POWER ELECTRONICS EUROPE

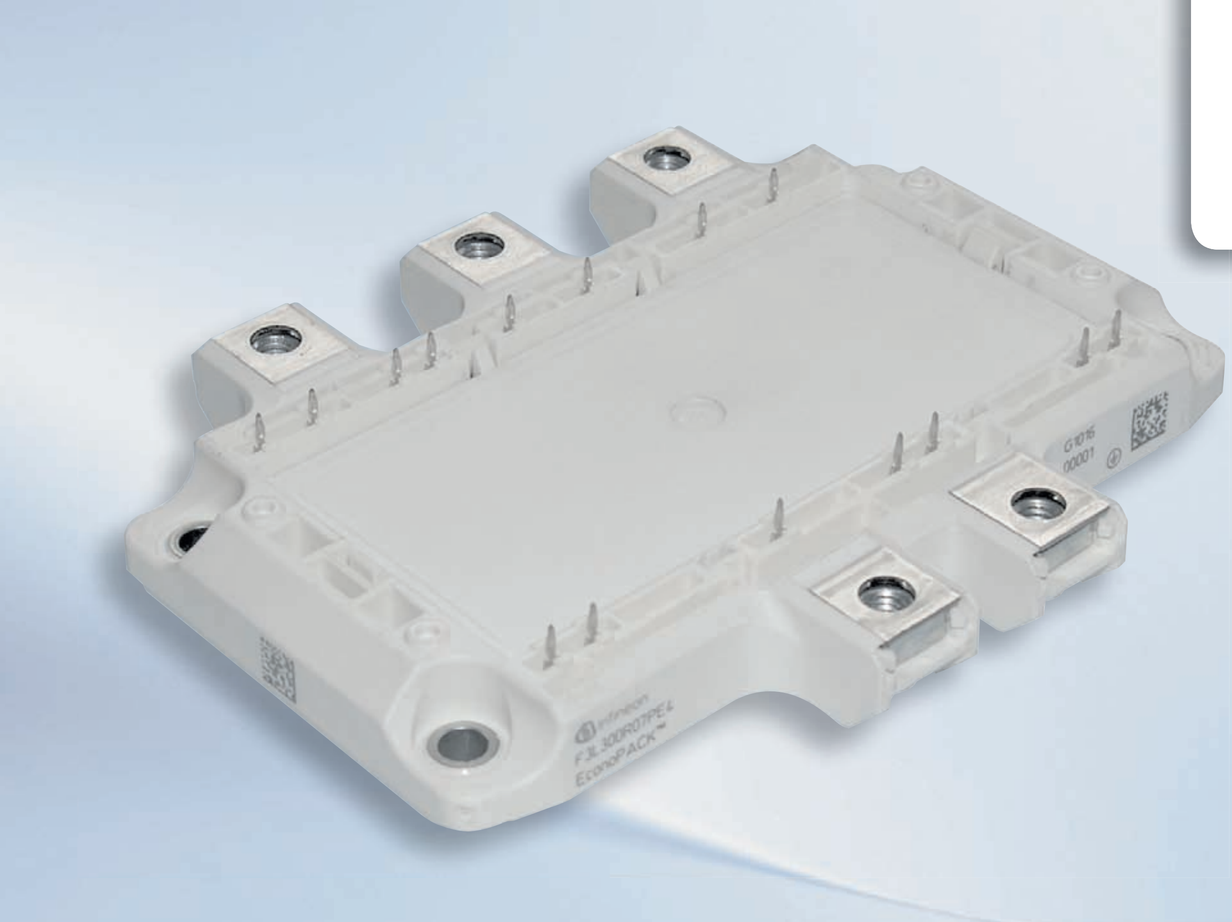
ISSUE 2 – March 2012 www.power-mag.com

TRACTION POWER
Measuring Currents with Railway Class Accuracy

THE EUROPEAN JOURNAL FOR POWER ELECTRONICS AND TECHNOLOGY

Also inside this issue

Opinion | Market News | APEC 2012 | CIPS 2012 | PCIM 2012 | Industry News | Power Modules | Products | Website Locator |



EconoPACK™ 4

The world standard for 3-level applications

The EconoPACK™ 4 is an optimized module for 3-level applications like

- Uninterruptible Power Supply
- Solar Inverter
- High Speed Drives

where a robust design, high efficiency and less harmonics are needed.

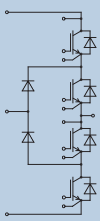
For these applications starting with 50 kW up to 125 kW, the EconoPACK™ 4 can be used to build up one phase. For higher power ratings modules can be switched in parallel.
All modules are equipped with the state-of-the-art IGBT4.
Further information are available on request.

The degree of efficiency for the two 3-level topologies, NPC1 and NPC2, has to be evaluated depending on the switching frequency.

- EconoPACK™ 4 NPC2 topology for low and medium switching frequencies (approx. f_{sw}< 12 kHz)
- EconoPACK™ 4 NPC1 topology for high switching frequencies (approx. f_{sw}≥12 kHz)

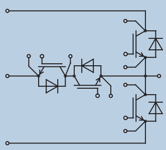
NPC1 topology

- 650V IGBT4
- Optimized for f_{sw}≥12 kHz
- Portfolio
  - F3L200R07PE4
  - F3L300R07PE4



NPC2 topology

- 650V/650V IGBT4
- 650V/1200V IGBT4
- Optimized for f_{sw}<12 kHz
- Portfolio
  - F3L400R07PE4_B26
  - F3L300R12PT4_B26
  - F3L400R12PT4_B26



[www.infineon.com/highpower]

Editor Achim Scharf
Tel: +49 (0)892865 9794
Fax: +49 (0)892800 132
Email: achimscharf@aol.com

Production Editor Chris Davis
Tel: +44 (0)1732 370340

Financial Clare Jackson
Tel: +44 (0)1732 370340
Fax: +44 (0)1732 360034

Circulation Manager Anne Backers
Tel: +44 (0)208 647 3133
Fax: +44 (0)208 669 8013
Email: anne@abdatalog.co.uk

INTERNATIONAL SALES OFFICES
Mainland Europe:
Victoria Hufmann, Norbert Hufmann
Tel: +49 911 9397 643 Fax: +49 911 9397 6459
Email: pee@hufmann.info

Armin Wezel
phone: +49 (0)30 52689192
mobile: +49 (0)172 767 8499
Email: armin@eurokom-media.d

Eastern US
Karen C Smith-Kernc
email: KarenKCS@aol.com
Western US and Canada
Alan A Kernc
Tel: +1 717 397 7100
Fax: +1 717 397 7800
email: AlanKCS@aol.com

Italy
Ferruccio Silvera
Tel: +39 022 846 716 Email: ferruccio@silvera.it

Japan:
Yoshinori Ikeda,
Pacific Business Inc
Tel: 81-(0)3-3661-6138
Fax: 81-(0)3-3661-6139
Email: pbi2010@gol.com

Taiwan
Prisco Ind. Service Corp.
Tel: 886 2 2322 5266 Fax: 886 2 2322 2205

Publisher & UK Sales Ian Atkinson
Tel: +44 (0)1732 370340
Fax: +44 (0)1732 360034
Email: ian@dfamedia.co.uk
www.power-mag.com

Circulation and subscription: **Power Electronics Europe** is available for the following subscription charges. **Power Electronics Europe**: annual charge UK/NI £60, overseas $130, EUR 120; single copies UK/NI £10, overseas US$32, EUR 25. Contact: DFA Media, Cape House, 60a Priory Road, Tonbridge, Kent TN9 2BL Great Britain.
Tel: +44 (0)1732 370340. Fax: +44 (0)1732 360034. Refunds on cancelled subscriptions will only be provided at the Publisher's discretion, unless specifically guaranteed within the terms of subscription offer.
Editorial information should be sent to The Editor, **Power Electronics Europe**, PO Box 340131, 80098 Munich, Germany.

Printed by: Garnett Dickinson.
ISSN 1748-3530

COVER STORY

Measuring Currents with Railway Class Accuracy

In common with many other areas of business across Europe, changes in the regulatory environment are leading to more demanding standards for Railway Energy Billing. European rail-freight markets are being liberalized with privatization of the rail networks, and the separation of operating entities in terms of infrastructure and operators. Since the beginning of January 2010 passenger rail markets have been opened to cross-border competition. Traction Units consume energy in each of the different countries they pass through. On-board energy measuring constitutes the system for measurement of electric energy that the traction unit takes from or returns to (during regenerative braking) the overhead contact line. Greater precision in this energy measurement allows operators to better understand their real consumption, and will enable energy management to reduce overall energy consumption, as well as monitoring total energy supplied from the external electric traction system. A new transducer for these applications will be introduced in our cover story. Full story on page 24.

Cover supplied by LEM SA, Switzerland

PAGE 6

Market News

PEE looks at the latest Market News and company developments

PAGE 10

APEC 2012

PAGE 14

CIPS 2012

PAGE 17

PCIM 2012

PAGE 20

Industry News

Driving Gallium Nitride Power FETs

Driver for Dimmable LED Lightings

PAGE 28

With Sinter-Technology Forward to Higher Reliability of Power Modules for Automotive Applications

A new kind of applications, the whole automotive market describes more and more a "high end"-power module. The unprecedented combinations of thermal, electrical, and reliability performance with a very small volume and weight are the challenge today. A consistent further development of sinter technology for power modules comprises and answers to all these requirements. Sinter technology substitute all solder connections and also the aluminum bond wires. These are at present the weak points in a standard power module. The thermal and reliability results of a 400 A/600 V Dual IGBT power module will be shown in this article. **Jürgen Steger, Project-leader, SEMIKRON Elektronik, Nuremberg, Germany**

PAGE 32

Flexible One-Step Mounting Technology

Aiming to cut assembly costs and avert inverter assembly flaws, several companies now offer power modules that can be mounted in a single step. Vincotech taken this notion and developed a novel Press-fit technology and made it available in a wide range of products, including modules with pre-applied phase change material and thermal grease. These power modules also enable low inductance designs. The article looks closer at how power modules, engineered for one-step assembly encompassing the PCB and heatsink, make life easier for manufacturers. **Patrick Baginski, Field Application Engineer, Vincotech, Unterhaching/Munich, Germany**

PAGE 35

Product Update

A digest of the latest innovations and new product launches

PAGE 37

Website Product Locator

Mitsubishi Electric offers a big variety of Power Semiconductors for a wide range of Industrial Motor Control applications from 0.4kW to several 100kW. Besides IGBT Modules also Intelligent Power Modules (IPM) and Dual Inline Package IPM (DIPIPM™) are available with extended voltage ratings.

The power modules feature state of the art CSTBT™ chip tech-

design as well as a high power cycling capability to ensure highest

PCIM

Stand 12-421

MITSUBISHI ELECTRIC

Changes for the Better

semis.info@meg.mee.com · www.mitsubishichips.eu

for a greener tomorrow

eco Changes

A New Era for Power Electronics on the Horizon

Recent power electronic conferences showed that higher operating temperatures along with higher levels of efficiency particularly for automotive applications are becoming feasible in the near future. Power modules for EV/HEV applications will represent more than $4.5 billion in 2020, according to market researcher Yole - almost 50 % of the total power module market. The EV/HEV market has specific requirements such as volume and weight reduction, higher temperature of operation or improved cooling, and manufacturability in very high volume for a reasonable price. EV/HEV is already leading the power module packaging innovation scheme, and these innovations are expected to be adopted in other power electronics applications.

In the last decade, the semiconductor industry has significantly improved the Silicon-based components with many generations of medium voltage IGBT and fast diodes. However, one recognizes that these components have reached a performance plateau and new expectations have been raised with other semiconductor materials, such as Silicon Carbide or Gallium Nitride on Silicon wafers. Today the IGBT modules of latest generations for inverter in an electric vehicle rated at 400 A and 650 V, have about 300 mm^2 of silicon per switch including the freewheeling diode. A 300 mm^2 of GaN/Si switch would reduce the power losses from 100 W to 10 W, according to Freescale's Global Powertrain Marketing Manager Cherif Assad at CIPS 2012. GaN on Silicon is a significant thread to the hegemony of Silicon. In thirty years GaN on Silicon will change the power semiconductor world in the same way as MOS versus Bipolar in the past, said IR's CEO Oleg Khaykin at APEC. GaN has the potential to displace the MOSFET in new applications up to 1200 V and above, added EPC's CEO Alex Lidow. Cost can not be reduced with multiple technologies - if GaN can do the job, there will be no SiC. If Silicon can do it, GaN will lose. But if GaN can do it, SiC will lose, stated also Transphorm's CEO Umesh Mishra. And other GaN entrants such as GaN Systems or NXP and Freescale in the near future will push the market, as well as support from established vendors such as Texas Instruments offering now high- and low-side drivers.

Toyota regards Silicon Carbide as an essential technology for improving power density. The on-state and switching losses of SiC are half and one-fourth that of Si, respectively, and the temperature limit of SiC is 250°C. Compared to Si, SiC devices have the merits of size and loss reduction, and allow the adoption of simpler cooling structures. In contrast, various issues must be resolved before SiC devices can be practically adopted. These include securing sufficient reliability, developing high-temperature materials, and reducing cost. In the oil and gas industry compressors are driven today by electrical variable-speed drives replacing all mechanics. And now SiC switches ranging up to 10 kV/120 A are replacing conventional power modules. In this case Cree has supplied the dies and Powerex did the packaging.

According to Prof. Nando Kaminsky from University of Bremen GaN devices will remain to be lateral for some time because of the non-conductive interlayers. But lateral devices are well suited for integration, due to the short gates and high velocity of the electrons they can switch at very high frequencies. So the ideal application for GaN transistors is HF ICs up to 1000 V (perhaps 2000 V) and currents around a few 10 A. Silicon Carbide is rather suited for discrete devices or modules above 1000 V breakdown voltage and basically no limit in current. Unipolar wide bandgap devices offer high switching speed and high temperature operation, but these properties cannot be used due to limitations in packaging. Thus a significant improvement in die attach, interconnection, moulding and other packaging techniques are necessary to fully exploit the advantages of the wide bandgap semiconductors. First attempts to solve this problem are sketched in this issue.

Thus power electronics is transforming all high-power industries, and this trend will create huge opportunities for our industry!

Achim Scharf
PEE Editor

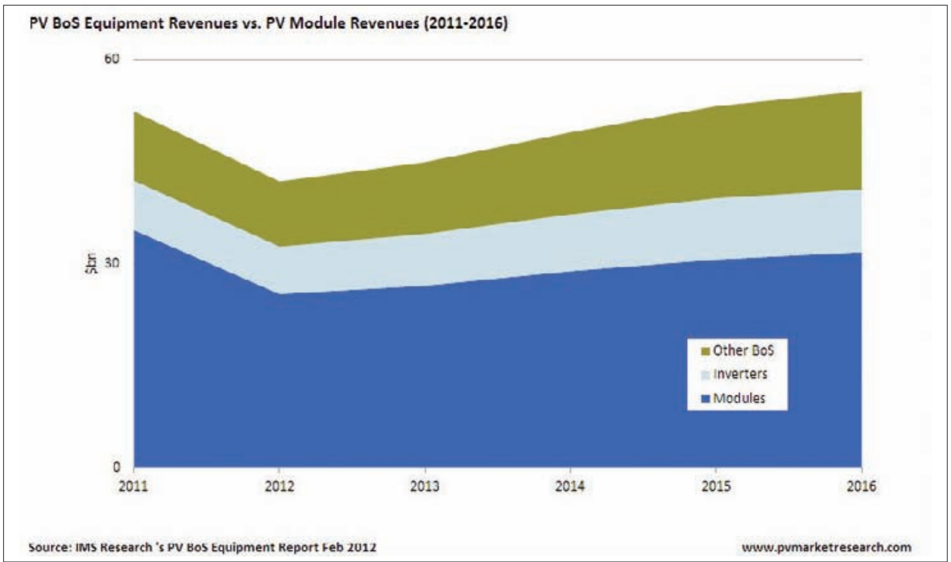
Record PV Inverter Shipments in 2011

The PV inverter market achieved a new record in 2011 with shipments exceeding 26 GW, a growth of more than 10% in 2011, despite the huge inventory overhang from the year before, IMS Research found out.

Germany remained the largest market, but saw shipments fall by more than a quarter in 2011. This was because of the very high inventory levels in the country at the start of the year as customers sat on high stocks of string inverters. Although many of these inverters were subsequently re-exported to other markets or returned to manufacturers, underlying demand was still not high enough and saw shipment sink considerably. Whilst the German marked performed poorly in 2011, this was more than offset by other markets. China performed extremely well following the country's introduction of its FiT and saw shipments of nearly 3 GW, whilst the Americas market achieved shipments of close to 4 GW. The report also found that whilst both Italy and the UK drove high inverter shipment growth, this was not enough to prevent the European market from falling in 2011. In total IMS Research estimates shipments grew by up to 15 % globally in 2011 but revenues were flat in US Dollar terms and slightly down in Euros.

The research firm estimates that inventory levels have returned to more "normal" levels, though again significant regional variations are occurring. "Inventory levels have greatly reduced in Europe, with inverters being re-exported from Germany, especially those not compliant with the new low-voltage directive requirements. However, inventory levels are understood to have increased considerably in the USA and Asia. In the USA this was caused by customers stock-piling large volumes of inverters ahead of the expiration of the 1603 program. These inverters will of course now be installed in 2012," explained Senior Research Director Ash Sharma.

PV balance of system (BoS) equipment revenues are projected to increase from $17 billion in 2011 to close to $24 billion in 2016. Whilst inverters will continue to be the largest part of the market, monitoring hardware, mounting structures and tracker systems will outpace the rest of the market to capture an increasing share. The fastest growing segment will be tracker systems, with revenues for these products predicted to grow by close to 30 % per annum up until 2016. Falling prices for these products are expected to boost penetration, particularly in high irradiation regions, such as California, South Africa and the Middle East which are all predicted to see high growth in PV deployment over the next few years. "Although the tracker market fell off a cliff at the end of 2008 when the Spanish market collapsed, it's now facing a major resurgence as falling prices and more efficient motor control allows for a much more cost-effective system", added Sharma.



Depending of the type of installation and the equipment used, BoS costs can sometimes outweigh the PV module costs. This means that customers are increasingly focusing on the BoS components to find cost savings and suppliers are experiencing price pressure that was previously reserved for module suppliers. Despite this, PV modules are still predicted to remain the largest single hardware cost in a PV system and will account for more than 50 % of total PV hardware revenues in 2016. Intensifying competition particularly for PV combiner boxes and mounting systems, especially from Chinese suppliers means that prices are forecast to continue to decline. However, price declines of BoS components will not be as severe as those experienced by module suppliers "Although there will remain great pressure on suppliers to reduce prices as incentives fall, new products such as enhanced monitoring hardware, smarter inverters and a shift towards ground-mount mounting structures will help maintain average prices", Sharma concluded.

www.pvmarketresearch.com

Guidance on Deployment of Hybrid Energy Solutions

With telecommunications networks already responsible for more than 1 % of energy consumption worldwide and demand for network access and mobile broadband consistently outpacing deployment, telecom providers are searching for ways to more efficiently power and operate their networks.

There are opportunities for improvement ranging from more precise configuration and dimensioning that make hybrid solutions even more efficient and change the value proposition for some network providers. "The hybrid market is evolving rapidly, and evolving differently in various parts of the world. Providers are looking for different blends of capital and operating expenses and technological capabilities to suit specific markets," said Wake Norris, director of product management - solutions for Emerson Network Power's Energy Systems business. "With that in mind and two decades of experience in engineering and managing hybrid energy solutions for customers, we offer some key observations and recommendations for providers".

Active Management and Smart Hybrids: Hybrid deployments traditionally have been purchased as static hardware with a general maintenance or warranty contract only. This is an acceptable solution to minimize immediate capital spending. However, for those operators focused on minimizing medium- to long-term operational and capital costs and maximizing ROI, smart hybrids with active management can

aid with achieving additional savings. Advanced analytics and remote management can deliver measurable load, environmental and performance improvements. Intelligent solutions can, for example, alert if a battery cell may be damaging an entire string or if a single dirty solar panel is reducing the output of an entire array. They also can adjust cooling operation if load or temperatures vary, change maintenance dispatch schedules if a generator is operating less than usual, and notify if fuel quality degrades.

Batteries are critical elements for successful cost minimization. Errors in battery selection and operation can be among the most costly for a provider, yet are the most common. Selection of the right batteries (among many options for chemistry and construction) must be based on clear capital and operational goals, rather than trends. More than any other element, batteries will benefit from active management of charge, ensuring long service life, minimal site cost and maximum uptime for the provider.

Solar is becoming a viable power source for cell sites around the world. Proper use of solar power begins with understanding solar intensity and seasonal variances in order to design sites for their unique physical conditions. Solar also is a low-density power solution and requires the greatest space or creativity to deploy. Security and maintenance also must be considered-protecting panels from theft, misalignment, and sub-optimal operation due to dirt is important. Periodic maintenance is required, but a smart hybrid system, actively managed, can minimize cost by dispatching service personnel only when cleaning or repair is necessary.

Wind is best in an array of turbines for large power delivery connected to a reliable electric grid. The scale of the utility turbines with multi-point deployment allows for cost-effective management of maintenance and wind variability. The use of wind turbines at a cell site needs to account for community acceptance, for the ability to run unattended under all conditions, and for the inevitable windless days. For a single-point, off-grid cell site, wind is a challenging power source to be effective-for cost or energy-but it can be successful in some locations.

Fuel cells are an option from an environmental point of view, and there are various technologies that have been deployed successfully. The biggest challenges to cost-effective use at cell sites are the startup time-a battery is always necessary-and the fuel supply-chain. Until these two items are addressed, this technology is best directed to sites with strict emissions mandates.

www.EmersonNetworkPower.com/EnergySystems

Training Support Box

SEMIKRON has put together a so-called SKillbox to offer professors and trainers a hands-on experience for their students on the different packaging technologies used in power electronic systems. First boxes were handed over during a recent company visit of Bavarian university professors and were on display at CIPS 2012.

"The Skillbox is a collection of 16 power electronic components such as dismantable assemblies and cross-sectional components, designed as an important visual aid for explaining the main packaging concepts used in power electronic systems," explains Dr. Uwe Scheuermann, who is responsible for component reliability at SEMIKRON and contract lecturer in the area of electronic packaging at the University of Erlangen. The box also comes with information on module specifications and application areas and includes the pressure-contact module SKiiP3, which is used in wind turbines and elevators, as well as driver module SKYPER 32 Pro, which is used to drive IGBT modules. Also in the box are bipolar pressure-contact modules, disc-type components and the spring-contact module MiniSKiiP for solder-free PCB mounting. "Besides sound knowledge of electronics, components and switching topologies, power electronic engineers also need to be experts in the area of packaging technology", added Eberhard Petri, cluster manager of Bavarian Power Electronics Cluster (ECPE). "This is the result of a survey on quality requirements conducted by ECPE among power electronic engineers in different companies. The SKillbox fills a gap in teaching materials at our colleges and universities".

www.semikron.com

"Professors and students need to have knowledge not only about power semiconductors, but also about the increasing role of packaging technologies - and that is the aim of our Skillbox", said Semikron's Uwe Scheuermann at CIPS 2012

GaN Gains Momentum at APEC

The 27th annual IEEE-Applied Power Electronics Conference and Exposition held from February 5-9 in Orlando/Florida once again was a great event with more than thousand delegates and 170 exhibitors. It opened the season for more power electronic events to come particularly in Europe and thus APEC served as an indicator of how this industry will develop in 2012. Regarding power semiconductors, Silicon Carbide and Gallium Nitride gained a lot of attention with some more entrants to the market.

"For more than a quarter century, APEC has excelled at showcasing creativity by providing an environment for technical exchange and networking. These APEC conferences emphasize the applied nature of power electronics by highlighting the latest achievements and breakthroughs", said General Chair Frank Cirolia at the opening ceremony. "The Plenary Session topics for 2012

General Chair Frank Cirolia opened the biggest APEC ever

include Fossil Fuels, Efficient Electric Drives, Modeling, Instrumentations, and High Power GaN, covered by speakers from industry and academia.

Following the Plenary, the Technical Sessions are selected from a base of 800 digests submitted from 41 different countries; these sessions reflect strong technical content, again delivered by both industry and academia".

News in Silicon Carbide

Thomas S. Buzak, President Tektronix Component Solutions **(www.tektronix.com)**, explained how the instrumentation industry responds to the challenges created by new power semiconductor technologies. "Silicon Carbide and Gallium Nitride both bring the ability for higher switching frequencies. We have responded to these trends by designing power probes up to 600 V and 200 MHz switching frequency. And recently we designed probes for up to 6 kV!"

GE's **(www.ge.com)** GM of Engineering and Technology Vlatko Vlatkovic described the advantages of SiC in high-power applications such as propulsion and power integration. "In the oil and gas industry compressors are driven today by by electrical variable-speed drives replacing all mechanics. And now SiC switches ranging up to 10 kV/120 A are replacing conventional power modules. Power electronics is transforming all high-power industries", he stated.

Fairchild's **(www.fairchildsemi.com)** CTO Dan Kinzer illustrated in his plenary presentation the role of power semiconductors for reducing green

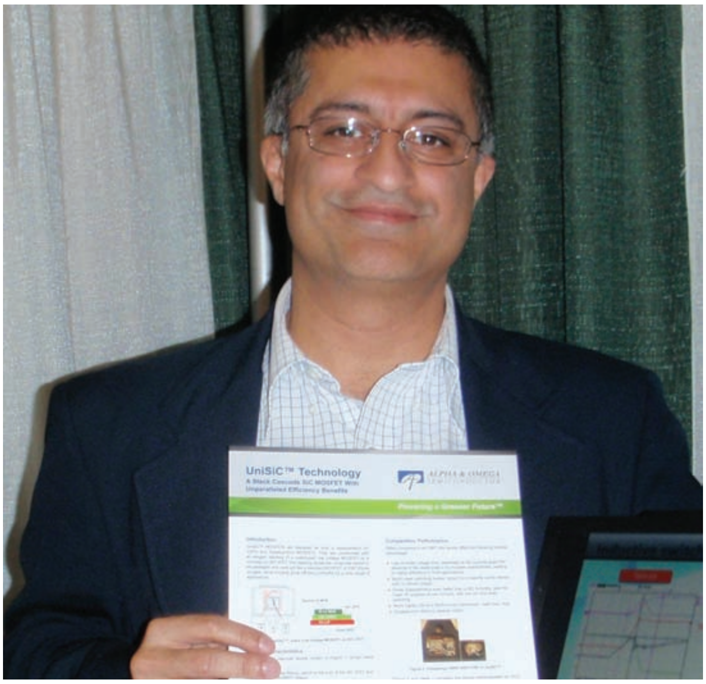
Fairchild's CTO Dan Kinzer: SiC is very suitable for higher voltages

house gases. "Automobiles are the biggest areas of improvement, followed by power generation and lighting. Power semiconductors have a huge role to play in this scenario, particularly Silicon Carbide and Gallium Nitride in applications such as solar energy or high-voltage DC transmission. Our SiC bipolar junction transistors are available in the 1200 V class with 15 A and 50 A current ratings and does not have the disadvantage of the bipolar transistor, in contrast they have the lowest on-resistance and positive temperature coefficient for ease of paralleling. A disadvantage is the DC drive current. We view SiC as a good solution for higher voltages, in three to five years or so other wide bandgap devices might penetrate the market".

GeneSiC **(www.GenesicSemi.com)** Dulles/USA is the second company to offer SiC BJTs called Super Junction Transistors (SJTs) in voltages ranging from 1.2 kV/7 A to 10 kV for power conversion in aerospace, defense, down-hole oil drilling, geothermal, Hybrid Electric Vehicle (HEV) and inverter applications. "The SiC SJT is a normally-off "Super-High" current gain SiC BJT that exhibits a square reverse biased safe operating area, high temperature operation capability, low on-voltage as well as fast switching capability. Unlike SiC MOSFETs, the SiC SJT is free from metal oxide semiconductor interface reliability concerns. The SiC SJTs have a lower positive temperature coefficient of on-resitance and higher temperature capability when compared with normally-off SiC JFETs", explained GeneSiC's President Ranbit Singh. SiC SJTs are packaged in industry standard TO-220 plastic packages and custom high-temperature metal-can packages. "The term Super Junction should not be confused with SJ MOSFETs, it's just for marketing", Singh confirmed. Products are available through Mouser.

Cree **(www.cree.com/power)** introduced a series of packaged SiC Schottky diodes in the 1700 V-class which virtually eliminate the reverse recovery losses. While the 1700 V bare die have been available for customers who design their own custom power modules, the TO-247-2 packages are intended for lower-power 1700 V designs. "The availability of 1700 V SiC Schottky diodes provides a number of advantages for design engineers in high-voltage power applications", said Cengiz Balkas, GM Power and RF. "Silicon Carbide diodes enable maximum power efficiency and better EMI performance. The switching loss improvement allows for increased system frequencies that can reduce the size of magnetic and capacitive components. Significant reductions in system size, weight and cost can be achieved. Moreover, the availability of 1700 V SiC diodes can eliminate the need for stacking multiple lower voltage silicon diodes, thereby cutting component count, improving thermal performance and increasing reliability". The company also demonstrated a fully-qualified SPICE model for their 1200 V SiC MOSFETs. The behavior-based, temperature-dependent SPICE model is compatible with the LTspice simulation program and reliably simulate the switching performance of CMF10120D and CMF20120D Z-FETs in board-level circuit designs.

Alpha and Omega Semiconductor **(www.aosmd.com)** demonstrated UniSiC, a 1200 V, 90 milliohm MOSFET in a TO262 package. The drastic reduction in form factor and figures-of-merit put this 1200 V MOSFET device in



Alpha & Omega's Stephen Chang: UniSiC achieves a drastic reduction in form factor and figures-of-merit

a class by itself, the company expressed. The UniSiC device is formed by stacking a specially designed low voltage Silicon MOSFET atop a normally-on SemiSouth SiC JFET. The low voltage MOSFET is specially engineered to allow optimal operation of the composite device with clean switching, low on-resistance, gate charge and superb diode characteristics. "The devices can be used like conventional discrete IGBTs and FETs using the same gate drives, allowing the user to realize huge efficiency gains without too much re-engineering", said Product Marketing Manager Stephen Chang. "First released in 2008, we have seen our JFETs gain rapid adoption in the market, and this first stack-cascode demonstration takes the performance and ease of use to the next level", added SemiSouth's CTO Jeff Casady.

GaN moves towards 1200 V

On the other hand, companies such as International Rectifier **(www.irf.com)**, EPC **(www.epc-co.com)**, Transphorm **(www.transphormusa.com)** or GaN Systems **(www.gansystems.com)** are pushing Gallium Nitride on Silicon to voltages up to 600 V today and perhaps 1200 V in the near future. Except EPC these companies will exhibit at the PCIM in May.

"Three years ago, when we introduced our roadmap for GaN on Silicon at PCIM in Nuremberg, there was a lot of scepticism about feasibility in the audience, two years ago the audience got bigger, last year the audience was massive, and at this year's APEC you see GaN everywhere! The point is, GaN on Silicon is a significant thread to the hegemony of Silicon. In thirty years GaN on Silicon will change the power semiconductor world in the same way as MOS versus Bipolar in the past. Silicon is running out of steam, pretty soon the MOSFET process will resemble in a 30-layer IC process to get the incremental performance, whereas with GaN you can get it for free. GaN on Silicon is out of the lab, we demonstrate 600 V GaN power devices, and GaN class D audio. In this year GaN on Silicon will become commercial in a broad range of voltages. Energy efficiency is becoming a worldwide concern, even in the US, and Digital Power as well as GaN will drive this evolution. Stay tuned for PCIM where more

IR's CEO Oleg Khaykin: Digital Power as well as GaN will drive the energy efficiency evolution

news will come", commented IR's CEO Oleg Khaykin. "Eight years ago we started to invest in GaN for power conversion applications, in 2011 we sampled 600-V-devices to key customers and this year GaN will turn into revenues", added Tim McDonald, IR's manager for new technologies.

Efficient Power Conversion (EPC) is an other player offering Enhancement-Mode GaN on Silicon (eGaN), led by former IR-CEO Alex Lidow. "According to market researchers the market for GaN power devices is evolving very rapidly to gain hundreds of million dollars in the next few years. That is still a small number, since the power MOSFET market is in the billions - but the growth rate is very high. I don't expect that GaN replaces the MOSFET, but it will create new markets such as wireless power transmission or radiation hardened devices, where the power MOSFET is lagging. Particularly wireless power transmission relies on high power switching beyond the switching frequencies of MOSFETs, also new MRI machines using hundreds of megahertz. Other

EPC's CEO Alex Lidow: By the year 2015 we expect to make eGaN FETs cheaper than MOSFETs

markets are Power over Ethernet, DC/DC power conversion, later perhaps AC/DC conversion, motor drives and eventually electric vehicles. GaN has the potential to displace the MOSFET in new applications up to 1200 V and above", Lidow expects. "Our eGaN FETs are very similar in their behavior to existing power MOSFETs, therefore users can rely on their past design experience. And we expect to make eGaN FETs by the year 2015 cheaper than MOSFETs, because wafer processing and assembly can be done at lower cost".

Transphorm went to market at APEC 2011. CEO Umesh Mishra worked previously with Cree and thus has profound experience in Silicon Carbide technology. "Silicon Carbide entered the market as a blue LED, not as a power device. When Gallium Nitride entered the market, SiC was terminated and GaN took over this role very shortly. The same argument was raised regarding switching frequencies and voltages over time. But there is no way that cost can be reduced with multiple technologies - if GaN can do the job, there will be no SiC! If Silicon can do it, GaN will lose. But if GaN can do it, SiC will lose, because there is no comparison in the cost structure. We are at 600 V now, but

Transphorm's CEO Umesh Mishra: 1200 V GaN FETs will dominate by the time the market switches away from the 1200 V Silicon IGBT

there is no inherent reason to make 1200 V GaN FETs. These devices will dominate by the time the market switches away from the 1200 V Silicon IGBT. In the kilovolt range I expect that Silicon will still dominate", stated Umesh Mishra. Among others the company demonstrated an electrical drive powered by 600 V GaN FETs.

The latest contender in the GaN arena is Canadian GaN Systems, as most as the others a fabless company with nine employees so far. "We come with a Nortel RF background and not with a Silicon legacy and realized very quickly, that the traditional finger layout would not work for GaN. After a lot of trial and error we came up with the "island layout" including squares and triangles as a geometrical optimum shape. As a result the die size can be decreased by a factor of 4, stray inductance is reduced significantly through a gold layer on the substrate for interconnection of the islands. We achieve breakdown voltages of 1200 V and 24 A current so far. Today we are working with SiC substrates, but we are aiming to be on Silicon within a year and thus competitively positioned", said CEO Girvan Patterson at a meeting with PEE. For that the company is working with six GaN on Silicon foundries (mainly in the US) and one RF foundry. The differentiator in this proprietary technology is the interconnect gold layer leading to very low inductance and in return to switching edges of 3 to 6 GHz for reduced switching losses. And due to the relatively huge gate width low on-resistances of typically 150 milliohms can be achieved. For coming high-voltage devices this value may be decreased down to 20 milliohms, expects Girvan Patterson.

Texas Instruments **(www.ti.com/gan-pr)** demonstrated a low-side gate driver for GaN FETs. The new LM5114 drives GaN FETs and MOSFETs in low-side applications, such as synchronous rectifiers and power factor converters.

GaN System's CEO Girvan Patterson: Island GaN transistor structure and gold interconnection layer leads to very low on-resistance and stray inductance

Together with the LM5113, the 100-V half-bridge high-side GaN FET driver announced in 2011 by National Semiconductor (now part of TI), the family provides an isolated DC/DC conversion driver solution for high-power GaN FETs. The LM5114 drives both standard MOSFETs and GaN FETs by using independent sink and source outputs from a 5-V supply voltage. It features a high 7.6-A check that turn-off current capability needed in high-power applications where larger or paralleled FETs are used. The increased pull-down strength also enables it to drive GaN FETs properly. The independent source and sink outputs eliminate the need for a diode in the driver path and allows tight control of the rise and fall times. "GaN emerges as viable option for high-performance power supplies. This new GaN FET driver is designed by TI and marks our commitment for GaN", said TI's

TI's Michael Gilbert: Our new low-side FET driver marks our commitment for GaN

Michael Gilbert at APEC. In the pipeline is also a 5.4-MHz, 4.5-V to 60-V synchronous buck controller for GaN FETs.

Other companies will enter the market soon. "We are looking for GaN in research and will come with products in 2014", stated NXP's **(www.nxp.com)** Power & Lighting Manager Marcel van Roosmalen. Others certainly will follow, which will give a momentum and perhaps will lead to a market consolidation. **AS**

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

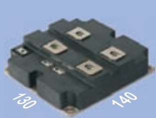
High Power IGBTs

1200V & 1700V

- Low thermal impedance
- Low internal inductance
- $T_{j,max}$ = 175°C
- $T_{j,op}$ = -40 ~ 150°C
- $T_{stg,min}$ = -40°C, on request -55°C
- V_{iso} = 4.0kV
- CTI > 600

1700V also available with AlSiC-Baseplate

1 in 1



1200A
1600A
2400A

2400A
3600A

2 in 1

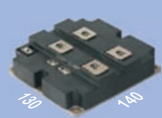
600A
800A
1200A

3300V

- Low thermal impedance
- Low internal inductance
- $T_{j,max}$ = 150°C
- $T_{j,op}$ = -40 ~ 150°C
- $T_{stg,min}$ = -40°C and -55°C
- V_{iso} = 6.0kV
- CTI > 600
- VPD = 2.6kV

AlSiC Baseplate

1 in 1



800A
1000A

1200A
1500A

FUJI ELECTRIC EUROPE
e-Front runners

Fuji Electric Europe GmbH
Goethering 58 · 63067 Offenbach am Main · Germany
Fon +49(0)69-66 90 29 0 ▸semi-info@fujielectric.de
Fax +49(0)69-66 90 29 56 ▸www.fujielectric.de
Products Overview ▸www.fujielectric-europe.de/info/overview.pdf

More Efficient Module Technologies

This year's conference on integrated power systems (CIPS) from March 6-8 in Nuremberg attrcted around 250 delegates. Among others new concepts for power modules were one of the topics, particularly regarding reliability and high operating temperatures.

In his invited presentation Alexandre Avron fom Yole Développement sketched the design efforts in power modules leading to higher operating temperatures and reliability. Improvements in packaging can be made in three aspects: Die interconnection, which is searching for innovative wire bonding or no-wires connection for better lifetime and reliability; die attach, which uses new materials for better lifetime; and DBC plus baseplate, which uses new materials and suppress layers for improved cooling and smaller size. Here different approached are used by selected companies.

CIPS Technical Chair Eckhard Wolfgang (left) applauded Alexandre Avron for his invited presentation on new technologies for power modules

For interconnection today Al wire bonding is widely used but number of wires and wire thickness for higher current carrying capability are limited. Also reliability issues (lift-off) are a major concern. A new approach by Infineon using copper wires promise a 40 % better electrical and 200 % better thermal conductivity, whereas Semikron with its in 2011 introduced SKiN (see PEE 5/2011, pages 23-27) can lead to a factor 70 improved lifetime expectancy due to silver sintering. This process is now in mass production at Semikron, it requires high pressure (up to 40 MPa) and temperature (250°C) to compress the silver (Ag) powder. A so-called flex layer is used for interconnection. Transient Liquid Phase Bonding or Eutectic soldering is used for die attach in Infineon's .XT technology, where stacked layers of Tin (Sn) and Copper (Cu) melts and diffuse through the other. Result is an alloy of Cu/Sn with progressive percentage (more on that see below).

DBC and baseplate materials depend on required performances and cost. Main issue is to match the CTE of the different layers, keeping the highest thermal conductivity. "We are now looking for improved lifetime and temperature performances and integrated cooling solutions will probably be the next step", Avron expects. Gel filling materials have to withstand higher temperatures up to 400°C in the future in order to meet the requirements of upcoming power semiconductors such as Silicon Carbide (see below).

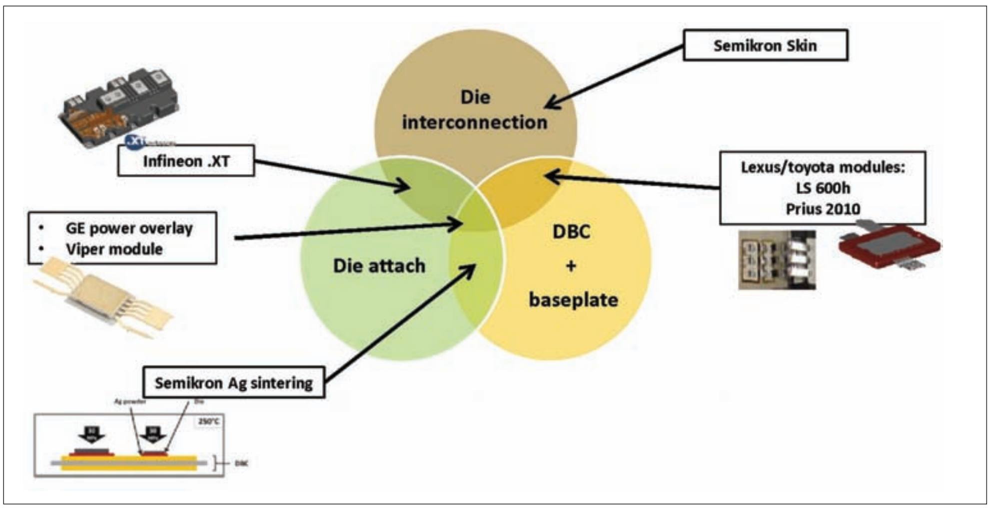
In terms of market figures power modules for EV/HEV applications will represent more than $4.5 billion in 2020, according to Avron almost 50 % of the total power module market. "The EV/HEV market has specific requirements such as volume and weight reduction, higher temperature of operation or improved cooling, and manufacturability in very high volume for a reasonable price. EV/HEV is already leading the power module packaging innovation scheme, and we expect these innovation to be adopted in other power electronics applications. Thus EV/HEV is boosting the power module packaging world!"

New die attach approach

Power electronics is facing two major challenges - the demand for hot environment applications in vehicles and lifetime increase. "As a result alternative joining technologies are needed to meet today's quality requirements for power modules. In case of the chip-to-substrate joint a high thermal and electrical conductivity as well as a good mechanical and chemical stability of the die attach material within the whole operation temperature range is needed both during long-term annealing and temperature cycling", explained Infineons Karsten Guth.

Common die attach technologies are based on soft solders with melting points below 250°C. As long as the operation temperature is limited well below the melting point soft solders have been the materials of choice for a reliable chip-to-substrate interconnect. Increasing the operation temperature to values of around 200°C leads to a significant decrease of the solders strength and reliability. In recent years two trends have been set to overcome these problems.

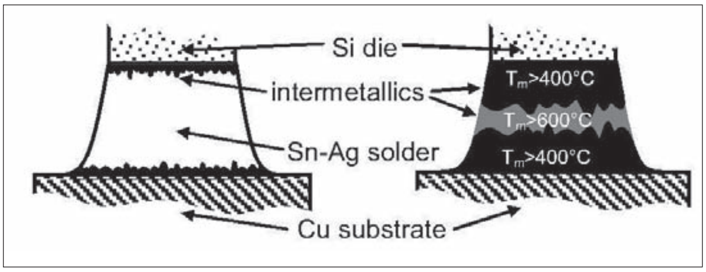
Sintering of silver particles (Low Temperature Joining or LTJ) is a well established technology. A silver powder is applied between chip and substrate and sintered under high pressure (30 MPa) and moderate temperatures (230°C) to form a compact joint. Infineon presented an alternative concept, here the phase formation reaction of the intermetallics during soldering is utilised to form a high melting bond between chip and substrate. Depending on the process parameters the resulting joints consist of one or more intermetallic phases with melting points well above 400°C. To create pure intermetallic joints with a remelting temperature >400°C a rapid solidification process using common Sn-Ag solder is utilised as a diffusion bonding process. The general formation of the intermetallic die attach system can be controlled by the solder thickness (10µm), the pressure (6MPa) as well as time and temperature. "While both joints are formed from a Sn-rich solder, in the standard joint only a fraction of the Sn is transformed into high melting Cu-Sn intermetallics. By contrast, in the diffusion bonded joint, the whole volume of low melting solder is consumed by the solidification process. The result is a high melting bond between chip and substrate". Guth pointed out.



LEFT: Improvement aspects for packaging of power modules

HEV are pushing technology

"Hybrid technology is key for environmentally friendly vehicles, and this technology uses a wide variety of power

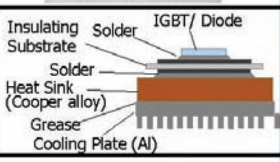
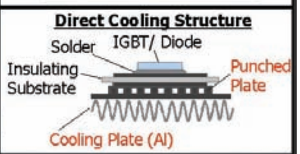


Standard solder (left) and diffusion bonded joint consisting of two different intermetallic phases

electronics components. For our 3rd generation Prius we developed a direct cooling structure for the intelligent power module, as well as a trench gate structure and thin wafer technology for Silicon IGBTs", said Kimimori Hamada from Toyota Motor Corporation. This directly cooled structure greatly improved the cooling efficiency of the IPM and achieved the required heat cycle performance without the use of the copper alloy cooling plate. However, with this structure, the thermal stress of the high linear thermal expansion Al heat sink is directly applied to the insulating substrate (IS), which adversely affects heat cycle performance. As a countermeasure, the IS and heat sink are joined by a brazed punched Al plate, which absorbs the thermal deformation in the structure. The holes of this punched metal plate are provided at the optimal locations to minimize deterioration in thermal resistance. Deformation of the holes also greatly reduces the amplitude of the deformation that concentrates at the edges of the IS during the heat cycle.

"However, these developments are approaching the limits of loss performance and it will soon be difficult to further improve the overall performance of components that utilize control and module technology. For these reasons, Silicon Carbide is attracting attention as a potential new breakthrough material for the development of the next generation of power electronic components", Hamada explained.

As a wide bandgap semiconductor, SiC is regarded as an essential technology for future improving power density. The on-state and switching losses of SiC are half and one-fourth that of Si, respectively, and the temperature limit of SiC is 250°C. Compared to Si, SiC devices have the merits of size and loss reduction, and allow the adoption of simpler cooling structures. In contrast, various issues must be resolved before SiC devices can be practically adopted. These include securing sufficient reliability, developing high-temperature materials, reducing costs, and the like. "Various studies have examined the potential of improving current materials to enable higher operation temperatures. However, it will be difficult to meet the requirements of automotive applications by this approach. Furthermore, even if performance requirements can be satisfied, the use of expensive materials will block further popularization of environmentally friendly vehicles. For this reason, collaboration with the material suppliers is a critical pre-condition for developing reasonably priced materials that can be used in high-temperature environments", Hamada concluded.

	2nd Prius	3rd Prius
IPM Appearance		
Cooling Structure	 Insulating Substrate, Solder, IGBT/ Diode, Solder, Heat Sink (Cooper alloy), Grease, Cooling Plate (Al)	 **Direct Cooling Structure**, Solder, IGBT/ Diode, Insulating Substrate, Punched Plate, Cooling Plate (Al)
Operating Maximum Voltage	500 V	+150 V → 650 V

IPM structure of 2nd and 3rd generations used in the Toyota Prius

On the Road Towards Ideal Power Semiconductors

PCIM
EUROPE

International Exhibition and Conference
for Power Electronics, Intelligent Motion,
Power Quality
Nuremberg, 8 - 10 May 2012

With over 310 exhibitors on an exhibition space of 14,500 square meters, PCIM Europe (8 - 10 May 2012 in Nuremberg) is set to reach a new record. The total space booked already exceeds the total for 2011. The figure of 7,000 pre-registered visitors not only surpasses the figure for the same time last year, it also confirms the industry's positive outlook for 2012. The many exhibitors from abroad (54 % of the total number) underline PCIM's position in the power electronics exhibition landscape. The conference, with more than 700 participants expected, also mirrors this growth trend. For the first time, PCIM Europe will be held in the two halls 11 and 12.

Before the conference gets underway, seven seminars on Sunday and eleven tutorials on Monday offer delegates the opportunity to focus on specific questions relating to power electronics. In addition to technical trends such as "Wireless Power Technologies" and "Battery Charging for Electric Vehicles", PCIM Europe will also offer a business topic on "The easy and straightforward way to a successful presentation of technical content".

Seminars and tutorials

Seminar 1 "Batteries for Beginners" by Richard Redl, Redl Consulting, Switzerland, is an entry-level seminar for power-electronics engineers, power-management IC designers, system designers, managers, engineering students and all other professionals interested in the characteristics and application aspects of batteries. This seminar presents a comprehensive introduction to batteries, covering technologies, applications, characteristics, charging techniques and charger circuits, battery alternatives, and also battery monitoring and management solutions.

Seminar 2 "Basics of Electromagnetic Compatibility (EMC) of Power Systems" by Jacques Laeuffer, Dtalents, France, is targeted towards engineers and project managers, who design, specify, integrate converters, inverters, and components, for power electronics and/or drive systems, optimized for E.M.C., global cost and reliability.

Seminar 3 "PCB Layout for Low EMI" by Bruce Carsten, Bruce Carsten Associates, USA, is directed largely towards the switchmode design engineer who is either directly involved in PCB layout, or needs to direct and assist layout technicians. However, the seminar will also be of some value to layout software users without an engineering background. Although related to previous comprehensive EMI seminars by the instructor, the focus of this new seminar is on the physical design and layout of a PCB to minimize EMI. A great deal of switchmode EMI can be produced or avoided in the layout and construction of a Printed Circuit Board (PCB), and EMI from a poor layout is usually very difficult to fix without a redesign. This half day seminar contains extracts from the full day seminar presented last year, focusing on the magnetic and electric shielding benefits of ground planes, and the use of "switching cell macros" to assist in a low EMI layout.

Seminar 4 "Frequency Response Measurements on Switching Power Supplies and Components" by Ray Ridley, Ridley Engineering Europe, France, is targeted for anyone designing switching power supplies at power levels from less than 1 W to 100 kW. This seminar will present the use of frequency response analysis for power systems design. Switching power supplies are unique in the wideband noise environment that they both generate and have to operate reliably in. Proper frequency response measurements are essential to characterize both the passive components and the power circuits. Capacitors used in power supply design should be properly characterized for their value, ESR, and resonant frequency before they are used in a power

PCIM 2012 exhibition will be larger than ever and will be held in the two halls 11 and 12

PCIM 2012 conference is the major European power event and starts already on May 6 with seminars and tutorials

circuit. The data provided by the manufacturer is often unreliable. These numbers are essential for proper power circuit design. Measurements can be made using available lab equipment if the proper test circuit setup is used. Since most magnetics are custom designed and manufactured, it is essential to measure as many of the equivalent circuit-model components as possible. It is also a requirement in many industries to measure input and output impedance transfer functions, plus noise transmission. Specialized injection techniques are demonstrated to facility the safe perturbation and measurement of high power circuits.

Seminar 5 "The Easy and Straight Way to Successful Presentation of Technical Content" by Mike Meinhardt, SMA Solar Technology, Germany, targets engineers or researchers writing papers and giving oral presentations at conferences - in particular Ph.D. students and engineers at the beginning of their career.

Seminar 6 "Wireless Power Technologies" by Ionel Dan Jitaru, Delta Energy Systems, USA, will present a comprehensive overview of the wireless power technologies in the last several years and its direction in the near future. In the last several years there was a significant interest in wireless power generated by the need of convenience for portable equipment users. The seminar will present some of the technology behind the lower power levels up to 5 W in the area of mobile phone and 15 W to 120 W for tablets and laptops to very high power (120 kW) for automotive applications. The seminar will focus mostly on the technological challenges of wireless power ranging from the magnetic, topology, communication and control. One of the biggest challenges in wireless power is magnetic structure, wherein the coupling is limited and the windings are placed in the vicinity of the gap, with all the negative consequences associated with the fringe magnetic field. New magnetic structures aimed in addressing these problems will be presented.

Seminar 7 "Control of MicroGrids" by Josep Maria Guerrero, Aalborg University, Denmark, targets mainly PhD students, Professors, or Industry engineers from Power Systems, Power Electronics, or Control area. A Microgrid can be defined as a part of the grid with elements like distributed energy sources, power electronics converters, energy storage devices and controllable local loads that can operate autonomously islanded but also interacting with the main power network, in a controlled, coordinated way. The distributed control of these elements will be presented.

Tutorial 1 "Trends in Soft Switching Topologies" again by Ionel Dan Jitaru, Delta Energy Systems, USA, concentrates on the soft switching topologies which are addressing the soft commutation both in the primary and the secondary side without adding complexity. The new developments in the semiconductor technology such as SiC and GaN have created the need for a reevaluation of the most suitable topologies in power conversion. Soft switching topologies have become popular in many power conversion applications in the last twenty years. Some of the soft switching topologies have added complexity and their practical use become more questionable with the availability of more ideal components. The progress in semiconductors, magnetic and packaging will increase the operation frequency, and soft switching topologies will become a necessity for higher efficiency.

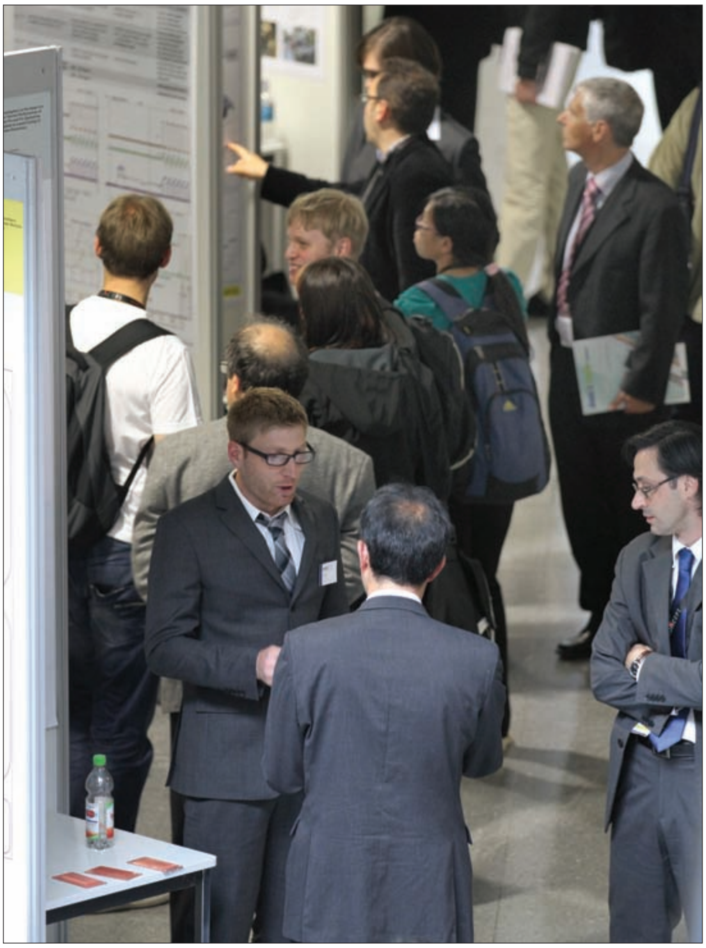
Tutorial 2 "Advanced Design with MOSFET and IGBT Power Modules" by Tobias Reimann (ISLE Steuerungstechnik) and Thomas Basler (Chemnitz University of Technology), Germany, tagets engineers designing converters with IGBT- and MOSFET power modules having basic knowledge in power devices and power converters. z

Tutorial 3 "Advanced Control Techniques for DC/DC Converters" again by Richard Redl, Redl Consulting, Switzerland, targets power-supply design engineers, power-management IC designers, system designers, project managers, engineering students, and all other professionals interested in advanced control of DC/DC converters. This tutorial presents advanced control concepts, first topic is a review of PWM control techniques, including both single-loop and two-loop (current-mode) control. Control for fast dynamic regulation (wide-band feedback loop, ripple regulators, feedforward control, voltage positioning), and for high efficiency (PFM, valley-mode control, adaptive bus voltage and adaptive frequency positioning) are discussed next. It concludes with an overview of controlling DC/DC converters for enhanced stability and robustness against parameter tolerances or external influences.

Tutorial 4 "Electromagnetic Design of High Frequency Converters and Drives" again by Jacques Laeuffer, Dtalents, France, targets engineers and project managers who design, specify, integrate converters, inverters.

Tutorial 5 "FPGA based Control of 2-level and 3-level Inverters" by Jens Onno Krah, University of Applied Sciences Cologne, Germany, targets R&D engineers and professionals working in the area of IGBT and MOSFET-based inverter design who wish to learn about power electronic specific usage of programmable logic. Advanced FPGA based control architectures are covered by discussing algorithms and new electronic components. The digital logic to implement an FPGA based full featured PWM generator for a 3-level inverter that determines all required switching sequences and the necessary blocking times can be fitted together with the fault detection and reaction and a supervising soft core CPU into one low cost device. Due to the straight forward VHDL respectively state machine programming such a solution is extremely fast and allows a cost efficient single chip implementation even for very high switching frequencies. Included is a memory stick with VHDL Files.

Although 6" SiC wafer capacity is now ramping-up for LED production at Cree, the power industry is not yet able to access it in volume. Yole Développement expects 2012 to be the starting point for a wide diffusion of this 150 mm substrate that should act as an incentive for the remaining reluctant companies, arguing that SiC wafers are not compatible with their existing tool-kit. GaN is always mentioned as the competing technology that



Poster sessions are an integral part of the conference and accessible free of charge by all exhibition visitors

can disrupt the expected natural and organic growth of the SiC business. Super Junction MOSFETs is to become a standard technology allowing for size reduction in switch-mode power supplies. This trend is to put in perspective with GaN devices commercially available at 200 V and 600 V soon targeting the same applications. SiC will be positioned at higher voltages, Yole expects. This will be one of the questions to be discussed at this Special Session. Nevertheless, PEE's Special Session will show that 600V and even 1200V GaN switches will soon become available, which will compete with SiC counterparts. More on that and on PCIM in general in our next issue. **AS**

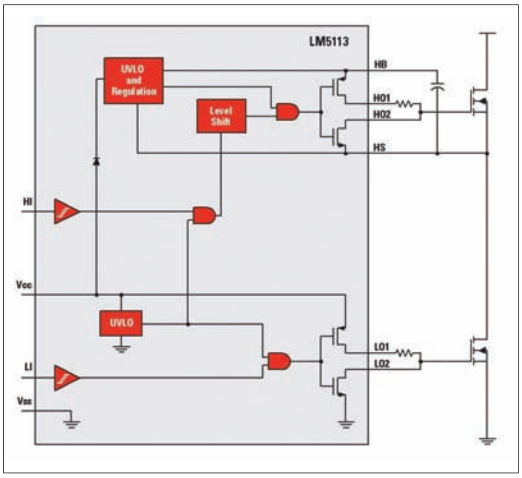
Driving Gallium Nitride Power FETs

Gallium Nitride (GaN) power FETs can provide significant power density benefits over Silicon MOSFETs in power converters. They have a much lower figure of merit (FOM) due to lower on-resistance and lower gate charge. With greater efficiencies, faster switching frequencies, and an ultra-small package footprint, GaN FETs enable higher density power converters.

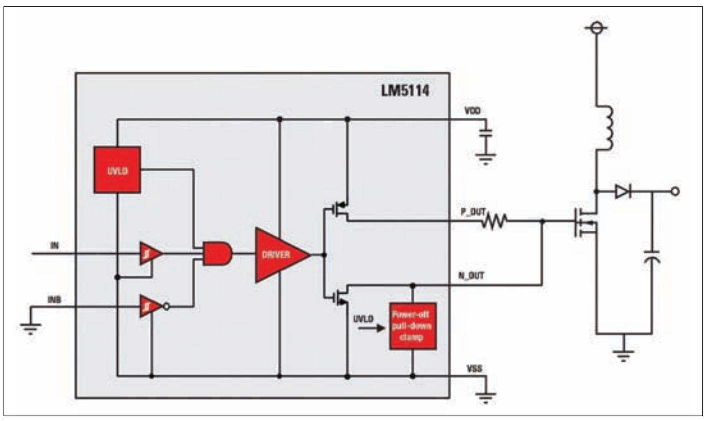
In recent years, enhancement mode Gallium-Nitride power transistors (eGaN FETs) have emerged as promising devices for high power density switch mode power supplies. Given the same die size, the GaN FET presents lower conduction resistance, smaller gate charge, and faster switching capability than the comparable MOSFET devices. The enhancement mode allows the GaN FET to operate similarly as power MOSFET, minimizing the learning curve for power supply designers. However, driving a GaN FET needs particular care, because the low gate-to-source maximum voltage (V_{gs}) rating and ultra low gate threshold voltage (V_{th}) raise some strict constrains and challenges. These stringent gate-source voltage drive requirements of GaN power FETs pose new challenges related to limiting the high-side FET drive level to less than 6 V, as well as preventing high dV/dt transients from causing erratic switching behavior.

On one hand V_{gs} must be limited below 5.5 V, leaving about 0.5 V safe margin. On the other hand, a V_{gs} voltage between 4.5 V and 5.5 V is desirable to realize full enhancement of the GaN FET in order to minimize its $R_{ds(ON)}$ and consequently the associated conduction losses. Observing both V_{gs} absolute maximum rating and the desirable full enhancement V_{gs} voltage, the gate drive bias supply should be tightly regulated at about 5.0 V. The conventional bias supply produced by a loosely cross-regulated transformer winding that is suitable for MOSFET drivers cannot be directly used.

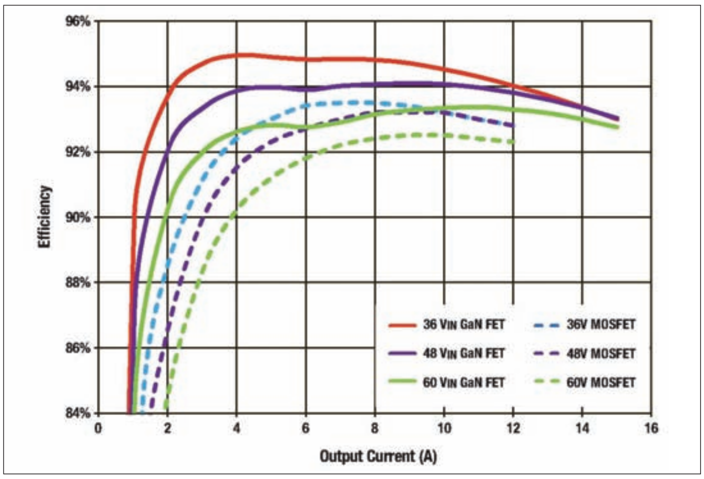
The second challenge comes from the fact that GaN FET does not have the body diode. When in reverse conduction with the GaN FET gate held low, the reverse drain-to-source voltage V_{sd} increases with increasing current. This causes a major problem in driving a high side GaN FET in a totem pole configuration such as synchronous Buck or half-bridge converters.



LEFT: GaN high-side driver LM5113 block diagram



BELLOW: GaN low-side driverLM5114 block diagram



GaN FET efficiency vs traditional MOSFET (input 36 to 75V; regulated output 12V; switching frequency at 333 kHz GaN FET, 250 kHz MOSFET)

The third challenge of driving GaN FET comes from the low gate threshold voltage V_{th}, which is less than 1.5 V. The minimum Vth can be as low as 0.7 V. In contrast, the threshold voltage of power MOSFET is usually greater than 2 V. The ultra low V_{th} of GaN FET imposes stringent requirements on the gate drive. Stray inductance along the gate drive path in a practical circuit board as well as the gate capacitance of the GaN FET can cause a resonance during switching transient, and some low magnitude voltage ringing can usually be observed at the gate. Though unwanted, such ringing is normally harmless for power MOSFET, but it can easily result in unintended turn-on of GaN FET during turn-off, increasing losses and even causing shoot-through. To improve the gate drive noise immunity, it is critical to minimize stray inductance by layout optimization techniques.

The GaN FET's ultra low V_{th} causes another problem. The most commonly used gate drive structure is the totem pole structure formed by two small MOSFETs with the P-channel FET on the high side and the N-channel FET on the low side. When driving a power MOSFET, designers often use a diode in parallel with a gate resistor to control the turn-on speed without affecting the turn-off speed. Unfortunately, this simple approach cannot be used with GaN FET, because the diode forward drop may exceed the ultra low gate threshold, preventing the GaN FET from being turned off.

High- and low-side drivers

Texas Instruments (TI) solves the challenges of driving GaN power FETs with the LM5113 (see PEE September 2011, pages 19 - 23), the industry's first 100V integrated half-bridge driver for GaN power FETs - and the new LM5114 - a 7.6 A single low-side driver with independent source and sink outputs. Compared to discrete implementations, these drivers provide significant PCB area savings to achieve high power density and efficiency while simplifying the task of driving GaN FETs reliably.

The LM5113 uses proprietary technology to regulate the high-side gate voltage at approximately 5.25V to optimally drive GaN power FETs without exceeding the maximum gate-source voltage rating of 6V.

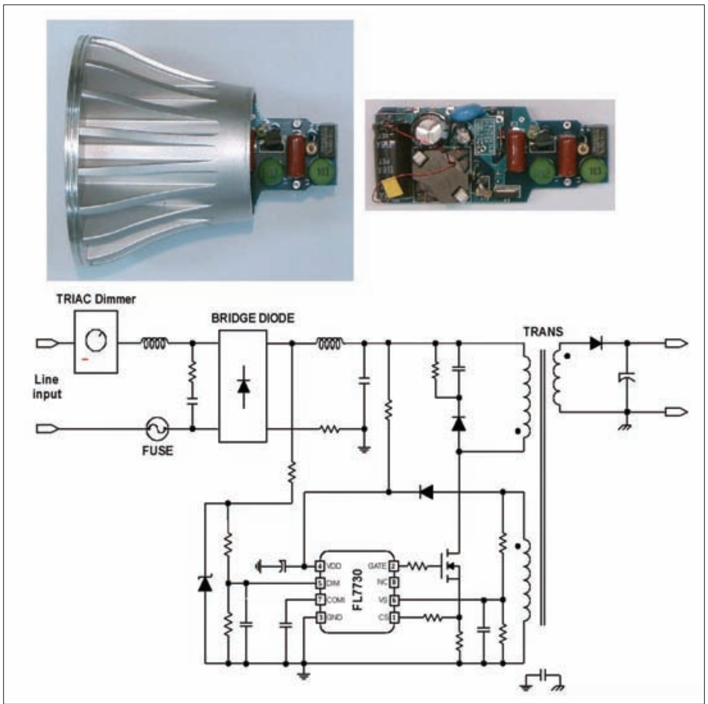
The bridge driver also features independent sink and source outputs for flexibility in the turn-on strength with respect to the turn-off strength. The LM5113 has a low impedance pull down path of 0.5Ω to prevent undesired dV/dt turn-on and provides a fast turn-off path of the low threshold voltage GaN power FET.

The LM5114 features a high 7.6 A drive capability needed in high-power applications where larger or paralleled FETs are used. Strong pull down strength makes it suited to drive the new enhancement mode GaN FETs. The independent source and sink outputs eliminate the need for a diode in the driver path and allow tight control of the rise and fall times.

www.ti.com/gan

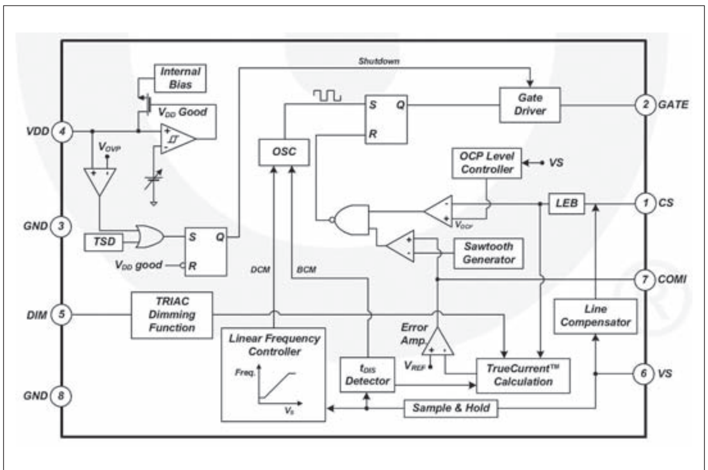
Driver for Dimmable LED Lighting

LED lighting has evolved into a promising solution for replacing conventional lighting sources, such as fluorescent and incandescent lights. However, designers face several obstacles in residential and commercial LED lighting applications up to 20 W including bulb, down lighting (GU10/E17, E26/27, PAR30/38) and Tube/Bar. Implementing dimming capabilities in a conventional TRIAC dimmer infrastructure is challenging because of dimmer compatibility. Additionally, small space requirements remain a consideration. To help designers address these challenges, Fairchild Semiconductor developed the FL7730 single-stage primary side regulation (PSR) controller with power factor correction (PFC), TRIAC and analog dimming compatibility, as well as the FL7732 for non-dimming applications.



TRIAC 8.8 W dimming board and schematic

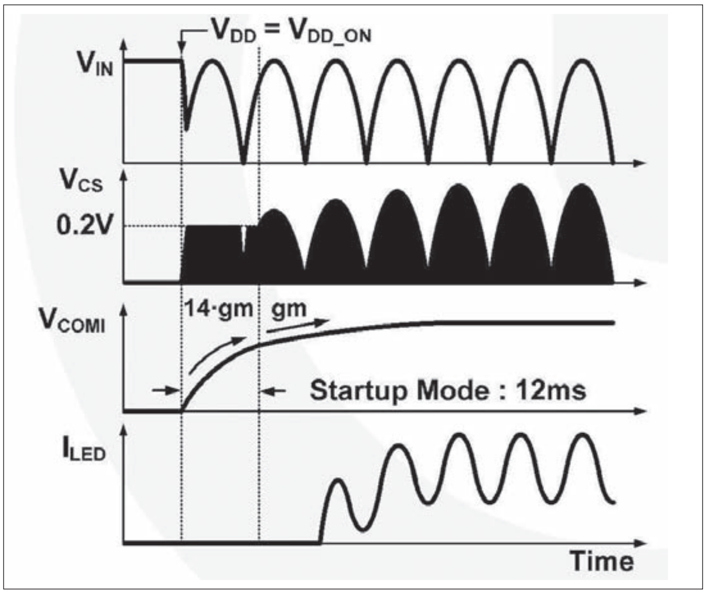
The FL7730 is an active PFC controller for single-stage flyback topology application. The device supports both TRIAC and analog dimming. Implemented with Fairchild's unique analog sensing technology, the device can achieve TRIAC dimming control without flicker over the full range of 0 to 100 % light output. The FL7730 and FL7732 combine primary-side regulation and a single-stage PFC topology to minimize total bill-of-material count, such as an input electrolytic capacitor and feedback circuitry, therefore allowing for a more compact, longer life, and lower system cost design.



Functional block diagram FL7730

To improve power factor and THD, both devices feature constant on-time control with an internal error amplifier and low bandwidth compensator. Precise Constant Current accuracy/control (± 5 percent) regulates accurate output current, independent of input and output voltage, allowing designers to achieve high and improved lighting quality. Operating frequency is proportionally adjusted by output voltage in both devices to guarantee DCM operation with optimized PF/THD and simpler design.

Truecurrent technique and internal line compensation regulates accurate LED current independent of input voltage, output voltage, and magnetizing inductance variations. The TRIAC dim function block provides smooth brightness dimming control compatible with a conventional TRIAC dimmer. The linear frequency control in the oscillator reduces conduction loss and maintains DCM operation in a wide range of output voltages, which implements high power factor correction in a single-stage flyback topology. A variety of protections; such as short-LED protection, open-LED protection, over-temperature protection, and cycle-by-cycle current limitation; stabilize system operation and protect external components.

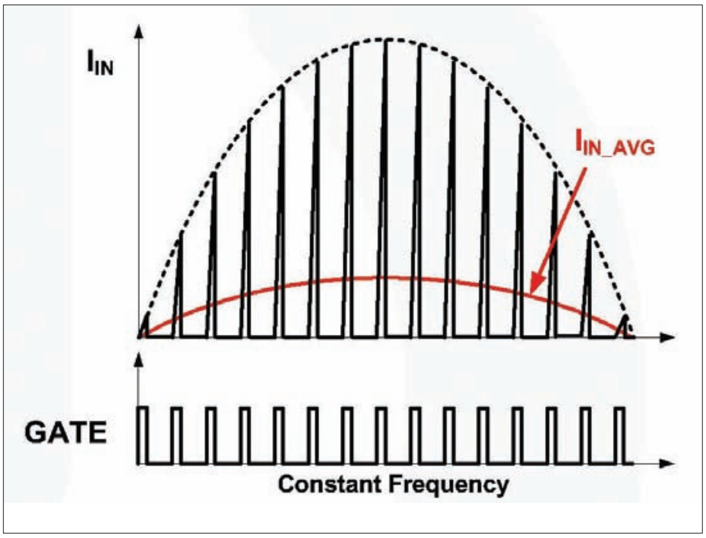


Startup sequence

Operation of the dimmable device

Powering at startup is slow due to the low feedback loop bandwidth in the PFC converter. To boost power during startup, an internal oscillator counts 12 ms to define startup mode. During startup, turn-on time is determined by Current Mode control with a 0.2 V CS voltage limit and transconductance becomes 14 times larger. After startup, turn-on time is controlled by Voltage Mode using the COMI voltage.

The output current is estimated using the peak drain current and inductor current discharge time because output current is same as the average of the diode current in steady state. The peak value of the drain current is determined by the CS pin. The inductor discharge time (t_{DIS}) is sensed by a detector. Using three sources of information (peak drain current, inductor discharging time, and operating switching period), a Truecurrent block calculates estimated output current. The output of the calculation is compared with an internal precise reference to generate an error voltage (V_{COMI}), which determines turn-on time in Voltage Mode control. With that technique,



Input current and switching

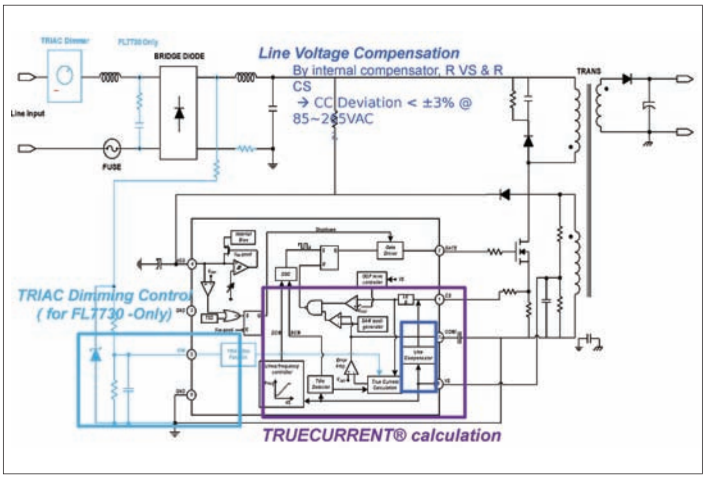
constant current output can be precisely controlled.

In a conventional boost converter, Boundary Conduction Mode (BCM) is generally used to keep input current in phase with input voltage for power factor (PF) and Total Harmonic Distortion (THD). However, in flyback / buck boost topology, constant turn-on time and constant frequency in Discontinuous Conduction Mode (DCM) can implement high PF and low THD. Constant turn-on time is maintained by an internal error amplifier and a large external capacitor (typically >1 μF) at the COMI pin. Constant frequency and DCM operation are managed by linear frequency control.

TRIAC dimmable control is implemented by simple and noise-immune external passive components and an internal dimming function block. Dimming angle is sensed by Zener diode and Zener diode voltage is divided by two resistors (R_{D1} and R_{D2}) to fit the sensing range of the DIM pin. The detected signal is filtered by capacitor C_D to provide DC voltage into the DIM pin. The internal dimming control adds CS_{offset} to the peak current value as the input of Truecurrent calculation block. When the dimming angle is small, lowered DIM voltage increases CS_{offset}, which makes calculated output current larger and reduces turn-on time to dim the LED brightness.

To disable the dimming function, a 1 nF filter capacitor can be added at the DIM pin. An internal current source (~7.5 μA) on the DIM pin charges the filter capacitor up to 4 V. FL7730 goes into IC Test Mode when DIM voltage is over 6 V; so the maximum DIM voltage should be limited to less than 5 V.

Excellent PF (≥0.9), low total harmonic distortion (Class C) and power efficiency of up to 85 % for the FL7730 allow to meet worldwide energy saving regulations. Fairchild offers a solution portfolio for low- (<20 W), mid- (20 W to 50 W) and high- (>50 W) LED driver applications.



Single-stage PFC, PSR flyback block diagram

Measuring Currents with Railway Class Accuracy

On-board energy measuring constitutes the system for measurement of electric energy that the traction unit takes from or returns to (during regenerative braking) the overhead contact line. Greater precision in this energy measurement allows operators to better understand their real consumption, and will enable energy management to reduce overall energy consumption, as well as monitoring total energy supplied from the external electric traction system. A new transducer for these applications will be introduced in the following.

Michel Ghilardi - R&D Project Manager, Marc Schaerrer - Development Engineer, Stéphane Rollier - Product & MarCom Manager, LEM SA, Geneva, Switzerland

In common with many other areas of business across Europe, changes in the regulatory environment are leading to more demanding standards for Railway Energy Billing. European rail-freight markets are being liberalized with privatization of the rail networks, and the separation of operating entities in terms of infrastructure and operators. Since the beginning of January 2010 passenger rail markets have been opened to cross-border competition.

Liberalization of European railway markets leads to a number of consequences, including the appearance of new competitors operating in each national market; increasing cross-border traffic and a greater number of services that operate through multiple countries; a new context of intra- and inter-modal competition; and rising demands in terms of cost transparency. This last point means that exact electricity consumption from supplies generated by every administration over which a service operates must be accurately invoiced.

Traction Units consume energy in each of the different countries they pass through; Railway Undertakings (RUs) have contractual relationships with each respective Infrastructure Manager (IM), and in order to be able to transparently bill the energy consumption, the RU must gather information regarding each border crossing, as the IM has to invoice the RU for the supply of energy. Greater precision in the energy measurement allows operators to better understand their real consumption, and will enable energy management to reduce overall energy consumption, as well as monitoring total energy supplied from the external electric traction system. The Energy Measurement Function (EMF) includes both voltage and current measurements; the relevant standard is the new EN 50463, which defines characteristics of transducers for current and voltage DC or AC measurement, as well as the energy measurement function itself.

New approach for current and voltage measurements

To comply with the required performance levels set out in the standard, LEM proposes different train solutions for current and voltage measurements. For DC voltage measurements of Class 0.5R for a single network voltage, the DV family of transducers is ideal. To carry out DC current measurement of Class 1R, a transducer from the DI family, used with a shunt of Class 0.2, will provide full compliance. For DC current measurements at the more demanding Class 0.5R, a unit from the new ITC family is the optimum solution (see Figure 1).

Measurement devices for service in the rail traction environment share a number of common features. They must measure

Figure 1: **The ITC current transducer series; the variant with remote signal processing module (left) facilitates mounting in traction-unit roof voids**

Percentage error limits — DC current transducers						
Accuracy class	± Maximum percentage current (ratio) error at percentage of rated primary current (I_{PN}) shown below, DC transducers Temperature condition: 23°C+/-2°C					
	1 %	5 %	10 %	20 %	100 %	120 %
0,2 R	2	0,4	0,2	0,2	0,2	0,2
0,5 R	5	1	0,5	0,5	0,5	0,5
0,75 R	7,5	1,5	0,75	0,75	0,75	0,75
1 R	10	2	1	1	1	1

Table 1: Permissible error limits for DC current transducers according to EN 50463

all power waveforms encountered; DC, AC, pulsed and complex. They must be of compact size for on-board deployment. They must exhibit low internal power consumption; excellent accuracy to meet the billing standards; low drift over temperature; high insulation and partial discharge levels in order to guarantee safety; and good levels of immunity against external electric, magnetic and electromagnetic fields for EMC protection. They are required to show low levels of emission; compliance to fire and smoke standards (these are mandatory in railway applications); and a range of features specific to the measurement function including immunity to common mode voltage effects, fast response time, large bandwidth, and low noise.

Desirable attributes include a modular construction approach allowing easy adaptation, with a range of connection options for the secondary side such as connectors, shielded cables, or terminals (threaded studs, M4, M5, UNC etc.). Reliability and lifetime must be designed-in and are demonstrated by an extensive series of environmental operating and ageing tests.

It is in the area of overall accuracy of the EMF (Energy Measurement Function) that EN 50463 imposes the greatest uplift in operating requirements. The EMF must have a total accuracy of 1.5% for active energy for AC, 3% for reactive energy for AC and 2% for DC, at +25°C. The accuracies of the current transducer, the voltage transducer and the Energy Meter are measured separately and combined for the overall accuracy using the following equation:

$$\varepsilon_{EMF} = \sqrt{\varepsilon_{VMF}^2 + \varepsilon_{CMF}^2 + \varepsilon_{ECF}^2}$$

where ε_{EMF} overall accuracy of EMF (system of current sensor, voltage sensor and energy meter); ε_{VMF} class accuracy of Voltage Measurement Function (voltage transducer); ε_{CMF} class accuracy of Current Measurement Function (current transducer); ε_{ECF} class accuracy of Energy Calculation Function (energy meter).

Among others, EN 50463 sets out the error limits for measurement of DC current shown in Table 1. For AC current transducers, the maximum permissible error at 1% of the rated primary current IPN is just 5% (class 1 R)! This is a significant challenge in terms of the linearity of the measurement system at the extremes of its range. Table 2 shows the permissible level of error with changes in ambient temperature, for specified ranges of DC current relative to the full-scale rated primary current. Once again, these are exacting requirements for a measur ement system.

If each of the different measurement devices - voltage transducer, current transducer and energy meter - has a Class accuracy of only 1R, the overall accuracy of the EMF is 1.732%, as calculated using the square root formula above. This is sufficient to meet the specified limits for a DC system (2.0% required). However, the required overall accuracy has to be valid over the whole re-verification time - this will be a period of several years and has yet to be finally defined. To ensure that an operating margin will be maintained over time, it is therefore advisable to choose lower class accuracies than the nominal values allowed in the standard. For multi-system trains, it is permissible to use a single voltage or current sensor for two or more voltage systems. Then the following applies:

1. The voltage sensor has to fulfil the accuracy requirements for each voltage system.
2. The current sensor has to fulfil the accuracy requirements for the highest rated current. For the lower rated currents, reduced accuracy requirements are specified.
3. For the energy meter the same constraints apply as for the current sensor.

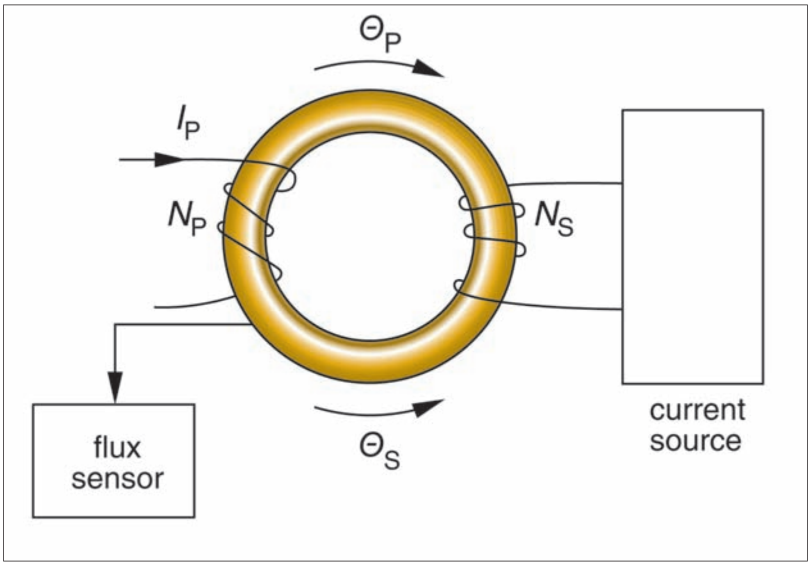
Meeting EN 50463 for current measurements

o address this developing rail-traction market and the problem of current measurement in both traction and industry applications, LEM has conceived and

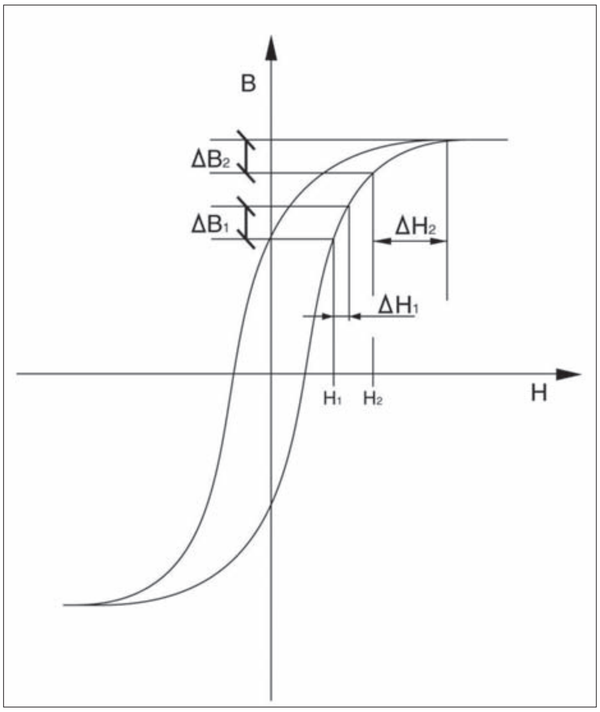
Value of current	System type	Transducer temperature coefficient [%/K]	
		Ambient temperature variation (main range) -10°C to +60°C*	Ambient temperature variation (extended range) -40°C to -10°C* and +60°C to +75°C*
$0.1\ I_{PN} \leq I \leq 1.2\ I_{PN}$	DC	0.01	0.02
$0.05\ I_{PN} \leq I \leq 0.1\ I_{PN}$	DC	0.02	0.04
$0.01\ I_{PN} \leq I \leq 0.05\ I_{PN}$	DC	0.1	0.2

* Note: reference temperature is at ±2%

Table 2: Maximum permitted deviations of DC current measurement with temperature variation



ABOVE Figure 2: Principle of the closed loop fluxgate current transducer



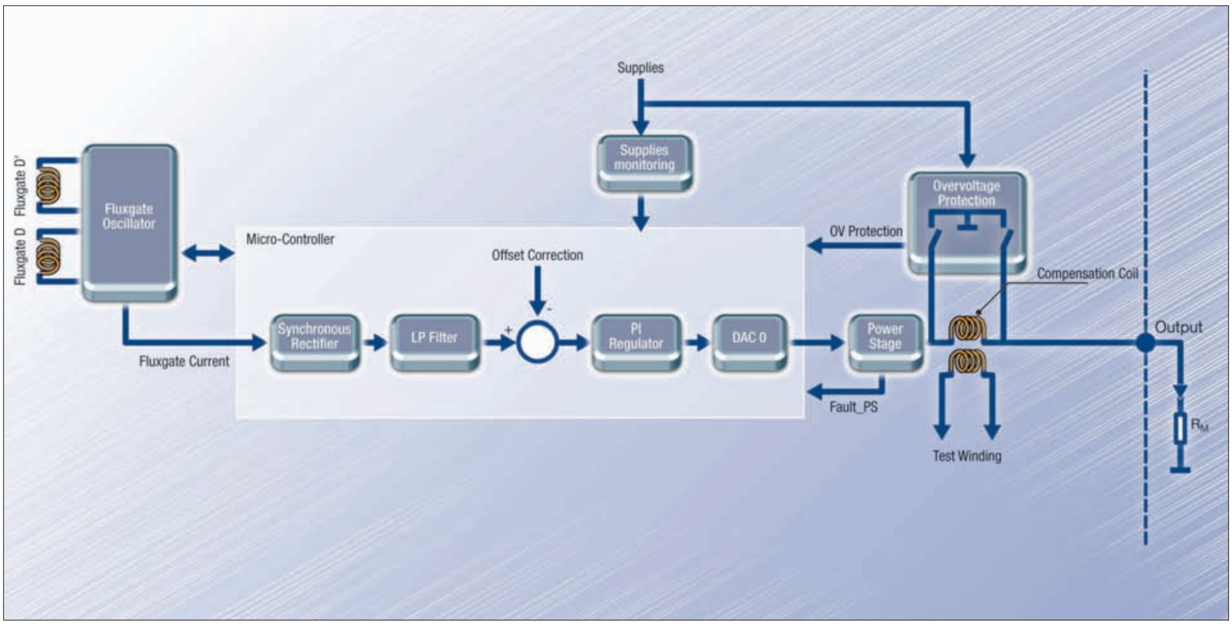
LEFT Figure 3: Hysteresis cycle of the magnetic cores; at different points on the curve, different increments of magnetic field strength H are required to yield the same change in flux density B

designed a new series of current transducers. Three models measure a current (DC or AC) up to 4000 A_{RMS} (6000 A peak) in vehicles that are supplied with energy from networks up to 3000 V. The transducers provide extra margin on the Class 1R ("R" indicating rail-traction) specification by achieving Class 0.5R accuracy.

Initial design studies confirmed that to reach this level of performance a transducer based on closed-loop fluxgate technology would be needed. The basic principle of the closed loop fluxgate measurement technique is shown in Figure 2. The primary (load) current I_P flows in a conductor that passes through the loop or core, giving rise to a current linkage Θ_P. For accurate measurement of DC currents, the method consists of compensating (balancing or nulling) Θ_P by an opposing current linkage Θ_S created by a current I_S.

To obtain an accurate measurement, it is necessary to have a highly accurate device to measure the condition $\Theta = 0$ precisely. Fluxgate detectors rely on the non-linear behavior of magnetic materials between the magnetic field strength H and the flux density B,as per Figure 3. The fluxgate detector employs a winding around the toroidal core in which an oscillating waveform continuously drives the core round its B-H hysteresis loop.

When applying this square wave voltage to a saturable inductor until its magnetic core starts to saturate, a current is created. Without primary current, $I_P=0$, this current is symmetric. When a DC current flows through the aperture of the core, the curve of the hysteresis cycle is then shifted, causing asymmetry of the current produced by the square wave voltage. This current is then measured using an



BELOW Figure 4: Signal processing path of the ITC series transducers, showing all the major functional blocks

accurate resistor and the asymmetry is used to adjust the secondary current in the compensation winding so that it exactly compensates the primary current (see Figure 4).

To this basic principle, LEM adds numerous refinements to yield a transducer that exceeds the demands of EN 50463 by a generous margin. For example, there is in fact not one fluxgate detector but two, to7 cancel out certain error terms in the measurement; a sophisticated microcontroller manages the measurement process, including a staged recovery from transient overload conditions supported up to 100 kA for 100 ms; measurement processing takes place in the digital domain, while a digital-to-analogue converter generates an analogue output signal that gives the reference to the PWM generator for the output stage; and a patented Class-D output amplifier design both reduces the power dissipation of the transducer but also decreases and balances the load currents from its power supply lines.

The ITC series meets the rail-traction industry sector's needs by reaching the Class accuracy 0.5R defined in the prEN 50463 standard for on-board energy monitoring operating over the temperature range -40 to +85°C. They are equally applicable to any situation in which kA-level current measurement accuracy of 0.5 % from 5 % to 120 % of the nominal current is required.

Standards governing rail traction measurements

A number of standards apply to any equipment used for rail traction applications. The EN 50155 standard that relates to "Electronic Equipment used on Rolling stock" in railway applications is the base standard of reference for electrical, environmental and mechanical parameters: it guarantees the overall performances of products in railway environments.

The new EN 50463 is specific to the energy measurement demand. It is worth noting that the transducers mentioned previously (DV, DI and ITC series) may be used for bi-voltage applications (that is, when switching from a network to another one when crossing from one supply domain to another) with only slightly derated accuracy. These transducers have a very low sensitivity to external magnetic DC or AC fields.

EMC (Electro-Magnetic Compatibility) is governed by EN 50121-3-2 standard for emission and susceptibility (the railway EMC standard) in its latest update, with EMC constraints higher than those of the typical industrial application standards. The DV, DI and ITC devices fully meet the higher specifications.

For Insulation and Safety, EN 50124-1 ("Basic requirements - clearances and creepage distances for all electrical and electronic equipment") has been used as a reference to design the creepage and clearance distances for the DV, DI, ITC products.

Similarly, the materials used in the construction of the units comply with the NFF 16101/2 standards for fire and smoke classification (tests report for materials available on request).

DV, DI, ITC models are produced in LEM facilities that are IRIS certified and the products are CE marked under European EMC directive 2004/108/EEC and the Low Voltage directive; LEM is able to contribute to energy savings and is certified ISO 14001 for environmental management standards.

With Sinter-Technology Forward to Higher Reliability of Power Modules for Automotive Applications

A new kind of applications, the whole automotive market describes more and more a "high end"-power module. The unprecedented combinations of thermal, electrical, and reliability performance with a very small volume and weight are the challenge today. A consistent further development of sinter technology for power modules comprises and answers to all these requirements. Sinter technology substitute all solder connections and also the aluminum bond wires. These are at present the weak points in a standard power module. The thermal and reliability results of a 400 A/600 V Dual IGBT power module will be shown in this article. **Jürgen Steger, Project-leader, SEMIKRON Elektronik, Nuremberg, Germany**

The motivation for a complete new development of a power electronic module is due two main reasons. First is the reliability for electric cars. Secondly, the latest generation of power semiconductor switching devices such as MOSFETs and IGBTs achieve very high power densities so that conventional thick aluminum wire bonding technology (Figure 1) represents a bottleneck for load current capability and reliability. The elimination of bond wires in power modules has been discussed for several years in industry and academia. Most of the new packaging approaches have been based on soldered or welded bumps.

Recently, attempts have been made to improve this technology [1]. However, these attempts lead to comparably large efforts in the power device metallization and processing. Environmental conditions such as humidity, temperature, industrial gas atmosphere, and mechanical shock and vibration play an increasingly important role for electric vehicles and other applications. However, not only these technical and environmental challenges have to be faced, but also power electronic modules need to be reduced in size and weight for use in vehicles and have to be interfaced in a simple and reliable manner, even at high load currents.

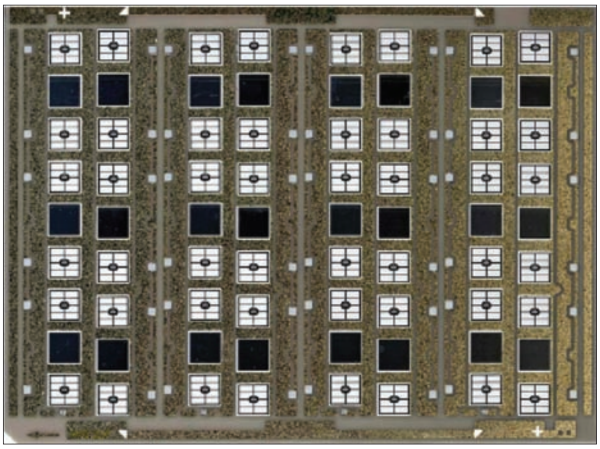


Figure 2: 5"x7" DBC card with four substrates (before laser cutting) with sintered chips

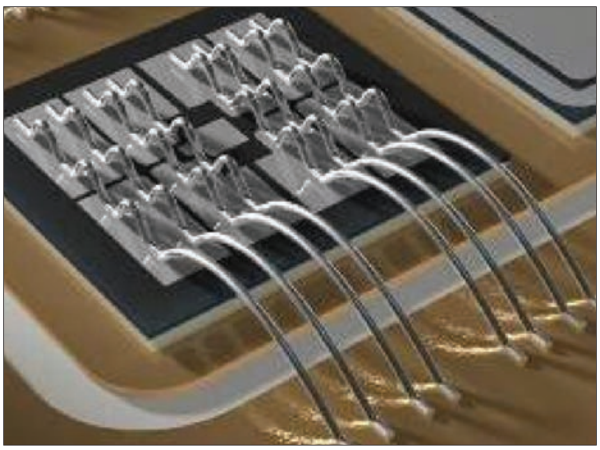


Figure 1: Conventional thick aluminium wire bonding technology

Chip-to-ceramic substrate sintering

Silver sintering is an established technology which has started to replace the soldering of chips to DBC substrates in mass production. Thanks to its unprecedented reliability and thermal behavior, this joining technology makes power modules better suited for higher temperatures and demanding applications, such as electric vehicles. However, two issues remain unaddressed: How to replace wire bonding on the chip front side, and how to interface the power module to the heat sink.

As examples, Figure 2 shows a 5"x7" DBC card which contains four substrates

Figure 3: **DBC substrate after mechanical stress test**

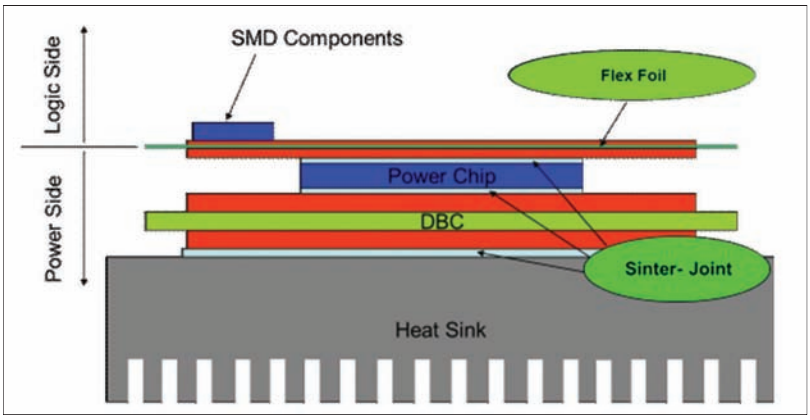


Figure 4: **Cross section of a newly designed power module integrated with a pin fin heat sink exhibiting no solder layers and wire bond interconnects**

(before separation by laser cutting) with sintered chips, as used today in series production for power modules in automotive applications. Figure 3 shows one substrate with sintered chips after an extreme mechanical stress test - the sinter joint are unbreakable.

Up to this point, the new technology follows this well established process. However, rather than continuing in the process sequence, which consists of Al-wire wedge bonding, electrical testing, laser cutting, and final automated optical inspection (AOI) as in conventional devices, sintering [3] proceeds differently.

New design possibilities

Figure 4 shows a schematic drawing of this packaging technology. The special flex foil with a metal layer on the bottom with a thickness comparable to bond wire diameters serves to connect the chip top side. A thin metal layer on the top represents the gate and sensor tracks which are connected to the power layer by vias. The two metal layers are insulated from each other by polyamide. Also, the top layer can be used for SMD components, such as temperature sensors and gate resistors. The second sinter joint connects the chip back side to a standard DBC substrate.

Figure 5 shows the flex board (top side), as it is prepared to be positioned and sintered within the next process step. In areas which are connected to the chips with the flex board, the power side of the board is screen or stencil printed with silver paste. In this particular design, the auxiliary contacts, such as gate and emitter, are carried out as tracks on the flex board, reaching out to the left and right to be folded-in later.

Interconnect and cooling

This new sinter technology proceeds in providing thermal and electrical interfaces by sintering the power terminals and the heat sink to the power device. Figure 6 shows the AC and DC power terminals, made from Ag-coated Al or Cu, as well as a pure Al pin-fin heat sink. On top of the heat sink, a defined area is stencil printed with silver paste where the power part will be attached.

Now the heat sink, the power terminals, and the power part are assembled into a sintering jig and put again into a conventional sinter press, this time forming the sinter connections from heat sink to substrate and substrate to power terminals. Afterwards a simple plastic frame is added to provide guidance for the auxiliary terminals and to provide alignment for the use of this device in the power electronic inverter system. Figure 7 shows how all parts are assembled together to form a 400 A, 600 V dual SKiN device. The device contains two 200 A IGBTs and one 400 A freewheeling (FWD) diode for the upper and the lower switch, as well as a temperature sensor chip.

Figure 8 shows the finished device as it is in production. In this specific layout, the auxiliary contacts are formed as flex layer tracks, folded in such way that they can be connected to a printed circuit board (not shown). The auxiliary contacts of the two switches come out to the left and the right of the long side of the heat sink, whereas the plus, minus and phase terminals come out on the short sides of the heat sink, opposing each other.

Test results

The electrical properties of the device demonstrate the superiority of a continuous metal layer on top of the chips, compared to discrete bond wires. A detailed comparison of electrical test results of the device with flex board, as shown here, versus a device with the very same design, but with bond wires instead of flex board has been published before [4]. The flex board leads to a significantly higher surge current capability of the free-

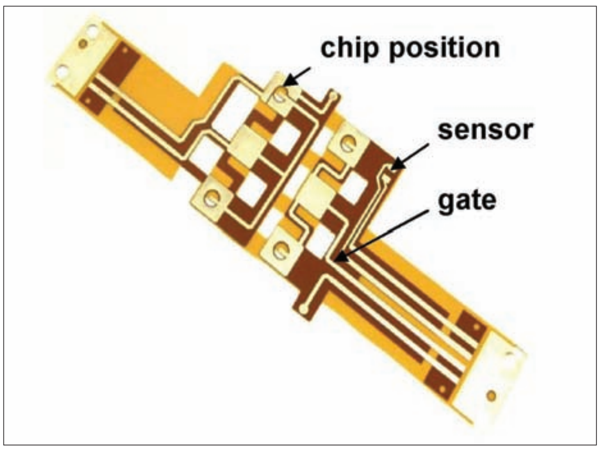


Figure 5: **Flex board (top side) prior to sintering to the substrate**

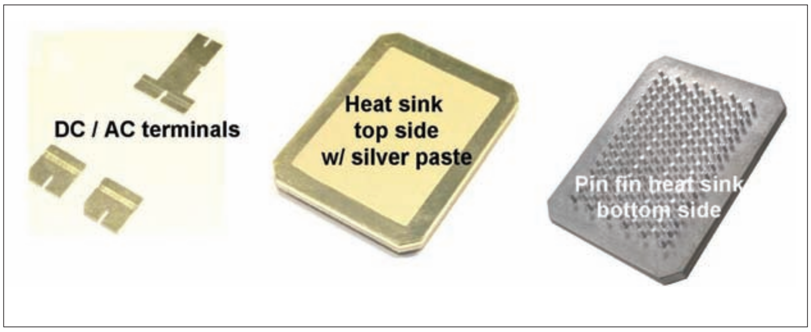


Figure 6: DC and AC power terminals as well as an Al pin-fin cooler with a silver paste area on the top side

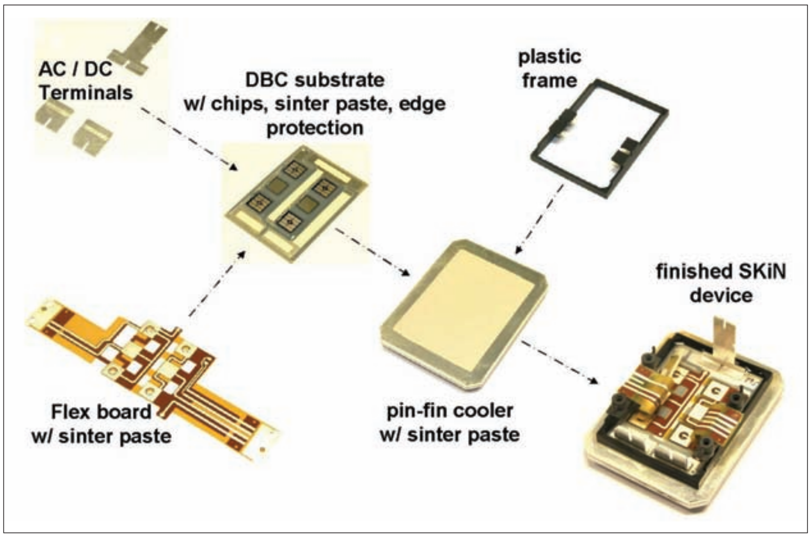


Figure 7: Exploded view of a 400 A, 600 V dual IGBT device comprising heat sink, DBC substrate with IGBT and FWD chips, flex board and power terminals - all being connected by silver sintering technology

wheeling diodes than for wire bonded diodes.

The device has a thermal resistance of junction to ambient of just 0.44 Kcm²/W which is 35 % lower than that for conventional power modules. Therefore, the current rating can be increased accordingly. Figure 9 shows infrared images of the device under load current, for the IGBT and the FWD, respectively. As shown, the chip temperature is very uniform across the chip and from chip to chip. The spacing between the chips is designed such that there is almost no thermal overlap between the chips.

In power cycling, the device is heated by the power dissipation during the conduction period and then cooled down when the maximum test temperature is reached. The maximum number of cycles can vary orders of magnitude, depending on the temperature difference between the highest and lowest temperature and the medium temperature. The raise and fall times of the temperature, as well as the test being carried out under constant maximum power, constant maximum temperature, or constant maximum current [5]. Figure 10 shows power cycling results.

Passive temperature cycling is challenging for such an integrated device, as the thermal coefficients of heat sink, substrate, chips, and flex board are all different. Therefore, extensive temperature cycling tests were carried out, typically cycling the devices between -50°C and +150°C, with a temperature rise and fall time of 3 K/min. Several hundred cycles up to a thousand cycles were achieved,

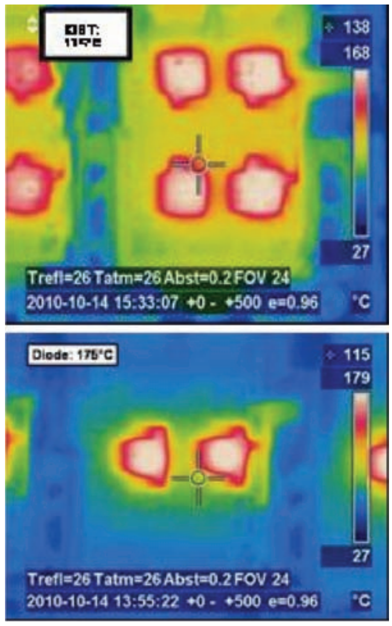


Figure 9: Infrared image of the device with DC IGBT load current of 400 A (upper image) and free-wheeling diodes heated by the same load current (lower image). The spacing between the chips is optimized to provide no thermal cross talk

before the DBC substrate started to delaminate from the heat sink. In various experiments it could be shown that thickness and morphology of the sinter layer between substrate and heat sink are key parameters to achieve a good passive thermal cycling performance.

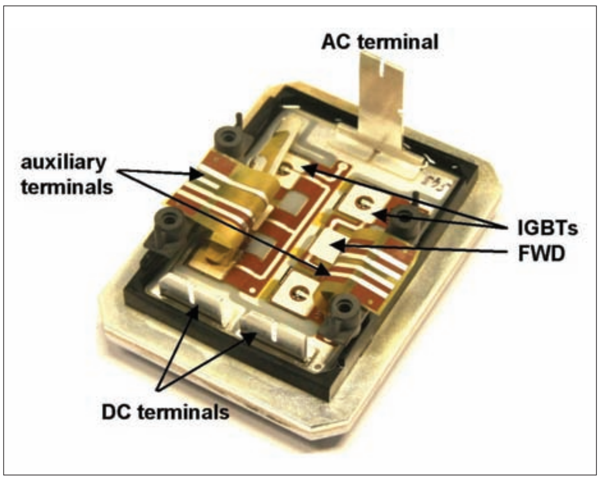


Figure 8: Series manufactured 400 A/600 V dual IGBT device in 74 mm x 56 mm x 11 mm dimension and 0,095 kg weight

Conclusions

SKiN, a new packaging technology without bond wires and solder layers has been introduced. All interconnections to chip top and bottom surface, DBC to heat sink and power terminals are made by an Ag sinter joint. The bond wires are replaced by a special flex foil which increases the chip top side attached contact area by a factor of 4.

In order to demonstrate the exceptional

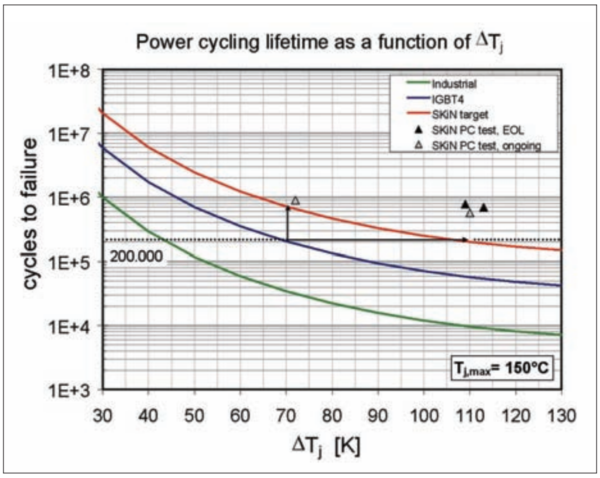


Figure 10: Power cycling capability of SKiN as a function of ΔT_j, compared to standard and improved conventional devices. 500,000 cycles can be reached at ΔT_j =110K

performance improvements of the overall construction and in particular the flex foil a comparison to a benchmark module with traditional Al bond wires has been made. Due to the elimination of thermal interface materials and the integration of a high performance pin fin heat sink it is possible to double the power dissipation in comparison to traditional designs. Just the elimination of the thermal grease layer exhibits an improvement of 25 % of the total thermal resistance junction to water. Due to the modified geometry and the increased chip contact area a 27 % increase of the diode surge forward current capability and a 2 nH reduction of the total commutation stray inductance has been achieved. The power cycling performance demonstrates an improvement of factor 70 over the industry standard and an improvement of 10 over the single sided sintered benchmark module.

Further activities are ongoing to exploit the new possibilities of the two layer flex foil. These are in particular a further improvement of the thermal resistance due to dual side cooling and the integration of passive and active components for gate drive, current and temperature sensing [6].

Literature

[1] *F. Hille, F. Umbach, T. Raker: "Failure mechanism and improvement potential of IGBT s short circuit operation", Proc. ISPSD 2010, pp. 33, Hiroshima, 2010*

[2] *C. Göbl: "Low Temperature Sinter Technology Die Attachment for Power Electronic Applications", Proc. CIPS 2010, pp. 327, Nuremberg, 2010*

[3] *German Patent DE 10 2007 006 706*

[4] *P. Beckedahl, M. Hermann, M. Kind, M. Knebel, J. Nascimento, A. Wintrich: "Performance comparison of traditional packaging technologies to a novel bond wire less all sintered power module", Proc. PCIM 2011, Nuremberg, 2011*

[5] *U. Scheuermann, S. Schuler: "Power cycling results for different control strategies", Microelectronics Reliability 50 (2010), 1203-1209*

[6] *T. Stockmeier, P. Beckedahl, C. Göbl, T. Malzer: "SKiN: Double side sindering technology for new packages", Proc. ISPSD 2011*

Flexible One-Step Mounting Technology

Aiming to cut assembly costs and avert inverter assembly flaws, several companies now offer power modules that can be mounted in a single step. Vincotech taken this notion and developed a novel Press-fit technology and made it available in a wide range of products, including modules with pre-applied phase change material and thermal grease. These power modules also enable low inductance designs. The article looks closer at how power modules, engineered for one-step assembly encompassing the PCB and heatsink, make life easier for manufacturers. **Patrick Baginski, Field Application Engineer, Vincotech, Unterhaching/Munich, Germany**

Most power modules today compel manufacturers to assemble units for their applications in several steps. Someone has to apply thermal interface material, mount the module to the heatsink, solder the module's pins to a printed circuit board (PCB), and fix the PCB to the module to relieve its pins of any mechanical stress. All this takes time and costs money. Manufacturers have been asking for something better and faster. Suppliers responded by marketing pressure, spring and press-in contacts. Vincotech's power modules enable low inductance designs and come along with pre-applied phase change material and thermal grease.

Mounting the power module, PCB and heat sink in a single step reduce effort and overhead. Figure 1 shows the basic structure of such modules:

1. The actual power module with optional pre-applied thermal grease or phase-change material
2. The PCB, which can be designed for modules with pressure contacts or with vias when using Press-fit pins
3. The pressure lid

The lid fixes the entire system, including the heat sink. There is no other way to apply pressure from the top on down to the bottom. But this setup has its drawbacks: The lid is relatively heavy because it has to bear up under considerable mechanical force bearing down from above. It also has to disperse this force across the entire area. Bracings have to be inserted in the structure to ensure mechanical stability. Some approches require the lid only during mounting; others need it to operate. Modules for higher power applications need two holes to handle the pressure and force. However, two screws defeat the purpose of one-step mounting.

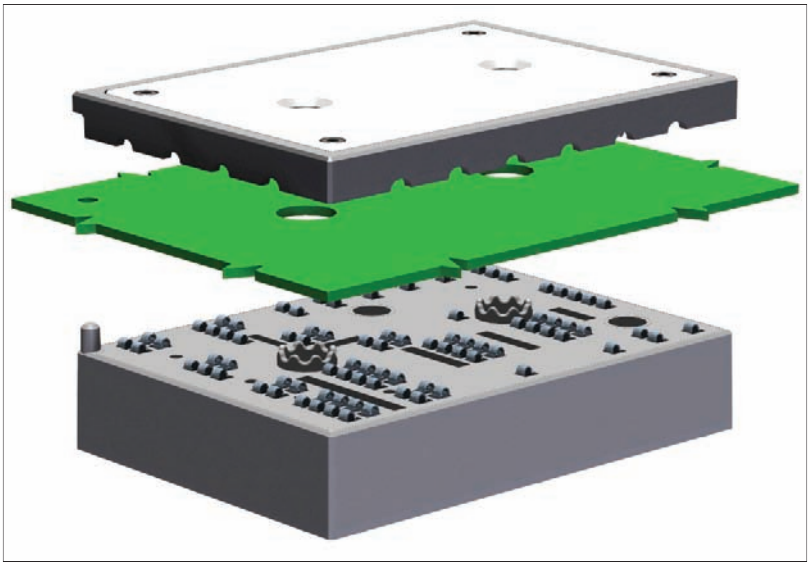


Figure 1: **State-of-the art one-step mounting technology**

Putting one or more holes in the middle of the module substrate takes up space better devoted to semiconductors. Bond wires have to be routed around the hole, which increases stray inductance within the module and throughout the application. Some legacy power modules' concave base requires more thermal interface material than a convex base, thereby increasing thermal resistance to the heat sink. A lid also limits the options when it comes to laying components out on the PCB.

The answer to one-step mounting solution

The answer to all these problems is a module without a lid and without holes in the middle of the housing. And the key is the interconnection between the module and heat sink. Vincotech's solution features two mounting holes at the module's edges. These holes are in the lateral mounting straps on the sides of the module, which means the base can be convex. The mounting straps are pressed down and fixed with the heat sink in one step. The modules' base bends, creating a flat surface, and a pre-applied thin layer of thermal interface material results in metal-to-metal contact where it is possible. For true one-step mounting, the module pins and PCB have to be interconnected at the same time.

The actual module is based on a combination of the flow technology and Press-fit contact pins. Every module has a pre-bent DBC and a step of a certain height between the mounting straps and the DBC to ensure long-term stability and very low thermal resistance to the heat sink. Thanks to flow technology, pins may be positioned freely. It also accommodates custom topologies.

Bushings and bolts rather than screws hold the module down, as illustrated in

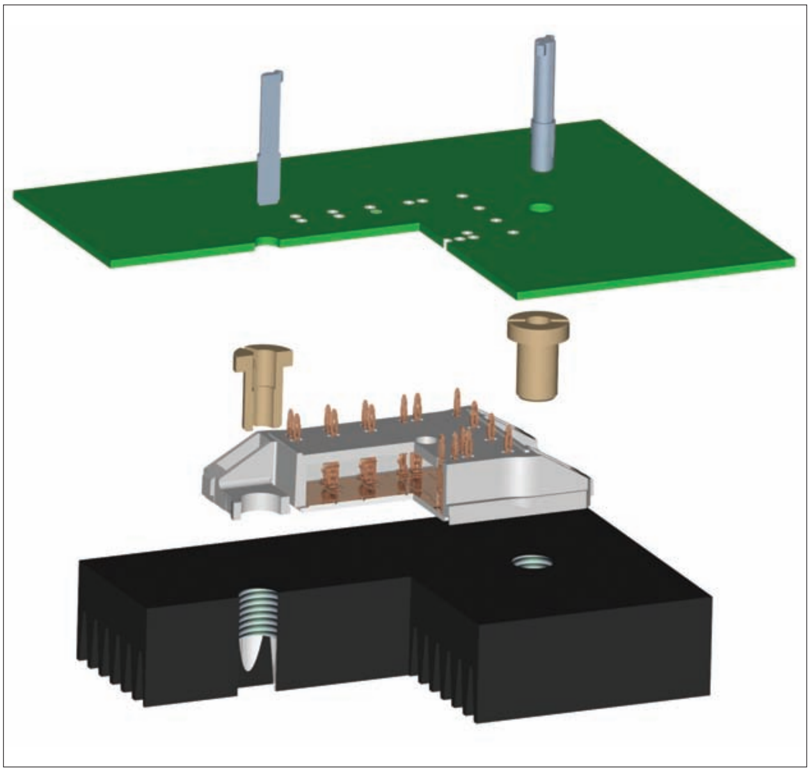


Figure 2: **Flexible one-step mounting**

Figure 2. The bushing needs a blind or through-hole in the heat sink. These bushings are inserted into mounting straps after the thermal interface material has been applied. This facilitates pasting with silk screens or stencils.

The bushings help align the module to the heat sink. Then the PCB is put in place. Next the bolts go through the PCB into th e bushings. These bolts serve several purposes. A specially contoured shoulder ensures that the module is pushed through the mounting straps towards the heatsink for the first millimeter of travel. The module bends to create a plane, and the remaining force is applied through the mounting straps. The bolts slide into the bushings and push them apart, attaching the module to the heatsink. This also presses t he PCB onto the module, achieving a mechanical and electrical contact between the module's Press-fit pins and the PCB. Two small retention nibs on the bolts hold the PCB permanently in place.

This one-step mounting technology retains all the advantages of conventional modules with Press-fit pins. The module can be assembled as a last step after all other SMD and through-hole components are placed on the PCB. It is just as reliable as conventional modules in terms of FIT rates. Discrete components can be sited in the space above the module on the PCB, both on the top and back sides. Without a mounting lid, there is one less part that costs money and one less part number to worry about.

All this can be done by simply putting a larger hole in the mounting straps to hold the bushings. That is the only change from a conventional module. The diameter of the hole in the mounting straps may be increased for modules of various sizes, particularly those without a base plate. Such low-power, high-volume modules are very cost-sensitive.

One-step mounting also solves a problem that has been widely accepted as a necessary evil - the creepage and clearance distances on the PCB required for metal parts or screws and track widths. These one-step mounting bolts are plastic, putting an end to concerns about the distance from the screw to the PCB tracks. The bolt hole in the PCB can be much smaller than a screw hole, affording engineers far greater flexibility in PCB design.

Disassembly is done in three steps. First the retention nibs have to be cut with a wire cutter. The next step is to push the bolts through the bushings with a press -out tool so they release the module from the heat sink. Then the PCB is pressed out with another tool.

Conclusion

Vincotech's one-step mounting solution works with the entire flow family, and brings all the advantages of free pin positioning, convex DBCs and pre-applied thermal interface material to bear. None of the PCB real estate is sacrificed for the sake of a lid, and the PCB may even be reused. Creepa ge and clearance distances and track widths on the PCB can also be reduced. Vincotech's approach of one-step mounting is the ticket to greater flexibility and low-inductance design possibilities built on proven technologies. And the novel Press-fit technology is available in many modules, even with pre-applied phase change material.

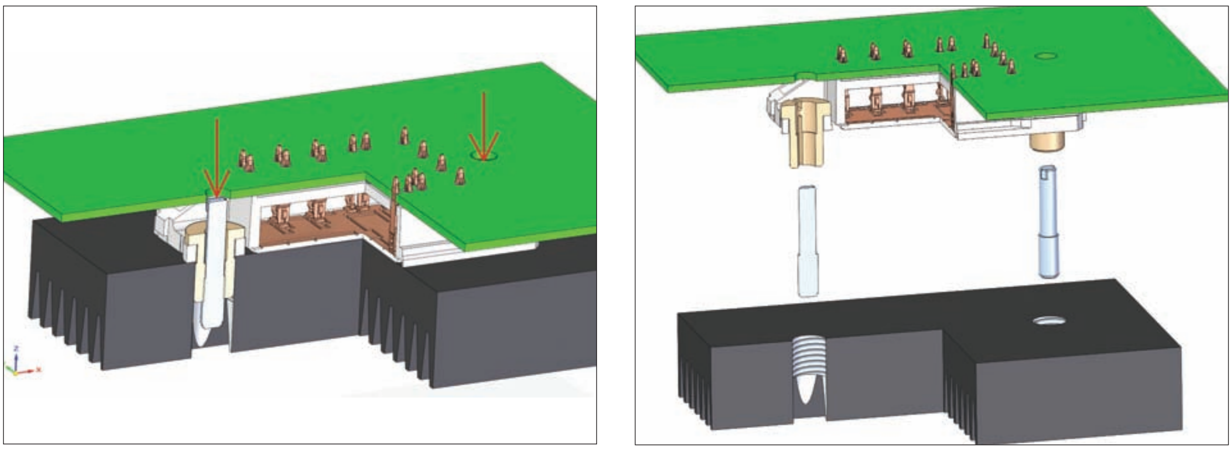


Figure 3: **Pushing bolts through the bushings**

DSCs for Digital Power

Microchip announces a 25 % performance increase for its dsPIC33F "GS" series of digital signal controllers (DSCs) for Switch Mode Power Supplies (SMPSs). Now featuring 50 MIPS performance, the dsPIC33F "GS" series of DSCs includes on-chip peripherals for digital-power applications, such as an ADC, PWM peripheral and analogue comparators. The performance increase achieve higher efficiencies in power-supply applications and allows to fully control using a single DSC. The DSCs are available in 28- to 100-pin packages, with 16 - 64K of Flash. The on-chip ADC operates at up to 4 Msps, and the PWM peripherals provide up to 1 nanosecond resolution, with modes supporting all power-conversion topologies. In addition, the DSCs feature up to four on-chip analogue comparators with integrated on-chip digital-to-analogue converters, enabling designers to set trip levels dynamically. The analogue comparators can be used to directly control the PWM functions. As the new dsPIC33F "GS" DSCs are 100% compatible with existing dsPIC33F "GS" devices, all existing tools and reference designs are supported.

www.microchip.com/get/JVX4

Film DC Link Capacitors

Kemet has expanded its C4AE Radial Film DC Link Capacitor Series for industrial and alternative energy applications. The C4AE Series now offers new 600 V DC and 105°C ambient temperature ranges as well as smaller case sizes to meet the requirements of modern solar microinverters and inverter-driven LED systems. C4AE high capacitance density capacitors are suited for applications that demand high ripple current, extra long life and outstanding quality and reliability capabilities. Solar inverters, AC motor drives, welding machines, LED lighting and other high-growth markets are targeted from this product enhancement.

www.kemet.com

Online Tool Simplifies Power Supply Design

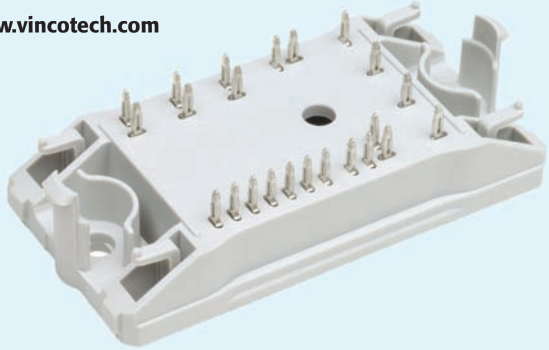
Intersil's iSim v4.0 design tool for switching regulators follows its predecessor iSim V3 for integrated FETs, and adds new capabilities for selecting, simulating and optimizing single-phase PWM controllers with external FETs. The new version of iSim permits users to input requirements for their power supply and also configure the schematic for desired switching frequency, soft-start and other options. Designers can quickly generate a complete prototype design without delving into datasheets and application notes for design equations or to complete a series of iterative optimization steps. Automating the power supply design process provides a fast and easy way to simulate electrical performance, control loop stability and efficiency. For more advanced power supply designers, iSim v4.0 offers a 'Custom Design' section that allows users to enter specific performance targets for the power supply and automatically select industry-standard component values to meet those targets. The custom design also lets users select power MOSFETs that can be optimized for total power supply efficiency and lowest junction temperature in the system. The result is a robust design and a complete bill of materials from DigiKey that can be ordered online. Both iSim v4.0 and the iSim:PE desktop simulator are available free-of-cost.

www.intersil.com/iSim.

Symmetrical Booster with Parallel Switch

Vincotech offers two new symmetrical boosters designed specifically for premium solar inverter and SMPS applications. Equipped with a parallel switch and SiC diodes to boost efficiency, the flowBOOST 0 sym modules come in compact flow 0 housing (measuring 66 mm by 33 mm and 12 mm in height). Both modules (600 V, 110/84 A) feature a parallel switch configuration combining the fast, low-loss switching performance of MOSFETs with the high current capability and low conduction losses of IGBTs. Both new modules benefit from ultra fast 600 V SiC boost diodes and bypass diodes with low forward voltage, making them the solution for input stages in solar and SMPS applications where high efficiency (99%) matters. The modules are also available with pre-applied thermal interface (3.4 K/W thermal conductivity) material for easy assembly.

www.vincotech.com



Single-Package Power Supply Modules

Rohm's BZ6A series are ultra-compact power supply modules that integrate an inductor, capacitors, and all the other components needed for power supply into a single package. The result is small size (2.3 mm _ 2.9 mm _ 1 mm), making them suitable for high-density mounting applications. The BZ6A series integrates a BU9000X series 6 MHz switching power supply LSI directly into the board and includes all necessary components in a single package. Additional features include a wide input voltage range, from 2.3V to 5.5V, making them suitable portable devices utilizing 5V USB, as well as an output voltage range between 1.0V and 3.3V, ensuring compatibility with a variety of sets.

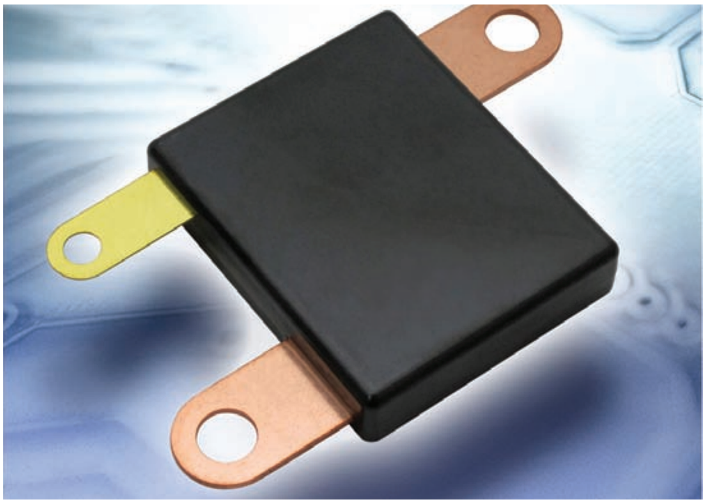
www.rohm.com/eu

Filter Modules for DC/DC Railway Applications

Vicor announced two 500 W additions to its family of Filtered Input Attenuator Modules (FIAMs) for railway applications. The new FIAM110 and FIAM072 provide protection for on-board equipment and systems against the effects of power-line transients, EMI and excessive in-rush currents. On-board power supplies in rail environments are subject to severe levels of transients and noise that can be disruptive or damaging to systems such as lighting, communications, and information displays unless properly filtered. The FIAM110 and FIAM072 meet EN50121-3-2 for EMI filtering and EN50155/EN50121-3-2 for transient protection - requirements that are crucial for rail applications. In addition, the FIAM110 and FIAM072 conform to RIA 12 surge and transient requirements and are qualified for demanding environmental standards. The FIAM072 accepts an input voltage of 43-110 V DC, the FIAM110 66-154 V DC. Both provide up to 500 W of output power, with efficiencies up to 98%, and remote on/off control.

www2.vicorpower.com/RailFIAM

Resettable Circuit Protection for Battery Packs



TE Circuit Protection announced a new Metal Hybrid PPTC (MHP) device offering a resettable alternative to typical methods of protecting high-power lithium battery and module applications. These include cordless power tools, e-scooters and light electric vehicles (LEVs) and standby power and energy storage systems (ESSs). The MHP-SA device helps provide over-charge protection in large multi-cell battery packs and modules in which circuit protection devices interface with electronics as part of a battery management system. The MHP-SA device's Smart Activation design feature accomplishes this via a third terminal signal line that enables external activation. In a typical scenario, an IC monitors the battery system's temperature, current and voltage and, if an abnormality is detected, it switches on a FET and activates the heater element (PPTC) of the MHP-SA device to heat the bimetal. The bimetal contacts then open and cut contact to the main line. The first in a series of planned devices, the new MHP-SA50-400-M5 device has a 50 A/400 V DC maximum rating and its hold current is 50 A on the main line. The device can be activated electronically with 3 A via the signal line. THP technology utilizes a hybrid circuit protection approach, combining a bimetal protector in parallel with a polymeric positive temperature coefficient (PPTC) device resulting in smaller size and thinner form factor compared to larger DC fuses or other protection devices.

www.circuitprotection.com

AC/DC Connverters

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

Busbars

www.auxel.com
Auxel FTG
Tel: +44 (0)7714 699967

Capacitors

www.powersemiconductors.co.uk
Power Semiconductors Ltd
Tel: +44 (0)1727 811110

Certification

www.productapprovals.co.uk
Product Approvals Ltd
Tel: +44 (0)1588 620192

Connectors & Terminal Blocks

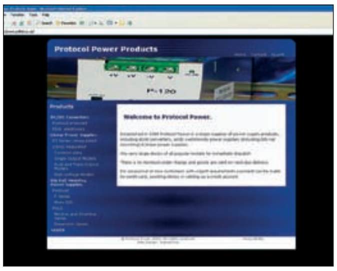
www.auxel.com
Auxel FTG
Tel: +44 (0)7714 699967

DC/DC Converters

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

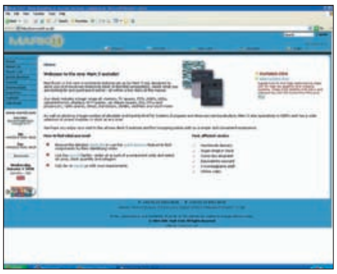
DC/DC Connverters

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399



www.protocol-power.com
Protocol Power Products
Tel: +44 (0)1582 477737

Diodes



www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

www.microsemi.com
Microsemi
Tel: 001 541 382 8028

www.neutronltd.co.uk
Neutron Ltd
Tel: +44 (0)1460 242200

www.proton-electrotex.com/
Proton-Electrotex JSC/
Tel: +7 4862 440642;

Direct Bonded Copper (DPC Substrates)

www.curamik.co.uk
curamik® electronics GmbH
Tel: +49 9645 9222 0

Discrete Semiconductors

www.digikey.com/europe
Digi-Key
Tel: +31 (0)53 484 9584

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

www.microsemi.com
Microsemi
Tel: 001 541 382 8028

Drivers ICS

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Fuses

www.powersemiconductors.co.uk
Power Semiconductors Ltd
Tel: +44 (0)1727 811110

GTO/Triacs

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

Hall Current Sensors

www.dgseals.com
dgseals.com
Tel: 001 972 931 8463

Harmonic Filters

www.murata-europe.com
Murata Electronics (UK) Ltd
Tel: +44 (0)1252 811666

IGBTs

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

www.microsemi.com
Microsemi
Tel: 001 541 382 8028

www.neutronltd.co.uk
Neutron Ltd
Tel: +44 (0)1460 242200

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Magnetic Materials/Products

www.rubadue.com
Rubadue Wire Co., Inc.
Tel. 001 970-351-6100

Mosfets

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

www.microsemi.com
Microsemi
Tel: 001 541 382 8028

www.neutronltd.co.uk
Neutron Ltd
Tel: +44 (0)1460 242200

Optoelectronic Devices

www.digikey.com/europe
Digi-Key Tel: +31 (0)53 484 9584

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Packaging & Packaging Materials

www.curamik.co.uk
curamik® electronics GmbH
Tel: +49 9645 9222 0

Power ICs

www.digikey.com/europe
Digi-Key Tel: +31 (0)53 484 9584

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Power Modules

www.auxel.com
Auxel FTG
Tel: +44 (0)7714 699967

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616

www.microsemi.com
Microsemi
Tel: 001 541 382 8028

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

www.proton-electrotex.com/
Proton-Electrotex JSC/
Tel: +7 4862 440642;

Power Protection Products

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Power Semiconductors

www.proton-electrotex.com/
Proton-Electrotex JSC/
Tel: +7 4862 440642;

Power Substrates

www.universal-science.com
Universal Science Ltd
Tel: +44 (0)1908 222211

Resistors & Potentiometers

www.isabellenhuette.de
Isabellenhütte Heusler GmbH KG
Tel: +49/(27 71) 9 34 2 82

RF & Microwave Test Equipment.

www.ar-europe.ie
AR Europe
Tel: 353-61-504300

Simulation Software

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

www.universal-science.com
Universal Science Ltd
Tel: +44 (0)1908 222211

Smartpower Devices

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

Switches & Relays

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

Switched Mode Power Supplies

www.biaspower.com
Bias Power, LLC
Tel: 001 847 215 2427

Switched Mode Power Supplies

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

Thermal Management & Heatsinks

www.abl-heatsinks.co.uk
ABL Components Ltd
Tel: +44 (0) 121 789 8686

www.curamik.co.uk
curamik® electronics GmbH
Tel: +49 9645 9222 0

www.dau-at.com
Dau GmbH & Co KG
Tel: +43 3143 23510

www.lairdtech.com
Laird Technologies Ltd
Tel: 00 44 1342 315044

www.power.ti.com
Texas Instruments
Tel: +44 (0)1604 663399

www.universal-science.com
Universal Science Ltd
Tel: +44 (0)1908 222211

Thyristors

www.irf.com
International Rectifier Co. (GB) Ltd
Tel: +44 (0)1737 227200

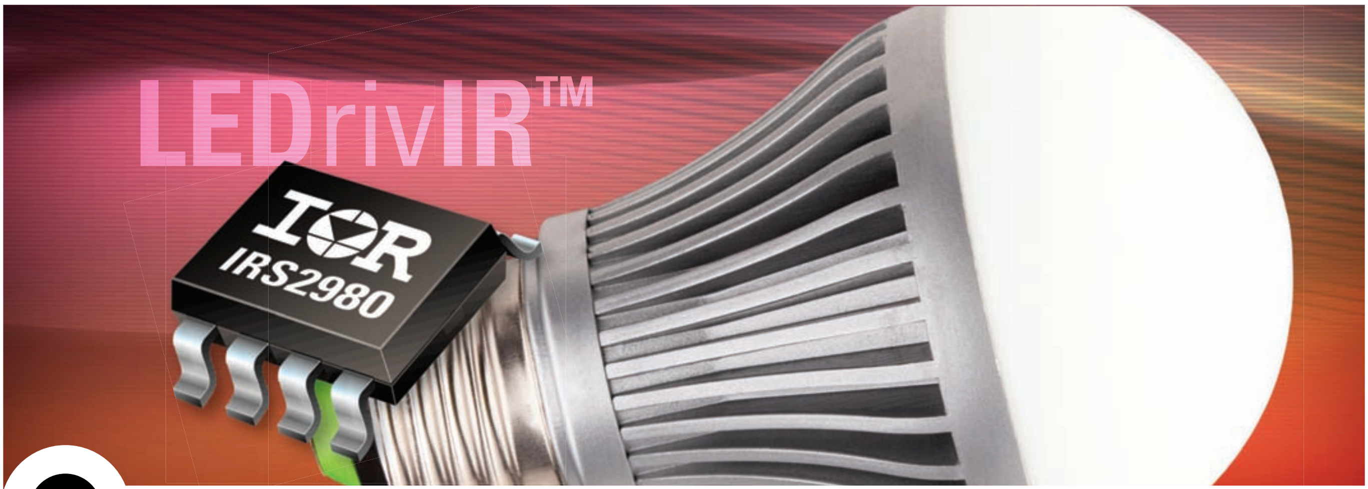
www.mark5.com
Mark 5 Ltd
Tel: +44 (0)2392 618616
www.proton-electrotex.com/
Proton-Electrotex JSC/
Tel: +7 4862 440642;

Voltage References

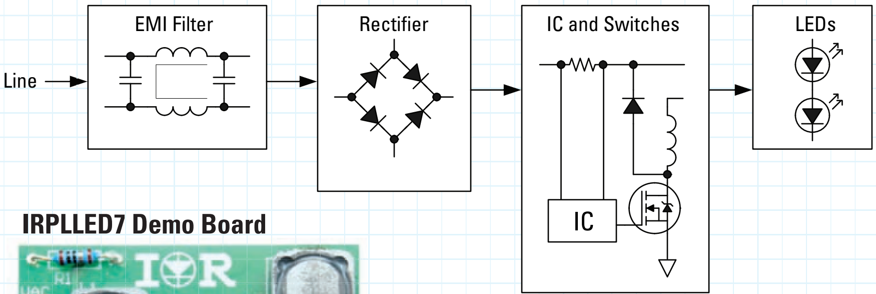
www.irf.com
International Rectifier Co.
(GB) Ltd
Tel: +44 (0)1737 227200

ADVERTISERS INDEX

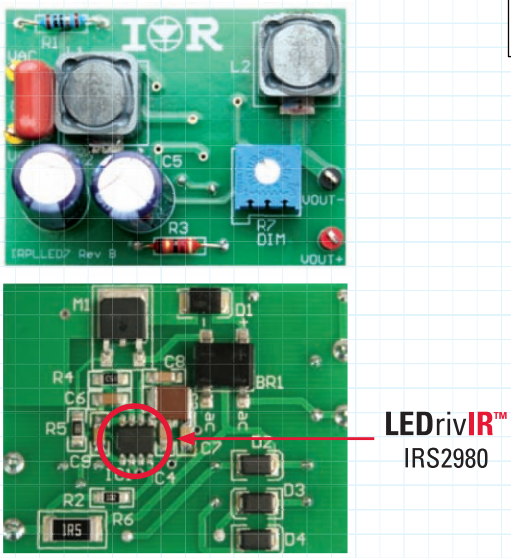
ABB	7	International Rectifier	OBC
CT Concepts	16	Ixys	27
CWIEME	35	LEM	15
Danfoss	19	Mitsubishi	4
DFA Media	31	National Electronics Week	34
Drives and Controls 2012	21	PCIM 2012	IBC
Fuji	13	Plant & Asset Management	23
Infineon	IFC	Proton-Electrolux	9



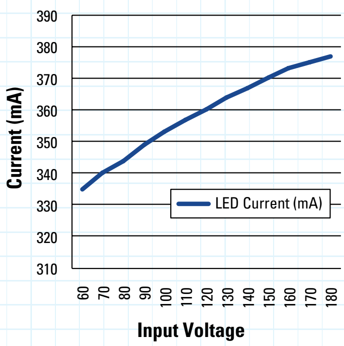
High-Voltage Buck Control ICs for Constant LED Current Regulation



IRPLLED7 Demo Board



IRPLLED7 Demo Board
LED Current vs Input Voltage



IRS2980 Features

- Internal high voltage regulator
- Hysteretic current control
- High side current sensing
- PWM dimming with analog or PWM control input
- Free running frequency with maximum limiting (150kHz)

IRS2980 Benefits

- Low component count
- Off-line operation
- Very simple design
- Inherent stability
- Inherent short circuit protection

Demo Board Specifications

- Input Voltage 70V to 250V (AC)
- Output Voltage 0V to 50V (DC)
- Regulated Output Current: 350mA
- Power Factor > 0.9
- Low component count
- Dimmable 0 to 100%
- Non-isolated Buck regulator

Part Number	Package	Voltage	Gate Drive Current	Startup Current	Frequency
IRS2980S	SO-8	450V	+180 / -260 mA	<250 µA	<150 kHz
IRS25401S	SO-8	200V	+500 / -700 mA	<500 µA	<500 kHz
IRS25411S	SO-8	600V	+500 / -700 mA	<500 µA	<500 kHz

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