POWER ELECTRONICS EUROPE

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MOTION CONTROL
The Efficiency Trend in Motor Control

THE EUROPEAN JOURNAL FOR POWER ELECTRONICS AND TECHNOLOGY

Also inside this issue

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

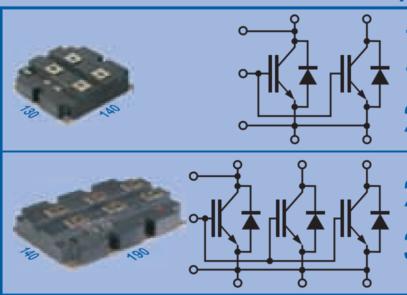
High Power IGBTs

Low internal inductance & Low thermal impedance

1200V: *With Cu Baseplate*
1700V: *With Cu or AlSiC Baseplate*

- $T_{j,max}$ = 175°C
- $T_{stg,min}$ = -40°C
- V_{iso} = 4.0kV
- CTI > 600

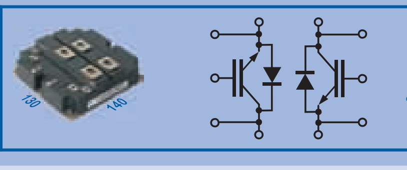
1 in 1



1200A
1600A
2400A

2400A
3600A

2 in 1



600A
800A
1200A

3300V: *With AlSiC Baseplate*

- $T_{j,max}$ = 150°C
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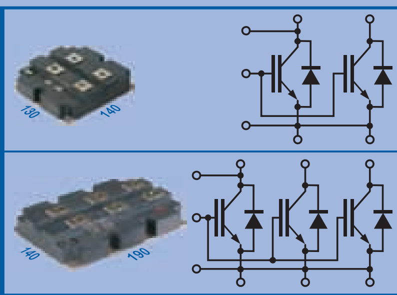
- V_{iso} = 6.0kV
- CTI > 600
- VPD = 2.6kV

1 in 1



800A
1000A

1200A
1500A

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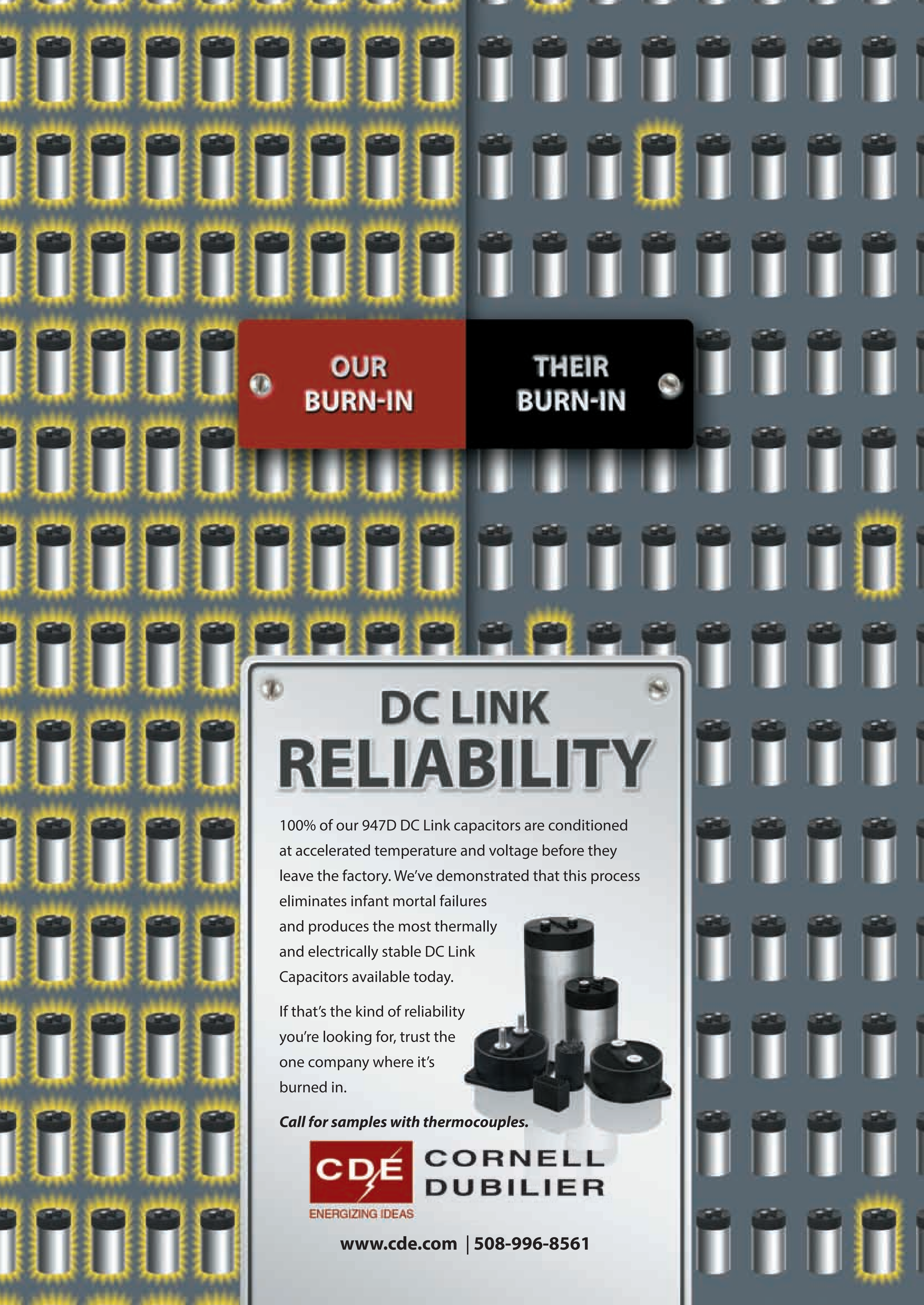
COVER STORY

The Efficiency Trend in Motor Control

Efficiency is the Holy Grail in all electric motor based applications. If we look at the different applications that are using electric motors today we can see the trend of continued improvement towards higher efficiency and lower cost. For example, in cars the original approach for driving pumps and fans under the hood was the serpentine belt, but even though this is a convenient way to utilize the engine rotation to drive these actuators it is not very efficient. Taking these actuators and drive them with motors adds flexibility and improved efficiency. Another example is washing machines, were the primary motor type has been AC induction, but with increased requirements for energy efficiency in home appliances and more control of the washing cycle to reduce water usage, the use of permanent magnet synchronous motors in new designs has been become dominant.
The trend towards higher efficiency for electrical motors started to accelerate at the turn of the century with advent of brushless permanent magnet motors and improved semiconductor cost and performance. Expanding into consumer products with the BLDC motor. Since then it has evolved to include the electronic commutation of ACIMs, revival of the SRM, and even removal of the magnets again with the SyncRM. A new family of 16-bit dsPIC33 Digital Signal Controllers (DSC) provides for these motors 5 V operation for improved noise immunity and robustness, well suited for devices operating in harsh environments such as appliance and automotive applications. More details on page 22.

Cover supplied by Microchip Technology Inc.



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A Challenging Year Ahead

In the More-than-Moore area, power electronics is increasingly important. It provides the necessary components and systems to interface between ICs and the real world, that is more and more electrified. And modern Power Semiconductor play an essential role energy saving and worldwide carbon dioxide reduction. They are used converting the electrical energy from AC to DC and DC to AC at the production site, transmission and transforming it down at the consumers sites to voltage needed. In all of these stages high efficiency is a vital factor to save natural resources and to reduce the emission into our atmosphere. Enabling higher switching frequencies help to reduce size, weight and usage of valuable materials like copper and iron at the production of the electrical appliances. Existing applications in railway transportation systems, household aids or power supplies for computers are becoming smaller and more efficient, while new fields of application like (hybrid) electrical vehicles or power supplies in medical equipments are emerging. There is a big demand for new technologies for high, medium and low voltage power semiconductors to carry forward the journey to higher efficiencies. For future power technologies new silicon based and other materials with fascinating properties are in development. Compound semiconductors (and mainly at the moment SiC and GaN) power devices have practically shown a quantum leap in the performances of power devices and in the possibility to enlarge the use of power electronics especially at very high voltages and high power. However, the status of SiC and GaN devices today is much less mature than that of Si power devices in terms of manufacturability, material quality and process control, cost and reliability – but progress is underway. GaN-on-Si technology creates very high expectations for Power Electronics as to provide the next-generation of switching devices. Silicon switching components are reaching their intrinsic physical limitations, wide bandgap are required to further reduce the losses. The decisive advantage of GaN-on-Si technology to break the Silicon boundaries for efficient power conversion resides in its excellent and unique combination of performance (breakdown voltage/reduced leakage/lower conducting and switching losses) and cost-efficiency. This mainly thanks to the use of low cost substrates, available in large diameters of 200 mm and perhaps 300 mm in the near future. To cope with the growing market demands in power semiconductors additional capacities are necessary and have to be built up. To save capital invest and to ensure future growth, the idea of 300mm production for power semiconductors was born at Infineon based on the experience in the manufacturing of memory chips in their former subsidary Quimonda - and the acquisition of this production equipment after Quimonda went bankrupt. Most recently Infineon has successfully closed the acquisition of International Rectifier, one of the most innovative power semiconductor companies mainly in MOSFETs and recently in GaN power devices. International Rectifier is highly complementary to Infineon - the combined company gains greater scope in product portfolio and regions, especially with small and medium enterprise customers in the US and Asia. The merger expands Infineon's expertise in power semiconductors, also combining leading knowledge in compound semiconductors, namely GaN. Furthermore, the acquisition will drive greater economies of scale in production, namely 300 mm wafer processing at Infineon. And Transphorm Japan Inc. announced end of January that Fujitsu Semiconductor group's CMOS-compatible, 150 mm wafer fab in Aizu-Wakamatsu, Fukushima, Japan, has started mass production of Gallium Nitride (GaN) power devices for switching applications. The large-scale, automotive-qualified facility is providing exclusive GaN foundry services for Transphorm. This stepped up production can satisfy the increasing market demands for power GaN devices, the companies commented.

Thus at APEC 2015 (March) in Charlotte/NC and PCIM (May) in Nuremberg SiC and GaN again will be discussed widely due to recent announcements in research and industry. In example one of the APEC keynotes will cover a speech on "Optimizing Performance and Reliability of GaN MOSFET Devices", and the Technical Sessions as well as one of the Rap Sessions will deal with these devices in detail. At PCIM one Special Session entitled "Power GaN for Automotive Applications" covering four papers is scheduled – initiated and organized by Power Electronics Europe. Certainly this GaN/Automotive topic will find a lot of interest, particularly in the "Automotive Country Germany". In order to extend the auditorium from the conference to the exhibition floor on the same day a Panel Discussion in PCIM's Industry Forum entitled "Quo Vadis Power GaN" moderated by PEE's editor including the speakers of this Special Session will be held.

Thus 2015 will be a fascinating year for power semiconductors.

Achim Scharf
PEE Editor

Infineon Closes Acquisition of International Rectifier

With effect from January 13, El Segundo-based International Rectifier (IR)has become part of Infineon following the approval of all necessary regulatory authorities and International Rectifier's shareholders.

"The acquisition of International Rectifier is an important step for Infineon to foster our position as a global market leader in power semiconductors. We are sure that International Rectifier and its employees will make a great contribution to a joint successful future. Together both companies make a powerful combination", commented Dr. Reinhard Ploss, CEO of Infineon. "The acquisition helps us to accelerate our strategic approach 'from product thinking to system understanding'."

The combined company is led by Reinhard Ploss, CEO, Arunjai Mittal, Member of the Management Board, and Dominik Asam, CFO. President of International Rectifier and of Infineon North America is Robert LeFort.

On August 20, 2014, Infineon announced to acquire International Rectifier in a deal worth approximately $3 billion. The Board of Directors of International Rectifier and Infineon's Supervisory Board unanimously supported the offer of Infineon to pay $40 per outstanding share. Subsequently, all regulatory authorities had approved the acquisition – as did the shareholders of International Rectifier with a majority of 99.5 percent of all votes cast.

International Rectifier is highly complementary to Infineon - the combined company gains greater scope in product portfolio and regions, especially with small and medium enterprise customers in the US and Asia. The merger taps additional system know-how in power management. It expands the expertise in power semiconductors, also combining leading knowledge in compound semiconductors, namely Gallium Nitride. Furthermore, the acquisition will drive greater economies of scale in production, strengthening the competitiveness of the combined company. For the quarter ended December 31, 2014, International Rectifier achieved revenue of $275 million and an adjusted operating income-margin of 7.0 percent in accordance with US GAAP (unaudited figures). Net cash stood at $658 million as of December 31, 2014.

Regarding the results of the first quarter of fiscal year 2015 and the running calendar year Infineon is optimistic. "We had a good start into the new fiscal year. Revenue and margin have developed

better than expected during the three-month period from September to December 2014, in particular due to the strength of the dollar. Even adjusted for the tailwind from the dollar and one-time effects, reported figures would have been at the upper end of the forecasted range, reflecting our ability to perform well, even in times of uncertainty. Compared in each case to the equivalent quarter of the previous year, our business has now grown for seven quarters in succession", stated Dr. Reinhard Ploss, CEO of Infineon Technologies AG. "Market conditions remain challenging. We are nevertheless confident that Infineon will continue to grow. The successful acquisition of International Rectifier will provide an additional boost." Revenue of the Infineon Group decreased by 4 percent quarter-on-quarter in the first quarter of the 2015 fiscal year to €1,128 million due to seasonality, compared with €1,175 million in the fourth quarter of the previous fiscal year. On a year-on-year basis it increased by 15 percent from €984 million in the first quarter of the 2014 fiscal year. Based on an assumed exchange rate of $1.20 (previously US$1.30) to the Euro, Infineon forecasts a year-on-year growth in revenue of 12 percent. So far, Infineon had expected sales growth of 8 percent.

www.infineon.com, www.irf.com

Infineon's CEO Reinhard Ploss (left) and IR's former CEO Oleg Khaykin initiated in August 2014 the merger of the two companies

Raytheon UK to develop Silicon Carbide MOSFETs for Automotive Applications

Raytheon UK's semiconductor business unit in Glenrothes, Scotland, has been selected by a leading automotive manufacturer to develop a SiC-based MOSFET for use in electric, hybrid-electric and plug-in hybrid electric vehicles.

As experts in the development of components and modules intended for safety-critical applications within harsh environments, Raytheon will employ its extensive SiC fabrication expertise to develop a MOSFET, rated at 650 V/60 A, which can be mass-produced cost-effectively and be fully compliant with the stringent ISO/TS 16949 automotive quality standard. John Kennedy, head of Raytheon UK's Integrated Power Solutions, comments: "The use of Silicon Carbide overcomes many of the problems restricting the use of traditional Silicon semiconductor devices for certain applications, within electric vehicles and their hybrid derivatives. The benefits of Silicon Carbide include higher temperature operation, low switching losses and low parasitics – making possible the production of reliable, high power devices in small and lightweight packages that do not have the same cooling requirements as Silicon-based components. Kennedy adds: We were selected for this particular MOSFET project because of our Silicon Carbide expertise, proven processes and project management skills, all of which combine to produce a reduced risk engagement for the customer. Moreover, we're an established fabricator of semiconductor devices for automotive power and control applications, using either Silicon Carbide or traditional Silicon."

Raytheon operates a SiC production foundry backed by a team of engineers experienced in the fabrication of MOSFETs, Schottky Barrier Diodes and bipolar devices. Also, the company has been active in the automotive industry for several years, supplying semiconductor devices for use in vehicle suspension system sensors, as employed by several well-known car manufacturers, since 1995.

Raytheon UK also designs, develops and manufactures a range of high-technology electronic systems and software at facilities in Harlow, Glenrothes, Uxbridge, Waddington and Broughton.

www.raytheon.co.uk/semiconductors

Raytheon UK's semiconductor business unit in Glenrothes, Scotland, is to develop a SiC based MOSFET for use in electric, hybrid-electric and plug-in hybrid electric vehicles

Transphorm and Fujitsu Semiconductor Start Mass Production of GaN Power Devices

Transphorm Japan Inc., and Fujitsu Semiconductor Limited announced end of January that Fujitsu Semiconductor group's CMOS-compatible, 150 mm wafer fab in Aizu-Wakamatsu, Fukushima, Japan, has started mass production of Gallium Nitride (GaN) power devices for switching applications. The large-scale, automotive-qualified facility is providing exclusive GaN foundry services for Transphorm. This stepped up production can satisfy the increasing market demands for power GaN devices.

Already in 2013, Fujitsu Semiconductor and Transphorm announced the business integration of their GaN power device solutions. "The start of the mass production in a CMOS-compatible fab is a significant step forward toward achieving the widespread use of GaN power devices, as well as a demonstration of the successful integration of both companies' strengths," said Haruki Okada, President of Fujitsu Semiconductor. Understanding that a highly reliable manufacturing production line is one of the essential requirements of any business expansion, the companies have successfully finished the development in Aizu-Wakamatsu. "Manufacturing Transphorm's GaN power devices at the Fujitsu Aizu-Wakamatsu facility will assure our customers a scalable, stable supply of products with the stamp of Fujitsu's proven, high-quality standard in mass manufacturing," commented Fumihide Esaka, CEO of Transphorm.

www.transphormusa.com

Global Rack PDU Market to Grow Over 5 Percent

Global revenue from rack power distribution units (PDU) is forecast to grow 5.6 percent in 2015 according to a recently published IHS report - Rack Power Distribution Units – 2015. This is twice as fast as the forecast unit shipment growth, highlighting the continued shift toward higher-priced rack PDU products.

The shift occurs for several reasons. The growth of intelligent products, for example, is driven by the need to monitor power usage, report efficiency metrics, decrease power use in the data center, and enable capacity planning. Three-phase rack PDUs and those with higher power ratings also command higher prices. Increased adoption of these products is driven by increasing rack densities. "While different regions of the world are at different stages in the adoption of the higher-priced product types, we do see an overall trend globally toward rack PDUs with intelligent features such as metering and switching and PDUs with higher power ratings," analyst Sarah McElroy commented. In 2014, intelligent rack PDUs accounted for 19 percent of unit shipments globally and 58 percent of revenue. They are forecast to grow over twice as fast as non-intelligent rack PDUs. Adoption of intelligent rack PDUs remains lower in Africa and some parts of Asia than in the Americas and Europe. According to McElroy, "The Middle East is an interesting market to keep an eye on because it is emerging market for intelligent rack PDUs and has been adopting them faster than other developing regions."

www.ihs.com

VC Funding in Smart Grid Totals $383 Million in 2014

Mercom Capital Group, a global clean energy communications and consulting firm, released its report on funding and mergers and acquisitions (M&A) activity for the smart grid sector for 2014.

Venture capital (VC) funding into smart grid technology companies was $383 million in 73 deals in 2014, compared to $410 million in 64 deals in 2013. Total corporate funding, including debt and public market financings, came to $844 million in 2014, compared to $584 million in 2013. There were 88 total VC investors in 2014, with eight active investors participating in multiple deals.

The Top VC funded companies in 2014 were led by Savant Systems, which raised $90 million. Zonoff brought in $31.8 million; this was followed by the $22.6 million raise by ChargePoint. SIGFOX raised $20.6 million and EnVerv, raised $15.4 million.

There were 32 Smart Grid M&A transactions (12 disclosed) in 2014 totaling $3.9 billion. The top disclosed transaction in 2014 was Google's acquisition of Nest Labs for $3.2 billion, followed by the $200 million acquisition of SmartThings by Samsung Electronics and the $150 million acquisition of Aclara Technologies by Sun Capital Partners. Bel Fuse acquired Power-One's Power Solutions business for $117 million and Sierra Wireless acquired Wireless Maingate for $90 million.

In 2014, Mercom expanded its coverage to include Storage/Battery and Energy Efficiency sectors.

Companies in the Storage/Battery space received $418 million in 32 deals. The top VC funding deal in 2014 was the $55 million raise by Aquion Energy, followed by Bloo m Energy, which raised $50 million. Ambri (formerly Liquid Metal Battery Corporation) raised $35 million, Amprius raised $30 million and Powin Energy raised $25 million. Sodium-based Storage/Battery companies received the most funding with $112 million.

There were also 19 debt and public market financing deals in Storage/Battery totaling $490 million including one Initial Public Offering in 2014. There were two third-party storage funds announced to finance no-money, no-upfront, behind-the-meter storage projects. M&A transactions in Battery/Storage totaled 18, of which six transactions were disclosed, totaling $232 million.

Energy Efficiency companies raised $797 million in 80 deals in 2014. The top VC deal was the $100 million raise by View (formerly Soladigm), followed by Lextar Electronics, which raised $83 million. LatticePower brought in $80 million, Renovate America raised $50 million and Phononic raised $44.5 million.

www.mercomcapital.com

Smart Grid - Top 5 VC Funded Companies in 2014

Company	Country	Funding Type	Amount ($M)	Investors
SAVANT	USA	Undisclosed	90	Kohlberg Kravis Roberts
zonoff	USA	Series B	31.8	Grotech Ventures, Valhalla Partners
chargepoint	USA	Undisclosed	22.6	Rho Ventures, Kleiner Perkins Caufield & Byers, Braemar Energy Ventures, Siemens Venture Capital, Voyager Capital, BMW
SIGFOX	France	Series B	20.6	Idinvest Partners, FSN PME, Digital Ambition Fund, Elaia Partners, Intel Capital, Iris Private Equity, Partech Ventures
enverve	USA	Series C	15.4	Cassiopeia Capital Partners, Cisco, UMC Capital, Benchmark Capital, New Enterprise Associates, Walden International

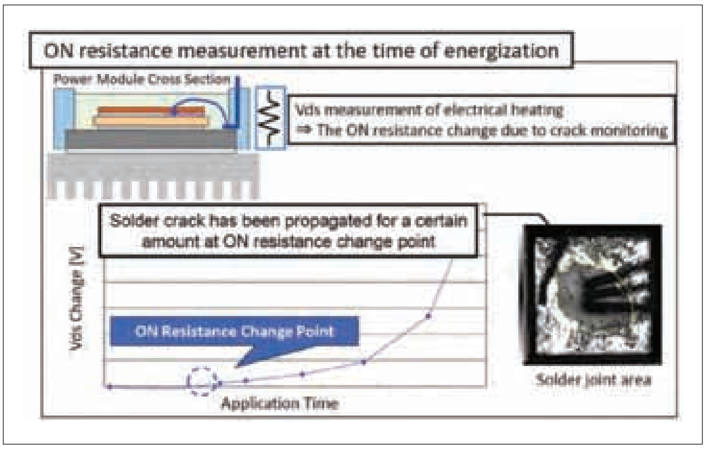
Source: Mercom Capital Group, llc

Top 5 VC financed Smart Grid companies

Delamination Evaluation of Power Modules at Yamaha

Yamaha Motor Co. Limited is a Japanese manufacturer of engines for a diverse set of industry sectors including motorcycles and other motorized products. The company was established in 1955 and has its headquarters in Shizuoka, while employing nearly 54,000 people worldwide and turning over annual revenues of $14 billion.

At the Technology Center of Yamaha Motor there is a recognized need to accelerate testing to speed up general product development and, in particular, electronic control units attached to engines and motors. Such PCB electronics can be exposed to high thermal loads during normal operation especially with high power density products. Reliability is paramount and temperature related issues due to electrical, mechanical, and thermal effects are critical. Indeed, most domestic automobile recalls in Japan are due to design related errors rather than problems in manufacturing, and the biggest source of design problems can be seen to be due to the lack of a good physical test method to validate and benchmark design approaches.



Relationship between solder crack over time and on-resistance, which was not sensitive enough to detect the initial solder delamination

In general, the use of electronic devices in engine control systems (ECS), safety systems and telecommunications is increasing rapidly across the world. When compared to consumer electronics, electronic devices for motor vehicles and engines are often exposed to much more severe environments such as higher temperatures, fluctuating temperatures, intense vibration, and high humidity. Furthermore, considering the longer product life expected for a motor vehicle, these electronic devices are expected to have a higher level of reliability and be something that lasts over a long period. The normal method used for attaching electronic components like resistors and capacitors to printed circuit boards for ECS electronic devices is soldering. Generally, circuit boards and the electronic components mounted on them have different coefficients of thermal expansion, and the difference in the amount of expansion and contraction they undergo causes thermal stress in the solder connecting them.

These in turn will result in "solder cracks" forming within the joint and eventually solder breakage which leads to defective electrical conductivity and ultimately product failure.

Thermal stress on wire bonding could cause lethal crack, too. Thermal fatigue characteristics of solder and PCB reliability can be evaluated by means of temperature cycling tests that subject the solder to repetitive cycles of high and low temperature conditions, but even these accelerated test cycles can require several months in a laboratory. Hence, there is a need to shorten development time and reduce the number of rework tasks involved, reducing cost by optimizing product quality up front of prototyping is also an important issue, and these two factors increased the need for the manufacturer to devise technology that can estimate the thermal fatigue life of solder joints and the detection of the formation of solder cracks rapidly.

Yamaha has been developing reliability methods and technologies for evaluating solder joints in electronic devices inside its products focused on temperature fluctuations in particular. In addition, test methods for detecting and preventing the delamination of power modules to speed up product development have been envisioned.

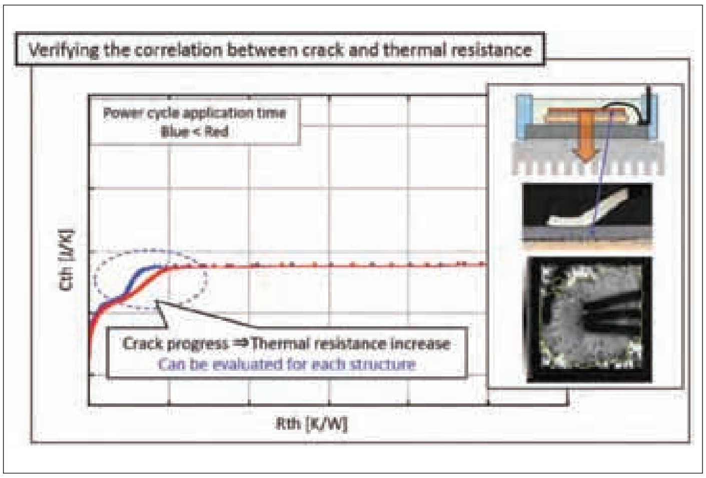
Accelerating thermal tests

An accelerated solder joints thermal benchmarking test methodology has been developed at Yamaha that's validated to reduce market complaints, help define a cost effective reliability target, and shorten overall product development time.

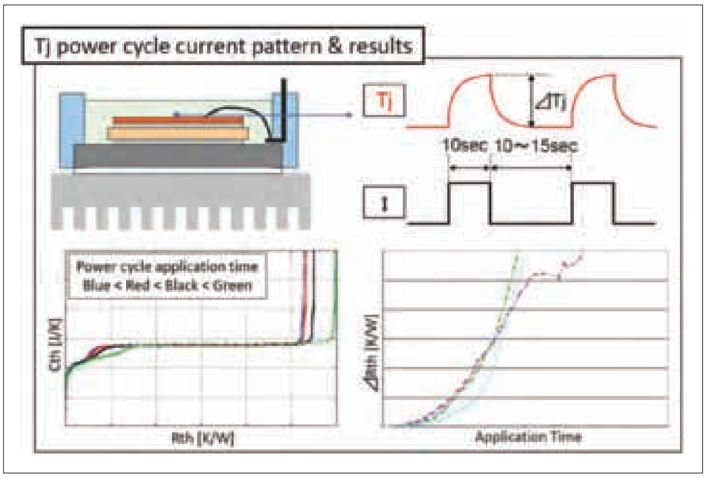
The novel approach involved three strands to accelerating our Delamination Testing Methodology called

- Stress Acceleration conditions (due to high temperature, high pressure etc.),
- Judgment Acceleration conditions (i.e. making our judgment on the delamination quicker with the minimum amount of test information possible), and
- Frequency Acceleration conditions (i.e. more sample cycling tests).

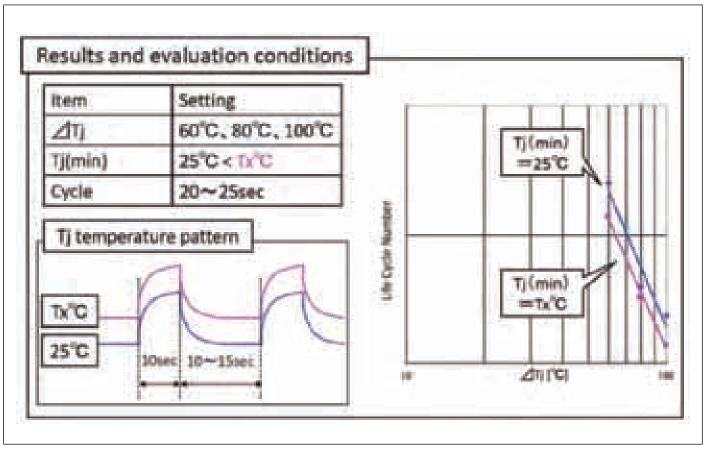
Frequency Acceleration was the easiest to control as it is part of standard test methodologies. For Stress Acceleration a proprietary



Structure Function thermal resistance increase from T3Ster can detect the initial solder delamination



Typical Lifecycle evaluation in junction temperature during a T3Ster power cycle test and the resultant change in thermal resistance, ΔR_{th}, versus number of test cycles



Solder Degradation - impact on sample lifetime of different T_j power cycle test conditions in T3Ster

Arrhenius type mathematical expression was devised that correlates the relationship between the lifetime of a solder being cycled with its operating temperature range. The Judgment Acceleration condition relies on a wide set of in-house tests on a wide range of Power Module devices that allows to produce a database of Yamaha measurements from which we can extrapolate from existing performance data.

The most important elemental technology for successful Judgment Acceleration and Stress Acceleration test is how to evaluate the degradation. Yamaha have been looking for an effective method to detect degradation, particularly for the evaluation of cracks in the targeted solder joints to be a non-destructive measurement technique that was not only fast, very accurate, close to real time, but also able to avoid intrusive measurement equipment errors. This led to use T3Ster thermal transient testing equipment from Mentor Graphics to meet the test criteria.

A typical Power Module resistance measurement during the cycling test was considered which can track the relationship between ON-resistance (by monitoring V_{ds} when the chip is powered) to crack formation, so that crack development over time can be seen. However, it was not sensitive enough to detect the initial solder delamination progress. So the T3Ster's structure function methodology was tried.

This non-destructive measurement technique is very valuable in determining the formation of delamination cracking not only from the beginning, but also its propagation and ultimately die-attach failure. The use of T3Ster in the delamination stress tests of solder joints therefore allows to quantify the process of solder crack development more sensitively and quicker than any other methods. The structure function allows to track the relationship between the changes in thermal resistance, ΔRth, of the sample under test relative to the number of test cycles it experiences.

By using T3Ster, Judgement Acceleration can be achieved since we now have the ability to detect the initial crack, and we know the speed of degradation after the initial crack. This in turn allows us to shorten our overall development time for such stress tests and T3Ster also provides valuable diagnostic data on what's happening to thermal paths inside each layer of the sample being tested.

By developing the technologies for Stress Acceleration, the dominant factors influencing lifetime were considered to be junction temperature (T_j). The relation between ΔT_j and lifetime was investigated while $T_{j(min)}$ was fixed to 25°C as the first step. The result showed lifetime is a function of ΔT_j and if we put field application environment and experiment environment into consideration, it was able to determine the acceleration factor and decide acceleration test configurations.

The second step was to study the influence of $T_{j(min)}$, $T_{j(min)}$) was set >25°C and then repeated step one. From the test data found, higher $T_{j(min)}$ led to shorter lifetime but slope of "lifetime vs. ΔT_j" does not change. This result demonstrated that acceleration test configurations are independent of $T_{j(min)}$ and the same test configuration can be applied to any $T_{j(min)}$. Furthermore, by clarifying the influence of thermal stress period, chip size and category of solder, a more accurate Stress Acceleration test configuration was discovered. T3Ster has proven to be very powerful to Yamaha and helps to accelerate reliability test methodology.

www.yamaha-motor.com, www.mentor.com

Mentor Graphics Corp. (www.mentor.com) is an European Centre for Power Electronics (ECPE, www.ecpe.org) member since August 28th 2014. It is the only electronic design automation (EDA) company represented in this industry driven research network, comprised of over 150 organizations. Mentor Graphics was selected as an ECPE member based on its expertise in both thermal simulation and test solutions including electronic component and power cycling for reliability prediction.

Member companies of the ECPE, such as ABB, Siemens, Bosch and Daimler, are able to access, share, and apply knowledge on technologies such as the MicReD power tester or T3Ster thermal transient testing system. Dr. John Parry, electronics industry manager for Mentor Graphics Mechanical Analysis Division, represents the company within the ECPE.

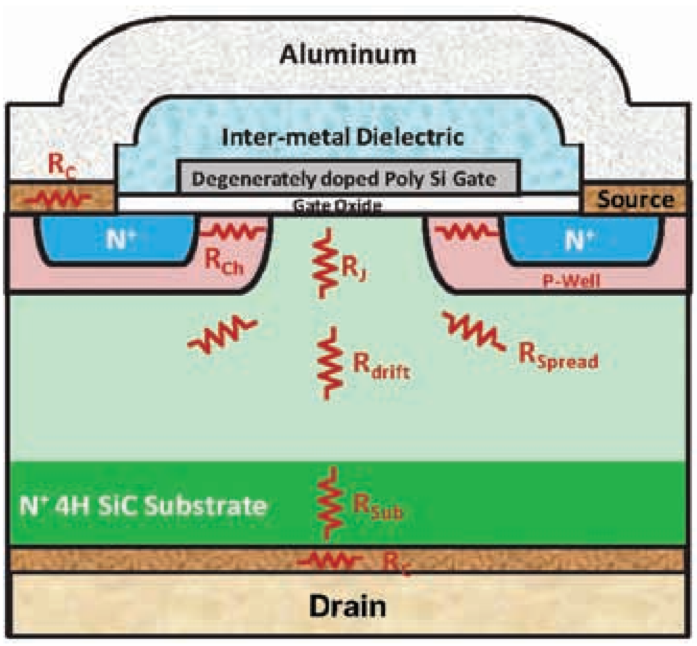
From Nanoscale to Power MOSFETs

On December 15-17, 2014, the 60th annual IEEE International Electron Devices Meeting (IEDM), continued the tradition of spotlighting technical breakthroughs in a wide range of applications such as logic, memory, MEMs, sensors, displays, flexible electronics, biomedical imaging, power electronics and energy harvesting.

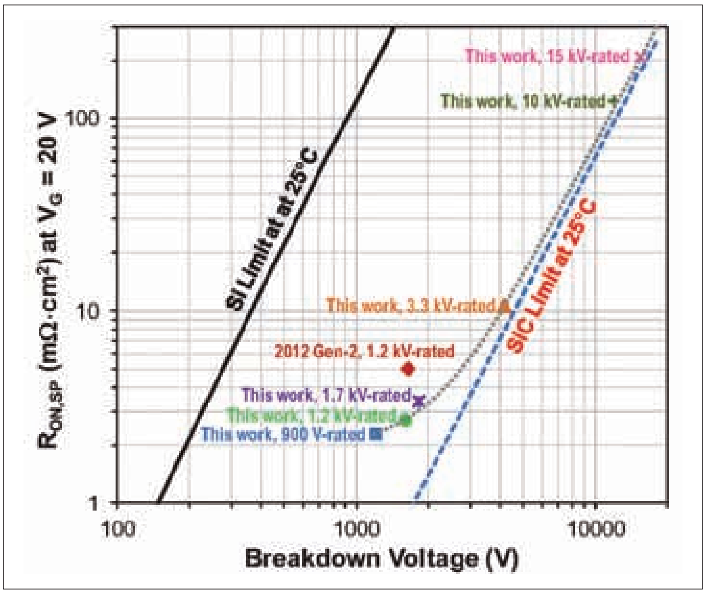
All modern transistors have a channel to conduct electricity and one or more gates to turn the current on and off. FinFETs have long, thin fin-like channels (hence the name) surrounded by multiple gates. This design leads to greater performance and enhanced energy efficiency. Both Intel (**www.intel.com**) and IBM (**www.ibm.com**) presented fully integrated 14 nm FinFET technologies.

Among the technical features Intel discussed were: a novel doping technique to prevent current leakage under the fins and to maintain very low doped fins, resulting in improvement in variation; two levels of air-gap-insulated interconnects (electrical connections) at ultra-narrow 80 and 160 nm minimum pitches, yielding a 17 % reduction in capacitance delays; eight layers of 52 nm pitch interconnects embedded in low-k dielectrics; an embedded 140 Mb SRAM memory with a tiny cell size of 0.0588 μm^2; and saturated drive currents significantly higher than for Intel's 22 nm first-generation FinFETs (improvements of 15 % and 41 % for NMOS and PMOS transistors, respectively). The transistors operate with a supply voltage of 0.7 V. The researchers also discussed how aggressive design rules enables very high aspect ratio rectangular fins (8 nm wide and 42 nm high) at unprecedented levels of uniformity.

IBM described a different approach to 14 nm FinFET transistors, their devices are made not from a standard bulk silicon substrate but from an insulating substrate known as SOI, a more expensive material but one which simplifies manufacturing in terms of device isolation. These devices are more than 35 % faster than IBM's 22 nm planar (i.e. standard, non-FinFET) transistors, with an operating voltage of 0.8 Volts.



Schematic cross-section of a unit cell showing resistive components of Cree's new 900 V to 15 kV SiC DMOSFETs

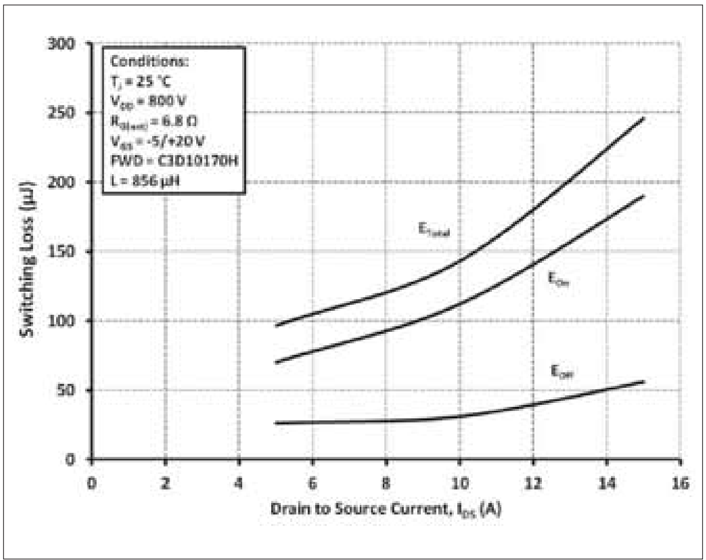


Specific on-resistance, $R_{ON,SP}$ in mΩcm² of the next generation SiC DMOSFETs measured at gate bias of 20 V as a function of breakdown voltage at 25°C

Importance of power semiconductors

Regarding the Social Impact of Power Semiconductor Devices, B. J. Baliga from North Carolina State University stated, that power semiconductor devices are used in all the major sectors of our economy. The largest impact on society has been a cost savings of $ 15 trillion and carbon dioxide emission reductions by over 75 trillion pounds due to commercialization of the IGBT in the early 1980s.

Infineon (**www.infineon.com**) presented a paper on "Application Specific Trade-offs for WBG SiC, GaN and High End Si Power Switch Technologies". In the last decade the competition of power semiconductor switch technologies



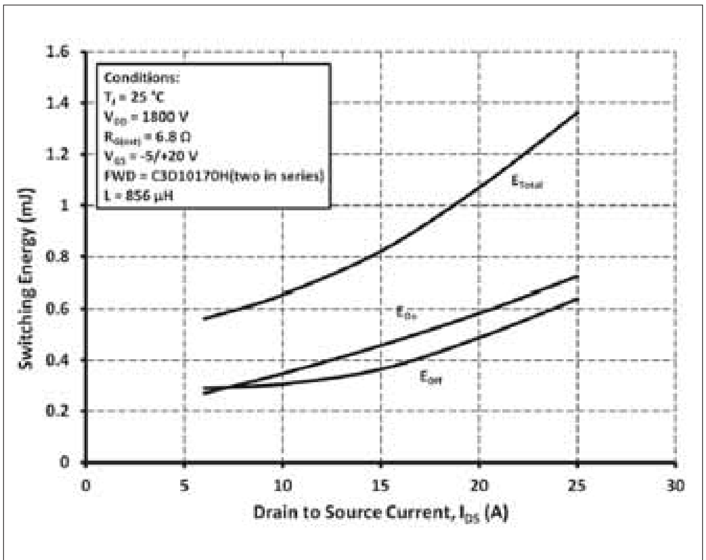
Switching losses as a function of drain current of the 1700 V, 15 A SiC MOSFET at 800 V and 25°C

was enriched by 2 new members: SiC-FETs (MOSFETs and JFETs) and lateral GaN-HEMTs. Whereas the SiC devices convince with great performance but still suffer from high wafer costs and wafer diameter limitations, GaN-HEMTs can be manufactured on large and cheap Si-wafers – but still have deficiencies with respect to ruggedness and require significant nominal voltage derating. In parallel to this new semiconductor switch solutions, the traditional Si-based technologies like IGBT and compensation MOSFETs like CoolMOS have improved continuously. Especially in the 600 – 1200 V blocking range this results in a very competitive situation, no clear long term winner can be identified today – the race will be decided differently for different applications.

The plenary presentations were opened by Cree's (**www.cree.com/power**) CTO John W. Palmour, he described the past, present and future of SiC technology (below a summary of this paper)

Silicon carbide power device development for industrial markets

Compared to silicon, 4H-silicon carbide (4H-SiC) is a wide bandgap semiconductor that offers a factor of > 8 times higher electric breakdown field, which allows SiC power devices to have a much thinner drift region and higher doping for a given voltage rating than their silicon counterparts. The much thinner and higher doped drift region in SiC greatly reduces the on-resistance

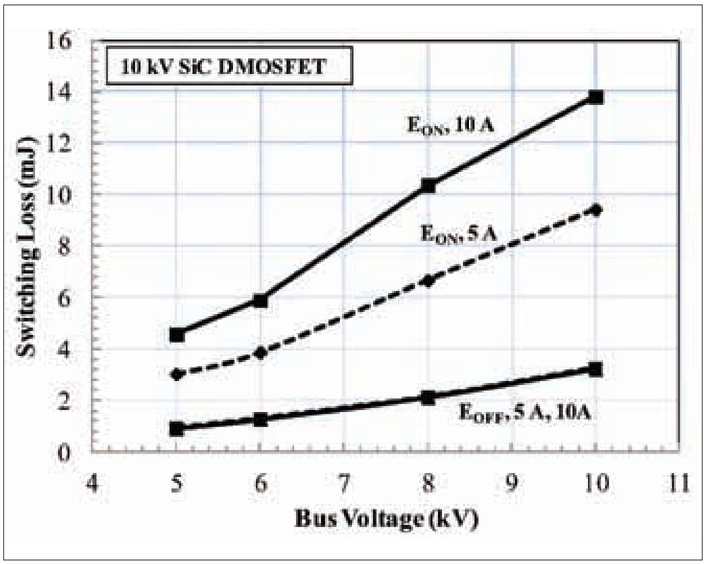


Switching losses as a function of drain current of the 3300 V, 25 A SiC MOSFET at 1800 V and 25°C

of the devices, which enables the use of a simple unipolar SiC power MOSFET device structure. Without the introduction of any complicated Super-Junction or bipolar device structures, SiC MOSFETs reported to date already significantly outperform any available Si-based power switches at the same voltage rating in terms of reduced switching losses and at least 5 - 10 times higher switching frequencies. As a result, one can fabricate unipolar power switches in SiC with voltage ratings more than 10 times higher than is feasible for Si unipolar devices.

SiC bulk crystals had long been plagued by a high density of defects termed "micropipes", which were the open core of a super screw dislocation that resulted in micron-sized holes that ran through the crystals. However, this defect has by and large been reduced to the point where they are no longer a major yield limiter for devices. Micropipe densities are generally less than 0.5 cm^{-2} for all wafer sizes.

While 100 mm diameter SiC wafers are still the norm for device production today, 150 mm diameter wafers have been commercially available for the last



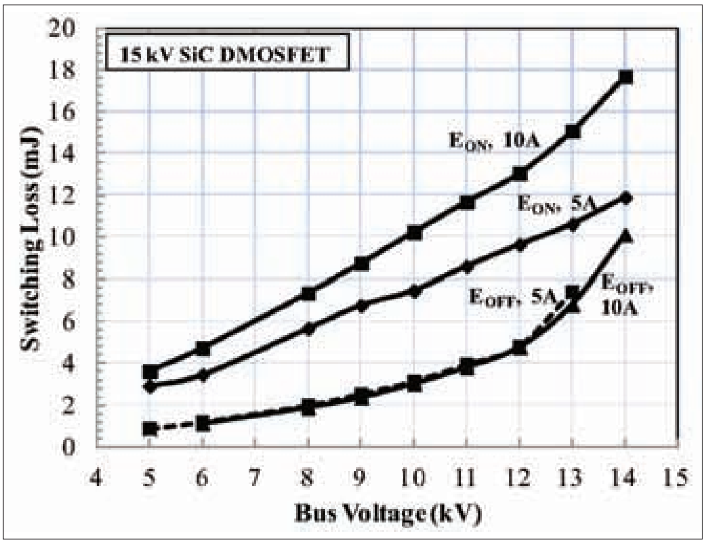
Switching losses as a function of bus voltage for the 10 kV SiC MOSFET at 5 A and 10A at 25°C

2 years from multiple sources, and there is a lot of activity by those with already existing 150 mm wafer fabs to migrate production to this larger size. As an example, a 150 mm diameter n^+ SiC today can contain only two micropipes on the wafer, resulting in a density of less than 0.05 cm^{-2}.

New SiC MOSFETs

Among the most commonly pursued switches, the SiC MOSFET offers the most desirable features in terms of device performance from a user's perspective, such as normally-off operation, low turn-off losses due to the lack of bipolar current tail, low conduction losses, and low gate charge. In early 2013, Cree commercially released its 2nd generation 25/80 mΩ, 1200 V, SiC MOSFETs. In 2011, 10 kV/10 A SiC power MOSFETs that can be switched at 20 kHz and above have been demonstrated. With further optimized device design and rapid advancement in SiC substrate and epitaxial material quality in recent years, the next-generation SiC power MOSFETs show even greater capability with a further reduction in on-state resistance and improved blocking performance, resulting in a further reduction in switching losses and fabrication cost at voltage ratings from 900 V up to 15 kV compared to our commercially released SiC MOSFETs.

When compared to state-of-the-art silicon high-voltage devices, like IGBTs, Thyristors, and PiN diodes, with a blocking voltage close to 8 kV, SiC MOSFETs with voltage ratings at and above 10 kV can offer a significant improvement in system efficiency, switching speed, and power density due to much lower switching losses, a reduced number of components required in series as well as the number of levels utilized to achieve desired blocking voltage, resulting in a much simplified system design with improved overall reliability at the



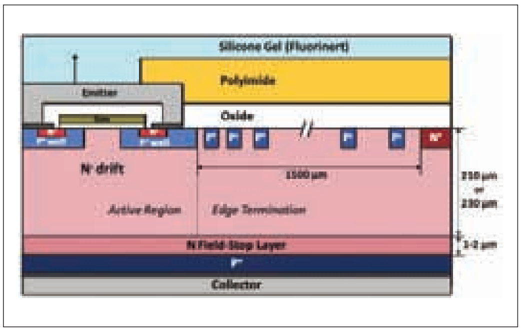
Switching losses as a function of bus voltage for the 15 kV SiC MOSFET at 5 A and 10A at 25°C

system level. The next-generation SiC power MOSFETs will allow even further penetration of SiC MOSFETs into energy conversion systems not only at lower voltages, but will also enable entirely new topologies to be achieved at very high voltages.

The new SiC MOSFETs have a chip size and an active conducting area of 6.79 mm^2 and 3.41 mm^2 for the 900 V, 1200 V, and 1700 V-ratings, 46.72 mm^2 and 28.11 mm^2 for the 3300 V-rating, 65.61 mm^2 and 32 mm^2 for the 10 kV-rating, and 63 mm^2 and 32 mm^2 for the 15 kV-rating. The total on-resistance (R_{ON}) consists of channel resistance (R_{ch}), JFET resistance (R_J), spreading resistance (R_{spd}), drift-layer resistance (R_d), and substrate resistance (R_{sub}), assuming that contact resistance (R_C) to the source and backside drain regions are negligible. The limitation of the SiC MOSFET structure for the 900 V ~ 1700 V-ratings is in the MOS channel, which currently suffers from relatively low effective channel mobility (μ_{eff}). Because of the low ?$_{eff}$, a moderately high gate bias is needed to fully turn-on the device. At higher voltages, the SiC bulk resistance becomes dominant over the SiC MOS-channel resistance.

Despite the much lower inversion channel mobility than in Si MOS-based power switches, extremely low specific on-state resistance ($R_{ON,SP}$) has been achieved by further optimization of the device design in the recently developed 900 V, 1200 V, 1700 V SiC power MOSFETs. As the voltage rating increases to 3300 V and higher, the SiC MOSFET channel resistance becomes much less significant as compared to the SiC bulk resistance, therefore the total on-resistance is closer to its theoretical value for the MOSFETs with higher breakdown voltage. By using the planar SiC MOS channel structure, the electric fields within the active region can be designed to ensure maximum reliability during high-voltage operation as opposed to the use of trench structures, but still outperform most published $R_{ON,SP}$ values for SiC trench MOSFETs. We have now achieved DMOS performance in SiC power MOSFETs with a $R_{ON,SP}$ as low as 2.3 mΩcm^2 for a BV of 1230 V and 900 V-rating, 2.7 mΩcm^2 for a breakdown voltage of 1620 V and 1200 V-rating, 3.38 mΩcm^2 for a breakdown voltage of 1830 V and 1700 V-rating, 10.6 mΩcm^2 for a breakdown voltage of 4106 V and 3300 V-rating, 123 mΩcm^2 for a breakdown voltage of 12 kV and 10 kV-rating, and 208 mΩcm^2 for a breakdown voltage of 15.5 kV and 15 kV-rating.

The switching losses of the 1700 and 3300 V SiC MOSFETs at 25°C were evaluated in an inductive load double-pulse switching setup. A rectifier built with C3D10170H 1700 V SiC JBS diodes connected in a parallel configuration was used as the freewheeling diode. A supply voltage of 800 V to the 1700 V MOSFET and 1800 V to the 3300 V MOSFET and an inductor of 856 µH were used. A V_G of +20 V was used to turn on the SiC MOSFET and a V_G of -5 V was used to turn off the MOSFET. Due to ~ 2x higher blocking voltage and about 7x larger active area, the total switching losses of the 3300 V MOSFET (1.35 mJ) is > 6x higher than that of the 1700 V MOSFET (245 µJ) when switched at about 50 % of the rated voltage and 100 % rated current.



Cross-section of fabricated 4H-SiC n-IGBTs including passivation scheme to achieve high blocking voltage

The device performance of the 10 kV and 15 kV SiC MOSFETs were evaluated using a different high-voltage double-pulse switching set-up. A low capacitance air-core 14 mH inductor was used for the measurement. The inductor current was commutated by two 10 kV SiC JBS diodes connected in series on the high side of the double pulse circuit. The external gate resistance used in the set up was 6.7 Ω. Both the 10 kV and 15 kV SiC MOSFETs were measured in the same set-up. Unlike bipolar devices, SiC MOSFETs have no current tail, and hence have small switching losses in both hard switched and soft switched topologies. The 10 kV SiC MOSFET was switched at 10 A and bus voltages from 5 kV to 10 kV, whereas the 15 kV MOSFET was switched at 10 A and bus voltages from 5 kV to 14 kV. The total energy losses at room temperature is about 17 mJ for the 10 kV MOSFET switched at 10 kV, 10 A and about 27.5 mJ for the 15 kV MOSFET switched at 14 kV, 10 A.

Furthermore, a boost converter efficiency based on the 15 kV SiC MOSFET was evaluated as a function of the output voltage under 20 kHz and 40 kHz for both soft-switching (ZVS, zero-voltage-switch) and hard-switching. When switched at ~ 6 kV and ~ 5 A, the 15 kV SiC MOSFET exhibits the capability of a very high conversion efficiency of 98.5% during the 20 kHz soft-switching, 98.2 % during the 40 kHz soft-switching, and 93.2 % during the 40 kHz hard-switching. These results are extremely promising for high power and high frequency applications that can significantly impact the system size, weight, and cost of the future advanced power conversion and transmission systems.

In summary, SiC technology has developed to the point where it can have a large impact on industrial markets. SiC substrates and epitaxy are now commercially available in 150 mm diameters with excellent crystal quality and uniformity. We have developed and demonstrated next generation 900 V up to 15 kV SiC power MOSFETs with excellent performance over a wide range of voltage-ratings from. By further optimizing device design and fabrication processes, these SiC MOSFETs show not only record low specific on-resistance but also exhibit very high switching frequency performance with extremely low switching losses over conventional Si power devices at the similar voltage ratings. The simple planar DMOS structure allows for very high reliability, and the threshold voltages are stable. At 10 kV and above, entirely new applications can be explored with 10-15 kV MOSFETs with extremely fast switching speeds. For even higher voltages, bipolar devices such as GTOs and IGBTs may be utilized. "We have demonstrated 22 kV GTOs with 200 A capability. The highest voltage switching device demonstrated to date is a 27 kV SiC IGBT", Palmour concluded.

APEC's 2015 home - Charlotte's downtown and convention center

First 2015 Power Highlight

APEC 2014 closed with a record attendance of more than 3,000 conference delegates and more than 330 exhibitors. Now it's time from March 15 – 19 for APEC's 30th anniversary in Charlotte/North Carolina.

The Professional Education Seminars will start on Sunday, March 15 before the official opening of the conference. Each of the three-and-a-half-hour seminars provides an in-depth discussion of important and complex power electronics topics and combines practical application with theory.

The Plenary Session on Monday, March 16, consists of distinguished speakers from industry and academia covering the key power electronics architectures, components, innovations, and technologies affecting our industry and society. First presenter will be Hao Huang, GE Aviation, "Challenges in Electrical Systems for More Electric Aircraft", followed by David Cox, Cree, "Power Architectures for the Next Generation of Solid-State Lighting"; Dhaval Dalal, ON Semiconductor, "PSMA Power Technology Roadmap"; Kerry Cheung, Department of Energy, "DOE Perspectives on Microgrids"; Veena Misra, North Carolina State University, "Optimizing Performance and Reliability of GaN MOSFET Devices"; and finally David Pesiri, Los Alamos National Laboratory, "A New Emphasis on Industry Partnerships at Los Alamos: Finding Win-Win Outcomes that Benefit the Nation".

Afterwards the exposition will be opened. To date 239 companies will be exhibiting at APEC, and are once again sold out with 366 exhibit booths on the show floor. These global exhibitors will showcase the state-of-art technologies, products, and solutions on applied power electronics augmented by the exhibitor seminars. The exhibit hall will be open Monday, March 16th 5:00 pm – 8:00 pm for the opening reception; Tuesday, March 17th 12:00 pm – 5:00 pm, and Wednesday, March 18th 10:00 am – 2:00 pm (lunch will be provided on both days).

With 540 papers selected for this year's Technical Sessions and an expanded Industry Sessions track, the program again is expanded.

The technical papers presented in lecture and dialogue formats (March 19) are selected from over 900 digests submitted from 44 countries. Increasingly popular industry sessions have reached an all-time high with 93 accepted presentations in 15 sessions. Thee Industry Sessions track runs in parallel with the technical sessions Track. Speakers are invited to make a presentation only, without submitting a formal manuscript. This allows to present information on current topics in power electronics from sources that would not otherwise be present at an industry conference. While many of these sessions are technical in nature, some also target business-oriented people such as electronic system designers, regulatory agencies, business-oriented people such as purchasing agents, and other people who support the power electronics industry.

This year's Rap Sessions include three moderated debates on Wireless Transfer of Power; Variable Speed Drives; and the Who, What, Where When and Why of Wide-Bandgap devices.

New this year is a new APEC Mobile App, which will provide attendees access to an interactive directory and map of the exhibitors on their mobile devices. For the first time, APEC will also start providing on-line proceedings at the conference for easier access.

Charlotte, a very-walkable and a first-time city for APEC, is located in the center of the East Coast, USA, with its major airport serving more than 143 destinations worldwide via all major carriers. The airport to Center City is only 7 miles (11 km).

Tuesday, March 17 | 8:30 a.m. – 12:00 p.m.
T1: Isolated DC-DC Converters
T2: Three-Phase & Higher Power AC-DC Converters
T3: Magnetic Devices and Components I
T4: Photovoltaic Applications
T5: Machines and Inverters
T6: Modeling of DC Energy Converters and Systems
T7: DC-DC Converter Control I
Wednesday, March 18 | 8:30 a.m. – 10:00 a.m.
T8: Integrated and HF DC-DC Converters
T9: Single Phase AC-DC Converters
T10: Miscellaneous Grid Topics
T11: Inverter Control I
T12: Conductive and Inductive Chargers for Electric Vehicles
T13: DC-DC Converter Control II
T14: Renewable Circuits I
Wednesday, March 18 | 2:00 p.m. – 5:30 p.m.
T15: Renewable Microgrids
T16: WBG Device Performance & Circuit Interactions
T17: Inverter Topologies
T18: LED Drivers
T19: Non-Isolated DC-DC Converters
T20: Multilevel Converters and Power Transformers
T21: Component Modeling
Thursday, March 19 | 8:30 a.m. – 11:20 a.m.
T22: DC-DC Converter Applications
T23: System Integration
T24: Modeling of AC Energy Converters and Systems
T25: What's in the Can, Combinational Semiconductors
T26: Renewable Wind I
T27: Power Electronics for Transportation Electrification
T28: WBG Power Device Based Applications
Thursday, March 19 | 2:00 p.m. – 5:30 p.m.
T29: Resonant and Soft-Switching DC-DC Converters
T30: Power Converter Control
T31: Inverter Control II
T32: Wireless Power Transfer
T33: Utility & Mixed Applications of Power Electronics
T34: Photovoltaics
T35: Grid and Microgrid Interfaces

Overview APEC 2015 technical sessions

D1:	AC-DC Converters
D2:	DC-DC Converters I
D3:	DC-DC Converters II
D4:	Power Electronics for Utility Interface I
D5:	Power Electronics for Utility Interface II
D6:	Power Electronics for Utility Interface III
D7:	Drives and Inverters I
D8:	Drives and Inverters II
D9:	High Performance Devices and Components
D10:	Magnetic Devices and Components II
D11:	Power System Solutions
D12:	Modeling and Simulation
D13:	Control
D14:	Manufacturing, Quality, and Business Issues
D15:	Renewable Grid
D16:	Renewable Wind II
D17:	Renewable Circuits II
D18:	Renewable PV Systems
D19:	Transportation Power Electronics
D20:	Power Electronics Applications I
D21:	Power Electronics Applications II

Overview APEC 2015 dialogue session on March 19

PCIM
EUROPE

International Exhibition and Conference
for Power Electronics, Intelligent Motion,
Renewable Energy and Energy Management

Most Important European Power Electronics Event

ABOVE: Again it's time from May 17 – 21 for PCIM Europe in Nuremberg

This year's PCIM will be held in Nuremberg from May 19. - 21. PCIM Europe 2014 ended with an outcome of approximately 8,000 visitors, 391 exhibitors and 97 representing companies at the show floor on an area of 20,000 square metres, and over 700 conference delegates. More is expected by organizer Mesago for this year's event.

Already on the Sunday (May 17) and Monday (May 18) seminars and tutorials will be offered.

Seminar 1 - Basics of Electromagnetic Compatibility (EMC) of Power Systems; Seminar 2 - Physical Limitations to Magnetics Power and Energy Densities, with Design approaches to Maximization; Seminar 3 - Ripple-Based Control of DC-DC Converters; Seminar 4 - Magnetic design for very high Efficiency Power Conversion; Seminar 5 - Power Supply Workshop for non-isolated DC/DC converters; Seminar 6 - Practical Application of 600 V GaN HEMTs in Power Electronics, and finally Seminar 7 - Design of Magnetic Components for High Power Converters.

On the Monday Seminar 8 - Fundamentals and Multi-Objective Design of Inductive Power Transfer Systems; and Seminar 9 - Solid-State Transformer Concepts in Traction and Smart Grid Applications will be offered.

Also on the Monday (May 18) Tutorial 1 - 99% Efficiency for AC-DC and DC-DC Converters; Tutorial 2 - Power-Factor Correction - from the Basics to the latest Developments; Tutorial 3 -

Electromagnetic Design of High Frequency Converters and Drives; Tutorial 4 - High Performance Control of Power Converters; Tutorial 5 - Power Electronics in renewable Energy Systems; Tutorial 6 - Advanced Design with MOSFET and IGBT Power Modules; Tutorial 7 - Switchmode Design and Layout Techniques for low EMI; Tutorial 8 - Reliability of IGBT Power Modules; and Tutorial 9 - IGBT Gate Drive Control-Principles, Optimization and Protection will be held.

Keynotes on current trends

First keynote on Tuesday morning (May 19) after the official opening and awards presentation is entitled "The State-of-The-Art and Future Trend of Power Semiconductor Devices" given by Tatsuhiko Fujihira, Fuji Electric Holdings Co. Ltd, Tokyo, Japan. Growing population and economy of this planet require us to build up a sustainable society system. In electric power conversion, more energy-saving and more resource-saving, efficient systems must be developed. Power devices are the key to develop more efficient power electronic systems. In this speech, state-of-the-art power devices, future trends, and some of their application examples to efficient power electronic systems are presented focused mainly on SiC devices and new types of Si IGBTs.

The second keynote on Wednesday morning (May 20) covers "Packaging and Reliability of Power Modules - Principles, Achievements and Future Challenges" by Prof. Dr. Uwe Scheuermann, SEMIKRON Elektronik GmbH & Co. KG, Nürnberg, Germany. A review of fundamental design principles for power modules shows, that module design is always a compromise between conflicting requirements. Nevertheless has the progress in interconnection technologies resulted in a considerable enhancement of module lifetime, allowing to extend the maximum junction temperatures to 200°C. However, this achievement is restricted to degradation phenomena, while reliability also has to take into account early life failures and random failures. Besides other challenges from new semiconductor materials, the consideration of all failure modes by better lifetime models will be an important task for the future.

The third keynote on Thursday morning (May 21) will deal with energy storage through "Electrochemical Battery Managements and Applications" by M.Eng. Daniel Chatroux, CEA-LITEN Centre d'Etues Nucleaires, Grenoble Cedex, France. Due to nomad applications the electrochemical energy storage in batteries is an important research and development domain with rapid progress. This keynote presents the different batteries technologies, the main applications and markets, the important differences between Lithium ion batteries and the other technologies, and the impacts on battery design and management. A focus is done on the batteries requirements for electric vehicle and plug-in hybrid, the impact on the battery pack design, performances and cost of ownership, and the challenges in this domain.

Special sessions on hot topics

Besides the technical sessions a number of special sessions will catch-up with the hot topics in industry. First special session on the Monday covers four papers on "Solar Inverter Technologies".

"Characterization of 1.2kV Silicon Carbide (SiC) semi-conductors in hard switching mode for three-phase Current Source Inverter (CSI) prototyping in solar applications" by Dr. Stéphane Catellani, Commissariat à l'énergie atomique et aux énergies alternatives, Le Bourget-du-Lac, France, is the first paper. A test bench is developed at the Dept of Solar Technologies (DTS) of the CEA. It allows to characterize SiC power semi-conductor TO-220/247 packaged operating in a current source inverter. The paper will include methodology to measure switching energies - transistor turn-on, turn-off and Schottky Diode turn-off, filters design, magnetics practical design, losses calculations models and electrical characterization of four prototypes of AC-400V three phase current source solar inverters.

"Future Challenges of Power Electronics for PV-Inverters" by Jens Friebe, SMA Solar Technology AG, Niestetal, Germany comes next. The costs of electrical energy from photovoltaic have been reduced by about 90% in the last two decades due to improved solar cell manufacturing and PV-Inverters. It is shown which innovations in the field of PV-Inverters helped to reduce the costs of the systems. It can also be seen, that there are new approaches needed to reduce the system costs even further. The requirements on the power electronic components because of additional functions are discussed. At the end of the paper it is shown how these topics will have an impact on the power electronics of PV-Inverters in the future.

"A Five-Level NPC Photovoltaic Inverter with Active Balanced Capacitive Voltage Divider" by Prof. Alfred Rufer, Industrial Electronics Laboratory, EPFL Lausanne, Lausanne, Switzerland, presents a new five-level NPC photovoltaic inverter, realized with an association of the principle of the Multistage Stacked Boost Architecture (MSBA). The 5-level NPC inverter is connected to the intermediary voltages of the multilevel set-up stage. Ahead of the MSBA conversion stage, a classical boost converter allows the operation of the PV cells with variable voltage according the MPPT control strategy. The paper describes a robust voltage balance control principle that includes local feed-forward for the current control references. Simulation results are presented, and practical verification will be included.

Finally in this session "A Single-Phase MISO HF-link Isolated Grid-Connected Inverter for Renewable Energy Sources Applications" will be introduced by M.Eng. Alejandro Aganza Torres, Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico. This paper presents a multiple-input single-output HF-link inverter for renewable energy sources grid-connected applications, commanded with a simple instantaneous power modulation scheme; the topology has no intermediate DC-link which reduces the number of power processing stages.

The Special Session "Digital Control Power - the Future of Power Electronics" on the Monday afternoon covers three papers.

"Software defined digital power conversion in medium to low power AC/DC SMPS applications" by Marc Fahlenkamp, Infineon Technologies AG, Neubiberg, Germany, will be the first presenter of this digital power session. Software defined power ICs are today mainly seen in the high performance SMPS applications. For the medium to low power AC/DC applications they are often oversized and usually need additional external peripheral components like high-voltage driver ICs, signal pre-processing, LDOs or a high voltage startup cell. The challenge is here to provide a core based HW architecture that supports the right flexibility for system innovations and reduction of the necessary external amount of components to the possible minimum by means of a specific partitioning for the HW and FW functions.

"Today's Relevance of Digital Control in Server- and Telecom Power Supplies" by Dr. Frank Schafmeister, Delta Energy Systems (Germany) GmbH, Soest, Germany, comes next. Today Server- and Telecom Power Supplies (PSUs) in most instances have made the way through adopting digital control methods. This is enabled on the one hand by the high flexibility of digital control solutions, and on the other hand by competitive prices and performances of DSPs. This paper will present a depicted set of digital control solutions and possibilities, most of them being in use in the industrial environment as for today. The presented methods are typically as well suitable for automotive power electronic applications, e.g. On-Board Chargers and DC-DC converters.

"Digital Power Conversion: Easy, flexible and efficient way to decrease BOM complexity" by Ales Loidl, STMicroelectronics, Praha, Czech Republic, finalizes this session. The digital control in power conversion is a topic of discussions for long time already. Despite of it still it was not too common to see it in the high volume consumer applications. Thanks to technology advancement the total application solution cost is getting to the point it has a smaller bill of material with more features. This paper on top of short summary on general digital power conversion facts would like to demonstrate on a real application (the 100W LED ballast for streetlighting consisting of advanced power factor control (PFC) and half-bridge LLC converter driven by single digital controller) how easy is to get in full digital control of power converter.

On the Wednesday (May 20) only one Special Session entitled "Power GaN for Automotive Applications" is scheduled – initiated and organized by Power Electronics Europe. It will take place from 10:00 – 12:30 in Room Brüssel 1 and covers four papers.

The first paper "Enhancement-Mode Gallium

Tuesday, 19 May 2015

Conference Opening and Award Ceremony				
KEYNOTE »The State-of-The-Art and Future Trend of Power Semiconductor Devices«				
Materials	SiC High Power	Control and Drive Strategies in Power Converters	Special Session Solar Inverter Topologies	Special Session Passive Components
High Power Low Inductive	Reliability Monitoring	New and Renewable Energy Systems	Control Techniques in Intelligent Motion Systems	Special Session Digital Control Power – the Future of Power Electronics
Poster/Dialogue Session				

Wednesday, 20 May 2015

KEYNOTE »Packaging and Reliability of Power Modules – Principles, Achievements and Future Challenges«				
Special Session Power GaN for Automotive Applications	HV-IGBT	DC/DC Converter	Advanced Packaging	Control and Drive Strategies in Power Converters
GaN	Robustness	Power Electronics in Transmission Systems	Applications for Drives & Motion Control	Passive Components and New Materials
Poster/Dialogue Session				

Thursday, 21 May 2015

KEYNOTE »Electrochemical Battery Managements and Applications«				
SiC Low Power	DC/AC Converter	Power Quality Solutions	Special Session E-Mobility	Motors
Power Module	Low Power Converters	Sensors	Power Electronics in Automotive, Traction and Aerospace	

LEFT: Condensed PCIM 2015 conference program

Nitride Transistors in Automotive Applications" will be given by Alexander Lidow, CEO Efficient Power Conversion (EPC) Corporation, El Segundo, USA. Enhancement mode gallium nitride transistors have been in production for over 5 years. As the technology has matured it has been adopted into a number of automotive applications such as LiDAR sensing, EV charging, class-D audio, cockpit wireless charging, and lighting, with many more to follow. In this presentation also the current and future applications of GaN technology in these automotive applications, as well as traction control of electric vehicles, will be discussed.

"Progress of GaN Transistors for Automotive Applications" by Yifeng Wu, TRANSPHORM Inc., Goleta, USA, comes next. Systematic voltage-accelerated stress tests reveal an intrinsic Mean Time to Failure (MTTF) >1E7 hours for qualified GaN switches at 600V. Application evaluation also show superior benefit over Si-based power devices in multiple dimensions including simplicity of circuit topology, higher conversion efficiency and operation frequencies. These advances indicates near term readiness for GaN in automotive applications starting from auxilliary power to the man drive.

"The Automotive Market Opportunity for GaN" by Girvan Patterson, GaN Systems Inc., Ottawa, Canada, includes studies of the market opportunity, current performance and projected performance of very large area GaN devices, with applicability to the automotive market. Comparisons are made regarding the performance differences between SiC, GaN, and Si IGBT devices. A large area GaN device having a Wg of 1000mm is described.

Finally, "GaN on Silicon Based Power Conversion for Automotive Applications: Progress and Potential", will be presented by Tim McDonald, International Rectifier Corp., El Segundo, USA (now an Infineon subsidary). The promise and potential of GaN-based power conversion is by now widely communicated and understood. Switch products in voltage range of 40 V to 600 V have been developed. 100 V products are in high volume manufacturing in consumer electronic systems and 600 V devices are being designed into high performance power conversion systems in consumer electronics and information technology applications. With such demonstrated high performance and technology maturity it follows quite naturally to ask what benefit Gallium Nitride on Silicon power devices offer in electric vehicle applications: what are the demonstrated and further expected possible performance benefits? What are the reliability requirements? When can Gallium Nitride on Silicon devices be ready for production use in automotive applications? This presentation will provide answers to these questions. Additionally, attendees will receive updates on the latest developments in Gallium Nitride on Silicon power conversion.

Certainly this GaN/Automotive topic will find a lot of interest, particularly in the "automotive country Germany". In order to extend the auditorium from the conference to the exhibition floor on the same day, but in the afternoon (Wednesday, May 20, 2:00 – 3:00 pm) a Panel Discussion in PCIM's Industry Forum entitled "Quo Vadis Power GaN" moderated by PEE-editor Achim Scharf will be held including the speakers of this Special Session.

The final Special Session on "E-Mobility" is scheduled for the Thursday morning.

"Smart Stator Tooth Design with novel Control and Safety Functions in Electric Vehicle Drivetrains" by Hubert Rauh, Fraunhofer IISB, Erlangen, Germany will introduce the EMiLE project pursueing a novel approach for the integration of motor, power electronics and control in an EV drivetrain. In this integrated electric drivetrain each stator segment of the electric motor is equipped with its own power electronics and intelligence to form a so called smart stator teeth. New control and safety functionalities can be realized with this fully integrated multiphase drive system.

"Determination and Comparison of equivalent Circuit Parameters in large-air-gap Transformers by different Methods" by Dr. Thomas Komma, Siemens AG, München, Germany, comes next.

Charging of electric vehicles by Wireless Inductive Power Transfer requires transformer structures labeled by large air-gaps. This results in high leakage inductances of the transformer and higher stray fluxes in the environment. The paper describes and compares different methods of determining equivalent circuit parameters of large-air-gap transformers by measurements and simulations. A possibility to extract important circuit parameters will be presented and validated by measurements.

"Design of a Switched Reluctance Machine as a Near-Wheel Motor for Electric Vehicles" by Dipl.-Ing. Samil Yavuz, Universität Stuttgart, Stuttgart, Germany, covers the design of a switched reluctance machine for a near-wheel drive application. The focus of this paper is the optimization of a switched reluctance machine for the electric kart. In the first step the dependence on the torque characteristic is analyzed by geometry parameters. The goal of the multi-objective optimization is to maximize the nominal torque and to minimize the torque ripple.

Finally, "A Pareto-Based Comparison of Power Electronic Topologies for Inductive Power Transfer" will be presented by Tobias Diekhans, Robert Bosch GmbH, Stuttgart, Germany. This work provides a simulative comparison of power electronic topologies suitable for contactless inductive vehicle charging. To enable a fair comparison, parametric simulation models of the contactless transformer and the power electronic components are implemented and each topology is holistically optimized using a multi-objective optimization approach. A detailed comparison of the resulting Pareto-fronts is provided with regard to achievable efficiency and estimated material costs.

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The Efficiency Trend in Motor Control

The trend towards higher efficiency for electrical motors started to accelerate at the turn of the century with advent of brushless permanent magnet motors and improved semiconductor cost and performance. Expanding into consumer products with the BLDC motor. Since then it has evolved to include the electronic commutation of ACIMs, revival of the SRM, and even removal of the magnets again with the SyncRM. A new family of 16-bit dsPIC33 Digital Signal Controllers (DSC) provides for these motors 5 V operation for improved noise immunity and robustness, well suited for devices operating in harsh environments such as appliance and automotive applications. **Erlendur Kristjansson, Product Marketing Manager, Microchip Technology Inc., Chandler, USA**

Efficiency is the Holy Grail in all electric motor based applications. If we look at the different applications that are using electric motors today we can see the trend of continued improvement towards higher efficiency and lower cost. For example, in cars the original approach for driving pumps and fans under the hood was the serpentine belt, but even though this is a convenient way to utilize the engine rotation to drive these actuators it is not very efficient. Taking these actuators and drive them with motors adds flexibility and improved efficiency. Another example is washing machines, were the primary motor type has been AC induction, but with increased requirements for energy efficiency in home appliances and more control of the washing cycle to reduce water usage, the use of permanent magnet synchronous motors in new designs has been become dominant.

Of course this trend has been heavily dependent on the improvement of the semiconductor components needed for the inverter stage and control. In the past the cost of the motor drive needed for electronic commutation has been a significant factor in limiting the use of synchronous motors in many applications. Today that is not as much the case and these motors have become the norm in many applications.

Motor options

The primary motor types that are being considered today in most applications where efficiency and dynamic controls are important are:

- AC Induction Motor (ACIM)
- Brushless DC Motor (BLCD motor)
- Surface Permanent Magnet Synchronous Motor (PMSM or SPM motor)
- Internal Permanent Magnet Synchronous Motor (IPMSM or IPM motor)
- Switched Reluctance Motor (SRM)
- Synchronous Reluctance Motor (SyncRM).

Efficiency of the various motor types can be ranked from most to the least efficient: IPM motor, PMSM, BLDC, SynchRM, SRM, and ACIM, with same order for power/torque density.

Of course the ACIM is the workhorse of industrial applications and the most common motor type in high wattage applications (>1kW). But with the increased demand for efficiency many ACIM installations are being updated with electronic commutation drives for improved efficiency. In applications were more dynamic control is needed the use

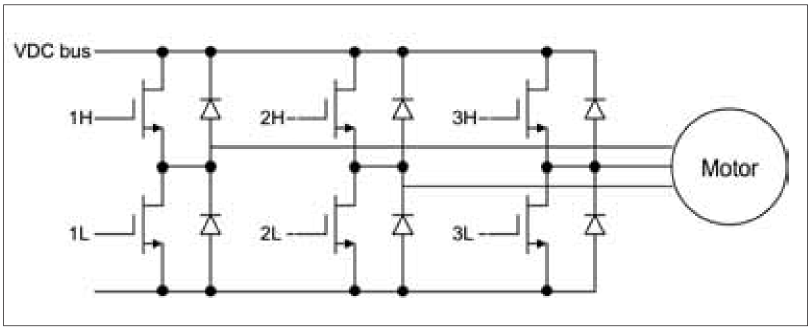
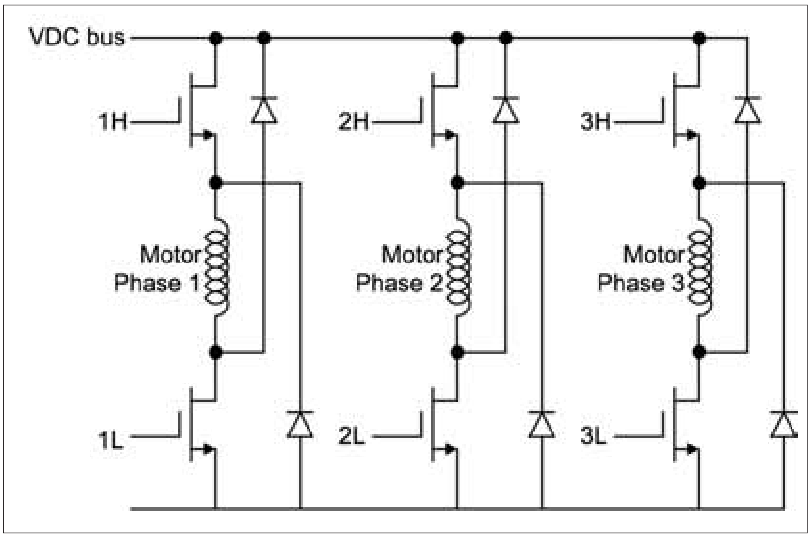


Figure 1: **Motor drive circuity for synchronous motors (above) and SRM drives (below)**



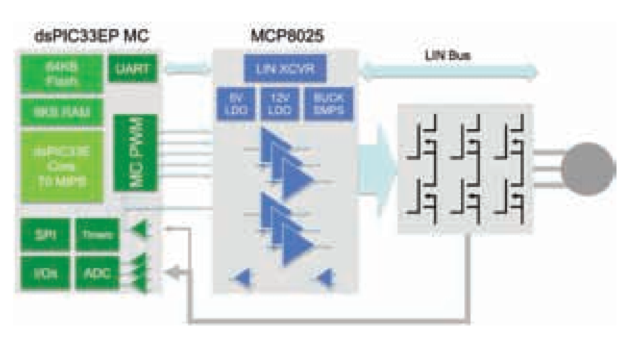


Figure 2: Automotive cooling fan implementation

of PMSM makes more sense. Then in some applications, were the cost is critical and factors like weight-to-torque ratio and robustness are needed, the use of SRM have been seen. Another classical industrial ACIM application is large HP (>15HP) compressors. Here SyncRM motors have started to appear as these are structured very similar to ACIMs, same stator design with different rotor, but for the same frame size you can increase the torque and efficiency, or reduce the frame size.

Then there is the applications were there haven't been any motors, like under the hood of a car. Here the electrical motor is used to replace the mechanical serpentine belt and increase efficiency as the load can come and go with motors, while with the belt it is always there even though it isn't needed. These days everything counts when it comes to efficiency and fuel economy. Here the trend has been from belt to BLDC motor to PMSM. Another application in cars that is utilizing electric motors is drive by wire. Here for example SRMs are being used to drive the hydraulic pumps in the brakes. The high-speed capability of the SRM can build up pressure quickly to allow for fast break response.

Another very different application space were the use of electrically commutated motors have had big impact, battery operated tools and appliances. With the improvements in battery technologies, like lithium-ion, we can now have vacuum cleaners and power tools utilizing the efficiency of the BLDC motors. Initially these applications used primarily brushed DC motors, but there was a limitation on speed and torque. With the higher power/torque density BLDC motors allow for reasonable weight, longevity and performance that is close to match the wired version.

In home appliances, washing machines, refrigerators, dishwashers, air conditioners etc., the primary workhorse, just like in the industrial space, has been the ACIM. Since the turn of the century the brushless synchronous motors, primarily BLDC motors and PMSMs, have become more and more important. The primary reason has to do with governmental efficiency requirements. The problem to do this transition away from ACIMs in the consumer product space has always been the cost, both for the motor and the drive circuit. Fortunately the cost for both has come down significantly to allow the majority of new appliances to utilize the more efficient technology.

Drive technology

As mentioned earlier the drive circuit (Figure 1) is an important part when using electronically commutated motors, actually mandatory. Without it nothing happens. For nearly all the motors that we are talking about the drive circuit has a very similar stucture (Figure 1 top). The odd man out is SRM (Figure 1 bottom). The biggest difference between these motor types is in the controls, i.e., how the drive signal is created for these circuits. This has to do with how each motor is constructed resulting in different electro-magnetic behaviors. This has to be considered when generating the voltages/currents waveforms for the motor so it operates optimally/efficiently.

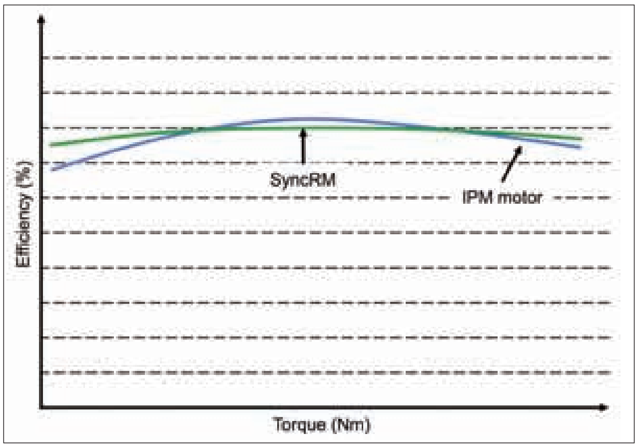
During the early days of the transitioning over to electronically commutated motors many of the targeted applications were very cost sensitive and as a result the BLDC motor was selected as it could be controlled with an 8-bit microcontroller using trapezoidal commutation. Even so the cost in some cases was still too high. Fast forward 15 years and the cost of high performance digital signal controllers and microcontrollers have come down enough to allow cost sensitive application use more advanced control algorithms like sensorless Field Oriented Control (FOC), for example circulation pumps for home heating systems or cooling fan for automobile (Figure 2).

So what does all these new fancy control algorithms give anyway? Why isn't the trapezoidal controlled BLDC motor good enough?

Efficiency

There are lot of talk about more efficient motors and drives, but in the end it is the whole system efficiency that matters. For example, we talked about the serpentine belt in car engines. Belt transmissions are very efficient, above 90 %, but don't it doesn't stop when something isn't needed. Instead it goes into idling, which has significant losses. So if we look at electro-mechanical systems there are additional losses like vibration, which can be caused by torque ripple, which are side effects of the way BLDC motor and SRM work. So based on the needs

Figure 3: Load/Efficiency curves (motor & drive)



of the application efficiency can be maximized further if the motor would run smoothly. This can be achieved by using an FOC algorithm or equivalent vector control.

Another factor is load the motor is running at. All motors have a load efficiency curve that looks something like the once in Figure 4 (this includes the drive). As can be seen, there is a peak, which is at the rated torque of the motor, but most applications don't have a fixed single load that the motor operates at. Some even have to work the full width of the operating range. An example of that is the air-conditioner compressor. Here the load changes based on how much the system has to cool or heat, and also during each piston cycle. Because compressors are nearly running all the time the use of IPM motors have become common as they have the highest efficiency. But, if we look at the efficiency curve an IPM motor and compare it to an equivalent SyncRM (Figure 3) we see that even though the IPM motor has higher efficiency at rated load the SyncRM's curve is flatter, i.e., the SyncRM maintains higher efficiency at lighter load making the over all efficiency for the application very similar to the IPM motor.

Conclusion

The trend towards higher efficiency for electrical motors started to accelerate at the turn of the century with advent of brushless permanent magnet motors and improved semiconductor cost and performance. Expanding into consumer products with the BLDC motor. Since then it has evolved to include the electronic commutation of ACIMs, revival of the SRM, and even removal of the magnets again with the SyncRM. What is important to remember in all of this is that the efficiency a system is the sum of all the pieces and how much you maximize it has to make financial sense. Therefore depending on the application there are different motor types and algorithms to chose from. There is no one motor technology that trumps all and therefore who ever is designing an electric motor based system has to understand the pros and cons of the available technologies.

5V dsPIC33 "EV" for Use in Harsh Environments

Microchip's new family of 16-bit dsPIC33 Digital Signal Controllers (DSC) with the dsPIC33 "EV" provides 5 V operation for improved noise immunity and robustness. It includes Error Correcting Code (ECC) Flash for increased reliability and safety, Cyclic Redundancy Check (CRC), Deadman Timer (DMT), and Windowed Watchdog Timer (WWDT) peripherals as well as a backup system oscillator and certified Class B software.

Other key features of this family include up to 6 advanced motor control PWMs, 12-bit ADC, and operational amplifiers, a combination for motor-control applications. The devices provide easy interface to 5V automotive sensors such as level or flow sensing, with improved noise immunity and enhanced reliability, and have 70 MIPS performance with DSP acceleration to execute smart sensor filter algorithms and integrate CAN communication software. For robust automotive touch user interfaces, the higher voltage operation enables more dynamic range and support for larger screen sizes. The dsPIC33EV devices offer up to 150°C operation with AEC-Q100 Grade 0 qualification enabling under-hood automotive applications.

The dsPIC33 "EV" family is supported by a C AN-LIN Starter Kit (DM330018) priced at $79.99 and a Motor Control Plug-In Module (MA330036), priced at $25.00, which is available to plug into the Low Voltage Motor Control Development Bundle (DV330100) priced at $369.00.

Microchip's dsPIC33 "EV" Motor Control Plug-In Module

MLC Capacitors in Automotive Power Electronics

The demand for better economy and lower CO2 emissions is driving automotive electronics in directions not previously experienced in this field. Electrical loads in automotive systems over the last few decades have evolved from simple lighting and battery-charging to engine management and control, sensors and safety and of course 'infotainment' making the car smarter and more sophisticated. All of which is driving Multilayer Ceramic Capacitors (MLCCs) into higher voltage and higher temperature applications.

Peter Scutt, Knowles Capacitors Syfer Technology facility, UK

While this trend continues increased use of electronics in high intensity lighting, safety systems, transmission & controls and power train systems for better propulsion can be observed. Incorporating electrical loads and replacing the conventional mechanical and hydraulic loads in the powertrain improves efficiency leading to more focus on electric vehicle concepts – hybrid (HEV) and pure (EV).

However, this increasing need and demand makes the conventional 12 V power system more challenging. As such, it is critical to have higher voltages in order to handle power train loads more efficiently – and with flexibility. Switched-mode power supplies (SMPS) provide the basis to do so. This is made possible due to advances in power electronics brought about by higher specified components such as MLCC's.

Implementation of power electronic circuits makes the system smaller and lighter and therefore provides the basis to improve the fuel efficiency as well. Advances in dielectric materials used on Multilayer Ceramic Capacitors, such as the X8R family, have resulted in increasing capacitance values along with increased voltage ratings (up to 3 kV). Increased MLC chip sizes and the inclusion of Syfer's patented StackiCap™ product has also given further increases in available capacitance values and added benefits of volumetric efficiency.

In response to changing market demands, Syfer have recently improved and expanded their range of AEC-Q200 automotive qualified capacitors (Figure 1) to include voltage ratings to 3 kV; safety rated class X&Y capacitors for AC charging circuits; X8R dielectrics to 150ºC; chip sizes to 3640; StackiCap capacitors with high volumetric efficiency and open-mode and tandem-cap options for improved

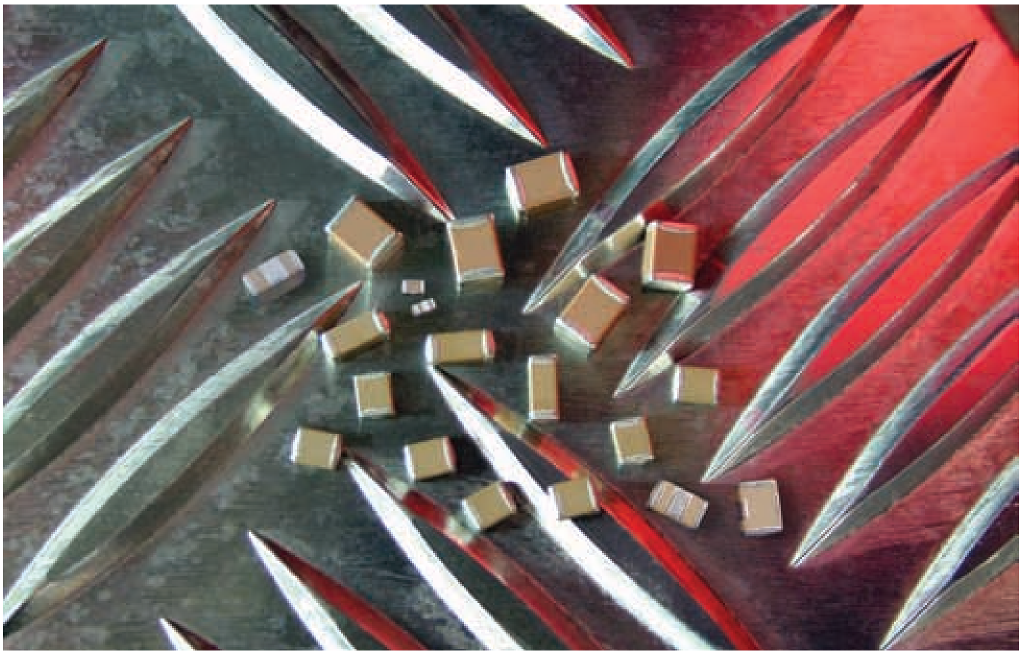


Figure 1: Multilayer Ceramic Capacitors, such as the X8R family, offer increased capacitance values along with higher voltage ratings (up to 3 kV)

Dielectric Classification	Lower Temperature (°C)	Upper Temperature (°C)	Maximum Cap Change
C0G	-55	+125	±30ppm/K
X5R	-55	+85	±15%
X7R	-55	+125	±15%
X8R	-55	+150	±15%

Table 1: Syfer products are normally rated over the temperature range of -55 to +150ºC

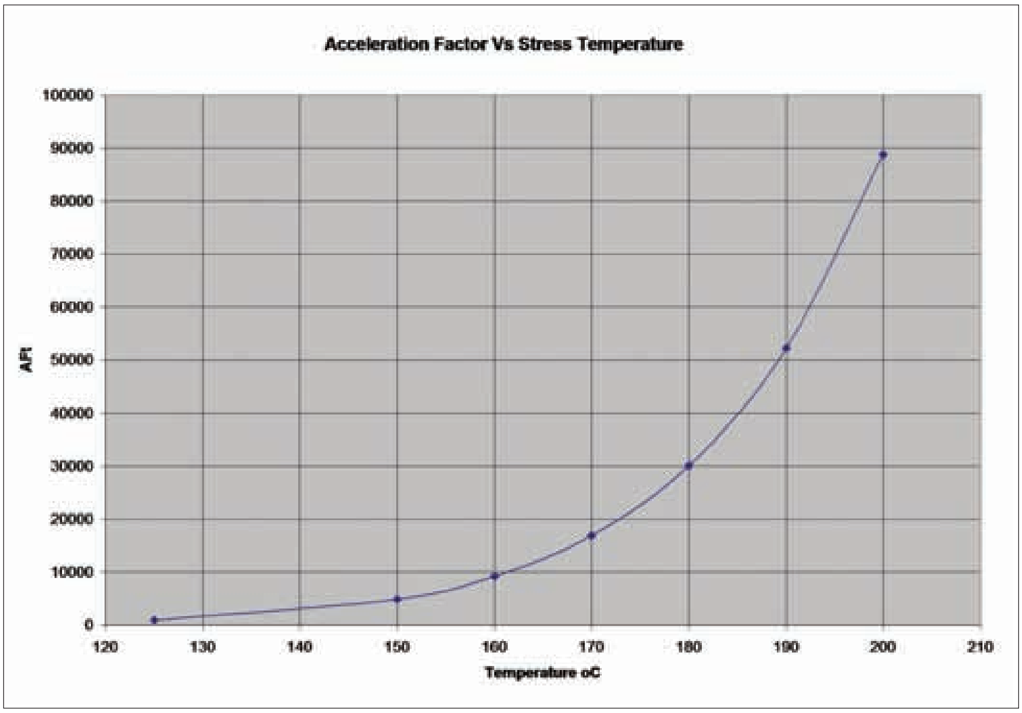


Figure 2: Temperature has a disproportionate affect and the reliability factor increases significantly as temperature rises

reliability. However the limiting factor is often the temperature performance of standard dielectric materials. In the case of Syfer products, they are normally rated over the temperature range of -55°C to +150°C (as shown in Table 1).

Use at extended temperatures

Beyond the expanded AEC-Q200 qualified ranges, Syfer have developed products with extended temperature capabilities. These parts are suitable for certain automotive and industrial applications where a wider temperature range is often requested, particularly for temperatures up to 200°C. After extensive testing performed at our manufacturing facility it is possible to make recommendations on part suitability for use at higher temperatures. Whilst not qualified to AEC-Q200, these meet Syfer's quality and reliability requirements. It should be noted however, that although parts will function at temperatures up to 200°C the electrical properties will not meet the normal C0G, X5R, X7R or X8R specifications.

The reliability of multilayer ceramic capacitors is directly related to the voltage applied and the operating temperature. Both voltage and temperature have an influence on the reliability acceleration factor, but temperature has a disproportionate affect and the reliability factor increases significantly as temperature rises (see Table 2 and Figure 2).

Thermal stress alone is sufficient to cause electrical failure. Thermal breakdown takes place when heat is generated in the dielectric at a higher rate than it can be conducted away. This leads to increased conductivity, more heat generation and eventually to instability in the form of an uncontrolled, often very rapid temperature rise. The temperatures attained when a capacitor discharges through a region of localized thermal runaway can be high enough to melt the dielectric material. When determining whether a particular component is suitable for use at high temperatures, customers must consider the thermal stress, and the effect of the elevated temperature on basic electrical properties such as capacitance, dissipation factor and insulation resistance.

Recommendations

Reliability testing of components at temperatures of up to 200°C has also been carried out. As component reliability is detrimentally affected due to thermal stresses it is not recommended that standard components are used at temperatures >125°C however:

For temperatures up to 160°C, most standard components will give reliable performance, but the Syfer recommendation is for the component user to select components with a voltage rating ≥30 % higher than the component that would normally be selected.

For example, if a 0805 50V 10 nF component would normally be used, the recommendation would be to use an 0805 100 V 10 nF part – NB the 0805 63V 10nF would not meet the recommendation as the voltage increase is only 26 %.

For temperatures >160°C, Syfer test data shows that the reliability is affected exponentially in a similar way to that shown on the thermal stress graph above. This makes it very difficult to provide a simple set of rules for component users to apply for use between >160°C and 200°C.

Consequently, for component use >160°C, Syfer recommends the user contacts our technical team with details of the exact application and they will recommend the most suitable component. This will ensure they will always get the most reliable and cost effective solution to their needs.

As an example, the recommended component size for a particular application may be a 1206 size chip for use at 170°C, but for the same capacitance value and working voltage an 1812 chip may be needed for use at 200°C.

Stress Temperature (°C)	125	150	160	170	180	190	200
Acceleration Factor	871	4884	9203	16854	30051	52258	88776

Table 2: Both voltage and temperature have an influence on the reliability acceleration factor

Single IC 48 V Power Management Battery Maintenance/Backup System

A common trend for electronic devices is increased portability; it is no longer universally acceptable for a device to turn off simply because somebody "pulled the plug." In order to implement portable functionality, devices must include advanced power management systems that can control the path of power from available sources to appropriate system outputs, keep a backup element charged and ready, and ensure that a system has adequate power at all times. Elegant, single-IC power management solutions are readily available for many portable devices, such as smart phones or tablets, which operate at low voltages and low power levels. Power management solutions for high power and high voltage systems, such as those required for many industrial or medical devices, generally require cumbersome and complex specialized discrete component solutions. The LTC4020 simplifies power management in these environments by incorporating advanced power management functions into a high voltage and high power single-IC solution.
Jay Celani, Design Engineer, Power Management Products, Linear Technology Corp., USA

The LTC4020 features an advanced 4-switch buck/boost DC/DC power converter, support for optimized battery charging, and Linear Technology's proprietary PowerPath™ system/battery power management functionality. The LTC4020 manages power distribution between the system input supply, the backup battery, and the converter output in response to load variations, battery charge requirements and input power limitations.

The single-inductor DC/DC buck/boost controller can accept input voltages up to 55 V and produce voltages that are lower, higher, or the same as the input voltage. The onboard battery charger can be configured to provide a constant-current/constant-voltage (CC/CV) charge profile optimized for lithium-based batteries, a 3-stage lead-acid battery charge profile, or a modified timer-terminated constant-current algorithm (CC), which is similar to the lithium profile but does not incorporate low voltage precondition and charge cycle restart functions.

Using CC mode charging to bend the rules for a 48 V lead-acid charger

When the LTC4020 is configured in the charge mode optimized for lead-acid batteries, the regulation voltage during absorption charging is 120 % of the typical battery system voltage, or 14.4V for a "12 V" lead-acid battery. Unfortunately, the built-in lead-acid charge algorithm cannot be used for a 48 V system battery, since the absorption charge voltage would exceed the operating maximum voltage for the LTC4020. This can be easily addressed by implementing a high current float charger using the constant-current (CC) charge algorithm.

The CC charge algorithm is enabled by leaving the LTC4020's MODE pin unconnected. A feedback resistor divider programs the desired battery float charge voltage, corresponding to $V_{FB} = 2.5$ V. The CC charge algorithm enables the full programmed charge current until the float regulation voltage is achieved. While maintaining the float regulation voltage, a lead-acid float charger must be able to continuously source current into the battery, so the charge function cannot terminate. CC charge mode can accommodate this by setting TIMER = 0 V, which disables the timer function and thus disables charge termination, so the charge cycle will continue indefinitely.

48 V system power supply with lead-acid battery backup

Figure 1 shows an LTC4020 configured as a 48 V system supply with an integrated backup battery float charger. The central component of this supply is an average current-mode buck/boost DC/DC controller, employing four external NFETs as switching elements, which provides 265 W of available output system power.

The converter operates from a 36 – 55 V input supply, with the converter limited to 8.3 A of average inductor current. The converter current limit is programmed by two 6 mΩ sense resistors (R_{SENSE1} and R_{SENSE2}) placed in series with SiS862DN switching FETs M1 and M2. The DC/DC converter supports at least 5 A at its output over the entire operating voltage range.

R_{SHDN1} and R_{SHDN2} form a divider at the SHDN pin, which sets the input shutdown voltage at $V_{IN} = 35$ V, disabling the DC/DC converter and battery charger functions when the input is below 35 V, so full load current is available whenever the supply is enabled. The SiS862DN switch FETs used here have a typical Q_G of about 10 nC each, so with the operating frequency set to 250 kHz by resistor R_T, the $Q_{G(TOTAL)} \cdot f_O$ at $V_{IN} = 55$ V falls within the LTC4020's specified INTVCC pass element SOA guidelines.

The IC charges and maintains a 24-cell (48 V) lead-acid backup battery using a constant-current/constant-voltage charge profile as previously described. The maximum battery charge current is programmed by R_{CS} to 5 A, which is available until the full-charge float voltage of 53.75 V is achieved (Figure 2). The battery voltage is monitored by a resistor divider (R_{FB1} and R_{FB2}), which programs the

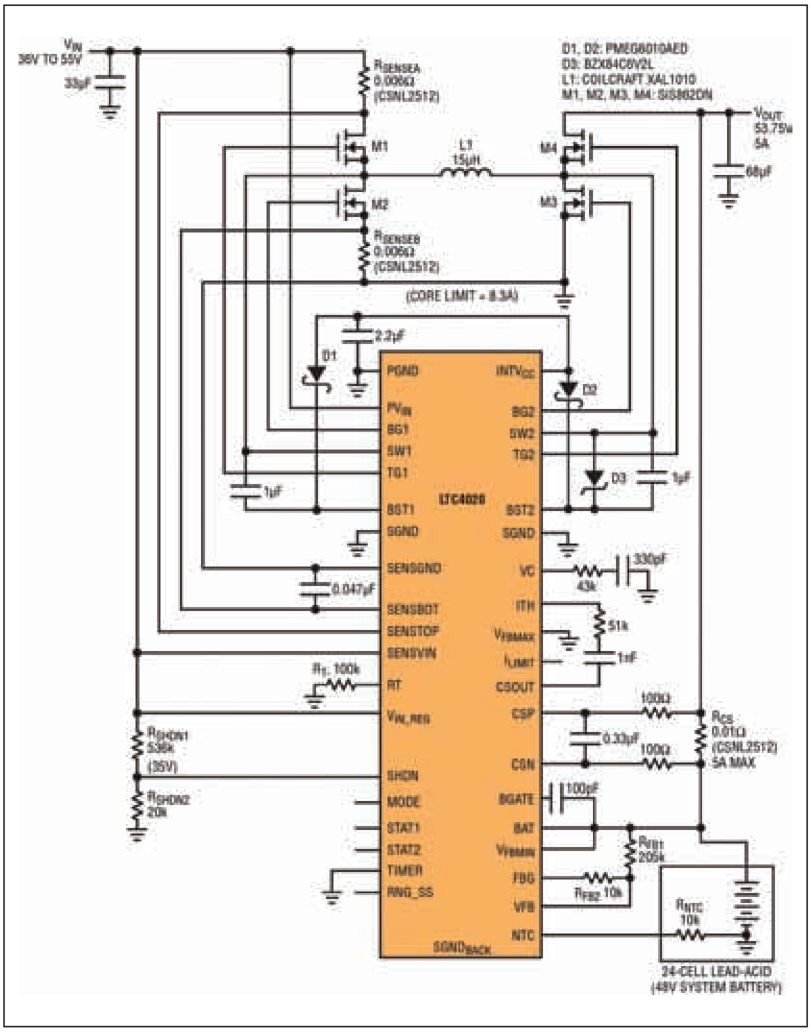


Figure 1: 36 V to 55 V to 24-cell lead-acid (48 V) float charger/system supply with 265 W converter output capability, 5 A battery charge current and 53.75 V system/float charge voltage output

full-charge float voltage of 53.75 V (or 2.24 V/cell). This divider is referenced through the FBG pin, which is shorted to ground when the LTC4020 is operating, but becomes high impedance when the IC is disabled, reducing the parasitic load on the battery.

The LTC4020 preferentially provides power to the system load and battery charging functions - the system load is always prioritized over charging power - so battery charge current is reduced when necessary during periods of heavy loads. Should the system load exceed the capabilities of the LTC4020 DC/DC converter, battery current will change direction, and load current will be sourced from the battery to supplement the converter output. Figure 3 shows the available converter output current (system load current + battery charge current) vs input voltage.

When the V_{IN} supply is disconnected, all LTC4020 functions cease and the battery supplies required power to the output. Reverse conduction from the battery through the converter is blocked by the switch FET M4, the battery voltage monitor resistor divider is disconnected via pin FBG, and total battery current into the IC is reduced to less than 10 µA, maximizing battery life should a no-load storage condition be required.

Conclusion

The LTC4020 is a single-IC power management solution for any high power device that requires battery backup or battery-powered remote operation. The integrated buck/boost DC/DC controller can provide power to a voltage rail that is above, below or equivalent to the input voltage. The IC employs an intelligent PowerPath topology, merging the controller output to a full-featured multi-chemistry battery charger. The charger includes an internal onboard timer for charge cycle control and real-time charge cycle monitoring using binary-coded status pins. Three pin-selectable charging profiles provide versatility to accommodate most common battery types with optimized charging characteristics.

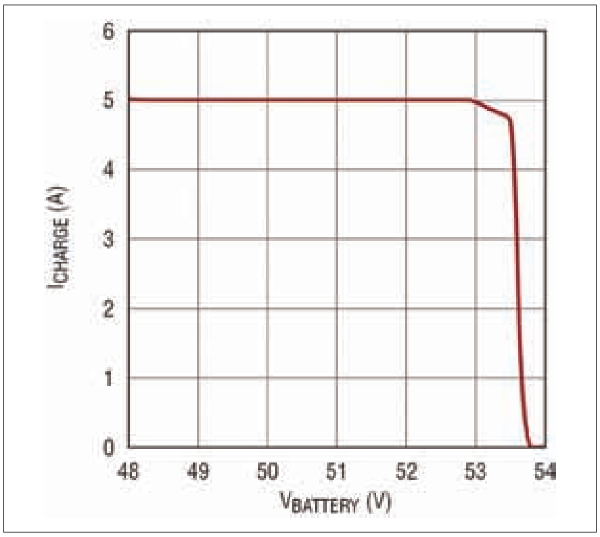


Figure 2: Maximum battery charge current for the circuit shown in Figure 1

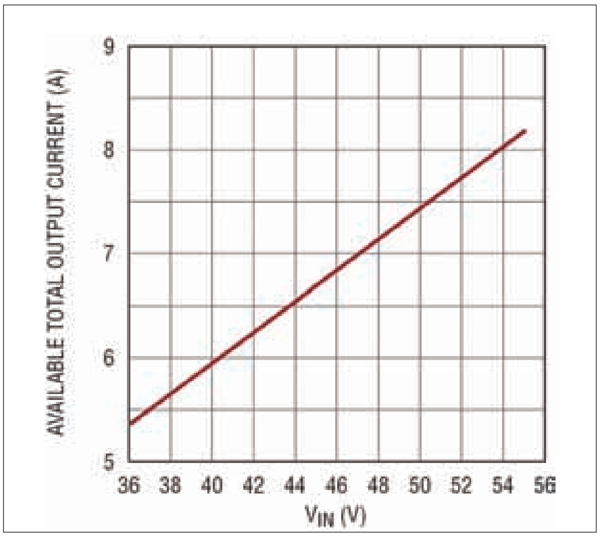
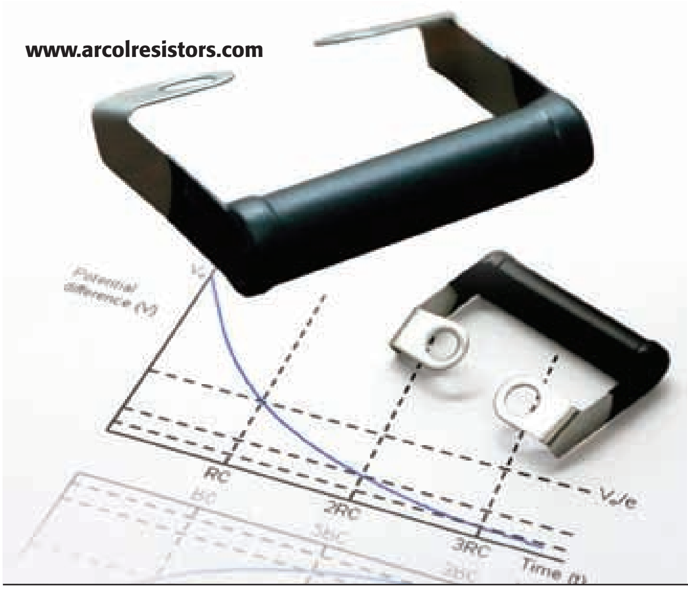


Figure 3: Available converter output current (system load current + battery charge current) vs input voltage

Capacitor Discharge Resistor

UK based ARCOL Resistors offers the RW Discharge Resistor – a wire-wound resistor designed for quick and easy mounting on to capacitors which is typically used as a discharge or balancing resistor. Discharge resistors are routinely connected across large value output capacitors found in electrical and electronic equipment which may store dangerous levels of energy after the equipment has been turned off. Providing a safe discharge avoids any hazardous conditions when connecting other equipment or during service or repair. Balancing resistors are used when a number of capacitors are connected in series to ensure voltages across any individual capacitor does not exceed its maximum rating. The RW discharge resistor provides simple to fit screw mounting, is rated up to 22 W, has a wide operating temperature range (-55 to 200°C) and is RoHS compliant. Three power ratings are available from 10W, with ohmic value range of 1-15 kΩ, 13 W with values from 1-2 kΩ and 22 W from 1-33 kΩ.

www.arcolresistors.com



High Temperature Low Leakage Automotive Varistors

Qualified to AEC-Q200, AVX's new high temperature, low leakage CANATL series automotive controlled area network varistors exhibit low leakage (≤1µA at 32V DC, 25°C) and are tested, qualified, and specified at 150°C, making them suited for use in high temperature underhood automotive applications, such as transmission control units (TCUs), brake control modules (BCMs), data lines, bus interface units, and other capacitance sensitive applications. Based on patented multilayer varistor (MLV) technology, which combines circuit protection and EMI/RFI attenuation functions in a single device, these zinc oxide based ceramic semiconductor devices exhibit non-linear, bi-directional voltage current characteristics similar to back-to-back Zener diodes and an EMC capacitor in parallel. CANATL varistors provide several performance advantages over diodes, including high in-rush current capacity (8 x 20 µS), a high 25 kV (HBM Level 6) ESD rating, low capacitance (10 pF) to minimize signal distortion, no derating over operating temperatures, and very fast response times, which conservatively clamp the energy before it reaches its maximum. The varistors also exhibit multi-strike capability, and an FIT rate of ≤0.1 per billion hours.

www.avx.com

100 W DC/DC Module

GE's Critical Power business introduced its new ERCW003A6R 100-W, one-eighth brick DC/DC converters, an addition to its OrcaTM-series family of isolated, board-mounted power amplifier modules. The new converters up to 3.6 A DC output current at a nominal output voltage of 28 V DC. The new modules have a typical efficiency of 93 % at full load, the output range can be trimmed from 15 to 35.2 V. In addition, with a maximum output ripple of 40 mV root mean square, the need for external filtering capacitors can be reduced. The ECRW003A6R's open-frame construction and heat-plated design offer through-hole packaging that enables designers to develop cost, space and energy-efficient end solutions. Its threaded through holes allow for easy mounting or for a heat sink to be added for high-temperature applications. The output is fully isolated from the input, enabling versatile polarity configurations and grounding connections.

www.gecriticalpower.com

High-Quality Open-Frame Power Supplies

Dengrove Electronic Components has the latest 48W and 60W open-frame power supplies from RECOM which are now ready to order. These power supplies, are compliant with worldwide safety standards as well as the European ErP Directive.

The RAC48/OF and RAC60/OF are ideal for use in systems such as industrial controls, computing, test gear, network equipment and medical applications. These compact AC/DC PSUs can typically operate reliably in high ambient temperatures without active cooling and have a specified operating-temperature range of -20°C to +50°C at 100% load and up to 70°C at derated load.

The power supplies, built with high-quality components for outstanding reliability, deliver performance advantages such as high efficiency, sub-0.5W standby power and a long hold-up time of 60ms.

Both series are available with output voltages of 5VDC, 12VDC, 15VDC and 24VDC, adjustable via the on-board preset. The DC outputs are fully protected with OCP, OVP and hiccup SCP. With their universal input voltage range of 90V to 265VAC and 3kVAC/1 minute isolation, they are suitable for worldwide use.

Major certifications include EN55022 EMC (Class B), IEC 60950-1 CB Report, EMC + LVD CE mark, FCC and UL 60950-1 certificates. The MTBF lifetime (MIL-HDBK217F) is approximately 450,000 hours. All units are covered by a three-year warranty.

www.dengrove.com

GaN Power Transistor Half Bridges

EPC announces the EPC2102, 60 V and the EPC2103, 80 V enhancement-mode GaN transistor half bridges. By integrating two eGaN® power FETs into a single device, interconnect inductances and the interstitial space needed on the PCB are eliminated, resulting in a 50 % reduction in board area occupied by the transistors. This increases both efficiency (especially at higher frequencies) and power density, while reducing assembly costs to the end user's power conversion system. The half bridges are ideal for high frequency DC/DC conversion. Using an EPC2103 in a typical buck converter, system efficiency is greater than 97 % at 20 A, when switching at 500 kHz and converting from 48 V to 12 V. A second device, the EPC2102 60 V half bridge is also being added to the portfolio. This device achieves 98 % system efficiency at 18 A, when switching at 500 kHz and converting from 42 V to 14 V. Both products come in a chip-scale package for improved switching speed and thermal performance and measure 6.05 mm x 2.3 mm. Design efforts can be reduced by using accompanied development boards such as the EPC9038 and EPC9039, sized 50.8 mm x 50.8 mm and containing one EPC2102 or EPC2103 integrated half-bridge component, respectively. Both boards use the Texas Instruments LM5113 gate driver and have onboard supply and bypass capacitors. The boards have been laid out for optimal switching performance and include various probe points to facilitate simple waveform measurement and efficiency calculation.

www.epc-co.com

New NexFET Power MOSFETs

Texas Instruments introduced 11 new N-channel power MOSFETs to its NexFET™ product line, including the 25-V CSD16570Q5B and 30-V CSD17570Q5B for hot swap and ORing applications with lowest on-resistance in a QFN package. In addition, the new 12-V FemtoFET™ CSD13383F4 for low-voltage battery-powered applications achieves the lowest resistance in a tiny 0.6 mm x 1 mm package. The CSD16570Q5B and CSD17570Q5B NexFET MOSFETs deliver higher power conversion efficiencies at higher currents, while ensuring safe operation in computer server and telecom applications. For instance, the 25-V CSD16570Q5B features a maximum of 0.59 mΩ, while the 30-V CSD17570Q5B achieves a maximum of 0.69 mΩ on-resistance. The CSD17573Q5B and CSD17577Q5A can be paired with the LM27403 for DC/DC controller applications to form a complete synchronous buck converter solution. The CSD16570Q5B and CSD17570Q5B NexFET power MOSFETs can be paired with a TI hot swap controller such as the TPS24720 ORing applications.

www.ti.com/csd16570q5b-pr-eu

IGBT Modules for up 350 kW Power Levels

SEMiX®5 completes Semikron's product family between 50 kW and 350 kW for 650V, 1200V and 1700V applications. The baseplate module features rugged power terminals with 17 mm height and Press-Fit contacts for a low cost solder-free assembly of the gate driver. A significantly reduced stray inductance allows for higher operating safety and lower module losses, supporting highly efficient solutions in UPS, solar, power supplies and motor drive applications. The Press-Fit contacts provide for a fast and solder-free driver board assembly, increasing reliability and reducing mounting cost. The housing features rugged moulded power terminals making the SEMiX5 suited for robust and compact inverters. The internal layout is optimized for high thermal conductivity and a homogenous temperature distribution, which reduces the risk of hotspots by lowering the thermal coupling between adjacent chips. The newly designed internal layout also provides higher flexibility for different architectures and topologies, giving room for a large power range and a broad variety of sixpack, NPC, T-NPC and customer specific topologies. The superior heat management, together with the integration of latest chip technologies allows to offer SEMiX5 in a comprehensive product range for 2-level and 3-level configurations, addressing a wide range of applications in UPS, solar, power supplies and motor drives.

www.semikron.com

Dual SIC MOSFET Driver Boards

Mouser is now stocking the PT62SCMDxx Dual SIC MOSFET Driver Boards from Cree. Designed to drive the CREE CAS300M17BM2 SIC MOSFET modules, the PT62SCMD12 and PT62SCMD17 single-board solutions are dual SiC MOSFET gate drivers optimized to ensure maximum performance for SiC modules. These boards are developed for Cree by Prodrive Technologies and are production-ready, with all the features required for an IGBT module gate driver. The SIC MOSFET Drivers feature a wide power supply range from 15 V to 24 V. The two single-board solutions provide different driving capabilities - the PT62SCMD12 is a 1200 V driver, whereas the PT62SCMD17 is a 1700 V driver. Each SIC MOSFET driver provides low jitter at 1 ns (typical), gate driving at +20 V/-6 V, switchable frequencies up to 125 kHz, and output currents up to +/- 20 A with high dV/dt immunity. Both solutions require no optocouplers, and communicate through an RS422 input interface. A built-in dead-time generator enables both solutions to be fully adjustable for both dead and blanking time. Other features of the PT62SCMDxx Dual SIC MOSFET Drivers include over-current protection and under- and over-voltage lockout. They can control multiple MOSFETs in parallel, and are available for purchase through Mouser Electronics for a variety of power management solutions, including HF resonant converters/inverters, solar and wind inverters, UPS and SMPS devices, motor drives and traction-based applications.

www.mouser.com/new/cree/cree-pt62scmdxx-drivers

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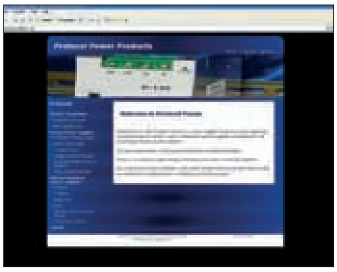

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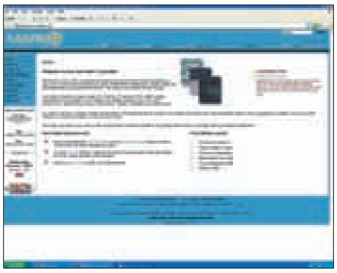

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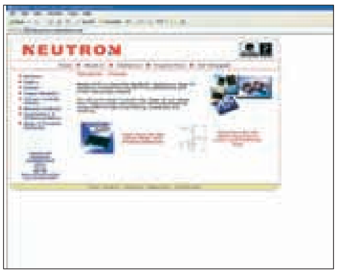

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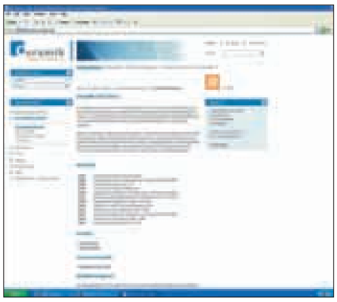

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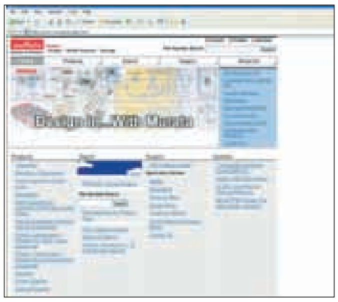

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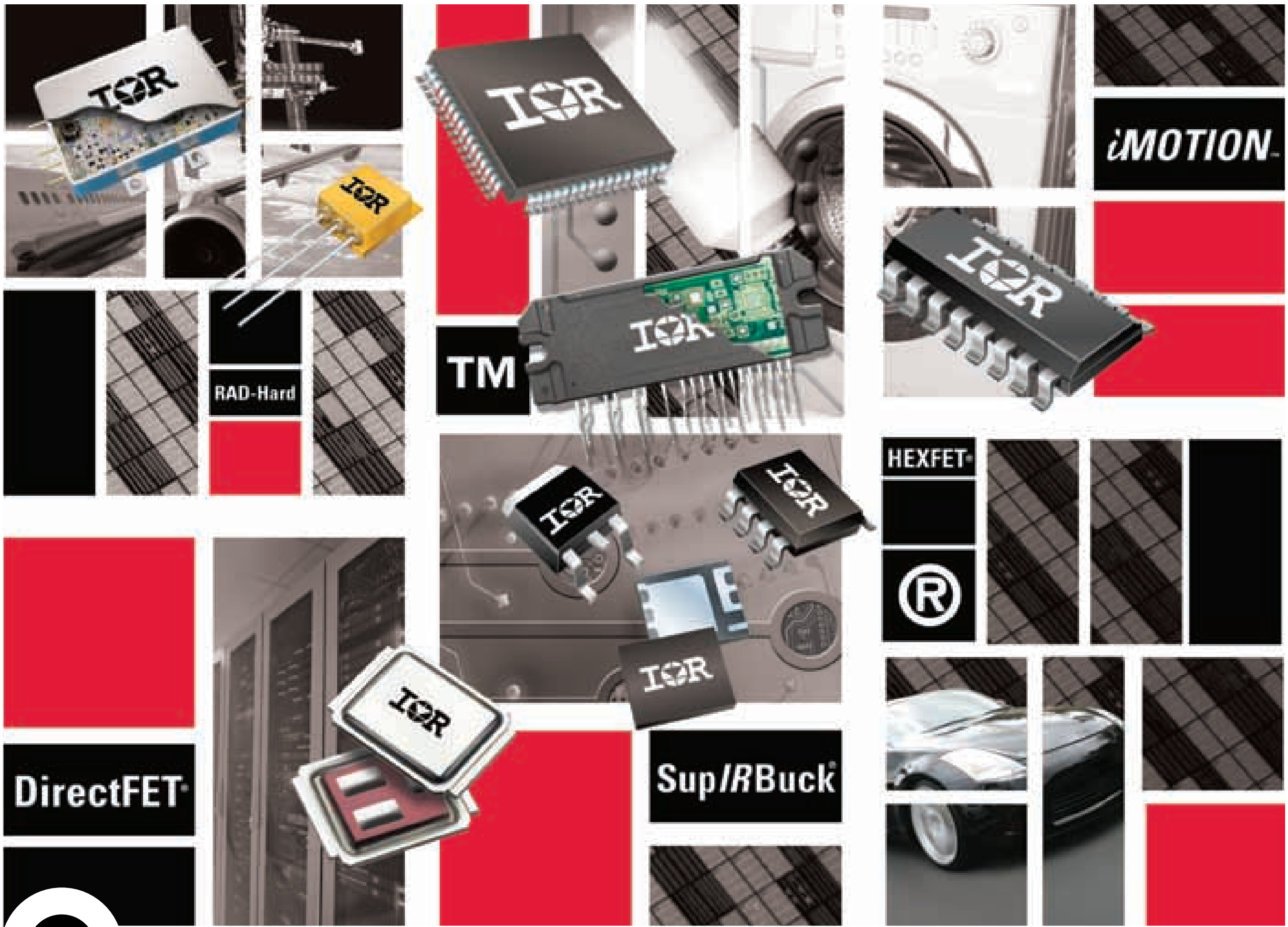

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