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POWER SUPPLY DESIGN

Designing Multiple Load System Power Supplies

THE EUROPEAN JOURNAL FOR POWER ELECTRONICS AND TECHNOLOGY

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COVER STORY

Designing Multiple Load System Power Supplies

Design tools have been developed over the past ten years to help power supply designers create single DC to DC power supplies. These tools feature parts selection, material cost calculation, simulation and prototype procurement. This has simplified the design process and reduced time-to-market. But with design complexity increasing, the need for ten or more power supplies on a PC board has increased the challenge. Now, a new breed of design tool has emerged that allows the configuration and design of multiple-load power supply systems at one time. Performance goals such as small footprint, high efficiency and low overall system cost can be applied to an entire system at once. Full story on page 27

Cover supplied by National Semiconductor

Alternatives for Power MOSFETs Ahead

For decades, Silicon Carbide (SiC) and Gallium Nitride (GaN) have been under consideration as alternatives to the ubiquitous silicon as the basis for semiconductor power devices. Even as the first silicon power devices were produced and started to displace germanium, SiC was proposed as a material with even wider bandgap and with attractive properties offering the prospect of more efficient power devices capable of operating over a wider range of operating conditions. Compared with Silicon, SiC and GaN power devices offer potentially lower switching and conduction losses, higher frequency operation, and operation to higher temperatures.

Power MOSFETs first started appearing in 1976 as alternatives to bipolar transistors. These majority carrier devices were faster, more rugged, and had higher current gain than their minority-carrier counterparts. As a result, switching power conversion became a commercial reality. AC/DC switching power supplies for early desktop computers were among the earliest volume consumers of power MOSFETs, followed by variable speed motor drives, fluorescent lights, DC/DC converters, and thousands of other applications that populate our daily lives, Alex Lidow looked back in his keynote at CIPS 2010. One of the earliest power MOSFETs was the IRF100 from International Rectifier Corporation, introduced in November 1978. It boasted a 100V drain-source breakdown voltage and a 0.1Ohm on-resistance; the benchmark of the era. With a die size over 40mm_, and with a $34 price tag, the product was not destined to broadly replace the venerable bipolar transistor immediately. Many generations of power MOSFETs have been developed by several manufacturers over the years. Benchmarks were set, and fell, every year or so for 30 plus years. More recently, CoolMOS devices and IGBTs have achieved conductivity improvements beyond the theoretical limits of a simple vertical majority carrier MOSFET. These innovations may still continue for quite some time and will certainly be able to leverage the low cost structure of the power MOSFET and the well-educated base of designers who, after many years, have learned to squeeze every gram of performance out of their power conversions circuits and systems.

In power MOSFETs there is a basic trade-off between the conductivity of a part and the amount of charge required to take the device from the ON to the OFF state (Or from the OFF to the ON state). From this trade-off comes the figure of merit (FOM) called RQ product. This is defined as a device's on-resistance multiplied by the total charge that must be supplied to the gate to switch the device at operating voltage and current. Improvements in this product have been shown to translate into improved conversion efficiency in high frequency DC/DC converters. The absolute value of RQ is also indicative of the minimum pulse widths achievable in a practical circuit. Whereas there have been great improvements in RQ product over the last several years, silicon cannot come close to the figure of merit achieved in first-generation HEMT devices. HEMT (High Electron Mobility Transistor) GaN transistors first started appearing in about 2004 with depletion-mode RF transistors. GaN RF transistors have continued to make inroads in RF applications as several other companies have entered in the market. Acceptance outside this market, however, has been limited by device cost as well as the inconvenience of depletion mode operation. The most significant new capabilities enabled by enhancement mode GaN HEMT devices (eHEMT) stem from the disruptive improvement in switching performance and overall device bandwidth.

Now, at APEC and CIPS 2010, two companies launched the first commercially available GaN power transistors, namely International Rectifier and Efficient Power Conversion (EPC), co-founded by Alex Lidow, formerly CEO of International Rectifier. IR's iP2010 and iP2011 family is designed for multiphase and point-of-load (POL) applications including servers, routers, switches and general purpose POL DC/DC converters. The devices integrate a driver IC matched to a multi-switch monolithic GaN-based power device, mounted in a flip chip package to deliver higher efficiency and more than double the switching frequency of state-of-the-art Silicon-based integrated power stage devices. The iP2010 features an input voltage range of 7V to 13.2V and output voltage range of 0.6V to 5.5V with an output current up to 30A. The device operates up to 3MHz. Operating up to 5MHz, the pin-compatible iP2011 features the same input and output voltage range but is optimised for an output current up to 20A. Pricing begins at $9.00 each and US $6.00 each respectively in 2,500-unit quantities for the iP2010 and iP2011. Spanning a range of 40V to 200V, EPC's GaN power transistors are priced between $0.80 and $5.00 in 1k quantities. And for higher voltages, SiC MOSFETs will become available soon.

Thus new application and market opportunities will be opened for the power electronics industry! We will keep you informed throughout this issue of Power Electronics Europe and of course in the future.

Achim Scharf
PEE Editor

Market Driver Energy Efficiency

After presenting improved results for fiscal year 2009 (see PEE 8/09, page 12) Infineon's CEO Peter Bauer outlined on occasion of the Annual General Meeting in February the company's strategy with a focus on energy efficiency and power semiconductors.

The global economy seems to be recovering faster than initially presumed. The positive trend of the fourth quarter is persisting in the new fiscal year. As an early-cycle company, we are at the forefront of this development. Our Automotive, Industrial & Multimarket divisions are benefiting particularly strongly from the upswing.

We want to take the lead especially in the market for power semiconductors, the IGBTs, the MOSFETs and mixed-signal products. Other examples are reducing the cost of testing and the innovative use of new, cheaper materials. It may sound trivial but it is an engineering feat to use copper wires instead of gold wires for bonded interconnections in high power chips. We will concentrate on higher-yield products. In this context we will fan out our product spectrum, in power electronics for instance, to address applications with fewer volume quantities, but with higher product profitability.

A further aspect of improving the gross margin is the better exploitation of our strong IP position: An example is the licensing of our patents to Fairchild. Fairchild paid us $6 million for this. In December 2009 Infineon has settled a patent infringement lawsuit with Fairchild Semiconductor. Infineon initiated the lawsuit in November 2008 in the US District Court for the District of Delaware. The patents in the suit and counter suit consisted of fourteen patents related to super-junction power transistors along with trench power MOSFETs and IGBT power transistors. The lawsuit has been settled through a broad patent cross license relating to semiconductor technology. As part of the agreement, Fairchild will make payments to Infineon. Also patent licensing discussions with other semiconductor companies are under way. Infineon views such discussions as essential to the continuing protection of its intellectual property and business

"Our high-power modules enable electrical wind energy of Germany's first commercial offshore wind farm to be fed efficiently into the grids", Infineon's CEO Peter stated

interests. And, by the way, more than 200 new MOSFETs are in the pipeline.

Asia is already essential and its importance will gain momentum. Our growth strategy is determined by the potential of the markets in Asia. China in particular came out of the economic crisis much faster than other countries and is setting the pace for the global upswing. In the Chinese economic stimulus program there are plans for multi-billion investments in renewable energy sources and expansion of the infrastructure. China aspires to a leading role in wind and solar energy. The expansion of the railway network and train fleet is in full swing. With our strong position in power semiconductors, we can benefit greatly from this development. We signed a letter of intent with the gouvernment to establish a another development centre - our fourth in China - in Yizhuan, an industrial park in Peking, where we intend to pursue application development for state-sponsored industries of the future, such as automotive, wind energy and mobile communications. This move means we stand a good chance of benefiting from the strong growth in the Chinese domestic market, which is a strong driver particularly for semiconductors. Given the growth of the Asian markets we will further expand production there and improve our payroll mix. Complete relocation of European plants to Asia is not planned though at present.

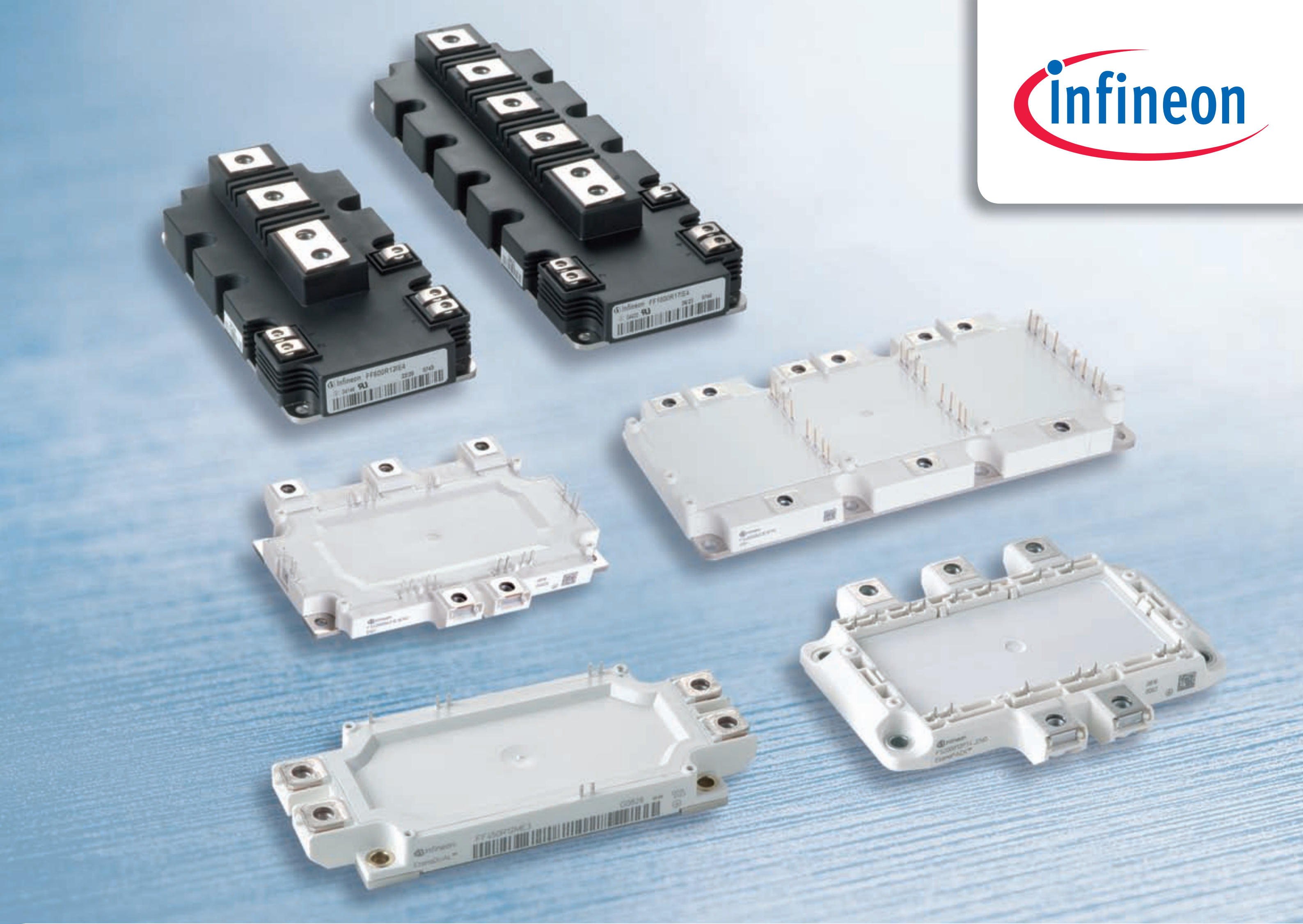
Preserving highly skilled workplaces in Europe near our large development locations also means we remain capable of ramping up new shrink technologies and developing innovative manufacturing and automation concepts very rapidly. The expansion of further production capacity will however take place in Asia. We will also continue to rigorously pursue our fab-light strategy in the field of CMOS production. That is to say, we will continue the shift towards outsourcing manufacturing to silicon foundries.

Energy efficiency affecting our future

The Copenhagen Climate Conference failed to deliver any concrete results, which is regrettable because the problems are pressing. We are already living clearly beyond our means, we are exhausting our planet. The World Energy Council has calculated that the energy demand will almost double by the middle of this century. This appetite for energy has to be satisfied with as little impact on the climate as possible. There are technical answers to the problem. Radical technical innovation represents the only possibility of making do with the available resources. We need innovation strategically geared to reducing energy consumption and to increasing the efficiency of regenerative energy sources. Success in this quest is reliant on highly innovative semiconductor solutions.

Our semiconductors are indispensable for the efficient generation, transmission and use of power.

Renewable energy sources will account for a significant proportion of the energy mix in tomorrow's world. In many countries there are already defined targets. Wind and solar energy in particular are gaining ground around the globe. As the subsidies for these alternative forms



Power Density – next Level of Energy efficiency

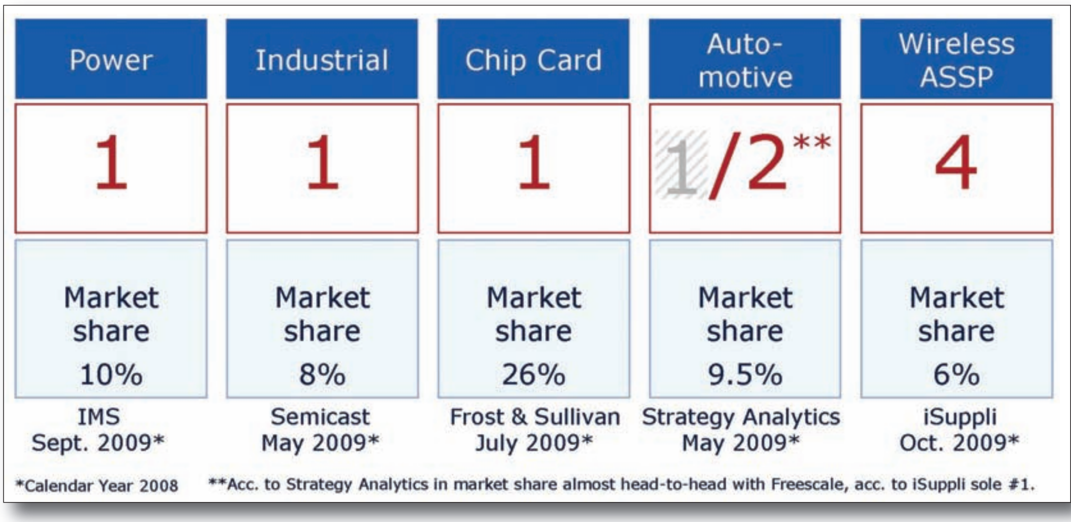
A complete solution for Commercial, Agriculture and Construction Vehicles

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

Key features:

- 600V, 1200V and 1700V IGBT modules in full/half-bridge and chopper configurations for both AC and switched reluctance electric machines
- 2 times higher power cycling capability at t_{vjop}=150°C operating temperature e.g. 2 mio@ΔT_j=40K
- up to 5 times higher thermal cycling compared to industrial modules
- extended lifetime compared to industry standard modules

[www.infineon.com/cav]



According to market researchers Infineon is securing leading market positions despite economic crisis

of energy are canceled, so the pressure for higher efficiency levels will increase. Our power semiconductors are the key. We are already a player for most systems. As an example - the World Games Stadium was opened in Taiwan in 2009. It is the first stadium operated using solar energy only. With our CoolMOS power transistors, over 1 million kilowatt hours p.a. of clean solar power is produced there, avoiding 660 tons of CO_2 emission a year. Also Germany's first commercial offshore wind farm, BARD Offshore I, is currently being installed 90 km off the coast of the North Sea island of Borkum. Our high-power modules enable electrical energy to be fed efficiently into the grids. In future we need grids for the lossless transmission of electric power over very large distances. Even today, our thyristors are used for ultra-efficient electricity transmission, for example from the coastal wind farms to the large cities situated far inland.

Another issue for the future is intelligent electricity grids or smart grids. The starting point is to maintain a balance between the demand and supply of electrical energy at all times. Since power generation from regenerative energy sources like sun and wind cannot be planned with precision, smart grids will control power consumption in future.

The automobile is another important area of energy efficiency. Automakers are called upon to significantly reduce CO_2 emissions. They are investing in fuel-saving engine management on the one hand and in alternative drive concepts on the other. Power semiconductors play a central role in both sectors.

The electric car market is still in its infancy. But the route has been defined. Automakers around the globe are gearing up for the age of the electric car. Infineon is in pole position for powertrain electrification. The HybridPACK 2 used in full hybrid vehicles is designed for a power range up to 80 kilowatt and feeds braking energy into the battery. We will profit even more from the pure electric car. The vehicle and the entire infrastructure needed are especially semiconductor-intensive. Our products will be used in the drive system, in the vehicle electronics, in the charging stations, and in the energy and network systems. Infineon is leading a pan-European, cross-company research project (E3Car) to boost the efficiency of electric cars. Incidentally, for many Germans the car carries emotional associations: A green car does not have to be boring. With their high starting torque, the acceleration performance of electric cars puts many sporty CO_2 emitters in the shade at traffic lights. Germany is the lead market for cars and industry electronics. Due to the global position, we can benefit greatly from the international growth markets, Bauer concluded.

www.infineon.com

SiC Gains More Attention in 2010

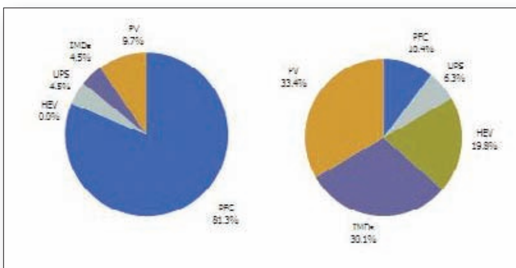
For decades, Silicon Carbide (SiC) and Gallium Nitride (GaN) have been under consideration as alternatives to the ubiquitous silicon as the basis for semiconductor power devices. Even as the first silicon power devices were produced and started to displace germanium, SiC was proposed as a material with even wider bandgap and with attractive properties offering the prospect of more efficient power devices capable of operating over a wider range of operating conditions. Compared with Silicon, SiC power devices offer potentially lower switching and conduction losses, higher frequency operation, and operation to higher temperatures.

However, there are always fundamental problems of technology and production engineering to be overcome, before an established, successful technology can be displaced. Only in 2001 were SiC power devices produced and used in significant volumes, in the form of Schottky diodes. And even in 2009, according to a report recently published by IMS Research, the total revenues from Silicon Carbide and Gallium Nitride power devices reached only $19 million, less than 0.2% of the world market for Silicon discrete power devices and modules. Even today, cost and limited device performance at high currents pose formidable obstacles to large-scale adoption.

Yet 2010 may prove a critical year for SiC and GaN as contenders in the power device market. Cree is expected to launch a SiC MOSFET, and International Rectifier a power device platform based on GaN. Power modules including SiC JFETs will add another shot in the SiC locker against silicon. Last, several established suppliers of silicon power devices have indicated that they will be introducing power devices based on SiC or GaN in the near future.

Increased efficiency

One highly promising application is low-power PV inverters. Using a SiC Schottky diode in a PV inverter can increase the overall system efficiency by nearly 0.5%. There was considerable industry excitement when the The Fraunhofer Institute for Solar Energy Systems recently announced it had set a new world record of over 99% efficiency for a PV inverter, using SiC JFETs (see Power Electronics Europe 6/2009, page 12 - 13). Although costs of SiC devices are relatively high, many of their supporters argue they are now competitive with those of silicon. Although manufacturers still pay a premium for the SiC diodes themselves, the inverters can be operated at higher frequencies than using silicon devices; this enables costs to be saved in other areas of



The world market segmentation for SiC power devices by key applications in 2009 (left) and 2015 (right) Source: IMS Research

the inverter, such as the inductors. Further, system noise may be reduced through running inverters at higher frequencies. Though the contest in PV inverters between Silicon Carbide and Silicon power devices is far from over, there is at last a contest.

However, for SiC and GaN power devices, much remains to be done. The cost per unit area of SiC start material has fallen by a factor of 15 from 2001 to today. A 2-inch wafer cost around $5000 in 2001; a 4-inch wafer cost between $1200 and $1500 in 2009. Strong shipment growth of SiC power devices hangs on costs falling further; the industry expects a 6-inch wafer being available for $700-$800 in 2012, a further fourfold reduction in unit area cost. Unlike for silicon, around half the current cost of manufacturing a SiC power device is the cost of its start material. Manufacturing yields in SiC still need to improve, as do defect rates. The limited currents handled by today's SiC devices have prevented their adoption in high-power applications, such as HVDC transmission and wind turbines.

" The SiC and GaN power device market will grow rapidly to over $100 million", predicts IMS Research analyst Josh Flood

IMS Research reviewed the short-term plans and medium-term expectations of major users of power devices in selected application areas where SiC and GaN might offer advantages; and the plans of the device suppliers. Based on this, IMS Research projects that the SiC and GaN power device market will grow rapidly to over $100 million; and reach over $160 million in 2013. SiC Schottky diodes are forecast to account for almost a third of this, with most revenues coming from PFC (Power Factor Correction) power supplies. Projecting to 2016, the total market for SiC is predicted to breach the $1 billion barrier. However, even this will equate to only around 6% of the power device total. Suppliers and designers of silicon power discretes and modules need not get too depressed just yet.

IMS Research published its report "The World Market for SiC & GaN Power Semiconductors" in Janurary 2010. For more information directly contact Josh.Flood@IMSResearch.Com

www.imsresearch.com

Custom Power Supply under 5 Minutes Configured

ACAL's Excelsys powerKit allows designers to use smallest power supplies to configure a plug-and-play custom power module in under five minutes.

Each powerKit contains an application-specific chassis module, and seven different DC output modules which can be inserted, removed or exchanged to create a custom power supply. These provide a range of output voltages, from 1.5V to 58V, with a maximum current of up to 50A. The kits are presented in a rugged case and include two pairs of serial, and two pairs of parallel, links as well as power and signal connectors, documentation, screwdriver and a voltage adjustment tool.

The Xgen series of power sources provides additional flexibility with a number of user-configurable functions. These include local and remote adjustment, adjustable straight-line or foldback current limit and output inhibit/enable functions. powerMods can be configured in parallel for higher-current applications and in series for operation at higher voltages. High-efficiency conversion techniques allow Xgen series power sources to achieve minimal power losses, whilst advanced packaging reduces their size to create the industry's smallest power supplies. The powerKit has been optimised for standard, medical, high-temperature and low-noise applications. The standard and medical versions are available with power ratings of 1340W or 750W, with 6 and 4 powerMod slots respectively; the powerKit for high-temperature applications has a 600W rating and six slots; whilst the low-noise powerKit is rated for 1200W and offers six slots. "Our powerKits introduce a new generation of flexibility and power density. Compared to alternative power sources, the Xgen series are smaller, ultra-efficient and provide the flexibility of being field configurable", explained Sean Say, Divisional Manager at ACAL Technology.

www.acaltechnology.com/uk/excelsys1

Technical Hurdles to Pure Electric Vehicles

The idea of the pure electric vehicle has been with us for many years and, indeed, longer than the internal combustion engine. Recently, with the launch of several electric cars - including a high-speed electric sports car - it has seemed that EVs are moving away from concept to commercial reality. However, there are still a number of barriers to their widespread adoption. Henning Hauenstein, Vice President and General Manager, Automotive Products Business Unit at International Rectifier

Probably the biggest challenge to the pure EVs lies with the battery requirements. The four major issues confronting the battery technology are the limited driving range (most EVs can only travel 250km or less before recharging while modern gasoline-powered vehicles travel many hundreds of kilometers before refueling); the long recharge time (fully recharging the battery pack can take four to eight hours); the high battery cost (large battery packs are expensive and usually must be replaced one or more times during the lifetime of the car); and the size and weight (battery packs are heavy and take up considerable vehicle space).

Out of the four, driving range and recharge time are key impediments that can have a negative influence on the market development and purchasing decisions of consumers. Many consumers like to make buying decisions with "just in case" considerations. For this reason, even if a range of 250-300 kilometers or less is more than good enough for most drivers in their day-to-day usage, many still want the peace of mind of being able to cover a larger distance 'just in case' there is a requirement for 500 kilometers or more of straight driving.

This concern could be easily overcome if the EV were to offer a recharge capability closer to the typical time required to re-fuel a regular car. So let's assume we develop batteries with such a fast charging capability and the corresponding electronics and AC/DC converters to transfer the energy from the power grid to our EV. Depending on the size and purpose of the electric vehicle, a typical state of the art Lithium-ion battery would roughly need a stored energy of 50-100 kWh to provide an acceptable driving distance of more than 300 km. If we want to refill this amount of energy in, say, a 10 minutes timeframe, we would need at least 50kWh/10minutes or 300 kW of power. This is far more than the amount of power available today in a standard private home (220V, 16A, approx. 3.5kW).

Ignoring completely the fast-charging limitations of current batteries, a 220V home power net would require over 1300 A of current and correspondingly large cables and connectors — even eight hours over night charging at home would still demand more than a 6 kW home power capability for a small electric vehicle! And a public "EV-fuel station" capable of delivering the expected 10 minutes re-charging capability would require a 1.2 to 2MW service when serving only four vehicles in parallel.

Thus, for broad penetration of EVs, the challenge of the power requirement would require a revolutionary change in the entire energy generation and distribution network as well as significantly modified driving behavior and range expectation among vehicle purchasers.

On top of these technical challenges, another major factor to be considered for market penetration of EVs comes in the form of environmental egislation (for example the California clean air act) designed to reduce pollution and CO2/NOx emissions. At first it might seem that such legislation would be a perfect driver for the adoption of environmentally friendly "zero-emission cars" such as the EV.

High battery cost and missing electrical infrastructure for fast charging are major hurdles for widespread u8se of electrical vehicles, believes Henning Hauenstein, IR's General Manager, Automotive Products Business

However, taking into account the energy required to charge the batteries, the overall emission balance sheet for EVs does not look so clean if the electricity is generated using coal or other fossil fuel-burning power stations. As long as we use such plants to generate the electricity, we continue to generate emissions and pollution. In short, to tap the full benefit of zero-emission EVs, the energy for the EVs must come from renewable or alternative energy sources such as water, solar or wind power.

Therefore, before we jump to conclusions, we really need to look at the entire picture and calculate the energy and emission efficiency across the electricity supply chain - from the electricity generating power plant all the way to the EV's battery. Doing this we see that countries like France that generate a significant amount of electric energy using emission-free nuclear power plants could theoretically benefit from a wide use of EVs. But in countries where fossil power plants generate most of the electricity and consequently contribute significantly to the nation's emissions, internal combustion engine-powered cars can still be a valid alternative to convert fuel and transfer it into mechanical motion. Applying consequently today's and future advanced technologies can achieve dramatic improvements of the combustion engine and the regular power train which will result in much better efficiency and lower emissions. Considering the high cost of an EV you can implement a lot of advanced electronics and technology to improve a standard car for the same or less amount of money. So a modern combustion engine car has a good chance to comply with the stricter emission laws and make a positive contribution to a greener way of driving, too.

In essence, to reap the full benefits of electric cars, the nation's energy generation and distribution technology must also be environmentally friendly. And that means, for the EV market to take off, the existing energy infrastructure must also undergo revolutionary changes.

www.irf.com

Cree Extend SiC Portfolio

Cree recently has acquired a portfolio of patents and patent applications related to semi-insulating silicon carbide (SiC) material and power device technology from German Daimler AG. The portfolio consists of approximately 20 patent families, including issued patents in the United States, Germany, Japan, and China. U.S. Patent No. 5,856,231 ('231) titled "Process for Producing High-Resistance Silicon Carbide" is an important piece of the portfolio that relates to the manufacturing of semi-insulating SiC using vanadium doping. "We had licensed this group of patents for many years and the full acquisition is a valuable addition to our already extensive intellectual property position", commented Cengiz Balkas, Cree's GM power and RF.

To widen its customer base the company entered a distribution agreement with Arrow Electronics for SiC power products. Among the Cree products available through Arrow will be the recently released series of 600V and the 1200V Schottky diode line. "Together, Cree and Arrow intend to accelerate the adoption of silicon carbide power semiconductors to create more efficient switching power supplies, alternative energy converters and motor drives", said Bob Pollock, Cree's VP sales. For its third quarter of fiscal 2010 ending March 28, 2010, Cree targets revenue in a range of $215 million to $225 million with GAAP net income of $37 million to $40 million.

www.arrownac.com/cree

Prototype of Liquid Cathode Fuel Cell Power Module

An important new development in fuel cell technology, a model hydrogen fuel cell system which uses a platinum-free liquid cathode, has been demonstrated at FC Expo 2010 in Tokyo as a practical product prototype which could well become a commercial reality in less than two years.

FlowCath® technology provides a radical step change in cost and performance, by replacing the platinum catalyst on the cathode in a proton exchange membrane (PEM) fuel cell with a low cost, durable liquid chemical. "This significantly reduces the overall platinum content, while delivering the same level of fuel cell power density as today's platinum cathode systems. The technology also inherently addresses the balance of plant costs by eliminating the need for hydration, pressurisation, separate cooling and other expensive mechanical sub-systems commonly found in conventional PEM fuel cells", explained Andrew Creeth, inventor of the Flowcath technology. ACAL Energy founded in 2004 is leading a £1.9 million collaborative project recently started to build the world's first installed system using this fuel cell technology in a practical application. The project is supported by the UK's Technology Strategy Board.

www.acalenergy.co.uk

Third German Battery Developer Forum

The 3rd Developer Forum Battery Technologies, hosted by the batteryuniversity.eu, takes place from April 13 to 15, 2010 in the Stadthalle Aschaffenburg, Germany. Attendees are offered a 2-day program with 24 technical presentations (mainly in German), a Light Electric Vehicle workshop with focus on battery standardisation, a half-day seminar on the topic of UN transportation regulations for Lithium batteries and a Lithium-ion introductory course for newcomers. Last year's event attracted 450 delegates.

During the first two days specialists from leading manufacturers and institutions - including A 123 Systems, Akasol Engineering, BaSyTec Batterie System Technik, BMZ Batterien-Montage-Zentrum, Boston Power, Cham Battery Technology, Digatron, enertech International, ESG Elektroniksysteme- und Logistik, Fraunhofer IIS Institut für Integrierte Schaltungen, Fraunhofer ISC Institut für Silikatforschung, Fraunhofer ISE Institut für solare Energiesysteme, LION Smart, Maxell Deutschland, Maxim Integrated Products, Panasonic Industrial Europe, Panasonic Electronic Devices Europe, RRC Power Solutions, Saft Batterien, Samsung SDI, Sanyo, Sony, Texas Instruments, Texsys and ZSW - Zentrum für Sonnenenergie- und Wasserstoffforschung Baden-Württemberg - will present the latest technology trends and solutions. An additional highlight this year is the national LEV Workshop, which is initiated by ExtraEnergy.org as a counterpart to the Chinese-language LEV Symposium, which takes place in Taipei in March, 2010. The workshop gets started with a presentation by SLG Prüf- und Zertifizierungs GmbH on the topic of safety in today's LEVs. Following this, EnergyBus e.V., Deutsche Gesellschaft für Sonnenenergie, Fachhochschule Pforzheim and CAN in Automation e.V. (CiA), show LEV standardisation chances and models. ZVEI Fachverband Batterien takes a closer look at the new battery regulations and in the concluding part of the workshop, BATSO, Li-Tec, TÜV Rheinland and IB-REC go into more detail regarding the requirements and practicable solutions. Combined with the conference is an exhibition, which is open on all 3 days. "In a world in which mobility in all sectors is playing an ever greater role, innovative battery technologies have an increasingly important key function. With our forum, we want to open the door to this mobile world for developers without them having first to search a long time for the right key. I think we can say that we have also been very successful in doing this", commented event founder Sven Bauer.

www.batteryuniversity.eu

CONCEPT
INTELLIGENT POWER ELECTRONICS

2SP0115T Gate Driver

Unleash the full power of your converter design using the new 2SP0115T Plug-and-Play driver. With its direct paralleling capability, the scalability of your design into highest power ratings is unlimited.
Rugged SCALE-2 technology enables the complete
the size of 17mm dual modules.
Combined with the CONCEPT advanced active clamping function, the electrical performance of the IGBT can be fully exploited while keeping the SOA of the IGBT. Needless to say that the high integration level provides the best possible reliability by a minimzed number of components.

Features

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Applied Power Electronics at APEC

The Applied Power Electronics Conference and Exposition (APEC) celebrated its 25th anniversary from February 21 - 25 in Palm Springs (California/USA). About 1200 attendants registered for the event, along with some 150 exhibitors, making it one of the most important power electronic events in 2010. APEC 2011 will be held from March 6 - 10 in Fort Worth, Texas.

The plenary session on February 22 gave an introduction to some of the main topics, starting with a look back on APEC history by John Kassakian, one of the four key contributors to the origin of APEC. The demise of the Power Concepts, Inc. International Power Electronics Conference (1975-1984), left the power electronics industry without a conference focused on the working engineer. The IEEE Power Electronics Council, the predecessor to the IEEE Power Electronics Society (PELS), acted to fill this void and created the Applied Power Electronics Conference and Exposition. The first APEC was held in April of 1986, only about nine months after the concept was first proposed. APEC has been held every year since.

Robert V. White, Chief Engineer at Embedded Power Labs, covered "Digital Power: After the Hype". Not so long ago it seemed every power electronic publication had an article on the wonders of digital power. Digital power was going to reduce cost, increase functionality, increase efficiency, have units send out messages they were failing, and with adaptive controls, put power electronics engineers out of work. Cycle by cycle loop compensation in new ICs coming to market offer eliminates instability problems once and for all. In the server world, PMBus is being use to enable energy saving system management functions. So while digital power has not yet, and probably never will, live up to the hype, it is becoming a powerful tool in the power electronics designer's toolbox. His conclusion - best tools but not best chips are going to win market share in the future.

According to Ron Van Dell, CEO SolarBridge Technologies, DC/AC inverters are key to overall photovoltaics system function yet only represent about 10% of total system cost. Distributed generation of solar power, particularly on residential and light commercial roof-tops, is major new segment to be developed, but poses some unique challenges, and has not been well served with current technologies based on high voltage DC feeds into centralised inverters. Recently, major strides are being made in micro-inverters by a number of companies with the objective of doing roof-top power conversion on a per-panel basis. This approach can yield significant gains in how many sites can qualify for PV, and increase energy harvest, while also decreasing installation cost. There are, however, some tough technical challenges that must be overcome if ACPV is to realise its full potential and accelerate the timing to grid parity. His conclusion - Micro inverters are the best approach for distributed PV generation, and grid parity can be reached already in the year 2012, not in 2015!

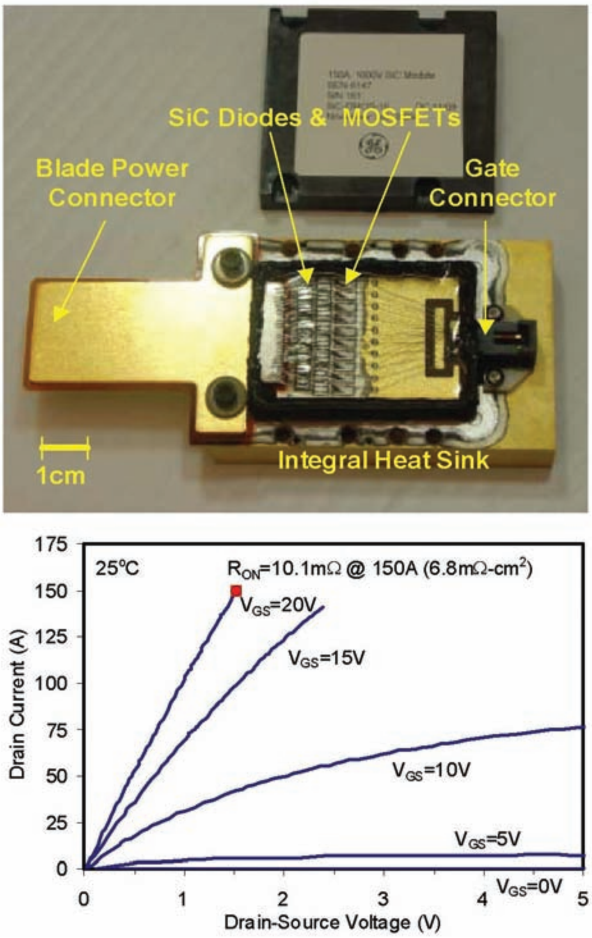
JB Straubel, CTO of Tesla Motors, gave a keynote on "Power Electronics and continued improvements in Electric Vehicle performance, efficiency and drivability". Batteries are usually the first topic of discussion for electric vehicles and with good reason due to their dominance over vehicle range but the power electronics that manage the flow of all electricity between the battery, motor and power grid have been improving quickly and offering dramatic improvements in overall vehicle acceleration, charging times, reliability and cost. Tesla Motors have moved through four generations of power electronics in the Roadster sports car (priced at $100,000) and each time increased current density and motor torque substantially while decreasing cost. The latest generation of 900A inverters allow for acceleration to 100km/h (60miles/h) in just 3.6 seconds. In just the last few years it has become possible to build an electric power-train with better overall performance than any internal combustion engine and these desirable driving characteristics will only accelerate EV adoption beyond the environmental benefits. Power electronics improvements and cost reductions are also allowing for faster charging rates and more sophisticated vehicle interfaces with the power grid. Though Tesla focuses on high-efficiency inverters, Silicon Carbide technology is not applicable today due to lack of appropriate devices. Instead massive paralleled TO247 IGBTs are used so far.

APEC 2010 opening by John Kassakian, one of the founders of this event celebrating its 25th anniversary

Silicon Carbide Power FETs to come

Silicon IGBTs are used in majority of today's power electronics applications with device voltage ratings between 1.2kV and 6.5kV. Developed almost thirty years ago and continually refined ever since, the IGBTs have reached performance entitlement of both material and device structure. A quantum leap in device performance requires either a better material or a better device structure. One such possibility are wide-bandgap (WBG) semiconductor materials, such as Silicon Carbide (SiC) or Gallium Nitride (GaN).

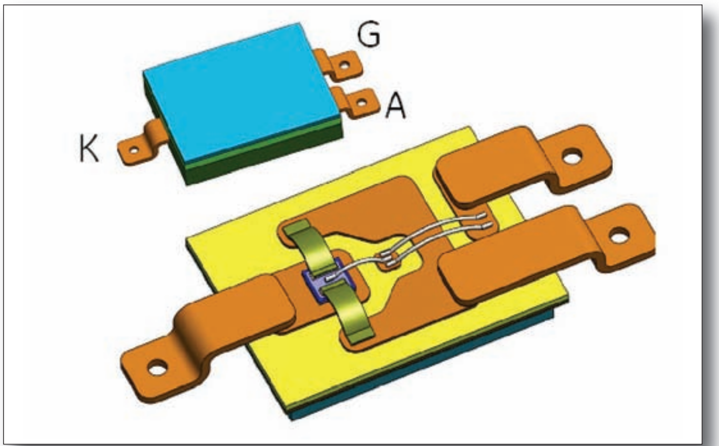
Emerging SiC MOSFET power



GE's all-SiC power module with low inductance blade power connector. The 150A, 1000V module has ten SiC MOSFETs and fifteen SiC diodes. Shown below are on-state characteristics at Tj = 25°C. At the rated current of 150A, the module's on-resistance is 10mΩ

devices promise to displace silicon IGBTs from the majority of challenging power electronics applications by enabling superiour efficiency and power density, as well as capability to operate at higher temperatures. A paper presented by Ljubisa D. Stevanovic (stevanov@ge.com) from General Electric's Global Research Center reported on the recent progress in development of 1200V SiC power MOSFETs. Two different chip sizes were fabricated and tested: 15A (2.25mm x 4.5mm) and 30A (4.5mm x 4.5mm) devices. First, the 30A MOSFETs were packaged as discrete components and static and switching measurements were performed. The device blocking voltage was 1200V and typical on-resistance was less than 50mΩ with gate/source voltages of 0V and 20V, respectively. The total switching losses were 0.6mJ, over five times lower than the competing Si devices. Next, a buck converter was built for evaluating long-term stability of the MOSFETs and typical switching waveforms. Finally, the 15A MOSFETs were used for fabrication of 150A SiC modules. The module's on-resistance values were in the range of 10 m_, resulting in the best-in-class on-state voltage values of 1.5V at nominal current. The module switching losses were 2.3mJ during turn-on and 1mJ during turn-off. The results validate performance advantages of the SiC MOSFETs, moving them a step closer to power electronics applications.

According to Stevanovic the key roadblock to SiC MOSFETs has been the reliability of its gate oxide. As in Silicon, availability of the native SiO2 oxide makes SiC uniquely suitable for implementation of MOS-gated devices. However, the MOSFET gate oxide growth and subsequent device fabrication steps are significantly different between Silicon and SiC MOSFETs. One obvious difference is the presence of carbon atoms in the



3000V/25A high temperature surface mount SiC thyristor package

SiC crystal lattice and their detrimental impact at the SiC-SiO2 interface. The other differences are higher processing temperatures during the gate oxide growth and subsequent fabrication steps. It was, therefore, not surprising that direct application of previously developed Silicon gate oxidation processes gave very poor SiC MOSFET results. Because the early results were so discouraging, the gate oxide was perceived as a showstopper to commercialisation of SiC MOSFETs. However, more recent research activities demonstrated reliable gate oxides. The focus can now be shifted to optimising device structure to reach its performance entitlement.

Zheng Chen from Virginia Tech (CPES) characterised Cree's 1.2kV SiC MOSFET, including its static and dynamic characteristics, and its high-frequency (1MHz), high-power (1.2kW) zero voltage switching (ZVS) operation in a half-bridge parallel resonant converter. The result: For high switching frequency operation, thermal constraint is the practical issue. Although the SiC MOSFET suffers relatively large switching loss partly due to larger capacitance density (capacitance per die size), it has a lower total power loss with its superiour on-resistance. In addition, SiC MOSFET has a higher power loss handling capability due to its high thermal conductivity and high junction temperature which is limited by the current package technology. When ZVS is desired in high switching frequency applications, the fast reverse recovery time of SiC MOSFET body diode makes it an unbeatable alternative to Si counterpart for high switching frequency ZVS operation.

Cree's head of development John Palmour looks in SiC MOSFET pricing at a system level where significant savings can be realised through elimination of snubbers and higher switching frequencies up to 20 times compared to Silicon devices. And 10kV SiC DMOS FETs could replace 6.5kV IGBTs, switching frequencies in the range of 200Hz will be possible. Additionally 12kV SiC IGBTs are in development at Cree.

The first commercially available pure enhancement-mode SiC power VJFET (EM SiC VJFET), introduced one year ago by Semisouth, has been gaining significant interest among power electronic designers. This new normally-off EM SiC VJFET has a low specific on-resistance of 2.8mΩ-cm^2 resulting in a die size of 9mm^2 for a 50mΩ device rated at 1.2kV. This design enables very low parasitic charges of 70nC gate charge. The EM SiC VJFET is in single die form, without any cascode and does not contain body diode or gate oxide.

Prior work has demonstrated the use of the EM SiC VJFET as a drop-in replacement for existing Si-MOSFETs and Si-IGBTs in high-side and low-side switch mode applications. With only a direct replacement of the semiconductor power switches in both a commercial solar inverter and commercial PFC demo board and addition of the RC gate driver with no other circuit optimisation performed, incremental efficiency improvements were realised. These socket replacement demonstrated a first step toward device acceptance; however, further system efficiency improvements could be realised from power circuits and gate drivers.

A newly optimised two-stage, DC coupled gate driver introduced by Robin Kelley demonstrated record low switching losses for the SJEP120R050 EM SiC VJFET. Fall time of only 25ns and turn-on energy loss of 137µJ have been measured with no resulting tail current at turn-off like that of an IGBT. Also the absence of a body diode, like that of a MOSFET, means there are no problems operating the EM SiC JFETs in a bridge configuration. The resulting optimised two-stage gate driver circuit presented here has overcome the limitations of the AC coupled RC driver and further optimisation led to a list of application recommendations that aid in achieving the best possible switching performance.

3000V/25A SiC thyristor

A 3000V/25A asymmetrical SiC thyristor for pulse power applications was presented by Ahmed Elasser (Ahmed.elasser@ge.com) from GE Global Research. The devices' chip area is 4mmx4mm. It was fabricated on ultra low micropipe density 4H-SiC wafers, the yield after screening for blocking voltage, leakage current, forward drop, and latching is over 80%, a very high yield by the standards of SiC power devices. The chips are packaged in a 200°C capable, low profile, surface mount package with a low junction to case thermal resistance. Pulse testing results show that the device is capable of very high current densities, and high peak currents. It also exhibits very low forward voltage at high pulse currents due to the thinner drift layer thickness.

The devices are asymmetrical, blocking high voltage only in the forward direction, and their reverse blocking voltage is on the order of 50V. For many pulse applications, only forward blocking is required. Although the total chip area is 16mm^2, most of the area is consumed by the terminations and contact pads. The device's active area is about 1/3 of the total area, hence the device current density is quite high. Interconnect metal and interlayer dielectrics are used to connect the interdigitated fingers together while keeping the gate and anode isolated from each other. Thick pad metal is used to enable high pulse currents, and high-voltage passivation is used for device protection. The P-contact anode resistance was optimised to reduce the forward drop during pulse conditions, where the anode-cathode current exceeds 1000A.

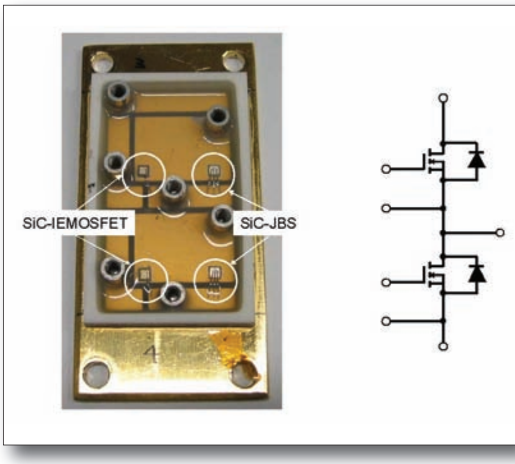
At 150°C, the maximum leakage current increases to 10µA. The high temperature (150°C) SiC leakage current is at least two to three orders of magnitude lower than the leakage current of an equivalent 3kV Silicon thyristor at 125°C junction temperature. At temperatures above 150°C, the SiC thyristors still exhibit very low leakage currents.

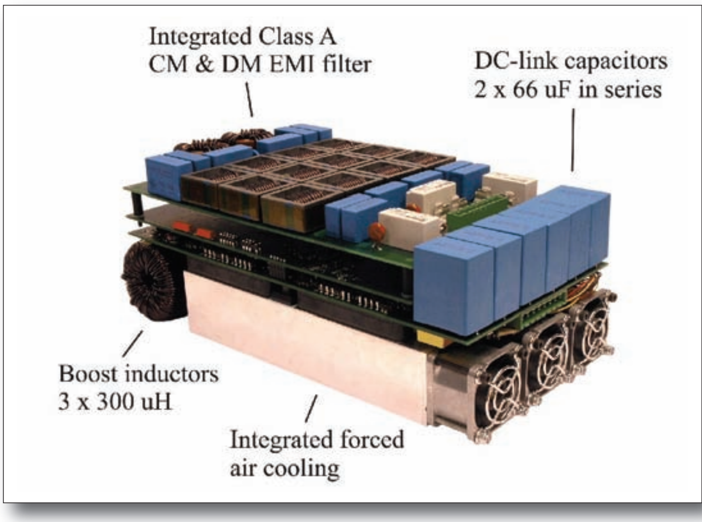
The devices were packaged in a high voltage, high temperature surface mount package.

For applications where high voltage, high pulse current, and high temperature are required, the SiC thyristor simplifies the circuit design, and enables reduced size and weight, hence compact power converters. The SiC parts significantly reduce conduction, leakage, and switching losses, thereby dramatically reducing cooling requirements and improving converter efficiency. The high current density under pulse conditions will lead to very high pulse current once large area SiC defect free substrate and material become a reality.

This progress is made possible by recent improvements in the quality of the SiC substrates (ultra low micropipe density), excellent epitaxial

SiC power module outline and equivalent circuit of the module





Compact 10kVA, 3LNPC-VLBBC prototype with 48kHz switching frequency

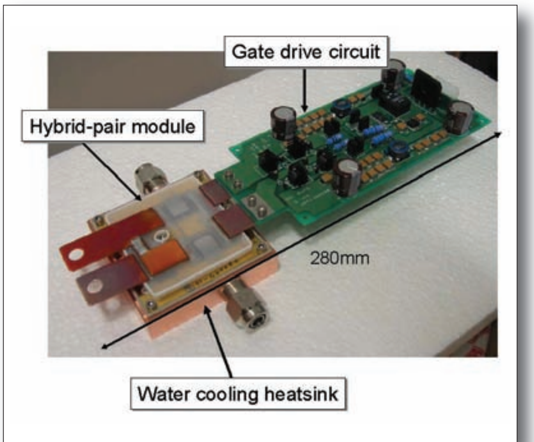
material (highly uniform with low defects and reduced internal stresses), great advances in device fabrication, packaging, and testing. With the continuous improvement in SiC substrates and material, and with the availability of SiC wafers from multiple suppliers, the cost of SiC devices will continue to decrease and will ultimately become competitive in the power device marketplace, Elasser concluded.

Silicon Carbide power modules

The power loss reductions attributable to the use of SiC power modules are influenced by operation conditions (switching frequency, junction temperature, and current density). In the case of Si-IGBTs with a voltage rating of 600V - 1200V, the future current density and junction temperature will approach 300A/cm^2 and 200°C. This means SiC MOSFETs are also required to have at least the same current densities and junction temperatures as Si IGBTs. According to Kazuto Takao (kazuta.takao@toshiba.co.jp) and Takashi Shinohe from Toshiba's Corporative Research & Development Center one should also consider the advantage of the SiC power modules compared with Si IGBT and SiC SBD hybrid pairs because of Si IGBTs' potential for performance improvements based on a nanometer-scale trench gate structure.

The presented paper evaluated power loss performances of a 1200V class SiC power module based on parameters of the junction temperature, current density, and switching frequency. The evaluated SiC power module comprises SiC IEMOSFETs and low on-voltage SiC JBSs. The SiC IEMOSFET has low on-resistance characteristics compared to those of SiC DIMOSFETs having conventional structure. The active areas of SiC IEMOSFETs and SiC JBS are 1.7mm x 1.7mm and 2.0mm x 2.0mm, respectively. The SiC IEMOSFET keeps the normally-off characteristic up to a junction temperature of 250°C. The switching characteristics of the SiC IEMOSFET depend on the temperature dependence of the threshold voltage.

As a result, in a three-phase PWM inverter, significant power loss reduction with the SiC power module can be realised in the case that the chip area of the SiC IEMOSFET is more than 1/2 that of the Si-IGBT. In the case of switching frequency of 5kHz and output power of 6800W, the power loss of the SiC IEMOSFETs is 54% compared to that of the hybrid-pair module. In the case of 20kHz switching, the power loss of the SiC module at 250°C is 52% of that of the hybrid pair module at 150°C and 6800W. This result indicates that the SiC module is advantageous in high-frequency switching operations compared with the hybrid pair module.



100A hybrid-pair switching unit

A high efficiency 10 kVA high frequency input and output Si IGBT and SiC Schottky diode 3-level neutral point clamped voltage DC-link back-to-back converter (3LNPC-VLBBC) was presented by Mario Schweizer (schweizer@lem.ee.ethz.ch) from Swiss Federal Institute of Technology (ETH Zurich). A switching frequency of 48kHz makes the converter suitable for driving high-speed and low-inductive machines. A detailed loss analysis reveals that only four of the six diodes in a 3-level bridge-leg have to be replaced by SiC diodes to enable high efficiency operation if an appropriate modulation scheme is used.

At the nominal switching frequency of 48kHz and at nominal output power of 10kVA the losses could be reduced by 10%. The converter built with the SiC module reaches a pure semiconductor efficiency of 97.0% compared to 96.6% of the standard Si version.

Compared to an equivalent 2-level converter with 1200V IGBTs of the same generation, the reduction of the losses is 42%. Interesting is also the very flat dependency of the efficiency on the switching frequency. This opens an additional degree of freedom for optimising the converter. A very compact system with small filtering components because of the higher switching frequency and a low volume cooling system due to the low losses could be realised.

It should be noted that in the real implementation additional loss sources as forced-air cooling fans (15W), digital control and gate drive power (15W) and also losses in the boost inductors (30W) are present. These will sum up to additional 60W and reduce the efficiency of the SiC 3LNPC-VLBBC to approximately 96.4%.

Considering the costs for the two modules, the custom SiC module is roughly 6.5 times more expensive than the conventional module. The converter costs accordingly will increase by roughly 300$. With a loss reduction of 10% = 32 W the energy payback time with an energy price of 0.1$/kWh will be equivalent to 10.5 years of uninterrupted operation at nominal power. At a switching frequency of 120 kHz the payback time reduces to 3.2 years of uninterrupted operation. This is quite a long operating time and restricts the application of the SiC 3-level converter to niche areas where exceptional high switching frequencies and efficiencies is required. This is the case e.g. in aircraft applications where weight and efficiency are of major interest.

A 3-level Power Converter with high-voltage SiC PiN diode and hard-gate driving of IEGT for future high-voltage power conversion systems has been presented again by Kazuto Takao from Toshiba's Corporative Research & Development Center. High-switching frequency operation is essential for reducing the volume of magnetic components. Hybrid pairs of 6kV SiC PiN diodes and 4.5kV Si IEGTs have been applied to realise the high switching frequency operation of medium voltage power converters. For low switching losses and series operation of power devices, a gate driving technique with an extremely low gate resistance (hard gate driving) is employed. Switching characteristics of the hybrid pair are measured experimentally. It has been demonstrated that the total switching loss can be reduced up to 50% with the hybrid pair. In order to demonstrate a 2kHz switching frequency of the hybrid pair, which is about 4 times higher than that of conventional medium voltage power converters, a 378kVA prototype 3-level inverter has been designed and constructed. **AS**

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More Power at APEC 2010

After around two years of public speculation about International Rectifier's Gallium Nitride (GaN) technology the company introduced at APEC 2010 the first commercially available power transistors. It is the result of five years research and development based on the company's proprietary GaN-on-Silicon epitaxial technology on 150mm wafers, together with subsequent device fabrication processes which are fully compatible with Silicon manufacturing facilities.

APEC 2010 exhibition was focused on new power MOSFETs and LED lighting controllers

The iP2010 and iP2011 family is designed for multiphase and point-of-load (POL) applications including servers, routers, switches and general purpose POL DC/DC converters. The devices integrate a driver IC matched to a multi-switch monolithic GaN-based power device. These devices are mounted in a flip chip package to deliver higher efficiency and more than double the switching frequency of state-of-the-art Silicon-based integrated power stage devices. "With a switching capability up to 5MHz, the iP201x family enables designers to drastically reduce the value and size of output capacitors and inductors where space is at premium. The devices can also be configured to operate at a lower switching frequency for applications that require the highest possible efficiencies", explained John Lambert, IR's POL product manager (jlamber1@irf.com). The iP2010 features an input voltage range of 7V to 13.2V and output voltage range of 0.6V to 5.5V with an output current up to 30A. The device operates up to 3MHz. Operating up to 5MHz, the pin-compatible iP2011 features the same input and output voltage range but is optimised for an output current up to 20A. Available in an LGA package with small footprint, both devices are optimised for very low power loss and feature highly efficient dual-sided cooling. Pricing begins at $9.00 each and US $6.00 each respectively in 2,500-unit quantities for the iP2010 and iP2011. Higher voltage classes will be introduced subsequently.

With an increasing number of countries banning incandescent lamps in favour of energy saving alternatives, LED lamps are expected to emerge as a replacement. Advantages of a well-designed LED bulb include 85% greater efficiency compared to an incandescent bulb. This higher efficiency can have a significant impact on carbon footprint, as lighting represents according to EuroStat nearly 20% of energy use. LED bulbs also are instant-on, are easily controlled in smart lighting systems, are rated high in quality of light and have an exceptionally long life (approximately 50,000 hours).

Infineon introduced its specific off-line driver IC for high-efficiency LED bulbs with dimming for residential lighting that supports 40W/60W/100W incandescent bulb replacement and all typical consumer lighting applications. The ICL8001G is an off-line switched mode power IC extending Infineon offering of a comprehensive range of LED driver solutions, it enables up to 90% efficiency, supports a broad variety of already installed wall dimmers, and is a primary controlled off-line LED drive solution with integrated PFC. It achieves a power factor exceeding 98%. Driver boards based on the ICL8001G implement a primary control technique to manage the power consumption of LEDs. Using just 25 components for a 10W LED (60W equivalent) lamp the printed circuit board area of the reference design is just 20mm x 70mm. At that size the PCB can easily be embedded within the common screw-in form factor of a lamp bulb. All components are assembled on a single-sided PCB, contributing to further cost reduction. Infineon's driver solution operates with many phase cut dimmers. Other features of the ICL8001G include isolated driver output for efficient thermal management; digital soft-start and an integrated start-up cell for instant on; cycle by cycle current limitation; short circuit, over-voltage protection and over-temperature detection. "Unlike many existing solutions where dimming reduces efficiency to about 30%, our solution maintains high efficiency above 80% over the complete dimming range. Consumers generally are not aware that lowering light intensity with today's fixtures does not actually reduce the energy consumed", commented Infineon's Industrial Lighting expert Robert Pizzuti.

Infineon also announced additions to its OptiMOS power MOSFET portfolio in the 25V device family that is optimised for voltage regulation in power supplies for computer servers and telecommunications / data communications switches. The new MOSFETs are also integrated into the TDA21220 DrMOS devices that are compliant with the Intel DrMOS specification. With significant reductions in three critical Figures of Merit (FOM) for efficiency, the new devices reduce MOSFET power losses up to 20%. Additionally, higher power density makes it possible to reduce the circuit board footprint of the buck converter by more than 40% in a typical power supply. For example, in a 6-phase voltage regulator (VRM) design, the new 25V devices deliver peak efficiency of 93% and greater than 90% efficiency across the output current range of 30A to 180A using a 5V gate drive. Device characteristics contributing to this efficiency include lowest on-state resistance, lowest gate charge and lowest output capacitance. Infineon believes it is the first power MOSFET optimised for all three of these efficiency characteristics. The company also plans to release 30V versions in the second calendar quarter. Paired with digital power controllers and other power management products, these devices will be ideal for notebook computer power supplies meeting both white box and Intel-specified efficiency and performance requirements.

On Semiconductor also launched a power factor corrected dimmable LED driver for residential and commercial lighting applications. Housed in 8-pin surface mount package, the NCL30000 achieves high power factor (> 0.95) in a single-stage topology by using a critical conduction mode (CrM) flyback architecture, thereby eliminating the need for a DC/DC conversion stage. Constant on-time CrM operation is particularly suited to isolated flyback LED applications. This is important in LED lighting in order to support compliance with regulatory requirements and meet overall system efficacy requirements. Typical applications include LED driver power supplies, LED-based down lights, TRIAC dimmable LED-based lamps and power factor corrected constant voltage supplies. This device is compatible with both leading edge TRIAC-based and trailing edge transistor-based dimmers. "Our customers have a need for dimmable LED driver solutions that are compatible with existing wiring and controls. The NCL30000 offers excellent dimming performance down to greater than 2%. This device is well suited for isolated flyback but can also be used with non-isolated buck topologies", commented On Semi's director of applications Bernie Weir. Additionally the company launched 500V and 600V N-channel power MOSFETs in planar stripe technology.

Among other products and technologies (LED lighting controllers, digital buck-boost microconverter with MPPT for solar applications, contactless power) Texas Instruments demonstrated so-called DualCool NexFET power MOSFETs enabling additional top side cooling allowing up to 80% higher power dissipation. NexFET combines vertical current flow with a lateral power MOSFET, providing a

IR's POL product manager John Lambert presented the company's first commercially available GaN power transistors

Infineon's industrial lighting expert Robert Pizzuti demonstrated a new driver for 10W LEDs featuring dimming without efficiency reduction

low on-resistance and an extremely low gate charge with high output currents and low duty cycles, resulting from LDMOS (laterally diffused metal oxide semiconductor) technology developed by Ciclon which can operate at high voltages and supports high power applications in the 400MHz to 3GHz frequency range. Ciclon was acquired by TI in early 2009.

In NexFETs the current flows from the source terminal provided by the top metallisation through the lateral channel underneath the planar gate, into the lightly doped drain extension region (LDD), then forwarded to the substrate by the vertical sinker with low resistance. The RF heritage provides minimum internal capacitances, and the vertical current flow offers a high-current density without gate de-biasing issues, typical for LDMOS transistor planar layouts. The NexFET transistor has a comparable body diode reverse recovery behaviour to an optimised trench device. The difference is that the NexFET can take advantage of a hard PWM drive where the turn-off of the transistor is sharp and has minimal tail current. Thus, the break-before-make delay time can be made very short, minimising the diode conduction time and, hence, the associated diode conduction power loss. In other words, when using NexFET switches the converter's efficiency can be further improved by reducing delay times dictated by the gate driver stage (see PEE 4/09, pages 26 - 27 for more details).

With DualCool the backside electrode of MOSFET die is attached to the leadframe of the package with solder and a copper clip is soldered to the topside electrode. In a standard QFN package the device is over molded with low thermal conductivity mold compound making the thermal resistance to the top of the device high. DualCool devices are manufactured with same set of tools used for the standard QFN device (SO-8 footprint compatible) so no major changes are needed in the QFN production line. "Thermal measurements confirm the improvement in performance in comparison with standard wire bond and clip package technologies. Systems level simulations show the improvement from a real application point of view enabling higher current densities for a given junction temperature or lower junction temperatures and lower PC board temperatures resulting in increased long term reliability", commented TI's marketing manager Barry Papermaster. Future higher voltage devices can be used also in automotive applications.

On Semi's Bernie Weir demonstrated new LED lighting solutions

National Semiconductor announced a monitoring, protection and control IC with on-chip power management bus (PMBus) that improves system reliability and reduces operating expenses in data centers. The LM25066 integrates monitoring, protection and control blocks that precisely control and manage the electrical operating conditions of each computing blade in the chassis. It also provides accurate monitoring of critical system power consumption and fault conditions. The LM25066 continuously supplies the system management host with real-time power, voltage, current, temperature and fault data for each blade subsystem. The system management bus (SMBus) communications interface delivers this data using the PMBus protocol. "The host's system diagnostic routines use the data to increase system reliability and minimise the data center's total power consumption", explained National's power specialist Dennis Hudgins. The device's monitoring block measures both current and voltage at 1,000 times per second with a current measurement accuracy of 3% over the temperature range of -40°C to 125°C. Additionally, its simultaneous sampling of current and voltage provides a true power measurement of the server blade power consumption. The monitoring block also captures the peak current and peak power and computes the average of subsystem operating parameters. A

"DualCool NexFET power MOSFETs enabling additional top side cooling allowing up to 80% higher power dissipation", underlined TI's Barry Papermaster

temperature monitoring block interfaces with an external diode for monitoring the temperature of the external MOSFET or other critical temperature source.

The LM25066 is supplied in a 4 mm by 5 mm, 24-lead LLP package and is priced at $5.95 each in 1,000-unit quantities. **AS**

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National's power specialist Dennis Hudgins demonstrated a monitoring, protection and control IC for blades in data centers

The Future of Power Electronics

CIPS (conference on integrated power systems) from March 16 - 18 in Nuremberg attracted 223 delegates from 19 countries. This bi-annual conference was held for the 6th time in Nuremberg which itself has been established as an European centre for Power Electronics.

"CIPS focuses on system integration. This important meeting is held to be a technical and scientific forum for engineers and researchers engaged in all the aspects of hybrid integration and reliability of power electronic systems. Particularly the quest of reliability is a magnitude higher than in microelectronics and also the electromagnetic interference, thus failure modes, reliability and lifetime are important task over the next years", pointed out General Chair J. Dan van Wyk in his opening speech.

Perfomance trends and limitations of power electronic systems

This was the title of the first keynote given by J. W. Kolar from ETH Zurich based on the roadmapping initiative of the European Center of Power Electronics (ECPE) based in Nuremberg.

In short: Power supplies have over the last two decades experienced a significant improvement in performance, but their inner structure and appearance has not fundamentally changed. After the essential development potential of converter systems is exhausted, and only cost reduction remains as the main development path, research must detach itself from the details of the converters and start considering system aspects. Here, in particular, the closer connection of power electronics with the grid (also in the form of smart housing or smart grids), and with the load (e.g. in the field of e-mobility) are main topics. Research of classical power electronics, orientated to converter topologies and control and modulation schemes, accordingly must be extended to energy systems, electromechanical energy conversion, mechanical systems and economic aspects. This will define a new, modern and strongly interdisciplinary picture of electrical energy technology. Also from an economic viewpoint, this path is extremely interesting, since on the system level simpler successes might be achieved than on the technological base with individual converters.

Independent of the orientation of the research, modern simulation-supported, multi-domain design tools will in future acquire fundamental importance. Apart from the power circuit simulation available today, which includes simulation of the control electronics, the modeling and simulation of high frequency losses in magnetic components, the (transient) thermal behaviour of power semiconductors and passive power components (inductors, transformer, capacitors), parasitic elements in connection technology (multilayer busbars or the wiring in power modules), conducted electromagnetic interference emission and finally reliability should primarily be supported. Here the field of reliability should be emphasised in particular, where starting from the mission profile of an application and knowledge of the mechanical construction of the component (e.g. of the material combinations of a power module) a statement on the reliability based on physical models should be possible.

In order to find new application areas and hence new research fields, the traditional value rangen of the main quantities in power electronics (power, voltage, temperature, frequency) must be analysed and those fields identified which are today not yet covered by applications. Through the development of new technologies, a push could potentially be triggered, which finally would lead to the opening of new business areas.

Such new business areas could emerge through wide-bandgap power semiconductors such as SiC and GaN, enabling significantly higher junction temperatures than for Silicon power semiconductors and can hence in principle be used in high temperature environments. However, there is a lack of suitable packaging materials and capacitor technologies as well as sensor technology and signal processing suitable for high temperature. Silicon with new die attach will reach 200°C, so the need for SiC is not evident regarding temperature. Today's packaging allows not for the high switching potential of SiC in higher power applications. Though

"Reliability of Power Electronic Systems is an important task over the coming years", stated CIPS General Chair J. Dan van Wyk in his opening speech

"Modern simulation-supported, multi-domain design tools will in future acquire fundamental importance in power electronics", J. W. Kolar pointed out in his keynote

5kV/100ns can be switched with current SiC devices, packaging is the bottleneck!

Solid state power transformers, i.e. medium frequency isolated DC/DC converters or 3-phase AC/AC converters with power in the range of 1 - 10MW represent core elements of future smart grids on the distribution level. The realisation of corresponding turn-off power semiconductors as well as associated low-inductance, partial-discharge-proof packages for medium voltage is one of the challenges. Furthermore, the consideration of the circuit topology, loss minimisation and cooling of the medium frequency transformers offers a broad field of research.

With increasing demands for energy efficiency and conservation of resources, the analysis of power electronics converters must be extended from µs and ms (control processes, mains cycles) to the entire lifetime. One example is the calculation of the overall energy Input for manufacturing (grey energy), operation and disposal or recycling of a converter. Only in this way higher initial costs can be justified for assurance of a higher performance. Furthermore, the efficiency characteristic can be tailored via later application profile and thus the maximum effectiveness of resource use assured.

The linear scale of present applications in power electronics ranges from typically 100m (HVDC) into the cm-range for point-of-load converters of IT systems. A reduction in the dimensions into the mm- and perhaps µm-range opens up a multitude of new applications. Examples are conventional power supplies with extreme form factor, or power supplies on chip for the power supply of future microprocessors or in connection with energy harvesting and PowerMEMS. Here, predominantly, new passive components must be created that can be realised with microelectronics technologies or in general, a Micro-Power Electronics that is more strongly based on capacitive than on inductive elements.

The second keynote covered the question on how GaN could replace Silicon in power MOSFETs (see our feature Can Gallium Nitride Replace Silicon?). More on CIPS 2010 will be published in PEE 3/10. **AS**

International Exhibition & Conference for POWER ELECTRONICS INTELLIGENT MOTION POWER QUALITY 4 – 6 May 2010 Exhibition Centre Nuremberg

The World of Power Electronics Technology

From May 4 - 6 this year the PCIM Europe Conference in Nuremberg offers a program with focus on energy savings and sustainability. It is the largest expo on power electronics worldwide and the most important conference on applied power electronics in Europe.

"Despite the ongoing crisis we expect increasing participation of conference delegates, visitors, and exhibitors as also sold floor space, since the 2009 figures has been reached already in January 2010", commented Udo Weller, organiser of PCIM Europe within Mesago PCIM GmbH. Up to 260 exhibitors and 6.200 professional visitors are expected at this year's event. "Special sessions organised by PEE, the Best Paper Award also sponsored by PEE, the Young Engineer Awards, and the Round Table Discussion organised by ECPE are important special events, which contribute to the success of the conference", Weller added.

"Despite the ongoing crisis we expect increasing participation of conference delegates, visitors, and exhibitors as also sold floor space, since the 2009 figures has been reached already in January 2010", stated Mesago's Udo Weller

Professional education through tutorials

On May 3 a series of tutorials will help answer the key questions currently being posed in the power electronics sector. New tutorials in 2010 are "Power Electronics and Control for Renewable Energy Systems; Batteries, Charger Solutions, Monitoring and Management Systems; Electromagnetic Design of High Frequency Converters; Switching Power Supply Design; Application design criteria for ultrafast switching MOS-controlled reverse conducting devices and management of their parasitic effects.

High Efficiency Power Conversion through „Intelligent" Power Processing is the subject of Ionel Dan Jitaru's tutorial. He is the founder of Rompower Inc., later Ascom Rompower Inc. and Delta Energy Systems (Arizona) Inc.

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

Advanced Design with MOSFET and IGBT Power Modules will be discussed by Prof. Josef Lutz, Chemnitz University of Technology, and Tobias Reimann, ISLE Steuerungstechnik und Leistungselektronik (Germany). The seminar covers Power Devices/Modules/Reliability (new developments in MOSFETs, IGBTs, freewheeling diodes module layouts, thermal mismatch, thermal stress, power cycling capability, design for reliability); Drive and Protection (principles, technical realisations, failure modes and detection as well as current, voltage, temperature protection); Topology-dependent Power Losses (DC/DC-converters, DC/AC-converters, load cycles, calculation of heatsink); Device Induced Electromagnetic Disturbance (parasitics, oscillations in power modules), and finally Special Aspects of Applications (paralleling and series connection, special effects in ZVS/ZCS topologies, special problems related to new device technologies, dynamic ruggedness of power diodes).

Tutorial 3 deals with **Batteries - Technologies, Charger Solutions, Monitoring and Management Systems** and will be given by Richard Redl, ELFI S.A., Switzerland. The first part introduces the general battery terminology and presents an overview and comparison of the most important battery types (lead-acid, NiCd, NiMH, and a variety of lithium-based battery types). Emphasis is placed on the lithium-based batteries, where the effects of the various cathode, anode, and electrolyte materials on the battery characteristics are discussed. In addition to the batteries, some battery-substituting or complementing devices (fuel cells, supercapacitors, superconductive and flywheel energy storage, radioisotope thermoelectric generators) are also covered. The second part focuses on battery charger solutions. Linear battery chargers are introduced, together with the related issues of compensating the voltage and current loops, minimizing the charger dissipation, reducing battery leakage, and shortening the charge time by cancelling the effect of the parasitic resistances of the battery pack and protection circuits. Energy-harvesting chargers are reviewed. The switch-mode battery chargers are presented next. Considerations for loop compensation and charge-time minimization are given. This part also discusses the impact of high-power off-line battery chargers on the power distribution network and discusses power-factor-corrected battery chargers. The third part presents battery and battery pack monitoring and managing solutions. Methods of determining the state of discharge and the health of batteries are reviewed and compared. The issues of monitoring and protecting single-cell and multi-cell Li-based battery packs are raised and solutions are provided. Methods of balancing the individual cells in battery packs are presented.

Jacques Laeuffer, Supèlec, France will explain the **Electromagnetic Design of High Frequency Converters.** At high frequencies, conventional circuit theories with localized constants like "parasitic capacitances" or "stray inductances" need to be replaced by a physical understanding of the electromagnetic propagation, in and around power circuits, leading to new ways for design.

Switching Power Supply Design is the subject of the tutorial given by Ray Ridley, Ridley Engineering Europe, France.

Power Electronics for Renewable Energy Systems will be discussed by Mike Meinhardt, SMA Solar Technology, and Prof. Dr. Siegfried Heier, Prof. Peter Zacharias, University of Kassel (Germany).

Tuesday 4 May 2010

Keynote »Energy Storage« D. Sauer, RWTH Aachen	Application Optimized Switches	Digital Power and Energy Efficiency	LUNCH	Power Electronics for Efficient Inverters in Renewable Energy Applications	Thermal Aspects in Power Systems	Poster / Dialogue Sessions
	High Power Converters	Sensorless Drives I		Power Electronics in Energy Generation and Distribution	Sensorless Drives II	

Wednesday 5 May 2010

Keynote »HVDC Light can deliver 1,100MW« B. Jacobson, ABB	High Speed Switching Applications	High Power Density Design	LUNCH	Reliability of Components	Interleaved Converters	Poster / Dialogue Sessions
	Module Design	Advanced Control in Drives		Energy Storage	Inverter Control in Motor Drives	

Thursday 6 May 2010

Keynote »Virtual Prototyping of Power Electronic Systems« J. Biela, ETH Zürich	Power Electronics in Automotive and Traction	High Voltage Components	LUNCH	New Components and Cooling	Inverters for Renewable Energy and UPS	
	ECPE Panel Discussion »Electronics for Energy Efficiency and Sustainability«	Motor Drives		Sensors and Metering	Electrical Machines	

As by January 2010/ subject to change without notice.

Power electronics is the key of future developments of the electrical power supply. All distributed generators (like photovoltaic, wind turbines, micro turbines and fuel cells) as well as storage devices are connected to the grid through power electronics. Power electronic offers also a lot of opportunities of controlling grid parameters like power balancing, frequency control and voltage regulation. This tutorial will give an overview of state-of-the-art of photovoltaic inverters including topologies and control in research and industry. Power electronics and control for wind energy systems will also be taught. Aspects of grid connection of large PV-plants and Wind parks will be discussed.

IGBT Gate Drive Technologies will be introduced in detail by Reinhard Herzer and Arendt Wintrich, SEMIKRON Elektronik, Germany. Power electronics systems are commonly used in motor drive, power supply and power conversion applications. They cover a wide output power spectrum: from several hundred watts in small drives up to megawatts in wind-power installations or large drive systems. Inside the system the gate driver circuit with its extensive control and monitoring func-tions forms the interface between the microcontroller and the power switches (IGBT). The seminar will provide an overview of different gate driver topologies for different power ranges and will show numerous examples for monolithic integration of the driver functionality. Chipsets for high power drivers with a real potential separation (galvanic insulation) are the starting point, and a new and innovative concept for a digital gate driver and its integration is presented. Fully integrated gate driver solutions for the low power range, their technologies, circuit aspects and specific designs are shown and discussed.

Application Design Criteria for Ultrafast Switching MOS-Controlled Reverse Conducting Devices and Management of their Parasitic Effects is the subject of the tutorial given by Wolfgang Frank and Lutz Goergens, Infineon Technologies Germany and Austria. The seminar will give fundamental knowledge on the latest low voltage MOSFET and reverse conducting IGBT technologies. The first part treats application aspects of reverse conducting IGBT for soft and hard switching schemes and provides detailed information on driving these IGBT as well as other design criteria for applications up to 3kW, which is the power range of these devices. Two case studies will deepen proximity with applications. The second part covers the operation of low-voltage MOSFETs as synchronous rectifiers and under free-wheel operation. Starting from an analysis of a power MOSFET operated under reverse conditions, the findings are applied to various applications and design-guidelines derived. Examples are given for embedded point-of-load converters in 12V systems and AC/DC power-supplies (~1kW) to clarify the mechanisms involved. Separate time slots are reserved for dedicated discussion. The participants are therefore able to transfer directly the tutorial contents into their everyday s working items.

PCIM 2010 conference will cover 170 papers, 67 will deal with power electronics

Bruce Carsten, Bruce Carsten Associates Inc., USA will discuss the fundamentals of **Switchmode Design and Layout Techniques for Low EMI.** Although related to previous EMI seminars by the instructor, the focus of this new seminar is the physical design and layout of a Printed Circuit Board (PCB) to minimize Electromagnetic Interference (EMI). A good PCB layout for low EMI is a technically demanding design task, ideally performed by one versed in the physics and visualization of electric and magnetic fields. Unfortunately, PCB layout is increasingly performed by someone trained only in the use of layout software, where arbitrary component placement and the use of auto-routing of conductor traces can be deadly to EMI performance.

Keynotes focus on current trends

In more than 170 papers authors from industry and science will present the results of their latest research and user reports. Power Electronics is with 67 oral presentations grouped in 16 sessions by far the main part of the conference. Dialog sessions on the Tuesday and Wednesday afternoon complement the conference program. Keynote papers will start the conference days.

The first keynote Tuesday morning is on **Energy storage: State-of-the-art and future trends** and will be presented by Dirk Uwe Sauer, RWTH Aachen (Germany). Energy storage systems are a key element in an ever increasing number of technical applications. This includes primary batteries for several electronic devices or mother boards in computers, and secondary rechargeable batteries for applications such as uninterruptible power supply systems for critical loads, server farms or telecommunication equipment, mobile applications such as mobile phones or laptops, and traction application such as electric vehicles or hybrid power trains for various applications. Another major future application for energy storage systems will be the power supply infrastructure for the integration of increasing amounts of fluctuating renewable energies. This presentation will discuss the state of the art of secondary battery technologies and their requirements with regard to charging and management electronics as well as the limitations of the different technologies. Lithium-ion batteries will be in the focus. Special emphasis will be made on a clear differentiation of the different material combinations and their special performance parameters. Beside this an outlook to future technology option for energy storage technologies will be given. For the design of battery systems, optimised management strategies and diagnostic algorithms and hardware are required. This needs to be combined with an optimised thermal management. This gives an outlook to the needs in electronics and power electronics for the energy storage systems.

The second keynote on Wednesday morning by Björn Jacobson, ABB Ludvika (Sweden) is entitled **HVDC Light can deliver 1,100MW.** An increasing share of new power generation comes from renewable sources, often located in remote areas. Since the mid 1990s, ABB has been developing a new system, called HVDC Light® (high voltage direct current), for electric power transmission, with the aim of providing a new transmission alternative, reducing some of the inherent disadvantages of the existing systems. With HVDC Light systems it is possible to transfer DC power over long distances on land by the use of robust and quick-to-install polymeric cable systems. Similarly, submarine cables can be used for sea crossings. HVDC Light converters enrich the electric transmission network with properties like improved black-start capabilities. This presentation will discuss the development of HVDC Light to 1100 MW and the applications of such transmission links. The present limitations of the technology and some important development drivers will also be discussed.

The third keynote on Thursday morning by Jürgen Biela, ETH Zürich (Switzerland) will discuss **Virtual Prototyping of Power Electronics Systems.** His current research interests include multidomain modelling, design and optimization of power electronic systems, in particular systems for future energy distribution and pulsed power applications, advanced power electronic systems based on novel semiconductor technologies, and integrated passive components for ultra compact and ultra efficient converter systems.

Special sessions on special subjects

For the third time time Power Electronics Europe has organised a Special Session on Tuesday afternoon with this year's focus on **Power Electronics for Efficient Inverters in Renewable Energy Applications** featuring papers from Björn Backlund, Munaf Rahimo, ABB Switzerland Ltd; Dejan Schreiber, SEMIKRON Elektronik (Germany); Alberto Guerra, International Rectifier (USA) and Shang Ming, Mitsubishi Electric Corporation (Japan).

The first paper entitled **Comparison of High Power Semiconductor Technologies for Renewable Energy Sources** will look at the features for the available high power semiconductors of choice and also takes a look at future devices and their expected impact on efficiency. High power semiconductors are key components for control of the generation and connection to the net work of renewable energy sources as wind turbines and photovoltaic. For highest efficiency of the energy source it is therefore essential to select the right device for the given conditions.

The second paper covers **High Power Renewable Energy Applications, Facts & New Design Proposals.** Renewable energy applications are a great challenge today. Efficiency and reliability are the prevailing requirements. The best solution for MW converter design is paralleling of inverters / power blocks. An alternative solution is a medium voltage source and transmission connected to MV grid-side inverter based on low-voltage silicon - power blocks - connected in series. In addition, interleaved PWM reduces the size of the sinusoidal filter and the switching frequency.

GaN-Based Power Device Technology and its Impact on Future Efficient Solar Grid Connected Micro and String Inverters will be introduced by the third paper within this Special Session. GaN-based power device technology is progressing rapidly and expanding its applicability in a wide range of power applications including Solar Inverters. Along with intrinsic scalability in low and high voltage power conversion topologies and coupled with dramatic FOM improvement vs. Si based devices, GaN power products are set to have a direct impact on future efficient grid connected PV micro and string inverters.

Finally, the paper **New Low Loss Transfer Mold IPM for Photovoltaic Generation** will introduce a low loss large-scale Dual In-line Package Intelligent Power Module with rating of 50A/600V. The low loss large-scale DIPIPM was achieved by using the V4 package with novel heat dissipating insulation sheet. High efficiency is required when DC electricity generated by solar cells is converted to AC electricity. To realize high efficiency, the switching loss is reduced by using fast 5th generation full gate CSTBT and high output current driver IC which leads to a higher switching speed.

Digital Power and Energy Efficiency is the focus of an other special session on Tuesday chaired by Manfred Schlenk, NMB-Minebea (Germany). Speakers are Carsten Deppe, Philips Technology (Germany), Willi Sterzik, Fujitsu Technology Solutions (Germany),

Daniel Luthi, EM Microelectronics (Switzerland), Wenqi Zhou, UAS Augsburg (Germany), and Ulrich Schwarzer, Infineon Technologies (Germany).

Reducing Standby Energy Consumption of Consumer Electronic Applications to Virtually Zero is the title of the first paper in this session. The energy consumption of consumer electronics while in off state is a never ending discussion and leads to always improving and more complex solutions. This paper shows our experiences with a concept completely removing such consumption while maintaining the most important remote control functionality. The concept has been evaluated on the example of a recent flat TV model, but can be adapted to many applications.

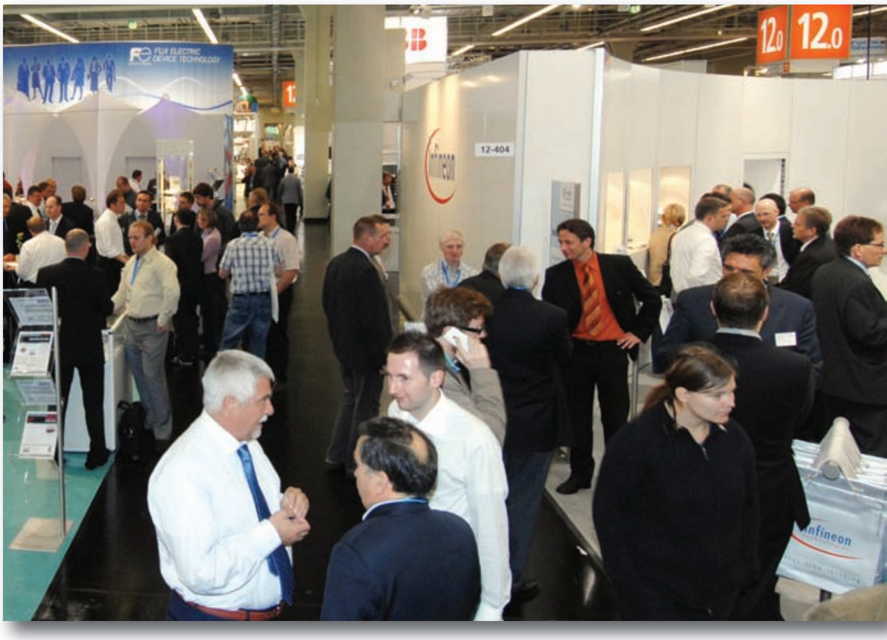
The 0W PC - New Opportunities for Energy Saving comes next after. In 2005 the EU commission has published the regulation 2005/32/EC. As a consequence all manufacturers of Energy using Products (EuP) had to cope with a new requirement for future devices. It was obvious, that energy saving will be a future key design criteria in the future. Efficiency in energy conversion, reduction of stand by losses gained importance in any market segment. Also the IT industry is facing this situation. However, reduction of stand by losses was linked in the past very closely to the reduction of "convenience functions". A very simple method to reduce the stand by losses to 0W, is to have just a mains switch in the power cord. However the user looses any convenience like automated shut down and power on or remote maintenance possibilities. Fujitsu Technology Solutions has developed a technology for IT equipment to overcome these drawbacks and still having 0W in stand by condition.

A new power supply topology, the **„Zero Power Platfrom"**, is presented is the third paper lowering standby power consumption to values below 10mW while maintaining wakeup capability (IR). The combination of a dedicated power supply microcontroller, a software implementation of control algorithms and a power converter system architecture is used in the construction of a fully functional platform. Digital control offers the chance to integrate power managment funtionality into power converters in a efficient way. Recently available microprocessor technologies allow to implementation of complex regulation principles for the power conversion stages. This will be demonstrated on examples for power supplies for consumer and IT equipment. The „Zero-Power" Platform demonstrates this new concept of low standby dissipation switched-mode power supplies.

A **New Cost-Effective Measuring Method for Bridgeless PFC Converter** will be introduced with the fourth paper. Because of the reduced conduction losses, bridgeless PFC converters have drawn more and more attention recently. In this paper, current sensing techniques are discussed. Compared with LEM-transformer, a state of the art current transformer is shown to reduce power losses and cost without any performance degradation. A newly developed current transformer is proposed to further reduce component count and power losses.

Finally, an **IGBT Module with Integrated Current Measurement Unit Using Sigma-Delta Conversion for Direct Digital Motor Control** will be described. System integration is one of the market driving issues in power electronics. In this paper the integration of precise shunts and complete A/D-conversion units with isolation interface into IGBT modules is compared to today's conventional solutions based on Hall effect sensors and additional A/D-converter chip sets for inverter output current measurements.

Also the **ECPE Round Table: Electronics for energy efficiency and sustainability (EEESy) - a strategic research agenda for Europe** on Thursday morning, is one of the outstanding events at PCIM Europe.



PCIM 2010 exhibition from May 4-6 in Nuremberg will have around 260 exhibitors at 10,900m² floorspace, a slight growth compared to PCIM 2009

Around 500 delegates again will attend PCIM 2010 conference

Designing Multiple Load System Power Supplies

Design tools have been developed over the past ten years to help power supply designers create single DC to DC power supplies. These tools feature parts selection, material cost calculation, simulation and prototype procurement. This has simplified the design process and reduced time-to-market. But with design complexity increasing, the need for ten or more power supplies on a PC board has increased the challenge. Now, a new breed of design tool has emerged that allows the configuration and design of multiple-load power supply systems at one time. Performance goals such as small footprint, high efficiency and low overall system cost can be applied to an entire system at once. **Jeff Perry, Senior Manager WEBENCH Tools, National Semiconductor Corp., USA**

To begin the power supply design process, the engineer needs to first determine the voltage and current specifications including minimum and maximum input voltage, output voltage and load current. The user must also decide the overall design goals for component footprint, efficiency and cost. Then the designer can use a tool such as National Semiconductor's WEBENCH® Designer to visualise the options to determine which solution is best for the design requirements.

Designing a single power supply

Figure 1 shows a graph of different solutions for a typical buck power supply that has 14-22V input, and 3.3V/1A output. The y axis shows the component footprint, the x axis shows the efficiency and the bubble size shows the total bill of material (BOM) cost. In this case, there are 50 different design possibilities shown for the given set of inputs and there is considerable variation in performance of the different designs. This is due to a) differences in switching frequency, b) devices having synchronous versus asynchronous switching, and c) controller devices with external FETs versus integrated FET devices. The graphical approach makes it easy to determine which solution fits the designer's goals and what the trade-offs are.

System level design

If one takes this single supply design approach and applies it to an entire system, then the number of possibilities increases dramatically. For example, Figure 2 shows a system board which has an FPGA, memory, communications and motor control elements.

This system has an input of 48V and nine loads. The first task in creating the system level power supply is to group the voltages together, which gives us a total of five outputs. Next the designer needs to

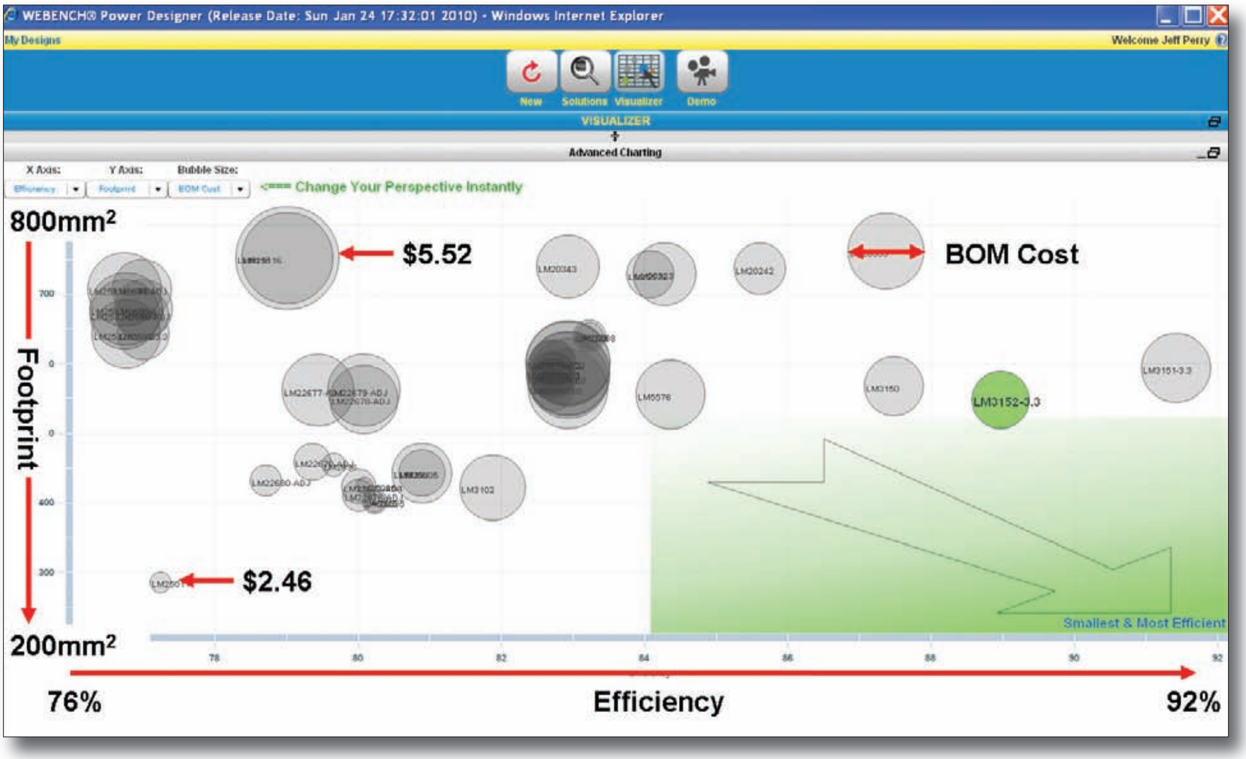
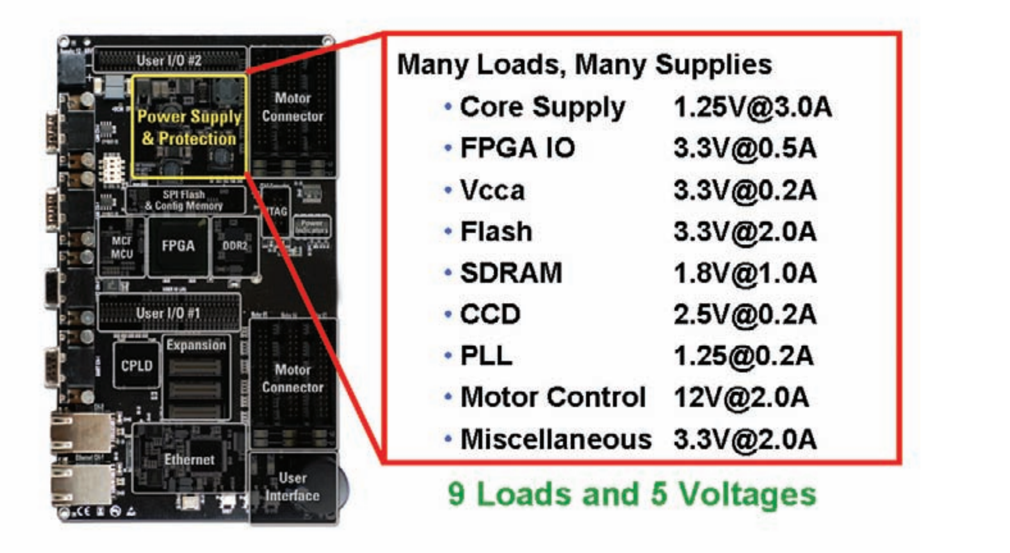


Figure 1: Graph of 50 different power supply solutions for a given set of inputs showing trade-offs between footprint, efficiency and BOM cost



Example of multiple DC loads within a single system board requiring multiple power supply solutions

determine the architecture required including the need for one or more intermediate voltage rails which are placed between the source supply and the point of load supplies. An example of this is shown in Figure 3.

An intermediate rail can often improve the performance of the system by restricting the duty cycles of the various supplies to optimal regimes to improve efficiency. It can also reduce cost and footprint by limiting higher voltage components to the intermediate supply and allowing the downstream supplies to use lower voltage components which tend to be less expensive and smaller, particularly in the case of ceramic capacitors. After determining the voltage rail architecture, the designer needs to optimise the supplies for small footprint, high efficiency and/or low cost.

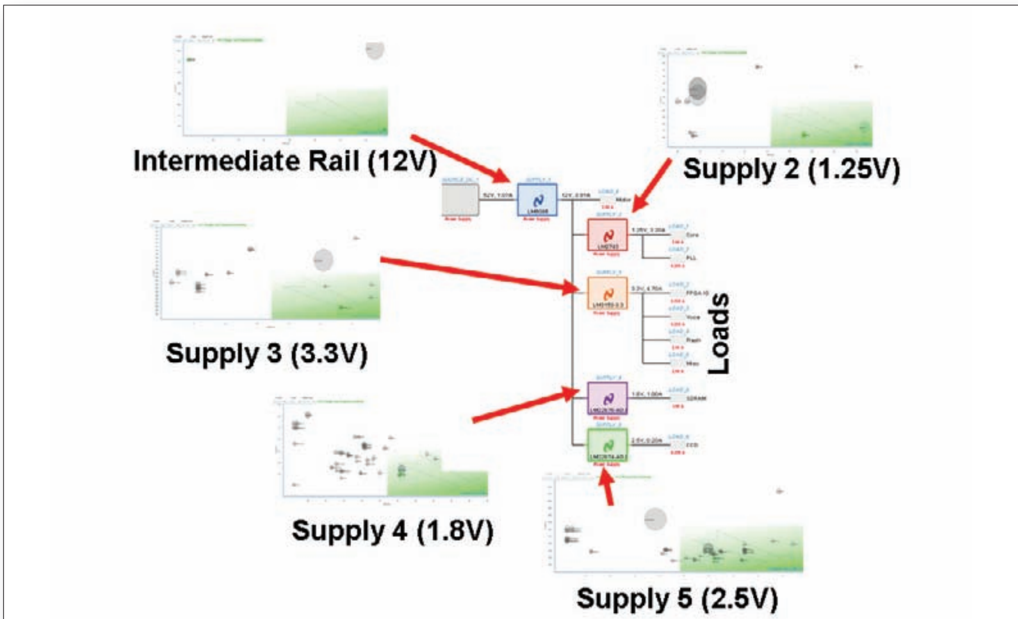
The problem with this approach is that possibilities multiply rapidly. For example, if there are five different voltage rail architectures, five different power supplies and fifty possible power supply solutions for each supply, the designer now has 1,250 options to be considered. Add in five different optimisations for efficiency, footprint and cost and the total grows to 6,250 solutions to review.

The key is to narrow the choices down and use visualisation tools to drive to the best solution for the design goals. Figure 4 shows a plot of different system level designs produced from the WEBENCH Power Architect tool. Each bubble in the chart represents a different architecture/rail configuration and different optimisation for footprint, BOM cost or efficiency. As can be seen, there is a significant variation in the results.

System design optimisation

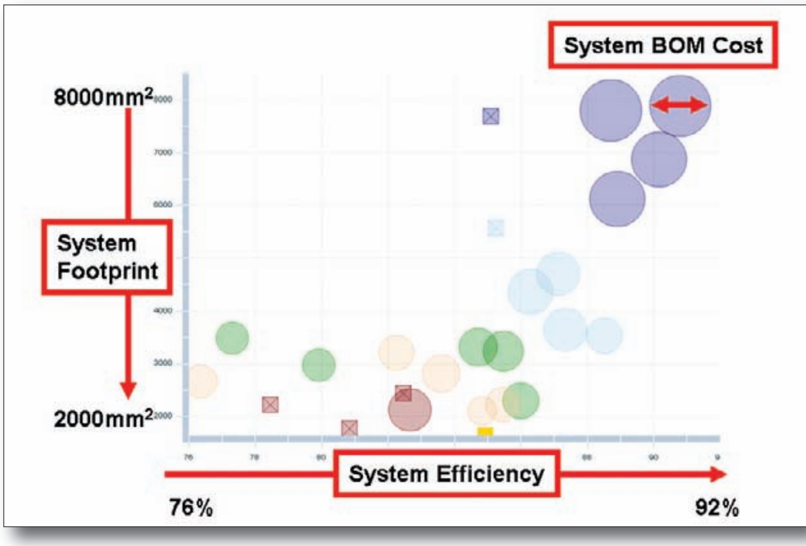
Within Figure 4, the different colours represent the various design optimisations. For the designs optimised for high efficiency, the switching frequency was lowered to reduce AC switching power losses and improve system efficiency. However, in order to keep the inductor ripple current constant at the lower frequency, the inductance was increased, which then increased the footprint of the inductor and led to a larger overall system footprint. Also, the BOM cost has been increased which is typical of larger components.

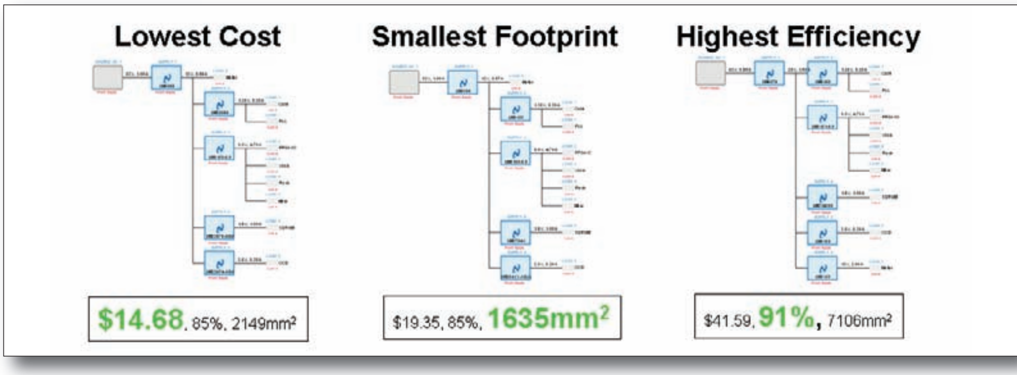
These designs are shown in the upper right corner of the graph in dark blue colour. On the other hand, for designs optimised for small system footprint, the frequency was decreased which allowed the inductance, and inductor size, to be reduced while maintaining the same inductor ripple current. The smaller parts tend to be less expensive so the overall BOM costs have been lowered. The trade-off is that the AC switching power losses have increased and the efficiency has gone down. These results are shown in the lower left portion of the graph in red colour. Other colours shown on the graph are compromises between the



Typical power supply system architecture using one intermediate rail supply at 12V and four point of load power supplies. Also shown are the trade-off graphs for each supply showing the large number of options to be considered

Graph of 25 system solutions for a nine load power supply system. The colors represent different optimisations emphasising small system footprint, low system BOM cost or high system efficiency





LEFT: Summary of system solutions for a nine load power supply system showing lowest BOM cost, lowest component footprint and highest efficiency options

two extremes.

The extreme values of the array of power supply solutions are shown in Figure 5 and the trade-offs to be made are evident. To achieve the highest system efficiency of 91%, the system BOM cost and component footprint are 2.8 and 4.3 times higher than the other extreme options. On the other hand, to get the lowest BOM cost or smallest footprint, the efficiency drops to 85%. But the designer can also choose options in between the extremes.

Thus we see that using tools which allow the user to narrow down and visualise large numbers of multiple load system-level power supply solutions can save a great deal of time during the design phase and lead to an outcome that is optimised for the designers specific needs.

Literature

National Enters Power Module Market, Power Electronics Europe 1/2010

Real-Time Comparison of Power Designs, Power Electronics Europe 8/2009

Can Gallium Nitride Replace Silicon?

For the past three decades, Silicon-based power management efficiency and cost have shown steady improvement. In the last few years, however, the rate of improvement has slowed as the Silicon power MOSFET has asymptotically approached its theoretical bounds. Gallium Nitride grown on top of a silicon substrate could displace Silicon across a significant portion of the power management market.

Alex Lidow, CEO Efficient Power Conversion Corp., El Segundo, USA

Power MOSFETs appeared in 1976 as alternatives to bipolar transistors. These majority carrier devices were faster, more rugged, and had higher current gain than their minority-carrier counterparts. As a result, switching power conversion became a commercial reality. AC/DC switching power supplies for early desktop computers were among the earliest volume consumers of power MOSFETs, followed by variable speed motor drives, fluorescent lights, or DC/DC converters.

Many generations of power MOSFETs have been developed by several manufacturers over the years. There are still improvements to be made. For example, Superjunction devices and IGBTs have achieved conductivity improvements beyond the theoretical limits of a simple vertical majority carrier MOSFET. These innovations may still continue for quite some time and will certainly be able to leverage the low cost structure of the power MOSFET and the well-educated base of designers.

Start of GaN in power electronics

HEMT (High Electron Mobility Transistor) GaN transistors appeared in 2004 with depletion-mode RF transistors made by Eudyna Corp. in Japan. Using GaN on Silicon Carbide substrates, Eudyna designed such transistors for the RF market. The HEMT structure demonstrated unusually high electron mobility near the interface between an AlGaN and GaN heterostructure interface. Adapting this phenomenon to Gallium Nitride grown on Silicon Carbide, Eudyna was able to produce benchmark power gain in the multi-gigahertz frequency range. In 2005, Nitronex Corp. introduced the first depletion mode RF HEMT transistor made with GaN on Silicon wafers.

GaN RF transistors have continued to make inroads in RF applications as several other companies have entered in the market. Acceptance outside this market, however, has been limited by device cost as well as the inconvenience of depletion mode operation.

In June 2009 Efficient Power Conversion Corp. (EPC) introduced its first enhancement-mode GaN on Silicon designed specifically as power MOSFET replacements. These products were designed to be produced in high-volume at low cost using standard Silicon manufacturing technology and facilities. The structure is relatively simple as shown in Figure 1. Figure 2 shows a size comparison between Silicon devices and GaN devices rated at 200V.

The new generation of enhancement mode GaN transistor is very similar in its behaviour to existing power MOSFETs and therefore users can greatly leverage their past design experience. Two key areas stand out as requiring special attention: relatively low gate dielectric strength (and finite gate leakage on the order of µA per mm of gate width) and relatively high frequency response.

The first of these two differences, relatively low gate dielectric strength, will be improved as the technology matures. In the mean time, measures need to be taken to eliminate workplace ESD and to design circuits that maintain the gate-to-source voltage below the maximum limits in the data sheet. The second difference, relatively high frequency response, is both a step function improvement over any prior silicon devices, and an added consideration for the user when laying out circuits. For example, small amounts of stray parasitic inductance can cause large overshoot in the gate-to-source voltage that could potentially damage devices.

On the other hand, there are several characteristics that render these devices easier to use than their silicon predecessors. For example, the threshold voltage is

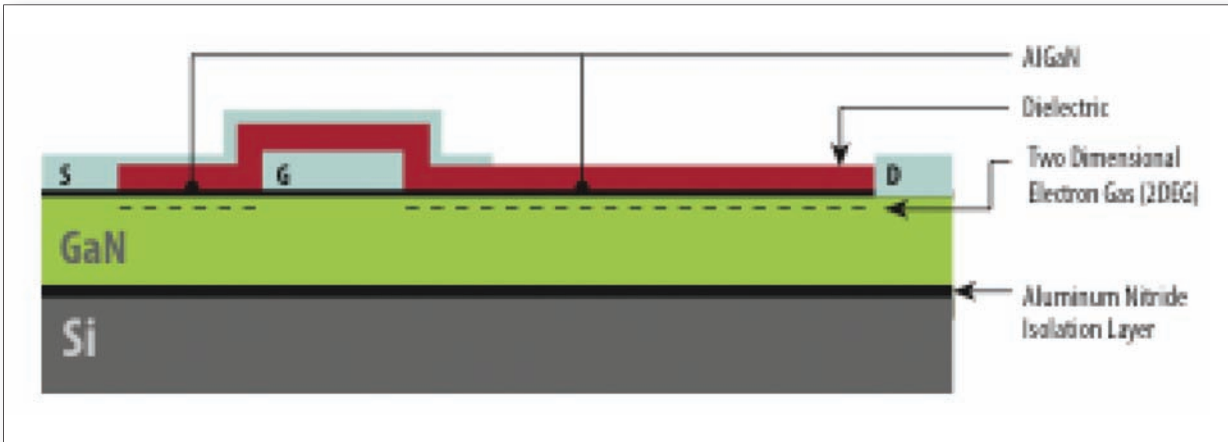


Figure 1: **GaN on Silicon devices have a very simple structure similar to a lateral DMOS and can be processed in a standard CMOS foundry**

Figure 2: Size comparison between Silicon devices and GaN devices rated at 200V

virtually independent of temperature over a wide range, and the on-resistance has a significantly lower temperature coefficient than silicon. GaN transistors are also able to operate at temperatures as high as 300°C, but solder connections to the printed circuit boad prevent practical application much above 125°C. The first commercial enhancement mode parts are therefore characterised up to 125°C.

New capabilities by GaN power transistors

In power MOSFETs there is a basic trade-off between the conductivity and the amount of charge required to switch the device. From this trade-off comes the figure of merit (FOM) called RQ product. This is defined as a device's on-resistance multiplied by the total charge that must be supplied to the gate to switch the device at operating voltage and current. Improvements in this product have been shown to translate into improved conversion efficiency in high frequency DC/DC converters. The absolute value of RQ is also indicative of the minimum pulse widths achievable in a practical circuit. Whereas there have been great improvements in RQ product, Silicon cannot come close to the FOM achieved in first-generation enhancement HEMT (eHEMT) devices already on the market.

The ability to switch quickly and with low power loss means users can go to much lower pulse widths in power conversion circuits. One significant new application needing this capability is non-isolated DC-DC converters. The basic limitation of Silicon power MOSFETs has restricted single-stage, non-isolated buck converters to a practical maximum ratio of input voltage to output voltage of 10:1. Beyond that ratio, the short pulse widths required of the top transistor in the buck circuit result in unacceptably high switching losses and consequently low conversion efficiency. GaN transistors reset this performance bar as indicated in Figure 3.

In addition to the added V_{IN}/V_{OUT} range made possible by GaN, existing buck converters can greatly reduce switching losses. AC/DC conversion, synchronous rectification, and power factor correction (PFC) are all candidates for major performance improvement as new GaN transistors rapidly cover the current and voltage range of today's power MOSFETs and IGBTs.

User-friendly tools can also make a big difference in how easy it is to apply a new type of device. EPC has developed a set of TSPICE device models available for download. Figure 4 shows a simple circuit and the comparison between actual device performance and the simulated result using the TSPICE model. Whereas more work refining these models needs to be done, the first-generation should provide reasonably reliable circuit performance predictions.

GaN on Silicon processes

GaN on Silicon wafers are produced typically on 150mm substrates (future products will migrate to 200mm) whereas power MOSFETs are produced on anything from 100mm through 200mm substrates by the many manufacturers. Because the GaN devices use standard silicon substrates, there is no cost penalty compared with power MOSFETs fabricated on similar diameter starting material. In fact, there is little cost difference per unit area between 150mm and 200mm silicon wafers and therefore we can conclude that, as far as starting material is concerned, there is no true cost difference per wafer. Taking into account the fact that the GaN device has less device area than a Silicon device with similar current-carrying capability, then the cost per function is lower for GaN.

Silicon epitaxial growth is a mature technology with many companies making highly efficient and automated machines. MOCVD GaN equipment is available from at least two sources, Veeco in the US and Aixtron in Germany. Both make capable and reliable machines whose primary use has been the growth of GaN epitaxy used in the fabrication of LEDs. None of the machines are optimised for GaN on Silicon epitaxy, nor do they have levels of automation that are common on Silicon machines. As a result, GaN epitaxy on Silicon is significantly more expensive than Silicon epitaxy today. But this is not fundamental. Processing times and temperatures, wafer diameter, materials costs, and machine productivity are all on a fast track of improvement with no

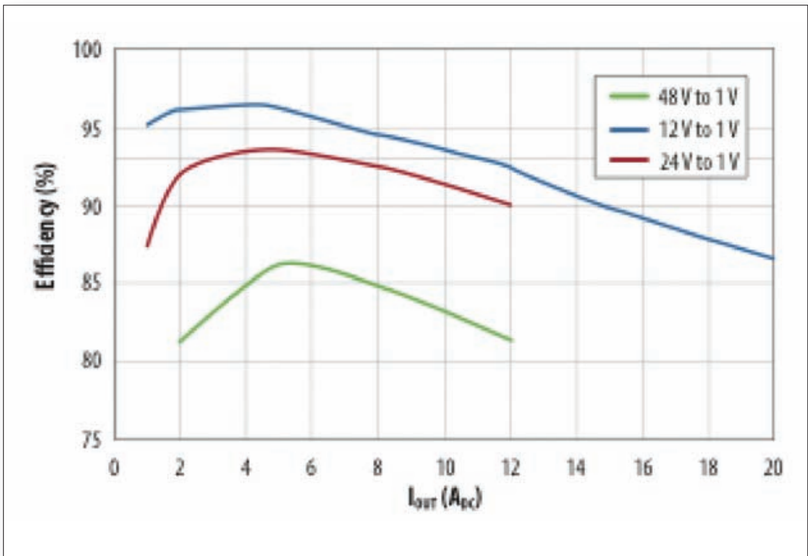


Figure 3: Buck converter efficiency vs current for various input voltages using a single 100V EPC1001 both as the top and bottom transistor

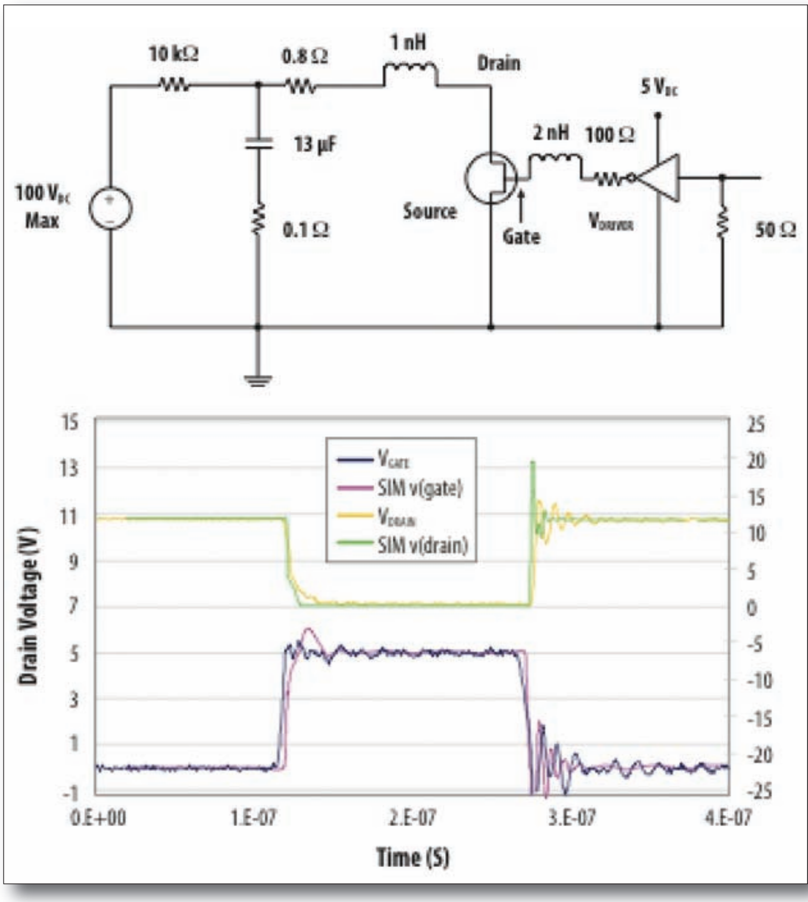


Figure 4: **Circuit diagram and oscillogram comparing EPC1001 TSPICE simulation results with actual measured circuit performance**

fundamental limit far away from Silicon limits. Within the next few years, assuming widespread adoption of GaN, it is expected that the cost of the GaN epitaxy will approach that of Silicon epitaxy.

The simple structure depicted in Figure 1 is not complicated to build in a standard Silicon wafer fab. Processing temperatures are similar to Silicon CMOS, and cross contamination can easily be managed. Today, EPC processes all their wafers in Episil Inc., a well-established foundry in Taiwan.

In the assembly process there are significant differences favouring the cost structure of GaN on Silicon devices whereas the testing costs are equivalent.

Silicon power MOSFETs need a surrounding package typically made of a copper leadframe, some aluminum, gold, or copper wires, all in a molded epoxy envelope. Connections need to be made to the top and bottom of the vertical silicon device, the plastic molding is needed to keep moisture from penetrating to the active device, and there needs to be a means of getting the heat out of the part. Establishedl power MOSFET packages such as the SO8, TO220, or DPAK add cost, electrical and thermal resistance, and increase reliability and quality risks to the product. GaN on Silicon can be used as a "flip chip" without compromise of electrical, thermal, or reliability characteristics.

Referring to Figure 5 it can be seen that the active device region is isolated from the Silicon substrate much like a Silicon-on-Sapphire device. As a result, the active GaN device can be completely encapsulated by passivating layers. In addition, the Silicon substrate can be directly attached to a heatsink for excellent thermal performance.

In short, GaN on Silicon eliminates the need for a package and therefore also reduces cost, wasted board space, added thermal and electrical resistance, and the most common reliability issues plaguing packaged power devices.

Is GaN reliable?

The cumulative reliability information available on Silicon power MOSFETs is staggering. Many years of work have gone into understanding failure mechanisms, controlling and refining processes, and designing products that have distinguished themselves as the highly-reliable backbone of any power conversion system. GaN on Silicon are just beginning this journey. Preliminary results, however, are encouraging. As of the date of this writing, EPC has established the basic capability of enhancement mode GaN on Silicon. A full reliability report with greater statistics is expected to be published later in March 2010.

Future directions

There are profound improvements that can be made in basic device performance as measured by the RQ figure of merit. As we learn more about the material and the process, a factor of 2 improvement can be reasonably expected over the next three years and a factor of 10 over the next ten years. We can also expect devices to emerge with much higher breakdown voltage in the near future as EPC plans to introduce 600 V devices in the second half of 2010 and other companies have discussed openly their intentions in this area. Higher voltages for GaN transistors with undoubtedly follow.

Perhaps the greatest opportunity for GaN to impact the performance of power

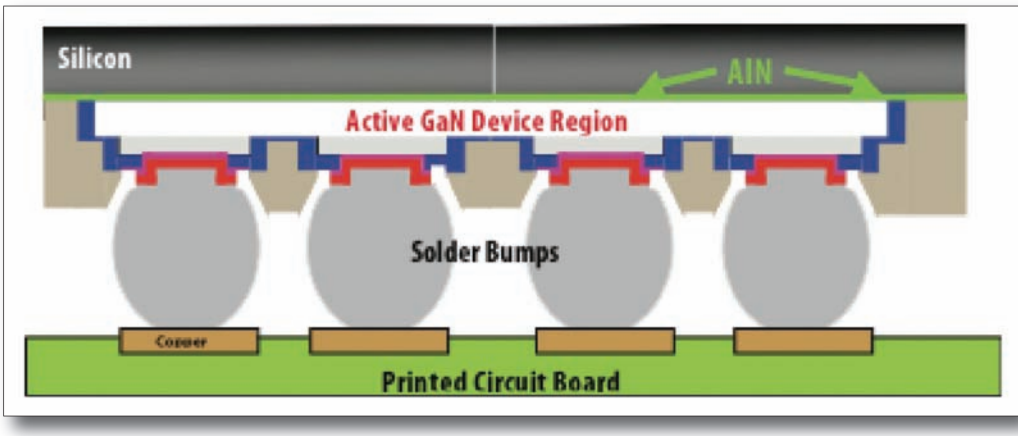


Figure 5: **GaN on Silicon can be used as a "flip chip" where the active device is isolated from the silicon substrate and can be completely encapsulated prior to singulation**

Figure 6: Power transistor with on-board drivers

conversion systems comes from the intrinsic ability to integrate both power-level and signal-level devices on the same substrate. GaN on Silicon, much like SOI, has no significant parasitic interaction between components, allowing designers to easily develop monolithic power systems on a single chip. Figure 6 shows a power transistor with on-board drivers from EPC.

Conclusion

In the late 1970's the pioneers in the development of power MOSFETs believed they had a technology that would displace bipolar transistors completely. Thirty years later, we still have plenty of applications that prefer bipolar transistors over power MOSFETs but the size of the power MOSFET market is many times larger than the bipolar market largely due to all the new applications and new markets enabled by that breakthrough technology.

Today, we are at that same threshold with enhancement mode GaN on Silicon. Like the power MOSFET of 1976, we are beginning an exciting journey with new products and breakthrough capabilities almost monthly. The power MOSFET is not dead, but is nearing the end of the road of major improvements in performance and cost. GaN will most probably become the dominant technology over the next decade due to its large advantages in both performance and cost; advantage gaps that promise to widen as we quickly climb the learning curve.

Literature

Alex Lidow PhD, CEO, Efficient Power Conversion Corporation, El Segundo, USA. Is it the End of the Road for Silicon in Power Conversion? Keynote of CIPS 2010, March 16 - 18, Nuremberg, Germany

EPC launches 40V to 200V EM GaN Power Transistors

EPC's enhancement mode (normally-off) GaN technology was explicitly developed to replace power MOSFETs. The products are produced in a standard silicon CMOS foundry on 150mm (6 inch) Silicon wafers. The use of this low-cost infrastructure has allowed to price the initial product offerings aggressively in order to accelerate the conversion from silicon power MOSFETs.

Spanning a range of 40V to 200V, and 4mΩ to 100mΩ, these power transistors have significant performance advantages over Silicon-based power MOSFETs. Applications that can benefit are DC/DC power supplies, point-of-load converters, class D audio amplifiers, notebook and netbook computers, LED drive circuits, telecom base stations, and cell phones, to name just a few. "Our GaN-on-Silicon power transistors represent a major breakthrough in power conversion technology since the development of the commercial power MOSFET. We have developed a very cost effective and reliable technology that is also very easy for anyone with power MOSFET experience to use in a way that will significantly boost their power management system performance", commented Alex Lidow, EPC's co-founder and CEO.

Established in 2007, EPC is a fabless company with subcontract manufacturing in Taiwan. EPC's key markets include voltage controllers, LED boost converters, power MOSFET and IGBT replacements, drivers, power amplifiers and RF MOSFETs. EPC's founders are committed to developing GaN products to be used as cost-effective Silicon product replacements. EPC's products for applications requiring 200V or less are available for purchase on Digi-Key's global websites. Additionally, these parts will be featured in future print and online catalogs. "Digi-Key has the fastest global logistics and the most efficient supply chain of any distributor with which I have worked over the last 30 years", Lidow said. "This will translate into fast and easy service to our global customer base who want to replace their power MOSFETs". "EPC's GaN-based power management products bring intriguing next-generation breakthrough benefits to existing MOSFET and Bipolar solutions, we are thrilled to be the first to offer these innovative products to the engineering community", said Dave Doherty, Digi-Key's VP of semiconductor product.

The product is priced between $0.80 and $5.00 in 1k quantities and can be ordered at http://digikey.com/Suppliers/us/Efficient-Power-Conversion.page?lang=en

More Efficiency for 3-Level Inverters

The use of renewable energy sources is one of the key issues when it comes to creating a new basis for worldwide energy supply. Wind power has been in use for over 20 years now, with technical advances leading to improvements in efficiency and reliability. The output of wind power units is steadily increasing. The switchover from 2 to 3 MW per unit is currently underway. Unlike wind power converters, central solar inverters bear huge potential for technical optimisation. At the moment, photovoltaic systems bear the biggest potential for increasing the efficiency of solar panels as well as of the overall system design.

Norbert Pluschke, Technical Director for Greater China, SEMIKRON Hong Kong, and Thomas Grasshoff, Head of Product Management International, SEMIKRON Germany

For applications below 250kVA a number of different solar power inverter concepts exist, similar to the string inverter for applications under 10kVA. To increase efficiency, higher switching frequencies are used. This is done to reduce what are known as copper losses and boost overall efficiency. Connecting photovoltaic modules in series can lead to an increase in DC current in the system, which in turn reduces losses.

The higher switching frequencies produce higher losses in the IGBTs, thus reducing the efficiency of the solar inverter. State-of-the-art IGBTs allow for junction temperatures of 175°C. This increase in junction temperature from 150°C to 175°C, however, also results in a higher collector-emitter voltage (positive IGBT temperature coefficient), which again affects the efficiency factor. Compromises in circuit dimensioning are therefore needed to find the optimum in face of these conflicting physical effects.

3-level modules for high switching frequencies

The SEMIKRON range includes 3-level modules for high-frequency applications. In the past, when designing a 3-level inverter, half bridge or chopper modules had to be used. Now, the integration of a phase into an individual module allows for a simpler driver concept and less costly overall solution for 3-level inverters. In the development of the modules, the focus was placed on the internal chip arrangement design and user-friendly connections within the device. These modules are suitable for applications from 50A to 400A for a collector-emitter blocking voltage of 600V. The modules feature integrated high-speed clamping diodes.

The 2-level and 3-level inverters are similar in function to DC/AC converters (see Figure 1). Both systems can produce a variable frequency and voltage from a DC voltage. The main difference between these two inverters is the number of IGBTs, diodes and capacitors required. The 3-level phase in NPC topology (Neutral Clamping Point) comprises four series connected IGBTs with corresponding freewheeling diodes and two clamping diodes for connection to the split DC link circuit.

2-level inverters have a two-state output stage, while a 3-level inverter can feature three states. Unlike the 2-le el design, where the IGBT has to switch the entire DC link voltage, in the 3-level architecture only half the DC link voltage is switched across the IGBT. The DC link capacitor has to be designed such that it is capable of halving the DC link voltage. In a 3-level phase, various commutation paths exist. The short commutation path runs between the clamping diode and an IGBT

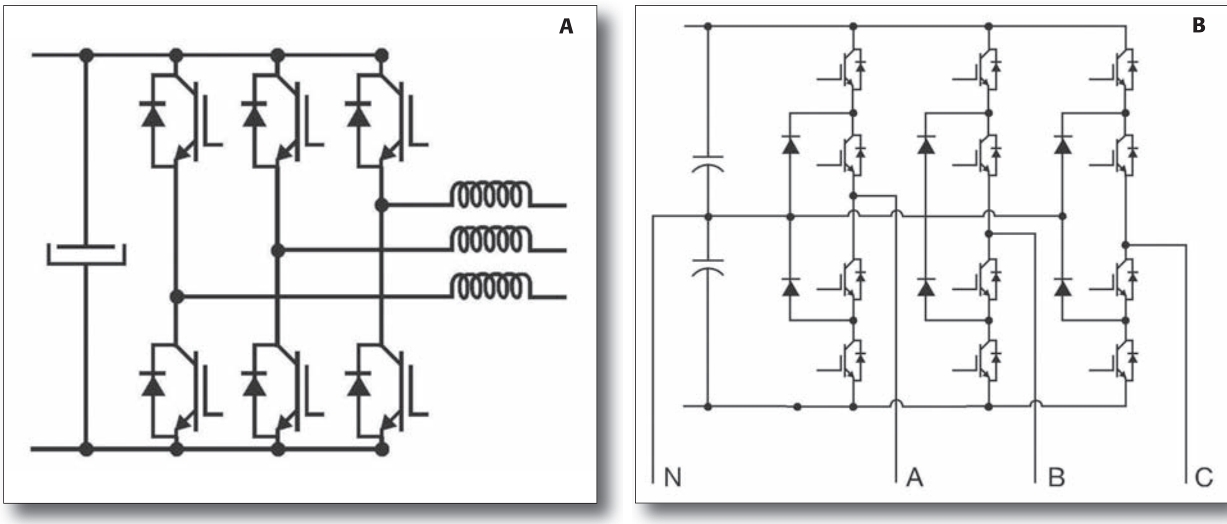


Figure 1: **The 2-level a) and 3-level inverters b) are similar in function to DC/AC converters, both systems can produce a variable frequency and voltage from a DC voltage**

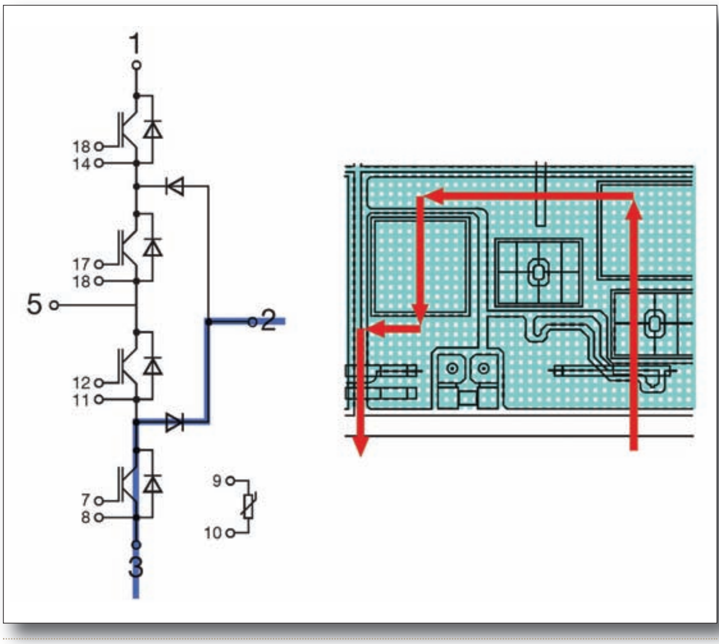


Figure 2: The internal chip arrangement is based on a clever DBC design and ensures that the commutation path has a very small stray inductance and that the outermost IGBTs are arranged symmetrically

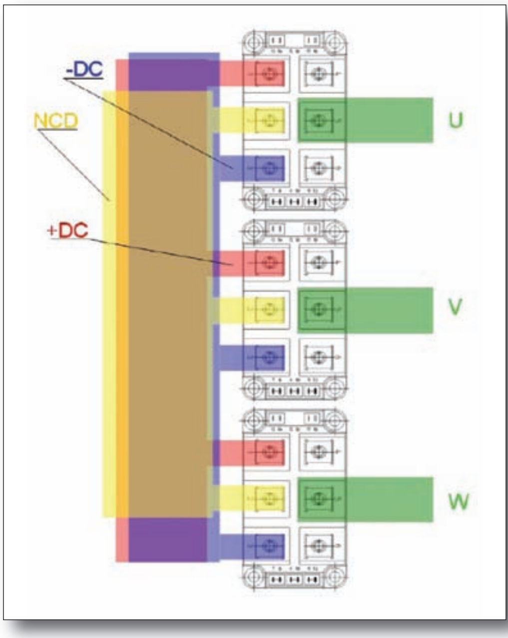
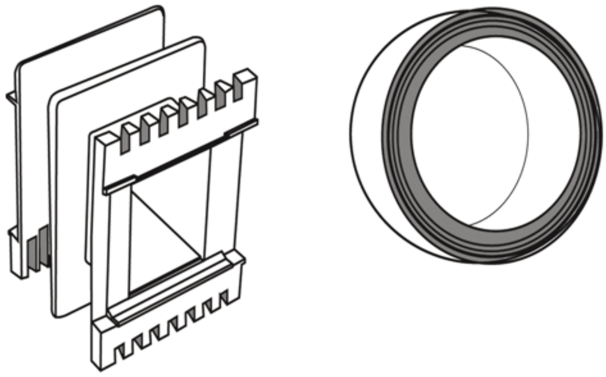
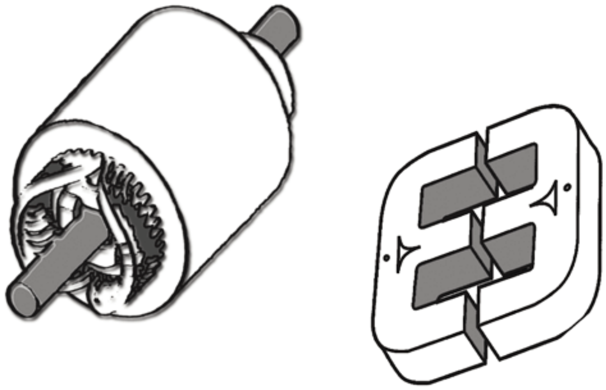


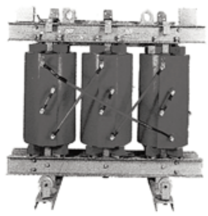
Figure 3: Layout of a 150KVA 3-level inverter. The 3-level modules feature 600V IGBTs (in future 650V) boasting low switching losses and low forward voltage drop

connected to the DC link circuit, while the long commutation path goes through three series connected IGBTs and the clamping diode. For this to happen, short current paths are needed and a symmetrical internal module layout. This is the only way of producing small switching over-voltages and using high DC link voltages to achieve a high efficiency factor.

The new 3-level IGBT modules are intended for use in compact, low-inductance 3-level inverters. When developing the new modules, our wealth of experience in the design of standard IGBT modules was drawn upon. The internal chip arrangement (Figure 2) which is based on a clever DBC design, ensures a very small stray inductance in the commutation path and comprises symmetrically positioned outermost IGBTs in







	3-level inverter		2-level inverter	
	SKM 150 MLI 066 T		SKM 400 GB 12 E4	
Conduction losses IGBT	Q1/Q4	88,1 W	Q1/Q2	61 W
Conduction losses IGBT	Q2/Q3	118,8 W	Q1/Q2	226 W
Switching losses IGBT	Q1/Q4	18,1 W		
Switching losses IGBT	Q2/Q3	negligible		
Total losses IGBT	Q1/Q4	106,2 W	Q1/Q2	288 W
Total losses IGBT	Q2/Q3	118,8 W		
IGBT: total losses per arm		**450 W**		**576 W**
Clamp diodes	D5/D6			
Conduction losses		56,6 W		31 W
Switching losses		13,6 W		89 W
Total losses per diode		70,2 W		120 W
Clamp diodes total losses		**140,4 W**		240 W
IGBT: total losses per arm		**590 W**		**816 W**
Total losses per inverter		**1770 W**		**2448 W**
Junction temperature IGBT		**111° C**		**132**
Junction temperature diode		**117°**		**128**

Table 1: Comparison of inverter losses clearly illustrates the benefits of the 3-level concept for switching frequencies over 10kHz

order to keep the commutation inductances symmetric.

A further advantage is the layout of the main terminals of the 3-level modules, which easily allow for low-inductance 3-level inverter designs (see Figure 3 - Layout of a 150KVA 3-level inverter) The 3-level modules feature 600V IGBTs (650V IGBTs are planned for the future), which are marked by their low switching losses and low forward voltage. A direct comparison of the IGBT data is given in Table 1. What can be seen here is that at higher switching frequencies, 600V IGBTs produce lower losses than 1200V or 1700V IGBTs. The gate resistance should be taken into account here, too.

Why are 3-level inverters so important?

The move towards higher switching frequencies results in reduced output filter requirements for solar power inverters or UPS converters, thus allowing for compact and inexpensive system designs. Smaller currents hand in hand with a higher DC link voltage reduce overall system losses. The more complex semiconductor requirements for 3-level architecture are compensated far by the lower requirements for chokes and filter capacitors. A cost comparison shows that integrating a phase into a module is a less costly solution than one featuring several modules.

Gate driving in the 3-level phase results in increased driver requirements (to drive 12 rather than 6 IGBTs), as well as reaction time requirements. Specifically, in 3-level inverters the chosen IGBT driver has to have a short reaction time to ensure high switching frequencies. Short dead times reduce non-linearities in the system and reduce the workload of the controller.

Protection concepts in the drivers are easy to achieve, as a direct bridge short circuit can never occur, as the top and bottom IGBT switch simultaneously. The drivers for the outer IGBTs should feature a monitoring function, while the inner IGBTs can be operated using simple IGBT drivers. What is very important here, however, is that the turn-on sequence of the IGBTs in a 3-level inverter has to be monitored, in order to ensure that the entire DC link voltage is not applied across one single IGBT. Discrete protection concepts are easy to achieve.

3-level inverters require more complex DC link monitoring than 2-level inverters, as the DC link circuit is actually split into two intermediate circuits. The high efficiency factor and the reduced filtering requirements achieved thanks to the high switching frequency force the design engineer to consider the 3-level concept.

A comparison of inverter losses clearly shows the benefits of the 3-level concept for switching frequencies over 10 kHz. (see also Table 1). Thanks to the low switching losses, IGBT junction temperatures are reduced.

In medium-output solar inverters (250KVA), a clear trend towards frequencies over 20kHz can be seen. Here, the use of 3-level topologies is the future, and many companies across the world, in particular Asia, are already developing 3-level solutions.

High switching frequencies also mean high switching speeds (du/dt), meaning that the harmonic distortion in the system has to be filtered using complex filtering technology. In a standard half-bridge circuit, a voltage of 800V can be switched in 100ns, which is equivalent to a switching speed of 8kV/µs. In the 3-level topology, a DC link voltage of 800V can be switched in half the time, as the individual IGBT only has half the voltage (400V) to switch. Less complex EMI filter designs can therefore be used.

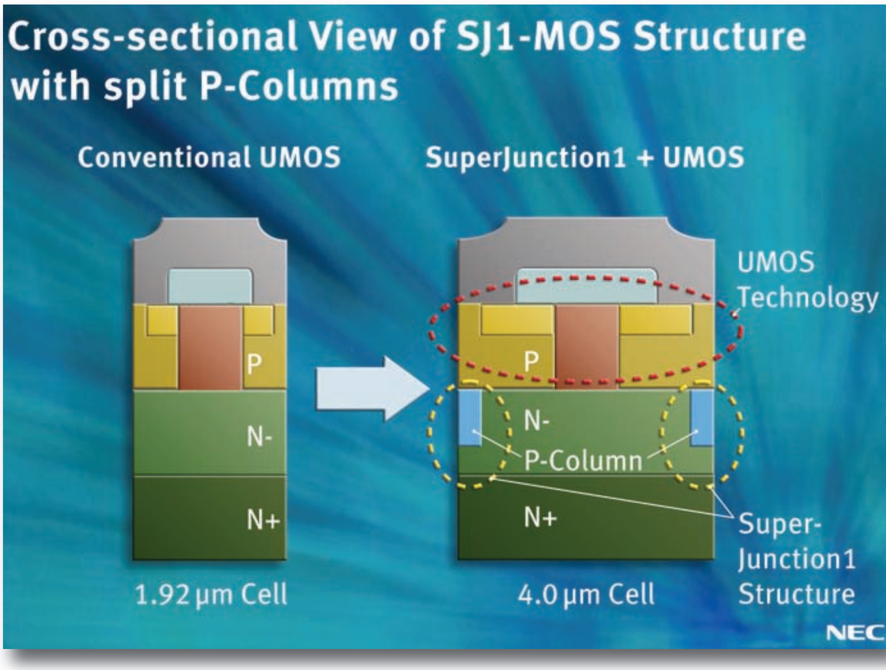
Conclusion

Thanks to the integration of a 3-level phase in a power module, SEMIKRON is now offering attractive solutions for the design of complex 3-level inverters. Driver concept scaling from 10KVA to 250kVA is possible, and the driver concept is ideal for both UPS systems and photovoltaic applications, where high efficiency and an inexpensive design are crucial.

SuperJunction Power MOSFETs for Automotive Applications

NEC Electronics Europe offers new low-voltage power MOSFETs with ultra-low on-state resistance and low gate charge. Compared with NECs' UMOS-4 trench technology, the SuperJunction1 technology reduces the gate charge and the input capacity by over 40% while maintaining the low on-resistance leading to 1.5 m_ and 2.3 m_ for the new NP180N04TUJ and NP180N055TUJ Power MOSFETs, respectively. Operating at 40V or 55V and 180 A, the new devices meet the demands of high performance applications such as electric power steering (EPS) or integrated starter generators (ISG) that require high current capability. Currently, eight devices are available with SuperJunction1 process technology, achieved by an ultra-fine design rule of 0.35µm. Four devices under development also feature a TO-263-7 pin package, which support high drain current rating up to 180A. Like all members of the NP Series, the new devices are qualified to AEC-Q101, support up to 175°C junction temperature and are lead free with tin-plated leads.

www.eu.necel.com



DC/DC Converters for 24V Industrial Applications

Murata Power Solutions has added a 3A output current surface mount series to its family of Okami(tm) non-isolated, DOSA compliant pinout, PoL DC/DC converters. The OKI-T/3-W40 series suited for use 24VDC input range applications that require a low voltage DC source for powering FPGAs and microprocessors. The 15W maximum output power OKI-T/3-W40 series has a wide input range of 16VDC to 40VDC and a programmable output voltage of 0.75VDC to 5.5VDC. The OKI-T/3-W40 series is able to drive up to 1000µF ceramic capacitors making it easy for users to keep ripple and noise under control. In addition to a wide voltage input range, the OKI-T/3-W40 series features on/off control, over-temperature, over-current, and under-voltage lock out protection. Overall dimensions of the new modules are 20.8mm x 11.9mm x 8.5mm high. Operating temperature range is -40°C to +85°C.

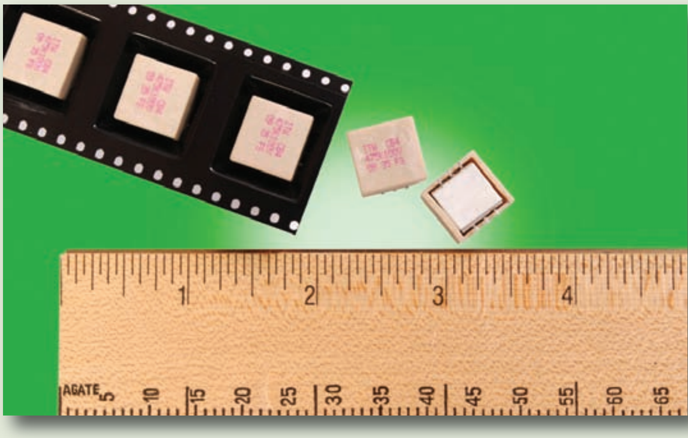
www.murata-ps.com/okami

Miniature Voltage/Current Threshold Detection Optocouplers

Avago Technologies offers two new miniature voltage/current threshold detection optocouplers for use in a wide range of industrial control applications. The ACPL-K370/K376 optocouplers are designed to detect AC/DC sources and convert the voltage to a logic interface across an optical coupling barrier to provide safe isolation in electronically noisy environments. These voltage/current sensing optocouplers are suited for applications such as limit switch sensors, low voltage detectors, relay contact monitors, relay coil voltage monitors, and current sensors. These devices are an upgrade from the HCPL-0370/3700/3760 optocoupler family, utilising threshold sensing input buffer ICs which permit control of threshold levels over a wide range of input voltages up to 1140Vpeak, with a single external resistor. Some of the key benefits provided by this new series include a smaller stretched SO-8 (SSO-8) package which meets 8mm clearance and creepage requirements, and requires 30% less board space compared to DIP-8 packages. Additionally, the input buffer of these optocouplers offer several key features to enhance threshold sensing such as hysteresis for extra noise and switching immunity, a diode bridge for easy use with AC input signals, and internal clamping diodes to protect the buffer and light emitting diode from a wide range of over-voltage and over-current transients. The ACPL-K376 is a low-current version of the ACPL-K370. To obtain lower current operation, the ACPL-K376 uses a high-efficiency AlGaAs LED which provides higher light output at lower drive currents.

www.avagotech.com

Thermally Shielded Capacitor



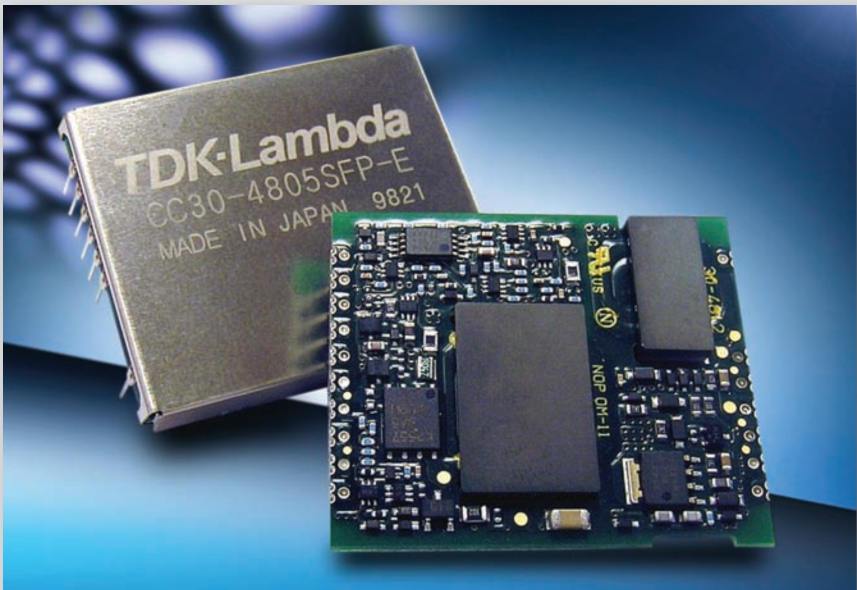
ITW Paktron has introduced a thermally shielded version of the standard Type CB4G capacitor, which is designed for lead-free surface mount assembly. The capacitor plate elements of the enhanced Type CB4G-FS version retain the same core construction, however, enhanced processing and improved packaging allows this thermally shielded version to handle the higher reflow soldering temperatures. The Type CB4G-FS product features ultra-low ESR and high ripple current capability in a small case size. Designed for high frequency filtering and EMI/RFI suppression in AC/DC or DC/DC power conversion applications, these capacitors provide improved stability, both electrically and mechanically, compared to large multilayer ceramics, in addition to offering "no-cracking" and "non-shorting" operation. Typical pricing for the 100-volt rating is in the range $2 to $5.

www.paktron.com

15/30W DC/DC Converters

TDK-Lambda has extended its CC-E range of DC/DC converters with the introduction of new 15W and 30W versions. Each CC-E power range comprises 32 models and is available in both SMT and through-hole packages with applications in factory automation systems, computers and communications devices. A low-loss ferrite core material ensures high efficiency of operation resulting in an extremely compact size with an ultra low profile. For instance, the 30W CC30-4805SHF-E model measures just 37.9mm x 31.6mm x 6.5mm, achieves an efficiency of 92.5%. Accepting a nominal input of either 24V or 48V, these DC/DC converters are available in the most popular output voltages from 3.3 to 15VDC. Operating temperature is from -40 to +85°C ambient with a choice of input to output isolation of 500VDC or 1500VDC. Representing an upgrade of the existing products, added functions include parallel operation, simultaneous start-up and start-up delay functions, as well as remote on/off and output trim feature. Standard protection features include low-voltage, over-voltage and over-current conditions.

http://uk.tdk-lambda.com/cc-e



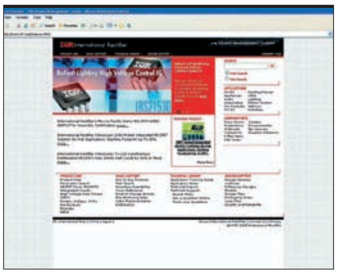
PWM Controllers for Light Load

Fairchild Semiconductors has developed a portfolio of PWM controllers, which enable notebook power-supply designers to meet the stringent international energy-saving regulations. These include the ENERGY STAR External Power Supply (EPS) version 2.0 requirement that mandates 87% average active-mode efficiency to obtain compliance.

To meet these requirements, Fairchild has developed integrated PWM controllers, like the FAN6754, which offers designers high-voltage start-up to improve energy savings at light load by 25%. It also eliminates external protection circuits by incorporating over-voltage, over-current and over-temperature protection plus brownout and line-compensation functions. Other advantages include frequency hopping, which reduces EMI emissions by as much as 5-10 dB, and internal soft start (8 ms) to reduce voltage stress on the MOSFET at start up.

www.fairchildsemi.com/ds/FA/FAN6754.pdf
www.fairchildsemi.com/cf/sales_con

AC/DC Connverters



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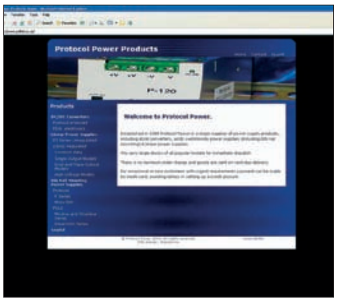

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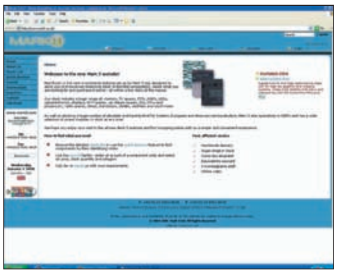

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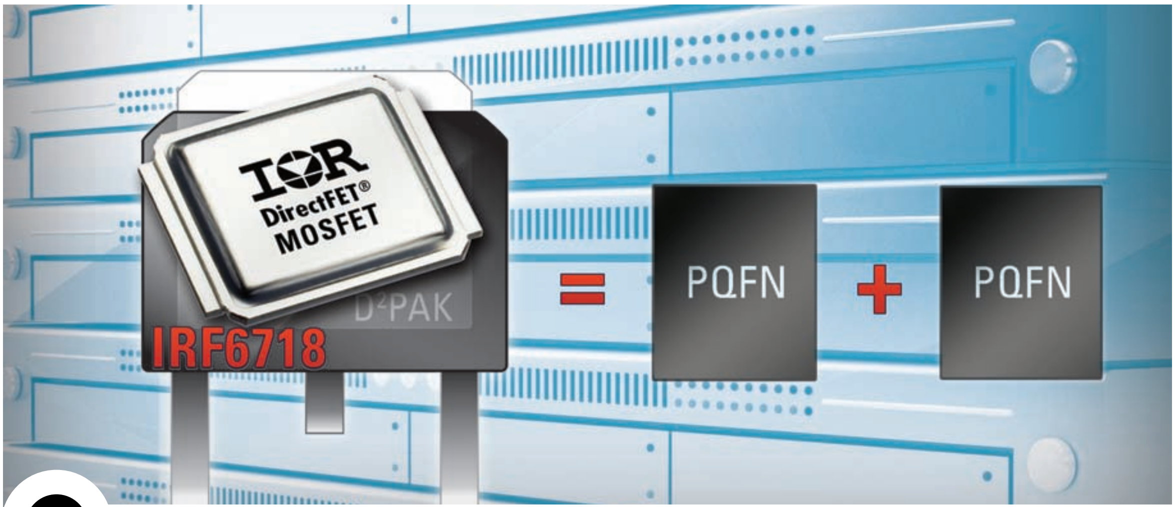

IR's IRF6718 Large Can DirectFET® MOSFET Delivers Industry's Lowest $R_{DS(ON)}$*

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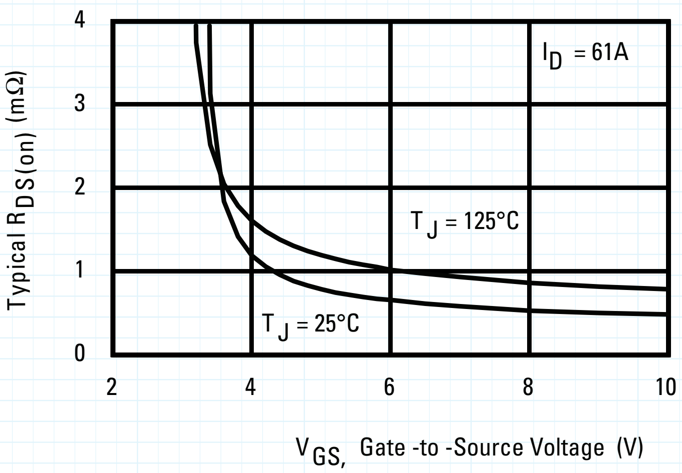
Optimized for Active ORing and Hot Swap Applications



The IRF6718L2 features IR's latest generation silicon technology in a new large can DirectFET® package delivering extremely low $R_{DS(on)}$ of only 0.5mOhm (typical) at 10V VGS in a 60% smaller footprint and 85% lower profile than a D²PAK. The IRF6718L2 significantly reduces conduction losses associated with the pass element in ORing or hot swap applications to dramatically improve the efficiency of the entire system.

FEATURES

- Industry Lowest $R_{DS(on)}$ for Reduced Conduction Losses
- Superior electrical and thermal performance in smaller footprint than D²Pak
- Dual-sided Cooling Compatible
- Reduces component count and board space compared to competing solutions
- Compatible with existing Surface Mount Techniques
- RoHS Compliant Containing no Lead or Bromide

Part Number	Package Size (mm x mm)	$R_{DS(on)}$ @10V typ. (mΩ)	I_D @ TA = 25°C (A)
IRF6718	7.1 x 9.1	0.5	270
Competitor 1	10.7 x 15.9	0.7	180
Competitor 2	5.1 x 6.1	0.95	60
Competitor 3	5.1 x 6.1	1.5	65

* Based on data compiled September 2009

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