: Power pulse duration t_{on} as a function of temperature swing for the test data set

The general form of the lifetime model is based on the well-known LESIT model [6], which determines the number of cycles to failure n_f from a fundamental scaling factor A, a Coffin-Manson term for the impact of the temperature swing ΔT_j and an Arrhenius term for the impact of the medium junction temperature T_{jm}. Two additional new factors were added to the model to account for the impact of the wire bond aspect ratio ar and for the impact of the power pulse duration t_{on}. Earlier investigations had shown, that the advantage of higher wire bond loops is more pronounced for smaller temperature swings, so that the exponent of this parameter is assumed to be a linear function of the temperature swing. The impact of the power pulse duration t_{on} is described by a function, which approaches an asymptotic value for increasing pulse durations, but reflects the increasing number of cycles for short (~1s) and very short (~0.1s) pulse durations.

Finally, a factor was added to account for differences found between tests on IGBTs and diodes. As was already reported by Bayerer et al. in the CIPS2008 model [7], the voltage class of the devices has an impact on the power cycling lifetime. This is in fact attributed to the thickness of the silicon devices used for different voltage classes. In the experimental data base, 1200V Infineon IGBTs with a device thickness of 120µm were implemented together with 1200V CAL diodes with a thickness of 260µm. According to the

CIPS2008 model, an increase of device thickness from 120µm to 260µm would result in a lifetime reduction to 59%. The experimental determined diode factor of ~0.62 corresponds well with this prediction. However, since no further variation of device thickness was integrated in the test data base, only a simple scaling factor for the diode test was applied.

$$n_f(\Delta T_j, T_{jm}, ar, t_{on}) = A \cdot \Delta T_j^{\alpha} \cdot ar^{\beta_1 \cdot \Delta T_j + \beta_0} \cdot \left(\frac{C + t_{on}^{\gamma}}{C+1}\right) \cdot \exp\left(\frac{E_a}{k_B \cdot T_{jm}}\right) \cdot f_{Diode}$$

The coefficients for the SKiM63 lifetime model were determined by a least square fit to the experimental test data set. The results are displayed in Table 1. A comparison between the experimental results and the model prediction is shown in Figure 6. For this illustration, the SKiM63 lifetime model prediction for each test parameter set was sorted for increasing number of cycles to failure and displayed together with the experimental results. As expected for a least square fit procedure, some experimental results are higher and some are lower than the predicted lifetime. Therefore, an additional margin factor of 0.8 is added to the final SKiM63 lifetime model. As is discussed in more detail in [8], this margin factor represents a module failure rate of 15% or a survival probability of 85%.

Figure 6: Comparison of the model prediction and the experimental power cycling results

Power Cycling Lifetime Model for SKiM63		
parameter:	value:	experimental data range:
A	3.4368E14	
α	-4.923	$64K \leq \Delta T_j \leq 113K$
β_1	-9.012E-3	$0.19 \leq ar \leq 0.42$
β_0	1.942	
C	1.434	$0.07s \leq t_{on} \leq 63s$
γ	-1.208	
E_a [eV]	0.06606	$32.5°C \leq T_{jm} \leq 122°C$
f_{diode}	0.6204	

Table 1: Parameter of the SKiM63 lifetime model

In Figure 7, characteristic lifetime curves for the SKiM63 are shown. With the margin factor of 0.8 and a wire bond aspect ratio of 0.31, the number of cycles to failure n_f is shown as the function of temperature swing ΔT_j for different power pulse durations t_{on}.

This new lifetime model now allows to calculate the estimated lifetime for application specific mission profiles. Therefore it is necessary to extrapolate the lifetime curves to smaller temperature swings outside the area of tested parameter variation. This is a general problem of lifetime estimation for power modules, since power electronic applications demand for lifetimes of 20 years and more. We must be aware, that such extrapolation cannot be validated by experiment. Even if a power cycling test would be started today for such a parameter combination, the test results received after two decades would only be of historical interest, since the power device generations will probably not be available anymore. This general limitation of empirical models can only be solved by physics based fatigue models, which could be used to verify the relative increase in lifetime for reduced stress.

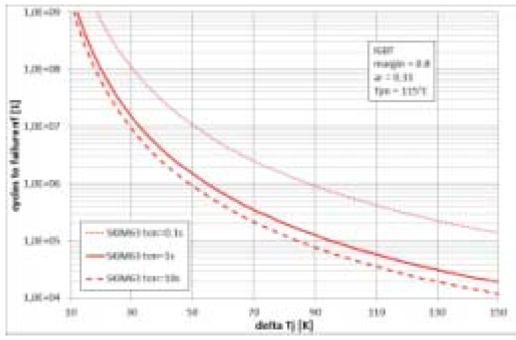

Figure 7: Lifetime curves for the SKiM63 module with a margin factor of 0.8 as a function of ΔT_j for different load pulse durations.

From Figure 7 we can estimate the lifetime of a SKiM63 module for a temperature swing of 110K at a medium temperature of 115°C, i.e. for a temperature swing between 60°C and 170°C. For a power pulse duration of 1s we obtain $5.8 \cdot 10^4$ cycles to failure, for a power pulse duration of 10s we can still expect $3.6 \cdot 10^4$ cycles to failure. For a classical industrial module with a copper base plate, solder chips and non-optimized Al wire bonds, a lifetime of $3.5 \cdot 10^3$ cycles to failure can be expected. This comparison shows, that the SKiM63 module is suitable for extended junction temperatures up to 175°C.

For an increase of the maximum junction temperature to 200°C, further improvements of the chip top side contact are required. Cu wire bonds or Al cladded Cu wire bonds, but also sintered Cu sheet contacts are potential candidates, which have proved their potential in first demonstration tests. However, no series products with these technologies are available today and it will take years to perform the power cycling tests to establish a consistent lifetime model for power modules with rated maximum junction temperatures of 200°C.

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Getting the Best Performance from AC to DC Power Supplies in Abusive Environments

By Ira J. Pitel Ph.D., Magna Power Electronics

INTRODUCTION

Ac to dc power supplies can be found in applications where power needs to be processed from the ac power mains to loads requiring a fixed or variable dc voltage or current. While such equipment has few input and output connections, engineers frequently struggle to obtain reliable performance in their particular environments. Troublesome issues can range from the quality of the ac source, cooling constraints, control wiring, air quality, or user understanding of the power conversion product. This article describes some common pitfalls and provides insight how to get maximum performance for specific applications.

POWER LINE QUALITY

Ac Mains

Connecting an ac to dc power supply to the power mains is oddly a common source of problems. Worldwide mains voltages vary in different parts of the word ranging from 200 Vac in Japan to 690 Vac in Europe. Line frequency also varies between 50 and 60 Hz, but with today's switching power supplies, frequency generally has little effect on performance.

Every year Magna-Power Electronics receives support calls that a customer's power supply has failed because of connection to the wrong AC mains voltage. Reading the specification label on the rear cover of the power supply and measuring the applied voltage can prevent catastrophic and costly failures.

Power quality, or the purity of voltage applied to the power supply, can be the source of some surprising behavior. Power distribution systems, with associated transformers and distribution impedances, can produce voltage drops or surges with other loads on the power network; these loads can circulate harmonic currents and exciting resonances between inductive and capacitive components. Industrial power supplies with 6-pulse waveforms have strong 5th and 7th harmonic components. Renewable energy sources with their associated power conversion equipment can also affect the voltage applied to a power supply.

Harmonics, as described above, and voltage transients on the ac power mains can damage the front end of the power conversion circuitry. Voltage transients can be suppressed with varistors or other voltage clamping devices, but these devices also have their limitations; they can only absorb limited amounts of the energy. Power line harmonics can be more destructive because these voltage excursions occur for longer time periods. To get past these types of problems, Magna-Power Electronics use front end components rated at 1600V. This voltage rating is sufficient to get past most of the power line conditions except for lightning strikes.

Phase rotation is the line voltage phase relationship of a three-phase power source. While there are standards, phase relationships in industrial facilities can vary. With incorrect phasing, motors can run backwards and power supplies using SCR's can misfire. Modern SCR power processing equipment circumvents SCR firing circuit issues by sensing and correcting for phase rotation variations.

Grounding

Grounding issues are frequently encountered in industrial installations. Proper grounding is poorly understood by many electrical contractors and in many cases, noncontiguous ground connections can frequently be found. The primary purpose for power supply grounding is for safety and for EMI suppression. Grounding places the protective enclosure at a safe, or near zero voltage differential from any surrounding equipment. Internal to the power supply, a ground connection is used with EMI filters to steer high-frequency components of current away from the input and output connections and stay within the confines of the power supply enclosure.

By electrical code and from a safety viewpoint, there should only be one connection to earth ground; the ground connection should be made at the electrical entrance of the building, the location of the metering equipment. It is at this point where ground and neutral are connected together and a ground rod is driven into the earth. If the facility's equipment is properly wired, there should only be a small current flowing in the ground path. In the event of a lightning strike, the entire facility rises to the same voltage potential thereby protecting objects or personnel from dangerous voltage differentials.

Unfortunately, not all power systems are wired to code and a common problem is that grounds used for computers and instrumentation equipment are not at the same voltage potential as the power equipment. While Magna-Power Electronics' power supplies attempt to adjust for such conditions, sometimes a poor ground connection between user and power equipment can cause strange power supply behavior. The most common problem is loss of communication between the power supply and computer equipment. In most cases, bonding grounds between user interface equipment and the power supply corrects this problem.

Some applications require connection to external monitoring or control circuitry. Many, if not most, power supplies have error and feedback circuitry referenced to the output terminals. Without suitable isolation, like optical isolators, ground loops can develop if external circuitry and the power supply load are grounded. Control errors can result if the external circuitry is grounded and the power supply load is left floating. In this case, conducted EMI is directed to the grounding leads of the external circuitry.

Magna-Power Electronics has circumvented many grounding issues by placing all of its control at near ground potential. Ground reference is established through a connection of a resistor and parallel connected capacitor. These components allow the power supply and external connected circuitry to be protected against poor grounding environments yet provide a suitable impedance for EMI suppression.

Even with a power system properly grounded, problems can develop from an EMI producing source creating a voltage potential in the grounding circuit. The impedance of the grounding circuit increases with frequency and the EMI source, depending on its location in the power system, can introduce voltages between the external monitoring and control circuitry. Like poor grounding conditions, bonding the external equipment to the power supply mitigates such electrical noise issues.

ENVIRONMENT

Power supplies contain heat producing components: transformers, inductors, power semiconductors, and the like. No matter how efficient, all of these components require cooling. Smaller power supplies sometimes rely on natural convection, but larger equipment requires forced air or water cooling. Water-cooled units are ideally suited for applications with poor air quality or for higher density rack mount installations that cannot meet airflow requirements. User introduced cooling issues is the dominate cause for field failure returns at Magna-Power Electronics.

Air Cooling

For power supplies requiring forced air cooling, thermal issues can result from blocking ventilation openings, poor air quality, and air restriction in cabinet enclosures. Blocking ventilation openings can obviously cause equipment failure. Placing thermal sensors on critical components can help detect this abuse, but there is a limit what is practically possible. Avoiding blockages of enclosure ventilation ensures life of the equipment as anticipated by the manufacturer.

Placing a power supply in an equipment enclosure can also lead to thermal problems. Air flow internal to the power supply requires the same air flow inside the enclosure. Self heating of equipment enclosures is a common problem. Poor location of intake and exhaust vents can cause warm air to be reheated and never be exhausted to the exterior. A conservative approach to equipment enclosure cooling is to place intake vents at the bottom of the enclosure and place fans, rated at the same cubic feet per minute, at the top of the enclosure. To minimize fan pressure and air restriction, the vent openings at the bottom of the enclosure should equal the vent openings at the top.

An environment with poor air quality usually finds it way to the interior of the power supply enclosure. Printed circuit boards are designed to support voltages sometimes in the order of several thousand volts. Layers of dust, paint, and other particulates can cause electrical breakdown. Placing air filters within the enclosure to purify incoming air can minimize this problem, but improper cleaning of these filters presents another. There is virtually no good tradeoff between poor air quality and filtration issues. With extremely poor environmental conditions, sealing the power supply and utilizing water cooling is the best alternative for heat management and obtaining reliable operation.

Water Cooling

Water cooling in abusive environments can solve many application problems. Magna-Power Electronics uses thermal sensors to control water flow to prevent condensation in heat sink assemblies. Following manufacturer specifications for water temperature, flow rate, and pressure are critical to making water-cooled equipment operate correctly.

Exiting heated water can be cooled with heat exchangers, water-to-air or water-to-water, in a closed loop system or disposed in an open loop system.

USER CONNECTIONS

Control and Monitoring Connections

Many applications require external equipment for monitoring and control of power supply parameters. Besides making sure that electrical connections do not exceed manufacturers' ratings, placement of cables can be critical. Voltages and currents, present at the input and output terminals of ac to dc power supplies, contain higher frequency components in the form of transients, EMI, and harmonics. Placing control and monitoring cables parallel with power carrying cables can produce unpredictable results. It is recommended that any control or monitoring cables be routed separately, in its own metal conduit, if possible.

Remote Sense Connections

Regulation of output voltage or current is dependent on sampling of the desired output parameter and adjusting it to a comparative reference. Both reference and output sampling parameters can be external to the power supply. Remote sensing of output voltage is commonly deployed to minimize voltage drop in the leads connected to the load. Properly used, remote sensing provides superior regulation at the point of load.

Switching remote sense connections or configuring the power supply for remote sensing and not connecting the remote sense leads is a common, but wrongly applied, configuration. A power supply operated without sampling an output parameter can either damage output components in the power supply or damage the load. Without an output parameter to control, feedback circuitry drives output voltage or current to its maximum. The maximum, non-regulated output can exceed the safe output rating of power supply components.

A common method to address this potential problem is to add resistors between the output terminals and remote sense terminals. Configuring a power supply for remote sensing and removing remote sense leads causes the output voltage to rise slightly above nominal conditions. The deviation above nominal conditions is a function of local sense resistors internal to the power supply.

Complications of remote sensing can arise when remote sense and power leads are switched. Figure 1 shows a common and wrongly configured system application; output terminals are defined as VO+ and VO- and voltage sense terminals are defined as VS+ and VS-. This configuration is deployed to switch power and remote sense leads to different loads using the same power supply. Electronic feedback circuitry is usually faster than the switching of mechanical relays and contactors and during the switching instant, the power supply is operated without sensing the output. Another issue with this configuration is operating the power supply with only the sense circuitry connected, relay K2 on and relay K1 off. This will virtually short the sense lead connections through the load. This causes protection resistors, R1 and R2, to be placed in series with the load when the power supply is operating at maximum.

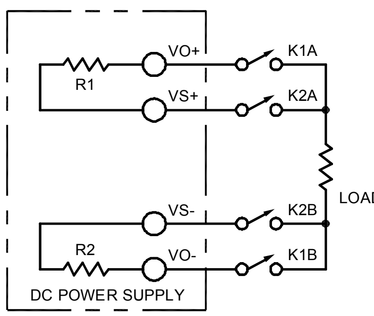


Figure 1 Remote sense protection with internal resistors

Magna-Power Electronics uses alternate approach for remote sense protection, but it too has some drawbacks. As shown in figure 2, the remote sense voltage, VSX+ minus VSX- , is tested at the beginning of the power-on cycle through electronic switching internal to the power supply. The power supply uses local sense during the beginning of the power-on cycle. It is then quickly switched, faster than the response of the feedback system, to the remote sense terminals to determine if the remote sense leads are connected to the load. If there is voltage present, the power supply remains in the remote sense configuration, if not, the local sense connection is reestablished. The scheme works well except for a user switching or removing remote sense connections after the power-on cycle.

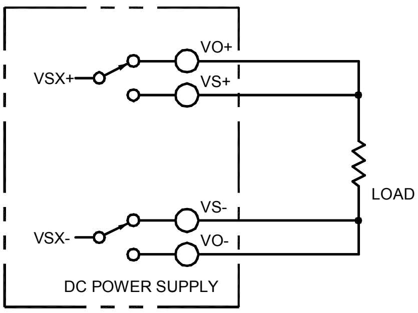


Figure 2 Remote sense protection with internal voltage sensing

ABUSIVE LOAD CONDITIONS

Output Current Ripple

Ac to dc power supplies normally have capacitors connected between the output terminals of the power supply. These capacitors provide a shunt path for reducing unwanted ac currents produced during the power conversion process. These capacitors have an internal series resistance, and when subjected to ac currents, produce power loss resulting in heat.

Maintaining capacitor currents within tolerable limits can become an issue, if ac currents from the load add to those generated by the power supply. Such conditions can be created with a switching type load, like a buck converter, connected to the output terminals of the power supply. As shown in figure 3, the power supply will sink a component ac load current depending on the ratio of internal series resistance, R1 and R2, of capacitor C1 and C2.

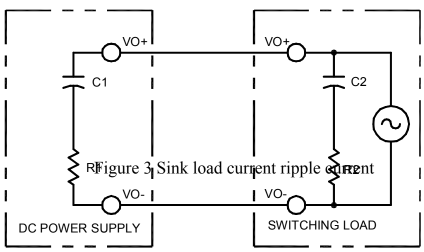


Figure 3 Sink load current ripple current

Repetitive Short Circuit Operation

Like excessive output current ripple, output capacitors, especially aluminum electrolytic type, can be damaged by shorting the power supply's output terminals. Peak current is limited only by the output capacitors' internal series resistance plus the lead impedance of the connecting cables. Energy stored in the capacitor is released as heat in the capacitor; repetitively shorting the output terminals can cause degradation or catastrophic failure. Film capacitors, such as those employing polypropylene film, have lower dissipation factors and can tolerate more abuse than aluminum electric capacitors, but these capacitors have lower capacitance ratings for a given size, which compromise filtering performance. The tradeoff between output ripple performance and reliable, repetitive short circuit operation is a design constraint.

Back Fed Voltage

Dc power supplies are frequently connected to loads that have their own source of energy or to loads that produce voltages and currents that exceed the ratings of the power supply. Typical examples are battery loads, dc motors, and motor controllers; these loads are capable of bidirectional flow.

Connecting a battery to the output terminals of the power supply can cause rapid charging of the output capacitors and produce excessive output current. As shown in figure 4, placing a series diode, D1, between the output of the power supply and the battery prevents voltage from being back fed to the power supply's output terminals. Configuring the power supply for remote sense at the load, eliminates the diode voltage offset. Also, the diode prevents the discharge of the battery through the power supply when the power supply is off. (Ac to dc power supplies typically have bleed resistors across output capacitors to discharge any stored charge when the power supply is off.)

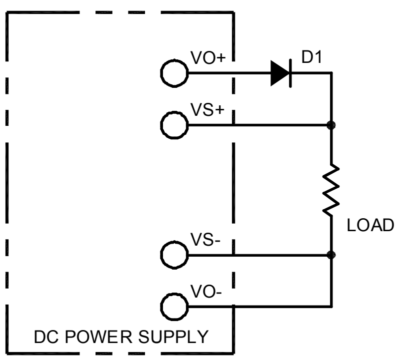


Figure 4 Back fed voltage protection with diode

Dc motors and motor controller combinations can back feed voltages while attempting to regenerate energy. If the power supply cannot dissipate energy, its output voltage floats at the voltage produced by the motor or controller. Placing a diode, as previously described, protects the power supply's output from exceeding its voltage rating.

Reverse Voltage

Most ac to dc power supplies utilize a diode or a synchronous rectifier circuit configuration in the final output power processing stage. These components clamp the output voltage to several volts in the reverse direction. Loading a power supply to produce a reverse voltage generally does not presently any reliability issues to the output stage, including aluminum electrolytic capacitors, as long as output currents stay within the ratings of the power supply. Applying a reverse voltage source, such as a battery, can damage output power semiconductors if currents are allowed to exceed ratings. As shown in figure 5, protection of reverse voltage can be accomplished with a series connected, fast acting, dc fuse, F1, and a diode, D1, with a surge rating beyond the i^2t of the fuse. With this protection scheme, a reverse voltage connection will clear the fuse by forcing current through the protection diode.

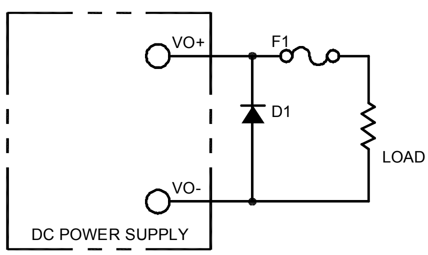
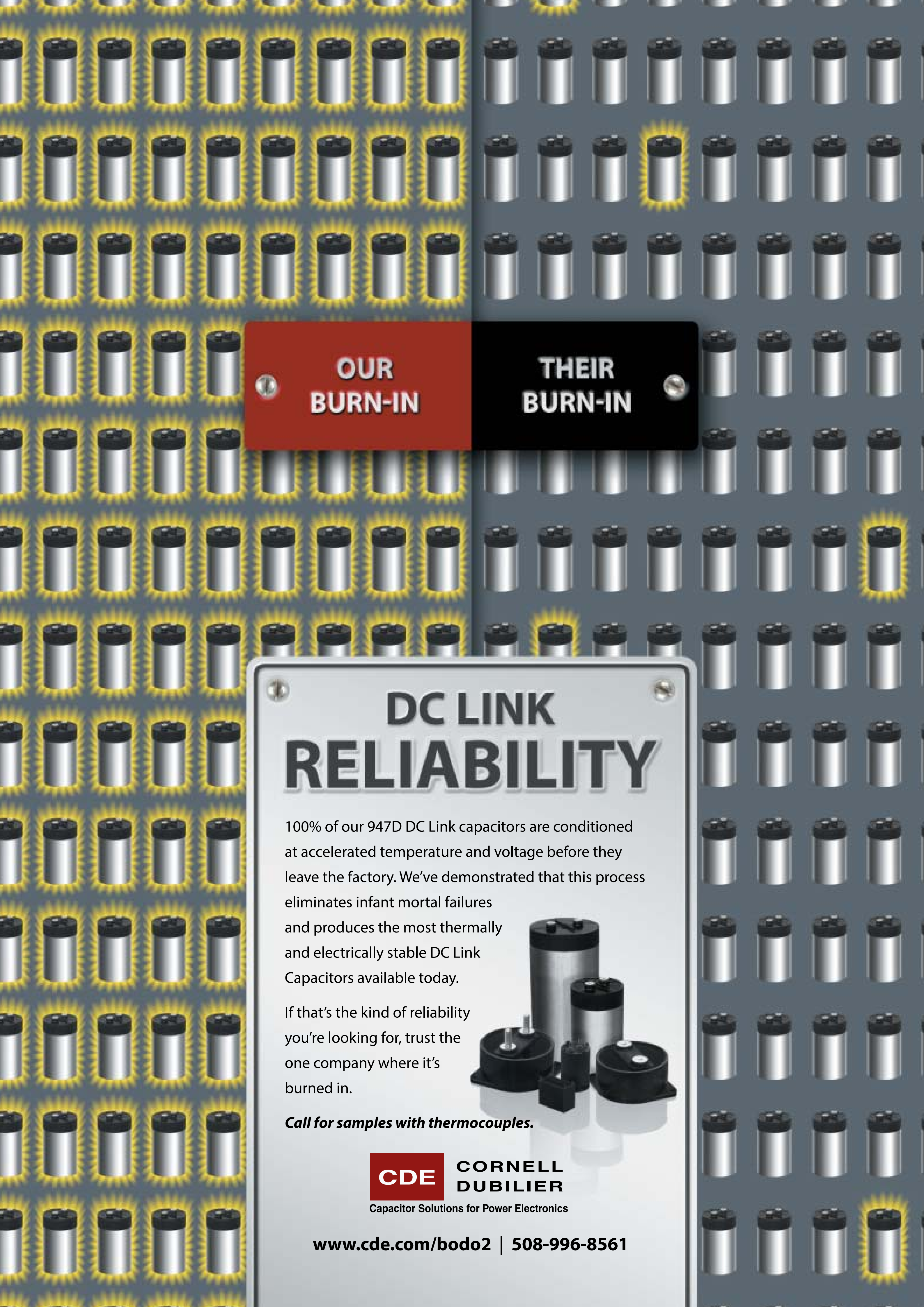


Figure 5 Reverse voltage protection with diode and fuse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Comparing the Benefits of Using an Integrated Power Module versus a Discrete Regulator

Today's power systems for communications and computing infrastructure support high current loads from increasingly power hungry FPGAs, ASICs and microprocessors. To supply these high current circuits, equipment makers often rely on discrete power solutions that are complicated, take up valuable real-estate and may have significant power output limitations.

By Chance Dunlap, Intersil Corporation

Step-down (buck) regulators are used to convert power from a distributed power bus to the individual point-of-loads (POLs) in infrastructure systems. Step-down converters convert a voltage from an input source to a lower output voltage and are capable of converting a voltage source (typically 5V to 25V or higher) into a lower regulated voltage (typically 0.5V to 5V). More recent infrastructure systems may utilize 20-40 point-of-load (step-down) converters in one system, each with different output voltage and output current needs, creating a challenge for system power supply design engineers.

To meet the challenge of designing the power sub-system for these systems, many designers are considering using power modules instead of traditional discrete POL designs, with time to market, size constraints, reliability and design capabilities being motivating factors. In this article, we will compare the benefits of using an integrated power module vs. a discrete step-down switching regulator.

Design of a Discrete Non-Isolated Step-Down Regulator

The building blocks of a non-isolated switching power supply are shown in Figure 1.

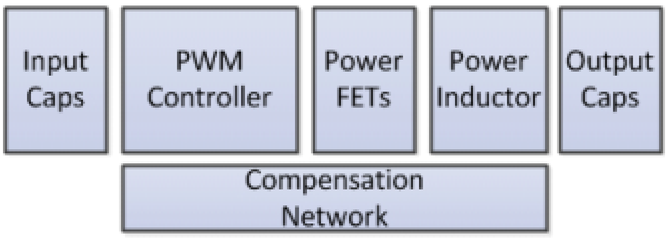

Figure 1: Discrete Power Supply Block Diagram

A discrete power supply requires a number of external components to build: a PWM controller, switching power MOSFETs, input capacitors, output capacitors and a power inductor. All of these components vary for each design. For example, if a system has 20 different power supply rails, the selection of these components must be done for each design, which makes the job of designing a power sub-system very challenging.

Let's look at an example of a non-isolated buck regulator. All of the components for the non-isolated buck regulator design in Figure 2 should be carefully selected to meet the design requirements.

Calculating the inductor value is most critical in designing a step-down switching converter. First, assume the converter is in continuous conduction mode (CCM), which is usually the case. CCM implies that the inductor does not fully discharge during the switch-off time. Peak current through the inductor determines the inductor's required saturation-current rating, which in turn dictates the approximate size of the inductor. Saturating the inductor core decreases the converter efficiency, while increasing the temperatures of the inductor, the MOSFET and the diode.

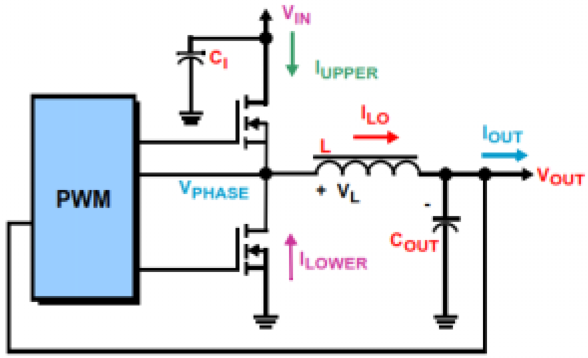

Figure 2: Basics of a Synchronous Buck Converter

The output capacitor selection is also a critical part of the design. The output capacitance determines the load transient performance of the power supply. Output capacitance is required to minimize the voltage overshoot and ripple present at the output of a step-down converter. Poor load transient performance or instability is caused by insufficient output capacitance, and large voltage ripple is caused by insufficient capacitance as well as a high equivalent-series resistance (ESR) in the output capacitor. The maximum allowed output voltage overshoot and ripple are usually specified at the time of design. Thus, to meet the ripple specification for a step-down converter circuit, you must include an output capacitor with ample capacitance and low ESR.

The input capacitor is used to suppress noise at the input of the power supply and reduce the ripple voltage seen at the input. Load current, duty cycle and switching frequency are some of the factors used to determine the magnitude of the input ripple voltage. Ceramic capacitors placed directly at the input of the regulator reduce ripple voltage amplitude. Only ceramics have the extremely low ESR that is

needed to reduce the ripple voltage amplitude. These capacitors must be placed close to the regulator input pins to be effective.

Careful selection of the upper and lower MOSFETs will determine the overall efficiency of the buck converter. The on-resistance of the power MOSFETs and switching losses will affect the overall efficiency. The compensation components must be selected to ensure that the design meet the stability criteria over the required operating conditions. Placement of the external components can also affect the performance of the power supply. Designers must use an optimal layout to minimize noise and maximize system efficiency.

This entire process must be repeated for each power rail. If there are 20 point-of-load power rails in the system, the process must be repeated 20 times, which can quickly become a daunting task for a power sub-system designer.

Use of a Power Module

System designers will make tradeoffs between cost, design effort and performance when selecting a power module. For systems with 1-5 power rails, designers may opt to use a discrete regulator to save cost and meet the time to market schedule. However, as the number of power rails increases and the current rating increases, the design of the power sub-system becomes challenging and requires significantly more design effort. To meet this challenge, designers may opt to use a power module solution. Designers will also consider the cost of ownership of a discrete design. The cost of ownership is the bill of materials (BOM) cost in addition to the power designer's time required to design and test the design. Potential re-design changes, manufacturing and assembly costs are additional expenses for discrete designs.

Figure 3 shows how a power module can integrate many of the blocks of the discrete design shown in Figure 1. A power module integrates the PWM controller, power MOSFETs, inductor and compensation network into the package. The designer typically only needs to select the input and output capacitors to complete a design.

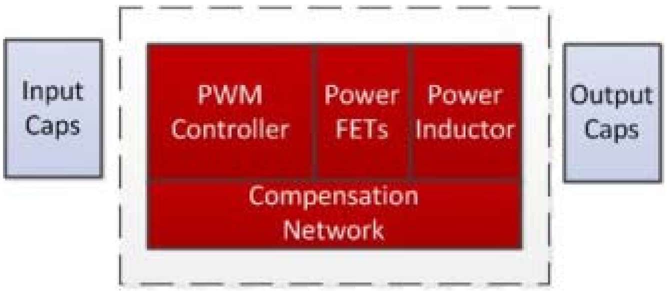

Figure 3: Power Module Implementation

Intersil offers a comprehensive portfolio of digital and analog point-of-load power modules to address the needs of infrastructure systems. Intersil power modules are complete DC/DC power sub-systems as shown in Figure 3. With industry-leading power technology, these modules reduce design time, lower cost and save board space. Intersil's optimized thermal packaging technology provides excellent thermal performance, providing high current operation and high power density without the need for an external heat sink or fan, reducing system cost.

Figure 4 shows the ISL8216M, Intersil's first high voltage power module. The ISL8216M supports a wide 10V to 80V input voltage range with an adjustable 2.5V to 30V output range, and delivers 4A of output current. The ISL8216M is an ideal choice for systems with a 12V, 24V, 36V or 48V input rail, making it well suited for infrastructure and industrial systems.

Intersil offers two pin-to-pin compatible step-down power modules for

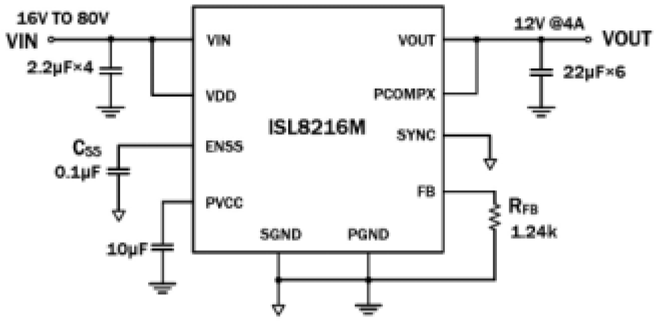

Figure 4: ISL8216M Application Circuit

maximum design flexibility. The popular ISL8225M dual 15A/single 30A step-down power module delivers up to 100W output power from a tiny 17mm x 17mm thermally enhanced QFN package. The two 15A outputs may be used independently or combined to deliver a 30A output.

If you need high voltage or more headroom, you can move to the ISL8240M dual 20A/single 40A step-down power module, which is well suited for power hungry ASIC, FPGA and microprocessor loads in infrastructure systems. Current sharing and phase interleaving allow up to six modules to be paralleled for up to 240A of current. Both power modules offer excellent efficiency and low thermal resistance to permit full power operation without heat sinks or fans.

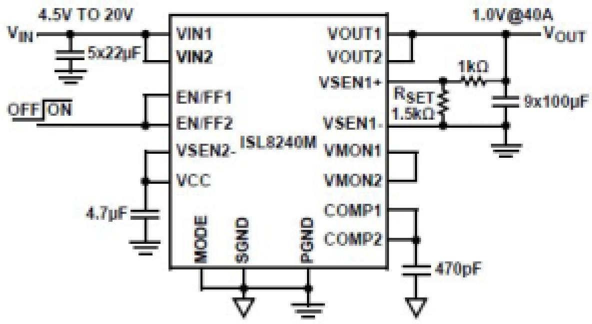

Figure 5: ISL8240M Single 1V/40A Output Application Diagram

Conclusion

The initial cost of implementing a discrete design may be cheaper than using a power module, but when considering time to market and long-term engineering and maintenance costs, a power module shows significant advantages, particularly for systems with 10 or more power rails. The cost of ownership, reduced design complexity, and a simplified and more flexible PCB layout are all important factors to consider. Intersil offers a rich portfolio of digital and analog power modules to address the wide input voltage range and load current range of infrastructure systems. Find out more about Intersil's power module solutions at:

www.intersil.com/powermodule

What to Watch for when Turning on a SMPS for the First Time

In the near future, SMPS will completely displace conventional supplies, hence also engineers who are no specialists will have to cope with them. Turning on a new or unknown SMPS, especially offline - SMPS, can have unexpected and disastrous effects. This article describes some dangers, precautions and procedures for setting up and testing SMPS.

By Dr.-Ing. Artur Seibt; Vienna

Basic Safety Considerations

This article is about how to start and test SMPS in laboratories. National safety rules for electronics laboratories have to be obeyed. Work on circuits above the low voltage limit is generally only allowed if: 1. at least another person is present who knows what to do in case of an accident, 2. if the circuit under test is connected to the mains via a certified adjustable safety isolation transformer, 3. if all measuring instruments are connected to the safety earth. SMPS for lower voltages may present no personal electrical hazard, but can well pose a fire hazard or release obnoxious gases. One should always wear at least spectacles. The isolation transformer cannot prevent harm by high voltages inside offline SMPS; the PFC output voltage of up to 420 V DC is mostly the highest one, but generally all voltages on the primary side are dangerous. Output voltages above the low voltage limit are seldomly encountered. The iron rule: if the circuit is live, only one hand is used, for all operations which require both hands, the circuit has to be switched off. Beware of capacitors which may remain charged!

Electrolytic Capacitors

Electrolytic capacitors can explode and burn: in the best case, the safety vent will open and spill the hot aggressive electrolyte all over the circuit, it is advisable to scrap the electronics affected! In the worst case, the capacitor will fly apart and cause personal injury. Many small cylindrical types can expel the innards like a bullet. Pitfall: most large electrolytics, especially high voltage types, use the standard 10 mm pin spacing and can be inserted wrongly, this constitutes the worst case of abuse and results in failure within seconds, depending on the current delivery potential of the circuit; if this is high like in offline SMPS, an enormous amount of gases will be generated which may be too much for the safety vent and cause an explosion. High current can also set the paper aflame. If a false capacitor with an insufficient voltage rating was installed, which is easy because they all have the same pinout, it will take some time before it fails, hence, if the SMPS seems to operate, the joy will be premature, the overstressed capacitor will soon fail. Experienced engineers will therefore switch off after a short time and test the temperature of the electrolytics and semiconductors, if one is already warm, it is probably overstressed.

Electrolytics function because the aluminum foil carries a thin oxyde film built up during manufacturing. In operation, a very small leakage current flows and keeps the oxyde film intact. During storage, the oxyde will deteriorate, so that the capacitor partly loses its voltage blocking capability. If it is suddenly connected to its nominal voltage or even less, a high leakage current with a positive TC will flow, it will quickly heat up the capacitor, thereby increasing exponentially. It is a race: depending on the quality of the capacitor, the length of storage, the ratio of applied voltage to the nominal one and the current capability of the source: the capacitor either survives, because the oxyde film restored itself quickly enough so that the leakage current decreases, or it fails within seconds. This danger is the greatest for high voltage electrolytics.

The experienced engineer will avoid this danger, because he knows that the “new” electrolytic may have been in stock for years. In order to prevent such unpleasant surprises, he will test each major capacitor before installing it. This is done by connecting the capacitor to a voltage source via a current limiting resistor of say 10 K; a voltmeter is connected across the capacitor. The voltage is increased in steps, and the rise of voltage across the capacitor watched. With a good capacitor, the voltage will rise quickly to just below the value set, then the voltage will be again increased and so on, until the capacitor voltage has risen close to its nominal one. It will then be discharged via a resistor, never by shorting it! This procedure is also necessary if an electronics gear has been stored for years. Some electrolytics will need several minutes, some can not be restored.

A word of caution: Most SMPS fail due to defective electrolytics! There is a lot of knowhow in the manufacturing of electrolytics, their quality and the load in the application determine when they fail. The author has instruments with electrolytics made 50 years ago which still function. Most renowned European manufacturers had to give up, so their knowhow was lost. There are many new manufacturers on the market; it is risky to trust their knowhow. Also, due to the ubiquitous cost and price sqeeze, design margins have become small. During manufacturing, the oxyde forming voltage used to be quite a bit higher than the nominal one, this, however, costs more and increases the size, hence, many manufacturers’ products barely meet their specs. The standard tolerance is - 20 + 50 %, but capacitors are hard to find which have more than - 20 %! Modern electrolytics contain very fragile aluminum foils, the leading Japanese manufacturers request not to use a capacitor which fell to the floor!

Far and above, it is the temperature which influences life and reliability most! When, after some time of operation with full load, the electrolytics of a SMPS are too hot to the touch: forget it, unless short life is expressly accepted. In the EU, manufacturers have to honor a 2 year warranty by law. On SMD boards the electrolytics are often heated by nearby diodes soldered to the board. Inexperienced designers place them close to semiconductor heat sinks or hot transformers. When testing SMPS, the temperatures of the electrolytics belong to the most important parameters, they are measured on top, “ambient” temperatures are immaterial. N.B.: Specs have to be carefully read, often “life” is specified only without any AC current load which is worthless. The maximum operating temperatures do not imply longer life: Life is cut by half for every 9 degrees C, this is valid up to appr. 85 C, above halving occurs already for every 4 to 5 C more! The electrolyte dries out with time, this raises the ESR which in turn causes higher temperature, then thermal run-away will set in. There is no way around: long life and high reliability sternly require high quality electrolytics, low AC loading and placement far from heat sources. Each degree less counts, it is an exponential relationship!

Foil Capacitors

The popular foils (PE, PP etc.) burn. Since many decades, the so-called X capacitors which are connected across the mains in offline SMPS have set many power supplies and then whole apartments aflame. Metal-paper capacitors are safe but too bulky. PE was abandoned, today’s X capacitors are almost exclusively made of PP and specified for a nominal voltage of 305 Vrms, although no higher mains voltage than 254 V is allowed. The mains carry overvoltages far into the KVp range which can ignite a X capacitor. Of course, test voltages and surges are standardized, but the mains may be disobedient to the standards committee and deliver still higher surges. They should be protected by VDR’s. Normal foil capacitors which are used in other parts of the circuit can also burn, this is less likely, because they are not subjected to unknown surges.

Ceramic Capacitors

Today’s SMD capacitors are predominantly MLCC’s (multi-layer ceramic capacitor). The renowned Japanese manufacturers state that no higher voltage than half the nominal one may be applied. The large-sized MLCC’s break often, if the voltage applied is high enough they will burn with fireworks. Another problem is the use of an inappropriate dielectric material. There are ceramic materials like Z5U, Y5V etc. which lose almost their whole capacitance when warm, also lose it when the voltage applied comes close to the nominal one, are highly nonlinear and exhibit very high losses at high frequencies. If they are used as filter capacitors in SMPS, they can become so hot that they unsolder and fall off the e.c. board. Ceramic capacitors are not marked, hence a wrong material will not show, in order to measure the capacitance, they must be unsoldered. Ceramic capacitors take substantial test overvoltage, hence it is impossible to determine their nominal voltage. By warming them up while they are hooked up to a measuring instrument one can find out whether it is class 1 material (COG) or class 2 or 3 material: class 1 will not change, classes 2 and 3 will decrease; if only by 10 %, it is likely X7R or X5R, if by 80 %, it is Z5U, Y5V or the like. SMPS which contain ceramics of the latter type should not be considered.

Power Semiconductors

If power semiconductors fail, they will usually short, but they can also burn red-hot inside until the current is turned off, the plastic will go up in smoke which should not be inhaled. SMD transistors or diodes can fall off the board.

In offline SMPS one can not rely on fuses for disconnecting in case of failure. According to the norms, a fuse must withstand 1.5 times its nominal current for at least one hour. If a power transistor or the main electrolytic is a dead short, it will blow the fuse, but it is also possible that another component in that circuit will burn such as common mode chokes or NTC’s because the current is not high enough to blow the

fuse. There are no electrical means to protect all SMPS components from burning. Therefore one should always provide a metal housing which also provides shielding

Visual Inspection

Experience showed that a thorough visual inspection is the most valuable and effective means to detect faults prior to turning on an unproven circuit. Semiconductors, resistors and the larger components are marked, SMD ceramic capacitors and glass diodes are not marked. As mentioned, it is especially necessary to check whether electrolytics and diodes are not installed backwards. The unmarked components pose a veritable problem in case the circuit malfunctions, especially the ceramic capacitors. In a worst case scenario one would have to unsolder and test all, one by one. Example: Assumed that instead of a 0.1 uF ceramic capacitor across the power supply pins of an ic a 1 nF one was installed; the ic will probably malfunction. How long will it take, before this is detected? Probably, the ic will be first suspected and exchanged. It would be still worse if the ic functions, but is in fact on the edge of malfunction!

It is advisable that, for the first engineering board, the designer himself places all components, this is the best way to ensure that the correct components are on the correct places. However, many components have become so small that manual installation is only possible under a microscope.

Test Set-Up for Offline SMPS

As mentioned, offline circuits are only operated via an adjustable certified isolation transformer! A Power Analyzer which displays: line voltage, current, active power, apparent power, power factor lambda is inserted between transformer and test object. On the output side variable resistive test loads and a DVM per output are connected. The resistors are initially set to emulate the nominal loads. For this purpose ceramic wirewound power potentiometers are ideal which are available up to more than 100 W and with values from a few ohms to several kiloohms.

It is not advisable to start without loads because there may be problems in the regulation circuit which would cause the output voltages to go high. Most SMPS are designed for regulation from the secondary side; this implies that the SMPS must be able to start with full loads plus a reserve. The regulation circuit in the secondary is inoperative during start-up because there is no supply voltage yet. As soon as the reference output reaches its nominal voltage, the regulation sets in by reducing the power in the primary. Consequently, a broken loop will always cause overvoltage! (There are SMPS where the output voltage is sensed on the primary side which suffices for many applications, however, without any load, the output voltage can still rise above nominal because voltage spikes from the transformer will be rectified.)

A well designed SMPS incorporates transil (transzorb) zener diodes across each output, they conduct when their specified voltage is transgressed and limit the voltage, if the current rises too high, they will short and thus protect the load in the application. If transils are provided, start-up without loads is possible, it is easy to identify and exchange a shorted one, but it is necessary to be on the quick switching off, because the shorted transil will cause overstressing of the diode and the transformer winding belonging to this output.

The most important converters are flybacks, which are superior to > 250 W, these are "constant power" converters, i.e. it is the regulation loop which changes the behaviour to "constant voltage". If they are not loaded, and the regulation loop is broken, the voltage will rise, theoretically, towards infinity, until some component will short; as the secondary voltage rise will be reflected into the primary, mostly components on both sides will be destroyed. It is not advisable to load only the reference output, because the unloaded outputs may rise so far that their capacitors are overstressed and fail. With other converters, the output voltage will rise, but not necessarily to destructive limits. NB: If a main power transistor in an offline SMPS shorts, a direct connection between the high voltage (rectified line resp. PFC output) and the low voltage control circuitry, typically 12 V, will be established so that the complete control circuit will be destroyed; depending on the size and worth of the SMPS, it will mostly not pay off to exchange all defective components, also for the reason that those components which seem to have survived may be already partly damaged!

The scope is the most important instrument, during the first test phase, the primary and secondary grounds can be connected, so that primary and secondary signals can be looked at by the same scope. It is highly recommended to use a > 100 MHz analog scope for that purpose, only top models of DSOs may be used instead, no middle- or low-priced ones. See the first article in this series for the explanation. For all high voltage measurements on drains etc. use only 100:1 passive probes; 10:1 probes are only good for 400 to 600 Vp! Their input impedance decreases at high frequencies which effectively dampens voltage peaks, so those are measured too low. The probes must be carefully adjusted, including their high frequency adjustments.

The most important signal to be measured at start-up is the drain voltage of the switching transistor(s). The second most important signal is the switching transistor current which is measured with a DC/AC current probe. The drain pin of the transistor has to be lifted off the board; one uses a small loop made of Teflon litz wire, the loop just large enough for the probe, the wires twisted for appr. 5 .. 7 cm, soldered between drain and board.

Turning on Offline SMPS

Of course, it matters whether it is a 10 oder a 1000 W unit. With low power SMPS, one can be a lot bolder, because the possible damage will be small. Before turn-on check the fuse, only ceramic sand-filled heavy-duty fuses should be used on the mains! Many SMPS on the market contain cheap glass fuses and also such with a much too high rating. This is irresponsible and does not recommend such products. If the line is switched on, there is a high current transient which charges the main electrolytic; if that is not limited by a NTC or a resistor, it may blow a correctly rated fuse. The solution is not to increase the rating, but to use a slow blow (T) or very slow blow (TT) fuse.

The normal procedure is to slowly increase the isolation transformer voltage while watching the Power Analyzer displays, the output voltage displays and the scope. A word of caution: a professionally designed SMPS can be turned on like this, however, there are SMPS which are not "brown-out proof"! If the 230 V are switched on, they will start, but if the voltage decreases much below the 207 V, they will break into wild oscillations which can lead to self-destruction. Caution: There may be defective transistor or capacitor, placing a short across the input, in such a case the line current will immediately rise drastically, hence increase cautiously at the beginning and watch the current display.

Normally, the converter(s) will already start switching, before the lower line voltage design limit is reached; the SMPS will deliver output power, in this voltage range between zero and the lower design limit the input current can rise above the value at the lower design limit, this can overstress components, hence the input voltage should not stay too long in this range, just long enough to take a look at the displays mentioned and then increased to the lower design limit. (With PFC in general 105 or 85 V, without PFC 207 V) The most important parameter is the active power display on the Power Analyzer! If these values are close to the correct ones at the respective mains voltages, it can be rather safely assumed that the whole SMPS is all right and functioning properly. The active power at 230 V and full load should be indicated in the specs, if not, it can be estimated by adding all loads connected and assume an efficiency of 85 %. After the full test of the first sample, the testing of more samples can be shortened to: Input voltage cranked up to the lower design limit, a look at the active power display and all output displays, then the input voltage increased to 230 V, then to 254 V, same checks.

With PFC

The PFC output is disconnected from the input of the main converter, a test load equivalent to the input power to the main converter is connected to its output. With rising mains voltage the output voltage will already follow before the PFC converter starts switching, because the current flows through the bypass diode (or flyback diode). The mains voltage must not stay too long at voltages below the PFC lower design limit, because the bypass diode, although husky, may be overstressed (without a bypass diode and with a marginal choke there is danger of destruction of the diode and the transistor). At 85 or 105 V the PFC regulation loop should lock, and the output voltage have reached its nominal design value between 360 and 420 V. 360 to 380 V: good design, above: poor design. It is assumed that the PFC is of the high quality "continuous" type where the fixed frequency converter current rides on the 100 Hz half sine and typically amounts to 20 %pp of the line current.

The scope is connected to the drain with the 100:1 probe. The DC/AC current probe is clamped around the "cold" conductor of the choke which will also require a test loop. The drain voltage is clamped by the diode at the output voltage level, the rise time should be around some ten ns. NB: The scope display will depend on the scope used.
If this is the very first turn-on, the choke must be checked, if the design data are not available. The absolute current peak consists of the 100 Hz current at low line plus the 10 % of the e.g. 125 KHz saw tooth. This peak current must not drive the ferrite into saturation at the highest temperature which the choke core can attain under wc circumstances. First the PFC is operated with full load for e.g. 1 h at low line, then the core temperature is measured with a contact thermometer, not with an infrared instrument. The winding temperature is either measured by measuring the resistances at 25 C and hot or by a sensor placed inside the winding. Because these measurements were at ambient room temperature, the difference to the maximum ambient around the choke expected in actual operation must be added. The result should not exceed 100 C except for special SMPS using special ferrites, see the part Transformer Saturation in the following text. Then the choke is heated with the use of a hair dryer to 100 C and the current watched. Impending saturation will be visible: the linear current rise of the sawtooth will change into a nonlinearly steep upward rising one. As soon as this appears, switch off! If this occurs at full load, low line, the choke must be redesigned and the procedure repeated. If the SMPS was bought or a test sample, it should be rejected. If it was of one's own design, the choke must be redesigned. An acceptable choke will allow + 10 to 25 % overload without signs of saturation.

At last, the line voltage is increased to 230 and then to 254 V and the active power and the output voltage checked; because this is a booster, the losses will decrease with rising line voltage hence also the active power.

After the test of the PFC, its output can be reconnected to the input of the main converter. A boost converter cannot be protected against overload due to the direct connection from input to output via the diodes. If the main converter is defective, it may draw an overcurrent from the PFC. It is recommended, for this test, to insert a fast or medium-speed fuse with a rating equivalent to the maximum design input current of the main converter. Use only sand-filled ceramic fuses, because this is DC, a standard fuse could ignite an arc rather than disconnect!
The start-up of the main converter is different with and without PFC: a PFC will deliver its full output voltage in the moment the line reaches its lower design limit; this means that the input voltage to the main converter will at first follow the increasing line voltage and then suddenly jump to the PFC design value of between 360 and 420 V. This should not surprise! If problems in the main converter are to be expected, this sudden application of the full voltage is discouraged. It is then better to leave PFC and main converters disconnected, and to install a connection between the output of the bridge recitifier and the input of the main converter, thus bypassing the PFC and follow the procedure below.

Without PFC.
The main converters in offline SMPS with and without a PFC differ hardly: the range for 230 V SMPS extends from 207 to 254 V, hence the converter must function from less than the recitified 207 V onwards, i.e. appr. 250 V DC, minus the peak ripple voltage which is often forgotten up to 310 V DC with load plus the peak ripple; at low load and high line the input voltage will rise to 360 V. If a PFC is on board, one might think that the input to the main converter is a stable e.g. 360 V; this is wishful thinking, because the standard PFC voltage regulation loop is very slow, hence load changes cause wide fluctuations of the output which the main converter has to digest without losing regulation.
Not all types of converters can be treated here, the flyback is chosen, because the bulk of offline SMPS are < 250 W which is flyback territory. The flyback is both the least expensive and the best converter, it not only delivers an excellently regulated reference output voltage, but in addition several output voltages which are well stabilized so that mostly postregulators can be dispensed with. Their voltages depend on the loads on all outputs. The transformer (the term is false but customary) determines the whole performance and especially the cross-regulation.
There are two modes of operation: voltage-mode and current-mode control (invented by the author at Tektronix). A current-mode controlled flyback will operate by nature over a wide range of input voltage and features the fastest response of all converters. At voltages below its lower limit, the switching transistor (and transformer) current will be limited by the primary inductance resp. the maximum turn on time resp. duty cycle of the transistor, i.e., the circuit is low-voltage resp. brown-out proof. As soon as the control circuit starts operating, the flyback will deliver, so that all secondary voltages start to rise, as soon as the lower input voltage limit is reached, the voltage regulation loop should lock, and the output voltages reach their nominal values.

Hence, with this type of converter, it is safe to slowly increase the line voltage from the isolation transformer and watch the active power, the scope drain voltage and current displays and the ouput voltage displays. Normally, the flyback will function below its lower design limit and already deliver full power; however, in this range the line current will be higher than designed for; hence one should not leave the SMPS in this range for extended periods of time.
The temperature measurements on all vital components must be performed at low and high line, because some losses are more current, others more voltage dependent. Basically, these are the transformer, the transistor, the diode(s) and the electrolytics. Because it is so easy to choose the false type of ceramic, the MLCCs' temperatures should also be checked.. NB: For measurements of temperatures at electrically hot points like transistor cases = drains, the SMPS must be switched off, even if handheld isolated instruments are used! The fast high amplitude pulses will disturb the measurements.

Output ripple measurements require the use of the special Tektronix probe connectors into which the probe is inserted.

Test Set-Up for Low Voltage SMPS
There are marked differences between offline and low voltage SMPS. A major difference is the existence of a negative input resistance with all converters which deliver a constant output power. If the input voltage rises, the current will decrease, this constitutes a negative resistance. The author refers to his article in "Bodo's Power August 2012". The design of the SMPS input circuit, the voltage source and the connections come into play. The whole input can oscillate wildly which has nothing to do with the regulation loop, which, however, can contribute.
As an example, here a buck converter is chosen. These are very popular in the shape of small modules. When testing (or selecting) it is important to check whether a module is a complete SMPS or whether the small size is misleading, and a whole lot of external components have to be added in order to complete a functional SMPS! As a rule, there are only rather small MLCC's at the input, and this is why the input circuitry external to the module is critical and determines whether wild oscillations will occur or not. A proper test set-up must therefore come as close to the set-up in the application as possible, or the test results will be of doubtful value. The "application circuits" provided by the manufacturers cannot be trusted, to the contrary: it happens that they produce oscillations which lead to massively increased p-p and rms input currents requiring a big capacitor which is superfluous if the input is properly damped with just a small RC. The ESR of the output capacitor is vital for the stability of the regulation loop, hence no MLCC's should be added there.
The scope is hooked up to the source of the transistor, the current probe is clamped around the cold conductor of the choke, if accessible, later it is clamped around the input conductor. The input current of a buck is a square wave, depending on the amount of capacitance at the input inside the module, at the input pin it will be filtered to some extent.

Turn-On of Low Voltage SMPS.
The adjustable load should first be set to perhaps half load. With this type of converter the worst which can happen is a short of the transistor: then the input voltage will appear at the output, if the short was caused by a shorted diode, the input will present a short. In proper operation the output voltage is equal to the input voltage multiplied by the duty cycle. Most SMPS of this kind are not overload- and short-circuit proof. While the input voltage is increased, the output will first follow, as soon as the input voltage exceeds the programmed output voltage, the regulation loop should lock. Further increases of the input voltage will just reduce the duty cycle. After ascertaining that the supply functions, and the transistor source voltage, the choke current and the output ripple voltages on the scope are all right, and there are no output oscillations, the input voltage and current should be measured in order to verify that there are no input oscillations and no excessive p-p and rms currents. Last, the temperature measurements on the transistor, diode, choke and output capacitor follow. With modules, in order to check whether the incorporated choke is adequate, the full load should be connected, then the module should be heated to

its maximum specified case temperature and left there for ½ to 1 h. Because the choke current is not directly accessible, output and input ripple voltages should be observed with the scope. The transistor is in danger, as soon as the choke approaches saturation, however, if the purpose is to select such modules, it is better to destroy some than to choose an inadequate product.

Some Special Problems

Transformer Saturation.

The design of flyback transformers requires enormous knowhow and experience as well as knowledge of ferrites and winding materials. Whereas true transformers like those in forward converters are comparatively simple, the flux density in their cores low, the flyback transformer is none, but a choke, and the flux density very high. Ferrites have a maximum operating temperature above which the losses rise steeply towards the Curie point; this minimum marks the highest temperature which the core may reach, for the customary power ferrites this is around 100°C. The saturation flux density is specified at 25 and 100°C, only the latter value is of interest; no specs are available for higher temperatures, hence it is wise to design the transformer for a 100°C maximum core temperature under wc circumstances. SMPS transformers are at least partly wound with TexE, TexELZ or TexF for class F; if the core is at 100°C, the winding will also be at or close to its maximum permissible temperature where its life is already shortened. The usable flux density is, of course, far below saturation, because near saturation the core loses its permeability and thus the transformer its primary inductance. The maximum flux density translates into a maximum current. The test whether the transformer is adequate as regards saturation is done as decribed for the PFC. If this is not performed with thoroughness, the following can happen: The SMPS functions until it warms up to a temperature at which the core saturates; due to the loss of inductance, the switching transistor current rises extremely sharply. In current-mode control, it depends on the speed of turn-off whether the transistor will survive. As a rule, it will be destroyed. Most probably, a bad transistor will be suspected, it will be replaced, but also the new one will be destroyed. It may take a lot of time, before the real cause, the transformer, will be found out!

Special Load Problems.

No SMPS should be designed without information about the exact type of load, this applies also to selecting SMPS, otherwise serious disappointments may be programmed. A typical case are motor loads. Few users of "DC" - motors realize that there are no "DC" - motors; this designation misleads, a DC field cannot cause rotation. Each "DC" - motor draws a high peak-to-peak AC current the average of which is the DC current! If a SMPS for motors is selected on the base of the nominal specified DC current of a motor, this will not work for 3 reasons: 1. The SMPS must be able to deliver the positive current peaks which can be several times the DC current, 2. It must be able to soak up the negative current peaks, 3. The AC current stresses the output capacitors which have to carry the rms sum of the SMPS and the motor currents. In addition, it is also often forgotten, that a motor draws a start-up current which can be several times the steady state DC current; if the peak start-up current can not be delivered, the motor will not start but stall.

Another typical case are incandescent lamp loads which draw typically 15 times as much current during the start phase; if the SMPS cannot deliver that much, it will "hang itself up", i.e. the load lines of the SMPS and the lamp intersect at a stable operating point at a low voltage, the lamp will glow dimly and never light up.

Regulation Problems.

SMPS regulation loops are tested with so called electronic loads, those are resistive loads which are switched by a transistor, the frequency and the duty cycle can be selected. The scope will show the reaction of the loop. The problem is that there are loads which do not load the supply periodically but stochastically, that is more severe and can cause hiccups of the regulation loop by overdriving the amplifier, because output voltage excursions overlap. The effect is that suddenly much larger excursions in both directions occur.

Temperature effects on components.

In general, the permissible loads on components decrease with rising temperature. Life will be impaired with all. "Cold electronics live longer."

Many vital components change their properties more or less drastically over temperature, this is one reason why SMPS must be tested over the full range of internal ambient temperature. Examples: The ESR of electrolytics decreases with rising temperature and vice versa, this has several effects: the ripple decreases, a minimum amount of ESR is often necessary for the stability of regulation loops, i.e. a SMPS may be quiet as long as it is cold, but start to oscillate wildly when it warms up!

Ceramic Y capacitors are made of the worst material Z5U, when warming up, they will lose almost their whole capacitance with the effect that conducted emi norms are violated! This is one reason why SMPS manufacturers mostly specify 25 C as the measuring temperature for emi. Ferrites were already mentioned. Semiconductor losses mostly increase, one big advantage of modern SiC components is the fact that losses do not increase.

http://members.aon.at/aseibt

Semiconductor Advances for Lower-Cost EVs

The world is getting ready to drive electric. Established car brands are adding new plug-in hybrids and full EVs to their ranges, and even supercar manufacturers are taking advantage of electric drive. Governments are also backing the move: a recent EU draft agreement proposes new national minimum targets for publicly accessible EV charging points, as part of a package of measures to help low-emissions vehicles move freely on the EU's roads.

By Jack Marcinkowski, Sr. Manager - TMA, International Rectifier Corp.

Even with such favourable terms on offer, a plug-in hybrid or EV today is still more expensive than a comparable vehicle with a conventional petrol or diesel engine. Consumers need car makers to find other ways of reducing the price differential, if sales of EVs are to increase.

Barriers to Cost Reduction

Although the battery pack is typically the single most expensive part of an EV, battery prices are falling relatively slowly, if at all. Technological development is currently aimed at improving energy density and power delivery for greater range and better performance.

The second most expensive component is the traction inverter. Within the traction inverter, semiconductor power modules account for as much as 25% to 30% of the total cost of the unit, whereas the cooling system represents around 15% to 20%. Reducing the cost of these power modules could have an important impact on the overall price of the vehicle.

The extreme demands placed on an EV traction inverter expose limitations in thermal performance that present a barrier to significant cost reduction. The key challenge lies in extracting heat from the dies of the power semiconductor switches, which are usually IGBTs and Diodes or MOSFETs, to prevent overheating leading to device failure.

Conventionally, the die is attached to a DBC (Direct Bonded Copper) substrate, using either solder or sintered metal as the die-attach medium. The top-side of the device is used only for electrical connections, which are implemented with wirebonds. The bottom side is used for electrical connection and heat transfer. The DBC substrate is attached to a thermal baseplate and a heatsink. The baseplate may also incorporate Direct Liquid Cooling (DLC).

The heat transfer achievable through the bottom side of the die only is inadequate to allow full utilisation of the device's switching capabilities. This forces designers to connect multiple devices in parallel to carry the maximum inverter current, which prevents significant cost savings. Moreover, since die size is closely related to device cost, the reduction in heat transfer associated with any reduction in die area of the latest generations of devices still prevents designers from full utilization of the devices.

Figure 1 shows how various combinations of DBC, baseplate and DLC, with single-sided die cooling, yield only limited reduction in thermal resistance from junction to coolant (Rth j-coolant). The addition of a baseplate and DLC, and choice of soldered or sintered die attach, deliver only incremental improvements that will not enable the cost of the module to be reduced significantly and instead may lead to cost increase.

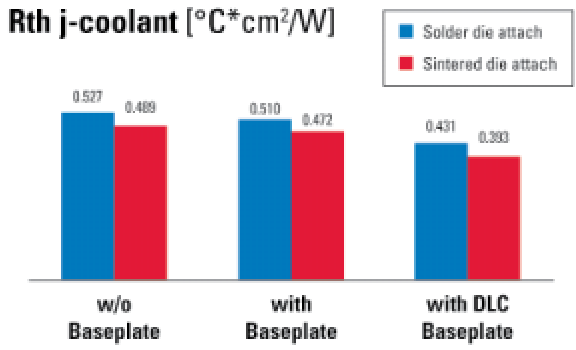

Figure 1: Established cooling techniques yield only incremental improvements in thermal resistance

Two-Sided Die Cooling

A real breakthrough can be achieved by using both sides of the semiconductor device to remove the heat. This is possible only by eliminating the traditional wire bonds. International Rectifier has developed an innovative packaging concept that reduces the thermal resistance by as much as 50%, and also improves reliability by an order of magnitude by eliminating the wirebonds.

The basic building block of this package is IR's COOLiR^{2}Die™ surface-mounted power switch, which comprises an IGBT die and a matching diode die mounted on a ceramic substrate. The resulting device has a voltage rating of 680V and current rating of 300A in a compact, 29mm x 13mm x 1mm assembly.

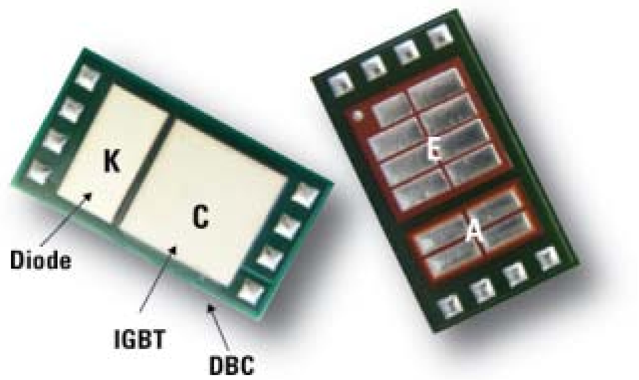

Figure 2: COOLiR^{2}Die™ – a "very large die discrete SMT component"

Two types of COOLiR²Die™ have been developed. As figure 2 shows, one has the emitter (E) side of the IGBT and the Anode (A) side of the diode attached to the substrate, while the other has the collector (C) side of the IGBT and the cathode (K) side of the diode attached to the substrate. Having both of these packages available simplifies inter-switch connections when building Half-bridges, H-bridges or custom power circuits. Typically, the COOLiR²Die building blocks are attached to a ceramic substrate to achieve best heat-transfer characteristics through the top and the bottom of the assembly.

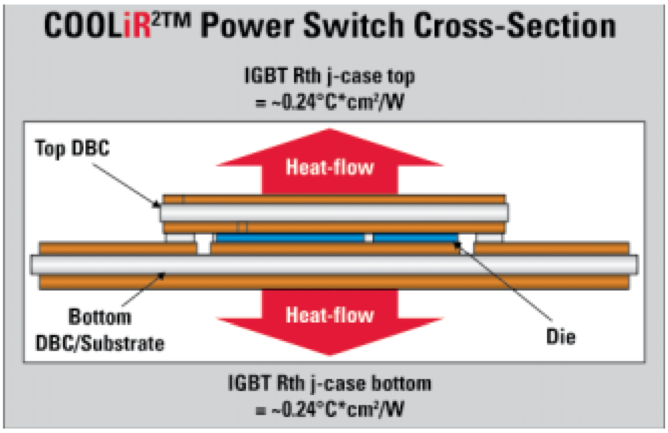

Figure 3: Dual-side cooled power switch cross-section and heat-flow paths

Depending on the type and thickness of the substrate, junction to case thermal resistances of approx. 0.24°C·cm²/W are easily achievable for both the bottom and the top side of the package. Further improvement is possible by using thinner substrates or substrates with higher thermal conductivity. The main improvement however comes from using both sides simultaneously to cool the semiconductor die.

Breakthrough in Amps/mm2

With the COOLiR²Die technology, the heat transfer takes place through the bottom and top sides of the semiconductor switch, as shown in figure 3. Theoretically, the thermal transfer capability can be doubled and the thermal resistance between the device and the coolant can be reduced by 50%. It is worth mentioning that this improvement can be achieved with existing thermal transfer and cooling materials and techniques. No other improvements are needed.

Even if cost-related factors or other practical constraints prevent designers maximising the performance of the top-side heat transfer path, a substantial improvement in heat transfer can still be achieved.

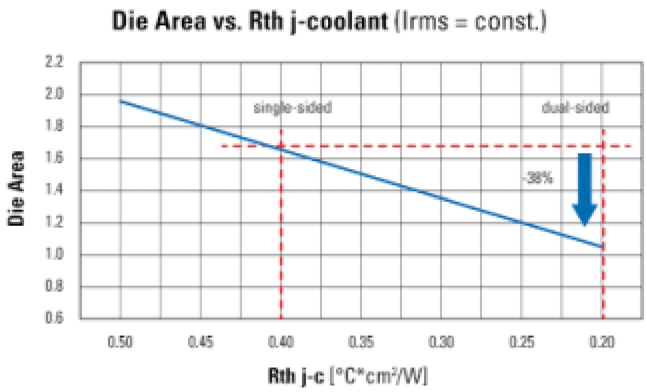

Figure 4: Die Area reduction potential due to reduced Rth junction-coolant (assuming constant Irms current)

For example if the top-side cooling path is only 50% as effective as the bottom-side path [Rth j-coolant (top) = 2x Rth j-coolant (bottom)], the total Rth j-coolant is 33% lower than with bottom-side cooling only.

Lowering the overall thermal resistance from junction to coolant allows for better utilisation of the semiconductor die area. This reduces the total die area needed to achieve a given current rating, resulting in lower bill-of-materials costs. Figure 4 illustrates that a saving of up to 38% die area is possible, if the top-side cooling can be made as effective as the bottom-side cooling.

Alternatively, the same die area can support a higher current rating, allowing designers to build higher-power modules without increasing cost. Higher PWM switching frequencies can also be used. Figure 5 shows that the module current (Irms) can be increased by up to 61%.

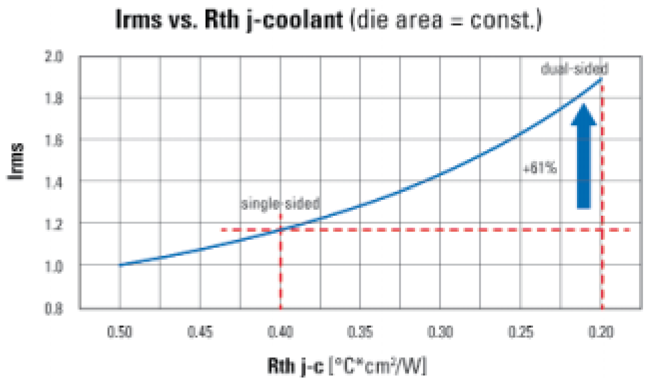

Figure 5: Potential increase of switch current rating with reduced Rth junction-coolant (assuming constant die area)

At the same time, the reliability and lifetime of the power module are increased since better heat transfer reduces the magnitude of temperature swings thereby reducing stress on the semiconductors and the packaging structure. The power-cycling ability of the dual-side cooled module is also increased.

Conclusion

Improved heat transfer with dual-sided cooling of IGBT switches delivers a breakthrough in cooling efficiency, in contrast to the incremental improvements currently achieved by refining single-sided implementations. This enables a significant increase in the current density of EV traction inverters, enabling smaller devices to be used for the same current rating, or boosting current-handling capability for a given die size and cost.

The bottom line is more Amperes per Dollar, enabling electric vehicles to move closer to price parity with conventional petrol or diesel cars.

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Going Mini

Another step towards small power applications

Vincotech goes mini with the next smaller housing size, taking another step towards small power applications where discrete components have figured so prominently in the past. Various topologies featuring diodes, IGBTs and MOSFETs may be implemented with the new housing to help miniaturize devices, minimize stray inductance and maximize efficiency.

By Patrick Baginski, Vincotech

Today's frequency inverters for pumps and fans, power supplies and other power applications are often equipped with discrete components, especially frequency inverters between 300 W and 1500 W and power supplies ranging up to 6000 W. One drawback of discrete components is that it takes a handful to build a complete application; another is assembly time. When operating at different potentials, these components have to be isolated to the heatsink. Legacy power modules are simply too large and inadequate for the purpose. They take up too much space, are a poor match for the requisite topologies and far more expensive than conventional solutions. Vincotech's new compact *flow* 0B housing prevails over these drawbacks.

Figure 1: The flow0B

Only one screw is needed to mount this small, innovative new housing to the heatsink. The mounting bridge works like a clamp, exerting plenty of pressure to wed the housing to the DCB and heatsink. This compact version offers all the features of its larger siblings, including free pin positioning, a stress-relieved zone for pins and a pre-bent DCB. Press-fit pins and pre-applied phase-change material are optionally available for *flow* 0B power modules. What's more, all modules are equipped with an NTC to measure the heatsink temperature below the power module.

Current ratings stated in Vincotech's datasheets, which have been determined during the characterization of the modules, reference a heat sink temperature of 80 °C. This is usually more in line with practical application environments. However, DIP molded as well as some TO-2xx modules often relate to a heat sink temperature of 25 °C.

AC to DC to AC conversion: PIM + PFC configuration

Single-phase, low-power applications generally have to meet the specifications for energy-using products set out in the EU Ecodesign Directive. Often these applications use an active PFC circuit to increase efficiency and reduce harmonic distortion. This is why the first topology to feature in the *flow* 0B housing is a PIM + PFC configuration. A single-phase rectifier, PFC switch and PFC diode as well as a three-phase inverter with 650 V semiconductors are integrated. This is an open emitter configuration enabling independent current measurement in each leg.

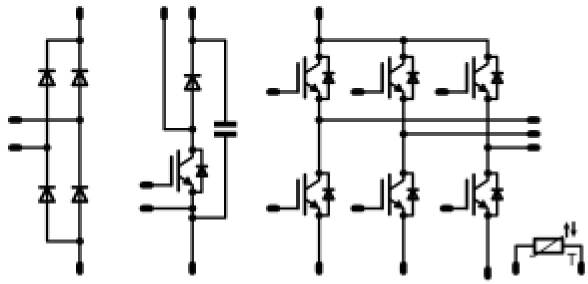

Figure 2: Components in the flowCIP 0B

The *flow* 0B module with the highest current rating features a PFC circuit based on a nominal chip current of 15 A and an inverter section equipped with 10 A components. This PFC circuit consists of very fast IGBT and diode components. Switching frequencies up to 100 kHz are achievable. The inverter section's fast reverse-conducting components are usually driven at 16 kHz to 30 kHz.

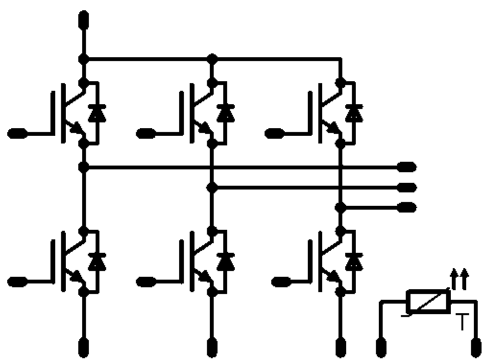

Figure 3: Components in the flowPACK 0B

Smaller versions with 6 A and 4 A inverter chip currents are also available to cover a wide power range.

This module is also well-suited for use in common frequency inverters as well as for servo drives. In many cases, a brake chopper will not be necessary for low power levels so this topology is also available on demand without brake chopper/PFC components.

AC conversion: Three-phase inverter configuration

The second topology slated for launch targets frequency inverters, and servo drive applications especially. This standard inverter topology with six IGBTs and freewheeling diodes will be available in 1200 V and 600 V versions.

This module also comes in an open emitter configuration to enable easy shunt current measurement. The 600 V version covers currents ranging from 6 A to 30 A, and the 1200 V variant currents ranging from 4 A to 15 A. The implemented IGBT technologies are designated for use at drive applications' usual switching frequencies, which range from 4 kHz to 20 kHz depending on the voltage rating.

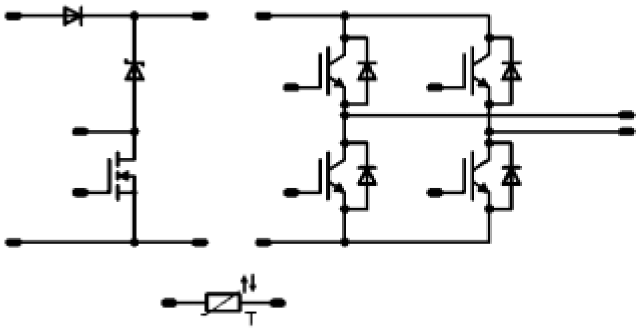

Figure 4: Components in the IGBT version of the flow0B Boost + H-Bridge

Boost + H-Bridge:

The *flow* 0B's application range is not limited to motor drives. With its new and very fast 650 V components, it is an interesting proposition for small, single-phase PV applications as well as for all kinds of power supplies. Both applications need a circuit to boost incoming voltage levels and a circuit to convert DC voltage into AC voltage.

To this end, Vincotech developed a semiconductor-based solution for switching frequencies between 40 kHz and 100 kHz. Lower switching frequencies are also possible.

The *flow* 0B provides room for a boost/PFC and for an H-bridge as shown in Figure 4.

Topologies with new IGBT H5/F5 components were engineered with price/performance considerations in mind, while topologies with MOSFET and SiC diode components are designed to satisfy the highest performance demands.

This topology also features 100 % reactive power capability. R&D is underway to address the power range up to 5 kW using high-speed 50 A semiconductors, and studies have reached an advanced stage.

Conclusion:

The new *flow* 0B is the little brother to the *flow* 0B, a popular housing that has proven its merits many times over in the real world.

The *flow* 0B meets application requirements in embedded drives, the usual frequency inverters, solar applications and switching mode power supplies.

The new housing's benefits are many: It allows various topologies to be implemented and devices to be miniaturized; all while driving stray inductance down and efficiency up. All the practical features of the line, including free pin positioning, a stress-relieved zone for pins and a pre-bent DCB, have been implemented here.

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Practical, Efficient and Safe Power Device Thermal Characterisation

By Hisao Kakitani, Koji Tokuno and Ryo Takeda; Keysight Technologies Japan

Power devices are used in a wide range of applications such as; train, automotive, traction, power generation etc. that are operated in harsh and extreme environmental conditions. Robust design for reliability and safety are paramount in these applications.

A key initial design requirement is the estimation of system maximum operating temperature by taking into account both maximum heat generation and cooling capacity. Once this is known an appropriate power device can be selected that will safely operate under all expected operating temperatures and conditions. To select such a device requires a thorough understanding of power device characteristics over the extremes of expected temperature. For example automotive Si power devices operating with a dedicated cooling system at 65°C are separated from the engine cooling system at 110°C. This requirement for two separate cooling systems originates from the maximum junction operating temperature limit for Silicon. Emerging SiC devices are capable of operating at over 200°C and have the ability to share the engine cooling system. This results in significant savings in both weight and cost. Accordingly, understanding SiC device characteristics at higher temperatures is important while reliable device operation under extreme cold, e.g. -50°C also has to be guaranteed.

Power devices have to operate reliably under wide temperature ranges. 150°C has been the maximum operating temperature for many years. However, it is on the rise (e.g. 175°C) and is projected to go even higher (e.g. 250°C) for SiC and GaN wide band gap devices.

Issues with measurement equipment cable extension

Power device evaluation, at both low and high temperatures, requires not only test equipment but also a thermostatic chamber. Although it is widely used a thermostatic chamber takes a significant time for the temperature to stabilize. It also necessitates the use of long connection cables between test equipment and the chamber which adversely affect measurement s.

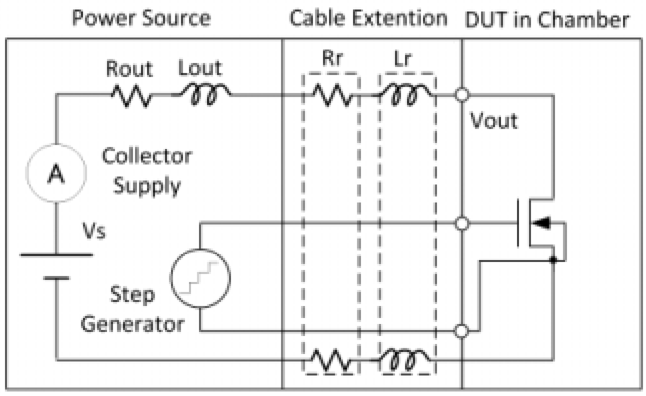

Figure 1: Cable extension from power source to thermostatic chamber

$$Iout = \frac{Vs - Vout}{Rout + Rr} \tag{1}$$

For test equipment that sources ultra-high currents long extension cables result in a reduction of maximum current due to voltage drop from cable residual resistance. Output current (Iout) is expressed by the following equation:

Defining output voltage of test equipment as Vs, resistance of test equipment as Rout, residual resistance of cable as Rr and DUT voltage as Vout.

Referencing Keysight Technologies B1505A or B1506A as an example of ultra-high current test equipment. Figure 2 shows the IV range of the B1505A. Rout on the 1500A range is 40 mΩ. Adding an extension cable with a typical residual resistance of 40 mΩ reduces the maximum current by half.

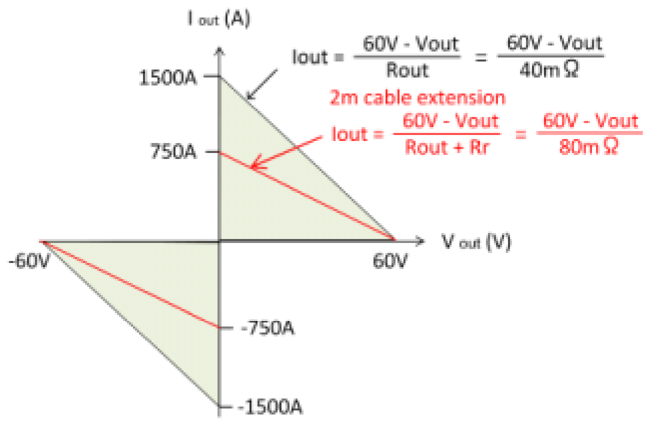

Figure 2: Limitation of output current by extension cable residual resistance

Another extension cable drawback is the limitation of fast pulses. At ultra-high currents fast pulsing is necessary to avoid device self-heating. However, longer cables result in larger pulse widths due to the residual inductance (Lr) of the extension cable. This increases the potential for device self-heating.

Time constant (τ) is expressed in equation (2) when the output inductance of test equipment is Lout.

$$\tau = \frac{Lout + Lr}{Rout + Rr + Rx} \tag{2}$$

A typical 2m extension cable has residual inductance of 4 µH. This is added to the sum of Lout and Lr, τ is calculated as 50 µs which results in 4.6τ or a 230 µs pulse width with 99% settling time. The long pulse width degrades measurements due to device self-heating. Figure 3 reveals on-resistance pulse width dependency on a Power MOS FET device.

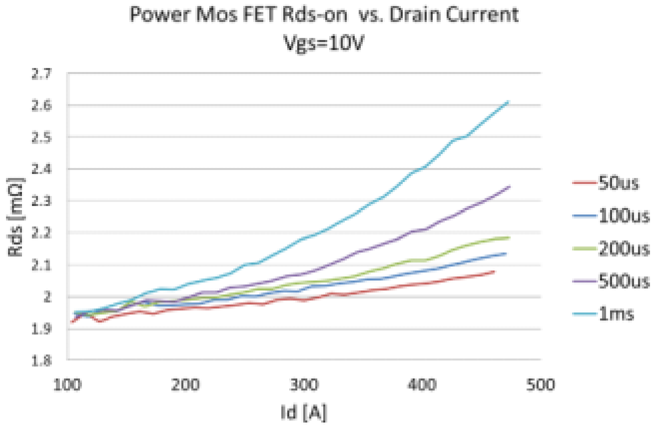

Figure 3: Pulse width dependency of Rds_on measurement

Another common and frustrating issue when using a thermostatic chamber in conjunction with an extension cable is oscillation. Residual inductance along the cable connection between gate and source is likely to initiate device oscillation.

Hot Plate in Test Fixture solution

One solution to the above problem of measuring temperature dependency with ultra-high current is to set up a temperature controlled environment alongside the test equipment. The simplest way is to place a temperature controlled hot plate in a test fixture that has integrated test resources. Figure 4 shows the Keysight B1506A test fixture which has an integrated thermal plate terminal. This configuration allows the measurement of device temperature dependency from ambient room temperature to +250°C. A safety interlock that is enabled by a closed top cover ensures a safe test environment. To efficiently transfer heat from the thermal plate to the device requires the use of a contact sheet or thermal grease. Although this method is quick and simple the temperature around the device is not necessarily uniform. Part of the hot plate is exposed to the air which results in temperature loss via heat radiation and convection. Additionally, heat transfer through device test leads is another source of temperature non-uniformity.

Thermostream*

The use of a Thermostream* enables significantly faster heat transfer than a thermostatic chamber and is popular equipment among semiconductor device manufactures. A hot or cold air stream is delivered to the test environment with precise control. The desired air temperature is obtained by heating dry air which is first cooled to around -100°C using a chiller. The temperature of the dry air is precisely controlled allowing a specified temperature test to be performed. This can be in an open environment as long as a device is placed in the air stream.

The above arrangement works for small size power devices. However, it does not work on large size power devices, such as IGBT modules. The temperature across the IGBT module is not uniform due to different air stream velocities. A more precise uniform temperature controlled test environment is possible by designing an enclosure that fully covers the device. Unlike a thermostatic chamber the shape and location of the enclosure is flexible due to the air stream as the thermal source.

A Thermostream* is ideal for the creation of a thermally controlled temperature environment which is located in the immediate vicinity of the test equipment. However, if there is no enclosure attached the test equipment may get damaged by hot air or condensation. A thermal enclosure attached to the test equipment and the Thermostream* resolves this issue and allows accurate, reliable and repeatable temperature dependency characterization.

* Thermostream* is a product of InTEST corporation. It is not supplied by Keysight Technologies.

Figure 4: Thermal plate in B1506A test fixture

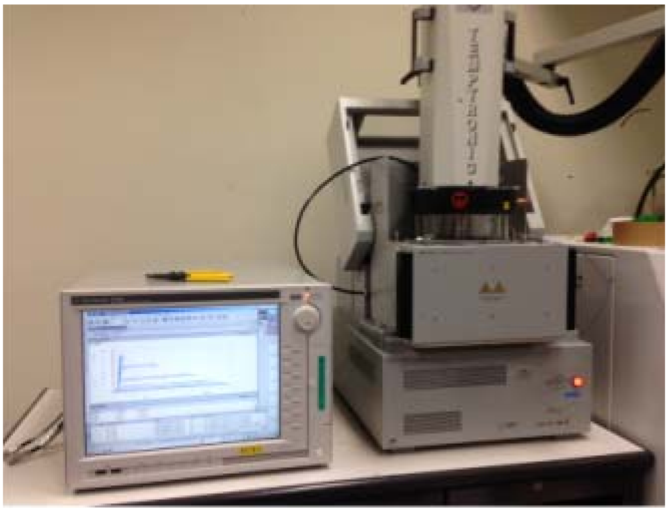

*Figure 5: B1506A Test Fixture Thermal Enclosure for Thermostream**

Thermal enclosure design

This section considers the evaluation of large size power devices, (e.g. IGBT modules) using a Thermostream*. Air forced from the Thermostream* circulates in the enclosure and is then exhausted. Graphical representation of heat transfer is shown in Figure 6. Examination of heat transfer from Thermostream* to the enclosure reveals three component mechanisms. Heat conduction in the enclosure material, enclosure heat convection to the outer air and heat radiation from the enclosure surface. The relationship between heat transfer quantity and temperature difference is expressed by the following thermal resistance equation.

Heat transfer quantity (W) = Temperature difference (°C) / Thermal resistance (°C / W).

As an example, if the air temperature of the Thermostream* is 150°C, the heat transfer quantity depends on the air volume and temperature and represented with the following equation:

Heat transfer quantity (W) = Air volume (m^3/s) * Specific gravity of air (kg/m^3) * Specific heat of air (J/kg °C) * Temperature change of the air (°C) … (3)

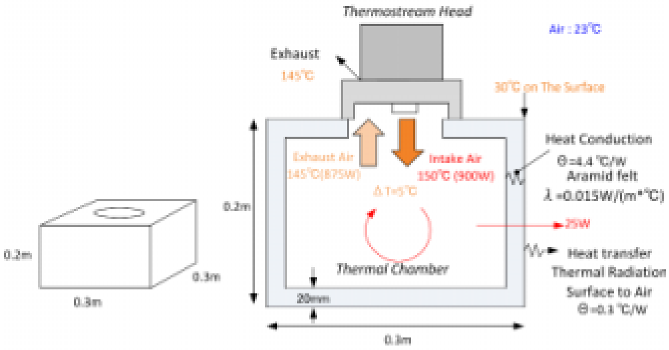

Figure 6: Thermal enclosure heat transfer block diagram

The following conditions apply: Ambient temperature 23°C, specific gravity of air at 150°C (0.83 kg/m^3), specific heat of air (1000 J/kg °C), air volume (0.0085 m^3/s or 18 scfm) which results in heat transfer of 900 W.
Heat from the Thermostream* passes to the outer air through heat conduction in the enclosure plus heat convection and radiation from the surface of the enclosure. This results in the temperature of the enclosure being lower than that of the air stream. Temperature may be better controlled by reducing the thermal loss inside and outside the enclosure thus allowing more accurate and repeatable temperature dependency measurements.
The choice of high temperature heat insulating material for the enclosure is limited. If Aramid Yam felt is used, the heat conductivity is 0.015 W/(m*°C). The thermal resistivity may be expressed as:

Thermal resistance (°C/W) = [1 / Thermal conductivity (W/m°C)] x [Thickness (m) / Area (m^2)] … (4)

For example; with an insulating material thickness of 20 mm and an enclosure size of 0.018 m^3, (0.3 m * 0.3 m * 0.2 m) the thermal resistance is calculated as 4.4°C/W.
The total heat transfer of the system is difficult to calculate as the thermal resistance of heat transfer and enclosure surface radiation is a nonlinear function of temperature. However, it may be solved by computer software. Calculation reveals that the total thermal loss in the enclosure is approximately 25 W. This implies that the average temperature in the enclosure is 145°C while the enclosure outer surface temperature is 30°C. Additionally, the outer surface thermal resistance due to heat convection and radiation is approximately 0.3°C/W. Enclosure temperature loss is significantly reduced if it is surrounded by thermal insulating material.
In this example the enclosure temperature decrease is 5°C whilst still able to accommodate a sizeable power device. However, in practice the thermal insulation effect will not be as efficient as in the above example due to air stream inlet and measurement cables holes in the enclosure.
What happens if the enclosure is not made of heat insulating material but only of heat conducting material, (e.g. aluminium)?

If only aluminium with heat conductivity of 138 W/(m°C) is used to fabricate the same size enclosure the calculated thermal resistance using equation (4) is negligibly small. In this particular case the total thermal resistance of the enclosure is the sum of thermal convection and radiation at the outer surface of the enclosure. The thermal loss and the average temperature in the enclosure is 340 W and 90°C resulting in a temperature decrease of 60°C due to the lack of heat insulating material.

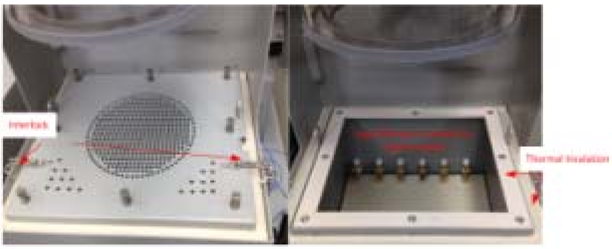

Figure 7: B1506A low thermal loss enclosure with safety interlock

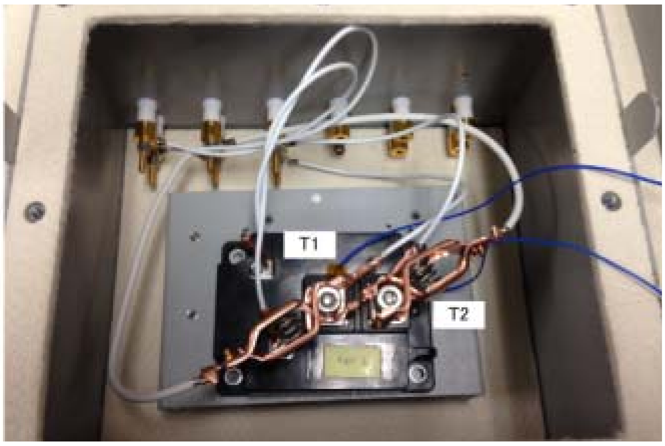

Figure 8: FUJI Electronics IGBT 1MBI800U4B-12 1- Pack module

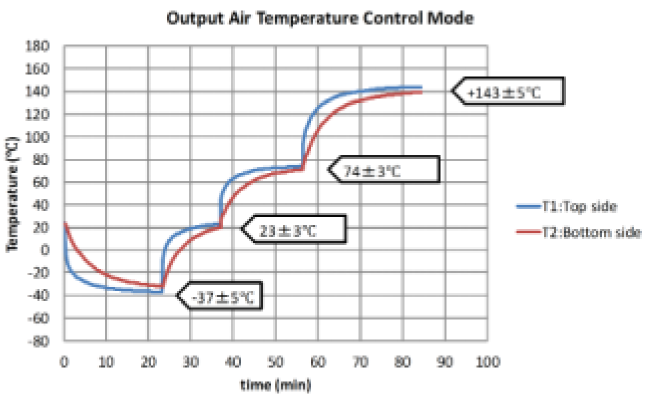

Figure 9: Thermal response of DUT

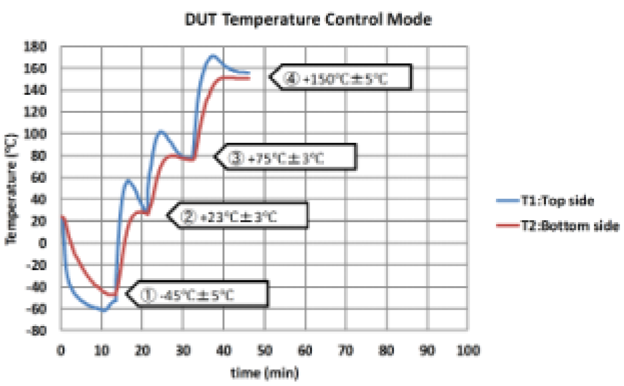

Figure 10: Thermal response of DUT with Thermostream thermal feedback enabled*

A Thermostream* fitted with a low thermal loss enclosure allows temperature evaluation of large power devices.

Figure 7 shows the thermal enclosure developed for Keysight B1506A. Measurement terminals installed at the back of the enclosure are 4 Φ banana terminals and are surrounded by PTFE. The safety interlock is only enabled when the top cover is fully closed thus creating a safe test environment.

Examination of the heat transfer quantity of the Thermostream* via equation (3) reveals dependency on temperature difference.

At an air flow volume of 0.0085 m^3/s (or 18 scrm) and an air stream temperature of 100°C, the heat transfer quantity is approximately 620 W. Increasing the air stream temperature to 200°C results in a heat transfer around 1100 W. Accordingly, a 200°C air stream gives an additional 500 W heat transfer over a 100°C air stream even when the target DUT temperature is 100°C. The time duration to change DUT temperature is proportional to its thermal capacity and given heat transfer quantity. Thus applying an additional quantity of heat transfer reduces the time for the DUT to reach target temperature. Accordingly, the total test time will be reduced by setting the air stream temperature higher than the target DUT temperature. Some Thermostream* models have a function to control DUT temperature quickly and efficiently by monitoring the DUT temperature with a thermocouple and automatically adjusting the air stream temperature.

Large device characterization under low temperature can also be performed using the enclosure. One advantage of a Thermostream* with enclosure is the ability to eliminate condensation. Temperature in a thermostatic chamber is controlled by continuous circulating air. If a temperature gap exists within the chamber condensation may occur as the circulating air is not necessarily dry air. In the case of a Thermostream* and enclosure the dry air stream is injected into the enclosure and then exhausted. The dew point is lower than the setting temperature thus condensation does not occur with the Thermostream* and enclosure combination even with a side wall temperature difference.

Low temperature device evaluation utilising a Thermostream* and enclosure combination is a simple way to avoid condensation.

Automated thermal testing

This section details experimental results derived from the Thermostream* and enclosure combination.

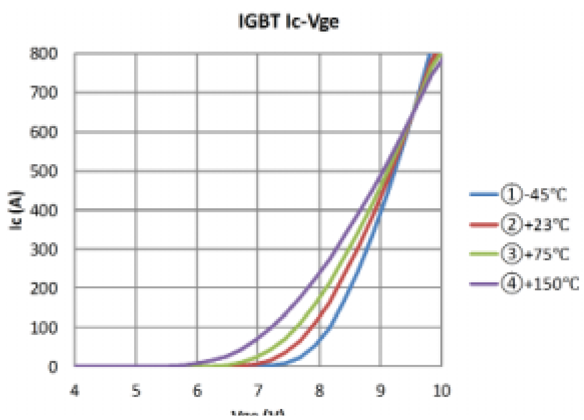

Figure 11: IGBT Ic-Vge characteristics at different Thermostream* tempertures

Two thermocouples are attached to the top and bottom sides of an IGBT module as shown in Figure 8. The IGBT module size is 110 mm x 80 mm. The thermocouples read T1 (top side) and T2 (bottom side) temperatures whose values are used to detect the DUT temperature and automatically trigger measurements. The Thermostream* is programmed to sequentially set the air stream temperature to: +23°C, -45°C, +23°C, +75°C and +150°C. The settling temperature is simultaneously monitored via the temperature difference between T1 and T2. When the temperature difference is less than 5°C the next temperature setting is enabled.

Figure 9 shows the thermal response taken by the two thermocouples attached to the DUT. The IGBT module temperature is well controlled to a small percentage of the programmed air stream temperature due to the trivial thermal loss of the enclosure.
Figure 10 shows the thermal response of the DUT when the Thermostream* adjusts air stream temperature by referencing the DUT thermocouple temperature. Although some temperature overshoot is observed the Thermostream* feedback mechanism reduces the temperature stability time by approximately 50% compared to the control time shown in Figure 9.

A Keysight B1506A can trigger measurement by utilizing the readings of the two thermocouples attached to the DUT. The B1506A automatically initiates measurements after waiting a predetermined soak time and the temperature difference between the two thermocouples is within a specified range.

Figure 11 shows the transfer characteristics of the IGBT module DUT taken simultaneously with the thermal response of Figure 10. The DUT characteristics are automatically measured at specified temperature points from -45°C to +150°C. The complete IGBT temperature characterisation is completed in less than fifty minutes.

The Keysight Technologies B1506A Power Device Analyser was specifically developed for Power Circuit designers. It was designed to automatically evaluate power device characteristics at temperatures from -50°C to +250°C. Testing is performed automatically and safely when the top cover is closed enabling the safety interlock on the insulated thermal enclosure. The length of connection cable between the measurement equipment and the DUT is minimized as the thermal enclosure is placed in the test fixture which also houses the current amplifier. This facilitates accurate ultra-high current temperature dependent measurements by maximizing source current and minimising device oscillation. Additionally, a positive temperature only thermal plate characterization option is also available for Keysight Technologies B1506A.

Emerging wide band gap devices allow significantly higher device operating temperatures with reduced cooling. Accordingly the circuit designer must fully understand the thermal characteristics of the power devices selected. The Keysight Technologies B1506A allows quick and easy thermal evaluation of power devices and is an essential tool for power electronics circuit designers and power device engineers respectively.

Keysight Technologies is created by the spin-off of Agilent Technologies' Electronic Measurement business.

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SiC: The Reliability Aspect and Practical Experience (Test)

By Jochen Hüskens, Product Marketing Manager, ROHM Semiconductor GmbH

Reliability of SiC SBDs
Obviously, breakdown issues in the outer periphery structure of SiC-SBD caused by high dV/dt were reported for conventional products but such breakdowns have not been observed in ROHM's SiC SBDs at dV/dt up to 50 kV/us. In life tests, the SiC SBDs were proofed with regard to the high temperature reverse bias, temperature humidity bias, temperature cycle, pressure cooker, high and low temperature storage. In stress tests, they were examined in terms of resistance to solder heat, solderability, thermal shock, terminal strength (pull as well as bending). Furthermore, Si-FRDs exhibit breakdown due to the very large reverse recovery current induced by high dI/dt. This is extremely unlikely with SiC-SBDs since they have much lower recovery current.

Reliability of SiC MOSFETs
Oxide is used as gate insulating layer. Its reliability directly affects SiC MOSFETs' reliability.

Development of high-quality oxide has been a challenging problem for the industry. ROHM solved this issue by a combination of appropriate oxide growth process and device structures. As the CCS-TDDB (Constant Current Stress Time Dependent Dielectric Breakdown) data show, its SiC MOSFETs have achieved quality equivalent to that of Si-MOSFETs and IGBTs.

Referring to Figure 1, QBD serves as quality indicator of the gate oxide layer. The value of 15 - 20C/cm2 is equivalent to that of Si-MOSFETs. Even with high quality gate insulating layer, there still remains crystal defects that may cause digital failures. ROHM uses unique screening technologies to identify and eliminate defective devices from the production chain. As the results of HTGB (High Temperature Gate Bias) tests conducted at +22V and 150°C, ROHM could confirm 1.000 operating ours without any failures and characteristic fluctuations in 1.000 devices and a lapse of 3.000 hours in 300 devices.

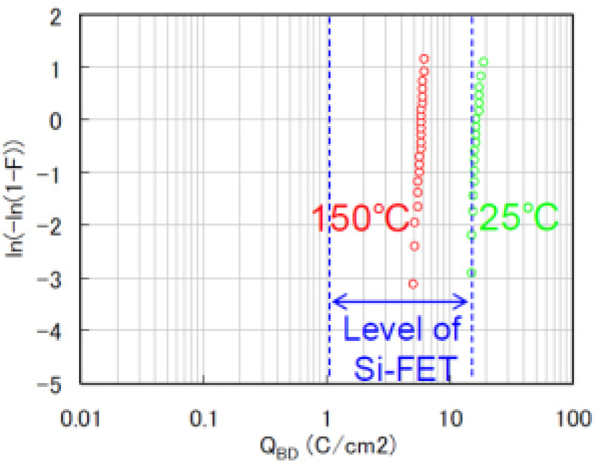

Figure 1: ROHM could confirm 1.000 operating ours without any failures

At the current technology level electron traps are formed at the interface between gate insulating layer and SiC body. Electrons can be trapped and in consequence, increase the threshold voltage if a continuous positive gate voltage is applied for an extended period of time. However, the shift in threshold voltage is very small, 0.2 – 0.3V, after 1.000 operating hours at 150°C and Vgs = + 22V. This shift is the smallest in the industry. Since most of the traps are all filled in the first several tens of hours, the threshold is fixed and remains stable after that.

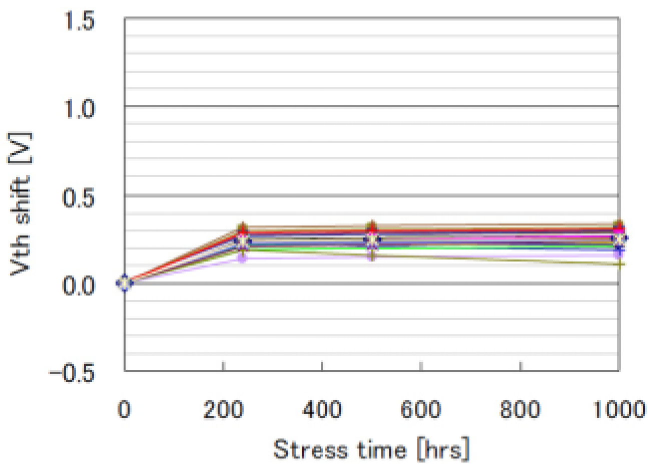

Figure 2: Shift in threshold voltage is very small, 0.2 – 0.3V, after 1.000 operating hours at 150°C and Vgs = + 22V

The threshold drops due to trapped holes when continuous negative voltage is applied to the gate for an extended period of time. This threshold shift is larger than that caused by positive gate voltage, e.g., the threshold drops by 0.5V or more when Vgs is set to -10V or more. With Rohm's second-generation MOSFETs (SCT2xxx series and SCH2xxx series), the shift does not exceed 0.3V, provided that the gate is not reverse biased beyond -6V. Negative gate voltage lower than -6V causes a significant drop in the threshold. In normal operation, gate voltage alternates between positive and negative biases and thus repeatedly charges and discharges the traps making unlikely to have significant changes in the threshold.

Reliability of body diodes
Another mechanism that affects SiC MOSFET's reliability is the degradation caused by its body diode's conduction. If forward current is continually applied to SiC P-N junction such as body diodes in MOSFETs, a plane defect called stacking fault will be extended due to the hole-electron recombination energy. Such faults block the current pathway, thus increasing on-resistance and Vf of the diode. Increasing the on-resistance by several times disrupts the thermal design. Furthermore stacking faults may degrade the blocking voltage. For this reason, using SiC MOSFETs whose body diodes degrade with conduction in circuit topologies that causes commutation to the body

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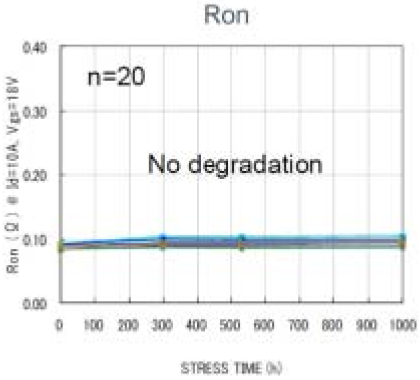
diode, e.g. bridge topologies in inverters, might result in serious problems. This reliability problem only occurs with bipolar devices, not with SiC-SBDs and the first-quadrant operation of SiC-MOSFETs.

ROHM has reduced crystal defects in SiC wafers and epitaxial layers and developed the proprietary process that prevents propagation of stacking faults, ensuring the reliability of body diode conduction. This is confirmed in 8A DC, 1.000-hour conduction tests which show no degradation in all characteristics, including on-resistance and leakage current. This ensures worry-free use of SiC-MOSFETs in circuits that cause commutation in the body diodes. Furthermore, reverse conduction reliability tests with Vgs = 18V and Id = 15 DC (also, 1.000 hours) shows no significant changes in electrical characteristics.



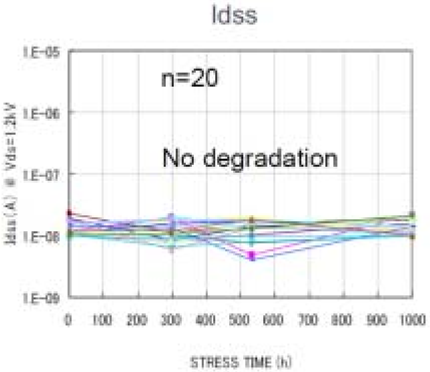


Figure 3: 8A DC, 1.000-hour conduction tests which show no degradation

Since SiC-MOSFETs have a smaller chip area and higher current density than Si devices, they tend to have lower short circuit withstand capability (thermal fracture mode) compared to the Si devices. 1,200V SiC-MOSFETs in TO247 package have short circuit withstand time (SCWT) of approximately 8 to 10 us when Vdd is set to 700V and Vgs is set to 18V. SCWT is longer with lower gate voltage, which reduces saturation current and lower power supply voltage, which generate less heat.

Many gate driver ICs incorporate functions that simplify detection and management of short circuit condition. For example, Rohm's BM6103FV-C can shutdown the switch in approximately 2 us once over current is detected. It has soft turn-off capability to gradually reduce the gate voltage during turnoff to prevent high surge voltage, which is induced by high dI/dt across the drain and source inductance. It is advised to pay careful attention not to apply over voltage by using such a soft turn on function or other preventative measures.

Si-MOSFETs involve a breakdown mode in which high dV/dt causes transient current to pass through the capacitance Cds and turn on the parasitic bipolar transistor, leading to device breakdown. This is less likely an issue with SiC-MOSFETs since the current gain of their parasitic bipolar transistors are low. So far such breakdown mode has never been observed with ROHM's SiC-MOSFETs operating with dV/dt at up to 50 kV/us. Since SiC-MOSFETs generate exceptionally low recovery current, reverse recovery current also will not cause high dV/dt. Consequently, SiC-MOSFETs are considered unlikely to cause this breakdown mode.

How to use SiC Power modules and their reliability

Since SiC modules support high switching speed and handles high currents, surge voltage (V= L x DI/Dt) is generated due to wire inductance L in the module or at its periphery and may exceed the rated voltage. Below is a list of recommendations to prevent or mitigate this problem. However, these measures may have an impact on the switching performance:

- Reduce wire inductance by using thick and short wirings in both main and snubber circuits.
- Place capacitors close to MOSFETs to reduce wire inductance.
- Add snubber circuit
- Increase gate resistance to reduce dI/dt

Referring to Figure 4, when the MOSFET M1 of the upper arm of a half bridge turns on, reverse recovery current flows through the freewheeling diode (external SiC-SBD or body diode) of the MOSFET M2 of the lower arm and raises the drain-source voltage of M2. Due to this dV/dt, transient gate current (I= Crss x dV/dt) through the reverse transfer capacitance Crss of M2 flows into the gate resistance, thus resulting in a rise in the gate voltage of M2. If this voltage rise exceeds the gate threshold voltage of M2, short-circuit current flows through both the upper and the lower arms.

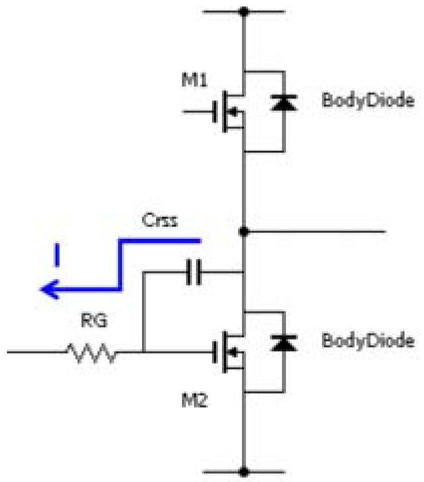


Figure 4: When the upper MOSFET M1 turns on, reverse recovery current flows through the freewheeling diode of the lower MOSFET M2 and raises the drain-source voltage of M2

While the threshold voltage of SiC-MOSFETs defined at several mill-amperes is as low as around 3V the gate voltage required to conduct high current is 8V or higher. As a result, withstand capability of bridge arm short circuit is not significantly different from that of IGBTs. However, to prevent this unexpected short circuit, it is recommended to take measures listed below which are also valid for Si power modules. The following measures may influence the switching performance, so adjustment of the circuit with monitoring waveforms to prevent self turn-off is advised:

- Increase negative gate bias voltage to turn OFF the MOSFET.
- Add a capacitor between the gate and the source.
- Add a transistor between the gate and the source that clamps Vgs to ground when the switch is off
- Increase the gate resistance to reduce the switching rate.

Like IGBT modules, the RBSOA (Reverse Bias Safe Operating Area) of SiC power modules covers the entire range of twice the rated current.

Summary - examples of applications and benefits of using SiC

Due to the above described characteristics, the deployment of SiC can be beneficial in many ways and in a broad number of applications: The usage in power factor correction (PFC) circuits (CCM – continuous conduction mode) leads to improvement of the conversion efficiency and noise reduction due to elimination of reverse recovery current and the downsizing of passive filter components under high frequency operation achieved by low Err. No significant improvement is ex-

pected for critical conduction mode PFCs as reverse recovery current from the diode does not influence the total conversion loss.
When used in solar inverters , reduction in Eoff, Err and conduction loss at low load condition can be achieved as well as the downsizing of the cooling system for power devices.
In DC/DC converters it can lead to the reduction in Eoff, Err and downsizing of a cooling system for power devices and the downsizing of transformers under high frequency operations.

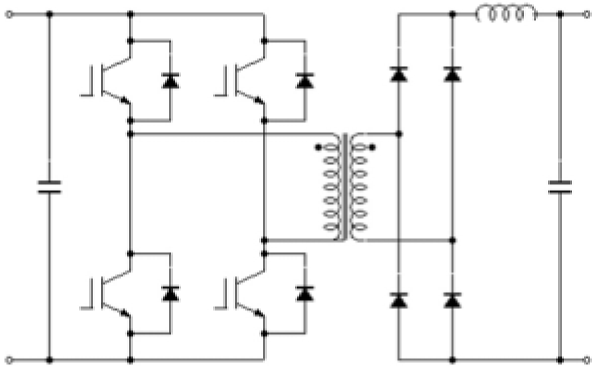


Figure 5: Using SIC in DC/DC converters leads to the reduction in Eoff, Err and downsizing of a cooling system for power devices and the downsizing of transformers under high frequency operations

DC/DC converters

In bi-directional converters the downsizing of passive filter components in high frequency operations as well as the reduction in Eoff, Err and size reduction of cooling systems for power devices are advantageous.

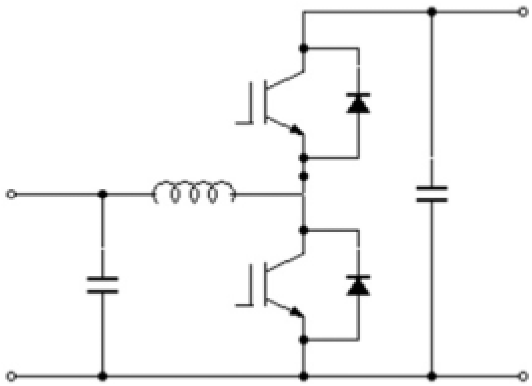


Figure 6: SIC in bi-directional converters allow downsizing of passive filter components in high frequency operations as well as the reduction in Eoff, Err and size reduction of cooling systems

Bi-directional converters

Usage in inverters for induction heating equipment benefit from the enlargement of operable conditions by increased frequency, reduced Eoff, Err and downsizing of the cooling system for the power devices. When deployed in motor drive inverters reduction in Eoff, Err and equally, downsizing of the cooling system for power devices can be observed. Buck converters operating in DCM (discontinuous conduction mode) and BCM (boundary conduction mode; also called critical conduction mode) do not benefit from SiC SBD's recovery performance but generally, buck converters avail of the reduction in Eoff and downsizing of a cooling system for power devices and the downsizing of passive filter components.

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Matching Circuit Topologies and Power Semiconductors for Energy Storage in Photovoltaic Systems

Due to recent changes of regulations and standards, energy storage is expected to become an increasingly interesting addition for photovoltaic installations, especially for systems below 30kW. A variety of circuit topologies can be used for the battery charger stage.

By Dr. Vladimir Scarpa, Pablo Cortes Lopez, Infineon Technologies AG

These will require a different amount of semiconductors, voltage classes of the power devices, and in some cases the use of a transformer. Among the decisive factors for the circuit topology are the battery's electrical parameters and the required isolation between the battery bank and the inverter.

This article describes possible circuit configurations and presents the best matching power semiconductor devices in both, discrete and module forms, in order to achieve highly efficient and compact systems. In addition, it also discusses the battery technologies expected to be implemented in such storage systems, presenting their main advantages and drawbacks.

Introduction

Several countries in the world have adopted photovoltaic energy in their electrical generation matrix recently. This fact has been boosted majorly by the price decrease of the main components of a photovoltaic (PV) system, namely the photovoltaic modules and the PV inverter, combined with governmental programs. Good examples in Europe are Germany and Italy, where the implementation of new photovoltaic plants has been subsidized. Financing was done with the main intention of boosting non-polluting, renewable energy. A growing number of decentralized energy sources were an additional consequence.

Figure 1 illustrates the current situation in Germany with about 30GW of photovoltaic power installed. The figure presents the contribution of each energy source to the total grid power in a day of high solar irradiation and moderate temperatures. This represents the optimal conditions for photovoltaic cells. It can be observed how the installed PV plants cause an energy generation peak around midday. In order to avoid disturbances within the grid, the energy demand has to follow the same profile. Alternatively, the remaining energy sources have to reduce their production accordingly, returning to their normal values in the evening, when the PV production usually is decreased.

With the increase of PV systems and the majority of them connected to the mains, a natural consequence is the influence of solar irradiation on the amount of energy injected to the grid. This requires additional considerations within the grid management to avoid fluctuation of electrical parameters such as frequency and voltage. Those variations can be considered to occur over a year, from season to season, between day and night and even during the same day in case of cloudy weather.

Energy Storage Implementation

A typical photovoltaic system is composed of photovoltaic modules connected in series and/or parallel and a DC/AC inverter to properly convert the DC voltage to an AC grid level. In order to store the energy coming from the PV modules, a charge controller stage must be added to the system. This stage is responsible for the correct charging of the battery bank, as well as for recovering the stored energy back into the DC link.

Non-Isolated Charge Controllers

A simple way to implement an energy storage system for photovoltaic plants is depicted in Figure 2. The single-phase photovoltaic inverter is composed of a booster stage followed by a full-bridge inverter. Tied to the DC link, there is a charger stage, composed of two switches, two diodes and a filter inductor connected to the battery bank.

The voltage level of the DC link is kept constant by the booster stage and is expected to be higher than the voltage of the battery

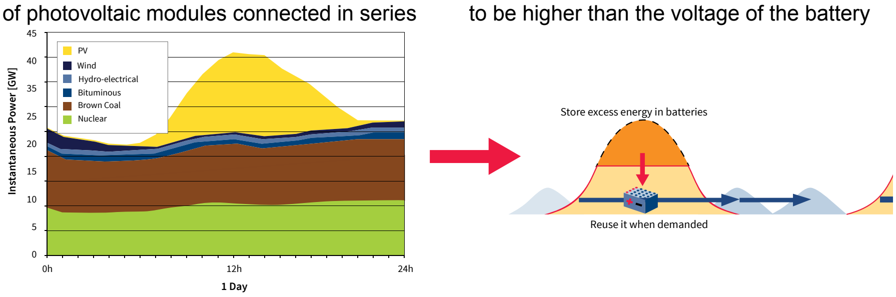

Figure 1: Contribution of PV power in Germany on a typical sunny day [1]. Peak generation storage and reuse [2].

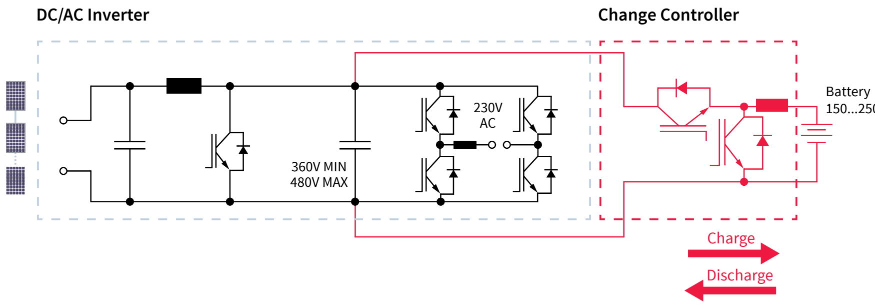

Figure 2: Non-isolated energy storage for photovoltaic systems.

bank. Common DC link values for single-phase systems are between 360V and 480V, while the voltage of the battery bank composed of several series-connected batteries is typically between 150V to 250V. Therefore, the controller stage will work as a step-down converter when charging the battery bank and as a step-up converter when transferring the energy from the batteries back into the DC link.

As main advantages of the configuration in Figure 2, a low amount of semiconductors is required and a high efficiency is achieved in both, charging and discharging paths. Figure 3 presents calculated efficiency values as a function of the charging current using a 50A 650V IGBT device from the TRENCHSTOP™ 5 family [3]. A DC link voltage of 400V and a battery voltage of 150V have been assumed. As it can be seen, efficiency levels close to 98% during the battery charge at switching frequency of 20kHz are possible. At 40kHz, an efficiency of almost 97% is achievable. For the complete charge and discharge cycle, the resulting efficiency is obtained by multiplying charge- and discharge efficiency. This results in a total efficiency of 96% at 20kHz and 94% at 40kHz, not considering the batteries' resistive losses.

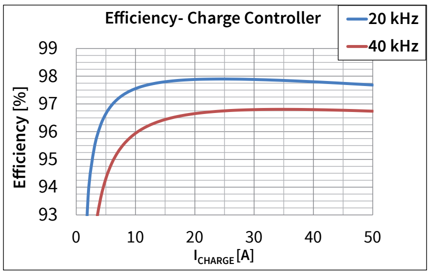

Figure 3: Efficiency results of a non-isolated charge controller based on IKW50N65H5 devices.

In case of three-phase systems, due to the fact that the DC link voltage can exceed 800V, power switches with blocking voltage of 1200V are required. The power module FF45R12W1J1_B11 [4] contains a half bridge based on CoolSiC™ JFET technology, which can be used in a step-up/down topology allowing for bidirectional energy transfer. Additionally, this module permits adding value to the power design by using the SiC JFET channel during the freewheeling period. This enhancement can be achieved thanks to the bidirectional conduction capability of the SiC JFET.

Based on measurements, Figure 4 illustrates the predicted efficiency for a simulated 5kW three-phase storage inverter. It can be observed, that the efficiency achieved using the power module FF45R12W1J1_B11 is slightly higher than the one achieved using CoolSiC JFET combined with a thinQ!™ SiC Schottky diode. Semiconductor losses are reduced by about 10%. In both cases, the efficiency for a 40kHz switching frequency and 650V DC link voltage exceeds 99% for almost all points of operation.

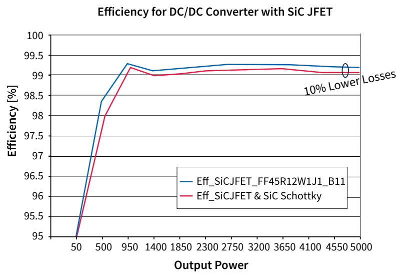

Figure 4: Efficiency results of a half-bridge topology with 1200V CoolSiC JFET power module.

Non-isolated topologies provide no galvanic isolation between the battery bank, the photovoltaic modules and the grid. For this reason, an extra circuitry is recommended in order to protect the battery bank from any overvoltage coming from the grid, for instance from lightning. This can be implemented for example by fuses connected to the positive and/or negative terminal of the battery bank, fast enough to disconnect it from the system. In addition, given the typical DC link voltage in both single- and three-phase systems, the non-isolated charge controllers require high-voltage batteries of 150V to 400V. The use of low voltage batteries would be technically feasible but the suboptimal modulation factor of the switches results in much lower system efficiency.

Isolated Charge Controllers

In order to overcome the drawbacks of the non-isolated charge controllers, a converter with a transformer providing an intrinsic galvanic isolation between the batteries and the other stages can be used. Moreover, by setting a suitable transformer ratio, it is possible to use low voltage batteries in the range of 12V to 96V.

Due to the high amount of semiconductors and the magnetic components, the isolated solution is expected to be more expensive and less efficient than the non-isolated charge controller. However, by using the latest IGBT technologies in association with soft-switching techniques, it is possible to reduce the semiconductor losses and thus obtain efficiency levels exceeding 95%.

The left part of Fig. 5 features the basic schematic of a zero voltage switching (ZVS) converter, where the two legs are driven using the phase-shift modulation technique. A similar converter is described in [5], including details of the modulation strategy.

The efficiency curve of a ZVS phase-shift converter is depicted on the right side of Figure 5. The use of additional output capacitors on

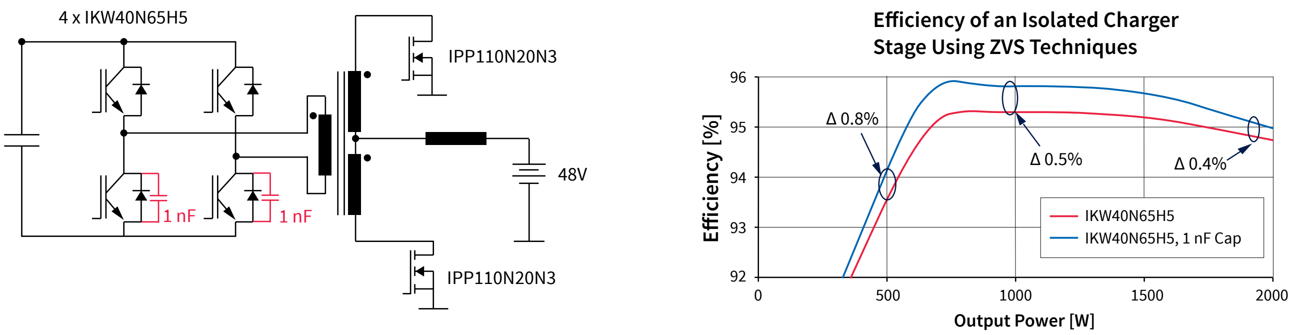

Figure 5: Schematic (left) and measured efficiency results (right) of a ZVS isolated charge controller, with and without the insertion of a 1 nF capacitor in parallel to the low-side IGBTs.

the low-side IGBTs enables up to 0.8% efficiency increase of the converter. The reason for this is the fact, that the capacitors enable a faster extraction of the minority carriers inside the device during turn-off. This will shorten the tail current time of the IGBT, thus reducing the turn-off losses. Using this ZVS topology, the energy stored in the capacitors is not dissipated but returns to the circuit before the turn-on of the switches [6].

	Lead-Acid	Li-Ion (LiFePO4)
Specific energy	30–40 Wh/kg	100–265 Wh/kg
Energy density	60–75 Wh/l	250–730 Wh/L
Specific power	180 W/kg	250-340 W/kg
Energy/price	7 Wh/U$	2.5 Wh/U$
Price per kWh	140 U$	400 U$
Self-discharge rate (per month)	3% – 20%	15% @ 40°C
Cycle stability (80% DoD)	200–400 cycles	400-1200 cycles
Nominal cell voltage	2.1 V	3.2 V

Table 1: Electrical characteristics of Lead-Acid and Li-Ion batteries. [7]

Battery Technologies

Various battery technologies have been used in electrical systems as storage components. They differ from each other in terms of chemical and electrical properties. Table 1 summarizes the main electrical properties of two battery technologies, namely lead-acid and lithium-ion (Li-Ion). Due to technical and economic reasons, these are the main technologies which are expected to be used as storage elements in PV systems.

From the parameters energy/price and charge stability, it is possible to observe a clear trade-off between cost and lifetime of the batteries. Li-Ion batteries are supposed to be three times more expensive than lead-acid batteries with a comparable capacity. On the other hand, Li-Ion batteries can achieve up to 20 years of operation, in contrast to only five years expected for the lead-acid types. An alternative to increase the lifetime of lead-acid batteries is to oversize the storage capacity of the system. This would avoid a deep discharge of the batteries, however it would increase the cost of the overall installation.

In energy storage systems already commercially available, the choice for battery technology has developed towards Li-Ion [6][8]. Main factor for this decision is the longer lifetime offered by these batteries. Short battery lifetime in solar systems would lead to several substitutions of the batteries during the operation lifetime, thus increasing the cost of ownership. Additionally, in some countries the minimum battery lifetime is a requirement to apply for governmental subsidies. This is currently the case in Germany, where a minimum manufacturer warranty of seven years is demanded [9].

In order to achieve attractive battery lifetimes, a full battery discharge ought to be avoided, regardless of the battery technology in use. Depth of Discharge (DoD), normally given by battery manufacturers, sets how deeply the battery shall be discharged in order to warrant a given number of charging cycles. DoD for lithium Li-Ion batteries is usually 70-80% whereas for lead-acid only 50% are recommended [10].

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Capacitors for Critical Applications Get Better by Design

Wherever electronic equipment is used – such as in the home, at work, in-car, or in defence equipment - users typically expect perfect reliability while the technology itself should ideally be invisible or transparent. Numerous aspects of today's components are evolving to realise this goal, from leading-edge nanometre semiconductor process nodes and chip-scale packages to improvements in devices such as capacitors.

By James C. Lewis, Technical Marketing Director, KEMET Electronics Corporation

The latest capacitor design features and screening methods ensure that devices in critical systems such as automotive electronics, street lighting, aircraft radar and missile-guidance systems can meet various different but equally challenging demands that may be imposed at any point during their lifetime.

Capacitors in Constant Use

Power supplies for systems such as street lights or automotive controllers are subjected to prolonged operation but must remain serviceable for periods of 10 years or sometimes more. Some street lighting applications, for example, are required to remain in service for 20 years or more. The operational lifetime of electrolytic capacitors (L_{OP}) can be a major factor limiting the effective life of the application.
The End of Life (EOL) of a capacitor can be defined in terms of parametric changes such as reduced capacitance, increased dissipation factor (tan δ), increased Equivalent Series Resistance (ESR), or excessive leakage current (I_L) compared to the initial value (I_{RL}). I_{RL} can vary greatly between manufacturers. As far as the EOL criteria for ESR are concerned, some manufacturers may specify a value of ESR, while others may specify a percentage change.

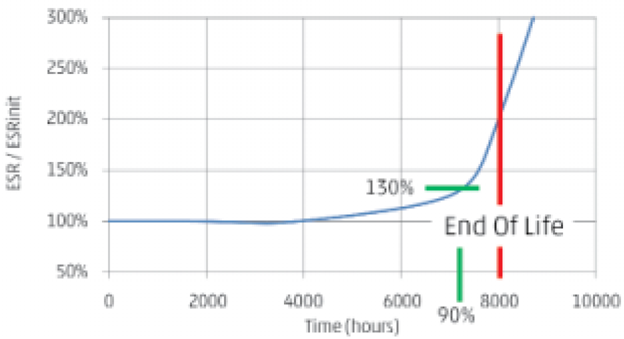


Figure 1: Aluminium Electrolytic capacitors are designed for longer operational life

Electrolytic capacitors often have an almost linear increase of ESR over time in operation. They can also be designed to have more stable ESR. With a more stable ESR, it is acceptable the design can be based on 130% of the specified maximum initial ESR value. This approach is valid provided the required application lifetime is no more than 90% of the specified capacitor's L_{OP}. The dissipation factor, tan δ, normally has an ageing characteristic similar to that of ESR.
The capacitance value also displays an almost linear change over the capacitor lifetime. The capacitance is at its lowest value at end of life, and should be calculated to be adequate to meet the needs of the application at this point. The leakage current during the operating lifetime is normally significantly lower than the specified value.

Electrolytic Design for Longer L_{OP}

Aspects of electrolytic capacitor construction such as electrolyte chemistry and thermal stability, the amount of electrolyte, and the gasket and lid design, have major impact on the capacitor's operational life. The ESR and thermal performance are also crucial factor influencing L_{OP}.

Gamma-butyrolactone based electrolytes are usually preferred in capacitors designed for high temperature stability, such as the KEMET PEG124 series of axial electrolytic capacitors. These devices have very stable parameters over the operational life: figure 1 shows that ESR and tan δ are typically within ±30% of their initial values for the first 90% of L_{OP}, and tests have indicated decreasing values compared with initial values during the test period of 7000 hours.

For axial and single-ended type electrolytic capacitors, EOL typically occurs due to drying out of the internal windings. The design of the capacitor and lid can have a significant impact on solvent diffusion, and therefore can be designed to keep diffusion at a low level so as to prevent drying. Care is required, however, to permit adequate diffusion so as to relieve the pressure due to internally generated gases such as hydrogen. Excessively low diffusion can cause parametric drift, or even catastrophic device failure. Axial electrolytic capacitors typically have an aluminium lid, which is immune to delamination. The PEG124 series also has a specially designed gasket that minimises diffusion while preventing excessive internal pressure.

The capacitor ESR can significantly influence L_{OP}, particularly if high ripple current is present, since internal heat generation and temperature rise due to the ripple current is proportional to ESR. A temperature increase of 10-12°C will reduce L_{OP} by 50%. Consequently, low thermal resistance from capacitor winding to ambient air also has an important effect on L_{OP} by promoting thermal dissipation and so helping maintain a lower internal temperature. The capacitor's internal thermal resistance has a minor impact on the temperature increase. The main factor is the external thermal resistance, which is minimised by positioning the capacitor to ensure adequate convection cooling and connecting efficiently to a heatsink. KEMET's PEG225 and PEG226 axial leaded electrolytic capacitors are optimised for mounting with heatsink, and all capacitors are designed with uniquely low internal thermal resistance.

Applications Applying Sudden Loads

At the other end of the usage spectrum, some types of equipment are required to remain dormant in the field for an extended period until suddenly called into action. At this point, they must be relied upon to perform faultlessly. Some types of defence equipment, such as Submarine-Launched Ballistic Missiles (SLBMs), can be included in this category. Surface-mount tantalum capacitors have been used to replace tantalum through-hole capacitors to reduce the size of electronic circuit boards in an SLBM, as part of a recent weapons-upgrade project. The missile is designed to have a maximum lifetime of more than 20 years, but the circuitry must start up immediately and function perfectly any time the missile is fired during this period.

Tantalum capacitors are preferred in this application to prevent unacceptable reduction in capacitor performance due to loss of capacitance caused by ageing. However, post-assembly reliability of surface-mount tantalum capacitors is known to be lower than that of through-hole devices. Hence a suitable tantalum capacitor must be able to withstand the reflow soldering process without acquiring latent defects that will lead to failure on power-up at the time the missile is fired.

KEMET engineers provided a solution to these challenges by specifying tantalum SMD capacitors featuring F-Tech Flawless Technology and subjected to Simulated-Breakdown Screening (SBDS).

KEMET's F-Tech technology eliminates imperfections in the dielectric layer caused during device manufacture. Such imperfections are known to be the major cause of failures in solid tantalum capacitors.

Although capacitor-grade tantalum powder is chemically pure, an organic lubricant is added during the anode manufacturing process, which can become trapped and form tantalum carbide during subsequent sintering. This causes local thinning or partial pores, while cooling of the anode after sintering also precipitates crystalline tantalum oxide in localised areas that can permit cracks to form in the dielectric.

KEMET's F-Tech Flawless technology utilises organic lubricants that can be washed off the anodes at low temperatures. Carbon is tested in every production lot after de-lubrication, and the process is repeated if necessary until the carbon level is equivalent to that in the original powder. The anodes are also de-oxidised, and a special passivation process is applied to minimise surface oxidation after sintering. In addition, F-Tech features argon welding to ensure a strong and reliable bond between the tantalum lead wire and the sintered anode.

Non-Destructive Screening

Tantalum capacitors are traditionally screened for dielectric defects by testing DC Leakage (DCL) at rated voltage. Although a high DCL can indicate impurities in the dielectric, a low DCL is not a reliable indication of a pure dielectric. Testing at high voltages approaching the breakdown voltage (BDV) is known to be the most efficient way to detect hidden defects in the dielectric. A low BDV indicates flaws in the dielectric, while high BDV close to the formation voltage indicates excellent purity. However, BDV testing is destructive, and hence cannot be used to perform 100% screening. In addition, testing at higher than rated voltage can introduce failure sites that may result in latent failures in application.

KEMET developed Simulated Breakdown Screening (SBDS) to isolate tantalum capacitors with low BDV without causing damage to good devices. SBDS analyses the voltage vs. time charging curve for the capacitor in series with a resistor. Prior to screening, the average BDV is determined by sampling from every production lot. Generally BDV can be up to 2x the rated voltage. A voltage equal to 1.3-1.5 times the average BDV is applied to the capacitor/resistor network, and is disconnected either when the voltage drop across the capacitor reaches the average BDV or after approximately one minute of charging. The final screening voltage correlates with the actual device BDV. Hence the purity of the dielectric can be inferred without exposing the capacitor to damaging over-stresses. This allows SBDS to be applied to 100% of units in any given lot.

A Surge Step Stress Test (SSST) also supplements F-Tech and SBDS, to ensure that the cathode top coating is adequate to protect the dielectric from thermal and mechanical stresses that can induce power-on failures. In SSST, a sample of capacitors is subjected to one or several reflow cycles, and then several short pulses of increasing amplitude are applied until all the capacitors fail short-circuit. The failure rate vs. pulse voltage allows the failure rate at a given applied voltage to be predicted.

High Pulse Loads

Other applications that require high reliability, such as aircraft radar systems, can subject capacitors to high pulse loads that impose extreme stresses, albeit for a short duration.

A military airborne radar system containing a conformally coated array of 330µF/25V MnO_2 tantalum capacitors encountered component failures as the high-power radar pulse was applied to the capacitors. In addition to reduced system performance, the failures resulted in thermal events causing undesirable flash and smoke in the aircraft cockpit.

In the MnO_2 capacitors originally used in this application, the pulse was found to expose the deficiencies in the capacitors arising from imperfections in the dielectric, leading to device failure. The cathode system provides fuel for the thermal event.

To prevent further failures, these capacitors were replaced with alternative surface-mount devices featuring a multi-anode design and polymer cathode system. The new devices were used in combination with a robust testing protocol called Polymer Capacitor Reliability Assessment Test (PCRAT), as well as SBDS screening.

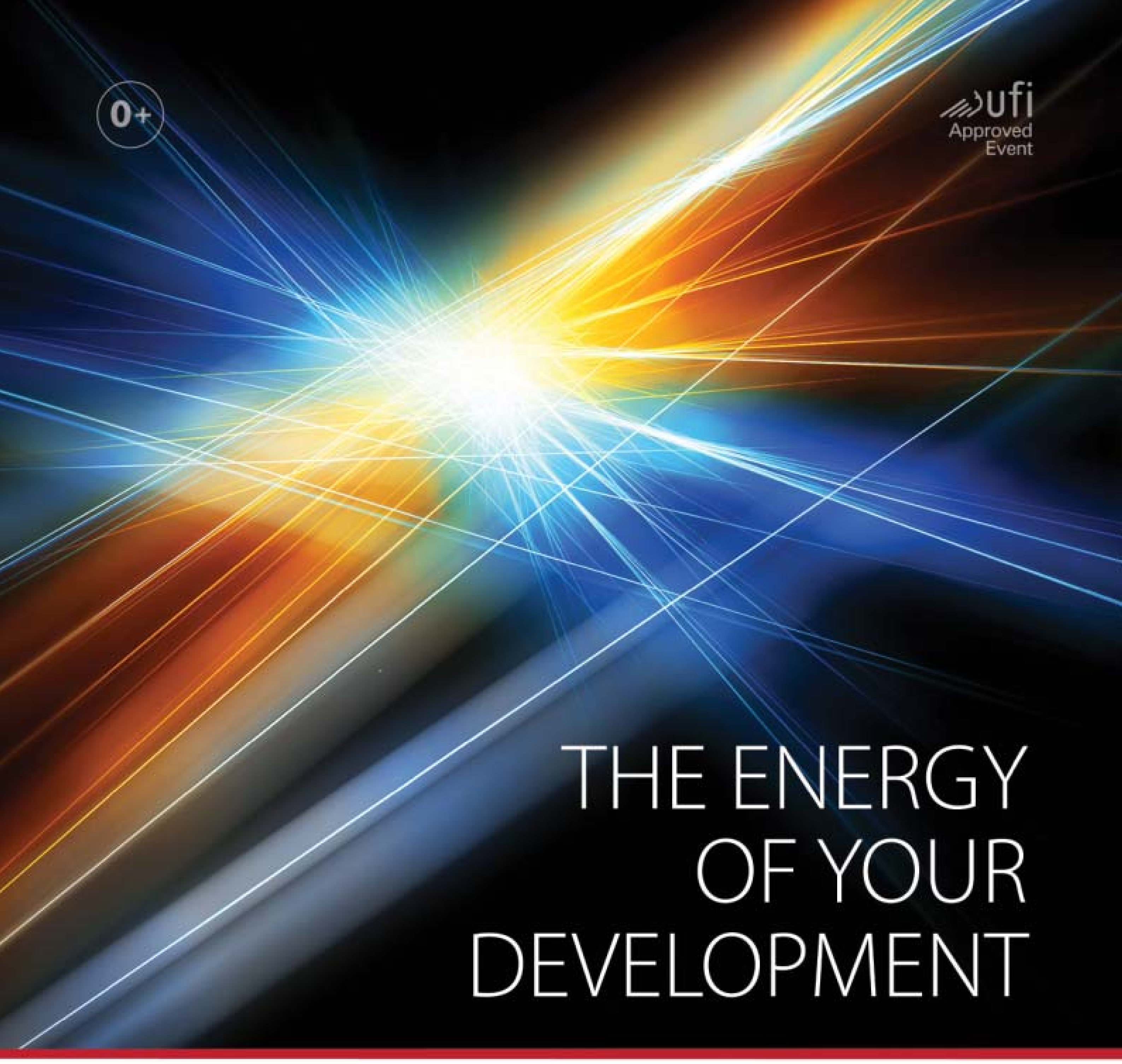
PCRAT is applicable to polymer capacitors only. A sample of devices is tested under highly accelerated voltage and temperature conditions to determine long-term device reliability. This enables an accurate failure rate to be assigned to the entire lot of material.

In the military radar application, changing to the alternative capacitors, with PCRAT and SBDS, significantly reduced the failure rate. Further advantages included improved system performance using only 3100 capacitors instead of 4200, as well as the benign failure mode of the organic, high-reliability COTS capacitors, which prevents ignition thereby avoiding occurrence of smoke in the cockpit.

Conclusion

Various types of electronic equipment that absolutely must perform reliably may need to withstand usage patterns such as continuous operation over an extended period, or long periods of inactivity followed by sudden use in an emergency or sudden high loading. These use modes can expose defects induced by ageing, or latent defects existing since manufacture. Fortunately, the design features and screening methods applied to electrolytic and tantalum capacitors typically used in critical or high-reliability applications are highly effective in preventing long-term deterioration or sudden unexpected failures.

www.kemet.com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A Protocol for the Intelligent Control of Power

A solution improves more than just the performance of IGBT modules

Many systems using IGBT modules today have no mechanism for exporting trustworthy data across the isolation barrier. Any measurements taken are prone to interference providing minimal useful data on the performance of the switch - typically the control signals are limited to on, off or fault. Amantys Power Insight™ allows the power electronics designer or the operator to gain new insights into the performance of the inverter system without a significant increase in overhead or change to the system design.

By Richard Ord, Amantys

Through the incorporation of a monitoring capability on an Amantys IGBT gate drive, a system integrated with Insight technology will provide data on the performance of the system and the logging of important system parameters such as fault codes and warnings. Today, the protocol reliably exports data on key system parameters. From such data, the Insight user can then build up information about system performance and from the knowledge gained, enhance the efficiency, reliability and performance of the overall inverter.

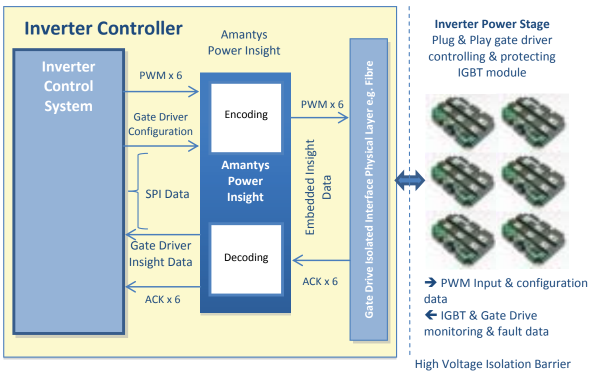


Figure 1: Amantys Power Insight exports critical data across the isolation barrier

This protocol can be used for transporting data to other parts of the power system including sensors and integrated power stages. In this way, Insight allows measurement of parameters, configuration and optimisation of the system during the development and commissioning phases of a project. It can also be used in deployed systems to track performance and diagnose abnormal behaviour.

The Challenge

As many systems using IGBT modules today have no mechanism for exporting trustworthy data across the isolation barrier, implementation of the Amantys Power Insight protocol gives the necessary communications channel for exporting dependable signals from the secondary high voltage side by encoding and transmitting across the fibre optic or electrical isolation barrier. The export of the first basic performance parameters (see Table 1) is the first step to developing a better understanding of the system and its mission profile, as well as providing a basis for learning more on how to adapt the system for specific applications.

Monitored Parameter	Identifier	Typical Resolution
Collector Emitter Voltage, IGBT OFF (DC Link voltage)	$V_{CE(OFF)}$	1V
Saturated Collector Emitter Voltage (IGBT ON)	$V_{CE(SAT)}$	100mV
Gate Drive Supply Voltage	V_{SUP}	10mV
Gate Emitter Voltage OFF (IGBT turn-off)	$V_{GE(OFF)}$	10mV
Gate Emitter Voltage ON (IGBT turn-on)	$V_{GE(ON)}$	10mV
Switch-on time. Input to V_{CE} going below $V_{CE(desat)}$ threshold at turn-on	$t_{sw(on)}$	25ns
Switch-off time. Input to V_{CE} going above $V_{CE(desat)}$ threshold at turn-off	$t_{sw(off)}$	25ns
Pulse Width	t_{pulse}	25ns
Gate Drive Ambient Temperature	T_G	0.5°C
IGBT Module Temperature Input (Where available)	T_M	0.5°C

Table 1: Monitored Parameter

How Insight Protocol Works

Insight is an integral feature of the Amantys Power Drive™ family of IGBT drivers, allowing the system to transport data in both directions across the physical interface between the system controller and the gate driver on the IGBT power module.

The system controller sends PWM pulses and configuration data to the gate drive, whilst the gate drive acknowledges the PWM pulses, it sends fault codes with counters and monitored parameters back to the system controller. Only two physical communication channels are used, one in each direction, which means the cost of adding this capability is reduced.

Amantys Power Insight enables:

- Gate driver parameters to be configured e.g. change of drive resistor value or potentially setting an alarm threshold value
- Specific parameter details to be requested e.g. how many type I short circuit events have occurred or the maximum value of $V_{CE(sat)}$ measured

- A continuous stream of data to be generated that contains measurements and event counts
- A platform capable of setting alarms and warnings- the gate drive can send messages to the system controller when a fault has occurred or when a parameter has moved outside a threshold value

This simple instrumentation of the gate driver and IGBT module parameters on the high voltage side of the isolation barrier allows Insight

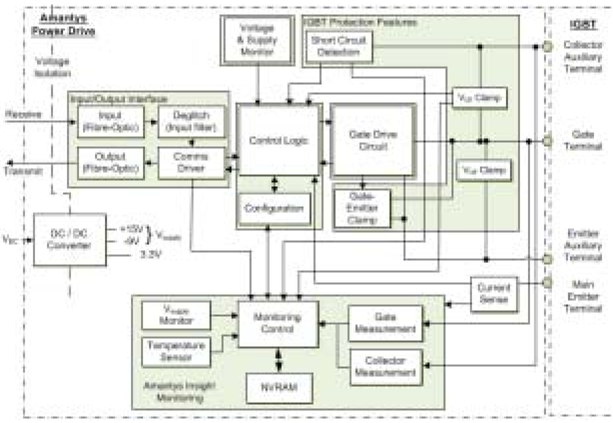


Figure 2: Insight-enabled Amantys Power Drive: internal block diagram

to access measurements and change configurations in a much safer and cost- effective way.

Of course, developers are cautious about the adoption of microprocessor-based systems controlling power switching, so it is worth noting that this protocol senses, communicates and configures switching characteristics, but the actual switching itself is controlled purely by hardware. If there's an error in the software or processor, the gate drive still behaves as a gate drive.

Gate driver architecture

Figure 2 shows the internal structure of a typical Amantys gate drive incorporating Insight. The standard gate driver features include an isolated DC/DC converter, IGBT gate drive and short-circuit protection circuitry, programmable and configurable system control logic, as well as isolated input and output for PWM signal (Receive) and ACK/STATUS signal (Transmit) respectively.

In addition, the monitoring and control block has the ability to: control the Insight functions, take measurement of the gate driver and IGBT parameters and log these parameters to non-volatile memory, as well as decode the configuration Insight data on the incoming PWM signal, encode the output Insight data on the outgoing ACK/STATUS signal, and to re-flash the programmable components on the board in the field over the Insight link.

An Amantys Power Drive enabled with Insight can monitor the gate drive temperature, the collector to emitter voltage (in both on and off states), the gate emitter voltage (in both on and off states) and the power supply voltage on the gate drive. In addition to this, the IGBT Driver can log data on the number of switching cycles performed, the type and number of short circuit events and the number of clamp events, which can then be used to build a picture of the historical operating environment of the IGBT.

During development, Insight provides valuable output in the way the switch is performing during its operation which helps to refine the profile before testing in earnest at full current, voltage and temperature. Often the switch will demonstrate strange or unexplained behaviour from the gate and this is only to be expected. Normally, analysis of the problem would be limited by the data available, and any fix would require the discharge, dismantling, and cooling of the equipment before making the necessary changes and the system would need to be brought back to temperature before the testing can recommence. However, this is where the benefits of Insight can be seen at operational testing. By obtaining valid data from inside the switch during operation the changes can often be made over the isolation barrier from outside the test set-up without the need for time-consuming disassembly and assembly, cooling and reheating, or energy discharge. This delivers real benefits when it comes to time and motion during commissioning. If there is a problem with an IGBT module on a cold plate, which is in turn buried deep inside a rack inside a complete power system assembly; the ability to observe the behaviour and modify the configuration from outside the assembly gives a major productivity boost during commissioning.

Future-Proof Technology

Product lifetime is an ever-recurring theme in the power industry.
A recent article from major traction suppliers noted that component obsolescence often leads to a complete redesign of the power system gate drive.
Last year EMEF and Amantys described how they collaborated to solve a similar problem, but in this instance, by replacing an entire

Figure 3: Insight-enabled Amantys Power Drive productivity in development, test and commissioning

GTO-based sub-system with a new power module, integrating 4500V IGBT Modules with Insight, and demonstrating how this system could diagnose real-time failures remotely over the web.
Since then, Amantys has collaborated further with Avago Technologies to develop a technique for enhancing the performance of plastic fibre optics. The developed system automatically senses received signal strength and moderates the transmit power to the optimum level, thus extending cable lifetime and flagging any connection issues- all through the Amantys Power Insight protocol.
By extending the scope of the Insight sub-system, our customers' systems are being given greater future-proofing, extending life and enhancing reliability for silicon-based IGBT module applications.

New Materials and the Intelligent Control of Power

Looking further ahead, the self-same Insight architecture is being adapted for the operation of newer, faster, wide band gap technologies such as silicon carbide and gallium nitride transistors, opening up new applications for high power systems.
Whatever the technology inside the switch, an embedded processor is at the heart of the system and provides intelligent control of power,

Figure 4: Test and configuration over Insight

determining at source what data to export and when, all as a function of the changing environment, load and condition of the equipment. This opens the door to condition monitoring, cloud-based data storage and fault diagnosis, bringing the Internet of Things to power electronic converters.
By providing a digital sensing and control interface at the system level, the host system maintains a continuity of architecture that outlives the underlying technology.

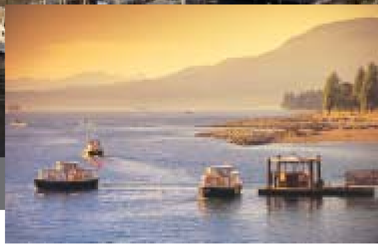
www.amantys.com

36th International Communications Energy Conference

The Vancouver Convention Centre East,
Vancouver, Canada

September 28 - October 2, 2014






Resilient Communications Energy for our Connected World.
This year's keynote address, "Time for Reflection: Telecommunications and Electric Power Resilience", will be given by Alex Tang, a consultant on earthquake engineering on lifelines, such as telecommunications and electric power. In addition, daily plenary sessions from industry leaders Victor Goncalves, P.Eng, FEC (Chief Technology Officer, Alpha Technologies Inc), Ewart Blackmore (Senior Research Scientist, TRIUMF) and Bruce Carsten (President, Bruce Carsten Associates) will provide their insights and industry perspectives on hot topics for the entire audience.

In addition, INTELEC 2014 promises to continue in its heritage of providing high quality oral and poster presentations on key issues confronting our industry. Coupled with the presentations are tutorials and workshops relevant to the group as well as commercial papers whereby attendees can gain training and insight to take home and implement at their own workplace.

SCOPE OF THE CONFERENCE

The scope of the conference will include but not limited to the following communications power and energy systems topics:

Communications Power Systems

- Outside plant power systems (twisted pair, customer premises etc.)
- Renewable energy generations (Wind, PV, Hybrid)
- Islanded and grid-connected autonomous power systems
- Power systems (High and/or low voltage DC; High and/or low voltage AC) for central offices/data centers
- Power distribution architectures for communications equipment
- Wireless power transfer for handheld communications devices

Energy Storage for Communications Systems

- Architectures for energy storage
- Battery technology (lead, zinc, lithium, sodium)
- Flow battery technology
- New fuel cell technology
- Energy management techniques
- Energy modeling and simulation

Power Conversion for Communications Equipment

- Circuit topologies and control techniques for AC/DC, DC/DC and DC/AC power converters
- Utility interface inverters for energy generation and storage
- AC and DC UPS
- High efficiency and high density power supplies

Site Support Systems

- Disaster recovery and mitigation
- Engine generator technology
- Physical and thermal design
- Grounding and EMC
- Codes, standards and specifications

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For more information, please visit
www.intelec2014.org

USB to Ethernet & UART Bridge Offers Unprecedented Integration and Ease of Use

Exar Corporation announced the introduction of its XR2280x family of USB to Ethernet Bridge ICs. These devices offer an unprecedented level of integration, combining a Hi-Speed USB 2.0 hub with controllers for 10/100 Ethernet, I2C, EDGE GPIO, and up to four UARTs in a single chip. This bridge solution, providing multiple communication standards from a single USB port, will allow many legacy product designs to be readily adapted for connection to the Internet of Things (IoT). The devices also serve the markets for industrial equipment, factory automation, networking, test and POS terminals, and many other embedded applications.

The XR22801 provides an upstream USB interface with an integrated USB 2.0 PHY and device controller that is compliant with USB 2.0 Hi-Speed (480Mbps) and Full-Speed (12Mbps) transfer rates. Downstream there is an Ethernet controller with integrated 10/100 Ethernet MAC and PHY compliant to IEEE 802.3, an enhanced UART with a fractional baud rate generator (supporting 300 bps to 15 Mbps), a multi-master capable I2C controller, and an Enhanced Dedicated GPIO Entity (EDGE) controller. The EDGE controller supports up to 16 GPIOs and both the EDGE pins or I2C interface can be used for controlling and monitoring other peripherals. Up to 2 EDGE pins can also be configured as a PWM generator. In addition to the XR22801, which integrates a single UART, Exar also offers the XR22800 with no UART, the XR22802 with 2 UARTS, and the XR22804 with 4 UARTs.

http://www.exar.com

800V Optically Isolated AC Power Switch Utilizing Dual-Power SCR Outputs

IXYS Integrated Circuits Division (ICD), Inc., a wholly owned subsidiary of IXYS Corporation, announced the availability of the CPC1964B, an AC Solid State Switch utilizing dual power SCR outputs. This device also includes zero-cross turn-on circuitry and is specified with a blocking voltage of 800Vp. The CPC1964B is well suited for industrial environments where electromagnetic interference would disrupt the operation of plant facility communication and control systems. The 8-Pin Power SOIC enables 800Vp of blocking voltage and 5kV of isolation; 12.5mm of external creepage distance can be achieved with the appropriate layout. The CPC1964B is approved to UL508 for General loads. The approval allows for operation at 1.5Arms on AC lines rated between 20Vrms to 280Vrms.

Typical applications include programmable controls, power control panels, remote switching, gas pump electronics, powerline communication, powerline control and power meters.

www.ixys.com

ECCE 2014

IEEE ENERGY CONVERSION CONGRESS & EXPO | PITTSBURGH, PA, USA | SEPTEMBER 14-18, 2014

The 6th Annual IEEE Energy Conversion Congress and Exposition (ECCE 2014) will be held in Pittsburgh, Pennsylvania, USA on September 14-18, 2014. ECCE has come to be regarded as the ideal environment for industry, academia, and startups to meet, collaborate, motivate, and innovate over global initiatives in research and industrial advancements. With a record number of submitted digests the conference expects to be the largest ECCE to date. An exciting list of events include 1) a plenary session featuring speakers from US national labs and global industry champions, 2) numerous technical sessions on energy conversion systems and technologies as well as components and materials, 3) exposition featuring exhibitors displaying the latest advances in energy conversion technology . Please visit http://2014.ecceconferences.org/ for more information and be a part of this international hotspot on all things related to energy!

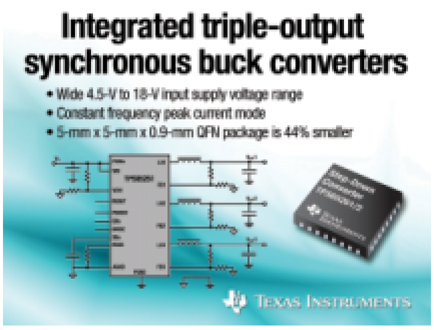
Integrated Lithium-Ion Battery Protection Controller for Smartphones and Tablets

ON Semiconductor has announced a Lithium-ion battery protection controller for smartphones and tablets. The highly-integrated LC05111CMT utilizes analog circuit technology, MOSFET technology, and advanced packaging expertise to incorporate controller and driver functions in a single circuit.
The LC05111CMT enables high-precision current control without using a current detection resistor. This current control reduces charging time by enabling higher charging current. The device includes highly accurate detection circuits and detection delay circuits, to prevent batteries from over-charging, over-discharging, over-current discharging, and over-current charging. The high level of integration reduces component count and therefore required board space in the space-constrained battery pack.

www.onsemi.com

Integrated Triple-Output Synchronous Buck Converters

Texas Instruments introduced the next generation of its integrated triple-output synchronous step-down switching regulators with smaller footprint and higher efficiency.



The TPS65261 and TPS65262 DC/DC converters feature small QFN packages and up to 96 percent efficiency for such applications as digital television, set-top boxes, home gateway and access point networks, wireless routers, point-of-sale machines, and surveillance equipment.
The family of DC/DC converters joins TI's family of multi-channel synchronous buck converters that include the TPS65250 and the TPS65251 developed for set-top box applications. TPS65261 and TPS65262 key features and benefits: Wide 4.5-V to 18-V input supply voltage range for intermediate bus voltages operating off 5-V, 9-V, 12-V or 15-V power buses or batteries. Constant frequency peak current mode simplifies design and enables system optimization. 5-mm by 5-mm by 0.9-mm QFN package is 44 percent smaller than previous generation. 0.6-V feedback reference supports processors demanding lower output voltage. Integrated automatic power up/down sequencing offers easy power control. The TPS65261 provides 82 percent light load efficiency at 10 mA and offers three outputs of rated current at 3A/2A/2A. It features an adjustable 250-kHz to 2-MHz switching frequency with pulse skipping.

www.ti.com

Digital Power Monitor Capable of Industry's Widest Common Mode Input Voltage Range

Intersil Corporation announced the ISL2802x family of digital power monitors capable of supporting a wide common mode input voltage range of 0V to 60V. The ISL2802x family is comprised of three devices offering a range of capability including full featured bi-directional, high-side and low-side digital current sense and voltage monitors with a serial interface with a high level of integration. Precision measurements are enabled by an integrated 16-bit ADC. Available in a tiny solution footprint and with a wide specified temperature range, the ISL2802x digital power monitor family is ideal for telecom, industrial and consumer applications.

Current, voltage and power measurements are fundamental to monitoring electronics and are critically important to measuring the health of a power system. Basic op amps and current sense amplifiers can be used for this purpose, but require complicated analog design while providing limited real-time system information. Through key architectural innovations, Intersil's ISL2802x digital power monitors integrate many common electronic building blocks resulting in system designs that have reduced complexity without compromising performance.
The ISL2802x family consists of the three unique products. The ISL28023 is a full featured PMBus compatible digital power monitor that integrates the analog comparators, a voltage regulator, a DAC and a low voltage auxiliary channel in a single chip. The ISL28025 is a high precision digital power monitor with integrated analog comparators and an integrated voltage regulator. The integrated analog comparators for the ISL28023/5 allow for continuous monitoring of the inputs. This results in a very fast response time (500nS) enabling real-time alerts for rapid system shut off if necessary. The ISL28022 is a highly efficient digital power monitor ideal for cost constrained applications.

http://go.intersil.com/digital-power-monitor.html

4 Watt Mini Power Supplies for Extreme Temperatures

While home electronics operate at relatively comfortable temperatures, the same is not true for many industrial applications. Due to their wide operating temperature range of -40°C to +80°C, RECOM's 4W mini power supplies are well equipped to supply outdoor sensors or control units in residential as well as industrial applications.

The new RAC04-C/230 series is particularly suitable for worldwide use due to its wide input voltage range of 80-264VAC. The modules have short-circuit protected outputs and are available as single 3.3V, 5V, 12V, 15V or 24V or dual 5/12V, ±5V or ±12V versions. Despite their compact size of 36.7 x 27.2 x 17.1mm (L x W x H), the modules meet the requirements of class B EN55022 without external components which is critical for home electronics. These high performance converters also achieve efficiencies of up to 79%.

www.recom-electronic.com

700 MHz–6 GHz Ultra-Low Noise Amplifier

Richardson RFPD, Inc. announced the availability and full design support capabilities for a new high dynamic range, single-stage MMIC low noise amplifier from MACOM Technology Solutions.

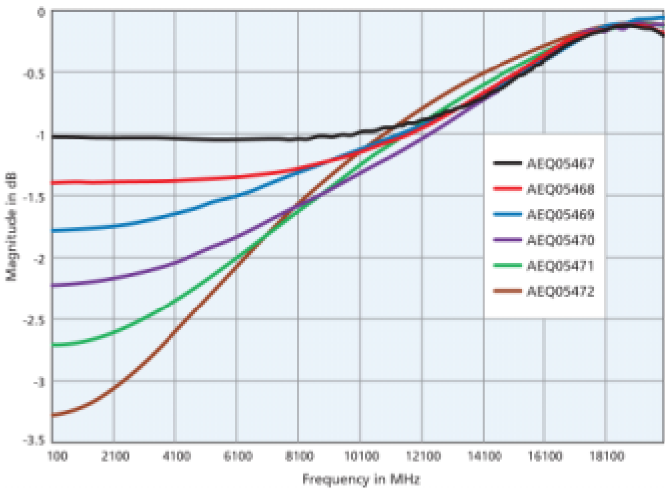
The MAAL-011078 is designed for operation from 700 MHz to 6 GHz and is housed in a lead-free 2 mm 8-lead PDFN plastic package. The LNA has an integrated active bias circuit, allowing direct connection to 3V or 5V bias and minimizing variations over temperature and process. The bias current is set by an external resistor, so the user can customize the power consumption to fit the application. VBIAS can be utilized as an enable pin to power the device up and down during operation.

The MAAL-011078 is ideally suited as a first-stage LNA for 3G/4G cellular infrastructure and Wi-Fi applications, including 802.11ac, as well as Aerospace & Defense applications.

www.richardsonrfpd.com

EW Range of DC to 18GHz Gain Equalizers

From Knowles Capacitors comes a line of Gain Equalizers from their Dielectric Laboratories (DLI) facility. They are designed to compensate for module Gain Slope and offer excellent, repeatable microwave performance. This is achieved by application of precision thin film fabrication, coupled with DLI's high permittivity ceramic materials, to give a unique design solution.



Latest to be released is the 0302 size EW Series - a new breed of Gain Equalizer. They are a low cost solution that provides slope correction from DC to 18 GHz. of greater than 3 dB. They are designed for superior, repeatable microwave performance to compensate for gain roll-off and VSWR mismatch losses and are a good match to a 50□ line width for optimal broadband performance. Six slopes are available and are footprint interchangeable for optimizing module gain flatness from 1 to 3.5dB. Solderable terminations are compatible with solder SMT & conductive epoxy assembly and pick and place equipment. No ground connection is required. They are available in tape and reel packaging for high volume applications. Engineering kits are offered which contain all 6 slope part types.

www.knowlescapacitors.com

Arbitrary/Function Generators Combine Intuitive Operation

The Yokogawa FG400 Series is a range of arbitrary/function generators that combine intuitive operation with comprehensive sweep and modulation facilities. The instruments allow the creation of basic, application specific and arbitrary waveforms, and feature isolated output channels which allows their use in the development of floating circuits in power electronics applications.

The range consists of two models: the single-channel FG410 and the two-channel FG420: both generating signals of up to 20 V peak-to-peak over the frequency range from 0.01 µHz to 30 MHz. Operation is via front-panel pushbuttons and a 3.5-inch LCD screen which displays alphanumeric values alongside the generated waveforms.
The instruments incorporate a number of basic waveforms as standard, including sine, DC, ramp, square and pulse. Advanced functions include sweep (frequency, phase, amplitude, DC offset and duty), modulation (FM, FSK, PM, PSK, AM, DC offset and PWM) and burst (auto, trigger, gate and triggered gate).
Up to 128 arbitrary waveforms of up to 512 kW per waveform can be generated and saved to the instrument's internal non-volatile memory, and can then be selected from a displayed list. The waveforms can be created in the FG400 or with the free editing software included. Sequences of different waveform patterns can be generated and edited by programming the appropriate parameters.

www.tmi.yokogawa.com

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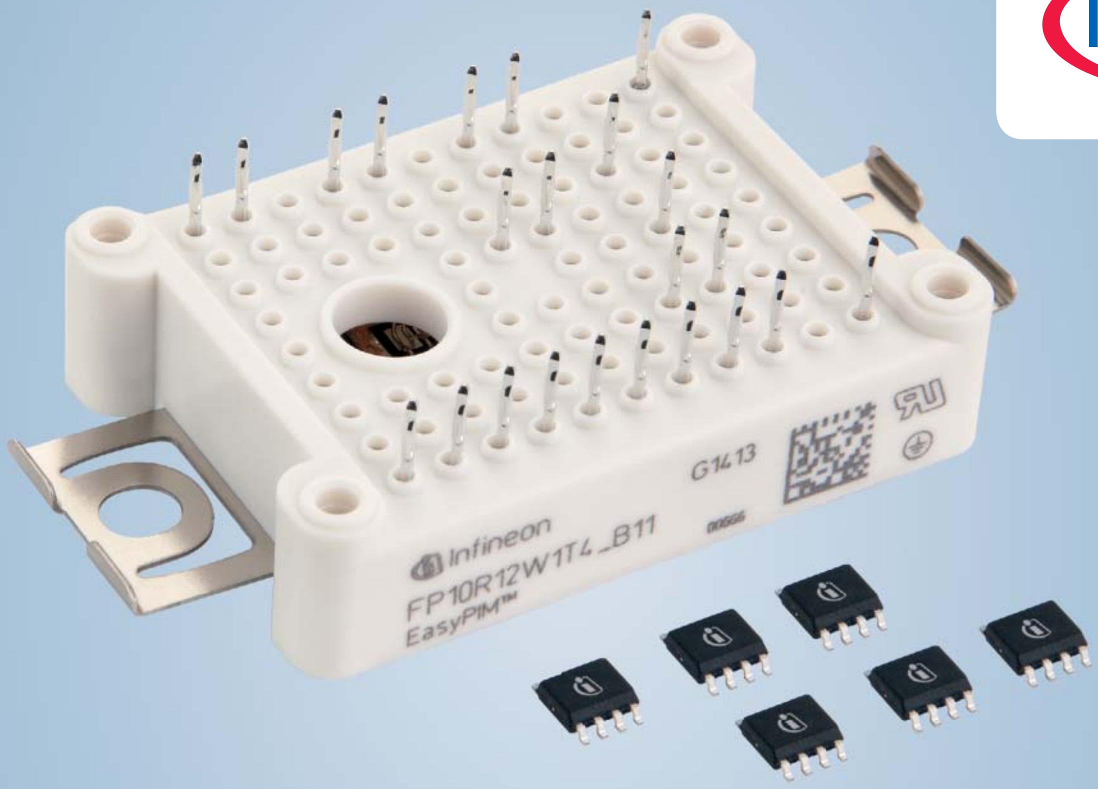


EiceDRIVER™ 1EDI Compact

1200 V galvanically isolated single-channel driver IC family

The new EiceDRIVER™ 1EDI Compact family supports efficiently a broad range of applications with MOSFETs and IGBTs up to 6A output current. The used Coreless Transformer technology with 1200V galvanic isolation is tailored for all 600V, 650V and 1200V IGBT and Power Modules.

With its benchmark in common mode transient immunity (CMTI) of 100kV/µs 1EDI Compact driver ICs are extremely robust and optimized for the latest generation of TRENCHSTOP™ 5 IGBT.

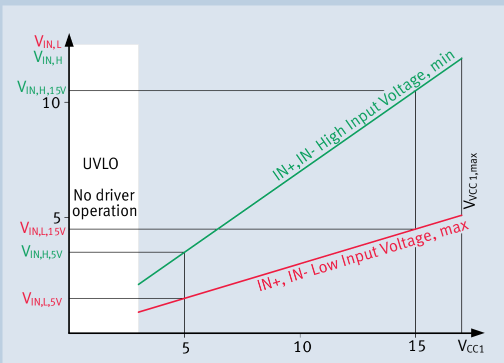
ED-C Compact

Main Features

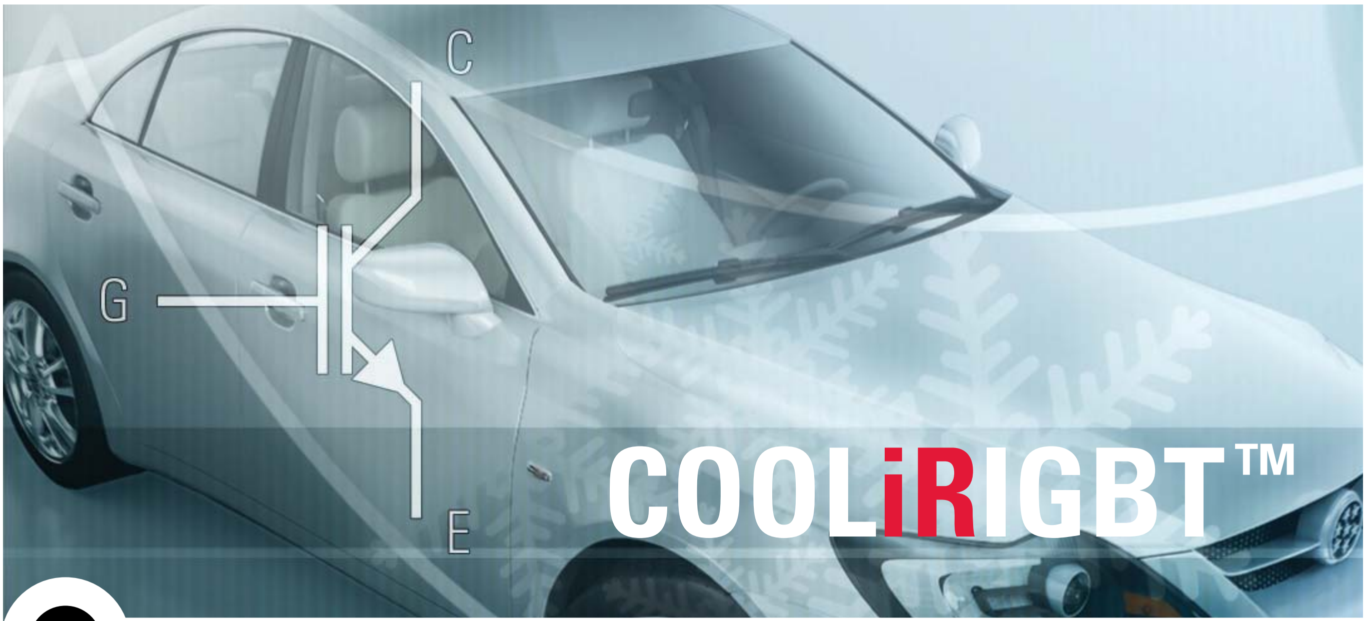
- Up to 6 A minimum peak rail-to-rail output
- Scaled input threshold voltages
- Input filter time 40ns or 240ns
- Propagation delay mismatch <20ns
- Compact SO8 150mil package

Benefits

- Simplifies circuit design and saves components
- Direct drive without booster
- Low area consumption



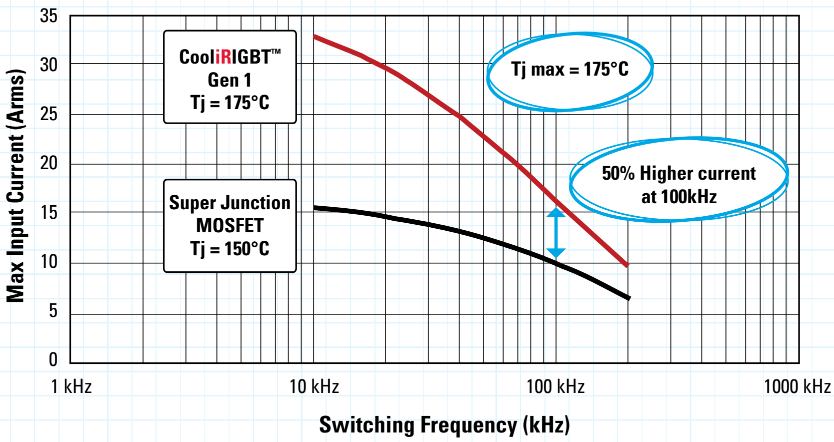
www.infineon.com/eicedriver-compact



Automotive COOLiRIGBT™ Gen 1

Ultra-fast Switching, Rugged 600V High Frequency IGBTs

CooliRIGBT™ offers 50% higher current than super junction MOSFETs



	Super Junction MOSFET	COOLiRIGBT™ Gen1
Tj Max	150°C	175°C
Manufacturability	Complex	Simple
Switching Frequency	High	High
Losses At High Currents	High	Low

COOLiRIGBT™ Gen 1 are designed to be used in a wide range of fast switching applications for electric (EV) and hybrid electric vehicles (HEV) including on-board DC-DC converters, and battery chargers.

Features:

- Switching frequencies up to 200kHz
- 600V rated devices with a short circuit rating of > 5µs
- Low $V_{CE(on)}$
- Positive $V_{CE(on)}$ temperature coefficient making the parts suitable for paralleling
- Square Reverse Bias Safe Operating Area
- Automotive qualified
- Tj max of 175ºC
- Rugged performance
- Designed specifically for automotive applications and manufactured to the 0PPM initiative

For more information call +49 (0) 6102 884 311
or visit us at www.irf.com

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THE POWER MANAGEMENT LEADER