POWER ELECTRONICS EUROPE

ISSUE 2 – MARCH 2009

DISTRIBUTED POWER

Improving Power Efficiency in IT and Telecom

THE EUROPEAN JOURNAL FOR POWER ELECTRONICS AND TECHNOLOGY

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FUJI ELECTRIC
DEVICE TECHNOLOGY
e-Front runners

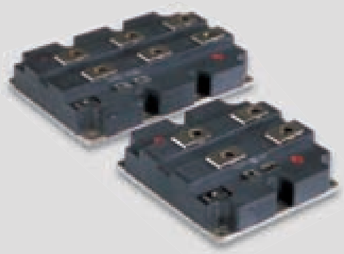
Knowledge is power
power is our knowledge

DualPack
with Soldering Pins
1200V : 225A - 450A

DualPack
with Spring Contacts
1200V : 225A - 450A

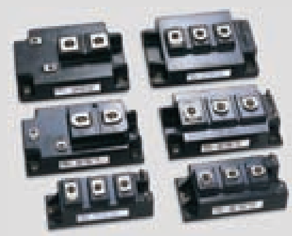
6-Pack IGBT
600V : 15A - 150A
1200V : 10A - 150A
1700V : 100A - 150A

PIM IGBT
600V : 30A - 100A
1200V : 10A - 75A



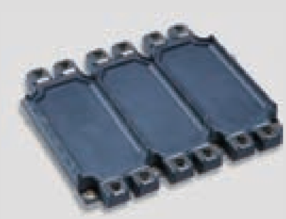
1-Pack
1200V : 1200A - 3600A
1700V : 1200A - 3600A

2-Pack
1200V : 800A & 1200A
1700V : 600A & 1200A



2-Pack IGBT
600V : 50A - 600A
1200V : 50A - 450A
1700V : 150A - 400A

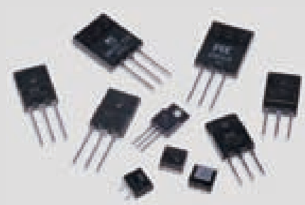
1-Pack IGBT
600V : 600A
1200V : 200A - 800A



High Power 6-Pack
1200V : 225A - 450A
1700V : 225A - 450A

Special version available
for rough environments

IPM-IGBT
600V : 15A - 300A
1200V : 15A - 150A



Discrete IGBT
600V : 5A - 75A
1200V : 3A - 25A

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Circulation and subscription: **Power Electronics Europe** is available for the following subscription charges. **Power Electronics Europe**: annual charge UK/NI £60, overseas $130, EUR 120; single copies UK/NI £10, overseas US$32, EUR 25. Contact: Techmedia International Ltd, Kildonan, St Mary's Road, Wrotham, Kent TN15 7AP, Great Britain. Tel: +44 (0)1732 886495. Fax: +44 (0)1732 886149. Refunds on cancelled subscriptions will only be provided at the Publisher's discretion, unless specifically guaranteed within the terms of subscription offer.

Editorial information should be sent to The Editor, **Power Electronics Europe**, PO Box 340131, 80098 Munich, Germany.

Origination: Elaine Gladwell
Printed by: Wyndeham Heron Limited.
ISSN 1748-3530

techMedia INTERNATIONAL

COVER STORY

Improving Power Efficiency in IT and Telecom

For high-end IT and telecom applications, the conventional approach to power conversion involves an AC/DC silver box followed by 12V-to-1.x V synchronous buck converter. This approach has inherent limitations in terms of system efficiency, due to a combination of distribution bus losses and fundamental restrictions in topology performance as processor voltages reach sub-volt levels. Recent advances in power train technology can better meet such power conversion demands by, for example, eliminating step-down stages and enabling direct 48V-to-load conversion. Higher (48V or 350/380V) bus voltages reduce distribution losses, but usually mean the addition of an extra stage or stages to get down to the processor voltages, which may lower conversion efficiencies. The approach of Factorized Power Architecture (FPA) improve high power system efficiency. Full story on p 29.

Cover supplied by Vicor UK

Efficiency Saves Energy

Green is the colour of choice for many events dealing with electronics and, in particular, with power electronics such as APEC 2009 and the upcoming PCIM 2009. In the US industry, authorities have realised that energy is not for free and that efficiency is the most affordable strategy to reduce carbon emissions and energy consumption in general. The Power Supply Manufacturer's Association (PSMA) roadmap i.e. outlined an industry vision on efficiency up to the year 2013. The market for power supply solutions is enormous since, ultimately, no electrically driven system can be operated without power. In particular, the rising demand in the area of consumer electronics, the increasingly complex design of power management systems and growing interest in energy-efficient products will catapult the world market for voltage-regulating systems to a volume of $15 billion by 2011. For AC/DC front ends, PSMA predicts an increase in efficiency from a maximum of 85% in the year 2003 to 92% in 2013, and also a penetration of digital control of 30% in 2013. With isolated bricks, efficiency will rise from 93% in 2003 to 95% in 2013. Drivers of efficiency enablers are, besides others, power semiconductors made of Silicon Carbide and Gallium Nitride.

Silicon Carbide now becomes a more adopted technology as device prices will fall and switches (JFETs, MOSFETs) will be available in the near future. At APEC, Munich-based Infineon Technologies introduced its third generation SiC Schottky diodes featuring lowest device capacitance and enhancing overall system efficiency at higher switching frequencies under light load conditions. Compared to the second generation (600 and 1200V), the device capacitances of the third generation SiC Schottky diodes are about 40% lower, which reduces switching losses. For example, in a 1kW PFC stage operating at 250kHz there will be an improvement of 0.4% in the overall efficiency under 20% load conditions. Higher switching frequencies allow the use of smaller and lower cost passive components, such as inductors and capacitors, resulting in higher power density designs. Reduced power losses result in several benefits, including reduced cooling requirements in terms of size and number of heatsinks and fans, which enables system cost reduction and increased reliability levels. This also contributes to reduced system level energy requirements to provide an appropriate cooling environment. Infineon expects system cost reductions in some SMPS applications of up to 20% using SiC Schottky diodes.

SiC technology is able to deliver benefits such as higher switching frequencies because no reverse recovery charge accumulates during the diode's normal conduction period. When a conventional bipolar silicon diode is turned off, this charge must be dispelled by recombination between groups of charge carriers close to the diode junction. The current flowing during this recombination period is called the reverse recovery current. This undesired current, when combined with the voltage across associated semiconductor power switches, generates heat that will be dissipated by the switches. By eliminating this reverse recovery charge, SiC Schottky diodes have much lower switching losses across the board, leading to higher efficiency and lower heat dissipation.

Another European player entering the SiC diode market is STMicroelectronics, the company plans to introduce SiC MOSFETs in the year 2011 and expect ten-fold better characteristics for on-resitance and gate charge compared to the best silicon devices which, in turn, will increase efficiency and reduces losses significantly.

According to market researchers such as Yole, SiC switches will boost the markets in various industries, from consumer over industrial to automotive electronics. Power factor correction is an emerging market and a good starter for SiC diodes, but this market is too price-sensitive. Solar and wind applications will give more cost flexibility. The overall PFC market is estimated at $6.2 billion in 2008; here eight silicon diodes are necessary for the desired performance. With SiC diodes this number will decrease to two, not taking into account savings in passive components such as inductors and capacitors. In 2008, around 14 million SiC diodes were produced. SiC switch mass production may start in 2010; in this case the market volume could reach $900 million by the year 2015.

Thus, SiC and also Gallium Nitride will play an increasingly important part in future power electronic designs, as our APEC report reveals. And the ending of one conference is the beginning of another. The next opportunity to meet the leading experts in this field is the Special Session 'Wide Bandgap Materials and Devices' at PCIM 2009 (May 12 – 14) in Nuremberg. This session on May 13, 10.00 – 12.00, is organised and chaired by Power Electronics Europe, the right place to be for our interested readers. See you there!

Achim Scharf
PEE Editor

Shade and Light for Power Supplies

The merchant power supply market grew fairly strongly in 2008, following 2007s remarkable growth. The datacom and telecom sectors are the largest, accounting for nearly 40% of the market. "Unsurprisingly, they are going to be badly hit with significant cuts during 2009 and 2010 due to economic conditions", IMS-Analyst Josh Flood commented. "With some experts predicting today's economic crisis being the most grave for many years, IMS Research projects the merchant power supply market will slow down over the coming years; nevertheless, some applications in the consumer and computing sector, particularly notebooks and LCD TVs, will continue to grow well". Already most design and production of merchant power supplies is in Asia. Perhaps more of the consumption of the devices in which they are used will need to be in Asia; supported by even stronger consumer markets in China, if the business is to continue to grow over the medium term and beyond.

The buzzword 'digital power' will take time to become a reality. The digital power supply market was worth close to $600 million in 2008, according to IMS Research. These products are starting to see increased penetration from a number of sectors and are forecast strong growth over the next five years to exceed $2 billion in 2013. However, it seems that the argument in favour of 'digital power' seems to have changed, as have the reasons customers are now choosing to go digital. "You only have to look at the recent product announcements by Ericsson and TDK Lambda to see that digital power is really beginning to gain traction in the market", commented IMS-Analyst David Dewan. "It's not the extra functionality that is driving demand, but rather the extra flexibility at the production stage which lowers the time to market that is driving digital as a viable solution".

Despite this, IMS Research still predicts that digital power will remain a high-end solution, with digital products accounting for only around 10% of the total power supply revenues in 2013.

www.imsresearch.com

"We offer complete foundry services for the power semiconductor industry with the additional capability of integrating flash memory with no extra layer", underlines Jazz's Todd Mahlen Photo: AS

Power Management Chips via Foundry Services

Tower/Jazz Semiconductor, an independent foundry, and Triune Systems, an IC design and test development provider, announced at APEC 2009 an agreement to collaborate on developing the most complete power management platform.

Through this collaboration, the companies will jointly design and develop intellectual property (IP) for Tower/Jazz's 0.18µm Bipolar-CMOS-DMOS (BCD) process to deliver a family of low and high voltage power management products and IP for a variety of applications to enable faster design cycles and lower cost designs. In particular, the companies will design and develop zero mask adder non-volatile memory blocks, based on Y-Flash technology, suitable specifically for 5V operation on high voltage platforms. High volume production for the co-developed high voltage power management products is expected to commence in the second half of 2009. Tower's 0.8/0.5µm Bipolar-CMOS-DMOS process platform is highly modular offering a very dense 5V-only option on 0.18µm design rules, a low on-resistance LDMOS portfolio with 5V gate drive capability, and up to 60V operating with an 80V breakdown voltage. In addition, there is an option to add dense 0.18µm I/Os and complex IP blocks. Through access to the process portfolio of its wholly owned subsidiary, Jazz Semiconductor, Tower offers RF CMOS, Analog CMOS, Silicon and SiGe BiCMOS, SiGe C-BiCMOS, Power CMOS and High Voltage CMOS. "Our process portfolio including flash memory up to 1MBit enables new opportunities particularly in power management and digital power to store variables or parameters", said Todd Mahlen, Director Business Development at Jazz Semiconductor. Tower maintains two manufacturing facilities in Israel with access to Jazz Semiconductor's fab in the US and manufacturing capacity in China through Jazz's partnerships with ASMC and HHNEC.

www.jazzsemi.com

Infineon Expands Production of Power Modules in Hungary

Infineon Technologies announced that it is expanding its manufacturing plant for power modules in Cegléd, Hungary, in response to increasing demand for renewable energy and traditional motor drive systems. Through 2012, the company will invest around Euro 17 million in buildings and manufacturing equipment, while Hungary's Ministry of Economic Affairs will provide Euro 1.4 million in project funding.

By 2012, Infineon plans to more than double the volume of IGBT modules produced in Cegléd to around six million annually. At present, the plant employs around 470 people, including some 290 involved in producing IGBT modules. Infineon expects to increase employees working in IGBT module production to roughly 500 by 2012, when output reaches the six million unit annual goal. Manufacturing will begin in new buildings in April 2009 after just ten months of construction work. Cegléd is a backend site shared by Infineon Technologies Cegléd Kft. and Infineon Technologies Bipoláris Kft.; the latter is a wholly owned subsidiary of Infineon Technologies Bipolar GmbH & Co KG, in Warstein, Germany, which is a joint venture of Infineon Technologies AG and Siemens AG. Besides IGBT modules, the Cegléd site also assembles and tests other components, including disk-type thyristors, diode discs, and bipolar modules. These are used in a range of industrial applications and, in particular, in power generation and distribution.

"Expanding our Cegléd site, where we assemble and test power modules, is an important investment in the future, and the backing we receive from Hungary's Ministry of Economic Affairs underscores Cegléd's importance as a semiconductor manufacturing location for the Hungarian government", said Dr. Reinhard Ploss, member of the board and responsible for Operations at Infineon Technologies AG.

www.infineon.com

"Greater efficiency in the utilisation of energy will become tomorrow's most important energy resource, and our chips and modules play a valuable role in minimising power loss and maximising power savings", commented Infineon's Reinhard Ploss on the company's investment in Hungary Photo: AS

Growth Expected in Vehicle Electrification

Electrification of cars such as plug-in hybrids will drive power semiconductors due to legislation and public investments
Photo: AS

Environmental regulations and fuel efficiency do provide a strong stimulus to adopt HEVs and plug-in hybrids, but they do not benefit from the technology as much as the other vehicle types. The automotive market is also very price-sensitive, and vehicle electrification is still an expensive proposition, market researcher Darnell points out.

The economic and business forces affecting these markets are currently in flux. Global automakers are focusing more on hybrid-electric and electric vehicles, due to the provisions of the US Congressional 'Financial Stimulus', package as well as efforts by other governments. One of the most critical components needed for the adoption of hybrid-electric, plug-in hybrid and pure electric vehicles is batteries and their concurrent battery management systems. The US financial stimulus package allocates $300 million for a federal fleet of hybrid and electric vehicles but, more importantly, it also provides $2 billion for grants that would support the manufacturing of advanced vehicle batteries and components.

The two most important technology drivers for powertrain vehicle electrification are stop-start function and varying loads. Commercial vehicles and off-road vehicles particularly benefit from stop-start functionality; while small task-oriented vehicles, heavy-duty trucks and off-road vehicles have varying loads. In addition, the emphasis on infrastructure spending in many national fiscal stimulus packages will be good for some of the non-automotive markets, such as heavy-duty trucks. Additional factors are pointing toward increased adoption of electric and hybrid-electric vehicles in a variety of transportation markets. For example, 2008 saw the 'first commercial volumes' of hybrid trucks go into production. Growth will accelerate in 2009 and beyond.

Like many emerging technologies, vehicle electrification has been around for a long time, but until recently, the technology has not really 'taken off'. Even though the automotive (i.e. passenger cars and light trucks) portion of the vehicle electrification market is expected to be large, the non-automotive segments represent a potential or roughly $900 million opportunity in 2009, growing to approximately $2 billion worldwide in 2014, a compound annual growth rate of 17%.

www.darnell.com/vehicle

From SJ MOSFETs to SiC MOSFETs

STMicroelectronics has announced a performance breakthrough for silicon power MOSFETs by achieving the best on-resistance per die area with its latest MDmeshV technology, an important step towards SiC MOSFETs.

MDmesh V will enable a new generation of 650V MOSFETs with on-resistance reaching below 0.079Ω for a 33A device in compact TO-220 package. These devices target power-conversion systems where small size and low energy consumption are major goals for design engineers. "We have specified the 650V breakdown voltage particlularly for outdoor applications such as solar inverters to guarantee, even at ambient temperatures of -20°C, a breakdown voltage of 600V. A further advantage is a cleaner turn-off waveform, enabling easier gate control and simpler filtering due to reduced EMI", explained ST's Director Applications Bernhard Rauscher.

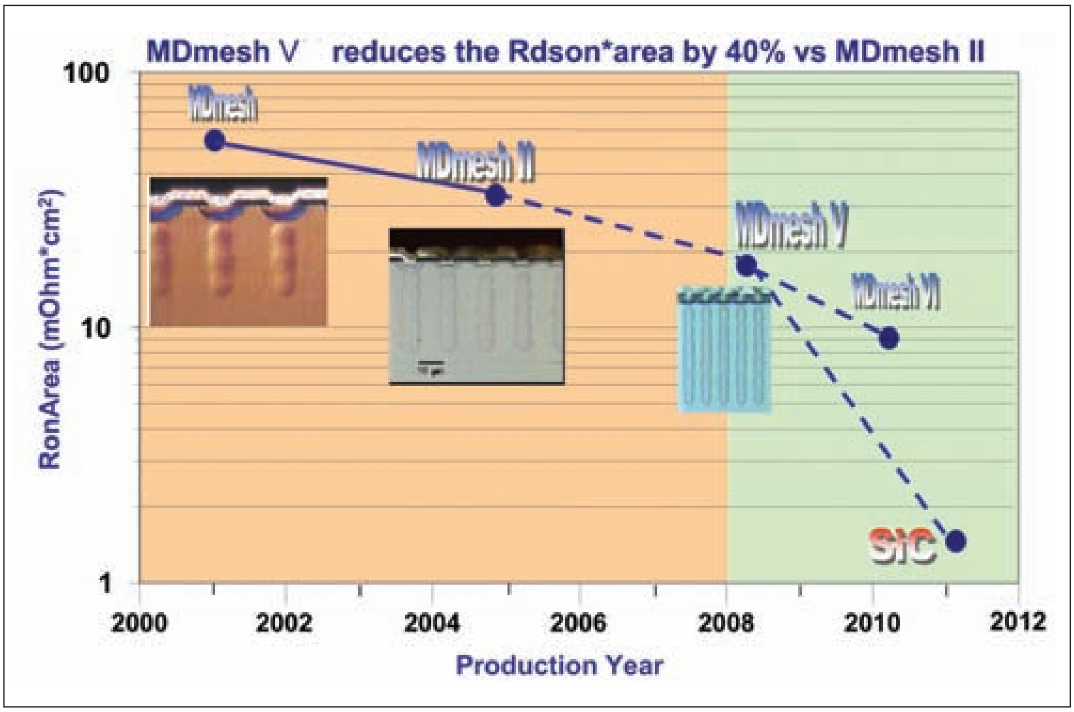
The complete STx42N65M5 family offers additional package options, including the surface-mount D2PAK, as well as TO-220FP, I2PAK, and TO-247. The STx16N65M5 family, also at 650V, is in full production, rated at 0.299Ω and 12A. The roadmap for MDmesh V 650V MOSFETs includes higher current devices with on-resistances as low as 0.022Ω in Max247 and 0.038Ω in TO-247 packages. These devices will be available in March 2009. "The improvement in on-resistance will significantly reduce losses in line-voltage PFC circuits and power supplies, which will, in turn, enable new generations of electronic products offering better energy ratings and smaller dimensions", said Sven Reinhard, Manager Product Marketing. "This new technology will help product designers tackle emerging challenges such as the high efficiency targets of new eco-design directives, and will also benefit the renewable energy sector by saving watts normally lost in power-control modules". Prices for the STx42N65M5 begin at $10.00 and the STx16N65M5 is available from $6.00, in quantities of 1000 units.

For the year 2011, the company plans the introduction of 60mΩ SiC MOSFETs. Early February, the company took a foot in the SiC arena by introducing SiC diodes. The STPSC806D and STPSC1006D SiC Schottky diodes are especially useful in converters for solar power systems, where every fractional efficiency percentage is valuable. Power supplies for servers and telecom systems, which are operational round the clock, will also benefit from the cumulative savings of this apparently small improvement in efficiency. These diodes can also be used in motor controllers, which are deployed in large numbers worldwide, thereby saving the environmental impact of many thousands of Watts of generated energy. The 8A rated STPSC806D and 10A STPSC1006D, for 600V applications, are in full production in the industry-standard TO-220AC package, and available at $3.9 and $4.9, respectively, in quantities of 10,000.

SiC technology is able to deliver benefits such as higher switching frequencies because no reverse recovery charge accumulates during the diode's normal conduction period. When a conventional bipolar silicon diode is turned off, this charge must be dispelled by recombination between groups of charge carriers close to the diode junction. The current flowing during this recombination period is called the reverse recovery current. This undesired current, when combined with the voltage across associated semiconductor power switches, generates heat that will be dissipated by the switches. By eliminating this reverse recovery charge, SiC Schottky diodes have much lower switching losses across the board, leading to higher efficiency and lower heat dissipation. "With SiC MOSFETs as switches, we expect ten-fold better characteristics for on-resitance and gate charge compared to the best silicon devices of this power range. The wafer are supplied by Cree and are porcessed in our Catania-based fab", Rauscher said.

AS

www.st.com



ST's high-voltage pwer MOSFET roadmap towards silicon carbide
Source: STMicroelectronics

Connecting to the Grid

AMSC PowerModule™ power converters enable renewable energy systems to meet utility requirements for connecting to the grid.

Connecting to the Grid

AMSC PowerModule converters are used to connect a variety of components to the grid, including distributed storage systems such as batteries and distributed generation sources such as wind, solar, fuel cell and hydro.

Inherent to the PowerModule PM1000 architecture is the ability to rapidly configure hardware and software for new applications. User-determined parameters allow quick customization of performance and can be changed in real time.

- High power density
- Rapid product development
- Scalable design
- Flexible architecture
- Grid interconnectivity

Connecting with the Wind™

The PowerModule PM3000W has unique capabilities you won't find in other wind turbines.

AMSC's PowerModule PM3000W is designed specifically to meet the power conversion needs of your wind turbine converter system. The PM3000W utilizes state-of-the-art ruggedized (thermally and mechanically enhanced) IGBTs in a high power density (130 W/in^3), liquid cooled, double conversion architecture.

- Intelligent and highly integrated power converter
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- Two dual-DSP embedded controllers and a common laminated DC bus with dynamic control

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Going Green in the USA

The Applied Power Electronics Conference (APEC) was held from February 15 – 19 in Washington DC. The bottom line in most presentations and product announcements was energy efficiency, from components to systems such as power supplies and inverters for drives or (hybrid) electric vehicles. That's why promising power semiconductor materials such as Gallium Nitride and Silicon Carbide were one of the top priorities.

APEC 2009 General Chair, Kevin Parmenter, was happy to announce that about 1900 attendants registered for the event

APEC 2009 General Chair, Kevin Parmenter, was happy to announce that about 1900 attendants registered for the event, just slightly down from last year, despite the financial crisis. APEC went Green and, as such, the opening remarks reflected the problems around energy efficiency from various angles. "Industry now has realised that energy is not for free. People the world over are struggling with the newfound reality that our reliance on traditional forms of energy is causing economic disruption and growing environmental harm", said Andrew Fanara, US ENERGY STAR Product Specifications Development Group. The US will use much more coal in the future, despite renewables which will grow, but at a lower rate. "Efficiency is the most affordable strategy to reduce carbon emissions and energy consumption in general".

Transitioning to a cleaner and affordable energy future will be one of the great business and societal challenges of our time. Government decision makers are faced with a complex array of policy options with uncertain outcomes from which to drive diverse market participants towards a sustainable future. Implementing a well-conceived strategy rapidly and with certainty will be essential to encourage the investment of the necessary billions on the part of industry and government to achieve the desired outcomes. "Today, the power electronics industry finds itself with the rare opportunity to insert itself squarely into the middle of the ongoing global energy debate, and to weigh-in with a blueprint of proven practical solutions that can reduce energy waste across varied economic sectors", Fanara promised.

"As the cost of motor fuel increases and our dependence on foreign oil causes controversy at home, the need for alternative transportation energy sources becomes more and more relevant. The idea of storing electrical energy on board the vehicle is making significant technical progress", added Jack Wagner from LiIon battery maker A123 Systems. "Competing with the incredible energy density of petroleum products poses quite the challenge, but nonetheless, if reducing the use of fossil fuel and eventually deriving our energy from clean sources are the goals, then batteries can play a big part in achieving these targets".

Higher power efficiency through GaN and SiC

Carl Blake, a well-known veteran in the power semiconductor industry, introduced the Power Supply Manufacturer's Association (PSMA) roadmap, outlining an industry vision up to the year 2013. "In 2008, leaders from key groups such as end-users, power supply manufacturers and component suppliers, got together to present, compare and discuss their views on the trends in power technology. This year, a new method of gathering the data was implemented in order to assure inputs from a wider range of participants. The end result is this report which offers a consolidated view of the latest trends in power management, control and power delivery technologies", Blake said.

Two major users of power supplies discussed their roadmap for computing trends. Six component suppliers

	2003	2008 Forecast from 2003	2008 Actual	2013 Forecast
Cost ($/W)*	0.10 – 0.20	0.08 – 0.14	0.095 – 0.14	0.08 – 0.12.5
Density (W/in³)	3 – 10	10 – 25	8 - 18	13 - 38
MTBF (kH)	500	750 +	550	750 +
Efficiency	80 – 85%	85 – 92%	88 – 94%	92 – 96%
Switching frequency (kHz)	100 – 200	100 – 500	95% < 500	92% < 500
Time to market	6 – 9 months	3 – 6	9	7
Control	Analog	Digital	15% Digital	30% Digital

* At high unit volume

PSMA's predictions on AC/DC frontends from technology roadmap 2009
Source: PSMA

	2003	2008 Forecast from 2003	2008 Actual	2013 Forecast
Cost ($/W)*	0.40 – 0.60	0.20 – 0.45	0.075	0.058
Density (W/in³)	75	100	300	400
MTBF (MH)	1 - 2	4	3 - 5	3 - 5
Efficiency	85 – 93%	90 – 95%	89 – 94%	92 – 95%
Switching frequency (kHz)	200 – 300	300 – 1000	90% < 500	85% < 500
Time to market	Off the shelf	Off the shelf	Off the shelf	Off the shelf
Control	Analog	Digital	Mixed	Mixed

* At high unit volume

PSMA's predictions on DC/DC Isolated Bricks or Intermediate Bus Converters from technology roadmap 2009 Source: PSMA

"The need for power electronics having greater compactness, better manufacturability, and higher performance motivates pursuit of increases in switching frequencies in the 30 to 300MHz range", expects MIT Professor David Perreault

provided trends on semiconductor ICs, power semiconductors, magnetic materials, inductive wiring, and capacitor technologies. The report also includes technology presentations on expected influence of digital power control and management technologies, advanced packaging trends on DC/DC converters, and an extensive review of university research now in progress around the world for DC/DC power conversion. Finally, there were three market perspective presentations on communication infrastructure, power component market trends and the very important review of world-wide energy-efficiency standards.

"It was a challenge to choose the set of products for the roadmap that would best represent the interests of PSMA members, and we decided to use the same four product sets used in the 2006 roadmap as the most representative: AC/DC front end power supplies, external AC/DC adapter supplies, DC/DC bus converters, and non-isolated DC/DC converters. For AC/DC front ends, we predict an increase in efficiency from a maximum of 85% in the year 2003 to 92% in 2013, and also a penetration of digital control of 30% in 2013. With isolated bricks efficiency will rise from 93% in 2003 to 95% in 2013. Drivers of efficiency enablers are, besides others, Silicon Carbide and Gallium Nitride", Blake stated.

"Drivers of efficiency enablers are, besides others, Silicon Carbide and Gallium Nitride", PSMA's Carl Blake stated.

VHF power conversion shrinks size

"The need for power electronics having greater compactness, better manufacturability, and higher performance motivates pursuit of dramatic increases in switching frequencies in the 30 to 300MHz range", stated MIT Professor David Perreault. Increases in switching frequency directly reduce the energy-storage requirements of power converters, improving achievable transient performance and enabling miniaturisation and better integration of the passive components.

Realising these advantages, however, requires devices, passive components, and circuit designs that can operate efficiently at the necessary frequencies. To achieve dramatic increases in switching frequency, it is typically necessary to mitigate frequency-dependent device loss mechanisms including switching loss and gating loss. Zero-voltage switching can be used to reduce capacitive discharge loss and voltage/current overlap losses at the switching transitions. Likewise, resonant gating can diminish losses resulting from charging and discharging device gates, provided that the gate time constants are short compared to the desired switching transition times.

"Considerable reduction in the size of magnetic components is possible through frequency scaling if appropriate materials and designs are employed. We also explored the impacts of frequency scaling on semiconductor devices, circuit topologies, and control methods. It may be concluded that VHF power conversion holds great promise for improvements in miniaturisation, integration, and bandwidth of power electronic systems", Perreault expects.

"Power supply miniaturisation is being increasingly addressed by semiconductor companies in systemin-package (SiP) and system-on-chip (SoC) platforms. These functionally integrated solutions can be seen as an inflection point in the power supply industry which is seeing a dramatic move away from traditional brick manufacturing to an increasing emphasis on monolithic circuits and technologies. The ultimate target is to develop miniaturised product formats referred to as power supply-in-package (PSiP) and power supply-onchip (PwrSoC) by integrating passives either into the PCB, or even on a silicon die", added Cian O'Mathuna from Tyndall National Institute in Ireland.

AS

www.apec-conf.org
www.psma.com
http://web.mit.edu
www.tyndall.ie

"Power supply miniaturisation is being increasingly addressed by semiconductor companies in systemin-package and system-on-chip platforms", Cian O'Mathuna from Tyndall National Institute believes

Breakthrough for Silicon Carbide Ahead

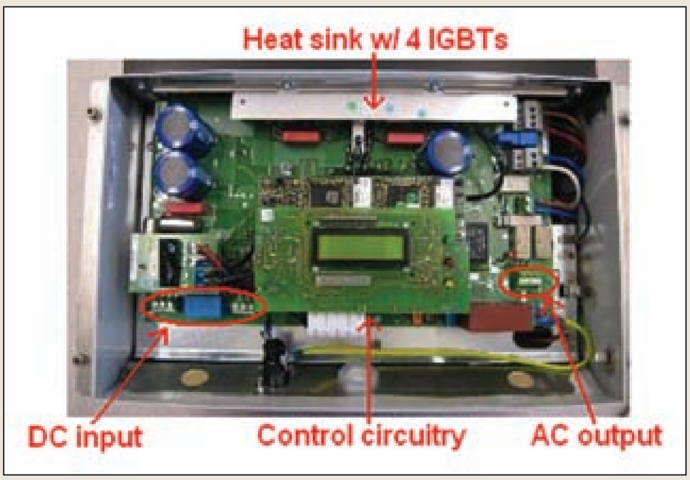
The release of an SiC switch on a broader scope will launch the market and drive new developments in the automotive, industrial and IT industry. A $ billion device market is forecasted by market researchers such as Yole Developpement by the year 2015.

Podium on SiC featuring Semisouth's Michael Mazzola (left), Yole's Philippe Roussel, Cree's Paul Kierstedt, and Qspeed's Syrus Ziai Photo: AS

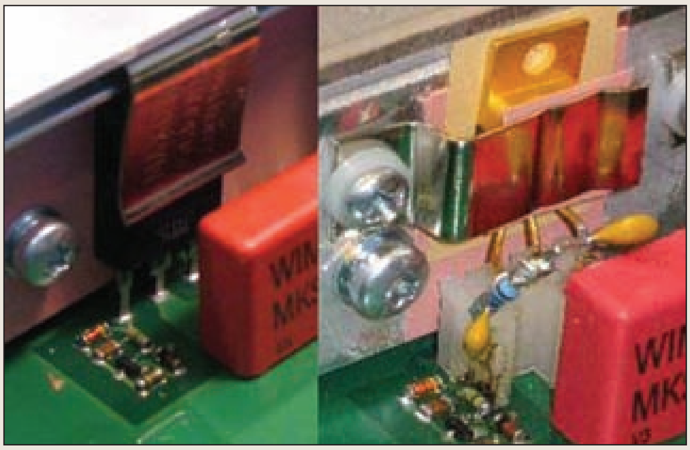
"SiC switches will boost the markets in various industries, from consumer over industrial to automotive electronics. Power factor correction is an emerging market and a good starter for SiC diodes, but this market is too price-sensitive. Solar and wind applications will give more cost flexibility", stated Yole analyst Philippe Roussel at APEC 2009. The overall PFC market is estimated at $6.2 billion in 2008. Here, eight silicon diodes are necessary for the desired performance; with SiC diodes this number will decrease to two, not taking in account savings in passive components such as inductors and capacitors. According to Yole, in 2008 around 14 million SiC diodes were produced. SiC switch mass production may start in 2010; in this case, the market volume could reach $900 million by the year 2015.

"But, according to our discussions with PFC makers, the cost for Silicon Carbide or Gallium Nitride devices must fall down to 20Cent/ Amp, to be cost competitive", Roussel stated. "In PFC applications particularly, fast recovery silicon diodes with low reverse recovery characteristics can be a good choice for a much lower price. Our diodes can offer a 90% SiC PFC performce at 30% price reduction", stated Qspeed's CEO Syrus Ziai.

Another point is the cost for the starting material. A 4in SiC wafer costs around $1700.00, and the price for GaN is $700.00. "Thus, 50% of the device cost is associated with the substrate material; with Silicon this is only 6%", Roussel explained. Another point is commercial viability, "and for today this means 1200V and not 10kV. Relating to switches, the Superjunction MOSFET, for example, is a complex device. Thus, the cost for SiC starting material is relatively high", said Michael Mazzola, co-founder of Semisouth. "But 10kV is a long-term vision", added Cree's Paul Kierstedt.



PCB of unmodified solar inverter
Source: Semisouth



Original IGBT mounting (left) replaced by SiC JFET
Source: Semisouth

Replacing an IGBT with SiC JFET

Semisouth's Michael Mazzola also presented a paper on SiC JETs as direct IGBT replacement in a solar inverter, on which an abstract is given in the following.

Conventional wisdom that the SiC JFET is only a normally-on device has recently been superseded by the first practical normally-off SiC JFET. This new true enhancement mode, three-terminal, pure-SiC design provides designers with a normally-off solution that retains all the benefits of the normally on SiC JFET. With only a simple change in series gate impedance, the enhanced mode (EM) SiC JFET can be used with common IC drivers and is a drop-in replacement for current silicon power devices in most applications. The device characteristics for the normally- off SiC JFET are superior to MOSFETs and IGBTs and offer the possibility of efficiency improvements from reduced conduction and switching losses.

An EM JFET operates in true 'enhancement mode', meaning that it is not a compound device formed by cascading a high-voltage normally-on SiC JFET with a low-voltage normally-off silicon MOSFET. This device uses a true vertical channel JFET with a channel pinched off at zero gate bias, and is designed to block rated terminal voltage (1200V) without negative bias on the gate. This true EM SiC JFET can operate as a drop-in replacement for any silicon MOSFET or IGBT power semiconductor device, as was recently demonstrated in a commercially available power factor correcting AC/DC power supply. The immediate benefit in the case of replacement of an IGBT is the reduction in conduction loss associated with the saturation voltage characteristic of the IGBT that a unipolar JFET, with an ohmic behavior, avoids. The true EM SiC JFET provides an alternative to other SiC normally-off devices, such as the MOSFET or the BJT that are far from commercially reliable technology.

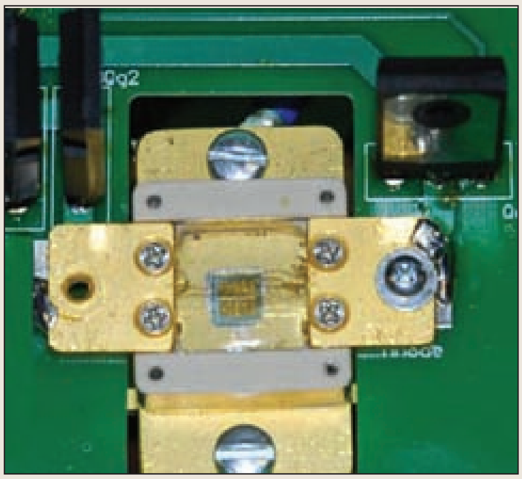
Since the EM SiC JFET can be operated safely without negative bias, it can be used with virtually any ICs (ASICs) common to MOSFET/IGBT control. With only minor changes to the interface between the gate driver IC and the gate of the device, the EM SiC JFET can be used to directly replace a MOSFET/IGBT in most applications.

As an application example, the commercially available solar inverter SMA Sunny Boy SWR 1800U was used, a transformer isolated design that uses a full-bridge topology for the main power inverter. This module was selected based on its ability to satisfy regulations requiring any equipment that is connected to the utility grid to be transformer isolated for safety. Due to the transformer isolated design, the loss budget for this inverter is dominated by non-semiconductor losses, so the upside for efficiency improvement due to a lower loss power switch such as the SiC EM JFET is modest. However, it is a readily available commercial inverter and thus, an excellent choice for evaluating the drop-in replacement of a SiC JFET in a widely used inverter.

After the SiC JFET drop-in replacement, the system efficiency of the inverter was analysed using a precision power analyser and compared against the efficiency curve of the unmodified system over a 1kW power range. This power range was limited by the rating of the 120V power circuit used as the load of this experiment. The best result demonstrated a nearly 1% efficiency improvement (93 to 93.8%) just by the replacement of the IGBTs with SiC JFETs. Since the JFET switching speeds were adjusted such that the dV/dt approximately matched that of the IGBTs, the main contribution to the efficiency improvement is the reduction in conduction losses. If more knowledge of the control and power circuit design had been available, the dV/dt could have been adjusted to provide additional efficiency improvements due to reduced switching losses.

Silicon carbide emitter turn-off Thyristor

A novel MOS-controlled SiC thyristor device, the SiC emitter turn-off thyristor (ETO), as a promising technology for future high voltage high frequency switching applications, has been developed at the Future Renewable Electric Energy Delivery and Management (FREEDM) Systems Center, Department of Electrical and Computer Engineering, North Carolina State University. "The world's first 4.5kV SiC p type ETO prototype based on a 0.36cm² SiC p type GTO shows a forward voltage drop of 4.6V at a current density of 25A/cm² and a turn-off energy loss of 9.88mJ. The low loss indicates that the SiC ETO could operate at a 4kHz frequency with a conventional thermal management system. This frequency capability is about four times higher than the 4.5kV-class silicon power devices. Numerical simulations have been carried out to discuss the potential improvement of the high voltage (10kV) SiC ETOs. The



The SiC ETO comprises the power packaged SiC GTO in series with a TO-247 silicon power MOSFET
Source: North Carolina State University

results show that the 10kV SiC n type ETO has much better trade-off performance than that of the p type ETO, due to a smaller current gain of the internal lower (PNP) bipolar transistor in the SiC n type GTO. The experimental and theoretical studies show that the SiC ETO is a promising candidate for high-voltage and high-frequency power conversion applications", stated speaker Jun Wang.

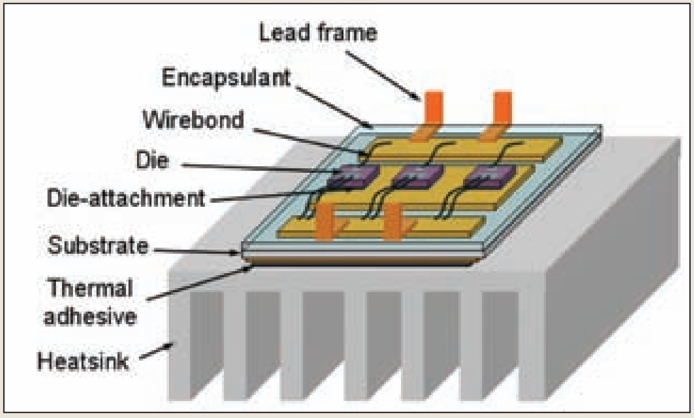
The SiC ETO comprises the power packaged SiC GTO in series with a TO-247 silicon power MOSFET. The SiC GTO is a p-type thyristor that uses an npnp thyristor structure because only the n type SiC substrates are commercially available. The emitters of the upper pnp and lower npn transistors form the anode and cathode respectively, and the upper base forms the gate contact.

A copper board with thermally conductive and electrically insulated dry-to-touch thermal interface pad in its bottom can be attached to the package base-plate below the cathode of the SiC GTO, so that the generated heat can be dissipated through the heat-sink, and another copper board can be attached to the drain of the silicon power MOSFETs if they are surface mounted together. Because the power losses in the silicon power MOSFETs are much smaller than that of the SiC GTO, the heat isolation between the SiC GTO and silicon power MOSFETs can enable the SiC GTO high temperature operation capability (>150°C) while keeping silicon power MOSFETs in a lower junction operation temperature (<150°C).

The SiC GTO was tested with gate floating at room temperature for blocking voltage measurement. A blocking voltage of 4.1kV at a leakage current density of 14µA/cm² has been achieved. The blocking voltage of the SiC ETO is the sum of the silicon power MOSFET's (100V) and the SiC GTO's, achieving 4.5kV at a current of about 20µA. The GTO shows a forward voltage drop of 4.2V at a current density of 25A/cm² and a gate drive current of 100mA at room temperature. The device shows a negative temperature coefficient due to the increase of carrier lifetime and the decrease of the built-in potential of the p-n junction with the increase of temperature.

Compared to the GTO test results, the integrated MOSFET contributes to only a small increase in the forward voltage drop, and there is no visible increase of the forward voltage drop in the SiC ETO, which indicates that the ETO preserved the excellent conduction capability of the SiC GTO. The demonstrated 4.5kV SiC p type ETO prototype shows a low loss and fast switching speed, indicating its attractive potential in high voltage (>5kV) power semiconductor devices. And further improvement in the SiC ETO is also possible.

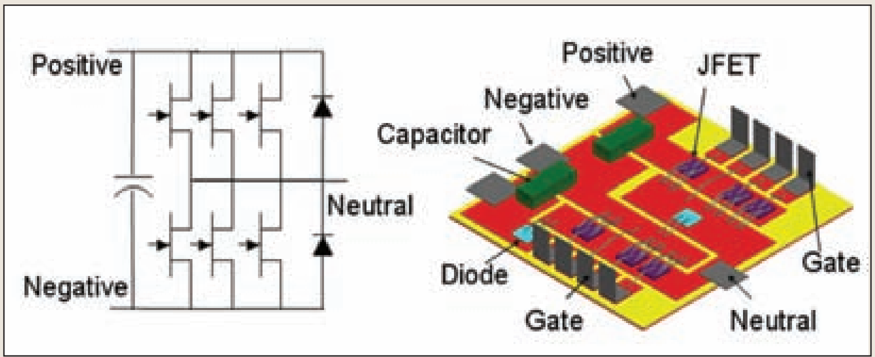
"Both SiC p type and n type ETOs based on SiC GTOs have a negative temperature coefficient in the forward conduction characteristics, due to the increase of the carrier lifetime with the temperature in the drift layer of SiC GTOs, thus maintaining a small forward voltage drop at elevated temperatures. At room temperature, the SiC p type ETO has a forward voltage drop of 4.43V at a collector current density of 30A/cm² with a gate drive current of 100mA, while the SiC n type ETO has a forward voltage drop of 4.3V at a collector current density of 30A/cm² with a gate drive current of 1.8A. The slightly smaller forward voltage drop of the SiC n type ETO at a low current density than that of the p type ETO can be explained by the larger electron mobility than the hole mobility in the weakly conductivity modulated drift layers of the SiC GTOs. The much faster switching speed and smaller turn-off loss of the SiC n type ETO than those of the SiC p type ETO can be mainly explained by the smaller lower transistor current gain of the SiC n type GTO than that of the p type GTO", Wang explained.



Wirebond packaging concept of SiC power module
Source: Virginia Polytechnic Institute

SiC wirebond multi-chip phase-leg module

In order to take full advantage of SiC, a high temperature wirebond package for multi-chip phase-leg power module using SiC devices was designed, developed, fabricated and tested at Virginia Polytechnic Institute and State University, Center for Power Electronics Systems. "The package supporting SiC devices are still inexplicit or inadequate on the thermo-mechanical reliability of high temperature operation and large temperature excursion. However, there is not enough experimental data on the power modules operation at high junction temperature and thermo-mechanical reliability evaluation for assemblies. Thus, further investigation on thermo-mechanical reliability for materials and assemblies is still a necessity", speaker Puqi Ning stated. "Therefore, the objective is to determine the packaging for the power module that is required to withstand 250°C operating and large temperature excursions (-55 to 250°C). Specifically, we have developed high temperature multi-chip phase-leg power modules based on the conventional wire-bond structure utilising paralleled SiC power JFET devices and



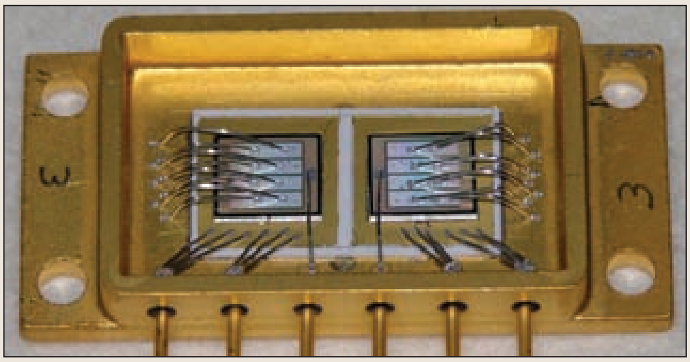
Circuit diagram and layout for SiC phase-leg power module
Source: Virginia Polytechnic Institute

designed for multi-kilowatt converters".

Considering the application requirement and device availability, 1200V SiC JFET and diodes (both from SiCED Germany) were selected. They can operate at high junction temperatures and high switching frequency. For the substrate, the first attempt was focused on the AlN DBC, because the coefficient of thermal expansion (CTE) of AlN DBC matches well with that of the SiC, and its other physical characteristics are average but adequate for 250°C operation. The metallisation of the DBC is electroplated Ni and Au, which can prevent the oxidation of the bare copper and improve the thermal reliability. Aluminum wires were selected for their maturity and reliable, repeatable bonding processing. Aluminum wires are bonded between the top aluminum metallisation of the SiC device surface and the DBC by ultrasonic wedge bonding.

The prototype power module was operated with 700V input voltage, 5A input current and the power rating of 3.5kW at the estimated junction temperature of 250°C. The continuous power test lasted 20 minutes after the system was running in the steady state. The test results prove that the designed wirebond package can support the SiC multi-chip power module operating at 250°C junction temperature. With the calculation and measurement, the estimated total power loss of the JFETs at rated power and 250°C junction temperature is approximately 60W, while the power loss of the diodes is 21W.

"The promising results of thermal cycling test on die-attachment and wirebond assemblies prove that the proposed package can perform well for large temperature excursion. Furthermore, the successful continuous power testing demonstrates that the designed package can support the SiC semiconductor devices operating at 250°C junction temperature", Ning concluded.



Non-encapsulated 100A dual SiC MOSFET module for military HEV application
Source: US Army Research Lab

SiC DC/DC converter for plug-in HEV

The University of Illinois at Chicago described an all-SiC DC/DC bidirectional converter equipped with SiCED JFET and Infineon SiC diodes operating to serve as the regulated charger for the intermediate high-voltage energy storage device (e.g. ultracapacitor) in the motoring/generating mode of a plug-in hybrid electrical vehicle. The converter is designed for high case temperature of 140°C and at a high switching frequency of 0.25MHz, even under hard-switched configurations.

Based on the loss-breakup, a soft switching scheme to mitigate the converter switching losses was chosen. The scheme improves converter efficiency across the whole range of load variation. However, the current soft-switching scheme has limited utility because it requires high peak currents to discharge the capacitance of the SiC VJFET (which has limited capability to handle high currents).

On a broader note, SiC devices can also be used at higher operating temperatures with improvements in packaging technologies. This could lead to further reduction in the size of the heat sink for hard-switched converters; therefore, the power density of the power electronics can be increased significantly. Also, the mass fabrication cost of the SiC VJFET and Schottky diode is expected to significantly decrease owing to ongoing improvements and innovations in SiC device and wafer design. This would further reduce the cost of the converter.

SiC for military applications

Improvements in the quality of 4H substrate material, epi growth, gate oxidation and post-oxidation anneal processes have advanced SiC technology to the point where a commercial DMOSFET now appears feasible. While it is clear that much progress has been made in DMOSFET development, it is also evident that there are still several challenges that must be overcome before true commercialisation is made possible. SiC MOSFET technology is an attractive alternative solution to the Si IGBT because it is capable of operating at junction temperatures of 300°C. The MOSFET has been the leading development focus in this field for the past 15 years, with the last 10 years dedicated to understanding the SiC MOS structure and, more specifically, to the reduction in the density of interface traps.

The US Army Research Laboratory (ARL) sponsored the development and fabrication of 50A SiC DMOSFETs and received first generation devices from Cree in the first quarter of 2008. Individual dies were tested to verify voltage blocking capability, gate leakage current, gate threshold voltage characteristics, and determined the on-state resistance. Each device has a chip size of 8mm x 7mm, active area of 0.406 cm^2, and a channel length of 0.5μm. The SiC MOSFETs are fabricated on n+ substrates with an 11μm epitaxial layer doped at $6x10^{15}$ cm^{-3}.

After the individual die-level characterisation was complete, dual MOSFET modules consisting of two SiC 50A dies placed in parallel were bonded in a non-encapsulated package having an aluminum-nitride substrate with liquid-cooled heatsink. Gate, drain and source connections to package terminals were made using aluminum wire bonds. Terminals of the MOSFET module were connected to an external pair of 75A SiC JBS diodes.

A commercial IGBT isolated 5A gate driver was used having 15V and -9V on-state and off-state gate voltages, respectively. Each MOSFET die had a dedicated gate resistor, in addition to a common 1Ω gate resistor located on the driver card. The dual MOSFET module was tested using gate resistor values ranging from 10Ω down to 1.75Ω. As gate resistance was decreased, gate lead length was reduced to minimise gate voltage spikes. A 5.2Ω gate resistor was implemented for experimental evaluation of the module as a suitable compromise between switching transition time and gate voltage stress.

The primary goal of the evaluation was to verify operation at an anticipated maximum individual MOSFET current of 44A with an inlet heatsink coolant temperature of 80°C, as determined by the traction drive inverter requirements. A secondary goal was to examine the maximum temperature operation of the die. Finally, each test condition was run for at least 30 minutes to provide insight into device reliability. Testing began at a coolant temperature of 50°C and 70A. Coolant temperature was increased over a 15°C range, while the current was held constant and a final predicted die temperature of 120°C was reached. Current was then increased to 80A and coolant temperature was stepped from 50 to 80°C, resulting in a predicted die temperature of 150°C. Again, current was increased to 90A and coolant temperature was stepped from 60 to 80°C. This test condition met the requirements of the primary goal.

Improvements in SiC MOSFET technology have recently yielded 1200V devices capable of 50A operation having specific on-state resistance of 20mΩ-cm² and a total chip area of 0.56cm². These devices are being used with SiC JBS diodes to develop high-current power modules in a phase-leg configuration to support large hybrid electric ground vehicle traction drive systems. The Army Research Lab is developing also a 400A phase-leg power module using 50A SiC DMOSFETs and 75A JBS diodes as an intermediate step towards meeting hybrid traction drive inverter requirements. This custom module features an integrated liquid-cooled heatsink and has the same overall form factor and pinout as the widely used 300 to 450A dual IGBT module (Infineon C-series package).

Cree is also working with both the United States Air Force Research Laboratory (AFRL) Propulsion Directorate and Powerex (a joint venture of GE and Mitsubishi in the US), developed a demonstration dual switch 1200V, 100A power module featuring SiC semiconductors and capable of operating at junction temperatures up to 200°C. Development of the SiC power module was funded by AFRL. It features Cree's SiC MOSFETs and SiC Schottky diodes, which were developed under ARL contracts. The SiC MOSFETs are normally-off devices and have drive requirements equivalent to the silicon IGBT devices they replace, making the SiC module a potential drop-in replacement for most applications. The all-SiC module has been jointly developed using materials and assembly processes common in the industry, offering a clear path to volume production. The module can also be easily scaled for higher currents and the layout can be modified for other switch configurations. "These 1200V, 100A SiC MOSFET modules represent the next level of integration for SiC power devices and a critical milestone in the technology progression towards high-reliability, energy-efficient power conditioning and control", commented Cree's CTO John Palmour.

These examples illustrate the efforts made in SiC not only in research labs worldwide. The next opportunity to meet the leading experts in this field is the Special Session 'Wide Bandgap Materials and Devices' at PCIM 2009 (May 12 – 14) in Nuremberg. This session on May 13, 10.00 – 12.00, is organised and chaired by Power Electronics Europe, the right place to be.

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Focus on Servers and Power Supplies

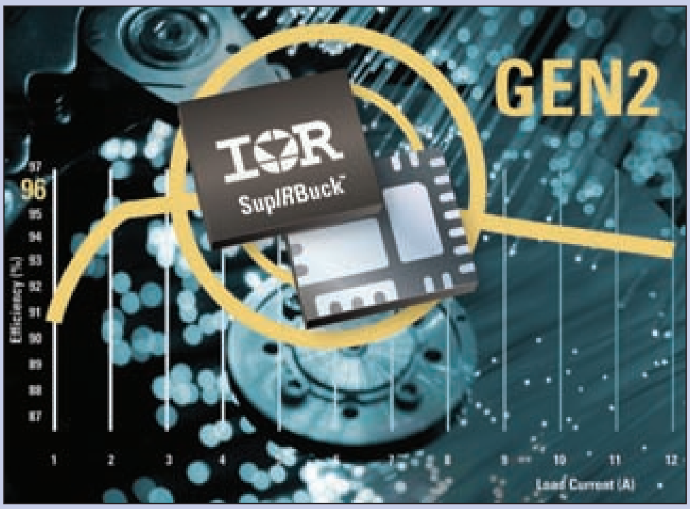
The APEC 2009 exhibition covered more than 150 exhibitors, with products focused mainly on power supplies and power management in various application fields.

APEC exhibition featured more than 150 exhibitors; the entry was strategically occupied by IR

Integrated voltage regulators

International Rectifier introduced its second generation (Gen2) of SupIRBuck integrated point-of-load (POL) voltage regulators for high performance server, storage and netcom applications delivering 4, 8, and 12A output current at 12V down to 3.3V inputs.

The new devices offer a high switching frequency up to 1.5MHz to allow the use of smaller inductors and fewer output capacitors. Tailored for data centre applications, the Gen2 devices significantly reduce overall system complexity and size, while delivering full current rating with no air flow and without heatsink, and allow back-side mounting on a motherboard to provide additional space savings. "Our Gen2 SupIRBuck family delivers benchmark peak efficiencies higher than 96% for greater energy savings and system reliability, and a very high switching frequency of 1.5MHz for significant overall system size reduction. Moreover, the devices' common scalable footprint offer a high level of flexibility to adapt to changing output current requirements", said Cecilia



IR's SupIRBuck Gen2 efficiency curve Source: IR

Contenti, IR's POL Products marketing manager. Other key features include over-current and over-temperature protection, programmable switching frequency, enable input with input voltage monitoring capability, hiccup current limit, soft-start, power good output, advanced pre-bias start-up, 1% accurate 0.7V reference voltage, sequencing, and a dedicated device for DDR memory tracking. Pricing for the IR3842 device begins at $1.20 each in 10,000-unit quantities. Pricing for the IR3831 and IR3841 devices begins at $1.30 each in 10,000-unit quantities, while the IR3840 devices begins at $1.75 each in 10,000-unit quantities.

Integrated power stages for POL applications

Primarion, an Infineon subsidary since one year, introduced the PX4650 and PX4640, integrated power stages (iPSTM) for high power density solutions required by servers, storage equipment and routers. The new power stages integrate low on-resistance n-channel MOSFETs for both high and low side FETs, together with high and low side MOSFET drivers. Full integration of drivers and FETs minimises switching losses while providing high power density integrated solutions. When combined with Primarion's digital multiphase or Di-POL controllers, PX4650 and PX4640 offer a complete high current small form factor voltage regulation solution that supports an average output current of up to 50A in 24mm² (per phase) surface area with high system efficiency and high output voltage accuracy, fast transient response and extensive protection features achieving 92 to 94% efficiency. "Efficiency has become a key industry driver in the computing and data storage industry. With iPS the inherent low on-resistance that improves on mid- to full-load efficiency, along with low switching losses that benefit light load efficiency, are the key advantages. The trend is from voltage regulator modules to voltage regulator devices", said Deepak Savadatti, Primarion's VP of marketing.

"The trend is from voltage regulator modules to voltage regulator devices", said Primarion's Deepak Savadatti

Integrated synchronous buck regulator

Micrel introduced a new member to its high power density family of products, the MIC22700. The device is a 7A integrated synchronous buck (step-down) regulator achieving more than 95% efficiency, while still switching at 1MHz over a broad load range with only 1µH inductor and a 47µF output capacitor. It also features built-in sequencing, tracking and ramp control — enabling all power-up sequencing and tracking protocols. The MIC22700 has a control loop that keeps the output voltage within regulation, even under extreme transient load swings that are commonly found in FPGAs and low voltage ASICs. The output voltage can be adjusted down to 0.7V to address all low voltage power needs, from a 3.3 or 5V power bus. A full range of sequencing and tracking options is available. "The MIC22700 is extremely easy to use, switches at a high PWM frequency and saves significant BOM cost, while setting a new standard in performance", stated Micrel's director of power products, John Lee. The MIC22700 is currently available in volume quantities with pricing starting at $3.27 for 1K quantities.

"Very high efficiency, combined with small footprint, offers high value in applications such as servers and base stations", stated Micrel's John Lee

TRIAC dimmable LED driver

National Semiconductor has introduced a constant-current controller that enables off-line, uniform, flicker-free dimming of high-brightness LEDs with a conventional TRIode for AC TRIAC forward or reverse phase-control wall dimmer. Today's TRIAC wall dimmers are designed to interface with a resistive load such as incandescent or halogen light bulbs. Since an LED bulb does not appear as a resistive load to the TRIAC wall dimmer, dimming an LED bulb using a conventional TRIAC wall dimmer does not yield optimal dimming performance. LED drivers available today cause either a 120Hz flicker of the LEDs or do not enable the full 100:1 dimming range. National's LM3445 overcomes this challenge by translating the TRIAC-chopped waveform to a DIM signal and decoding it for a full-range of uniform, flicker-free dimming. The driver's patent-pending control architecture maintains constant ripple through the LEDs, which extends the life of the LEDs.

The LM3445 LED driver enables direct LED bulb replacement of existing incandescent or halogen bulb systems connected to standard TRIAC wall dimmers. In addition, the LM3445 allows master-slave operation, enabling control of multiple strings of LED bulbs. It is an adaptive constant off-time AC/DC buck (step-down) constant current controller that includes a TRIAC dimming decoder. The decoder allows wide-range LED dimming using standard TRIAC dimmers. The high-frequency capable architecture allows the use of small external passive components. The device includes a bleeder circuit to ensure proper TRIAC operation by allowing current flow while the line voltage is low to enable proper firing of the TRIAC. A passive power factor correction circuit ensures good power factor by drawing current directly from the line for most of the cycle, and provides a constant positive voltage to the buck regulator. Additional features include thermal shutdown, current limit and under-voltage lockout.

The LM3445 dimmable LED

"With our WEBENCH LED Designer suite of tools, engineers can configure a system with up to 60 LEDs in serial or parallel strings, along with a complete bill of materials for the LED circuit and the ability to quickly ship a custom prototype kit containing the selected LED, PC board, driver IC and passive components", explained National's John Garett

driver enables a full 100:1 range of dimming capability and can maintain greater than 1A of constant current to large strings of LEDs in a variety of residential, architectural, commercial and industrial applications. The device is available now and priced at $1.75 in 1,000-unit quantities.

"With our WEBENCH LED Designer suite of tools, engineers can configure a system with up to 60 LEDs in serial or parallel strings. The tool selects from hundreds of high brightness LEDs, matches an LED with one of PowerWise energy-efficient LED drivers and creates an optimised power supply circuit. The designer can input their size and efficiency requirements, and then simulate the circuit behaviour under dynamic conditions, including start-up, steady state, pulse-width modulation dimming and line transient. After fine-tuning the system in just minutes, the BuildIt feature provides a complete bill of materials for the LED circuit and the ability to quickly ship a custom prototype kit containing the selected LED, PC board, driver IC and passive components", National's John Garett explained at an APEC demo.

Third generation Silicon Carbide Schottky diodes

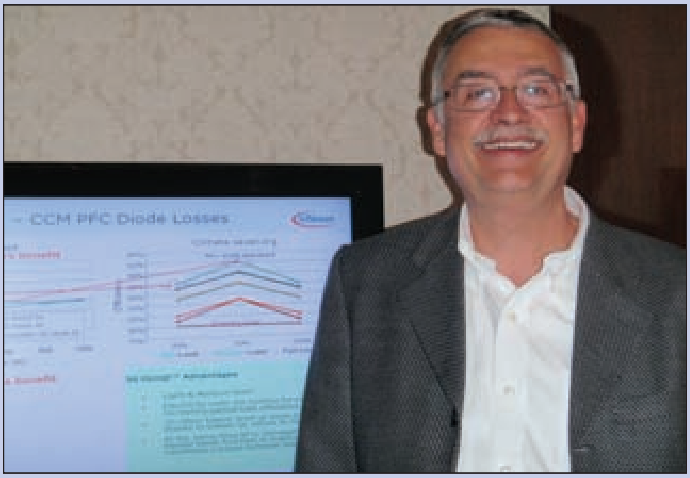
As expressed in our previous APEC conference section, Silicon Carbide will play an important role in the near future. The main application areas for SiC Schottky diodes are active Power Factor Correction (CCM PFC) in Switched-Mode Power Supplies (SMPS) and other AC/DC and DC/DC power conversion applications such as solar inverters and motor drives.

Munich-based Infineon Technologies introduced its third generation thinQ! SiC Schottky diodes featuring lowest device capacitance and enhancing overall system efficiency at higher switching frequencies and under light load conditions. The SiC Schottky diodes are not only packaged in the TO-220 (2 pins) but, also the DPAK package for high power density surface mount designs.

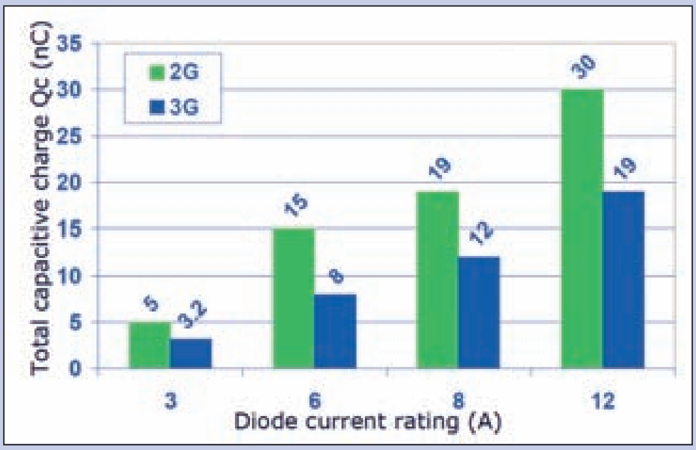
Compared to the second generation (600 and 1200V), the device capacitances of the third generation SiC Schottky diodes are about 40% lower, which reduces switching losses. For example, in a 1kW PFC stage operating at 250kHz, there will be an improvement of 0.4% in the overall efficiency under 20% load conditions. Higher switching frequencies allow the use of smaller and lower cost passive components, such as inductors and capacitors, resulting in higher power density designs. Reduced power losses result in several benefits, including reduced cooling requirements in terms of size and number of heatsinks and fans, which enables system cost reduction and increased reliability levels. This also contributes to reduced system level energy requirements to provide an appropriate cooling environment. Infineon expects system cost reductions in some SMPS applications of up to 20% using SiC Schottky diodes. Gen 3 diodes also utilise a newly developed soldering process, resulting in a much lower lower thermal resistance between the chip and the package.

"Infineon was the world's first provider of SiC Schottky diodes, introducing its first products in 2001. During the last eight years, we have made a number of significant improvements in areas such as surge current stability, switching performance and in product cost, extending the benefits of SiC technology to more applications and making solutions more affordable. SiC is an innovative technology which drives new markets such as solar energy and high-efficiency lighting systems", said Dean Henderson, Infineon's Director of Power Management in the US.

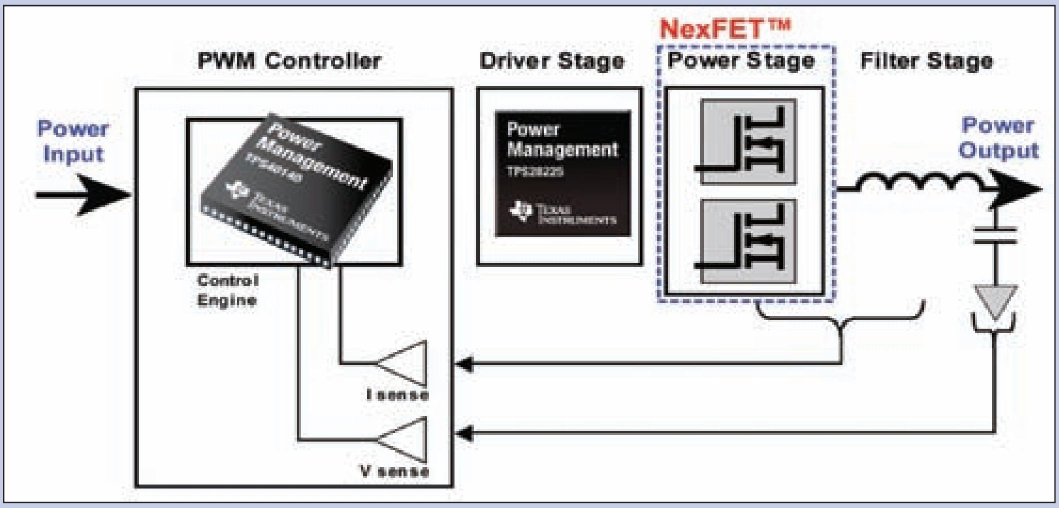
SiC Schottky diodes are available in 21 types of 600V (3, 4, 5, 6, 8, 9, 10, and 12A, in both TO-220 and DPAK packages, and in 1200V ratings (2, 5, 8, 10 and 15A) in a TO-220 package. Sampling started in January 2009, with series production scheduled in early spring 2009. In quantities of 10,000 pieces,



"SiC is an innovative technology which drives new markets such as solar energy and high-efficiency lighting systems", stated Infineon's Dean Henderson



Total capacitive charge of Gen2/3 SiC diodes at different current ranges Source: Infineon



Ciclon's NexFETs complements TI's power management offering for the power stage Source: TI

third generation SiC Schottky diodes with a blocking voltage of 600V (3A) are priced at Euro 0.61 (US $0.85) per unit. The 4A version is priced at Euro 0.85 (US $1.19) per unit, the 8A version at Euro 1.89 (US $2.65) per unit. Thus, the price point given by Yole at 20Cent/Amp (see previous section) has not been achieved, but is coming closer.

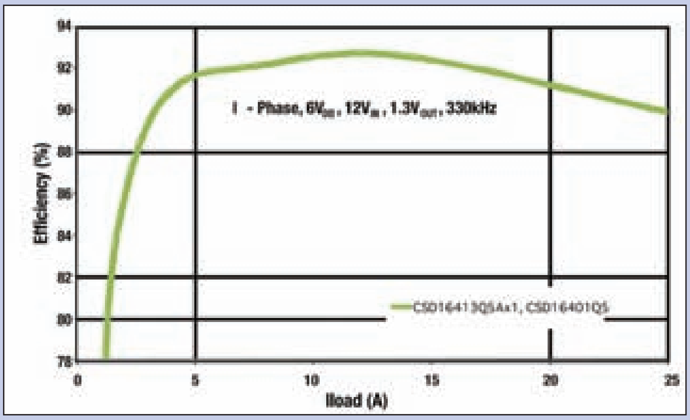
TI enters discrete high-power MOSFET market

But one of the breaking news stories on the APEC 2009 exhibition floor was Texas Instruments' acquisition of Ciclon Semiconductor, a Pennsylvania-based fabless power MOSFET and RF LDMOS supplier, formed in 2004 with the intention of becoming the leader in the high frequency power device market. In April 2005, Ciclon acquired the Lateral Diffusion MOSFET (LDMOS) Product Line of Agere Systems. With this acquisition, Agere transferred certain research and development and manufacturing assets, and inventory to Ciclon. The team, led by CEO Mark Granahan, is composed primarily of former Agere Systems management and technologists who have extensive experience in RF and LDMOS product development and production. Key members of the team were involved in the ground-breaking development and qualification of Agere's first generation technology, ARF4. LDMOS (laterally diffused metal oxide semiconductor) technology can operate at high voltages and supports high power applications in the 400MHz to 3GHz frequency range.

Designers who incorporate Ciclon's state-of-the-art power management technology can double a power system's operating frequency and achieve greater than 90% power efficiency from light to full load in a footprint up to 20% smaller than today's power supply. The company's MOSFET technology, known as NexFET technology, attains these performance and size improvements by delivering a drastic reduction in gate charge. NexFET combines vertical current flow with a lateral power MOSFET, providing a low on-resistance and an extremely low gate charge with high output currents and low duty cycles, representing a breakthrough in discrete designs.

In synchronous buck-converter power supplies used in computing, networking and server systems, the power MOSFET is a critical element in driving the DC/DC efficiency. The two main parameters driving power MOSFET efficiency are gate charge and on resistance, the so-called figure of merit (FOM).

When compared to industry standard trench-type power MOSFETs with the same on-resistance, NexFET technology delivers less than half the gate charge (Qg). Lower charge



NexFETs delivers 90% efficiency from light to full load Source: TI

"The Ciclon acquisition also opens doors for us to engage in the high-current power MOSFET space", commented TI's Steve Anderson

means that converters can run at higher frequencies while maintaining the same power loss, or run more efficiently at the same frequency. Such a large reduction in gate charge enables a potential doubling of power supply switching frequency, which delivers a reduction of as much as half the size of the power supply output filter.

"The acquisition expands our capability to improve energy efficiency in today's end-equipment designs, including high-power computing and server systems. Combining Ciclon's technology and expertise with our power management semiconductor portfolio gives us a tremendous advantage when solving customers' complex power design requirements. The acquisition also opens doors for us to engage in the high-current power MOSFET space", commented Steve Anderson, senior vice president for TI's Power Management business unit. "The heritage of Ciclon's technology was in the Bell Labs and later with Agere; over the last four years we produced power MOSFETs with a very low gate charge, leading to higher efficiency or higher switching frequency, particularly in power supplies for servers, giving them an efficiency level of 90%. We are in production with our first generation of so-called NexFETs, and TI will now offer these discrete power MOSFETs to the market", added power marketing manager Chris Bull.

AS

www.irf.com
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www.national.com/led
www.primarion.com
www.infineon.com/sic
www.ti.com/mosfet

Professional Education through 10 Workshops

Despite the crisis in the financial sector, PCIM 2009 from May 11 – 14 looks quite healthy with 260 exhibitors and 6500 visitors expected. The event will start with one-day tutorials on Monday (May 11), held by professionals in the power electronics industry, guaranteeing high-quality technical education.

Digital control, wide bandgap materials and devices as well as high-frequency switching are today's buzzwords in the power electronics industry. PCIM 2009 addresses these subjects not only within the conference and exhibition, but also more in-depth within the 10 tutorials given one day before official opening. A brief description of the seminars is given below.

Higher Efficiency Power Conversion through 'Intelligent' Power Processing

This tutorial will be given by Ionel Dan Jitaru, Delta Energy Systems (USA), the founder of Rompower Inc., later Ascom Rompower Inc. and Delta Energy Systems (Arizona) Inc. Presently, he is the president of Delta Energy Systems (Arizona) Inc., the world's largest power supply company. He has published 46 papers and held 34 professional seminars at different International Conferences in the power conversion field, wherein several of them have received the best paper award. He has also pioneered several trends in power conversion technologies such as 'Soft Switching', 'Full integrated multilayer PCB packaging concept', 'Synchronized rectification' and 'Intelligent power processing'. Some of these technologies have been covered by 22 granted patents and 10 pending patents.

The seminar will present a comprehensive overview of the latest techniques aimed at maximizing the efficiency. The first part will focus on the topology selection, wherein new topology structures will be presented. The latest topologies are developed as a result of the latest changes in the system architecture and the availability of digital control. A special section will be dedicated to the rectification techniques and 'intelligent' rectification for low and high voltage application. Another section is dedicated to the new magnetic structures for efficiency optimization. The magnetic section will be presented together with the latest packaging technologies, which play a critical role in efficiency optimization through the minimization of the parasitic elements in the circuit and heat management. The last section is dedicated to the digital control and digital assisted power conversion for efficiency optimization. This new section underlines the future of power conversion using 'intelligent' power processing for efficiency optimization. The presentation will be highlighted with design guidance, design example and experimental results.

Summertime is PCIM time; the 2009 event will start on May 11 with a series of professional seminars

Advanced Design with MOSFET and IGBT Power Modules

Tutorial 2 will be given by Prof. Josef Lutz, Chemnitz University of Technology, and Dr. Tobias Reimann, ISLE GmbH, Ilmenau, both Germany. Josef Lutz joined Semikron Electronics, Nuremberg, Germany in 1983. First he worked in the development of GTO Thyristors, then in the field of fast recovery diodes. He introduced the Controlled Axial Lifetime (CAL) diode. Since August 2001 he has been Professor for Power Electronics and Electromagnetic Compatibility at the Chemnitz University of Technology, Germany. His main fields of research are ruggedness and reliability of power devices. In 1994, Tobias Reimann received his PhD from the Ilmenau Technical University in the field of power semiconductor applications for hard and soft switching converters. He works as scientific assistant in the Department of Power Electronics of the TUI. His special fields are power electronic circuits and power semiconductor applications. In 1994, he was one of the founders of the ISLE company which is engaged in system development for power electronics and electrical drives.

PCIM Europe 2009
International Exhibition & Conference for
POWER ELECTRONICS
INTELLIGENT MOTION
POWER QUALITY
12 – 14 May 2009
Exhibition Centre Nuremberg

The tutorial will cover the topics Power Devices/Modules/Reliability, including new Developments in MOSFETs, IGBTs, free-wheeling diodes, module layouts, thermal mismatch, thermal stress, power cycling capability, and design for reliability; Drive and Protection including principles, technical realisations, failure modes, failure detection, current, voltage, temperature protection; Topology-dependent Power Losses including DC/DC-Converters, DC/AC-Converters, load cycles, calculation of heatsink; Device Induced Electromagnetic Disturbance including parasitics and oscillations in power modules, and finally Special Aspects of Application including paralleling and series Connection, special effects in ZVS/ZCS topologies, special problems related to new device technologies, and dynamic ruggedness of power diodes.

Design Considerations for High Frequency Linear Magnetics

Tutorial 3 will be given by Bruce Carsten, who has 34 years of design and development experience in high frequency and switch-mode magnetics, at power levels from 100mW to 20kW and frequencies from kHz to MHz. The focus of his two magnetics design seminars is on an intuitive but detailed understanding of how transformers and inductors work at high frequencies. This understanding will aid the practicing design engineer in the synthesis of suitable power magnetics with extensive time spent in 'cut and try' design cycles, as opposed to heavily analytical approaches which often provide little practical guidance in design. Formulas are provided for quantification of effects whenever possible, but maths is largely kept to a minimum.

Advanced Control Techniques for Switchmode Power Supplies

Tutorial 4 presents advanced control concepts for switchmode power supplies, including single-loop (PWM, ripple regulators) and multi-loop (current-mode, feedforward) analog control, and also digital control. Auxiliary control functions (efficiency optimisation, balancing paralleled or multiphase converters, overload protection, and reducing noise emission and sensitivity) are also discussed. Emphasis is on practical considerations and on providing guidelines about selecting the best control technique for an application. The presenter Dr. Richard Redl is the director of ELFI S.A., an electronics consulting company in Switzerland, specializing in power supplies and other power-conversion equipment, electronic ballasts, and integrated circuits for power management. He holds 22 patents, has written over 100 technical papers, and co-authored a book on the dynamic analysis of power converters. He is a Fellow of the IEEE.

Electromagnetic Compatibility for Higher Frequencies Power Designs

Over about 1MHz, conventional circuit theories with localized constants like 'parasitic capacitances' or 'stray inductances' need to be improved with a physical understanding of the electromagnetic propagation in and around power circuit. Thus, Tutorial 5 focuses on how to manage high frequency (HF) parasitic resonances just after semiconductors commutation, i.e. between MOS capacitance and transformer stray inductance; how to balance inductances reduction with capacitances increase; how to choose and design EMC optimized power converters (from 100W up to 100kW), and how to avoid expensive shielding and improve reliability. Presenter Jacques Laeuffer has a 25 years' experience in the field of Power Electronics for various applications including inverters for radar servo controls, high frequency resonant converters, high voltage transformers for X-Ray generators, and automotive drive systems for hybrid vehicles. He has written 74 technical papers, and is inventor of 27 patents. He received the 'Grand Prix de l'Innovation' of PSA Peugeot Citroen for year 2004. He is 'Habilité à Diriger des Recherches' (HDR) by University of Paris 6, and is a teacher of E.M.C. at Ecole Supérieure d'Electricité, an Engineering University close to Paris.

FPGAs in Drive Technology

More and more functions like feedback processing or field bus implementations are realized in Field Programmable Gate Arrays (FPGA). Due to the innovation cycles of the semiconductor suppliers, the size and the cost of the more and more complex and powerful inverter systems is not increasing. Thus, Tutorial 6 will include training on Sigma-Delta Analog to Digital Conversion Technology and will be presented by Prof. Dr.-Ing. Jens Onno Krah, who studied electrical engineering at the University Wuppertal and obtained his PhD 1993 by Prof. Holtz within electrical drives research. Until February 2004, he worked as technical director for Danaher Motion, formerly Seidel Servo Drives. He was responsible for the development of the Danaher Motion Servo Drives. Since March 2004, Prof. Krah has been teaching control engineering at the University of Applied Sciences Cologne.

Control and Measurement of DC/DC Converters

Tutorial 7 will present an in-depth discussion of many of the issues involved in controlling converters. Many aspects of the design of control systems will be covered, including topologies, modes of operation, passive components, compensation, optocouplers, and filters. Live demonstrations will be presented of loop gain and impedance measurements on working converters and power stage components. The course is recommended to all levels of engineers who work with switching power supplies at power levels from less than 1W to 100kW. Presenter Dr. Ray Ridley is the president of Ridley Engineering Inc. in the US, and Ridley Engineering Europe. He provides assistance to companies worldwide in the form of consulting, test equipment, design software, and hands-on power supply design courses. Dr. Ridley has been designing switching power supplies for over 28 years.

Sensorless Control of PM Synchronous Motors

Tutorial 8 will focus on methods of speed-sensorless control of permanent magnet synchronous machines (PMSMs, EC motors, Brushless DC motors, respectively). The presented methods offer the possibility of a relatively simple implementation in industrial drives and hence, methods with high mathematical expense will only be mentioned briefly.

EMF-based models for high speed as well as saturation-based and reluctance-based models for low speed and standstill will be discussed. The tutorial starts with basic mathematical methods for transient description of PM motors and basic inverter structures. Then, a short overview about control of PM motors will be given. The main part of the tutorial is the sensorless control at high and low speed including standstill with high starting torque and/or positioning capabilities. Presenter Prof. Dr. Manfred Schroedl achieved his habilitation degree (1992) at TU Vienna. Between 1992 and 1996, he was head of the development department of ELIN Vienna; from 1996 to 1998 he was head of central technical division of ATB Austria Antriebstechnik, Spielberg (Styria, Austria). Since February, 1998 he has been head of the Institute of Electrical Drives and Machines at Vienna University of Technology. He has about 70 publications and 10 patents mainly in the field of Electrical Drives.

ABC of Inductors and Transformers for Power Applications

Tutorial 9 will recall the basics around magnetics and clarify the important parameters needed for selecting and choosing the right Power Inductor and how to calculate your own power transformer. How to read the datasheet definitions correctly and how do they influence the DC/DC-converter design? What are the important parameters for selecting Power Inductors? When do I choose a Flyback or Forward converter and how to find the best Transformer for my design? What can I do to prevent EMI problems in my design? Presenters are Alexander Gerfer and Thomas Brander, WÜRTH ELEKTRONIK eiSos (Germany). While studying, Alexander Gerfer published numerous application notes for the field of consumer electronics. After his degree he worked in the distribution for electronic components and, since 1997, he has been responsible for the inductive components at Würth Elektronik eiSos. Several seminars in Europe and USA, as well as in China, were given by him, to explain away the black magic around Inductors and Ferrites. As a co-author he worked on the Application Handbook 'Trilogy of Inductors'. Thomas Brander is responsible for the DC/DC and AC/DC Power Transformer design.

IGBT Gate Drive Technologies

Finally, Tutorial 10 will cover driver fundamentals such as Gate Driver Topologies, influence of different gate driver components on the switching behaviour, transmission of control signal and driving energy, transmission principles, galvanic isolation and level shift, variants of power supply (DC/DC converter, bootstrap power supply, charge pump), and gate driving technologies and different gate drive circuits; using IGBT Drivers including input and output signals, dimensioning and design of gate resistors, gate clamping, connection between gate driver and IGBT module, paralleling of modules, system design (DC-link design, choice of right snubber, design of AC-terminal connection), and application circuits. Presenters Reinhard Herzer and Arendt Wintrich work with SEMIKRON Elektronik (Germany). Reinhard Herzer studied Electrical Engineering and received his PhD in the field of Microelectronics in 1984, and in 1992 his habilitation in the field of Power Devices and Smart Power ICs from the Ilmenau Technical University. He joined Semikron Electronics in 1995 as head of the MOSFET, IGBT and IC research department. Furthermore, he is Associated Professor at the Technical University of Ilmenau. Arendt Wintrich studied electrical engineering with a focus on power electronics at the Technical University Chemnitz. He received his doctorate in electrical engineering with the subject 'Modelling of power semiconductors'. He joined Semikron in 1999 as Applications Manager, focusing on customer consulting and system design.

www.mesago.de/en/PCIM

Power Transistor Technology Delivers More Efficiency

The trend within the electronics market is for more functionality using less power; seemingly opposed demands given the nature of the applications. However, through innovative developments in power transistor technology, both in the form of MOSFETs and IGBTs, this challenge will be met. The need for 'greener' electronics is likely to increase also, presenting OEMs with their own challenge, of choosing a supplier that demonstrates a focus on innovation and is able to deliver the power needed to enable tomorrow's applications. **Georges Tchouangue, Toshiba Electronics Europe, Germany**

The continued effort to improve the operational efficiency of electronic products now represents a predominant driving force in the development of integrated devices. This extends beyond densely populated processors which may feature billions of transistors; it impacts all solid-state devices and is arguably more relevant in the power management domain, where the scales involved can translate in to massive efficiency gains or losses.

Within this domain there are two often competing technologies that constantly vie for design wins; the IGBT and power MOSFET, which rely on fundamentally different physical characteristics of silicon; the IGBT is essentially a bipolar device while the MOSFET is unipolar. These characteristic differences have, historically, provided advantages in specific applications for each type of device, but developments in the technology means there is an increasing overlap in application areas.

The growing number of application areas for high power solid-state devices is typically limited only by their operational characteristics. As a result, recent development efforts have been directed towards improving the switching speed, transconductance and channel resistance – particularly of power MOSFETs.

MOSFET or IGBT?

The transconductance of a field effect transistor can dictate its application areas, as can the on-resistance; the higher the on-resistance the more power dissipated in operation. This can be mitigated in a bipolar device such as an IGBT, thanks to its use of both holes and electrons as charge carriers, which effectively reduces the on-state voltage. However, the drawback of having both majority and minority charge carriers in the channel is that IGBTs typically take longer to switch off than a MOSFET or, in other words, power MOSFETs have a higher operating frequency - a parameter that becomes more important in switching power supplies, for instance.

These are well-known issues and ones that the industry hasn't avoided; developments in both IGBT and MOSFET processes are delivering significant improvements in these parameters, which is creating greater competition between the two technologies and, as a result, promoting even more innovation.

A contemporary example is the increasing number of plasma displays now available; an application area that has unique requirements normally addressed using power MOSFETs. Specifically, the display elements of a plasma display exhibit capacitance which, in operation, manifests itself in a charge/discharge pattern.

Figure 1: Toshiba's IGBT technology enables devices that can specifically target the sustain and recovery circuits essential within plasma displays

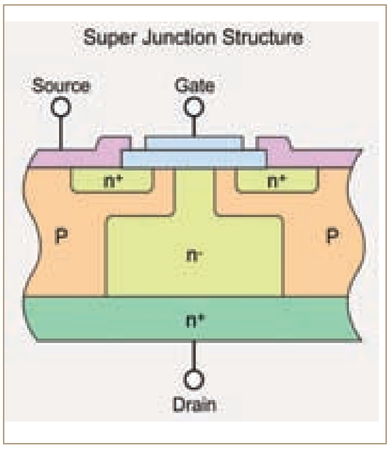


Figure 2: DTMOS Super Junction structure

For consumer displays, where viewable areas are now in excess of 42in (106cm), the losses associated with the discharge cycle are too high to tolerate, particularly with increasing pressure on energy efficiency. Subsequently, manufacturers now employ some form of energy recovery circuit which minimises the losses associated with the discharge cycle. Here, MOSFETs have typically dominated as they offer benefits over IGBTs in this application, but recent developments in IGBT technology has enabled Toshiba to create devices that specifically target this application. By combining trench technology that delivers low saturation voltages and low conduction losses, with n-channel injection enhancement mode operation to improve switching characteristics, Toshiba has developed its 5th generation of high power IGBT technology, which enables devices that can specifically target the sustain and recovery circuits now essential within plasma displays (Figure 1).

Despite their obvious similarities in application areas, MOSFETs still exhibit some significant advantages over IGBT technology. This is evidenced in part by its scalability; Toshiba now offers integrated MOSFET devices covering a range of application areas dictated by the operational parameters. This may take the form of compact devices which are available in the SOT-363 and SOT-323 packages; measuring 2 x 2.1 x 0.7mm, targeting battery powered applications with severe PCB space limitations.

Due to the trend towards hand-held devices running from ever lower battery voltages, it is now necessary to provide multiple core voltages, driving demand for smaller and more efficient DC/DC converters. The UMOS V-H series of high speed switching MOSFETs target synchronous DC/DC converters in power supplies. The key parameters in the UMOS V-H series address the requirements made of low-side MOSFETs in a synchronous DC/DC converter, such as lower on-state resistance ($R_{DS(ON)}$) and reduced self-turn-on loss. These have been achieved by creating a process with lower gate-to-drain capacitance (C_{gd}), lower C_{gd}/C_{gs} ratio, lower gate resistance (R_g), and optimised gate threshold voltage. On the high-side MOSFET, UMOS V-H technology enables fast switching thanks to its low gate switch charge (Q_{SW}) and gate resistance.

More recently, developments have led to the DTMOS II range of rugged, high efficiency and high speed power MOSFETs which employ the latest version of Super Junction MOSFET technology. This delivers a 'figure of merit' 68% lower than conventional MOSFETs and a 15% improvement over DTMOS I range. The 'figure of merit' represents the product of the on-resistance ($R_{DS(ON)}$) and the gate charge (Q_g), both of which impact a MOSFET's performance. The three initial devices offer 20, 15 and 12A current ratings. This makes them suitable for applications that need high efficiency, high-speed switching, such as switch mode power supplies, lighting ballasts and motor drives (Figures 2 and 3).

Towards better efficiency

This highlights a growing trend in the industry; the need for more efficient motor control circuits. With a significant amount of the energy we consume being attributed to motors in labour saving devices, such as white goods, along with the growing use of motor drives in man-to-machine applications, the industry is applying increased efforts in this area.

The technology of choice here is, increasingly, brushless DC motors (BLDC), which offer efficiency benefits over traditional motors but require more sophisticated drive controls. As a result, it represents a growing opportunity for optimised solutions that combine efficient

Figure 3: DTMOS II delivers a 'figure of merit' 68% lower than conventional MOSFETs

Figure 4: Evaluation platform featuring single-chip inverter and controller that will simplify and speed the development of BLDC motor drives

power transistors with sophisticated drive control in a single device.

A new generation of single-chip inverters are using silicon-on-insulator trench technology to integrate high and low side drivers with six IGBTs to directly drive the BLDC's stators. Integrated fast recovery bootstrap diodes reduce component count and cost, while additional on-board functions include protection against over-temperature, over-current and under-voltage conditions. Three members of the family also incorporate PWM circuitry and three-phase distribution logic in the same DIP26 package.

The TB6582FG_EVB3 (Figure 4) brings together a motor controller IC and the single-chip inverter to provide a complete sensorless sine-wave motor control and driver solution on a single board with input main voltages to 220VAC and output currents from 1 to 3A. Control of motor rotation speed in both forward and reverse directions is achieved by changing the PWM duty cycle based on the input from a host microcontroller. The board features integral circuitry that calculates rotor speed and position using phase current information, eliminating the need for Hall sensors. A triangular wave generator with a carrier wave frequency of 252Hz and an integrated dead time function are also incorporated into the device. In addition, a lead angle adjustment capability allows applications to be tuned for optimum efficiency.

Improving Power Efficiency in IT and Telecom

For high-end IT and telecom applications, the conventional approach to power conversion involves an AC/DC silver box followed by 12V-to-1.x V synchronous buck converter. This approach has inherent limitations in terms of system efficiency due to a combination of distribution bus losses and fundamental restrictions in topology performance as processor voltages reach sub-volt levels. Recent advances in power train technology can better meet such power conversion demands, by, for example, eliminating step-down stages and enabling direct 48V-to-load conversion. **Paul Yeaman, Principal Engineer V•I Chip Applications, Vicor, Andover, USA**

Higher (48V or 350/380V) bus voltages reduce distribution losses, but usually mean the addition of an extra stage or stages to get down to the processor voltages, which may lower conversion efficiencies. The approach of Factorized Power Architecture (FPA) building blocks (V•I Chips: BCM bus converters, PRM regulators, VTM voltage transformers, see Figure 1) are shown here to improve high power system efficiency. New is the 330W, 380 to 48VDC, 1/16th brick footprint BCM bus converter to complete the powertrain conversion to processor and memory loads in HV DC distribution data centres.

The VIB0002TFJ uses a MHz-switching ZVS, ZCS Sine Amplitude Converter (SAC) with a power density of 1,150W per cubic inch and more than 95% efficiency, providing more than 4000V of safety isolated 330W power for downstream loads (Figure 2). In parallel 'eco-array' configurations, 380 to 48V conversion is achieved at more than 90% efficiency from 10% light load all the way to full-load at multi kW power levels (Figure 3).

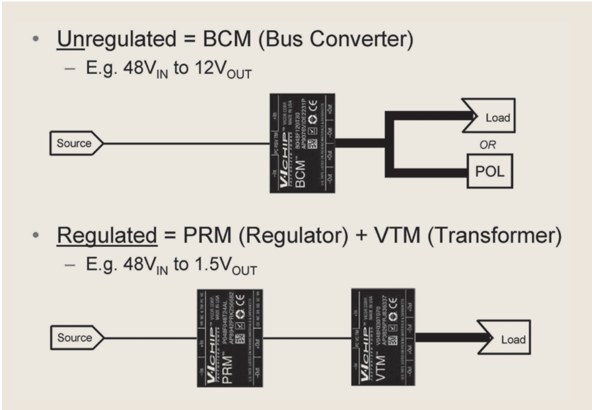


Figure 1: Architecture for improved power supply efficiency in IT and datacentre applications

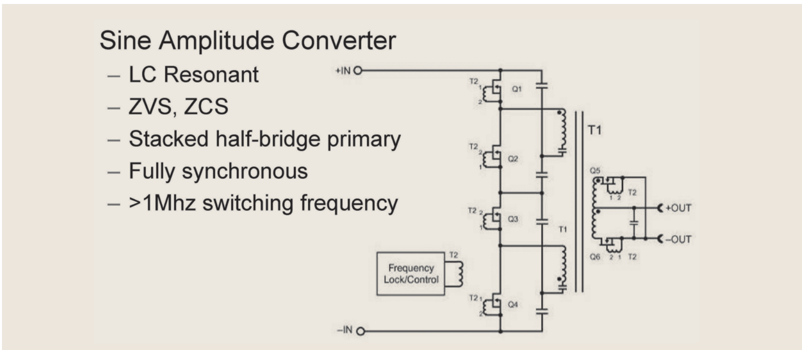


Figure 2: HV BCM topology featuring SAC switching

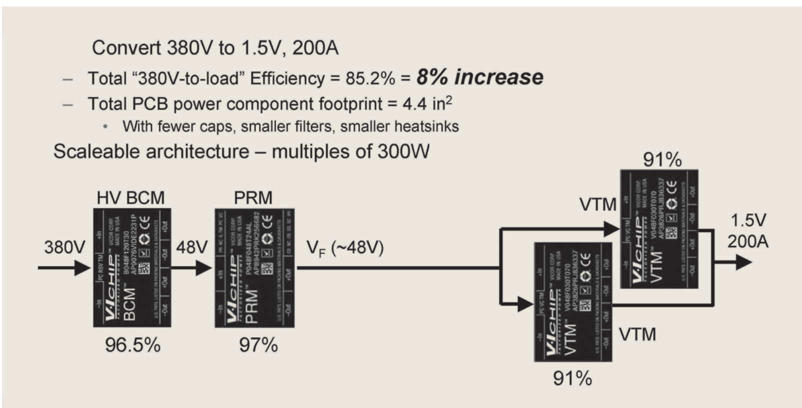


Figure 3: HV distribution example for increased efficiency

Steps for improving efficiency

Consider, for example, a mid-range/high-end data processing system with one or more blocks of eight microprocessors, each running at 1.2V and 100A for a combined load of 960W per block. The system is fed via an AC-to-48 VDC front end from a 208VAC input. As shown in Figure 4a, a conventional AC to 48 VDC to 1.x V system – which will serve as a baseline – has an overall 67% efficiency from AC to point-of-load (POL) which means that for our 960W load, the system draws ~1430W from the AC line. The difference of 470W is lost as heat – further increasing the demands on heat sinking/air conditioning systems and increasing the operating costs of the datacentre.

Topological assumptions are that the AC

to 48VDC unit comprises a standard bridge, filter and boost PFC generating 380V and then using a two-transistor forward converter with diode rectification to 48VDC. The 48/1.2V conversion assumes four 48V:12V unregulated bus converters in 1/4-brick format followed by a four or five-phase VRM (voltage regulator module) to the processor.

As a first step to improve the efficiency of the conventional system, the basic BCM topology can be applied to both the HV DC/DC and MV DC/DC sections. The 300W BCM converter has a transformation ratio (K) of 1/32 that feeds directly from the PFC bus voltage and generates a 12V output. A four-up array with paralleled inputs and serial outputs creates 1,200W at 48V with 94% efficiency. The HV BCM enables a 2% efficiency increase for this stage versus traditional topologies. Step 1 results (replacing HV and MV DC-DC stages with BCMs) are shown in Figure 4b.

Traditional VRMs rely on the tried and trusted synchronous buck PWM converter. However, as processor voltages fall towards 1V and below, the duty cycle from 12V reaches 12:1 (Synch FET: Control FET). Using this pulse width modulation (PWM) topology from 48V in a high power, high efficiency system is challenging due to the extremes of duty cycle coupled with the higher MOSFET voltage requirements and subsequent higher $R_{DS(ON)}$.

FPA enables the separation of the regulation and voltage transformation stages into two separate blocks. The PRM generates a factorized bus, controlled to a typical level of 48V, and the VTM (a current multiplier with very low output impedance up to 1MHz switching frequncy) provides high efficiency voltage transformation directly at the processor.

In a second step of improvement (Figure 4c), the MV BCM is replaced with a PRM producing a regulated factorized bus voltage of 48V. The LV DC/DC converter is replaced with a VTM that converts the 48V to the required 1.2V. For the 960W load, 8 VTMs are used (1 per 100A processor). PRM V•I Chips are capable of much higher powers (up to 320W each); as a result, only four are needed (in parallel with connected outputs).

For each version, the summarised system power losses and efficiencies per step are shown in Figures 5 and 6. Using BCMs to replace the HV and MV DC-DC stages (step 1) results in a modest 1.1% overall efficiency increase but a 30% size reduction versus the baseline system. Changing the MV and LV DC/DC stages from traditional bus converters and VRMs to an FPA solution (step 2) means a 7.4% rise in efficiency and a 45% reduction in size versus the original.

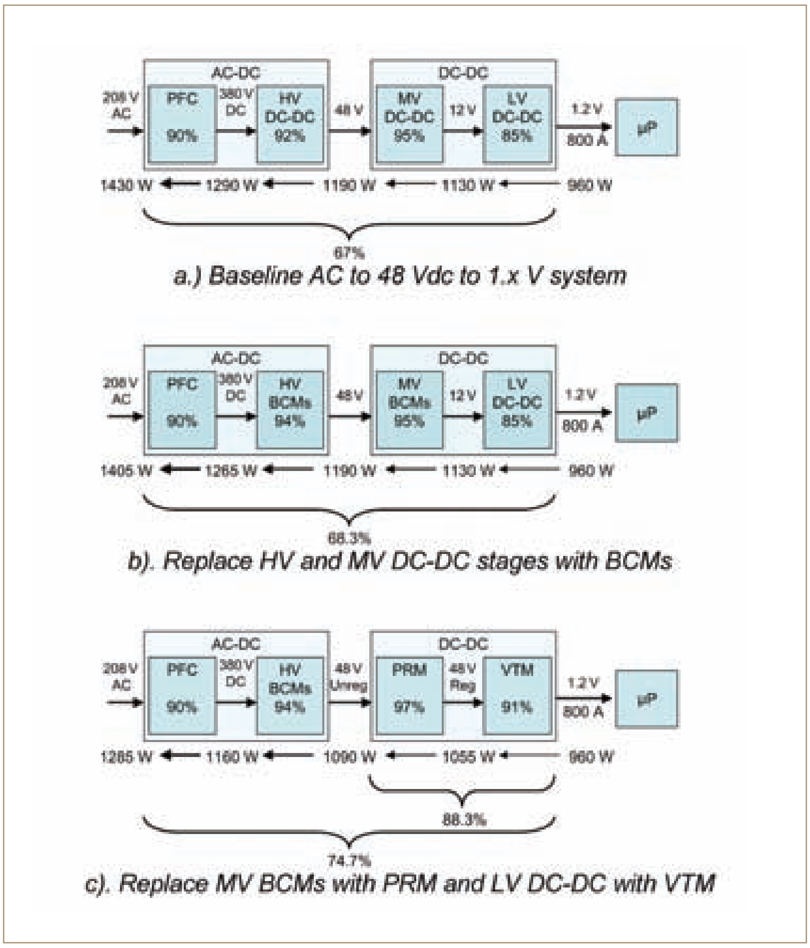


Figure 4: Two-step improvement in efficiency over baseline system

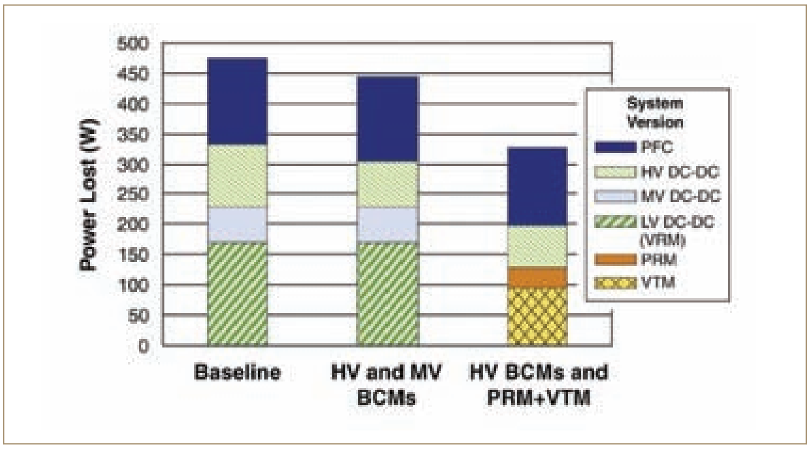


Figure 5: Power losses per step

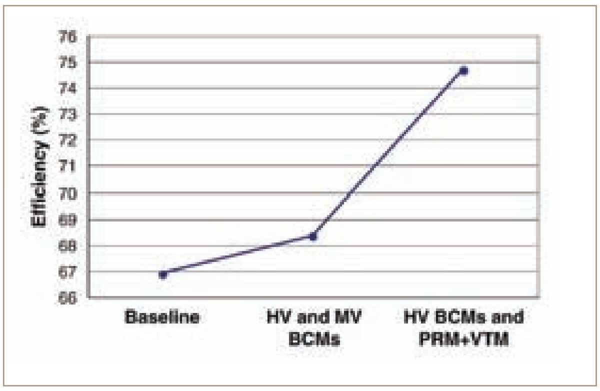
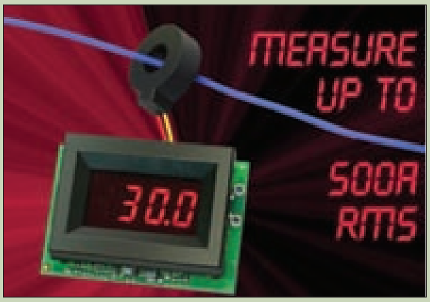


Figure 6: System efficiencies per step

RMS AC Ammeters Interface with Current Transformers



The Datel ACA5-20RM series from Murata Power Solutions is a new family of functionally complete, high current, RMS responding AC ammeters designed to interface directly with an external 5A output current transformer.

Covering input ranges from 100 to 500A, the ACA5-20RM series is suited for use in electronic equipment that uses switching power supplies such as inverters and generators, battery chargers, power distribution units and AC/DC power supplies. RMS responding ammeters provide accurate and reliable performance in switching power supply applications where input currents are typically distorted and do not resemble the universally recognised sine-wave shape. Other approaches to measurement such as average responding AC ammeters can result in reading errors in excess of 20% of their full-scale output. In critical applications, this may lead to inadvertent overloading of circuit breakers or fuses, which in turn can cause costly power outages. The ACA5-20RM family scales and displays the output of 5A 'donut' style current transformers. The series covers 100, 200 and 500A. A choice of 85 to 140VAC or 170 to 264VAC (at 47 to 63Hz) operating supply voltages is offered for each range. Maximum power consumption is less than 50mA and operating temperature range is 0 to 60°C.

www.murata-ps.com

High Precision Thin-Film Resistors

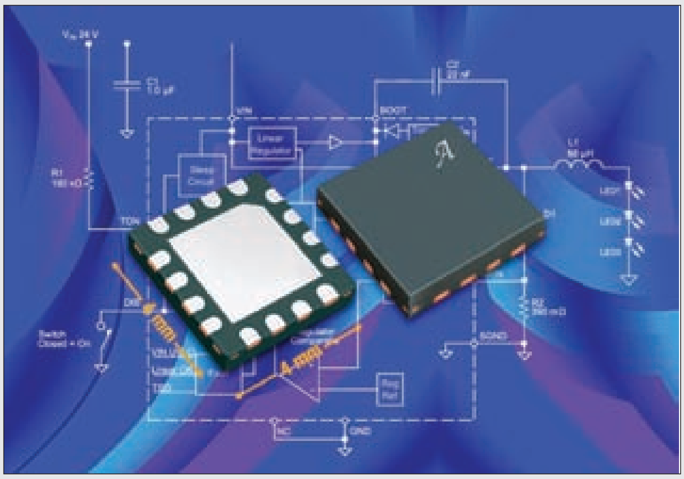
KOA Expands its series of high precision thin-film flat chip resistors, RN73H, with the size 0402 and higher ohmic values in all other sizes. The RN73H series provides excellent long-term stability, typically below 0.05% resistance change over 1000hr. The typical resistance change due to soldering heat is below 0.01%. Available initial tolerances go down to 0.05% and the excellent temperature coefficient of resistance available is 5 ppm/K.

The available resistance range for the size 0402 contains 10? up to 100k? . The size 0603 offers now resistance values up to 360k? . All other sizes are now available up to 1M? . All sizes are available in the series E24 and E96.

On request KOA can also provide E192 series.

www.koaeurope.de

LED Driver IC



The new A6210 packaged in 4mm QFN from Allegro MicroSystems Europe is an LED driver IC based on a buck regulator circuit using constant 'on' time with valley current-mode control.

This control scheme allows the use of very short switch 'on' times for applications requiring high switching frequencies combined with high input voltages and low output voltages. System cost is reduced as a result of the high switching frequencies (up to 2MHz), which allow small, low-value ancillary components such as inductors and capacitors to be used. In addition, fewer external components are required because of the high levels of integration in the device, which includes a 3A switch. Optimal drive circuits are used to minimise switching losses, allowing over 90% efficiency in realistic conditions.

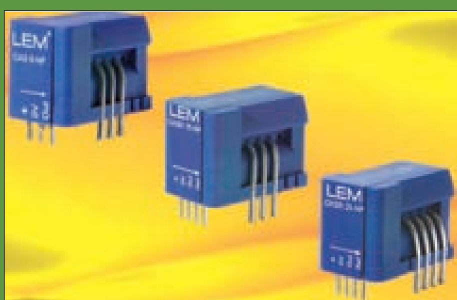
The A6210 will operate over a wide input voltage range of 9 to 46V, including 12V nominal or maximum Class II power supplies, and produces an output voltage over the range from 0.8 to 40V. This means that it can drive a single LED or a series string of ten or more LEDs. The output current rating of 3A, combined with the internal switch, allow it to directly drive the new generation of very high current LEDs and LED modules. Standby current is less than 100µA.

www.allegromicro.com

PCB-Mounted Current Transducers Measure up to 50A

LEM introduces PCB-mounted current transducers housed in a package 30% smaller than the company's LTS devices. The CAS, CASR and CKSR family of transducers are intended for AC and DC isolated current measurement from 6 to 50A(RMS) nominal, up to three times the nominal values for the peak measurement and up to 300kHz (+/-3dB).

All the models (6, 15, 25 and 50A) are housed in the same compact package and can be set up on PCB according to the needs for different ranges from 1.5 to 50A (according to the models). The new transducers have been specially designed to respond to the technology advances in drives and inverters, which require better performance in areas such as common-mode influence, thermal drifts (7 to 30ppm/K according to the models), response time (less than 0.3µs), levels of insulation and size. To obtain this performance the Closed Loop Fluxgate technology has been used. Although the new transducers are 30% smaller than the existing LTS family, their insulation performance allows use in industrial applications without a special layout of the PCB. The CKSR model has one more primary pin than the three pins of the CAS and CASR models and a different primary footprint enabling higher creepage and clearance distances of 8.2mm to be achieved. This is particularly useful when higher insulation is required in applications with high working voltages such as 600V(RMS) according to EN 50178. This additional primary pin also allows a configuration of the CKSR 6-NP model for a nominal current range of 1.5A(RMS).



www.lem.com

New SJ Power MOSFETs

NEC Electronics Europe has announced an expansion of its low-voltage Power MOSFETs offering. Based on SuperJunction1 technology, the new devices NP110N04PUJ and NP110N055PUJ feature a gate charge of just 150nC for an on-resistance of 1.8 and 2.4mΩ, respectively. Compared with the UMOS-4 trench technology, the SuperJunction1 technology reduces the gate charge and the input capacity by over 30%, while maintaining the extremely low on-resistance. The process involves adding P-doped regions below the active P-well of the trench cell which reduces the resistance of the N-epitaxial layer through higher doping. This means that for the same on-resistance the design rule can be increased and the gate charge thus reduced.

Currently, four components in a popular D2PAK package with drain-source voltages of 40 and 55V are being readied for mass production. The new devices are qualified to AEC-Q101, support a channel temperature up to 175°C and are fully RoHS-compliant thanks to tin-plated leads. PowerMOSFETs with SuperJunction1 technology are intended for applications where large currents have to be switched with high efficiency. These include EPS (electric power steering) or ABS in automotive, or low-voltage industrial drives in forklift trucks or other battery-operated equipment.

Samples are available now; volume production is scheduled to start during the first half of 2009.

www.eu.necel.com/mosfet

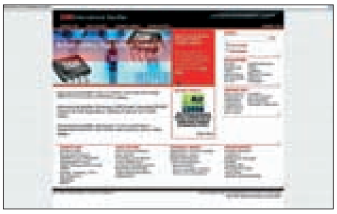
DC/DC Converter Reference Design for Operation up to 225°C

CISSOID from Belgium introduced ETNA, a DC/DC Converter Reference Design suitable for operation from -55 up to 225°C. This reference design is the first product of a family of DC/DC converters named Volcano implementing a buck DC/DC converter with CISSOID products as active components. ETNA can provide output voltages going from 2.5 to 10V, while driving loads from 10mA to 1A across the entire operating temperature range at efficiency of over 80% at 200°C. Its input voltage can extend from 7 to 30V while providing very good line regulation (1mV/V), load regulation (5mV/A), as well as output voltage drift with temperature (150µV/K).

The architecture includes Input Voltage Feedforward enabling very good DC line regulation and a fast response to input transients. ETNA can be implemented with packaged components on a high-temperature PCB or as a Multi-Chip-Module on the basis of bare dies. Further integrated solutions are under development.

www.cissoid.com

AC/DC Connverters



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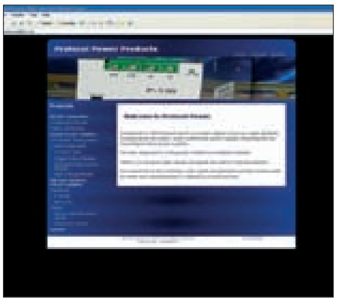

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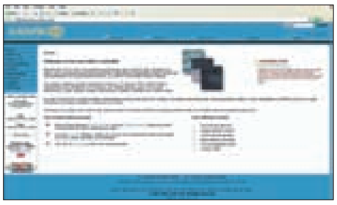

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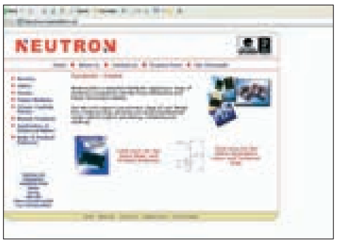

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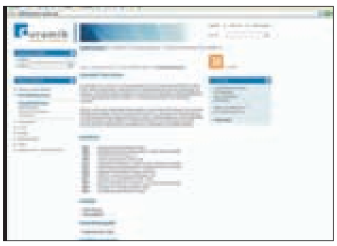

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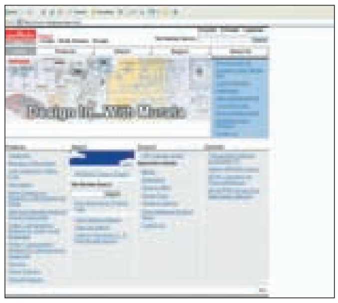

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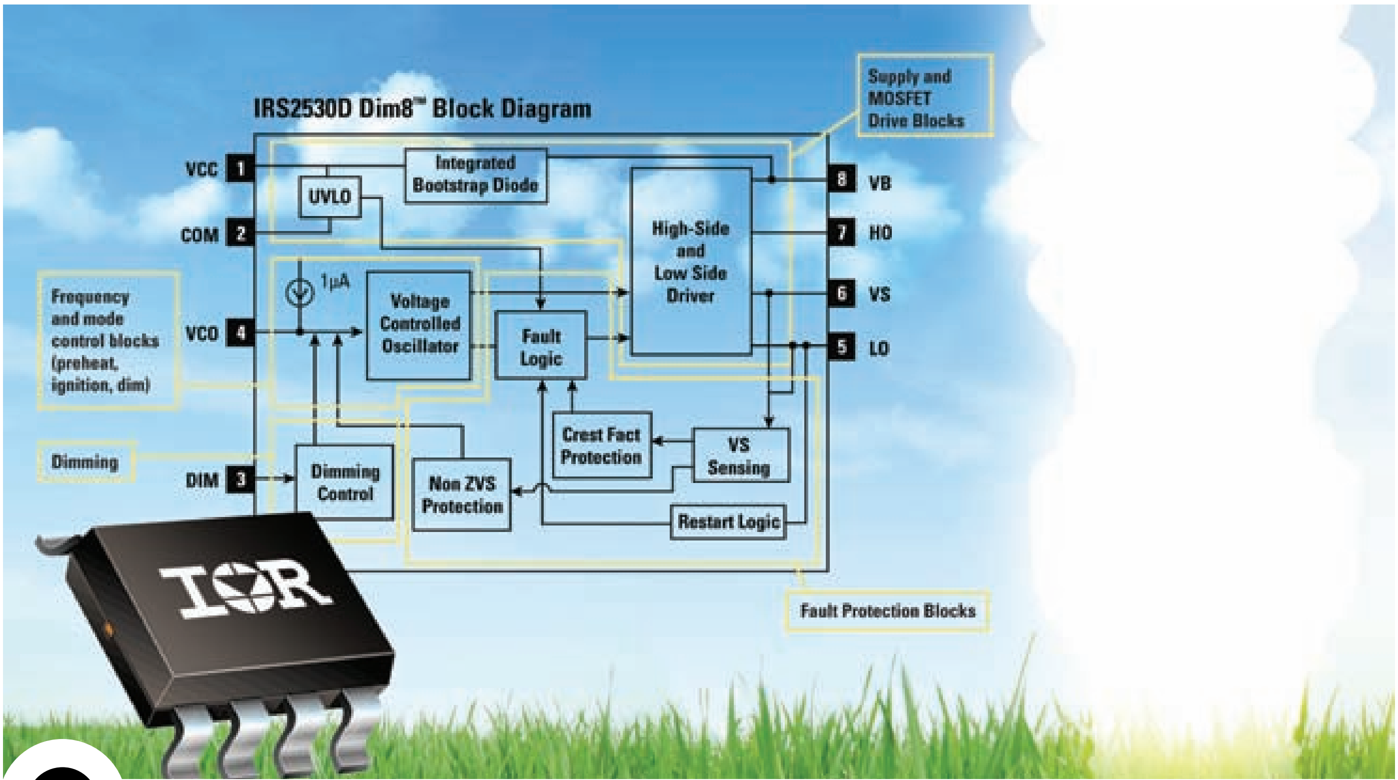
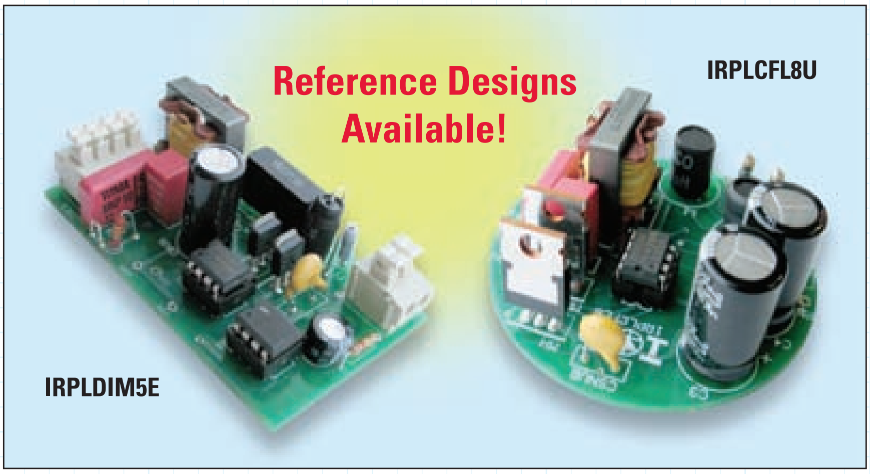


Slash Component Count; Simplify Design

PCIM Europe 2009
Hall 12, Stand 202

IRS2530D *DIM8*™ dimming ballast control IC with half-bridge driver in compact 8-pin form factor.

Part Number	Package	Voltage	Dimming	Fixed Dead Time
IRS2530D	8-lead DIP and 8-lead SOIC	600V	10%	2.0 µs



Requiring only several small external components, the IRS2530D significantly simplifies and shrinks circuit design and delivers a dimming system performance of up to 10 percent for compact fluorescent lamps as well as linear ballasts.

IRS2530D *DIM8*™ Features:

- 8-pin dimming ballast controller
- Dimming to 10%
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