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Bodo's Power Systems®

Electronics in Motion and Conversion

May 2013

Bodo´s Power Systems®

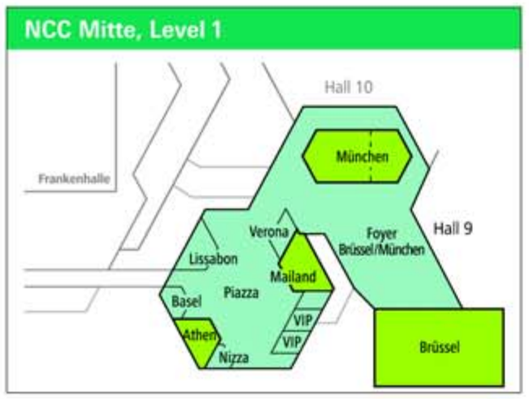
Podium at Forum 2

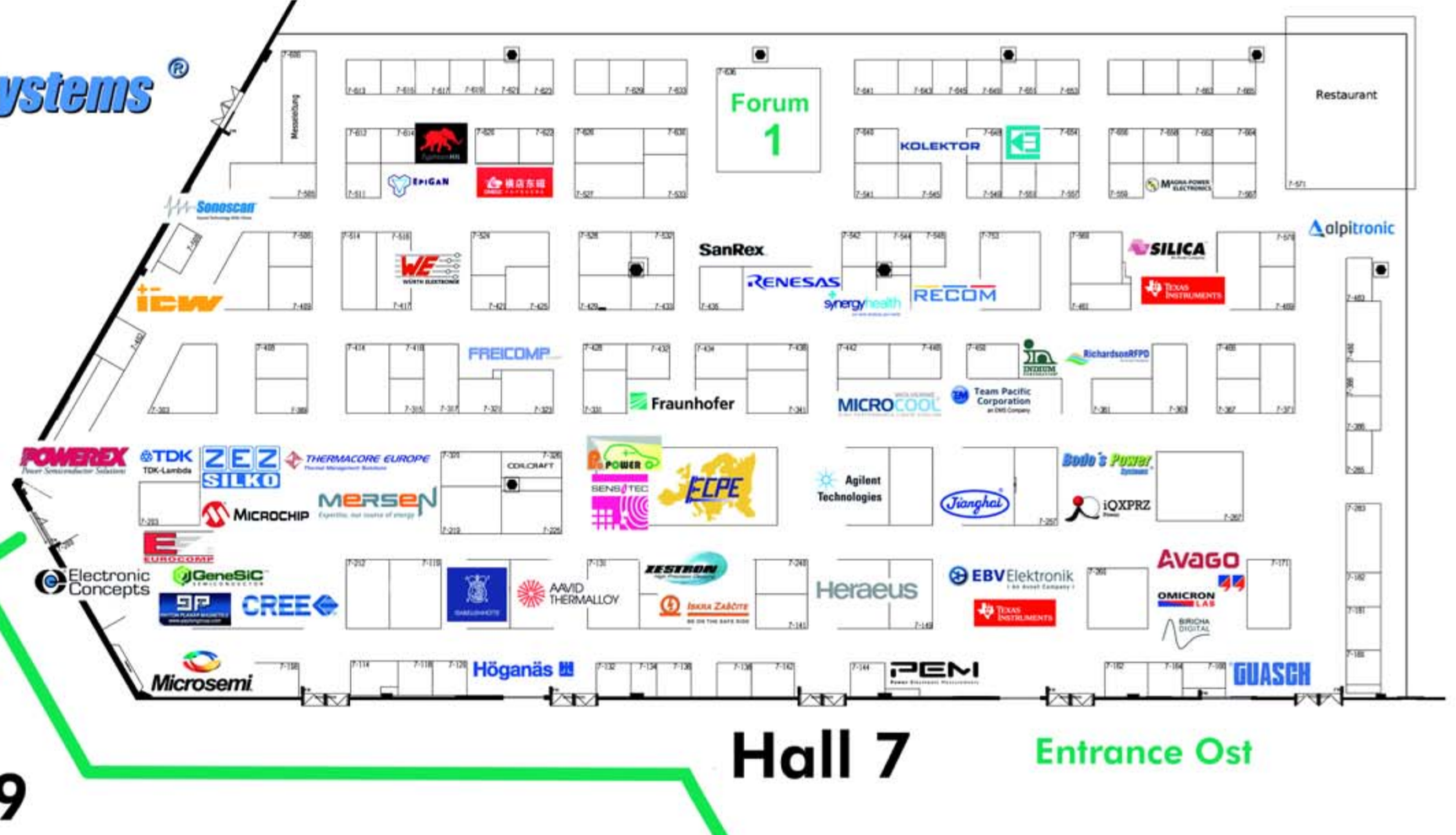
Hall 9, Booth 461

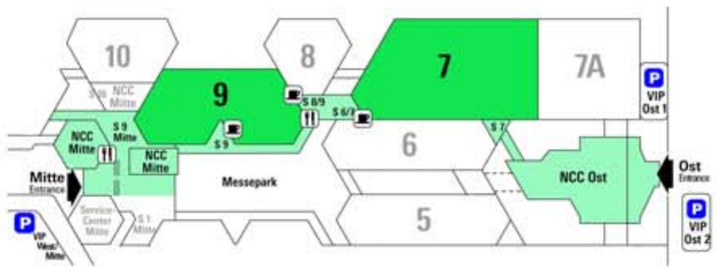
Wednesday the 15th

from 12^{20} - 13^{20}

"Energy Harvesting"







PCIM

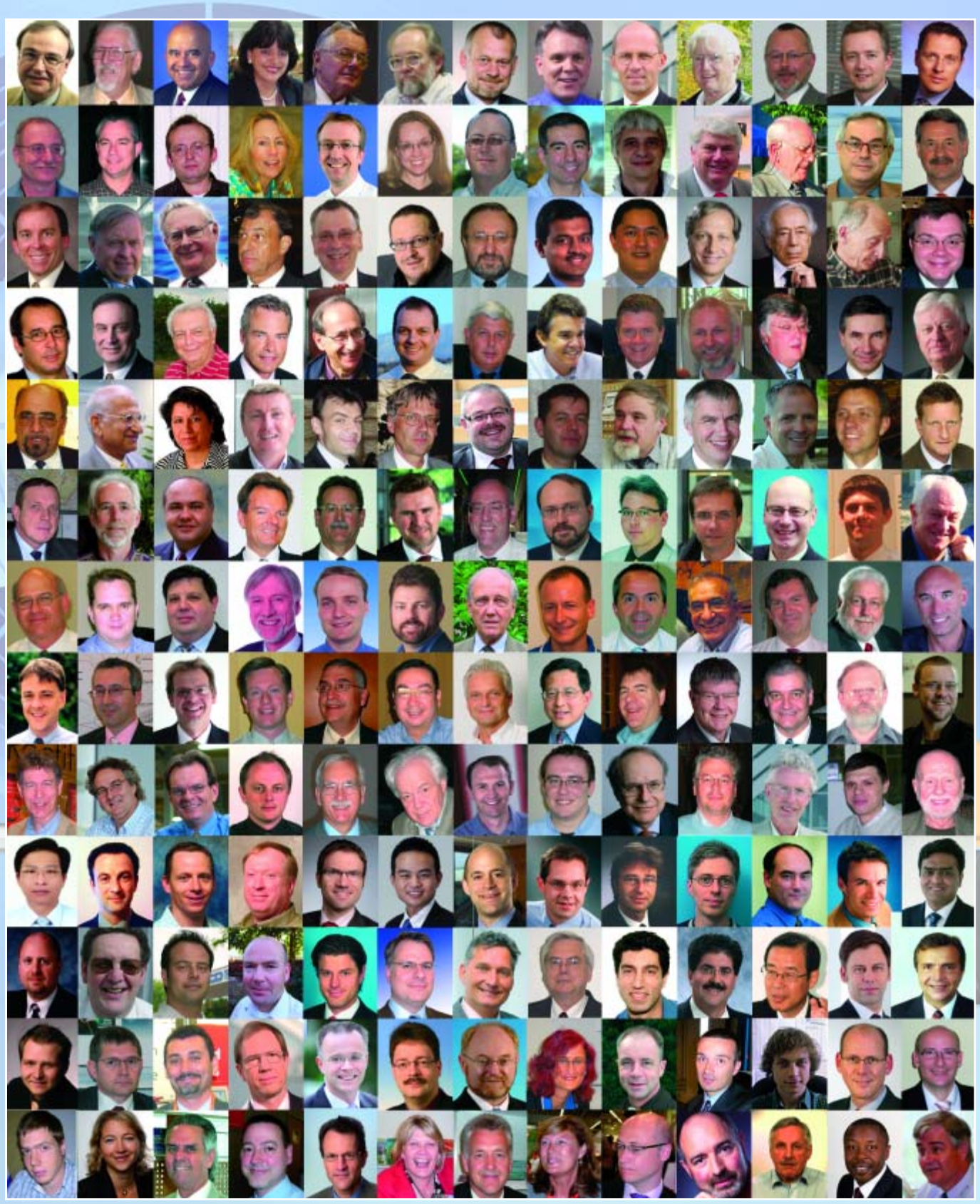
EUROPE

International Exhibition and Conference
for Power Electronics, Intelligent Motion,
Renewable Energy and Energy Management
Nuremberg, 14 – 16 May 2013

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

powerguru.org

The Gallery



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A Media
Katzbek 17a
D-24235 Laboe, Germany
Phone: +49 4343 42 17 90
Fax: +49 4343 42 17 89
editor@bodospower.com
www.bodospower.com

Publishing Editor
Bodo Arlt, *Dipl.-Ing.*
editor@bodospower.com

Senior Editor
Donald E. Burke, *BSEE, Dr. Sc(hc)*
don@bodospower.com

Corresponding Editor
Marisa Robles Consée,
Marisa@bodospower.com

Creative Direction & Production
Repro Studio Peschke
Repro.Peschke@t-online.de

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Events

IEEE Int. Electric Machines and Drives, Chicago, IL, May 12th-15th www.IEMDC13.org

PCIM Europe 2013, Nuremberg, Germany, May 14th -16th www.mesago.de/de/PCIM/home.htm

Sensor + Test 2013, Nuremberg, Germany, May 14th -16th www.sensor-test.de

Thermal Management 2013, Denver, CO, June 6-7, www.thermalnews.com/conferences/

ISiCPEAW 2013, Stockholm, Sweden, June 9th -11th, www.acreo.se

PCIM Asia 2013, Shanghai, China, June 18th -20th www.mesago.de/de/AsiaPCIM/home.htm

COWEC Wind Energy, Berlin, Germany, June 18th -19th www.vdi-wissensforum.de

Intersolar 2013, Munich, Germany, June 19th – 21st http://www.intersolar.de/

Back in Nuremberg for Asparagus!

We are now approaching the annual European highlight – the PCIM Europe in Nuremberg - after a successful start in the year with the APEC show in Long Beach. Nuremberg has been an innovations hub since Peter Henlein started making, and possibly even invented watches, back in 1505. Today, it is semiconductors and drive applications that play the important role in Nuremberg.

New power semiconductor materials are gaining more and more momentum for practical applications in volume. GaN serves higher voltages and is being put to use in inverter drives. Significant steps were evident at APEC and we will see more coming. Contributed articles in this issue cover much of this.

Again, this year, my "Podiums" discussion will take place at the PCIM Industry Forum in Hall 9, Booth 461, on ***Wednesday the 15th*** from **12:20 to 13:20**. The subject this year is "Energy Harvesting".
I look forward to seeing you there!

My friends at PowerGuru have put several apps in place to access the articles in my magazine and on the PowerGuru (www.powerguru.com) portal directly on your smart phone. The apps can be downloaded by searching on Google Play or Apple iTunes for 'power electronics', 'PowerGuru', or 'Bodo's Power.' We welcome and look forward to comments, suggestions and feedback from those who are reading us on their mobile devices.

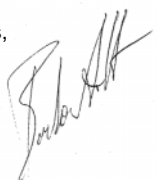
There are significant challenges and opportunities facing renewable energy sources. Through more efficient usage, overall electrical power consumption has recently decreased and the portion thereof provided by renewables has increased. Nevertheless, it would be a great to be able to store energy when the wind blows and the sun shines and there is no immediate need. The old-fashioned way has been pumped storage with water turbine-generators, but now experts are focusing on storing energy in basements in super capacitors or batteries, and on developing a smart grid with the batteries of electric vehicles.

The introduction of electric vehicles is proceeding slowly. There are too many problems that still need solutions to make an all-electric car universally attractive. Hybrid-electrics can provide a more efficient drive system and can recuperate braking energy, but still incorporate a combustion engine. The well-publicized issues with Boeing's Dreamliner have shown that the industry is still in a learning phase with regards to high-energy battery packs.

But communication is the way to progress. We delivered twelve issues last year and will continue this year, each month, on time, every time. Last year I published nearly 900 pages and 132 technical articles, a continuous growth since I started my publication. This year, with my May issue, we have 52 technical articles amongst 322 pages. As a media partner, Bodo's Power Systems is internationally positioned. If you speak the language, or just want to take to look, don't miss our Chinese version: www.bodospowerchina.com

My Green Power Tip for May:
Eat harvest-fresh white asparagus freshly peeled and cooked! Without refrigeration, you save electric energy consumption. So, enjoy the short asparagus season in Germany while visiting PCIM Europe in Nuremberg. See you there!

Best Regards,



PCIM Europe 2013
Hall 9-204

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High Reliability Power Semiconductors for Japanese Shinkansen Bullet Trains

IXYS Corporation announced the full qualification and first order series for its IXYS UK division for hermetic power semiconductor thyristors (SCR) and fast recovery diode capsules to be installed on Japan's latest generation of Shinkansen bullet trains.

The N700 series is a Japanese Shinkansen high-speed train with tilting capability developed in 2007 for operation by Japanese Rail (JR) on the Tokaido line between Tokyo and Hakata.

N700 series trains (also referred to as the NOZOMI Super Express) have a maximum speed of 300 km/h (186 mph) and is the forerunner of tilting technology. The latest generation, the N700A, is planned for commissioning from December 2013 with a plan to produce a total of 53 trains (16 cars each train) over the next couple of years.

The N700A utilizes the improved power efficiency and highest reliability of IXYS UK's high voltage capsule thyristors and fast recovery diodes. With this design win, IXYS UK has again succeeded in meeting the advanced qualification processes required within the Japanese traction industry.

IXYS UK provides the semiconductor solution for the Static Inverter (SIV) rectifier and inrush current limiter stages requiring operating voltages up to five thousand volts.

"We are extremely proud to announce our successful qualification and first series of orders for such a high profile application which demands the very best performance of our products," commented Bradley Green, President of International Sales and Business Development at IXYS. "The qualification of more of our products into the Japanese rail system builds on our growing business platform in the Japanese market against strong domestic competition, and continues our penetration of the global traction industry."

www.ixys.com

Nanotechnology Team Created

Indium Corporation announces the creation of a Nanotechnology Team to support Indium Corporation's continued expansion into novel nanotechnology materials and markets. "Nanotechnology" is a term that describes materials that are less than 100 nanometers (0.1microns) in one or more dimensions. It also encompasses products that are made using nanotechnology, as well as products that are used in nanotechnology-based processes and materials manufacturing.

Led by Andy C. Mackie, PhD, MSc, Senior Product Manager for Semiconductor Materials, the team includes:

Dr. Ning-Cheng Lee, Vice President of Technology

Jim Slattery, Vice President of Metals and Compounds Technical Service Group

Carol Gowans, Incubator Market Manager

Jim Hisert, Applications Engineer for Thin-Film and Solar Assembly Materials

One of Indium Corporation's key nanotechnology materials is its patented NanoFoil®. NanoFoil® is comprised of nanoscale layers of aluminum and nickel, which can be instantaneously activated to produce intense, highly localized heat for a variety of applications and industries, such as semiconductor sputtering materials, semiconductor assembly, aerospace, automotive, and electronics.

According to Mackie, "Indium Corporation has a long history of innovative materials development for semiconductors, electronics assembly, solar assembly, thin-film, and thermal interface applications, amongst many others. Our increasing focus on nanotechnology reflects our desire to supply next-generation materials that meet our customers' current and emerging process needs."

www.indium.com

Cost-Effective 20kW DC Fast Charger for the Americas

ABB launched the Terra SmartConnect (SC), a breakthrough product that will significantly improve the business case for installing electric-vehicle (EV) fast chargers throughout North America. The Terra SC will be available for delivery in the Americas in the second quarter. Initial shipments will support the CHAdeMO fast-charging standard, with SAE / Combined Charging System units available later this year. The Terra SC is a cost-effective direct-current (DC) charger specifically designed for convenient fast charging in commercial and office areas. It fully charges an electric car in 30 to 120 minutes, while the driver attends a business meeting, goes to the movies or enjoys a meal. The Terra SC is also ideal for people who want to keep driving but don't necessarily need a full charge: it can charge the battery of currently available EVs from 30% to 80% in less than half an hour. More applications include workplaces, fleet operators, parking operators, rental companies, car dealerships, shopping malls, and the EV infrastructure service providers who serve those applications.

Seamless integration into AC networks Through the use of open standards, the ABB DC chargers have the ability to integrate seamlessly into existing AC charging networks. "Electric vehicle service providers will find a great benefit in the easy integration of DC charging into their offering," notes Cal Lankton, Director of the Electric Vehicle Charging Infrastructure business for North America. "In congested areas, where EV drivers are vying for charging station access, the speed of DC technology will free up more charging stations and capacity for more drivers. This directly translates into greater flexibility for service providers to increase the number, and use frequency, of customers."

Easy to install, easy to use, with optimal connectivity Despite its focus on cost minimization, the Terra SC will be fully UL-listed, and comes standard with an outdoor-rated steel housing, a full-color, eight inch, intuitive touch-screen user interface and all the smart connectivity features that ABB's Terra chargers are known for.

www.abb.com

150

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WWEA Launches Small Wind Portal

On the occasion of the 4th World Summit for Small Wind in Husum, the World Wind Energy Association has launched a special internet portal that is exclusively dedicated towards small wind turbines. The aim of the portal is to offer an exchange platform for the small wind sector. The portal has a public area which is accessible for everybody and an area that is accessible for all members of WWEA Small Wind, offering more in-depth information for small wind professionals. The main features of small-wind.org are:

- general information about small wind
- small wind statistics
- information about standards, certification and policies
- a buyer's guide for consumers who are interested in installing small wind generators
- a forum for discussion of important topics within the small wind sector

Nico Peterschmidt, Chair of the WWEA Small Wind section: "Small wind today is subject to continuous technological innovation, changes of legal frameworks and changes in standards and certification required to enter into small wind markets. The internet portal of WWEA Small Wind brings all small wind stakeholders together, encourages discussions in its forums and provides important information required to harvest more of the vast small wind potential."

www.WWindEA.org

www.small-wind.org

New President for Yokogawa Europe from 1st April 2013

The Board of Directors of Yokogawa Electric Corporation resolved in a meeting on the 19th February to appoint Herman van den Berg to the position of President of Yokogawa Europe B.V. Herman van den Berg succeeds Harry Hauptmeijer, who has been Yokogawa Europe's president since 2002 and will continue as director until the 1st October 2013 to support the transition. Yokogawa Europe B.V. has developed to a growing, resilient and financially healthy company with a strong focus on customers and delivering its promise. It has a solid base to further expand business in its Test & Measurement and Industrial Automation activities in the future.

In fiscal years 2009 and 2010, Yokogawa modified its business structure and sought to make the Yokogawa Group's operations more efficient. Based on the success of these structural reforms, Yokogawa announced the Evolution 2015 mid-term business plan in November 2011 with the aim of growing its business. Now that the company has successfully completed its first full year under the Evolution 2015 plan, the decision has been made to reorganize the management team and set the stage for the continued implementation of this growth plan.

Mr. van den Berg was born on January 15, 1958, and started his engineering career in a uranium enrichment facility before moving to an offshore platform and refinery engineering team with a project company. He became involved in global projects and eventually became the global electrical, control and instrumentation manager for the company.

He joined Yokogawa in 2005 as Managing Director for Yokogawa South Africa, and moved in 2011 to Yokogawa's European headquarters in Amersfoort, the Netherlands, as Vice President for delivery and service with the Industrial Automation Division.

www.yokogawa.com

Development Board Featuring 100 V Enhancement Mode Gallium Nitride (eGaN®) FETs

Efficient Power Conversion Corporation (EPC) introduces the EPC9010 development board to make it easier for engineers to start designing with a 100 V enhancement-mode gallium nitride (eGaN) field effect transistor (FET) in applications such as high-speed DC-DC power supplies, point-of-load converters, class D audio amplifiers, hard-switched and high frequency circuits.

The EPC9010 development board is a 100 V maximum device voltage, 7 A maximum output current, half bridge with onboard gate drives, featuring the EPC2016 enhancement mode (eGaN) field effect transistor (FET). The purpose of this development board is to simplify the evaluation process of eGaN FETs by including all the critical components on a single board that can be easily connected into any existing converter.

The EPC9010 development board is 2" x 1.5" and contains not only two EPC2016 eGaN FET in a half bridge configuration using the LM5113 gate driver from Texas Instruments, as well as supply and bypass capacitors. The board contains all critical components and layout for optimal switching performance. There are also various probe points to facilitate simple waveform measurement and efficiency calculation. A Quick Start Guide, http://epc-co.com/epc/documents/guides/EPC9010_qsg.pdf, is included with the EPC9010 development board for reference and ease of use.

www.epc-co.com

www.rogerscorp.com
www.curamik.com

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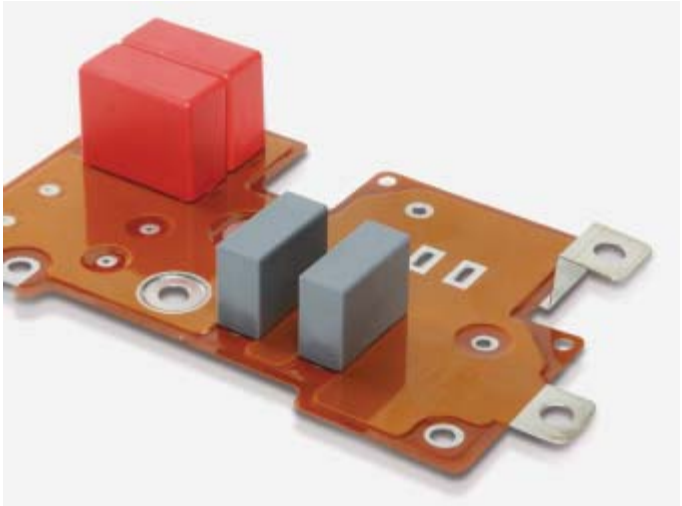

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14 – 16 May **PCIM Europe 2013**
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Wide Range of Products and Great Visitor Response

New Energy Husum closes its doors after a great four days. With around 300 exhibitors and 15,000 visitors, it has once again proven itself to be one of the most important trade fairs in the renewable energy sector. The range of exhibitors and products, and the visitor response, were greater than ever. “I am delighted by the great interest shown by trade visitors and the general public at this year’s New Energy Husum”, said exhibitor Ole Hering, managing director of NorthTec Maschinenbau GmbH. And the number of lectures was also greater than ever before. “The general public is far more interested in and aware of renewable energy, and this was confirmed by the great interest in our lectures and seminars. Questions asked of exhibitors were more detailed, and the discussions much more active”, said Thomas Seifried, New Energy Husum project manager. The international World Summit for Small Wind was better attended than ever before, and it was enhanced by additional sessions on the planning, erection and operation of small wind turbines (SWTs), and about the building laws pertaining to SWTs.

www.messehusum.de

www.new-energy.de

Automated Production Plant for Lithium Rechargeable Battery Packs

BMZ GmbH will shortly start construction of Europe’s first highly automated rechargeable battery production plant at the company’s headquarters in Karlstein near Aschaffenburg. It will be possible to almost fully automatically assemble, weld and test up to 200,000 rechargeable batteries to individual customer requirements annually in the 800 m² of the large new production facility’s first expansion stage, which is expected to be completed by the beginning of 2014. The investment costs are estimated to be around 5 million Euros. BMZ founder and sole proprietor Sven Bauer sees the significant extension of production capacity at the Karlstein location as a further important milestone on the way to become one of the globally leading specialists for intelligent rechargeable battery solutions
The aim of the future production processes is to combine the highest possible degree of quality and safety with maximum speed and flexibility, explains Bauer. Individual production steps such as feeding the cells, the placement of the cell holders and also the welding of cell connectors by resistance welding are divided into several interchangeable production cells in order to be able to make any necessary future adjustments with a minimum of subsequent time and effort. Inverter welding machines guarantee continuously high welding quality with precise monitoring of the process. Subsequent tests of the batteries are virtually completely automated apart from a few exceptions which depend on the type and configuration of the respective battery packs.
The first expansion stage of the new production facility is already designed for a variety of battery sizes in the 200 g to 3 kg weight range. This enables both small units for domestic appliances and big batteries for e-bikes to be produced.

www.bmz-gmbh.de

Digitally-Improved Battery Management Technology

Zilog, a wholly-owned subsidiary of IXYS Corporation and a pioneer supplier of application-specific, embedded microcontroller (MCU) system-on-chip (SoC) solutions for industrial and consumer power management applications, introduces its new Buck Converter Battery Charger Reference Design that employs Zilog’s Z8F042A MCU to control a step-down DC-DC converter (also known as a buck converter) that functions as a regulated power source.
This buck converter battery charger hardware is capable of regulating charger output in a number of modes such as constant voltage, or constant current with set current limits. The charger can be viewed as a complete control system. The type and capacity of the battery determines the mode of operation of the battery controller. The voltage and current setpoints are also determined by the type and capacity of the battery. All battery control loop operations can be controlled by the user via the Z8F042A MCU’s UART block, and feedback is provided in the HyperTerminal console. Additionally, LEDs provide a visual status of the charging process.
This low-cost reference design demonstrates a lithium ion battery charger consisting of a Z8F042A MCU and a buck converter. The charging process utilizes the highly accurate ADC peripheral and alternates between current and voltage monitoring which is controlled in the background software routine to allow for the UART to be processed in the main function. With the HyperTerminal GUI, the user can enter desired setvoltages and setcurrents. A proportional/integral (PI) control loop is used to charge the battery and to monitor the battery voltage after the charging process is completed. To save memory resources, the provided UART does not implement the STDIO.H libraries. Instead, a simple UART using only integer values is used.

www.ixys.com

www.zilog.com

PCIM Europe 2013: A Power Trade Show's 30th Anniversary

When the tradeshow PCIM Europe 2013 opens its doors from 14th to 16th of May 2013, all the major companies in the field of power electronics will be presenting their latest innovations in Nuremberg.

Prof. Dr. Leo Lorenz (General Chairman of the Advisory Board of PCIM Europe), Lisette Hausser (Vice President Mesago PCIM) and Alexander Kaiser (Senior Project Manager PCIM Europe, Mesago PCIM) present this year's highlights at the PCIM Europe 2013

The exhibition will be held in halls 7 and 9 for the first time, taking into account the growing demand for space from existing exhibitors as well as an increasing number of new ones. In the last three years alone, the exhibition area of PCIM Europe has grown by 30 % and is supposed to reach 18,500 sqm this year. A novelty is the second Forum, which will link together cross-sector topic areas and offer panel discussions, roundtables, short seminars and other highlights. Companies in the energy storage sector are getting their own specialist marketplace at PCIM Europe 2013. Manufacturers will have the opportunity to present their products and solutions as well as meet development engineers from user industries such as renewable energy, e-mobility and smart grid at a specially tailored "Focus Area".

Also the PCIM Conference targets the development of power electronics with regard to leading edge technologies such as solar and wind power, e-mobility and new materials. Six special sessions will highlight what the new drivers for these technologies are likely to be. Delegates can expect a total of more than 230 presentations and poster displays in over 40 sessions, providing a comprehensive overview of the most up-to-date power electronics topics. Highlights at the beginning of each conference day will be the three keynote speeches on "HVDC – State of the art and future trends", "New Generation of Traction Drives based on SiC Power Components" and "High-density Fast-transient Voltage Regulator Module", led by first rate speakers from Siemens, Alstom and Virginia Polytechnic Institute and State University. Six seminars and ten tutorials will offer delegates on the two days prior to the conference the opportunity to educate themselves about particular power electronics topics. These will be led by specially invited internationally renowned industry experts who will be able to speak on the issues in their own specialist area.

www.pcim-europe.com

Intersolar Europe 2013 Focuses on Renewable Heat and Solar

Solar process heat, the use of solar heat for industrial production processes, is one of the most promising markets of the future for solar thermal technology. Improved subsidies provided by the Federal Office of Economics and Export Control (BAFA) have been offering financial incentives for using solar thermal plants in commercial and industrial operations since last year. System solutions are another trend in solar thermal technology, integrating efficient heat storage systems as multifunctional storage tanks. Not only do they store heat for the solar installation but they can also be fed by several heat generators, for example by a combination of gas-fired systems and heat pumps. One of the major topics at Intersolar Europe 2013 (taking place June 19–21 at Messe München) covers the opportunities and potentials of renewable heating. Last year, more than 500 exhibitors showcased their latest products and current developments in the field. From June 17–20, 2013, the accompanying Intersolar Europe Conference offers additional insight into and an overview of the most important technologies and trends world-wide.

www.intersolar.de

Wind Energy is the Energy of the Future – Without it the Energy Revolution is Impossible

Unlimited, environmentally friendly and comparatively inexpensive – wind energy offers a lot of advantages. This is why it is expanding globally at a tearing pace. Wind power is one of the renewable energy sources experiencing particularly rapid growth. According to figures released by the Global Wind Energy Council (GWEC), installations generating some 45 gigawatts of electric power from wind energy were newly built in 2012, corresponding to a 20 percent increase over 2011.

If wind energy is to make further progress throughout the world, countries must exchange their knowledge of the latest findings and technology. It is against this background that the VDI Wissensforum GmbH is holding the Conference of the Wind Power Engineering Community (COWEC) on 18th and 19th June 2013 in Berlin. With Prof. Dr. Andreas Reuter of the Fraunhofer Institute of Wind Energy and Energy System Technology (IWES) and Dr. Andrew Garrad of GL Garrad Hassan as technical co-directors of the conference, more than 80 speakers from 20 different countries will cover the entire wind energy installations concept. “We are very proud to have been able to secure Prof. Reuter and Dr. Garrad as conference directors”, says Timo Taubitz, CEO of VDI Wissensforum GmbH.

http://www.vdi-wissensforum.de/en/cowec-landingpage/event/02KO181013/

www.vdi-wissensforum.de

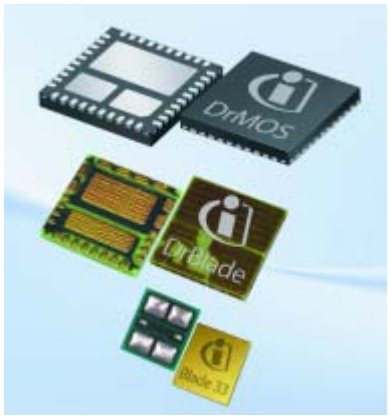
batteryuniversity.eu: 6th Developer Forum Battery Technologies

The 6th Developer Forum Battery Technologies presents the latest technologies, products and market developments in the mobile power supply industry. The forum is hosted by the batteryuniversity.eu and takes place from June 25 to 27, 2013 in the "Stadthalle Aschaffenburg", Germany.

This annual forum has established itself as one of the most important events of its kind in Europe. More than 30 top-class speakers from industry and research as well as more than 500 participants are expected . This year for the first time, the first day of the forum is dedicated to training courses. Dr. Jochen Mähliß, director of the batteryuniversity.eu, explained that this change to the forum procedure is in order to meet the desire of many participants, who would like to update and deepen their knowledge of batteries before the start of the main part of the forum. “The response so far to this additional offer has been extremely positive. This is also confirmed by the number of registrations for our half-day fundamentals training courses on the topics of lithium-ion battery technologies and battery management systems,” said Dr. Jochen Mähliß.

On June 26 and 27, a variety of presentations offer attendees a wide range of information including topics such as fire protection concepts for lithium-ion batteries, requirements for future battery charger generations, fundamentals for international product approvals, perspectives for metal-air batteries or stationary energy storage systems and their network integration/coupling with photovoltaic (PV) systems. “Our explicit goal is to offer battery developers and users an extensive overview of the latest market and technology developments. In just two days, we want to give attendees the opportunity to gather comprehensive first-hand information in direct dialogue with experts from leading companies and organizations. These high expectations are also reflected in this year’s selection of topics and speakers,” said Dr. Jochen Mähliß, director of the batteryuniversity.eu. Experts from companies and organizations such as Akasol, batteryuniversity.eu, BMZ, Aschaffenburg University of Applied Sciences, Fraunhofer, Karlsruhe Institute of Technology (KIT), LG, Maxell, Panasonic, Samsung, Siemens, Texas Instruments, the Association for Electrical, Electronic & Information Technologies

www.batteryuniversity.eu



DrBlade, the New Generation DrMOS in Innovative Chip-Embedded Packaging

Infineon Technologies AG introduced DrBlade – the first integrated DC/DC driver and MOSFET VR power stage implemented in an innovative chip-embedded package technology. DrBlade contains the latest generation low voltage DC/DC driver technology and OptiMOS™ MOSFET devices. The MOSFET technology features lowest area specific resistance and application specific optimized Figures of Merit to achieve highest efficiency in DC/DC voltage regulation systems for computing and telecom, including Blade and Rack servers, PC-motherboards, notebooks and game consoles. Infineon`s highly innovative Blade packaging technology is based on chip embedding concepts. Standard packaging processes like wire or clip bonding, as well as common molding techniques, are replaced with galvanic processes. The die also is protected by a laminate foil. The results are a significantly reduced package footprint, package resistance and inductance, as well as low thermal resistance.

“Infineon is the first semiconductor company to introduce an integrated driver and MOSFET halfbridge in Blade technology. DrBlade is another proof of our leading role in power semiconductors, making server applications highly efficient over the whole load range,” said Richard Kuncic, Senior Director Low Voltage Power Conversion at Infineon Technologies.

The DrBlade package measures 5x5mm and has a low profile of 0.5mm, fulfilling demand for higher power density and space saving in computing systems. Due to the optimized pin assignment DrBlade enables a simplified PCB layout. The new chip-embedded packaging technology in combination with OptiMOS MOSFETs by Infineon makes DrBlade the best solution for voltage regulators in the low-voltage segment.

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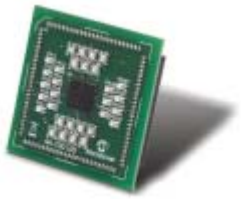

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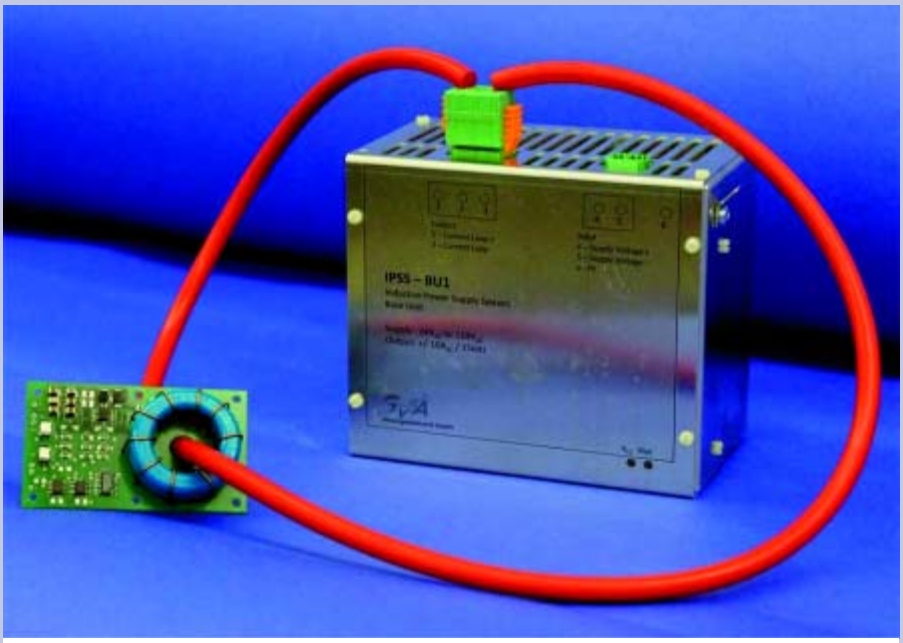
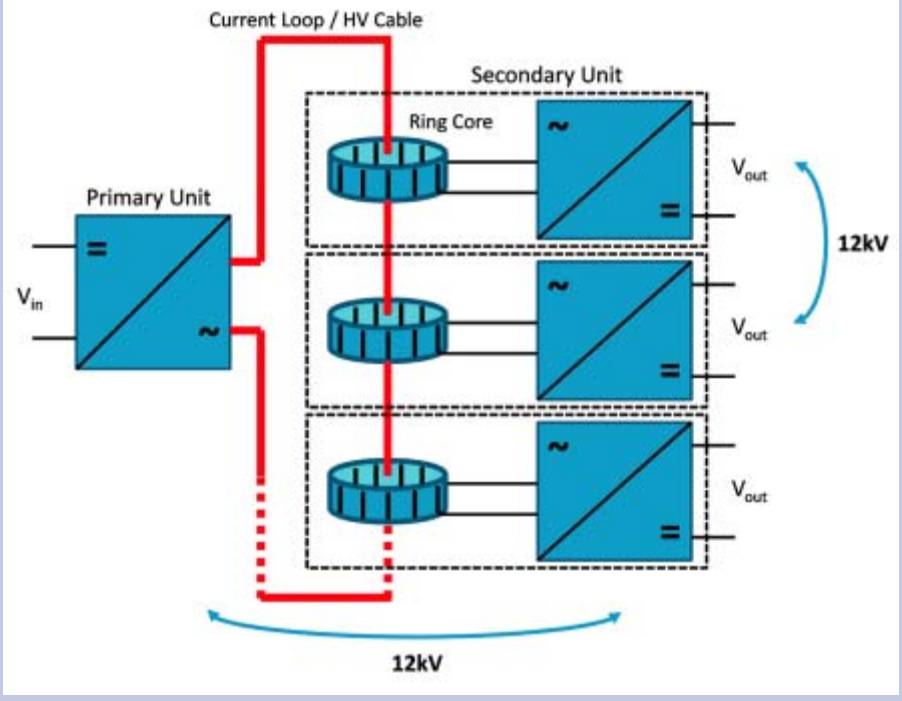


The newly developed inductive current loop power supply IPSS consists of a primary unit on the “low-voltage side”, the secondary high pot secondary units and the current loop itselfs. The required number of secondary units usually depends on the isolation requirements (inception system voltage e.g. typically 12kVAC) and the number of series-connected power semiconductors (maximum 16 secondary units at maximum secondary output voltage). The primary unit features a wide input voltage range from 24VDC to 110VDC and is therefore universally applicable for all standard DC voltage sources.

The output voltage of the secondary units can be selected between 12VDC, 15VDC and 24VDC as single unit, or e.g. +5VDC and +/-12VDC as multi secondary unit. Other secondary voltages are available upon request. The secondary unit output voltage is closed-loop controlled and therefore is largely unaffected by the magnitude of the output current and the load respectively. The unit smooths out load variations within milliseconds. The maximum output current of one secondary unit is 1000mA in the standard version. The secondary unit also features visual monitoring for voltage OK and overload.



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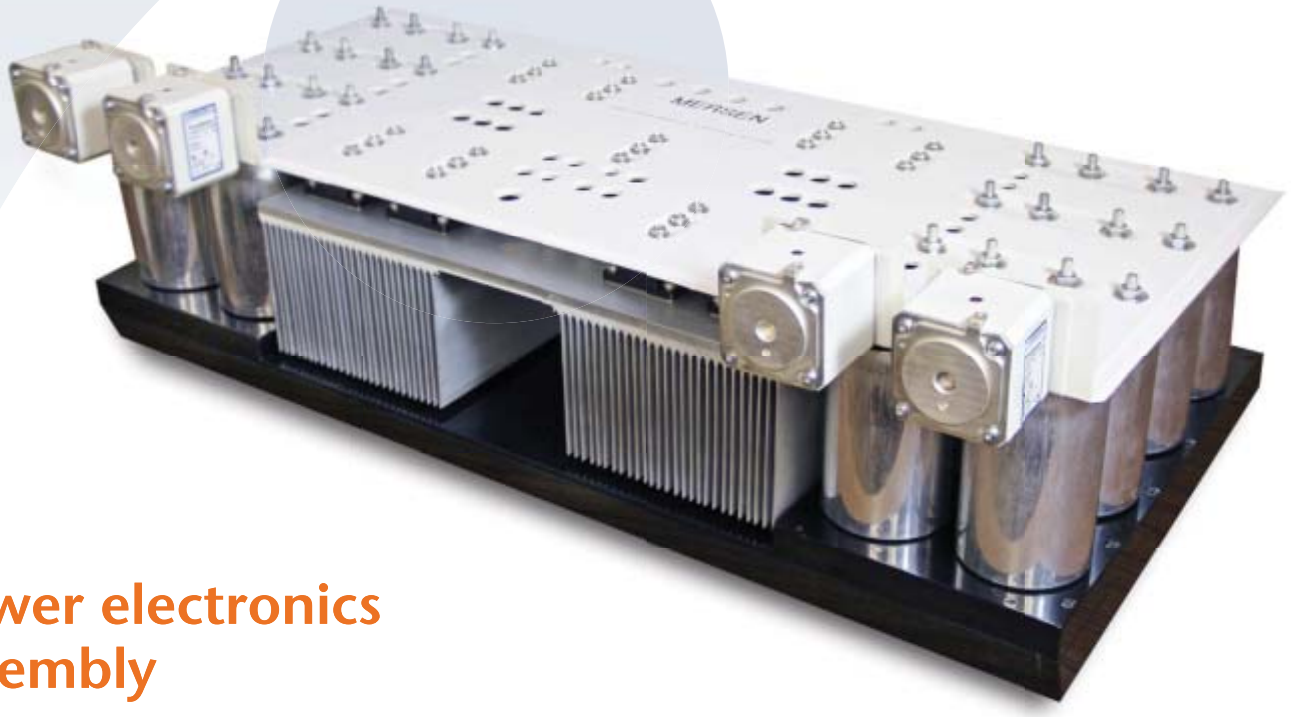

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Regional Activities are Necessary to Secure the Power Electronics Recruitment Base

By Dr.-Ing. Frank Osterwald, Senior Director Research & Development, Danfoss Silicon Power GmbH and
Prof. Dr. Ronald Eisele, Professor for Mechatronics, University of Applied Sciences Kiel

We always like Bodo announcing the coming summer season, creating pictures in our minds about sunny beaches, blue seas and cold drinks in a sunset panorama. Particularly, we in the very north of Germany, in Schleswig Holstein and in Denmark are known for making good use of nice weather conditions - like a 20 knots sea breeze - by racing our sailing boats on the Baltic. However, this is definitely not the only way to benefit from the wind up here. The Federal State of Schleswig Holstein and the Region of Southern Denmark have a remarkable share of energy generated by wind turbines. Currently, the discussion is ongoing how to further develop the HV grid lines to transport the energy to the south and to make the "Energy Turnaround" happen.

Wouldn't it be easier, if we were able to bottle wind and to deliver it to the south? However, as this currently is not possible, we need Power Electronics (PE) as a key technology, which is the good part of the story for the Power Electronics industry. In recent years, innovation within Power Electronics has become an increasingly important driver of economic growth in the Danish-German border region. According to a survey on Power Electronics of EPINION and dsn (Danish and German strategic consultants) for the LEAN ENERGY CLUSTER, the border region has a unique position within Power Electronics. About 86 Danish and German companies working in Power Electronics are located in the Region of Southern Denmark, Schleswig Holstein and Hamburg. These companies employ a total of 27,000 people and generate a revenue of around EUR 7.7 billion. PE development also has a decisive importance, with a revenue of about EUR 1.8 billion. Most of the companies expect significant growth in the field of Power Electronics, which is forecasted to be at least 20% on average per year for the next five years.

It seems as if the "northern lights", as we like to regard ourselves, among others are facing a bright and powerful future. Historically, there is a strong indication that heavy industry prefers being located at places where energy is generated. And our region has the wind …

However, there is another historically proven context: knowledge driven industry prefers being located at places where qualified personnel are available. And it turns out that, for some reason, our region faces a challenge because of potentially not being attractive enough to retain the strongest candidates. The lack of attractiveness does not seem to have to do with the quality of our beaches. They are great, at least if the weather is with us. Year by year millions of tourists travel to our region to stay here for their vacation. So, what is missing in the eyes of the young people leaving the region?

- It might be the lack of big cities, where they can meet hundred thousands of their age.
- It might be that the grass always seems to be greener in the neighbor's garden.
- It might be lack of awareness that the region offers excellent universities and challenging jobs in Power Electronics.
- It might still be the general impression that Power Electronics is not attractive.

We cannot do anything about the size of our cities in a few months. Certainly, we could try to let grass grow greener or at least to let energy get greener. And definitely, we should encourage our young people to first take a look at the job opportunities and universities they are living next to, before they go abroad. And sure, we need to increase our effort to point out the many technologies and modern, challenging jobs, that are related to Power Electronics.

Yes, we can do something about the attractiveness of Power Electronics in the awareness of young people: Create networks between schools, industry and universities. The experienced should tell the young ones about the fun of solving problems – of solving problems having worldwide importance!

As Antoine de Saint-Exupery already said: "If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea."

Translated to our world of Power Electronics - it should be such a fantastic story of increased efficiency that creates better living conditions. We must be enabling teachers and schools, professors and universities, industry, politics and decision-makers to invest in more electrifying education.

Minister Dr. Robert Habeck, responsible for the energy turnaround in the state of Schleswig Holstein, lately stated that, in his eyes, the energy turnaround can be considered to be a forced transition towards the "more electrical world" of tomorrow. Furthermore he pointed out, that it is a pre-requisite for the success of the energy

turnaround to provide a solid recruitment base of young talents for the Power Electronics industry in the northern region.

Small steps first: Local networks are efficient because young people (still living at home) are not yet mobile and not yet free in their decision. Imagine university based centers of Power Electronics, busy with problem solving for companies and educating their students - but also open for young people from schools and vocational colleges.

A successful example of local networking is the Power Electronics Network KLSH (kompetenzzentrum-leistungselektronik.com) in the state of Schleswig Holstein: Partly financed by the EU, more than a dozen local companies and three universities cooperate under the guidance of the Fraunhofer Institute of Silicon Technologies (FhG-ISiT) and with the support of WTSH-Wirtschaftsförderung und Technologietransfer Schleswig Holstein GmbH. In a number of activities this consortium has shown efficient cooperation ranging from finding technical solutions to supporting young talents in their career ambitions. With the beginning of 2013 a new funded research program under the supervision of FhG-ISiT and WTSH has been started: "Power Electronics for Renewable Energy Supply". Over the next three years the local industry (lead by RePower and Danfoss Silicon Power) and scientists, engineers and students from universities in Schleswig Holstein are designing and building multi-stack power inverters with increased power density.

Another successful example is the establishment of the Competence Center for E-Mobility Schleswig Holstein (KESH) at the University of Applied Sciences in Kiel (UASK). Their student's activities around electric vehicles are quite visible in the region and are creating awareness and attracting more young talents. The positive effects of this center encouraged the UASK to widen the scope of activities and to include other universities in their plans. These plans are about a center focusing on industry collaboration, academic education, and involvement of schools and vocational colleges in a wider frame of Power Electronics. Power Electronics for E-Mobility, renewables and drives will be further developed as well as Power Electronics components, technologies and cooling. The center is going to provide space and capacity for running industry projects, where young people – students as well as trainees - will play an important role in. By solving problems in industry, they will be in close touch with their potential employers and vice versa. Being involved so early and so deeply, they will find out how thrilling working on these tasks can be. Can you imagine a better way of creating a solid commitment of young talents forming the recruitment base for the Power Electronics industry in the region?

For many years, the European Center for Power Electronics (ECPE) has been supporting their members and competence centers to get in touch with young talents and to create awareness for the need of Power Electronics in our society. The European and even global horizon of the ECPE needs to be complemented by the local activities described above, in order to increase the speed of change towards the "more electric world".

Even a so well prepared career in Power Electronics from time to time needs recreation time. Therefore you are all invited to relax at our beautiful beaches and have a long look at the blue seas, reading Bodo's Power Systems May issue.

www.fh-kiel.de

www.ecpe.org

Electronics Industry Digest

By Aubrey Dunford, Europartners

SEMICONDUCTORS

Renesas Electronics has also decided to explore divestiture of its subsidiary, Renesas Mobile (RMC) or explore alternative business models for RMC. This review would include all RMC's mobile business activities in all geographies, other than the business operations related to car information system and the industrial equipment business conducted by RMC: these business areas would not be affected by this review, and the group is committed to continue its operation in these areas. Renesas intends to sell the mobile chip unit which currently has about 1,900 employees to a foreign company.

Global semiconductor inventories held by chip suppliers fell at a surprisingly fast rate in the fourth quarter, led by dramatic reductions for market leader Intel, so IHS iSuppli. Days of Inventory (DOI) for semiconductor suppliers in the fourth quarter declined by 5 percent compared to the third quarter.

Intersil, a supplier of high-performance analog, mixed signal and power management semiconductors, announced the appointment of Necip Sayiner, 47, as President and Chief Executive Officer.

Altis Semiconductor, an established global specialty foundry based in France, announced the finalization of a foundry agreement with IBM Microelectronics. Under the terms of this agreement, Altis will be the foundry partner for the IBM 180nm SOI technology.

SEMI reported that worldwide sales of semiconductor manufacturing equipment totaled $ 36.93 billion in 2012, representing a year-over-year decrease of 15 percent. Spending rates declined for all the regions, except for Korea and Taiwan. Taiwan surpassed North America as the region with the highest amount of spending with $ 9.53 billion in equipment sales. The Korea market claimed the second place for the third year in a row with $ 8.67 billion in sales; North America fell to the third position with a regional decrease of 12 percent. European sales of semiconductor manufacturing equipment totalled $ 2.55 billion in 2012, representing a year-over-year decrease of 39 percent.

OPTOELECTRONICS

Sharp will issue new shares through a third-party allotment to Samsung Electronics and form a capital alliance with the Korean company. Sharp will receive capital investment of approximately 10.4 billion yen from Samsung Electronics and will issue new shares equivalent to 3.08 percent of the voting rights after such capital investment. Sharp has been currently supplying Samsung Electronics with LCD panels.

PASSIVE COMPONENTS

PCB sales in Germany increased by 50 percent in January compared to the previous month, so the Zvei. Sales are traditionally high in January and January sales in previous years were usually about a 25 percent to 30 percent higher than in December. Meanwhile, order intake rose by 13 percent in January 2013 compared with December 2012. Compared to January 2012, however, the value is 3.5 percent lower. Because of the unusually high turnover, book-to-bill ratio fell to 0.95.

Aavid, a provider of thermal management, engineering, design and manufacturing solutions operating with more than 2,800 employees, announces the addition of fans and blowers to their extensive global product line of total thermal solutions to the electronics market.

OTHER COMPONENTS

Cadence Design Systems, a leader in electronic design innovation, has entered into a definitive agreement to acquire Tensilica, a supplier in dataplane processing IP, for approximately $ 380 M in cash. Tensilica had approximately $ 30 M of cash as of December 31, 2012. Further expanding Cadence's IP portfolio, Tensilica provides configurable dataplane processing units that are optimized for embedded data and signal processing targeted at mobile wireless, network infrastructure, auto infotainment and home applications. More than 200 licensees, including system OEMs and seven of the top 10 semiconductor companies have shipped over 2 billion Tensilica IP cores.

DISTRIBUTION

Acal has entered into a conditional agreement to acquire the French Myrra Group through the acquisition of its holding company, Aramys, for an up-front cash consideration of € 9.5 M. A further future payment of up to a maximum of € 1.8 M will be payable in March 2016 subject to the Myrra Group's performance over the three year period to 31 December 2015 following completion.

The Myrra Group designs and manufactures customised magnetic electronic products generating sales of € 20.8 M and an underlying operating profit of € 1.7 M in the financial year ended 31 December 2012.

Richardson RFPD, an Arrow Electronics company involved in the RF and wireless communications, power conversion and renewable energy markets, announced the launch of several new website resources focused on Silicon Carbide technology (SiC) for energy and power applications, Gallium Nitride (GaN) technology, and Silicon-On-Insulator (SOI) wafer processes. Richardson RFPD also announced the launch of its M2M Tech Hub, a micro-website featuring the latest products from M2M suppliers, along with extensive technical resources and tips, and online shopping.

Avnet Memec has been appointed as pan-European distributor for Wyless, a supplier of wireless M2M managed services. The new agreement adds Mobile Virtual Network Enabler (MVNE) services to Avnet Memec's wireless solutions. Avnet Memec has also been appointed as the Coilcraft distributor for UK and Ireland.

Silica, an Avnet company, announced the launch of an engineering support initiative called ArchiTech. With ArchiTech, the semiconductor distributor aims at providing a full solution and single-point-of-contact for all requirements related to design tools.

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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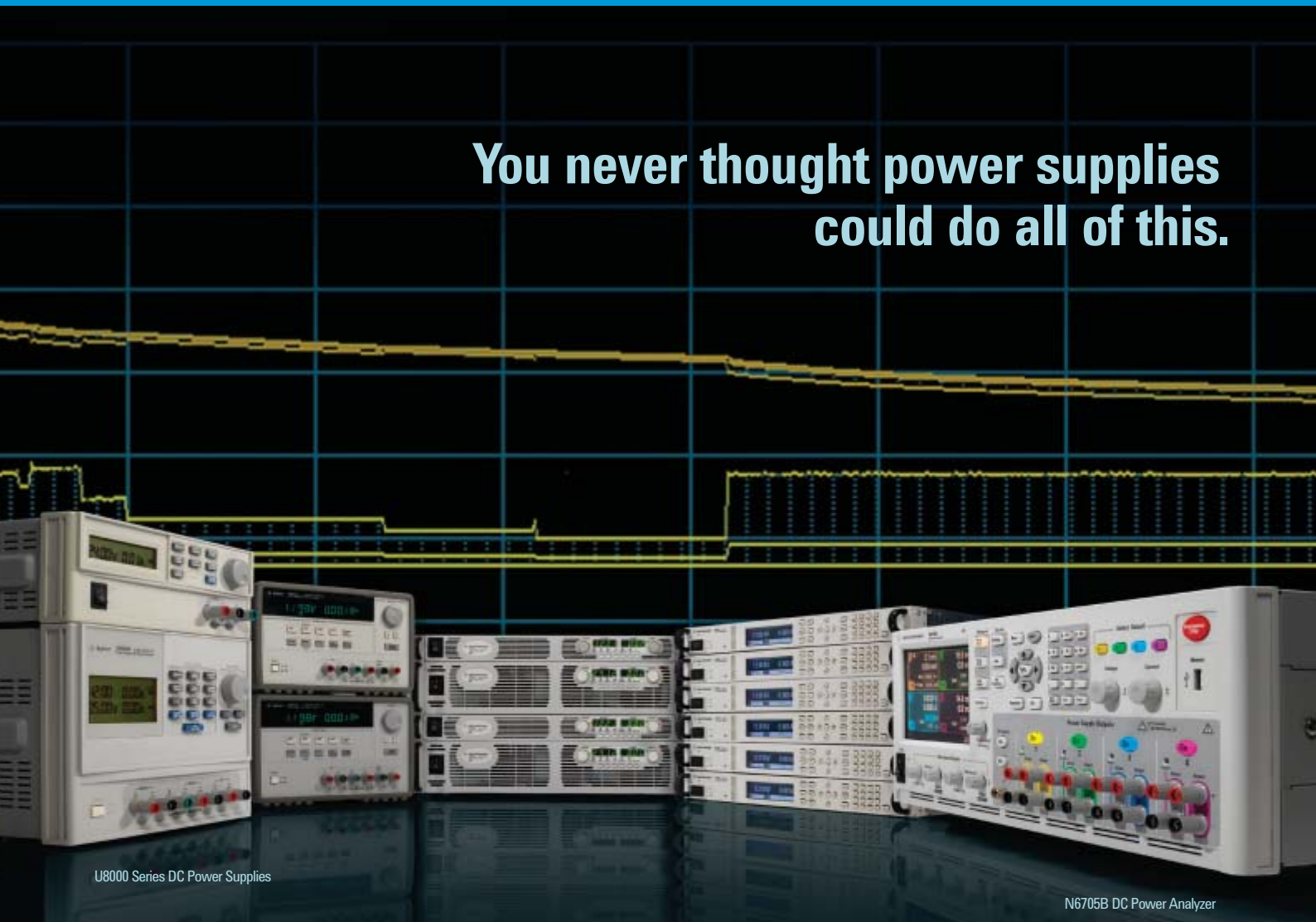

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Wireless Power is No Longer Just for Portable Consumer Devices

By Jeff Shepard, President, Darnell Group

Initially conceived as a convenient way to recharge portable electronic devices such as handsets and laptops, various wireless charging technologies are currently expanding far beyond those early beginnings. Active product development activity is underway to apply this technology to industrial devices, automotive applications, small household appliances, medical devices and other areas. Among the companies targeting these “non-consumer-portable” applications are PowerbyProxi, TE Connectivity, Fulton Innovation, and Evatran.

In addition, while first-generation devices were limited in capability and worked with only one of the several wireless charging standards in the market, today there is a trend toward multi-protocol devices combining two or more protocols. Integrated Device Technology, Inc. (IDT) has already introduced the industry’s first dual-mode wireless power receiver IC that provides compatibility with both the Wireless Power Consortium (WPC) and Power Matters Alliance (PMA) standards. IDT’s innovative receiver bridges the technology gap between competing transmission standards, empowering mobile device and accessory.

Expanding its effort to bring wireless power capabilities to the market, Texas Instruments Inc. (TI) has announced plans to develop multi-mode wireless power integrated circuits (ICs) for smartphones and other portable electronics. TI will continue to develop new bqTESLA™ wireless power receiver and transmitter integrated circuits that comply with existing and future versions of the Wireless Power Consortium (WPC) Qi standard. In addition, TI announced today it will create products that support both Qi and the PMA wireless charging specification. The first multi-mode solutions from TI are expected later this year.

Demonstrating the widening applications and the flexibility of wireless charging, Fulton Innovation showed an example of two-way wireless power at the Consumer Electronics Show (CES) earlier this year in Las Vegas. Using the Qi, Fulton demonstrated a tablet being charged wirelessly, which in turn was used to charge a Qi enabled mobile phone. By simply placing the two devices back-to-back, the power transfers wirelessly between them.

In another demonstration of the flexibility of wireless power, Fulton showed an interactive printed poster with an illustration of a DJ console that can actually be played. Music is made by tapping the speakers, mixer, and turntable, while placing the same tablet that wirelessly charges a mobile phone near the poster for power. The combination of printed electronics and two-way wireless power creates a new way of connecting to consumers through interactive posters, magazines, food packaging, and more.

Using its new Adaptive Resonance technology, Fulton demonstrated a surface that wirelessly charges multiple Qi-compatible devices at once. Placing the phones or tablets on one pad will charge simultaneously, recognizing and adapting to the power needs of each device. Other demonstrations included: A set top box and TV that automatically turns on or off when the remote is removed or placed on the box, where it charges a super capacitor with no batteries when not in use, and wireless kitchen appliances that use direct power, rather than charging like mobile phones.

Targeting industrial applications, TE Connectivity and PowerbyProxi formed a partnership combining TE’s history and market position in the industrial connector space with PowerbyProxi’s expertise and intellectual property in wireless power. In fact, TE has taken an equity stake in PowerbyProxi.

"Our proven innovation and miniaturization in the field of wireless power transfer was compelling to TE and we are excited to work with the TE team on the future of wireless power " said Greg Cross, Executive Chairman of PowerbyProxi. "This new round of investment demonstrates faith in the growth of this sector and the milestones we have achieved. We will use the funds to grow our international sales and customer support structures and to accelerate the development of new technology platforms," said Cross.

The first outcome of PowerbyProxi’s partnership with TE is the ARISO Contactless Connectivity Platform, a miniaturized contactless connectivity solution, small enough to be easily integrated into new applications for industrial machinery and equipment. The new line of non-contact couplers, being sold and marketed by TE, incorporates PowerbyProxi’s Proxi-Wave technology, which is ideal for miniaturization. The platform offers the smallest footprint solution available for contactless power connectivity on manufacturing machinery and equipment for sensor and control applications.

TE is now manufacturing evaluation kits so its customers can test the hardware in their own environments, alongside TE’s field engineers. The ARISO Contactless Connectivity system is 70% smaller than currently available systems and brings the possibility of wireless power transfer to applications where it was previously considered impossible.

Turning to examples of multi-mode charging ICs, the IDTP9021 from IDT is an enhanced version of IDT’s IDTP9020 wireless power receiver that complies with the PMA Type 1 Interoperability Specification in addition to the WPC "Qi" standard, allowing customers to consolidate multi-chip configurations into a single-chip solution. IDT’s device is the industry’s first to receive pre-certification from the PMA, and is the only solution with demonstrated compatibility between the two most popular magnetic induction-based wireless power standards. The IDTP9021 is targeted for use in a myriad of mobile devices, including smart phones, tablets, MIDs, digital cameras, MP3 players, remote controls, portable medical devices, and other personal electronics.

The IDTP9021 integrates a high-efficiency synchronous full bridge rectifier, high-efficiency synchronous buck converter, and control circuits to wirelessly receive an AC power signal from a compatible

transmitter and convert it into a regulated 5 V output voltage for powering and charging portal electronics. It automatically switches between WPC and PMA protocols and negotiates the power exchange without user supervision.

This simplifies the system architecture and ensures seamless operation during everyday use. The device delivers 5W in WPC and PMA modes in accordance with those standards. When paired with IDT wireless power transmitters, systems can make use of the proprietary power control loop embedded in the communication protocol to achieve a 50% increase in output power to 7.5W.

Commenting on the efforts of Texas Instruments to develop wireless power ICs, Sami Kiriaki, senior vice president of TI Power Management, recently commented: “We are shipping wireless power circuits to most major handset makers. And those companies continue to develop phones that support WPC’s Qi, which is currently the most mature and accessible design standard. With A4WP and PMA entering the wireless power space, we naturally expect a need for multi-protocol solutions, and are prepared to address this need.”

TI also recently announced it will develop products that support the Alliance for Wireless Power (A4WP) magnetic resonance specification. A4WP is a group of electronics companies, including Samsung, Qualcomm and others, focused on advancing spatial freedom in wireless power. Wireless power is an emerging technology that creates a better charging experience for consumers, just as Wi-Fi replaced the need to use an Ethernet cable for Internet connectivity. TI’s advanced receiver and transmitter integrated circuits include the recently announced bq51050B single-chip wireless power receiver with integrated charger and the bq500410A 3-coil transmitter with spatial freedom.

Also earlier this year, Evatran announced, in cooperation with U.S. Oak Ridge National Lab (ORNL), that it has been awarded a subcontract under ORNL’s DOE Project, "Wireless Power Transfer (WPT) and Charging of Plug-In Electric Vehicles." The three-year project covers high power wireless charging technology integration into electric vehicles currently on-sale in select US markets. Evatran’s knowledge of efficient wireless power transfer, system controls, and intuitive user interfaces coupled with the Company’s documented success in prototype field trials led ORNL to select the three year-old, Virginia-based start-up for inclusion.

Evatran will focus on vehicle integration and supply production designs for the Project Team. "This is our area of expertise," commented Rebecca Hough, Evatran CEO and co-founder. "We’ve spent the last three years focusing on how to efficiently and safely integrate wireless charging systems into electric vehicles. The information and learnings gathered from our field trials will be extremely valuable in helping ORNL to create an efficient, low cost production design. We couldn’t be more excited to work with such strong industry leaders on this initiative to bring wireless charging into the mainstream."

The project team, led by ORNL, also includes two major international automotive manufacturers, Clemson University’s International Center for Automotive Research (CU-ICAR), Cisco, and Duke Energy. After a first year of design research, the team will integrate 6.6kW and 10kW designs into six production electric vehicles during the second year of the project. The third year of the project will see those vehicles placed into the field for limited field trials. The project team will install static wireless charging systems and show capability for dynamic wireless charging (wireless charging while vehicle is in motion).

In the future, a single home will have one or more wireless charging “stations” in each room. These wireless chargers will represent a wide variety of application devices with power levels ranging from a few watts to multi-kilowatts. Whenever appropriate, each of those wireless charging devices will have multi-protocol capabilities. In some cases, they will even “beam” power over distances of a meter of more. As a result, the market for wireless chargers will be hundreds of millions of units annually and further in the future, they will mostly replace today’s external ac-dc power supplies and chargers.

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Compact and Powerful 600V Half Bridge Driver ICs for Consumer Electronics and Home Appliances

Developers of consumer electronics and home appliances strive continuously for higher efficiency of applications and smaller form factors. One area of interest in power supply design is that the switching behaviour and power losses of new power MOSFETs, such as the latest generations of CoolMOS™ with dramatically reduced gate charges, can be optimized by dedicated driver ICs.

By Wolfgang Frank, Oliver Hellmund and Viktor Boguszewicz, Infineon Technologies AG, Neubiberg, Germany

A new family of half bridge gate driver IC supports both design goals. With its monolithic integrated ultrafast bootstrap function this new generation 2EDL EiceDRIVER™ is a benchmark for driver ICs in the market with more than 2A output current. The new 600V gate driver IC family currently contains seven devices, with output currents of 0.5A and 2.3A, for applications with either IGBTs or MOSFETs.
With the new 2EDL driver ICs, Infineon also introduces a new device segment; EiceDRIVER™ C (Compact) for consumer electronics and home appliances.
This article discusses the driver's operation range and the properties of the bootstrap function in terms of dependency on temperature and IC supply.

Introduction

The new 2EDL half bridge driver ICs represent a new class of gate drivers with integrated bootstrap function for the high side supply. The reasons there are few devices of this class on market include a rather high voltage drop at low duty cycles and the additional high power dissipation in the IC at high switching frequencies. Existing devices are typically limited to applications such as consumer drives. They have 600V blocking voltage, which is the low power drives market. Other half bridge driver ICs, which do not have an integrated bootstrap diode are used in low end switch mode power supply (SMPS) applications. Since there is no bootstrap function integrated into the IC, these products have a slightly better temperature budget due to less power dissipation.

However, the advantages of a powerful integrated bootstrap function are striking: simpler layout, less PCB space and better component placement in respect of distance to the gate terminal of the power transistor. This keeps also the EMI low and optimizes the switching performance, hence the switching losses.

For these reasons, Infineon developed the new concept of a half bridge Gate driver IC that fully supports the design considerations of consumer electronic equipment including SMPS and computing, and home appliance drive systems.

The new half bridge driver IC family 2EDL is designed to support all mega trends in low power drives designs, such as ease of use and short bill of materials while simultaneously offering a high number of features.

Technology

Thin-Film-SOI (Silicon-On-Insulator) technology is an advanced technique for MOS/CMOS fabrications. Based on conventional bulk process the SOI technology uses an insulator called buried oxide underneath the active device layer, as shown in Figure 1.

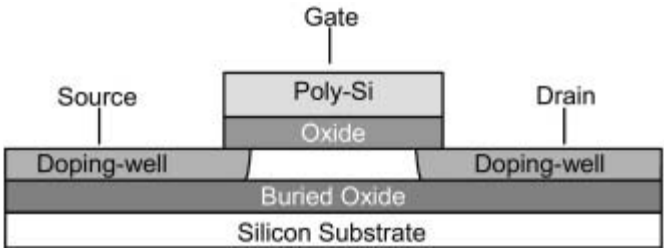

Figure 1: Silicon-On-Insulator transistor

The lateral insulation of elements inside the silicon film is achieved by a simple local oxidation (LOCOS) process. In this way all active device regions are fully insulated from each other. Thus, there is no need for CMOS-wells to prevent the "latch-up" effect. Additionally, leakage current and junction capacitances are reduced significantly. The small size of PN-junctions inside the thin silicon film leads also to higher switching speed.

Element	Characteristics
CMOS analogue transistors	30 V / 12 V / 5 V
CMOS digital transistors	5 V
SOI-PIN-diode	30 V
Z-diodes	5.2 V
Resistors	18.5 Ω/square – 7.5 kΩ /square
Capacitor	0.84 fF/µm²
HV bootstrap SOI-diode	600 V, -50 V
High-voltage SOI-transistor	600 V (N-Channel)

Table 1: Devices and characteristics of the thin-film-SOI process

Different devices inside the individual silicon regions can be implemented as shown in Table 1. The presented technology contains 600V devices like level-shift transistor and high-voltage bootstrap diode, which are also realized in the thin silicon film. The 600V voltage ability is achieved by special junction termination structures, which allow monolithic realization of circuits like half or full bridge drivers for 600V applications.

Device family

The 2EDL EiceDRIVER™ Compact family covers the full range of peak output currents from 0.5A to 2.3A. The 0.5A device is available in DSO8 and DSO14 package, while the 2.3A device is available in DSO14. All packages are RoHS compliant, green and halogen-free. The device in DSO8 package provides a floating high side section with a limited functional set and feature set.

The 2EDL05I06BF is well-suited for SMPS. It does not have a dead time and interlock function, so that both the high side output and the low side output can be activated simultaneously.

A full set of protection functions and features, such as an enable function, a failure indication, separate return path for the gate current (power ground) incl. an overcurrent protection (OCP), is realised in two parts with high output current of 2.3A. Therefore, all applications with higher integration and safety requirements can be addressed.

part number	Ipk	Asym. UVLO	BS diode	UVLO for	EN	/FLT	PGND	OCP	DT	Pack.
2EDL05I06PF	0.5 A	✓	Yes	IGBT	-	-	-	-	✓	DSO8
2EDL05I06PJ	0.5 A	✓	Yes	IGBT	-	-	-	-	✓	DSO14
2EDL05I06BF	0.5 A	✓	Yes	IGBT	-	-	-	-	-	DSO8
2EDL05N06PF	0.5 A	-	Yes	MOSFET	-	-	-	-	✓	DSO8
2EDL05N06PJ	0.5 A	-	Yes	MOSFET	-	-	-	-	✓	DSO14
2EDL23I06PJ	2.3 A	✓	Yes	IGBT	✓	✓	✓	✓	✓	DSO14
2EDL23N06PJ	2.3 A	-	Yes	MOSFET	✓	✓	✓	✓	✓	DSO14

Table 2: Individual function set realized in new concept

Bootstrap diode

The integrated bootstrap function is typically realized by integrated high voltage MOSFET structures, as indicated on the left side of Fig. 2. The MOSFET structures are turned on and off in phase with the LS transistor. This is a crucial point, because the driver IC is neither aware of the delay times of the power transistors nor of the power factor of the motor. Thus, the control of the bootstrap FET must consider this by additional bootstrap delays. These delays reduce the available time for bootstrapping, so that the bootstrap voltage is further reduced.

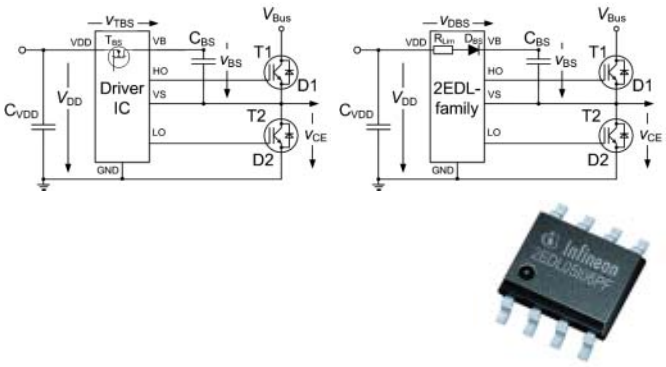

Figure 2: Conventional (left) and high performance (right) bootstrap circuit of a half bridge
Below: One of two packages of 2EDL EiceDRIVER™ Compact

Another drawback of using a MOSFET for bootstrapping is the temperature dependency of MOSFET over temperature. Usually, MOSFETs double their $R_{DS(on)}$ – value when the junction temperature increases by 100 °C. This means, that the above mentioned situation gets worse. The higher $R_{DS(on)}$ also causes more power dissipation inside the driver IC and limits the thermal safe operation area in respect to switching frequency and gate charge. It can be seen in Fig. 3, that the bootstrap diode is superior to existing bootstrap functions as soon as the diode forward characteristic is above the MOSFET characteristic. This is the case for a forward current of approx. 5 mA – 10 mA under elevated temperature.

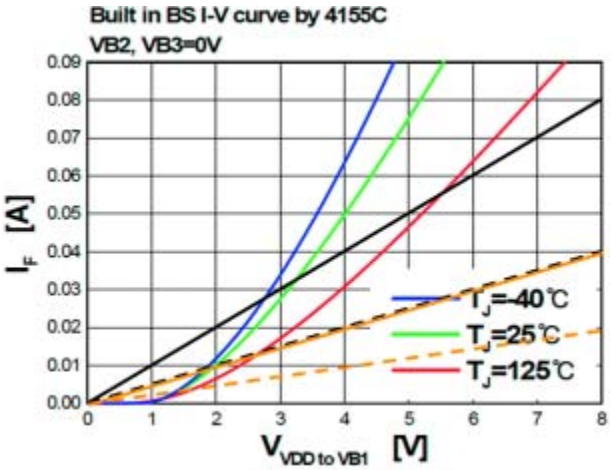

Figure 3: Bootstrap diode forward characteristic compared to MOSFET with $R_{ds(on)}$ = 100 Ω (black T_j = 25°C, dashed: T_j = 125°C) and $R_{ds(on)}$ = 200 Ω (orange, T_j = 25°C, dashed: T_j = 125°C)

The effects of the output characteristics are visible in a diagram showing the nominal voltage reduction of the bootstrap capacitor voltage in respect to the supply voltage versus the duty cycle. As an example, a single half bridge configuration is used as a representative of a SMPS topology. A small duty cycle of the low side transistor or diode leads to an uncompleted recharging of the bootstrap capacitor CBS, as seen on the right side of Figure 2. As a consequence, the bootstrap voltage decreases until a new steady state operation is reached in respect to the supply voltage of the driver IC. Figure 4 shows the diagram for operating conditions of switching frequency f_p = 20kHz and a bootstrap capacitor of C_{BS} = 22µF.

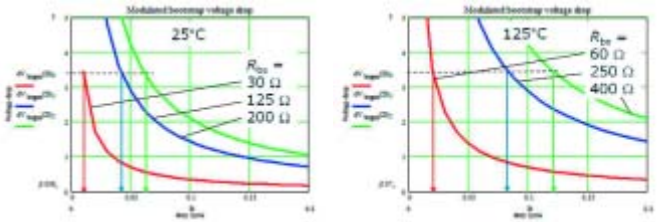

Figure 4: Calculation of steady state bootstrap capacitor voltage drop vs. duty cycle for a buck converter

The left part in Figure 4 shows the conditions at a junction temperature of T_j = 25°C and the right part shows the same parameter at T_j = 125°C. The proposed driver IC concept of EiceDRIVER™ 2EDL realizes a bootstrap resistance of R_{BS} = 30Ω at a junction temperature of T_j = 25°C, while other concepts have R_{BS} = 125Ω or R_{BS} = 200Ω For reasons of simplicity, it is assumed that the bipolar drift region resistance of a pn-diode doubles its resistance every 100°C. Note that the size of the bootstrap capacitor does not influence the diagrams of Figure 4. It only influences the transition phase from one bias point to another.

The influence of the low resistance of the new EiceDRIVER™ 2EDL is significant. It is easy to see that the new driver IC concept is much more stable against high junction temperatures compared to standard parts. The usable duty cycle range can go down to 1% with the new 2EDL driver concept, without coming into an undervoltage lockout area.

Other driver ICs cannot serve duty cycle ranges below 4% (R_{bs} = 125Ω) or 7% (R_{bs} = 200Ω). This means that many applications which require operating at low duty cycles cannot use these ICs. This is the case for SMPS operating in hard switching under high load condition or drive systems, which operate with high torque at low speed in field oriented control. In these examples the control is either in steady state or quasi steady state operation in the critical duty cycle range.

Asymmetric undervoltage lockout

The EiceDRIVER™ 2EDL family is supported with dedicated designs for operation with IGBTs. Other on market driver IC's only support MOSFET transistors in respect with the undervoltage lockout (UVLO) function. Gate threshold voltage of MOSFETs (e.g. 3V) compared with IGBTs (e.g. 4.6V – 5V) allow operation of the MOSFETs with much lower gate voltages. This is represented as well in the UVLO levels of the driver IC. On the other hand, it is dangerous to operate IGBTs using driver ICs that provide MOSFET UVLO levels, because the MOSFET UVLO levels are so low that the IGBT partially or fully desaturates. This effect causes highly increased losses and temporary operation in this mode can cause severe damage at the IGBT. It is therefore essential to operate IGBTs only with driver ICs that provide suitable UVLO levels for the IGBT.

An important aspect of the design of undervoltage lockout (UVLO) levels is the support of integrated bootstrap diodes. They have a relatively high forward voltage drop which contributes to the bootstrap voltage reduction compared to the supply voltage VDD of the IC seen in Fig. 4. The static bootstrap voltage vBS is in total

$$v_{BS} = V_{DD} - v_{DBS} - v_{CE} \qquad (1)$$

where vCE is the transistor voltage of the low side transistor in a half bridge configuration. Please note that this converts into the diode forward voltage when operating the low side diode.

Parameter	Min. [V]	Typ. [V]	Max. [V]
V_{CCUV+}	11.8	12.5	13.2
V_{BSUV+}	10.9	11.6	12.4
V_{CCUV-}	10.9	11.6	12.4
V_{BSUV-}	10	10.7	11

Table 3: Asymmetric high side and low side UVLO levels

It is easy to see that the high side output HO generates a smaller voltage, because the voltage v_{BS} at the IC terminals VB and VS is reduced by the values v_{DBS} and v_{CE}. However, it is favourable to activate the UVLO for the high side supply V_{BS} at a similar point of time as the low side supply V_{DD} in order to prevent insufficient supply of the high side gate. Therefore the low side UVLO is activated at approx. 1V higher levels as the high side UVLO function. It also allows shifting the shut down levels V_{CCUV-} of the low side towards slightly higher value. This can be achieved by implementing an asymmetric UVLO which considers different thresholds for high side and low side as shown in Table 3.

Other helpful features

UVLO filter

It is often very difficult for design engineers to realise a good trade-off with system boundaries such as geometry and component placement in order to achieve the best performance. An important item is the placement of the blocking capacitors for the supply voltages VDD and VBS. The above mentioned restrictions lead often to some distance between the IC and the blocking capacitor. This can cause inductive voltage drops at the pin VDD or VB during the turn-on transient with the consequence of undesired UVLO events according to Figure 5.

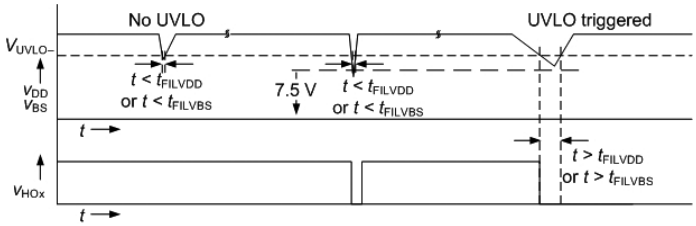

Figure 5: Small filters for UVLO improve the noise robustness of the 2EDL family

A filter to suppress such short time voltage drops makes the IC more robust against noise on the supply lines. This is shown as an example on the very left side of Figure 5. The filter time is approximately 1.5µs, which is enough to filter all regular transients in respect with switching transients. However, the IC will control an UVLO and therefore the turn-off of the correlated outputs if the voltage drop is lower than 7.5V, which is given in the middle of Figure 5. The IC will also shut down its outputs, if the voltage drop is longer than the filter time.

of IGBT gate or MOSFET gate to the supply pin. The sink transistor inside the driver IC is activated when the supply voltage exceeds approximately 3V. The sink transistor is operated in its linear region and will clamp the gate. Small leakage currents in the range of µA can be clamped very efficiently as shown in Figure 6. As a consequence, gate-emitter resistors can be omitted.

Conclusion

Infineon introduced its 2EDL half bridge gate driver IC family as part of the segment EiceDRIVER™ Compact. This new driver IC concept for half bridge configurations is proposed for consumer electronic equipment including SMPS and computing, and home appliance drive systems. It is optimised for the two mostly used transistor technologies, IGBT and MOSFET. The integrated bootstrap diode has a very low ohmic series resistance and hence enables the widest operating range in respect with controlled duty cycles. The bootstrap diode dissipates minimal power inside the IC. This makes this 2EDL driver ICs a benchmark in the market. Further functions, such as the asymmetric under-

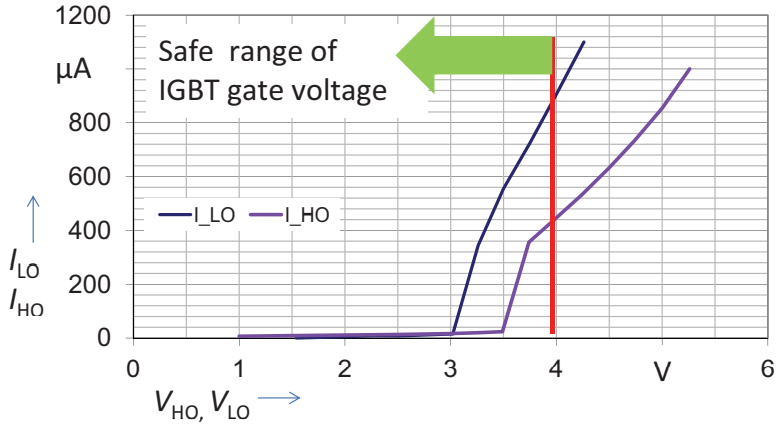

Figure 6: Output sections keep IGBT below its threshold voltage even without supply voltage

Active shut down

The active shut down function is activated as soon as the supply voltage either on VDD or VBS reaches 3V – 4V. Leakage currents which may flow via the gate-collector path can potentially turn-on the device. The proposed concept clamps any leakage current

voltage lockout or the active shut down support in particular help IGBTs overcome restrictions in terms of component placement and performance.

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Innovations in Technology Brings the Thyristor into the 21st Century

The latest market research reports show an expected annual growth rate of 10 to 12 % for power modules in general. For today's more recent fashion - the IGBT module, growth is well understood but a more unlikely candidate for a major factor of this growth will be from the often overlooked Bi-Polar module. Indeed research indicates that the Thyristor and Diode module market is growing in line with the IGBT power module markets. IXYS continues to challenge the historic design limits attributed to thyristor and diode technology with its "MORE POWER LESS PACKAGE" strategy. IXYS directs its designers to make use of improved structures, production processes and materials to maximize the power to weight ratio and providing attractive solutions to today's more complicated problems. The target is to improve current density, reducing module size and raising efficiency expectations in a space which has seen little evolvement from a level developed decades ago. IXYS illustrates its commitment for continuous innovation by highlighting several new developments in die design, packaging technology.

By Bradley Green, Holger Ostmann and Jeroen van Zeeland – IXYS Semiconductor GmbH

Thyristor technology is known already for many of years and is often the first power product to be taught in power electronic laboratories. IXYS' Lampertheim facility in Germany introduced commercially available thyristor technology in 1961. The thyristor module got a real boost in reliability when IXYS introduced its Direct Copper Bonded (DCB) based modules in 1981 which formed a new standard in modules that competition continue to try and emulate. The DCB substrates, which provide a rugged isolation layer for today's modules, are produced in-house at IXYS retaining focus on the development of this technology as well as operational benefits. All these years of experience resulted in not one but several available thyristor technologies. Figure 1 shows a simplified overview of all available thyristor technologies within IXYS. CWP is the standard thyristor die format with the anode on the back (soldered) side and the cathode on top of the die. The gate current as related to the cathode is positive. The next design step was to create a new anode-gated thyristor with the cathode on the backside driven by the need to create a phase-leg on a common base for the AC terminal. Here the gate current has a negative convention. Further developments indicated that in some mechanical constructions a thyristor with the contacts reversed were of interest. So the cathode-gated CWRP was developed featuring the cathode at the back (soldered) side and anode on the top. Furthermore IXYS developed a standard CWP that could turn on not only with positive but also with a negative gate current. This allowed in combination with a CWN die to build up a TRIAC with a simple yet effective two-die-design.

	CWP	CWRP	CWN	CWRN	CWP-N
Anode	Backside	Topside	Topside	Backside	Backside
Cathode	Topside	Backside	Backside	Topside	Topside
Gate side	Cathode	Cathode	Anode	Anode	Cathode
Gate current	positive	positive	negative	negative	positive negative

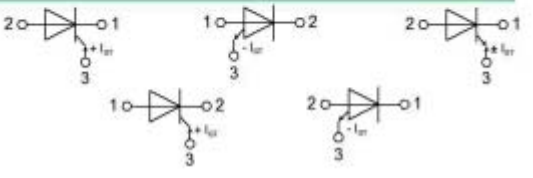

Figure 1: Thyristor technology overview

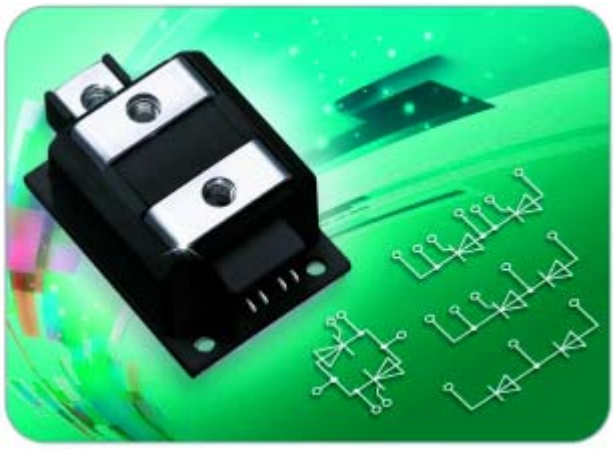

Figure 2: ComPack module

The different die technologies available in IXYS give flexibility in the design of bipolar solutions in many different soft starter, general inverter, UPS, current control and pulse circuit applications. Just as an example, the combination of the anode and the cathode soldered thyristor in a discrete package can be mounted to a non-isolated backplane or heat sink, creating a half bridge configuration with less materials, weight and size.

The ComPack Module

There are also other benefits by combining the cathode- and anode-soldered thyristor dies. One example is the ComPack Thyristor module. The ComPack is a soldered module with current ratings up to

800A using a combination of the anode- and cathode-soldered technology for thyristor phase-leg configurations. The maximum junction temperature of the thyristor dies is 140°C. The bus-bar connections are directly contacted with the top side of the dies.

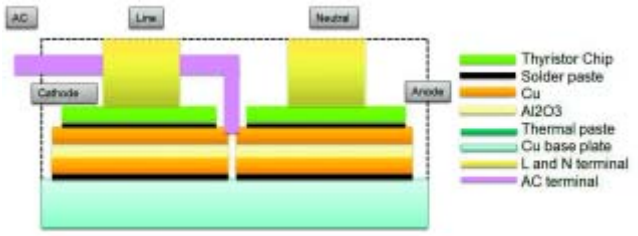

Figure 3: improved module current density (ComPack)

The inverse thyristor technology together with a solderable top side metallization makes this possible. So as shown in Figure 3 the line connection is directly connected to the top side cathode and the Neutral is connected to a top side anode. This shows optimal usage of the different technologies to get the highest current density possible. The result is a small and light module with only a weight of 500 grams. It is about 1 kg lighter than its direct replacement which is using pressure contact technology. Additional to this the footprint of the ComPack is about 30% smaller than the competitor illustrating how IXYS' MORE POWER, LESS PACKAGE design philosophy can reduce transportation costs across the whole of the value chain from supplier to the very end customer . This all is enabled by using the latest IXYS innovative thyristor technologies and combining it with new module designs.

IXYS' Direct Copper Bonded (DCB) ceramic technology provides a high isolation voltage of up to 4800 V which is in accordance with Underwriters Laboratory (UL) requirements. With the adapted copper base plate the ComPack concept achieves very low thermal impedance whilst improved use of materials helps to reduce the module weight. The improved design goes further to support longer term reliability under the highest power output operation by optimizing the thermal interfaces from its heat flow to the heat sink. The main difference compared with existing competitive module offerings is shown below in Figure 4. The thermal resistance has been improved by reducing the DCB thickness from 0.63 mm to 0.38 mm where the copper thickness on both sides of the DCB stayed constant. Additionally in the ComPack module the thinner DCB is soldered to the copper base plate where in the Y1-Pack this connection is established with thermal paste. This significantly improves the thermal impedance (Rth) by a minimum of 30%.

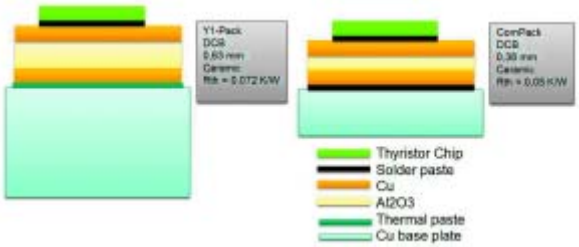

Figure 4: improved thermal construction (ComPack)

Configurations are traditionally phase-legs featuring two thyristors or diodes in one module. Also single die parts and thyristor/diode combinations are available. Further development is planned to widen the silicon options to take benefits of the mechanical module advantages that the ComPack provides including an un-isolated TRIAC version for higher current ranges than are typically available today. With this development, IXYS is allowing the designer to switch more power

than historically existing at a lower weight than before thereby facilitating higher power densities, greater material efficiency and lower system cost. It is often a priority of customers to get access to new productivity in the traditional outlines and bi-polar technologies that are ubiquitously implemented in today's UPS, Motor drive and power converter topologies. IXYS are confident that by the adoption of new outlines illustrated by the ComPack, customers will enjoy the benefits of the bi-polar power product solutions.

The IXYS TRIAC

There are currently available many thyristor and TRIAC products which provide solutions for an extremely wide set of applications. One of the main topologies is that of an AC-Controller that traditionally is made up from two back to back thyristors. However, this topology is implementing standard anode back (solder) side and cathode top side create challenges for low cost reliable modules. By using IXYS reverse contact die technology building up AC-Controllers with two complementing thyristors offer several advantages and opportunities. Using a standard anode back and cathode back die technologies allows IXYS to build the AC-Controller in un-isolated packages, and with adapted gates of anode- and cathode-gated thyristors that allow positive and negative gate currents to extend control to the different quadrants (Figure 5). Most obvious advantage is of course the use of just one gate unit. With it the possibility of using packages with just three terminals becomes achievable. Less obvious is the benefit that the specially designed thyristors keep their general advantages

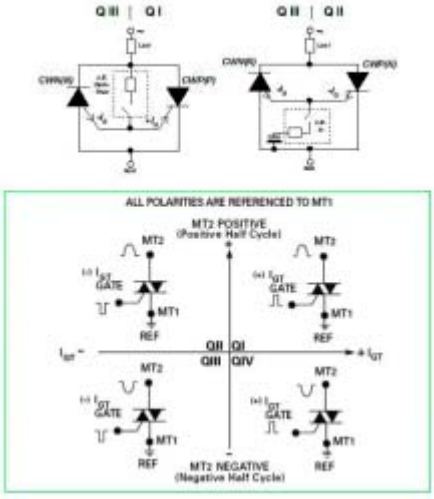

Figure 5: Thyristor configurations and Quadrant operations

compared to a standard TRIAC. Especially useful to the product designer are the higher dv/dt and di/dt stability inherent in this technology which can reduce the need for external components. This double die solution removes the weak links in standard TRIAC design in terms of limitations in current size and limitations in the forward and reverse blocking voltages. Using this technology power TRIACs for forward currents in excess of 25A and blocking voltages in excess of 1000V are finally commercially viable. This greatly improves the TRIAC portfolio in discrete packages such as standard TO-220 , TO-247 or similar packages that currently have these limits. Engineers designing products for world-wide application often have to produce two designs to take into account varying supply voltages. The new IXYS TRIAC allows them to select just one design for all their global customers. First released product is a 60A TRIAC with 1200V available in TO-247, ISO247 and TO-268 (D3-Pak): CLA60MT1200HB. IXYS have a full portfolio planned in order to increase the voltage and current ranges for this technology for such applications as motor control, soft start, power control heaters and lighting.

The Reverse Conducting Thyristor (Triode)

One of the latest innovations from IXYS is the development of a fast switching thyristor that includes a monolithic body diode. This development results in a single die solution to fit into various power topologies. The resultant reverse conducting thyristor (Triode) provides an extremely fast turn on with high efficiency. In previous silicon solutions the designer would be limited to multiple die solutions which not only increase the complexity, space and cost of the solution but allow for unwanted parasitic inductances that can have the effect of reducing efficiency or reliability. The integrated diode in reverse polarity (anti-parallel) allows the usage of this thyristor in resonant discharge applications. The Triode is a direct replacement for spark gaps in ignition circuits for High Intensity Discharge (HID) lamps for automotive, street or commercial lighting applications. Solid state solutions have many benefits over spark gaps including an improved repeatability of the switching characteristics over the lifetime of the component. Also other electrical discharge applications such as electrical fences or simple resonant circuits are predestinated for a Triode having many operational benefits. First product of this new design is packaged in a TO-220 outline: CLA30EF1200PB being a 30A 1200V reverse conducting thyristor (Triode).

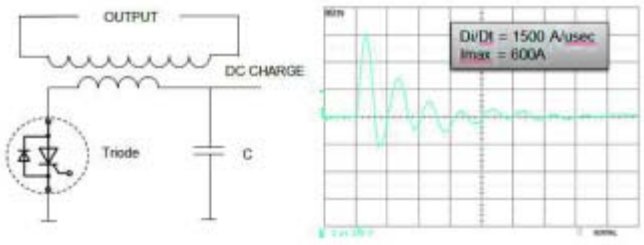

Figure 6: Typical Triode application circuit

Conclusion

IXYS has shown innovations in bi-polar die technologies and in packaging design. IXYS has illustrated this to describe various new thyristor technologies and improved thermal constructions which combined can be utilized to provide soldered thyristor modules up to 800A to the market. Additionally creative implementation of this newly developed technology can realize a wide product range of single-gated AC-controllers. The new technology allows access to higher current higher voltage TRIACs. Mechanical spark gaps can be replaced by the monolithic reverse conduction thyristor (Triode) which is another step in the improvement in efficiency and reliability of several applications. The products described in the article are summarized in Figure 7, but represent only a small percentage of the new product development activities and available new product portfolios in IXYS. Therefore bi-polar technology which may have been eclipsed by more fashionable products such as the IGBT in recent times, is in fact benefiting from the attention it deserves at IXYS to drive innovation well into the 21st century.

Part number	Vrrm / V	ITav / A	Configuration	Package
MDMA800P1600CA	up to 2200	600	Diode Phase-leg	ComPack
MCMA700PD1600CA	up to 2200	700	SCR/Diode Phase-leg	ComPack
MCMA800P1600CA	up to 2200	800	SCR Phase-leg	ComPack
CLA30E1200HB	1200	30	SCR	TO-247
CLB30I1200HB	1200	30	SCR - Anode Gated	TO-247
CLA60MT1200NTZ	1200	60	TRIAC	TO-268 (D3-Pak)
CLA60MT1200NHB	1200	60	TRIAC	TO-247
CLA30EF1200PB	1200	30	Triode	TO-220

Figure 7: Product table

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MiniSKiiP® Half Bridge Modules and High Power PCBs

A new approach for cost effective inverters up to 90kW

More than 20 million MiniSKiiP® modules can be found in drives and frequency converters across the globe. European inverter manufacturers, in particular, use these modules for low-power applications of up to 30-40kW.
Three quarters of these applications are standard drives for pumps, robotic arms, printing presses or compressors. This figure is expected to increase by a further three million MiniSKiiP modules.

By Volker Demuth, Thomas Hürtgen, Semikron

Besides the established European market, the MiniSKiiP family is gaining ground on Asian markets, too. This product is also available from two other suppliers, a fact that ensures that customer demand for improved supply reliability is met. The key features of MiniSKiiP are low material usage as well as an easy and cost effective assembly. The assembly of MiniSKiiP is indeed very simple: the module is connected to the heat sink and driver board with a single screw, creating the electrical and thermal connection up to 150A rated module current. By the use of SPRiNG contact technology, time-consuming and costly solder processes are eliminated, and easy replacement of the module is possible – if necessary. This cost-effective module concept, the single-step mounting, combined with a comprehensive product portfolio, made the MiniSKiiP an industrial standard for inverters up to 40kW [1].

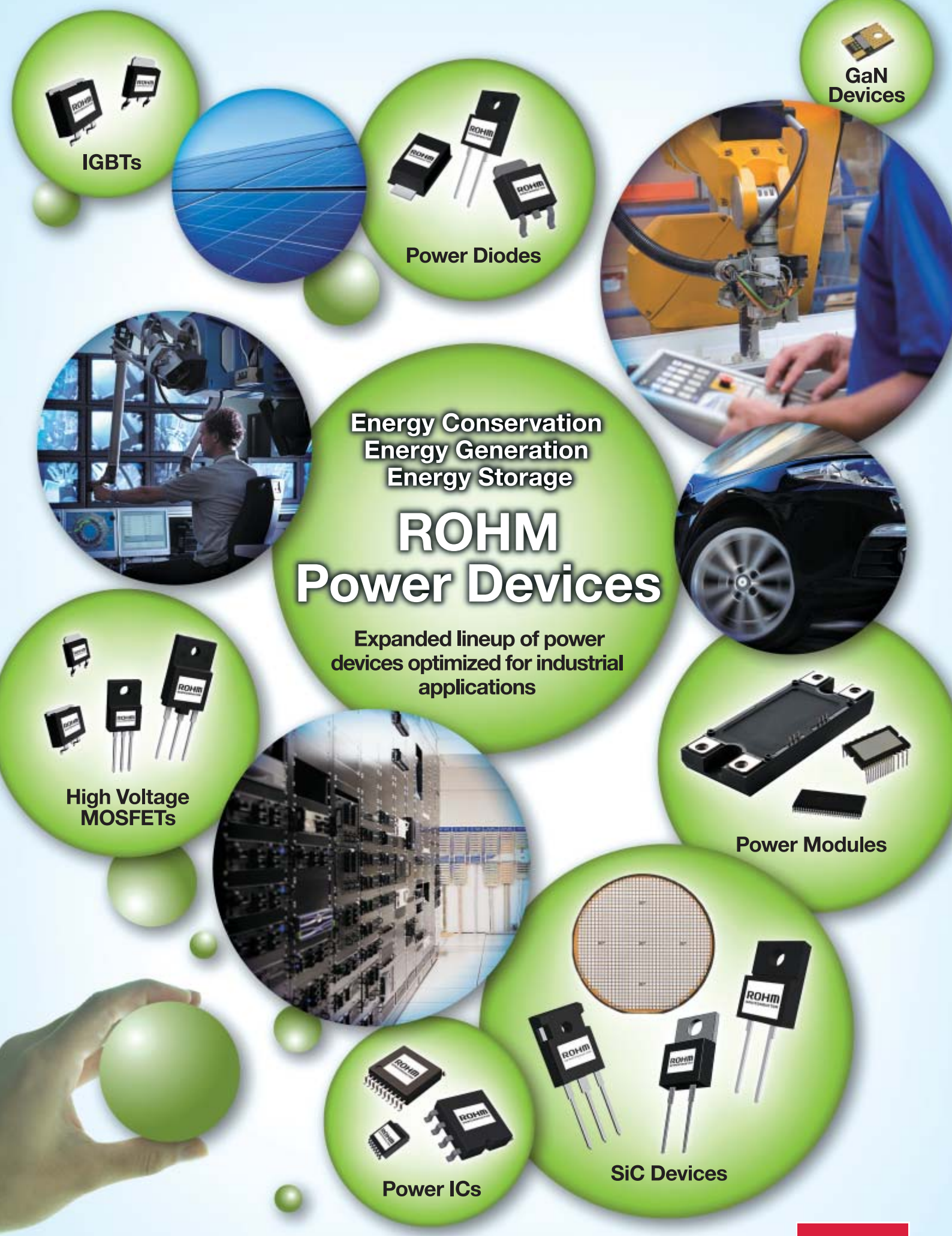
Also in the range of 40kW to 90kW, the major manufacturers of frequency inverters expect average market prices to drop by around 3% each year. In order to stay competitive, drive and inverter manufacturers need to optimise their products by way of cost-efficient production and reduced material costs. The module solutions for frequency inverters in the range of 40kW to 90kW are currently dominated by baseplate modules with screwed bus bar connections. By cutting down on costly bus bars, reducing module costs and using quick and easy single-screw assembly, the MiniSKiiP concept is an excellent way to reduce costs for power modules, connectors and assembly also in the 40kW-90kW power range.

In order to meet the constant market requirement for cost reduction, and to make the advantages of MiniSKiiP available also for the higher power range, the MiniSKiiP product platform is extended with MiniSKiiP half bridge modules. The new MiniSKiiP Dual allows customers to use the well-established easy one/two screw mounted modules up to 90kW in the voltage classes of 650V, 1200V and 1700V. The new MiniSKiiP Dual features an optimised module design and printed circuit board (PCB) connection concept for 3-phase inverter applications, especially developed for compact inverter solutions and it significantly reduces the overall system cost compared to present module solutions.

To enable module solutions with PCB power connectors to be applicable for higher power ratings, several design considerations have to be made. The reason for the approximately 40kW power limit of MiniSKiiP is not that baseplate-free modules could not be used for high power. Baseplate-free solutions like SKiM and SKiiP are in the market for drives, wind, UPS and automotive applications up to MW range. In those modules, an intelligent internal chip layout provides optimum heat spread and, compared to baseplate modules, the required thickness of thermal interface material can be reduced by approx. 50%. Enhanced dissipation of thermal losses combined with pressure contact technology lead to low operating temperatures and increased reliability. However, all these solutions use screwed bus bar terminals for the power connection, whereas one-screw mounting concepts require the usage of PCB contacts for the power connectors. Using the MiniSKiiP, auxiliary and power signals are transferred via the PCB board. Especially when high currents are transferred via the board, the operating temperature of the PCB will rise. However, 70-80°C operating temperature of the PCB should not be exceeded for reliable and safe operation. Due to width and thickness of the metal layers used in standard PCB boards, the maximum current is limited to about 150A rated module current. In order to extend the MiniSKiiP to 80-90kW, nominal currents of up to 300A are required, which corresponds to about 180A RMS for 1200V configurations.

Furthermore, the power density and heat generation inside the power module need to be addressed as the MiniSKiiP is already a highly integrated module: topologies with three phase inverters, rectifier input bridges and a brake chopper and driver IC's can be integrated in one housing. On the one hand, a high level of integration enables low volume and cost-effective inverter designs. On the other hand, thermal losses need to be managed and as power has to be increased further, the heat generated inside the modules requires optimised thermal management.

For the MiniSKiiP Dual, three main design objectives were important. Firstly, the use of existing module sizes of the MiniSKiiP module platform. Together with the SPRING contacting concept, this ensures maximum compatibility of the MiniSKiiP Dual with the existing MiniSKiiP models. Secondly, the adaptation of the thermal management to the higher power in order to reduce chip and module operat-



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ing temperatures. Thirdly, the increase of maximum usable current transferred by the PCB.

Module design

The basic concept of the MiniSKiiP Dual connects three MiniSKiiP modules in parallel, one for each phase. The alignment of the power terminals is designed for 3-phase applications: the AC terminals are located opposite the DC connections as shown in figure 1.

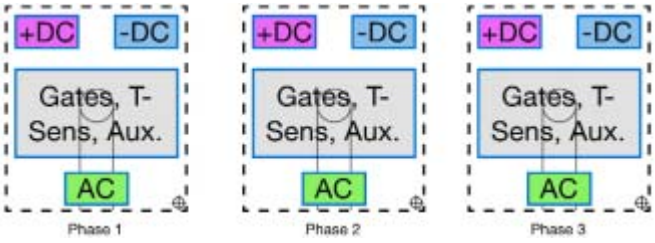

Figure 1: Case layout of the MiniSKiiP Dual. The MiniSKiiP housings are paralleled for each phase, the AC terminals are opposite the DC terminals.

The advantages of this power terminal alignment include the easy paralleling of MiniSKiiP Dual modules and a low inductive connection of the DC terminals, allowing faster switching of the IGBTs and a higher DC link voltage due to the lower overvoltage peaks. These features are required for the design of efficient and space-saving inverters. In addition, the separation of the three phases into different modules improves the heat spread and increases the overall dissipation of thermal losses. The heated areas on the heat sink, caused by the thermal losses of the modules, are separated from each other. Heat build-up und heat concentration in the heat sink are avoided, and module temperatures are reduced even if operated at high current and power densities.

The next design step was to adapt the SPRiNG contact concept to higher currents. Standard MiniSKiiP modules are available in 6-Pack configurations up to nominal currents of 150A and CIB (Converter Inverter Brake) configurations up 100A nominal current. Up to eight SPRiNGs in parallel are used for the AC, DC minus and DC plus connections. With one SPRiNG being capable of 20A RMS, a maximum of 160A per power connection is reached with this concept. Enabling the MiniSKiiP Dual for high currents, up to 16 SPRiNG terminals per power contact are used. This ensures a maximum output current of approx. 320A RMS and leaves enough safety margin for the targeted 170-180A RMS, even if operated on overload.

Thermal management

The thermal management is one of the most important factors regarding the design of power modules. Maximum chip temperatures of 175°C and continuous operating temperatures of 150°C require efficient heat transfer to the heat sink. The heat transfer from chip to heat sink is influenced by several factors, mainly the heat conduction capability of the materials involved and the total area of heat dissipation. In case of baseplate-free modules like MiniSKiiP, the heat path requires heat flow through chip, solder, DCB, thermal paste layer and the heat sink. Compared to baseplate concepts, the total number of interfaces and materials involved in the heat patch are reduced, as no base plate is present. Thus, the heat flow becomes more efficient. On the other hand, the elimination of the baseplate also has a disadvantage. In most module designs, the baseplate is not only used to establish the mechanical contact between module and heat sink, but it also acts as a heat spreader. The heat generated locally in the IGBT and diode chips spreads horizontally inside the copper baseplate, which increases the total area of heat transfer between module and heat sink. In turn, the total thermal resistance from the chip to the heat sink is reduced. Designing a baseplate-free module without countermeasures for the heat spread would increase the thermal resistance compared to a solution with baseplate. Therefore, the design of baseplate-free modules follows different design rules. For the MiniSKiiP Dual, the design requirements of high power modules come in handy: higher power requires paralleling of the several power semiconductor chips inside the module. For instance, in a standard baseplate module with 300A nominal current, two 150A IGBT's and two 150A freewheeling diodes are switched in parallel for top and bottom switch - a principle sketch is shown in figure 2a.

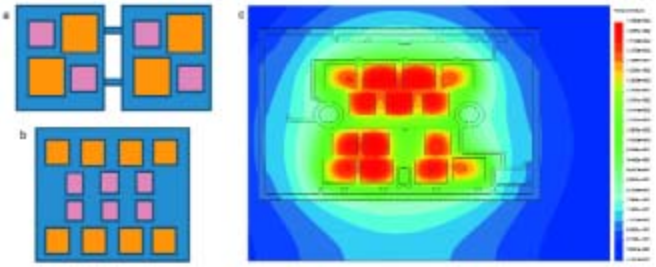

Figure 2a: Schematic chip and DCB layout of a 300A baseplate module. Two 150A IGBT's and diodes are paralleled for top and bottom switch. 2b: Chip layout of MiniSKiiP Dual, showing four 75A IGBT's and 3 diodes are in parallel. 2c: Heat distribution of 300A/1200V MiniSKiiP Dual module. Thermal simulation of a MiniSKiiP Dual on an air-cooled heat sink by finite element analysis (Al_2O_3 substrate, $T_{ambient}$: 25°C, convection: 1800Wm^{-2}K, power losses for IGBT's and diodes: 1 Wmm^{-2}, thermal paste thickness 50µm)

For the MiniSKiiP Dual, this design was optimised by increasing the number of chips while maintaining the overall nominal current the same: four 75A IGBTs and three diodes are paralleled per switch, Figure 2b. In principle, the heat spread otherwise provided by the baseplate is now transferred into the module and resolved by the chip and DCB layout itself. The heat generated in each power device is distributed over a larger area, thus increasing the total area of heat flow to the heat sink, overcoming the missing thermal spread provided by the base plate.

In addition, as no baseplate is present, the DCB can be pressed more homogeneously to the heat sink. Using the pressure system concept of MiniSKiiP, the pressure stress of the central screw is transferred via several pressure points to the DCB, ensuring a tight contact between module and heat sink. As the pressure stress of the DCB to the heat sink is much more homogenous compared to baseplate solutions, the thickness of the thermal paste can be reduced by up to 50%. Since the thermal paste has the highest thermal resistance of all materials involved in the thermal path, the reduction of thermal paste thickness is a significant advantage of baseplate-free concepts, since the thermal resistance of the whole assembly is reduced significantly. Combining the reduced thermal paste thickness with the optimised internal chip layout, the heat dissipation and thermal spread of the MiniSKiiP Dual are significantly increased, shown by finite element calculations in Figure 2c. To analyze the limits of the current design, thermal losses of IGBT and freewheeling diode chips were subjected to the same thermal losses. This is a somewhat artificial operating condition for a drives application, but represents the condition of highest heat generation as heat is generated in all chips simultaneously. In the finite element calculation, the losses of the IGBT and the freewheeling diodes could be increased to 1Wmm^{-2} until a junction temperature close to 150°C was reached for the

hottest devices, which is the recommended maximum operating temperature for current chip generations. As expected, the highest temperatures are seen in the chips at the center of the module. A total power loss of 280W for IGBT and 160W for the freewheeling diodes can be efficiently dissipated by the multi-chip layout of the MiniSKiiP Dual, which is the same range of conventional half bridge baseplate modules with equivalent nominal current.

Replacing bus bars by high power PCBs

So far, the use of a printed circuit board for power and control terminals instead of copper bus bars was limited due to the maximum current capability of the PCBs. Standard PCBs for MiniSKiiP use copper layers of 75µm – 105µm thickness, which is sufficient for up to 40kW. Using the MiniSKiiP concept with SPRiNG connections for up to 90kW requires the replacement of screwed bus bar connections with solder- free PCB connections. In the case of 1200V modules, continuous RMS currents as high as 150A – 180A have to be transferred by the PCB board, which makes it necessary to optimise the PCB design and the routing of the power tracks. In a first step, the copper layers inside the PCB were more than doubled and increased to 210µm in order to decrease the resistivity of the power tracks and reduce heat generation inside the PCB. In a second step, the line width of the PCB tracks has been increased, leading to a further reduction of the track resistance. An additional advantage coming with larger track width is the larger area where the heat generated in the power track is cooled by convection of air. Thermal measurements performed on MiniSKiiP modules show that with multi-layer PCBs with copper track thicknesses of up to 210µm or copper profiles [2], maximum continuous load currents of up to 170A are possible. In-situ temperature measurements of the PCB with an infrared camera shows progress in PCB temperature control, figure 3.

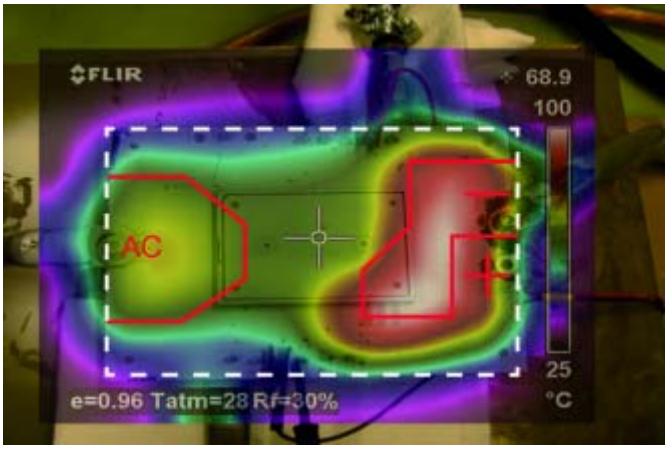

Figure 3: PCB temperature measurement with an infrared camera, top view overlay of the infrared picture and of the high power PCB. The broken white line indicates the shape if the high power PCB. The red lines outline the 210µm copper power lines in the PCB for AC and DC minus connections. I=170A (DC) between AC and DC minus terminal.

The setup shows a two-layer high power PCB with 210µm copper thickness mounted on a 300A/1200V MiniSKiiP Dual. The MiniSKiiP Dual is mounted on a water cooled heat sink. To simulate the conditions in inverter operation, the heat sink temperature was set to 83°C throughout the test. In order to study the effect of track width and PCB layout on the PCB operating temperature, different track routing was used for AC and DC terminals. For the AC terminal, a track width of 7cm was used, whereas at the DC minus terminal the track width is significantly smaller. A continuous DC current of 170A was applied

from AC to DC minus terminal. The temperature measurement reveals an average PCB temperature of ~70°C. However, areas of higher temperatures can be observed in regions of higher current density close to the AC and DC minus connections. Especially at the DC minus terminal, temperatures above 90°C occur, whereas at the AC terminal the PCB temperature is between 70°C-80°C, showing the effect of layout and track width on the operating temperature on the PCB. The larger track width at the AC terminal reduces the track resistance and leads to lower operating temperatures. These analyses and considerations are used to define basic design rules for track width and PCB routing. Following these design rules which will be part of the technical documentation, low operating temperatures of the PCB are achieved, even if subjected to continuous currents as high as 170A, maintaining safe and reliable operation of the MiniSKiiP Dual in inverters up to 90kW. In conclusion, high power PCBs can be used for high current densities, and continuous currents up to 170A can be handled by commercially available PCBs. This allows for replacing the copper bus bars with PCBs, and makes the technical opportunities of the MiniSKiiP concept usable in higher power ranges.

Output Power

The above design considerations and experimental results of module layout and thermal management were used as input for thermal loss calculations to address the usable output power of the MiniSKiiP Dual.

In figure 4, the output current of a 3-phase inverter with a 300A/1200V MiniSKiiP Dual mounted on a standard air cooled heat sink is shown.

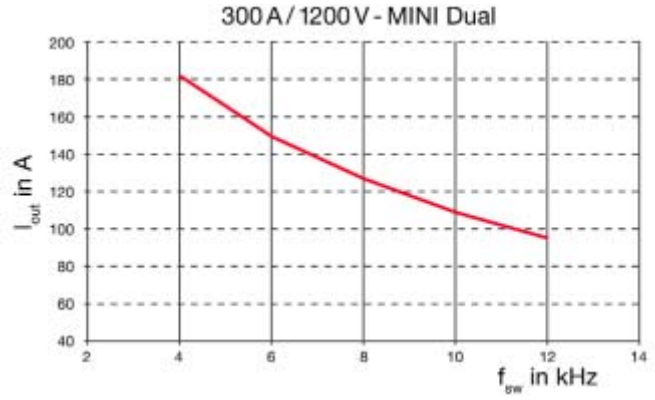

Figure 4: Output current I_{out} as a function of switching frequency f_{sw}. DC link voltage = 750V, output voltage = 400V. Output frequency 50Hz, power factor = 0.85. Forced air cooling at 40°C ambient temperature.

For the latest IGBT and freewheeling diode generations, a junction temperature of 150°C is the maximum temperature for continuous operation. The output current in Figure 4 refers to a maximum calculated junction temperature of 150°C of IGBT or freewheeling diode, depending on the chip representing the highest temperature for given application conditions. With a 4kHz switching frequency, an output current of 180A RMS can be achieved. This is equivalent to an output power of more than 100kW at a DC link voltage of 750V. At 8kHz, an output current of 125A can be achieved (74kW output power), and even at 12Khz 90A output current it's possible to utilize more than 50kW output power. The considerations and design features of MiniSKiiP Dual concerning the thermal management are pushing the output power of the MiniSKiiP Dual right into the power range of comparable baseplate module designs up to 90kW, leaving enough headroom for overload conditions.

Conclusion

MiniSKiiP is an established name in the world of power electronics. These modules are prized for their excellent power density, but also their fast and easy assembly. In fact, to connect the MiniSKiiP module, PCB and heat sink, just one single screw is needed. Instead of soldered contacts, all of the power, gate and auxiliary connections to the PCB use pressure contacts. Thanks to the SPRiNG contact system - a unique selling point of this system over competitor IGBT modules – the electrical contacts boast longer service life and greater reliability, and the vibration resistance of the entire system is improved.

The new addition to the MiniSKiiP platform, the high power MiniSKiiP Dual, now offers all design and cost reduction benefits that come with the MiniSKiiP concept for a higher power range between 40-90kW, a power range which was not accessible so far and that used to be dominated by baseplate modules. A comprehensive portfolio for 650V, 1200V and 1700V applications will be available, covering a broad range of different applications – see table 1.

The MiniSKiiP Dual comes with nominal chip currents from 150A to 300A, using Trench IGBTs in combination with SEMIKRON CAL diodes. The housing sizes of the MiniSKiiP Dual are equivalent to the standard MiniSKiiP 2 and 3 housings, with the advantage that the principle design of existing power inverters with MiniSKiiP can be transferred to higher power, saving cost and development time.

In order to enable the MiniSKiiP for higher power, several design features have been implemented. For a 3-phase inverter, three MiniSKiiP half bridge modules are connected in parallel, one for each phase. AC and DC connectors sit opposite each other, supporting a compact and low inductive inverter layout. As the three phases are separated into different modules, a better thermal spread is obtained, giving more headroom for effective thermal management. The chip layout on the DCBs was designed for a baseplate-free module layout by paralleling of up to 4 IGBTs and 3 freewheeling diodes. The better heat spread obtained by this, combined with the reduced thermal paste thickness, enables the MiniSKiiP Dual to handle output currents up to 180A in a 1200V setup. Special care has been taken to address the replacement of solid copper bus bars with high power PCBs. With the use of 210µm thick copper layer PCBs, increased track width and optimised PCB layout, phase currents of 170A can be used, keeping the PCB operating temperatures at a moderate 70°C to 80°C. The proven MiniSKiiP SPRiNG technology is expanded by paralleling up to 16 SPRiNGs for AC and DC connections. This allows for using the high reliability and easy mounting concept by SPRiNG contacts even for high current densities.

Type designation	V_{CES} in V	I_{nom} in A	Housing size
SKiiP 24 GB 07 E3 V1	650	150	MiniSKiiP 2
SKiiP 26 GB 07 E3 V1		200	MiniSKiiP 2
SKiiP 38 GB 07 E3 V1		300	MiniSKiiP 3
SKiiP 24 GB 12 T4 V1	1200	150	MiniSKiiP 2
SKiiP 26 GB 12 T4 V1		200	MiniSKiiP 2
SKiiP 38 GB 12 E4 V1		300	MiniSKiiP 3
SKiiP 22 GB 17 E4 V1	1700	100	MiniSKiiP 2
SKiiP 24 GB 17 E4 V1		150	MiniSKiiP 2
SKiiP 36 GB 17 E4 V1		200	MiniSKiiP 3

Table 1: MiniSKiiP Dual Portfolio

In conclusion, the MiniSKiiP Dual opens the door for new, cost-effective inverter designs in the 40-90kW range, addressing the cost pressure that inverter manufacturers are facing. The key feature is the replacement of copper bus bars with high power PCBs. Cutting down on costly bus bars, reducing module costs and using the quick and easy single-screw assembly, MiniSKiiP modules can be used to reduce the costs of inverter systems by more than 15% over inverters based on standard modules with baseplate and screw connections. The MiniSKiiP Dual is an ideal extension of the existing MiniSKiiP platform. Together with the MiniSKiiP standard topologies, the 3-level MiniSKiiP MLI and the MiniIPM, featuring an integrated driver, MiniSKiiPs cover a power range from 2-90kW and a large variety of different applications.

References

[1] Alexander Langenbucher, "Taking Power Density to a New Level", Bodo´s Power Systems, Sept. 2011

[2] Andreas Gießmann, Alexander Langenbucher, "A Look into the Future: Savings Potential in Inverter Design", Bodo´s Power Systems, Dec. 2011

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High-Voltage 600V/650V Class Super Junction PowerMOSFET

Benchmark for the lowest drain-source resistances and fast switching speeds

An ideal choice for applications requiring highest energy efficiency in motor control, renewable energies, powers supplies and other fields

By Steffen Hering, ICBG, A&P Product Management, Renesas Electronics Europe

Introduction

The increasing demands on efficiency of power electronics necessitate continual search for best possible solutions. Applications like power supplies, motor control, renewable energies lighting techniques are typical examples in strongly growing markets requiring power semiconductors maximizing economic viability. This implies highest efficiency under static as well as under ever increasing switching frequency conditions. Conventional semiconductor structures like planar construction of a power MOSFET are often at their physical limits here. Renesas therefore has developed a fully new line of power MOSFETs with so-called Super Junction structure. This fulfills the prescribed requirements in the static as well as dynamic properties field. Typical static and dynamic property parameters are the RDSON (Drain-Source resistance in on state) and the QGD (Gate-Drain charge) respectively.

Basics of Power losses, formulas and parameters

In a Power MOSFET, the so-called RDSON has major influence on static the losses

$$P = I^2_D \times R_{DS}$$

Power loss of a Power MOSFET in static operation

During switching operation, Body-Diode losses must be added to calculate the total losses. The following formula and its approximation are used:

$$P = \frac{1}{T}\int_0^T (V_{D0} \cdot I_F(t) + R_{DS\,ON} \cdot I^2(t))\,dt$$

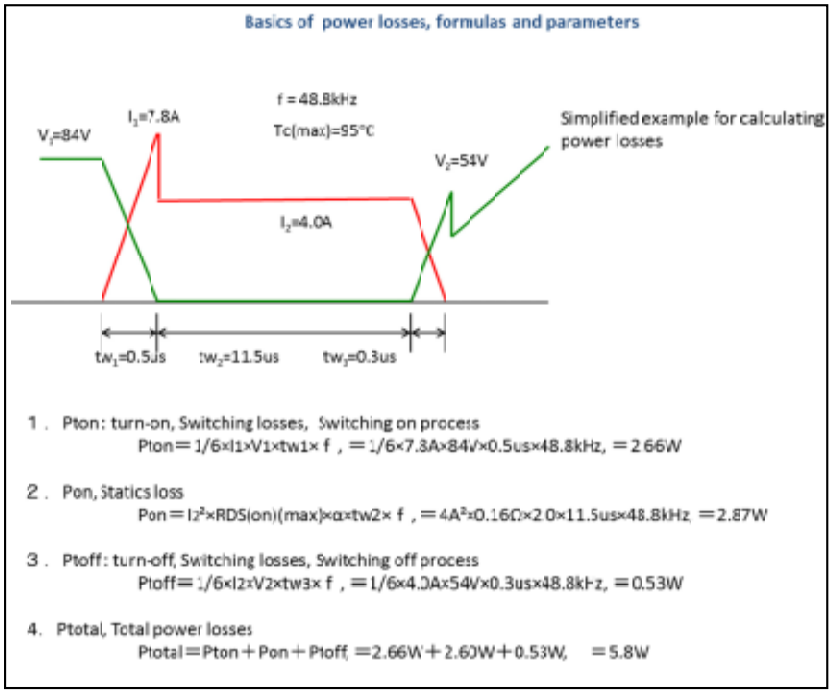
$$\frac{1}{3} V_{DS} \cdot I_D \cdot (tr+tf) \cdot f_{SWITCH} + I^2 \cdot R_{DS\,ON} \cdot \alpha \cdot ton \cdot f_{SWITCH} + I_F \cdot V_{D0} \cdot (1 - ton \cdot f_{SWITCH})$$

Body-Diode losses

The power in the driver stage can as well be considered as loss. The Gate charge Q_G has the major influence on these losses.

The calculation is done as follows:

$$P_{DRIVE} = f_{SWITCH} \cdot Q_G \cdot \Delta U_{GS}$$



exchange by

$$P_{DRIVE} = f_{SWITCH} \cdot Q_G \cdot \Delta V_{GS}$$

Therefore, both R_{DSON} and Q_G parameters influence the losses. The term "Figure of Merit" FOM, combines both parameters through multiplication. This is a simple benchmark of efficiency.

$$FOM = R_{DSON} \times Q_G$$

$$FOM = R_{DSON} \times Q_{GD}$$

For Gate-Drain charge, the symbol "Q_{GD}" is used as well.

Renesas has developed a fully new Super Junction PowerMOSFET (SJ-PMOSFET) product line. The 600V/650V voltage range combined with 6.1A up to 55A current range cover the majority of all consumer and industrial applications. The low RDSON and QG values achieved result in a FOM, which provides an ideal basis for energy efficient circuit design. For the static losses range, this product line offers distinct advantages compared to the conventional PowerMOSFET structures. At higher frequencies (> 50 kHz), the SJ-PMOSFETs are significantly superior even to IGBTs in terms of total power losses.

Example of standard packages

SJ-PMOSFETs are typically built-on an N+ substrate. Multiple layered-columns of P-doped material within a low-doped N-material constitute the structure. A multi-step epitaxial growth process builds up the columns layer by layer, thereby increasing the total implanted layer thickness until the required voltage tolerance is achieved. This process variant is shown in figure 3 (center) below. The downside of this production process however is the relatively slow epitaxial growth process of column layers into columns and the complexity through multiple repetitions of steps.

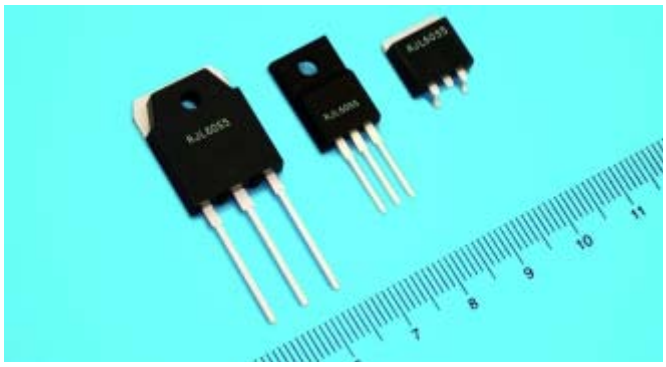


Figure 2:

Renesas has developed a new proprietary method to build Super Junction structures avoiding the said disadvantages. Renesas applies the so-called deep-trench technique. The deep-trench production process requires etching trenches in the low-doped N-type material to form regions of P- type material. Figure 3 (right side) shows the deep-trench structure. By virtue of reliable production process, high precision mask alignment and doping in conjunction with miniaturization of P-material columns allow realization of very low RDSON values as well as extremely low internal capacitance, which in turn again lead to low QG (QGD) values. This results in best FOM (Figure of Merit) values.

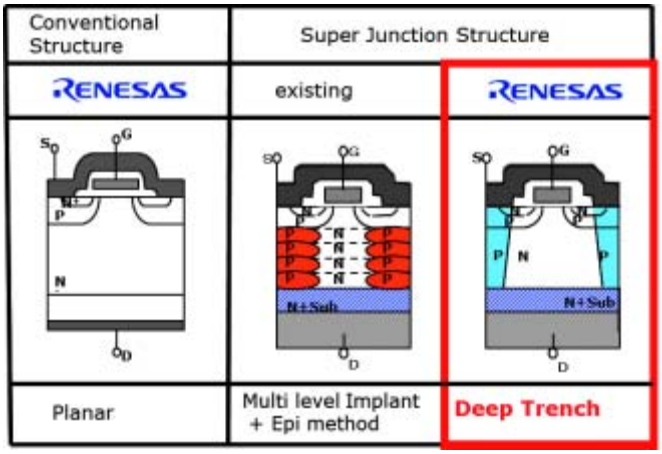


Figure 3: P-type material columns in N-type material build the deep-trench structure

Figure 4 shows a cross section of the deep-trench structure.

One member of the family is the RJK60S5DPK device, with absolute maximum ratings of 600V, 20A; it achieves excellent results with respect to static losses and switching properties. The specific resist-

ance per unit area is about 52 percent less than that of conventional structures. The exceptionally low values of Gate-Drain charge Q_{GD}, which are about 80 percent less than that of conventional structures, allow fast switching with low losses. The advantages for the user, compared with conventional structures is the low heat generation in the device which allows compact circuit designs, use of smaller packages as well as favorable heat sinks.

Figure 4: Cross section of the SJ deep-trench structure developed by Renesas

A derivate of this device is available with specifically Fast-Recovery-Diode (FRD), which, through its enhanced switching speed, reduces the power losses further during switching and thus achieves less heat generation (figure 6).

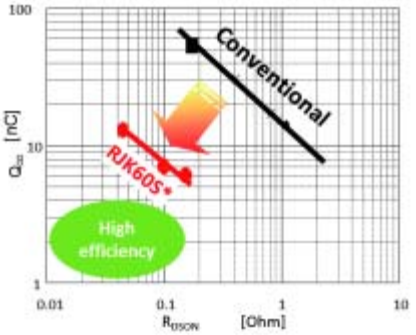


Figure 5: FOM, Conventional vs. SJ-PMOSFET characteristics comparison

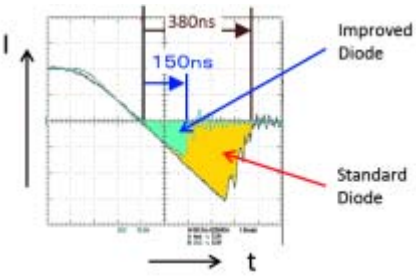


Figure 6: Diode switching characteristics

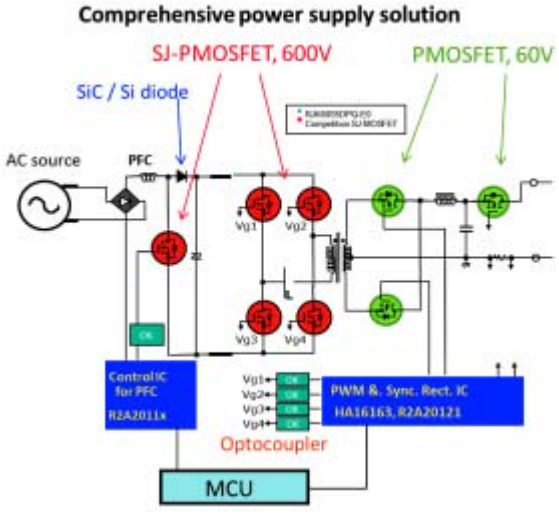


Figure 7: Power supply topology

In the coming years, the Super Junction PowerMOSFET family will be continually extended with regard to additional current ranges and higher voltage classes. Further, Renesas will offer variants with optimized characteristics for dedicated application areas.

Application example: Power supply

To demonstrate the increasing demand on the efficiency of an application, power supply can be cited as an example.

The example shows the circuit topology (figure 5) of a power supply with synchronous rectification. The topology contains a PFC (Power Factor Correction) control and an H-Bridge, both equipped with "Deep-Trench" SJ-PMOSFET on the primary side. The secondary side is equipped with medium voltage range PowerMOSFET having 60V voltage tolerances. Besides discrete components, Renesas also delivers all other key components such as the PFC IC and the ICs for synchronous rectification, Optocouplers for galvanically isolated control signals; an MCU (Micro Controller Unit) for the overall controls.

The implemented SJ-PMOSFETs make decisive contribution towards efficiency increase.

The diagram in figure 8 shows the increase in efficiency achieved through the "Deep Trench" SJ-PMOSFET introduced here compared with a competition product with epitaxial built SJ structure.

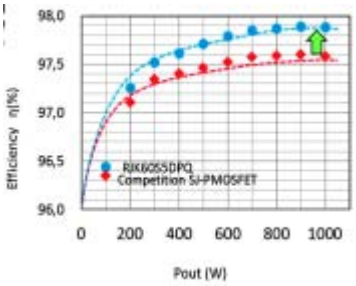


Figure 8: Efficiency increase through "Deep-Trench" SJ-PMOSFET

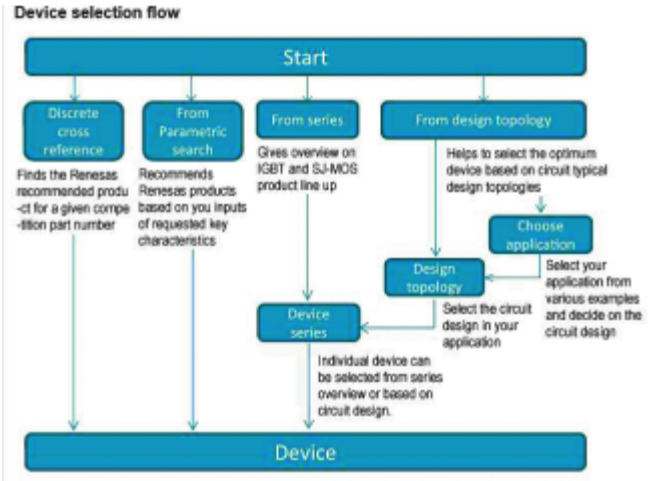


Figure 9: Flow diagram showing different product selection options

On-line support for product selection

Through restructuring and enhancing the already familiar cross-reference search and parametric search support, Renesas has simplified the product selection process significantly. Additional application oriented support, which go beyond the pure device selection support, have a big added value for the user.

The product selection support introduced below is accessible through a central website:
http://www.renesa.eu/products/discrete/peerguide.jsp

Clearly laid out graphic of a flow diagram (Figure 9) assists in product selection. Starting from a presumed target application and circuit topology to be developed, a click on the appropriate field triggers the

desired function such as the cross-reference search, the parametric search, or product overview.

The Internet cross reference link:
http://www.renesas.eu/req/other_product_search.do?event=other

ProductSearch assists in finding the closest equivalent Renesas device match for a given competition device; multiple options are offered wherever appropriate. Most important parameters are shown directly and the complete data sheet can be downloaded instantaneously.

The cross-reference is available not only for the new Super Junction PowerMOSFET product series but for the complete product spectrum.
For many products, especially for the SJ-PMOSFETs, set of SPICE parameters can additionally be downloaded so that the basic device behavior in the circuit can be simulated even before the samples are available.

Another product selection tool is the parametric search tool, which can be accessed on the website:
http://www.renesas.eu/req/parametric_search.do?prdCategoryKey=12&selectedConList=&region=

Here, the search for desired products can be narrowed by entering or selecting parameters either through a mouse-click or through moving slider. The list of proposed products is displayed accordingly. Another very useful extra of this tool is the possibility to export the list of proposals into an Excel sheet for further processing.
Yet another utility for product selection uses instead of product features, the application to be developed and its topology itself as the starting point. This, very practice orientated approach allows developer a quick overview as to which devices are proposed for the circuit topologies to be developed.

On-line simulation support
Besides the possibility to analyze the basic suitability of SJ- PowerMOSFET in circuit with the help of SPICE parameters on one's own computer, Renesas also offers a comprehensive simulation environment called the “Powere SIM” on its homepage.
This tool is provided free of cost to the user. For example, starting from the selected circuit topology and components, one can simulate signal waveforms, frequency response, thermal behavior, efficiency and so on. The simulation environment features are continually enhanced and offer an ideal platform for the user to speed up the development process significantly with minimum of efforts.

Summary
With its new Super Junction PowerMOSFET series based on proprietary developed deep-trench technology, Renesas has established a benchmark for highly efficient power semiconductors. This allows achieving significant increase in application efficiency. The production process is fully proprietary thus guaranteeing uniformly high product quality.

For users, Renesas provides a number of comfortable product selection tools on-line. All support tools are accessible centrally on the website. The product selection based on presumed circuit topology is a novelty to make the selection process even more effective. The products so selected can be directly simulated in circuits through free of cost on-line tool " Powere SIM " which speeds up the development process. Product identification and implementation has been simplified!

www.renesas.eu

GaN Power Devices Enable High Efficiency Totem Pole PFC

Elegant active power factor correction circuit achieves up to 99% efficiency

The widespread use of active Power Factor Correction (PFC) circuit is becoming even more popular as government agencies demand more effective use of grid supply capacities. A typical PFC circuit includes a diode bridge for rectifying the ac source and a boost stage to force the input current proportional to the input voltage. The rectifier bridge consumes a significant part of the circuit loss; therefore, many topology innovations for bridge-less PFCs have emerged. But most suffer from either common-mode (CM) electromagnetic interference (EMI) or other issues and, therefore, are not practical.

By YiFeng Wu and Liang Zhou, Transphorm Inc.

One unique topology called the totem pole PFC has both simple power loops and low EMI [1]. However, this topology demands very-low reverse recovery charges (Qrr) for the MOSFET body diodes – not possible with high-voltage silicon (Si) MOSFETs. With the advent of Gallium Nitride (GaN) power devices [2] [3], new 600V-class low Qrr transistors make this highly promising circuit a practical reality.

PFC Topologies

The evolution of representative PFC topologies is shown in Figure1. A traditional PFC circuit (Figure 1a) consists of a slow-recovery full-bridge line rectifier (D_1-D_4), a fast boost diode (D_B) and a fast transistor switch (S_B). In addition to D_B or S_B, the main current passes through two of the four slow diodes at a given time, which can account for an efficiency loss by 0.6% to 1.2% (at high line and low line, respectively) due to the forward diode drop.

The basic bridge-less PFC (Figure 1b) eliminates all slow diodes, but requires two fast diodes (D_{B1} and D_{B2}) and two fast switches (S_{B1} and S_{B2}) [4]. The main current path includes only one switch, plus either one diode or another switch, capable of a significantly higher efficiency. However, both ac input nodes during the negative ac cycle are floating with respect to the two dc output terminals, leading to a high CM EMI [5]. For this reason this topology has limited practical use.

Attempts have been made to modify the basic bridge-less PFC for lower EMI. A successful example is the dual-separate-boost bridge-less PFC, shown in Figure 1c [6]. Employing two boost inductors (L_{B1} and L_{B2}), two fast diodes (D_{B1} and D_{B2}) and two fast transistors (S_{B1} and S_{B2}), in addition to two slow-recovery rectifying diodes (D_1 & D_2), this PFC ensures the potential of one ac input node to be effectively tied to an dc output terminal at any given time. Consequently, this approach significantly reduces CM noises and has earned popularity among power circuit designers [7]. However, this circuit requires the largest number of fast devices (D_{B1}, D_{B2}, S_{B1} and S_{B2}) and inductors (L_{B1} and L_{B2}), yet eliminates only one diode drop compared to the traditional PFC shown in Figure 1a.

Figure 1d shows the totem pole bridgeless PFC with two fast devices (S_{B1} and S_{B2}), one inductor (L_B) and two low-cost, slow diodes (D_1, D_2). The ability to ensure low EMI is realized by the fact that one ac node is always clamped by a slow diode to either the top or bottom of the two dc output terminals. Additionally, no voltage drop of a fast diode is involved, offering potential for further efficiency enhancement.

The difficulty of implementing this circuit lies in the fact that during dead-time, when both transistor switches are off, one of the body diodes is turned on to allow free-wheeling current in continuous current mode (CCM) operation. In the subsequent hard-switching

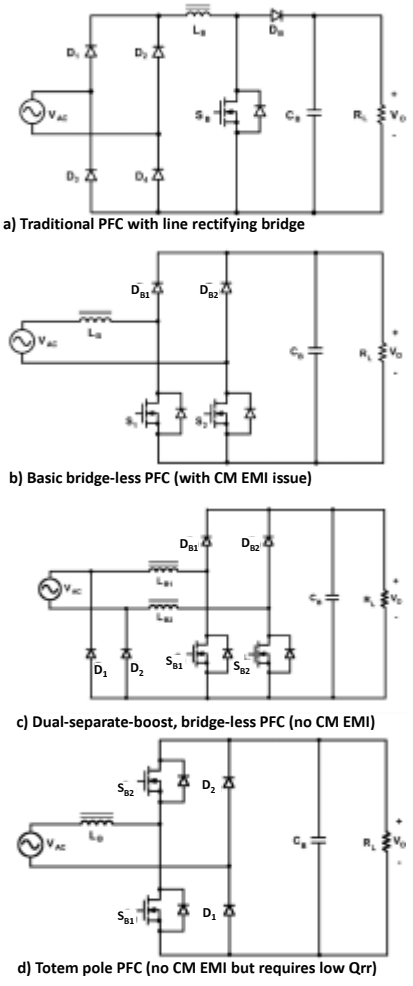


Figure 1: Representative PFC topologies: a) traditional, b) basic bridge-less, c) dual-separate-boost and d) totem pole.

event, the Qrr of the body diode in a high-voltage Si MOSFETs could cause significant current-voltage spikes, making the circuit unstable in addition to causing high switching losses. The key to implementing a successful totem pole PFC relies on new generation semiconductors with simultaneously low on-resistance and low recovery charge.

GaN TOTEM POLE PFC

The industry's first qualified 600-V GaN HEMTs (high electron mobility transistors) made on a low-cost Si substrate have been introduced by Transphorm Inc. These first-generation GaN power devices show a low on-resistance of 0.15 ohm typical and are capable of reverse conduction during dead time with a low Qrr of 54 nC, which is 20 times lower than state-of-the-art Si counterpart (Figure 2). These features can remarkably expand operation space of a hard-switched bridge. Moreover, these devices are offered in Quiet-tab™ configurations with choices of the metal tab connected to the drain or source terminals. When a drain tab package is used for the high-side device (e.g., S_{B2} in Figure 1) and a source tab as low-side device (e.g., S_{B1} in Figure 1), the capacitive coupling between device and heat sink is minimized, further reducing EMI.

A GaN HEMT totem pole PFC in CCM mode focusing on minimizing conduction losses was designed with a simplified schematic (Figure 3a). It consists of a pair of fast GaN HEMT switches (Q_1 and $Q_{2)}$ operating at a high pulse-width-modulation (PWM) frequency, as well as a pair of slow but very-low resistance MOSFETs (S_1 and S_2) operating at a much slower frequency (60Hz). The primary current path includes one fast switch and one slow switch only, with no diode drop. The function of S_1 and S_2 is that of a synchronized rectifier, as illustrated in Figures 3a and 3b. During positive ac cycle, S_1 is on and S_1 off, forcing the ac neutral line tied to the negative terminal of the dc output. The opposite applies for the negative cycle.

In either ac polarity, the two GaN HEMTs form a synchronized boost converter with one transistor acting as a master switch to allow energy intake by the boost inductor (L_B) and another transistor as a slave switch to release energy to the dc output. The roles of the two GaN devices interchange when the polarity of the ac input changes, therefore each transistor must be able to perform both master and slave functions. To avoid shoot through, a dead time is built in between two switching events during which both transistors are momentarily off. To allow CCM operation, the body diode of the slave transistor has to function as a free-wheeling diode for the inductor current to flow during dead time. The diode current however, has to quickly reduce to zero and transition to the reverse blocking state once the master switch turns on.

This is the critical process for a totem pole PFC, which previously led to abnormal spikes, instability and associated high switching losses due to the high Qrr of the body diode in modern high-voltage Si MOSFETs. The low Qrr of the GaN switches allow designers to overcome this barrier. As seen

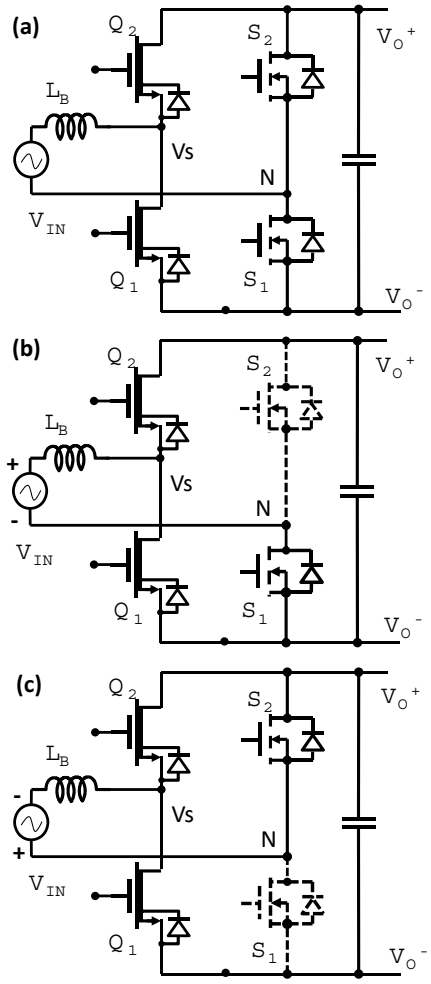


Figure 3: GaN totem pole PFC (a) simplified schematics and illustration during (b) positive ac cycle and (b) negative ac cycle.

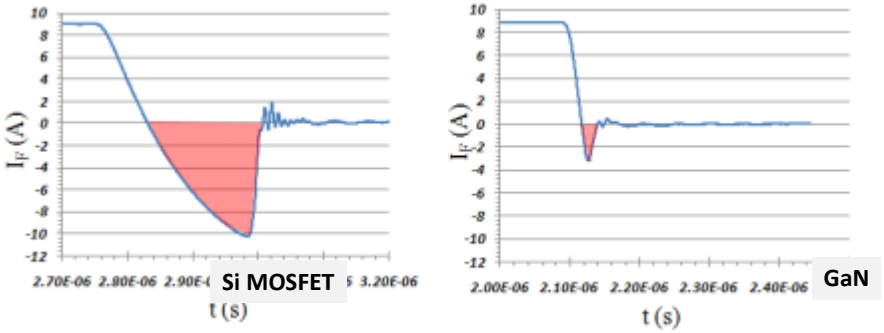


Figure 2: Reverse recovery charge test result for a Si MOSFET and a GaN HEMT with similar on resistance, showing a 20x reduction of Qrr for GaN.

in Figure 4, inductive tests at 400-V bus using either low-side or high-side GaN transistor as a master switch show healthy voltage waveforms up to inductor current exceeding 12 A. With a design goal of 1 kW output power in CCM mode at 230V ac input the required inductor current is 6 A. This test conforms a successful totem-pole power block with two times the current overhead.

PFC Prototype

A PFC has been implemented on a four-layer PCB, as shown in Figure 5. The slow switches (S_1 and S_2) are 600V super junction MOSFETs with 0.1 ohm on resistance. The inductor is made of a MPP core with inductance of 1.3 mH and a dc resistance 88 mohm and is designed to operate at 50 kHz. Drain-tab and source-tab surface-mount GaN HEMT packages are used with one mounted on the top and another on the bottom side for the shortest electrical lengths between these fast switches, which minimizes power loop inductances.

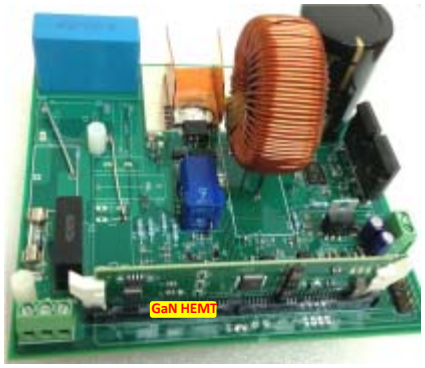


Figure 5: Prototype GaN totem pole PFC. The GaN HEMT pair is mounted on top and bottom of the PCB with a vertical alignment to minimize between them.

A simple 0.5-A rated high/low side driver IC with 0/10 V as on/off states directly drives each GaN HEMT. A low-cost fixed-point 60 MHz DSP controller (TMS320F28027DSP) handles the control algorithm in this first version of prototype. The voltage and current loop control is similar to conventional boost PFC converter. The feedback signals are dc output voltage (V_O), ac input potentials (V_{ACP} and V_{ACN}) and inductor current (I_L). The input voltage polarity and RMS value are determined from V_{ACP} and V_{ACN}. The outer voltage loop output multiplied by $|V_{AC}|$ gives sinusoidal current reference. The current loop gives the proper duty-ratio for the boost circuit. The polarity determines how PWM signal is distributed to drive Q_1 & Q_2. A soft-start sequence with a duty ratio ramps is employed for a short-period at each ac zero-crossing for better stability.

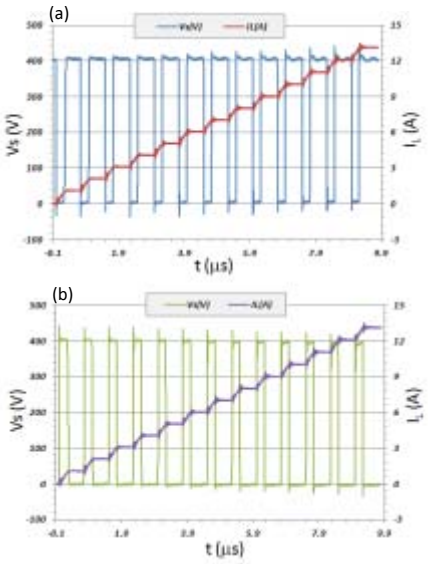


Figure 4. Hard-switched waveforms of a pair of GaN HEMT switches when setting a) low side as master device and b) high side as master.

Performance as a function of output power measured with a Yokogawa WT1800 power analyzer at 230 Vac input and 400 Vdc output is shown in Figure 6. A peak efficiency of 99.0% is achieved at 400 W while the overall efficiency is >98.6% from 180W to 1kW. This outstanding performance from a simple topology is attributed to higher performance features of the new wide band-gap GaN power devices.

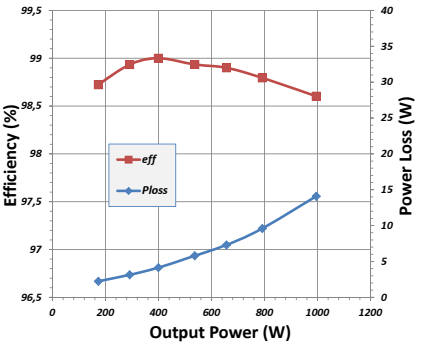


Figure 6: Measure efficiency performance of the GaN totem pole PFC with no diode drop in the current loop.

Summary

Although new device technologies that continuously improve performance of popular circuits is desirable, a higher impact can be achieved if a development enables new functions and revives a dormant topology to outperform its existing counterparts. The advent of high-voltage GaN power transistors makes this advancement by enabling PFC circuits that were previously impractical to implement. The simultaneous benefits of low on-resistance and low reverse recovery charge from the first-generation GaN-on-Si HEMT are key to building a long-awaited totem pole PFC.

Compared to traditional topologies, the GaN-on-Si PFC circuit consists of the fewest number of fast power devices and features the least resistance current paths without a diode drop, thereby achieving state-of-the-art conversion efficiency. As further circuit discoveries and innovations are implemented, the power electronics industry can benefit tremendously from the introduction of GaN power devices.

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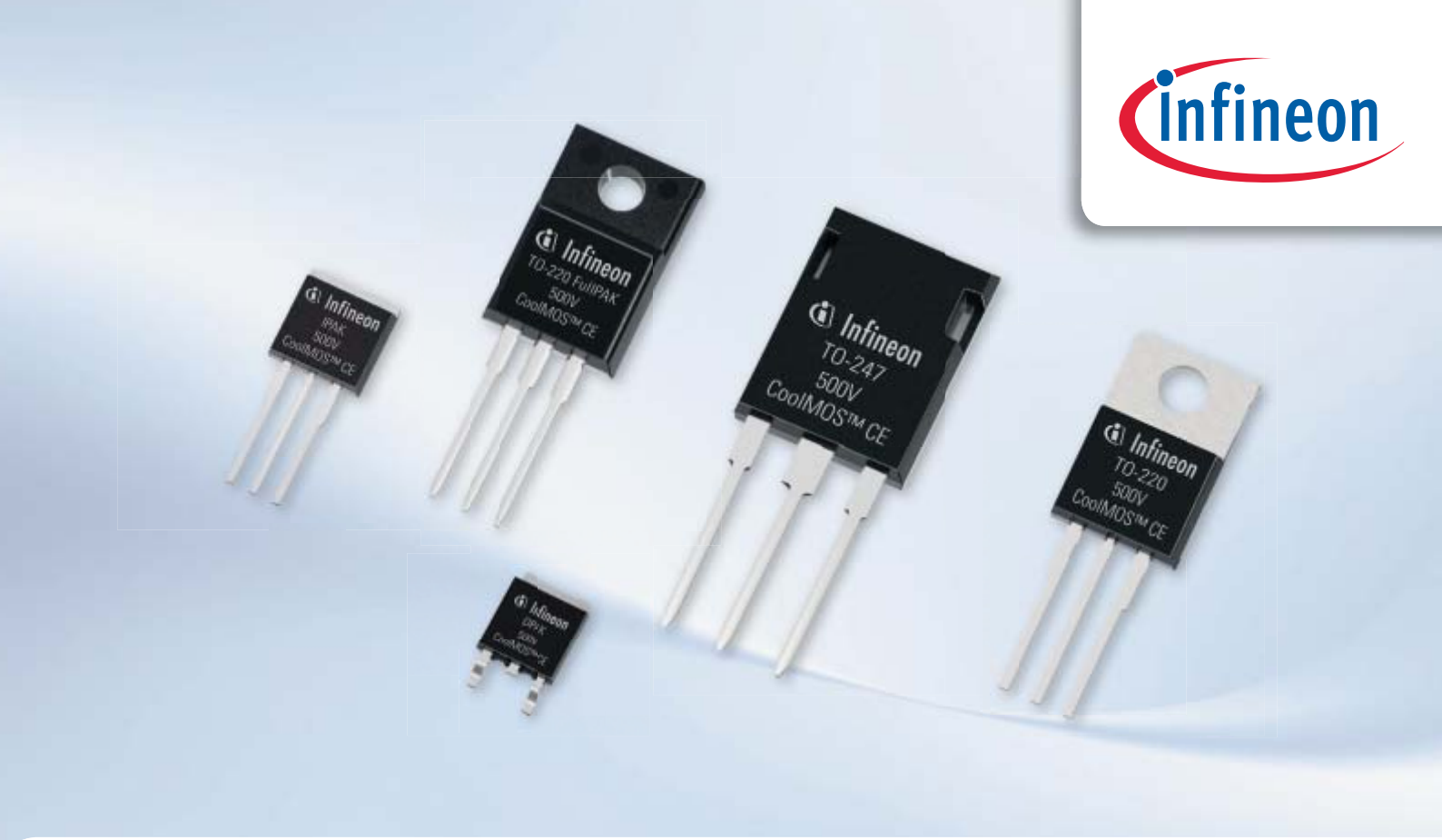

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EMV 2013: Where Experts Meets Experts

For more than 20 years now the trade show EMV 2013 for electromagnetic compatibility with its conference and half-day workshops has been organized by Mesago. This year's event took place from March 5th to 7th in Stuttgart, Germany. The main topic of the show and conference was e-mobility. Here, professionals had the opportunity to acquire information on trends and developments first-hand.

By Marisa Robles Consée, Corresponding Editor; Bodo's Power Systems

In times of accelerating technical innovation, the challenges in the EMC area are continuously increasing. E-mobility and other new developments place high demands on EMC and safety. Unusually high voltages and currents, increasing shielding requirements and new charging technologies for electric vehicles make discussions and the exchange of ideas and solutions important for the entire industry. The rapid development in the electronics industry is expected to continue, so it is necessary to guarantee reliable functioning of all the highly complex systems.

Figure 1: More than 2,600 visitors gathered information from exhibitors about the latest developments and trends in the field of electromagnetic compatibility. Picture: Mesago/Nino Halm

Successful exhibition and workshops

EMV 2013 offered the opportunity to gain hands-on experience in this area. A special action zone on e-mobility showcased electric cars and other exhibits. Impulse speeches informed the visitors and workshop participants about the latest development in this field. Another opportunity to gather information was the exhibitor forum. Parallel to the exhibition, EMV 2013 offered numerous user-oriented half-day workshops. Topics ranged from EMC basics to legal aspects and niche topics. For the participants these workshops provided a decent opportunity to keep up with the current state of technology. The speakers had the chance to share their knowledge and experiences with their colleagues.

Electromagnetic compatibility continues to gain in importance as the ongoing development of electronic systems poses more and more questions about electromagnetic behaviour. Adhering to EMC guidelines ensures the necessary safety and reliability of electronic systems that play an increasing role in our everyday lives. A total of 113 suppliers of EMC equipment, components and services once again seized this opportunity to show their solutions to trade visitors from the EMC sector. 49 exhibitors came from abroad from 16 different countries – mainly from United States, United Kingdom and France. This gave the trade show an international touch. The exhibition area was about 3600 m².

Figure 2: A total of 113 exhibitors presented EMC equipment, components and services on an exhibition area of about 3600 m². Picture: Marisa Robles Consée

More than 2,600 visitors gathered information from exhibitors about the latest developments and trends in the field of electromagnetic compatibility. The 39 accompanying workshops with about 1000 bookings also proved to be rather successful. Their leitmotif, electromobility, also governed the exhibition. The e-Mobility space, organized by EMC Test NRW, was a strong crowd puller, offering exhibits and spontaneous expert lectures. With its extensive solution proposals and trendsetting topics in electromagnetic compatibility, the EMV show once again turned out a central meeting point for the EMC sector.

Product Highlights

EM Test presented its NetWave, a three-phase programmable AC/DC power source. With its wide frequency bandwidth, the NetWave

series offers waveform generation capabilities suitable for different test requirements such as IEC/EN 61000-4-13/-14/-17/-28 and -29 as well as for avionics testing according to DO-160, MIL-STD-704 and Airbus. Due to its high output power with very low harmonics distortion and the high stability of output voltage and frequency even with dynamically changing loads the NetWave seems to be well suited for compliant harmonics and flicker measurements as per IEC/EN 61000-3-2/-3/-11/-12 and JIS C 61000-3-2. Optionally the NetWave 3-phase series can be equipped with a power-recovery module to absorb feed-back power (AC/DC) up to the nominal power of the NetWave. Based on a Dual-Processor technology, with an integrated high-performance PC, a digital signal processor (DSP) and equipped with a hard disk the NetWave Series is capable to generate and record waveforms in real-time. The output voltage of the NetWave series has a distortion (THD) of less than 0.1% regardless of the load. Interfaces like GPIB and Ethernet are common features.

Aaronia exhibited its handheld spectrum analyzer Spectran V4. The analyzers have a rather compact design and a high sensitivity up to 170 dBm (1 Hz). They detect sources of interference, find out more about their causes, determine the frequency and intensity of the signal sources, and measure limits by using the company's high-end PC software. All Spectrans are developed, manufactured and calibrated in Germany at the Aaronia plant. That's one of the reasons the company gives a full warranty of 10 years for all Spectran spectrum analyzers and EMC antennas. The spectrum analyzer software "MCS" for PC, MAC or Linux shows the real potential of the devices. The software can be used in addition to the Spectrum Analyzer. The connection works in real time, i.e. there is no discernible time difference between signal analysis and representation on the screen.

Rohde & Schwarz speeds up

The ESRP EMI test receiver from Rohde & Schwarz is the ideal instrument for developers to employ in the early stages of design to detect and eliminate EMC problems in components and instruments. The measurement company designed the new ESRP for diagnostic and pre-compliance measurements in the frequency range from 10 Hz to 7 GHz. The device is not only a fast EMI test receiver with standard-compliant bandwidths and detectors but a full-featured spectrum analyzer as well. It offers two methods for measuring disturbance signals: the fast, FFT-based time domain scan and the traditional – but slower – stepped frequency scan. Both methods comply with the CISPR 16-1-1 standard for EMC measurements. In the time domain scan mode, the R&S ESRP measures conducted disturbances in the CISPR band B with quasi-peak weighting faster, by many orders of magnitude, than conventional EMI test receivers using the traditional method.

Figure 3: The ESRP EMI test receiver from Rohde & Schwarz speeds up precompliance measurements. Picture: Rohde & Schwarz

Also, it allows manufacturers of modules, boards, instruments and systems to detect and eliminate EMC problems early in development. The receiver measures conducted and radiated electromagnetic interference (EMI). The preselection option protects the front end against overloading and delivers reproducible measurement results. As a result, the element of unpleasant surprise is taken out of certification in EMC test labs to some extent . The fast time domain scan mode has the potential to significantly reduce measurement times. This makes the measurement system suitable for testing DUTs with function-specific short operating times in the automotive and lighting industries, such as starters and window lifters or fluorescent lamps in the warm-up phase. In addition, the device is a full-featured spectrum analyzer that offers many other useful functions that allow users to better identify disturbances. The spectrogram function displays and records the spectrum versus time. The field-tested IF analysis function displays the spectrum around disturbance signals.

The ESRP is operated by touchscreen and has clearly structured measurement modes. Users can switch between modes by simply pressing a button and easily configure complex measurements and automated test sequences right from the touchscreen. It can remotely control simple automatic tests with the help of the ES-SCAN EMI software which records, evaluates and documents the data. The EMC32 application software for automated test routines, including report generation, can be used to integrate the receiver into large-scale EMC systems with additional components such as mast, turntable and absorbing clamp/slideway systems, and for the remote control of these components. The ESRP can even be operated in environments without any AC supply because it also runs on DC power, making it suitable for mobile use in vehicles or battery operation during open area testing.

First ETSI standard compliant solution

Addtionally, Rohde & Schwarz presented with the TS8997 test system its first ETSI standard compliant solution for certification testing in the 2.4 GHz band. More and more devices are using wideband interfaces that operate in the 2.4 GHz band. Diverse radio services such as WLAN and Bluetooth as well as radio remote controls and wireless devices today share the 2.4 GHz band, which is unlicensed and being more and more widely utilized. Since radio channels interfere with each other , the ETSI EN 300 328 standard has been revised. Existing scenarios have been modified, and special tests for verifying improved coexistence behaviour have been introduced. On December 31, 2014, the standard will become mandatory for all devices using this frequency band and being sold in the European Union.

The TS8997 test system is the first solution on the market that can perform certification tests in line with the new ETSI EN 300 328 V1.8.1 standard for wireless devices in the 2.4 GHz band, says Jürgen Kausche, Product Management Aerospace & Defence Systems and Products Test and Measurement Division of Rohde & Schwarz. “During development and certification, device manufacturers and test houses can now verify whether new products meet the upcoming certification requirements”, he states. Version V1.8.1 of the ETSI standard specifies a special type of power measurement. Thanks to the test system’s four antenna ports and integrated OSP switching module, the TS8997 can perform this measurement fully time-synchronized and in compliance with the standard on up to four channels, allowing it to characterize devices with MIMO and beamforming capability. Via menu control, the user first selects the radio technology implemented in the device under test.

Figure 4: Jürgen Kausche of Rohde & Schwarz is presenting the TS8997 test system. Picture: Marisa Robles Consée

The test system meets the requirements of the ETSI standard. This is due, among other things, to the system’s high sampling rate greater than 1 MSample/s with a measurement time of up to 32 seconds. A long measurement time is necessary in order to carry out a wideband measurement covering the entire scope of the signal and determine various parameters such as output power, average power and peak power. Power measurement and measured-value recording are controlled by a shared trigger, allowing for the reliable determination of the total transmit power.

The EMC32 software, a standard solution in EMC test labs, guides the user through the individual test cases, which actually run fully automatically. “The test system saves all samples taken and subsequently evaluates them. No alternative commercial solution for this type of power measurement has been available until now”, Jürgen Kausche affirms. In addition, the EMC32 basic software includes several upgrade options, making the test system ready for the future. Other equipment of the company can be used with the test system if required. The system also supports measurements in the 5 GHz band in line with ETSI EN 301 893 V1.7.1. This is especially beneficial to manufacturers of WLAN devices that support both the 2.4 GHz and the 5 GHz band in line with IEEE 802.11 a/b/g/n.

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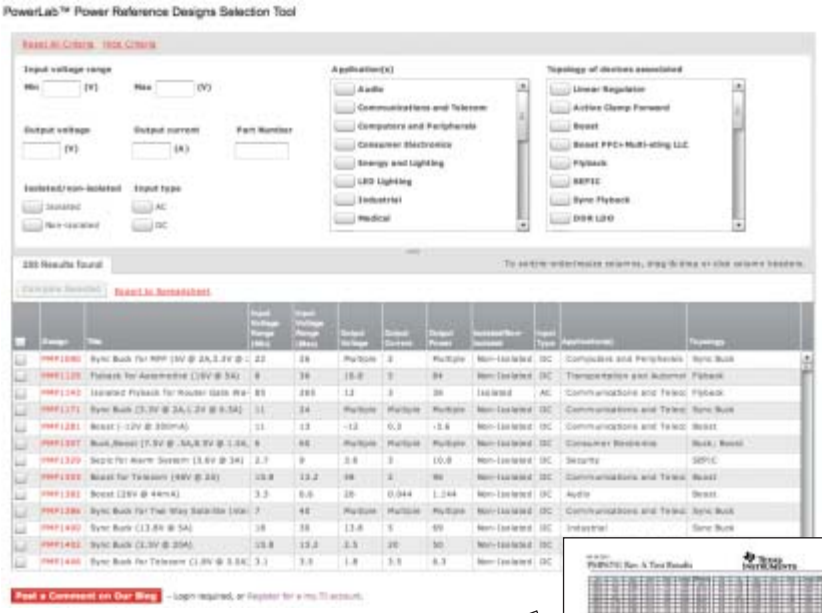

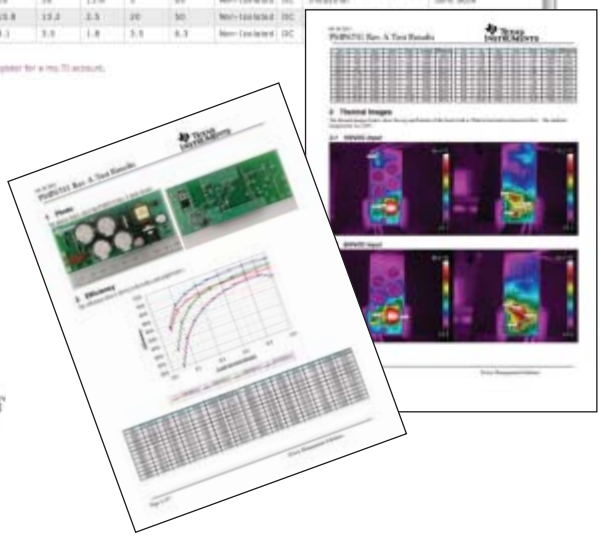

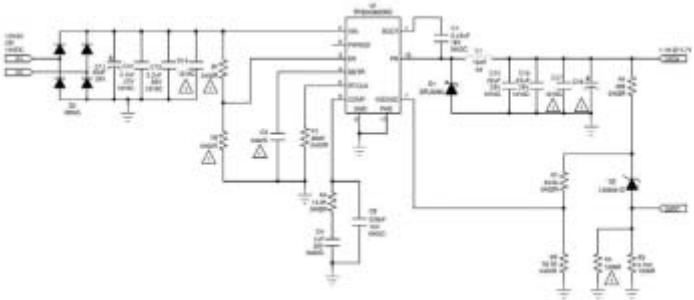

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By Michael A Briere, ACOO Enterprises LLC, under contract to International Rectifier

Once these pre-requisites are satisfactorily established, the revolutionary enabling benefits of GaN based power devices can be taken advantage of in a wide variety of power electronic applications. The current status of the development and current performance of the required 600 V rated GaN on Si based devices at International Rectifier are discussed.

Introduction

It has been well documented that the advent of high voltage GaN based power devices provides unprecedented opportunities to reduce both conduction (Rdson) and switching losses (Qsw) in a wide variety of power conversion circuits [1]. The combination of hetero-epitaxy using silicon substrates and device fabrication alongside silicon CMOS products in high volume factories provides the necessary cost structure to compete commercially with silicon based alternatives.

The capability to grow thick crack free AlxGayN alloys on standard thickness silicon substrates in manufacturing volumes has often been underestimated either as an essential element to commercialization of GaN based power devices or as a significant technological hurdle when moving from non-commercially viable substrates such as SiC. In the ranking of required capabilities to successfully compete in the commercialization of GaN based power devices, such capability, together with supporting intellectual property should be considered the most important. As such, International Rectifier is among the very few institutions which have demonstrated such capability. As an example, IR has previously demonstrated the manufacturability of up to 5 um thick AlxGayN alloy epitaxy on standard thickness 150 mm Si substrates [2]. In addition the volume manufacturability of low distortion (bow = 15+/-10 um) crack free GaN on Si epitaxy for 2.25 um thick films on standard thickness (725 um) 200 mm diameter silicon substrates is demonstrated in Figure 1 for over 20 multi-wafer batches. These results are made possible through the use of IR's proprietary compositionally graded transition layer III-N on Si epitaxial technology [2]. Another essential requirement for commercialization is the ability to produce devices alongside the incumbent high volume silicon based power devices. Such capability has also previously been demonstrated by IR.

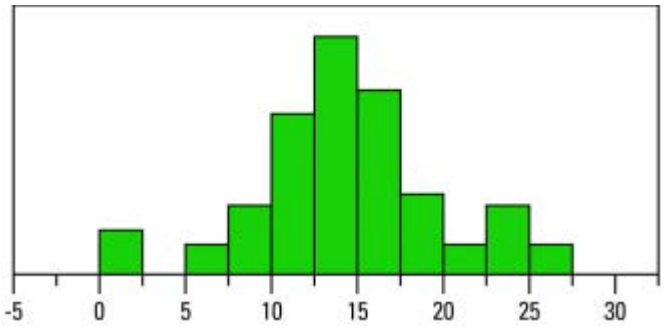

Figure 1: Measured distribution of final wafer bow for over 20 multi-wafer process runs producing more than 60 crack free 2.25 um thick AlGaN alloys based hetero-epitaxy on 200 mm standard thickness (725 um) silicon substrate.

It is often stated that development of an enhancement mode GaN based high electron mobility transistor (HEMT) is an essential element of commercialization. This is not a valid assertion. Besides the opportunity to use depletion mode, normally on devices, in a majority of power electronic circuits (e.g. using dc enable switch based topologies), several topologies, such as ac-ac converters used for motor drive, actually are superior when implemented with the inherently bi-directional capable depletion mode GaN based HEMT devices. In addition, the inherent instability of the two dimensional electron gas to positive applied fields which collapse the built in barrier potential of the AlGaN barrier layer (in AlGaN-GaN HEMTs) presents a severe crippling restriction of gate drive to any enhancement mode barrier based 2DEG device, through the limitation of applied overdrive gate voltage above threshold. Therefore, in the cases where normally off behavior is preferred, the cascoded configuration, using a low voltage MOSFET is recommended. In addition to providing a well established and reliable gate drive interface for external circuits, this approach has many advantages not found in an enhancement mode GaN based power device [3].

In addition to inherent and revolutionary integratability, the lateral GaN based (HEMTs) exhibit advantages of significantly lower terminal capacitances, several times lower specific source-drain resistance and essentially zero reverse recovery charge compared to either silicon based superjunction FETs or IGBT alternatives. It has been shown that the often feared current handling capability limitation associated with the lateral nature of the HEMTs can be effectively addressed through the use of front side solderable devices and dual sided surface mount packaging techniques. Current handling densities of more than 500 A /cm^2 at 150°C are demonstrated with large

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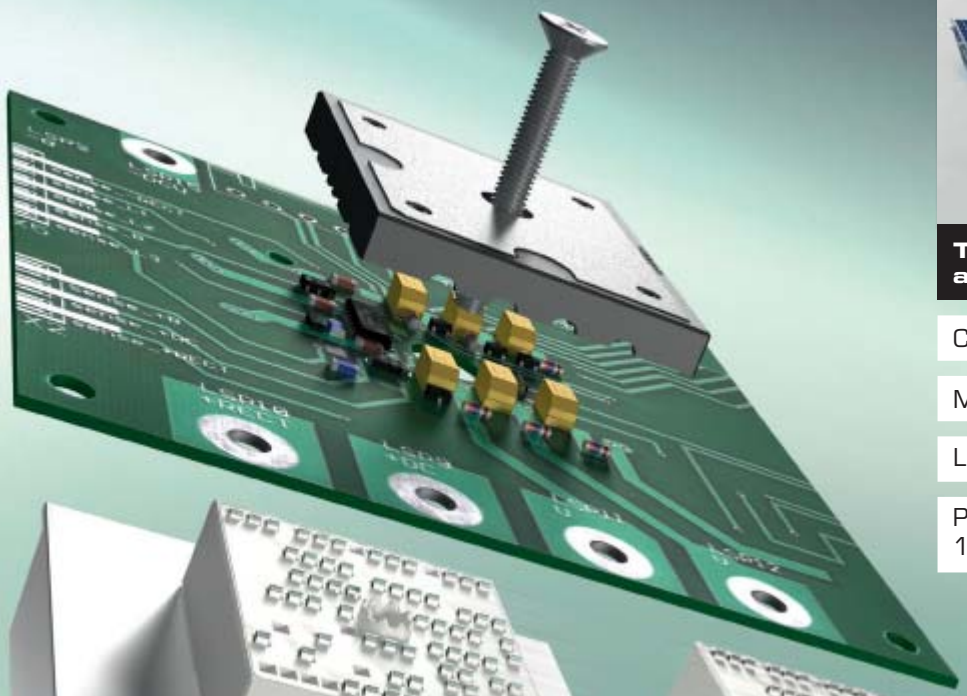
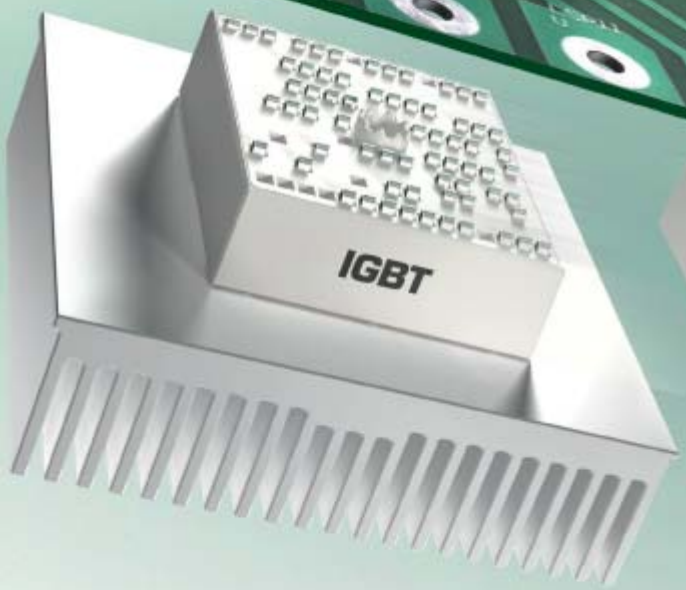
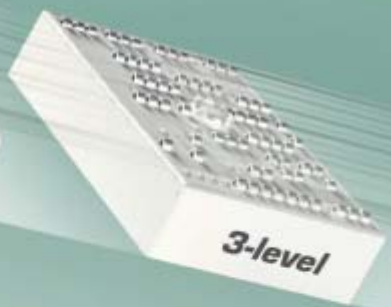
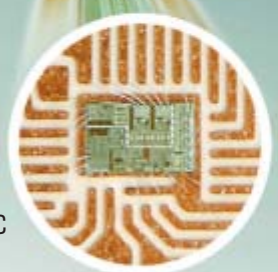


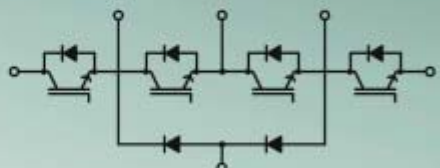




Integrated
SOI driver IC



NPC (Neutral Point Clamped)



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(Wg = 330 mm, AA = 8 mm^2) 600 V rated devices capable of processing more than 80 A at room temperature [4,5].

Early long term reliability results for 600 V rated devices, which have previously been shown to exhibit negligible dynamic Rdson [6], under accelerated stress conditions of 480 V drain to source reverse bias for 5000 hrs at 150°C are presented in Figures 2 and 3; demonstrating the production readiness of IR's GaNpowIR® technology platform.

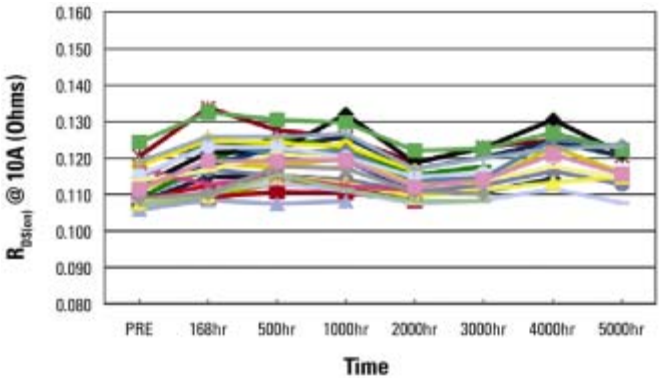

Figure 2: Source-drain resistance, Rdson of 600 V rated cascode switch for a population of representative cascoded GaN-on-Si based HEMT devices with Wg = 120 mm, under a drain bias of 480 V and 0 gate bias for 5000 hrs at 150°C.

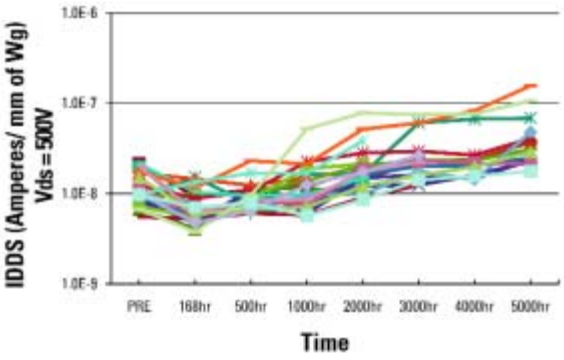

Figure 3: Source to drain leakage, Idss, current measured with 500 V drain bias and 0V gate bias of 600 V rated cascode switch for a population of representative cascoded GaN-on-Si based HEMT devices with Wg = 120 mm, under a drain bias of 480 V and 0 gate bias for 5000 hrs at 150°C.

The performance of these 600 V rated GaN-on-Si based devices in several widely used power topologies such as point of load dc-dc or ac-dc conversion have previously been presented [1]. One of the most wide-spread applications for 600 V rated devices is in the inverter drive circuitry for motors. It is therefore important to assess the value provided by GaN based power devices in motor drive applications. Figure 4 shows the dramatic improvement in power loss in a nominally 400 W motor drive inverter circuit, using state - of - the - art silicon based IGBTs or first generation 600 V GaN based cascaded switches. As can be seen the conduction losses are reduced by a factor of 6, while at the same time, the switching losses are reduced by a factor of 2. This remarkable result is based on the 4-10 x (depending on load current) improvement in the VceonxEsw (or RdsonxQsw) in the performance figure of merit of the GaN based devices over the silicon based IGBTs previously reported [6]. Such improvements in power handling capability allow for the related increase in the inverter power density of a factor of more than 10. In this instance, taking into account that the GaN based inverter does not require the heat sink of the silicon based inverters, the power processing volume density is increased by more than 100. Such revolutionary simultaneous improvements in power processing efficiency and density are examples of the potential of GaN based power devices to transform power electronics.

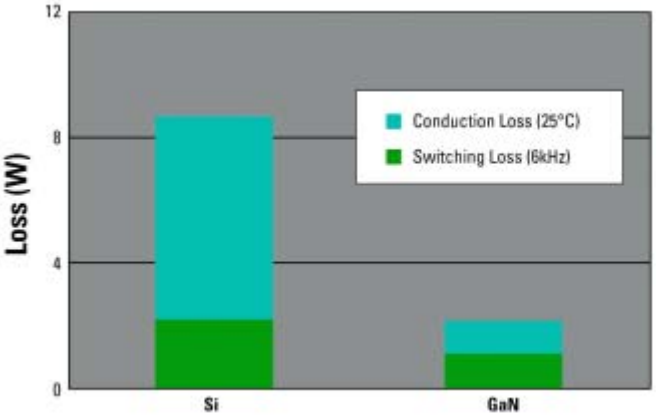

Figure 4: Measured conversion efficiency for nominally 400 W motor drive inverter, using either IR's GaNpowIR® based devices or state - of - the - art silicon based IGBTs and diodes.
Test Condition: IC = 1.5A, Vbus = 300V, Output voltage = 160V, Output Power = 415W, Tcase=150C.

Conclusion

The readiness of 600 V GaN-on-Si based power devices fabricated using International Rectifiers GaNpowIR® technology platform for large scale production is demonstrated. The combined improvement in power efficiency and density for these high power applications is nothing short of revolutionary.

Acknowledgment:

The author would like to thank the entire International Rectifier GaN Technology development team for their continued efforts in bringing this platform to commercial realization.

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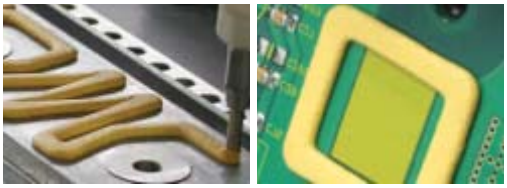

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From Mercury-Arc to Hybrid Breaker

100 years in power electronics

2013 marks the centenary of ABB's involvement in power electronics. Power electronics have become ever-present in a vast range of applications ranging from large HVDC installations - transmitting gigawatts over thousands of kilometers - to everyday household devices. The development of power electronics was driven by the desire to convert electricity from one frequency or voltage level to another without having to resort to moving, maintenance-intensive mechanical parts. In the early days, converters used mercury-arc rectifiers, which were replaced by semiconductors in the 1950s and 1960s. Throughout its 100 year history, ABB has been a pioneer of both power electronic technology and its applications.

By Andreas Moglestue and Christoph Holtmann, ABB Switzerland Ltd.

The early years of the commercial use of electricity were marked by competition between different distribution technologies. Edison's DC vied with Tesla's AC in a battle that the latter ultimately won. Whereas many applications are well suited to AC, there are also uses for which DC remains indispensable, thus requiring a means of converting AC to DC. These applications include electrolysis (such as for the manufacture of aluminum), battery charging, wireless communications and the electrification of tramways, metros and some local railways. These applications are still an important part of ABB's business today. The list has since been extended with the addition of newer applications such as datacenters and HVDC transmission.

From an early stage in the development of electrical systems, inventors were seeking to convert AC to DC (rectification) and DC to AC (inversion), as well as to create variable output from fixed input (e.g. for variable-speed drives). Most power electronic applications today can still be placed in one of these three categories.

A precursor technology for AC to DC conversion was the motor-generator (a motor and generator fixed to a common drive shaft). The principle could also be reversed (for DC to AC conversion), or indeed used to convert between two different frequencies of AC. For example, several European countries electrified their railways at 16 2/3 Hz. The motor-generator setup could even be expanded for variable output applications.

One valuable property of motor-generators is their ride-through resilience. Short power interruptions are bridged by the kinetic energy of the rotating mass. It is interesting to note that this energy-buffering function is mirrored by DC-link capacitors in today's power electronic converters.

The drawbacks of mechanical converters include maintenance on moving parts such as lubrication and changing of carbon brushes.

Switching

Whereas motor-generators feature a complete galvanic separation of the input and output, power electronics achieve conversion by changing the current path at discrete moments through switching actions. In its simplest form, the principle of path switching can be observed in the DC motor, where a commutator reverses the flow of current in the rotor winding in function of its position. Another more general-purpose AC-conversion is the contact converter. This converter features fast-moving externally-activated mechanical contacts (effectively an H-bridge, but with mechanical switches rather than valves). One notable weakness was that the waveform of the AC output was not a sine wave but a rectangle. This drawback was shared with many power electronic circuits. Overcoming this was to be one of the major points of progress in the area of modern power electronics.

Despite their apparent drawbacks, contact converters were able to fulfill current ratings beyond the scope of mercury-arc valves, and their production continued until the rise of silicon-based converters.

The mercury-arc valves

In the early years of the 19th century, the British chemist and inventor, Humphry Davy, showed that an electric arc could be created by passing current through two touching rods and then drawing them apart. A plasma (gas of ionized particles) forms in the gap between the electrodes and conducts current. The recombination of ionized particles in the plasma causes the emission of light, whereas the heat generated by the current creates new ions (excitation) and sustains the arc. It is interesting to observe that the underlying physics of today's semiconductor switches is equally concerned with the excitation, movement and recombination of charge carriers.

In 1902, the American inventor, Percy C. Hewitt, demonstrated a setup with one electrode made of mercury and the other of steel (carbon in later versions), enclosed in a glass bulb containing mercury vapor. An interesting property was that current would conduct from the carbon to the mercury electrode but not vice versa. Whereas the pool of mercury readily emitted electrons once the arc was ignited, the carbon anode did not to any appreciable extent (in the operating temperature range). The mercury vapor was ionized by the arc, and the bombardment of mercury ions onto the cathode generated sufficient heat to sustain its continued emission of electrons. The mercury-arc valve was born, and with it, power electronics.

In the following years, numerous inventors and companies sought to improve and commercialize this rectification principle.

Manufacture of mercury-arc rectifiers

In 1908, the Hungarian engineer Béla B. Schäfer began research on mercury-arc valves for the Frankfurt based company H&B (Hartmann & Braun). As H&B's main business was the manufacture of scientific instruments and the company had little experience with industrial high-current applications, a joint venture was created with Swiss-based BBC (Brown, Boveri & Cie) in 1913. The new company was called GELAG (Gleichrichter AG) and was based in Glarus, Switzerland. GELAG was mainly concerned with research and development, with BBC manufacturing the valves in Baden, Switzerland. In 1916, BBC also commenced production in Mannheim, Germany. In 1921, production was transferred to a larger factory in Lampertheim, Germany (Figure 1) and was joined by a second site that same year when BBC acquired the Berlin-based Gleichrichter GmbH (founded in 1919).

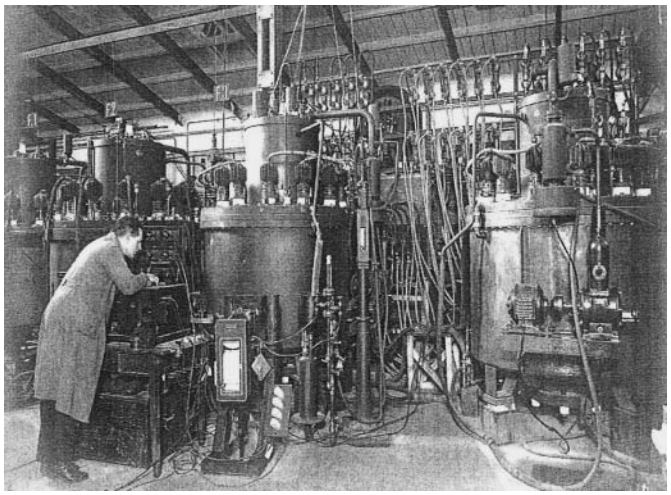

Figure 1: BBC production facility for mercury-arc rectifiers in Lampertheim, Germany (1921)

BBC took over H&B's stake in GELAG in the 1920s, and finally dissolved the latter in 1939, absorbing its activities into the parent company. Later, H&B also became part of ABB's heritage: The company was acquired by Elsag Bailey in 1995, which itself became part of ABB in 1999.

The first mercury-arc rectifiers were made of glass.

Due to the glass' low thermal conductivity and hence the restricted power capability, steel tanks were adapted instead with increasing power ratings. The market for mercury-arc valves boomed, and with it BBC's production (Figures 2 and 3). The company assumed a leading position in the development of the technology.

A simple rectifier circuit is shown in Figure 4. It is equivalent to an H-bridge in which a single enclosure with six anodes performs the function of six discrete diodes.

Whereas operation of such a valve could be sustained only under certain conditions, it could not start-up without aid. By providing a starting electrode, the ability to trigger conduction at an arbitrary point in time selective switching was made possible.

Starting in 1930, development of switchable valves began, enabling phase-fired controls (these valves fulfilled the same functionality that is today performed by thyristors - they can be switched-on arbitrarily but must wait for the current to reach zero to extinguish). By connecting them in an H-bridge, a line-commutated inverter can be made. As the term “rectifier” became increasingly incorrect in view of such new applications, in 1934, BBC began referring to its valves collectively as “mutators”.

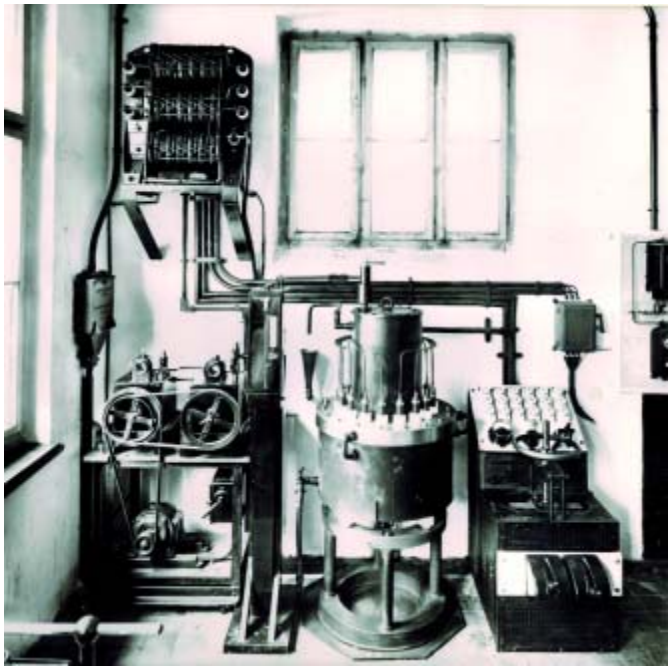

Figure 2: A BBC mercury-arc rectifier in the children’s hospital in Zurich, Switzerland (1914)

With both rectifier and converter functionality now feasible, BBC built a temporary demonstration line for the 1939 Swiss National Fair and Exhibition. The 500kW, 50kV DC link had a converter station at either end and transmitted electricity 25km from Wettingen to the company’s exhibition pavilion in Zurich using a single pole cable (Figure 5). This link was a precursor of today’s HVDC technology.

Figure 3 First locomotive using multi-anode mercury-arc rectifiers from BBC Mannheim, Germany (1938)

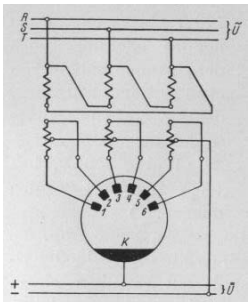

Figure 4: A simple rectifier circuit with a 6 anode mercury-arc rectifier equivalent to an H-bridge (Source: Wikipedia)

The manufacture of mercury-arc rectifiers continued until the mid-1960s. It was replaced by another revolution in power electronics: power semiconductors. Advantages of power semiconductors included greater power density and speeds, lower weight and losses as well as avoiding the toxic aspects of handling mercury.

The continuation will be published in the next issue of Bodo’s Power Systems in June 2013.

Figure 5: First HVDC transmission line Wettingen-Zurich, Switzerland. Pilot installation at the Swiss National Fair and Exhibition in 1939

Further reading

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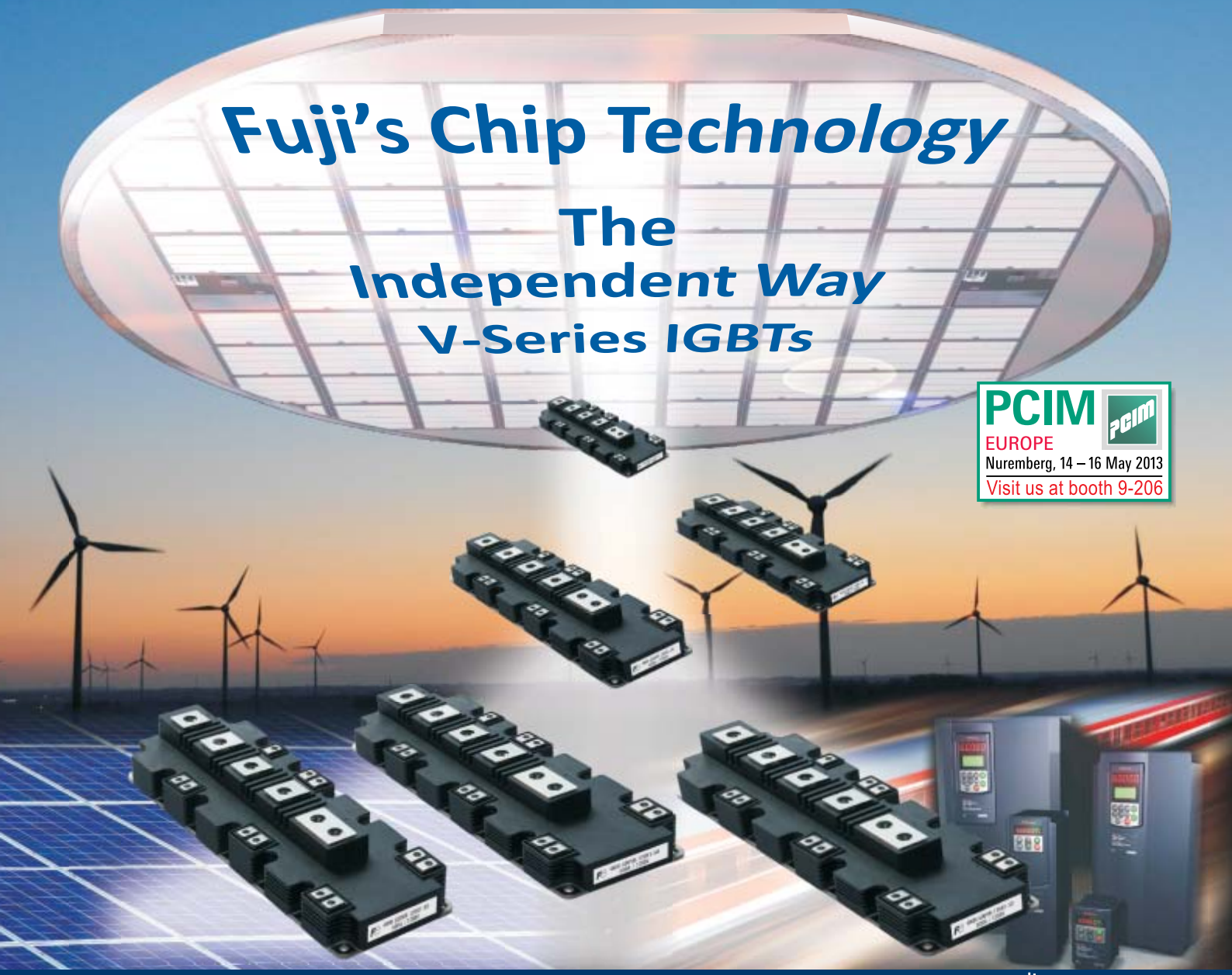

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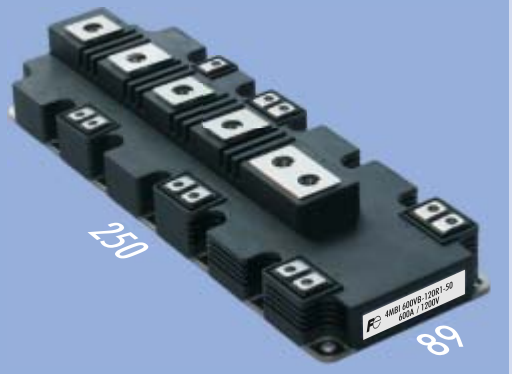
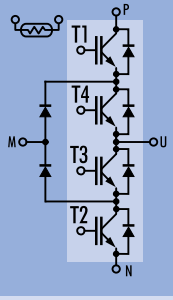
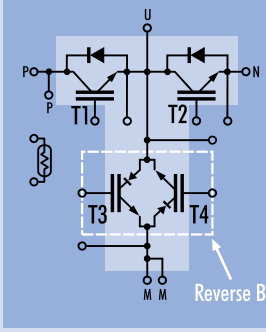


I-Type

I_C	T1 , T2 , T3 , T4
600A	1200V



T-Type
with Reverse-Blocking IGBT



I_C	T1 & T2	T3 & T4
450A	1200V	900V
650A		
900A		
450A	1700V	1200V
600A		

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Power GaN and SiC Demands High Performance Modules

New GaN and SiC Packaging Architecture Enables New Faster, More Efficient, and Higher Power Density Surface Mount Devices and Modules, like the µMaxPak and µMaxMod

By Courtney R. Furnival, Semiconductor Packaging Solutions, Lake Arrowhead, CA

Introduction

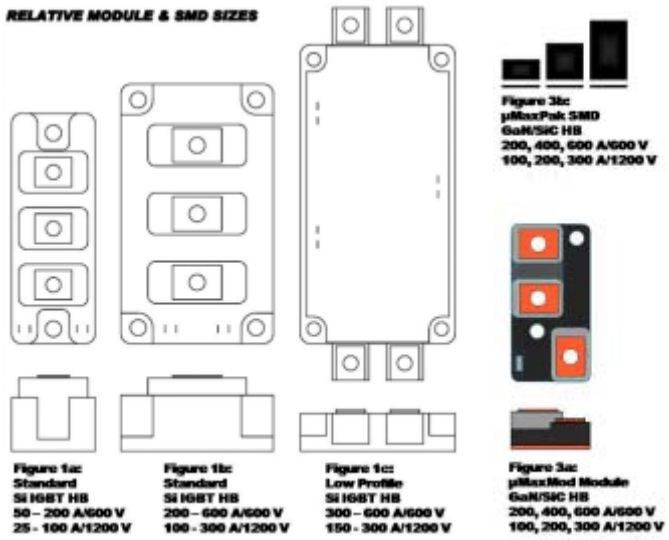
Power Module architecture for high-voltage (HV) power silicon controlled rectifier (SCR) and thyristor switches have changed little over the past four decades, slowly transitioning to bi-polar transistors and then to IGBTs and diodes. These modules have continued to be large and bulky with large screw terminals and high voltage (HV) spacing. They accommodate easy installation and replacement, but limit performance of ever faster and more efficient silicon IGBT devices. The advent of 600 V, 1200 V, and higher power silicon carbide (SiC) and gallium nitride (GaN) devices that are much faster, more efficient, and provide higher power density can no longer tolerate these limitations. The smaller die and lower losses offered by the compound semiconductor power switches enable new smaller structures, which accommodate high-speed switches, more integration, newer materials, and lower cost assembly. Power compound semiconductors extend the range of co-packaged surface mount device (SMD) power switches to power levels that were the exclusive domain of power IGBT modules, and create high-performance building-blocks for the next generation power modules. This article examines new criteria demanded by compound semiconductors, and offers new packaging solutions that enable smaller, faster, more efficient, and lower cost HV power compound semiconductor switches, bridges, and smart-bridges.

Legacy Modules

Standard industrial 600 V and 1200 V insulated gate bipolar transistor (IGBT) half-bridge (HB) modules are common, but single-switch (SS), full-bridge (FB) and three-phase-bridge (3φ) are available for many applications. These modules are bolted to large heatsinks, and high current terminals are bolted to power leads and bus bars. Usually fast-on leads are used for gate and sense connections, and for power leads at currents up to 50A. Figures 1a & 1b show such industrial HB power modules commonly used for 240 and 480 V ac applications with currents of 50 to 600 A and maximum voltages of 600-1200V plus. These modules limit switching speeds due to high stray inductance of 40nH. These modules also have long leads and wire bonds that have high resistance that creates significant conductive losses.

The standard modules modified by some manufacturers better accommodate faster IGBTs, but performance improvements were limited, and turn-on and turn-off still creates excessive switching voltages. Inductances were reduced incrementally to 20nH with the low profile package shown in Figure 1c. These packages have larger footprint, simpler construction, and slightly higher current ratings, but the di/dt is even limited for faster silicon IGBT switches.

This discussion omits two product categories due to their uniqueness. First, there are the lower current 3-phase (3φ) bridges for home appliance applications. Due to their lower current rating in the 1 to 15 A range, they are less constrained by inductance and resistance. The high current 600 V electric vehicle (EV) and hybrid electric vehicle (HEV) modules are another exception.



Paradigm Shift for GaN & SiC

GaN and SiC devices can potentially be 1/10th the size and have 1/5th the loss[1], and can operate at much higher switching speeds and temperatures. These devices require high density and high performance packages and modules, which enable their full performance and cost effectiveness. Early SiC and GaN power devices have not yet reached their potential, but the chart in Figures 2a & 2b shows the dramatic potential size reduction for 600V and 1200V GaN and SiC die, relative to Si die.

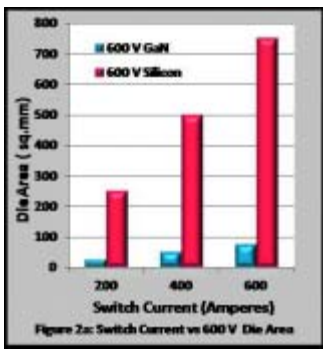


Figure 2a: Switch Current vs 600 V Die Area

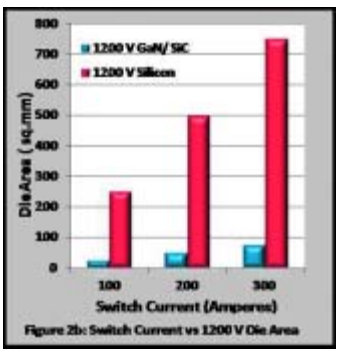


Figure 2b: Switch Current vs 1200 V Die Area

Power GaN and SiC packages and modules must accommodate smaller devices with higher power and current densities, must enable much higher switching speed, and must provide significantly lower conduction losses. They need lower DC and AC resistance connec-

tions, very low stray inductance, and lower thermal resistance, while accommodating higher operating temperatures and the same high isolation voltages. Higher density functionality further enables high speed switching, through co-packaging of multi-switch bridges, gate drives, and integrated control, protection, and isolation.

Historically the HV power IGBT market has been 80% modules, and 20% discrete packages like D2Pak, TO220, and TO247. Faster, smaller and more efficient power GaN and SiC switches should increase the discrete and co-pak package bridge market share. However, with the growing demand for more efficient high power conversion, modules will certainly maintain a dominant position in the market.

Next Generation Power GaN and SiC Packages

Power GaN & SiC die require a quantum leap in packaging with higher power density and performance, but smaller die and higher efficiency provide new freedoms to package architecture, materials, and assembly. Smaller die can be soldered directly to copper leadframes, and can contact rigid molding compounds. This enables packaging with lower cost commercial package platforms, which are readily available and easily customizable to power application. Leadless and wire-bondless package platforms have been refined, are produced in high volume for high frequency computer and telecom applications, and they have all the attributes required for power devices.

New Semiconductor Packaging Solutions "µMaxPak" architecture for power GaN and SiC devices is "nearly chip-scale," and the surface mount package is built on leadless and wire-bondless modified DFN/QFN platform. It removes heat from both top and bottom of thinned compound semiconductor die, and can provide an Rjc of 0.1 ºC/W with 5x5mm die. The power leads provide low inductance of 0.1 to 0.2nH and low DC resistance of 100-200µohms. The geometry minimizes resistance increases at higher frequencies from skin-effect constraints. The µMaxPak further reduces power lead inductance and resistance with parallel die, and in compact multi-chip HB, FB, 3φ and others power switch configurations. Figure 3b shows approximate size of 200, 400, and 600 A at 600 V and 100, 200, and 300 A at 1200 V HB µMaxPak SMD packages with one, two, and three 5x5

mm GaN die switches, respectively. The HB µMaxPak can include the gate drive ICs, which are a key enabler for optimum paralleled die switches. SiC die have similar potential, but generally require anti-parallel diodes.

The SMD µMaxPak does not include isolation and screw terminals, so you must use it on isolated boards or substrates. SMD ?MaxPaks on thermal PCBs or IMS are simple and economical, but at higher current levels, you must use the µMaxPak on open DBC assemblies or as building-blocks in higher power DBC modules. In all cases, the µMaxPak provides pre-tested building blocks with environmental and handling protection, and provides well controlled performance, parasitics, and die paralleling at higher currents. They are flexible and easy to use, and allow the end-user to mount and connect for specific applications.

The µMaxPak GaN and SiC SMDs enable 3-D internal architecture, allowing gate driver ICs to be assembled with output pads directly over the power switch gate pads. This is critical for switching speed, noise immunity, and tight voltage control and temperature compensation. Additionally, you can co-package isolation and control circuitry for optimum and consistent power switch parasitic, control, and protection. Integration or co-packaging in the molded packages is possible by reduced component and/or circuit size with high frequency GaN and SiC operation. Furthermore, pre-tested and well controlled building-blocks are essential for high yields with increased integration, and for well controlled parallel die switches.

Next Generation µMaxMod Modules for Power GaN and SiC

The GaN and SiC module size can and must be reduced with smaller compound semiconductor die and reduced power dissipation, but module size reduction is limited by screw terminal size and the HV spacing requirements of UL and other safety agencies. The package outline drawing in Figure 3a shows a projected minimum HB module size for 600 to 1200V GaN or SiC modules with currents of 200 to 600 A, while retaining standard terminals. In the same outline, the modules can also include integrated gate drivers and associated isolation, control, and protection functions. Table 1 compares the estimated module sizes and performance between new GaN HB modules and typical Si IGBT HB modules. The GaN µMaxMod modules, shown in Figure 3a, were modeled with the µMaxPak HB building blocks shown in Figure 3b. The µMaxMod GaN module is possible with chip and wire (C&W) construction; however, C&W increases inductance, DC/AC resistance, and thermal resistance, not to mention omitting all of the other advantages of a well controlled building-block. Table 1 shows the key metrics for comparing 200 to 600 A HB modules.

Small size is important to lower inductance, resistance, and capacitance, and provide further inherent advantages to user and system integration. If the base plate is reduces by 10X to 20X, the smaller base plate not only minimize mounting force and screw size/quantity, but more importantly makes hi-performance metal matrix materials (like Al-SiC) very economically viable, The accompanying 6X reduced size isolation substrate makes high thermally conductive DBC materials (like AlN and Si3N4) also quite economical. Smaller packages not only contribute to lower stray inductance and lead resistance, but enables further reductions in system bus bars and power leads. Integration of gate drive, isolation, protection, and control devices are practical for Low Profile GaN and SiC modules, because of smaller component sizes with higher frequency operation.

TABLE 1:	Low Profile GaN HB µMaxMod	Standard Silicon HB IGBT Modules		Low Profile Silicon HB IGBT Modules	
			% larger than uMaxMod		% larger than uMaxMod
Module LxWxH (mm)	64x32x17	106x62x31	600%	152x63x17	480%
Module Footprint (cm^2)	20	66	320%	96	450%
Module Volume (cm^3)	348	2037	600%	1628	450%
Base Plate, min. (cm^2)	7.8	158.6	2000%	76.6	1000%
DBC Substrate, min. (cm^2)	6.7	40.6	600%	40.6	600%
Stray Inductance (nH)	7	40	600%	20	300%
Lead Resistance, Relative	1.0	3-5	300% - 500%	3-5	300% - 500%

Values shown are 80% of potential practical minimum size and loss limits.

Future Trends

The µMaxMod type modules improve performance, and minimize size and cost of high power GaN and SiC modules with traditional terminals, but large terminals and spacings still account for the majority of a module's size and mass. Higher density module schemes are possible for specific applications, and can further improve performance and reduce material and manufacturing costs. Potential interconnect options include soldering, welding, and leadless or direct connects to final system locations, and the lead spacing can be reduced further with molded sleeves, potting, coating, and/or other insulation techniques. Smaller lower loss modules are more integratable into end-products. Examples of such integration are Motor Drives into motor housings and Solar Micro-Inverters into the panel connector boxes. The end user may do application specific customization, leaving the GaN or SiC device manufacturer to focus on module building-blocks like the SMD µMaxPak SS or HB because they can better control performance, parasitics, reliability, and cost effectiveness in their fully automated clean-room assembly and test facilities. Smart integration and co-packaging of more functionality continues, enabling higher speeds and lower losses.

[1] "Is it the end of the road for silicon in Power Conversion", Alex Lidow, EPC, Inc., April 10,2012, pp 1,2 on EPC Website

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Calculation of Stress-Deformation States in Power Semiconductor Modules with Soldered Interfaces

This article presents the results of digital simulations of stress-deformation states in system silicon – ceramic – metal-matrix composite, in power IGBT module with soldered interfaces as example. Influence of design materials and assembling technology on residual stresses in system was studied. The results can be used in power electronics by design and reliability evaluation of power semiconductor devices for cycle operation.

By A.A. Khapugin, V.A. Martynenko (Electrovipryamitel JSC) and K.N. Nischev, M.I. Novopoltsev (Ogaryov-name Mordovian State University), Saransk, Russia

The basic connection technology in power semiconductor modules is nowadays soldering. The main challenge is strength of soldered joints. Properties of connected materials and solders should be taken into account, as well as physical, chemical, constructive and technological factors that are responsible for soldered joints.

Solder material is of most importance in this case. It should restrict residual thermal stresses to minimum and create conditions for uniform distribution of stresses all over the interface between main design elements: semiconductor chip – DCB – base plate.

It is known from experimental investigations that most vulnerable places in soldered joints are boundaries of interfaces semiconductor chip – DCB and DCB – base plate. Analytical calculations and digital simulations show [1] that stresses in these regions depend on mechanical and thermal loadings. The lower are residual stresses after soldering, the higher is joint strength, on condition that both mechanical and thermal loadings influence the same region simultaneously. Evaluation criterion of interface optimal structure and composition is very important for prediction of solder layer strength. Maximal stretching residual stress is used often as criterion for measurement of connection strength. Other affected the destruction factors should be taken in account too. Some authors [2] propose elastic deformation energy as damage measure.

Digital simulations are most acceptable method of stress-deformation states calculation in heterogeneous systems, in the first place finite element method that is widely used in modern software for design element analysis – COSMOS/Design STAR, ANSYS, LS Dyna and other.

From mathematical point of view, the problem comes to founding of displacement vector U (x, y, z) – edge problem solution for equation system of constrained thermal elasticity. This problem can be turned into equivalent variation problem that consist in the finding of solution U (x, y, z) for minimal free energy functional. Elastic deformation energy is calculated in this method by means of elastic energy summarization for all elements of investigating area

$$W_d = \Sigma s_{ij} \cdot \varepsilon_{ij} \cdot V_{ij} \qquad (1)$$

where: W_d – elastic deformation energy, s_{ij} and ε_{ij} – characteristic values of stress and deformation for element with volume V_{ij}. It is considered that stipulated by residual thermal stresses minimal elastic energy corresponds to maximal strength of soldered joint.

The simplified 2D model of power semiconductor module with soldered interfaces was used for determination of solder joint physical and mechanical characteristics, as well as influence of solder layers thickness and properties on mechanical stresses. “Electrovipryamitel” IGBT module with AlSiC base plate was used as example for calculations (Figure 1a).

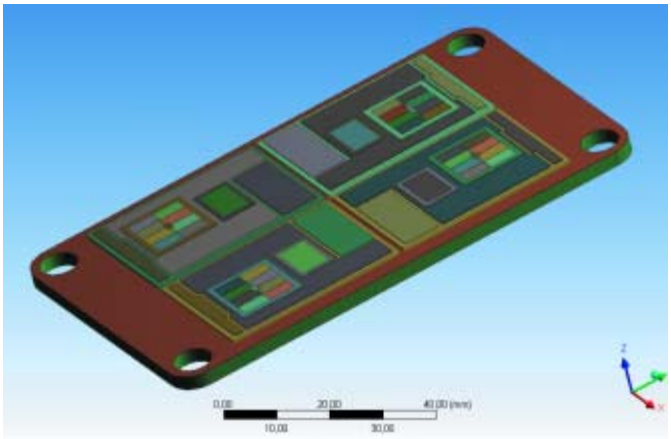


Figure 1a: IGBT module with AlSiC base plate, 3D-Pattern of IGBT module

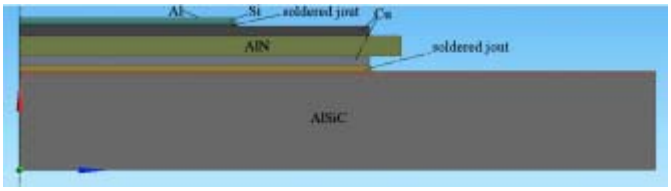


Figure 1b: IGBT module with AlSiC base plate, 2D model of IGBT module

Figure 1b shows 2D model of IGBT module multilayer soldered joint having structure Al–Si–Cu–AlN–Cu–AlSiC.

The model includes following main components:
- IGBT chip 0,19 mm thick with contacts from Al and Ni 4 and 0,5µm thick, accordingly;
- DCB substrate including AlN ceramic 0,63 mm thick and two Cu layers 0,3 mm thick with electric circuit layout;
- AlSiC base plate 3 mm thick with Al and Ni plating.

These components are connected during two successive soldering processes:
- soldering of IGBT chip on DCB substrate by means of solder alloy 95,5Sn-3,8Ag-0,5Cu with melting point 217ºC:
- soldering of DCB substrate on AlSiC base plate by means of solder alloy 62,5Sn-37Pb-0,5Ag with melting point 182ºC.

These two processes determine basic residual stresses in layers of investigating structure.

Figure 2 shows two-dimensional finite element model of multilayer soldered structure in x-y plane with calculation grid created in software complex ANSYS.

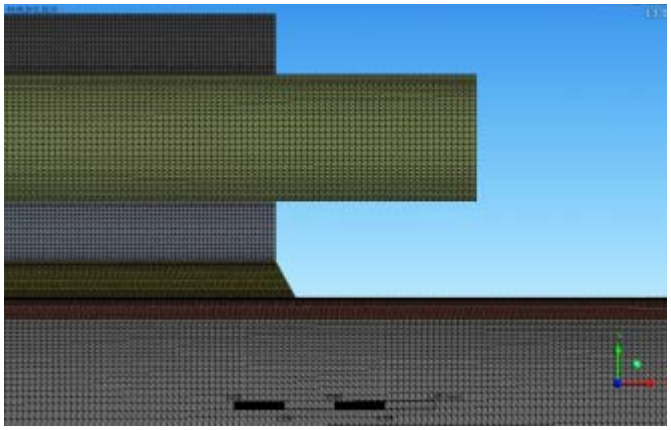


Figure 2: Finite element model of IGBT module multilayer soldered structure

Assuming that in z-direction model is not deforming, flat deformation approximation can be used in 2D-interface of solid state mechanics. Supposing that model is subjected only to thermal loads, general differential equations can be written as:

$$\sigma = D\varepsilon_{el} + \sigma_0 = D(\varepsilon - \varepsilon_{th} - \varepsilon_0) + \sigma_0 \qquad (2)$$

and

$$\varepsilon_{th} = \begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \gamma_{xy} \\ \gamma_{yz} \\ \gamma_{xz} \end{bmatrix}_{th} = \alpha_{vec}(T - T_{ref}) \qquad (3)$$

where: σ – stress vector, D – elasticity matrix, ε_x, ε_y, ε_z, γ_{xy}, γ_{yz}, γ_{xz} – deformation components, α_{vec} – thermal expansion coefficient, T – temperature, initial temperature when mechanical stresses are equal to zero.

The next assumptions were taken during elastic energy calculation by means of finite element method:
- external influence is absent,
- design elements operate in elasticity limits on $\varepsilon(\sigma)$ diagram,
- elasticity properties change with temperature is not considered.

Four mechanical and thermal parameters of design materials are sufficient to calculation of stresses and deformations in soldered joints according to described above model. Table 1 summarized physical properties of materials used in calculation.

Material	Elasticity module, GPa	Poisson's ratio	CTE, 10^{-6} K^{-1}	Density, kg/m^3
Al-SiC-9	188	0,237	See fig. 9	3010
Silicon	131	0,266	4,2	2200
Copper	110	0,37	24	8900
Nickel	210	0,31	17	8500
Aluminum	68	0,33	23,6	2700
Solder alloy 99,5Sn-3,8Ag-0,5Cu	40	0,45	18	7000
Solder alloy 2 62,5Sn-37Pb-0,5Ag	30	0,42	17	6700
Ceramic AlN	345	0,22	4,5	3300

Software complex ANSYS allows choice of different material properties including their temperature dependencies of AlSiC produced by CPS Company.

Calculation of multilayer soldered structure is very complicated because of contact layer soldering in different processes by means of solder alloys with different melting points, taken for reference temperatures T_{ref}. Calculation model can be simplyfied by means of exclusion of layers that weackly influence system stress-deformation state (SDS), and dividing of calculation into some stages in each of them only one process is modelled.

Three stage calculation algorythm of contact joint stress-deformation state for model figure 2 is descriebed below.

- Stage 1. DCB substrate heating from T_{ref} = 20ºC up to first soldering temperature and SDS transmission into second model.
- Stage 2. Soldering of IGBT chip and DCB substrate by means of solder alloy 95,5Sn-3,8Ag-0,5Cu ond cooling from T_{ref} = 217ºC up to second soldering temperature and SBS transmission into third model.
- Stage 3. Soldering of DCB substrate and AlSiC base plate by means of solder alloy 62,5Sn-37Pb-0,5Ag and cooling from T_{ref} = 182ºC up to T = 20ºC.

SBS calculations in accordance with this algorythm were made for IGBT module with AlSiC base plate and IGBT module with copper base plate.

Figure 3 shows SDS distribution on deformed AlN DCB substrate heated up to first soldering temperature.

Figure 3: Distribution of mechanical stresses in DCB substrate by first soldering temperature

Stresses are concentrated on the copper edges where copper layer contacts with ceramic.

Figure 4 shows SDS calculation results for DCB substrate with IGBT chip by room temperature after first soldering (a) and during second soldering (b).
a) Room temperature
b) Second soldering temperature

Figure 4a: Stress-deformation state of AlN DCB substrate with soldered IGBT chip by room temperature

Figure 4b Stress-deformation state of AlN DCB substrate with soldered IGBT chip during second soldering

It can be seen from fig.5 that maximal stresses after first soldering arise in the solder joint area of IGBT chip with DCB substrate. These stresses decrease after heating up to second soldering temperature.

Figure 5 shows SDS of system chip – Al_2O_3 DCB substrate by the same temperatures.
a) Room temperature
b) Second soldering temperature

Figure 5a: Stress-deformation state of Al2O3 DCB substrate with soldered IGBT chip by room temperature

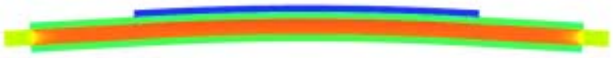


Figure 5b Stress-deformation state of Al2O3 DCB substrate with soldered IGBT chip during second soldering

Figure 6 shows for comparison calculated bottom surface profiles of Al_2O_3 and AlN DCB substrates by room temperature after first soldering.

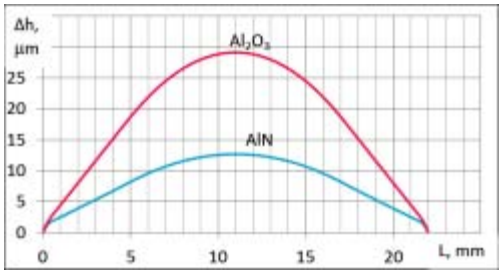
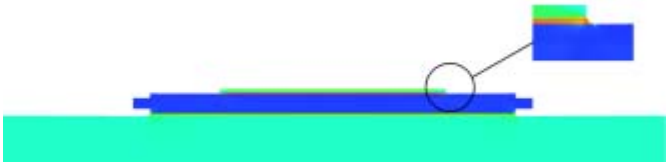


Figure 6 Bottom surface profile of DCB substrates with soldered IGBT chip by room temperature

It can be seen from figures that substrate deformation and stress-deformation state in system Al-Si-Cu-AlN-Cu are suffuciently lower that in system Al-Si-Cu-Al_2O_3-Cu. It can be explained by lower CTE difference between Si and AlN ceramic in comparison with that between Si and Al_2O_3 ceramic.

Next calculations of stress-deformation states were made for systems chip – substrate – base plate in IGBT modules. Two systems were chosen for calculations: Si – AlN – AlSiC and Si – Al_2O_3 – Cu.

Figure 7 shows SDS calculation results for IGBT module model by room temperature after DCB substrate soldering on AlSiC base plate (a) and on Cu base plate (b).
a) AlSiC base plate



b) Cu base plate

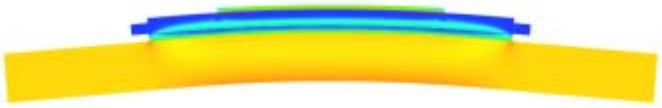


Figure 7 Residual stress-deformation state of IGBT module model with AlSiC base plate and Cu plate after soldering of substrate on base plate (deformation is 10-times magnified).

It can be seen from fig.7 that maximal mechanical stresses after second soldering lay in contact area chip-solder. It is also seen that system with Al_2O_3 DCB substrate and Cu base plate has sufficient stresses between ceramic and copper layer of DCB substrate (Fig. 7b). System AlN – AlSiC (Fig. 7a) has no similar stresses.

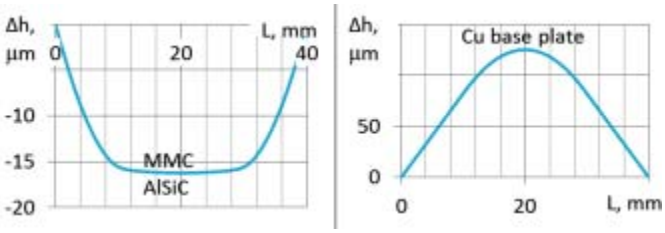


Figure 8 Bottom surface profile of Cu base plate and AlSiC base plate after second soldering. Positive deformation values show concavity, and negative deformation values show convexity of bottom surface

Figure 8 shows bottom surface profiles of Cu base plate and AlSiC base plate after second soldering.

Conclusion

Simulations of stress-deformation states in power IGBT modules were carried out in several stages in accordance with manufacturing process. Calculation results of bottom surface shape are in good agreement with measurement results. Calculations confirm well known advantages of AlSiC as material for base plate. Proposed calculation method can be useful for IGBT module designers for material choice and geometry parameter determination of substrates, solder layers and base plates providing minimal stress-deformation states, hence minimal thermal resistance and high power cycling capability.

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Warehouse Automation in Modern Industrial Production Company

Proton-Electrotex JSC was founded in 1996 on production basis of Proton company, which earlier was a part of electronic industry department in USSR. The company is growing rapidly and cooperates with manufacturers and suppliers all around the world.

Production cycle takes from one up to two and a half months. This process includes a lot of complicated steps, which require close attention of specialists. To increase labor productivity some production steps are being automated. In 2009 an automated enterprise resources control system ERP SyteLine was implemented.

By Chikin M.V., Semenov P.A., Mordovets O.P., Proton-Electrotex JSC

In 2012 it was complemented with computerized warehouse control system WMS, which was developed by specialists of Proton-Electrotex.

WMS is utility software that combines general operations of ERP SyteLine, which are used by warehouse personnel during deposition and stock removal.

Up to the present moment all warehouse operations were done by personnel with help of enterprise resource planning. This system is quite complex and has a multilevel structure of operations, which of course has human factor and as a result longer rendering time. Warehouse personnel searched and issued the materials from memory. Warehouse materials record was quite insufficient.

In terms of production facilities growth and organization of new warehouses an idea to reform and implement addressed storage system.

To develop the idea company personnel suggested some methods to automatize stock control:

- Order form on bringing on charge materials by purchasing department managers for warehousemen control and verification of primary documentation
- Record and stock removal according to arrival and storage terms (FiFo method)
- Implementation of barcoding to simplify data input
- Automated label and supporting documents printing
- Automatic integration with 1C:Bukhgalteriya software

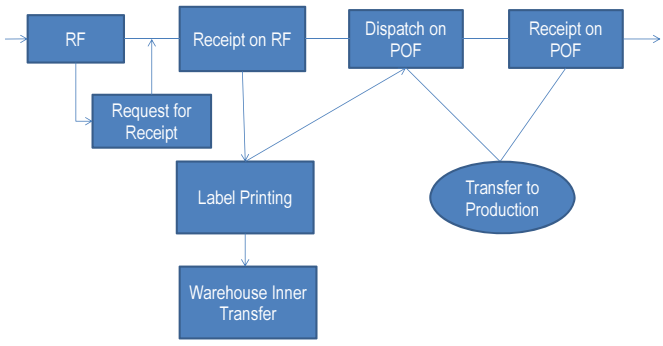

Figure 1:General Operational Structure of WMS

First of all it was important to define the strategy in this direction. At the first stage warehouse automation conception was approved. After management approval technical requirements were prepared and on their basis development of the third party software started. Such order provides an opportunity not just thoroughly define, but also coordinate with all participants of the process, aims, which developers pursue – describe general requirements for functionality, define the direction for further project development. Technical requirements included the following conditions:

- Conduct of operation efficiency
- Reduction of operations by warehouse personnel
- Strict storage order
- Simplicity and search operativeness of necessary materials in warehouse
- Generation of request for stock removal without disruption from work place
- Possibility of simultaneous relocation of several material positions using one transfer order

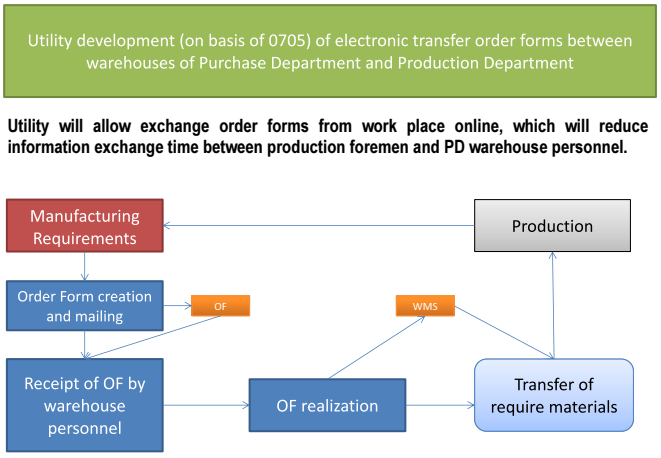

Figure 2: Utility development of electronic transfer order

In the frame of introduction of bin location warehousing a ten digit letter-figure code was developed, which contains information on location of the materials. This code is also enciphered in barcode and keyed on storage location.

Simultaneously with main software development a virtual multilevel warehouse structure with barcode and material name search system was launched. The scheme was aimed to complement ready-to-use software and give personnel an opportunity to easily guide the warehouse. After input of the necessary device code the system shows location of the material on scheme with possibility to track it with very high accuracy.

Requirements to development of the main part of the software were grouped into five general operations, which are to be completed by warehouse personnel after final launch of WMS system:

- Bringing on charge the materials from suppliers to company warehouses
- Stock removal
- Receipt of materials on coded designation
- Warehouse internal transfer (from shelf to shelf)
- Label printing with definition of stored materials and quantity

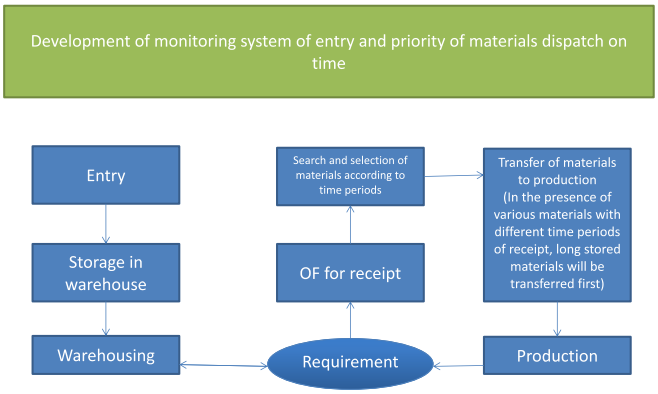

Figure 3: Development of monitoring system of entry

Besides above mentioned requirements in terms of development simplification of interface and making program complex user-friendly was a priority.

Warehouse personnel training to use the software and test period of exploitation took short time due to reduction of operations done by personnel and user-friendly interface.

As a result WMS was developed – system for bin location warehousing and material determination. WMS is integrated with ERP SyteLine database – all operations are mirrored in ERP SyteLine online. Due to WMS implementation deposition and stock removal operations are possible to simultaneously coordinate all requested materials, which essentially reduce labour intensity.

Stock removal operation is accompanied with automated printing of requisition slip, which is given to recipient directly in warehouse.

Stock removal is done with direct visual and software control of warehouse personnel to the certain storage location.

To reduce passing route of inventory, the warehouse facilities were moved closer to main production facility but further from working place of warehouse personnel, which caused some difficulties with on-time complete action reflection in warehouse. Solution for this issue was achieved using collection unit and input/output data adjusted with help of wireless access to company network.

If necessary received batches of materials can be distributed to various storage locations, which will be recorded in system.

Materials are transferred to warehouse with new labels produced on incoming inspection. One of the requirements for labels was information on materials storage conditions. Based on this, code system for storage conditions of each and every device was developed.

In case of bringing on charge of materials, which do not pass incoming inspection, software allows to print the labels directly by warehouse personnel.

According to the results of external audit, which took place in February 2013, WMS got a very wide acclaim by the inspecting company.

As a prospective it is planned to develop additional utilities to form digital request for stock removal by warehouse personnel, and also additional specification for WMS for incoming inspection. This specification will include status system for received onto warehouse materials online.

Automation of incoming inspection in the future will give an opportunity to store information on batch of materials from certain supplier, which will make life cycle of products more clear and let cancel nonconforming products on any production stage.

Status change will initiate transfer of materials operation in background mode within the warehouse for higher quality record of materials in storage location. Nonconforming products will never be stored with conforming ones. Moreover, identification of nonconforming products will also be different - the labels will be in different color.

Following the results of these developments all internal logistics starting from request up to stock removal to production will be automated.

State of the Art PE Control Solutions Development

The development and validation of control algorithms in record time

Since 1991 Končar Electrical Engineering Institute (KEEI) Inc. has been involved in development and delivery of embedded power electronics controls solutions to companies within KONČAR Group and for the open market.

By Zlatka Tecec Ribaric, Sinisa Marijan, KONČAR Electrical Engineering Institute Inc.

The Project

KEEI was asked to develop an embedded control solution for scalable/modular 150kW, 400V, 50Hz three-phase, single-stage central photovoltaic (PV) converters. The specifications required a state of the art solution, fully developed and tested within six months.

The Challenge

Development and implementation of a robust fully tested control system that would ensure optimal control of active and reactive power, maximum power-point tracking, fault ride-through and anti islanding functionalities.

Usually, KEEI's teams follow the standard sequence of development steps for power electronic control solutions:

1) analysis of requirements, related norms and in-house knowledge and experience
2) development of a switching model of the power hardware with an off-line simulation package for system analysis at switching frequency time scales
3) development of a linear model (in millisecond or longer time scales)
4) simulation and verification of the performance of the proposed converter topology, typically using various software tools (due to software limitations, component model complexity and other issues).
5) synthesis and testing of control algorithms using different simulation tools depending on the observed time scale and other requirements
6) iteration of the previous steps until the required converter behavior is achieved,
7) preparation of production documentation for embedded control system
8) conversion of control algorithms developed by means of simulation software to real time application program of the target embedded control system
9) building of the prototype embedded control system
10) verification of a complete control system and debugging of implemented control algorithms on a prototype controller platform
11) qualification of the complex system
12) building, testing, validation, delivery and commissioning.

Typically, most of the time allocated to a project is spent on Steps 2 to 6 as one major group and later on Steps 7 to 9, i.e. in waiting for completion of the prototype converter and its associated embedded control system.

The Solution

For the purposes of this project, due to a tight development timeframe, a different approach was tested. For the first time, KEEI's team used a Hardware-in-the-Loop emulator system, a Typhoon HIL600, which is able to model power electronic converters as well as associated passive components.

With the emulator system, we managed to drastically shorten the time needed for Steps 2 to 10. On the Hardware-in-the-Loop emulators, a model of a PV converter with all the passive and active components was realized, which particularly shortened steps 2 to 4.

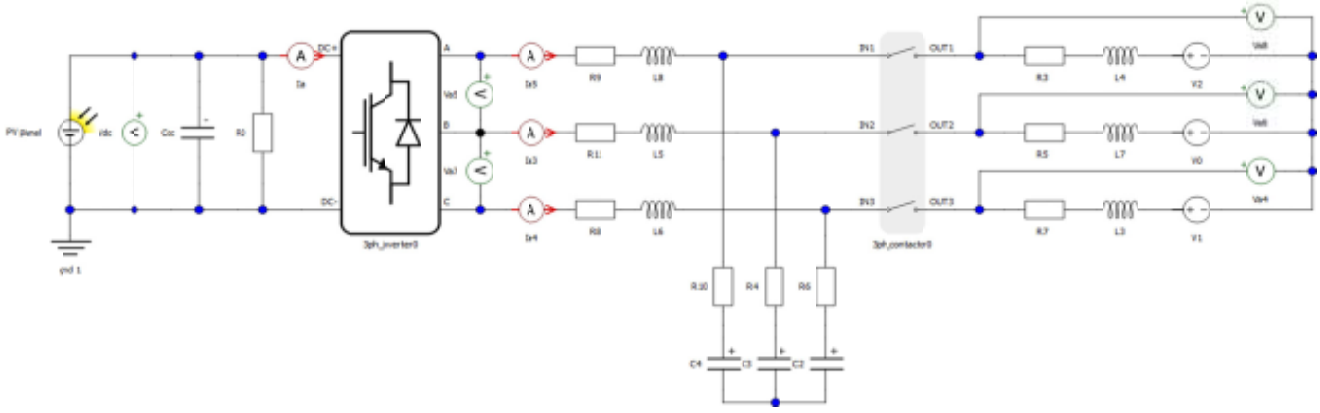

Figure 1: The configuration of the central photovoltaic inverter

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Implementation of the control algorithms and automated testing procedures could now start on a rapid prototyping platform which comprised the aforementioned emulator and a proprietary TI docking station, with a Texas Instruments TMS28335 control card. Instead of using the usual textual programming of the control algorithms within the TMS28335, we adapted and used our proprietary Graphical Programming Integrated Development Environment GRAP IDE. Within KONCAR, this software tool is used for the development of power electronics and other special control solutions. The combination of our GRAP IDE and Typhoon HIL600 helped us to simultaneously develop and test all aspects of the control algorithms directly in the target DSP, which saved many time-consuming simulate?implement?test sequences. The result was a fully tested control algorithm implementation before production of the embedded control system was finished. Thus, it was possible to influence changes in the hardware concept of the embedded control system prior to release of the first version of production documentation.

Figure 2: Proprietary graphical programming integrated development environment GRAP IDE

For example, the filtering requirements (slope and bandwidth) on analog inputs could be corrected and additional error-signaling and temperature probe inputs implemented.

The next steps were functional tests of the produced embedded control system. Rather than waiting for the converter to be assembled, this step was also performed on the Typhoon HIL600 which was now connected to the produced control system via a custom interface.

With such a rapid prototyping platform it was easy to repetitively test conditions that could be prohibitively expensive or impossible to test in the laboratory. These conditions include sudden changes in insolation (due to cloud-cover), PV panel dropout, extreme harmonic pollution, grid faults and so on. Those complicated and sometimes dangerous tests were performed in the safety of an office with the help of this emulator. All changes in the application program were implemented on-line with no concerns about expensive component failure. PID controller tuning is a good example. Our developers could change PID controller parameters by several orders of magnitude. For instance, time constants could be changed from microseconds to several milliseconds to check system stability (and to purposely push it to oscillation limits) with no concern about the hardware. The effects of the modifications were visible instantly which allowed the complete testing and debugging of the control system before applying it to the PE converter.

Figure 3: The delivered control system in cabinet of developed PV converter

An important parameter that was clearly seen and could be easily assessed by using GRAP IDE on the rapid prototyping platform (instead of the simulation tools) was the influence of different “correct” PWM frequencies (which lead to symmetric PWM signal generation) such as 3.6kHz or 2.4kHz and “odd” frequencies such as 2.6kHz, on the generated harmonics and stability of the complete control system.
A lot of troubleshooting was done using the rapid prototyping platform. Some abnormal and non-consistent harmonic components were tracked down to the faulty order of execution of program blocks. Several ill-defined program blocks were found during the automated testing (a problem that could stay dormant for months if a system were immediately deployed in a converter) and program cycle times were adjusted according to the test results. In addition to that, we were able to optimize the program by slowing down the operation of program blocks, which were found to be non-crucial, from microsecond to millisecond time ranges. Furthermore, some high performance digital filters (that were using a lot of processing time) were, after the testing in the hardware-in-the-loop, transferred to the control system FPGA component.

Results

The development of the embedded control solution for the central PV converter was completed in only five months and with only four full-time developers. The control system has successfully met all the applicable standards and proved to be a robust and reliable system. The PV converter, as a result, showed great performance on the EN50530 defined tests and was able to fulfill national grid code requirements.

Conclusions

By using the described HIL-GRAP rapid prototyping platform, our team could directly implement their ideas and no time was spent on iterative and time-consuming simulations. For example, complete variable time step simulation of the converter and control system took about 4 hours per second of converter operation versus real-time operation on the rapid prototyping platform. Many errors connected with the simulation tools themselves, e.g. adjusting time-step range and computing precision were bypassed altogether.
Finally, cumbersome hardware configurations and costly laboratory testing were cut down considerably: there was no need for disconnection of converter components to fit the precision current transducers required for grid compliance measurements and moreover, our developers could work in a completely safe environment – there were no PV field-related high DC currents (of up to 400A) and voltages (of up to 1000V). As a consequence our time-to-market was the shortest ever!

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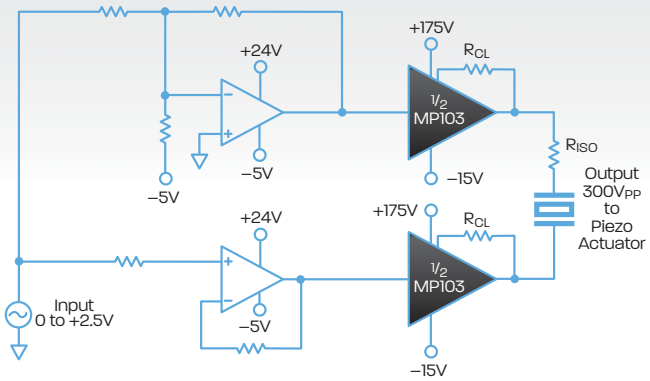

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APEX MICROTECHNOLOGY

Flexible Development of Energy Harvesting Wireless Solutions

Compared to wired systems, wireless offers far greater flexibility and convenience in home and building automation, as well as in industrial installations. In particular, batteryless energy harvesting wireless technology scores with no maintenance and a sustainable power supply. That's an important reason for manufacturers (OEMs) and developers to consider this green technology for new product designs.

By Frank Schmidt, Chief Technology Officer and Co-Founder of EnOcean

The applications of energy harvesting wireless technology are so varied and different fields have such individual needs for a successful product development. To support OEMs facing this challenge, EnOcean has set up a cost-effective and customised development platform for fast integration of energy harvesting wireless technology into building and industry automation, smart home as well as machine-to-machine or transportation systems.

The concept is based on several kits – ranging from a starter kit and programming kit to developer and thermo developer kit. Due to the modular concept, OEMs benefit from a higher flexibility in product development meeting their specific, product-related requirements and assure them a competitive edge.

Ready-made for faster development

At the core of EnOcean's modular developer offer is the EDK 350 developer kit covering the entire product range, from energy harvesting and wireless modules to ready-made product solutions. The developer kit's central element is a universal programmer board. In combination with the DolphinStudio PC software, the board is used to configure and program Dolphin-based modules.

The complete EDK 350 includes: TCM 320 (transceiver module), STM 300 (universal wireless sensor module), ECO 200 (mechanical energy converter), PTM 330 (transmitter module for ECO 200), PTM 210/PTM 215 (energy harvesting switch module, PTM 215 includes data encryption function), STM 330 (energy harvesting temperature sensor module), USB 300 (USB wireless gateway), DolphinStudio (configuration and programming software) and DolphinAPI (application programming interface).

Figure 1: Complete EDK 350 developer kit

The package is completed by the DolphinView PC software for visualising and mapping the wireless protocol. The application profiles (EnOcean Equipment Profiles or EEP), now in the latest 2.5 version, can also be interpreted and sent by using the kit. This enables the interoperability of new products with existing ones from different vendors as they can communicate seamlessly with each other or with other automation standards via gateways.

Prepared for building automation

The development kit offers a variety of energy converters and modules enabling the creation of energy harvesting wireless solutions. The TCM 320 transceiver module has already several pre-implemented features for building automation, for instance. The 1-channel relay mode is used to switch on and off a module pin. If developers connect a relay to this pin they can switch mains-powered devices such as lighting. The DolphinView software receives EnOcean telegrams via the USB 300 and visualises as well as interprets them.

The PTM 210/PTM 215 push-button radio transmitter module enables the implementation of wireless remote controls without batteries. Key applications are wall-mounted flat rocker switches with one or two rockers, as well as handheld remote controls with up to four single push-buttons.

Figure 2: Secure wireless communication for several use cases

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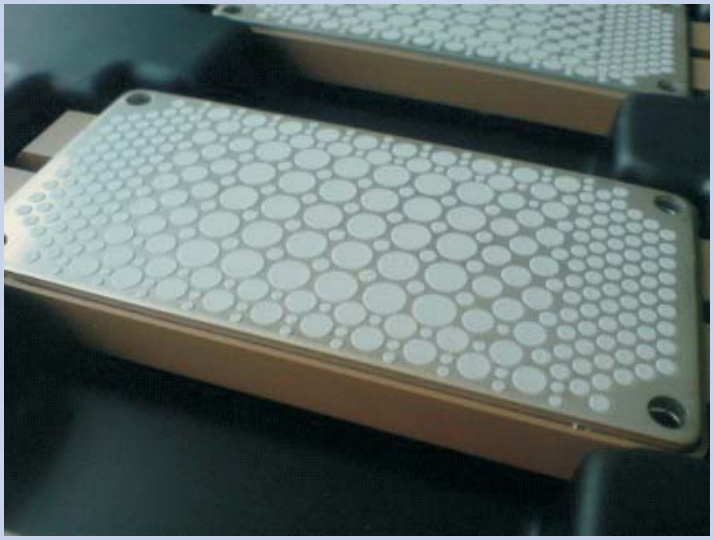

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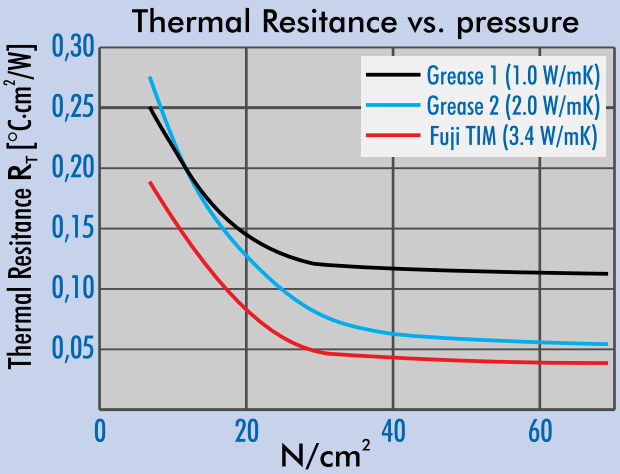

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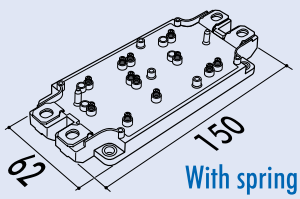
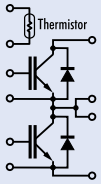
2 in 1  	450A
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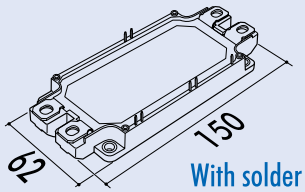
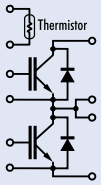
2 in 1  	225A
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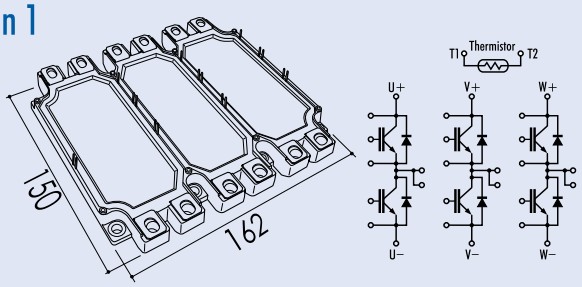
6 in 1 	225A
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Fuji Electric
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Security on demand
The self-powered PTM 215 switch comes with implemented security functionalities for a secure wireless communication in smart home, security access control systems and other critical applications. It creates a 16 bit rolling code for each wireless telegram. The telegram header, telegram data and current rolling code in turn form the basis for generating a 24 bit message authentication code (MAC). The receiving system can use this code to check the authenticity of the data package.

To enable easy integration of data decryption and encryption functions into existing products, OEMs can use the DolphinAPI function library and equip a receiver with data decryption functionality, for instance, to communicate with the switch module PTM 215.

Energy at the press of a button
The duo of ECO 200 energy harvester and the PTM 330 transmitter module of the developer kit enables an entire system for batteryless wireless switch operations. The mechanical energy converter ECO 200 converts mechanical energy into electrical energy, which it makes immediately available. With an energy output of 120 µWs, a stabilised voltage of 2 V and the wireless batteryless module, it is possible to transmit three radio telegrams per operation. This energy conversion can be used for functions such as door and blind control or light control and dimming.

Figure 3: ECO 200 mechanical energy harvester

The maximum allowed contact travel of 0.04 inches enables a typical completion of more than 300,000 switching cycles. With shorter contact travel (the converter switches after 0.03 inches of spring deviation, at the latest) significantly more than a million switching cycles are possible. This means a switch can be operated 100 times a day for more than 25 years.

The batteryless PTM 330 wireless module can be connected to the energy converter by spring contacts, with no soldering and features four digital inputs to map up to four switching states. Additionally, an interface allows configuration of the content of the wireless telegrams during manufacture of a user device. Like every EnOcean wireless module, the PTM 330 has a unique 32-bit identification number to eliminate any overlap with other wireless sensors. Wireless range is up to 30 metres inside buildings and 300 metres in the open. This complete ready-to-go system eases the implementation of switching solutions enabled by energy harvesting wireless technology.

Lighted by low power
Finally, the solar-powered STM 330 sensor can measure temperature in a room or on machinery, for example. This module is characterised by its extremely low-power consumption plus high reliability. If a measured value is transmitted every 15 minutes for instance, 3.6 hours of charging in daytime and 200 Lux are adequate for uninterrupted operation. With its energy storage mechanism fully charged, the module is functional for four days in complete darkness. The USB 300 bidirectional gateway transfers both measured data and switch commands to a PC, received and visualised over the DolphinView Basic software.

Customised development step by step
In addition to the developer kit, the ESK 300 starter kit is a part of the modular offering for developers. The starter kit is ideal for initial tests and offers a basic approach to product design-ins using energy harvesting wireless technology the first time. The starter kit contains a switch module, components for different switch applications, a temperature sensor module, a USB gateway and PC software for visualisation. If configuration, hardware or software development is required, the ESK 300 starter kit can be upgraded to the developer kit at any time via the EPK 350 programmer kit consisting of the universal programmer board, a transceiver module and the universal sensor module.

The power of temperature
Furthermore, developers can extend the EDK 350 developer kit with the EDK 352 thermo developer kit. This includes the STM 312 energy harvesting wireless sensor module and the ultra-low voltage ECT 310 DC/DC converter in conjunction with a peltier element to power EnOcean modules by differences in temperature.

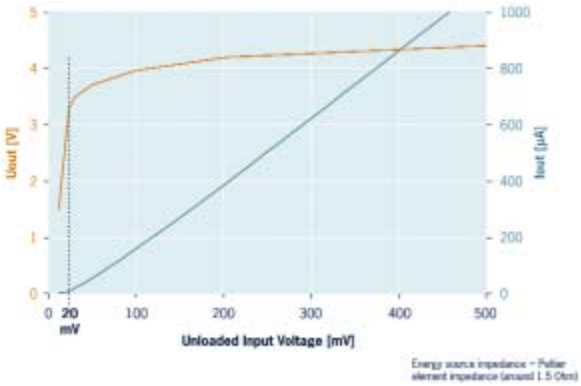

Figure 4: ECT 310 DC/DC converter, output versus Input

Temperature differences contain a lot of energy. Just the cooling of a drop of water by 1 degree Celcius releases energy for about 20,000 EnOcean wireless telegrams. That is enough to operate not just a wireless sensor but even a number of wireless actuators. The energy is delivered by thermo generators.
But such low-cost Peltier elements have a pronounced drawback, namely that they only produce very small voltages of about 10 mV per degree Kelvin. Electronic circuitry connected to this, a sensor module for example, needs a typical supply voltage of 3 V. The ECT 310 DC/DC converter closes this gap. This optimised oscillator already starts to resonate upwards of 10 mV input voltage. On 20 mV or more (i.e. about 2 °C) a useful output voltage of more than 3 V is generated. To enable this high converter efficiency of 30%, the output voltage is only roughly regulated to less than 5 V over the entire input voltage range up to 500 mV. This is similar to the unregulated supply voltage from solar cells.

The modular development kits structure offers more flexibility in product development. Manufacturers can further develop existing products with ease and, at the same time, open up and react quicker to new fields of application for energy harvesting wireless technology using all three energy sources.

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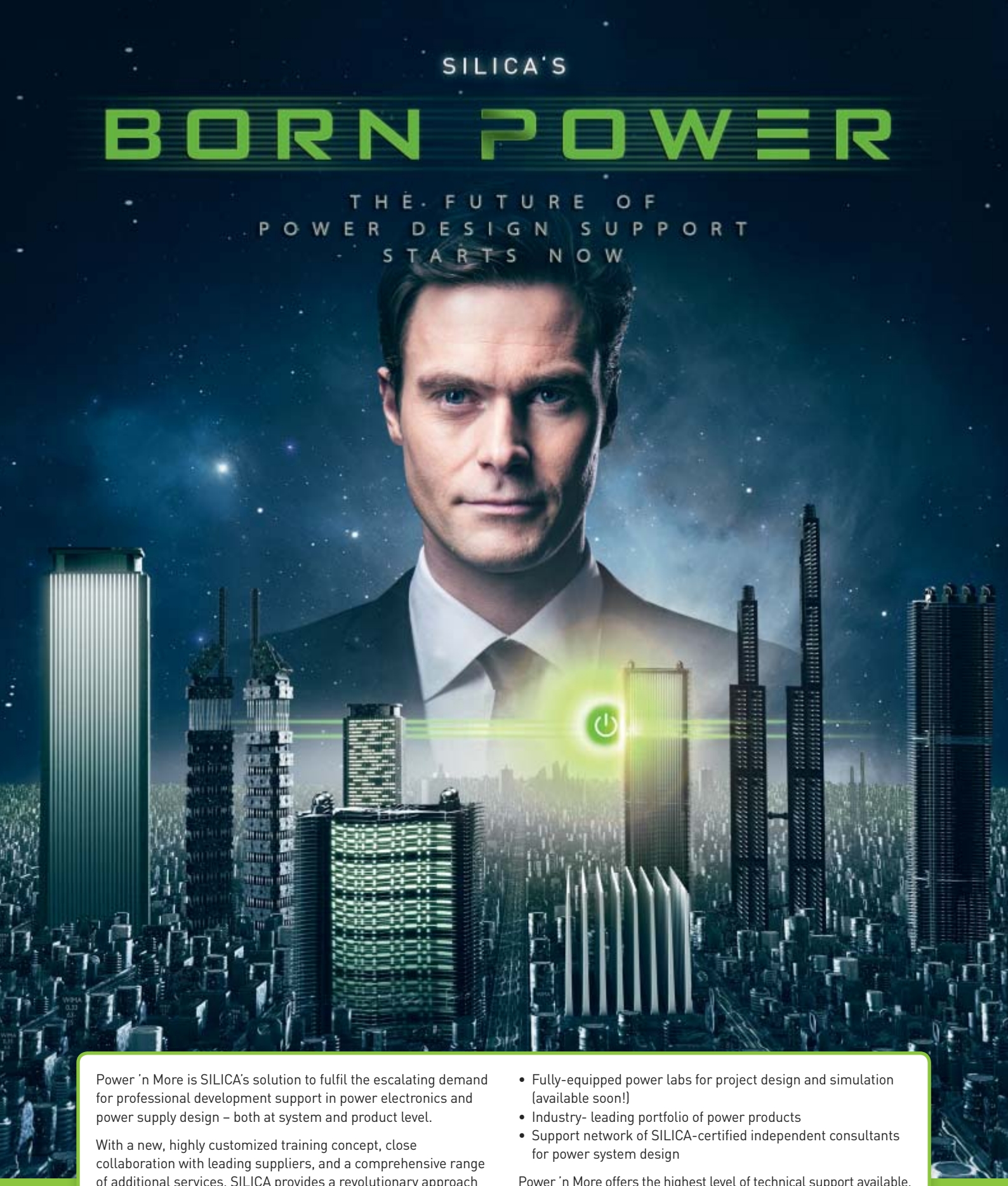

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Predictive Energy Balancing for Agile Control of Switched-Mode Power Converters

The absence of compensation simplifies development and testing.

The number 6 billion turns up often as the number of cell phones in use worldwide. Published estimates average to around 25 power converters per cell phone. If the typical switching frequency is 50 kHz, that works out to 7.5 x 10^{15} switching decisions per second in cell phones. Add in computers and file servers and consumer goods and motor controls and the number of switched-mode power decisions made daily is astronomic.

By Tom Lawson, CogniPower, LLC, Founder and President

You might think such frequent decisions would be based on the best information available, but that is generally not the case. Take a basic flyback converter:

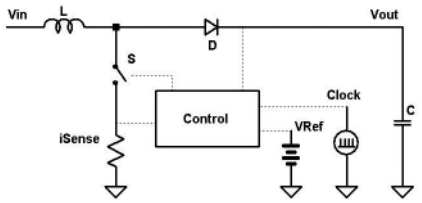

Figure 1: Basic Flyback Converter Block Diagram

When switch S is closed, inductor L is energized from the voltage source, Vin. When the switch is subsequently opened, that inductive energy passes through Diode, D, into filter capacitor, C. Ideally, one would want to switch from energizing the switched inductor to transferring energy to the output, Vout, at the instant that would result in the best regulation. Typically, the decision is based instead on what was happening, on the average, during some previous time period. The result is that such regulators underrespond to step changes at first, and then over-respond afterward. To mitigate the problem, compensation is used to change the gain during disruptions. Compensation can involve a little or a lot of calculation or circuitry, but it always involves a compromise between stability under DC conditions and improving transient response under AC conditions. Since positive feedback in power converters can cause destructive runaway, careful attention must be paid to compensation. But, there is a better way. Let's go back to the ideal case:

Ideal Step 1: Energize the inductor to the correct level for best regulation.

Ideal Step 2: Transfer that inductive energy to the output filter, resulting in the output voltage reaching the regulation point.

The ideal case may seem to require a preternatural ability to predict the future, but the underlying physics provide the key. There is a relatively simple calculation, based on the fundamental energy equations, that can determine just when the correct amount of energy has been loaded into the switched inductor.

The amount of energy required to supply to the output is the difference between the instantaneous kinetic energy at the output filter capacitor and the desired kinetic energy at the output filter capacitor:

KEC = (V^2 x C) / 2
Where:
KEC = capacitive energy in joules;
V = voltage in volts;
C = filter capacitance in farads

KEReg = (Reg^2 x C) / 2
Where:
KEReg = desired energy in joules;
Reg = Reference point in volts;
C = filter capacitance in farads

The difference is energy demand:

Demand = KEReg - KEC

The kinetic energy in the switched inductor is:

KEL = (I^2 x L) / 2
Where:
KEL = inductive energy in joules;
I = current in Amps;
L = switched inductance in henries

The inductive term is the energy Supply. When Supply equals Demand, it is time to stop the energizing period and to begin the transfer period.

Each control cycle is then self-contained. There is no history (integral) or rate sensitivity (differential). The gain becomes a function of the ratio of the switched inductance to the filter capacitance.

We call this process Predictive Energy Balancing (PEB). A block diagram of circuitry to perform the calculation appears here (Fig 2). The VSCALE input adjusts for the L/C ratio. The same, or similar, computational block can control a flyback or forward converter, a discontinuous buck converter, or a switched-mode power amplifier. The calculations scale for any size power converter. With one or two more energy terms, Continuous Mode converters can be controlled, too. Note that the energy balance calculations can be made in an analog or a digital fashion.

The best conventional power converters respond to a load step in six control cycles. PEB controls respond in a single cycle. That might not sound like a dramatic difference, but it changes the ground rules for what is practical when controlling switched mode power. Because of the averaging which takes place over those six control cycles, there is an inevitable time delay which introduces a tendency to alternately overcorrect and undercorrect. That oscillatory tendency generates sub-harmonics.

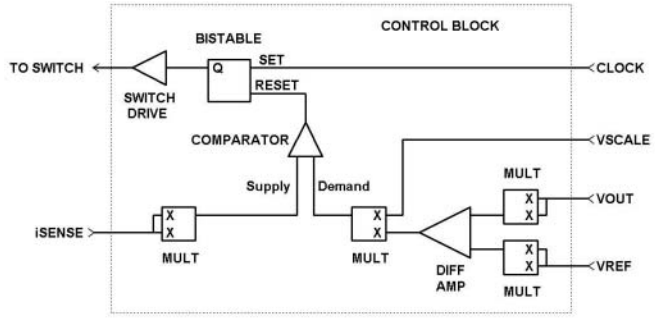

Figure 2: Predictive Energy Balancing Flyback Converter Control Block Diagram

Predictive Energy Balancing eliminates the need to compromise between stability and agility. The smallest theoretic filter capacitors can be used. Because of the intrinsic stability, catch diodes and protection circuits can be reduced or eliminated. Because there is no averaging in PEB, the controls can be synchronous or asynchronous, and a synchronous clock frequency can be adjusted at will. Because the controls are based on the underlying physics, and do not require compensation, they accept a wider range of operating conditions. That makes PEB control convenient for digital power.

To illustrate the capabilities of PEB, CogniPower built a power converter in the form of an audio amplifier. (Imagine what would happen if you asked a conventional power converter to track an audio signal.) PEB is agile enough to reproduce a 20 kHz sine wave with excellent fidelity while driving a load that is capacitive, inductive or resistive in any combination. The PEB amplifier was demonstrated live at APEC 2013, in Long Beach, CA.

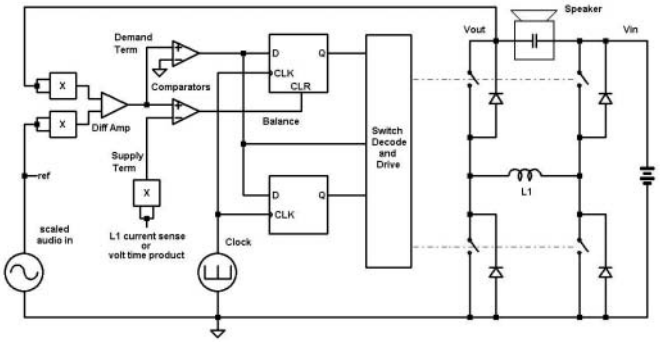

Figure 3: PEB Audio Amplifier for Driving Cell Phone Piezo Speaker

Figure 3 shows an efficient PEB power converter that doubles the drive voltage available (similar to a bridge-tied load Class D amplifier). Four ordinary FET switches form two totem poles. When the magnitude of the output is increasing, energy is predictively transferred from the battery to the speaker capacitance. When the magnitude is decreasing, energy is deterministically transferred from the speaker to the battery.

CogniPower set out to build a proof-of-concept demonstrator for voice-quality audio, and found instead a high fidelity amplifier. Distortion has been measured at 0.1%. The screen shots here are from a Yokogawa DLM2000. The sine wave reference, in purple, is 10 kHz. The output is the yellow trace. Current in the switched inductor is shown in green.

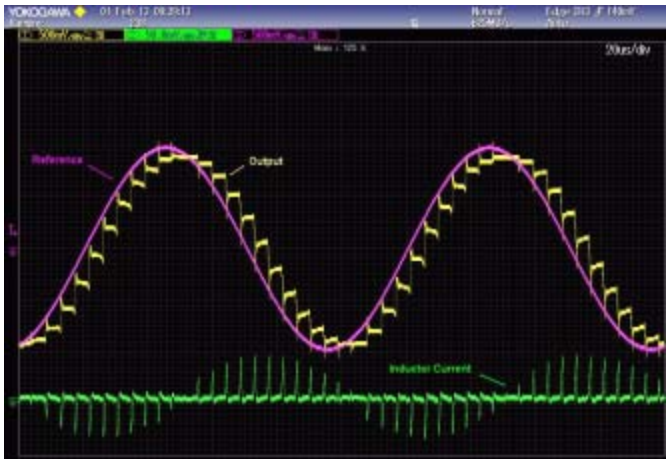

Figure 4: PEB Amplifier Screen Shot Reproducing a 10 kHz Sine Wave

The regulation points are reached with good accuracy on both the increasing and decreasing portions of the waveform. Note that a notch, or low pass, filter placed after the feedback will remove the chopping frequency from the output. You probably do not need your power converter to make music, but you may be burdened by sub-harmonic behavior. That is absent from a PEB converter.

To illustrate, the same demonstration system will act as a DC/DC converter. With a DC reference and a 10 kHz AC load, a very similar current waveform will be seen as the output is held at the desired DC level. In Figure 5 the load is shown in purple. The output in yellow, AC coupled for the oscilloscope, is held constant. The inductor current, in green, reflects the bipolar sinusoidal AC load.

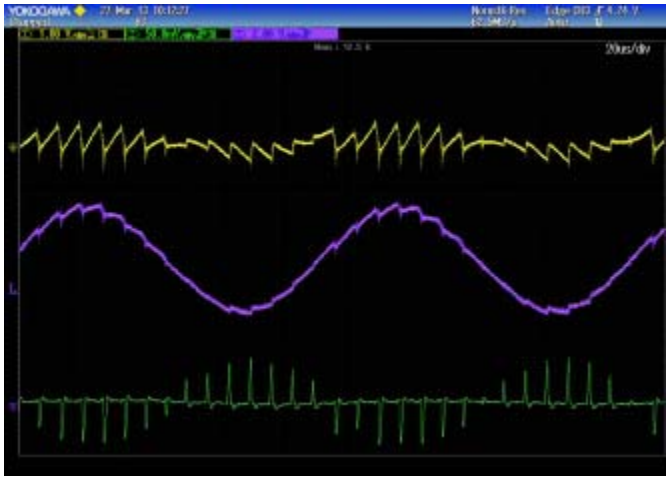

Figure 5: PEB amplifier with DC Output and Sine Wave Load

The next screen shot is of a more familiar type. The load is unipolar, changing from approximately 20% to 80% of full load. This time the load is a square wave, again at 10 kHz. The output filter capacitor here is only 470 nF which is appropriate for amplifier application. For a DC/DC power converter, 800mv of output ripple would likely be excessive. However, a 10µf filter would result in 40 mv of ripple. The converter is running at 166kHz in Figure 6. It will operate comfortably at over 5 times that rate, so the output ripple can be just a few mv, if required.

The more important thing to note regarding Figure 6 is the single-cycle regulation. The fastest Pulse Width Modulated (PWM) power converters settle in 6 cycles after a step change. Under these conditions, a PWM converter would never reach proper regulation.

Figure 6: PEB Amplifier Running as a DC/DC Converter with a Step Load

There is an operational difference to keep in mind when applying PEB. The dynamic gain is determined by the ratio of L to C. If the ratio of the switched inductance to the filter capacitance isn't known, or, if it can change significantly during operation, a conventional feedback loop should be added to set the predictive gain. That conventional loop can be very slow and have very little gain, so that it can only tune the PEB behavior over a long period, but will not interact with the dynamic response.

The bidirectional nature of the PEB audio amplifier makes it as efficient as the best Class D amplifiers while the distortion is that of a good linear amp. In general, PEB can offer incremental efficiency gains when replacing conventional power converters, but can provide larger gains in cases where entire stages of power conversion can be eliminated.

Conclusions

When near-ideal cycle-by-cycle switching decisions are made, the first advantage for PEB control is best transient performance. That advantage is evident in the elimination of a compromise between stability and agility. Intrinsic stability reduces the need for added protection components, and brings reliability benefits. Additional benefits can be achieved depending on design priorities. Possibilities include smaller filter capacitors, flexible switching speeds, increased efficiency, increased operational range, ease of digital control, and compatibility with aggressive power management techniques. Because there are fewer assumptions built into the hardware, PEB converters can be adapted to new applications with less engineering effort. The absence of compensation simplifies development and testing.

After the integration of PEB controls, expect a size and cost advantage, as well. Circuitry for performing Predictive Energy Balancing is simpler than that required for the more computationally intensive compensation schemes. The PEB Audio Amplifier is covered by four issued US patents with overseas patents pending.

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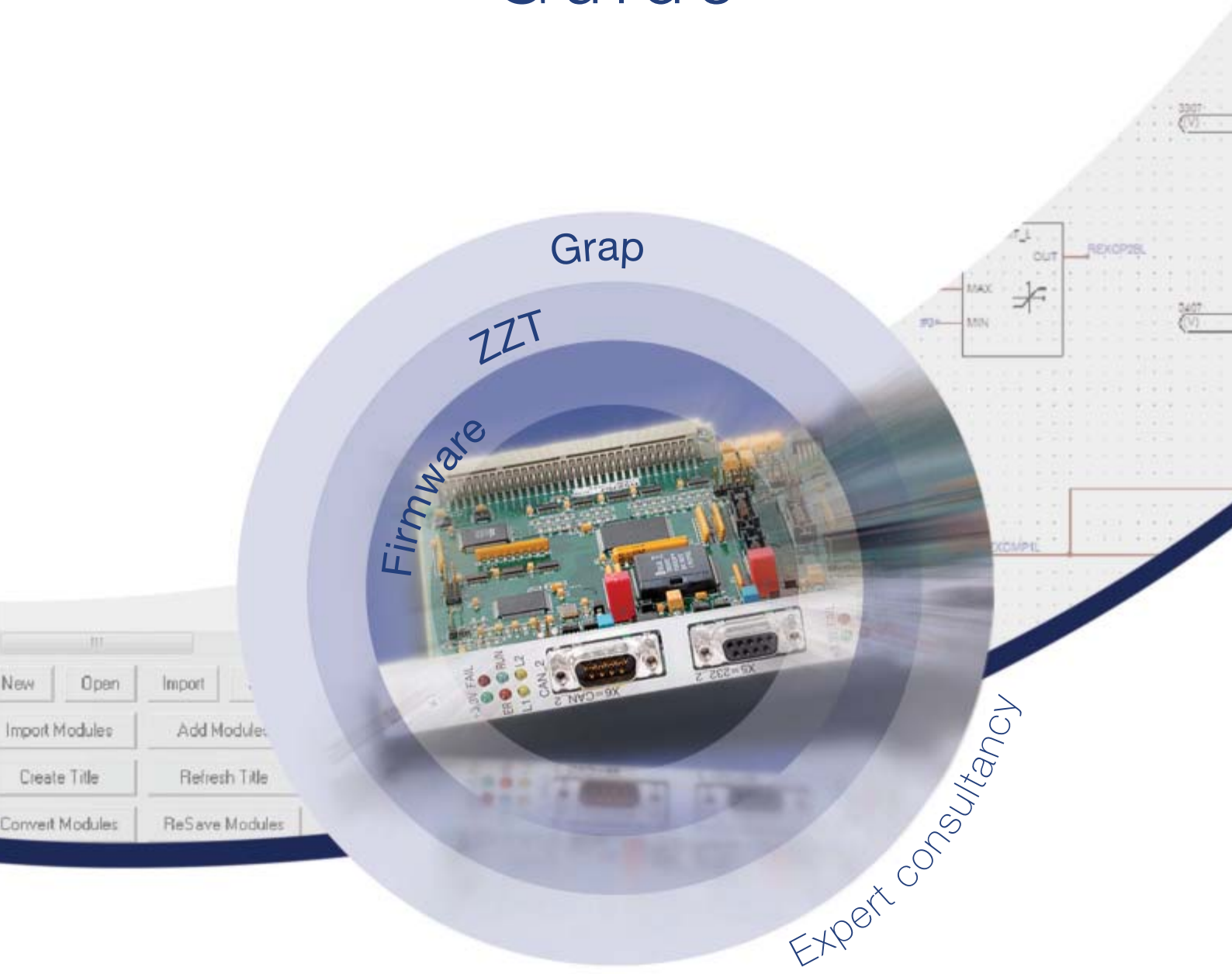

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MnZn Ferrites with High Saturation Flux Density for High Frequency Transformers and Inductors

MnZn ferrites are widely used in high frequency transformers and inductors. Requirements for ferrite cores used in the electronic components include soft magnetism, easy magnetization with a small external magnetic field, and low loss.

By Chong Yan, Yang-zhong Du, Su-ping Wang, Hengdian Group DMEGC Magnetic Limited Company, Dongyang 322118, China

Soft magnetic materials are classified into soft metallic materials and soft oxide materials. Because the electric resistance of the soft metallic materials is generally lower, driving the high frequency transformers and inductors cause large eddy current loss. In order to suppress loss, magnetic oxide materials, especially MnZn ferrites, are used in high frequency transformers and inductors rather than metallic materials.

Compared with metallic powder core, the drawback of MnZn ferrites is their saturation magnetic flux density. In general, the saturation magnetic flux density of MnZn ferrites is about 500mT at room temperature, which is lower than those in metallic powder cores. The comparison of saturation magnetic flux density of MnZn and metallic powder core material is shown in figure 1. This means that a larger volume of ferrite core is required to produce the same amount of magnetic flux as metallic cores produce. In order to enhance saturation magnetic flux density of MnZn ferrites, a new MnZn ferrite material DMR28 based on the ternary MnO-ZnO-Fe_2O_3 system had been developed by DMEGC.

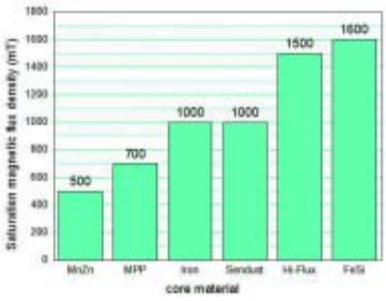

Figure 1: The comparison of saturation magnetic flux density of MnZn and metallic powder core material at room temperature

DMR28 material characteristics are listed in table 1. From the table 1, the saturation magnetic flux density of DMR28 material is 600mT at room temperature (25°C) and 490mT at high temperature (100°C), which is about 20% higher as DMR40 material and about 10%. Higher as DMR24 material. The comparison of saturation magnetic flux density of DMR28, DMR24 and DMR40 material is shown in figure 2. Possible methods to increase saturation magnetic flux density include: Increasing the density of the sintered body of the core, increasing the total of the magnetic moments of the constituent ions in the spinel matrix phase, and raising the Curie temperature.

Symbol	Test Conditions	Test Temperature	Value
Initial Permeability(μ)	10kHz,B<0.25mT	25℃	2000±25%
Saturation Magnetic Flux Density(mT)	50Hz,1194A/m	25℃	600
		100℃	490
Residual Magnetic Flux Density(mT)		25℃	150
		100℃	250
Coercive Force(A/m)		25℃	19
		100℃	18
Power Loss(mW/cm³)	25kHz,200mT	25℃	200
		60℃	280
		100℃	330
Curie Temperature (℃)	10kHz,B<0.25mT		>300
Density(g/cm³)		25℃	4.9

Table 1: DMR28 material characteristics

It is clear that enhancing the density of the core will result in an increase in saturation magnetic flux density. For this purpose, optimizing the sintering conditions and the kinds and amounts of additive trace elements is very important. In order to increasing the total of the magnetic moments and raising the Curie temperature, it is essential to enhance the contents of Fe_2O_3 in MnZn raw materials. The main composition of DMR28 material is the contents of about 65 mol% Fe_2O_3, 20 mol% MnO and 15mol% ZnO as oxide equivalents. The contents of Fe_2O_3 in DMR28 are more than in DMR40 and DMR24 material.

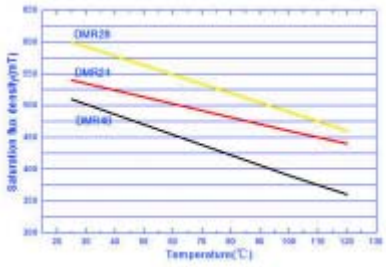

Figure 2: The comparison of saturation magnetic flux density of DMR28, DMR24 and DMR40 material

When ferrite cores are used in the design of chokes or filters, which are required to carry direct current, it is necessary to prevent the inductance degradation caused by the static field. When DC flows through the winding of a ferromagnetic device, it tends to pre-magnetize the core and reduce its inductance. The permeability of a ferrite material measured with superimposed DC might increase slightly for very low values of DC ampere-turns, but then it progressively decreases as the DC field is increased and the core approaches saturation. This permeability is referred to as the incremental permeability μΔ. It is necessary to enlarge ΔB(ΔB=Bs-Br) for increasing μΔ. The B-H curves of DMR28 and DMR24 are shown in figure 3. The ΔB of DMR28 about 450mT is higher than that of DMR24 about 360mT at room temperature. The DC superposition characteristic of DMR28 exceeds that of DMR24's conventional high saturation magnetic flux density at 25°C is shown in figure 4. The test cores are the standard φ25×φ15×8 toroid cores without gap. DMR28 has a DC superposition characteristic superior to that of DMR24 by as much as 30% at 100A/m DC magnetic field.

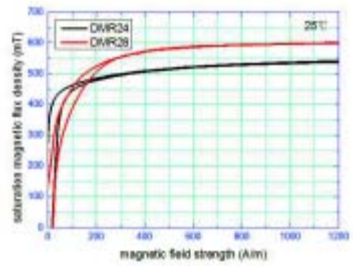

Figure 3: The B-H curves of DMR28 and DMR24 at room temperature

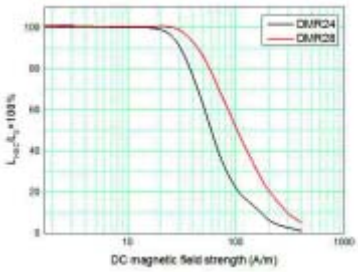

Figure 4: The comparison of DC superposition of DMR24 and DMR28 at 25°C

Conclusion

A new MnZn ferrite material DMR28 was developed by DMEGC, and exhibits 20% higher saturation magnetic flux density compared to that of the conventional DMR40 material. The saturation magnetic flux density of this ternary MnO-ZnO-Fe_2O_3 system ferrite is increased by increasing the Fe_2O_3 content and enhancing the sintering density of the core. The transformers using DMR28 can be downsized and the choke made of this material exhibits super DC superposition characteristics. The characteristics exceed those of conventional high saturation magnetic flux density DMR24 material by about 30% at room temperature.

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Fiber Optics in Arc Flash Detection Applications

An arc develops and becomes destructive within milliseconds

When failures occur in the electrical disconnect switches, fuses and/or circuit breakers that control, protect and isolate electrical equipment in electrical power systems, also known as switchgear, they can endanger the operation of an entire electrical power system, the equipment using that power and nearby personnel as well. This is especially true of short circuits.

By Alek Indra, Avago

Of the two types of short circuits typically encountered, the metal short circuit and the arc short circuit, the latter poses the greatest danger. If not detected and responded to in time, an arc flash can cause fires, damage equipment and even cause physical harm. Typical damage includes overheating copper wiring and melting the aluminum rod, as well as toxic gasification. Overheating also causes dangerous increases in pressures that may even cause the switchgear to explode.

There are several protection methods used in switchgear, including fast bus protection, backup over current protection and arc flash protection. Fast bus protection is available only for high-voltage switchgear, and the backup over current protection method requires too much time to switch the circuit breaker. Therefore, low and medium voltage switchgear need a faster detection system.

Response time is key

An arc develops and becomes destructive within milliseconds. Failure to open a circuit breaker in time can result in enormous losses (Figure 1). The damage resulting from an arcing accident relates directly to the amount of current flowing through the short and the time duration, however, of the two parameters, time duration is the more critical. Thus, to maximize protection, both the arc flash detector and the entire switchgear system must have a quick response time.

I^2t

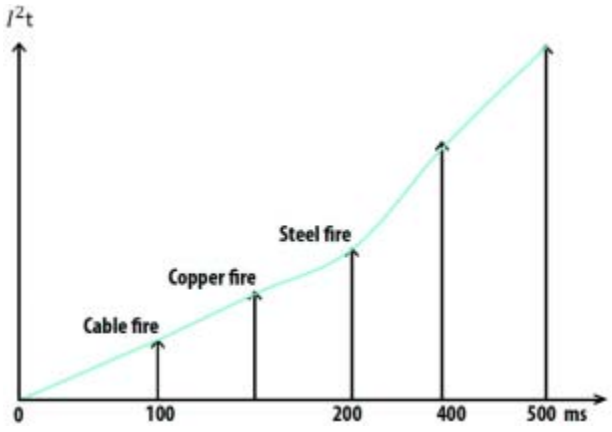

Figure 1: Arcing time vs. resulting damage

Arc flash detection methods

An arcing fault instantaneously releases large amounts of radiant energy, including both light and thermal energy. The light intensity resulting from an arc can be thousands of times higher than normal ambient light. An arc flash detection relay takes advantage of this phenomenon to achieve significantly faster response times—thereby affording significantly greater protection from damage—than the conventional relay. Thus, arc flash detection has become a critical requirement for all switchgear installations. However, light is only one of many indicators that an arc flash has occurred.

An arc flash dramatically increases light, pressure, heat, current and even sound, all of which a switchgear system can be designed to monitor and detect. Although detecting light is perhaps the easiest and fastest detection method, many systems detect two and sometimes a combination of three or more parameters (i.e., light, current and sound). Though the latter is more thorough, the additional cost and complexity of this method can be prohibitive. The most efficient, cost effective, and therefore the most commonly used method combines the detection of light and current. This method has quickly become the solution of choice for the realization of a reliable arc flash detection system.

Arc flash detection system

The primary components of an arc flash detection system (light and current detector) are the arc monitor unit, control unit, optical detector, current detector and current transformer. The control unit receives signals from both a high-sensitivity light detector and the upstream current transformer, enabling it to determine whether to trigger the circuit breaker. Clearly, this signaling process must be

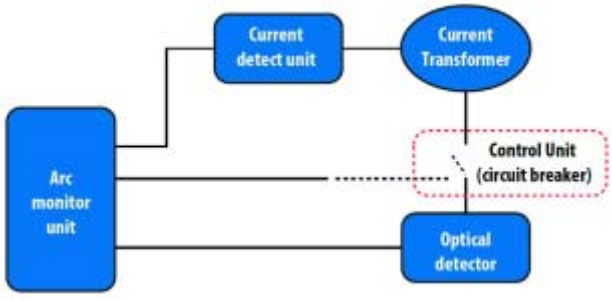

Figure 2: Generic arc guard system diagram

both fast and reliable to minimize danger and damage. Thus, the speed and EMI immunity inherent to fiber optics make it the perfect medium for an arc flash detection system in these environments.

The optical detector unit includes an optical emitter and receiver, an optical sensor in the form of a bare fiber loop, and fiber optic cable. The optical sensor collects the flash light and transfers it via fiber optic cable to the fiber optic receiver, which converts the optical signal to an electrical signal that informs the control system when an arc flash is occurring. There are two types of optical sensors commonly used in such systems: the point sensor and the loop sensor. The point sensor approach uses a light sensor and an optical receiver to detect light in a given area, while the loop sensor (Figures 3) uses a loop of bare fiber positioned strategically throughout the equipment.

Figure 3: Loop sensor

Light Source	Distance	Illumination (lux)
Moon light		0.2
Cinema screen		20-80
Sun(summer, in room)		100-1000
General light	1m	750-1000
Operating room light	1m	1500-3000
Arc flash	6-7m	9000

Table 1: Different light sources and illumination

Loop sensor technology offers several advantages when compared to the point sensor. First, it dramatically reduces the cost of installation. A single optical fiber sensor can be as long as 200 feet, typically covering the same protection zone associated with conventional bus-differential protection but at a much lower cost than point sensors. Second, the loop approach eliminates any concerns about shadows from internal structures that might block the direct exposure to an arc flash. Third, if the fiber sensor is configured in a loop, it can provide regular self-checking of the sensor's integrity and continuity, alarming if a problem is detected.

Wavelength and illumination

Generally, the wavelength range of an arc flash is 300-1500nm compound light. Therefore, one can use a 650nm or 820nm fiber optic receiver to detect the arc flash light. There are two types of fiber optic cables one can use within this wavelength range—Plastic Optical Fiber (POF) or Multimode Glass Fiber cable.

POF cable is best suited for 650nm because it has the lowest attenuation at this wavelength. POF is also lower cost and easier to install than other types of fiber optic cables. Multimode Glass fiber cable has lower attenuation at 820nm than the POF cable has at 650nm.

Table 1 shows the typical illumination of various light sources. Arc flash illumination is usually from 5K-50K lux, so it is easy to differentiate the arc flash light from the ambient light.

Avago related products

Avago offers numerous fiber optic products, including transmitters and receivers, with wavelengths of 650nm, 820nm and 1300nm. The products most suitable for arc flash detectors are the connector-less, Versatile Link and Miniature Link series. The linearity behavior, good sensitivity performance and fast response time offered by these devices are quite suitable for an arc flash detection system.

Conclusion

Short circuits are one of the most common faults that occur in switchgear. If the switchgear is not equipped with detection and protection capability, the cost may extend far beyond monetary losses to personal injuries. Therefore, it is imperative to ensure each system can detect a fault as soon as it happens to prevent a disaster. The arc flash detection system presented here is one of the most effective detection methods, both in terms of cost and performance. Fiber optic components offer the easiest and most reliable solution for creating an arc flash detection system.

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Temporary Overvoltage immunity by Surge Protection Devices

Effect of temporary overvoltage (TOVs) on surge protective devices (SPDs)

If the SPD has been selected with a maximum continuous operating voltage Uc, lower than the overvoltage generated by the low voltage (LV) insulation failures or the loss of a supply conductor, the current flowing through the SPD increases very quickly and the resulting heat destroys the SPD. The effects of this failure are restricted to the SPD itself by its incorporated thermal protection. As a consequence, the installation or the equipment often remains without other overvoltage protection.

By Aleš Štagoj, Iskra Zaščite d.o.o.

It is recognized that if the U_C of the SPD is selected equal to or higher than 1.45 for TN systems and higher than $\sqrt{3}\ U_0$ for TT systems, a tolerable risk of loss of protection against over-voltages is achieved in all situations, except IT systems. SPD selected with a high U_C (high U_{1mA} - voltage across the varistor measured at 1 mA d. c.) will be immune to most temporary overvoltages, but at the price of diminished surge protection – higher limiting voltage (voltage protection level U_P). With low U_C (low varistor voltage U_{1mA}) selected SPD we will get low limiting voltage (low U_P), but at a greater risk of destruction under temporary overvoltage conditions.

Is there a solution to avoid TOV effects on SPD?
Tactic which is chosen in competitive SPDs is to use higher voltage rated SPD in order to be more resistant to TOV – but in that case U_P is higher.

Iskra Zaščite d. o. o. developed a new group of products, SAFETEC® family (Fig. 1), with an innovative technology, immunity to TOVs higher than 1, 5 times U_C. SAFETEC® is the product with low limiting voltage (U_P) which, in case of the TOV higher than its U_C, will not be destroyed, as other SPDs on the market.

Figure 1: SAFETEC® innovative technology, patented solutions

How does SAFETEC® work on TOV?
In case of voltage increasing above the maximum value of the SPD (U_C), the operating path with the current limiter (TC, Figure 2) is activated, limiting the current passing through the varistor (MOV) to the value of 10 mA. This current is below the value of the energy capability of the varistor. This means that even after the overvoltage ends, the varistor will still be functional **(no need for SPD replacement!)**.

With our technology, we limit the current through the varistor to the value of a few 10 mA already at the very beginning, which consequently means if the thermal protection operates (disconnects), arc cannot develop or it can be broken more easily.

In cases where it comes to an overload or where the varistor is loaded beyond its capability, a release of the thermal safety occurs. The thermal safety has a patented mechanical construction, which allows the termination of the arc and permanently divides two different potentials **(increase creapage distance)**.

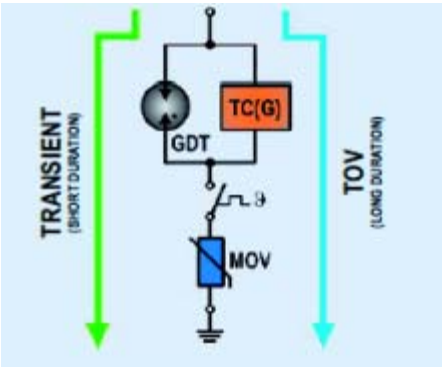
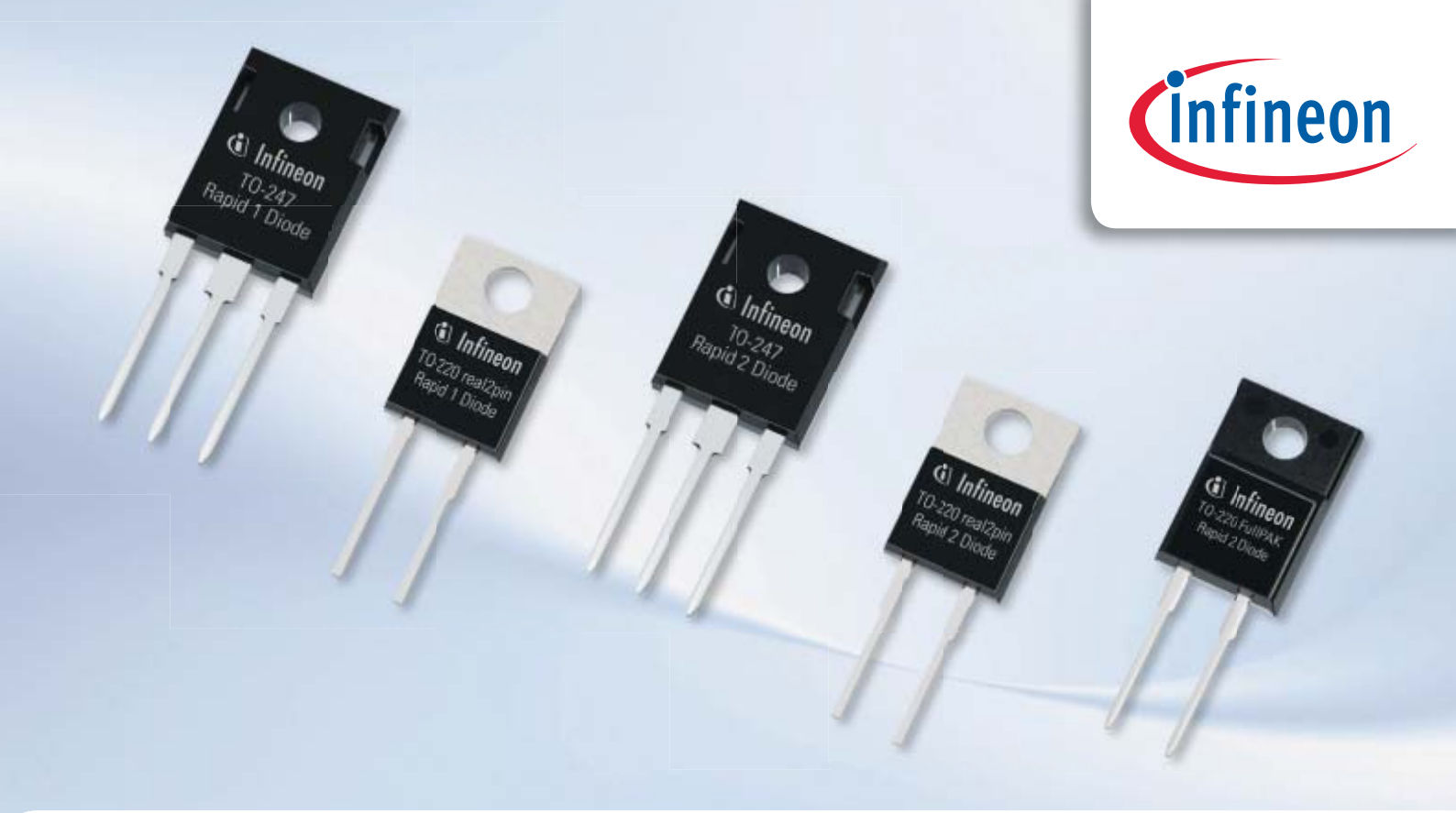


Figure 2: Topology of SAFETEC®

Behaviour of TOV tests between competitors
In our laboratory we have compared SPDs´ behavior on TOV, based on IEC 61643-11:2011. We have loaded individual tested sample with 253 V, nominal a.c. *r.m.s.* line voltage to earth with added 10% voltage regulation (Figure 3). After 10 seconds we have switched to 438 V (previous connected voltage multiplied with $\sqrt{3}$ - TOV due to LV installation fault to earth). Both voltage sources had the capability of delivering a prospective short-circuit current of 100 A. The time interval between switching off first connected voltage and switching on second TOV voltage has not exceeded 100 ms. Through the whole



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- Rapid 1 Diode – V_F of 1.35V, t_{rr} ‹ 100ns
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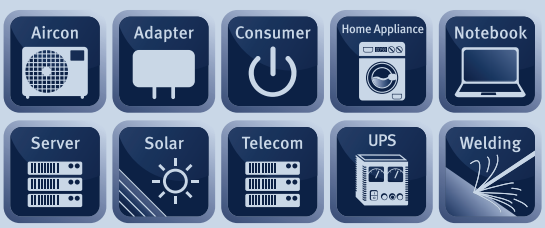

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test we had monitored current through the sample, measured through current clamp and voltage drop on the SPD terminals.

The samples for comparison test were picked up from open sales market in September 2012. We chose the 1TE DIN rail mounted pluggable products with varistor as protective element, with buildup thermal protection and declared maximum continuous operating voltage, U_C closest to 275 V (Table 1).

Sample No. 4 has higher max. continuous operating voltage UC and higher voltage protection level U_P - due to the higher varistor voltage U_{1mA}. SAFETEC® with U_C 275 V also has higher U_P – but not because of high U_{1mA}. Varistor voltage U_{1mA} was measured on each sample before starting TOV test (Table 2).

Samples have been tested according to the latest IEC 61643-11:2011 on TOV due to LV installation fault to earth. Possible real-life conditions resulted with devastating failure to the SPDs No. 1, 2 and 3 – **fire and explosion**.

On the other hand, sample No. 4 (with higher measured varistor voltage U_{1mA}) disconnected after few seconds of current flowing through the SPD (Figure 4).

In the case of SAFETEC® (Figure 5), when 438 V was applied on SPD, the current limiter (TC) was activated with limiting the initial 446 mA peak current passing through the varistor (MOV) to the peak 48 mA after 120 seconds and following reduction to the peak 10 mA (value of the varistor´s energy capability) - the varistor is still fully functional - **after the overvoltage ends, no need for SPD replacement!**

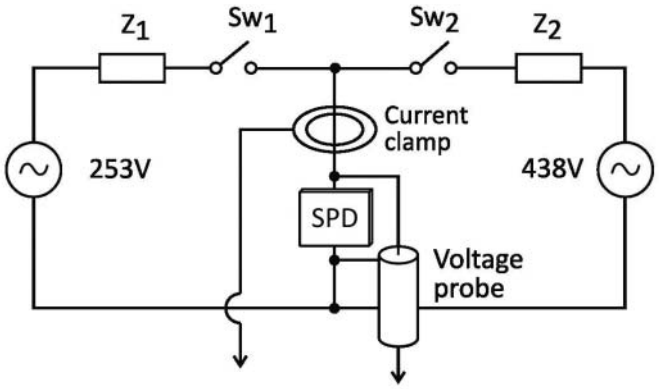

Figure 3: Test circuit to perform the comparison test, similar as in IEC 61643-11:2011, Fig. 14 (test under TOVs caused by faults in the low voltage system)

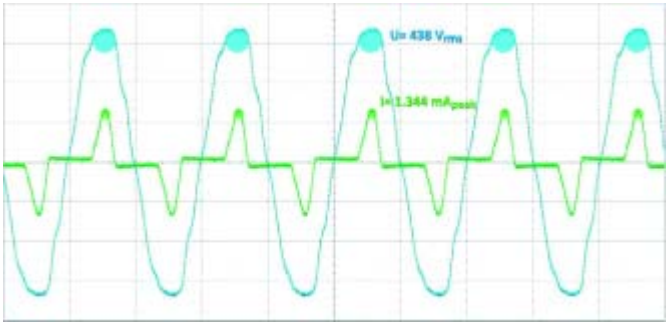

Figure 4: Oscillogram of sample No. 4, current flowing through the SPD at applied 438 V

Sample	Low voltage system network	Max. continuous operating a.c. voltage (U_C)	Nominal discharge current 8/20 µs (I_n)	Max. discharge current 8/20 µs (I_{max})	Voltage protection level (U_P)
No. 1	230/400 V	275 V	20 kA	65 kA	< 1,25 kV
No. 2	230/400 V	255 V	20 kA	40 kA	< 1,25 kV
No. 3	230/400 V	280 V	20 kA	40 kA	< 1,3 kV
No. 4	230/400 V	335 V	20 kA	40 kA	< 1,6 kV
SAFETEC	230/400 V	275 V	20 kA	40 kA	< 1,6 kV

Table 1: Comparison of declared parameters IEC on four competitive products and SAFETEC®

Sample	Voltage across the varistor measured at 1 mA d.c.(U_{1mA})	Current flowing through the SPD at connected Sw1, 253 V	Current flowing through the SPD at connected Sw2, 438 V	Result
No. 1	425 V	No	High	Caught Fire and Exploded
No. 2	430 V	No	High	Caught Fire and Exploded
No. 3	455 V	No	High	Caught Fire and Exploded
No. 4	530 V	No	Small	Disconnected - needs to be replaced
SAFETEC®	469 V	No	Small & decreasing	Survived – No need for replacement

Table 2: Test results on four competitive products and SAFETEC®

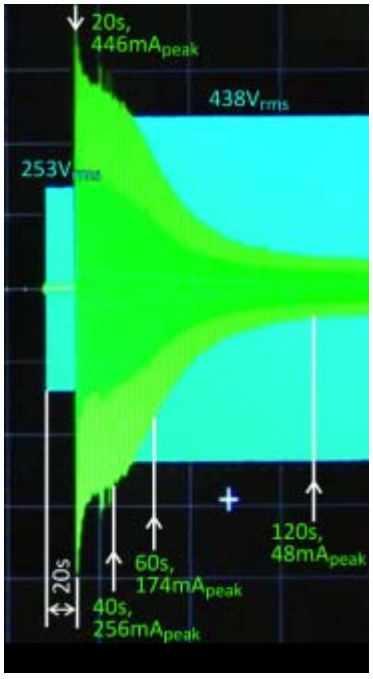

Figure 5: Oscillogram of sample SAFETEC®, current flowing through the SPD at applied 438 V

Conclusion

In the case of TOV resistance test, all four competitive surge protection devices have conducted and let through SPD high level of energy, depending of the source availability **(danger!)**.

Current conduction caused destruction of the SPD, lead to the disconnection of thermal protection (sample No. 4), or fire and explosion (samples No. 1, 2, 3) - result: **SPD replacement and danger!**

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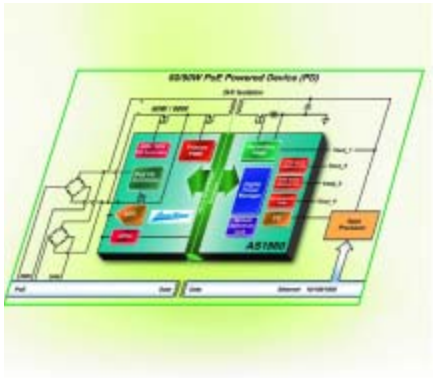
Integrated Digital Isolation Supports 60W and 90W PoE Applications

Akros Silicon Inc., announces the availability of the AS1860, the member of the company's GreenEdge™ family of system-on-a-chip (SoC) energy management ICs. The AS1860, equipped with Akros' proprietary GreenEdge digital isolation technology, is uniquely suited to support deployments of 60W and above Power over Ethernet (PoE) Powered Device (PD) applications such as thin clients, monitors, industrial Ethernet, IPTV, building management, Industrial Networking and many other high power designs. This unique single-package solution offers benefits not provided by existing solutions, including higher efficiency and reliability as well as dramatic reductions in system costs and board real estate.



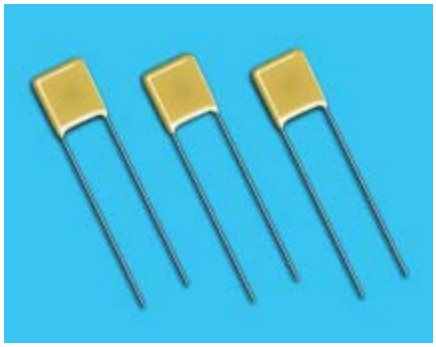
Akros Silicon SoC with Integrated Digital Isolation Supports 60W and 90W PoE Applications

All other existing approaches to higher power (60W and above) PoE deployments require multiple components, such as two or three power management ICs, several optocouplers and custom transformers. In addition to adding component cost, consuming board space and increasing design complexity, these approaches are vulnerable to shoot-through issues and losses due to rectifier diode and reverse recovery. In contrast, Akros' approach can accommodate 60W and above PoE applications using just two components: one AS1860 SoC and one external FET. Moreover, by integrating GreenEdge digital isolation, the AS1860 enables the implementation of many advanced diagnostic and high-voltage telemetry features that allow operators to remotely manage power, which in turn enhances reliability and energy efficiency.

www.akrossilicon.com

Super Dielectric Option to High-Voltage MLC Radial Capacitor

AVX Corporation has added an N1500 super dielectric option to its high-voltage, multilayer ceramic (MLC), radial leaded capacitor series. An extension of the SV Series, the new N1500 super dielectric capacitors take up less board space and offer higher capacitance values than comparable C0G dielectric capacitors and are ideally suited for applications including snubbers in high-frequency power converters, resonators in SMPS, AC line filtering, and high-voltage coupling/DC blocking.



AVX's high-voltage SV Series MLC radial leaded capacitors are coated with high insulation resistance and high dielectric strength epoxy, which eliminates the possibility of arc flashover. The series also exhibits low ESRs at high frequencies.

The N1500 dielectric SV Series capacitors feature a capacitance range of 100pF to 0.47µF with tolerances of ±5%, ±10%, and 20%, a voltage range of 600-5000V, and a maximum dissipation factor of 0.15%. The operating temperature range for the series is -55°C to +125°C. Additionally, a Hi-Rel screening option (100% Group A testing per MIL-PRF-49467) is available.

www.avx.com

Silicon Carbide Solutions Offer Industry-Leading Efficiency

Fairchild Semiconductor extends its leadership position in innovative high-performance power transistor technology with the announcement of silicon carbide (SiC) technology solutions ideally suited for power conversion systems.

Advanced technologies that simplify engineering challenges with functional integration and design support resources that minimize components while reducing engineering time

Meeting the needs of device manufacturers and chipset suppliers by integrating leading device technologies into smaller advanced packages that offer size, cost and power advantages

Among the first products to be released in Fairchild's SiC portfolio is a family of advanced SiC bipolar junction transistors (BJTs) that offer high efficiency, high-current density, robustness, and easy high-temperature operation. By leveraging exceptionally efficient transistors, Fairchild's SiC BJTs enable higher switching frequencies due to lower conduction and switching losses (ranging from 30-50 percent) that provide up to 40 percent higher output power in the same system form factor.

www.fairchildsemi.com/sic

Automotive-Grade, Multi-Phase Synchronous Boost Controller up to 100-V

Texas Instruments Incorporated introduced three wide-input voltage synchronous boost controllers with high efficiency and high power density. The LM5122Q multi-phase boost controller features the industry's widest input and output voltage range. The low quiescent-current TPS43060 and TPS43061 boost controllers feature 1-MHz operation and a small QFN package.

TI's synchronous boost controllers increase efficiency by up to 10-percent over non-synchronous boost controllers by replacing the freewheeling diode with a synchronous switch. Lossless inductor DCR current sensing further improves efficiency and reduces heat dissipation to save board space and

lower bill of materials cost. Each boost controller features thermal shutdown, frequency synchronization, hiccup-mode current limit and an adjustable line under-voltage lockout.

The LM5122Q is an AEC-Q100-qualified synchronous boost controller with a 3-V to 65-V input and up to 100-V output voltage range. The controller can be configured easily for interleaved multi-phase operation, which is required for high power applications like start-stop voltage stabilizers and high power audio amplifiers. A powerful 3-A gate drive circuit supports voltages up to 16-V, enabling flexibility to tune the step-up DC/DC for efficiency and size.

www.ti.com

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3A Ultra-Low Dropout Linear Regulator

Advanced Power Electronics Corp. (USA), a leading Taiwanese manufacturer of MOS power semiconductors for DC-DC power conversion applications, has introduced the APE8968MP-HF3, a new series of 3A, ultra-low dropout linear regulators designed to provide simple POL DC-DC conversion in board-level applications, including motherboard and notebook applications. Requiring two supply voltages – one for the control circuitry and the other for the main supply – the IC reduces power consumption and provides a dropout of just 0.23V (typ) at 3A.

APE8968MP-HF3 integrates many functions, and has a Power-On-Reset (POR) circuit to monitor both supply voltages to prevent incorrect operation. Thermal shutdown and current limit protection features are included, and a POK indicates output status with a time delay which is set internally. The APE8968MP-HF3 can control another converter for power sequencing, and can also be controlled by another power system. Pulling and holding the EN pin below 0.4V shuts off the output.

www.a-powerusa.com

Safest and Fastest Possible Charge for Mobile Equipment

Maxim Integrated announced that it is now sampling the MAX77301 Li+ battery charger. It integrates the intelligence to enumerate with the host device, automatically identify the adapter type, and then determine the fastest rate to charge a battery. With advanced temperature monitoring, the MAX77301 modulates the charge current and battery regulation voltage automatically to maximize safety in any temperature environment. It performs all of these functions without an external CPU or system hardware. The MAX77301 is ideal for mobile equipment, such as cameras, Bluetooth® headsets, MP3 players, and portable medical devices.

To enhance battery safety, battery makers often recommend charging "gently" in cold or hot ambient temperatures. This often necessitates use of a microcontroller to monitor and control the charger. The MAX77301 solves this charging problem by automatically setting charge parameters at a safe level. The device also provides full programmability via the I2C interface, increasing flexibility. Furthermore, it integrates an enumeration and adapter detection engine to maximize charge current. This safety feature and the adapter detection ensure the fastest and safest possible charging.

www.maximintegrated.com

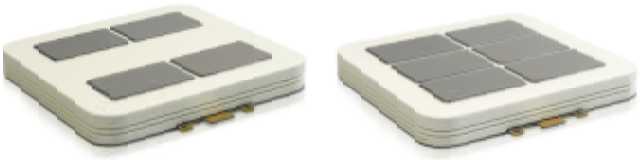
Gallium Nitride Evaluation Kit

GaN Systems Inc, a leading developer of gallium nitride power switching semiconductors, has announced special pricing for its gallium nitride evaluation kits for customers who pre-order at the PCIM (Nuremburg, Germany, May 14-16) power event.
The evaluation kits will consist of a 400 volt 1MHz boost converter demo board and a pair of their GS30610M 650 volt gallium nitride switches. These components will be on display at GaN Systems' booths at APEC (1128) and PCIM (9-523).The special show offer reduces the price of the kits from $2,495 to $1,995 price, and no deposit is required. Orders will be supplied in a strict priority order following product availability starting in July 2013.
Comments Girvan Patterson, CEO of GaN Systems: "We hope that by providing these evaluation kits at a special price, design engineers will be able to appreciate the benefits of our new gallium nitride products as easily as possible."

www.gansystems.com

StakPak, the Industry's most Powerful IGBT

ABB's new release, the StakPak module rated at 4500V, is the most powerful IGBT on the market. With nominal currents of 1300A and 2000A and featuring the established StakPak press-pack technology, the StakPak is an ideal fit where series connection, exceptional power and reliability are required.
The StakPak features an integrated free-wheeling diode and is available in IGBT to diode area ratios of 2:1 or 1:1, where high diode performance is required. The unique pressure contact technology with individual spring contacts for each IGBT/diode chip allows for easy mounting even in large stacks, due to Stakpak's excellent pressure tolerance.

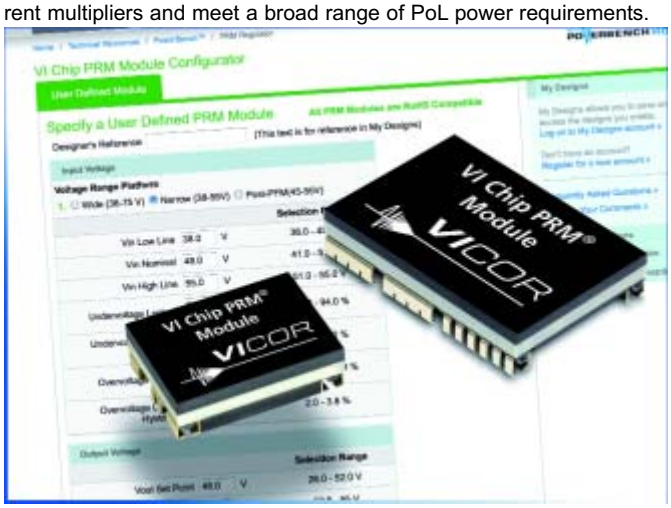


In case of an IGBT or diode failure, the StakPak fails into a stable short-circuit, making it ideally suited for reliable series connection and redundant operation.

www.abb.com/semiconductor

User-Defined, High-Performance VI Chip PRM Modules

Vicor Corporation unveiled user-configurability capabilities for its high-performance VI Chip® PRM® modules. The new PowerBench tool suite equips designers to customize and simulate efficient PRM modules for use as PoL buck-boost regulators or to drive VTM® current multipliers and meet a broad range of PoL power requirements.



Vicor's easy to use PowerBench online tool suite gives designers the flexibility to specify the voltage, current and protection parameters of their PRM module and immediately simulate their models in application-specific operating conditions.

Incorporating Vicor's high-frequency ZVS buck-boost technology, customer-configurable VI Chip PRM modules can deliver up to 500 Watts at over 97% efficiency, at unprecedented power densities of up to 1,700 W/in3 (103 W/cm3). Models are available in both full-chip and half-chip packages with input voltage ranges of both 36 - 75 V and 38 - 55 V, and, when used as a PoL buck-boost regulator, provides a user-defined output between 26 V and 52 V. When used with VI Chip VTM current multiplier modules, PRMs efficiently support output voltages from 0.5 V to 55 Vdc. Vicor's online PowerBench tools afford designers a fast and efficient pathway to customizing VI Chip PRM modules to meet their exacting requirements for high-power applications. Data sheets, part numbers and pricing information are provided for designers' uniquely-configured devices, and devices are shipped to customers within 5 business days.

www.vicorpower.com

PI Expert Suite 9.0 Power Supply Design Software Supports LED Lighting

Power Integrations announced that the latest version of its popular power supply design software, PI Expert Suite 9.0, now includes support for its LinkSwitch™-PL and LinkSwitch-PH LED-driver ICs and its recently introduced TinySwitch™-4 off-line switcher IC family. Version 9.0 includes an enhanced schematics-manipulation tool. It also enables designers to upload the resulting BOM from the auto-generated schematic layout to selected, leading design-fulfillment distributors.

PI Expert Suite 9.0 improves the productivity of power supply design teams by greatly reducing the time to first prototype and by slashing the number of prototype iterations required to reach a finished product. The software now includes support for solid-state-lighting products, enabling LED designs to be optimized for CC, dimming and harmonic emissions. As with previous-generations, PI Expert Suite 9.0 generates a complete schematic of the power supply and offers power transformer optimization techniques, even specifying the transformer design and offering links to wound component manufacturers. A heatsink calculation tool provides the designer with an estimation of the thermal design requirements for a new power supply which may be used to guide layout and mechanical prototyping decisions - avoiding iterations and wasted time. Enhanced PCB layout recommendations based on the IC device and package chosen allow the designer to minimize trace-induced EMI and board area, and also maximize electrical noise immunity and surge tolerance.

www.powerint.com/rtss

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Extended Temperature, Low Current Drive, High-Speed Photocouplers

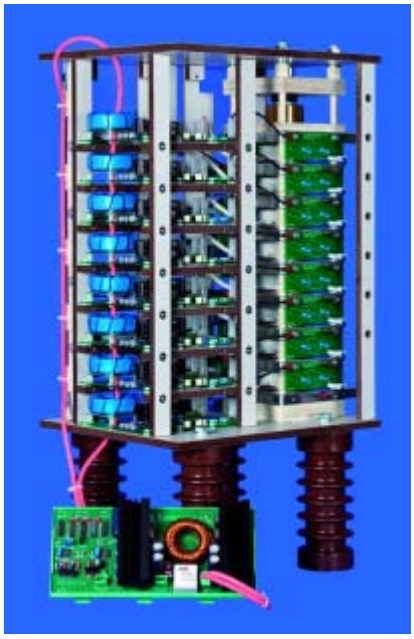
Toshiba Electronics Europe (TEE) has extended its family of high-speed photocouplers* for industrial applications. Supplied in a DIP8 package, the new TLP2955 and TLP2958 low-current drive devices provide guaranteed operation at temperatures from -40°C to 125°C.

The TLP2955 and TLP2958 have a minimum isolation voltage of 5000Vrms and support data rates up to 5Mbps. Target applications include intelligent power module signal isolation, programmable logic controllers (PLCs) and high-speed digital interfaces for instrumentation and control devices.

Toshiba's photocouplers can accommodate a wide input range of 3V to 20V. This minimises the need for additional voltage conversion circuitry and ensures compatibility with 3.3V power schemes. A maximum threshold input current of just 1.6mA keeps power consumption to a minimum

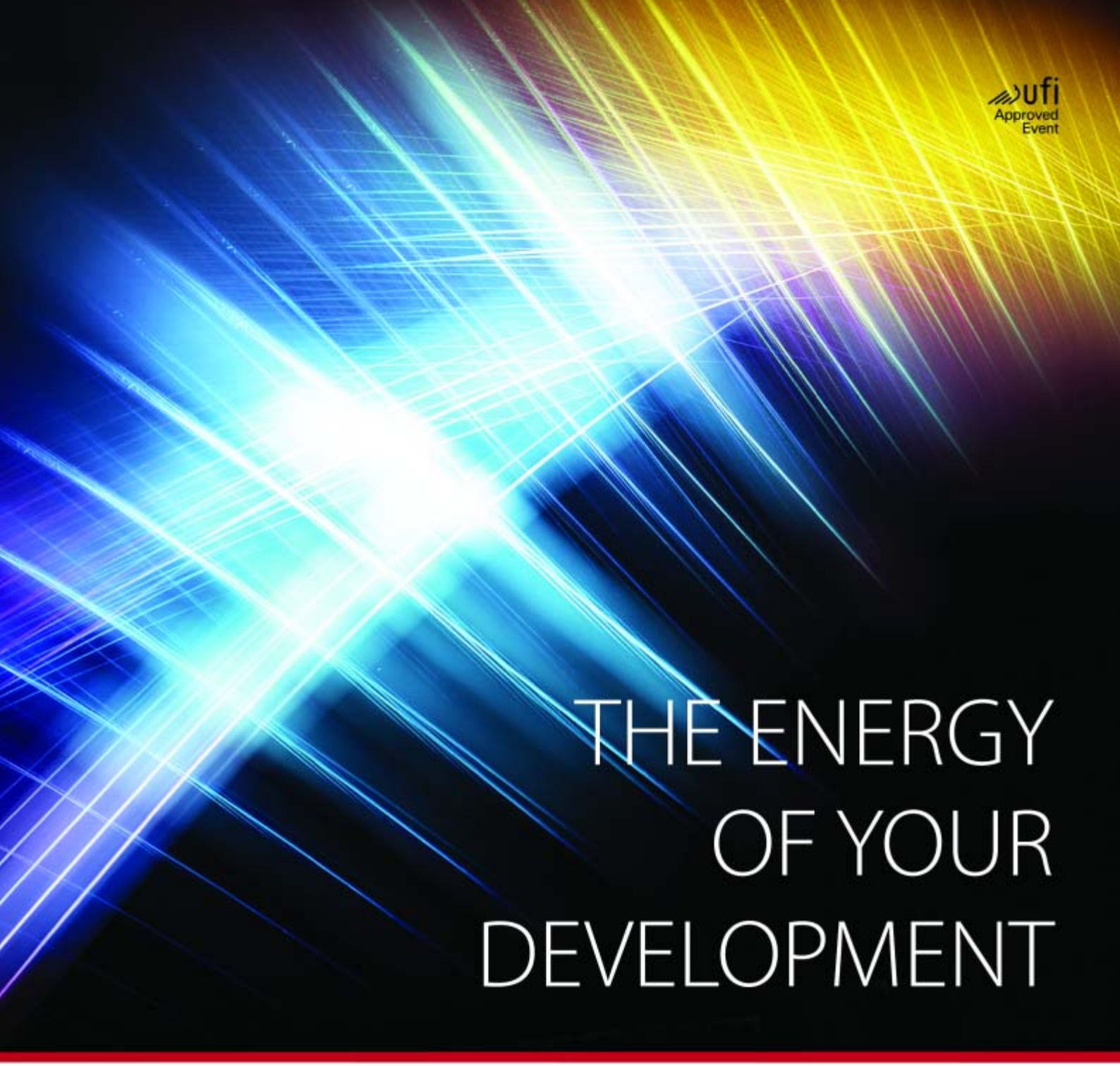
www.toshiba-components.com

Bidirectional Pulse-Power Medium-Voltage Thyristor switch W1C 12kV / 32kA



This newly developed, ready-to-use medium-voltage switch W1C-12kV-32000A-F-Disk in thyristor design consists of 8 series-connected switching stages (thyristor disks) with suppressor circuit, voltage balancing and overvoltage protection. The switch is designed to be used as a high-current pulser with a current carrying capacity of up to 32,000A at a foot pulse width of up to 100ms. The unit is air-cooled but optionally also available in liquid-cooled design. Triggering is carried out by means of the intelligent Thyristor Gate Unit ZBG which is fed by the inductive current loop supply unit IEV. The medium-voltage switch features optical triggering with status monitoring and status feedback via optical fiber. The same applies to the electrically isolated acquisition of the heat sink temperature via optical fiber.

www.gva-leistungselektronik.de



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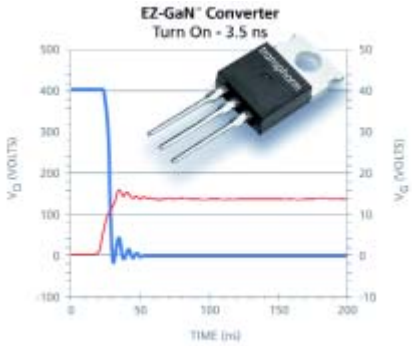
First JEDEC-Qualified 600 Volt GaN on Silicon Power Devices

Transphorm Inc. announced the Total GaNTM family of GaN (Gallium Nitride) on silicon transistors and diodes, establishing the world's first JEDEC-qualified 600 V GaN device platform. This marks a significant milestone in the broad adoption of GaN-based power electronics in power supplies and adapters, PV inverters for solar panels, motor drives, as well as power conversion for electric vehicles.



Based on Transphorm's patented, high-performance EZ-GaNTM technology, the TPH3006PS GaN high electron mobility transistor (HEMT) combines low switching and conduction losses to reduce energy loss by 50 percent compared to conventional silicon-based power conversion designs. The TO-220-packaged GaN transistor features low on-state resistance (RDS(on)) of 150 milliohms (m?), low reverse-recovery charge (Qrr) of 54 nanocoulombs (nC) and high-frequency switching capability — all of which result in more compact, lower cost systems. Also available in industry-standard TO-220 packages, the TPS3410PK and TPS3411PK GaN diodes offer 6 A and 4 A operating currents, respectively, with a forward voltage (Vf) of 1.3 Volts. In addition, three application kits — PFC (TDPS400E1A7), Daughter Board (TDPS500E0A) and Motor Drive (TDMC4000E0I) — are available for rapidly benchmarking the in-circuit performance of Transphorm's products.

www.transphormusa.com

PDG-2500 Handheld +5V Digital Pulse Generator

IXYS Corporation announced the introduction of the PDG-2500 Handheld +5V Digital Pulse Generator by its IXYS Colorado division.

The PDG-2500 portable handheld pulse generator produces single-shot pulses from 80ns to 1s in width and pulse frequencies from 5 Hz to 1 MHz. It features an intuitive touch screen interface to control both the high resolution digital pulse generator as well as an additional user-adjustable voltage, variable from 0 to +5V DC. This DC voltage can be used as a control voltage to set high voltage power supply levels or other equipment parameters that are controlled with a DC voltage. In addition to touch screen user control, the PDG-2500 includes a USB computer interface for straightforward computer control and operation.

Portability included! The PDG-2500 can operate on internal battery power for up to six hours, or on 100-240VAC power with the included power supply. The PDG-2500 brings the pulse to the application.

www.ixyscolorado.com

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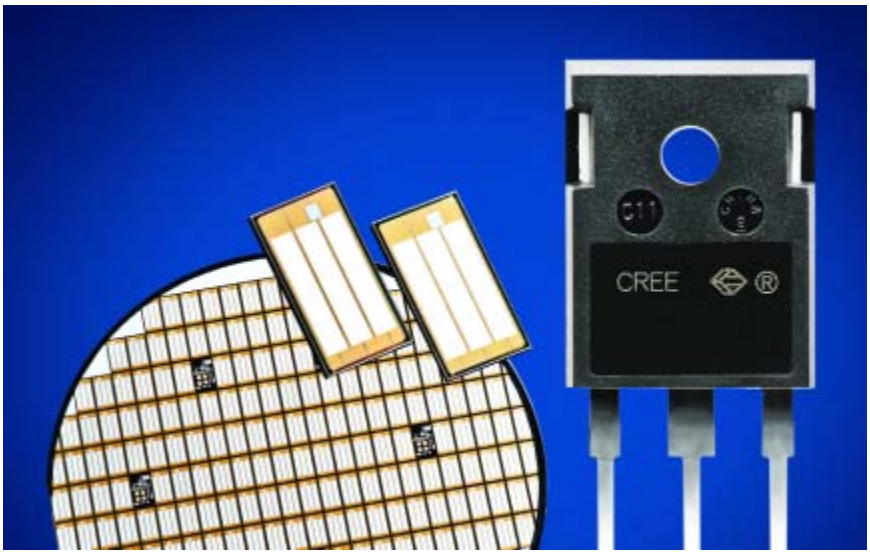
Second Generation SiC MOSFET Bringing Significant Cost Savings



Cree, Inc. announces the release of its second generation SiC MOSFET enabling systems to have higher efficiency and smaller size at cost parity with silicon-based solutions. These 1200V MOSFETs deliver industry-leading power density and switching efficiency at half the cost per amp of Cree's previous generation MOSFETs. "We have evaluated Cree's second generation SiC MOSFET in our advanced solar circuits," stated Prof. Dr. Bruno Burger, renowned industry expert at the Fraunhofer-Institute in Freiburg, Germany. "They have state-of-the-art efficiency and enable system operation at higher switching frequencies that result in smaller passive components, especially smaller inductors. This substantially improves the cost-performance tradeoff in solar inverters in favor of smaller, lighter and more efficient systems."

The superior performance of these new SiC MOSFETs enables the reduction of required current rating by 50-70 percent in some high power applications. When properly optimized, customers can now get the performance benefits of SiC with the same or lower systems cost as with previous silicon solutions. For solar inverters and uninterruptible power supply (UPS) systems, the efficiency improvement is accompanied by size and weight reductions. In motor drive applications the power density can be more than doubled while increasing efficiency and providing up to twice the maximum torque of similarly rated silicon solutions. Die are available with ratings of 25 mOhms, intended as a 50 Amp building block for high power modules, and 80 mOhm. The 80 mOhm MOSFET in a TO-247 package is intended as a higher performance, lower cost replacement for Cree's first-generation CMF20120D.

www.cree.com/power

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Dietmar Zembrot
President of LightingEurope and CEO of TRILUX, Germany

"Challenges and Opportunities of the European Lighting Industry"
Effects of Solid-State Lighting on products manufactured by European companies and the strategies of the new LightingEurope organization.

Menno Treffers
General Secretary of the Zhaga Consortium, The Netherlands

"Zhaga - Lowering the Risk and Cost of Getting LED Technology Innovation to Market"
An in-depth discussion of the impact of the Zhaga interface specifications on the competitive light market.

Dr. Alfred Felder
CEO of Tridonic, Austria

"Lighting Module and Component Industry - Market and Technology Opportunities"
Correlations between market and technology activities in Solid-State Lighting; risks and opportunities for module and component manufacturers in a rapidly changing environment.

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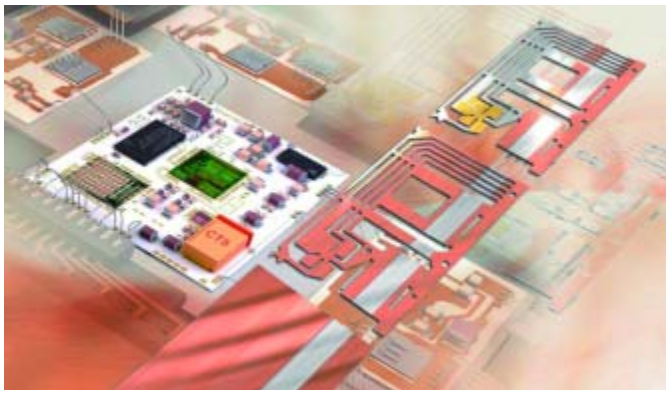
Effectively Connecting Roll Clad Strips with Battery Cells

The roll clad strips of Heraeus consist of a copper and aluminum part. The connection of these two metal parts with each other is executed by roll cladding and subsequent tempering in such a way that the current is transmitted as losslessly as possible.
Hence, an adhesive bonding (alu-alu and copper-copper) emerges at the particular positive and negative terminal, for example by laser welding – which thus is executed as a monometal system. Without loss the power is transmitted from terminal to terminal via the roll clad strip.



Storage technology and power electronics
The battery technology represents only one of the numerous challenges, though. It is at least equally important to provide the stored power as lossless as possible and to convert it into operating power. For this, the power electronic in an electric or hybrid car must be executed accordingly and is an important component in the complete e-mobility system. Besides the mentioned cladded semimanufactured products, Heraeus contributes to the fulfillment of the requirements in the area of packaging of integrated circuits with the following materials: Sinter pastes; Diffusion solder pastes;
Copper bonding wires; Bonding optimized frames; Thick film metallizing paste system; Substrates/stamped parts with functional surfaces and Roll clad strips.

www.heraeus-materials-technology.de

Multiple New Devices to Non-Punch-Through (NPT) IGBTs

Microsemi Corporation announced the availability of more than a dozen new devices in its new generation of 1200 volt (V) non-punch through (NPT) IGBTs which include 25A, 50A and 70A current ratings. Microsemi's NPT IGBT product family is designed for a wide range of industrial applications requiring high power and high performance, with the newest devices well-suited for arc welders, solar inverters, and uninterruptible and switch mode power supplies. All of the devices in this 1200V product family are based on Microsemi's advanced Power MOS 8™ technology, which enables a significant reduction of at least 20 percent in total switching and conduction losses as compared to competitive solutions.
Consistent with all devices in the product family, Microsemi's new NPT IGBT solutions can be packaged with Microsemi's FREDs or silicon carbide Schottky diodes to provide engineers with a highly integrated solution that allows them to streamline product development efforts.

www.microsemi.com

Four-Channel LED Driver IC for Automotive Interior

The A6263 is the latest addition to the family of automotive qualified LED driver ICs from Allegro MicroSystems Europe. The device incorporates a linear programmable current regulator providing up to 100 mA from each of four outputs to drive arrays of high brightness LEDs. It is targeted at the automotive market for applications such as map and dome lighting as well as exterior accent lighting.

The device outputs can be connected in parallel or left unused as required. The regulated LED current from each output is set by a single reference resistor. Current is matched in each string without the use of ballast resistors. Driving LEDs with constant current ensures safe operation with maximum possible light output.

The A6263 incorporates protection against a range of common faults, including LED string shorted to ground, single or multiple LED shorts, LED string open, IC pin open or short, and over-temperature. If one LED string is open or shorted to ground, the offending string is disabled, while other LED strings continue to work.

A temperature monitor is included to reduce the LED drive current if the chip temperature exceeds a thermal threshold. If necessary, this thermal de-rating threshold can be adjusted or disabled.

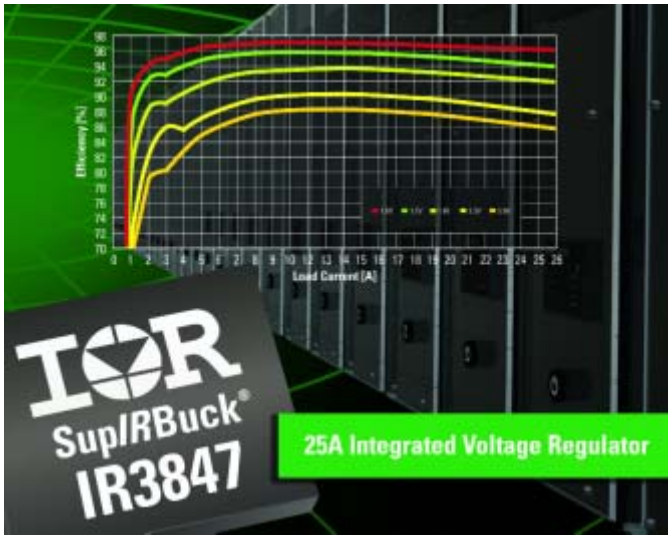
The Allegro A6263KLJTR-T is offered in an 8-pin SOICN package (suffix LJ) with exposed thermal pad for enhanced thermal dissipation.

www.allegromicro.com

High Current Gen3 SupIRBuck® Delivers Superior Performance

International Rectifier announced the introduction of the IR3847 high current Point-of-Load (POL) integrated voltage regulator that extends the current rating of IR's third generation SupIRBuck® family up to 25A in a compact 5x6 mm package.

As a result of a new thermally enhanced package using copper clip and several proprietary innovations in the controller, the IR3847 can operate at 25A without heatsink, and reduces PCB size by 20% compared to alternative integrated solutions and 70% compared to discrete solutions using a controller and power MOSFETs. A complete 25A power supply solution can be implemented in as little as 168mm2.



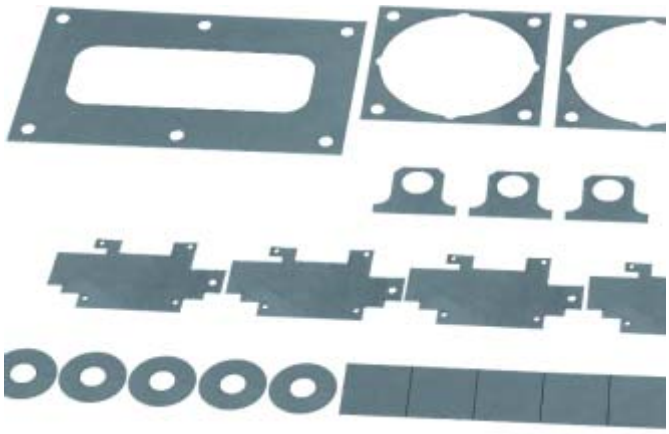
Available in a compact 5x6mm PQFN package, the IR3847 also offers market-leading electrical and thermal performance for 15A – 25A applications such as peak efficiency greater than 96% and temperature rise at 25A as low as 50°C. Other advanced features include external synchronization, sequencing, VTT tracking, and output voltage margining.

The IR3847 offers the standard SupIRBuck features of switching frequency up to 1.5MHz, pre-biased start-up, input voltage aware enable, over voltage protection, power good, optional true output voltage sensing for open line feedback and adjustable OVP, internal soft-start and minimum input voltage of 1.0V (with ext. bias) and operating junction temperatures of -40oC to 125oC. The device is qualified for the industrial market.

www.irf.com

High-Heat WLFG Conduction Graphite Films

Small heat input areas or transient heat inputs require an especially well-conceived cooling concept with free convection. For efficient cooling of the electronic components, the existing heat must be absorbed quickly, e.g. through a heat sink and dissipated into the environment Here the heat contact of the components on the heat sink plays a crucial role. Effective immediately, Fischer Elektronik is expanding its product portfolio with high heat conduction graphite films of the WLFG series, which also provide excellent solutions for this purpose and also heat spreading. These innovative heat conduction films consist of a highly compressed natural graphite with an application temperature range from -40°C +500°C. The anistrophy of the basic material allows very good heat conductivity in the x, y and z direction. Different models are available in the material strengths of 0.15 to 0.25mm, with an adhesive coating applied on one side for better attachment. By default, we offer material sold by the metre. However, it is also possible to produce customised contours and punch-outs according to diagrams. Please contact us. The product specialists of Fischer Elektronik are very happy to help you at



www.fischerelektronik.de

Digital Power System Interface

CUI Inc announced that as part of its presence at the Applied Power Electronics Conference (APEC), the company will demonstrate a new graphical user interface for its digital power modules named Novum ACE™. Providing a system-level approach to power management, the Novum ACE platform enables the user to configure and control all Novum® Advanced Power products while monitoring the operation of the entire power system.

Novum ACE was developed on a single click, one entry concept that would support all products within the Novum Advanced Power portfolio. The interface allows designers to easily and quickly configure several

parameters, including power sequencing, margining, current sharing, fault limits, and output voltage. Users are also able to monitor, in real time, multiple data points including output current, input voltage, internal module temperature, and a range of module and system faults.

"Our aim in designing the Novum ACE software platform was to take an intuitive, system-level approach to digital power management," explained CUI Inc's Senior Vice President, Mark Adams. "Digital power has long been stigmatized as being too complex for many organizations to implement. Novum ACE takes much of the complexity out of the system thanks to its simple one-click design," concluded Adams.

www.cui.com

Integrated Thyristor and IGBT in the SMPD Module Platform

IXYS Corporation announced the release of its latest addition to the ISOPLUSTM Surface Mount Power Device (SMPD) range which successfully reduces the amount of discrete devices for designers that need to apply Insulated Gate Bipolar Transistors (IGBT), thyristor and fast diode technologies in one circuit.

The patented SMPD Module platform has successfully improved reliability and reduced board size by offering surface mount solutions for systems up to 15kW. Using IXYS' proprietary DCB isolated substrates the SMPD Module flexibility provides a platform for mixed technology and multiple die content, e.g., thyristor, IGBT, MOSFET and diode in boost, buck, parallel, half bridge, full and three phase bridges or two switches side by side topologies.

"Incorporating our thyristors with our IGBT's has been a natural extension of our depth in power semiconductor technologies. The thyristors have been the highest power density switches for the industry and are relatively easy to drive as high side switches in bridge configuration. They conduct higher currents with higher efficiencies than FETs and IGBTs, thus a combination with FETs or IGBTs creates almost an ideal switch, where the high-side-high currents, are conducted by the thyristors, and high speed switching is done with the low side IGBTs in this product," commented Dr. Nathan Zommer, CEO of IXYS Corporation. "More combinations of these technologies are possible, and will be introduced to our customers' needs as applications power devices (ASPD)."

http://ixapps.ixys.com/DataSheet/IXA20PT1200LB.pdf

ADVERTISING INDEX

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1947: IR opens for business, launching selenium rectifiers

1954: Commercializes germanium rectifiers

1959: A pioneer in silicon controlled rectifier (SCR)

1962: Introduces new epitaxial process for producing industry's most stable high voltage SCRs

1979: Patents first commercially viable Power MOSFET (HEXFET®)

1980: Introduces high reliability power semiconductor devices for space programs

1983: Launches first commercially viable high voltage power ICs

1996: Introduces MOSFET and Schottky in a single package

1950 **1960** **1970** **1980** **1990**

2000

Introduces wafer level package (FlipFET™)

2001: Invents integrated building blocks for DC-DC converters (*iPOWIR*™)

2002: Invents first dual-sided surface mount package (DirectFET®)

2003: Introduces *iMOTION*™ Integrated Design Platform

Invents scalable multi-phase architecture (xPHASE®)

2006: Introduces AC-DC Smart Rectifier™ IC

2007: Introduces Sup*IR*Buck® Integrated Voltage Regulators

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2012: Introduces *µIPM*™ power modules

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