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Bodo´s Power Systems®

Electronics in Motion and Conversion

July 2014

Citius, Altius, Fortius:

New Developments from the Russian Power Semiconductors Manufacturer

PROTON-ELECTROTEX

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Does this sound familiar? Voltage increases, whenever it is least expected. Good for thrillers. Not so good for power electronic installations. That is why we developed our "ready-to-use switch components" based on IGBT and Thyristor technology, specifically for use in MV applications. They are even available with or without control or current loop feed power supply. So sit back, relax and look forward to an exciting conversation with your House of Competence. It's worth it.

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- **MV Thyristor AC switches**
- **MV IGBT / Thyristor control**
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The Gallery

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Events

Thermal Management 2014,
Denver CO, August, 6-7
www.thermalnews.com/conferences/

EPE ECCE 2014,
Lappeenranta, Finland, August 26-28
www.epe2014.com/

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

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

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

Strawberries and IGBTs !

It is summer, and time for fresh strawberries. My memories bring back picking strawberries in Mountaintop, Pennsylvania, while working for RCA, later GE, Harris, now Fairchild. In frequent visits, I learned from Design and Application Engineers how to put the newly invented IGBT to use in the European market. The world's first volume application started at Braun in Kronenberg, Germany, with a 10 Amp, 500 Volt COMFET, the RCA name, in the variable speed motor drive of a kitchen appliance. The IGBT was invented and patented by RCA engineers Becke and Wheatley, in December 1982, as their approach to reducing the conduction voltage-drop in "High Voltage" Power MOS transistors. The device will soon be 32 years old. The IGBT became the most important switch for power applications at line voltage and higher, and is now rated to several kV and hundreds of Amps in a single chip, and thousands in multiphase modules.

At several Conferences this year we saw progress being made in bringing wide band gap semiconductors into appropriate applications. Still silicon will hold its position as the basic material for semiconductors for quite a while.

On a recent trip to Dresden my friend Don Burke and I attended the 20th anniversary celebration for Infineon's Wafer Fab and their conversion to 300 mm silicon wafer processing. One of the main products to run on 300 mm will be the IGBT. This is certainly another milestone.

Infineon in Dresden is investing for a more efficient world of power electronic products. At the ceremony, Dr. Ploss, CEO of Infineon, had guests from the German government who support such future growth: Mr. Tillich, Prime Minister of Saxony, Prof. Dr. Johanna Wanka, State Minister for education and research and Helma Orosz, Lord Mayor of Dresden. The reunification of Germany is another milestone in a continuing story of success.

Dresden, with its history and technical attractions from the past, is a worthwhile place to spend a few days. An evening cruise on

the river Elbe, powered by steam and using paddle wheels, is a reminder of progress in motion. The many museums and buildings represent a life history to us - I remember 20 years ago seeing the pieces of the Church of our Lady lying numbered on the ground. Now the beautiful Frauenkirche has been amazingly reconstructed, with the other buildings surrounding the Plaza still in the process of renovation.

Communication is the only way to progress. We delivered twelve issues last year, each month, on time, every time. This year, the June issue marks 75 technical articles published, amongst 440 pages. They are all archived and retrievable at PowerGuru. As a media partner, 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 June:
Learning from history is always important. More important is to not duplicate political failures of the past. Peace around the world should be our goal. We each have a responsibility to see that peace and freedom continue to progress.

See you soon at EPE, ECCE, and around the world.

Best Regards

ENERGY UNDER CONTROL

HO - A Range of Choices

A breakthrough in the tradeoff between performance, cost, size & mounting versatility. Whatever current you need to measure, mounting constraints or performance required, the HO current transducer range offers you the perfect solution.
6 families cover nominal currents from 2.67 A to 250 A, PCB-through-hole, surface-mount or multiple panel mounting versions, and offer an aperture or integrated primary conductor. LEM ASIC technology brings Open Loop transducer performance closer to Closed Loop transducers, providing you with better control and increasing the efficiency of your system, but at a significantly lower price.

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INTELEC 2014 - Resilient Communications Energy for our Connected World

INTELEC 2014 announces that registration is now open for the 36th annual conference held September 28 - October 2 in the Vancouver Convention Center in Vancouver. To register for the conference go to www.intelec2014.org/registration

This year's technical program will focus on communication power systems, energy storage, power conversion equipment and site support. From batteries to power supplies, disaster recovery to renewable energy, INTELEC 2014 is the place to see where the industry is heading, what new products are being introduced and will be the place to personally interact with the key suppliers and decision makers in the industry.

INTELEC©, the International Telecommunications Energy Conference, is the annual world-class technical forum which presents the latest developments in communications energy systems and related power-processing devices and circuits. This Conference, which serves the broad community of researchers, suppliers and operators, explores new technologies of power conversion, energy storage and systems for telecom applications and environment.

www.intelec2014.org

Advanced Circuit Materials Division to Increase RO3000 Capacity

Rogers Corporation's Advanced Circuit Materials Division, a global leader in Microwave Printed Circuit Board (PCB) Materials, announced today that it received board approval to install a RO3000® dielectric production line to increase capacity in Chandler, Arizona. Dielectric is a specialty polymeric substrate that is laminated at high temperature between two sheets of copper foil to create PCB material.

"We have decided to accelerate our investments in capacity expansion to support the strong global demand for RO3000 laminate materials, such as those used in 4G/LTE Base Station applications," said Jeff Grudzien, Vice President of Advanced Circuit Materials. "In addition, this investment puts us in a strong position to meet the future material needs of a growing number of Radio Frequency (RF) designs using RO3000 materials in 77 GHz automotive sensors and Mobile Internet Devices such as tablets and smart phones. It is an exciting time for us at Rogers given the number of customers and applications that are seeking the advantages and unique properties that our high frequency circuit materials provide."

www.rogerscorp.com

Vincotech Lives Up to Its Performance Promise at the PCIM

Vincotech, a supplier of module-based solutions for power electronics, staged a charity fun-run at the PCIM Europe show. Vincotech's committed partners and a fit team of staffers at the booth kept the

treadmill spinning throughout the three-day fair. Thanks to their efforts, the company is proud to announce that about 230 km logged on the treadmill. The company matched all contributions and a donation of € 12.000 could be endowed for a good cause.

As posted on www.vincotech.com/charity-fun-run, Vincotech pledged € 50 to Plan International for every kilometer. The funds have been donated and will go to support the Water for Ethiopia project. The company wishes to thank everyone who stepped up to the treadmill challenge as well as fellow sponsors Precor Fitness Germany, Bodo's Power System, Mesago, Messe Nürnberg and Biesalski & Company.

Vincotech is Driven to Drive Development with people and products in mind and customers' applications at the top of our agenda.

www.vincotech.com/charity-fun-run

Becoming a Founding Member of "Labor der Zukunft e.V."

EBV Elektronik, an Avnet group company (NYSE: AVT) and leading specialist in EMEA semiconductor distribution, has become a member of the "Labor der Zukunft" association of forward-looking laboratories. Founded in February 2014, the association is an initiative of the Fraunhofer Institute for Biomedical Engineering (IBMT) with the support of the Saarland state government. EBV Elektronik supports the association as a leading innovator in the field of electronics and automation.

The Labor der Zukunft e.V. association aims to provide non-material and advisory support for the development and standardisation of innovative laboratory technologies. Besides looking at the technological components of analytical tools and diagnostic devices, holistic consideration is also given to the entire vertical system of value creation in the design of a laboratory. An increasing amount of electronics will also be used to advance and develop these laboratory technologies – whether in cooling or analytical processes or for suitable data storage.

www.labor-der-zukunft.org

The World’s Leading Trade Fair for the Electronics Industry is 50

The world’s leading trade fair for Electronic Components, Systems and Applications is celebrating its 50th birthday in 2014. Since 1964, electronica has been showing the electronic trends of tomorrow and providing a comprehensive overview of the international industry. From November 11 to 14, 2014, the key topics will be automotive, embedded systems, lighting and medical electronics, as well as the over-arching themes of security and energy efficiency.
The success story of electronica began 50 years ago with the founding of Messe München. Already in that first year of 1964, exhibitors and visitors from Germany and abroad packed the exhibition halls. Established on the initiative of U.S. companies, the trade fair soon evolved into the top event of the electronics industry. More than any other trade show, it has offered a complete overview of the market for decades, encompassing the entire range of the electronics industry, from components and systems via applications to electronics services. In the last 50 years, many technologies and innovations, such as the microchip, have taken their bow here.

www.messe-muenchen.de

Outstanding Keynote Speakers from Leading Companies

The SEMICON Europa technology and business program agenda addresses the critical issues and challenges in microelectronics design and manufacturing, and provides the information, education, and guidance that you need to move your innovations and products to market. This year’s edition of SEMICON Europa will be enriched with new programs including electronic applications, the Innovation Village, and much more!

http://www.semiconeuropa.org/

Cooperating to Transform the Capability of the Industrial Fibre Optics

Amantys has announced the successful implementation of its Amantys Power Insight communications protocol over Avago’s 50MBd Versatile Link transmitters and receivers. Avago, the leading supplier of industrial fibre optic solutions, is working with Amantys to bring improved system information to its customers. As part of this cooperation Avago will develop a Versatile Link solution that benefits from the Amantys Power Insight capability.
Commenting on the announcement, Amantys CEO Erwin Wolf said: “This announcement endorses our strategy to develop solutions for intelligent control to power electronics systems. Our customers widely use Avago fibre optics in their systems so this development is of significant benefit to both companies.”
Martin Weigert, Vice President and General Manager for Industrial Fibre Products at Avago, added, “We are delighted with the rapid progress we’ve made since Avago engaged with Amantys last year and this announcement marks the first results of our partnership.”
The development of Insight is being driven to bring more intelligence into the power switching process. Armed with information harvested from the heart of the power switching system via Insight developers have the exciting prospect of being able to make use of it in their control plane to adapt their system during operation to achieve improved performance, availability and product life.
Amantys Power Insight provides several important capabilities including:
Monitoring of key system parameters at the IGBT switch during system operation
Reporting back detailed fault codes which help the system operator understand the nature of problems in the switch

www.amantys.com

A Positive Future for Silicon Manufacturing in Dresden

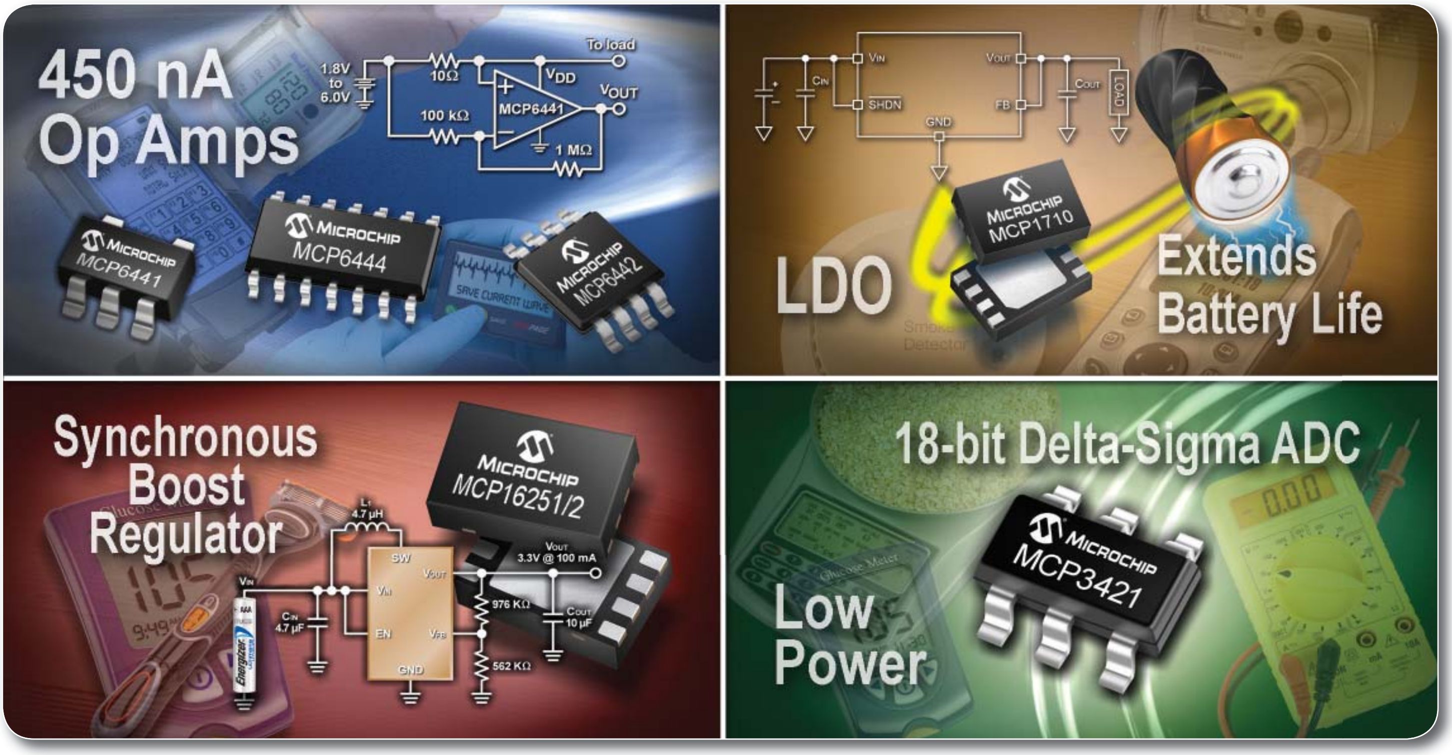
From left to right: Dr. Reinhard Ploss, CEO Infineon Technologies AG / Helma Orosz, Lordmayor Dresden / Prof. Dr. Johanna Wanka, Federal Minister of Education and Research / Stanislaw Tillich, Prime Minister of Saxonia / Pantelis Haidas, General Manager Infineon Technologies Dresden GmbH / Helmut Warnecke, General Manager Finance der Infineon Technologies Dresden GmbH

At the 20th Anniversary of the Infineon factory in Dresden, Dr Reinhard Ploss, CEO Infineon, described a bright future to guests from government, industry and academia. On June 6th 1994 this factory was founded. Now, the new 300 mm silicon wafer production facility represents another milestone for power semiconductors. Since 50 percent of the Infineon turnover comes from power semiconductors, more investment can be expected, above the 200 million Euro’s represented here.
From the Government of Germany, the Minister for Education and Research, Prof.Dr Johanna Wanka, stated that Germany must continue in high tech products that drive innovation.
For the State of Saxonia, Prime Minister Stanislaw Tillich stated that it was fortunate indeed to have Infineon in Dresden. Today Dresden has the largest Microelectronic Cluster in Europe.

www.infineon.com

Does Your Design Require Low Power Analog?

Microchip has the answer ...



Microchip offers a broad portfolio of low power analog products that support a wide variety of applications. With over 800 unique stand-alone analog products covering thermal management, power management, battery management, mixed-signal, linear, interface and safety and security.

Operational Amplifiers

MCP6441/2/4

- 450 nA quiescent current per channel
- Operating voltage down to 1.4V
- Small SOT-23 and SC-70 packaging

Switching Regulators

MCP16251/2 Sync Boost Regulator

- 0.8V start-up voltage
- < 4 µA quiescent current
- True load disconnect or Input to Output bypass
- > 100 mA output with 1.2 V_{IN} 3.3 V_{OUT}

Low Dropout Regulators

MCP1710

- 20 µA quiescent current
- 2 × 2 mm DFN package
- Ceramic capacitor stable

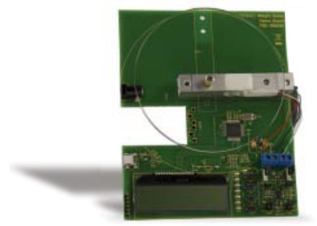
Analog-to-Digital Converters

MCP342X

- 145 µA quiescent current
- Up to 18 bit resolution
- Operating voltage down to 2.7V

GET STARTED WITH YOUR LOW POWER ANALOG DESIGN TODAY!

www.microchip.com/analog



MCP3421 Weight Scale Demo Board (MCP3421DM-WS)

MICROCHIP

Microcontrollers • Digital Signal Controllers • Analog • Memory • Wireless

IGBT System Design with 3D STEP Files and Interactive Models

CT-Concept Technologie has announced that 3D STEP files of all its SCALE™-2 IGBT gate drivers are freely available to help designers model new systems faster and more accurately. 3D interactive models of the company's drivers are also included in new application manuals.
SCALE™-2 IGBT gatedrivers use an ASIC chipset to reduce component count and size, and increase performance, scalability and reliability. This enables designers to optimize dynamic switching performance, accuracy and functionality, providing design flexibility and reducing time-to-market for applications ranging from 150A to 3600A and 600V to 6500V. 3D STEP models are used by design engineers to check if there are mechanical conflicts between the driver and other parts of the system. This is especially useful if the design is mechanically very dense.
STEP files and DWG files are freely available for download at:

www.igbt-driver.com

Innovation Award for Prof. Dr. Johann Walter Kolar and Dr. Johann Miniböck

The award honours the outstanding innovation on ´Multiple-Interleaved Triangular-Current-Mode Converters´. With their work the researchers have pushed the borderline of efficiency and power density of PFC stages.
The SEMIKRON Foundation and the ECPE European Centre for Power Electronics e.V. jointly honoured Prof. Dr. Johann Walter Kolar, Power Electronic Systems Laboratory, ETH Zurich, Switzerland and Dr. Johann Miniböck, M-PEC Power Electronics Consulting, Austria with the SEMIKRON Innovation Award 2014 at the PCIM 2014 for their outstanding innovation on ´Multiple-Interleaved Triangular-Current-Mode Converters´.
The SEMIKRON Young Engineer Award goes to Benjamin Zeller, Fujitsu Technology Solutions in Augsburg, Germany for his contributions to the development of a high-efficient and high volume 65W power supply on a PC mainboard. The key element was to design a very efficient transformer with an excellent coupling and a low primary leakage inductance. This innovation has shown that it is possible to bring back added value to Europe also in the cost-sensitive PC market by introducing a high level of integration on the board.
With these awards, the SEMIKRON Foundation and the European ECPE Research Network honour outstanding innovations in projects, products, prototypes, services and innovative concepts in the field of power electronics.

Photo: (left to right) Prof. Leo Lorenz (ECPE), Benjamin Zeller, Dr. Johann Miniböck, Bettina Heidenreich-Martin (SEMIKRON Foundation) Source: Mesago PCIM GmbH/Thomas Geiger

www.semikron-stiftung.com

www.ecpe.org

Entering the European Market with Power Electronic Modules

StarPower Semiconductor Ltd. opens its European branch StarPower Europe in Cadenazzo/ Switzerland, thus marking a milestone in its growth in Europe.
In the financial year last expired, StarPower boasted a record turnover of 60 million US dollars. According to the study Power Semiconductor Discretes and Modules – World – 2013 published by IHS, an independent provider of market research, the market share held by StarPower almost doubled within a year in 2012, mainly owing to the growth potential in the drives and renewable energy markets in China. Some renowned European global players have already audited the Chinese production sites and released the IGBT modules for sampling.

StarPower was founded in 2005 in Jiaxing near Shanghai/ China with investment from United States and, presently, has 350 employees. Tight networking of sales engineers ensures fast response times and efficient local customer support in China.
StarPower produces power semiconductors on a total production area of 70,000 square metres. Modules are manufactured in a clean-room environment. The high-quality production sites are equipped with state-of-the-art production facilities, such as a fully automated production and testing line in compliance with ISO 9001 standard.

www.starpowereurope.com

Russian Distributor as Part of Expansion across Europe and into India

Amantys has expanded its global reach with the announcement of a significant partnership with Moscow-based Micro EM. This follows the appointment of Lintronic to cover the Spanish and Portuguese markets and BSM Technology to bring its Amantys Power Drive family of products to the Indian market.

The agreement with Micro EM signals the arrival of Amantys in Russia and continues the company's development into key global markets. The new regions are particularly important in locomotive traction, industrial motor drives, and renewable energy generation through solar and wind power.

Amantys is already working closely with Lintronic in the Spanish and Portuguese markets and recently signed up with BSM Technology to target the rapidly growing Indian market.

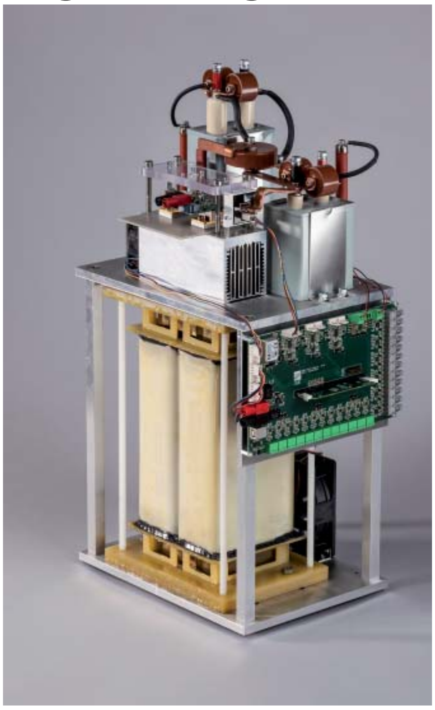
It was Amantys' innovative approach to power electronics that attracted the attention of Micro EM Deputy Marketing Director, Oleg Antonov: "Micro EM has been working with Amantys in the Russian market in preparation for this agreement and we've already won some new designs with the Amantys Power Drive range of IGBT Drivers.

The Amantys Power DriveTM range is available in operating voltages from 1.2 kV to 6.5kV IGBTs with a current load rating up to 3600A. They are compatible with all popular modules from ABB, Dynex, Fuji Electric, Hitachi, Infineon, Mitsubishi or Westcode/IXYS – an excellent match with the franchise portfolio at Micro EM.

www.amantys.com

www.microem.ru

High Voltage Silicon Carbide Power Devices



Researchers at the Fraunhofer Institute for Solar Energy Systems ISE have now successfully implemented silicon carbide (SiC) devices with a blocking voltage of 10 kV in a DC-DC converter for medium-voltage applications. This demonstrator can be used in renewable power plants which are gaining significance for the energy grid of the future.

Silicon carbide (SiC) devices enable the construction of extremely efficient and compact power electronic systems. For some time, SiC devices with blocking voltages of up to 1700 V have been commercially available. Now research is focusing on SiC semiconductors with even higher voltages and lower switching losses. First prototype devices have already been developed. "In the past we have experienced significant success in the implementation of SiC semiconductors in power electronic systems for the low voltage range. The logical step for us was to use these 10 kV devices for medium voltage applications," says Dirk Kranzer, group leader of "Advanced Devices and Technologies" at Fraunhofer ISE. "With this step, entirely new power electronic system structures become conceivable, supporting renewable power generation in large plants and power transmission in the next-generation energy grid."

Fraunhofer ISE developed the first demonstrator with SiC semiconductors for the medium-voltage range within the "Supergrid" project of the Fraunhofer-Gesellschaft.

The 30 kW DC voltage converter with 3.5 kV input voltage and 8.5 kV output voltage reached an efficiency of 98.5%. The switching frequency was 15 times higher than the value possible for conventional silicon devices within the same voltage range. The SiC semiconductors used in the circuit of the Fraunhofer DC-DC converter were developed by CREE, one of the leading companies for SiC semiconductor devices.

www.ise.fraunhofer.de

Second Generation IPM Family Shrinks and Simplifies Appliance Motor Drive Design

International Rectifier has introduced a new generation of energy-efficient Intelligent Power Modules (IPM). The new second generation (Gen2) family of IRAM System-In-Package (SIP) IPMs shrinks and simplifies the design of appliance motor drive applications including air conditioners, fans, compressors and washing machines.

Leveraging IR's advanced Trench Insulated-Gate Bipolar Transistors (IGBTs) and next-generation three-phase gate driver IC, the IRAM SiP1A Gen2 modules also feature state-of-the-art thermo-mechanical technology to further improve thermal performance and system efficiency by delivering increased power density and enhanced system ruggedness and reliability. The new devices are pin-to-pin compatible with the existing IRAM SiP1A series.

"Improving the industry standard benchmark established by IR with the previous IRAM generation was not an easy task. However, the new IRAM Gen2 platform utilizes state-of-the-art technology for next-generation IRAM System-In-Package intelligent power modules to address the growing demand for more efficient motor drives in appliance applications through improved thermal performance and reduced electromagnetic noise," said Alberto Guerra, Vice President, Strategic Market Development, IR's Energy Saving Products Business Unit.

The new Gen2 IRAM modules are an addition to IR's iMOTION™ design platform which integrates digital, analog and power technologies together in a flexible, mixed signal chipset to simplify motor control designs and bring energy-efficient, cost-effective solutions to market faster.

Specifications

Part Number	Package	V	$I_{O\ (RMS}$	F_{PWM}	$T_{J\ MAX}$	Application
IRAM256-1067A	SIP1A+	600V	10A	≤ 20KHz	150°C	Washing Machine, A/C, Fan, Compressor
IRAM256-1567A	SIP1A+	600V	15A	≤ 20KHz	150°C	A/C, Fan, Pump, Compressor
IRAM256-2067A	SIP1A+	600V	20A	≤ 20KHz	150°C	A/C, Fan, Pump Compressor

Datasheets are available on the International Rectifier website at www.irf.com. The IRMCF371 and IRMCS3071 reference designs featuring the IRAM SiP Gen 2 modules are also offered.

Availability and Pricing

Pricing for the Gen2 IRAM family begins at US $5.95 each in 10,000 unit quantities. Production quantities are available immediately. Prices are subject to change.

About International Rectifier

International Rectifier (NYSE:IRF) is a world leader in power management technology. IR's analog and mixed signal ICs, advanced circuit devices, integrated power systems and components enable high performance computing and reduce energy waste from motors, the world's single largest consumer of electricity. Leading manufacturers of computers, energy efficient appliances, lighting, automobiles, satellites, aircraft and defense systems rely on IR's power management benchmarks to power their next generation products. For more information, go to:

www.irf.com

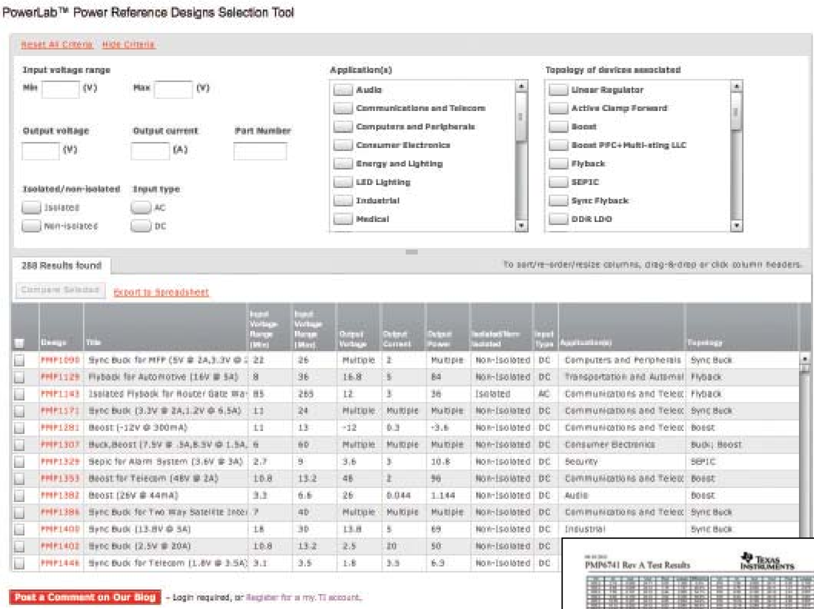
PowerLab™

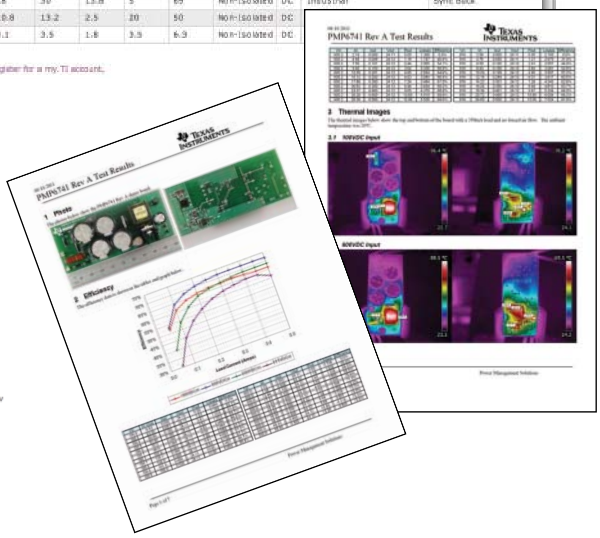
Power Reference Design Library

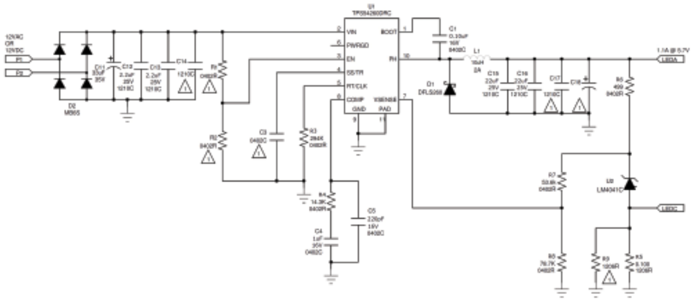
The PowerLab™ library includes an interactive and powerful search engine for design engineers looking for a proven and tested solution to their power supply requirements. This interactive search tool allows engineers to find designs by application, topology, input type, input voltage or output voltage.

Features

- The industry's most extensive collection of tested power management reference designs.
- Hundreds of power management designs for a wide range of applications and power conversion topologies.
- Reference designs include both isolated and non-isolated designs for lighting, telecommunication, computing, consumer electronics and more.







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Learn more, find answers and stay up to date

TEXAS INSTRUMENTS

Next Generation Low-Voltage MOSFETs

U-MOS IX-H product family drives down $R_{DS(ON)}$ and output charge for 40V MOSFETs

Toshiba Electronics Europe (TEE) has announced its latest family of low-voltage, ultra-efficiency Trench-MOSFETs based on the company's next generation U-MOS IX-H semiconductor process.

The new MOSFETs deliver industry leading RDS(ON)*QOSS (on resistance to output charge product) figure of merit for this class of devices. Initially available in 40V versions, the family will be extended in the coming months with devices offering ratings of 30V to 60V. The first device in the series has a typical RDS(ON) of only 0.7mΩ (max 0.85mΩ) and a typical output capacitance (Coss) of 1930pF. Rated for 40V, the TPHR8504PL is supplied in an ultra-miniature SOP-Advance package measuring just 5mm x 6mm

Target applications for the ninth generation U-MOS family include DC-DC converters, synchronous rectification and other power management circuitry where low-power operation, high-speed switching and minimum PCB real estate are needed.

U-MOS IX-H MOSFETs are ideal for high-side and low-side switching in DC-DC converters and secondary side synchronous rectification in AC-DC conversion circuitry. By improving the RDS(ON)*A value, U-MOS IX-H technology supports die size reductions of 65% for the same RDS(ON) - or RDS(ON) reductions of 65% for the same die size compared to the previous 40V UMOS VI-H generation.

In addition, a better trade off between output charge (Qoss) and RDS(ON) leads to increased efficiency. As a result U-MOS IX-H MOSFETs can help designers to reduce both power consumption and equipment size.

Designers will be able to choose from a variety of surface mount packages and, in future, also an option that offers dual-side cooling.

About Toshiba

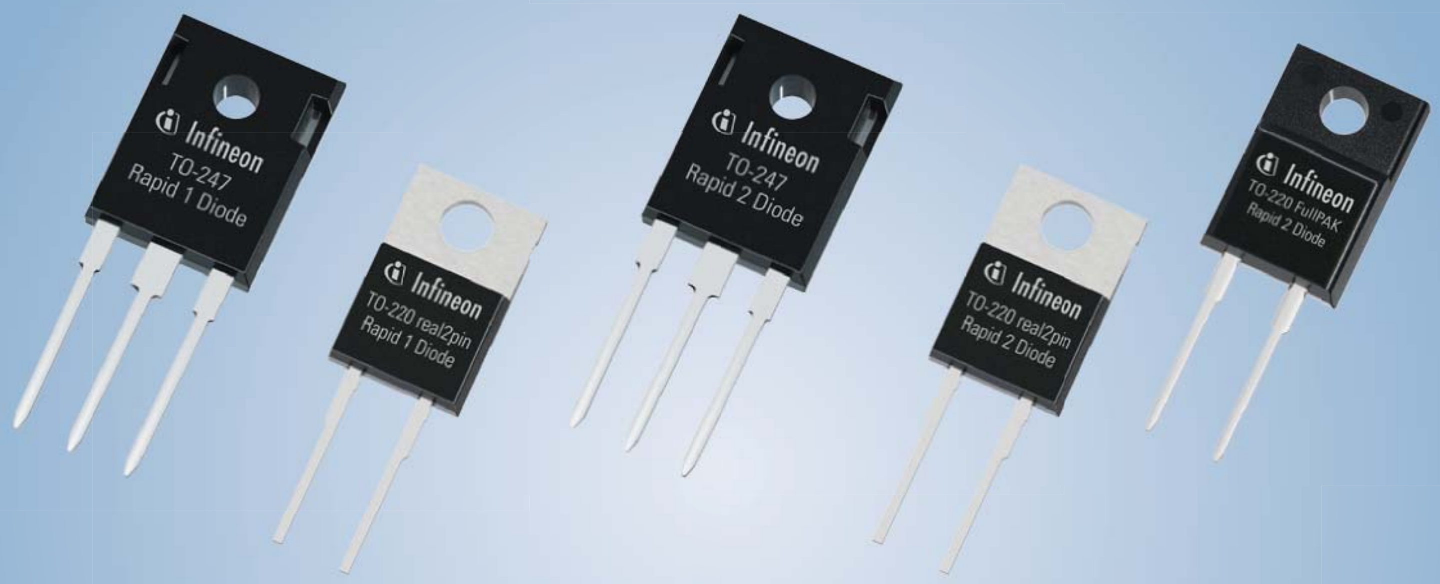
Toshiba Electronics Europe (TEE) is the European electronic components business of Toshiba Corporation, which is ranked among the world's largest semiconductor vendors. TEE offers one of the industry's broadest IC and discrete product lines including high-end memory, microcontrollers, ASICs and ASSPs for automotive, multimedia, industrial, telecoms and networking applications. The company also has a wide range of power semiconductor solutions as well as storage products like HDDs, SSDs, SD Cards and USB sticks.

TEE was formed in 1973 in Neuss, Germany, providing design, manufacturing, marketing and sales and now has headquarters in Düsseldorf, Germany, with branch offices in France, Italy, Spain, Sweden and the United Kingdom. TEE employs approximately 300 people in Europe. Company president is Mr. Takashi Nagasawa.

Toshiba Corporation is a world-leading diversified manufacturer, solutions provider and marketer of advanced electronic and electrical products and systems. Toshiba Group brings innovation and imagination to a wide range of businesses: digital products, including LCD TVs, notebook PCs, retail solutions and MFPs; electronic devices, including semiconductors, storage products and materials; industrial and social infrastructure systems, including power generation systems, smart community solutions, medical systems and escalators & elevators; and home appliances. Toshiba was founded in 1875, and today operates a global network of more than 590 consolidated companies, with 206,000 employees worldwide and annual sales surpassing US$61 billion.

For more company information visit Toshiba's web site at:

www.toshiba-components.com



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Watch the video!

GaN for Power: from “If and When” to “Yes” and “Now”

EpiGaN positions as the European GaN wafer supplier

By Marianne Germain, CEO and co-founder, EpiGaN nv, Hasselt, Belgium

When founding EpiGaN in 2010 after 10 years pioneering GaN technology for electronics in imec, my co-founders, Stefan Degroote, Joff Derluyn, and I were already convinced that the main question to be answered wasn’t “if” GaN would happen, but “when” and “how”. It was then already obvious that the intrinsic superior material properties of GaN semiconductor were offering an entirely new field of opportunities to power engineers. Indeed GaN uniquely combines high voltage, high carrier density and high frequency. The perspectives to break the Si limits, reducing the conduction losses by orders of magnitude, and thus energy consumption, and simultaneously enabling very fast switching devices are clear. This enables the possibility to significantly reduce the power converters’ size and weight.

Besides GaN superior physical properties, it is even more the cost-efficiency perspective when using Si substrates that pushed us to start-up the company: for the first time in compound semiconductor history, components can be processed on large wafer diameters in the same manufacturing lines as Si power MOSFET, eventually simultaneously. While most of the GaN activities today are occurring on 150mm wafer diameter, the next-generation of 200mm wafer size has already been demonstrated, including by the EpiGaN team. GaN technology makes sense economically with a real billion–range Total Accessible Market.

Four years later, GaN for power electronics has never been so exciting: the “when” question is being answered. In PCIM, last May in Nuremberg, five to ten industrial players were announcing or sampling GaN devices with operation at 650V. Several impressive application demonstrations including battery chargers, motor drives, solar inverters… are published, demonstrating the expected performance improvement on real cases. While in 2010 only one out of the top 20 power electronics manufacturers had announced a R&D program on GaN, it is fair to say that today, they all have defined a clear strategy towards this technology. More and more serious players have moved into the field, instead of watching from outside.

EpiGaN also experiences these market indications directly from the market: in 2010, we mostly got wafer requests for tests or sampling from people with very different ideas that were willing to test this new attractive stuff. Now, customers are moving from “sampling mode” to “ramp-up mode”, as predicted by market analysts. The market is consolidating, with first industrial products and real players populating the field.

This allows epiwafer suppliers, like EpiGaN, to come to more standardization of the GaN wafer products, mandatory for better product stability. We offer standard structures, with defined targets in terms of electrical characteristics. We recently developed our latest generation of 650V wafers with reduced leakage current and are following up our roadmap for next-generation products. The core focus is in the range of 650V where GaN more easily outperforms the Si performance. We are however fairly convinced that its use will then spread into two directions. First this will occur towards lower voltages, challenging Si devices in the lower voltage range. But GaN also will move towards higher voltages, challenging SiC positioning in the 1000V and above range.

Now remains the question “how”! Yole, the market research company in France, was recently addressing the question about internal or external sourcing for GaN epiwafer supply. No doubt in EpiGaN we answered this question from the start. It appeared as evidence that the main barrier for newcomers isn’t the process, nor the device design or use, but more basically, the material itself. GaN MOCVD growth processes are very complex, requiring adequate compound semiconductor chemistry expertise. Even more demanding is the stress engineering in the stack that has to be controlled in order to meet the high voltage requirements (thick buffer) simultaneously with the bow specifications, set by manufacturing line. This requires expertise and requires focus. This is in particular why we have decided in EpiGaN not to address the optoelectronic market but to remain focus on power electronics, relying on a strong in-house expertise in GaN electronic devices. This focus is key for a company, willing to establish as the best partner to power electronic industry, to be closer to its customer requirements, and to best meet their expectations. Within EpiGaN, we now offer a solution for epiwafer source, based on a long-standing expertise. This allows our customers to focus on their internal device developments and reduce their time-to-market. An interesting point is also that external wafer supplier shall be in a better position to adress “the chicken and the egg” problem of price/volume: by supplying multiple customers, wafer suppliers will be able to drive the price roadmap down to the level expected for large market adoption. By offering our customers to enter a long-term relationship, we are working on the price-efficiency roadmap.

Our value proposition is further based on our proprietary in-situ SiN surface passivation. While we were the first ones to develop MOCVD growth of SiN as surface electrical passivation for III-Nitrides, we are now using it for far broader purpose, such as unique gate dielectric, or for achieving smooth and contamination-free surface, facilitating entrance in Si fabs, and last but not least for reducing the Ron. Very recently, an exciting result was achieved by Prof. Medjdoub from IEMN (France) on an EpiGaN in-situ SiN passivated wafer, combining a record low Ron of 1.6mOhmcm^2 with a breakdown voltage of 1900V! More exciting possibilities are ahead with the GaN!

www.epigan.com

Some Personal Reflections on PCIM 2014

By Donald E. Burke, BSEE, Dr. Sc (hc), Senior Editor Bodo's Power Systems

My friend Bodo needs a guest editorial, and I am encouraged to provide one, preferably about the recent PCIM. This is not so easy for me, as I am so long retired as to have few causes to champion, and old enough to favor my memories – possibly not so interesting.

To state the obvious first – PCIM is an amazing Conference for those dedicated to Power Electronics. I am young enough to "Get It". But I do believe this will be my last visit; infirmities are catching up, "You look wonderful", I hear, but I know differently. So these reflections may be bitter sweet - it is hard to be just an observer of all this technology under development. And the show has become too large for me, too far to walk, too many steps, and too many interesting papers to listen to, and displays to see, amazing stuff to me.

Another observation: I have participated in five technology changes in devices: Mercury Arc Converters in drives, Germanium Rectifiers in copper refining (I only glanced in on the mechanical rectifiers they replaced, with my ear muffs on), Silicon Thyristors and Bipolar Transistors, the conversion to MOS Power, then IGBT's. Phew, enough already!

And now Wide Band Gap emerges – so similar to the Bipolar to MOS transition so many years ago, the apps remain the same, just more of them – but more physics to study. The two panel discussions among the participants were enjoyable, I remember being on one year's ago, defending a product that subsequently deceased. An uneasy peace is emerging, GaN for 600V and SiC above that, though you never know. For a few seconds in one presentation, I saw a GaN BV curve out to 1700 Volts, and with a little hook at the end.

The market is so much bigger now, the users so much more sophisticated, with higher expectations for the new switches, yet driven by the new realization that efficiency counts, energy is not for free, WBG is about to triumph. I recall a conduction drop in Mercury-Arc of 20 Volts, no one worried, so it was 12,000 HP peaks – just make the water cooler adequate. Can you imagine an Aluminum pot line, 100,000 Amps DC with a 15 Volt Vf. We have come a long way. The new issue is to charge a billion cell phones at an Rds(on) of a milliohm. Well anyway, thank goodness bipolar transistor SOA is behind us, and Power MOS UIS avalanche energy may be soon be relegated to the unimportant bin. All to be left for those issues are some of my grey hairs.

Everything has gotten smaller – now PCIM can be filled with thousands of products on display, some controlling MW's. That's what nano-seconds will do for you, I heard of milliseconds only once. And that in reference to 8kV DC Circuit breakers for the smart grid, necessary to mesh and transport all those distributed renewable power sources. I wonder if that presenter knows what he is accomplishing – maybe I should tell him, as I once learned to watch the arcshutes of DC Circuit breakers as they interrupted 50,000 Amps at 'only' a 1000 Volts. And now fast semiconductor switches at 5 KV, 8 kV, 15 kV, . . . amazing. And quiet, I'll bet.

The one, flat, interconnected, world shows up at PCIM – technical papers from everywhere, manufacturers we never knew existed, on display. When I was young and in Canada, all I needed to keep abreast were the quarterly publications of Siemens and AEG and one or two others and I was up to date with what's new in Power Electronics. Thank God for Wi-Fi and the Internet. Where were they when I needed them?

I enjoyed the three keynote speakers, each well based on technology and a good review of the current status and where things are going. I learned from them all, but the one subject I knew little of, the infrastructure needs for electric mobility, truly staggered me. No way, I thought, can all that get done – well, pure electrics won't be the norm until 2050 he said.

So I guess we have time, or at least, you have time.

donaldb4@ieee.org

Electronics Industry Digest

By Aubrey Dunford, Europartners

SEMICONDUCTORS

Worldwide sales of semiconductors reached $ 78.47 billion during the first quarter of 2014, marking the industry's highest-ever first quarter sales, so the WSTS. Global sales reached $ 26.16 billion in March 2014, an increase of 11.4 percent from March 2013 and a slight uptick of 0.4 percent compared to February 2014. March increased across all regions and every semiconductor product category compared to last year, demonstrating the market's broad and diverse strength. Regionally, year-toyear sales increased in the Americas (16.1 percent), Asia Pacific (12.9 percent), Europe (8 percent), and Japan (0.4 percent), marking the first time in more than three years that year-to-year sales increased across all regions. Sales were up compared to the previous month in Europe (3.9 percent), Asia Pacific (1.4 percent), and Japan (0.3 percent), but down slightly in the Americas (-4.3 percent).

In Europe, the main drivers of March's sales were Discretes, Optoelectronics, Analog IC and MCU.

Measured in Euro, semiconductor sales were € 2.243 billion in March 2014, an increase of 3.5 percent versus February 2014 and an increase of 4.0 percent versus the same month in 2013.

Exar, a provider of analog mixed-signal, video and data management solutions, has signed a definitive agreement to acquire Integrated Memory Logic (iML), a Taiwanese provider of analog mixed-signal solutions for the flat panel display market. The iML acquisition supports Exar's strategy of building a large scale diversified analog mixedsignal business. The gross transaction value will be $ 223 M, or approximately $ 94 M, net of cash acquired.

Avago has completed its acquisition of LSI in an all-cash transaction valued at approximately $ 6.6 billion. The acquisition creates a highly diversified semiconductor market leader with approximately $ 5 billion in projected annual revenues. Avago believes the acquisition of LSI positions the company as a leader in the enterprise storage market. Avago continues to anticipate achieving annual cost savings at a run rate of $ 200 M by the end of the fiscal year ending November 1, 2015.

With effect from the 2015 fiscal year, Infineon Technologies intends to reduce its target ratio of investments to revenue over the cycle from the current about 15 percent to about 13 percent. Even with the reduced capital intensity, it will still be possible to achieve its targeted average revenue growth rate of approximately 8 percent over the cycle. Infineon is beginning to reap the fruits of 300-mm thin-wafer technology for power semiconductors, enabling it to achieve growth with a substantially lower level of capital employed compared with 200-mm wafers. Infineon is also in the early stages of a growth curve for products manufactured using standard-CMOS-based technologies with 65-nm and lower process structures.

Crocus Nano Electronics (CNE), the joint venture founded in 2011 by Crocus Technology, a developer of magnetically enhanced semiconductor technologies, and Rusnano, Russian state-owned investment company focused on developing the Russian nanotechnology industry, has raised $ 60 M from its historical investors in additional capital. The new funding will enable CNE to finalize construction and installation works and complete procurement and installation of all capital equipment to support factory operations. CNE's factory in Moscow is the first semiconductor factory in Russia to use 300mm diameter wafer for MRAM manufacturing. CNE is ramping up with the objective to turn out 500 wafers per week by the end of 2014.

Worldwide semiconductor capital equipment spending is projected to total $ 37.5 billion in 2014, an increase of 12.2 percent from 2013, so Gartner. Total capital spending will increase 5.5 percent at $ 60.9 billion in 2014 as the industry begins to recover from the recent economic downturn and total spending will follow a generally increasing pattern in all sectors through 2018.

OTHER COMPONENTS

Bel Fuse has entered into a definitive agreement to acquire the Power-One Power Solutions business of ABB. Bel will pay approximately $ 117 M in cash to acquire the Power Solutions business, which had 2013 revenue of approximately $ 251 M. Headquartered in San Jose, California, and with manufacturing facilities in Slovakia and China. Power Solutions is a provider of high efficiency and high-density power conversion products for server, storage and networking equipment, industrial applications and power systems.

Ansys, a global supplier of engineering simulation software, has acquired SpaceClaim, a provider of fast and intuitive 3-D modeling software for engineers, for a purchase price of $ 85 M in cash. SpaceClaim offers the first powerful and easy-to-use 3-D modeling tool that can be utilized by any engineer during the product development process.

DISTRIBUTION

Arrow Electronics reported first-quarter 2014 net income of $ 107.1 M, compared with net income of $ 77.9 M in the first quarter of 2013. First quarter sales of $ 5.08 billion increased 5 percent from the prior year.

TTI, a specialist distributor of passive, connector, electromechanical and discrete components, has appointed industry veteran Norbert Piefer as Marketing Director Industrial in Europe. Piefer's previous roles – most recently at TE Connectivity– suit him to this new position role at TTI.

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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"Normally-Off" GaN Gathers Growing Interest during PCIM Europe

By Jeff Shepard, Darnell

While there is a growing cadre of start-ups developing GaN power devices, this year's PCIM Europe was notable for the number of major semiconductor makers introducing and showing GaN products. Major GaN developments were revealed by International Rectifier Corp. (IR), ON Semiconductor, Inc., Panasonic Industrial Devices Semiconductor Division and RF Micro Devices, Inc. (RFMD). All these major suppliers were showing high-voltage GaN power switches in various configurations and packages. And in each case, the devices are offered as ‚normally-off' switches.

Of the major power semiconductor makers, IR has been offering GaN devices in production for the longest time. IR was not only showing their "GaNpowIR" devices being used in a commercial audio amplifier, they shared their product roadmap for the next couple of years with PowerPulse. That roadmap starts with the 5x7.65 LGA packaged 100V, 35mOhm GaN half bridge device being used in the audio amplifier. At this year's PCIM, IR was showing its new 135mOhm and 70mOhm GaN cascade devices both in a 6x8mm QFN package and rated for 600V. Next year, the company plans to increase the complexity of its GaN offering with a 600V Cascode half-bridge including an integrated driver IC all in a 8x9mm QFN package.

Both RFMD and Panasonic were showing GaN switches that are currently available for sampling and are scheduled to enter production by the fourth quarter of this year. RFMD was showing two GaN devices and three evaluation boards (EVBs). The devices included the RFJS3006F a 650V normally-off source-switched FET (SSFET) that is RFMD's version of a Cascode structure. It is rated for 30A and 45 mOhms in a TO247 package. RMFD's RFJS1506Q SSFET is a 15A, 85 mOhm device offered in a 8x8mm PQFN package. RFMD also was showing three EVBs, a 1kW synchronous boost converter using the PQFN-packaged GaN device; plus a 2.4kW boost converter and a 3kW bridgeless totem-pole PFC design both using the TO247 GaN device.

Panasonic was showing a single device, but with a roadmap for three additional devices in the same family scheduled for near-term introduction. The first device in Panasonic's GaN offering is rated for 600V and 15A with an on-resistance of 71 mOhms in a TO-220D package. All the Panasonic GaN devices feature the company's proprietary "gate injection transistor" (GIT) structure that is a single-chip, Normally OFF device structure, but is not a Cascode. It features stable Vth over the entire temperature range, allows switching up to 1MHz+ and provides a "zero reverse recovery" characteristics. These initial devices are currently in sampling with production scheduled for the fourth-quarter of this year.

Panasonic was also showing four EVBs including a 1kW boost circuit operating at 500kHz, a 1.2kW bridgeless totem-pole PFC section operating at 100kHz, a full-bridge LLC resonant dc-dc converter rated for 1kW switching at 1MHz and a second full-bridge LLC resonant dc-dc converter rated for 1kw and operating at 350kHz. The company also showed laboratory samples of three additional GaN devices, all rated for 600V. A 10A, 147 mOhm device and a 30A, 34 mOhm device both in a TO-220D package and a 15A, 56 mOhm device in a 8x8mm QFN package. Those three devices are expected to enter production in 2015.

Aiming further in the future, ON Semiconductor was showing its comprehensive program started in 2013 to bring GaN-based 650V products to the market in 2016. ON has established a GaN Pilot line leveraging existing silicon manufacturing facilities in Oudenaarde, Belgium. The company has established a 650V GaN D-HEMT platform development program with engineering and production masksets with current/Ron scalability from 1Ohm (2A) down to 38mOhm (50A). And the company is actively engaged with numerous European GaN development programs as well as several R&D partnerships with major power electronic system OEMs. The result of these development activities is expected to be the announcement of GaN-based power modules in 2016.

Cascade Microtech, Inc. announced new additions to round out its power device test and measurement solutions from the engineering lab through production volume. The Ultra High-Power (UHP) probe, coupled with the expansion of thermal chuck capabilities, now supports testing at both high-current and high-voltage with one contact. Recent developments in semiconductor technology, including both GaN and SiC, allow devices to operate at higher voltages and handle higher currents. To fully characterize these devices, manufacturers will need to test efficiently under extreme conditions. The industry is driving new test and measurement capabilities, such as the ability to switch between states and characterize the device in both high-current and high-voltage modes.

The UHP probe has a maximum working voltage of 10 kV at temperatures up to 200 degrees C and 8kV at 300 degrees C to meet the needs of MOSFET and IGBT devices. The probe has a maximum current handling capability of 300 A (allowing 600 A when using two probes in parallel), and is operational up to 300 degrees C to address SiC devices used in automotive and powertrain applications. The UHP probe comes with a selection of probe tips to accommodate different pad sizes.

Automated On-wafer Power Device Probing
Cascade Microtech has also been meeting high-power device measurement challenges in a production environment with the first fully-automated on-wafer probe system. Rated up to 10k V/400 A, the APS200TESLA delivers unmatched electrical performance for high-voltage and high-current device characterization at production speeds. The APS200TESLA allows customers to save time by avoiding unnecessary dicing and packaging prior to final test. By testing on-wafer in a production environment, the APS200TESLA enables customers to reduce test costs and get their products to market faster.

Finally, GaN Systems, Inc. and Efficient Power Conversion Corp. both presented technical papers during PCIM Europe highlighting the benefits of GaN devices. Larry Spaziani from GaN Systems presented a paper at the PCIM Conference entitled „Lateral GaN Transistors – A Replacement for IGBT devices in Automotive Applications“ written by John Roberts, Chief Technical Officer GaN Systems. The paper explains the performance improvements that GaN devices achieve in drive train power requirements for hybrid and electric vehicles.

Worldwide, several groups of researchers are undertaking work on replacing Silicon IGBTs in these applications. Spaziani will present results achieved by GaN Systems' devices, which are based on its unique Island Technology®™ IP. The presentation will include a comparison between the company's products and competitive offerings.

EPC presented three application-focused technical presentations at PCIM Europe. Participants attending EPC sessions learned about the enabling capability of eGaN FETs in 10-MHz buck converters for envelope tracking, how a novel new topology featuring eGaN FETs increases efficiency in wireless power transfer by 20%, and how an optimized parallel layout of eGaN power transistors achieves efficiencies above 96.5% in a 480-W converter. During the conference EPC's CEO, Alex Lidow, also participated in two industry expert panel discussions on the accelerated adoption of wide band gap semiconductors like gallium nitride in a vast array of applications.

Technical presentations featuring GaN FETs by EPC experts included: "Multi Megahertz Buck Converters Using eGaN® FETs for Envelope Tracking," by Johan Strydom; "Improving Performance of High Speed GaN Transistors Operating in Parallel for High Current Applications" by David Reush;"eGaN® FET Based Wireless Energy Transfer Topology Performance" by Michael de Rooij; Podium Discussion: "Mature Wide Band Gap Semiconductors" by Alex Lidow; and "Si vs. SiC/GaN – Competition or Coexistence" by Alex Lidow.

www.darnell.com

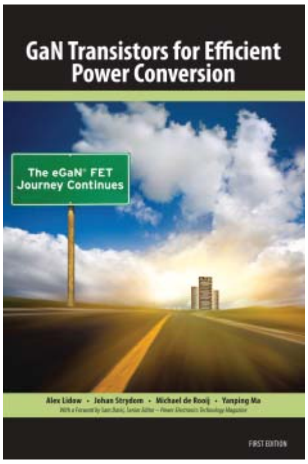
Displacing the Silicon Power MOSFET with eGaN® FETs

By Alex Lidow Ph.D.; Efficient Power Conversion

KEY TAKE AWAYS
Gallium nitride (GaN) transistors will continue to displace silicon power MOSFETs in power conversion applications.

Enhancement-mode devices, such as EPC's eGaN® FETs, are smaller and 10 times faster with comparable cost to power MOSFETs

Four key factors that control the rate at which eGaN FETs will displace power MOSFETs – growth of new applications, ease of use by designers, cost, and reliability.



As discussed previously in *Technology Driving Markets*, gallium nitride (GaN) and silicon carbide (SiC) have started to displace silicon (Si) in power conversion due to higher performance and lower cost. It is anticipated that GaN transistors will continue to become the dominant power device.

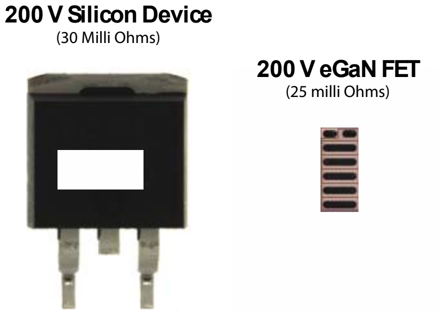
This issue of *Technology Driving Markets* discusses attributes of enhancement-mode GaN transistors that make it a disruptive technology and identifies four factors required for GaN technology to displace the silicon MOSFET as the "power transistor of choice."

Enhancement-Mode FETs – A Disruptive Technology at a Competitive Cost
EPC introduced the first "off-the-shelf" enhancement-mode GaN field effect transistor (eGaN® FET) in mid-2009. These first products were for voltage ratings from 40 V to 200 V, a range that represents 76% of the $6.3B power MOSFET market! Three fundamental attributes eGaN FETs offer the power designer are switching speed, small size and competitive cost.

For comparison, there are two types of GaN transistors – depletion mode (normally "off") and enhancement mode (normally "on"). Depletion-mode devices are inconvenient because, at the startup of a power converter, a negative voltage must first be applied to the control electrode (gate of the device) to avoid a catastrophic failure. Compensating for this inherent limitation requires the addition of a MOSFET, which adds to its cost. An enhancement-mode device, on the other hand, does not have this inherent start-up limitation and does not require a MOSFET be included in its design.

Since their introduction, eGaN FETs have proved to be the simplest and lowest cost GaN device to manufacture since they are processed in a standard silicon wafer foundry using standard, existing silicon processing equipment.

Furthermore, eGaN FETs have a lateral structure, which enables chip-level packaging thus eliminating the need for the costly outer plastic package required by standard silicon MOSFETs. The size comparison between an eGaN FET and a power MOSFET is obvious in side-by-side comparison of equivalent power conversion circuits (see figure). In addition to consuming valuable space in a power conversion system, the plastic packages used by MOSFETs are, on average, 50% of the final power MOSFET's cost.



In addition to this size advantage, the switching speed of eGaN FETs is 10 times faster than the best available silicon transistors. This speed advantage is the reason gallium nitride transistors can increase power conversion efficiency, lower overall system costs, and enable new, exciting applications that are simply beyond the reach of the venerable silicon power MOSFET.

Displacing the Silicon Power MOSFET with eGaN FETs
35 years ago, the silicon power MOSFET was a disruptive technology that displaced the bipolar transistor. The dynamics of this transition taught us that there were four key factors controlling the adoption rate of a new power conversion technology:
1. Does it enable significant new applications?
2. Is it easy to use?
3. Is it VERY cost effective to the user?
4. Is it reliable?

Let's now address each of these questions individually for the next generation of technology – eGaN FETs compared with silicon power MOSFETs.

1. Does it enable significant new applications?
Some examples of large new applications that are made possible primarily because of the higher switching speed of eGaN FETs include:

a. **Envelope Tracking:** This is a power supply technique that can double the energy efficiency of RF power amplifiers used to transmit all of our voice and data through satellites, base stations, and cell phones. Envelope tracking is accomplished by tracking the power demand precisely and providing the power to exactly fit the amplifiers signal modulation needs. Today, RF power amplifiers operate at a fixed power level delivering maximum power whether or not the transmitter needs it. Excitingly enough, eGaN FETs are the first transistors capable of tracking power demands at the high data transmission rates used in 4G LTE networks!

b. **Wireless Power:** Cut the cord! Wireless power transfer enables cell phone, game controllers, laptop computers, tablets, and even electric vehicles to re-charge without being plugged in. A high frequency standard (6.78 MHz) for power transmission is currently being adopted by an industry consortium (A4WP). MOSFETS do not perform well at speeds this fast, whereas eGaN FETs offer an alternative that switches fast enough to be ideal.

c. **LiDAR (Light Distancing And Ranging):** LiDAR uses pulsed lasers to rapidly create a three dimensional image of a surrounding area. This technique is widely used for geographic mapping functions and is technology driving (so to speak) the Google Maps “driverless” cars. The higher switching speed of eGaN FETs drive superior resolution and response time that enable LiDAR applications beyond the mapping functions to applications such as real-time motion detection for video gaming, computers that no longer require touch screens, and fully autonomous vehicles.

2. Is it easy to use?
eGaN transistors from EPC are designed to be very similar in behavior to existing power MOSFETs, and therefore power systems engineers can use their design experience with minimal additional training. To assist design engineers up the learning curve, EPC has established itself as the leader in educating the industry about gallium nitride devices and their applications. As a matter of fact, in addition to publishing over 50 articles and presentations, in 2011 EPC published the industry’s first GaN transistor textbook (in English and Chinese) – GaN Transistors for Efficient Power Conversion. The second edition is being written now and will be published by the world wide textbook publisher, John Wiley, in late 2014. EPC is working with more than 30 universities around the world in order to lay the groundwork for the next generation of highly skilled power system designers trained in getting the most out of eGaN FETs.

3. Is it VERY cost effective to the user?
As noted previously, EPC’s eGaN FETs are produced using processes similar to silicon power MOSFETs and actually have many fewer processing steps than MOSFETs. The only step that is more costly is the growth of the thin “epitaxial” gallium nitride crystal layer on top of a standard silicon wafer. Going forward, improved machine design will mean that this epitaxial growth will not be a significant cost adder. As GaN transistors mature, and taking into account the significant packaging advantage discussed above, the cost of producing eGaN FETs has the potential for being significantly lower than that of MOSFETs – at which point the designer does not even need to take advantage of the higher performance of GaN to realize cost savings in the system!

4. Is it reliable?
GaN on silicon transistors are in the early stages of establishing their reliability. To date, tens of millions of hours of stress testing from several manufacturers suggest this technology is capable of performing at acceptable levels of reliability in commercial applications today. Thus, fast switching speed, small size and competitive cost give the enhancement- mode GaN transistor the attributes to continue to displace the silicon MOSFET. As a measure of their success, GaN FETs are conquering the four factors required to displace the silicon MOSFET as the “power transistor of choice.”

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Freewheeling Diodes for High Performance Inverter Systems

The engineers at Proton-Electrotex developed freewheeling diodes to operate at the reverse recovery process with high change rate of reverse recovery current (dI_{rrm}/dt), and high power supply reverse voltage (V_R) by means of proton irradiation technology, sintering technology and implementation of n'-buffer. The diodes are designed to be used as reverse diodes for high voltage stacks assembled using IGBT and IGCT.

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Complex circuits of multilevel voltage inverters assembled using power press-pack IGCT and IGBT require corresponding complementary diodes. Conventional fast recovery diodes have dynamic limitations at operating in similar circuits. They decrease inverter efficiency and reliability making cost higher.

To increase inverters efficiency by means of lowering power losses of IGBT at turn-on it is necessary to execute its commutation at high rate of rise of on-state current (dI/dt), which for modern IGBT reaches 10 000 A/µs. However complementary diodes are required to have same change rate of reverse recovery current (dI_{rrm}/dt), which for conventional fast recovery diodes equals 500 A/µs.

That is why to get all the advantages of the modern IGBTs and IGCTs, which ensure increased inverters efficiency, it is necessary for the complementary diodes to have the following requirements:

- increased change rate of reverse recovery current (dI_{rrm}/dt);
- low reverse recovery current (I_{rrm});
- improved reverse recovery softness (s);
- possibility to operate without snubber RC circuits;
- resistivity to snappy effect and dynamic avalanche breakdown;
- high operating temperature.

During the process of reverse recovery of the diodes in such modes there can occur the following problems:

- snappy-effect of the excess electrons and holes charge in n^--base of the diode during reverse recovery process. During the second phase of the reverse recovery diode has a very high density of reverse current in the n^--base, which is being supported by means of recombination of residual charge of excess electrons and holes accumulated in the n^--base earlier during direct current flow. Since voltage is very high, then rate of rise of reverse voltage in the second phase is high as well, that is why shifting process of the excess holes is accompanied by rapid increase of the thickness of space charge region of p-n-junction. Space charge region boarder moves inside the base, the holes are being captured by the field of p-n-junction and shifted into p^+-emitter. For conventional diodes, as a rule, a similar process of appearance and expansion of high-field domain adjacent to n^+-layer is carried out, and this pseudo-space charge region by expanding captures the electrons out of the n^--base. If both these areas contact a snappy effect of excess electrons and holes occurs in the n^--base, which is being accompanied by extremely rapid reverse recovery current drop what leads to voltage outburst, which, as a rule, exceeds avalanche breakdown voltage of the diode. Even if the diode has resistivity to avalanche breakdown and is still operating, such mode leads to appearance of extremely high frequency electromagnetic noise, which is not acceptable for the majority of the modern equipment, because it generates the conditions for failure of drivers;
- dynamic avalanche breakdown. In the second phase of recovery through space charge region of p-n-junction there is a high hole current flow. Holes transmission speed is limited and equals about $0.8*10^7$ cm/s that is why holes current flow is accompanied by generation of additional positive charge in space charge region (mobile holes). For example if current density equals 30 A/cm^2 (i.e. current 600A for the diode with diameter of silicon element 56mm and 1200A for the diode with diameter of silicon element 80mm) additional concentration will be $2{,}34*10^{13}$ cm^{-3}, which is similar to concentration of ionized donors for the diode on silicon wafer with electrical resistivity 200 Ohm*cm. Presence of this moving additional charge in space charge region of p-n-junction leads to the decrease in avalanche breakdown voltage. The problem is not that there is a physical process of avalanche in p-n-junction, but that in this mode the large area diode is biased to reverse recovery current filamentation, which leads to its failure.

That is why this is a relevant objective to develop high voltage soft recovery diodes with expanded safe operating area during reverse recovery adapted to operate with high power IGCT and IGBT.

It is well-known that [1, 2] there is a novel technology, which allows developing soft fast recovery diodes that are resistant to snappy effect and applicable for operation in wide range of reverse voltage values (V_R) and change rate of reverse recovery current (dI_{rrm}/dt). It is fabrication of axial inhomogeneous distribution of carrier lifetime (τ) in semiconductor element. For conventional diodes with p-n^--n^+-element it is necessary to lower lifetime value in lightly doped layers close to p-n-junction and increase in the area of n^- - layer adjacent to n^+ - layer.

Despite the huge number of successful applications of such approach to produce soft high voltage diodes the question of detailed type of ideal axial inhomogeneous distribution of carrier lifetime (t) is still open [3 - 6]. There are two main reasons for that:

1. Technical level of high power fast recovery diode can be characterized by repetitive peak reverse voltage (V_{RRM}), voltage forward drop (V_{FM}), reverse recovery charge (Q_{rr}), reverse recovery energy losses (E_{RQ}), reverse recovery current (I_{rrm}), reverse recovery soft-

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ness (s). If V_{RRM} and V_{FM} are fixed as some constant values then the technical level of fast recovery diode will be the higher the less Q_{rr}, E_{RQ}, I_{rrm} and the higher s. Experience has shown that type of axial inhomogeneous distribution of carrier lifetime (τ), ideal from the minimization of Q_{rr} and E_{RQ} point of view, differs from axial inhomogeneous distribution of carrier lifetime (τ) ideal from minimum Irrm point of view and maximum s. For example, fabrication of axial inhomogeneous distribution of carrier lifetime (τ) of steplike type with very low value of t in p-n-junction area and very high value of τ in the remaining area of n^--layer allows having high softness (s) and low values of reverse recovery current (I_{rrm}), however Q_{rr} and E_{RQ} values are far from ideal due to the presence of long tail of reverse recovery current in the process of reverse recovery. In such a way, form of ideal distribution of carrier lifetime (τ) is determined by certain requirements set for combination of Q_{rr}, E_{RQ}, I_{rrm} and s of power diode.

2. Limitations of usage of one of the fabrication technologies of axial inhomogeneous distribution of carrier lifetime (τ). To have an inhomogeneous distribution of carrier lifetime (τ) atoms diffusion of noble metals (gold, platinum) is usually used, or irradiation with light high energy ions (hydrogen, helium etc.). In case of usage of atoms doping of noble metals possibilities of carrier lifetime distribution form variations are limited. Irradiation with light ions has more options to change this distribution. It is known that at the end of light ion path in semiconductor a local area with extremely low carrier lifetime appears. Therefore varying ion energy spectrum during irradiation it might seem easy to have carrier lifetime distribution of any form. However, as proven by detailed investigations [7, 8], space distribution of carrier lifetime (τ) generated during irradiation with monoenergetic ions significantly differs from δ–function or narrow Gauss distribution as a result of radiation damage of smaller layers of the semiconductor than ion path depth as well as due to diffusion of ion energy spectrum during passing through semiconductor layers. As a result, these effects set certain limits on possibilities to fabrication required distributions of carrier lifetime (τ).

Further the investigation results of characteristics combination optimization of V_{FM}, Q_{rr}, E_{RQ}, I_{rrM}, S of high voltage fast recovery diodes by means proton irradiation technology for fabrication of inhomogeneous distribution of carrier lifetime are being described [8].

Design and Process Features of High Power Freewheeling Diodes

High power freewheeling diodes produced by Proton-Electrotex are designed for current from several hundred up to several thousand amperes and voltage from 1000 up to 4500 volt. A round semiconductor element has a diameter from 24 up to 100 mm for different types of the diodes.

To ensure electric thermal cycling resistivity of the large area diodes the following features were taken:

- semiconductor element is joined with molybdenum disc;
- semiconductor element connected with molybdenum disc is encapsulated in press-pack metal-ceramic case.

The described design allows simultaneously ensure high electric thermal cycling resistivity, low thermal resistance, high energy ratio to accumulate energy loss in pulse and emergency modes.

Adjustment of Q_{rr}, E_{RQ}, I_{rrM}, S characteristics is done with the help of proton irradiation. There was used a proton beam with initial energy of 24 MeV. The beam was streamed in the air and with the help of special baffles was partially dissipated to generate the working area enough for irradiation of large area semiconductor elements. Final adjustment of the proton path depth in the semiconductor element was done with the help of plug-in aluminum baffles with various thickness. The described technology allows irradiating of semiconductor elements with diameter up to 125 mm at a depth of 1000 µm with 15 µm adjustment interval for the proton path depth. In the figure 1 there is a diagram of typical distribution of carrier lifetime after proton irradiation.

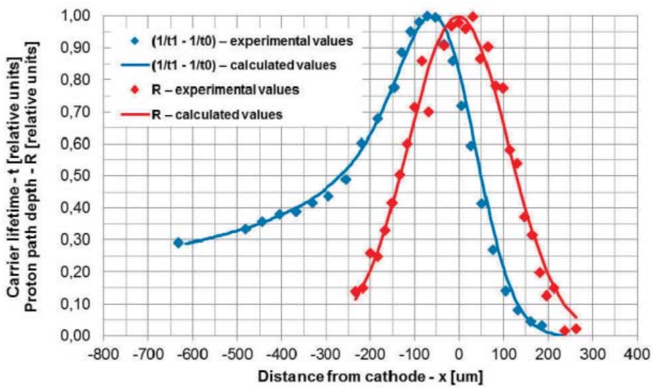


Figure 1: Typical relative carrier lifetime distribution ($1/\tau_1$-$1/\tau 0$) and proton path depth R_p in semiconductor element after proton irradiation with initial energy of 24 MeV. τ_1 and τ_0 – carrier lifetime values before and after irradiation.

Conventional production technology means joining the semiconductor element with the molybdenum disc by means of alloying – high temperature vacuum soldering using Al-Si-discs. To get a reliable ohmic contact it is necessary to join molybdenum disc with the surface of p-type connectivity (anode surface), because this connection partially dissipate the surface layer of silicon with consecutive generation of p^+-type connectivity after cooling of the recrystallized surface layer.

After joining high thickness of the molybdenum disc do not let irradiation process to be done from the side of anode surface. Proton irradiation of the semiconductor element before joining with molybdenum disc is impossible as well, since the joining process is undergoing with high temperature of about 700 0C.

In such a way the diodes with conventional design can be irradiated with the protons only from the side of cathode surface, which is quite a serious limitation from the point of possibility of optimization carrier lifetime distribution form. During fabrication the layer with decreased carrier lifetime value near the p-n-junction the protons have to preliminary go through all n-type conductivity layers, i.e. through the major part of the semiconductor element. After that there is quite a smooth carrier lifetime distribution and its values near the p-n-junction cannot be decreased lower than 0,2-0,3 of the value close to the n^+-layer border. In the figure 2 (a) there is a typical carrier lifetime distribution during proton irradiation through the cathode surface of the semiconductor element.

In order to expand variations of carrier lifetime distribution form the technology of joining semiconductor element with molybdenum disc was changed using silver paste [9]. The joining process using this technology is carried out at temperature about 250 0C, which allows proton irradiation before joining with molybdenum disc, as well from the anode side of the semiconductor element surface. Furthermore, the protons do not get into the layers of the semiconductor element close to the cathode surface, that is why generation of carrier lifetime with higher asymmetry comparing to the conventional semiconductor elements technology. In the figure 2 (b) there is a typical carrier lifetime distribution during proton irradiation through the anode surface of the semiconductor element.

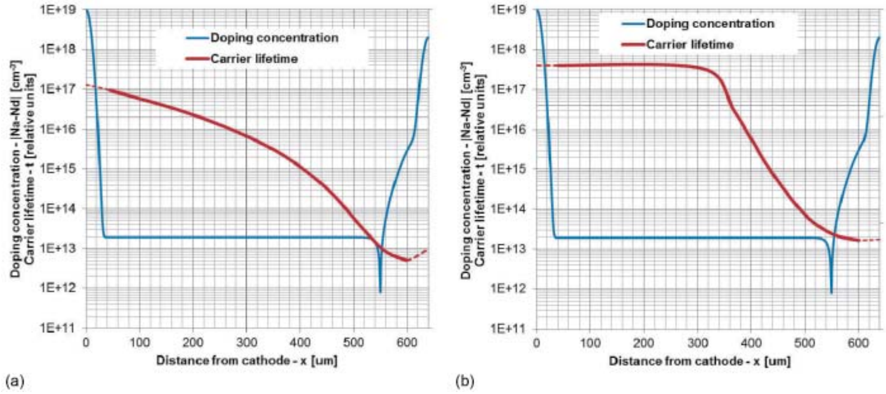


Figure 2. Typical carrier lifetime distribution (t) during proton irradiation through the cathode surface of the semiconductor element (a) and during proton irradiation through the anode surface of the semiconductor element (b)

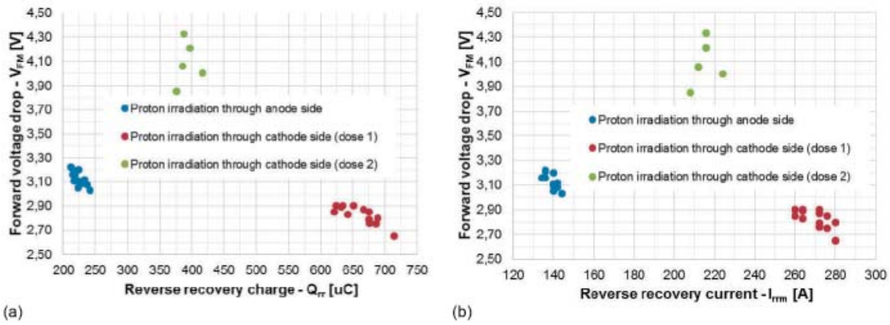


Figure 3: Correlation of V_{FM} / Q_{rr} (a) and V_{FM} / I_{rrm} (b) for the experimental diodes (proton irradiation from the anode side) comparing to the diodes produced using the conventional technology (proton irradiation from the cathode side)

Characteristics	V_{BR}	I_{RRM}	V_{FM}	I_{rrm}	Q_{rr-i}	Q_{rr}	Notes
Measure unit	V	mA	V	A	μC	μC	
Testing modes	T_j = 25 °C	V_{RRM} = 4500 V, T_j = 140 °C	I_{FM} = 2500 A, T_j = 140 °C	T_j = 140 °C, I_{FM} = 1000 A, dI_{rrm}/dt = - 100 A/μs, V_{RDC} = 100 V			
SCE number							
9Ag/12672	5700	56	3.12	142	1032	233	Experimental diodes
10Ag/12672	5800	53	3.21	136	941	214	
11Ag/12672	5600	61	3.16	136	950	218	
12Ag/12672	5700	56	3.16	134	948	215	
13Ag/12672	5700	56	3.03	144	1019	242	
14Ag/12672	5700	60	3.11	140	982	222	
15Ag/12672	5700	65	3.09	140	999	229	
16Ag/12672	5700	75	3.08	142	1019	237	
17Ag/12672	5700	57	3.05	140	1009	223	
18Ag/12672	5700	70	3.11	140	990	217	
19Ag/12672	5600	71	3.22	136	931	212	
20Ag/12672	5700	63	3.20	140	365	224	
1/12674	5900	28	2.76	272	1077	676	Conventional technology diodes (dose 1)
2/12674	5850	27	2.65	280	1136	714	
3/12674	5840	32	3.54	236	758	481	
6/12674	5890	30	2.87	272	1068	667	
7/12674	5980	29	2.85	276	1081	675	
8/12674	5900	32	2.85	260	1003	621	
9/12674	5890	30	2.76	272	1066	676	
10/12674	5900	32	2.89	264	997	632	
11/12674	5780	33	2.90	264	1015	635	
12/12674	5980	29	2.90	272	1028	651	
13/12674	5900	29	2.80	280	1104	689	
14/12674	5900	29	2.79	272	1068	675	
15/12674	5950	30	2.83	264	1040	642	
16/12674	5900	31	2.90	260	998	624	
19/12674	5780	28	2.75	276	1095	686	
17/12674	5780	37	4.06	212	608	386	Conventional technology diodes (dose 2)
18/12674	5400	49	3.85	208	599	376	
20/12674	5620	43	4.00	224	664	416	
21/12674	5800	54	4.33	216	627	387	
22/12674	5900	51	4.21	216	631	397	

Table 1: Electrical Characteristics of the Diodes

Experimental Samples
To evaluate the offered constrictive technological solutions, which are planned to be used for mass production, the experimental diode samples were produced with semiconductor element 56 mm in diameter designed for repetitive reverse voltage 4500 V and average current 800 A. The diodes were produced with the wafers of neutron transmutation doped silicon with electrical resistivity 250 Ohm*cm and thickness 640 µm.

1. The diodes with conventional design were produced using technology of alloying the silicon wafer with molybdenum disc. The proton irradiation was done after alloying from the side of cathode surface. The proton irradiation was done with two various doses in order to ensure the most complete base to compare with the experimental diodes. The carrier lifetime distribution form (t) in the semiconductor element corresponded to the figure 2 (a).

2. The experimental diodes were produced using proton irradiation from the side of anode surface, after which the joining of silicon wafer with molybdenum disc was done by means of sintering technology using silver paste. The carrier lifetime distribution form (τ) in the semiconductor element corresponded to the figure 2 (b).

Experimental Results
The obtained electrical characteristics of the diodes are shown in the table 1. Analyzing these characteristics it is, first of all, necessary to note that the experimental diodes have significantly lower values of I_{rrm} and Q_{rr} (second phase of reverse recovery – reverse current drop – chord approximation through the points $0,9*I_{rrm}$ and $0,25*I_{rrm}$). In the figures 3 (a) and 3 (b) correlation of V_{FM} / I_{rrm} and V_{FM} / Q_{rr} for the experimental diodes are shown in comparison with the diodes produced using conventional technology. However, correlation of VFM and integral reverse recovery charge (Qrr-i) for both groups of the diodes is almost the same, as shown in the figure 4.

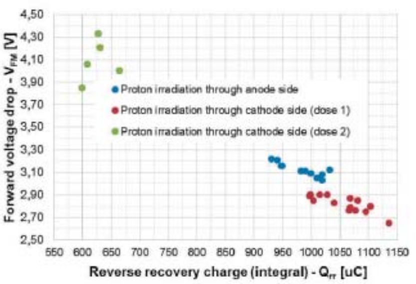


Figure 4: Correlation of V_{FM} / Q_{rr-i} for the experimental diodes (proton irradiation from the anode side) comparing to the diodes produced using the conventional technology (proton irradiation from the cathode side)

In the figure 5 there is a circuit of experimental equipment, which was used to study the reverse recovery characteristics at high change rate of reverse recovery current (dI_{rrm}/dt) and high power supply reverse voltage (V_R). Direct current pulse was formed during discharge of oscillating circuit L1-C1, commuted by the thyristor VS1. The current pulse with adjustable amplitude (0 – 2000 A) and 1ms period is being ap-

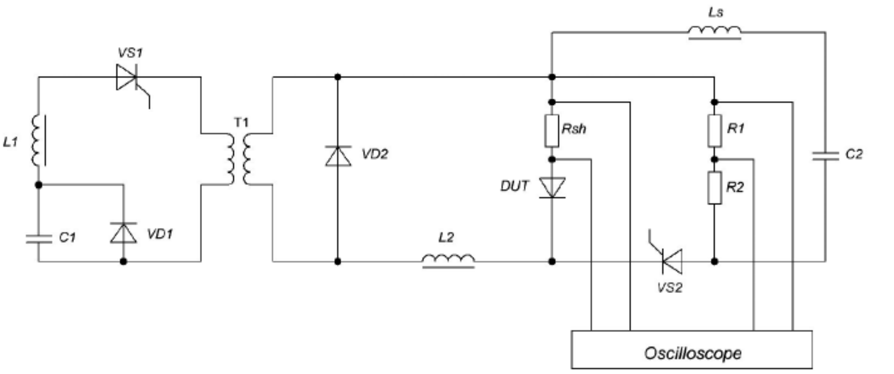


Figure 5: Circuit of experimental equipment to study the reverse recovery characteristics at high change rate of reverse recovery current (dIrrm/dt) and power supply reverse voltage (VR)

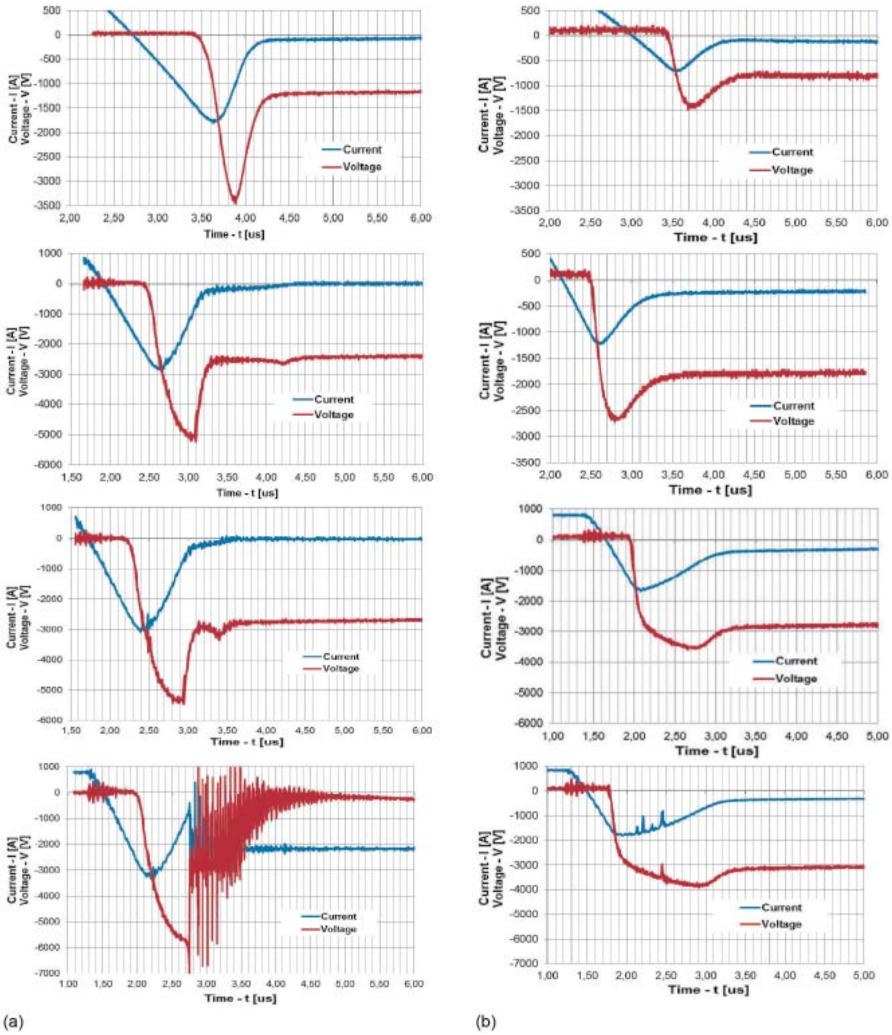
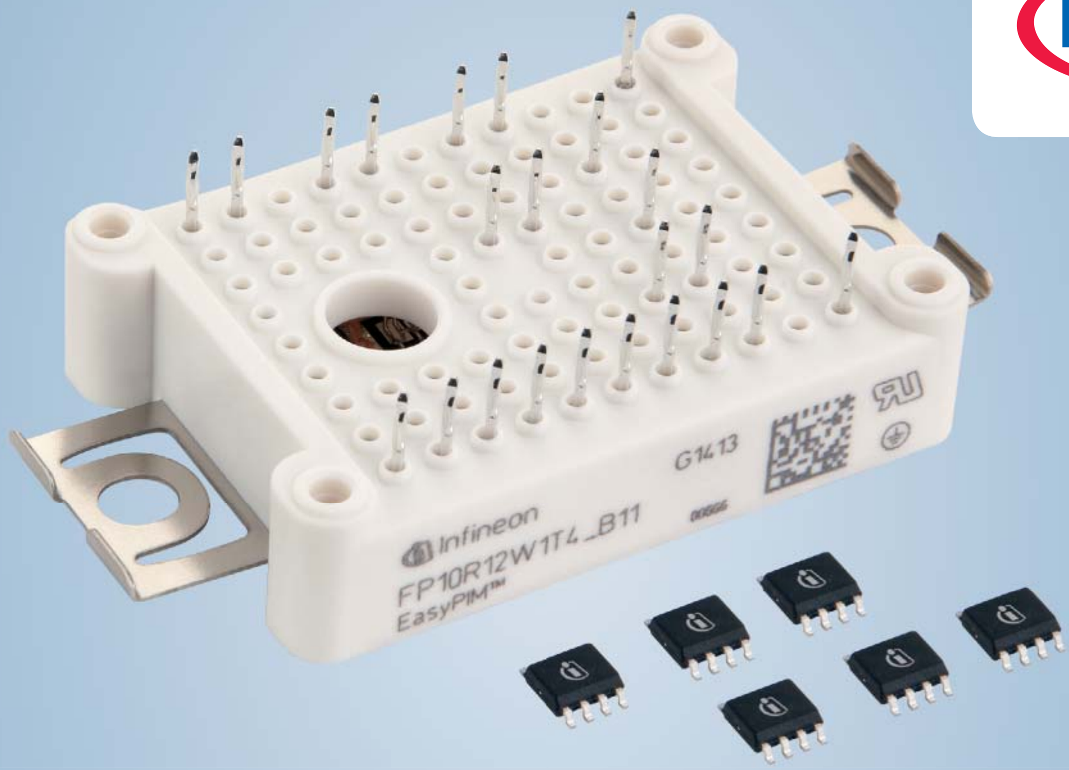


Figure 6. Oscillograph records of anode current and voltage during reverse recovery for the diodes produced using the conventional technology (a) and experimental diodes (b) at various reverse voltage values V_{RDC}.



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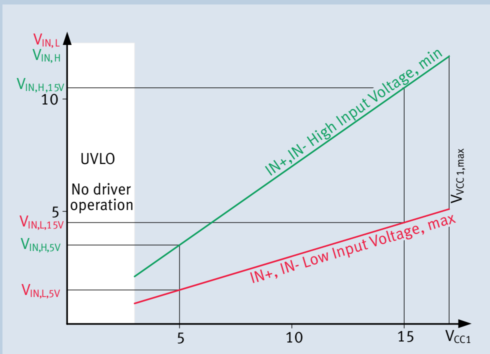

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plied to the tested diode through the pulse transformer. At the moment when direct current reaches its maximum thyristor VS2 commutes the charge in low inductance contour C2-Ls (Ls ~ 0.5 μH), which ensures reverse recovery of the tested diode. Reverse recovery of the tested diode is done in snubberless mode, reverse voltage (V_{RDC}) was adjusted in range of 500 – 3000 V. As a result, changing VRDC it was possible to adjust the change rate of reverse recovery current in range of 1000 – 5000 A/μs.

Typical oscillograph records of anode current and voltage during reverse recovery produced using conventional technology at various reverse voltage values V_{RDC} are shown in the figure 6 (a),

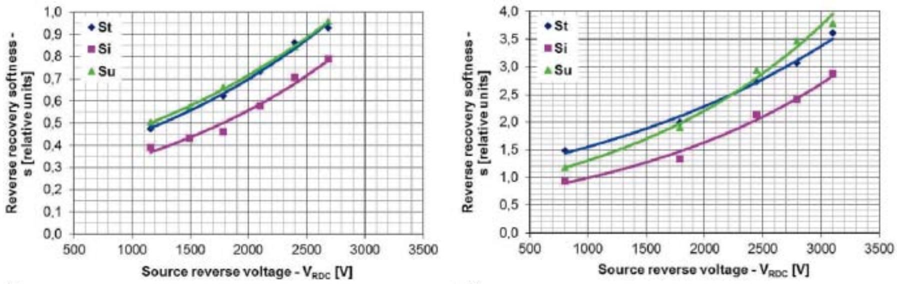
There was a breakdown of the diodes produced using the conventional technology in the range of reverse voltage values V_{RDC} = 2600-2800 V, which was accompanied with the destruction of the semiconductor element. The typical oscillograph records of the anode current and voltage during the breakdown are shown in the figure 6 (a, the last one).

Typical oscillograph records of anode current and voltage during reverse recovery of the experimental diodes at various reverse voltage values V_{RDC} are shown in the figure 6 (b).

It is worth mentioning that the experimental diodes were stable and fail-safe operating till the reverse voltage value V_{RDC} ~ 3200 V. Reverse recovery softness value was over 1 (figure 7 (b)).

Moreover, total reverse voltage value (V_{rrm}) at all modes of reverse recovery was not exceeding 4000 V (figure 8), i.e. the experimental diodes are fit for operation in snubberless circuits in complementary pair with IGCT and IGBT calculated for the repetitive pulse voltage of 4500 V.

There are the formulas 1,2 and 3, which were used to calculate the reverse recovery softness values:



(a) (b)

Figure 7: Typical dependencies of reverse recovery softness on power supply reverse voltage V_{RDC} for the diodes produced using the conventional technology – proton irradiation from the cathode side (a) and for the experimental diodes – proton irradiation from the anode side (b).

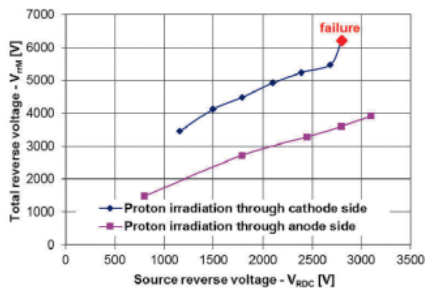


Figure 8: Dependencies of the total reverse voltage (Vrrm) on power supply reverse voltage (VRDC) for the diodes produced using the conventional technology and for the experimental diodes.

$s_t = t_s / t_f$ (1);

$s_i = |(di/dt)_f^{max} / (di/dt)_s|$ (2);

$s_u = V_{RDC} / (V_{rrM} - V_{RDC})$ (3).

Conclusion

Based on the above presented design and process approaches and made investigations the range of the freewheeling diodes was developed adapted to operate in complementary pair with the commercial IGBT and IGCT. Main electrical and thermal characteristics of such diodes are shown in the table 2.

Such diodes allow getting new advantages to engineering of inverters for induction heating systems and motor drives systems due to compliance with all necessary requirements for reliable operation with the modern press-pack IGCT and IGBT:

– increased change rate of reverse recovery current (dIrrm/dt);
– low reverse recovery current (I_{rrm});
– improved reverse recovery softness (over 1);
– possibility to operate without snubber RC circuits;
– resistivity to snappy effect and dynamic avalanche breakdown;

Device Description	V_{RRM}	I_{RRM}	V_{RDC}	I_{FAV} (T_C)	I_{FSM} (T_{jmax}, 10 ms)	$V_{F(TO)}$	r_T	I_{rrM}	Q_{rr}	T_{jmax}	R_{thjc}	Ø max Ø contact/ height
	V	mA	V	A (°C)	kA	V	mOhm	A	µC	°C	°C/W	mm
DF853-1000-46	4600	80	2800	1 390 (70)	18	1,25	0,45	800	3000	140	0,0180	75/51/26
								Tj = 140 °C; It = 1 kA; -dIt/dt = 250 A/µs; V_R = 1000 V				
DF873-1600-46	4600	100	2800	1 600 (70)	23	1,78	0,97	1500	3500	140	0,0080	112/75/26
								Tj = 140 °C; It = 2,5 kA; -dIt/dt = 1000 A/µs ; V_R = 2800 V				

Table 2: Main Electrical and Thermal Characteristics of the Developed Diodes

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Efficient Microcontroller Peripheral Modeling with PLECS

Microcontrollers play an integral part in controlling modern power electronic systems. Often, for system level simulations, the peripheral modules are simplified to improve overall simulation efficiency. In this study, efficient modeling of high fidelity peripheral models is discussed and the advantages of simulating power electronic systems with these models have been investigated in detail using PLECS.

By Felix Prausse, Plexim GmbH, and Munadir Ahmed, Plexim Inc.

Introduction

Microcontroller units (MCUs) are often used to control modern power electronic systems. They typically contain Analog-to-Digital Converter (ADC) peripheral modules for reading sensor signals and Pulse Width Modulator (PWM) peripherals for converting the outputs of the control algorithms to switch gating signals.

When modeling power controls at the system level with a circuit simulator such as PLECS, the focus is typically on modeling the algorithms, while models for MCU peripherals are often idealized to improve overall simulation efficiency and speed. In fact, frequently, the ADC peripheral modules are modeled as simple sample-and-hold blocks, and basic pulse generators are used for generating PWM waveforms. These simplified models have inherent limitations in comparison to the functionality provided by the real peripheral modules. As a result, the fidelity of the system model is substantially reduced and effects that are critical to the power controls may be lost or inaccurately simulated. Furthermore, the limited functionality provided by basic peripheral models may be insufficient to model advanced modulation and sampling techniques.

For example, typical PWM modules provide the flexibility to trigger start of conversion (SOC) of the ADC module at different events. For systems with high current or voltage ripple, this provides engineers the ability to sample the ADC inputs at a desired instance of the PWM waveform. Both the PWM and ADC modules can be used to trigger the control interrupt as would be done in the real system. Additionally, with high fidelity peripheral models (HFPMs) engineers can verify the effect of their PWM and ADC configuration on the overall system. It is therefore desirable to utilize detailed peripheral models to more accurately reflect the complex functionality offered by an MCU to facilitate the implementation of sophisticated control strategies. However, it is critical that such peripheral models are implemented in the most efficient fashion to ensure that their impact on simulation time is minimal.

In this article, an efficient approach to detailed peripheral modeling using PLECS is presented for a Pulse Width Modulator. Subsequently, the modeling of a specific ePWM module from Texas Instruments (TI) is discussed. A current-controlled buck converter with high fidelity PWM and ADC models is investigated. To illustrate the advantages of HFPMs, an inexpensive shunt current measurement is modeled. Such a configuration requires sampling the current while the diode is conducting. This can be achieved by having the PWM peripheral trigger the ADC peripheral, which in turn triggers the control algorithm.

Efficient peripheral modeling using PLECS

Two major types of solvers are available to simulate power electronic systems. A fixed-step solver discretizes the modeled system to a user-specified step size. The solver does not have the ability to change the step size during the simulation to meet the accuracy requirements of the system. In the context of modeling a PWM module, the step size must be chosen to have enough resolution to capture the duty cycle, period, and dead time effects accurately. This would result in a step size defined by the counter period (e.g. 10 ns for a peripheral clocked at 100 MHz) and therefore result in a very inefficient simulation. To achieve higher simulation efficiency, the step size must be increased to multiples of the counter period at the expense of the available PWM resolution.

The second class of solvers is the variable-step solver that has the ability to change the step-size during simulation. This dynamic nature allows a more efficient modeling of the PWM module. The solver takes steps ranging from small multiples of the counter period when capturing dead time effects to large multiples of the counter period to capture the duty cycle and period of the generated PWM signal. Compared to a fixed simulation step, this allows the user to model the PWM module with enhanced functionality very efficiently.

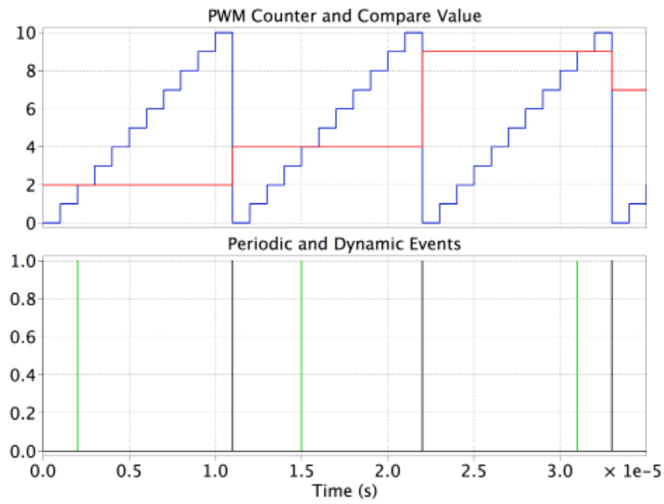
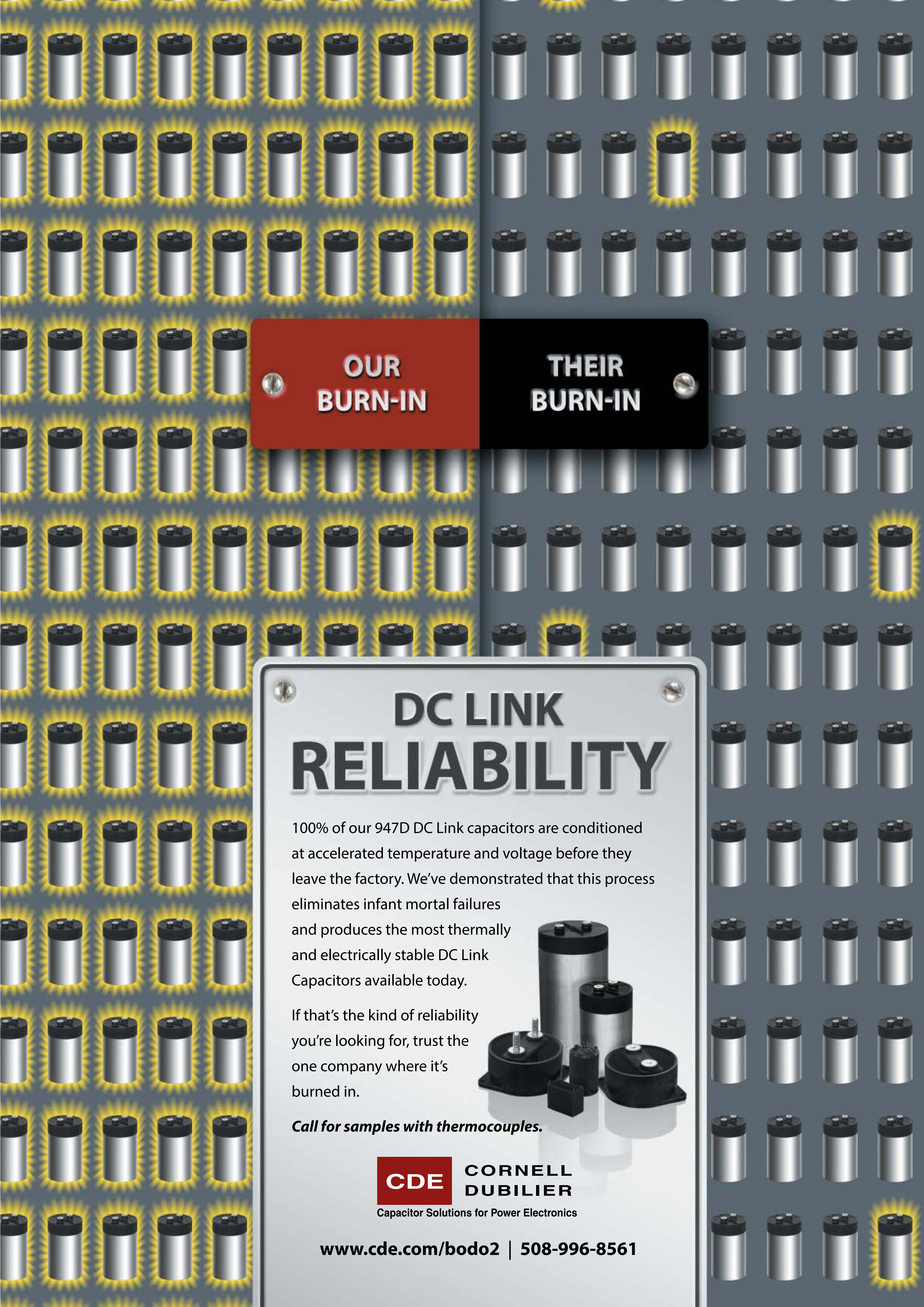


Figure 1: Typical counter behavior of a PWM module

Figure 1 shows a typical behavior of an actual PWM counter (blue trace) running with a fixed period. The compare value (red trace) is changed at every period of the PWM. In a typical modulator, the PWM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outputs are changed at certain events that could either be periodic or dependent on an external configuration. In this particular case, the dynamic events (green trace) are determined by the compare value, while the periodic events (black trace) are determined by the PWM period. For a high fidelity PWM model, with a full duty cycle resolution, we either need a fixed-step solver with a step size defined by the counter period or a variable-step solver and the ability to invoke a solver step at every periodic and dynamic event.

The features required for the efficient modeling of HFPMs are available in the C-Script block in the PLECS component library. This block allows users to develop custom controllers and components for use in their simulation. It provides the advanced capabilities of the C programming language combined with the flexibility of using variable and/or fixed sample time settings.

A fixed sample time for a C-Script means that the block is evaluated with a specified period. A variable sample time gives the user the ability to manually specify the next evaluation of the C-Script block. This makes the C-Script a versatile tool that is well suited for the efficient development of high fidelity peripheral models.

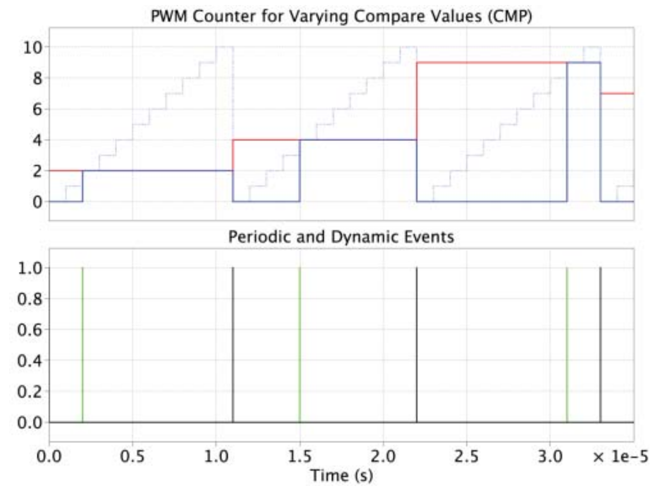

Figure 2: Efficient implementation of a PWM behavior

For the efficient modeling of a PWM module, the C-Script block is defined to use a fixed sample time, which determines the periodic events (black trace) at the PWM period. At those events, the time for the next dynamic event (green trace) is calculated and the solver evaluates the block at that instant using the variable sample time of the C-Script block.

This allows the PWM model to be evaluated at only the relevant points in time and therefore is the most efficient approach for implementing a high fidelity PWM. As seen in Figure 2, the modeled counter value (blue trace) is only updated at those instants, but coincides with the actual counter value (dotted trace). This approach achieves the full PWM resolution without requiring a very inefficient sampling of the model based on the counter period.

Modeling of a TI ePWM (Type 0) module in PLECS

A Type 0 ePWM module from TI's C2000 series was modeled in PLECS. This module is capable of generating two independent PWM output signals. It also includes functionality provided by an Event Trigger submodule that can be used to dynamically trigger ADC conversions and/or control interrupts. Furthermore, it contains a Deadband submodule that can be configured to invert the PWM outputs or to implement a dead time between the two outputs.

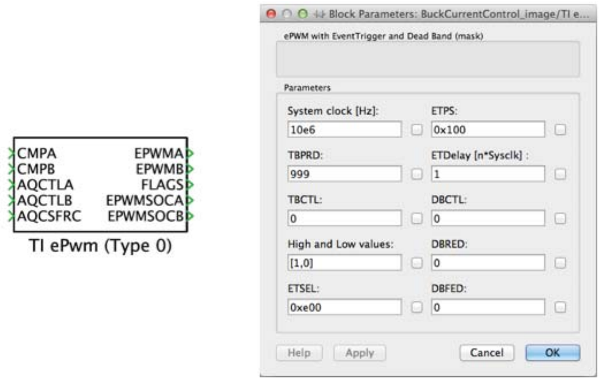

Figure 3: Model of a TI Type 0 ePWM module implemented in PLECS

Figure 3 shows a PLECS model of the ePWM module and its parameter mask. The block's configuration is split into static and non-static parameters. Users can specify general static parameters such as the basic counter period (System Clock), the PWM period (TBPRD) and the behavior of the counter (TBCTL) in the mask parameters. Furthermore, the ETx parameters define the behavior of the Event Trigger submodule and the DBx parameters can be used to configure the Deadband submodule. These parameters directly correspond to the registers used in the hardware and can be entered as integer, binary or hexadecimal values. This gives the user the ability to test a hardware configuration in a simulation environment.

The two counter compare inputs (CMPA and CMPB) define the dynamic events of the ePWM model and the Action Qualifier Control Registers (AQCTLx) inputs are used to configure the actions at those events. For example, the output EPWMA can be configured to be set high when the counter equals CMPB and reset at the PWM period. The registers are implemented as inputs to the ePWM block, and can may be modified while the simulation is running.

More detailed information on the Type 0 ePWM module and its configurations is found in the TI technical reference guides, available on the TI website.

Simulation results

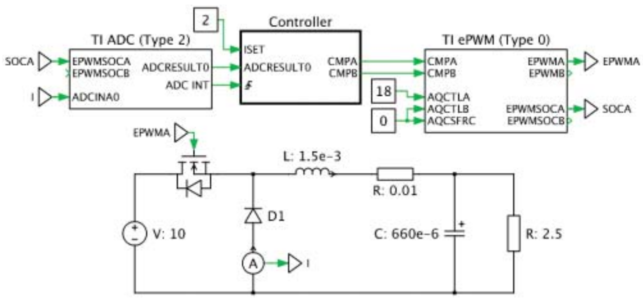

Figure 4: Current-controlled buck converter with peripheral models

To further illustrate the advantages of HFPMs, a current-controlled buck converter was developed with the above discussed ePWM module as well as a HFPM for a TI type 2 ADC module. As seen in Figure 4, the current measurement is realized using a simple shunt resistor (moldeled here as an ammeter) in series with the diode. Such a configuration requires the current to be sampled while the diode is conducting, ideally at the center of the conducting phase.

The ePWM is configured to operate in up-counting mode with a frequency of 10kHz. Furthermore, the EPWMA signal is configured to be set high when the counter equals zero and set low when a CTR = CMPA event (green trace) occurs as defined by the AQCTLA register. Fig. 5 shows the resulting characteristics of the ePWM module. As already mentioned, this block is only evaluated at the relevant points in time and therefore the counter value is only updated at those instants.

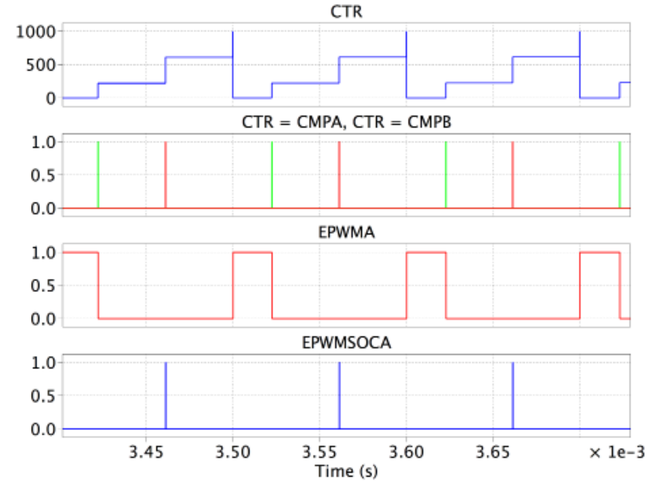

Figure 5: PWM modulation and conversion trigger based on the ePWM model

Additionally, the internal Event Trigger module is configured to invoke an EPWMSOCA trigger for every CTR = CMPB event (red trace). This is used to trigger an ADC SOC for current measurement, as seen in Figure 4. Once the measurement is finished, an ADC interrupt is generated to trigger the controller, which then updates the CMPA and CMPB registers for the ePWM module.

Figure 6 shows the actual diode current (red trace) and the sampled current (blue trace) during the startup transient. As shown, the ADC is always triggered to measure the current at the midpoint of the interval during which the diode is conducting current. The graph also shows the EPWMSOCA signal used as the SOC trigger for the ADC module.

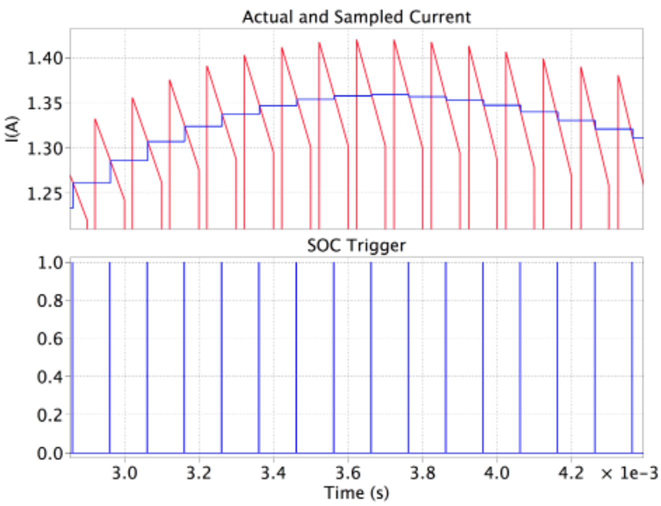

Figure 6: Current measurement invoked by the ePWM module

The HFPM allows users to develop a model that is a closer representation of the real system. Further, the proposed implementation enables an efficient integration into a system level simulation without limiting the PWM resolution or the supported functionalities.

Conclusion

Often in circuit simulators, PWM and ADC modules in MCUs are modeled simply as pulse generator and sample-and-hold blocks, respectively. This simplification limits the functionality of the MCU model as compared to the real hardware. In PLECS, the C-Script block along with a variable-step solver provides efficient and accurate means to develop high fidelity peripheral models. Such models provide power electronic engineers the ability to simulate the effects of different peripheral configurations on the overall system. The buck converter with high fidelity peripheral modules discussed in this article is provided as a PLECS Application Example and can be further explored using the Demo Mode of PLECS Standalone from the following link:

www.plexim.com/support/application-examples

To download PLECS Standalone, please visit:

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Sensor Module Ensures Optimum Battery Utilisation in Heavy-Duty Vehicles, called omniMoves

Precise battery diagnostics makes manoeuvring large, heavy-duty loads easier

Isabellenhütte's shunt-based IVT Modular sensor module measures the basic battery components' current and voltage with an error rate of less than 0.1 per cent. This exceptional degree of accuracy provides for consistent power control and efficient utilisation, especially for high-capacity battery systems. This is the reason why KUKA Roboter GmbH standardly equips their mobile platforms for heavy, difficult-to-transport loads with IVT sensor modules.

By Henning Meckel, Application & Sales Engineer Precision Measurement, Isabellenhütte

Components and manufacturing tools used to construct aircraft, wind turbines and rail vehicles can weigh up to 100 tonnes. Despite the great weight and occasionally large dimensions of these loads, workers need to be able to flexibly transport and precisely manoeuvre them, within a production shop for instance. In addition to crane technologies, manufacturing companies also use mobile platforms, which rank among heavy-load vehicles, for in-plant transport. These mobile platforms make it possible to transport loads that are otherwise extremely difficult to move on the ground without it becoming necessary to convert the production shops, which is the case with crane systems. The mobile platforms can also be moved with a high degree of flexibility and precision in any direction between the different working positions and workstations. This reduces the floor space required for logistical processes and guarantees more space for the production area.

KUKA's omniMove platform design stands apart because it achieves an ideal level of manoeuvrability for guiding heavy loads in any direction and is able to rotate about its own axis. "With omniMove, it is possible to move heavy parts in a very small space with extreme precision – with 360-degree flexibility and positioning accuracy of ± 2 millimetres," said Paul Wyszynski, developer at KUKA Roboter GmbH. "The omniMove's lifting platform version means that omniMove itself can move within a range of millimetres even in a raised position, a feature useful for painting and coating aircraft, for example," Wyszynski added. The mobile platform is also used to transport gas turbines the size of a single-family house between the individual production areas or to the test area. The freely scalable modular platform system varies in height, width and length and can be combined with other vehicles for a dual- or triple-vehicle transport configuration. This also makes it possible to transport loads such as an entire aircraft body. The system can be operated by remote control, by optical steering and guidance or completely autonomously with laser scanners.

Precisely calculated battery capacity, high utilisation rate

The omniMove's electric drive concept is highly efficient, quiet and can operate for prolonged periods. The KoM UTV-2 E375 model, for example, has a minimum operating time of four hours. For technical and economic reasons, it is essential that a heavy-load vehicle's available power can always be used efficiently. This is the reason why the lead-gel batteries standardly used in omniMove are equipped with current and voltage sensors based on Isabellenhütte sensor modules, which are considered the leader in shunt-based current measurement technology.

Figure1: KUKA's omniMove mobile platforms are used during aircraft construction, among other things, to transport extremely heavy loads weighing up to 100 tonnes.

Informed, reliable statements about a battery's functionality, such as its state of charge or state of health, or a battery's state of function (namely its ability to meet certain requirements such as starting performance) are only possible if current and voltage can be calculated to an extremely accurate degree. "Based on these measurement values, the flow of energy can take place in a controlled fashion, loading times and loading cycles can be optimised and the operating life of the battery can ultimately be extended," confirmed Jens Hartmann, Sales Director ISAscale at Isabellenhütte. The high utilisation rate of omniMove batteries is achieved thanks to the precise measurement of battery capacity.

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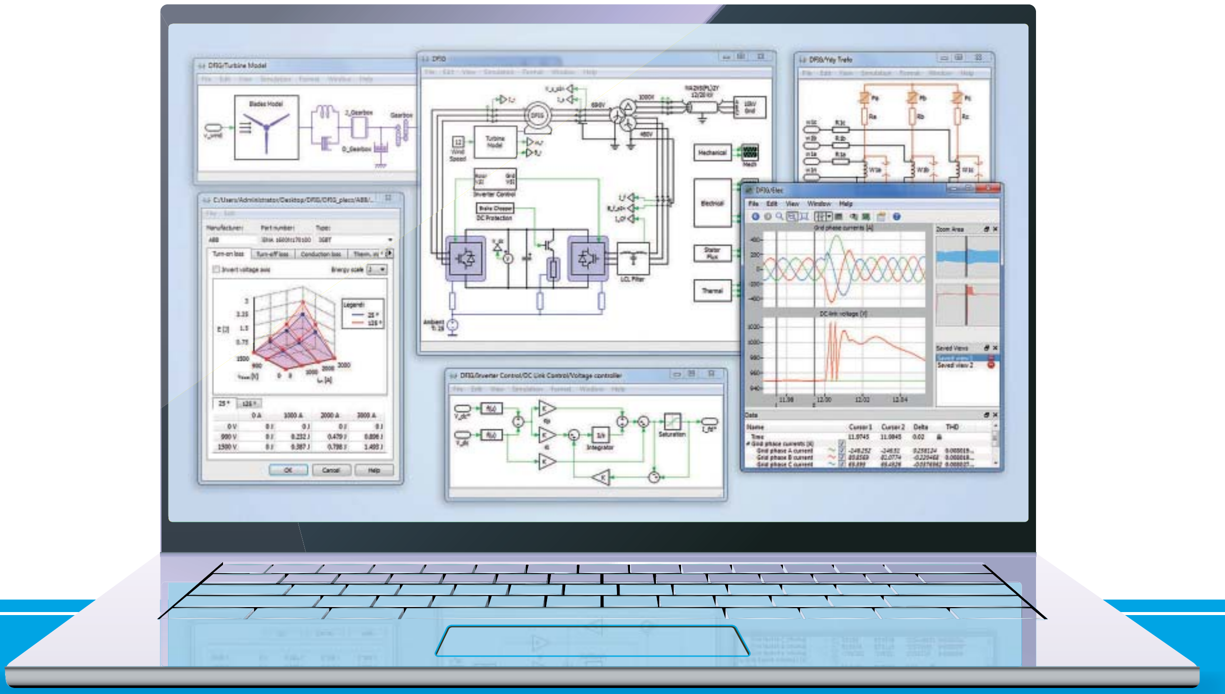

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KUKA uses Isabellenhütte's IVT Modular sensor module to measure current and voltage in omniMove vehicles. Isabellenhütte further developed this field-tested IVT sensor module to allow individual configurations with custom-selected modules. This ensures that the system can be adapted to customer requirements at short notice. "The standardisation of modular functionalities saves time during the manufacturing of sensor modules individually selected by the customer," explained Jens Hartmann. "This has a favourable impact on development costs."

Figure 2: KUKA's vehicles feature high-capacity battery systems. The systems come standardly equipped with Isabellenhütte's IVT Modular sensor modules, which ensure consistent power control and efficient utilisation.

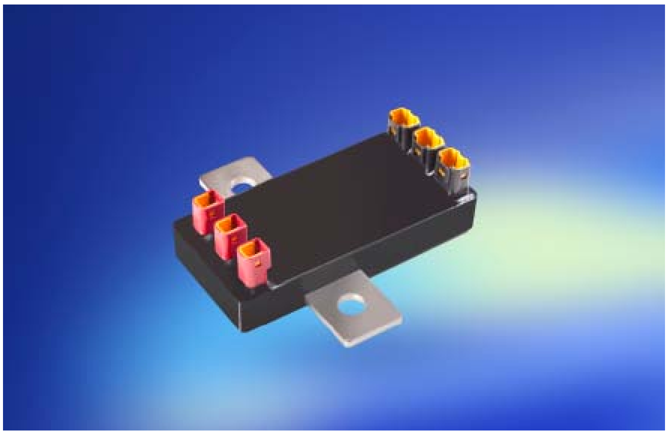

Figure 3: Isabellenhütte's shunt-based IVT Modular sensor module measures current and voltage in the battery systems of KUKA's omniMove platforms with an error rate of less than 0.1 per cent.

CAN interface proves to be a winning choice

The components that customers can select are isolation, overcurrent detection, hardware and software triggers, current measurement range, voltage measurement channels, interfaces and input voltage. With regard to input voltage, the IVT Modular can be configured to a 5-V regulated supply or to an unregulated supply voltage of 5 to 16 V or 9 to 40 V. Galvanic isolation is possible for high voltages of up to 800 V. A hardware trigger – an extra pin that makes it possible to initiate the series of measurements with an external trigger mechanism – can also be selected. An additional software trigger is part of the internal software and integrated in each module. There are five different current measurement ranges, starting from ± 100 A with a resolution of 3 mA up to ± 2.500 A at a resolution of 186 mA. The IVT Modular has three voltage measurement channels for a measurement range of up to 800 V. The three voltage inputs can be configured to monitor three other potentials in the system.

The CAN interface configuration option proved to be the main factor in the decision to use the IVT Modular in the battery system of KUKA's mobile platforms. "Before switching to Isabellenhütte's sensor modules, we were using sensors that had a serial interface only. That made analysing the data more costly and complex, as the units used to conduct the analysis had to be heavily adapted and customised," according to Paul Wyszynski. Another feature of the IVT is overvoltage detection for positive and negative currents flowing while batteries are charged or discharged, for example. The software can be used to set the threshold value and a hysteresis.

"In making the decision to go with Isabellenhütte, it was also important to us that we would get a sensor that provides extremely precise measurements." Before the IVT Modular was implemented, current measurement was conducted using Hall sensors with an accuracy of no more than one ampere. In contrast, logging measurement values with the help of Isabellenhütte's sensor module is based on shunt technology and has the advantage that the accuracy of current and voltage measurement is extremely high across the entire potential range of temperatures and under all technical environmental conditions. The IVT's initial measuring accuracy comes to within 0.1 per cent and 0.5 per cent across the entire temperature range. Thanks to extremely low resistance values of 5 μΩ to 285 μΩ, power loss is likewise kept to a minimum. Isabellenhütte's shunts experience virtually no drift in the temperature range from -40° to +85° C, making them almost impervious to the effects of temperature.

In addition to the modules that can be selected, the IVT boasts other features. A bootloader makes it possible to load new firmware, which can be used to receive new functionalities. Diagnostics provide information about the sensor's functional range, which means that while in use, the sensor logs and stores certain values, such as maximum voltage, current, temperature and operating hours, all of which can be used for statistical analyses.

Alarm sounds when low capacity detected

KUKA's omniMove vehicles have been standardly equipped with the sensor module ever since the IVT Modular was implemented last year. The sensor module sends data on current and voltage to the central computer via the CAN interface. Every 100 milliseconds, the computer in omniMove recalculates the capacity for each battery using this data and the specific curves. With these calculations, it is possible to determine whether there is enough energy for the present task. "If not, then we take action accordingly. An alarm on the vehicle is sounded and the operator and the higher-level control system are notified," said Paul Wyszynski.

At the same time, the collected data is analysed in a way that is specifically suited to the batteries used in omniMove since the chemical reactions inside a battery are never linear, but rather dependent on variables such as ambient temperature, how high the current drain is and the age of the battery. According to Paul Wyszynski, "For our omniMove platforms, there is one battery unit per drive, and each battery unit consists of eight large high-capacity battery trays. Unused capacities would have a major effect on our vehicles. Determining the exact flow of energy in the batteries is therefore crucial to our vehicles."

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Isabellenhütte's shunt-based IVT Modular sensor module measures current and voltage in the battery systems of KUKA's omniMove platforms with an error rate of less than 0.1 per cent.

Precise Evaluation of Input, Output, and Reverse Transfer Capacitances of Power Devices

Increasing importance of capacitance measurement

The switching frequency in power conversion circuits is increasing. This is primarily to reduce the size of passive components such as smoothing capacitors and reactors. Accurate characterization of device parameters affecting switching performance become more important as higher switching frequencies increase power circuit switching losses.

By Hisao Kakitani and Ryo Takeda – Agilent Technologies International, Japan Ltd.

Let's use the power MOSFET shown in Fig 1 as an example.
Gate resistance (Rg), input, output and reverse transfer capacitances (Ciss, Coss and Crss) are described in a device datasheet as typical parameters related to switching performance.

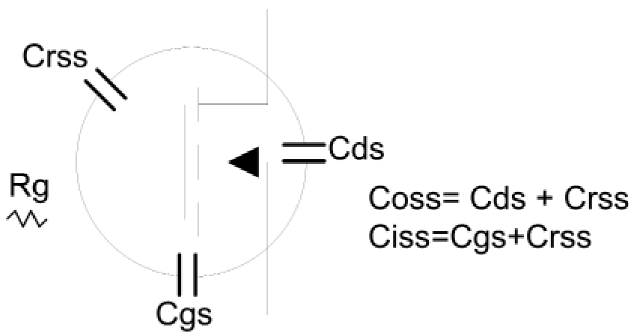


Figure 1: Three Capacitance of Power MOSFET

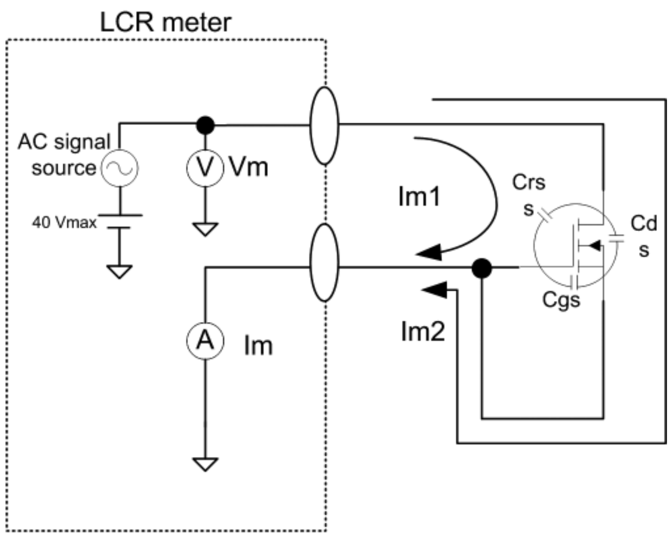
Rg and Crss dictate switching speed while Ciss determines driving condition. Power loss due to charging and discharging Coss is the primary component of switching loss in the case of a resonant converter. Crss and Coss have voltage dependency in the nano-farad range due to the power device's depletion region modulating with applied varying operational voltages.

These capacitances are conventionally measured by LCR meter. However, the maximum voltage of an integrated LCR voltage source is limited to around +/-40 V. Therefore, most device data sheets do not include capacitance measurement data with more than +/-40 V bias.

Circuit designers traditionally use curve fitting capacitance characteristics in their design work for voltages greater than 40 V. However, curve fitting is no longer viable due to complicated device structures based upon trench or super junction structures. In addition, complicated manufacturing processes induce additional variation in device performance. e.g. capacitance gap between high side FET and low side FET. Performance difference identification is key to device selection and failure analysis. Accordingly, for these reasons, device capacitance characterization from actual chip and module level measurements becomes essential.

Application notes provided by device manufacturers describe the power device capacitance measurement method. However, it is not a simple measurement. Many factors such as the determination of good peripheral circuit constants, measurement circuit compensation and appropriate measurement frequency have to be considered. This article discusses power device measurement methods and practical tips.

Basic Device Capacitance measurement.
Capacitance measurement on a three terminal device such as IGBT or MOSFET requires AC guarding plus peripheral circuits and an external bias source. Basic measurement set ups for a power MOSFET are discussed in this chapter.



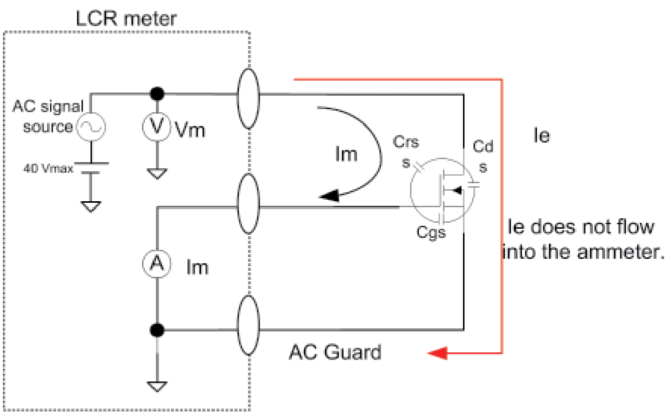
$$Coss = -1/(j\omega{*}Z)$$
$$Z = Vm / (Im1+Im2)$$

Figure 2: Coss measurement by LCR meter

Coss measurement.
Figure 2 shows the measurement circuit for output capacitance (Coss = Crss + Cds) of a MOSFET.

High and low ports of the LCR meter are connected to the device after shorting the gate and the source terminals. The device impedance is calculated from applied voltage, Vm, and measured current, Im. Coss voltage dependency, (+/-40 V) is measured by the integrated LCR meter voltage source.

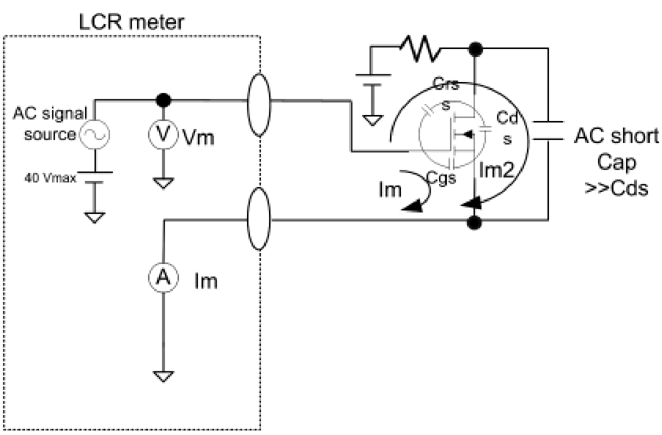
Crss measurement.
Figure 3 shows the measurement circuit for reverse transfer capacitance (Crss) of a MOSFET. High and low ports of the LCR meter are connected to gate and drain terminals. The AC guard terminal of the LCR meter is connected to the source terminal. The AC guard directs current flowing through Cds directly to LCR meter circuit common without going through the current meter.



$$Crss = -1/(j\omega{*}Z)$$
$$Z = Vm / Im$$

Figure 3: Crss measurement by LCR meter

Ciss measurement
Figure 4 shows the measurement circuit for input capacitance (Ciss) of a MOSFET. High and low ports of the LCR meter are connected to gate and source terminals. An external power supply is necessary to bias the drain terminal. A resistor or an inductor is necessary between the power supply and the drain in order to block the measurement AC signal flowing into the power supply. In addition, a large capacitor is necessary between drain and source terminals in order to short the



$$Ciss = -1/(j\omega{*}Z)$$
$$Z = Vm / (Im1+Im2)$$

Figure 4: Ciss measurement by LCR meter

AC measurement signal and to block the DC bias being applied to the drain terminal. The measurement signals flowing through Cgs and Crss are measured by the LCR current meter.

Rg measurement
Figure 5 shows the measurement circuit for gate resistance (Rg) of a MOSFET. High and low ports of LCR meter are connected to gate and source terminals. Drain and source terminals can be shorted together. Occasionally, Rg is defined with the drain terminal open, as shown in Figure 5. The LCR meter is set to Rs-Cs mode and Rg is obtained from the measured input voltage (Vm) and output current (Im). The measurement frequency should be set to high in order to minimize the influence of Ciss. Gate voltage dependency of Ciss can be measured simultaneously with Rg by shorting drain and source terminals.

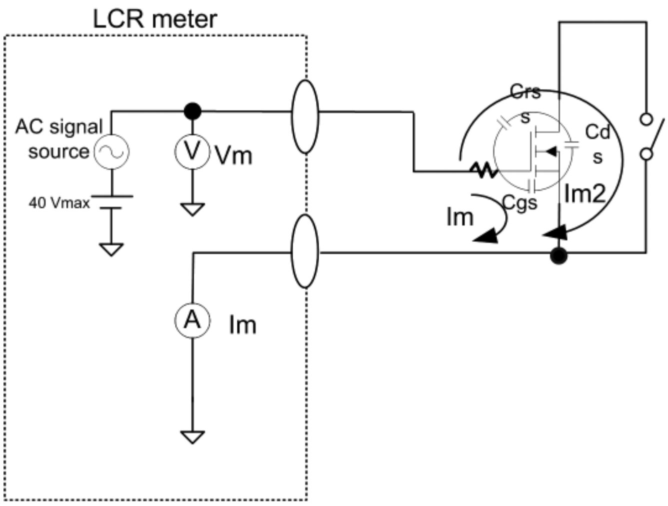


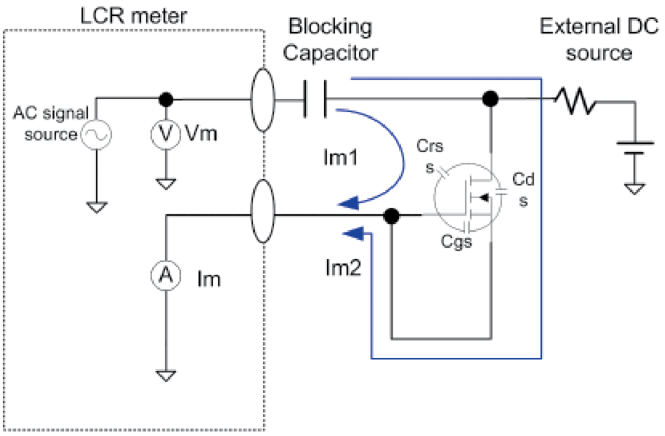
Figure 5: Rg / Ciss measurement by LCR meter

As discussed above the device connection and measurement circuitry wiring has to be changed for each different capacitance in three terminal device capacitance measurements.

Challenges in High Voltage device capacitance measurement

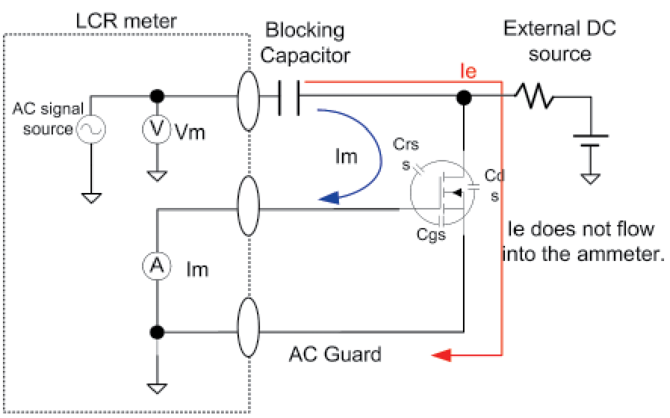
High Voltage Bias Tee
For capacitance measurements on high voltage power devices an external high voltage DC source is necessary due to the inadequacy of the integrated +/-40 V LCR power supply.

A resistor or an inductor is necessary at the output of the external DC source to avoid leakage of the measurement AC signal. In addition, a blocking capacitor is mandatory to superimpose the measurement AC signal on the voltage bias source. A large capacitor is ideal to minimize measurement AC signal attenuation at the DUT terminal. However, too large a capacitor slows down measurement speed. Typically the appropriate blocking capacitor size is around ten times larger than the largest DUT capacitance. The capacitor type should be thin film as it has less voltage dependency. Figures 6, 7 and 8 are capacitance measurement circuits for high voltage devices and correspond to figures 2, 3 and 4, respectively. A significant issue to consider is the risk of destroying measurement equipment due to the sudden inrush of voltage or current from the blocking capacitor when the DUT catastrophically fails. A protection circuit should be configured using a voltage clamp diode, a surge absorber and a resistor, (not shown in any of the figures). It is recommended that the breakdown voltage of the DUT is measured in advance of capacitance measurements and that capacitance bias voltage be well below the device breakdown voltage. Additionally, the measurement circuit has to be fully enclosed for safety reasons as the stored energy in the blocking capacitor is potentially fatal. Figure 9 shows hazardous energy range described in IEC60950-1 and IEC61010-1.



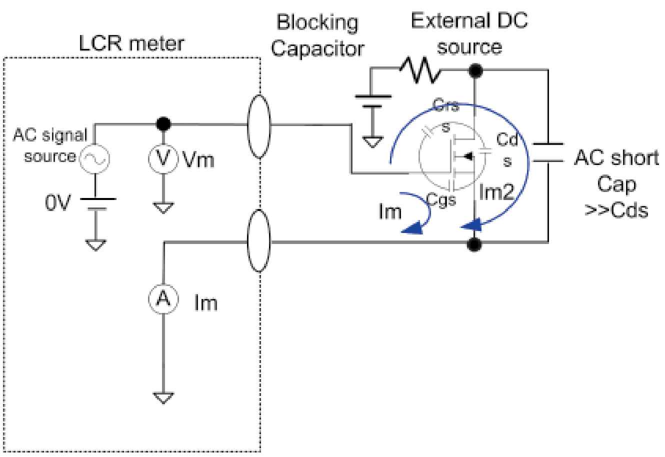
Coss = -1/(jω*Z)
Z = Vm / (Im1+Im2)

Figure 6: Coss measurement at High Voltage Bais



Crss = -1/(jω*Z)
Z= Vm / Im

Figure 7: Crss measurement at High Voltage Bais



Ciss = -1/(jω*Z)
Z = Vm / (Im1+Im2)

Figure 8: Ciss measurement at High Voltage Bias

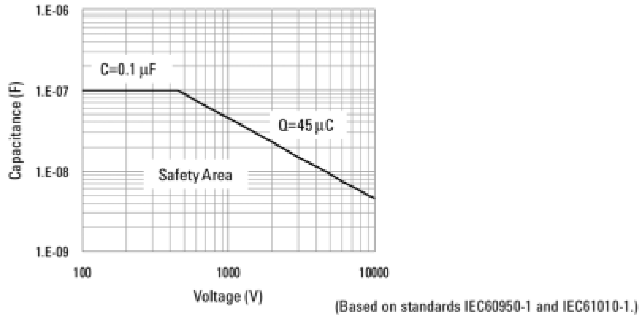
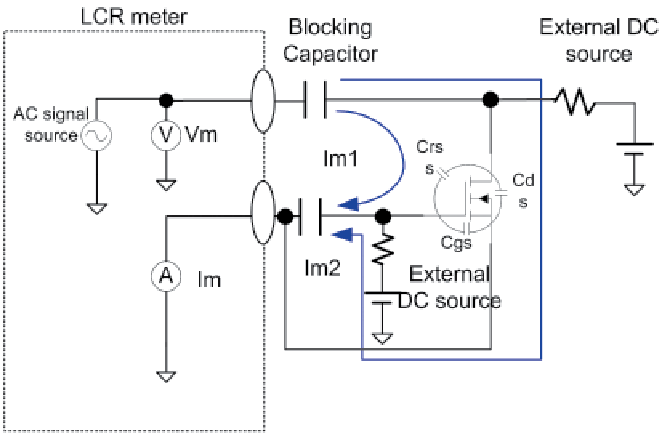


Figure 9: Capacitance Charge generally considered as safety

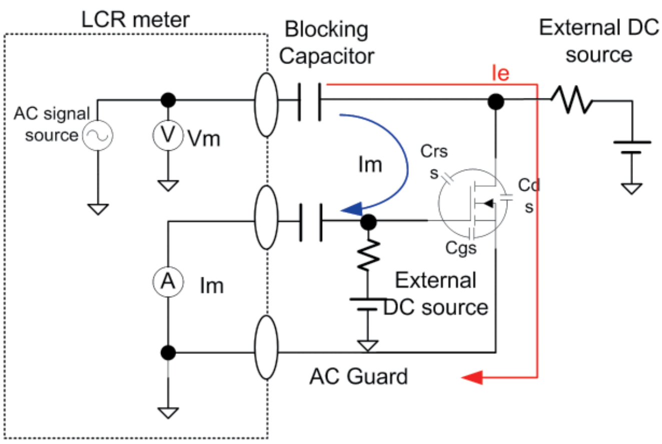
Normally On Device.

For depletion type devices, typically seen in GaN FET or SiC JFET, a negative voltage has to be applied to the gate terminal to turn off the device when making capacitance measurements. This measurement circuitry requires an additional blocking capacitor and an additional external DC source. Consequently it becomes complicated and troublesome to construct the test set up. Measurement circuitry examples are shown in figures 10 and 11.



Coss = -1/(jω*Z)
Z = Vm / (Im1+Im2)

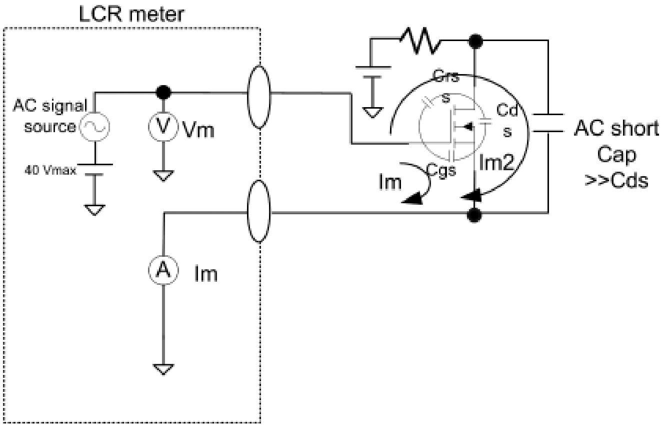
Figure 10: Coss measurement for normally on devices at High Voltage Bais



Crss = -1/(jω*Z)
Z= Vm / Im

Figure 11: Crss measurement for normally on devices at High Voltage Bais

Power Module.
A power module, (e.g. 2-in-1 or 6-in-1) has multiple FETs inside. When measuring the capacitance of a FET in such a module the AC guard plays a key role in accurate measurements by nullifying the capacitance of other FETs. Fig 13 shows an example of AC guard connection when measuring Crss of high side FET 1 in the 6-in-1 module. Gate and source terminals of the other FETs are connected to the AC guard.



Ciss = -1/(jω*Z)

Z = Vm / (Im1+Im2)

Figure 12: Ciss measurement for normally on device at High Voltage Basis

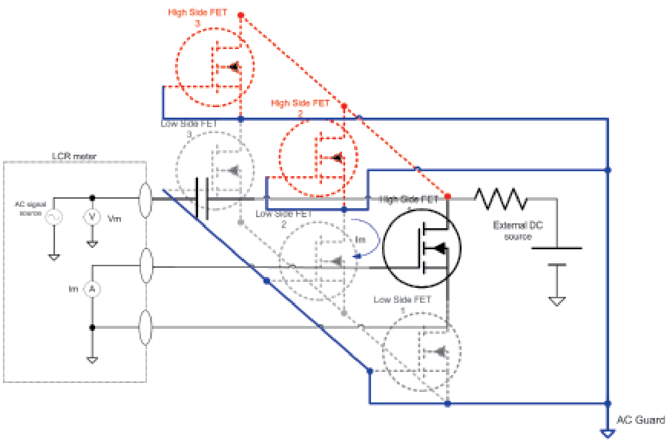


Figure 13: 6 in 1 Module, Crss measurement at High Voltage Bais

Compensation of Test Lead Inductance
After constructing measurement circuitry utilizing the above techniques appropriate compensation should be performed.

The first is open compensation to cancel stray capacitance in the measurement path using the "open compensation" function within the LCR meter.

Secondly, short compensation should be performed in order to cancel out the residual inductance of the test leads. The "short compensation" function in an LCR meter is designed for a two terminal device and it needs to be extended for a three terminal device. Today it is rare practice to perform short compensation even although the influence of residual inductance is far from negligible. Fig 14 shows a circuit designed to compensate parasitic inductances in test circuitry. In this example the guard connection retains the residual parasitic inductance without correction. This, in turn, adds an additional potential error factor to power device capacitance measurements. If the capacitance of a power device is large the measurement error tends to be large when the measurement frequency is close to the resonant frequency. Resonant frequency is determined by the uncompensated residual inductance and device capacitance. E.g. the resonant frequency is 1.6 MHz for the combination of a 10 nF device capacitance and 1 m long test lead; (the equivalent residual inductance of a 1m wire connection lead is around 1 μH.) If the measurement frequency is set to 1 MHz, the error will be significant because it is close to the resonant frequency. For power device capacitance measurement at 1 MHz the residual inductance in the measurement circuitry has to be small. Alternatively, the measurement frequency has to be reduced (e.g. 100 kHz) in order to make an accurate measurement.

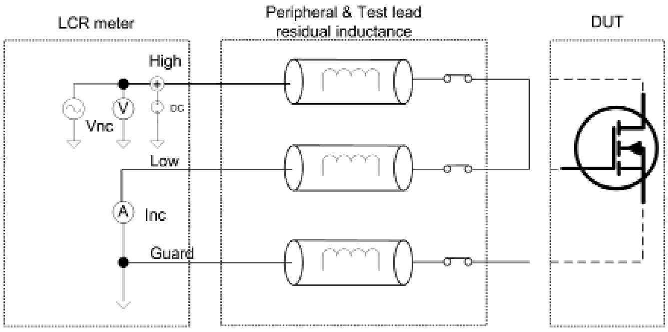


Figure 14: Short correction including Guard terminals is required for compensating residual inductance

When a large capacitance exists between the current meter and the AC guard, (e.g. Crss measurement) as shown in Figures 3, 7 and 11 phase compensation for the current meter feedback loop may be necessary. If an LCR meter shows an error status such as "bridge unbalanced" when making this measurement, (Crss) it usually means that phase compensation is required.

Practical Use of C-V measurement data.
In this chapter the influence of power device capacitances on switching circuit operation are discussed. Crss can be seen as a mirror capacitor in the switching circuit. Charging and discharging Crss determines the switching speed of the circuit. The curve integral of Crss vs. drain voltage is the cross switching charge (Qsw). Switching time can be calculated by dividing Qsw by gate drive current.

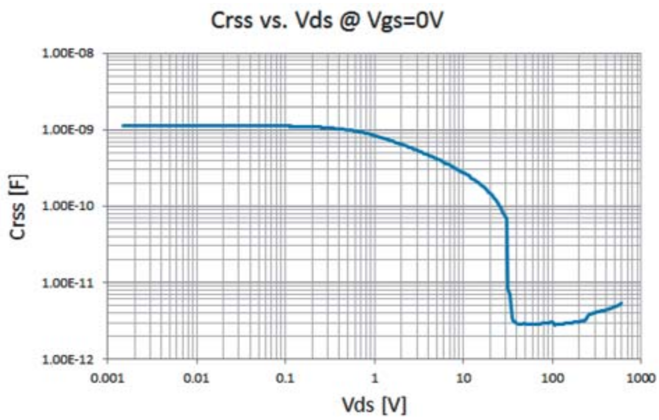


Figure 15: Crss voltage dependency

$$Qsw = \int_0^{Vds-Vgs} Crss * dVds \qquad \text{---(1)}$$

$$Tsw(on) = \frac{Qsw}{ig} \qquad \text{--- (2)}$$

Power loss due to Coss is a component of switching loss. This loss is generated in any type of switching converter. In order to determine the loss it is necessary to calculate the total charge supplied to Coss during the switching period. Total charge is calculated by integrating Coss with respect to drain voltage from 0 V to device operating voltage. Dividing total charge by device operating voltage is called Equivalent Effective Output Capacitance of energy, (Coss_eff). The power loss caused by the effective output capacitance is calculated using the Coss_eff, device operation voltage and the switching frequency.

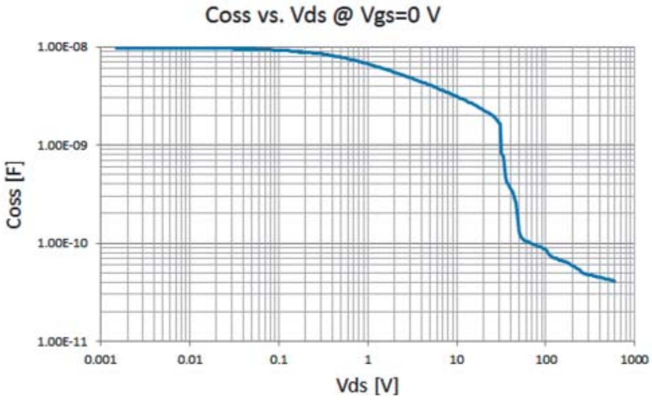


Figure 16: Coss voltage dependency

$$Coss\_eff = \frac{1}{Vds}\int_0^{Vds} Coss * dVds \quad \text{---(3)}$$

$$Powerloss\ by\ Coss_{eff} = \frac{1}{2} * Coss_{eff} * Vds^2 * \text{freq.} \quad \text{--- (4)}$$

Ciss is a key parameter for gate drive circuit design. Drain voltage dependence on Ciss at Vgs = 0 V is initiated by its component Crss. Measurement of the gate drive charge when the device is off is straightforward. However, measuring drive capacitance when the device is on or when sweeping gate voltage from negative to positive in order to avoid unexpected turn on due to Vgs dependency on Ciss is essential. Both can be evaluated using the measurement set up shown in Figure 5.

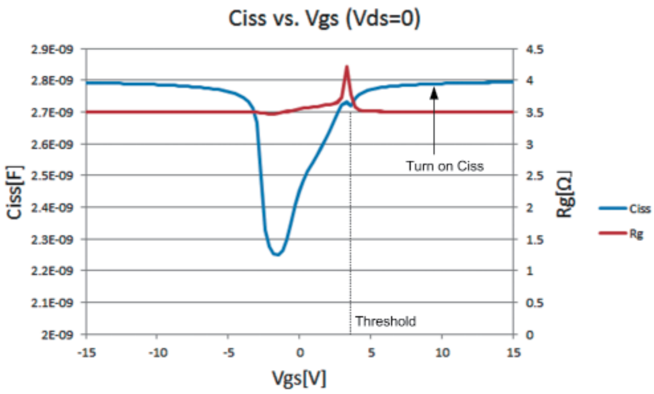


Figure 17: Ciss voltage dependency

Application of device capacitances within a circuit simulator.
Accurate simulation and verification of switching operation is possible by applying device capacitance measurement results as a non-linear model within a circuit simulator, e.g. SPICE. Cgs, Crss and Cds are all necessary for the simulation. These parameters can be measured by connecting the AC guard to the free terminal on a three terminal transistor. Alternatively, Cgs and Cds can be calculated from the Ciss,

Coss and Crss measurement result as Ciss = Cgs + Crss and Coss = Cds + Crss.

Crss characteristics deployed in a simulator should show Vdg dependency not Vds dependency. Vdg = Vds – Vgs. Figure 15 shows Crss characteristics in depletion mode (Vdg > 0, in depletion). However, for a complete simulation it is not sufficient as the Crss characteristics in enhancement mode (Vdg < 0 or Vds < Vgs) are missing. When Vdg < 0 the device is turned on and Crss rapidly increases. The approximate capacitance at turn on can be found in the Ciss – Vgs curve. The relevant non-linear Crss characteristics to apply should be derived from Figure 19.

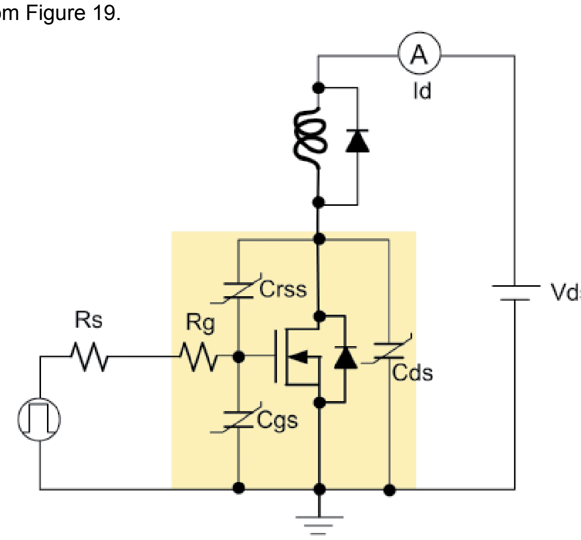


Figure 18: Apply device capacitance to simulator

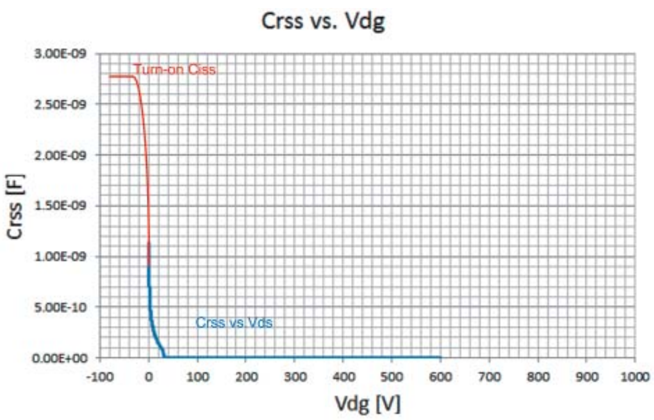


Figure 19: Crss Vdg dependency

Fully automated capacitance evaluation utilizing the Agilent B1507A switching characterization solutionAgilent Technologies has developed a power device capacitance analyzer which can automatically measure all power device junction capacitances and gate resistances without the need to reconfigure or re-cable the device under evaluation. This includes Normally-on and normally-off devices with all the appropriate connections being made by a special selector for power device capacitance test. (Figure 20).

Fully automating the solution eliminates connection and settings error. In addition it includes capacitance open, short and phase compensation for all three terminal devices. It is literally insert device, click measure and view results.

Figure 21 shows (a) Power MOS FET capacitance measurement to 3kV drain bias and (b) Power MOS FET gate resistance measurement. It allows device designers to develop and optimize high performance power devices. Additionally, it enables power circuit designers to select optimum power devices and eliminate substandard and counterfeit components.

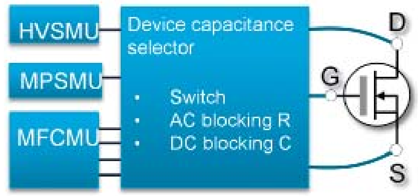
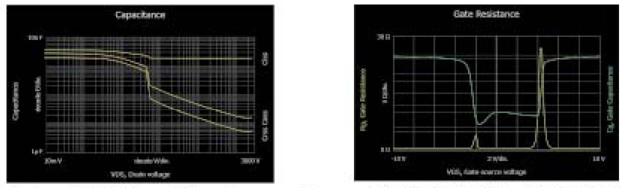


Figure 20: Agilent B1507A Hardware Block Diagram



(a) Up to 3 kV biased Ciss, Coss and Crss (b) Rg (yellow) vs. gate voltage.

Figure 21: Measurement examples

Precise power MOSFET capacitance measurement brings about further benefit to power circuit designers. Although switching loss dominates in switch mode power supply applications switching characteristics measurement is never a trivial task. There are many factors that make direct evaluation of switching characteristics far more difficult than static measurements. The main bottlenecks are: bandwidth of the current probe, ringing in the switching waveform due to parasitic inductance in the measurement path, creation of an appropriate gate driving circuit etc. On the other hand, since the measurement reproducibility of power MOSFET capacitance and gate resistance is high you can use these data to enhance the accuracy of switching circuit simulation. In addition enhanced models with drain voltage dependency on Crss, gate voltage dependency on Ciss and gate resistance can be introduced which will significantly increase the overall accuracy of the circuit simulator.

Figure 22 shows example simulation results which correlate well with the datasheet figures. Switching characteristics utilizing specific operating conditions can be simulated accurately with this method.

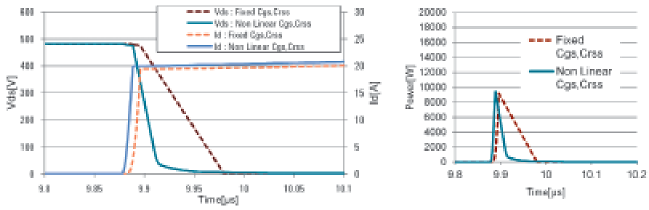


Figure 22: Simulated switching characteristics and power loss

Finally the Agilent B1506A, another power device analyzer, can also be used for characterizing power device capacitances. It is a superset of B1507A having not only the same capacitance measurement capabilities but also wider IV, thermal, and gate charge measurement abilities.

www.agilent.com

Three Stability Assessment Methods Every Engineer Should Know About

Many engineers are familiar with the Bode plot as an effective stability assessment method. However, some authors suggest and even teach that the Bode plot is the only method needed. This article shows why this thinking is short-sighted. A single, low cost instrument that can produce Bode plots, as well as two other stability assessment methods is discussed providing a more comprehensive stability assessment set of guidelines.

By Steve Sandler, Picotest.com

A single word illustrates why Bode plots cannot be the only voltage regulator stability assessment method you need to use

Preceding the words voltage regulator with “fixed” is sufficient proof that the Bode plot cannot be our only assessment method. The fixed output voltage regulator does not provide an accessible point to either inject a signal or to measure the Bode response of the control loop [1, 2]. As a result, these fixed voltage regulators are often not assessed for stability margin and, unsurprisingly, are often found to have poor stability. Fixed regulators absolutely need stability assessment just as much or more than variable output regulators. Of course the fixed voltage regulator is not alone in this predicament. Other devices such as voltage references, integrated POLs, simple switchers, integrated class D audio amplifiers and many other devices fall into this category as well. They simply lack access to the feedback loop, prohibiting the use of the Bode plot for assessment, thereby eliminating it as potential measurement solution.

There are other conditions that can prohibit the use of Bode plots as well [3]. Some examples include opamps, which while the loop might be accessible can have bandwidths that are too high to allow injection without influencing the measurement result. Other examples include hysteretic regulators, as well as regulators with multiple control loops, which might only provide access to one of several of the control loops [4].

Another circuit that cannot make use of a Bode plot is an input filter with a switching regulator. The switching regulator presents a negative resistance which can easily oscillate when connected to an input filter. This stability issue was popularized by R.D Middlebrook in 1974 and the minor loop gain assessment method was devised in order to assess such applications [5]. This has become a very well researched and published topic within the academic electronics community.

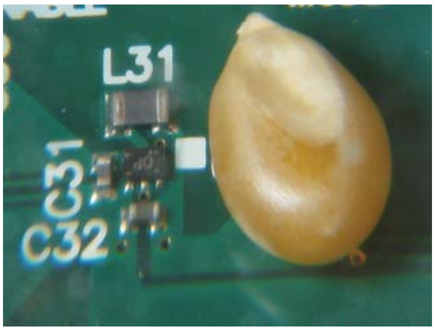


Figure 1: A recently introduced switching regulator along with a single popcorn kernel clearly showing the limited access for injection and measurement probe for stability assessment. The POL regulator also lacks access to the feedback loop.

There are also many applications, and it seems more as time goes on, where there is limited physical access does not allow injection access or space for the probes. An example of such a regulator is shown in Figure 1.

The work of Bode concludes that if a control loop simultaneously has positive gain margin and positive phase margin the circuit is assuredly stable, which only assures that the circuit will not oscillate. The Bode plot may not be a reliable indicator of relative stability. Stating this more simply, a circuit which has a greater phase margin is not necessarily more stable than a circuit with a lower phase margin. [6, 7]

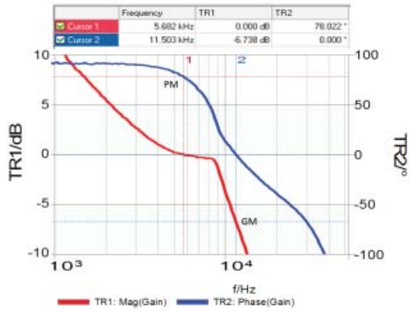


Figure 2: Bode plot of a DC/DC converter.

An illustrative example

The Bode plot of a switching DC/DC “brick” converter, measured with the OMICRON Bode 100 VNA, is shown in Figure 2. A schematic diagram of the converter is not available; however, the availability of external remote sense connection provides access for injection and measurement of the Bode plot.

The phase margin of this converter is indicated as 78 degrees and the gain margin is 6.7dB. These are both reasonable

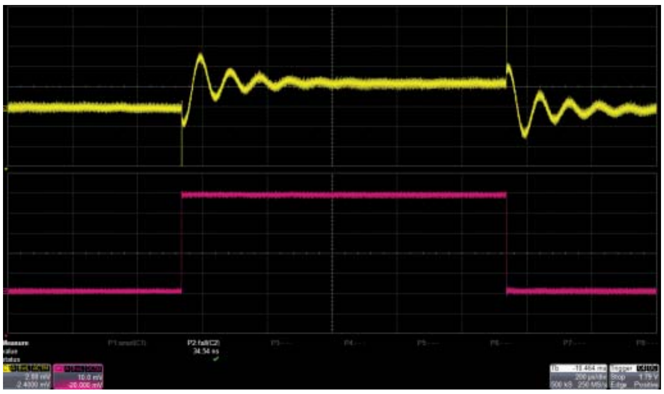


Figure 3: 500mA Step load response of the DC/DC converter. The upper trace is the output voltage at 2mV/div. the lower trace is the current step at 100mA/div and the timescale is 200us/div. The rise and fall time of the step are 35ns.

margins and would be interpreted as a stable control loop. A step load response of the converter is shown in Figure 3 and the voltage response would seem to contradict the stability of the control loop as determined by the phase/gain margins.

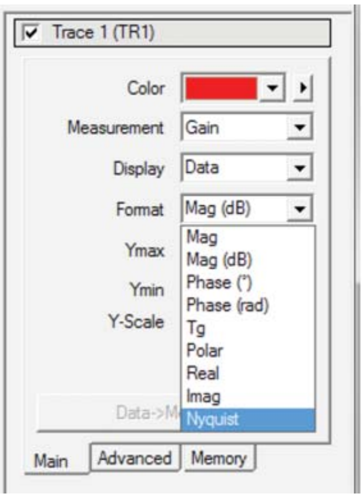


Figure 4: The Bode 100 Format menu offers Nyquist as a display type

The Nyquist plot as an alternate assessment method

The Bode 100 can display the Bode plot measurement as a Nyquist plot simply by selecting Nyquist from the Format menu as shown in Figure 4.

The resulting Nyquist plot is shown in Figure 5.

Three points are indicated on the Nyquist chart; phase margin, gain margin and stability margin. The stability margin is defined as the closest distance between the singular unstable point (1,0) and the transfer function. If the curve touches the singular unstable point the circuit will oscillate. The raw data for this chart and a graph showing the distance from (1,0) at each frequency is shown in Figure 6.

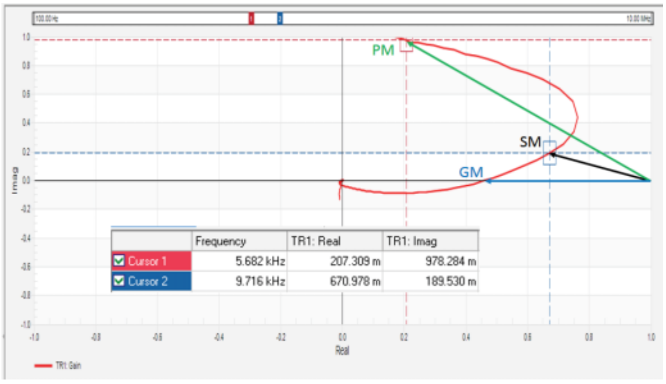


Figure 5: Nyquist chart created from the Bode plot data in Figure 2 shows the phase margin, gain margin, and stability margin.

Freq(Hz)	REAL	IMAG	Mag	SM
4597.27	0.088752	1.058091	1.061807	1.396399
4731.513	0.10558	1.040922	1.046263	1.372409
4869.675	0.115288	1.030106	1.036537	1.357878
5011.872	0.140942	1.013528	1.023281	1.328616
5158.222	0.144393	1.009613	1.019886	1.323097
5308.844	0.162106	1.000459	1.013507	1.304985
5463.865	0.185793	0.987645	1.004968	1.279991
5623.413	0.198594	0.987158	1.006936	1.271508
5787.62	0.223031	0.962278	0.987786	1.236794
5956.621	0.245283	0.9593	0.990162	1.220596
6130.558	0.271631	0.950005	0.988075	1.197092
6309.573	0.295455	0.940444	0.985763	1.175082
6493.816	0.326305	0.925079	0.980941	1.144393
6683.439	0.362266	0.908764	0.978309	1.110206
6878.599	0.397294	0.878717	0.962536	1.063902
7079.458	0.434754	0.86977	0.972374	1.037306
7286.182	0.466871	0.845583	0.965733	0.999449
7498.942	0.502114	0.822793	0.963902	0.961706
7717.915	0.546115	0.782481	0.954211	0.904593
7943.282	0.596374	0.750855	0.958877	0.852465
8175.23	0.648043	0.704708	0.957379	0.78771
8413.951	0.7044	0.638535	0.949398	0.701823
8659.643	0.747661	0.550847	0.928671	0.605894
8912.509	0.763327	0.442599	0.882362	0.501904
9172.759	0.750248	0.338327	0.823004	0.420525
9440.609	0.715742	0.254361	0.759596	0.381447
9716.28	0.670933	0.189465	0.697171	0.379713
10000	0.629219	0.144482	0.645594	0.397937
10292.01	0.59003	0.106442	0.599555	0.423562
10592.54	0.554824	0.074379	0.559787	0.451347
10901.84	0.519522	0.044683	0.521438	0.482549
11220.18	0.488105	0.018204	0.488444	0.512219
11547.82	0.456072	-0.00267	0.456079	0.543935

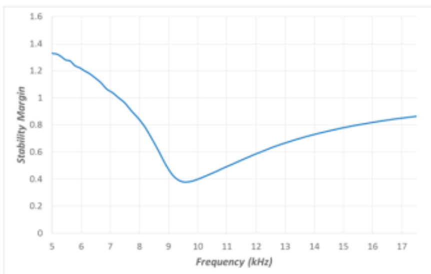


Figure 6: An excerpt of the raw uninterpolated bode plot data with calculations of the gain magnitude and the stability margin or distance from the singular unstable point at (1,0).

Three frequencies are highlighted in the raw data; the phase margin, indicated by the gain magnitude being unity (approximately 5464Hz), the gain margin indicated by the phase being 0 deg (approximately 11,548Hz) and the stability margin, represented by the smallest value of stability margin (approximately 9,716Hz). Looking back at the step load response, the ringing cycle period is seen to be approximately 100us and corresponds with the frequency of the stability margin.

We can calculate the phase margin from the raw data, by first confirming that the gain magnitude at 5464Hz is 1. Using the real and imaginary gain values the magnitude is calculated as:

$$Mag = \sqrt{0.978^2 + 0.207^2} = 1.0$$

The magnitude being equal to 1.0 confirms that this is the location of the phase margin. The phase margin can then be calculated from the real and imaginary gain terms as:

$$PM = atan\left(\frac{0.978}{0.207}\right) = 78°$$

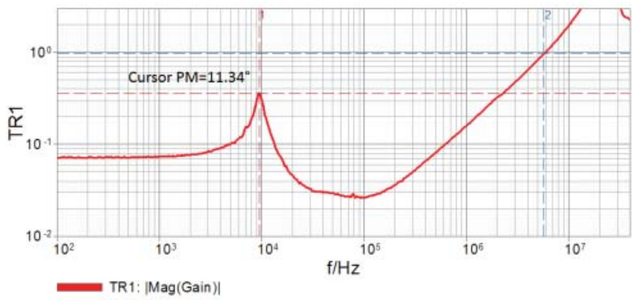


Figure 7: Output impedance measurement and cursor reported stability margin.

This agrees with the Bode plot cursor measurement. While it may seem contradictory for the Bode plot to indicate good stability while the stability margin is poor, this is a well-known phenomenon. In these cases, the stability margin generated by the Nyquist plot gives the correct assessment, while the Bode plot is in error. [8, 9]

The non-invasive measurement as an alternate assessment method

The stability margin can be computed from the impedance vs. frequency response at the output of the regulator [10, 11]. The output impedance can be measured non-invasively, that is, without impacting the circuit operation. Non-invasive measurements have many advantages. [12]

The unique mathematical solution [13], included in the OMICRON Lab Bode 100 Vector Network Analyzer, transforms the cursor value in real time to an equivalent phase margin value. The impedance waveform, cursor, and stability margin measurement are shown in Figure 6.

In this case, the stability margin is effectively 11.34 degrees. The peak impedance frequency of just under 10kHz and agrees with the ringing frequency seen in the step load response.

The Nyquist plot is a valuable solution in cases where the signal injection and probing is possible, but the control loop is not linear or has many poles and zeros. The non-invasive impedance measurement technique is valid in nearly all cases and is particularly useful in cases where a Bode plot cannot be measured, such as in voltage references and fixed voltage regulators that do not have an available control loop access point.

New measurement probes, being developed by Picotest, will further simplify the non-invasive measurement, especially in cases where physical access is severely limited. The non-invasive method also allows the assessment of multiple loop converters, as well as input filter stability.

The non-invasive method also works well with high bandwidth opamps, where breaking the loop could interfere with the measurement and in hi-reliability applications where it is not possible to cut a trace or wire to break the control loop.

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Fast Thyristors for Induction Heating and Metal Melting Units

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Besides the weak temperature dependence of reverse recovery charge Qrr is typical for thyristors TFI393-2500-28 and TFI393Ag-2500-28. And the precision grouping of these thyristors by Qrr and UTM is possible what makes the thyristors adaptive for application in serial and parallel applications.

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The advanced monitors incorporate cell-balancing drivers, regulated output supplies and other unique features to reduce external component count and provide heightened protection against overvoltage, undervoltage and overcurrent conditions. Simplifying battery design and optimizing board space, the bq76920 supports 3- to 5-series cells or typical 18-V packs; the bq76930 manages up to 10-series cells or 36-V packs; and bq76940 monitors up to 15 cells or typical 48-V batteries.

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Complete battery measurement: Accurately measures cell voltages, temperature and pack current to determine remaining battery capacity and battery state-of-health.

Built-in hardware protection: Cell balancing, integrated analog-to-digital converters and built-in hardware protection provide the highest degree of battery safety.

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At Heiden the TDK Lambda series extends the successful launched series of programmable laboratory power supplies with the Z+ High-Voltage. This Z+ HV series have an output power of 200 to 800 W with max. output voltages of 160, 320 and 650 V DC and output currents of up to max. 72 A. The Z+ HV power supplies are just as flexible and extensively equipped as the other Z+ models with identical design. They have an efficiency of up to 86%.

This high quality products can be used in R&D, rack applications in ATE and OEM applications. In addition, the Z+ HV series particularly can be used in deposition processes, ROV (flight simulators), as well as for general use in industry and in the laboratory environment.

All models operate as a constant current or constant voltage source with automatic crossover. They have a wide AC input range (85-265 VAC) with active power factor correction (PFC), temperature-controlled

fan and comprehensive security features. Furthermore a user adjustable safe-start and auto-restart function. The Z+ models are 70 mm wide, so that 6 power supplies fit side by side in a 19" rack. Up to 6 units can be operated in parallel in a master-slave network with active load sharing. To increase the output voltage or to provide a bipolar output that two identical devices can be connected in series with the external diode.

Furthermore, all Z+ high-voltage power devices via USB, RS-232 and RS-485 interfaces. Other digital and isolated interfaces are optionally available (LAN / IEEE). The laboratory power supplies have the CE mark in accordance with Low Voltage Directive and have an emission (conducted and radiated) according to EN55022-B, FCC and VCCI-B. The safety approvals include UL/EN/IEC61010-1.

In addition, the Z+ Series complies with the requirements of the UL/EN60950-1.

www.heidenpower.com

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!

Dual N-Channel Enhancement-Mode MOSFET for Battery Applications

Advanced Power Electronics Corp. has announced a new dual N-channel enhancement-mode power MOSFET well-suited for battery applications. The AP9922AGEO-HF-3 device supports 1.8V gate drive and features a low on-resistance of 18mΩ, a drain-source breakdown voltage of 20V and a continuous drain current of 6A. RoHS-compliant and halogen-free, the device is available in the small and thin TSSOP-8 package.

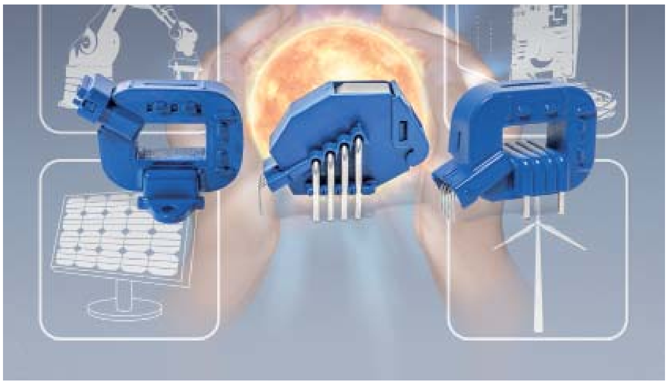
Comments Ralph Waggitt, President/CEO, Advanced Power Electronics Corp. (USA): "We specialise in providing the designer with the best combination of fast switching, ruggedness, ultra low on-resistance and cost-effectiveness. As designers of battery-powered applications continue to focus on battery life, it becomes increasingly more important to address the need to manage the battery efficiently."

www.a-powerusa.com/docs/AP9922AGEO-3.pdf

Extended Measurement Range up to 250A for HO Current Transducers

LEM announces the addition of three new HO series of high performance current transducers which extend nominal current measurement up to 250A and offer a range of mounting options.

The recent launch of the first devices in the HO series enabled a breakthrough in the trade-off between performance, cost, size and mounting versatility. These three new HO series provide the mounting



the user needs: PCB or panel or busbar, integrating the conductor or with an aperture (15 x 8 mm), a range of choices. The mounting options provide customers with the flexibility of up to three interchangeable mounts for the HO xxx-S panel mounted current transducers: one vertically, one horizontally and one on the busbar when used. The mount can be changed by the user for additional versatility.

HO series current transducers measure DC, AC, and pulsed signals using the latest generation of LEM's Open-loop Hall-effect Application Specific Integrated Circuit (ASIC) which was introduced with the launch of the HO 8, 15, 25-NP and -NSM series and the HO 6, 10 and 25-P models.

Operating from a single supply voltage of 3.3V or 5V, the HO series can measure up to x 2.5 the primary nominal current and integrate an additional pin which provides over-current detection set at x 2.93 the nominal current I PN (peak value). They also provide fault reporting in the event of memory corruption.

www.lem.com

Hybrid SiC Power Modules for High-Frequency Applications

Mitsubishi Electric Corporation introduces hybrid silicon carbide power semiconductor modules for high-frequency switching applications. These latest additions to the NFH series of power semiconductor modules enable design engineers to reduce electric power losses by

40%. Featuring SiC Schottky Barrier Diodes (SBD) and Silicon IGBTs, the modules achieve high efficiency, downsizing and weight reduction in inverters. The Modules are designed for typical switching frequencies of more than 20 kHz.

The new hybrid SiC power modules are packaged as 2in1 configurations with a rating of 1200V and currents of 100A (CMH100DY-24NFH), 150A (CMH150DY-24NFH), 200A (CMH200DU-24NFH), 300A (CMH300DU-24NFH), 400A (CMH400DU-24NFH) or 600A (CMH600DU-24NFH). All module packages are compatible with Mitsubishi Electric's conventional pure-silicon based power modules. The 100A and 150A modules, which are integrated in a package with a footprint of 48mm x 94mm, offer a reduced internal inductance which is about 30% lower than in the conventional modules. The 200A and 300A modules' footprint measures 62mm x 108mm, while the 400A and 600A modules require just 80mm x 110mm baseplate size. Typical applications are e. g. uninterruptible power supplies (UPS) and medical device power supplies.

http://www.mitsubishichips.eu/

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XR71211 Operates Down to 1.4V VIN Requiring No Charge Pump or External Bias

Exar Corporation announced the expansion of its low voltage, low-dropout (LDO) regulators with the new XR71211. This LDO provides 1.5A from voltages as low as 1.4V and a guaranteed dropout voltage of 250mV at maximum junction temperature. The XR71211 is targeted at 1.5V to 1.2V and 1.8V to 1.5V conversions. The new LDO is targeted at a wide range of markets including communications, enterprise solutions, industrial systems and space constrained consumer devices.

Exar achieves the low dropout performance of the XR71211 regulator without requiring either an external bias voltage or an internal charge pump, which can often generate unwanted noise and affect system operation. The new LDO uses a single supply which reduces board layout complexity by avoiding the need to route a secondary bias rail to the LDO. Operating input voltage range is 1.4V to 2.625V and the device provides output voltages down to 0.6V with an accuracy of 0.5% using ceramic capacitors. In addition, precision enable and power good functions allow for easy sequencing and control.

www.exar.com

Slew Rate Control EiceDRIVER™

Infineon Technologies AG presented the single channel gate driver of the latest EiceDRIVER™ product family, developed especially for high-end systems in the industrial sector. The type 1EDS20I12SV EiceDRIVER™ Safe driver component features the first Slew Rate Control ("SRC") adjustable in real-time at the IGBT. The secure electric isolation of the 1EDS-SRC EiceDRIVER Safe complies with the strict specifications of VDE 0884-10 and has specially developed short-circuit protection functions. The driver component presented thus offers a wide application range and high system efficiency in applications with isolation voltages as high as 1200V.

The Slew Rate Control lets developers choose from among a total of eleven collector emitter voltages at turn-on. Depending on design requirements, this means the switching speed of the IGBTs and the EMI behavior can be varied flexibly during operations. Fast IGBT turn-on enables high switching frequencies. On the other hand, slow turn-on reduces electromagnetic interference (EMI) and voltage peaks by reflection at the motor. This means a reduced burden on isolations and increased motor service life, and thus lower overall system costs for the customer.

The improved switching behavior lets developers use smaller dv/dt filters or even eliminate them completely in application design, also cutting overall system costs. Compared to conventional driver components without Slew Rate Control, the 1EDS-SRC EiceDRIVER Safe saves approximately 30 percent of turn-on loss reduction. The new driver IC presented achieves this performance for the first time among driver components with secure electric insulation.

www.infineon.com/eicedriver

USB Power Delivery controllers

Microchip announces, from Computex Taipei, a family of USB Power Delivery (UPD) controllers - the UPD100X with an industry-standard

power delivery and battery charging protocol. A single USB cable can be used for data and simultaneously deliver up to 100W of power from a single standard USB port which is 40 times the power compared to USB 2.0. With up to 100W of available power, designers can dynamically allocate this power to fast battery charging and system power

The UPD1001 is the first of the family and is a highly flexible and configurable solution that supports the five USB-IF standard UPD power profiles plus an additional 25 UPD-compliant profiles for a total of 30 profiles supported by a single chip. This will allow designers to select the optimum power profiles in order to meet their specific application requirements. Simple configuration is achieved by strapping the two configuration select pins on the UPD1001. A multitude of configurations are available to provide utmost flexibility. Integrated quad-banks of one-time programmable memory allow for further system customisation without the need for any external memory components.

www.microchip.com/get/6FH0

3rd Generation SiC MOSFETs with Trench Gate Structure

ROHM Semiconductor demonstrated its new 3rd Gen SiC MOSFETs based on Trench Gate structure technology, marking another milestone in the development of SiC MOSFET which the company started back in 2010. Compared to conventional planar MOSFETs which

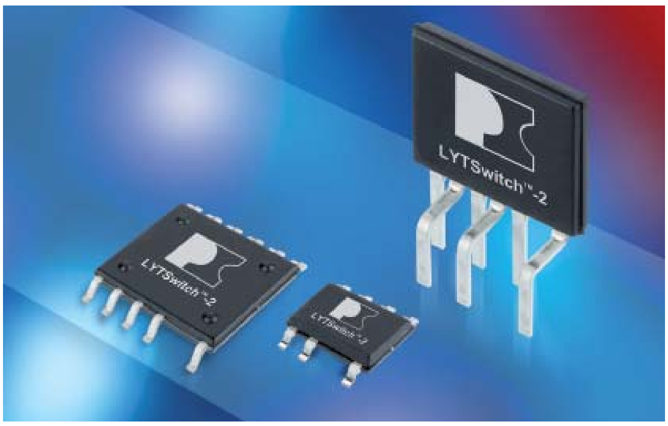
have JFET regions increasing the on-resistance, the new MOSFET types only reach about half of the same on-resistance over the whole temperature range while the stability of the Gate oxide film and of the Body Diode remains as high as with ROHM's 2nd Generation SiC MOSFETs. Since the company managed to overcome issues regarding oxide breakdown during high-drain source voltage, the result is higher reliability and increased current-carrying capacity at reduced cell density, minimum conductivity loss and minimum switching loss while keeping a compact format.

Retrospectively, ROHM already developed SiC planar MOSFETs which have suppressed the degradation of parasitic PN junction diodes when forward current penetrates. Now, the low on resistance of the trench SiC MOSFETs is ideal to improve inverter power density and performance. The new devices deliver optimized RDS(ON) and Ciss characteristics in order to tweak efficiency and switching speed. The parasitic diode only shows minimal reverse recovery behaviour and degradation caused by its conduction is widely eliminated.

www.rohm.com/eu

LYTSwitch-2 Isolated LED-Driver ICs Deliver More Output Power

Power Integrations announced its LYTSwitch™-2 family of isolated LED drivers. The new IC family, which delivers up to 12 watts of accurately controlled output power, substantially reduces component count, resulting in simpler, smaller, more reliable LED lighting designs.



LYTSwitch-2 LED-driver ICs use primary-side control, resulting in cost-effective, single-sided PCBs with low component counts. In addition, driver isolation allows the LEDs to be affixed directly to a metal heat sink, avoiding the added expense of an electrically isolating enclosure that is often required for non-isolated drivers. Accurate constant-current (CC) output tolerance across temperature (better than +/-5% at both low-line and high-line voltages) reduces the need to over-design systems in order to meet requirements such as the U.S. ENERGY STAR® minimum-lumens-delivered specification. Designs using LYTSwitch-2 ICs are also highly efficient – up to 90% in typical applications. LYTSwitch-2 ICs protect the LED load from surges in line voltage, increasing bulb lifetime in regions where the mains voltage is subject to frequent peaks. The constant-current and constant-voltage (CC/CV) control function maintains a constant voltage on the output of the driver during no-load operation, preventing damage to the output filter or shutting down the driver when being tested or installed with no LED string connected.

www.powerint.com

650V Normally-off GaN Transistor Family Announced by GaN Systems

GaN Systems has announced five new normally-off 650V GaN transistors optimised for high speed system design. The GS66502P, GS66504P, GS66506P and GS66508P are respectively 8.5A/165mΩ, 17A/82mΩ, 25A/55mΩ and 34A/41mΩ parts, while the GS43106L is a 30A/60mΩ cascode.

The 650V enhancement mode parts feature a reverse current capability, zero reverse recovery charge and source-sense for optimal high speed design. RoHS compliant, the devices are delivered in GaN Systems' near chipscale, embedded GaNPX package which eliminates wire bonds thereby minimising inductance. This package also optimises thermal performance and is extremely compact.

Girvan Patterson, President of GaN Systems comments: "With these new 650V parts as well as our recently-announced 100V family, GaN Systems offers a very wide range of parts which are available for are sampling now. Applications include high speed DC-DC converters, resonant converters, AC motor drives, inverters, battery chargers and switched mode power supplies."

www.gansystems.com

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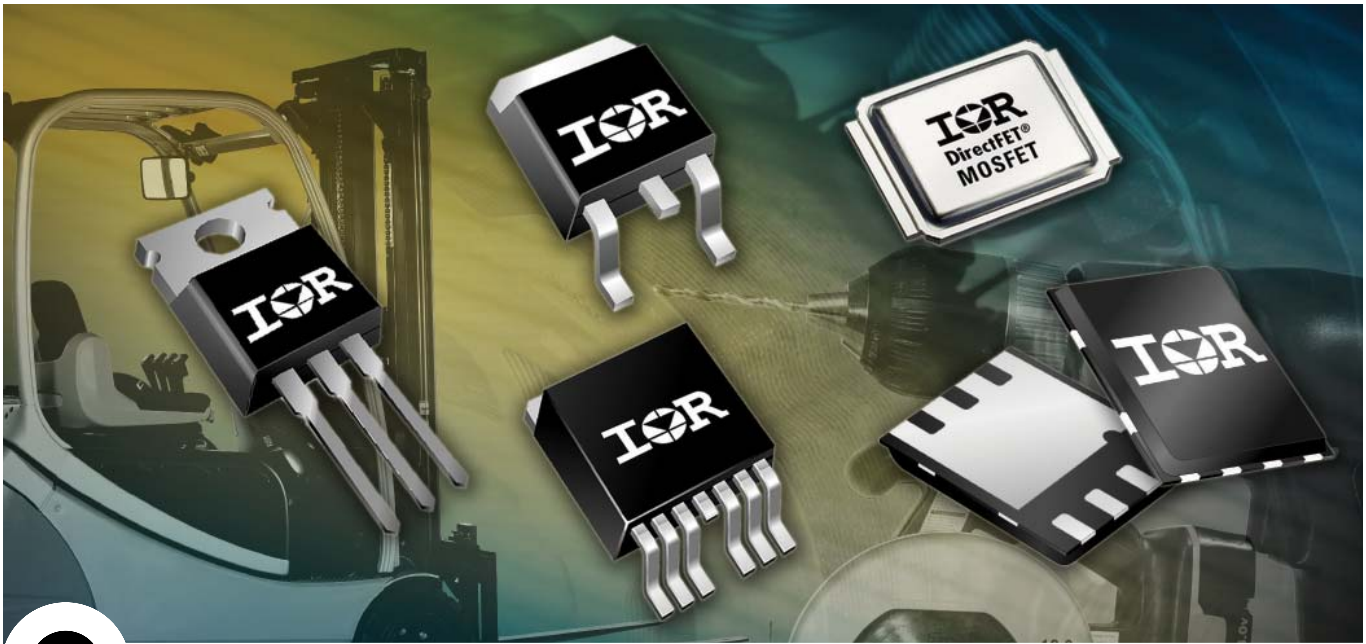

StrongIRFET™ Rugged, Reliable MOSFETs

Specifications

Package	B_{VDSS} (V)	ID @25°C (A)	$R_{DS(on)}$ max @Vgs = 10V (mΩ)	Qg@ Vgs = 10V (nC)	Part Number
PQFN 5x6	25	100	0.95	56	IRFH8201TRPbF
	25	100	1.05	52	IRFH8202TRPbF
	30	100	1.1	58	IRFH8303TRPbF
	30	100	1.3	50	IRFH8307TRPbF
	40	100	1.4	134	IRFH7004TRPbF
	40	85	2.4	92	IRFH7440TRPbF
	40	85	3.3	65	IRFH7446TRPbF
DirectFET Med.Can	30	192	1.3	51	IRF8301MTRPbF
	40	90	1.4	141	IRF7946TRPbF
	60	114	3.6	120	IRF7580MTRPBF
D²-Pak	40	195	1.8	150	IRFS7437TRLPbF
	40	120	2.8	90	IRFS7440TRLPbF
	60	120	5.34	86	IRFS7540TRLPbF
D²-Pak 7pin	40	195	1.5	150	IRFS7437TRL7PP
	60	240	1.4	236	IRFS7530-7PP
D-Pak	40	90	2.5	89	IRFR7440TRPbF
	60	90	4	86	IRFR7540TRPbF
TO-220AB	40	195	1.3	300	IRFB7430PbF
	40	195	1.6	216	IRFB7434PbF
	40	195	2	150	IRFB7437PbF
	40	120	2.5	90	IRFB7440PbF
	40	118	3.3	62	IRFB7446PbF
	60	195	2.0	274	IRFB7530PbF
TO-247	40	195	1.3	300	IRFP7430PbF

Features:

- Ultra low $R_{DS(on)}$
- High current capability
- Industrial qualified
- Broad portfolio offering

Applications:

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- Inverters
- UPS
- Solar Inverter
- ORing or Hotswap
- Battery Packs

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