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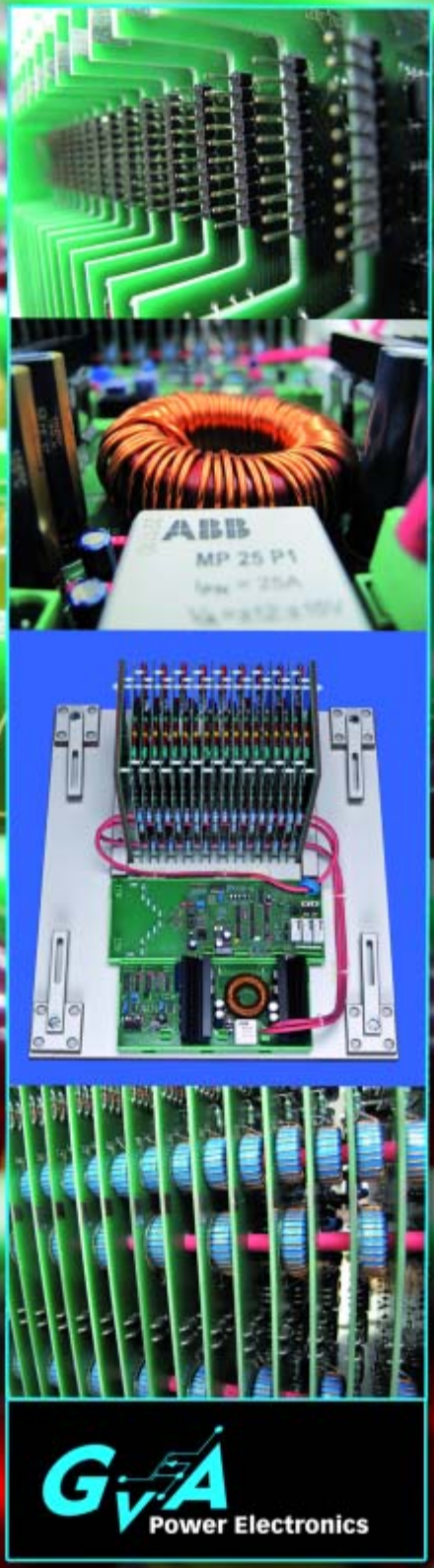
Bodo´s Power Systems®

Electronics in Motion and Conversion

December 2012



CONTENT

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

powerguru.org

Viewpoint 4
100 Years Young - Happy Birthday Mr. Lidow!

Events 4

News 6-12

Blue Product of the Month 14-15
Join the eMobility Revolution
By Marisa Robles Consée,
Corresponding Editor; Bodo's Power Systems

Guest Editorial 16
Let the Purchaser Beware
By Ralph Waggitt, Advanced Power Electronics Corp.

Market 18
Electronics Industry Digest
By Aubrey Dunford, Europartners

Market 20-21
Immediate Growth Opportunities for Portable Power
By Richard Ruiz, Research Analyst, Darnell

Coverstory 22-25
Medium-Voltage High-Speed Switches
with IGBT Power Semiconductors
By Johannes Soldan and Werner Bresch,
GvA Leistungselektronik GmbH

Power Supply 26-28
EN50155 Compliance to Railway Standards
By Steve Roberts M.Sc. B.Sc.; Technical Director;
RECOM Development in Gmunden, Austria

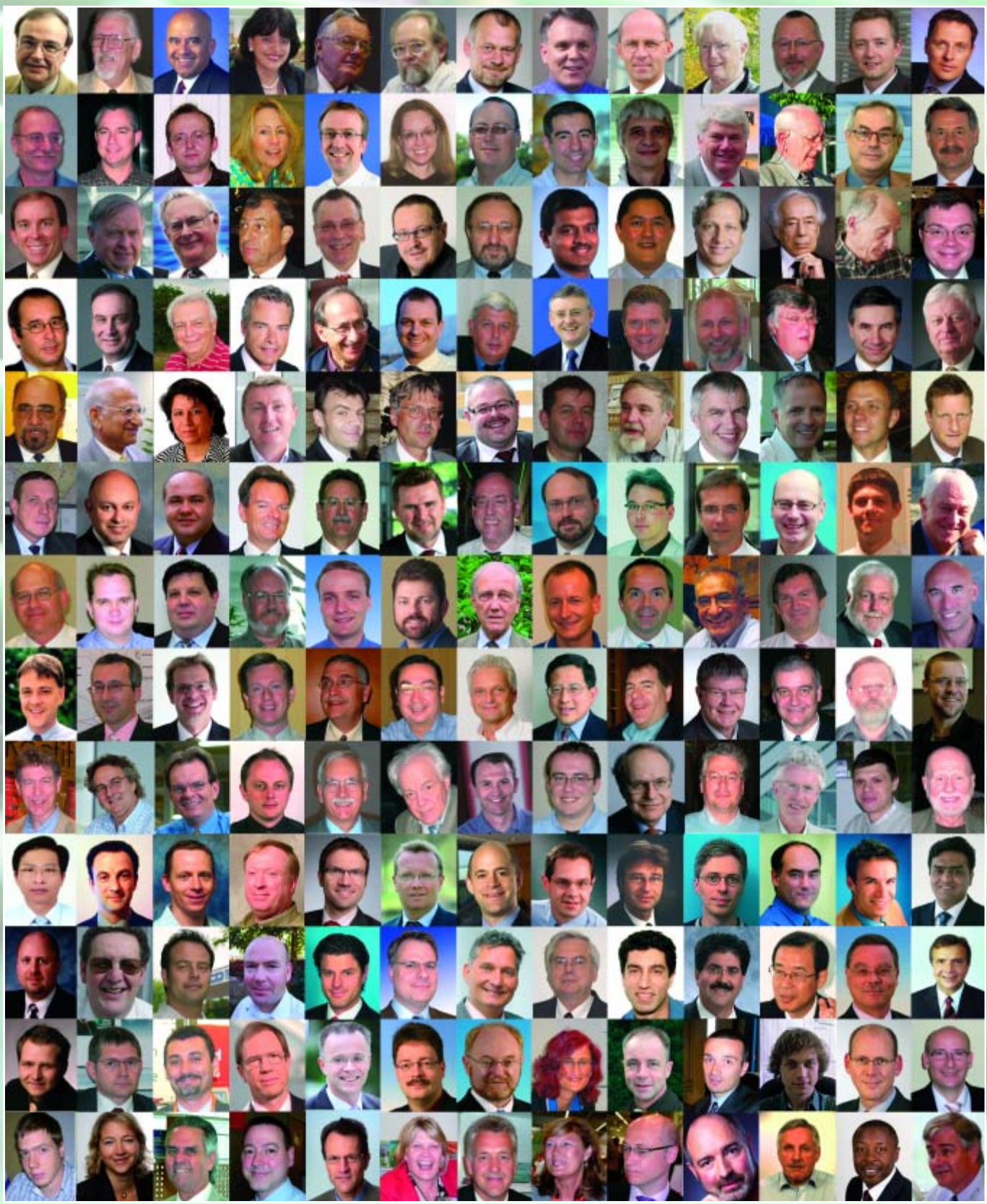
Capacitors 30-32
Faster Switching in Inverters
By Dr. Günter Engel, Director Innovation Themes,
Corporate Material Research and Development and
Wolfgang Dreipelcher, Senior Director Global
Reference Designs, Epcos

Thermal Management 34-37
Thermal Interface, A Key Factor in Improving Lifetime
in Power Electronics
By Dr.-Ing. Martin Schulz, Infineon Technologies

Technology 38-40
Silicon Carbide 10KW Interleaved Boost Converter
Achieves 99.1% Peak Efficiency
By Jimmy Liu and Kin Lap Wong, Cree Inc.

New Products 42-48

The Gallery



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www.thesmartgridsummit.com

Embedded World 2013,
Nuremberg, Germany,
February 26th - 28th
www.embedded-world.eu

New Energy 2013,
Husum Germany, March 21st-24th
www.new-energy.de

EMC 2013,
Stuttgart, Germany March.5th – 7th
www.mesago.de/de/EMV

APEC 2013 Long Beach CA USA,
March 17th - 21st
www.apec-conf.org/

100 Years Young -

Happy Birthday, Mr. Lidow

It is my honor to wish Mr. Eric Lidow all the best on becoming 100 years young.
He and I first met during a lunch meeting in El Segundo with a number of other executives from International Rectifier. While the others discussed business, Mr. Lidow and I talked about cameras and the City of Kiel, my birth place. Our conversation started when he noticed that I was using a Leica camera to take photos and he related old stories of how such a camera had been a currency that helped him survive in bad times.

Born in Vilnius, Lithuania, Mr. Lidow graduated in 1937 from the Technical University of Berlin with a degree in Electrical Engineering. He immigrated to the US in 1937 and is now a Life Associate of Caltech, a Life Member of IEEE and a Life Trustee of the Los Angeles County Museum of Art. He also holds an Honorary Doctorate from Technion.

Kiel was the place from which Mr. Lidow travelled by boat on his journey to the US. It was fascinating for me to hear his stories about the past and his life in Europe during the 1930s. These stories reminded me of my parents, who also left their home to come to Kiel and start a new life. I saw picture of a time before I was born - a time full of changes, new challenges and new adventures.

Using my age as a reference point in understanding semiconductor innovations, the major milestones in semiconductors happened after I was born. Mr. Lidow and his company have been at the forefront of such innovations for about 70 years. Technology has been Mr. Lidow's life. Achievements in the technical area began in 1940 with rectifiers in selenium - as co-founder and General Manager of Selenium Corporation of America. His International Rectifier Company moved on to introduce HEXFETs, propelling MOSFET technology to be the most popular switch manufactured in silicon technology today. MOSFET cell density and device structure have both developed, but still both FET's and IGBT's are based in MOS technology. Today, development emphasis is on new semiconductor materials, while structures stay much the same. All these products have changed the world and made applications more efficient through reduced losses in both switching and conduction.

As we talked about age and wisdom, Mr. Lidow said that the best time of his life was between 50 and 70. At that time I was just nearing 50, but now I can confirm his experience as I near 60. Thank you Mr. Lidow for all the great discussions we had through the years, and not just on technology.

Communication is the only way to progress. We delivered twelve issues in 2012 and will continue each month, on time, every time. So far this year we have published 132 technical articles, amidst 788 pages of information overall. 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 December is:
To stay young, never retire. Joy in work will keep you happy. The wisdom you pass on to younger generations helps them avoid mistakes. This helps to conserve energy in many, many ways.

Merry Christmas

The Perfect Fit

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The perfect fit for your design: a cost-effective current transducer that out-performs shunts in every way. The compact package of the HLSR requires only 387 mm^2, less board area than many shunt solutions. Large clearance/creepage distances ensure safety, and high performance produces accurate measurements across a wide temperature range of -40°C to +105°C. The LEM HLSR – a single compact device that eliminates complexity in your design.

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- 8 mm clearance/creepage + CTI 600
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- Through-hole and SMT packages

www.lem.com

At the heart of power electronics.

40 Years Anniversary 1972 - 2012

LEM

Overall Head of Development

Over the past three decades, Isabellenhütte Heusler has gone through a process of fundamental change. The company based in Dillenburg, Germany, has evolved from a supplier of semi-finished products into a globally active company. In his new role, Dr Marien will be making use of his experience as head of development and head of technological development at Sensitec, a manufacturer of sensor solutions, for which he worked from 2003 to 2010.

www.isabellenhuette.de

European Manager to Head Fuji Electric Europe First Time

In October 2012, Peter Hermann Maier took over management of Fuji Electric Europe GmbH in Offenbach (Germany), succeeding Hiroshi Miki.

Maier was the founder and managing partner of curamik electronics until 2005, a world-leading manufacturer of substrates for power semiconductor modules. The last 7 years he mainly focussed on utility scale photovoltaic projects. He brings vast experience in power semiconductors and renewable energies to the company.

In his new position he will promote and accelerate the development of Fuji Electric to a customer driven, globally competitive provider of energy related products and systems: „We are going to emphasize on the development of customer specific solutions, utilizing the well known high quality and long life of Fuji Electric‘s semiconductors and drives. Our focus will also be on competitive pricing, shorter delivery times and faster product-innovation“.

After 25 years of Japanese management the CEO in Tokyo has decided to implement European management. This suggests that products and services are going to be more targeted for European customers.

Maier is the first non-Japanese President and speaker of the management board of Fuji Electric Europe. The subsidiary of the Japanese high-tech-company with the slogan „Innovating Energy Technology“, is responsible for the sale and marketing of electric drives and power semiconductors as well as for the introduction of new products into Europe, Russia, the Middle East and.Africa.

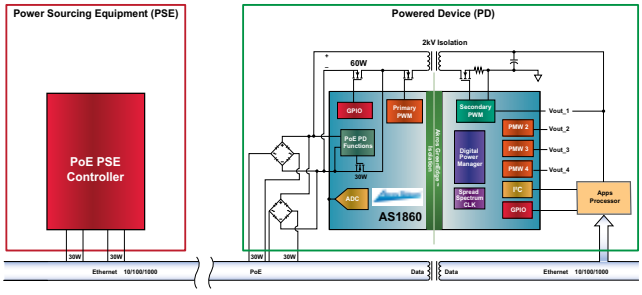
Fuji Electric was founded in 1923 by Furukawa and Siemens in Tokyo and employs 25.000 people worldwide

www.fujielectric.com/europe/

Interoperability Collaboration Supports New PoE 60 Watt Deployments

Akros Silicon Inc. announced an interoperability collaboration with Broadcom Corporation to provide fully integrated support of the emerging PoE (Power over Ethernet) 60 Watt extension.

Broadcom, a global innovator and leader in semiconductor solutions for wired and wireless communications, has a family of PoE PSE (Power Sourcing Equipment) controllers (model BCM59111) that supports the rapidly emerging 60W application requirements.



Akros Silicon is uniquely suited to collaborate with Broadcom to enable seamless 60W PoE connectivity. Akros' GreenEdge™ technology, integrated into a family of PoE system-on-a-chip (SoC) energy management ICs, allows high-speed digital communication across an integrated isolation barrier. This technology provides necessary handshaking and telemetry information with the power source to allow for safe and controlled power transfer, while eliminating optocouplers and their associated complex compensation networks. The result is significant improvement in reliability, reduced real estate, unmatched efficiency in power conversion and more accurate output-voltage sensing. Additionally, this technology enables significant system-level cost reduction.

Broadcom's PoE solutions are the most flexible and scalable solutions on the market. The BCM59111 is a highly integrated PSE solution offering world-class thermal performance. The adoption of PoE in the market continues to grow as more devices are connected to the network. Expanding to 60W will allow even more devices to be connected. "Broadcom is pleased to continue efforts in the PoE market and offer solutions capable of providing 60 watts," said Kevin Brown, Vice President and General Manager, PHY, Broadcom Corporation.

"The AS18xx family of GreenEdge™ energy management SoCs, introduced in 2009, has established itself as a leading solution in PoE applications adopted by major OEMs worldwide," said Parviz Ghaffaripour, Akros Silicon's President & CEO. "The AS1860 is in full production and offers field-proven technology designed to immediately support the 60W requirements. Our flagship digital isolation technology, GreenEdge, allows digital communication, power control and health monitoring across the isolation barrier. These features accommodate flexibility within systems to create robust power management, while eliminating long-term reliability concerns related to optocouplers."

PoE technology provides DC power from Power Sourcing Equipment (PSE) over twisted pair Ethernet cables to Powered Devices (PDs) within enterprise, small business or home networks. The PoE standard has evolved from 13W (IEEE 802.3af) to 30W (IEEE 802.3at) and now the industry is rapidly moving to 60W of power per switch port. This 60W requirement is driven by the need to support applications such as thin clients, monitors, industrial Ethernet, IPTV, building management and lighting control systems, nurse call systems in hospitals, point-of-sale terminals and other higher power applications. The move to 60W PoE will allow deployment of PoE-enabled PDs into new markets while facilitating easier, more energy-efficient power management across the entire enterprise.

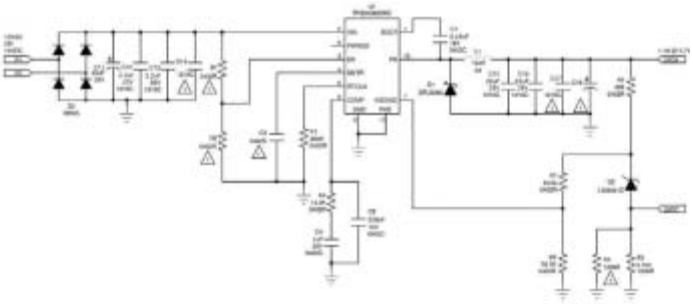
www.akrossilicon.com

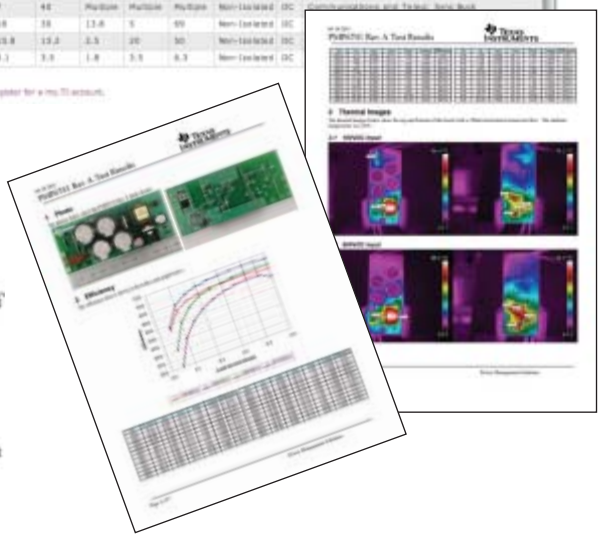
PowerLab™ Power Reference Design Library

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

Features

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





www.ti.com/powerlab

Learn more, find answers and stay up to date

Texas Instruments

Expansion of KCC sales network

In order to improve response times and communications, KCC Corporation has expanded its sales network in Europe. The new subsidiary KCC Europe GmbH is a 100% daughter company of KCC Corporation with its seat in Köln and branch offices in Regensburg and Hamburg.

Under the management of Mr. S.K. Park, KCC Europe will be responsible for all commercial activities in Europe. Fine ceramics for power electronics will be managed by a branch office in Regensburg, Germany. Product range includes ceramic substrates (alumina and ALN) in DBC and AMB-Technology, ceramic housings for thyristor discs as well as ceramic for vacuum interrupters.

www.kccworld.co.kr

GaN Systems Expands to New US Location

GaN Systems Inc, announced the opening of a new office located in Ann Arbor, Michigan. The company has appointed Mr. Julian Styles, as Director of Business Development, to lead business development in the United States. This expansion in the U.S. will aid the company in continuing to impact key industries, like manufacturing and automotive, where the need for clean technology power conversion applications continue to grow. GaN Systems' head office is currently located in Ottawa, Canada.

"We're excited to better serve our clients in the U.S. with the addition of an experienced, well versed executive in the electronic and automotive sectors," said Girvan Patterson, chief executive officer of GaN Systems. "We have worked hard to develop viable, effective GaN applications, including making hybrid and all electric vehicles cost effective. Julian's broad experience and strong technical background including electric vehicle and grid systems, will complement the existing team to meet the needs of a growing company, like ours."

www.gansystems.com

Online Shop for Printed Circuit Boards and Stencils

The PCB manufacturer Würth Elektronik complements its portfolio of services with the WEdirekt online shop. Whether a PCB or stencil is required, an easy-to-use configurator with 24-hour availability provides numerous options and alternatives, and calculates a final price that reflects the configuration request. In just a few clicks the order is transmitted and sent immediately into production. Delivery depends on the customer's requirements, and includes the option of express delivery service within 48 hours.

The Würth Elektronik online shop offers an intuitive user interface and is presented in a clear and structured design. The main sections of the website are two user-friendly configurators for the ordering of PCBs and stencils. Each product has its own configuration menu where the customer enters the relevant data into predefined fields, then uploads their layout files. The customer selects various parameters to design their own individual product. Options include up to eight layers, various thickness tolerances, conductive pattern structures down to 100 ìm, and the ability to select the surface finish, in addition to other selections.

www.we-online.com

World's Smallest Engine Management IC for Two- and Three-Wheelers

Infineon Technologies launched the world's smallest engine management ICs, saving up to two-thirds of board space in control systems for two- and three-wheelers compared to today's solutions. The new TLE808x device family provides all the functionality required for state-of-the-art electronic fuel injection (EFI) in one-cylinder combustion engines.

The TLE808x family was specifically developed to improve emission and fuel efficiency of four-stroke small combustion engines used in motorcycles, scooters and three-wheelers, lawn tractors and lawn mowers, small gasoline power generators, and marine vehicles, jet-ski- and snow mobiles.

Currently, the TLE808x family includes two devices available in high-volume: The TLE8088 and the TLE8080 with Variable Reluctance Sensor (VRS) interface and enhanced functionality.

In many fast-growing countries in Asia, Africa and South America, motorcycles are the most popular and affordable mode of transportation. However, a traditional carburetor motorcycle has a higher global warming potential than the average automobile. To meet ever stricter exhaust gas and fuel efficiency regulations of motorcycles, highly integrated and cost-effective electronic fuel injection systems must be introduced for small combustion engines. The TLE808x engine management solutions of Infineon support this development.

www.infineon.com

Fuji's Chip Technology

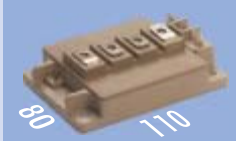
The Independent Way

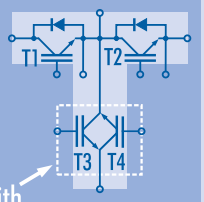
V-Series IGBTs

- Trench-FS IGBT
- High thermal cycling capability
- Low spike voltage & oscillation free
- Excellent turn-on dI_C/dt control by R_G

Innovative Reverse-Blocking IGBT for 3-Level inverters with T-configuration

1 phase IGBT modules





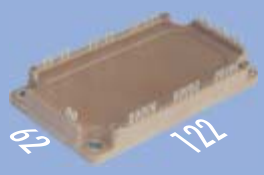
Advanced solution with Reverse-Blocking-IGBT

	T1 & T2	T3 & T4
200A*)	1700V	1200V
300A	1200V	600V
400A	600V	600V

*) Under development

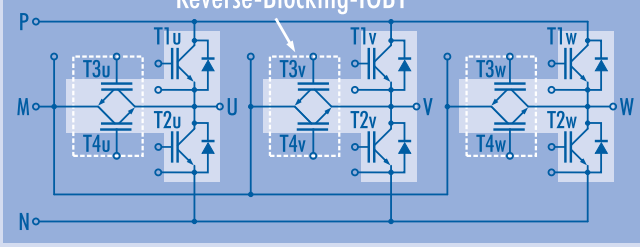
3 phase IGBT modules

With solder pins



With PressFit contacts

Advanced solution with Reverse-Blocking-IGBT



	T1 & T2	T3 & T4
50A	1200V	600V
75A	1200V	600V
100A	1200V	600V

Fuji Electric
Innovating Energy Technology

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Fax +49(0)69-66 90 29 56 ▸www.fujielectric.de
Products Overview ▸www.fujielectric-europe.de/info/overview.pdf

PCB Design Award

Michael Schleicher, PCB designer at Semikron has won the PCB Design Award by the Fachverband für Design, Leiterplatten und Elektronikfertigung FED in the High Power category. A jury of six people evaluated the designs in more than 50 criteria. The Semikron circuit board prevailed over contestants from Germany, Austria and Switzerland.

The award-winning circuit board is part of the MCB assembly (Multi-Converter-Box; IGBT-based multiple drive unit for automotive applications). The assembly presented includes more than eight technical challenges, such as distances for air and creepage, ampacity of the eleven power paths in a 105° C environment and low heat input, meandering structure of the placement, analog inverter phase current measurement, low-resistance power supply and separately routed bus systems.

"With the support from Häusermann technologists, we were able to find the perfect packaging technology for our clients. The HSMtec circuit board technology empowers the embedding of high voltage lines with ideal cross-sections with high-precision positioning into the board. Understanding the challenge and implementing it was fun", says Michael Schleicher. "I am also very delighted about my award for the documentation." In his award speech, presenter Stephan Weyhe of FED pointed out the paramount function of a perfect documentation in electronic design. Given this background, the jury would explicitly point out the quality of the presented documentation, which is by far the most professional one in the competition.

The work of the circuit board designer impacts the costs and quality of a circuit board's future production as well as its fitting and assembly. The Fachverband für Design, Leiterplatten und Elektronikfertigung FED issued the PCB Design Award for the first time this year, awarding the performance of circuit board designer in the German-speaking markets. Other categories include 3D/form factor, HDI and creativity.

www.semikron.com

BMZ Founder Sven Bauer Named "Entrepreneur of the Year 2012"

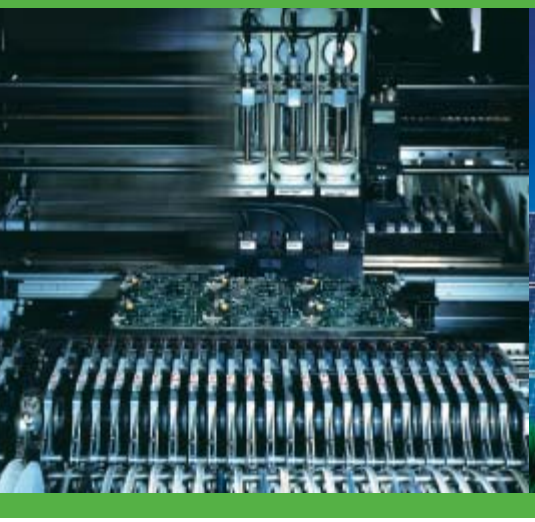
Sven Bauer, the co-founder and present sole owner of the Karlstein-based specialist battery company Batterien-Montage-Zentrum GmbH (BMZ), has been awarded the prestigious title of "Entrepreneur of the Year 2012" by the international auditing and accountancy group Ernst & Young. The prize was given in the Industry Category and was conferred by an extremely high-calibre independent jury comprising the former Prime Minister of Baden-Württemberg Lothar Späth, Fraunhofer Institute President Hans-Jörg Bullinger, Wolfgang Franz, President of the Centre for European Economic Research, August-Wilhelm Scheer, founder of IDS Scheer AG and Dr. Patrick Adenauer, Managing Director of Bauwens GmbH & Co. KG. At the same time, Sven Bauer was also nominated as a "World Entrepreneur of the Year 2013", the only German representative to be honoured in this category.

At a formal ceremony held in the Old Opera in Frankfurt on 21 September, Ernst & Young awarded prizes to the best

SME entrepreneurs in Germany in the five categories of Service, Trade, Industry, Information and Communications Technology/Media and Start-up. This is the 16th occasion upon which the programme has been staged. "As well as the ability to do business in a sustainable manner, one of the things that the jury was looking for this year was a capacity to react quickly to different market conditions by launching innovative products and services", commented Project Head Wolfgang Glauner.

www.bmz-gmbh.de

Tamura's New Flux-Gate Current Sensors – The Ideal Solution



The time has come to consider Tamura's flux-gate current sensors as the "ideal solution" for your current application and next generation designs. Here's why:

- **Tamura's highest accuracy sensor series**
- **Industry-standard mounting configurations for drop-in replacement for all major brands**
- **Optimized design for PV inverter & array monitoring applications**
- **Improved electromagnetic immunity**
- **Small footprint, low profile**

As Tamura's global channel partner, Richardson RFPD provides the engineering support to identify the best solution for your application. Contact Richardson RFPD today for samples of Tamura's new Flux-Gate Current Sensor series.

TAMURA

"the ideal solution..."

New Flux-Gate Current Sensors Available!

Download Tamura's Current Sensor Selector Guide at: www.richardsonrfpd.com/Tamura

Series	Primary DC Current	Power	Mounting Supply	Primary	Output Connection	UL 508
F01P***S05	±6A, ±15A, ±25A, ±50A	+5VDC	PCB	Integrated Primary	2.5V±0.625V	Yes
F02P***S05	±6A, ±15A, ±25A, ±50A	+5VDC	PCB	Integrated Primary	2.5V±.625V & VREF IN/OUT	Yes
F03P***S05	±6A, ±15A, ±25A, ±50A	+5VDC	PCB	Integrated Primary	2.5V±.625V & VREF IN/OUT	Yes

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www.richardsonrfpd.com

Proposal to Set up a Manufacturing Facility in China

Syfer Technology of Arminghall has announced a proposal to set up a manufacturing facility in China. Syfer was purchased by the Dover Corporation (USA) in 2000 and the company has seen continued growth since then. Export sales, especially from the Far East, have contributed greatly to the company's success. It is this Far East business that has encouraged Syfer to consider taking space in an existing Dover manufacturing plant in Suzhou, a major city located in the southeast of Jiangsu Province in Eastern China. The Suzhou Industrial Park (SIP) is the largest cooperative project between the Chinese and Singaporean governments. It is located beside Jinji Lake, which lies to the east of the Suzhou Old City.

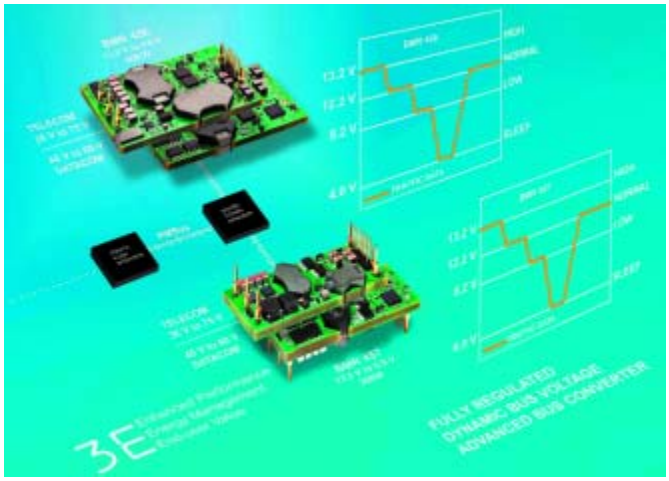
Over the last decade Syfer's R & D engineers have made great strides in the development of their range of Multilayer Ceramic products. To that end the Queens Award for Enterprise was won in 2008 with the launch of a revolutionary product 'FlexiCap' to be used in safety-critical environments. Other innovations include; 'Protecti-Cap™', a range of compact devices, supplied with a built-in protective coating, designed to prevent flashover in high voltage applications, and 'StackiCap™' a new product family set to revolutionise the world of Multilayer Chip Capacitors (MLCCs) by dramatically increasing the maximum capacitance values available in larger case size and high voltage parts.

The company is now on the verge of investing in new technology and production processes requiring high capital investment. In assessing how to manage this Syfer is looking east. MD Howard Ingleson explained, "Many of our raw materials come from that area of the world and, with much of our sales going that way too, it is right that we consider manufacturing there too. The opportunity of an existing Dover factory would also mean we could be up and running much quicker."

www.syfer.com

Dynamic-Bus-Voltage Architecture to Save Power in Datacenters

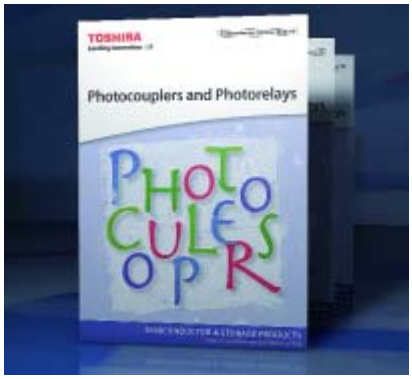
A long-term pioneer in delivering leading-edge digital power solutions to reduce board power consumption, Ericsson has laid out its vision to system architects developing equipment for computing-intensive environments such as datacenters. The increasing demand for more Internet services and cloud computing is driving both the expansion and building of new datacenters around the world. A key challenge for operators is the minimization of energy expenditure at the board level. Ericsson believes that a significant aid to this process is the use of advanced Dynamic Bus Voltage architectures. This vision was presented by Ericsson at last month's Electronics Goes Green (EGG) congress in Berlin.



The Dynamic Bus Voltage is an evolution of the Intermediate Bus Architecture and provides the possibility to dynamically adjust the power envelope to meet load conditions. It achieves this by adjusting the intermediate bus voltage, previously the 12 VDC fixed bus voltage, via the use of advanced digital power control and optimized hardware combined with an energy-optimizer series of algorithms. This can lead to reductions in both energy consumption and power dissipation, which in turn contributes to a reduction in the amount of cooling that is required.

www.ericsson.com/powermodules

Photocouplers and Photorelays Publication for Optical Isolation



Toshiba Electronics Europe (TEE) has launched a new Photocouplers and Photorelays guide that is set to become an essential reference for engineers looking to build galvanic isolation and noise protection into their applications.

The free guide will speed the design and implementation of optically isolated circuits in a wide variety of applications ranging from factory automation and renewable energy systems to consumer and office automation products.

Featuring over 80 pages of information, the Photocouplers and Photorelays guide includes product data, technical drawings, application circuit examples and details on board assembly. Technologies covered include high-speed photo-IC couplers, phototransistor couplers, phototriac couplers, photovoltaic couplers and photorelays. Product identification is simplified thanks to a comprehensive selection guide, details on packaging information and a competitor cross-reference table.

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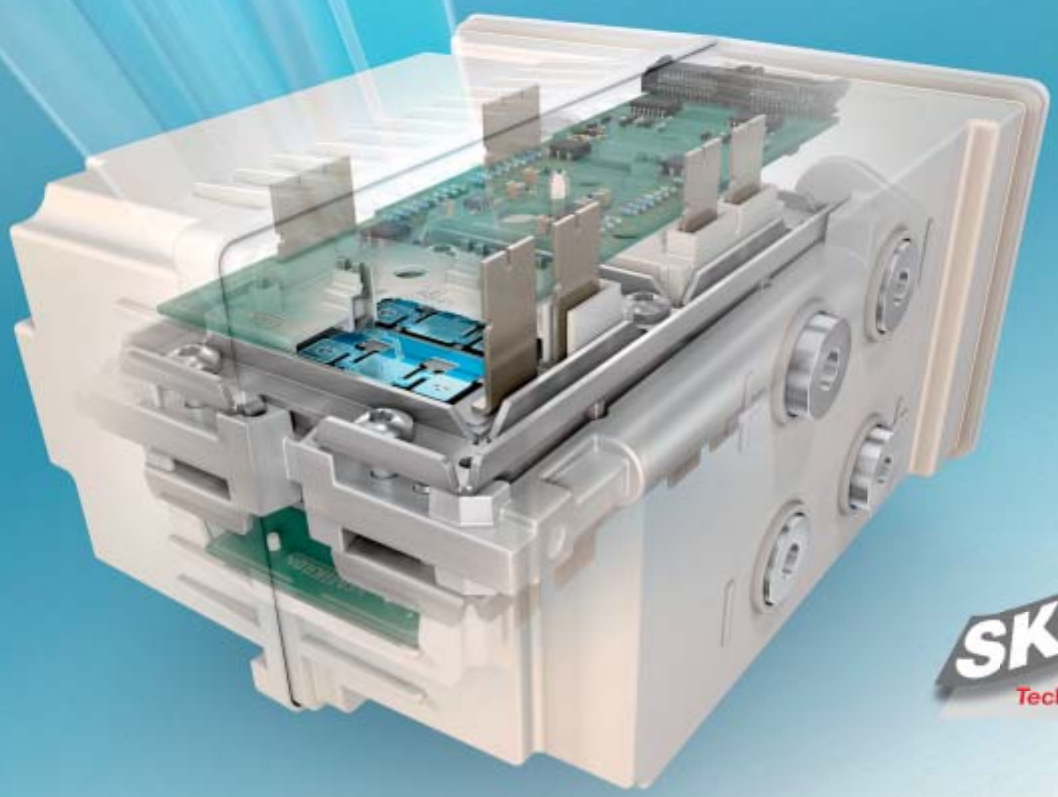

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Join the eMobility Revolution!

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

A clear result of the 4th International eCarTec trade show: Despite the improvements on battery technology, the highest priority is the development of the charging infrastructure for electric vehicles. The power distribution networks for this purpose already exist but the installation of charging stations into residences, office buildings and public spaces leaves much to be desired.

Power from renewable energies turns electromobility into an alternative suitable for everyday use. It can cater for the requirements of our society for individual mobility in a clean and low-noise manner, and thus help to achieve increased independence from fossil fuels. Electric battery vehicles are considered "local" emission-free because they do not produce drive-related emissions, as to say CO^2, noise, fine particulates, NO^x, etc..

The German federal government has therefore set a goal to put one million electric vehicles on German roads by 2020. But also the goal of France to have 100,000 vehicles on its roads by 2015 is rather ambitious. Countries such as the U.S., Japan and China have also recognized the enormous potential of electric mobility and are encouraging their industries with major programs supporting electrically powered traffic. The basic technologies regarding electric drives, energy storage and network infrastructure are well-developed.

However, the power generation itself is blended out. When using power from renewable energies, it is evident that the CO^2 emissions of electric cars are almost zero – meaning that they lie within a value range which a purely conventionally-operated vehicle cannot achieve. The discussion about this is going to take years. At least, the awareness of energy providers is growing. An example for it is the German company Vattenfall. The supplier promises that its car power consists of 100 % renewable energies. But that's not all. If more energy is produced than is actually required, regenerative energy can be stored in electric vehicles. The special thing about the Vattenfall concept is that it is also possible to feed current back out of the battery into the mains – Vehicle to Grid (V2G). This is expedient for peak loads during the day. In this way, the intelligent charging concept provides the basis for the harmonization of four major factors: the available regenerative energy, the local network load, the filling requirements and the technical framework conditions.

Vattenfall's car power consists of 100 % renewable energies
Picture: Vattenfall

The increasing number of electric vehicles is certainly going to affect the power supplies. Together with partners, the Deutsches Zentrum für Luft- und Raumfahrt (DLR) has investigated the opportunities and challenges this change poses on the energy systems and power supply. Their conclusion: electric vehicles can – with a high share of renewable energy – improve the efficiency of electricity generation, relieve the electric mains and lead to significant CO^2 savings. The corresponding study provides improved simulation models and new results.

Outlook to 2050

It is hard for the researchers to say just how fast electric vehicles will become established on the market. New vehicles will have to be developed to maturity and customers will have to take the plunge into electromobility. This process also depends on the progress made in the technological development of electric vehicles and their cost. The future price of oil and the binding CO^2 limits for vehicles also play a role. In a scenario with a successful market development of electric vehicles by the year 2050, scientists at the DLR institute for vehicle concepts assume a 28 % share of purely battery-powered vehicles and a 34 % share of hybrid vehicles. The power consumption of this total of 27 million electric vehicles in Germany would be 53.5 TWh per year, corresponding to roughly 10 % of the current total electricity consumption in Germany.

Electric vehicles may play a major role as decentralized energy storages in future grids Picture: Marisa Robles Consée

80 % potential CO^2 savings in the mobility sector

Despite the high power consumption, the burden on the environment would be relieved if electric vehicles were to be successfully introduced: vehicles with an electric drive are more efficient than vehicles with a combustion engine. Compared to the year 2012, the total energy consumption for individual transport would drop by two thirds. Assuming the electric vehicles run on electricity from renewable energies, the CO^2-emissions for the fleet of cars would fall by 80 %

The study suggests that the power supply network would benefit when the charging of electric vehicles takes place at controlled times. While e-cars increase the demand for electricity they can also dampen supply peak loads introduced by the preferential use of wind and solar power. In consequence, power generation from fossil-fuel power stations can be reduced on account of smaller peak loads.

By controlling the charging process it will be possible to charge the battery when the power provided from renewable energies is high. “This is important for the integration of electric vehicles in the energy system”, says Thomas Pregger, Project Manager for the study at the DLR institute of technical thermodynamics. The simulations showed that excess current up to around 4 TWh per year can be used. On the whole, electric vehicles could reduce the excess power by up to 20 GW (scenario for 2050) under these conditions.

The researchers also examined the user profiles of car drivers in Germany for their study. These show that the potential for charge management varies greatly throughout the day and the storage capacities of the batteries can generally only be used in part. The potential is lowest in the morning when most owners commute to work with their car, and highest in the evening and in the night, as was to be expected. Apart from time-lag charging processes, the batteries of a fleet of vehicles connected to the electric mains can also feed current into the mains if the demand is high. However, today's batteries age so quickly on account of charging and discharging that the cost of such a storage facility would be very high.

The DLR institute for vehicle concepts investigated also how electric vehicles and fleets of cars will develop in future, and the resulting time profiles for power consumption as well as battery storage capacity in the mains. The institute of technical thermodynamics dealt with the question of how electric vehicles can best be integrated in a European power grid and what role they could play for current balancing.

The RoboMObil (ROMO) which DLR has developed achieved one of this years' eCarTEc Award and embodies an innovative two-seater electromobility concept incorporating technologies from planetary rovers and robotics.
Picture: Marisa Robles Consée

The Fraunhofer Institute for Solar Energy Systems (ISE) investigated the effects on house energy systems and local grids, the High Voltage Technology of RWTH Aachen University took a look at the distribution grid level, and the Forschungsgemeinschaft für Elektrische Anlagen und Stromwirtschaft e.V., Aachen (FGH) delved into the effects on the transmission grids. DLR's work in the study was sponsored by the Federal Ministry of Economics and Technology (BMWi) with about 318,000 €.

www.vattenfall.de

Let the Purchaser Beware

By Ralph Waggitt, Advanced Power Electronics Corp.

Discrete power components and basic power ICs may seem simple to obtain, but there are some general and specific issues which buyers should be aware of, including the hazards of using recycled parts and the varying characteristics of supposedly identical devices with different process 'recipes'

There is an old adage which runs: if something seems to be too good to be true, it probably is! However, when supplies run short and lines stop, finding a source of parts that are on allocation or long leadtimes – any source, let alone one that appears to be offering devices at rock bottom prices – may seem like a godsend. The temptation is to bypass normal safety checks, slap the order in and move on to the next 'challenge'.

The internet has made things so much easier. A buyer in Europe or the USA can simply run a Google search, see which broker in Asia is currently claiming to have parts and enter his credit card details. But – and there is always a but – there is usually a reason why someone can get parts while the rest of the world is in shortage, or why the available devices are so cheap.

Counterfeit components crop up in the world of discrete components and power ICs, just like the rest of the components business. But a much more insidious problem occurs with re-cycled parts. Suppliers like Advanced Power Electronics Corp. ship millions of power MOSFETs to makers of motherboards, graphics cards and other high volume consumer products. A few years down the line, the PCs containing those boards will have been junked and recycled, leaving certain 'enterprising' people – usually based in Asia – to de-solder the components, clean up the leads and then sell them to a broker.

Now we all want to be 'green' these days – in fact this magazine often celebrates environmental advances through new low power technology and the 'Green (or is it 'Blue', Bodo?) Product of the Month'. However, the type of recycling that we have just been discussing has obvious risks and potentially very damaging consequences. Careless de-soldering can induce excessive thermal shock, and the de-soldering process is unlikely to have been undertaken with any consideration paid to ESD best practice. All these factors can have a serious effect on reliability – especially long term reliability.

How often do such re-cycled parts get into the supply chain? It's impossible to get an accurate view, but just for fun, Google 'electronic component brokers' and you'll see a huge number of different names appear. These guys have to be getting their stock from somewhere. What's worse is that some well-known distributors will also be buying through brokers. They may be being 100% transparent with their customers by admitting that they are sourcing parts out of franchise, but the simple fact is that no one will know the true provenance of every device bought in this way.

As well as the problems of counterfeit or recycled components, buyers of power semiconductors face another problem: no two makers of nominally similar parts use exactly the same process recipe – and sometimes the recipe differ widely. For example, I know of at least 10 manufacturers of standard 10m Ω 30V MOSFETS, and every one has their own recipe. So devices with the same spec can be totally different and can exhibit hugely different second order characteristics. Switching characteristics will vary with parts being slower to switch on and off, and ruggedness will also be affected. Efficiency can be compromised and thermal performance impacted.

Put candidly, there is no such thing as a paper qualification; users must test and qualify samples of a different discrete component or power IC in the system in a lab before putting it into production.

There is one final problem which adversely affects the supply of discretes and simple power ICs: allocation of wafer capacity based on revenue per wafer. Large general semiconductor producers offer a wide range of parts, most of which will have a higher selling price than your average MOSFET, LDO or regulator, for example. So if a manufacturer hits a capacity limit, he is going to opt to produce the higher-priced parts so that his revenue/wafer is maximised. This can lead to shortages and increased leadtimes. A similar problem exists with packaging, where popular package types are used for a broad range of products with a range of selling prices, and manufacturers may concentrate only on the higher priced packages, with resulting shortages in other package styles.

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Electronics Industry Digest

By Aubrey Dunford, Europartners

SEMICONDUCTORS
Measured in Euro, semiconductor sales were € 2.224 billion in September 2012, down 0.2 percent on the previous month and up 0.2 percent versus the same month a year ago, so the WSTS. On an YTD basis semiconductor sales declined by 4.6 percent versus the same period in the year 2011. Measured in dollars, sales on the European Semiconductor market in September increased by 0.7 percent compared to August. Main drivers for the September growth were discrete semiconductors (up 2.2 percent), optoelectronics (up 0.6 percent), sensors & actuators (up 1.7 percent), MOS microcontroller devices, (up 1 percent) MOS microprocessor units (up 1 percent), and total logic ICs (up 1.9 percent).

X-FAB Silicon Foundries has increased its share in the German-based MEMS Foundry Itzehoe (MFI) from 25.5 percent to 51 percent – becoming the majority shareholder – and also renamed MFI as X-FAB MEMS Foundry Itzehoe. These moves reflect X-FAB's focus on MEMS manufacturing services and technologies. The Itzehoe site complements the MEMS capabilities and resources of the recently announced X-FAB MEMS Foundry in Erfurt, adding technologies for micro sensors, actuators, microoptical structures and hermetic wafer-level packaging processes. X-FAB MEMS Foundry Itzehoe will continue its long-term cooperation with the Fraunhofer ISIT MEMS group to accelerate the exploitation and commercialization of existing and emerging technologies, applications and intellectual property for automotive and other markets.

In order to improve its profitability, BE Semiconductor Industries, a Dutch manufacturer of assembly equipment for the semiconductor industry, announced a headcount reduction plan to reduce its personnel costs by € 11 M on an annualized basis. The plan calls for a reduction of approximately 13 percent of Besi's total worldwide headcount of 1,674 at June 30, 2012 of which approximately 55 percent represents a decrease of temporary personnel and the balance from contract personnel.

Brooks Automation, a provider of automation, vacuum and instrumentation solutions for multiple markets including semiconductor manufacturing, has entered into a definitive agreement to acquire Crossing Automation, a Californian company which provides automation products primarily to semiconductor Front End markets. The cash purchase price is $ 63 M. For the trailing twelve months ended September 30, 2012, Crossing had revenues of approximately $ 51 M, and operating profits of $ 3 M.

Soitec and Shin-Etsu Handotai (SEH), the world leader in the manufacturing of silicon wafers announced a licensing extension and expanded technology cooperation agreement. The new partnership includes an extended 10year licensing agreement between the two companies and establishes a new level of joint technology cooperation. It will facilitate the development and wafer supply of Silicon on Insulator (SOI) wafers to meet major market opportunities such as SOI for RF devices, FinFETs on SOI and Fully Depleted (FD) planar circuits.

OPTOELECTRONICS
Flat panel display (FPD) manufacturing equipment spending fell 69 percent Y/Y in 2012 to $ 3.8 billion— making 2012 the weakest year in history for FPD equipment makers, so NPD DisplaySearch. Despite the challenges facing the FPD industry, including slow demand growth as TV and PC markets mature, 2013 offers hope of significantly improved conditions. Spending on manufacturing equipment for FPDs is forecast to rise 121 percent to $ 8.3 billion in 2013. The majority of FPD equipment spending in 2013 will be used for new low temperature polysilicon (LTPS) fabs or conversion of a-Si (amorphous silicon) capacity to LTPS for use in both TFT LCD and AMOLED production.

PASSIVE COMPONENTS
PCB supplier NCAB Group, with headquarters in Sweden, has completed the acquisition of P. D. Circuits, a US-based PCB supplier. NCAB Group will, after the acquisition, have sales in excess of $ 100 M with 13 locations around the world and 210 employees, including 70 people located in China.

Revenues for German PCB manufacturers in August were marginally higher compared to the previous month, so the ZVEI. Incoming orders in August went up by 24 percent on-month, while order volume exceeded the 10-year average for August by 6 percent. Total orders from January to August were just 3 percent lower compared to the same period last year. Overall, the book-to-bill ratio reached 1.01. Compared to last year, there were around 5 percent less people employed in the PCB segment.

OTHER COMPONENTS
TDK announces that TDK-Lambda is investing in new production equipment at its power supply manufacturing facility in Ilfracombe. TDK-Lambda's decision for this new investment in the UK is primarily driven by the company's aggressive new products development strategy.

DISTRIBUTION
Avnet sales for the quarter ended September 29, 2012 decreased 8.7 percent year over year to $ 5.87 billion. Avnet reported net income of $ 100.3 M, compared with net income of $ 139 M in 2011. Avnet has now completed $ 90 M of cost reductions that will positively impact the December 2012 quarter, and is in the process of identifying additional cost reduction actions that will impact future quarters. Avnet Electronics Marketing revenue decreased 4.3 percent year over year to $ 3.65 billion. EMEA was down 7 percent in constant currency. Avnet Technology Solutions declined 15.1 percent year over year to $ 2.2 billion.

Mouser Electronics has signed an expanded global distribution agreement with Hirose Electric Company, a Japanese specialty manufacturer of high-quality connectors. Mouser is now authorized to distribute Hirose's full product portfolio to its 375,000-plus customers across the globe.

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: eid@europartners.eu.com

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Immediate Growth Opportunities for Portable Power

By Richard Ruiz, Research Analyst, Darnell

The worldwide power packs (battery packs) for portable electronic devices market is projected to see substantial growth over the next five years. The addition of new power architectures, smaller form factors, more efficient designs and improved power management technology, combined with growing demand in a variety of applications ranging from power tools to small electronic devices is expected to create new opportunities. Made up of the communications, computer, consumer, portable medical and portable military segments, the battery packs industry will experience a number of significant opportunities over the forecast period, as manufacturers scramble to produce products designed for the latest demanding applications.

There are four different chemistry types covered in this report: Lithium-ion (Li-ion), Lithium Polymer (Li-polymer), Nickel-Metal Hydride (NiMH) and nickel–cadmium (NiCd). These are the four main chemistry types that dominate today's portable battery pack market. Of these, Li-ion is expected to make up the largest number of battery packs over the forecast period, while Li-polymer, fueled by the growing demand for increased energy density and thin form factor necessary for today's electronic devices, is projected to be the fastest growing over the forecast period. Growth in the NiCd sector is expected to be extremely modest, while the NiMH sector will see a decline in both unit and dollar market.

Although the forecasts presented in this report include both NiMH and NiCd chemistries, the focus is heavy on Lithium-ion (Li-ion) technology, which is expected to make up about 95.0% of both unit and dollar market over the forecast period. Lithium has emerged as the preferred choice for consumer electronic products such as laptops, mobile phones, MP3 players, GPS, ebooks and other portable devices. In fact, as this report will detail, additional applications including as power tools, medical, and military equipment are increasingly transitioning to Li-ion technology.

The portable power battery pack forecasts presented in this year's edition are based on a detailed and quantitative analysis of 20 applications divided among five categories. Our forecasts show that the worldwide battery power pack market is expected to grow from 2.5 billion units in 2012 to 4.1 billion units in 2017. Driven by all five segments, especially the large communications segment, it is projected to grow at a compounded annual growth rate (CAGR) of 10.2%. The dollar market will grow at a somewhat slower pace, at a CAGR of 9.1%. The larger and more expensive batteries in the computer segment are expected to fuel this growth, which is projected to increase from $13.8 billion in 2012 to $21.3 billion in 2017.

In an effort to more accurately reflect recent updates in consumer preferences, regulation, advancements in technology and preferences in battery chemistry, a number of important changes have been made since the last edition. Among them are the addition of several new applications and the elimination of others. New applications that have been added to the forecast include tablet computers (which, due to significant growth potential and unique functional characteristics, were taken out of the traditional notebook category and put into their own category), ultra books, pico projectors, ebooks, universal battery packs, gaming devices and portable military.

The communications segment is expected to maintain the largest unit market over the forecast period. Smart phones and their applications are projected to be the catalyst behind the growth in this segment. In 2012, just over one-third of all the devices sold are projected to be smartphones, which continue to grow well even as the overall market (which includes feature phones) slows down. Despite the high degree of commoditization of the battery industry in this segment, it will record the second largest dollar market and will present a significant opportunity.

The computer segment will record the second-largest unit market and the largest dollar market covered in this report. Fueled primarily by the sales of notebook computers and tablets, the unit market for this segment is also projected to see the highest rate of growth among application categories. As both notebook computers and tablets continue to become functionally richer, their demand for power and runtime increases and they require larger and more expensive power supplies.

The consumer segment has the largest number of applications with eleven, with several new promising applications including ebooks, pico projectors and universal battery packs. In contrast to the unit market, which includes a large number of similar sized applications, the dollar market will be dominated by two applications, digital cameras and power tools, making up over 60.0% of the dollar market over the forecast period.

The portable medical device market is one of the smaller segments covered in this report. Despite its size, it will remain one of the more promising markets for the battery packs industry. Traditionally, the low volumes of medical device sales have often deterred companies from entering the medical power supply market, particularly with the large number of regulatory hurdles involved. However, the evolution of the market toward home-based, consumer products is expected to change this landscape. Over the forecast period and beyond, the number of applications using portable medical devices is expected to continue growing. As they do, they take on larger and more complicated tasks, many of which require larger and more expensive batteries, further expanding the opportunities for manufacturers.

The Portable Military market is one the new applications in this report. Like the Medical sector described above, the portable military sector must meet and comply with a number of strict standards and regulations that do not typically apply to other applications, and due to the rigorous design specifications and barriers to entry, the market is expected to remain challenging. In addition, government defense contracts are competitive, and companies often need the reputation

and experienced track records to successfully procure military projects. This section is unique in that it is one of the few areas where traditional NiCd technology is expected to continue to play a significant role. However, It will remain one of the smaller markets covered in this report and will not offer the number of opportunities as the other applications

Encouraged by the success of Li-ion technology, there are a number of variations of the basic lithium chemistry including Lithium Nickel Manganese Cobalt Oxide, Lithium Nickel Cobalt Aluminum, Lithium Sulfur and others that are in development for specific applications. Although many of these chemistries are not specifically designed for portable power devices, ongoing research and development in these areas may allow their use or have implications for portable electronics applications in the future.

Although lithium-ion continues to gain ground in a number of applications, other technologies such as ultra-capacitors, fuel cells and thin film batteries are considered to be potential long-term alternatives to standard lithium-ion battery packs. Each of these technologies has its advantages which include: quick surges of power with thousands of life cycles, greater energy density and much smaller form factors combined with higher energy storage capacity. Although each of these technologies is either relatively new or still early in the commercial stages of development, they are expected to have an impact the battery packs industry over the coming years.

The manufacture and transportation of lithium batteries also presents a number of regulatory and safety issues. In order to address some of the safety risks associated with the use of lithium batteries, a number of standards and testing protocols, developed by a variety of public and private organizations, have been developed to provide manufacturers with guidance on how to more safely construct and use lithium-ion batteries. The product safety standards presented in this report have been developed through a consensus process, relying on participation by representatives from regulatory bodies, manufacturers, industry groups, consumer advocacy organizations, insurance companies and other key safety stakeholders.

This report looks at the original equipment manufacturer (OEM) market, and will not include the battery pack replacement market. The market figures presented are based on the cost of power packs to OEMs, not to end users. Over 60 tables, graphs and illustrations are presented in this report covering the worldwide battery packs market for twenty applications. The focus of this comprehensive analysis is to provide decision makers with a detailed and insightful look at the current and future opportunities available in the portable power battery packs market.

More information on this 144-page, seventh-edition report is at:

www.darnell.com/powerpacks/

Medium-Voltage High-Speed Switches with IGBT Power Semiconductors

Solid-state semiconductor circuit-breakers have been used successfully for years in low voltage applications in the form of solid-state relays or, in the higher power range, using larger discrete power semiconductors. Since they work without any mechanical switching contacts, there is no mechanical wear and no need for any maintenance with this type of switch.

By Johannes Soldan, Werner Bresch GvA Leistungselektronik GmbH

Depending on the choice or design of the semiconductor component, the number of switching cycles is practically unlimited. The switching speeds, the minimal switch-on times and the switching cycles are no longer dictated by the shortcomings of a mechanical switching operation.

These properties would be extremely useful at higher voltages as well, in particular if high speeds are required in order to protect plant components or the number of switching cycles or the pulse length prohibits the use of mechanical switches.

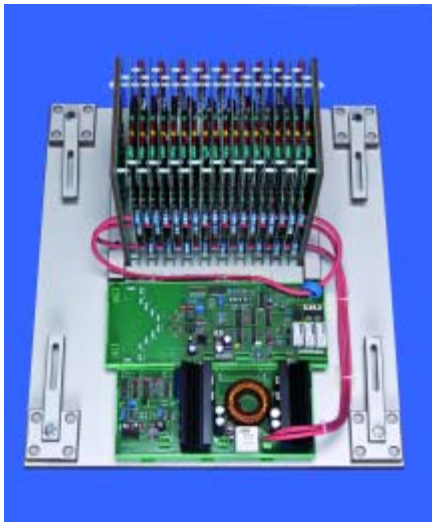

Figure 1: Medium Voltage High Speed IGBT Switch with Low side Gate Controller Unit and Low Side Auxiliary Power Supply

IGBT power switches for 16kV DC operating voltage

While the operation, driving and monitoring of IGBTs in the usual applications involving operating voltages of up to around 1000V DC can be regarded as „state of the art" and is therefore judged to be managed easily the situation in the medium-voltage range is entirely different. Industrially produced components and electronics such as IGBT drivers, auxiliary voltage supplies for the IGBT drivers, transmission electronics for control signals and error feedback of the IGBTs as well as sensor systems for monitoring are either non-existent or cannot be used on account of insufficient insulation strength. Usually it is also not possible to reinforce such components due to the high insulation requirements.

The solution leads to a combination of switching topologies typically employed in medium or high voltage applications using bipolar power semiconductors and control and monitoring concepts known from the operation of BiMos components.

The IGBT circuit breaker, which is presented below, has been designed for an operating voltage of 16kV DC and a permanent load current of 10A DC. The maximum turn-off current is 300 A peak. For the operating voltage of 16kV DC, a total of 18 IGBTs with a reverse voltage of 2500V are connected in series. The switch can also be scaled to other currents and voltages.

Insulation coordination

As already described, the IGBT DC switch consists of a total of 18 individual stages connected in series in order to reliably block the operating voltage of 16kV DC. The basic prerequisite for such a configuration is a fail-safe management of the insulation requirements of the individual stages among each other as well as with regard to ground / earth potential in relation to the individual stages and the overall mechanical structure of the complete series circuit. The assembly and the used materials must be designed to provide the necessary insulation values and also clearance distances and creep age distances. In this case it is less about achieving very high values for the insulation voltage because this represents just one voltage value which is applied to the device under test for a defined short period of time without any voltage discharge or flashover occurring. Consideration is therefore given to whether there is any initial damage to the insulation, e.g. caused by tracking, when the insulation test voltage is applied. In this case subsequent insulation tests may only be carried out with a reduced test voltage. The insulation voltage has no significance in respect of forecasting the resistance to ageing of the insulation sections.

At this point it would be much more reasonable to specify a voltage value for the partial discharge dielectric strength, ideally the

Figure 2: Visual Control and Failure Feedback

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value for the corona inception voltage which is always higher than the corona extinction voltage. If no partial discharge occurs when a test voltage is applied, it can safely be assumed that the insulation barrier is not subject to any ageing provided that the defined levels of contamination are complied with.

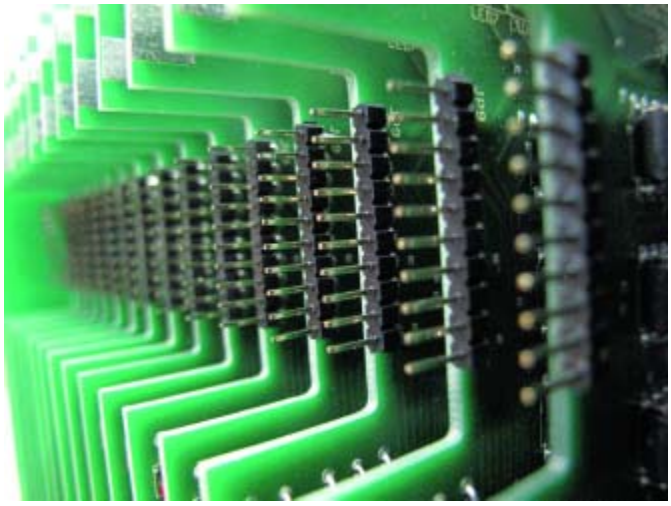


Figure 3: Electronic Control, Communication and Failure Feedback Interface

IGBT in series circuit

As is common knowledge, a switching power semiconductor must be activated by control electronics. This requires an auxiliary voltage supply which provides the necessary control power taking into account the insulation coordination previously described.

In addition, it must be ensured that the three operating states of the switching power semiconductor „static off", „transition on" and „transition off" are also safely managed taking account of the insulation coordination which has been described.

Finally, the switching power semiconductors in such a highly complex system must be monitored to ensure that they are working safely and that the different operating states are managed safely. Possible malfunctions must be reliably identified and reported back taking account of the insulation coordination.

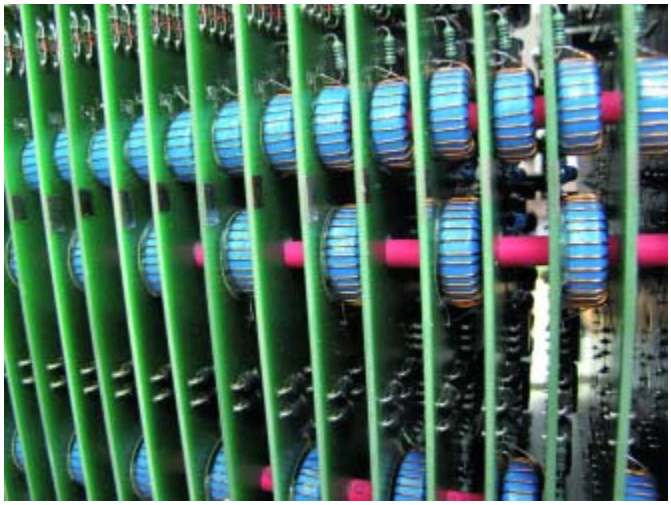


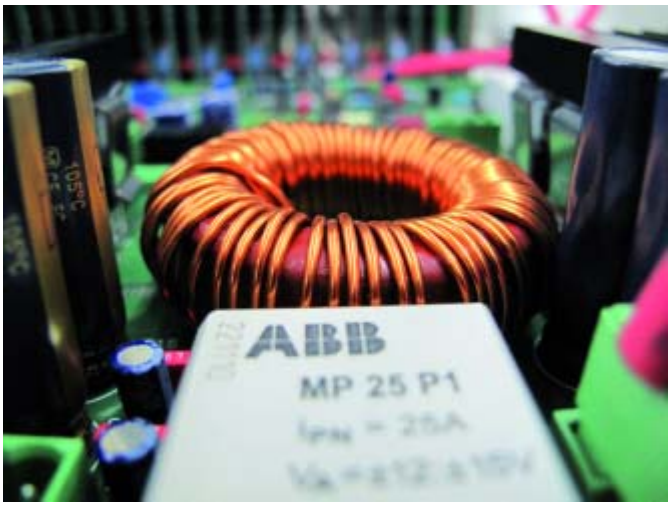
Figure 4: Current Loop Auxiliary Power Supply and Gate Control Transformers on High Potential Side

Auxiliary voltage supply at the medium-voltage level

For generating the control power which is required for activation, the following approaches to solving the problem are possible:

Use of individual auxiliary power supply units which ensure the required insulation among the individual stages and with respect to earth potential: In addition, these power supply units should also have a small coupling capacitance in order to achieve a high level of noise immunity between the individual stages. In our example, 18 such power supply units would be required. This is an expensive solution which takes up a considerable amount of space.

Generation of the required control power from the load circuit: Here each stage would automatically be supplied with power when the load circuit is switched to the operating voltage. However, in this case the control electronics pass through all voltage levels from 0V up to the rated operating voltage and thus voltage values which result in an undefined operating state. In order to ensure operational safety and reliability, such a solution has not been employed.



Figured 5: Current Loop Auxiliary Power Supply on Low Potential Side

In the described application an auxiliary voltage supply was implemented in the form of a current loop which is looped through all switch stages. Each stage can take power from the current loop by using a ring core and thus supply power to the electronics. The insulation is achieved by the use of a special high voltage cable. This means that a high level of operational safety and reliability is achieved with a small coupling capacitance and compact construction volume.

Voltage sharing

One essential aspect for the operational safety and reliability of such a system is the secure control of voltage sharing within the 18 switching stages both when the switch is in the static state and during switch-on and switch-off.

When the switch is in the static state, external components ensures even sharing of the voltage between the individual stages, taking account of the corresponding IGBT data sheet values. Possible incorrect voltage sharing on account of parasitic earth capacitances should be taken into account with spatial optimisation and corresponding wiring measures.

Controlling voltage sharing during the switch-on and switch-off of the IGBTs is a much more complex task. The basic prerequisite for even

voltage sharing is to ensure that the IGBTs used have a switching characteristic that is as identical as possible and that the switch commands have an identical processing time. For this reason, a transformer-based form of control was chosen and implemented instead of an optical form of control. For this purpose, a transformer was configured discretely in which the switch signal is initially converted into a current signal which flows through each switch stage and is converted back into a switch signal there. External wiring measures complete the voltage control concept.

Control and monitoring

In addition to the semiconductor elements, each switch stage also consists of a control and monitoring unit, a voltage supply, a switch signal receiver and switch signal transmitter. These are fitted together on a printed circuit board and are connected to the adjacent stages by means of pins.

A central control logic circuit takes care of the communication and reports the switching status and further status signals (e.g. temperature, supply voltage) to the higher-level controller. In addition it also sends the switching signals to the switch stages and monitors their status.

Summary

As a result of dividing the switch into many identical switch stages, it is possible to adjust the blocking capacity of the entire switch without any problems. This makes it possible to use the switch in a very wide voltage range of up to several 10kV DC.

It is also possible to further upscale the current-carrying capacity of the switch by connecting larger or several power semiconductors in parallel.

This opens up numerous application possibilities in which high voltages need to be switched, e.g. protective circuit breakers, various converter topologies (DC/DC converters for high voltage) etc.

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EN50155 Compliance to Railway Standards

The whole process requires dedication and commitment

"Ich verstehe nur Bahnhof" is a common German phase which translates literally into "I understand only train station", but has the same meaning as "it's all Greek to me!" I must admit, it was the first thought that popped into my head when I started reading through the European Standard EN50155: Railway applications – Electronic equipment used on rolling stock.

By Steve Roberts M.Sc. B.Sc.; Technical Director; RECOM Development in Gmunden, Austria

In fact, the EN50155 standard is one of the few well-written EN standards as it is simultaneously precise and encompassing. However, the price of this clarity is a multi-layered structure which calls on many other standards (36 in total). This article is an attempt to peel back some of the onion-skin layers to explain how the standard translates into a practical power supply specification.

Figure 1: RECOMs new RPR-Family of DC/DC converters is designed to meet the needs of "on board" and "track side" railway applications. The converters are available with power ratings of 20, 30, 40 and 50 W at efficiencies of >89%.

The first section in the standard after the usual scope and definitions preamble concerns environmental conditions of operation, the first major point being the ambient temperature. The specification is surprisingly relaxed compared to the typical industrial operating range requirements of -40°C to +85°C, as only the highest specification of TX rated parts need to cover this ambient temperature range for just 10 minutes during start up conditions. On the other hand, the expectation that rolling stock electronics function reliably over many years of operation is only realistic if the temperature range is benign. In practice, the operating temperature range means three things for the design of a power supply; firstly, the power supply must work efficiently (85% or higher) to reduce the dissipated power that would be otherwise lost as heat, secondly, this efficiency must remain effectively constant over a wide range of input voltage and load conditions, and thirdly, usually some form of thermal management is required such as a heat sink or baseplate.

Conversely, the shock and vibration requirements are anything but benign, as one would expect in such a hostile environment as rolling stock. The requirements are detailed enough to warrant the calling up of a separate standard, EN 61373: Railway Applications – Rolling stock equipment – Shock and vibration tests, just to explain how to conduct the tests to fulfil EN50155. The shock and vibration requirements are split into three application categories of increasing severity; Body mounted (Class A and B), Bogie mounted and Axle mounted. While the axle mounted requirements are astounding (up to 30g for 5 hours with 1km/s shocks), the body mounting specs are on a more human scale (less than 1g vibration, 5g shocks). As almost all power supplies will be body-mounted in the railcar, shock and vibration compliance is not such a big issue as long as no component hits resonance or is poorly mechanically supported. Obviously the smaller and lighter the power supply, the better for shock and vibration.

The next section in the EN50155 standard covers the power supply requirements. The nominal input voltages are 24, 48, 72, 96 and 110VDC, of which 24, 48 and 110 are the most commonly used. Although not covered in the standard, 36V is also often requested. The standard defines the continuous input voltage range as being between 0.7 and 1.25 nominal, with short-term fluctuations between 0.6 and 1.4 being allowed. In practice, power supplies must work continuously between 0.6 and 1.4 nominal as no "deviation of function" is tolerated.

Nominal Input Voltage (Un)	Minimum (0.6 Un)	Maximum (1.4Un)	4:1 input range
24V	14.4V	33.6V	10-40V
(36V)	21.6V	50.4V	18-72V
48V	28.8V	67.2V	18-72V
72V	43.2V	100.8V	40-160V
96V	57.6V	134.4V	40-160V
110V	66.0V	154.0V	40-160V

Table 1: Input voltage ranges

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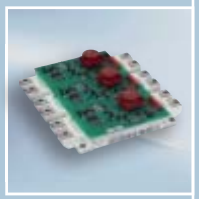

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A basic rule-of-thumb for DC/DC converter design is that a 4:1 input voltage range is the practical limit for most typical designs. Thus all of the nominal input voltages can be covered by just three standard converters (see column 4 above). There are special DC/DC converters available that cover the entire 11:1 range and while an all-in-one design sounds attractive, care has to be taken that high efficiency is maintained across the entire input voltage range. It may be that using three interchangeable converters instead of just one is better in terms of reliability, efficiency and compactness. One final point to mention is that EN50155 supersedes the French railway standard NFF01-150, but for backwards compatibility the old NFF maximum input voltage of 1.6 nominal (176V with 110VDC supplies) is sometimes requested.

The input voltage specification also includes a requirement to deal with supply interruptions. Class S2 requires the power supply to still deliver an output during a 10ms power-outage. The 10ms loss of supply can only be bridged using capacitors to hold up the input voltage. The size of input capacitor required can be calculated using the formula:

$$C(F) = \frac{20 * Power\ W\ \ * time\ s}{Efficiency * (Unom^2 - Umin^2)}$$

So for a 50W converter with 88% efficiency running from a 48V nominal supply with an 18V minimum input voltage, the bridging capacitor required for 10ms would be:

$$C = \frac{20 * 50 * 0.01}{88 * (48^2 - 18^2)} \cong 58\mu F$$

An additional advantage of having an input capacitor is to smooth out the input ripple voltage. EN50155 specifies that power supplies must cope with a DC ripple factor of up to 15% nominal, but as EN50155 also requires a form of reverse polarity protection (usually a simple diode in series with the DC input), the diode/capacitor combination will automatically smooth out most ripple. Care must only be taken that the peak currents in the diode are taken into account and that the inrush current to the capacitors does not overload any input fuses or over-current protection devices.

An extreme example of the layered approach of EN50155 is the section in the standard regarding EMC, surges, ESD and transients. The standard covers these points in just two short sentences by referring to another standard called EN50121-3-2: Railway Applications – Electromagnetic compatibility Part 3-2: Rolling Stock – Apparatus. The catch is that although the EN50121-3-2 standard is only 20 pages long, it calls heavily on the general industry standards EN55011 and EN61000- 4-2, 3, 4, 5 and 6. Talk about Inception! As it turned out for our railways certified converters, the test report just for EN50121-3-2 alone is 176 pages long. We found that although the converters could cope with the DC input voltage conditions without problems, the transient and ESD requirements meant that we had to add additional transient suppressors and input capacitors to absorb the surges and spikes. The complete input filter for our DC/DC converters is shown in Figure 2. For other manufacturer's power supplies, a more complex or even an active filter network may be required to reach compliance.

The performance and reliability of railway rolling stock is of the highest importance. In this respect it is as dependant on the quality of the electronic equipment used on board as on any other parts. In order to promote good design, the EN50155 sets out requirements for quality management (the manufacturer of the equipment must be ISO9001 certified) and required safety features, such as fault protection and under-voltage lockout. While these features are pretty much standard in most industrial-grade power supplies, EN50155 also sets out other optional (application specific) requirements concerning construction, wiring, connectors, layout and materials as well as providing checklists for hardware and software documentation.

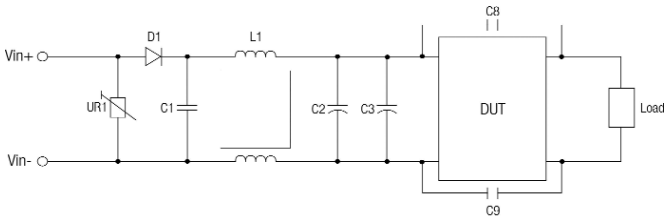

Figure 2: Input filter for our DC/DC converters

The last section of EN50155 sets out a useful checklist of all of the mandatory or optional type approval tests, along with a description of how to carry out the test or a reference to another standard which defines the test and pass/fail criteria. The mandatory tests are a visual inspection, a performance test, a low temperature operation test (minimum operating temperature for 2 hours), a dry heat test (maximum operating temperature for 6 hours), confirmation of operation over the full input voltage range, surge, ESD and transient tests, an electrical insulation test and finally the vibration, shock and bump test. The optional tests (to be agreed with the end customer) are a Damp heat cyclic test (usually required), water-tightness (depending on the final application), Production stress screening and low temperature storage (-40°C for 16 hours). Surprisingly, the EMC test is also given as optional, but as all power supplies must be CE marked, the EMC test is actually also mandatory. Of these tests, only the visual test, performance test and electrical insulation test are required to be carried out on each production batch.

In conclusion, the EN50155 is a standard that needs to be read through a dozen times to pick up on all of the nuances and coded references to other standards, but the demanding application of rolling stock requires that the manufacturing processes must be rigorously controlled in order to ensure consistency of performance. The whole process requires dedication and commitment, but at the end you can say "I really do understand "Bahnhof"!

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The CeraLink™ capacitors offers many benefits for stabilizing and filtering the DC link circuits of power inverters – particularly in comparison with conventional capacitor technologies. Developers of topologies with new fast-switching IGBT modules will profit from this innovation.

By Dr. Günter Engel, Director Innovation Themes, Corporate Material Research and Development and Wolfgang Dreipelcher, Senior Director Global Reference Designs, Epcos

The power semiconductor switches used in power supplies and inverters are determined by two technologies, namely MOSFETs and IGBTs. MOSFETs can be operated at relatively high switching frequencies significantly above 30 kHz, but unlike IGBTs, they have a very large chip surface area. A new generation of IGBT modules from Infineon Technologies operates at frequencies of up to 100 kHz. Line-based and turn-off losses are of about the same magnitude in both systems. Fast IGBTs, whose manufacturing complexity is significantly lower and chip areas are often smaller than superjunction MOSFETs, are the basis of an IGBT3 technology with high switching frequencies and an excellent price-performance ratio.

Fast-switching systems require circuit designs with minimized ESR and ESL values. Accordingly, the passive components – inductors, but especially capacitors – must also keep pace with the high switching frequencies. These in turn permit more compact and lightweight passive components to be used, producing lower losses and increasing efficiency.

Capacitors are at the focus of these developments. They must combine high switching frequencies with low ESL and ESR values as well as an extremely compact design. Conventional capacitor technologies are only partially able to meet these requirements. The EPCOS CeraLink represents a completely new approach: This advanced component is a ceramic multilayer ripple-current suppressor, also known as a link circuit or DC link capacitor; moreover, it functions as a snubber.

New inverter designs possible

The EPCOS CeraLink was developed in the company's Competence Center for Ceramic Components in Deutschlandsberg, Austria. The know-how that formed the basis for this advanced component was gained, among others, over many years in the volume manufacture of piezo actuators. The EPCOS CeraLink offers the advantages of ceramic capacitors without their unfavorable characteristics. The patented multilayer component that is based on antiferroelectric ceramic material with special copper internal electrodes allows both standard IGBTs and the new high-speed types with significantly higher switching frequencies to be used even more economically. This naturally also applies to circuits with corresponding superjunction MOSFETs. The innovative CeraLink combines high capacitance per volume with lowest ESL and ESR values, which thus enables significant improvements in efficiency, reliability and space requirement for future IGBT and MOSFET inverter designs. Moreover, CeraLink is also available in a low-profile SMD design, making it suitable as a snubber solution for integration in power modules. The EPCOS CeraLink components were adapted and continuously optimized for the first designs of special IGBT modules in close cooperation with Infineon Technologies, the market leader in IGBTs. This allowed the best results to be achieved in terms of performance and energy efficiency. For both the EASY automotive series from Infineon Technologies and the corresponding types in industrial applications, all the relevant capacitor parameters and properties were optimized towards more economy and efficiency (Table 1).

Optimized parameters	
Insulation resistance	With typical values of 1 GΩ to 10 GΩ very high, thus resulting in a very low leakage current, especially at high temperatures
ESL	<4 nH and thus extremely low
ESR	Typically <4 mΩ and thus extremely low even at low capacitances, resulting in low losses
Operating temperature	-40 °C to +125 °C (for short periods up to +150 °C), thus also suitable for SiC
Design benefits	
Internal copper electrodes	Lowest losses and extremely high current handling capability
Internal busbar	Optimized for variable use
Various terminal configurations	Terminals for soldering and press-fit assembly technology
Compact case design	Case height optimized for widespread semiconductor modules
Rugged design	Designed for snubber and power applications in industrial and automotive systems
Compatibility	Special types for integration in power modules based on IGBTs, MOSFETs or SiC
Further benefits	
Ideally suited for rapid rise times and high switching frequencies	
Positive DC bias effect on the capacitance	
Active cooling not always necessary	
Easy traceability thanks to QR codes	

Table 1:
Optimized parameters and properties of the EPCOS CeraLink

The first designs of an on-board inverter, the Infineon EASYKIT DCDC, were based on existing OEM specifications for rated voltages of about 400 V DC on the high-voltage side.

The EPCOS CeraLink is currently available in several designs. Its capacitance range extends from 1 µF to 100 µF at rated voltages of 400 V DC and 800 V DC. The various terminal designs are shown in Figure 1. The SMD versions (LP and SMD) are designed for direct integration in semiconductor power modules in view of the restricted space available (Figure 1). They can be soldered, bonded or sintered.

In close cooperation with EPCOS, Infineon Technologies has developed an HV/LV DC-DC demo board with an output of 2.7 kW. The requirements included a high-voltage input range from 200 V DC to 400 V DC – depending on the HV battery used – and a low-voltage output range from 8 V DC to 16 V DC that is typically standard in automobile electronics systems. Furthermore, the demo board had to cover a current range of up to 200 A DC.

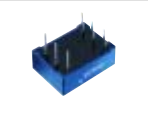
Terminal	Low Profile (LP)	SMD	Soldering pin (SP)	Press-fit busbar (PFBB)
				
Capacitance [µF]	1	5	5 / 20	100
Rated voltage [V DC]	400	400	800 / 400	400
Dimensions [mm] (without terminals)	6.84 x 7.85 x 2.65	12.8 x 8.4 x 8.8	33 x 22 x 11.5	52.5 x 30.5 x 10.5

Figure 1: Various design versions of the EPCOS CeraLink

Nearly 100 EPCOS and TDK components

Various types of circuit topologies are available on the DC-DC converter market. However, the most widely used is the full-bridge circuit with a zero-voltage transition (ZVT) based on MOSFET transistors. Infineon Technologies has redesigned these circuits with various EPCOS components and adapted them to its EASY series of fast-switching IGBTs (Figure 2). They employ a large number of diverse EPCOS and TDK components (Table 2).

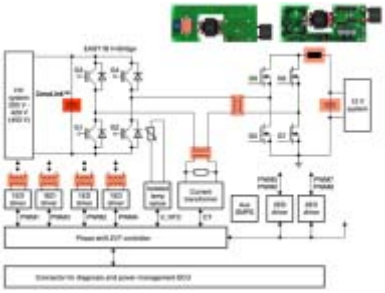


Figure 2: Infineon EASY 2.7 kW inverter

Component		Quantity
CeraLink with 20 µF for 400 V DC	EPCOS	1
Aluminum electrolytic capacitors	EPCOS	3
MLCCs	TDK	80
SMT power inductors	EPCOS	7
PCEM T7921 power choke from the Electromobility Platform with peak current of 225 A	EPCOS	1
PTEM T6973 power transformer from the Electromobility Platform	EPCOS	1
GTEM T7509 gate drive transformer from the Electromobility Platform	EPCOS	4
CTEM T7078 current sense transformer from the Electromobility Platform	EPCOS	1

Table 2: EPCOS and TDK components for fast-switching IGBTs from Infineon Technologies. This circuit contains almost 100 EPCOS and TDK components.

The EPCOS CeraLink combines high capacitance per volume, low ESL and ESR values, as well as a minimum leakage current, and thus satisfies all the requirements of high-speed IGBT modules or MOSFETs. This system configuration also permits high current change rates (di/dt) of up to 10 kA/µs to be controlled. Despite these extremely high potential rates, the generated voltage peaks (V = L * di/dt) are extremely low thanks to the low ESL of the CeraLink.

Parasitic inductances are not only caused by the capacitor. Noticeable stray inductances occur in a normal system configuration for several reasons, including the contacting inside the IGBT module and the feed line to the capacitor. The EPCOS CeraLink allows the values for the feed line to be dramatically reduced to the same extent as the values for the capacitor itself, thanks to its compact design. The compact link to the IGBT module simultaneously attenuates its overvoltages, and a snubber capacitor is usually not necessary. Figure 3 shows the voltage curve at turn-off of the IGBTs with and without an EPCOS CeraLink. The voltage rise is thus only minimal and is within the safe range for the IGBTs. A switching frequency of 100 kHz is used in this case, meaning a ripple current frequency of 200 kHz for the capacitor. Figure 4 shows the impedance and ESR curves as a function of the frequency.

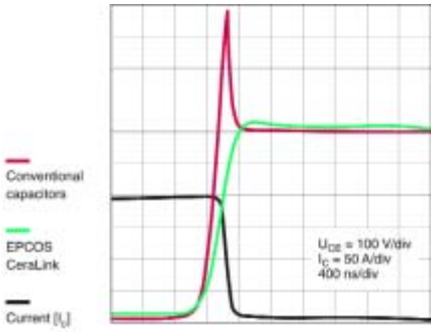


Figure 3: Overvoltage attenuation by the EPCOS CeraLink. Voltage across the IGBT due to parasitic inductances when switching

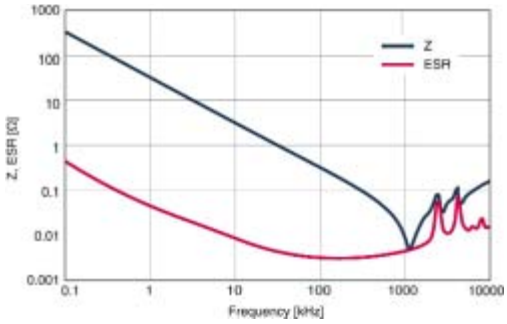


Figure 4: Impedance and ESR as a function of the frequency. Thanks to its very low ESR values, the EPCOS CeraLink attenuates the overvoltage peaks very effectively. As a rule, therefore, additional snubber capacitors are not necessary.

Although the capacitance of the EPCOS CeraLink is usually sufficient for pure DC-DC applications, it may be too low for motor operation, for example. This can be remedied by connecting aluminum electrolytic or film capacitors in parallel, as their high capacitance carries the low-frequency current component. The EPCOS CeraLink then handles the high-frequency component, including the snubber component.

Samples are available to fit Infineon's EASY Modules and may be obtained via the regional sales offices.

The series production currently in preparation makes use of the existing volume technology for EPCOS piezo actuators for fuel injection systems.

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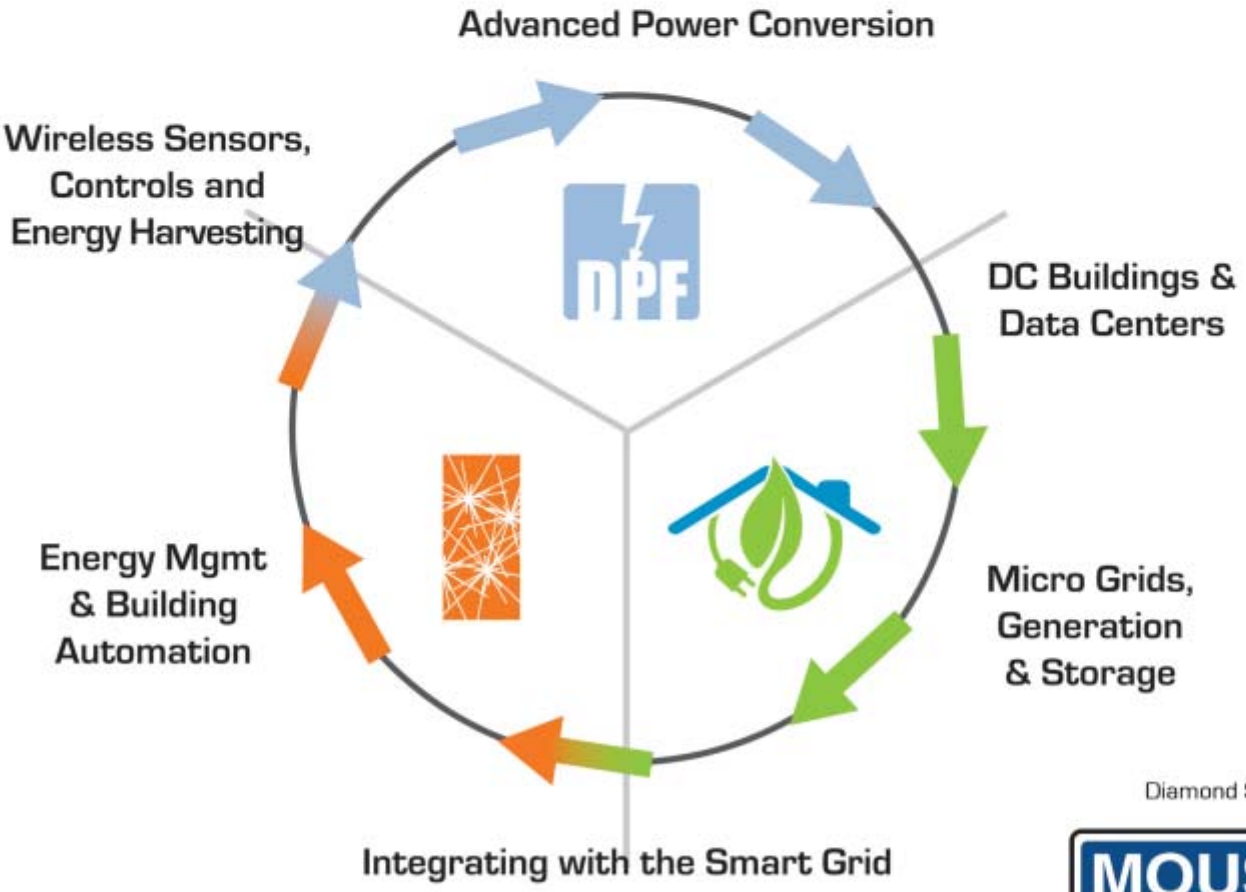

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Thermal Interface, A Key Factor in Improving Lifetime in Power Electronics

Dedicated materials can dramatically improve the thermal situation

In the majority of applications, the thermal interface dominates the thermal transfer with massive influence on the lifetime

By Dr.-Ing. Martin Schulz, Infineon Technologies

Increased demand in lifetime is an ongoing trend especially in applications like e-mobility or renewable energies. Likewise, the demand in power density is increasing as well, leading to contradicting effects. As higher power densities lead to increased temperature levels, higher temperatures result in higher stress levels thus threatening to reduce the lifetime. Though new developments in power electronic components target to increase the lifetime, thermal management becomes more important to fully exploit the benefits from these modern devices.

Basics

Two basic things are most common to semiconductors in all power electronic applications:

- Switching and forward losses lead to temperature increase
- Temperature swing in form of active and passive thermal cycles leads to stress limiting the lifetime

While power cycling is an effect taking place in the range of seconds, thermal cycling is related to longer periods of time. Though the two effects trigger different failure mechanisms, both are characterized by the temperature swing and the maximum temperature reached. A lifetime prediction for a specific design can best be done based on an accurate load profile. Detailed knowledge about load current development, cooling conditions and power semiconductor itself is mandatory to precisely calculate the temperature and temperature swing in the setup, leading to a reliable statement about the expected lifetime.

Simplified thermal model

To evaluate the thermal performance of a given power electronic component based on a load profile, a simplified model as depicted in figure 1 becomes helpful.

The model includes the two sources for heat, the IGBT and the diode die. The dies as a source of losses drive a certain power P_V through the chain of thermal resistances towards ambient.

In case the resistances are known exactly, the junction temperature can be calculated from the according values.

Up to the base plate, the module's construction is responsible for the thermal transfer and therefore defines the thermal performance. The shaded box in figure 1 introduces the thermal path from the module's case to the heat sink R_{thch}. In simulations and calculations, this value is often spuriously considered to be the datasheet value of thermal grease, defined by its bulk conductivity and layer thickness. Experimental results however substantiate that this is a misleading approach.

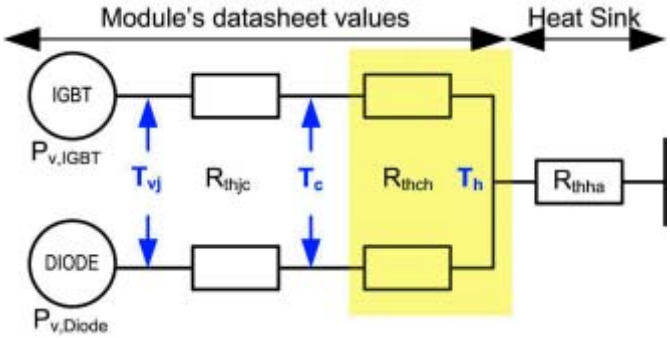

Figure 1: Simplified thermal model of a power electronic setup

It is a challenge, to implement a high performance heat transfer path that is reliable, reproducible and long-term stable. Therefore, Infineon has decided to develop a dedicated thermal interface material and apply it to power modules. This way, designers benefit from a well defined thermal situation eliminating most of the uncertainties in thermal management.

Evaluating the thermal situation

Today, converters in industrial applications are designed to last for at least 10 years or 80.000 operating hours. In windmill applications 20 years are considered. Traction and automotive applications are even more demanding. Reworking the inverter in these fields just because a malfunctioning thermal interface was detected is an expensive and therefore highly unwanted option. A thermal interface material dedicated to power electronic has to cope with these demands.

During the development of a new thermal interface material (TIM) especially dedicated to power electronics, returned material analysis was done on power modules that were destroyed during operation due to exceeding the temperature limits. The analysis also focused on the question what kind of TIM was used. However, first investigations done to pinpoint the failure mechanisms of TIM were inconclusive. It turned out to be difficult to get reliable information in short-term tests. As a consequence, a whole set of reliability tests was done on specimen consisting of power modules mounted to a com-

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Date and venue:
March 5–6, 2013
Hamburg, Germany

Chairman:
Prof. Dr.-Ing. Andreas Reuter, Director Fraunhofer Institute of Wind Energy and Energy System Technology (IWES), Bremerhaven, Germany

An event organized by VDI Wissensforum
www.vdi.de/maintenance

mercially available heat sinks in conjunction with TIM. Environmental tests done included:

- High Temperature Reverse Blocking (HTRB):
- DUT is stored at 85°C with reverse voltage applied. A change in leakage current can be used to determine damage to the device
- H3TRB, a test that applies humidity >85% at temperatures >85°C with reverse voltage applied
- H2S, Corrosive gas tests with sulfurous atmosphere

All these tests were passed without noteworthy changes to the thermal capabilities of the tested setups. Active Thermal Cycling as an electrical stress test followed. The modules were periodically heated by current flowing through the IGBT. 100,000 cycles were done.

The modules were turned on for about one minute and turned off for two minutes afterwards. The current was chosen to achieve a junction temperature of about 120°C. Variations depended on the TIM in use.

Using a thermographic camera, chip temperatures in a test setup were recorded. The setup consisted of three blocks; each carrying two power electronic modules mounted to a common forced air cooled heat sink. The test included six final TIM candidates chosen from more than 80 alternatives that were initially considered. Due to series connection, both modules on one block carry identical currents during power cycling stress. A typical measurement result is depicted on the left side of figure 2.

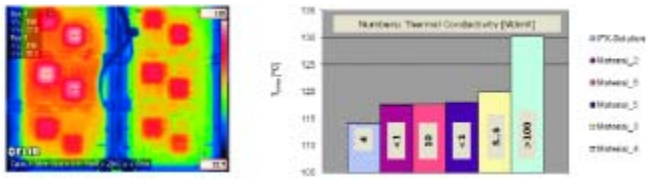

Figure 2: Thermographic measurement of chip temperatures using different thermal interfaces along with data gathered from six different materials

Of utmost interest is the maximum temperature reached within the modules. The measurement equipment allows marking the area to be investigated and determines the maximum temperature within this area; four measurements are taken per square millimeter.

The diagram on the right side 2 summarizes the thermal results gathered from this experiment in a 100,000 cycle test run. It can clearly be seen that there is no correlation between the datasheet value given for thermal conductivity and the chip temperature reached in the experiment.

A cycling test like the one conducted gives a good first insight whether or not a material produces an acceptable result in thermal aspects. In addition it allows observing mechanical aspects. TIM may not be pumped out from below the modules as a consequence of thermal mechanical movement. It may as well not start to flow in vertically mounted conditions if heated to common operating temperatures and in no case should separate due to capillary effects caused from the heat sinks microscopic surface structure. All these effects can easily be investigated in the setup described. However especially for power electronics, a reliable statement regarding long-term stability of the material is mandatory.

It is of great importance for the lifetime calculations that the die's temperature at a given point of operation remains at constant levels throughout the predicted lifetime. The final test conducted was related to higher temperature levels. In High Temperature Storing Test (HTS) the modules are subjected to 125°C for a duration of 1,000 hours. The initial thermal behavior is recorded and once a week the measurement is repeated.

If a change in temperature occurred within these tests it can without a doubt clearly be related to degrading of the thermal interface material. Different, partially unexpected effects became visible. The test results for four materials are depicted in figure 3.

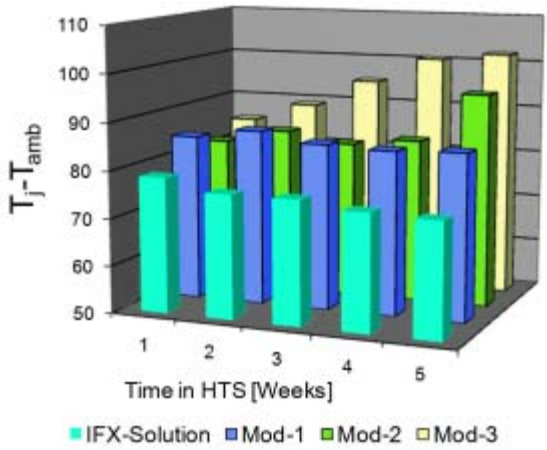

Figure 3: Thermal results from the 1,000h HTS-Test showing the supremacy of Infineon's newly developed material

The material labeled Mod-3 shows continuous degradation as a consequence of ageing. Drying, separation or loss of flexibility are reasons for this effect. Specimen Mod-2 performs quite well at first, however a sudden jump in chip temperature after five weeks in the test gives a clear hint that the material suffers and loses its thermal capabilities. Mod-1 shows the constant behavior as it is expected from TIM in power electronics; however the general purpose component is outperformed by the dedicated material labeled IFX-Solution.

Lifetime Considerations

Based on the findings documented in figure 2 it becomes obvious, that uncertainties in thermal models used for the calculations lead to unpredicted thermal results and therefore to wrong assumptions regarding the predicted lifetime.

A predestined example is found in material 4 displayed in figure 2. Calculating the thermal conditions purely based on datasheet values would have lead to the lowest junction temperature corresponding to the lowest stress and the most optimistic lifetime prediction. Contra-

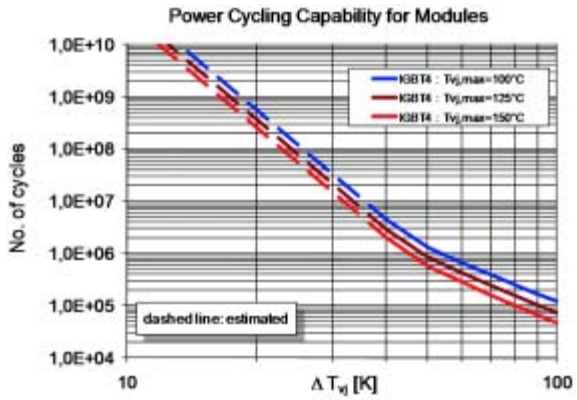

Figure 4: Power Cycling curve for industrial modules based on IGBT4

dictory, the experimental results show, that the measured results were the worst among all candidates. The consequences for the final design would have been fatal. The additional temperature swing turns out to be of a massively detrimental influence which can best be explained looking at the graph in figure 4.

At an ambient temperature of 25°C, the temperature swing ΔT_{vj} using material 4 is measured to be about 107 K. According to the graph for $T_{vj,max}$=125°C, this resembles a power cycling capability of about $7 \bullet 10^4$ cycles. Upgrading the experiment with the best material in the test, a reduction of the chip temperature of 18K can be achieved. This correlates to an improvement in power cycling capability to $1{,}5 \bullet 10^5$ cycles even if the reference remains the line for Tvj,max=125°C; twice the cycling capability as a consequence of thermal interface materials. As the junction temperature drops below 125°C, this estimation is conservative.

Conclusion

Proper thermal management is a key factor in designing power electronic devices. Despite the efforts done to improve the thermal capabilities of every single component, special care has to be taken in building an adequate thermal interface connecting the power electronic components to their heat sink. Dedicated materials, especially designed for these applications can dramatically improve the thermal situation leading to massive improvements regarding the device's lifetime.

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www.infineon.com

Silicon Carbide (SiC) 10KW Interleaved Boost Converter Achieves 99.1% Peak Efficiency

SiC can help maximize performance while maintaining and even lowering overall system cost

This article demonstrates a 10KW interleaved DC/DC boost converter with next generation 1200V silicon carbide (SiC) MOSFETs and Schottky diodes. The converter design proves the advantage of using SiC power devices with high frequency operation compared to conventional silicon IGBT based design.

By Jimmy Liu and Kin Lap Wong, Cree Inc.

The experimental results confirm that SiC enables high efficiency to 99.1%, nearly 1% higher than silicon, and operating temperature improvement of up to 34% while running 50% higher switching speeds. Overall, SiC provides better performance while enabling smaller, lighter and less costly systems.

INTRODUCTION

SiC devices are characterized by a number of promising properties like low switching losses, low on state resistance, high blocking voltages and high radiation hardness. Within the growing list of SiC device vendors and products, Cree introduced the industry's first true normally-off SiC MOSFET to complement its established line of SiC schottky diodes. Cree devices have outstanding performance combined with the ease of design-in offered by a standard MOSFET switch architecture. Driving the SiC MOSFET is similar to conventional Si MOSFETs or IGBTs and can replace silicon in many power applications. With system optimization, the SiC MOSFET goes well beyond silicon enabling high frequency operation without sacrificing efficiency and thermal performance.

Compared to silicon devices, the SiC MOSFET has lower Rds(on) per unit device area resulting in lower conduction losses and lower switching losses due to inherently fast switching. Versus IGBTs, switching losses are further reduced by elimination of IGBT tail currents that result from their bipolar device architecture. Figure 1 shows the ideal Vds or Vce and Id waveforms for a SiC MOSFET and Si IGBT. The SiC MOSFET has lower losses than IGBT for both switching and conduction.

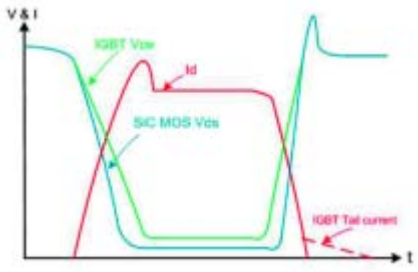

Figure 1: The ideal Vds (Vce) and Id waveforms for SiC MOSFET and IGBT

In order to demonstrate the SiC MOSFET performance, Cree has developed a 10KW interleaved DC/DC boost reference design using Cree's new silicon carbide (SiC) 1200V 20A (CMF20120D) MOSFET and SiC 1200V 20A (C4D20120D) schottky diode. Use of high performance silicon carbide power devices allows a significant performance gain for a 10KW solar inverter, for example, enabling higher frequency operation to 60KHZ-100KHZ and higher efficiency. This reference design can also be used for any other non-isolated boost applications in systems such as EV chargers, Uninterruptable Power Supplies and other high power DC/DC converters.

DESIGN CONSIDERATIONS

An interleaved architecture was chosen to maximize the benefits higher effective switching frequency. The reasons are further discussed later in this section. Figure 2 shows the reference design block diagram. Each channel of the interleaved architecture includes one SiC 1200V 20A MOSFET (CMF20120D) and one SiC 1200V 20A diode (C4D20120D) to achieve the 10kW boost function. A commercially available interleaved PWM controller UCC28220 from Texas Instruments was used to control the two-channel boost converter. The control method is peak current mode with slope compensation so that the converter can

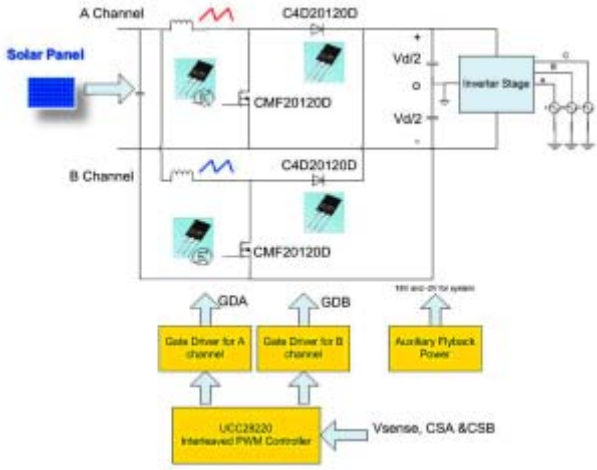

Figure 2: Block diagram for 10KW Boost Converter with Cree SiC power devices

operate at duty cycles over 50% with current sharing for each channel. There are two gate PCB daughter boards to drive the MOSFETs of each channel and one daughter board with the converter control. The MOSFET driver boards are Cree reference design fully described on the Cree Power website, www.cree.com/power. The design utilizes off-the-shelf devices and is optimized for highest efficiency and minimized parasitic parameters to enable ultra-fast switching.

Due to the desired high frequency, the inductor design is very important for cost and power density. IGBT switching losses limit the conventional systems to a maximum of 20KHZ to 40KHZ for a 10KW converter. However, SiC MOSFETs enable increased frequency above 60KHZ without sacrificing system efficiency. Table 1 compares the inductor design solutions when frequency is at 20KHZ for IGBT versus 60KHZ and 100KHZ for SiC. By increasing the frequency, the size and cost of the inductor can be reduced lowering the system bill-of-material cost. 60KHZ produces an inductor with the lowest energy losses and a big reduction in cost versus the 20kHz inductor. At 100kHz the inductor cost is reduced even further while maintaining overall efficiency superior to the IGBT's 20kHz requirement.

Solutions	Silicon IGBT	SiC MOSFET	SiC MOSFET
Frequency	20KHZ	60KHZ	100KHZ
Inductor (uH)	1400	650	200
Core Material	Kool Mu powder +Ferrite	Kool Mu powder +Ferrite	Ferrite
Coil Type	Standard round wires	Flat coil	Litz wires
DCR (mohm)	52	32	25
Size (mm)	2*(128x120X68)	128x120X68	114x79x90
Coil Losses (W)	23.38	14.11	11.39
Core Losses (W)	16.8	6.4	25
Reference Price(USD)	75	35	20

Table 1: Inductor comparisons with 20KHZ, 60KHZ and 100KHZ frequency

With frequencies exceeding 60KHZ, EMI design requires special attention. In this reference design, some experienced approaches were used to limit the influence of noise when switching so fast.

Two channel interleaved boost converter. Figure 3 shows the differential mode (DM) noise difference between two phases with interleaving operation and single phase with non-interleaving operation. Due to interleaving operation, the first order DM noise will occur at two times the switching frequency (2fs) and the input/output ripples can be cancelled. Thus, the EMI filter frequency will be higher for interleaved operation, which means less attenuation is required for the EMI filter and smaller EMI filter components can be used to meet

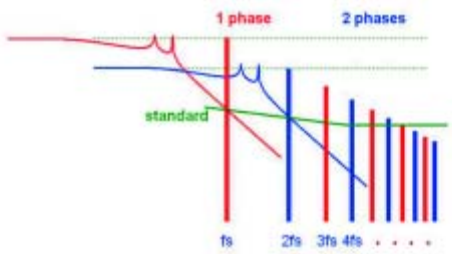

Figure 3: DM noise difference with 1 phase non-interleaved and 2-phase interleaved

the standard. That is the reason for the choice of interleaved system architecture.

Reduce the parasitic parameters for the inductor. When frequency increases, the drain voltage ringing is potentially much higher due to the parasitic oscillation. In order to reducing the ringing at high frequency, a flat coil can be used for the inductor design. Figure 4 shows the parasitic capacitance difference using standard round wire versus flat coil wire. Flat coil wire can enable single layer winding with good flux coupling, dramatically reducing the parasitic capacitance of the inductor. The result is reduced ringing within the Vds switching node.

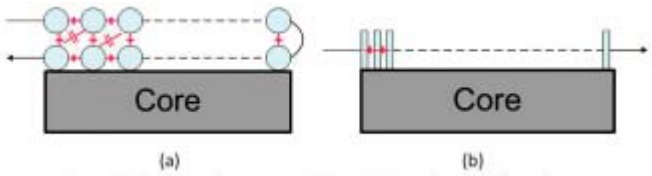

Figure 4: Inductor winding structure: (a) standard round wire; (b) flat coil wire

Minimizing the switching loop for PCB layout. Figure 5 gives the key switching loops of the boost converter. Loop 1 and loop 3 are the main switching loops of power conversion with high dv/dt. Minimizing the layout spacing will help to reduce stray inductance in these loops, thus reducing the ringing on the switching node. In this reference design, the inductor is put under the PCB board and can be directly connected to the MOSFET and output diode to minimize the power loop 1 and loop 3. Since SiC MOSFETs are fast switching devices, loop 2 for the gate drive layout is also critical. Kelvin gate connection with separate source return is highly recommended. Gate driver daughter boards are located to assure as short a driver electrical path as possible. Also, the ground of gate driver daughter is independently connected to the source of MOSFET. An external gate resistor is used as damping resistor to minimize the influence of fast rise/fall time on the gate. However, there is a trade-off for the external gate resistor between EMI performance and efficiency. Lower gate resistance helps to improve the efficiency but reduces the damping effects for gate ringing.

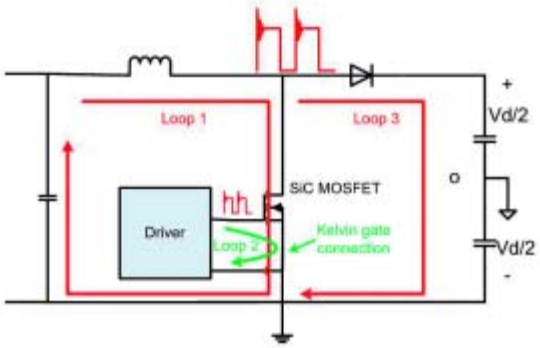

Figure 5: Layout guide line for 10KW Boost Converter

EXPERIMENTAL RESULTS

The physical design of the 10kW boost converter is shown in figure 6. Note the placement of the MOSFET driver boards. The entire system has been achieved in a space of 240mm X 140mm X 210mm. Key specifications for this reference design is as follows:

Input voltage:	200Vdc to 400Vdc
Input power:	Max 10KW
Output voltage:	450Vdc to 800Vdc
Operation Frequency:	60KHZ to 100KHZ for SiC MOSFET

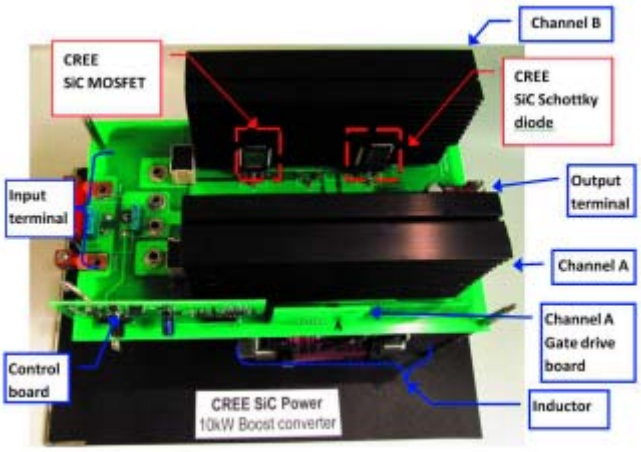

Figure 6: Cree 10KW Boost Converter reference design demo board

EFFICIENCY

The SiC design efficiency data shown in figure 7 below was tested at 200Vdc, 300Vdc and 350Vdc input voltage with 520Vdc output. The maximum 99.1% efficiency was achieved with 350Vdc input voltage and half rated load. The efficiency for figure 7 is tested with external gate resistor of 12ohms giving reasonable balance between efficiency and EMI.

Figure 8 compares the maximum efficiency with different external gate resistances when using IGBT IWD40N120H3 at 40KHZ and SiC MOSFET at 60KHZ and 100KHZ. From the test results, 1200V/20A SiC MOSFET with 60KHZ can achieve highest efficiency for this 10KW boost converter reduces losses by 43% compared to 40A/1200V IGBT. Higher external gate resistance reduces the efficiency but minimizes noise for gate signals. Gate resistor variance will balance EMI performance and efficiency for SiC MOSFETs as is done in IGBT designs.

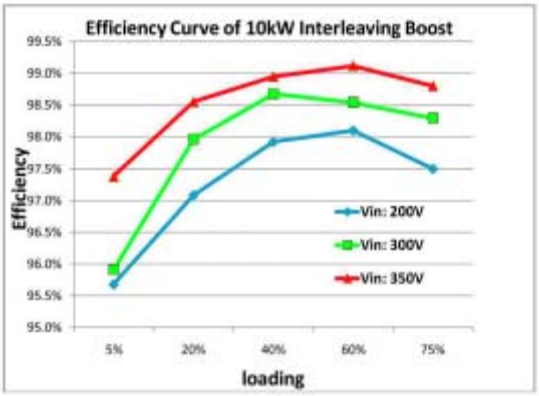

Figure 7: Efficiency curve with Vs loading with Cree SiC MOSFET

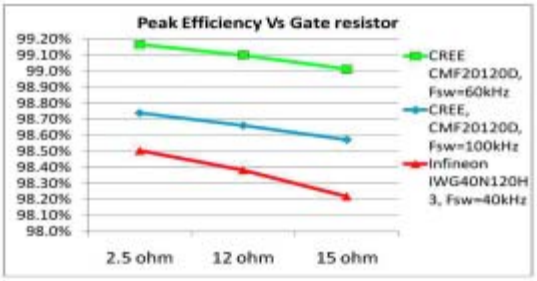

Figure 8: Maximum efficiency curve Vs external gate resistor with SiC MOSFET and Si IGBT

THERMAL PERFORMANCE

In figure 9, thermal performance is compared between the SiC MOSFET and the silicon IGBT implementations. Test results are shown with input voltage of 300Vdc and output voltage of 520Vdc with 2x5KW full load. The ambient temperature was 25DegC with 30W AC fan cooling for the system. Output diodes used for both switch devices were Cree SiC schottky diode C4D20120D assuring a fair comparison for SiC MOSFET and Si IGBT. The SiC MOSFET had lower losses and thus a lower operating temperature by more than 34% versus the Si IGBT.

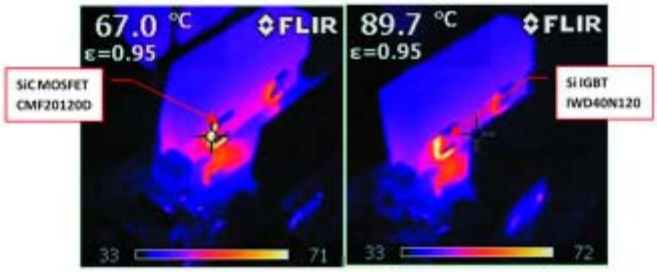

Figure 9: Thermal comparison at full load with SiC MOSFET and Si IGBT

SUMMARY

The 10kW boost converter reference design described in this article clearly demonstrates the advantages of using SiC power MOSFETs and diodes in high power systems. The benefit of using SiC's inherent energy efficiency are broadly displayed in the reduction of energy losses, small system size and weight, lower bill-of-materials cost and impressive reduction in device operating temperature. For boost designs as well as other power conversion circuits, SiC can help system designers maximize performance while maintaining and even lowering overall system cost to build, install and maintain. More and more SiC devices and packaging options are making their way to the commercial market. With them will come wide-spread replacement of silicon devices and power modules in systems from a hundreds of watts to hundreds of kilowatts.

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A Freely Configurable Sensor Module for Current, Voltage and Temperature

Charge and discharge cycles have an impact on the longevity of lithium ion batteries used in electric vehicles and the ultracapacitors used for energy storage in photovoltaic systems. For this reason, it is necessary for battery safety and longevity to be able to establish the state of charge (SoC) and the state of function (SoF). Isabellenhütte has a solution to this challenge in the form of the tried-and-trusted IVT sensor module for measuring current, voltage and temperature, which is now available in a modular design enabling customers to select individual components and configure their own made-to-measure IVT in accordance with their specific needs.

For instance, a customer might choose communication between SPI or CAN interfaces, between a sensor module with or without galvanic separation or many other configuration possibilities. As well as the current input, up to three voltage inputs are possible; these can be fitted with input filters. Likewise, customers can choose from three different power supplies. The IVT can be equipped with an optional overcurrent detection facility. As well as the off-the-shelf products, customers can order specific solutions upon request.

The new modular design of the sensor module has the additional benefit of prompt availability. Jens Hartmann, Sales Director ISAscale, confirms: "Standardising the components saves time when producing the sensor modules individually selected by customers."

Technical data on the IVT Modular: Power supply 7 – 60 V; 5 V 5 – 12 V; Current range 150 A ... 1500 A; Extended current range up to 5600 A; Current precision < 0.1 % (20 °C…60 °C); Voltage range +/- 800 V; Voltage measurement resolution 5 mA … 186 mV; Temperature range -40 °C ... 125 °C; Temperature measurement resolution 1 °C and Operating temperature -40...105 °C.

www.isabellenhuette.de

Broadest Portfolio of R2Couplers™ Isolation Products for Automotive

Avago Technologies announced the addition of three new isolation optocouplers to their R2Coupler family. These new automotive optocouplers provide safe isolation for electric vehicle (EV) and hybrid/electric vehicle (HEV) applications such as onboard charging systems and powertrain inverters in these vehicles while extending the working voltage range of existing R2Couplers optocouplers.

These devices provide high integration of functions in modules, isolated smart gate drives, analog sensing and digital communications. Powertrain inverters, onboard chargers and DC-DC convertersdraw on gate drives for driving power devices like MOSFETs and IGBTs. They need isolation amplifiers to sense high voltage bus levels and digital isolation to communicate status and feedback information from the high voltage side of the optocoupler to the microprocessor on the low voltage side.

The high voltage, high current switching generates a noisy environment. Optocouplers are very suitable with their immunity against high dV/dt transient noise, as well as immunity against electro-magnetic coupling from the high current cables. By providing safe isolation for all isolation needs in EV and HEV applications there is an improvement in power efficiency and a reduction in system power loss.

Avago optocouplers are proven in the automotive field and have established component safety regulatory standards(UL1577, CSA, IEC 60747-5-5).

www.avagotech.com

Low-Side MOSFET Driver in Ultra-Small Four-Pin Package

Micrel, Inc. introduced the MIC4414/15, two low-side MOSFET drivers designed to switch an N-Channel enhancement-mode MOSFET in low-side applications. The devices are ideal for switch-mode power supplies, solenoid drivers and motor-driver applications.

The MIC4414/15 series features a tiny 4-pin 1.2mm x 1.2mm thin QFN package and a 4.5 to 18V operating supply voltage range. It can sink and source peak currents up to 1.5A (3.5 Ohm output resistance at 18V and 9 Ohm output resistance at 5V) and is capable of switching a 1000pF load in 12ns. Operating at a low steady-state supply current, the devices feature 77µA control input low and 445 µA control input high. The device operates at -40C to +125C-degrees junction temperature range.

www.micrel.com

E Series Multilayer Varistors

Mouser Electronics, Inc. announced it is stocking the new E series of EPCOS multilayer varistors, which will protect automotive electronics from current surge pulses.

TDK Corporation has extended its product range of EPCOS multilayer varistors with the new E series, designed to assure protection from current surge pulses in automotive electronics. This new series features high energy absorption capability and bidirectional clamping. Thanks to their innovative glass passivation, the SMD protection components that are qualified to AEC-Q200 with an extended stress test are even more rugged and reliable than before. The range of their operating voltages extends from 14V DC to 40V DC. In addition to greatly reduced leakage currents, the new components are characterized particularly by increased temperature stability up to +150°C. The electrical characteristics of these components remain stable even after exposure to repeated pulses. The portfolio has also been extended by large case sizes up to EIA 2220. The components of the B725*E* series are lead-free and RoHS-compatible.

www.mouser.com/new/EPCOS/epcos-e-MLV-auto/

Fastest Designs with the »Energy Harvesting Solution To Go«-Kit

Energy Micro, LT and Würth Elektronik present the development platform »Energy Harvesting Solution To Go« today.
Developer receive a complete solution from harvesting of the energy, energy management and storage to the application. The transfer of this solution to the development of a battery less product is made easy by providing the selection of the right components, schematics and software examples. The application of the highest efficient components in the market allow to utilize the precious harvested energy for the application.

The two basic parts of the kits are an energy harvesting board and the Giant Gecko starter kit. There are four voltage converters of Linear Technology on the multi-source energy harvesting board. Linear Technology offers the LTC3588 for AC sources up to 20V like for piezo-electric and inductive energy generators. The IC LTC3108 supports very small input voltages of a few mV which are usually supplied by thermo-electric generators (TEG). Solar cells would be utilized ideally with the LTC3105, because this IC provides „maximum power point control“ (MPPC).
The user can select the appropriate energy converter on the energy harvesting board by setting a jumper. Optionally a bigger capacity could be selected if the energy harvesting cannot be performed well continuously.
The Giant Gecko Starter Kit is the second part of this development kit. The board contains the most energy friendly microcontroller EFM32 Giant Gecko with the most comprehensive feature set: ARM Cortex M3, 48MHz, 1024KB Flash, 128KB RAM, USB, LCD Control, Low Energy Sense, etc..
All necessary development tools, code examples, software libraries and application notes can be found in Energy Micro's Simplicity Studio.
The Giant Gecko Starter Kit can be connected by a 20 pin expansion header to the energy harvesting board. You can connect all starter kits of the EFM32 family – which consist of 240 compatible parts (4KB-1024KB Flash, 24-120pins) – to the energy harvesting board by this expansion header.

www.we-online.com/harvest

Wireless Network Processor

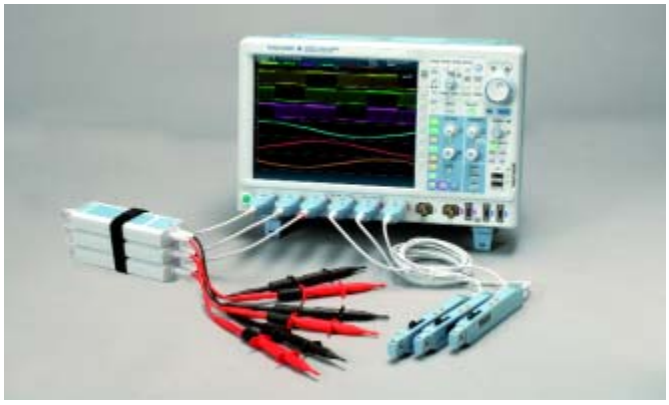
Texas Instruments announced that the CC2538 is the industry's first ZigBee® wireless network processor to offer the three most popular ZigBee standards for one end-device (ZigBee Smart Energy™, ZigBee Home Automation™ and ZigBee Light Link™). Now a single end-equipment can support these three standards, offering a seamless user experience with fast switching between each standard making it seem like concurrent operation. In turn, manufacturers of smart meters, home appliances, home gateways and connected lighting products are able to deliver better quality of service.

The CC2538 ZigBee network processor and Z-Stack™ 2.5 with ZigBee and ZigBee PRO support offer the broadest feature set, which can be tailored for specific end-device(s). With a CC2538-enabled device, consumers can more easily network within their homes as well as monitor and interface to the smart grid to save money and energy. The CC2538 features a robust IEEE 802.15.4 radio and a powerful ARM® Cortex™-M3 microcontroller system. All security operations are handled by dedicated accelerators, leaving enough processing power and memory to handle multiple ZigBee standards concurrently.

www.ti.com

8-Channel Mixed-Signal Oscilloscope

The Yokogawa DLM4000 is the industry's first mixed-signal oscilloscope to feature eight channels. Combining the large screen and 8-channel capability of Yokogawa's earlier 8-channel DL7480 oscilloscope with the mixed-signal technology of the company's pioneering DLM2000 Series, the new instrument is ideally suited to test and debugging applications in the embedded systems, power electronics, mechatronics and automotive sectors.

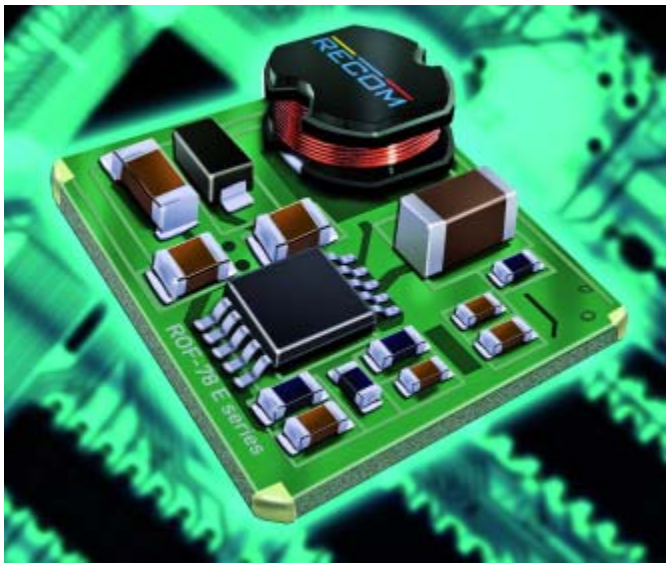


"As intelligent control permeates more and more sectors of the industry from consumer electronics to industrial drives, the signals that engineers need to look at for testing become faster and more complex", comments Terry Marrinan, Yokogawa's Vice President, Test & Measurement, for Europe & Africa: "As a result, the four analogue channels of the traditional oscilloscope are no longer adequate to address these challenges – hence the need for an 8-channel instrument like the DLM4000."
The DLM4000 Series comprises two models, with bandwidths of 350 and 500 MHz and a sampling rate of 1.25 GS/s (gigasamples per second), expandable to 2.5 GS/s with interleaving. The channels can be allocated as eight analogue channels or seven analogue channels plus one 8-bit digital input. A future option will add 16 more channels of logic to allow seven channels of analogue plus a 24-bit digital input.

www.tmi.yokogawa.com

Low Cost SMD DC/DC Switching Regulator Module

Recom has released a new low cost SMD switching regulator module for board-level power supplies. The ROF-78E is a low profile, postage-stamp-sized SMD DC/DC power supply module designed to provide 5V or 3.3V at up to 0.5A continuous load (0.95A peak). The wide input voltage range of 5V to 36V has been chosen to accommodate standard fixed 12V or 24V bus supply voltages as well as lead acid battery supplies. The module is a complete SMD DC/DC power supply that requires no external components for normal operation. It is also short circuit, overload and over-temperature protected. An enable connection is provided to allow sequential start-up and shut-down control.



The modules small footprint of 12.5 x 13.5mm and a height of only 4.5mm will find many applications in low-profile PCBs, rack-mounted cards and restricted space designs. The high efficiency of up to 87% means that no heatsinks or forced cooling is required to meet the -40°C to +75°C ambient temperature range (no derating). The ROF-78E comes in tape-and-reel packaging as standard and its low weight of 1g means that it is ideally suited for high speed automatic SMD board production. The four EPC (Edge Plated Castellation) pads allow easy electrical testing and solder joint inspection after reflow soldering.

Despite its low cost, the ROF-78E is subjected to the same rigorous RECOM quality checks as all other SMD products and carries the same 3 year warranty. Priced at below 1.80€ for production quantities, the ROF-78E series is an economic alternative to discrete in-house designs.

www.recom-electronic.com

Dual, 14-Bit, 80 MSPS/125 MSPS ADC

Richardson RFPD, Inc. announced the immediate availability and full design support capabilities for a new dual, 14-bit analog-to-digital converter (ADC) from Analog Devices, Inc. (ADI).

The AD9645 includes an on-chip sample-and-hold circuit designed for low cost, low power, small size and ease of use. The device operates at a conversion rate of up to 125 MSPS and is optimized for outstanding dynamic performance and low power in applications where a small package size is critical, including diversity radio systems, 3G and 4G Cellular, smart antenna systems, broadband data applications, portable medical imaging and ultrasound, and Radar/LIDAR.

www.richardsonrfpd.com

3rd Generation Reverse Conducting IGBT Portfolio

Infineon Technologies expands its portfolio of the 3rd generation Reverse Conducting (RC) Soft Switching IGBT (Insulated Gate Bipolar Transistor) introducing 1200V and 1350V devices in 30A and 40A, thus responding to the growing demand for higher reliability.

Infineon has a strong record in resonant switching IGBT technologies well-suited for induction cooking applications. The 3rd generation of IGBT was optimized for lower switching and conduction losses and provides best-in-class efficiency in 1100V, 1200V and 1350V.

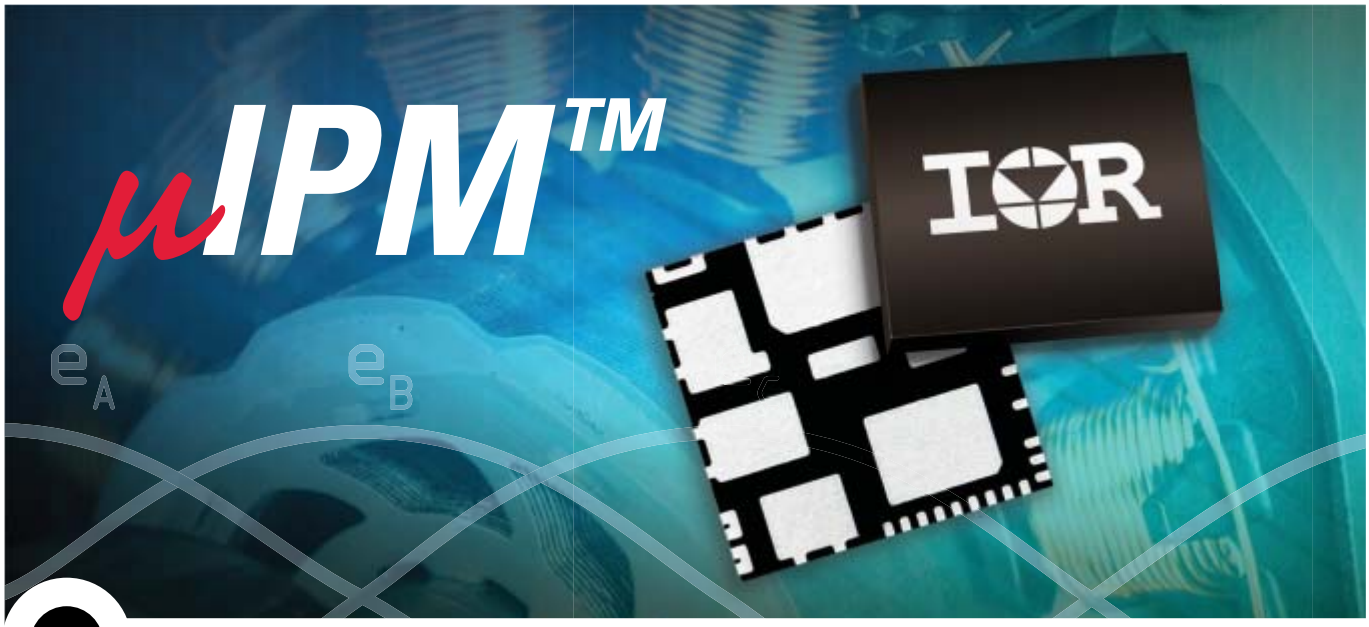
The new generation provides more than 20 percent lower switching losses resulting in a 5K case temperature reduction during application tests in comparison to the 2nd generation RC IGBT from Infineon. Lower switching losses reduce the thermal stress on the device and lead to longer lifetime and higher reliability. High efficiency, excellent thermal performance and EMI behavior, due to soft switching operation, make it the best suited IGBT on the market for induction cooking, solar and other resonant switching applications.

The portfolio extension of 30A and 40A in 1350V addresses the need of designers to have devices with higher breakthrough voltage and current withstand capabilities, which allow for the development of higher power rated designs in single-end topologies, for example up to 3.6kW.

www.infineon.com/rch3

ADVERTISING INDEX

ABB Semi	C3	embedded world	44	Mitsubishi	23
AEPS	3	EMV	45	New Energy Husum	31
APEC	47	Fuji Electric Europe	9	Omicron	43
CDE	29	GVA	C2	PCIM	41
Centraldruck	42	Infineon	27	Richardson	11
CT Concept Technologie	17	International Rectifier	C4	Semikron	13
CUI	21	Intersil	19	Smart Grid WTG	37
Danfoss	25	KCC	10	Texas Instruments	7
Darnell	33	Lem	5	VDI	35
Electronicon	15	Maxon	1	VMI	37



Innovative Power Module Reduces System Size

µIPM™ Power Modules Deliver up to 60% Smaller Footprint

Specifications:

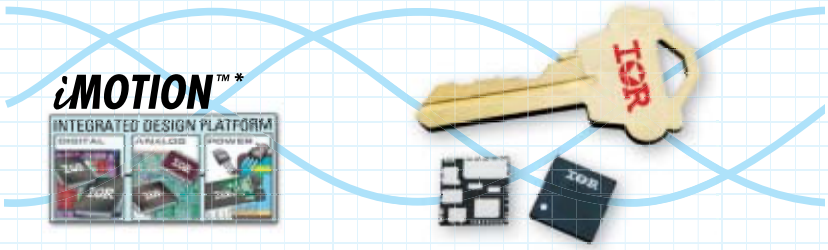
Part Number	Size (mm)	Voltage	IO (DC@ 25°C)	Motor Current**		Motor Power VO=150/75VRMS	Topology
				w/o HS	w/HS		
IRSM836-024MA	12x12	250V	2A	470mA	550mA	60W/72W	3P Open Source
IRSM836-044MA	12x12	250V	4A	750mA	850mA	95W/110W	3P Open Source
IRSM836-025MA	12x12	500V	2A	360mA	440mA	93W/114W	3P Open Source
IRSM836-035MB	12x12	500V	3A	420mA	510mA	108W/135W	3P Common Source
IRSM836-035MA	12x12	500V	3A	420mA	510mA	100W/130W	3P Open Source
IRSM836-045MA	12x12	500V	4A	550mA	750mA	145W/195W	3P Open Source

Features:

- 3-phase motor control IC
- 12x12x0.9mm PQFN package offers up to 60% smaller footprint
- Eliminates the need for heat sink
- DC current ratings from 2A to 4A
- Voltage range of 250V – 500V

µIPM™ Advantages:

- Shortens design time
- Shrinks board space requirements
- Simplicity - Eliminates Heat Sink
- Replaces more than 20 discrete parts to deliver a complete motor drive stage
- Slashes assembly time and cost
- Simplifies procurement and inventory management
- Reference design kits available for quick evaluation on any 3-phase motor



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International IOR Rectifier
THE POWER MANAGEMENT LEADER

* IR's iMOTION™ (ai mo shan), representing the intelligent motion control, is a trademark of International Rectifier
** RMS, Fc=16kHz, 2-phase PWM, ΔTCA=70°C, TA ≈ 25°C