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AUTOMOTIVE POWER

Silicon Carbide in Automotive

THE EUROPEAN JOURNAL
FOR POWER ELECTRONICS
AND TECHNOLOGY

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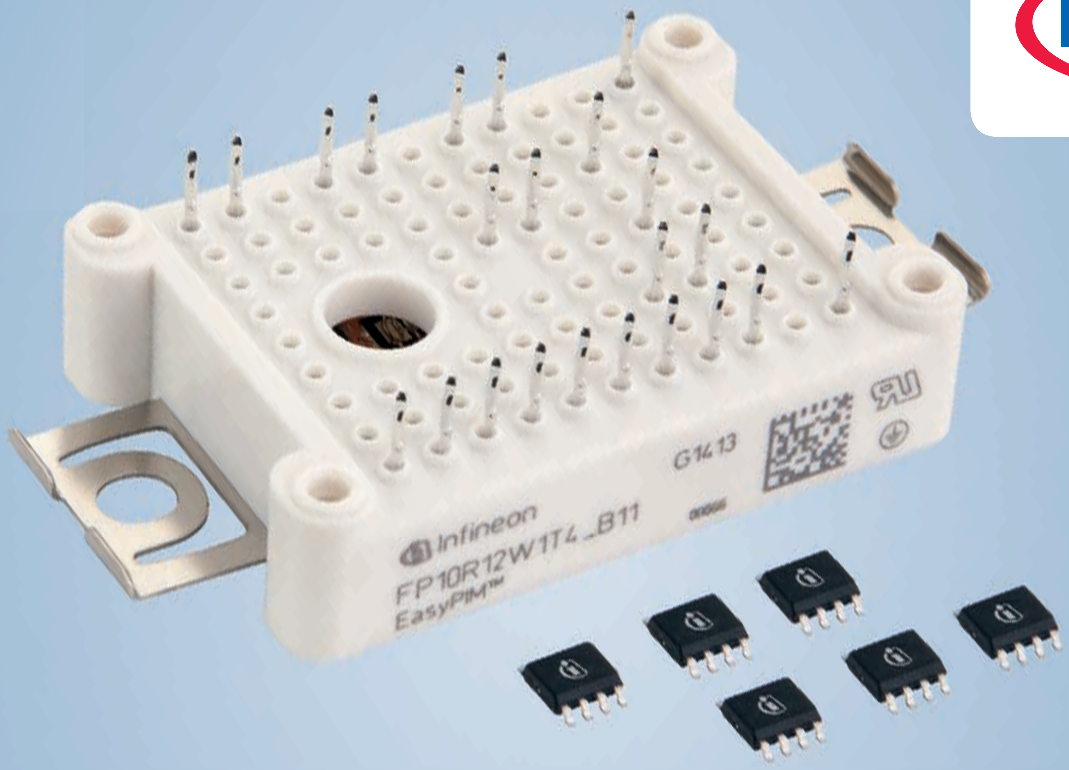

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Benefits

- Simplifies circuit design and saves components
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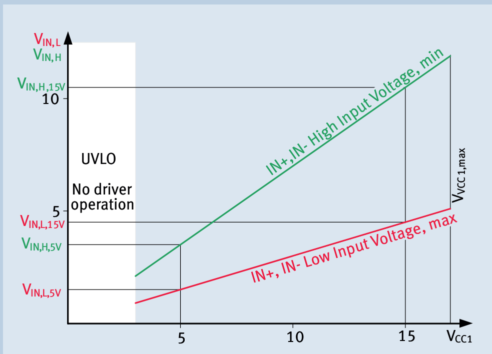

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Editor Achim Scharf
Tel: +49 (0)892865 9794
Fax: +49 (0)892800 132
Email: achimscharf@aol.com

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

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

Reader/Circulation Enquiries
Capsule Publishing Services Ltd
Tel: 0333 577 0801 Fax: 0845 604 2327
Email: circulation@capsule-group.com

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

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

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

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

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

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

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

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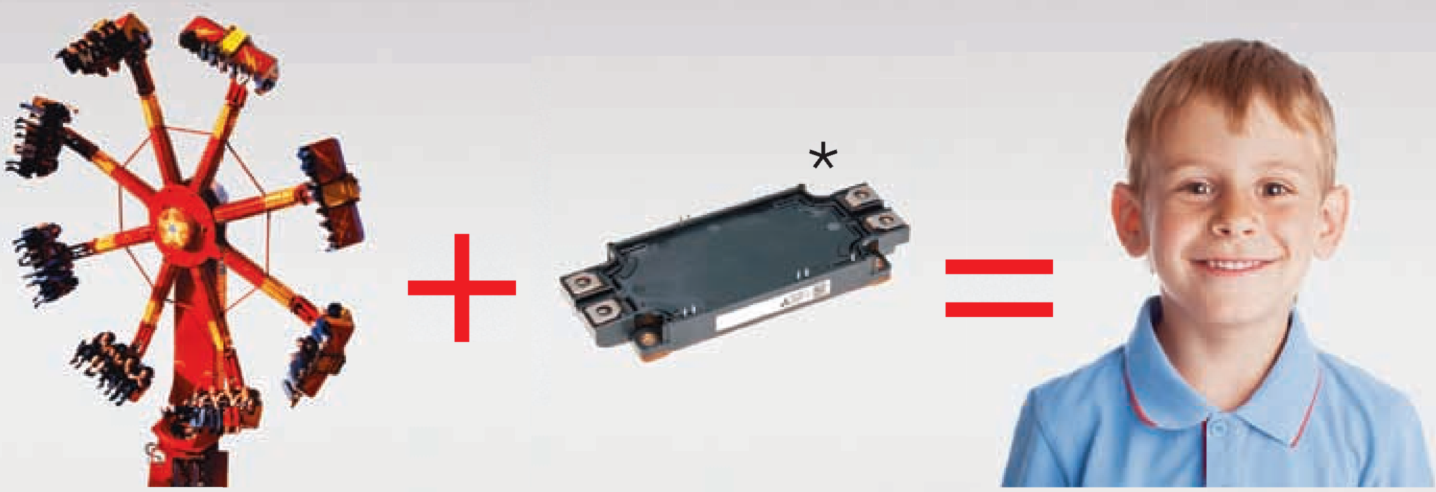
COVER STORY

Silicon Carbide in Automotive

The SiC power semiconductor industry has penetrated many markets since the first full release of SiC diodes in 2001, SiC power transistors in 2011, and SiC power modules in 2012. Some of the first markets to use SiC include the server, industrial, telecom, lighting, and induction heating power supply markets. Since then, SiC has also penetrated the solar, UPS inverter, drives, and avionics markets. Most recently, SiC power components have begun to permeate automotive applications such as on-board and off-board chargers, and on-board auxiliary power supplies in electric vehicles (EVs) and hybrid electric vehicles (HEVs). Now, for the first time, 900 V SiC power transistors are being considered for automotive EV/HEV drivetrain inverters and (when applicable) boost stages. Estimated impact of 900 V SiC MOSFET on specific power and power density in automotive traction inverters at this early stage is limited, but demonstrations elsewhere strongly suggest the potential of obtaining high power densities (well above 20 kW/l) with very high (99 % peak) efficiency. At 400-700 V bus voltages, Cree's new 900 V SiC MOSFET allows system level performance and cost not possible with 650 V Silicon IGBTs or MOSFETs.

More details on page 26.

Cover supplied by Cree Inc./USA.



The Race for More Efficient Power Electronics

The European Commission has presented an innovation investment package including plans for five Joint Technology Initiatives (JTIs) in EU-funded research, representing €25 billion over the next seven years. This includes a proposal for a JTI bringing together the EU and Member States in Electronic Components & Systems (ECSEL). The main goals of the initiative are among others to reverse the decline of the EU's global share in the electronic components and systems area and to maintain Europe's leadership in areas as embedded systems, semiconductor equipment and materials supply, the design of complex electronic systems and e.g. energy efficient electronic components.

One of the most important European research projects focused on energy efficiency was launched in April. The objective of the three-year project "eRamp" is to strengthen and expand Germany and Europe as centers of expertise for the manufacture of power electronics. 26 research partners from six countries are participating. Infineon is leading the Euro 55 million project. eRamp research activities will focus on the rapid introduction of new production technologies and further exploration of chip packaging technologies for power semiconductors. The German project partners will investigate and develop new methods for speeding up the start of the production run. In order to investigate research results for practical viability exactly where the new production technologies will be implemented, the German research partners will use existing pilot lines and comprehensive production expertise at various German sites, including Dresden (Infineon: power semiconductors based on 300 mm wafers), Reutlingen (Bosch: power semiconductors, smart power and sensors based on 200 mm wafers) and Regensburg (Infineon: chip packaging technologies for power semiconductors). Infineon, Osram and Siemens will work together closely to research and construct testing equipment and demonstrators for the evaluation of newly developed chip embedding technologies.

In the USA the Next Generation Power Electronics Institute for Clean Energy Manufacturing Innovation in the USA will provide the infrastructure needed to support new product and process technologies, education, and training to become a global center of excellence for the development of wide bandgap semiconductor devices and industry-relevant processes. This new institute, led by North Carolina State University, brings together a consortium of US based companies that include the world's leading wide band gap semiconductor manufacturers, leading materials providers, and critical end-users with universities on the cutting edge of technology development and research. The institute will enable the next generation of energy-efficient, high-power electronic chips and devices by making wide bandgap semiconductor technologies cost-competitive with current Silicon-based power electronics in the next five years. The Department of Energy is awarding $70 million over five years, matched by at least $70 million in non-federal commitments by the winning team of businesses and universities, along with the state of North Carolina.

At APEC 2014 the ARPA-E agency introduced its SWITCHES program, which is short for "Strategies for Wide Bandgap, Inexpensive Transistors for Controlling High-Efficiency Systems, are focused on developing next-generation power switching devices. SWITCHES projects are funded $27 million aiming to find innovative new wide bandgap semiconductor materials, device architectures, and device fabrication processes that will enable increased switching frequency, enhanced temperature control, and reduced power losses, at substantially lower cost relative to today's solutions. More specifically, SWITCHES projects are advancing bulk gallium nitride (GaN) power semiconductor devices, the manufacture of Silicon Carbide (SiC) devices using a foundry model, and the design of synthetic diamond-based transistors.

Emergence of wide bandgap (WBG) technologies will definitely reshape part of the established power electronics industry, especially on the high voltage side with Silicon Carbide (>1.7 kV). They offer higher frequency switching, higher power density, higher junction temperature and higher voltage capabilities (>15 kV). That is consensus among market researchers. At APEC new market entrants and developments in GaN and SiC have been shown. Remarkably is the introduction of 900-V SiC MOSFETs at the upcoming PCIM (see our cover story). This will challenge the vendors of GaN devices also looking for automotive applications.

In general the question arises on the position of Silicon versus SiC and GaN, and that is exactly the subject of PEE's Panel Discussion at PCIM in hall 6/340 on May 21 from 2.00-4.00 pm. Under the headline "Si vs SiC/GaN - Competition or Coexistence" these technologies in typical applications as well as cost and market trends are being debated. Leading representatives of ABB, Cree, EPC, Infineon, International Rectifier, Mitsubishi, Semikron, ST Microelectronics, Toshiba and Transphorm will participate at this panel discussion round. This is one of the rare opportunities for direct information from a number of sources and from different angles. I will try my best to raise the appropriate questions.

I am looking forward to see you there!

Achim Scharf
PEE Editor

Next-Generation PV Technologies to Take Center Stage

Advanced photovoltaic (PV) technologies such as diamond wire and n-type substrates will increasingly find their way into mainstream solar manufacturing, especially with capital expenditures set to bounce back this year, according to market researcher IHS.

In a move that will coincide with the launch of a new spending cycle within solar circles, manufacturers along the PV supply chain will transition from standardized technologies at present to next-generation mechanisms for solar-related mass production in the near future. Capital spending will reach an expected $3.4 billion by year-end, IHS believes, after bottoming out in 2013.

"Innovative technologies will be atop the agendas of major solar manufacturers globally now that supply and demand has come to closer alignment", said analyst Jon Campos. "While most experts thought that overcapacity issue would remain significantly longer, the fundamental assumptions made by IHS were that the industry would move toward market equilibrium behind increasing demand in the emerging markets, and that PV manufacturers would turn to advanced technologies to compete with traditional forms of energy production—assumptions that are now coming to fruition".

Solar technology changes will also extend to p-type substrates, which have generally been the solar industry norm. However, significant research and development is being conducted on n-type Silicon, shown to have a higher tolerance to common impurities and resulting in high minority carrier diffusion lengths compared to p-type. Furthermore, n-type crystalline does not suffer from the boron-oxygen-related light-induced degradation (LID) that is common on p-type Czochralski Silicon. IHS forecasts that n-type applications will mature and find their way into mainstream manufacturing. N-type will be mostly a monocrystalline technology, growing from 5 percent of total cell production capacity last year to approximately 32 percent by 2020.

String Inverters Increasingly Used in Megawatt-Scale PV Projects

In a recent IHS survey, more than 300 solar installers, distributors and engineering, procurement and construction companies were asked about their preferences and opinions on PV inverters, in order to help suppliers better understand the needs and requirements of their customers.

Of the more than 200 purchasers of PV string inverters that completed the survey, 80 percent indicated they might use string inverters in systems larger than 100 kW. All told, nearly half reported they would consider using the inverters in systems larger than 1 MW. This marks a huge increase from the previous year's survey when only 17 percent considered using string inverters in systems larger than 1 MW. "The survey confirmed that the acceptance of string inverters in large systems has accelerated over the last year, mirroring the IHS forecast that these products will gain share in several key PV markets," said Cormac Gilligan, PV market analyst. "The most common reasons given for solar purchasers preferring string inverters increasingly over central inverters in large systems were better system design flexibility, minimizing losses in the case of failure and lower lifetime system costs". IHS predicts that low power three-phase inverter shipments will increase by 14 percent a year on average for the next four years, with annual shipments of nearly 20 GW in 2017.

More entities are also using or buying microinverters in 2013, according to the survey, with 42 percent now utilizing such products. Microinverters perform the same general functions as traditional string inverters except that they work on a per-module basis rather than for a string of modules. "Following several years of intense marketing and training for installers, microinverters have now progressed from being a 'niche' product, to gaining wide acceptance in the PV market", said Gilligan. "Major suppliers, such as SMA and Power-One, have also released microinverters, helping them to gain acceptance and traction in key markets".

www.ihs.com

Wide Bandgap Technologies Evolve

Emergence of wide bandgap (WBG) technologies will definitely reshape part of the established power electronics industry, especially on the high voltage side with Silicon Carbide (>1.7 kV). They offer higher frequency switching, higher power density, higher junction temperature and higher voltage capabilities (>15 kV). To now, the incumbent packaging solution does not fit their specifications. Only a tiny part of the WBG added-value could be captured using current approaches. "Some companies offer a new enhanced package strategy addressing demand for WBG specifications. At midterm, these new modules could target a $200 million market in 2016, exceeding $1B at longer term by the year 2020+", comments Jérôme Azemar, analyst at Yole Développement. "We now see the WBG industry, especially SiC, reshaping, starting from a discrete device business and now evolving into a power module business. Originally, this was initiated by Powerex, MicroSemi, Vincotech or GeneSiC with hybrid Si/SiC products, then other players such as Mitsubishi, GPE and more recently Rohm have reached the market with full SiC modules.

Photovoltaic (PV) inverters are the biggest consumer of SiC devices together with PFCs. SiC device (bare-dies or packaged discretes) market reached about $75 million in 2012.

There are now more than 50 companies worldwide which have established a dedicated SiC or GaN device manufacturing capability with related commercial and promotion activities. Virtually, all other existing Silicon-based power device makers are also more or less active in the SiC or GaN market but at different stages. All together, SiC and GaN devices and modules market is expected to top $1.4 billion by 2020, Yole forecasts.

A WBG semiconductor-based inverter, which switches electricity from direct current to alternating current, could be four times more powerful, half the cost and one-fourth the size and weight of a traditional inverter, market researcher IDTechEx states. Indeed, adoption of WBG semiconductors is already happening today, notably in PV power generation - solar power replacing power stations - followed by more general power grid applications. Next, WBG semiconductors will transform the plug-in EV industry - making it easier and cheaper to own an EV and/or give it longer range. They may reduce the size of a vehicle cooling system by about 60 % and cut the size of a fast DC charging station (eg 60 kW) to the size of a kitchen microwave.

The power conversion in future EVs will encompass such things as converting high DC voltages to lower DC voltages in fast charging, converting AC to DC in other charging, converting low voltage DC to higher voltage DC in photovoltaic and thermoelectric energy conversion in the vehicle and in photovoltaic roadside chargers, for example. The cost of the electronics and electrics in an EV will rise sharply as a consequence of this and of electrics and electronics replacing mechanics as when clutches and differentials are eliminated. In due course, IDTechEx won't say the battery is the EV but the electrics/electronics is equally or more important as a component of cost and performance.

EVs have tougher requirements on cost, size, weight and performance but they should be the

largest WBG application by 2020 (see also our cover story).

GaN-on-Si Technology will be Widely Adopted

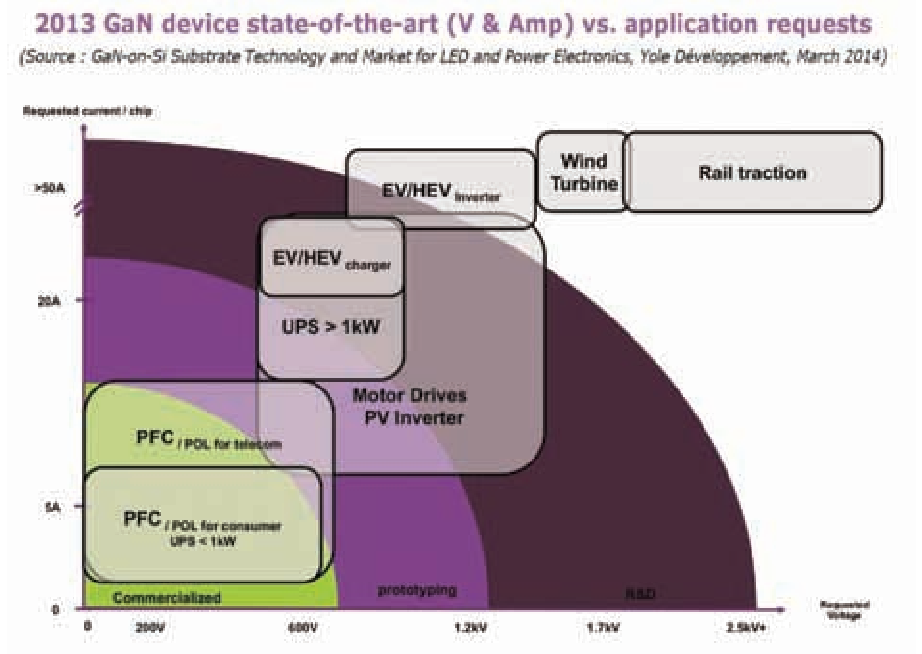
The power electronics market addresses applications such as AC/DC or DC/AC conversion, which is always associated with substantial energy losses that increase with higher power and operating frequencies. Incumbent silicon based technology is reaching its limit and it is difficult to meet higher requirements. GaN based power electronics have the potential to significantly improve efficiency at both high power and frequencies while reducing device complexity and weight. Power GaN are therefore emerging as a substitution to the Silicon based technology. Today, Power GaN remains at its early stage and presents only a tiny part of power electronics market.

"We are quite optimistic about the adoption of GaN-on-Si technology for Power GaN devices.

GaN-on-Si technology have brought to market the first GaN devices. Contrary to the LED industry, where GaN-on-Sapphire technology is main stream and presents a challenging target, GaN-on-Si will dominate the GaN based power electronics market because of its lower cost and CMOS compatibility", says Yole Développement's analyst Eric Virey. Although GaN based devices remain more expensive than Si based devices today, the overall cost of GaN devices for some applications are expected to be lower than Si devices three years from now, according to some manufacturers.

"In our nominal case, GaN based devices could reach more than 7 percent of the overall power device market by 2020. GaN-on-Si wafers will capture more than 1.5 percent of the overall power substrate volume, representing more than 50 percent of the overall GaN-on-Si wafer volume, subjecting to the hypothesis that the 600V devices would take off in 2014-2015", Virey expects.

To adopt the GaN-on-Si technology, device makers have the choice between buying epi-wafers or templates on the open market, or buying MOCVD reactors and making epi-wafer by themselves. Today, there is a limited number of players selling either epi-wafers or templates or both on the open market. These players comes from Japan, US and Europe. Yole Dévelopement considers that buying epi-wafers could work as long as the price on the open market keeps decreasing.



GaN Vendor Strategies

GaN power technology, in addition to SiC, remains the only viable technology available for a wide scale commercialization of high-voltage power devices for the next-generation power systems. This implies that long-term commercialization prospects for the GaN power devices are high. However, in the near-term commercialization prospects are constrained by a range of technology, manufacturing, and industry infrastructure issues. Vendors use a diverse range of strategies to mitigate these constraints, which could be segmented into three major categories, including volume manufacturing of reliable GaN power devices, cost reduction, and application enablement, according to a new report from market researcher VentureQ.

Vendors engaged in commercialization of GaN power devices include a broad range of vendor types featuring diverse business attributes. As a result, vendor-specific commercialization strategies are equally numerous. In order to address and analyze this diversity, market researcher Venture-Q segmented vendors by type and common business attributes into four major categories, including new ventures, market leaders in power discretes and modules, vertically integrated semiconductor vendors, and mainstream vendors of discretes and ICs.

A comparison of the November 2013 vendors' GaN power devices commercialization status with the same one from December 2012 reveals that little has changed in the playing field. This indicates that all vendors face similar issues in dealing with the prior discussed technology and industry infrastructure constraints. The figure also indicates that only a handful of vendors are potentially capable to deliver commercially viable products in the near future. Since March 2010, Efficient Power Conversion (EPC) remains the only vendor offering GaN power devices (less than 200 V) on the open merchant market. Recently announced Fujitsu-Transphorm engagement is according to VentureQ the only significant commercialization relevant development.

Vendors Developing GaN-on-Si HEMTs for Power Conversion
(Status as of November 2013)

Semiconductor Vendor	Product Availability		Technology Availability			Process Development		Product Types		
	Open market	Closed market	Foundry services	R&D services	IP licens.	Collabora-tive	In-house	Discrete	IC	Module
IRF		●			●		●	●	○	●
EPC	●					▲		●	○	
Transphorm		●					●	●		●
Fujitsu Semi		●	●	●			●	●		
Sanken							●	●	●	
MicroGaN		●	●	●			●	●		
Infineon							●	○		○
HRL				●	●		●	●		
Panasonic							●	●	●	
STMicro							●	○	○	
ON Semi						●	●	○	○	
Toshiba							●	●		
Samsung							●	●		
NXP						●	●	○		
TI							●	○	○	○
POWI							●		○	
Powdec			●	●			●	●		
Renesas							●	○		
Furukawa				●			●	●		
Intersil					○					
GaN Systems								○		○

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Billion Investment Boosting Europe's Electronics

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The new ECSEL JTI is a merger of the ARTEMIS initiative on embedded systems and the ENIAC initiative on nano-electronics that both were set up in 2008. It also incorporates research and innovation on smart systems. ECSEL is expected to start in early 2014 and to run for 10 years. ECSEL will bring together large and small companies, world-class European research and technology organisations and academia. In particular three private industrial associations (ARTEMISIA, AENEAS and EPoSS) will be involved, from the areas of micro-/nanoelectronics, smart integrated systems and embedded/cyber-physical systems, joining partners from 25 EU member states: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom.

The ECSEL JTI is likely to have a budget of €4.8 billion, with an EU contribution up to €1.2 billion, matched by the contribution from Member States. The industrial partners will contribute at least half of the total costs of around €2.4 billion. The administrative costs will not exceed €40 million and will be borne by the EU and industry.

http://ec.europa.eu/digital-agenda/en/time-ecsel

European Project eRamp to Strengthen the Electronics Industry

One of the most important European research projects focused on energy efficiency was launched in April at Infineon Technologies in Dresden. The objective of the three-year project "eRamp" is to strengthen and expand Germany and Europe as centers of expertise for the manufacture of power electronics. 26 research partners from six countries are participating. Infineon is leading the Euro 55 million project.

eRamp research activities will focus on the rapid introduction of new production technologies and further exploration of chip packaging technologies for power semiconductors. The German project partners will investigate and develop new methods for speeding up the start of the production run.

In order to investigate research results for practical viability exactly where the new production technologies will be implemented, the German research partners will use existing pilot lines and comprehensive production expertise at various German sites, including Dresden (Infineon: power semiconductors based on 300 mm wafers), Reutlingen (Bosch: power semiconductors, smart power and sensors based on 200 mm wafers) and Regensburg (Infineon: chip packaging technologies for power semiconductors). Infineon, Osram and Siemens will work together closely to research and construct testing equipment and demonstrators for the evaluation of newly developed chip embedding technologies. "The research results from eRamp will be an important contribution to even more efficiently use energy," says Dr. Reinhard Ploss, CEO of Infineon Technologies AG. "Europe and Germany are distinguished by their characteristic knowledge and expertise. The partners in the eRamp project have the entire power electronics value creation chain in mind, from generation and transmission all the way to consumption of electric energy. Together we will create new knowledge and thus new products that will mean economic and ecological progress for Europe."

In Germany, the Technical University of Dresden and West Saxon University of Applied Sciences Zwickau are also participating in research. In addition to Bosch, Infineon, Osram and Siemens, German business is represented by the companies SYSTEMA Dresden, an IT specialist vendor for automation in the manufacturing industry, HSEB Dresden, provider of optical inspection, review and installation, and SGS INSTITUT FRESENIUS, a leading vendor of chemical and physical laboratory analysis.

The research partners in the eRamp project are AMS AG (Unterpremstatten, Austria), CISC Semiconductor GmbH (Klagenfurt, Austria), HSEB Dresden GmbH (Dresden, Germany), Infineon Technologies (Germany: Dresden, Regensburg, Munich; Villach, Austria and Bucharest, Romania), JOANNEUM RESEARCH Forschungsgesellschaft GmbH (Graz, Austria), Lantiq (Villach, Austria), Materials Center Leoben Forschung GmbH (Leoben, Austria), NXP Semiconductors (Gratkorn, Austria and Eindhoven, Netherlands), Osram GmbH (Munich), Polymer Competence Center Leoben GmbH (Leoben, Austria), Robert Bosch GmbH (Stuttgart, Germany), SGS INSTITUT FRESENIUS (Taunusstein, Germany), Siemens AG (Berlin, Munich), SPTS Technologies Ltd (Newport, UK), Stichting IMEC Nederland (Eindhoven, Netherlands), SYSTEMA Systementwicklung Dipl.-Inf. Manfred Austen GmbH (Dresden), Slovak University of Technology (Bratislava, Slovakia), Technical University Vienna and University of Innsbruck (both in Austria) as well as Technical University Dresden and the West Saxon University of Applied Sciences, Zwickau (Germany).

eRamp kick-off with Prof. Wolf-Dieter Lukas (left), department head at the German Federal Ministry of Education and Research (BMBF); Dr. Andreas Wild, Executive Director ENIAC Joint Undertaking; Helmut Warnecke, Managing Director Infineon Technologies Dresden; and Reinhard Ploss, CEO of Infineon Technologies

Photo: Infineon Technologies

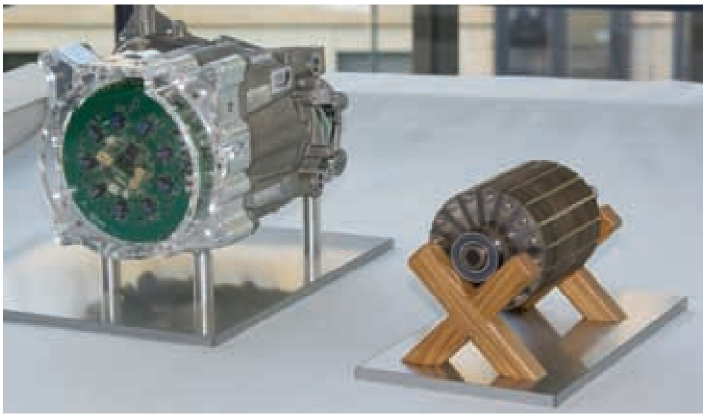
MotorBrain Research Team Presented First Prototype

The European research project "MotorBrain" presented at the Hannover Messe in April the prototype of an electric motor that may shape the future of electromobility - small, light and efficient. The motor was constructed by the four German partners Infineon Technologies, Siemens, the Technical University Dresden and ZF Friedrichshafen.

Led by Infineon, a total of 30 partners from nine European countries are conducting research in MotorBrain with the goal of increasing the range and safety of electric vehicles while at the same time reducing dependency on rare earth metals. The interdisciplinary team represents all development and production sectors relevant to electromobility. The team includes universities, non-university research facilities, semiconductor manufacturers, electric motor builders, automobile component suppliers and automobile manufacturers. The MotorBrain project began in the fall of 2011. A budget of approximately Euro 36 million makes Motor-Brain one of the largest European research projects in the area of electromobility, with financing coming from business and from national funding providers such as Germany's Federal Ministry of Education and Research (BMBF) and the European ENIAC Joint Undertaking.

The MotorBrain prototype is a highly integrated electric motor that unifies the most important components of the powertrain for an electric vehicle. The researchers have succeeded in designing a highly compact electric motor that could easily fit in a conventional-sized laptop or notebook backpack. By the integration of motor, gear drive and inverter the researchers were able to cut down the weight of the powertrain by approximately 15 %, from 90 kg to less than 77 kg, compared to a first attempt in 2011. A medium-sized vehicle with MotorBrain electric motor and performance of 60 kW (equal to about 80 hp) would be able to drive a good 30 to 40 km farther than today's electric vehicles with their average range of approximately 150 km per battery charge. Furthermore, the partners succeeded in building the MotorBrain prototype without using rare earth metals, which are currently a fundamental cost driver in hybrid and electric vehicles. Today rare earth metals are an important component in the permanent magnet of any electric motor, generating a particularly strong, constant magnetic field. The stronger the magnetic field, the higher the performance capabilities of the motor. However, obtaining rare earth metals is extremely complicated and environmentally harmful. Also, rare earth metal prices are high due to Chinese monopoly. The MotorBrain electric motor therefore utilizes readily available and less expensive ferrite magnets. The lower performance level of ferrite magnets is compensated for by the specially developed high-RPM (revolutions per minute) rotor.

www.motorbrain.eu



The MotorBrain prototype - a highly compact electric motor without using rare earth metals in the rotor **Photo: MotorBrain**

Another Push for Wide Bandgap Devices

APEC 2014 from March 17-20 closed with a record attendence of more than 3,000 conference delegates and more than 330 exhibitors. Again SiC with new players and one giving up its BJT activities as well as GaN were of major interest within the conference and on the exhibition floor.

APEC 2014 was opened by the plenary session speakers. First David Freeman, CTO of Power Management at Texas Instruments, sketched the environment of future power electronic applications. Power and energy management enable every portable device to be portable, and without it the run-time alone would have limited many markets. Advanced power management strategies developed in the portable world have been transformed into new power technologies used in many transportation and stationary applications. These include new circuit solutions that minimize losses, while improving the response to load variations. Developments in leading-edge semiconductors, circuits, packaging and manufacturing allow designers to now take a systems approach to power and energy management, which will help fuel growth for power electronics in markets, such as portable, transportation, computing and communication. "The industry needs to move from power management to energy management. In the year 2015 around 20 TW will be needed to power the mobile cloud, thus sufficient technologies are necessary. And in today's automobiles most of the power comes from fossile sources, some 3.5 kW in average are consumed in a car. Each additionally 10 W cost $5".

Dong F. Tan from Northrop Grumman underlined these remarks because power electronics is moving towards multi-disciplined technologies due to the increased applications fields such as renewable energies, HVDC or smart grids. "Hot topics in this sense today are solid-state digitally controlled transformers and solid-state circuit breakers. For certain high-power applications Silicon Carbide devices will find a niche, also Gallium Nitride for high-speed applications. But in general for high power multi-level Silicon architectures will be used more widely since they are scalable in power and phases, whereas in low power monolithic ICs become realistic".

According to Miguel Chavez, R&D Director at UPS maker Eaton, fourty percent of the electrical energy consumed in data centers is used for IT equipment, but fifty percent for cooling! "Wide bandgap power semiconductors can hopefully meet the cost points that are expected by commercial users, since we see these devices will increase efficiency. Today 97 percent UPS efficiency is possible with three-level IGBT inverters and digital control".

Significant developments and trends in 3D packaging have been discussed by Brian Narveson, Co-Chairman of the PSMA Packaging Committee **(www.psma.com)**. "The power supply industry is constantly challenged by its customers to deliver more power in a smaller volume. This applies whether selling 1 W modules or multi kW AC/DC product. The focus on footprint alone is no longer adequate. The efficient use of the z-dimension to minimize the volume of the package is now in the forefront. Cost effective, volume efficient 3D packaging is rapidly being adopted by the power industry". In his talk Narveson referred to many developments on embedded PCBs particularly in Europe as an example (see PEE March 2014, page 10-12, 22). At APEC a working group for 3D packaging has been established.

"We are focusing our efforts on strenghtening the US wide bandgap position with the SWITCHES program", ARPA-E program director Timothy Heidel pointed out at APEC's plenary session

Supporting US Industry

The projects in ARPA-E's SWITCHES program **(www.arpa-e.energy.gov)**, which is short for "Strategies for Wide Bandgap, Inexpensive Transistors for Controlling High-Efficiency Systems, are focused on developing next-generation power switching devices that could dramatically improve energy efficiency in a wide range of applications, including new lighting technologies, computer power supplies, industrial motor drives, and automobiles", program director Timothy Heidel pointed out. SWITCHES projects are funded $27 million aiming to find innovative new wide bandgap semiconductor materials, device architectures, and device fabrication processes that will enable increased switching frequency, enhanced temperature control, and reduced power losses, at substantially lower cost relative to today's solutions. More specifically, SWITCHES projects are advancing bulk gallium nitride (GaN) power semiconductor devices, the manufacture of Silicon Carbide (SiC) devices using a foundry model, and the design of synthetic diamond-based transistors. A number of SWITCHES projects are small businesses being funded through ARPA-E's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) program.

SWITCHES will closely collaborate with the Next Generation Power Electronics Institute for Clean Energy Manufacturing Innovation which will provide the infrastructure needed to support new product and process technologies, education, and training to become a global center of excellence for the development of wide bandgap semiconductor devices and industry-relevant processes. This new institute, led by North Carolina State University, brings together a consortium of US-based companies that include the world's leading wide band gap semiconductor manufacturers, materials providers, and critical end-users with universities on the cutting edge of technology development and research. Eighteen companies such as ABB, APEI, Avogy, Cree, Delphi, Delta Products, DfR Solutions, Gridbridge, Hesse Mechantronics, II-VI, IQE, John Deere, Monolith Semiconductor, RF Micro Devices, Toshiba International, Transphorm, United Silicon Carbide (USCi), and Vacon as well as seven Universities and Labs such as North Carolina State, Arizona State University, Florida State University, University of California at Santa Barbara, Virginia Polytechnic Institute, National Renewable Energy Laboratory, and U.S. Naval Research Laboratory will participate in this program.

Other funded projects are 2-phase power ICs at Virginia Tech featuring integrated micro-fabricated magnetics, bi-directional SiC vehicle battery charger led by Cree **(www.cree.com/power)**, or 600-900 V E-Mode GaN on Silicon led by Transphorm **(www.transphormusa.com).**

SiC broadening market

"We are very proud to be part of the Next Generation Power Electronics Institute and look forward to working with other industry leading companies to enable the widespread adoption of wide bandgap semiconductors. The world needs this technology and American innovation will now be at the forefront of the development and implementation", said Guy Moxey, VP of product marketing at USCi. United Silicon Carbide **(www.unitedsic.com)** will act as

"We act as second source to Semisouth's SiC JFET closed operation", United Silicon Carbide's Guy Moxey stated

second source to Semisouth's closed operation and runs a 150-mm wafer foundry. Their normally-on SiC JFETs feature a propriety trenched-and-implanted vertical channel structure and can be manufactured with a simple self-aligned fabrication process. The major steps include a) defining a dry etching mask for the mesas, b) performing a deep trench dry etching to create the JFET source mesas, c) defining a metal implantation mask, d) performing the critical, self-aligned P+ gate implantation process to define, together with the source mesa width, the vertical channel opening of the JFETs to ensure the depletion-mode operation, e) annealing the wafer to activate the implanted Al atoms, f) forming junction termination extension to ensure the high blocking capability, g) forming surface passivation, h) forming source, gate and drain contacts and annealing of the wafer to form ohmic contacts, i) adding thick overlay metal to the gate by a self-aligned process, j) filling the trenches with dielectrics, and k) opening the source contact window and depositing a thick source-overlay metal. The 1.2 kV/60 mΩ JFETs have an active area of 5.57 mm^2 and are packaged in TO-254 metal package suitable for high temperature operations. Unlike MOSFETs, this JFET has no parasitic bipolar transistors and its main failure mechanism is thermal failure.

Cree **(www.cree.com/power)** promoted its new family of 50 A SiC

Cree's CTO John Palmour demonstrated the capabilities of the new SiC devices on the example of a non-optimized 50 kW boost converter achieving 7 kW/kg

ST's new 1200V SiC power MOSFET, the SCT30N120, will enter volume production by June 2014

Schottky diodes for high-power systems from 50 kW to over 1 MW and its new 25 mΩ SiC MOSFETs. "Developed to facilitate the direct matching of 50 A diodes to 50 A MOSFETs or IGBTs, the CPW5 Schottky diodes reduce system complexity and cost by enabling the replacement of multiple low-voltage, low-current SiC Schottky diodes, or Silicon PiN diodes, with a single CPW5 rectifier. Additional cost savings can be achieved through reduced maximum voltage ratings and the elimination of snubber circuitry due to the diminished voltage overshoot during switching in Silicon Carbide", commented CTO John Palmour. He demonstrated these capabilities on the example of a non-optimized 50 kW boost converter achieving 7 kW/kg. The company also presented a conference paper describing a single-end Flyback auxiliary power supply based on 1700V SiC MOSFET. A 60 W DC power supply design based on this SiC MOSFET shows higher blocking voltage margin, lower system cost and higher performance than a Silicon-based power MOSFET design in typical three-phase applications. compared to Si devices. An other paper dealt with the parallel operation of packaged SiC MOSFETs. The parameters that affect the static and dynamic current sharing behavior of the devices have been studied, also the sensitivity of those parameters to the junction temperature of the devices. The case temperature difference for paralleled MOSFETs has been experimentally measured on a SEPIC converter for different gate driver resistance and different switching frequency, the results show the current and temperature can be well balanced for the latest generation of SiC MOSFETs with low gate driver resistance.

According to ST Microelectronics **(www.st.com/sicmos)** SiC offer some advantages over Silicon in the 1200V voltage range due to increased power density, safer thermal operation, better efficiency and reduced system form factor. ST's new 1200V SiC power MOSFET, the SCT30N120, is currently sampling and will enter volume production by June 2014. It is available in a proprietary HiP247 package, which has an industry-standard outline and is optimized for high thermal performance. The guide price is $35.00 in quantities of 1,000 units. It features ≤100 mΩ on-resistance over the entire temperature range to 200°C and has been introduced as an "ideal" high voltage switch through the results found in a 5kW boost converter within a conference paper. The most relevant aspect of this work consists in exploiting the SiC MOSFET's reverse mode capability through its extremely fast intrinsic body diode as well as with the synchronous rectification technique. The 5 kW boost converter reference design demonstrates the advantages of using SiC MOSFETs vs. state-of-the-art IGBT both in terms of efficiency (much lower switching losses) and reduction in device operating temperature. Based on such reference design a further experimental evaluation has been carried out to exploit the SiC MOSFET reverse mode capability and the possibility to use the SiC MOSFET as an active rectifier by implementing the synchronous rectification technique has been proved.

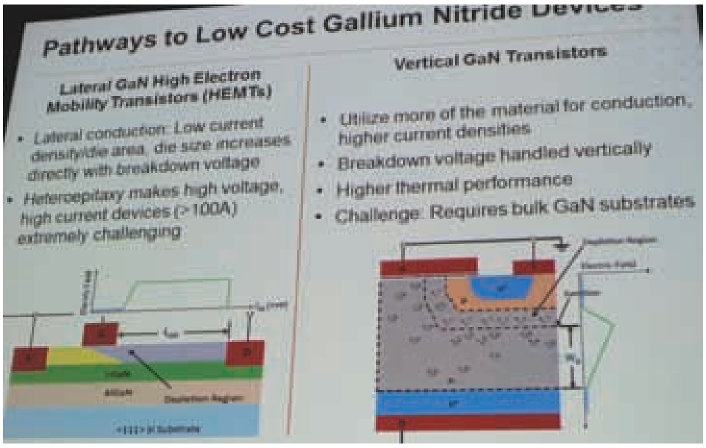
Swedish Ascatron **(www.ascatron.com)** used the APEC exhibition floor to offer its SiC foundry services., Mårten Armgarth, CEO of the Swedish research institute Acreo founded the company in September 2011 based on the in-house SiC technology. At this time the demand for epi services has increased significantly and two R&D reactors run at maximum capacity. "We have developed epitaxial growth processes for 20 years. Now, we want to focus on issues that remain in SiC epitaxial materials and establish growth technologies to enable high voltage power devices for applications above 10 kV. SiC devices could really make a difference in high voltage applications in the future. For high voltages, the substrate is the same as lower voltages but epitaxial layers have to grow over 100 µm thick on top. To do that in a cost-effective way, growth rate must be increased and the growth process also must be tailored to reduce defects penetrating from the substrate and avoid generation of new defects during epitaxial growth", said Technology Director Adolf Schöner. He envisions higher voltage and higher current up 10 kV and 100 A per die in the midterm. Device size will be increased to at least 1 cm^2 , today we are still limited by material quality, which is why currently available commercial devices can handle up to 50 A. But as substrate and epilayer quality improves and total material defect density decreases we will be able to make devices for more than 100 A current handling capability. "Ascatron is the first independent pure play SiC foundry offering the complete fabrication service from device epitaxy to diced wafers", Chairman Bo Hammerlund added. Ascatron specializes on the manufacturing of energy efficient SiC semiconductors. Target customers are suppliers of power devices and modules to the power electronic industry.

David Doan, Senior Technical Product Marketing Manager at ROHM USA **(www.rohm.com)**, highlighted the performance advantages of next-generation SiC devices for high-volume power applications, including Trench Schottky Barrier Diodes and MOSFETs in a dedicated Industry Session. "Power SiC diodes are already in high-volume applications such as power factor correction, air conditioners and now moving into EV charging stations. SiC MOSFETs dropped down in price by a factor 3 over the last three years. Reliability is the main issue for demanding applications such as traction or renewable energy systems. In inverters 50 % of the cost are SiC-related, thus device cost must come down. And plastic packages are the limiting factor in temperature behavior, but this is not the first priority today. The recent trend are solid state transformers which require breakdown voltages up to 12 kV". He foresees a SiC market broadening and thus pricing decrease through one new SiC MOSFET manufacturer and one new SiC foundry.

Finally Fairchild **(www.fairchildsemi.com)** has stopped its activities on SiC BJTs (former TranSiC acquisition) because of low market acceptance and will now concentrate its R&D efforts on SiC MOSFETs. Additionally the company has launched a major brand campaign, comprised of a new logo and message directed to its customer base; the "Power to Amaze". The new logo symbolizes the company's evolving direction, leveraging 40 years of brand. "Our vision is clear – anticipate the power efficiencies demanded by tomorrow's electronic products and deliver an amazing design experience," said Vijay Ullal, Fairchild's COO.

GaN supported by ARPA-E

In particular, the ARPA-E SWITCHES program (see above) deals with devices at 1,200 V, higher than most consumer devices. Devices with this voltage level are often used in applications with relatively high power ratings including in data center power supplies, air conditioning systems and some solar inverters.



Bulk gallium nitride is a particularly promising area for progress within the industry and thus within ARPA-E's SWITCHES program

The largest market would be for industrial motor drives, like those used for conveyor belts, elevators and manufacturing. "Bulk gallium nitride is a particularly promising area for progress within the industry. Currently, these devices have to be grown on top of Silicon wafers before being patterned and cut into chips. This results in a number of important technical limitations in how we can design GaN chips. We're exploring a new process to create GaN devices that are built directly on GaN wafers, known as bulk GaN devices. Bulk GaN is at a very early stage of development today, and through these ARPA-E projects, we could provide a credible path to cost parity with Silicon devices. Our goal is to put these devices everywhere, moving them out of the limited niche applications where they are typically found today", Timothy Heidel commented.

Soraa **(www.soraa.com)** was selected to conduct the first phase of a 4-year, $3.2 million project to develop a US-based technology for a large-area, low-cost, high-quality bulk GaN substrates, and to validate their performance in state-of-the-art power switches. Founded in 2008, Soraa is located in Fremont/California, where it manufactures its GaN on GaN LEDs in the company's state-of-the-art facility.

Efficient Power Conversion **(www.EPC-co.com)** was not present at the exhibition floor, but with two papers within the conference. In the paper "Evaluation of Gallium Nitride Transistors in High Frequency Resonant and Soft-Switching DC-DC Converters" David Reusch and Johan Strydom identified the device parameters critical to providing improved high frequency performance in hard-switching and resonant and soft-switching applications and distilled them into simple FOMs which were compared for GaN and Si technologies. For all applications, GaN shows the ability to significantly improve performance. This main focus of this paper was on the evaluation of GaN transistors in resonant and soft-switching applications and the proposed FOMs were verified for GaN and Si based 48 V bus converters operating at 1.2 MHz. The importance of output charge and gate charge were quantified for resonant and soft-switching applications and the benefits of GaN in these applications

"Since our eGaN products are available via distribution we have won a number of design-ins", said EPC CEO Alex Lidow

were demonstrated. Putting eGaN FETs to work in high frequency applications can help push the frequency without sacrificing converter performance. The second paper, "Design and Evaluation of a 10 MHz Gallium Nitride Based 42 V DC-DC Converter" frequency at higher voltages a 40 W buck converter suitable for envelope tracking showing a peak efficiency of over 89% was presented. With discrete eGaN FETs capable of switching at slew rates beyond 40 V/ns, these devices were designed to address high-frequency hard-switching power applications not practical with Si MOSFETs, thus enabling applications requiring high frequency at higher voltages. But the system performance is greatly impacted by aspects outside the power devices, such as high speed gate drivers and PCB layout. These limitations were identified and discussed while demonstrating the ability of new family of high frequency enhancement mode gallium nitride power transistors. To fully utilize the capability of the high frequency eGaN FETs will require a significant improvement in the gate driver structure beyond the LM5113 capabilities. This will allow a further increase in efficiency and switching frequency capability.

In order to use the tiny chips properly EPC have designed a number of demo boards for various applications. "Since all our products are available via distribution we have won a number of design-ins for automotive such as LED headlights or even robotic controls by German DLR", CEO Alex Lidow stated. In general the interest in power GaN has increased heavily within the last year, Lidow expects a market breakthrough very soon.

Canadian GaN Systems' **(www.gansystems.com)** lateral E-Mode GaN power switch has been shown to offer the possibility of providing a monolithic structure; combining the driver and power switch. One version of this attractive structure has been simulated using SPICE models that include the vital thermal module, according to an APEC paper "Advanced SPICE Models Applied to High Power GaN Devices and Integrated GaN Drive Circuits". The device used as the power switch was modeled using a variety of drive structures. Several commercial research groups are aiming to provide GaN

"Our GaN Island Technology is moving forward and is being commercialized in 2014, while the company is expanding globally", GaN Systems' CEO Girvan Patterson noted

devices that source over 100A. Yielding devices of this capability will be a challenge. An intense race to consistently achieve high yield, large area GaN devices is in progress. According to an APEC Seminar given by Krishna Shenai, Principal Engineer at Argonne National Labs, GaN Systems will soon introduce a 650 V E-GaN bidirectional switch featuring 250 A current carrying capability. "This will be a game changer", he said. GaN Systems' power conversion devices, based on its proprietary Island Technology, are being commercialized in 2014 and the company is expanding globally.

Transphorm **(www.transphormusa.com)** announced 600V GaN-based, low-profile PQFN products and the expansion of its product portfolio in the industry-standard TO220 packages. The PQFN88 devices, TPH3002LD and TPH3002LS, feature 290 mΩ on-resistance and 29 nC reverse recovery

"GaN products are available today and are actually being used in a multitude of real-world applications", said Transphorm's President Primit Parikh

charge as well as low inductance for high-frequency switching capability. The "LD" devices also feature a kelvin connection to better isolate the gate circuit from the high-current output circuit to further reduce EMI. In addition, the TPH3002PD and TPH3002PS TO220-packaged 600 V GaN HEMTs have been released for use in smaller, lower power applications such as adapters and all-in-one computer power supplies. Extended lifetime testing has been achieved via high-temperature tests at 175°C for 3,000 hours and elevated voltages of 1100/1050 V. 77 parts were tested until one fails, predicted lifetime is more than 100 million years and still going. Due to acquisition of Fujitsu's GaN E-Mode operation (see PEE 1/2014 page 7) large scale manufacturing as a foundry for Transphorm's D-Mode GaNs is now in place. "This dispels the widespread misconception that GaN isn't ready for prime-time. GaN products are available today and are actually being used in a multitude of real-world applications", said President Primit Parikh. The TO220-packaged TPH3002PD and TPH3002PS and the PQFN-packaged TPH3002LD and TPH3002LS are available for sale to qualified customers, directly or through distribution channels. Additionally, evaluation boards are available with the 600V TO220 GaN HEMT devices in configurations for LLC DC-DC converter, totem-pole PFC and all-in-one power supply.

Power Management

IR's **(www.irf.com)** new digital PMBus enabled CHiL digital PWM controllers meet Intel VR12 and VR12.5 specifications, and support multiphase designs from 1 to 8 phases operating 1 to 2 loops. These digital controllers can be

"Our new digital power solutions meet the challenging requirements of CPU and DDR memory designs for servers or high-end motherboards", said IR's Carl Smith

used in combination with a choice of seven new PowIRstage products to deliver an optimized high-performance end-to-end multiphase solution for CPU and DDR memory applications. "Our new CHiL digital controller family and PowIRstage solutions offer a complete end-to-end solution satisfying the challenging requirements of CPU and DDR memory designs for servers, high-end motherboards and other computing systems. These new solutions boost in-circuit efficiencies and offer a substantial upgrade in system-level telemetry and reporting, fault protection and PMBus capability," said Carl Smith, Marketing Director, IR's Enterprise Power Business Unit. The new PowIRstage devices integrate a driver, control and synchronous MOSFETs with temperature compensated, on-chip current sense reporting and provide cycle-by-cycle over-current protection to self-protect against harsh circuit conditions such as inductor saturation events. Temperature sensing, reporting and over-temperature protection are also available in addition to a fault-flag output. PowIRstage devices are offered in 6 mm x 6 mm PQFN packages rated at 40 A, 50 A and 60 A with over-molded and exposed top options. Demo boards and fully documented reference designs are available. CHiL digital power solutions are supported by IR's real-time GUI for design and development, and hardware interface tools to communicate and program the devices.

Texas Instruments **(www.ti.com)** introduced two flyback power solutions that achieve high energy efficiency and low standby power consumption for 5- to 100-W AC/DC power supplies - the UCC28910 700-V flyback switcher and UCC28630 controller. "TI has been known for low voltage devices, now the 700-V device represents our first high-voltage process implemented on 300-mm wafers in our Richardson fab", said TI's CTO of Power Management, David Freeman. "Also we have raised the breakdown voltage for our high-speed NexFETs from 30 to 100 V". The UCC28910 achieves 80 % average efficiency in 7.5-W designs and 78 % efficiency at a 10 % load. The UCC28630 achieves greater than 88 % average efficiency in 65-W to 130-W designs, and 87 % at 10 % load. Both flyback solutions support primary side regulation and eliminate the need for an optocoupler feedback circuit to increase reliability. With the introduction of WEBENCH Schematic Editor at APEC, engineers can now add components and wiring to modify the power supply design, conduct SPICE simulations on the new circuit, and then export the modified schematic to a computer-aided design (CAD) platform. CAD development platforms supported include Cadence OrCAD Capture CIS, Mentor Graphics Xpedition xDX Designer, CADSoft EAGLE, and Altium formats, such as Altium Designer. Component libraries include more than 40,000 components from 120 manufacturers. Price and availability are updated hourly by TI's distribution partners for design optimization and production planning. Offered in eight languages, the user can compare complete system designs and make supply chain decisions quickly.

"TI has been known for low voltage devices, now the 700-V device represents our first high-voltage process implemented on 300-mm wafers in our Richardson fab", said TI's CTO of Power Management, David Freeman

CUI **(www.cui.com)** introduced the NDM3ZS-60, a non-isolated module outputting 60 A in low-profile vertical and horizontal packages. The series is the first non-isolated design to incorporate

CUI's patented Solus Power Topology which integrates a conventional buck converter into a SEPIC converter to form a SEPIC-fed buck converter; a single stage topology with one magnetic element, one control switch and two commutation switches that are PWM controlled. With lower voltage and current stresses in the topology coupled with an inherent gate charge extraction process, the topology is able to reduce switching turn-on losses by 75 % and switching turn-off losses by 99% on the control FET when compared to a conventional buck converter. Efficiency peaks at 91.3 % at 12 VDC in to 1.0 VDC out, 50 % load. Efficiency remains high up to full load at 88.5%. Transient response is also greatly improved with the SEPIC-fed buck. At 12 V in to 1 V out with a 30 A load step (from 15 A to 45 A) and a 10 A/?s slew rate, peak voltage is 16 mV with typical external capacitance required.

The NDM3ZS-60 is also the first released module to use Intersil's **(www.intersil.com)** newest digital power controller, the ZL8800, incorporating a range of advanced digital features (see PEE 8/2013, pages 18-21). The ZL8800's ChargeMode Control technology further enhances the module's transient response performance by responding to a transient load step in a single switching cycle. With zero compensation required, the modules autonomously balance the trade-offs between dynamic performance and system stability on a continuous basis.

Micrel **(www.micrel.com)** previewed the MIC2111 DC/DC multi-mode controller which is capable of operating in a valley current mode or a voltage mode configuration. This controller provides the necessary PWM signal to interface with industry standard DrMOS. It also interfaces with fully discrete power stages to deliver a high current, low voltage solution to high performance power demanding core rails in the server, communication, and networking applications. In a valley current mode configuration, the MIC2111 allows high frequency operation (up to 2 MHz) even under low duty cycle conditions. This resolves a common challenge often present when powering high current, low-voltage core power rails associated with FPGAs, ASICs, and processors from a 12 V bus supply. The device can also be configured in a voltage mode operation, providing for even better immunity in noise sensitive applications. "This device offers design flexibility to optimize for a specific power requirement while minimizing the need to use different controllers, thus eliminating the component qualification process and simplifying inventory management," noted Brian Hedayati, VP of marketing. Other new exhibits included the MIC28304/MIC45205/MIC45208/MIC45212 family of power modules operating from 4.5 V to 26.5 V (70 V for MIC28304) input and are capable of delivering currents of 3A, 6A, 10A and 14A, respectively. The devices integrate a PWM controller, power MOSFETs, inductor, and associated discrete components. The MIC33163/164 and MIC33263/64 family are high-efficiency, 4 MHz, synchronous buck regulators with an integrated inductor capable of delivering current of 1 A and 2 A. Micrel also demonstrated its brushless motor solution. The MIC4605 is a half bridge MOSFET driver designed to address a wide variety of applications including motor drives, UPS and DC/AC invertors, and the MIC4605 is an 85 V half bridge MOSFET driver that features Adaptive-Dead-Time and Shoot-Through Protection.

NXP Semiconductors **(www.nxp.com)** introduced the TEA1836 and TEA1892 platform that enables the design of ultra-small 45W adapters and power supplies. The TEA1836 GreenChip, an AC/DC controller, and the TEA1892, a Synchronous Rectification controller, offer a more efficient power supply with low standby power losses. Combining both parts enables the design of a highly efficient, very small size adapter. The efficiency exceeds 93 %, allowing the components inside to be well within thermal limits in a small form factor. "The combination of the TEA1836 and the TEA1892 enables very high efficiency and low standby power consumption in a form factor getting close to half the size of a candy bar. The increased power density allows integration of power adapters and battery charges into the wall plug itself", said Marcel van Roosmalen, general manager power solutions.

Toshiba America Electronic Components **(www.toshiba.com/taec)** introduced a new series of high-speed switching type super junction MOSFETs. The new DTMOS IV-H series consists of the TK31N60X, TK39N60X and TK62N60X, and is based on Toshiba's fourth generation 600 V super junction MOSFET DTMOS IV series. The new series achieves a high speed switching performance while keeping the low ON-resistance level of conventional DTMOS IV - all without loss of power. This is accomplished through the reduction of parasitic capacitance between Gate and Drain, which also contributes to improved power efficiency and downsizing of products. The 60-A version features a gate charge of 135 nC and an on-resistance of 0.04 Ω. **AS**

PCIM
EUROPE

Nuremberg, 20 – 22 May 2014

Power Electronics for Europe and the World

From May 20-22 PCIM Europe 2014 will take place on Nuremberg Fairgrounds. PCIM Europe 2013 ended with a 15 percent increase in visitors up to 7,883 and 395 exhibitors. At this major European Power Electronics event again around 400 exhibitors and more than 700 conference delegates from all over the world are expected.

PCIM Europe 2014 focuses on the latest trends in power electronics components and systems for use in the wind and solar energy sector. Together the exhibition and conference have a role to play in the ambitious project to significantly increase the proportion of renewable energies in generating electricity. In three halls (6, 7, 9) and over an area of approximately 20,000 square meters, the key companies in the sector will showcase their products and services to an international trade audience.

On all days of exhibition over 50 exhibitors will each present their newest developments, innovations and solutions during a 20 minute presentation in the Exhibitor Forum (hall 9). Vishay Electronic, Thales Microelectronic, Indium, Mentor Graphics, Vincotech, Magnetec, Fairchild, Rohm Semiconductor, Yokogawa, Alpha, Heraeus, Powersem, Analog Devices and Hitachi are just few of the companies which will inform the visitors of this forum compactly about their product highlights.

Next to the nearly 400 exhibitors in halls 7 and 9 the industry forum in the newly opened hall 6 offer visitors and of course conference delegates an exclusive, unique and free program with panel discussions and project presentations.

On Tuesday 20 May 2014 the European Power electronic research network ECPE and EU-projects which support the idea of "European Power Electronics Leadership" will present the program of Horizon 2020. Herein the EU provides 4.8 billion Euros which is being partly used for a leading European role in power electronics. Simona Rucareanu, ENIAC JU will give a program overview and will present the funding opportunities for power electronics in Europe.

On Wednesday 21 May 2014 (2.00 – 4.00 pm) current topics such as advantages of using Silicon compared to Silicon Carbide (SiC) and Gallium Nitride (GaN) technologies in inverter and energy supply applications are being debated in the industry forum. Representatives of ABB, Cree, EPC, Infineon, International Rectifier, Mitsubishi,

From May 20-22 it's again time for PCIM 2014 conference & exhition at Nuremberg fairgrounds

Semikron, ST Microelectronics, Toshiba and Transphorm will participate at this panel discussion round hosted by Power Electronics Europe.

Comprehensive Conference Program

With more than 240 presentations on new technological trends in power electronics components and systems, the conference program offers a comprehensive overview of the latest power electronics topics.

"This year again we have seen a high quality of papers submitted and selected the best and most important for inclusion in the program of oral and poster presentations. Special attention has been given to research carried out by young engineers; the presentation of the Young Engineers and Best Paper Awards at the opening ceremony ranks amongst the conference highlights. This years is special focus on technologies for future energy supply systems, e-mobility and advanced power converters driven by efficiency and power density. The drivers for these applications include advanced power semiconductor devices, new materials to improve device and system reliability, and ideas on managing parasitic effects in the circuit set up. Presentations on power converter topologies and control techniques in intelligent motion systems form the backbone of the PCIM Europe Conference. Keynote papers cover the progress in power semiconductor devices and its impact on future power delivery systems including key technologies for electric vehicles and their

infrastructure in a low carbon society. The conference highlights include the special sessions on the challenges for future energy transmission lines and the management of parasitics for ultra-fast switching devices", general conference director Leo Lorenz points out..

The regular conference program covers 62 oral presentations in Power Electronics, 21

Around 8.000 visitors and 400 exhibitors are expected at this year's PCIM

presentations in Intelligent Motion, 19 presentations in Renewable Energy and Energy Management, and 175 Poster Papers. Each of the three days a keynote speech will be given such as "Progress in Power Semiconductor Devices and Applications" delivered by Dan Kinzer of Fairchild Semiconductors, "Ultra High Voltage SiC Power Devices and Its Impact on Future Power Delivery System" by Alex Huang of NSF FREEDM Systems Center and "E-Mobility 2020: Power Electronics, a Key Technology for the Effective Deployment of Electric Vehicles in a Low Carbon Society" by Enrique J. Dede of ETSE University Valencia. The keynotes have been already introduced in PEE March 2014, pages 23-24. This preview focuses on some highlights of the power electronics section.

In Search for the Best Paper

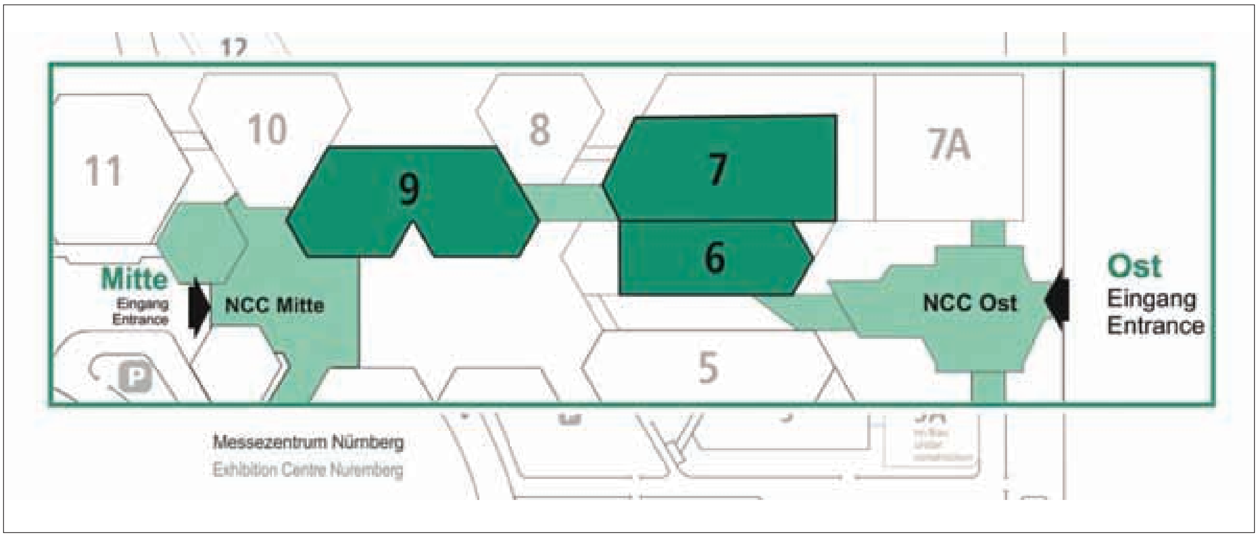
The Best Paper Award, sponsored by Semikron and Power Electronics Europe, comprises a free trip to PCIM Asia 2015. The nominees have been selected already by the conference directors, the final winner will be honored during the opening ceremony on May 20.

The respective papers and nominees are:

* High Dynamic Rotor Oriented Current Control for Permanent Magnet Synchronous Machines with Saturation Characteristics by Tobias Gemaßmer, Jan Richter, Mathias Schnarrenberger, Michael Braun, KIT Karlsruhe Institute of Technology, Germany
* Breakthrough Analog and Logic SiC Integrated Circuits Enable Ultra High Temperature Control Applications by Peter Alexandrov, Matt O'Grady, John Hostetler, Xueqing Li, United Silicon Carbide, USA
* 99.3 % Efficiency of Boost-up Converter for Totem-pole Bridgeless PFC using GaN Gate Injection Transistor by Tatsuo Morita, Hiroyuki Handa, Shinji Ujita, Masahiro Ishida, Tetsuzo Ueda, Panasonic Corporation, Japan
* Configurable Modular Multilevel Converter (CMMC) for a Universal and Flexible Integrated Charging System by Martel Tsirinomeny, Alfred Rufer, EPFL, Switzerland
* Illusion to Accurately Predict Power Losses in Magnetic Materials on the Base of Standard Manufacturer's Datasheets by Robert J. Pasterczyk, Schneider Electric, France; Timote Delaforge, Saint Martin d'Heres, France
* Hybrid Control of 2- and 3-Level Converters by Jens Onno Krah, Markus Höltgen, Cologne University of Applied Sciences, Germany

This first paper presents a new approach to adapt classic linear current control design to permanent magnet synchronous machines with saturation characteristics. All needed parameters for current controller are online calculated from stationary machine measurements. The additional effort compared to control of linear machines is kept as low as possible in order to meet user-oriented requirements. A way to adapt classic control schemes to highly utilized PMSM with saturation effects will be proposed. The additional calculation and memory effort has been reduced to a minimum of two flux linkage look-up tables for both decoupling and derivation of the time constants. Decoupling and voltage saturation are optimized with regard to both steady state and reference steps. The proposed control scheme has been verified by experimental results.

With the advance of wide bandgap power devices and modules, there is an essential need for comparable high temperature analog control and sensing electronics that can operate in close proximity to "Point of Load" i.e. mounted alongside the power devices and sensors. This second nominee will present preliminary results on developing basic analog and logic integrated circuits based on innovative SiC JFET technology that achieve operation in excess of 300°C. Operational amplifiers and logic gates were built



Additionally hall 6 featuring the industry forum will be available for this year's PCIM

and their operation is demonstrated at temperatures up to 310°C, limited by the available test environment. More characterization will be done at higher temperatures to evaluate the circuit ultimate temperature capability.

In the third paper a highly efficient operation of a boost-up converter for bridgeless power factor correction (PFC) using normally-off GaN Gate Injection Transistors (GITs) in a novel totem-pole output circuitry will be presented. The normally-off device by a single chip enables its flip-chip assembly which effectively reduces the loop inductance in the circuit. The fabricated boost-up converter exhibits the peak efficiency of 99.3% and efficiency of over 99% is maintained in the wide range of the output power from 450 W to 2 kW. The maximum output power of 2 kW is the highest ever reported for the efficient boost-up converter. The GaN-based converter is very promising for the highly efficient power supply expected in the future.

Electric Vehicles (EVs) owners are confronted by the limited compatibility of available charging infrastructures. Therefore, the fourth paper is focused on presenting a Configurable Modular Multilevel Converter (CMMC) for a universal and flexible integrated charging system, where the motor windings are used as filter during the charging operation and the battery pack is split into modules. This concept is designed for a large range of charging infrastructure; from AC household basic supply to AC or DC ultrafast charging. Particular attention will be paid to the fundamental dynamical processes that govern the transfer of energy during ultrafast charging. In fact, the switching mode is controlled by a shifted angle between the upper-arm and lower-arm currents. This concept allows interfacing to worldwide charging infrastructures.

One of the key indispensable component in any switched power converter is an inductance or transformer utilizing obviously the magnetic core. Designing teams are constantly challenged to optimize their performances and cost basing on supplier's datasheets. The fifth BPA nominee will present an overview of common engineering errors made on powder core losses prediction and proposes modifications to be done for more accurate approach. The data given by manufacturers are investigated and drawbacks are shown. A survey of existing modifications are also to be presented. New necessary considerations are explained and their relevance is documented with figures and examples. This work is a part of a global new approach to power converters conception by accurate modeling and mathematical optimal sizing.

Current control is essential to ensure required performance of the power converter in the presence of uncertainties and to provide means for attenuating system disturbances especially for low inductance systems. The final nominee BPA paper will present a new FPGA based approach to control inverters by utilizing space vector pulse width modulation and simultaneously by a supervising 3-phase hysteresis current controller for fast suppression of significant disturbances. By utilizing the proposed Hybrid Control operating an inverter with space vector pulse width modulation is getting as easy as a standard laboratory power supply. If the current reaches specified bounds it will be automatically limited. The presented FPGA implementation of Hybrid Control is lean and straight forward. Laboratory results will be presented and discussed.

	Dienstag, 20. Mai		Mittwoch, 21. Mai		Donnerstag, 22. Mai
10:00 -10:40	**Innovation - Award** ECPE/ Semikron	10:00 - 12:00	**B2B eBusiness & Social Media in Power Electronics** SindoPower - Semikron	10:00 - 11:00	**Forecasted trends for power packaging** Yole Développement
11:00 -12:00	**The ECPE Network** ECPE	12:20-13:20	**Mature Wide Band Gap Semiconductors** Bodo's Power Systems	11:00 - 12:00	**Life-Time Testing of IGBT power modules** Mentor Graphics
12:30 -13:30	**European Power Electronics Leadership** ENIAC Joint Undertaking	14:00 - 16:00	**Si vs SiC/GaN Competition or Coexistence** Power Electronics Europe	12:30 - 14:30	**E-Mobility** Fraunhofer IISB
14:00 -15:00	**Power Semiconductors** Infineon			14:30 - 15:30	**Introducing "Clipper®" technology** Springburo GmbH
15:30 -16:30	**Public Funded Project "ProPower„** BMBF				

Young Engineers at Work

Three outstanding contributions from authors not older than 35 years old will receive the "young engineers awards", sponsored by ECPE, Infineon and Mitsubishi Electric, which will be also honored in the PCIM Europe conference opening ceremony. Ten nominees are looking to receive one of these three awards.

A Fast Switching, Scalable DC-Breaker for Meshed HVDC-SuperGrids by Yeqi Wang, University of the Federal Armed Forces Munich, Germany, is the first nominee. The increasing importance of electric energy and the necessary shift from fossil fuels to regenerative sources imposes great challenges for the High-Voltage Grid. A large meshed HVDC-Super Grid has been proposed by several experts as the best solution. The paper deals with the requirements of the main components of such a grid with focus on their fault handling abilities. A new concept for a fast switching DC-Breaker will be presented and investigated. The final paper will present measuring results of a prototype of this new type of DC-Breaker.

Interleaved Switching of Symmetrical Six Phase Drives by Daniel Glose, Technical University of

LEFT: Industry Forum program in hall 6

LEFT: More than 700 conference delegates from all over the world are expected for this year's PCIM

Munich, Germany, is the second nominee. Six-phase machine drives are a cost effective alternative for high power applications. Due to their higher amount of phases and switching elements compared to three-phase drives, they provide an increased reliability through redundancy and additional degrees of freedom for control. In total, 64 voltage vectors can be generated, including nominal and medium length vectors. Thus, new modulation techniques are applicable. In this paper, an interleaved variant of conventional space vector modulation is discussed. The machine and the inverter models are derived from a decomposition technique and the total harmonic distortions in each decomposed subspace is calculated. Simulations and experiments show a good correlation of the current distortion between the model and a real 15 kW system.

Advanced Control Scheme to Improve the Efficiency of 3-Level Active Front End Inverters for Servo Drives by Markus Höltgen, Cologne University of Applied Sciences, Germany, is third. Utilizing the burst mode well known from single phase rectifiers with active power factor correction can improve the energy efficiency of 3-phase active front end converters and can also simplify the converter schematics. Especially if the current smoothing inductors are not inverter integrated replacing the 3-phase line voltage measurement by reliable line voltage estimation is an advantage.

Highly Efficient Low-Voltage DC-DC Converter at 2-5 MHz with High Operating Current Using GaN Gate Injection Transistors by Hidekazu Umeda, Panasonic, Japan, is the fourth YEA nominee. A low-voltage DC-DC converter using GaN Gate Injection Transistors (GITs) demonstrates highly efficient operation at 2-5 MHz with high output current. Reduction of the gate lengths of the GITs and optimized design of the field plates significantly improve the figure-of-merit down to 19 mΩnC. The peak operating efficiency at 2 MHz reaches 90 % for the conversion from 12 V to 1.2 V, while the operating current can be increased up to 50 A by a single converter module. The converter also can serve 5 MHz operation with the peak efficiency of 81 %, while conventional Si devices cannot be operated at such high frequencies.

A Novel Design Concept for Modular Multilevel Converter Power Modules by Uwe Waltrich, Fraunhofer IISB, Germany, is the fifth YEA candidate. Modular multilevel converters are subdivided into identical submodules. Current high power systems for transmission (i.e. HVDC) consist of state of the art industrial semiconductor modules. Therefore great improvements are possible by optimizing the construction of the power modules for this special application. A promising concept is to silver-sinter the bottom switch directly onto the heat sink, which removes unnecessary isolation barriers. In this work the thermal resistances of different design concepts were simulated and compared to the state of the art. As a result, an improvement of 300 % in the thermal performance is attainable, which was confirmed by measurements.

Application of Nucleate Boiling with Micro Structured Surfaces for Electronic Cooling by Mike Zinecker, Chemnitz University, Germany, is the sixth YEA applicant. In his study a cooling technology based on a two-phase-change of a working fluid will be presented. With special micro structured heat transfer surfaces, the boiling rate increases compared to smooth surfaces. Large amounts of heat up to several kilowatts can be removed by intense boiling of the working fluid, also with small surface areas. For the generation of appropriate micro structures, different micro manufacturing technologies can be applied, as demonstrated in this paper. The presented results of systematic experiments show the capability of this cooling technology for power and high-power electronics.

Improving Performance of High Speed GaN Transistors Operating in Parallel for High Current Applications by David Reusch, Efficient Power Conversion (EPC) Corp, USA, is also looking for the YEA. GaN-based power devices are rapidly being adopted due to their ability to operate at frequencies and switching speeds beyond the capability of silicon power MOSFETs. In this paper, paralleling high speed GaN devices in applications requiring higher output current will be discussed. This work will include the impact of in-circuit parasitics on performance and propose PCB layout methods to improve parallel performance of high speed GaN transistors. A 48 V to 12 V, 480 W, 40 A buck converter operating at a switching frequency of 300 kHz in an optimized parallel layout achieving efficiencies above 96.5 % from 35 % to 100 % load will be demonstrated.

Impact of Module Parasitics on the Performance of Fast-Switching Devices by Christian Müller, Infineon Technologies, Germany, is the eighth YEA applicant. The interaction between the switching performance of fast-switching devices, e.g. a high-voltage power MOSFET, and module parasitics in the gate circuit or in the module layout is investigated. For this purpose, the effects and interactions of the parasitics with gate resistance, chip current, and temperature are explored by the help of a full-factorial approach. A model is derived for describing this interdependency, and critical parameter values are identified to safely utilize fast-switching devices. Furthermore, it is shown that a reduction of the switching losses up to 30 % is achieved by proper design of the parasitics in the gate-driver circuit.

High Efficiency Parallel-parallel Interleaved LLC Resonant Converter for HV/LV Conversion in Electric/Hybrid Vehicles by Gang Yang, Supelec, France, is the nineth YEA nominee. A hybrid/electric automobile oriented 2.5 kW, 250 kHz, HV/LV double phase parallel-parallel interleaved LLC resonant converter is presented. This paper proposes the concept of parallel-parallel LLC topology with its double loop control strategy to share the power equally between the two power cells and to maintain a high efficiency among a wide output power range. The influence of secondary leakage inductance into the LLC's voltage conversion ratio is presented and discussed. This paper also presents an innovative transformer design to minimize the total magnetic component volume and a novel power module for LV MOSFET synchronous rectification. This converter prototype adopts a vapor chamber as a cooling solution and is totally air-cooled. The resonant converter is targeted for utilization in electric vehicles and hybrid vehicles with an input voltage range of 220-410 V, an output voltage range of 12-16 V, and a nominal output power of 2.5 kW. The total prototype performs 3 kg, 2.5 l, with a nominal efficiency higher than 94 % and a power density 1W/cm^3.

Simultaneous Online Estimation of Junction Temperature and Current of IGBTs Using Emitter-auxiliary Emitter Parasitic Inductance by Vinoth Kumar Sundaramoorthy, ABB Switzerland, is the

	Sonntag, 18. Mai 2014		Montag, 19. Mai 2014
14:00 –17:30	Seminare	9:00 – 17:00	Tutorials

	Dienstag, 20. Mai 2014		Mittwoch, 21. Mai 2014		Donnerstag, 22. Mai 2014
09:00	Eröffnung und Keynote	08:45	Keynote	08:45	Keynote
11:00	Oral Sessions	10:00	Oral Sessions	10:00	Oral Sessions
14:00	Oral Sessions	14:00	Oral Sessions	14:00	Oral Sessions
15:30	Poster Sessions	15:30	Poster Sessions		

Conference outline at a glance

final YEA applicant. A novel method is presented for online estimation of the junction temperature of semiconductor chips in IGBT modules, based on the voltage drop across the parasitic inductor that exists between the main emitter and auxiliary emitter terminals. The peak amplitude of the voltage drop was found to depend on the junction temperature at a known current and DC link voltage. Also, the collector current can be estimated without the use of any additional sensors. Measurement circuits were implemented to estimate junction temperature and the current, and their results are discussed.

Special Sessions

HVDC – A Challenge in the Future, is scheduled for the morning session on May 20. This session chaired by Josef Lutz from Chemnitz University of Technology comprised four papers: Calculating the harmonics at the connection point of a modular multilevel HVDC converter by Mike Dommaschk from Siemens (D); A New Thyristor Platform for UHVDC (>1 MV) Transmission by Jan Vobecky, ABB Switzerland; A New 4.5 kV IGBT and diode chip set for HVDC Transmission Applications by Josef Georg Bauer, Infineon Technologies (D); and A fast switching, scalable DC-Breaker for meshed HVDC-SuperGrids by Yeqi Wang, University of the Federal Armed Forces Munich (see YEA awards).

Designing Packages for Fast Switching is scheduled for the morning session on May 22 and chaired by Eckhard Hoene from Fraunhofer IZM. This session covers three papers: Integrated Packaging Allows for Improvement in Switching Characteristics of Silicon Carbide Devices by Cyril Buttay, University of Nottingham (UK); SiC-JFET in Half-bridge Configuration – Parasitic Turn-on at Current Commutation by Daniel Heer, Infineon Technologies (D); and Packages for Fast Switching HV GaN Power Devices by Kirill Klein, Fraunhofer IZM (D).

Seminars and Tutorials

On the two days before the conference gets underway, internationally renowned experts will share their knowledge on the principles and specific topics of power electronics in six half day seminars and 10 full day tutorials. For the first time, the program will include the tutorial “Power Electronics and Control for Grid Integration of Renewable Energies and Energy Storage Systems”. This tutorial serves the growing demand for training in power electronics and solutions for renewable energies. **AS**

Silicon Carbide in Automotive

Some of the first markets to use SiC include the server, industrial, telecom, lighting, and induction heating power supply markets. Since then, SiC has also penetrated the solar, UPS inverter, drives, and avionics markets. Most recently, SiC power components have begun to permeate automotive applications such as on-board and off-board chargers, and on-board auxiliary power supplies in electric vehicles (EVs) and hybrid electric vehicles (HEVs). **Jeffrey B. Casady, Ph.D., Business Development & Programs Manager, Cree Power & RF, Durham, USA**

The SiC power semiconductor industry has penetrated many markets since the first full release of SiC diodes in 2001, SiC power transistors in 2011, and SiC power modules in 2012 [1-4]. Now, for the first time, 900 V SiC power transistors are being considered for automotive EV/HEV drivetrain inverters and (when applicable) boost stages.

SiC Diodes

For automotive applications, voltage ratings of 600 V to 900 V are most common. SiC diodes are a mature technology, with over 100 different products in the market and over 13 years of field history. Cree alone manufactures more than 70 diode products with voltage ratings ranging from 600 V to 1700 V, current ratings spanning 1 A to 50 A, and package options including through-hole, surface mount, and bare die. Several other power semiconductor vendors also offer SiC diodes.

Cree 650 V and 1200 V SiC diodes are currently designed in, and being shipped for, multiple on-board and off-board charger products in mainstream commercial automotive markets. Using SiC, customers can achieve compact power densities and lower heat dissipation not possible in Si. The SiC diodes used are fully automotive qualified. Not only do the customers value the compact size, lower heat dissipation, and higher efficiency SiC offers, the reliability is a key selling point as well. After more than 13 years in the market, the failure-in-time (FIT) rate of SiC diodes is better than Si, and is less than one fail per billion hours of operation for Cree.

SiC MOSFETs

For SiC, 1200 V and higher MOSFETs have been fully released in the marketplace since 2011, and these MOSFETs are currently being used in automotive for auxiliary power supplies and off-board chargers connected to three-phase power. 650 V to 900 V SiC MOSFETs in development are targeted at automotive OEMs and Tier One suppliers as pre-released products in 2013-14 for primarily on-board drivetrain applications.

Last year, the Cree C2M0080120D 1200 V SiC MOSFET was designed into the HEV/EV power converter (auxiliary power supply) pictured in Figure 1, which achieved a 25 % reduction in product size and reduced peak power losses by 60 % according to the manufacturer, Shinry Technologies [5]. This converter was designed for use in an HEV/EV bus using a 750 V DC input and 27 V DC output with an active clamp topology. The DC-DC topology with SiC MOSFET is active clamp forward topology. Key improvements enabled by the SiC MOSFET include: raising efficiency from 88 % to 96 %, reducing size and weight by 25 % to 60 %, and eliminating cooling fans, which realized reductions in both cost and audible noise

By using 1200 V SiC MOSFETs in its 3- to 10-kW DC-DC converters in place of comparable Si components, Shinry achieved considerable efficiency improvement and significant size and weight reduction that were not possible with Si components due to the inherent switching efficiency advantages of SiC relative to Si power switches. The benefits achieved in this example are typical of automotive applications that adopt SiC technology in place of Si. With SiC adoption, users can expect to achieve one or more metrics – system cost, power density, form, fit, and/or function – that are not attainable with Si [6-7]. Consequently, the 1200 V C2M SiC MOSFETs (available in a TO-247 package with 25-, 40-, 80-, 160-, or 280-m? ratings or multiple module platforms) are now employed in the on- and off-board HEV/EV chargers and auxiliary power supplies manufactured by a number of customers. Like IGBTs, the C2M family of SiC MOSFETs is also well suited for paralleling to be used in higher current rated applications [8].

In addition to substantive performance gains, the SiC MOSFET has some other salient advantages. For example, SiC MOSFETs contain a rugged built-in body diode, which eliminates the need for an external anti-parallel Schottky diode in some applications. Body diodes are not present in Si IGBTs and are often unused in Si super junction MOSFETs as well due to poor turn-off performance. In SiC MOSFETs, the body diode has a minimal turn-off loss, enabling reliability improvements in the system. The built-in body diode also reduces the part count, which cuts costs and mitigates implied

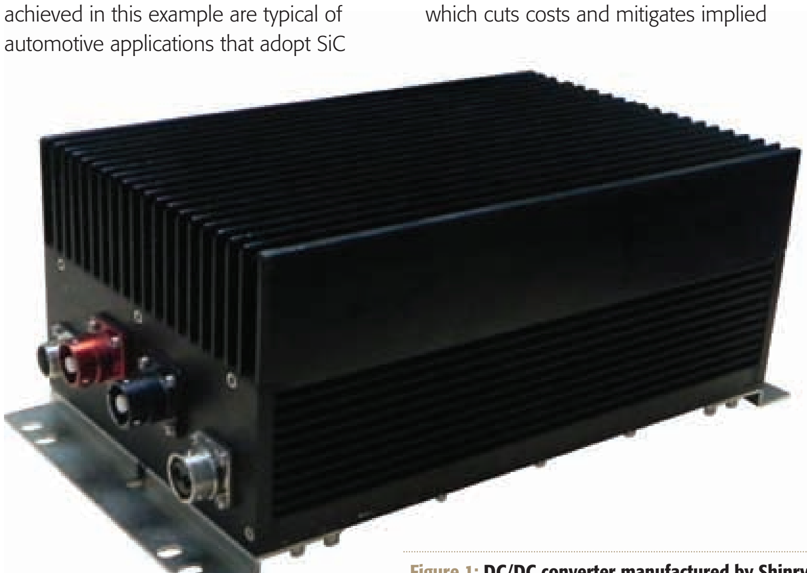


Figure 1: **DC/DC converter manufactured by Shinry Technologies for an HEV/EV bus application**

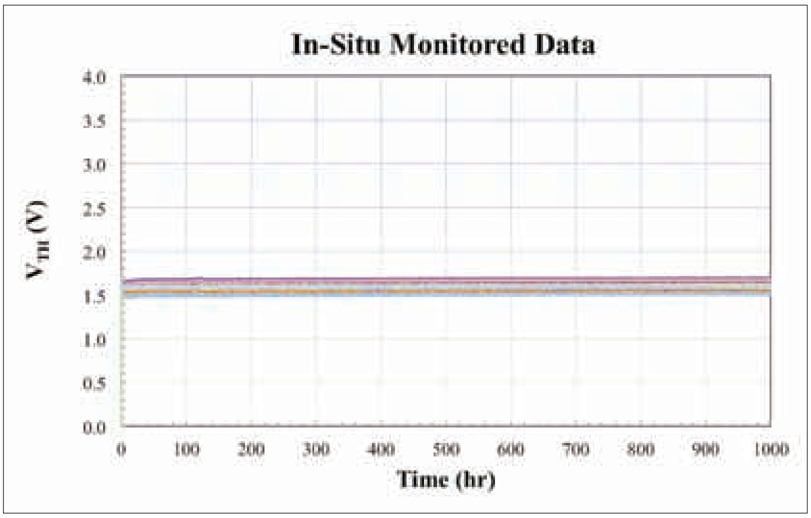


Figure 2: A bias of -15 V applied to Cree's C2M0160120D 1200 V SiC MOSFETs for 1,000 hours at 150°C, which exceeded the maximum recommended value of -10 V in the datasheet. Test results measure an average threshold voltage shift of a negligible 10 mV over the duration

reliability concerns from additional components, wire bonds, and die attach.

Reliability testing conducted on C2M080120D SiC MOSFETs at 150°C for 1,000 hours, constant gate voltage of -5 V, and constant diode current of 10 A reveals that the use of this body diode is very stable. A total of 39 parts were sampled and the only voltage shifts measured were a negligible 0.68 mV shift in the body diode forward voltage drop and a similarly low 4.5 mV shift in the MOSFET on-state voltage [7]. SiC MOSFETs are also extremely stable at higher temperatures. Per Figure 2, a bias of -15 V was applied to C2M0160120D 1200 V SiC MOSFETs for 1,000 hours at 150°C, which exceeded the maximum recommended value of -10 V in the datasheet. Despite this fact, test results measured only a slight 10 mV average shift in V_{TH} and a modest 3.2 mΩ in R_{DSON} [7].

900 V SiC MOSFET Breakthrough

New MOSFET technology will enable even better efficiency, cost, and gate driver control via breakthrough improvements in the on-resistance per unit area, which has progressed from 5 mΩ·cm² in 1200 V commercial SiC MOSFETs (such as the C2M0160120D) to 2-3 mΩ·cm² in 900 V SiC planar MOSFETs [9]. This latest SiC MOSFET technology still uses the same basic, reliable, planar DMOS structure shown in Figure 3, which allows 900 V SiC power transistors to provide breakthrough performance with specific RDSON reductions of over 40 % when compared to the best available 1200 V Si MOSFETs on the market today. This development will enable more cost effective, lower voltage SiC power transistors that exhibit more efficient switching capabilities at higher frequencies. These SiC MOSFET design improvements and their subsequent performance benefits provide opportunities to reduce the overall system cost in next-generation automotive traction inverters.

900 V SiC MOSFET vs. Si Super Junction MOSFET

To benchmark the performance of the new 900 V SiC MOSFET, we can compare the energy stored in the output capacitance (E_{OSS}) of the 900 V SiC MOSFET with advanced super junction Silicon MOSFETs available commercially at 650 V and 900 V. In Figure 4, the E_{OSS} of Cree's 900 V SiC MOSFET is contrasted at 150°C with 900 V Si super-junction and found to be approximately three times lower over the measured R_{DSON} values. In fact, the E_{OSS} of the 900 V SiC MOSFET is comparable (20-30 %) to a 650 V Si super junction MOSFET even though the SiC MOSFET offers 50 % higher breakdown voltage for greater safety margin and also uses the internal body diode.

Another advantageous feature of the 900 V SiC MOSFET is that its high temperature conduction losses are notably reduced relative to Si or GaN. Figure 5 [9] illustrates the normalized R_{DSON} of the 900 V SiC MOSFET, a 600 V GaN transistor, and a 600 V Si super junction transistor compared up to 150°C. At 150°C, the GaN transistor R_{DSON} has increased almost twice (1.85) as much as the 900 V SiC MOSFET, and the 600 V Si super junction transistor has increased almost 2.5 times as much.

900 V SiC MOSFET vs. 650 V Si IGBT

When comparing a 900 V, 65 mΩ SiC MOSFET to a 600 V, 30 A IGBT under the same test conditions (400 V, 150°C, and 10 A), the switching energies measure approximately 60 µJ for the 900 V SiC MOSFET and 260 µJ for the 600 V Si IGBT, which means that the SiC MOSFET exhibits switching energies that are over a

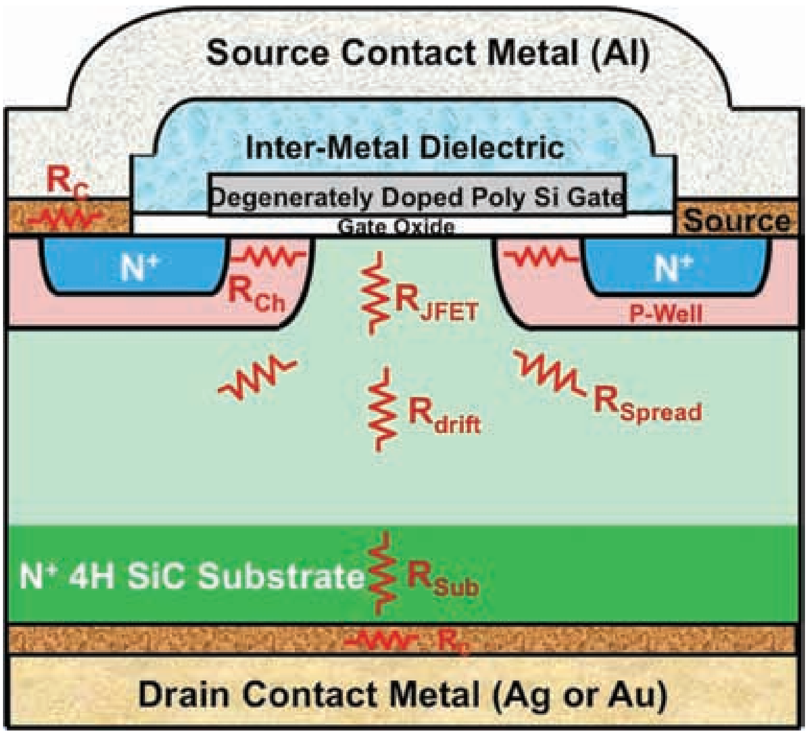


Figure 3: Cree commercially released the Planar SiC double-implanted metal oxide semiconductor (DMOS) structure shown here in 2011. A second-generation (C2M) family was released in 2013, and development samples are being sampled to key customers in 2014. Each generation retains the same basic structure, but specific on-resistance improves with each new series

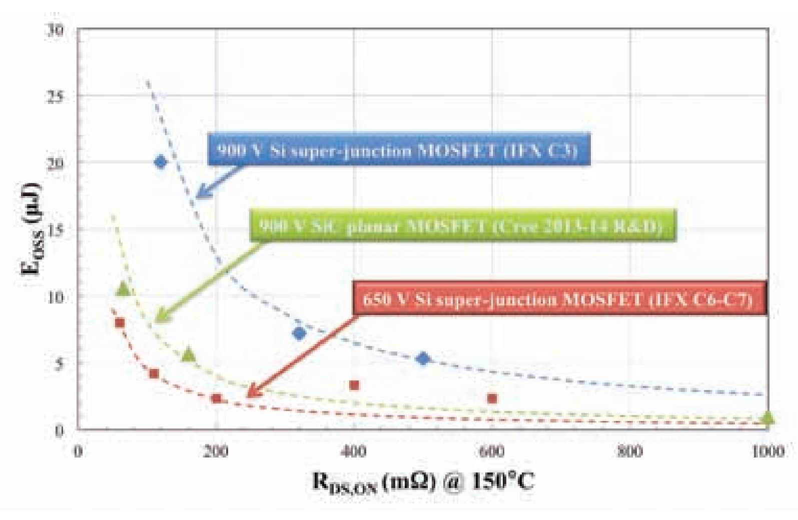


Figure 4: **EOSS over RDSON range for Cree's new 900 V SiC MOSFET compared to Si SJ MOSFETs at 650 V and 900 V. The new 900 V SiC MOSFET offers substantially (3X) better performance than the 900 V Si SJ MOSFETs, and is comparable to 650 V Si SJ MOSFETs**

factor of 4 lower than those of the Si IGBT despite having a 50 % higher rated blocking voltage, use of an internal body diode, and bi-directional conduction without a knee voltage.

Estimated impact of 900 V SiC MOSFET on specific power and power density in automotive traction inverters at this early stage is limited, but demonstrations elsewhere strongly suggest the potential of obtaining high power densities (well above 20 kW/l) with very high (99 % peak) efficiency [10]. For customers with 400-700 V bus voltages, Cree's new 900 V SiC MOSFET allows system level performance and cost not possible with 650 V Silicon IGBTs or MOSFETs. Higher breakdown voltage, lower on-state and switching losses, reduced part count (through use of the MOSFET body diode), and enhanced ruggedness are now able to be realized at a system level. With other SiC power components, such as the 650 V diodes and 1200 V SJ MOSFETs already in production on automotive platforms, this new 900 V SiC MOSFET will be ready for timely evaluation in traction inverter designs for HEVs/EVs.

Literature

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[9] J. W. Palmour, L. Cheng, V. Pala, D. J. Lichtenwalner, E. V. Brunt, G-Y Wang, J. Richmond, M. O?Loughlin, S. T. Allen, A. A. Burk, and C. Scozzie, "Silicon Carbide Power MOSFETs: Breakthrough Performance from 900 V up to 15 kV," International Symposium on Power Semiconductor Devices and ICs, June 15th-19th, 2014.

[10] K. Sasaki, S. Sato, K. Matsui, Y. Murakami, S. Tanimoto, and H. Tanisawa, "40 kW/L High Switching Frequency Three-Phase 400 Vac All-SiC Inverter," Materials Science Forum Vols. 740-742, pp 1081-108, © (2013) Trans Tech Publications, Switzerland.

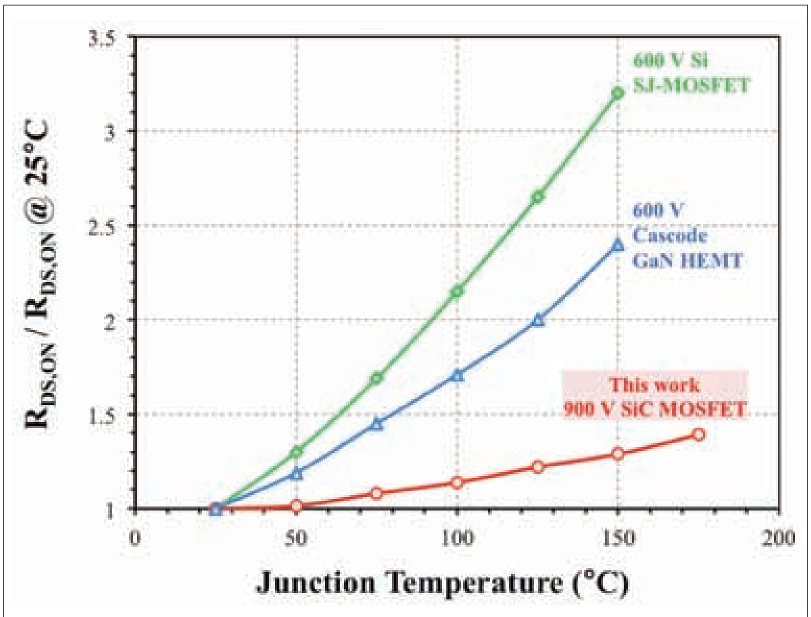


Figure 5: **New breakthrough 900 V SiC MOSFETs have a much lower increase in RDSON over temperature relative to both 600 V Si and GaN power transistors**

A New Gate Driver IC Family that Fits All

Infineon Technologies presents the new EiceDRIVER™ Compact family, a single channel gate driver IC for general purpose. The different variants of the family are intended to support discrete IGBTs, IGBT modules and MOS transistors, but also SiC and GaN switches. **Oliver Hellmund, Heiko Rettinger and Michael Wendt, Infineon Technologies, Germany**

Ranging from 0.5A up to 6A output current, the available devices allow gate driving of IGBTs and MOS transistors with different power classes. The DSO-8 package of the EiceDRIVER™ Compact ensures a small footprint and higher power density. Additionaly, the reduced complexity facilitates the integration into system designs. The coreless transformer isolation technology ensures an undisturbed operation at offset voltages up to ± 1200 V and a common mode transient immunity (CMTI) of more than 100 kV/µs. This is a significant improvement in robustness and a new milestone when it comes to galvanically isolated drivers.

The 1EDI20N12AF and 1EDI60N12AF are intended to drive MOSFETs, SiC, and GaN switches. The output current to drive the gate is set at a minimum of 2 A or 6 A. Both devices have a separate charge and discharge output to adapt the turn on and turn off phase to the application by using different resistor values. With the propagation delay below 105 ns and the input filter time of only 40 ns the device can be used up to 4 MHz for high switching frequency applications as SMPS. Both types are optimized for utilization with power semiconductors based on the CoolMOS™ technology. The undervoltage threshold UVLO is fitting to proper MOS transistors operation. The EiceDRIVER Compact in conjunction with the new CoolMOS C7 device in a 4 pin package enables an additional gain in efficiency of 0.5 %. Besides SMPS these drivers are recommended for applications such as PFC, server, telecom, solar, buck/boost converter and PC power.

The 1EDI05I12AF, 1EDI20I12AF, 1EDI40I12AF and 1EDI60I12AF are intended to drive discrete IGBTs and IGBT modules with a gate output current from at least 0.5 A to 6 A. The four variants also have separate outputs for charging and discharging the gate, similar to the 1EDI20N12AF and 1EDI60N12AF. The drivers are designed with a large built in input filter of 230 ns for robust PWM operation in harsh environments. As a result, these driver ICs are characterized by an enlarged propagation delay of 300 ns. The delay time is trimmed for better matching of the switching behavior of different devices. Typical applications are drives, solar inverters, welding or inductive cooking.

Also belonging to the EiceDRIVER Compact family, the 1EDI10I12MF, 1EDI20I12MF and 1EDI30I12MF feature an Active Miller Clamp instead of the separated charge/discharge outputs. This solution keeps the transistor turned off at high dV/dt across the IGBT even with an unipolar power supply. Details of the Compact family are shown in Table 1.

Coreless Transformer

Compared to previous designs the coreless transformer technology enables higher output currents and therefore higher power density while the same compact DSO-8 package can be used.

Fast switching of the power stage can have a major impact on the system functionality if the driver is not designed for such an application environment. The robust design of the new coreless transformer ensures a high CMTI at a dV/dt operation of more than 100 kV/µs, as tested in an application circuit with CoolMOS transistors [1].

The internal input noise filter will cancel any noise up to a pulse duration of T_{MININ} ±40 ns for MOSFET and T_{MININ} ±240 ns for IGBT variants. Thus, no external filter is needed in standard applications.

The input logic was designed for a wide operating range while the input threshold voltage levels are always linked to the positive input supply voltage. The integrated under voltage lockout circuit will activate the chip at 3 V and, from this level onward, the input high threshold

Sales Code	1EDI60N12AF	1EDI20N12AF	1EDI60I12AF	1EDI40I12AF	1EDI20I12AF	1EDI05I12AF	1EDI30I12MF	1EDI20I12MF	1EDI10I12MF
Package	DSO-8 (150mil)		DSO-8 (150mil)				DSO-8 (150mil)		
Applications	SMPS, PFC, telecom, server, solar, buck/boost converter, PC power		General purpose inverter (GPI), drives (general purpose & servo), welding, IH industrial and cooking, solar inverter, UPS				General purpose inverter (GPI), industrial drives, welding, IH industrial, solar inverter, UPS		
Voltage class	up to 1200V		up to 1200V				up to 1200V		
Output Current	6 A / -6 A	2 A / -2 A	6 A / -6 A	4 A / -4 A	2 A / -2 A	0.5 A / -0.5 A	3 A / -3 A	2 A / -2 A	1 A / -1 A
Separate source / sink output	✓	✓	✓	✓	✓	✓	-	-	-
Active miller clamp	-	-	-	-	-	-	✓	✓	✓
UVLO	MOSFET		IGBT				IGBT		
Propagation delay	105ns	105ns	300ns				300ns		
Max. switching frequency	4 MHz	4 MHz	1 MHz				1 MHz		
Recommendation	CoolMOS™ C7, CP		All 650V and 1200V IGBT modules				All 650V and 1200V IGBT modules		

Table 1: **Product overview of the new EiceDRIVER™ 1EDI Compact family**

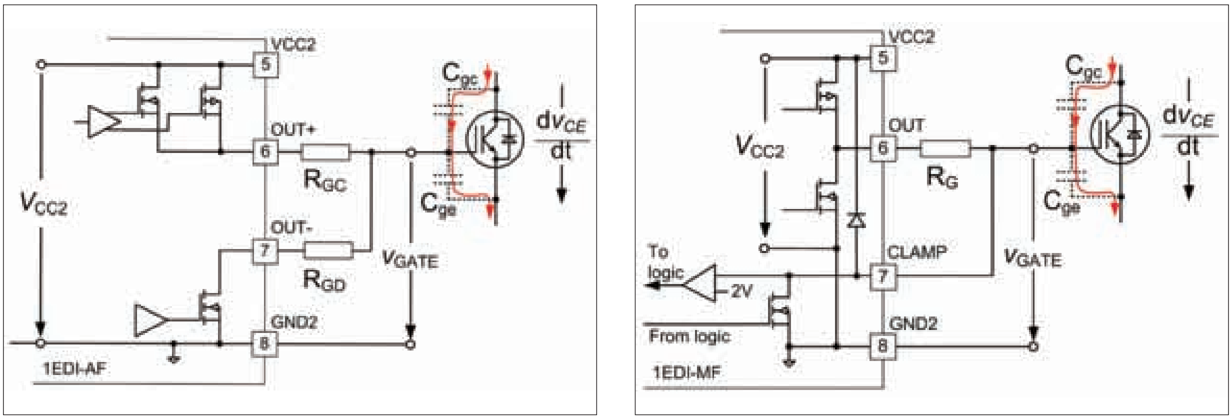


Figure 1: Output block diagram (left: separate output variant; right: CLAMP variant)

voltage will always be at $V_{IN,H}=0.7 \cdot V_{VCC1}$. The input low threshold voltage is set at $V_{IN,L}=0.3 \cdot V_{VCC1}$ accordingly. This linear scaling allows for operations directly from a 3.3 V digital signal processor but is also capable of accepting output signals from a 12 V PFC controller to boost its signal. The maximum input voltage rating is $V_{VCC1,max}=17$ V.

Inverting and Non-Inverting Input

The new 1EDI Compact family members provide the option to use two input signals, one inverting and one non-inverting. These inputs can be utilized in various combinations depending on the application needs. For example, the non inverting input can be used as PWM input while the inverting input can operate as kind of enable signal or vice versa. Another example is the inverted driving of the input, IN+ is high while IN- is low. This can be useful for safety reasons.

If two devices are used to drive IGBTs or MOS transistors in a half bridge configuration, the IN+ signal of the High Side Driver can be connected to the IN- signal of the Low Side Driver and vice versa. In such a configuration a cross conduction is avoided.

The IN+ terminal is internally pulled down to favor off state and the IN- terminal is pulled up respectively. This setup also ensures an off state in all other configurations where an input signal might be connected to a high impedance output, a weak solder joint or a wire break.

Various Output Configurations

The 1EDI Compact family targets a broad range of applications. Different variants are offered to support individual requirements.

The devices with separate output for source and sink are usefull to adapt the application circuit for turned on and off switching behavior. This is made possible by implementing separate gate charge and discharge resistors without the need of an additional external diode. Details are shown in Figure 1, left hand side. The supply voltage can be up to $V_{CC2}=35$V. The IC can be used with unipolar power supply for bipolar gate voltages. As a result, the driving circuit can be simplified with less PCB space and minimized parasitics in the gate loop leading to a better performance.

Another output configuration is shown in Figure 1, right hand side. Here, a common charge/discharge path is combined with an Active Miller Clamp. The advantage of this setup is that the transistor is turned off even with high dV/dt. In this solution the bipolar supply can be avoided to reduce the circuit efforts and PCB space. The driver IC supports unipolar supply of up to $V_{CC2}=20$V which is sufficient for most of the applications.

Due to the low quiescent current of the driver, a simplified supply voltage generation with bootstrap circuit can be used. The driver supports a high modulation index without the need of being equipped with a huge bootstrap capacitor.

An additional benefit of the Active Miller Clamp variant is the integrated diode which clamps the pin CLAMP to V_{CC2}. Since this pin is directly connected to the gate of the power switch there is no additional resistive path compared to the body diode of the general gate output and gate resistor path – normally to be found in similar configurations. Thus, space is saved for another external diode on the PCB. The CLAMP function itself has the same current capability as the output. The 1EDI30I12MF has a minimum peak current of $I_{OUT}=3$ A. The CLAMP circuit becomes active at turn off when the voltage at the CLAMP pin drops below $V_{GATE}=2$ V. At the next turn on the CLAMP circuit is switched into a tri-state mode.

Thermal Performance

The dual chip design of the EiceDRIVER Compact family creates two independent sections of power loss within the package. The input section has been evaluated on its own to exclude effects from the output chip. In the second step of the evaluation the input and output operation have been combined as described in Figure 2.

The temperature increase of a 1EDI60N12AF as a function of input switching frequency of up to 5 MHz and the supply voltage of up to $V_{CC1}=17$ V was tested. The driver IC shows a temperature increase in the area of the input chip of up to 5.5 K at $V_{CC1}=5$ V and of up to 14 K at $V_{CC1}=17$ V.

For the evaluation of the output section, the input was supplied with a

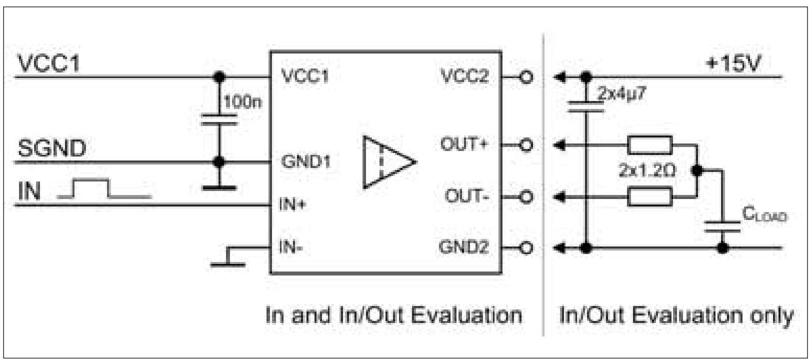


Figure 2: Application usage of logic input

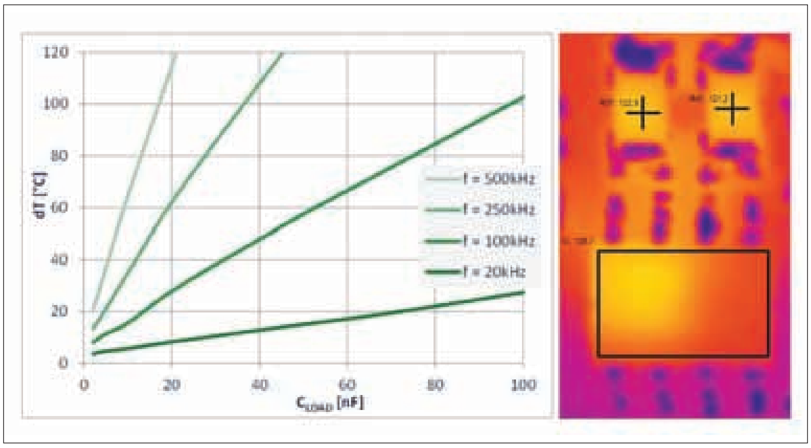


Figure 3: Overall temperature evaluation over capacitive load at various switching frequencies

constant voltage of VCC1=5 V. However the influence of the input chip is minor compared to the power loss in the output chip at V_{CC2}=15 V and 50 % duty cycle. The thermal effects of capacitive load (C_{LOAD}) variation and different switching frequencies are recorded in Figure 3. The power loss was shared between the driver output stage and the two external gate resistors of 1.2Ω each.

Output Current Capability

The output current is one of the most important parameters of a driver IC. The strongest driver ICs of the family, 1EDI60I12AF and 1EDI60N12AF, are rated with a minimum peak current of I_{gate}=6 A at V_{DS}=15 V across the output device. This rating is valid over the whole temperature range, so typical values nearly double during a dynamic short circuit test without external gate resistors. Therefore, the additional booster circuit common to older designs is not needed anymore for many applications. Since the driver can deliver the output voltage up to the supply voltage in on state and down to GND in off state, the disadvantage of the reduced output voltage of a simple boost circuit can be avoided.

Switching Results

The driver 1EDI60N12AF was evaluated in a test circuit by using the CoolMOS IPZ65R095C7 as load for the driver in a boost configuration running at 50 % duty cycle and switching frequency f_{sw}=1 MHz. The typical total gate charge of the transistor is 45 nC [3]. In this test circuit the power supply voltage was 50 V and the gate driver supply voltage was V_{CC2}=12 V. The gate charge resistance and the gate discharge resistance was 1.2 Ω. The output load current was 0.5 A and the supply current of the driver was 56 mA.

With this operation conditions the maximum temperature at the CoolMOS was T_{CM}=81°C and at the driver with T_{Drv}=64°C. For this reason, the capacity of the 1EDI Compact is more than sufficient to drive the CoolMOS C7. Even at high switching frequencies the driver shows proper behavior.

Conclusion

The EiceDRIVER Compact family was developed to be operated with a wide range of discrete IGBT, MOS, modules, SiC and GaN switches. One example of the thermal performance in a test circuit and one typical application circuit were shown and discussed, both proofing the outstanding performance of the new driver family. Due to its innovative design the efforts for the application circuit can be reduced. Wide input supply range and flexible input signal configurations minimize external circuit requirements, complexity and PCB space. The strong driver output and high switching frequency capability eliminates the need for booster stages which, again, saves PCB space and increases overall power density. Several output current / gate current classes and configurations of the driver family guarantee for an optimized system design in terms of layout, performance and cost. With the integrated features and the smart solution of the driver it's easy to use. Thus, the device family matches the requirements of the applications in a cost-driven, high performance and high power density markets. Further details are available at [4].

Literature

1] H. Rettinger, "1ED Compact – A new high performance, cost efficient, high voltage gate driver IC family", PCIM 2014, Germany

[2] J. Hancock, F. Stückler, E. Vecino, "C7 CoolMOS™: Mastering the Art of Quickness", Application Note AN 2012-11 V1.0, Infineon Technologies

[3] Datasheet IPZ65R095C7

[4] http://www.infineon.com/eicedriver-compact

A New Standard in Dual Power MOSFET Packaging

International Rectifier's patented (US6946740) new dual Power MOSFET in a Power Quad Flat No-lead (PQFN) package leverages the latest advances in packaging technology to increase power density, efficiency, and thermal capability in non-isolated DC/DC converters. **Kevin Ream, Power MOSFET Marketing Manager, International Rectifier, El Segundo, USA**

In today's fast paced digital world, technology is constantly evolving at breakneck speeds. Whether it's pushing more content across the web or handheld devices, information in the forms of data, video, or sound is constantly pushing the extremes of communications, data storage, and server technology. The increased bandwidth, memory size, and switching speeds required to support this comes at the expense of increased power. When you throw in variables such as environmental concerns and limited form factors, power density and efficiency become the driving factors in today's power system designs.

Many of today's high performance, high power systems use a distributed architecture for distributing power within. An intermediate bus converter will take the system input voltage and down convert it to a lower bus voltage, typically 8-14 V. This voltage is locally converted to a lower voltage (5 V, 3.3 V, 1.8 V, 1.2 V, 0.9 V,...) to power the processors, DSPs, FPGAs, and/or memory and is typically handled by a synchronous buck DC/DC converter (see Figure 1). Power designers are tasked with optimizing this circuit by trading off efficiency, size, and cost. One option for reducing the size and cost of the circuit is to use a dual MOSFET as opposed to two singles. Given today's advances in Silicon technology and packaging, this has now become a viable alternative.

Traditional Dual MOSFET

A traditional dual MOSFET in a 5 mm x 6 mm PQFN package targeted at synchronous buck DC/DC converters originated from duals in the standard SOIC-8 package and is supported by many vendors in the industry today. It contains both a Control and Synchronous MOSFET whose cross sectional view is shown embedded into Figure 1's simplified DC/DC converter schematic and footprint. The die from the Control MOSFET's source is connected to the Synchronous MOSFET's drain by a copper clip via a common exposed pad. This exposed pad is connected to the switch node in the DC/DC converter. The Synchronous MOSFET's source is connected to the lead frame via a clip. This in-turn is connected to the GND plane of the DC/DC converter.

There are two key disadvantages to the traditional dual MOSFET approach. The main disadvantage is that the drain of the Synchronous MOSFET is connected to the board. Since the Synchronous MOSFET's clip is a thermal bottleneck, most of the heat is transferred out of the PQFN package via the exposed drain pads at the bottom of the board and this drain pad is localized around the switch node of the DC/DC converter. Another major source of heat is the circuit's output inductor, L1 in Figure 1. This is also localized around the circuits switch node. Both of these contribute to a concentrated thermal hot spot at the switch node which leads to unnecessary levels of heat. Note that, this is also true for approaches which use two single MOSFETs. Recall that a MOSFET has a positive RDS(on) temperature coefficient and this unnecessary increase in temperature leads to an increase in conduction losses (I^2R). It is quite ironic that a power designer will sacrifice cost to design in the lowest $R_{DS(on)}$ Synchronous MOSFET only to experience an unwanted rise in conduction losses due to poor thermal performance.

The second disadvantage of the traditional dual MOSFET in a PQFN power

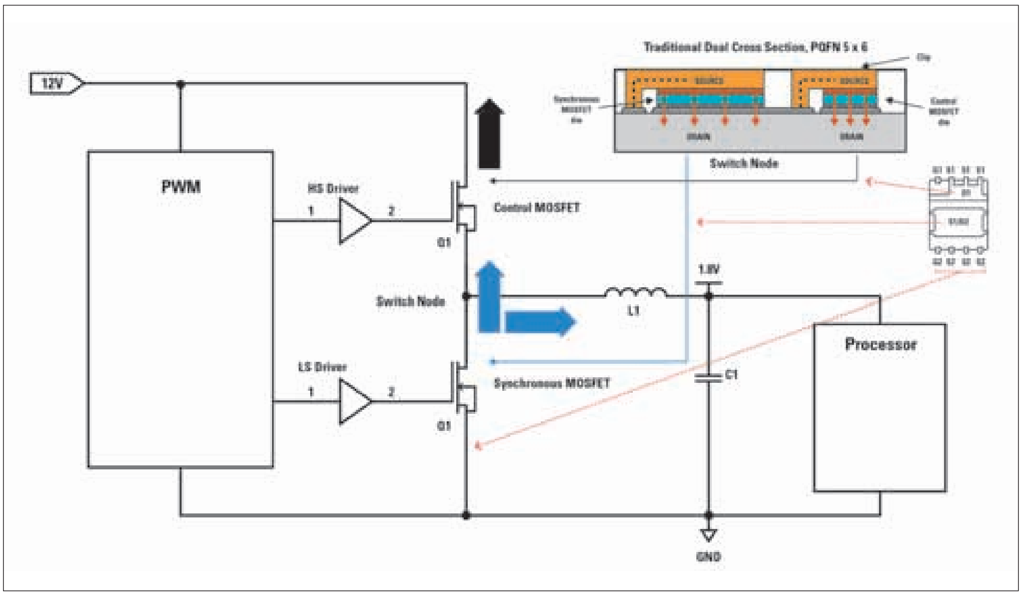


Figure 1: Simplified schematic of Synchronous Buck DC/DC Converter utilizing traditional dual MOSFET

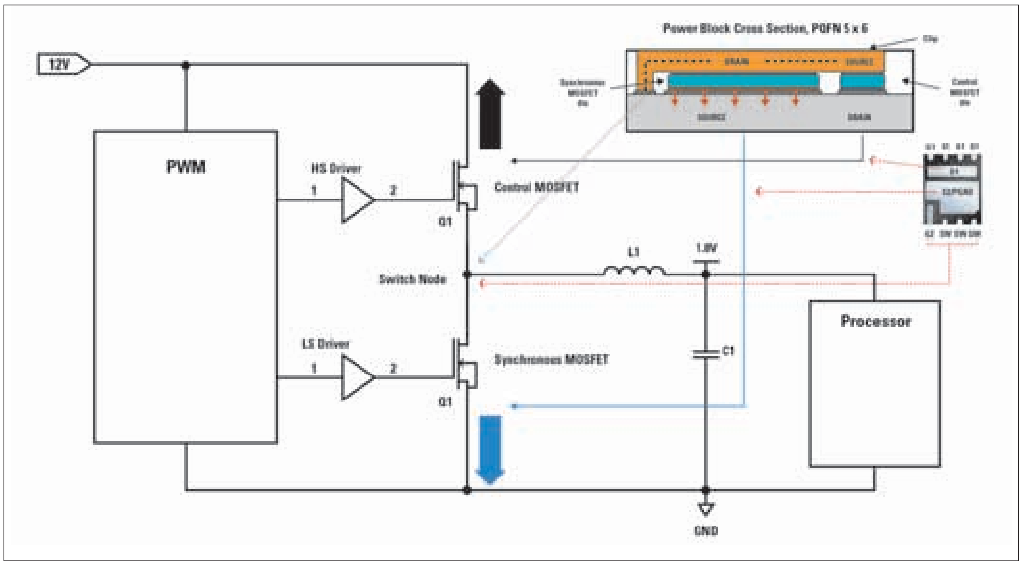


Figure 2: Simplified schematic of Synchronous Buck DC/DC Converter utilizing the power block

package is that it relies on two copper clips for interconnecting the Synchronous and Control MOSFETs. This takes up valuable internal package space which could be used for a larger die, i.e., lower $R_{DS(on)}$ Synchronous MOSFET, leading to a decrease in power density. It also does not allow for optimal placement of the die within the package leading to increased package parasitics and higher peak ringing.

Power Block

Recently, a new package that also contains the Synchronous and Control MOSFET in a single 5 mm x 6 mm PQFN package was introduced. The advantages to this package over a traditional dual include:

- Synchronous MOSFET source (not drain) is facing the PCB
- Single clip to connect the Synchronous and Control MOSFETs
- Multi sourced

Figure 2 shows the cross section of the power block package embedded within the DC/DC converter simplified schematic. Recall that the majority of heat generated in a low-voltage MOSFET is at the junction/source of the device. Notice that the Synchronous MOSFET's source is facing the PCB in the power block package and the single copper clip is the switch node. This source-down configuration allows the majority of the heat within the package to be directed towards the GND plane of the board and away from the switch node and output inductor. This translates into lower PCB and MOSFET temperatures thereby improving the efficiency of the converter.

The power block also employs a MonoFETky synchronous MOSFET which minimizes QRR related switching losses and dead-time diode conduction losses. Combined with an ultra-low package interconnect inductance, this minimizes the reverse recovery current yielding a 0.2-0.4% efficiency improvement over traditional dual MOSFETs. Figure 3 shows the improvements in both efficiency and thermals when comparing the power block to best in-class similarly specified MOSFETs.

Flipping the Synchronous MOSFET also allows for the use of a single copper clip to connect the two MOSFETs within the package whereas the traditional dual uses two clips. This has the following advantages:

- Increased utilization of die area within the package -> higher power density
- Excellent die placement allow optimal input bypassing -> lower peak ringing
- Reduction in package parasitics -> lower peak ringing.

Using a single copper clip also allows for the exposure of the clip on the topside of the package by simple, inexpensive grinding techniques. This could not be reliably achieved with the traditional dual two clip package due to the discrepancies in clip height. Comparing two similarly specified power blocks, both exposed to 200 LFM of air flow, one could realize a 12°C lower PCB temperature (based upon simulation results) leading to a 24% improvement in Total Thermal Resistance (θ_{JMA}).

Given that today's high performance DC/DC converters switch as high as 400-600 kHz, package parasitics become an increasing concern. One of the advantages to connecting the control MOSFET's source to the synchronous MOSFET's drain (switch node) internally via a single copper clip is a significant reduction in package parasitics. If you couple this benefit with the very tight layout of the internal die, designs which

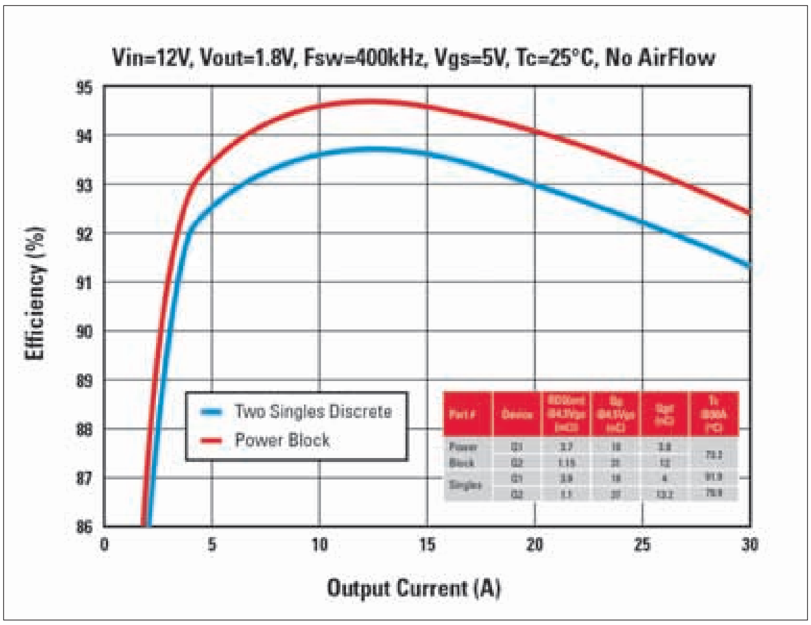


Figure 3: Efficiency and thermal results for power block vs. best in-class singles

had typically used 30 V MOSFETs in the past to accommodate ringing and overshoot can now utilize 25 V Silicon. This translates into a cost savings due to the fact that for the same $R_{DS(on)}$ a 25 V MOSFET's Silicon is smaller than a 30 V device.

Stacked Dual MOSFET

One additional dual used within the industry today stacks the Control MOSFET on top of the Synchronous MOSFET. Similar to the power block, the Synchronous MOSFET's source faces the PCB so efficient heat transfer to the GND plane is realized. One of the main disadvantages to this approach is that by stacking the MOSFETs, the heat from each MOSFET interact causing an unwanted rise in $R_{DS(on)}$, thereby leading to increased power dissipation and lower efficiency when compared to the power block. Additionally, two copper clips are required adding to manufacturing complexity and higher profile of the device. A summary of the pros and cons of each dual package technology is shown in Table 1.

	Traditional Dual MOSFET	Stacked Dual MOSFET	Power Block 
Pro	• Smaller than 2 discretes	• Smaller than 2 discretes • Synchronous MOSFETs source is facing the PCB	• Smaller than 2 discretes • Synchronous MOSFETs source is facing the PCB • Using single copper clip
Con	• Synchronous MOSFET drain (not the source) is facing the PCB • Using 2 copper clips	• Proprietary footprint for a long time (due to unique silicon technology) • Stacked MOSFET makes them heat each other more than non-stacked • Using 2 copper clips	
Foot print	• Industry-standard	• Proprietary	• Industry-standard

Table 1: Pros and Cons of Dual MOSFET package technology

Conclusion

In order to meet the power density and efficiency targets of today's high performance systems, the very best MOSFET silicon AND packaging technology is required. By flipping the synchronous MOSFET so the source side is down (facing the PCB), and internally connecting its drain to the source of the control MOSFET via a single copper clip, the power block package is capable of achieving power densities never before realized by traditional duals. Couple this with the latest high performance silicon, excellent die placement and package utilization, the new power block package is poised to become the industry standard dual for high performance, non-isolated DC/DC converters.

Balancing the Tradeoffs in 3-Phase BLDC Motor-Control Designs

Brushless DC (BLDC) motors are gaining increased market share over other motor technologies, particularly in the automotive and medical markets, and this has prompted the development of new approaches to motor-control design. Now, designers have to decide which approach is best for each application.

Brian Chu, Product Line, Analog and Interface Marketing Manager, Microchip, Chandler, USA

The traditional approach is to develop the motor-control circuit from discrete components, but more recent developments offer single-chip solutions, based on a System on Chip (SoC) or an Application-Specific Standard Product (ASSP), as well as a two-chip approach.

Whilst all of the more recent one- and two-chip solutions offer a reduction in the number of components and in design complexity, each approach has specific advantages and disadvantages. It is these that the designer must understand so that it is possible to make the best possible trade-off between flexibility and space-saving integration.

Regardless of which approach is used, a typical motor system is comprised of three main elements: the power supply section, the motor driver, and the control unit. A traditional, discrete-based circuit, as shown in Figure 1, uses a simple RISC processor with on-chip Flash to control the gate drivers which, in turn, drive the external MOSFETs. An alternative method is to drive the motor directly from a processor, with integrated MOSFETs and a voltage regulator to power the processor and the driver.

All of these elements are typically integrated into a SoC motor driver. In addition, a SoC offers the benefit of programmability, which enables it to be used across different applications. As a single-chip approach, a SoC is also suitable for applications which have limited board-space.

The drawback of using a SoC-based design is that its lower processing performance and limited internal memory mean that it cannot meet the demands of applications which need advanced motor control. A further drawback is that, compared to the broad development toolsets provided by microcontroller manufacturers, there is significantly less support for firmware development in SoC motor drivers.

Alternative Control Designs

The alternative single-chip approach is to use an Application-Specific Standard Product (ASSP) motor driver, designed specifically for each application. The advantages of using an ASSP are that they occupy minimum space on the board which makes them ideal for space-constrained applications. A 10-pin DFN standalone fan motor-driver is shown Figure 2. ASSPs also eliminate the need for software tuning whilst offering an excellent price-performance ratio in high-volume applications and performance which can match that of a high-end microcontroller. An ASSP motor driver can, for example, be used to drive a BLDC motor using sensorless and sinusoidal algorithms. Despite these advantages, ASSPs lack the programmability which would enable them to be scaled up to higher drive strengths and the flexibility to adapt to future changes in the market.

Whilst the design strategies based on a SoC or an ASSP can help designers to meet the continual trend towards miniaturisation, other applications are using the two-chip approach combining a microcontroller optimised for intelligent analogue in conjunction with an external driver. This approach allows the designer to choose from a broad range of microcontrollers optimised for sensor or sensorless commutation using trapezoidal or sinusoidal drive techniques.

Power MOSFET adaption

When choosing the companion driver chip for the microcontroller, it is essential that the driver should do more than provide suitable power-ratings for the MOSFET or

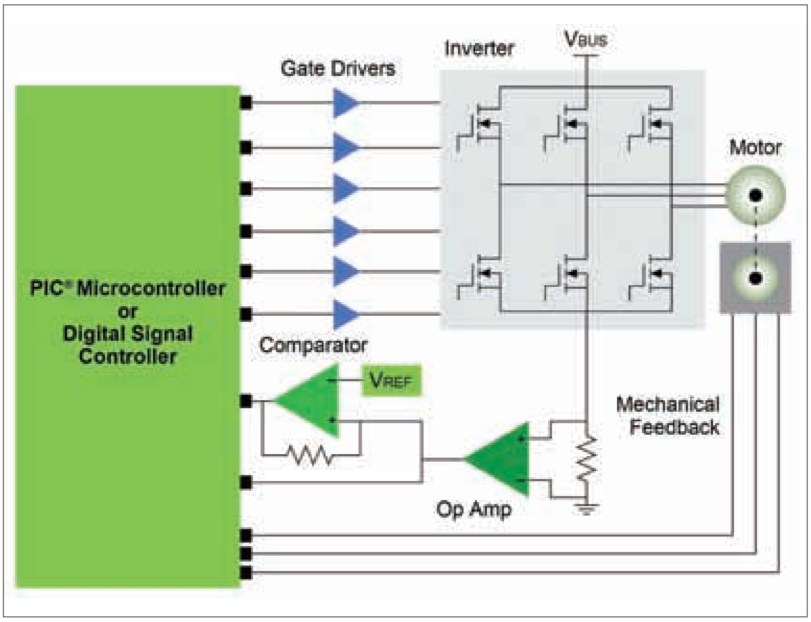


Figure 1: Block diagram of a traditional, discrete-based BLDC motor

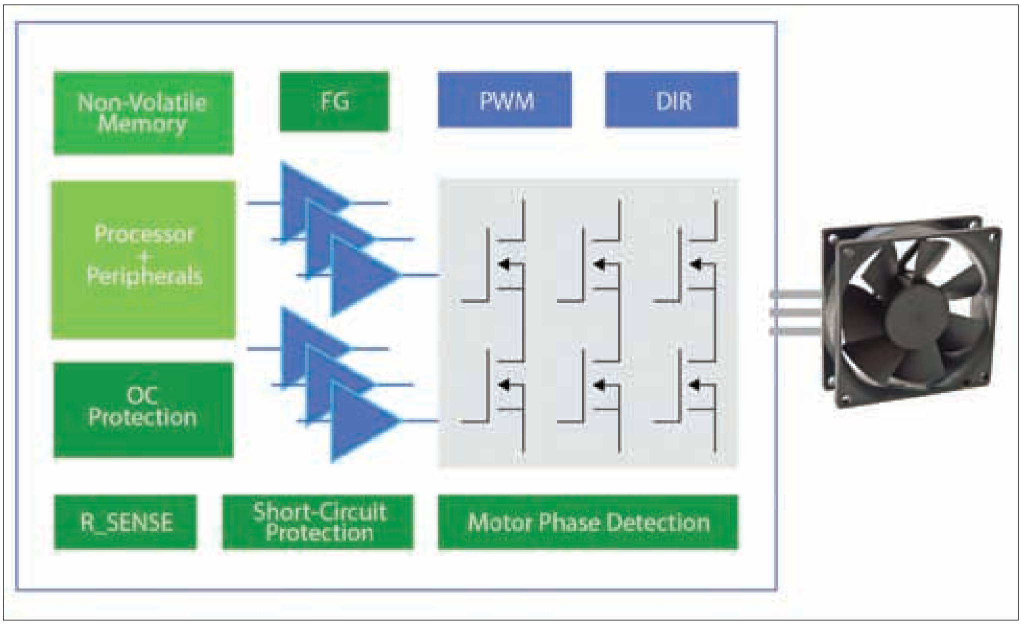


Figure 2: Block diagram of a standalone fan motor driver

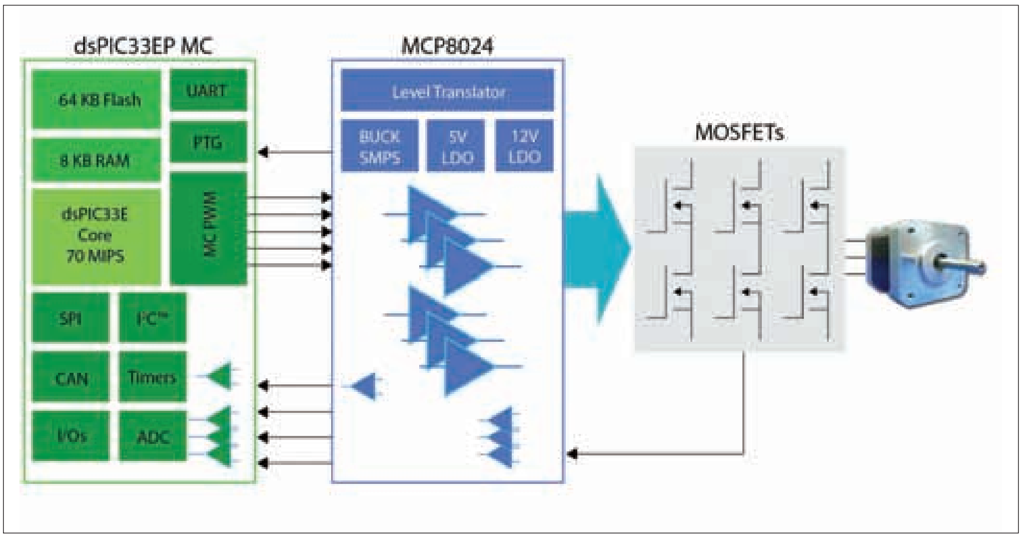


Figure 3: Two-chip BLDC design with external MOSFETs

BLDC motor. It should also integrate a high-efficiency, adjustable voltage regulator capable of minimizing power dissipation whilst powering a wide range of microcontrollers. Monitoring and housekeeping blocks are also essential to ensure the safe operation of the motor and to enable bi-directional communication between the host and the driver. Selectable parameters will enable the performance of the driver to be optimized without any additional programming.

A typical two-chip solution is shown in Figure 3. This approach combines a feature-rich, 3-phase motor driver, such as Microchip's MCP8024, with a high-performance dsPIC33EP MC digital signal controller (DSC) to drive six N-channel MOSFETs for the field-oriented control of a Permanent-Magnet Synchronous Motor (PMSM). A lower-cost, baseline 8-bit microcontroller can be used in place of the DSC when using a simple, six-step control architecture. The change from a DSC to an 8-bit microcontroller can be implemented without altering the drive circuit if a BLDC motor with a similar power rating is used.

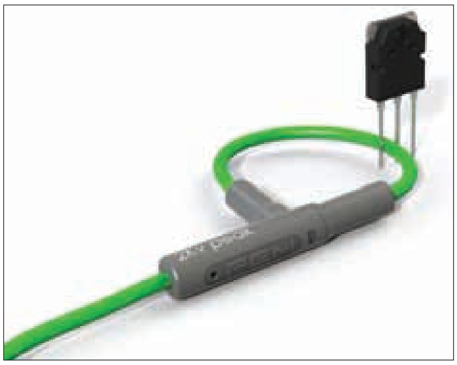
The relative advantages of single-chip BLDC motor-control designs, based on a SoC or ASSP, and the two-chip approach using a microcontroller or DSC and a companion driver, are shown in Table 1. This shows that, whilst a SoC or ASSP will meet the needs of a space-constrained application, their fixed feature-sets combined with limited memory and processing power significantly reduce the flexibility and scalability of the design.

The emergence of single-chip and two-chip approaches to BLDC motor control enable designers to reduce component cost and board-space compared to traditional discrete-based circuits. The hardware and firmware reference designs and libraries, supplied by manufacturers such as Microchip, also significantly reduce the development time for bringing an advanced motor-control and drive designs to market.

	SoC	ASSP	Two-Chip Solution
Programmability	Limited	No	Yes
Flash Memory	32 KB or less	No	16 KB to 256 KB
PCB Space	Medium	Small	Medium
Pin Count	Medium	Low	High
Controller Selection	None	None	Broad
Reusability Across Power Ratings	Medium	Small	High
Firmware Development Tools	Limited	Not Required	Standard from Supplier

Table 1: Comparison of single-chip and two-chip BLDC motor-control designs

Next-generation Rogowski CWT current probes



At next month's PCIM Europe, PEM (Power Electronic Measurements) will launch its next-generation CWT current probes for high-speed and high power-density applications. Clip-on Rogowski current probes provide a convenient means of measuring alternating currents. The company's latest wideband probes use a shielding technique to eliminate the effects of high field strengths in today's high power-density and high-speed circuits. Pictured here is a CWT shielded mini coil, threaded through the legs of a TO247 semiconductor package. Visitors to the company's stand (Hall 7 – 152) will also be able to see the company's full range of Rogowski waveform transducers, probes and industrial sensors, which includes the CWT and RCT ranges. The company's managing director, Dr Chris Hewson, will also introduce the new probes during his presentation on 'Next Generation Rogowski Current Probes' on Tuesday, 20th May 4.00 – 4.20pm.

www.pemuk.com

25A Hall-Effect Current Sensors

LEM has added three new members to its HO series of PCB-through-hole mounting current transducers, which provide an aperture of 8 x 8 mm to carry the primary conductor under measurement. The new models, for 6, 10 or 25 A nominal measurements of DC, AC, and pulsed signals benefit from the revised Open-loop Hall-effect ASIC introduced with the launch of the HO 8, 15 and 25-NP & –NSM models. The HO 6, 10 and 25-P models' offset and gain drift are twice as accurate (over the temperature range -25 to +85°C) as the previous generation. A high level of insulation between primary and measurement circuits, due to the high clearance and creepage distances of more than 8 mm and a CTI (comparative tracking index) of 600, allows a test isolation voltage of 4.3 kV RMS/50Hz/1 min. The transducers require an area of only 2.88 cm? and weigh 10 g. The transducers also provide fault reporting in the case of memory contents being corrupted. LEM's HO xx-P transducers operate from a single supply voltage at 3.3 or 5 V.

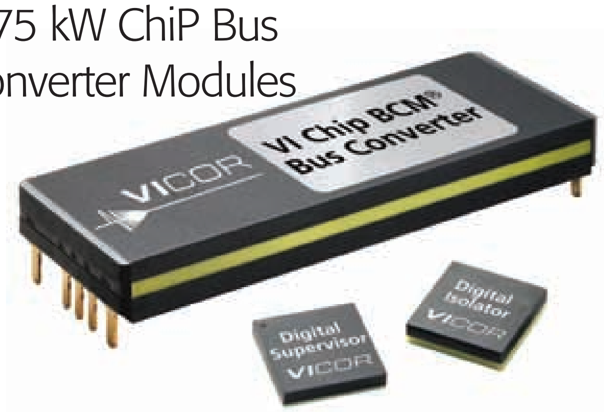
www.lem.com

Modular Stackable U-Cores

EPCOS stackable U-cores feature a unique modular ferrite design that offers flexibility and economy for high-voltage transformer and HF filter applications. The new U-cores are tooled by Dexter Magnetic Technologies as Dexter StackPack™ U-Cores. US-based Dexter Magnetic Technologies is a provider of optimized magnetic solutions and distributor of TDK and EPCOS products. The new modular EPCOS stackable U-cores provide standard options that can fit any application. This is a major advantage in applications that require large ferrite cores but are limited by manufacturing constraints and high tooling costs. As a result, designers have been cutting and gluing large U and I cores together to make them bigger. The standardized design of the StackPack U-Cores enables multiple configurations as well as lower costs than custom tooling or machining. With short lead times, Dexter Magnetic Technologies can provide customers with standard modular cores that allow rapid prototyping.

www.epcos.com/140408

1.75 kW ChiP Bus Converter Modules



VICOR announced the newest entries in its portfolio of isolated bus converter modules (BCMs®) based on the Converter housed in Package (ChiP) power platform which supplies up to 1.75 kW at 50 V with 98% peak efficiency. ChiP BCMs' power performance profile is made possible by the underlying ZCS/ZVS Sine Amplitude Converter™ topology operating at megahertz switching frequency. High fixed frequency operation also simplifies and reduces the size of external filter designs. The new ETSI and ITU compliant 1.75 kW modules support a nominal input voltage of 400 V and nominal output voltage of 50 V, with a K-factor of 1/8. The 1.75 kW BCMs are offered in the 6123 package. Standard BCM features include bidirectional operation, under-over-voltage lockout, over-current, short circuit and over-temperature protection. A PMBus™ compliant digital interface option gives system designers access to the ChiP BCM's internal controller, enabling digital communication via a single bus for control, configuration, monitoring and other telemetry functions.

www.vicorpower.com

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New

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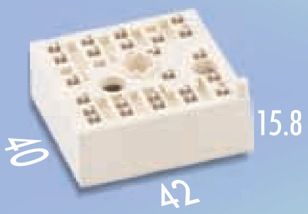
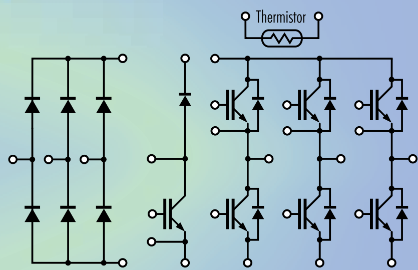
MiniSKiiP® 1

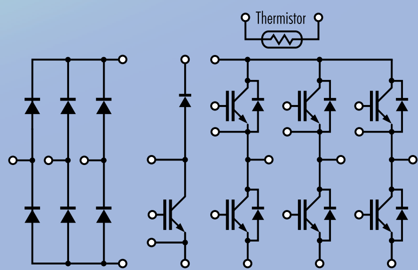


1200V
8A
15A

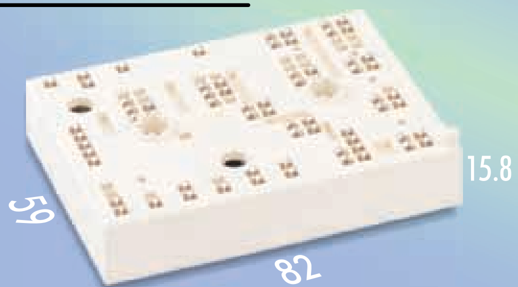


MiniSKiiP® 2

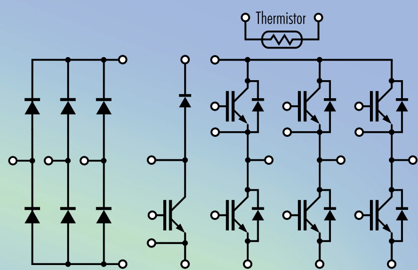
1200V
25A
35A



MiniSKiiP® 3



1200V
50A
75A
100A



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60 A Dual Phase Buck Controller

The dual phase synchronous rectified buck controller AP3595 from Rutronik/Diodes is designed to provide a high integrity supply for distributed high-power architectures. With an operating frequency adjustable over the range of 50 Hz to 1 MHz per phase, the buck controller can deliver an output current of up to 60A. Available in the standard QFN4x4-24 package, integrated bootstrapped MOSFET drivers ensure high efficiency power conversion. In addition, the bootstrap diode is itself built into the device. To optimize system performance, the AP3595's gate drive voltage is fully configurable, regulated via a reference input set using external voltage divider. By tuning the duty cycle of each channel in response to internal MOSFET on-resistance sensing, the controller ensures phase currents are always balanced. With a power saving interface (PSI), the controller can switch between single and dual mode to help reduce losses. To ensure high reliability operation at high currents, the AP3595 buck controller features a comprehensive range of in-built protection features, including over-current, input/output under-voltage, over-voltage and over-temperature protection. An adjustable soft start facility is integrated.

www.rutronik.com/86d70fea

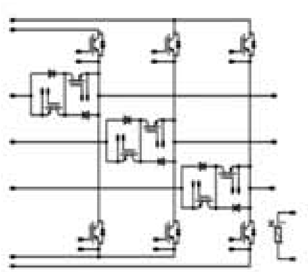
Soft Shutdown 110 kW IGB T Driver

IGBT driver manufacturer CT-Concept has announced shipments of its first products to include its SCALE™-2+ gate driver chip set enabling soft shutdown (SSD) to be implemented in the event of a short circuit without requiring additional components. SCALE™-2+ drivers offer high levels of integration by including an integrated trigger mechanism which limits IGBT Collector-Emitter, or MOSFET Source-Drain voltages in the event of a short circuit. implemented SSD is implemented on-chip without any additional external circuitry by controlling the on-chip high-side N-Channel booster stage. By increasing the output impedance of the gate driver enables the IGBT or MOSFET to turn off with a reduced di/dt, thereby limiting the Collector-Emitter or Source-Drain over-voltage. As a result, the new SCALE™-2+ drivers have integrated, cost-effective, short-circuit protection as well as increased flexibility and reduced size. The first product to ship with the new SCALE™-2+ chip set is the 2SC0106T2A0-12, a two-channel IGBT/MOSFET gate driver core for 1200 V IGBTs in the 37 kW to 110 kW power range.

www.IGBT-Driver.com

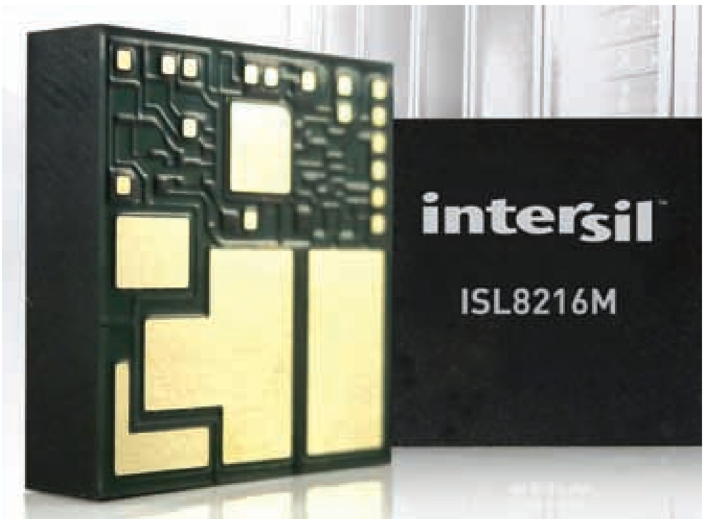
Three-Level Power Module

Vincotech has unveiled the flow3xMNPC 1 modules featuring three mixed-voltage NPCs in a single flow 1 housing. Developed for 1200 V solar three-phase inverter applications, they enable compact, space-saving inverters with 98.7%efficiency ratings in typical 16-kHz solar applications. Measuring 82 mm x 38 mm and 12 or 17 mm in height, these modules support three phases in one flow 1 housing. They are equipped with 1200 V IGBT4 HS3s (high speed) in the half bridge and 600 V IGBT3s with low saturation voltage and ultra fast StealthTM diodes in the neutral path. The actually dual-module solutions combine a booster and three-phase inverter, which makes them a option for smaller inverters where space is limited. Rather than using a common emitter that requires seven power supplies, the M74x topology features a common collector configuration, thereby reducing the number of power supplies for the gate driver to five. The IGBTs are equipped with Kelvin Emitters to boost switching performance and an NTC for measuring temperature. Vincotech's ISE simulation tool provides flow3xMNPC 1 simulation models. Press-fit versions are also available on request.



www.vincotech.com/flow3xmnpc-1

4 A DC/DC Step-Down Power Module



Intersil announced the ISL8216M 80 V, 4 A non-isolated DC/DC step-down power module. This integrated module provides a complete power supply in a package that can be used across multiple applications from telecom and network infrastructure to factory test equipment with minimal design effort. The ISL8216M supports a wide input voltage range from 10 V up to 80 V with an adjustable 2.5 V to 30 V output range, making it a flexible solution for 12 V, 24 V, 36 V and 48V inputs, including high voltage embedded board controllers. The turnkey power module solution requires only five external components, and is packaged in a rugged thermally enhanced 15 mm x 15 mm x 3.6 mm over-molded High-Density Array (HDA) Package, which permits full load operation without a heat sink or fans. The protection features include over-current, over- / under-voltage and over-temperature shutdown.

www.intersil.com/products/ISL8216m

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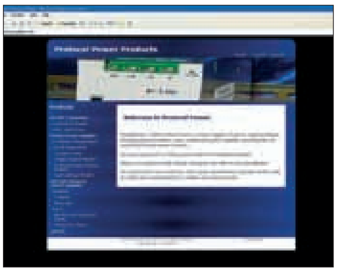

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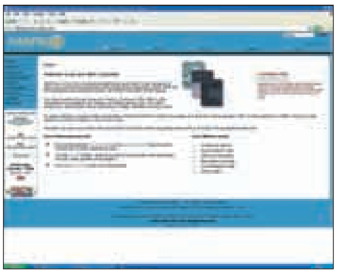

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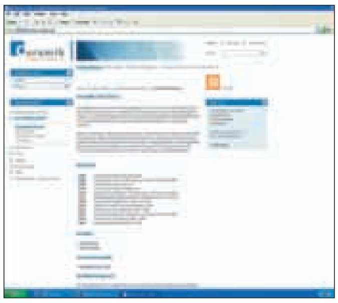

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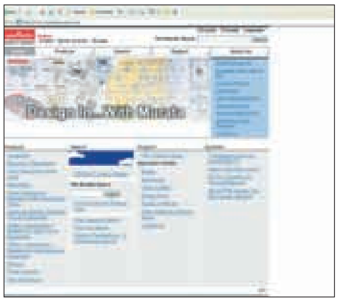

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	1.0	210	240	0.51˚C/W	AUIRFS8408-7P
	1.3	150	240	0.65˚C/W	AUIRFS8407-7P
D²PAK	1.2	300	195	0.40˚C/W	AUIRFS8409
	1.6	216	195	0.51˚C/W	AUIRFS8408
	1.8	150	195	0.65˚C/W	AUIRFS8407
	2.3	107	120	0.92˚C/W	AUIRFS8405
	3.3	62	120	1.52˚C/W	AUIRFS8403
TO-262	1.2	300	195	0.40˚C/W	AUIRFSL8409
	1.6	216	195	0.51˚C/W	AUIRFSL8408
	1.8	150	195	0.65˚C/W	AUIRFSL8407
	2.3	107	120	0.92˚C/W	AUIRFSL8405
	3.3	62	120	1.52˚C/W	AUIRFSL8403
TO-220	1.3	300	195	0.40 ˚C/W	AUIRFB8409
	2.0	150	195	0.65 ˚C/W	AUIRFB8407
	2.5	107	120	0.92 ˚C/W	AUIRFB8405
DPAK	1.98	103	100	0.92 ˚C/W	AUIRFR8405
	3.1	66	100	1.52 ˚C/W	AUIRFR8403
	4.25	42	100	1.90 ˚C/W	AUIRFR8401
IPAK	1.98	103	100	0.92 ˚C/W	AUIRFU8405
	3.1	66	100	1.52 ˚C/W	AUIRFU8403
	4.25	42	100	1.90 ˚C/W	AUIRFU8401

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