POWER MODULES
Sinter Technology for Power Modules

Also inside this issue
Power Density – next Level of Energy efficiency
A complete solution for Commercial, Agriculture and Construction Vehicles

As electrification in Commercial, Agriculture and Construction Vehicles becomes a standard, Infineon offers a complete IGBT module portfolio dedicated to these applications. The reliability requirements of power switches in terms of extreme vibration and extended cycling capabilities have been practically implemented. Due to new joining techniques, optimum thermal impedance and longer lifetime for the power modules have been achieved.

Key features:

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- 2 times higher power cycling capability at $TV_{JOP} = 150^\circ C$ operating temperature e.g. $2\ \text{mio} @ \Delta T_J = 40K$
- up to 5 times higher thermal cycling compared to industrial modules
- extended lifetime compared to industry standard modules

[www.infineon.com/highpower]
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Market News
PEE looks at the latest Market News and company developments

PAGE 10
PCIM 2009 - Higher Efficiency through Better Power Electronics
Despite the crisis in the financial sector, PCIM 2009 from May 11 – 14 in Nuremberg looks quite healthy with 260 exhibitors and 6500 visitors expected. The conference will see about 600 delegates. Power Electronics is by far the main part of PCIM 2009, since it covers 15 of the total 23 sessions.

COVER STORY
Sinter Technology for Power Modules
High-power applications such as automotive, wind, solar and standard industrial drives require power modules which fulfil the demand for high reliability, thermal and electrical ruggedness. These demands are met by deploying state-of-the-art packaging technologies such as solder-free pressures and spring contacts, but also sinter technology. Silver sinter technology has been used to connect chips to substrates since 1994. Even back then, the properties of sintered silver bonding layers and the benefits they boast in terms of reliability were analyzed and reported on within the contexts of numerous international congresses. At that time, however, it turned out that this type of bonding technology was not quite ready for use in large-scale industrial electronics. The engineers in SEMIKRON’s New Technologies Department then were challenged to develop, optimize and employ this packaging technology. Full story on page 28.

Cover supplied by SEMIKRON

PAGE 20
PCIM 2009 - The Whole World of Power Electronics
The PCIM 2009 exhibition looks quite healthy with 260 exhibitors and 6500 visitors expected, quite similar to the year 2008 event. Following is an overview on interesting exhibits in company order.

PAGE 26
Next Generation of Power MOSFETs
NexFET technology is a new generation of MOSFETs for power applications with its roots in a laterally diffused MOS (LDMOS) device used successfully for RF signal amplifications. The RF heritage provides minimum internal capacitances, and the vertical current flow offers a high-current density without gate de-biasing issues. By using NexFET switches, a converter’s efficiency can be significantly improved. Jack Korec and Shuming Xu, Power Stage Group, Texas Instruments, USA

PAGE 30
Power Modules for Fast Switching Motor Drive Applications
Most of the current high power semiconductors are optimized for switching frequencies between 4 and 8kHz. Today, however, more and more applications require frequencies of 10kHz and higher. New power modules can now fill that gap. Andreas Johannsen, Product Marketing Manager Industrial Products, Vincotech, Unterhaching/Munich, Germany

PAGE 32
Gate Drivers for High Performance and Low Cost
Cost and performance are two fundamental cornerstones of any power system component. In the case of the gate drive module, the cost performance ratio strongly influences the make-or-buy decision for that small, yet crucial building component. In the case of the gate drive module, the cost performance ratio strongly influences the make-or-buy decision for that small, yet crucial building block. Continuous advances in monolithic integration, as well as high voltage transformer technology, have now made it possible to combine advanced gate drive functions and high output power density at low cost. Sascha Pawel and Wolfgang Ademmer, CT-Concept Technologie AG, Switzerland

PAGE 35
Improving the Efficiency of PFC Stages Using Interleaved BCM
Higher levels of integration in analog control circuits have enabled newer power factor correction (PFC) techniques which further improve efficiency. The interleaved boundary conduction mode (BCM) PFC approach is a good alternative to non-interleaved continuous conduction mode (CCM) PFC method for input power levels from 300W up to and over 1000W. Jon Harper, Market Development Manager, Power Conversion & Industrial Systems, Fairchild Semiconductor Europe

PAGE 41
Website Product Locator
Motor Control

Mitsubishi, a leading manufacturer of Power Modules, offers a variety of products like IGBT Module, Intelligent Power Module (IPM), DIPCIIB and DIPIPM for a wide range of Industrial Motor Control applications. Covering a drive range from 0.4 kW to several 100 kW, the RoHS compliant modules with the latest chip and production technologies ensure the best efficiency and the highest reliability. The easy to use features, compact size and mechanical compatibility with previous generations make the offered products more attractive on the market.

Please visit us: PCIM 2009, Hall 12, Stand 421
New Power Devices Lift Off

The demand for low switching loss, low conduction loss and high temperature devices has been the driving force of technology development in power semiconductors. In recent years, SiC (silicon carbide) based diodes have been introduced to the market since the year 2001 as discrete devices in standard TO packages. These new diodes do have superior performance compared to Si-based devices, mainly with respect to switching losses and thermal performance, and are well established in up to 600V hard switching applications in high end power supplies. According to market researcher Yole Developpement, SiC business is now ramping up with an estimated 2008 market size of about $22M at device level, mainly due to the SiC Schottky barrier diode (SBD) business. Leading SiC device makers such as Cree or Infineon are sharing the market with that product, but new entrants (Mitsubishi Electric, Rohm, Denso, Fuji, Hitachi, STMicroelectronics) are challenging them, developing new products and related technologies. But the ‘Holy Grail’ now is to get a reliable and affordable SiC switch. MOSFET is the most studied device, but BJT and JFET are exhibiting very promising results and some start-ups (SemiSouth, TranSiC, GeneSiC) are proposing very pertinent demo products. The applications that shape this market are currently in the 600 to 1200V range and in the 6 to 20A maximum range.

The first commercially available high power module containing SiC Schottky diodes is a 600A, 1200V PrimePACK2 IGBT power module (FF600R12IS4F) from Infineon Technologies. The 1200V SiC diodes used are rare 15A Schottky diodes. The required current rating is achieved by paralleling of multiple diode chips, which is easily possible due to positive temperature coefficient of these devices. Due to the reduction of turn-on losses with SiC freewheeling diodes, the efficiency or the output power of converter systems can increase. This is very attractive for applications which treat efficiency as first priority (e.g. solar application). But efficiency is not the only benefit when using SiC freewheeling diodes. With decreased turn-on losses, the switching frequency can also increase. This leads to the possibility of choosing a much smaller output filter and thus, lower system volume and cost. But the performance of Si based MOSFETs is quickly decreasing when the blocking voltage of the switch is getting higher than 1000V. IGBT is a good choice for switches with blocking voltage >1000V. But, due to the tail current during switching off, switching losses have certain physical limits. The desire for a faster switch with low conduction loss has driven the development of a new switch based on SiC material, the SiC based junction field-effect transistor (JFET) which is implemented by Infineon now in an H-bridge power module.

From the calculated results and comparison between Si and SiC, the advantages of SiC based devices can be observed immediately. The utilisation of SiC diode or SiC JFET can decrease the switching losses dramatically. The configuration of IGBT together with SiC diode as freewheeling diodes combines the conduction performance of IGBT and the ultra-low reverse recovery losses of SiC Schottky diodes. Even lower switching losses can be achieved with SiC JFET. Due to the physical property of a unipolar component, the conduction loss of JFET is however slightly higher than IGBTs (trade-off between chip area and cost). According to the switching frequency or the requirements from application, one can choose between these different configurations. The benefits of utilising SiC devices include: with the same converter design, the efficiency of whole system can increase; smaller heatsink or passive cooling systems can be used; with the same thermal design, the output power and power density of the inverter system can increase; and by increasing the switching frequency, the size of output filter and thus, system cost can be reduced. First applications which can benefit from these advantages are those which need high efficiency (for example, solar converter) or contain an output filter (for example, medical equipment or UPS). In the long run, and mainly depending on the cost and diameter development of silicon carbide base material, it is believed that silicon carbide and perhaps gallium nitride (GaN) based power semiconductors will become the next generation of power devices.

All these factors are explained and described in detail by the first keynote at PCIM 2009, the Best Paper of PCIM 2009 and last, but not least, by the speakers of our Special Session ‘Wide Bandgap Material and Devices’ on Wednesday, May 13, 10.00 – 12.00 in Room Paris. More details in our PCIM 2009 preview on the following pages.

Hope to meet you at PCIM 2009 in general, at our booth 12-544 in particular, and of course, on May 13 from 10.00 – 12.00 in Room Paris.

Achim Scharf
PEE Editor
Infineon and Bosch Collaborate in Power Semiconductors

Environmental regulations and new limits on fuel consumption and carbon emissions mean that every subsystem in a motor vehicle needs to consume less energy while continuing to deliver the same, or better, performance. This calls for the development of new breeds of generators, starter-generators, engine management systems, air-conditioning systems, and power steering, for example. Power semiconductors play an important role in meeting automotive energy-saving targets.

The collaboration between the companies has two key aspects: First, Bosch is to license from Infineon certain manufacturing processes for power semiconductors – specifically, for low-voltage power MOSFETs – along with the requisite manufacturing technologies. Secondly, parallel to Bosch’s own semiconductor manufacturing in Reutlingen, Infineon will produce components developed on the basis of these processes and will supply Bosch with these components. Going forward, the two companies will also work jointly on the development of enabling technologies for the production of power semiconductors. By working with Bosch, Infineon is not just expanding its share of the semiconductor market in the automotive segment, it will also be Bosch’s preferred supplier of power semiconductors. “We are the world leader in power semiconductors and have carved out a significant and sustainable lead in this field of technology”, said Peter Bauer, spokesman for Infineon Technologies AG’s Management Board. “Besides setting new standards in power semiconductors, a market that will grow in the long-term, this collaboration will put the supply of Bosch power semiconductors on a much broader footing”. Infineon and Bosch have already been working together for many years, and Infineon has received the Bosch Supplier Award on four separate occasions. “In particular, this collaboration will enable us to expand our supply portfolio for new drive technologies in automobiles, including hybrid and purely electrical drive systems”, added Volkmann Denner, Bosch’s Board of Management member responsible for automotive electronics.

www.infineon.com/automotive

New CEO at CT-Concept Technologie

Swiss CT-Concept Technologie AG, the market leader in IGBT gate drive units, has reorganised its structure in order to support future growth. The newly formed CT-Concept Holding AG will own the IP and thus, all forms of driver licensing and cooperation. CT-Concept Technologie AG will continue to act as the operational division covering development, production, logistics, sales and marketing.

After presiding over more than 22 years of successful business growth, the founder and chairman of CONCEPT, Heinz Rüedi, is taking a step back from active involvement and will continue as CEO of CT-Concept Holding AG. The board of directors has named Wolfgang Ademmer as the new CEO of CT-Concept Technologie AG. Ademmer, 41, was Senior Director at Infineon Technologies AG responsible for power electronics for hybrid vehicle and white goods since 2005. Prior to this position, he directed and handled the IGBT power module business at eupec GmbH as Vice President Sales & Marketing, establishing a solution-oriented strategy to cope with market trends, including a business plan for IGBT drivers. “Knowing CONCEPT for more than ten years, I’m excited about their potential to create further success in a healthy market. Stimulated by the macroeconomic demand for more electricity, the market for medium and high-power converter solutions will grow steadily, unlike the purely end-consumer driven markets. We will help to create efficient and reliable solutions in all medium and high-power applications, with an emphasis on a cost/performance ratio that competes with in-house developments”, Ademmer stated.

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Wolfgang Ademmer (left) has been appointed as CT-Concept Technologie’s CEO, while Founder Heinz Rüedi will continue as CEO of CT-Concept Holding.
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IRIS Certification for Mitsubishi Electric

Mitsubishi Electric Corporation is the first company in Japan, which has received the International Railway Industry Standard (IRIS) certification in March 2009.

Mitsubishi Electric Corporation Power Device Works in Fukuoka, in Kumamoto and Sun-A factory in Nijo have been successfully audited their research, production and testing facility of semiconductor components. Mitsubishi Electric Europe BV offers a wide range of HV-IGBT and Intelligent Power Modules. Shoichi Nakagawa (Division Manager Semiconductor European Business Group) appreciates the certification as a proof of Mitsubishi’s position in the development and production of semiconductor components.

The IRIS quality standard is defined by the UNIFE, the European association for the railway supply industry. The IRIS standard covers project management (from design, development to after sales services), management of tender bids, change management and also reliability, maintenance and safety levels of products.

IRIS, an extension of ISO 9001, is unique to the railway industry and has been widely asked for by all large railway manufacturers such as Alstom, Bombardier transportation, Siemens, and AnsaldoBreda. Mitsubishi has more than 40 years experience in developing and producing power semiconductors. It has been successfully directed the development of power semiconductor devices starting from current controlled GTO and Bipolar Darlington transistor to the first voltage controlled IGBT. With its constant innovative research and development in this field, Mitsubishi Electric has secured its top position.

www.mitsubishichips.com

PV Market to Contract in 2009

According to IMS Research’s latest analysis, the global PV market is set to contract for the first time in 2009 in terms of new installations.

Although the PV market doubled in 2008 in MW terms, a contraction in shipments is anticipated in 2009. This will be caused by the sudden drop-off in demand from Spain, with its newly implemented 500MW cap. This is likely to result in a shortfall of some 1.5 to 2GW in 2009. Although this will, in part, be counterbalanced by growth in Italy and Eastern Europe, the dramatic decline of the Spanish market will lead to an overall drop in worldwide shipments.

"Despite credit issues, most major PV markets look healthy and are showing promise of significant growth. However, even if their countries’ solar capacities grow at the high levels they saw in 2008, they cannot make up for the unprecedented contraction that the Spanish market will see this year", Analyst Sam Wilkinson commented. “Many analysts are now predicting a decline in PV module revenues this year; IMS Research, having analysed the likely performance of individual countries, believes that MW shipments will also be lower”. In spite of this, underlying demand for PV remains very healthy; long-term, double-digit annual growth rates can be expected. The market is likely to see dramatic changes in the next few years, with the emergence of new technologies such as micro-inverters; and the development of new and attractive regional markets such as the US, which to date has made up a low proportion of the overall global market.

Difficulties in obtaining financing will restrain US market growth this year. However, in the medium-term, it is anticipated to become one of the largest markets for PV.

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Despite the crisis in the financial sector, PCIM 2009 from May 11 – 14 in Nuremberg looks quite healthy with 260 exhibitors and 6500 visitors expected. The conference will see about 600 delegates. Power Electronics is by far the main part of PCIM 2009, since it covers 15 of the total 23 sessions.

“The power and energy sector has never been as important as it is today and this is leading to promising opportunities for engineers,” says Prof. Alfred Rufer, General Conference Director PCIM Europe.

Having introduced the first day of the conference in our April issue (see pages 18 – 23) we now cover the remaining program of the power electronics sessions.

As with the first day, the second conference day starts with a keynote. Christian Gerster, heading Bombardier transportation’s ‘Competence center High-Power Propulsion’ in Zurich, will give this keynote on May 13, 8.45 – 9.30 in the Room Paris. Current trends in railway traction technology are addressing objectives in three areas: Cost, size and weight reduction, energy efficiency increase, and enabling new functions. The presentation will give an overview of these trends, explaining the technical concepts used and showing various examples of recent developments.

In Room Paris (10.00 – 12.00) PEE’s Special Session ‘Wide Bandgap Materials and Devices’ featuring papers from Cree, International Rectifier, Infineon Technologies and Mitsubishi Electric will be held after this keynote (see sidebar).

Innovative devices and components

The session ‘Innovative Devices and Components’ takes place in Room London (10.00 – 12.00).

Hans-Günter Eckel, University of Rostock (Germany) will talk about the ‘Potential of Reverse-Conducting IGBTs in Voltage Source Inverters’. Reverse Conducting IGBTs integrate the functionality of the IGBT and the free-wheeling diode into one chip. This reduces the current density in the IGBT mode and especially in the diode mode. Therefore, the output current of the inverter can be increased. This paper analyses, how the performance improvement depends on the application conditions. With RC-IGBT, the output power of the inverter can be increased from a few percent to more than a factor of 2.

Philippe Roussel, Yole Developpement (France) will examine the ‘Market opportunities of SiC high-voltage devices in the rail transportation field’. Train makers have perceived the Silicon Carbide (SiC) electronics as a highly valuable technology for their next-gen power products. However, the current SiC industry is focusing on the 600-1200V range applications to benefit from the huge potential market size. 3.3, 6.5 and even 10kV+ have already been demonstrated and transportation industry is now expecting to find commercial products in the very near future.

Robin Kelley, SemiSouth (USA) will present an ‘Optimized Gate Driver for Enhancement-mode SiC JFET’. The first normally-off SiC JFET has been used to replace MOSFETs/IGBTs in a variety of applications. As device...
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acceptance grows, developers will require optimized drive circuits that yield the best possible switching results. This paper details the gate characteristics of enhancement-mode SiC JFET and presents an optimal gate driver for driving the device in a half-bridge circuit. Noise-immunity for the low-threshold device in a high-side position will be addressed.

Roman Karmazin, Siemens (Germany) will introduce ‘New materials for integrated inductors’. Power electronic inductors of several µH inductances have been integrated into ceramic multilayer circuit boards. Use of ferrite tapes in low temperature cofired ceramic (LTCC) technology.

Markus Billmann, Fraunhofer IISB (Germany) will present ‘Explosion proof housings for IGBT module based high power inverters in HVDC transmission application’. This paper evaluates the measures that can be taken to guarantee that no particles and no plasma clouds give impact to nearby inverter stages for energies in the range of several ten kilowatts. Several protection strategies are discussed. Soft coated as well as hard moulded IGBT modules are considered. Pictures from high speed video sequences show the influence and benefits of different protection measures.

**Power electronics in automotive and traction**

The session ‘Power Electronics in Automotive and Traction’ comes in parallel in Room Amsterdam also featuring five papers.

Mathias Baumann, Daimler (Germany) will present a ‘Comparison of different cooling systems for power modules in automotive application’. A PowerCooler power of the newest generation, is compared to a standard diamond-shaped pin fin cooler. Water and a water-glycol-mixture (40 vol.-% glycol) have come into operation as cooling agents. Particular attention is paid to the caused pressure drop, the heat transfer coefficient and the thermal resistance respectively, against the flow rate. Furthermore, the heat distribution within the power module is investigated.

Andre Christmann, Infineon Technologies (Germany) will talk about the ‘Reliability of Power Modules in Hybrid Vehicles’. To evaluate the necessarily thermal/power cycle stability of a power module in a vehicle, a driving cycle profile is used to calculate the thermal reliability requirements. This paper discusses the reliability requirements due to active and passive thermal stress on various joints such as solder or bond joints resulting by using different connections of a power module to varied cooling systems. Akira Nishiyama, Fuji Electric Device Technology (Japan) introduces ‘Evolved life of IGBT modules suitable for electric propulsion system’. The IGBT module for automotive propulsion, the lifetime is required equal to the car (150,000 miles in 1.5years). The parts which compose the IGBT module are joined by solder. The lifetime of the module is reduced because of the crack in solder layers which occurs by repetitive temperature swings. From the result of our study, the solder which contains Sn and antimony is suitable for automotive application. The developed solder has more than 20,000 cycle lifetime in the thermal fatigue test.

Eric Fernandez, CEA Grenoble (France) reveals ‘Experience feedback on electric vehicles - battery impact’. Nearly 10,000 electric vehicles appeared the French car fleet. The main problem of reliability encountered on these vehicles comes from the batteries and their cost impact. The high price and the low number of cycles, cause a kilometric cost two to three times superior than with a thermal vehicle. The CEA of Grenoble invests itself in the monitoring of electric vehicles and replaces the Ni-Cd battery in a Citroen AX by a high security Lithium Iron Phosphate one.

Daniel Chatroux from CEA Grenoble refers to the ‘Toyota PRIUS: battery in microcycle mode, cost of use doubled by five’. The goal of this presentation is to summarize the key points of the Toyota PRIUS hybrid synergy drive technology and to focus on the impact of microcycle mode on the battery cost of use. This hybrid technology is first a high efficiency electrical continuous variable transmission. So, the gasoline engine is used only in the high efficiency zone to have low fuel consumptions. The microcycle mode provides a cost of battery use divided by five. It’s competitive with gasoline one.

**Vehicle to grid**

Wednesday afternoon (14:00 – 16:00) will start in Room Paris with the Round Table ‘Vehicle to Grid’, organized by ECPE (European Center for Power Electronics).

Plug-in hybrid electric vehicles (PHEVs) which combine today’s hybrid automotive technology with larger battery systems that can be recharged from the electrical grid are announced to enter the market in 2010. At the same time, full electric city cars using lithium-ion energy storage technology enabling a driving range of 100 – 250km will be available. Fleet tests are running in several European cities e.g. in London and Berlin. Recently, four German Federal Ministries have launched a ‘National Development Plan on Electric Mobility’, announcing a plan to put a million plug-in cars on the roads by 2020.

This move to a more electric mobility will challenge the electrical grids. An infrastructure is needed to charge the electric vehicles from the grid which has to supply the energy for this additional load. On the other side, it is discussed to make the distributed energy storage capacity of these EVs available for the grid, while increasing the share of fluctuating renewable energy sources. Power electronics together with information and communication technologies is the key to meeting these challenges, providing the bidirectional flow of energy and information between the electric car and the grid.

**High power devices**

High Power Devices are the subject of the parallel session in Room London covering four papers.

Horst Gruening, Mitsubishi Electric Corp. (Japan) has entitled his paper ‘Extending 6-inch 6kV-6kA-GCT turn-off to TJ = –20ºC’. Turn-off operation of a standard high speed 6in GCT is investigated towards low temperature TJ = –20ºC. Due to improvements of the gate drive unit fully rated gate turn-off is achieved. GCT turn-off speeds up, but dynamic avalanche damping enhances to cut dangerous over-voltage spikes. GCT turn-off further is investigated by mixed mode device simulation: under dynamic avalanche damping at low temperature some GCT segments carry current for a considerably longer amount of time than others.

Ayumi Maruta, also from Mitsubishi Electric, will introduce a ‘2500A/1200V Dual IGBT module’. The 2500A/1200V dual IGBT module is developed for industrial use. Small internal inductance wiring from P to N terminal is developed for this large current device. The chip layout is considered for liquid cooling. The base
plate piece of the package is considered to be a common part, to be able to apply some other size and circuit in future. And the power loss is reduced from 5th generation by using 6th generation IGBT chip and new developed diode chip for 6th generation IGBT.

**Liutauras Storasta**, ABB Switzerland introduces a ‘4500V IGBT HiPak Module rated at 1200A, a New Milestone with SPT+ Technology’. A newly developed 4500V and 1200A HiPak module having the highest current rating available today in the market for this voltage class will be presented. The module employs SPT+ IGBT chips in the HiPak module allowed higher power densities in the module to be achieved.

**Marta Cammarata**, ABB Switzerland will present a ‘1200V SPT+ IGBT and Diode chip-set for high DC-link Voltage applications’. A new 1200V SPT+ IGBT and Diode chip-set which has been mainly developed for applications demanding higher DC-link voltages while operating under higher temperature conditions of up to 175°C will be introduced. In addition, the main focus was to achieve higher reliability performance while maintaining exceptional electrical performance in terms of low losses and controllable switching characteristics.

**Renewable energy systems and energy storage**

The parallel Power Quality session in Room Amsterdam covers three papers.

**Benjamin Sahan**, University of Kassel (Germany) will receive the Best Paper Award sponsored by Power Electronics Europe (see sidebar) for his paper ‘Photovoltaic converter topologies suitable for SiC-JFETS’. SiC semiconductors offer very interesting characteristics and are considered as a future perspective in photovoltaic converter technology. The vertical JFET is an example of a very promising device, mainly due to its relative structural simplicity. Nevertheless, the inherent normally-on characteristic calls for specially tailored topologies that will be presented and discussed.

**Engin Ozdemir**, Kocaeli University (Turkey) will talk about a ‘High-Performance Grid-Connected Single-Phase Residential PV Power Generation System’. This study develops a high-performance grid-connected single-phase residential photovoltaic power generation system. The PV power generation system is composed of a step-up converter and a two-level pulse width modulation inverters for mains and critical loads. The inverter output waveforms have very little harmonics and the efficiency is also high. Experimental results are given to verify the validity and reliability of the residential PV power generation system.

**Davide Azzoni**, LEM SA (Switzerland) introduces ‘An innovative Low-Cost, High Performances Current Transducer for Battery Monitoring Applications: Prototype Preliminary Results’. The current measurement range in battery monitoring applications can vary from 10mA up to 1000A. Today’s available current sensors are not well adapted to work in this very large domain. A new current sensor is presented in this paper which makes use of the magnetic field created by the battery current through a saturable inductance. By evaluating the saturation times and the inductance load current, it is possible to accurately measure the battery current in the whole range.

**Integrated modules**

The final Wednesday session in Room Cairo features three papers.

**Takuya Yamamoto**, Fuji Electric Device Technology (Japan) introduces ‘High-Power IGBT Modules for Industrial Use’. The new High-Power IGBT Modules for industrial use are described in this paper. The module line-up consists of 1,200 and 1,700V voltage classes, three types of packages, and current ratings of 600 to 3,600A among a total of 14 types of products. This High-Power IGBT Modules have been developed based on the concepts of the ‘low thermal impedance’ and ‘high environmental performance’.

**Wolfgang Frank**, Infineon Technologies (Germany) presents ‘A new intelligent power module for home appliances’. This paper discusses a new approach of an intelligent power module in terms of thermal design and form factor. The new module incorporates the newly introduced reverse conducting IGBT technology and combines it with a package technology, which allows a significant shrinking of its dimensions. This paper presents measurements of this module in a washing machine verifying the projected simulation results.

**Masahiro Kato**, Mitsubishi Electric Corporation (Japan) introduces ‘New Transfer Molding PFC series with Compact Package’. This paper presents a new version mini Dual In-line Package Power Factor Correction (DIPPC) developed by Mitsubishi Electric for the high power air conditioner and general inverter use. In new DIPPPC series, low thermal resistance was realized by using the insulation sheet structure with high heat dissipation. Because of the low thermal resistance, package size of mini DIPPPC is reduced compared with the conventional large DIPPPC, and input AC amperage rating is expanded up to 30A.

The second Poster/Dialogue Session covering 45 papers will be held from 16.00 – 17.00 on the Ground Floor Entrance, concluding the second day of the PCIM 2009 conference.

**Energy efficiency in data centres**

**André Rouyer**, director of Standardization & Environment for the Critical Power and Cooling Services business unit at Schneider Electric/ APC, will give the third keynote in Room Paris on Thursday, May 14, 8.45 – 9.30. He provides an update on current status with Energy Efficiency in Data Centres, on the main organisations involved and on the recommendations for improving Energy Efficiency in the future. It will also address the challenges that the business stakeholders will have to face in the next few years.

**Reliability and cooling**

This session on Thursday from 10.00 – 12.00 in Room Paris consists of five papers dealing with reliability concerns of power modules.

**Stéphane Lefebvre** from SATIE (France), the winner of the Best Paper Award at PCIM 2008, will talk about ‘Thermal fatigue and failure of power device substrates’. His research activities are focused on power semiconductor devices, especially on lifetime limitations at high temperature for automotive or avionics applications or under severe working conditions.

**Thomas Hunger**, Infineon Technologies (Germany) presents ‘A new intelligent power module for home appliances’. This paper discusses a new approach of an intelligent power module in terms of thermal design and form factor. The new module incorporates the newly introduced reverse conducting IGBT technology and combines it with a package technology, which allows a significant shrinking of its dimensions. This paper presents measurements of this module in a washing machine verifying the projected simulation results.

The poster sessions on the Tuesday and Wednesday will cover more than 60 papers.
Technologies (Germany) covers ‘Reliability of Substrate Solder Joints from Power Cycling Tests’. The life-time of the solder joint between base-plate and substrate is usually tested by thermal cycling. In the application the device is actively heated. This is commonly tested via power cycling. Those tests are utilized as effective thermal cycling for the solder joints. A key factor in the prediction of the solder temperature during power cycling. The solder joint life-times are compared for both test set-ups at low temperature swings. Details of the tests are studied numerically.

Tilo Poller, Chemnitz University of Technology (Germany) concentrates on ‘Thermal-Mechanical Behaviour of Solder Layers in Power Modules.’ After power cycling, break-up of solder layers below an inclusion of the power chip is found. This contradicts models of crack propagation starting at the edge of the device. FEM-simulations of temperature distribution and resulting mechanical deformation show a maximum of mechanical stress in the middle region of the device. This stress will initiate micro-cracks, which destroy the connections.

Ronald Eisele, University of Applied Sciences Kiel (Germany) focuses on ‘Reliable Chip Contact Joining’. Assembly techniques and concepts for top chip contacts are presented in this paper. Power cycling tests show significant improvements in the achievable lifetime compared to conventional Al-wire bonding. The demonstrator and test object is a diode power module which is typically used in welding applications. The module is actively heated with a cooling fin. Using a newly designed solder compound, the temperature distribution and resulting thermal conductivity of the solder joint are improved within a factor of 3.

Erich Neubauer, Austrian Research Centers, talks about ‘Material development of diamond based composites for cooling of future high performance electronics’. New materials with tailored thermophysical properties will be one solution to solve thermal management problems of future generations of electronic power modules, as well as a possibility to increase the reliability of existing electronic systems. This paper reports the material properties of Cu, Al and Ag-diamond composites with thermal conductivities in the range 300 to almost 700 W/mK in combination with a coefficient of thermal expansion in the range of 6 to 10ppm/K.

Control and drive strategies in power converters

This parallel session in Room London features also five papers.

Simon Effler, University of Limerick (Ireland) investigates ‘Current Sharing and Phase Alignment for Independent Parallel Power Supplies’. The trend in next-generation low-voltage high-current DC/DC converters will lead to modular, scalable solutions which can deliver power efficiently utilizing multi-phase solutions. This paper details a new approach to introduce more advanced control features like current sharing and phase dropping, which improve the efficiency of the overall system. The system does not require communication signals between the individual controllers and is therefore fully scalable.

Daniel Domes, Infineon Technologies (Germany) introduces an ‘IGBT-Module integrated Current and Temperature Sense Features based on Sigma-Delta Converter’. System integration is one of the market driving issues in power electronics. In this paper, the integration of precise shunts into IGBT modules are compared to on-IGBT-chip current sense functionality. Temperature measurement via NTC-resistor on DBC-level or on-IGBT-chip integrated temp-sense-diodes will be treated as well. Further processing of the low voltage sense signals is done by sigma delta converter including a functional isolation barrier by Coreless Transformer Technology (CLT).

Tomas Reiter, BMW Group (Germany) focuses on ‘Implementation Aspects of the Observer based PWM Dead Time Optimization for DC/DC-Converters’. In hard-switching DC/DC-converters with synchronous rectifiers the method of the observer based PWM dead time optimization can be used to reduce power losses. Parameters for the optimization algorithm and general conditions for the method are derived from the analysis of PWM dead times dependent switching losses. Experimental results are used to verify the proposed models, approximations, and assumptions.

Sascha Pawel, CT-Concept Technologie (Switzerland) will talk on ‘1700V Planar Transformers for High Power Gate Drives’. His paper discusses the development process for a novel HV insulation topology. HV insulation is established by the PCB, using planar transformers. Extensive testing has been performed to access the performance of the planar insulation topology. The system’s reliability has been investigated using accelerated testing for thermal aging, growth of conductive anodic filaments (CAF) and mechanical shock.

Davide Respighi, International Rectifier (Italy) introduces a ‘Ground fault detector IGBT for complete short circuit protection in motor drive applications’. An integrated fault detector in junction isolated high voltage technology. The IGBT’s goal is the detection of different faults typical in motor drives. The fault is detected sensing a shunt on the inverter DC-bus and communicated to a DSP or a gate-driver using an open drain pin. The IC is simple, inexpensive and can be used with the inverter DC-bus up to 600V. Moreover, it is self-supplied and allows to set the detection threshold for the over current. Measurements are reported.

Software tools and applications

This parallel morning session consists of three papers.

Lawrence Meares, Intusoft (USA) has entitled his paper ‘Automating Digital, DSP, Design using augmented spice simulation’. A new Z-Delay model coupled with a matrix solution based on SPICE simulation provides the core for automatic DSP code generation. An example, using a Kalman filter plant model, shows how increased software complexity can be used to reduce hardware cost.

Romeo Letor, STMicroelectronics (Italy) focuses on ‘User-friendly and effortless electro-thermal simulation of power actuators boards with standard software office’. His paper describes a simplified model with distributed constant parameters embedded in office EXCEL. The paper explains the method based on the application of the semi-empirical equations that describe heat propagation and how distributed constant parameters can be used for simplified thermal modelling. Calculation results compared with junction temperature measurements and infrared analysis on practical application examples demonstrate that precise calculation of the junction temperature can be performed with this tool, so saving time consuming resources. User-friendly graphic interfaces implemented on a spreadsheet are also demonstrated.

Holger Ross, dSPACE (Germany) will talk about ‘Rapid Control Development for Mobile, Brushless Electric Motors’. Because of their ideal properties, electronically commutated brushless electric motors (EC motors) are also being used more often in nonstationary, power-line-independent application fields such as automobiles. A new in-vehicle capable rapid control prototyping (RCP) solution from dSPACE makes it possible to validate commutation methods and control strategies for motor control on real devices, without special programming knowledge and at an early stage.

Thermal management and packaging

The first Thursday afternoon session in Room Paris covers four papers on power module technology.

Uwe Scheuermann, Semikron Elektronik (Germany) reports on ‘Investigations on the VCE(T)-Method to Determine the Junction Temperature by Using the Chip itself as Sensor’. Using the temperature dependence of the diffusion voltage of a p-n-junction the VCE(T)-method permits the chip to be used as a temperature sensor and thus allows to determine the Tj without mechanical obstruction of the device package. The presented investigation analyses an actively heated modern IGBT chip with a pronounced lateral temperature profile. The simulation proves that the Tj determined by the VCE(T)-method is equivalent to the area-related mean temperature of the chip.

Waleri Brekel, Infineon Technologies (Germany) focuses on ‘Time Resolved In Situ TVI Measurements of 6.5kV IGBTs during Inverter Operation’. Although the device temperature is one of the most critical parameters in the dimensioning of an inverter, experimental studies focusing on TVI in running inverter are scarcely found. In this work, the feasibility of four different practical methods is compared. Special focus is set on routines with a high time resolution that enable tracking the time-dependent-temperature during one period of the sinusoidal output current. Details of the procedures are explained and compared with simulations.

Yoshitaka Nishimura, Fuji Electric Device Technology (Japan) covers ‘Thermal management of IGBT module systems’. His paper presents the thermal management of IGBT module systems. Among IGBT module materials, thermal compound has the lowest thermal conductivity. So, thermal compound thickness influences IGBT chip junction temperature. This time, they investigated the method to thin the compound between IGBT module and cooling fin. Using a newly designed
on power electronics in Room London with four papers.

Francisco Javier Azcón, University of Cantabria (Spain) introduces a ‘Flexible power architecture for high quality welding application’. Architecture of multiple two-phase resonant converters in current source mode is proposed to generate a power supply for arc-welding applications. Output current can be tuned from 1.5 to 600A. Current shape can be continuous or pulsating at different frequencies from 10Hz to 10kHz and pulsewidths from 25 to 75%. Current control is performed by tuning the overlap between the each phase control signals. Arc strike is achieved at low voltage with an initial switching frequency sweep.

Giuseppe Griffiero, SAET Group (Italy) describes ‘A novel modular power supply system for induction heating applications’. Some remarks will be presented as for the topology used, reliable for induction hardening and induction tube welding, and for the control technique. Some considerations about the load matching circuit will be proposed together with some novel solutions. Experimental results related to recent installations will be presented and discussed in comparison with other solutions currently available in the market.

Christian Mößlacher, Infineon Technologies Austria will give a paper on ‘Improving efficiency of synchronous rectification by analysis of the MOSFET power loss mechanism in hard switched topologies’. Driven from the 80 PLUS program, the overall system efficiency in SMPS is targeting the 90% line. Reaching this efficiency level is therefore only possible with synchronous rectification. But for achieving ideal switching behavior and high efficiency, the power loss mechanism of a SR MOSFET has to be well understood. Therefore, this paper is analysing the turn-off process of the SR MOSFET and proposes a simple model for calculating the power losses to optimize system efficiency.

Jérémy Martin, PEARL-ALSTOM Transport (France) will present the final paper on power electronics entitled ‘Characterisation of IGBTs and IGCTs in Soft Commutation Mode for Medium Frequency Transformer Application in Railway Traction’. A specific test bench is installed at PEARL laboratory with a view to characterise 6.5kV IGBTs and 6.5kV IGCTs in soft commutation mode. This test bench enables to study the switching losses, the conduction losses and the frequency limit of these components. In this paper, characterization results of IGBTs and IGCTs in ZVS mode are presented.

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And the Winner is...

Power Electronics Europe has sponsored and will hand over for the second time the Best Paper Award at the PCIM 2009 opening ceremony. The awardee will be invited to participate at PCIM China 2010, including flight and accommodation.

The best paper has been selected by the PCIM Conference directors and the winner is Benjamin Sahan from the University of Kassel (Germany) with the paper ‘Photovoltaic converter topologies suitable for SiC-JFETs’.

Silicon Carbide (SiC) material is characterised by electrical field strength almost 9 times higher than normal Si, allowing the design of semiconductor devices with very thin drift layers and, as a consequence, low on-state resistance and reduced switching losses. In other words, such characteristic can be translated into the possibility of operating at higher blocking voltages with reduced losses.

These characteristics are especially interesting when applied in photovoltaic converters. There, efficiency is still one of the main market drivers in the industry. Today, enhancing the PV inverter efficiency by 1% could yield up to 45€/kWp...97€/kWp additional profit after ten years of operation. For this reason, PV inverter technology rapidly improved during the last decade, as a peak efficiency of 99% will soon be achieved. From that point on, further increase of efficiency is not cost-effective anymore. As a future trend, SiC offers the possibility of operating at higher switching frequencies without significant prejudice on the efficiency, which leads to the possibility of reducing the size of passive components and consequently the cost and volume of the circuit. However, since SiC characteristics are quite different from conventional semiconductors, new design strategies are required. Besides SiC basics, this paper presents a 1kW laboratory prototype inverter which was constructed to further evaluate the performance of SiC-JFETs. A fairly high efficiency using just one JFET was measured which gives a positive outlook for its future application in PV systems.

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Test board of the 1kW SiC Indirect Current Source Inverter

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The Almost Perfect Switch is Ahead

These are exciting times for power electronics, with technological breakthroughs at the horizon, namely silicon carbide (SiC) and gallium nitride (GaN) for power semiconductors. Here, Power Electronics Europe is at the forefront by organising and chairing a session on ‘Wide Bandgap Materials and Devices’ to be held on Wednesday (May 13, 10.00-12.00, Room Paris).

“The main session within Power Electronics is the subject Wide Bandgap Materials and Devices’, stated PCIM Co-Chair Uwe Scheuermann. Invited speakers from well recognised companies such as Cree, Infineon Technologies, International Rectifier and Mitsubishi Electric will present their view on ongoing innovations. The bottom line can be summarised that diodes with almost no reverse recovery losses are here, and switches are already in sampling. That’s what the power electronics designer is waiting for, a pair of quasi loss-less switch (JFET, MOSFET) and freewheeling diode (as described i.e. by the PCIM 2009 best paper and the first keynote).

John W. Palmour, CTO of Cree (USA) has entitled his paper ‘Silicon Carbide Switching Devices: Pros and Cons for MOSFETs, JFETs and BJTs’. The most commonly pursued switches in SiC are compared in terms of device performance, reliability, and cost of manufacturing. The DMOSFET structure offers the most features, but it can be more expensive to manufacture. Normally-on JFETs can be manufactured at a lower cost and provide excellent characteristics, but will have difficulty winning wide acceptance in the power electronics field. Normally-off JFET devices can also be produced at a lower cost, but sensitivity to materials and processing requirements may result in low yields, which can negate the lower fabrication cost, and provide relatively poor performance compared to other structures. BJTs offer good performance and lower cost of manufacturing, but device stability is yet to be resolved. Detailed analysis and comparison are presented in this paper.

Zhang Xi from Infineon Technologies Warstein (Germany) will talk about ‘Efficiency improvement with silicon carbide based power modules’. In this paper, the utilization of SiC based diodes and switches in power modules will be presented, discussed and compared with Si-based power modules. Whereas SiC switches have the overall lowest dynamic losses, they show higher static losses due to the lack of conductivity modulation and the necessary chip size limitations due to the still high SiC base material price. The frequency dependence of the total losses of the various 1200V configurations (Si-IGBT + Si freewheeling diode, Si IGBT + SiC Schottky diode, SiC-JFET cascode + internal body diode of the cascode) shows, that a module solution containing a state of the art SiC switch will outperform all other options for switching frequencies >20kHz.

Michael A. Briere, ACOO Enterprises LLC/International Rectifier (USA) refers to ‘GaN Based Power Conversion: A New Era in Power Electronics’. GaN based power devices such as HEMTs promise to deliver a figure-of-merit (FOM) performance that is at least an order of magnitude better than state of the art silicon MOSFETs. In addition to reviewing the distinct advantages of a new GaN-on-Si technology platform, this paper will also demonstrate how DC/DC converters built using the new GaN technology platform will enable a new era in high frequency, high density, highly efficiency power conversion solutions. Prototype 600V switches and rectifiers have been developed and characterized and demonstrated in such application circuits as PFC AC/DC converters and motor drive inverters. The behaviour of these devices in terms of reverse recovery and on-resistance are similar to that of well publicized SiC based devices.

Gourab Majumdar, CTO at Power Device Works, Mitsubishi Electric Corporation (Japan) will present ‘Some key researches on SiC device technologies and their predicted advantages’. This paper attempts to analyse SiC performances in actual device application through outcomes from some key researches. To analyze advantages of SiC based power devices over their silicon based counterparts, a high volume and standard application segment, such as the 400-480VAC line rated motor drives group, is considered to be ideal. From this viewpoint, the present research work has focussed on 1200V class device technologies. 4H-SiC based MOSFET and SBD structures have been considered to be the best fit device configurations for the targeted application category, and have been thoroughly investigated. New SiC-MOSFET/SBD structures have been developed aiming at high power density applications. Performance details of such newly fabricated SiC devices, along with their evaluation under actual operating conditions, are also introduced.
The Whole World of Power Electronics

The PCIM 2009 exhibition looks quite healthy with 260 exhibitors and 6500 visitors expected, quite similar to the year 2008 event. Following is an overview on interesting exhibits in company order.

In spite of the current economic crisis, PCIM Europe 2009 in Nuremberg emphasises its position as Europe’s leading exhibition for power electronics, intelligent motion and power quality. More than 255 exhibitors (2008: 257) will present their products and innovations on 10.700m² exhibition space (2008: 10.600m²). Thus, they show the importance of contacting existing and future exhibitors especially in difficult times.

How much savings in travel and training budgets will affect the participant numbers at the conference, can’t be estimated at the moment. “The tide might still turn. Many companies could recognise that this conference would limber up their employees for the future. This was in particular important when the industry’s development cycles were getting faster all the time”, states Udo Weller, President of the organiser Mesago PCIM. Another indication for a successful PCIM Europe 2009 are the visitor pre-registrations. They are above previous year. “The possibility to get an overview over the whole branch’s product range can only be provided by an exhibition. PCIM Europe is the place to be in times of crises as well”, Weller says.

4500V/1200A IGBT HiPak Module
ABB Switzerland (12-408/506) has already presented the 4500V/1000A HiPak module based on the SPT+ platform. SPT+ is the latest generation of planar devices with enhanced carrier profiles which offers significantly reduced static losses compared to the SPT platform at the same time providing improvements in turn-off ruggedness. These features ensure an increased margin for further increase of power density in the...
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module up to 1200A. The new module offers the same smooth switching characteristics and high dynamic ruggedness as its predecessor and is optimised for parallel operation. For the 4500V HiPak modules, this new design will provide high voltage system designers with enhanced current ratings combined with the smooth switching characteristics. Production of this new module is scheduled for July 2009. www.abb.com/semiconductors

**1200/1700V IGBT Modules**

Fuji Electric’s (12-407) new power module line-up consists of 1200 and 1700V voltage classes, three types of packages, and current ratings of 600 to 3600A among a total of 14 types of products. These High-Power IGBT Modules have been developed based on the concepts of the ‘low thermal impedance’ and ‘high environmental performance’. To realise high-voltage, high-capacity inverter systems with larger capacity, it is necessary for many modules to be connected in parallel and in series. Since power semiconductors are generally mounted on the equipment heatsink and electrically be isolated, it is necessary to choose a substrate material with both high isolation and thermal conductivity. Thus, Fuji has developed a new package technology of applying silicon nitride as the DCB material, since Si3N4 has very attractive features of low thermal impedance, leakage capacitance compatibility and good physical strength. From experimental measurement it is possible to reduce the thermal-resistance Rth(j-c) as much as 33% at IGBT level compared to the conventional Al2O3 based DCB. Also a very high environmental performance of as high as <600 CTI (comparative track index) has been achieved, which is the highest value for IGBT modules available on the market. www.fujielectric.de

[CeramCool Liquid Cooling](#)

Ceramtech (12-442) introduces CeramCool, since air cooling reaches its limits at very high power densities. This is where liquid cooling is best suited. The new ceramic heatsink for high power applications profits from the electrically insulating characteristic and inertness of ceramics. No corrosion can cause trouble. The concept follows the same goal as for air-cooled heatsinks - shortest (thermal) distance between heat source and heat drain. With CeramCool liquid cooling, it is feasible that, for example, cooling water is only 2mm away from the heat slug. No other concept can do this in combination with the durable nature of ceramics. Almost any needed cooling capacity is feasible. Additionally, multilayer electrical circuits can be printed directly on CeramCool without creating thermal barriers. www.ceramtech.de

**Power Trench MOSFETs for SMPS Applications**

Fairchild Semiconductor’s (12-601) new medium voltage PowerTrench technology MOSFET has very low specific RDS(on), low Qg, and Qgd/Qgs ratio. Additionally, the excellent body diode characteristics not only reduce the power losses to improve efficiency, but also improve reliability. New minimum efficiency limits are being imposed for SMPS, even at 10 to 20% of the operating load conditions and these new MOSFETs are instrumental in improving efficiency in these designs. This advanced trench gate MOSFET technology has improved performance over existing trench gate power MOSFETs in these applications. The new device has an on-resistance improvement in range of 40%, and less than half the gate to drain charge of latest generation trench devices. www.fairchildsemi.com

**SiC JFET Power Module**

Infineon Technologies (12-404) introduces its first power module containing silicon carbide switches. The performance of Si based MOSFETs is quickly decreasing when the blocking voltage of the switch is getting higher than 1000V. The IGBT is a good choice for switches with blocking voltage >1000V. But, due to the tail current during switching off, switching losses have certain physical limits. The desire for a faster switch with low conduction loss has driven the development of a new switch based on SiC material - SiC based junction field-effect transistor (JFET). Whereas SiC switches have the overall lowest dynamic losses, they show higher static losses due to the lack of conductivity modulation. The frequency dependence of the total losses of the various 1200V configurations (Si-IGBT + Si freewheeling diode, SiC IGBT + SiC Schottky diode, SiC-JFET cascode + internal body diode of the cascode) shows, that a module solution employing a state of the art SiC switch will outperform all other options for frequencies >50kHz. Infineon’s SiC JFET is a normally-on component with a pinch off voltage of ~ 15V, for compatibility with standard applications it is better to provide normally-off switches (cascade configuration) formed by a 40V low-voltage Si-MOSFET (OptiMOS) in series with 1200V SiC JFET. Each of the switches in the new Easy2B H-bridge module contain six pieces of SiC JFETs in parallel and has an on-resistance of about 70mΩ. www.infineon.com

**Automotive-Qualified Dual Low-Side Driver IC**

International Rectifier (12-202) introduces the AUIRS4427S dual low-side driver IC for low-mid and high-voltage automotive applications including general purpose motor drives, automotive DC-DC converters and hybrid powertrain drives. The AUIRS4427S is a low-voltage, high speed power MOSFET and IGBT driver qualified to AEC-Q100 standards. The output drivers feature a high pulse current buffer stage for minimum driver cross-conduction and matched propagation delay for both channels. Negative voltage spike (Vs) immunity is provided to protect against catastrophic events during high-current switching...
and short circuit conditions. The device, which is 3.3 and 5V logic compatible with standard CMOS or LSTTL output, features gate voltage (VOUT) up to 20V, CMOS Schmitt-triggered inputs, two independent gate drivers, and outputs in phase with inputs.

The new IR3725 input power monitor IC with digital PC interface is intended for low-voltage DC/DC converters used in energy-efficient CPU, server and storage applications. It is a highly versatile input power, voltage and current monitor IC for 12V power supplies. Unlike alternative solutions that depend on costly A/D converters to measure a system’s power, the new device utilises patent-pending TruePower technology to output average power during a specified interval over a serial digital interface. This information is used by the system controller to optimise overall power consumption, delivering benchmark current accuracy of 1%.

www.irf.com

Power MOSFETs/IGBTs
IXYS introduces the Linear L2 Power MOSFET family in 250, 500 and 600V ratings. These new devices are designed to sustain high power in linear mode operation and feature low static drain to source on-resistances. They provide high performance and reliability in controlled current output applications which require robust and reliable devices for use in linear-mode operations. The list of possible applications includes circuit breakers, current sources, programmable loads, power controllers, power regulators, motor control, power amplifiers and soft start applications. L2 MOSFETs are optimised to endure the high thermo-electrical stress caused by the simultaneous occurrence of high drain voltage and current commonly present in applications operating in linear-mode. The forward bias safe operating area (FBSOA) is one such key characteristic that was optimized to overcome limitations and constraints posed by conventional power MOSFETs in linear applications.

L2 MOSFETs are presented with drain current ratings from 15 to 90A and are available in a variety of discrete industry standard package housings. The GenXSTM IGBT portfolio to has been extended to 1200V. These IGBTs are offered in various standard and ISOPLUS packages with collector current ratings 20 to 120A. Standard packages include the TO-263, TO-247, PLUS247, TO-220, TO-264 and TO-268.

Co-packed variants of these new devices are available with HiPerFRED (suffix ‘D1’) and SONIC-FRD (suffix ‘H1’), ultra-fast recovery diodes providing exceptional fast recovery and soft switching characteristics. Additional product attributes include avalanche capabilities and a square reverse bias safe operating area, allowing the device to safely switch in a snubberless hard switching application.

www.ixys.com

Fluxgate Current Transducers
LEM (12-402) will be highlighting a range of current transducers, including the CAS, CASR and CKSR family. Using the Closed Loop Fluxgate technology, these PCB-mounted transducers are housed in a package 30% smaller than the company’s LTS devices. They have been designed to respond to the technology advances in drives and inverters which require better performance in areas such as common-mode influence, thermal drifts (offset and gain; maximum thermal offset drift for the models with reference access: 7 – 30ppm/K according to the models), response time (less than 0.3µs), levels of insulation and size. All transducer models have been designed for direct mounting onto a printed circuit board for primary and secondary connections. They all operate from a single 5V supply. The CASR and CKSR models provide their internal reference voltage to a VREF pin. An external voltage reference between 0 and 4V can also be applied to this pin. The CAS, CASR and CKSR family of transducers are suitable for industrial applications such as variable speed drives, UPS, SMPS, air conditioning, home appliances, solar inverters and also precision systems such as servo drives for wafer production and high-accuracy robots.

www.lem.com

Digital Power Reference Design
Microchip (12-344) shows an AC/DC reference design based on the new dsPIC33F ‘GS’ series of digital power Digital Signal Controllers (DSCs). This reference design demonstrates how digital power techniques are applied to reduce component count, lower product cost, eliminate oversized components and incorporate topology flexibility. The Reference Design unit works with a universal input voltage range and produces three output voltages, with a continuous power output rating of 300W. The front-end power factor correction (PFC) boost circuit converts universal AC input voltages to a 420VDC bus voltage. A full bridge transformer isolated buck converter, incorporating a phase-shift Zero Voltage Transition (ZVT) circuit, produces 12V at 30A from the 420V bus. The phase-shift ZVT converter also provides output-voltage isolation from the AC mains input. A multi-phase synchronous buck converter then produces 3.3VDC at 69A from the 12VDC bus, and a single-phase buck converter produces 5VDC at 23A from the 12V bus. The dsPIC33F controls the PFC boost circuit and the primary-side ZVT full-bridge circuit. A second ‘GS’ series dsPIC33F monitors the 12VDC bus voltage and controls the four buck converters.

www.microchip.com/5MPS

2500A/1200V Dual IGBT Power Module
Mitsubishi Electric’s (12-301/421/431) conventional MPD (Mega Power Dual) 1400A/1200V IGBT module is used in larger power industrial equipment. By the expansion of the renewable energy generation systems like wind power and photovoltaic larger power systems are required. Thus, a simpler 2500A/1200V dual IGBT module with low internal stray inductance and fitted for liquid cooling has been developed. It contains Mitsubishi’s 6th generation IGBTs with reduced VCE_Eo and a trade-off of 0.7V compared to 5th IGBT generation. The NX series also equipped with 6th generation IGBTs has novel flexibility of its terminal and circuit configuration by using some unified package parts and power devices. Also, a range of 3in1 three-level IGBT modules, e.g. an ‘all in one’, up to current rating
of 75A and a 4in1 configuration, e.g. one leg of a three-level inverter, modules up to 200A have been developed. Furthermore, two 2in1 modules split for upper and lower part of the leg of the three-level configuration for up to 600A of module current have been developed to cover the higher power range of inverters.

**DOSA-Compliant DC/DC Converters**

Murata Power Solutions (12-548) extends its offering of Okami (Japanese for ‘wolf’) non-isolated single point-of-load (PoL) DC/DC converters with 3/5A modules and 5V nominal input. The new parts complement the 12V input 3, 5, 10 and 16A modules recently introduced. The new Distributed-Power Open Standards Alliance (DOSA) compatible modules are housed in industry-standard surface-mount (SMT) packages and can act as a drop-in replacement for other DOSA compliant parts. Typical applications include powering CPUs, datacom/telecom systems, server and storage equipment, industrial systems and programmable logic and mixed voltage designs. The new DC/DC converters offer efficiency levels up to 94.5% and are able to drive 1000µF ceramic capacitive loads. This makes them suited for powering applications with tight output load regulation requirements such as latest generation FPGAs and DSPs.

[www.murata-ps.com/okami](http://www.murata-ps.com/okami)

**Frequency Inverter Test System**

Scienlab electronic systems GmbH (12-549) introduces a test system for frequency converters which overcomes limitations that result from usage of electrical machines for inverter testing. Extremal points of operation are examined realistically without risk of damage for machine or battery. The inverter under test is provided DC link voltage from an electronic DC source which emulates the desired front-end or battery characteristics. Instead of an electrical machine, an inverter emulating any desired three-phase AC machine is used as load for the inverter under test. This set-up offers great flexibility and allows even for inclusion of drive train dynamics into the simulated load characteristics. The only limitations result from the maximum values of output power, output voltage, and output frequency of the emulators (60kW, 1kV, 1kHz projected). The inverter can be tested in combination with various machine or source characteristics within a very limited period of time without costly mechanical modifications. The tester is dedicated to both laboratory examination and end-of-line testing in series production of frequency converters.

[www.scienlab.de](http://www.scienlab.de)

**Sixth-Generation StripFETs**

STMicroelectronics (12-414) introduces a new series of 30V surface-mount power transistors, achieving on-resistance as low as 2mΩ to increase the energy efficiency of products such as computers, telecom and networking equipment. This is around 20% better than the previous generation and allows the use of small surface-mount power packages in switching regulators and DC/DC converters. The STripFET VI DeepCATE technology also benefits from inherently low gate charge, which allows engineers to use high switching frequencies and thereby specify smaller passive components such as inductors and capacitors. The broad choice of industry-standard outlines, including SO-8, DPAK, 5x6mm PowerFLAT, 3.3 x 3.3mm PowerFLAT, PolarPAK, through-hole IPAK and SOT23-6L, offer compatibility with existing pad/pin layouts at the same time as improving efficiency and power density. The first devices include the STL150N3LLH6, which offers the lowest on-resistance per area in the 5 x 6mm PowerFLAT package. The STD150N3LLH6 in the DPAK package comes with an on-resistance of 2.4mΩ. Samples are available for both devices, with production availability scheduled for June 2009.

[www.st.com/pmos](http://www.st.com/pmos)

**Multi-Phase Fusion Digital Power Controller**

Texas Instruments (12-329) introduces a new dual-output, multi-phase synchronous buck controller that can support various point-of-load configurations. The UC9220 device provides 250ps of pulse-width-modulation, a 2MHz switching frequency and high DC conversion ratios, while maintaining stable operation. The flexible controller meets complex power design requirements in telecommunications, server, data storage and industrial test and measurement applications. Designers can use the Digital Power Designer, a full-featured graphical user interface, to configure the device easily and speed time-to-market.

The UC9220 is available in a QFN-48 package and is priced at $2.65 in quantities of 1,000. The evaluation module will be available in late second quarter 2009.

[www.ti.com/ucd9220-pr](http://www.ti.com/ucd9220-pr)

**6.5kV Phase Control Thyristor**

Westcode Semiconductors Limited (12-401) launches a new 6.5kV phase control thyristor for ‘mega-watts’ power applications. The device is optimised for low forward conduction loss, has a nominal RMS current rating of 1695A and a surge current rating of 10.5kA. The device is encapsulated in a 47mm (1.85in) pole face hermetic pressure contact package using an alloy free process. The device is optimised for very low on-state voltage, when compared to similar devices in the same voltage class, with a forward volt drop of 2.0V at 1000A. The low conduction loss makes the device ideal for line frequency applications such as front-end rectification as well as all controlled rectifier applications up to a few hundred hertz.

Other applications for which the device is suited include DC drives, load commutated inverters and excitation equipment, power and motor control for electrical trains, high power generators, UPS and renewable energy applications, including solar power generators and wind turbine generators.

The optimisation of the conduction losses achieves lowest system losses and minimises the cooling requirements for applications up to 2.3kV line voltage. Thus, the new phase control device is also ideal for use in crowbars, particularly for traction, in applications up to 1500V DC.

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Next Generation of Power MOSFETs

NexFET technology is a new generation of MOSFETs for power applications with its roots in a laterally diffused MOS (LDMOS) device used successfully for RF signal amplifications. The RF heritage provides minimum internal capacitances, and the vertical current flow offers a high-current density without gate de-biasing issues. By using NexFET switches, a converter’s efficiency can be significantly improved.

Jacek Korec and Shuming Xu, Power Stage Group, Texas Instruments, USA

Power MOSFETs are used, for example, as switches for high-frequency pulse width modulation (PWM) applications such as voltage regulators and/or switches that control current to and from a load in power applications. When used as a load switch where switching times are usually long, the device’s cost, size and on-resistance are the prevailing design considerations. When used in PWM applications the transistors must exhibit minimal power loss during switching, which imposes an additional requirement of small internal capacitances that make the MOSFET design challenging and often more expensive. Special attention has to be paid to the gate-to-drain (Cgd) capacitance, as this capacitance determines the voltage transient time during switching. It is the most important parameter affecting the switching power loss!

Pursuing the ideal switch

The requirements for an ‘ideal’ switch used in a synchronous buck converter, which is the most popular converter topology used for computer applications, are low conduction losses (low RDS(on)), low switching losses (small Cgd), low driver losses (small Ciss), no cross-current losses (small Cgd/Ciss ratio to avoid shoot-through effect), and low body diode losses (small Qb and hard switching enabling short break-before-make delay time).

Of course, the device used as a switch must have a robust structure allowing large amounts of avalanche energy to be dissipated, ensuring reliable operation over the full safe operating area (SOA) range.

In NexFETs (see schematic cross-section in Figure 1) the current flows from the source terminal provided by the top metallization through the lateral channel underneath the planar gate, into the lightly doped drain extension region (LDD), then forwarded to the substrate by the vertical sinker with low resistance. The RF heritage provides minimum internal capacitances, and the vertical current flow offers a high-current density without gate de-biasing issues, typical for LDMOS transistor planar layouts.

The NexFET device’s source metallization has a unique topology, providing a field-plate effect at the gate’s drain corner. The field-plate stretches the electric field distribution along the LDD region, reducing the high electric field peak at the gate corner. In turn, it provides good reliability against hot carrier effects that deteriorate the gate oxide quality in conventional LDMOS transistors.

The LDD region is doped to a high level of carrier concentration taking advantage of the charge balance between the LDD, the field-plate, and the deep-P region underneath. This helps minimise the device’s resistance (RDS(on)). The deep-P doping is also used to provide a large charge below the channel region, suppressing short channel effects. By doing so, short channel length can be designed without problems related to punch-through effects. The source contact is performed in a shallow trench reaching through the source implant region. A doping profile engineering technique is used to pin the location of the electric breakdown at a.
high-drain voltage. This locates the avalanche generation’s hot carriers far away from the gate oxide, and guarantees that the internal bipolar transistor structure will not be triggered up to very high avalanche current densities.

In the last two decades, the trench MOSFET has established itself as the most successful technology for low-voltage (< 100V) power switches. Figure 2 compares trench and NexFET technologies. The major advantage of the trench approach is the high-channel density within a small pitch of the active cell. Alternatively, the large area of the trench walls makes it difficult to keep the internal capacitances small. Also, the moderate doping level of the epitaxial layer below the trench results in a non-scalable contribution to the transistor’s resistance, and limits the advantage of designing the FETs for low-drain voltage applications (e.g., below 20V VDSmax).

By taking advantage of readily available modern, fine lithography fabrication processes, you can combine a narrow gate line coupled with a high doping of the LOD region. This novel structure now has resistance competitive with trench MOSFET technology, yet retains very low charge characteristics. The gate’s minimum overlap over the source and drain regions keeps the internal Cgs and Cgd capacitances small, thus, delivering excellent switching performance. Additionally, the source metal field-plate over the LDD region acts as a shield decoupling gate from the drain terminals. This forces Cgs to drop significantly, even at small drain voltages. Low Cgs and Cgd values make the NexFET-FOM (Ron*Qg and RDSon*Qgd figure of merits) much better than the FOM observed for leading edge trench MOSFETs.

NexFET switching performance

Experimental data on benchmarking NexFET devices versus state-of-the-art trench MOSFETs (Figure 3) for application in PWM switching converters using synchronous buck topology is very popular in the field of low-voltage power supplies. Converter efficiency is shown as a function of the output current for the case of a six-phase commercial evaluation board. The results obtained using leading edge trench devices lay within a close group of data and differ by ±0.5% only. The converter efficiency achieved by a NexFET chip set is higher by 2 to 3% in the full range of load current.

The NexFET transistor has a comparable body diode reverse recovery behaviour to an optimised trench device. The difference is that the NexFET can take advantage of a hard PWM drive where the turn-off of the transistor is sharp and has minimal tail current. Thus, the break-before-make delay time can be made very short, minimising the diode conduction time and, hence, the associated diode conduction power loss. In other words, you can expect that when using NexFET switches the converter’s efficiency can be further improved by reducing delay times dictated by the gate driver stage.

Figure 4 compares a plot of power loss versus the switching frequency of a 12V synchronous buck converter for a leading edge trench FET chip set compared to a NexFET solution. In conclusion, the converter’s efficiency can be kept above 90% (power loss of 3W). The switching frequency can be increased from 500kHz to 1MHz by using NexFET devices. It is actually feasible to increase this frequency beyond 1MHz by optimising driving conditions.

Summary and Outlook

In response to the quest for an ideal switch, the NexFET technology delivers following features:

- Specific Ron*Qg is comparable to state-of-art trench FETs,
- much lower Cgs and Cgd improves FOM,
- switching losses and driver losses are significantly improved,
- the ratio of Cgs to Cgd is similar to trench FETs, but absolute Cgs value is very small and shoot-through immunity is improved by minimising the total amount of charge feedback through Miller capacitance,
- The body diode’s Qrr is similar, but NexFET transistors can be switched much harder, and the dead time dictated by the driver can be made significantly shorter.

A distinct advantage in converter efficiency can be observed simply by dropping-in NexFET chip sets into an existing system. NexFET technology enables converters to run at much higher switching frequencies, minimising both size and cost of filter components.

Literature

APEC 2009, ‘TI enters discrete high-power MOSFET market’, Power Electronics Europe 2/2009 (March), page 23
Sinter Technology for Power Modules

High-power applications such as automotive, wind, solar and standard industrial drives require power modules which fulfil the demand for high reliability, thermal and electrical ruggedness. These demands are met by deploying state-of-the-art packaging technologies such as solder-free pressure and spring contacts, but also sinter technology. The engineers in the New Technologies Department were challenged to develop, optimise and employ this new packaging technology. Christian Göbl, Head of New Technologies, SEMIKRON, Nuremberg, Germany

Silver sinter technology has been used to connect chips to substrates since 1994. Even back then, the properties of sintered silver bonding layers and the benefits they boast in terms of reliability were analysed and reported on within the contexts of numerous international congresses. At that time, however, it turned out that this type of bonding technology was not quite ready for use in large-scale industrial electronics.

Sinter technology basics

These sinter chip/substrate connections are made solely out of special silver particles which, in certain circumstances, produce sinter bridge formations that create a reliable connection between the two bond parts. Figure 1 shows the silver particles before and after sintering. In relation to this, it is important to know that each and every one of these particles is surrounded by a special coating material. Producing a bond is simple: just place the amount of particles needed for the desired layer thickness between the two bond parts and apply a given temperature and pressure to the bond for a given time. The result is a stable sinter connection. This basic process is, however, only sufficient for the first technology evaluations.

The past years have been devoted to the industrialisation of sinter technology. An independent sinter paste has been developed, which today is the basis of the sinter paste approved and implemented by Semikron. Additionally, sinter engineering tools have been developed to manufacture multi-chip DCBs in formats of 5 x 7in. The sinter press was designed to handle pressure loads depending on the process action. The production staff that are responsible for the assembly are well-trained and the process in place continuously improved.

The contact strength achieved by the sinter layer between chips and substrates is extraordinarily high. The sintered layers display high load cycling capability in the reliability tests. A further advantage of sinter technology is that no solder stop layers have to be washed out. The achieved accuracy of chip position relative to the substrates is as much as 50µm. In solder technology, in contrast, a positional accuracy of just 400µm is achieved, a fact which Table 1: Material parameters for the silver diffusion sinter layer in comparison to a standard solder layer (the high temperature stability of sinter technology indicates that the connecting layers do not age)

<table>
<thead>
<tr>
<th>Property</th>
<th>Ag pure silver</th>
<th>Ag sinter layer</th>
<th>SnAg solder layer</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquidus (ºC)</td>
<td>961</td>
<td>961</td>
<td>221</td>
<td>4</td>
</tr>
<tr>
<td>Electric conductivity (MS/m)</td>
<td>68</td>
<td>41</td>
<td>7.8</td>
<td>5</td>
</tr>
<tr>
<td>Thermal conductivity (W/mK)</td>
<td>429</td>
<td>250</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>10.5</td>
<td>8.5</td>
<td>8.4</td>
<td>1</td>
</tr>
<tr>
<td>CTE (µm/mK)</td>
<td>19.3</td>
<td>19</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td>Tensile strength (MPa)</td>
<td>139</td>
<td>55</td>
<td>30</td>
<td>2</td>
</tr>
</tbody>
</table>
that can be considerably encumbering in the subsequent image processing procedures.

Considering the thickness of the sintered layers, the sintered layer is 4.5 times thinner than a standard soldered layer and has 4 times the thermal conductivity. This results in excellent thermal properties in the sintered connection. The layers also demonstrate far higher cycling capability than soldered layers (see Figure 2). This is due to the fact that the melting point of the silver used in the sintered connection is also four times higher than that of the lead-free solders commonly used today (see Table 1). The long-term experience has paid off – an alternative packaging technology, completely solder-free, has been established.

**Sinter technology in application**

Sinter technology was employed in the SKiM IGBT module family for 22 to 150kW train drive converters in electric and hybrid vehicles. SKiM has five times the thermal cycling capability compared to modules with base plate and soldered terminals. Instead of soldering the DCB, the ceramic substrate required for isolation, to the copper base plate, the connection to the heat sink is assured by way of pressure contact technology for all thermal and electrical contacts (see Figure 3). Pressure points positioned directly beside each chip guarantee that the DCB is connected evenly. The fact that no base plate is used ensures superior thermal cycling capability and low thermal resistance.

Solder connections are omitted entirely. This makes the SKiM family the first ever 100%-solder-free module series on the market. The combination of sinter technology, pressure contact technology and base plate-less design ensures five times the thermal cycling capability of a soldered module with base plate.

In the past 15 years, the maximum permissible chip temperatures have risen steadily. Today, state-of-the-art silicon components, for instance IGBT 4/CAL 4 diodes, can be operated at a maximum chip temperature of 175°C. In the future, the use of silicon carbide will create even greater challenges in terms of sufficient thermal cycling ability in the connecting layers. Silicon carbide components can be operated at temperatures as high as 300°C. The sinter technology however, is ideally suited for such high temperature ranges. This is due to the fact that the melting point of these connecting layers is 961°C, around 740°C higher than for the solder connections commonly used today. This high temperature stability that this sinter technology boasts means that the connecting layers do not age, as verified in reliability tests performed today.

Over the years, the areas of application for power semiconductor modules have changed dramatically. In the past, semiconductor modules were used in easily accessible and stationary control cabinets with defined cooling technology/ systems. Today, in contrast, power modules are to be used in mobile applications, i.e. vehicles with cooling conditions of up to 110°C. The challenge faced today is how to ensure that the power semiconductor component can generate its maximum permissible current $I_{\text{max}}$ under the cooling conditions. Figure 4 illustrates the relation between these two parameters, as well as the current that can be controlled at increased chip temperatures with no compromise to reliability.

**The future of sintering**

Sinter technology is a key technology that allows for the production of components that are more powerful and reliable with a longer life-time. The same principles applicable to the SKiM module family for electric and hybrid vehicles – base plate-less module, pressure contact system and sinter technology – were applied in the development of the 4th generation of the intelligent power module SkiiP for applications, for example, in the fields of wind and solar power, elevator systems, trolley buses, metro and underground vehicles.

The benefits of sinter technology continue in the 4th generation of SkiiP power modules such as five times the thermal cycling capability thanks to the silver layer, unbreakable joint between the die and DCB, and twice the power cycling capability.
Power Modules for Fast Switching Motor Drive Applications

Most of the current high power semiconductors are optimized for switching frequencies between 4 and 8kHz. Today, however, more and more applications require frequencies of 10kHz and higher. New power modules can now fill that gap. Andreas Johannsen, Product Marketing Manager Industrial Products, Vincotech, Unterhaching/Munich, Germany

According to current surveys, about 40% of the power consumption of motor driven systems in the European Union comes from fans and pumps. Most of these systems are outdated and not electronically controlled. A state-of-the-art system with a high frequency inverter can be up to 30% more efficient. While most of these systems are running day and night, the energy and cost saving potential is enormous. In times of increasing energy costs and the growing importance of environmentally-conscious behaviour, energy efficiency is becoming increasingly important.

Reasons for higher switching frequencies

Fans and pumps are often seen in heating, ventilation, air conditioning and refrigeration applications, which are usually, installed in audible noise sensitive environments. Electromechanical effects from switching high power can cause audible noise. For that reason, a common feature in all these application areas is a switching frequency of >16kHz, above the audible range.

Further application areas include motor drives with highly accurate torque control, e.g. when used for surface processing, or drives for ultra high dynamic operations. Other reasons for higher switching frequencies are the possibility to use smaller passive components, such as capacitors and coils. This leads to smaller packaging sizes and lower system costs.

Power Semiconductors for higher switching frequencies

For a powerful, reliable and cost-effective motor drive, the right choice of power semiconductors is very important. Most of the current high power motor inverters use IGBTs for the power switches.

IGBTs currently available in the market are optimised for different application areas. In most cases, the optimization is a trade-off between static and dynamic losses, two very important parameters of an IGBT. The static losses are the losses while the IGBT is switched on, given by the Collector-Emitter-Voltage $V_{CE}$. The dynamic losses are the losses during the switch-on and switch-off of the IGBT. A special disadvantage of the IGBT is the current tail during switch-off. The reason for this is that during turn-off, the electron flow can be stopped rather abruptly by reducing the gate-emitter voltage below the threshold voltage. However, holes are left in the drift region, and there is no way to remove them except via a voltage gradient and recombination. The IGBT exhibits a tail current during turn-off until all the holes are swept out or recombined. A short current tail is therefore a very important feature of an IGBT with low dynamic losses.

Compared with 600V, there are only a few 1200V-rated IGBTs available for higher power applications, running with switching frequencies of more than 10kHz. The most common components are built in Trench Field Stop technology and are optimised for switching frequencies below 8kHz. The reason is that the main application field for IGBTs are industrial drives. And most of these applications currently work at switching frequencies between 4 and 8kHz.

The standard Trench Field Stop IGBTs is optimised for $V_{CE}$ and therefore lower switching frequencies and exhibits due to the trench technology a rather high gate capacity. The gate capacity is up to three times higher compared with devices using planar structures.

Another technology group, optimised for fast switching applications, are the Fast Non Punched (Fast-NPT) Through IGBTs. They are typically used in applications with switching frequencies from 30kHz up to a few hundred kHz, e.g. in power supplies or welding equipment. The disadvantages of Fast-NPT are the very high static losses and missing of short circuit capabilities. This makes this technology unusable for motor drive applications.

A real alternative might be the Planar Field Stop technology. It promises low static losses, with much lower gate capacity and faster switching capabilities.

Planar Cell Field Stop – the right choice?

To figure out if the Planar Cell Field Stop technology is the right choice for motor drive applications with higher switching frequencies, the total losses have to be...
observed. Figure 1 shows the total losses of different chip types in a typical motor drive application. The comparison between two IGBTs with 25A nominal current (red and blue line) shows, that the losses of the Planar Cell Field Stop technology are also lower for lower switching frequencies. The reason is that the static losses of the two chips are nearly the same, while the dynamic losses are lower for the Planar Cell Field Stop technology (see Figure 2).

But even more interesting is the comparison between devices of the same size. The 35A Trench Field Stop IGBT (yellow line) and the 25A Planar Cell Field Stop IGBT (blue line) in Figure 1 have nearly the same chip size. Beginning from switching frequencies of 10kHz, the total losses of the Planar Cell Field Stop chip are lower than the 35A Trench Field Stop IGBT and therefore more cost-effective.

At 20kHz, the power loss is lower by 24%, making an output power of 10kW possible, which could only be achieved using 50 to 75A standard IGBT components from Infineon. Because the power losses are much lower, the heatsink can also be sized down. This means the application will not only have much higher energy efficiency, but can also save component costs or provide higher output power at the same size.

Disadvantages of Planar Cell Field Stop

One might ask “Nothing is for free. What are the disadvantages of Planar Cell Field Stop technology?”

The Planar Cell Field Stop IGBT is more sensitive to parasitic inductance that can cause problems in the switch-off behaviour. This can be solved with a conclusive, low inductive module design. Furthermore, an additional emitter contact directly wire-bonded onto the chip is required. This measure protects the gate-emitter-voltage from any parasitic inductance.

Another disadvantage is the bigger chip size, compared to Trench Field Stop IGBTs with the same nominal current. But the comparison for different switching frequencies shows that for higher frequencies the dynamic losses become increasingly important. At switching frequencies higher than 10kHz, the Planar Cell technology can compete or even outperform chips at the same size and much higher current rating.

Available module solutions

Vincotech offers several module solutions optimised for fast switching applications. All these modules supporting the above mentioned design requirements, like low inductive design and emitter sensing down to chip level. As part of the flowPIM 1 family, the V23990-P589-A31-PM integrates all the power semiconductors needed for motor drive applications (rectifier, inverter and optional brake). The module has a voltage rating of 1200V and a nominal current of 25A.

For higher power requirements, a half-bridge module with 1200V and 100A is also available (V23990-P569-F31-PM) which is part of the fastPHASE 0 family (see Figure 3).

To make full use of the advantages of the Planar Cell Field Stop IGBTs, the modules also feature special fast freewheeling diodes.

Conclusion

The Trench Field Stop IGBT is designed for motor drive applications with a typical switching frequency of up to 4kHz. At higher frequencies, the Planar Cell Field Stop components are the optimal choice. This technology seems to be the favourite for nearly all 1200V motor drive applications using switching frequencies above 8kHz.
Gate Drivers for High Performance and Low Cost

Cost and performance are two fundamental cornerstones of any power system component. In the case of the gate drive module, the cost-performance ratio strongly influences the make-or-buy decision for that small, yet crucial building block. Continuous advances in monolithic integration, as well as high voltage transformer technology, have now made it possible to combine advanced gate drive functions and high output power density at low cost. Sascha Pawel and Wolfgang Ademmer, CT-Concept Technologie AG, Switzerland

It is well known that the number of individual components interacting in a system is important for the overall system reliability. Fewer components means higher reliability in non-redundant systems, as long as the component failure rates are comparable. This principle is successfully applied to monolithic integration of electronic functions into ICs for nearly all application aspects. In power electronics, however, design cycles are considerably slower and the designers are more conservative in adopting technical advances. This risk-minimising attitude has brought today’s power systems to a very high reliability level. However, as the number of electronic functions is increasing, the reliability limitation due to the large number of discrete components and off-the-shelf ICs is becoming more and more severe.

Specialising in gate driver solutions

CONCEPT is focusing on gate drivers to overcome the obstacles of monolithic integration in this highly specific market. Monolithic integration requires considerable initial efforts. Thus, it is simple truth that the best price performance ratio can be achieved by a specialised company. Broad application coverage and the large combined quantity of CONCEPT drivers delivered to a great variety of customers makes it possible to merge all common functions of a driver into a platform of dedicated application specific ICs (ASICs).

SCALE, the first generation of dedicated chipset of ASICs for gate drivers, allows 70% reduction in component count for a complete gate driver core. Cores are driver modules including DC/DC conversion, bidirectional signal transmission, high voltage insulation, output stages, and advanced protection and monitoring functions.

The recently introduced SCALE-2 chipset is continuing the successful SCALE philosophy with the improvements and additional capabilities of modern IC technology. SCALE-2 further reduces the component count by two thirds. Up to 90% of the discrete devices have thus been monolithically integrated into the ASICs. This reduction is directly visible in the very high reliability figures of the gate drive modules build with these drivers. The new chipset naturally complements the SCALE technology and helps to implement significant cost saving options. The product line-up will therefore continue to rely on a balanced combination of both technology steps, where the specific advantages of each are fully utilised. Figure 1 shows an overview of the current SCALE technology options.

Two new SCALE-2 gate drivers are currently under development that will extend the application range of ASIC based...
The first one is following a rigid low cost approach while still maintaining full functionality. The second one targets applications where highest driver performance is required.

**Half-bridge driver module with planar transformers**

Driver performance is a complex parameter associated with gate drive power, maximum switching frequency, peak current capability and many more. The combination of newly developed planar transformer technology for 1700V class systems with the integrated SCALE-2 platform yields the highest density of power and functionality seen so far in a driver core. Figure 2 shows the half-bridge driver 2SC0107T. On 57 x 62mm board space, the driver delivers more than 5W output power per channel. The peak current capability reaches 50A, which is important for parallel operation of several high current IGBT modules. With its high maximum frequency limit of more than 200kHz the driver is ready to serve both today’s resonant converter applications as well as prospective SiC and GaN devices.

Dedicated build-up of the driver PCB and careful optimisation of the whole production process have made reliable planar transformers for the 1700V class of insulation systems feasible. The apparent benefits are automated manufacturing with high reproducibility and low tolerances, a driver height of less than 7mm, high power density, and superior immunity to magnetic fields.

The driver targets fast-switching applications, high current modules up to IHM 1700V/3600A, and parallel connection.

**Lower cost half-bridge driver**

The cost saving capability of ASIC integration is fully exploited towards the lower end of the driver power spectrum. Figure 3 shows a picture of the low cost driver 2SC0107T. The PCB contains only 23 components, including transformer and ICs, to form a complete IGBT and MOSFET driver core with all functions known from existing SCALE drivers. The output power rating is 1W per channel at up to 7A maximum output current.

The driver core 2SC0107T is designed to control IGBT modules between 1200V/100A at 50kHz and 1700V/450A at 10kHz. The driver also features a dedicated MOSFET mode which allows faster switching at reduced gate voltage swing.

**Pricing and availability**

The pricing of the 2SC0107T is very competitive, thanks to the low production costs of the SCALE-2 platform. At quantities of 10,000 pieces, the driver will be priced $20 ($10 per channel). It thus compares very favourably with discrete solutions for bidirectional signal transmission, isolated DC/DC power, and gate drive output. The benefits of high reliability and tried and tested SCALE technology are also included. Samples of the two new driver cores will be available summer 2009.

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**Figure 3: Half-bridge driver core 2SC0107T measuring 45 x 34 x 16mm**

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**1SC2060P Gate Driver**

The 1SC2060P is a new, powerful member of the CONCEPT family of driver cores. The introduction of the patented planar transformer technology for gate drivers allows a leap forward in power density, noise immunity and reliability. Equipped with the latest SCALE-2 chipset, this gate driver supports switching at a frequency of up to 500kHz frequency at best-in-class efficiency. It is suited for high-power IGBTs and MOSFETs with blocking voltages up to 1700V. Let this versatile artist perform in your high-frequency or high-power applications.

**Features**

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Improving the Efficiency of PFC Stages Using Interleaved BCM

Higher levels of integration in analog control circuits have enabled newer power factor correction (PFC) techniques which further improve efficiency. The interleaved boundary conduction mode (BCM) PFC approach is a good alternative to non-interleaved continuous conduction mode (CCM) PFC method for input power levels from 300W up to and over 1000W.

Jon Harper, Market Development Manager, Power Conversion & Industrial Systems, Fairchild Semiconductor Europe

The increasing demand for power factor correction (PFC) is being driven by energy-saving initiatives. PFC cuts energy wasted in the electricity distribution networks by reducing the peak currents and minimising the harmonic currents. Newer draft energy saving regulations in lighting, power supplies and motion control will further increase the demand for PFC. For example, a permanent magnet synchronous motor driven from an inverter will have better efficiency, but worse power factor, than an induction motor driven from a simple triac control. An additional PFC stage improves the power factor, reducing losses and problems with harmonic currents in the energy distribution network. The PFC stage needs to have high efficiency, so as not to reduce the benefit gained from using the newer type of motor.

Principle of operation

The principle of interleaving is a well-established technique applied in power electronics. Most microprocessors are driven from a multi-phase synchronous buck power supply. In interleaving, two or more output stages are connected in parallel, where each of the output stages is switched at a different time. The same technique can be applied to BCM PFC and CCM PFC. Most methods of PFC use a boost stage. The two interleaved output stages share the same output capacitor (see Figure 1).

In a perfectly synchronised interleaved BCM PFC system, the currents drawn by the first phase will partially cancel out the

Figure 1: Interleaved boundary conduction mode circuit
currents from the second phase as shown in Figure 2. The overall input current and capacitor currents have a much lower ripple which is at twice the frequency of the ripple frequency of the individual stages. Both these factors simplify the dimensioning of the EMI filter needed to reduce the input ripple current harmonics to meet EMI standards. The reduced ripple current flowing through the output capacitor results in longer system lifetime if the same capacitor is used, or a reduction in system volume and cost if the output capacitor size is redimensioned to meet the lower ripple current ratings.

The second aspect of interleaving is that the current flowing through each of the stages is halved. This does not have any effect on the conduction losses if the MOSFETs used in the interleaved version have exactly twice the RDS(ON) of the MOSFETs used in the non-interleaved version, in other words, if the same silicon area is used for the switches. In this case the switching losses could however be reduced. The smaller MOSFETs have half the gate charge and switch only half the currents seen in the non-interleaved version, resulting in one quarter of the switching losses for each device, or one half of the switching losses in total. Effects such as higher switching dv/dt need to be considered here.

As interleaved controllers use newer technologies than the standard BCM controllers, it is possible to take further steps to improve the switching efficiency. The FAN9612 interleaved BCM PFC controller from Fairchild Semiconductor has two notable features which improve the efficiency of the boost circuit. First, the detection of the zero voltage switching point is performed accurately without the need for an additional RC delay circuit. Standard BCM controllers will switch on the zero crossing from the boost inductor winding, the FAN9612 switches at the zero current point. Second, the use of two separate sense resistors to detect over-current conditions for each MOSFET actually reduces overall resistor losses in addition to improving system reliability.

The reduction in ripple currents, increase of ripple current frequency and improvement in efficiency extends the working power level beyond the simple doubling in power levels which would be expected by interleaving. Standard BCM PFC is used up to around 300W, whereas interleaved BCM PFC can be extended to 800W and upwards.

Interleaved BCM PFC compared with standard CCM PFC
The use of interleaving in a BCM PFC stage extends the power range of operation to that traditionally covered by a non-interleaved CCM PFC stage. The classical non-interleaved BCM to CCM comparisons no longer apply, so it is important to compare these two approaches on their own merits.

The first area of discussion is inductor size. Consider the design of a 400W power supply with wide range input (85 to 265VAC). Using the calculations shown in the application note for the FAN9612 [1] results in two inductors dimensioned with an inductance of 220µH and a peak current of 7A. Using the same conditions for a CCM controller [2] results in an inductance of 790µH and a peak current of 8A. It is also interesting to note that the inductor dimensions for this power level for a non-interleaved BCM controller would be 110µH and 14A, further illustrating why non-interleaved BCM is less desirable at such power levels.

For a compact design, two inductors based on PQ3220 cores can be used for the 400W interleaved BCM PFC power supply. The core size used for the CCM PFC is estimated to be around PQ4040.
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The next area of consideration is the reverse recovery losses of the boost diode. In continuous conduction mode, the boost diode is switched while there is current flowing through it. This results in extra switching losses as this current flows through the boost MOSFET during turn-on. Additionally, this extra current spike causes problems with common-mode EMI due to the fast switching transitions. This is one of the more difficult problems to address in practical CCM PFC circuits. As there is no body diode conduction in interleaved BCM PFC operation, the switching losses are far lower, resulting in higher efficiency, with the additional benefit of lower common-mode EMI.

One other source of switching losses is the output capacitance. For low-line voltage conditions, BCM PFC circuits such as those based on the FAN9612 have zero voltage switching as the controller waits until the minimum point of the voltage waveform in the resonance occurring after turn off. So there is no loss due to discharging the output capacitance of the MOSFET. In CCM PFC applications, the MOSFET is always switched on at the instantaneous input voltage, meaning that there is never any zero voltage switching. Interleaved BCM PFC circuits have higher conduction losses than CCM PFC applications. However, initial comparisons have clearly shown that this disadvantage is outweighed by the higher switching losses seen in CCM PFC applications, even when high performance diodes and MOSFETs are used in the CCM circuit. In conclusion, interleaved BCM PFC circuits are generally more efficient.

EMI problems are easier to address with interleaved BCM than with CCM. The main source of EMI is caused by differential-mode noise which is addressed with an input filter. The inherent frequency variation and low ripple current ease this task. The ringing of output diode causes common-mode noise in CCM systems. This can be reduced using expensive silicon carbide diodes.

**Synchronisation and soft-start**

Synchronisation of the two interleaved boost stages is a difficult problem which has been successfully solved on the FAN9612. Synchronisation under steady state conditions is relatively straightforward. However it is the dynamics of synchronisation under start-up and load changing conditions which has made interleaved BCM PFC such a challenge for system designers of integrated circuits.

At light load conditions, the efficiency would suffer if both phases were kept on. So at lighter load conditions it is important to switch off one of the loads, and when the load increases, to turn this back on again. The circuit responds to these changes within a single switching cycle. Figure 3 shows the phase adding and shedding. The gates of each MOSFET and the currents flowing through each MOSFET are shown. Phase adding and shedding function without any transient.

The soft-start used in the FAN9612 is a closed-loop rather than an open-loop soft-start, removing the output voltage overshoot normally seen in such applications. Soft-start is such a problem in PFC circuits as there is a large output capacitor which has to be charged without saturating the control loop.

In conclusion, the FAN9612 addresses these two difficult areas for interleaved PFC design.

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