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POWER GaN

On the Transition from Silicon to GaN-Based Drive Inverters

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Market News

PEE looks at the latest Market News and company developments

COVER STORY

On the Transition from Silicon to GaN-Based Drive Inverters

The recent announcement by several well established suppliers of the near term availability of 600 V rated GaN based devices to the power electronics market, has prompted significant interest in the nature of the resulting transition from Silicon to GaN based inverters for motor drives. Several inherent advantages of GaN based HEMTs, including one to two orders of magnitude reduction in reverse recovery charge, as well as significantly higher current handling capability and lower equivalent on resistance for a given device active area, have already been shown to reduce power losses in actual use conditions of applications such as appliances and electric vehicle drive trains by more than a factor of 2.

Perhaps the greatest potential innovation for power electronics using GaN based devices is in the field of integration. As GaN HEMTs are inherently integratable, as opposed to state of the art Silicon based power devices, a great revolution in performance, cost, reliability and novel functionality is now made possible. Despite these overwhelming advantages, the adoption rate for GaN based devices will naturally be determined by the design cycles of the power electronic system suppliers, which are typically two to four years. Of course, it is possible that compelling competitive advantages may drive more rapid design cycles as economic factors become more evident.

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Cover supplied by International Rectifier.

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Programmable Power Management for Small Networks

Modern electronic systems require a large number of rails for DSP, Core, RF PA, IO and Memory. A case in point is Smaller Communications Networks such as Small Cells, Picocells and Femtocells. **Alan Elbanhawy, Exar Corp., Fremont, USA**

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Powering Planet Earth

In today's society with a "greener and leaner" focus on one's lifestyle, most would agree that increasing energy efficiency is a good thing; in fact, the general consensus seems to be that reducing global energy usage is more than a personal choice, it has become a worldwide priority. While each region of the world is driven by differing needs and requirements, ultimately everyone benefits from increased energy efficiency. **Miguel Mendoza, Micrel, San Jose, USA**

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Product Update

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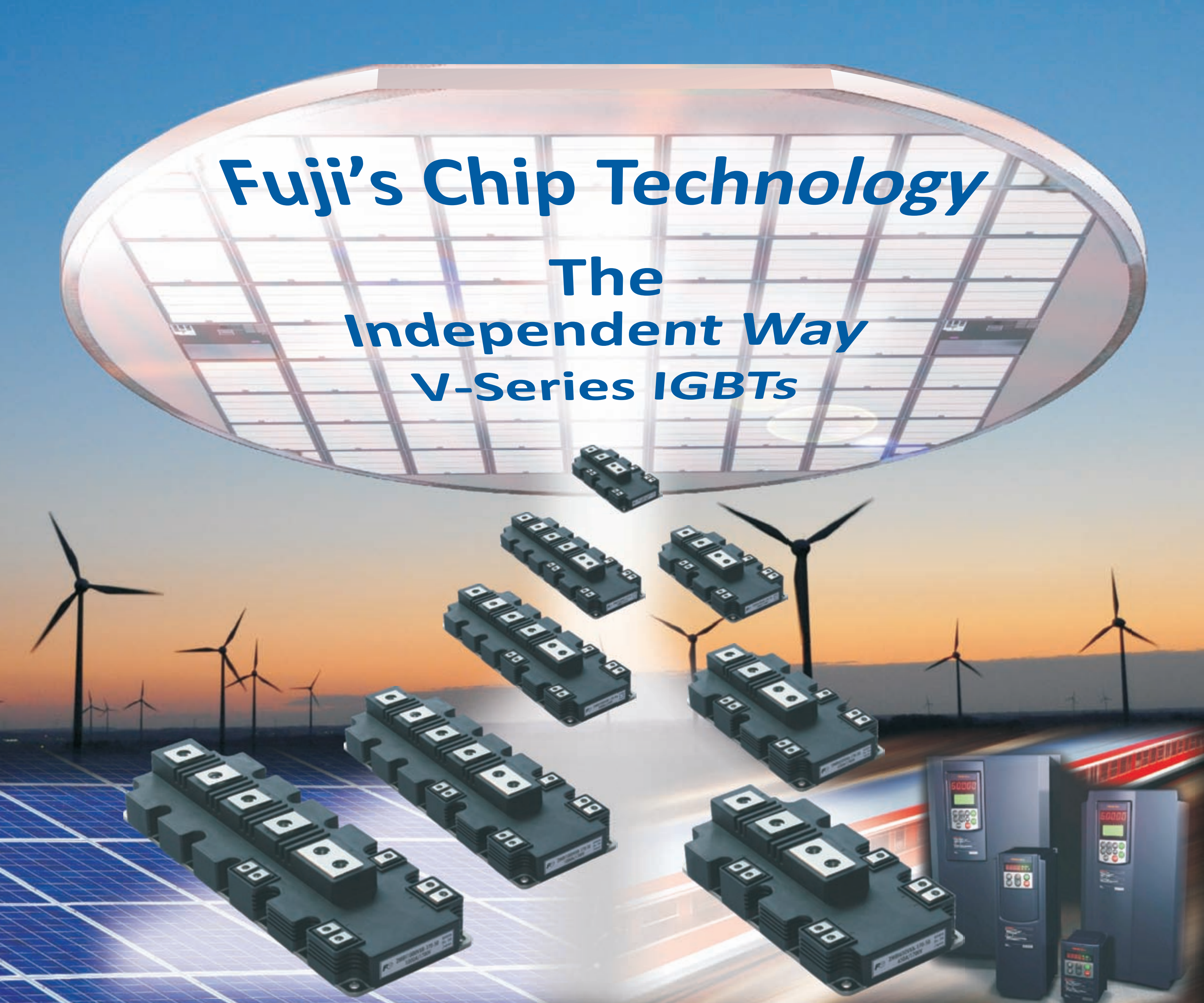
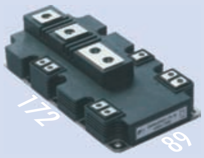


• Trench-FS IGBT • High thermal cycling capability • Low spike voltage & oscillation free • Excellent turn-on dI_C/dt control by R_G

High Power Modules, 2-Pack & Chopper

	I_C	1200 V	1700 V
2-Pack	1000A		E E+ P
	1400A	E P	E P
Chopper	1000A		E
	1400A	P	E
Chopper	1000A		E
	1400A	P	E



	I_C	1200 V	1700 V
2-Pack	600A	E	
	650A		E E+
	900A	E P	
Chopper	650A		E
Chopper	650A		E

E : E-type (low switching losses) E+ : E-type with large Free Wheeling Diode P : P-type (low $V_{CE,sat}$ & soft turn-off)

Fuji Electric
Innovating Energy Technology

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Moving from Power to Energy

With CIPS 2014 the power electronics season was opened in Europe, and not surprisingly Silicon Carbide and Gallium Nitride appeared in various dimensions. GaN will drive the future of power electronics, Johann Kolar said in his keynote. An example for that is a 3 x 3 matrix converter in 25 mm x 18 mm footprint fabricated by Panasonic. Emergence of new wide bandgap technologies such as SiC and GaN will definitely reshape part of the established power electronics industry, especially on the high and very high-voltage side, Yole Dèveloppement pointed out. Up to now, the incumbent packaging solution does not fit SiC/GaN specifications. In particular, Only a tiny part of the WBG added-value could be captured by using current approaches. Some companies offer a new enhanced package strategy that can help addressing the demand for improved performance, in line with SiC and GaN specifications. At midterm, these new power modules could create a $200 million market in 2016, exceeding $1 billion in the longer term.

GaN-on-Si based low-cost and high performance power switches entered the focus of several companies including PV inverter maker SMA, as they are predicted to be promising candidates to take over an increasing portion of the power electronics market, especially in 600 V class fast switching applications. However, numerous technical challenges still need to be addressed and solutions are needed to successfully manage the transition from sampling of early prototypes towards high volume products. Since prerequisite to successful market penetration is to achieve high performance combined with low cost, two key topics need to be addressed, namely fabrication cost and cost-per-die as well as performance of the switch. GaN in comparison to state-of-the-art Silicon have been analyzed during the German BMBF founded project 'NeuLand'. The determined 600V GaN High Electron Mobility Transistors were fabricated by MicroGaN in Germany and packed by Infineon. At SMA a 1.2 kW, 200 kHz PV boost converter has been developed reaching a peak efficiency of 99.2 % using a tremendously shrunken choke. The project was targeted until mid 2013 on the development of new highly efficient devices made from compound semiconductor materials and evaluation in application related tests. SMA's job in 'NeuLand' was the application-oriented test of the GaN devices, which included the steps investigation of slopes and package influence on switching and cooling, studies on drivers, normally-off and cascode operation, etc. Another relevant result came from the boost converter test, in which several WBG devices are compared to each other and to a fast Silicon reference. The state-of-the-art normally-off Silicon transistor (CoolMOS C7) was just 0.1 % behind the best in test device.

But the majority of the CIPS papers dealt with packaging. In power modules the weakest point is the soldered die attach. One alternative is silver sintering. A further alternative is diffusion soldering. Both diffusion soldering and silver sintering do not longer limit the power cycling capability. If one of these technologies are used, the lifetime is determined by the Al bond wires. Copper bond wires need a new die metallization with a thick copper layer as top layer. In combination with silver sintering or diffusion soldering this bonding will lead to increased lifetime by a factor of 30. Now the substrate was found to become the limiting factor. But here also some progress is visible.

According to our cover story the recent announcement by several well established suppliers, notably Panasonic and International Rectifier of the near term availability of 600 V rated GaN based devices to the power electronics market, has prompted significant interest in the nature of the resulting transition from Silicon to GaN based inverters for motor drives. Several inherent advantages of GaN based HEMTs, including one to two orders of magnitude reduction in reverse recovery charge, as well as significantly higher current handling capability and lower equivalent on resistance for a given device active area, have already been shown to reduce power losses in actual use conditions of applications such as appliances and electric vehicle drive trains by more than a factor of 2. The adoption rate for GaN based devices will naturally be determined by the design cycles of the power electronic system suppliers, which are typically two to four years. Of course, it is possible that compelling competitive advantages may drive more rapid design cycles as economic factors become more evident.

Wide bandgap technologies and digital power are the drivers of future power electronics, but industry also have to move from a component to a system approach – from power to energy – that is the way.

Have a look on the following pages!

Achim Scharf
PEE Editor

Maintaining the Power Balance in Europe

The challenge of finding a balance between affordable, clean and reliable electricity has become ever more acute for the European power sector in recent years. Only now, however, are the costs and strategic implications of meeting this challenge becoming apparent. Navigating the transition to a low carbon future for the power industry provides the pressing theme for energy professionals at POWER-GEN Europe 2014.

"Change is sweeping the European power industry as the integration of renewables gains pace. How Europe eventually navigates through these dramatic changes will fascinate power decision makers globally. The debate over whether renewables would form a significant part of the future power generation infrastructure has moved on considerably within the last two years: the question is no longer 'if' the transition will take place, but 'how' an industry traditionally comprised of large units of coal, gas or nuclear power generation running 24/7 as base load is going to adapt to accommodate it", Conference Director Nigel Blackaby notes.

Renewables and low carbon technologies are only going to increase as a proportion of the installed base, yet genuine integration of these onto European grids has been relatively slow and the practical implications of this industry transformation are becoming ever more evident. Moreover, many European nations are actually burning more coal now than they have been in recent years, due largely to the drop in coal prices relative to gas prices (the shale boom in the US leading to a flood of cheap coal on world markets) and also because the collapse of the EU's emissions trading scheme has enabled nations to rely more heavily on older, less clean and efficient coal plants still in operation. As such, Europe is struggling both on the delivery of its clean energy goal and the provision of affordable power. Although the debate surrounding the recent price hikes by large utilities in countries such as the UK and Germany is somewhat ill-informed and politicised, there is no doubt that consumers are feeling the pain and all indicators are that this may get worse before it gets any better.

The lights may not have gone out yet, but experts are predicting that within the next year or two, some European countries will see power cuts, brownouts or rolling blackouts because of aging infrastructure no longer being available to cover the intermittency of renewable power. The fact is that the European power industry has so far failed to put in place the necessary framework to support renewed investment in its aging infrastructure. Add in the perverse situation that modern, often relatively new gas fired power plants across Europe are being mothballed or closed down because they don't fit the current market model and it becomes very clear that the industry urgently needs renewed focus.

Nowhere has the scale and complexity of the challenge been more apparent than in Germany, where the politically driven 'Energiewende' (Energy Transition) has placed the delicate balancing act that Europe's power industry must perform at the heart of business and political discussion: on the one hand, consumers want clean and affordable energy, politicians want reliable supply, greater interconnection and a single market for electricity; on the other, the rise in renewables is placing the margins of established utilities under immense pressure, whilst replacing conventional power with intermittent sources that ultimately are less reliable and more costly for the electricity system as a whole.

Germany's mandated phase-out of nuclear power and boom in renewable energy has cut dependency on major utilities to the extent that some have seen the value of their balance sheet drop by half since 2008. This brings with it a significant impact on the ability of these established players to invest in the infrastructure required to support for example, the transmission of electricity to heavy load areas in the South of the country from the offshore wind turbines being constructed in the North.

To address this challenge, one of Germany's major utilities, RWE, is looking to adopt a new 'capital-light' approach under which it will partner with third parties to fund more expensive renewable projects. It has also outlined plans to expand in the retail market, in areas such as energy services and management. Meanwhile, Germany is also seeing the role of its municipal utilities – which are known as 'Stadtwerke' – grow in prominence as dependence on larger players declines.

Municipal utilities are majority state-owned, have more flexibility in that they offer combined heat and power, and in some cases water and steam, and their success is cited by those in Germany pushing for a renationalising of the power industry – a trend known as 're-municipalisation'. One other model being explored by municipals in partnership with technology providers is the creation of 'virtual power plants', in which a number of small-scale, distributed energy sources are pooled and operated as a single installation.

Certainly, utilities across Europe will need to reconfigure their business models in light of the role they will play moving forward. Their core expertise lies in constructing and operating plants, but they own assets across the value chain – i.e. power generation, transmission grid, and renewables. It will be vital for the industry to exploit this invaluable expertise and for the utilities to position themselves more as enablers of the system, rather than being centralised producers of power.

Decentralisation of the system is already apparent in Germany and other countries such as Scandinavia and Eastern Europe where municipal models are already established, but outside these markets, other solutions will be needed. One potential option is greater cross-border interconnectivity, but this too can be a mixed blessing. Poland's interconnection with Germany for example, has seen the influx of surplus German wind power place its domestic power plants under extreme pressure.

In ideal generating conditions renewables can lead to occasional oversupply, but since their delivery is intermittent, conventional power plants must back them up in order to guarantee supply and balance of the grid. Fossil-fired generation and traditional plants are large scale, operating at extremely high pressures and temperatures, and therefore cannot simply be fired up and down on demand. Much like a car, they cannot be taken on frequent short journeys without requiring shorter gaps between servicing. As this type of maintenance can take large plants off-grid, this has serious implications for both cost and security of supply. Up until recently, carbon capture and storage (CCS) technology was seen as a means of continuing with large amounts of fossil-fired power to support base load and at the same time de-carbonization. However, development of CCS technologies has not progressed as anticipated and has failed to materialize on any commercial scale.

The recession and economic slowdown across Europe has meant the political focus has been on financial markets, with energy pushed to the sidelines. But as the economy recovers and the banks become stronger, the power industry needs to ensure it doesn't become the next crisis. At a time when the market is in transition and flux, and with on-going conflict between European energy policies and those of individual member states, it is all the more important for power industry professionals to come together to devise strategies and solutions to keep the lights on and the industry pumping.

Combining POWER-GEN Europe and Renewables Energy World, POWER-GEN Europe 2014 conference and exhibition provides a unique forum to discuss how the conventional power sector is going to operate in markets where at times there is enough wind and solar generation to provide a large proportion, if not all of the supply. It will address strategic and operational questions in relation to the European power business across conventional, nuclear and renewable generation, and will feature the latest developments in storage and integration technologies such as Smart Grid.

Being held in Cologne in Germany on 3-5 June 2014, POWER-GEN Europe 2014 is the meeting place for power industry professionals from around the globe.

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The world's first digitally enhanced power analog controller

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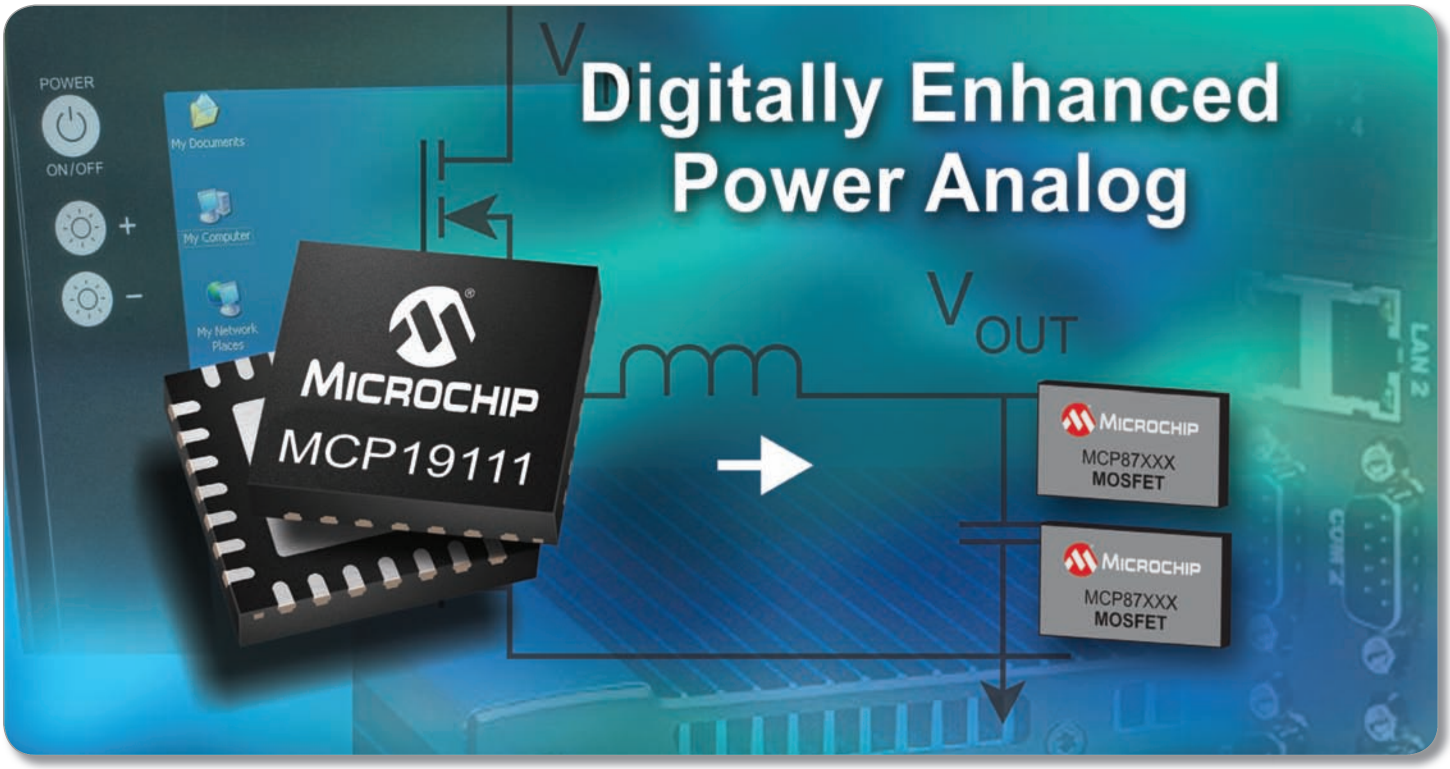

Combine the flexibility and I²C communication of digital DC/DC power conversion, with the speed, performance and resolution of analog-based control, by using Microchip's new MCP19111 power management controller.

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Albion Invests in Wind turbine in South Wales

Albion Community Power (ACP) has invested £1.5m in partnership with Welsh developer Infinite Renewables to fund the development of a 500 kW single wind turbine in Blaencilgoed, in South Wales.

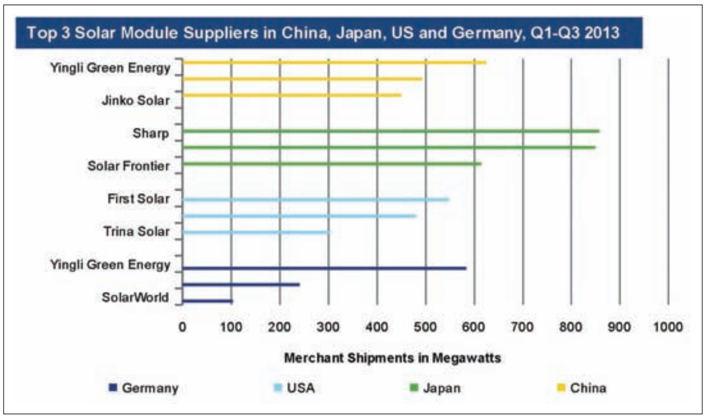
The wind turbine, which is the first investment made by ACP, will supply electricity to a local quarry. It is expected to produce its first power in September and is predicted to generate over 1,700,000 kWh of electricity per year. ACP aims to be a major producer of community scale renewable energy by raising up to £100 million in due course to power some 35,000 homes, targeting sites where power can be sold to the community at a discount of up to 50%. The ACP team will invest in a range of renewable energy projects using proven technologies including brownfield wind, solar, hydroelectricity, biogas and biomass.

World's Leading Solar Markets

China was the largest solar market in the world in 2013, besting a hotly contested field that included Japan, the United States and Germany, and Chinese manufacturer Yingli Green Energy was also the globe's foremost supplier of solar modules for the second year in a row.

In all, the four countries accounted for two-thirds of worldwide PV demand last year, according to IHS Technology. Chinese manufacturer Yingli, based in the northeastern province of Hebei near Beijing, was a dazzling, high-output producer in three of those four markets. Shipping more than 3 GW of solar modules last year, the Chinese maker expanded its share of the market to 8.3 %, up from 7.4 percent in 2012 when it was already the world's brightest solar player. Overall in 2013, Yingli was the No. 1 producer in both China and Germany, second in the USA, and ninth in Japan, as shown in the figure depicting shipments for the first three quarters of last year. "A strong footprint in each of the world's leading PV markets was the basis for the phenomenal growth behind Yingli," said Stefan de Haan, principal PV analyst at IHS.

In China, Yingli's solar module shipments amounted to 625 (MW) from the first to the third quarter in 2013, ahead of other Chinese-



In 2013 Chines Yingli was the No. 1 PV producer in both China and Germany, second in the USA, and ninth in Japan Source: IHS

based rivals like Trina Solar and Jinko Solar. Yingli was also the leader in Germany, long the world's top PV market but ranked fourth last year. Shipping an estimated 584 MW of solar modules, Yingli was more than double the size of closest competitor Trina. And although impacted in Germany by the antidumping trade conflict, Chinese solar suppliers continued to maintain significant activity in the German market, with five out of that country's Top 10 suppliers based out of China. Only two suppliers, SolarWorld and Conergy, were German. For the United States, the No. 3 PV market in the world, Yingli came in second after Arizona-based First Solar. The US PV market grew by more than 50 % in 2013, and Yingli's total shipments of 480 MW represented just 70 MW short of First Solar's delivery.

The only market where Yingli did not place within the Top 3 was Japan, the world's second-largest solar space, where it ranked ninth after homegrown producers like Sharp and Kyocera. Foreign suppliers do not have an easy time entering the Japanese solar space, even though entry barriers there are not as high as in China.

"Global PV was robust and will remain healthy in 2014. After turning around in the first half of 2013 from a decline in 2012, solar markets worldwide continued their recovery as last year came to a close. Driven by strong demand in Asia, global PV installations rose to 9.2 GW in the third quarter, up from 8.7 GW in the second", de Haan noted. As a result, global solar module shipments increased accordingly to 10.1 GW during the period, an all-time high as shipments exceeded 10 GW in a single quarter for the first time ever. Then in the fourth quarter global PV installations grew to 10.6 GW, and shipments rose as well to 10.3 GW. The global PV industry can expect further robust expansion this year, likely at double-digit levels. However, some growth momentum could be lost during the course of the year as the Chinese and Japan markets experience decelerating growth following an installation boom in 2013. "Such expected movements this year imply that the relatively healthy situation PV manufacturers experienced in the second half of 2013 will persist in 2014", de Haan observed.

www.ihs.com

Maximising Solar PV Portfolio Returns

The UK solar market has endured a rollercoaster ride as government incentive levels have fluctuated, driving large peaks and troughs in consumer and professional investor demand. However the UK solar industry is currently one of the most active markets in Europe, with over 1GW installed in the last 2 years. The near-term future looks promising, with the UK set to become the largest solar market in Europe for the first time during the first quarter of 2014.

The underlying trend has been one of steady growth and solar PV remains a core component of government policy in the UK Renewable Energy Roadmap. Solar PV currently accounts for 12% of renewable electricity capacity in the UK and 2.9% of renewable electricity generation with the majority being used in domestic applications. "Despite the well documented challenges that have been faced by the UK solar PV market, it remains an attractive investment opportunity. Portfolio owners have successfully driven improvements into the supply chain and operation and maintenance contracts have become more sophisticated in how they assure performance is maintained", said Ian Rose, Professional Services Director at PassivSystems.

With falling Feed in Tariff (FiT) rates, today's solar PV dealmakers (banks, investors, developers, social landlords etc) demand maximized yields from their solar investments. As they push for Lowest Levelised Cost of Energy (LCOE), investors are seeking new ways to guarantee their returns and increase on-going ROI.

Numerous academic studies have investigated the real performance of panels in the field. Typically these have tended to focus on the ability of the technology to deliver against forecast performance. PassivSystems decided to compare actual performance with the theory reported by these studies.

PassivSystems has now built up a portfolio of 16,000 monitored systems covering 42 portfolios of homes. These data sets go back to 2010, providing 30-minute interval generation data for the majority of homes, but with 1-minute interval data for homes that have been monitored over a broadband connection. We also have MCS and equipment data for all monitored installations.

PassivSystems used this rich data asset along with geographically aligned historical weather station irradiance data to analyse the performance of our portfolios against a range of different criteria. Performance is measured as the percentage over/under performance of the portfolio against the MCS anticipated yield.

In a recent study, PassivSystems performed an analysis of multiple portfolios, considering how the installation, maintenance and monitoring activities influenced the outturn. The results show that performance between portfolios varies by as much as 35%. On a system designed to generate £800 a year that is an efficiency range of £280 per annum.

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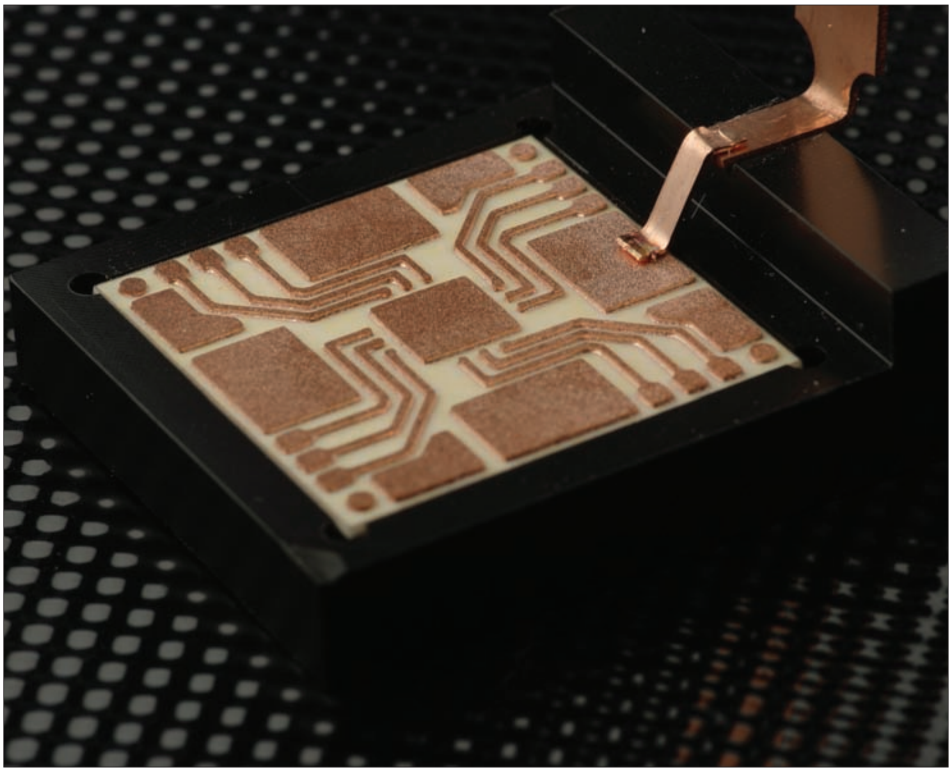
On the Way to Planar Power Modules

In power electronics systems bonded connections create the central electrical connections between adjoining surfaces. The quality of these bonded connections is one of the main factors that determines the reliability and availability of drive systems in electric vehicles, and hence constitutes a major design challenge for auto manufacturers aiming to electrify their vehicles.

Now the partners participating in the RoBE (Robust Bonds in Electric Vehicles) collaborative research project have developed a reliable means of predicting the service life of these bonded connections, and also developed an alternative bonding technique based on laser micro welding that is ready for industrial implementation.

This technique opens up a wider range of options for the use of wire bonding, especially in applications requiring the joining of copper. Here, modern laser sources with a very high beam quality ensure precise, reproducible weld joints in copper and aluminum. Through the additional use of oscillation welding in combination with adapted design of the wire and ribbon joining zones, the strength of the joint can be improved still further. By comparison with conventional wire bonding, this process offers a higher surface quality and requires less cleaning. Moreover, the process is less dependent on the nature of the underlying surface or the vibration characteristics of the workpiece.

A standard bonding machine was adapted to allow the laser bonding process to be combined with traditional bonding technologies. The new machine now allows the use of a laser in the bonding process. The main applications of this system include ribbon bonding on DCB substrates and copper terminals in the packaging of power electronics assemblies.



Bonding technique based on laser micro welding

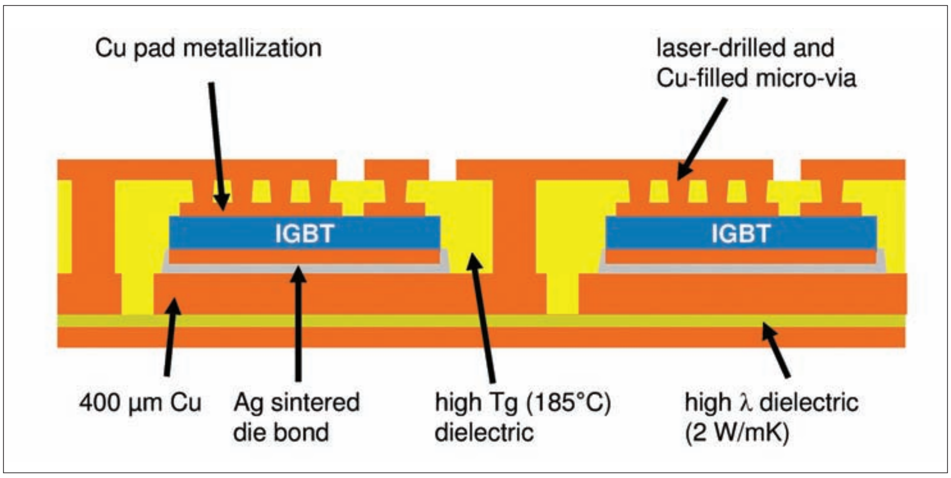
Getting rid of bonding

The demand for reliable and affordable Electric Vehicles requests new materials and packaging solutions. The German HI-LEVEL research activities face these challenges for Power Modules. Partners are RWTH Aachen (system design), Heraeus (materials), Schweizer Electronic (process technology), Infineon (components), Continental (product) and Daimler (end user).

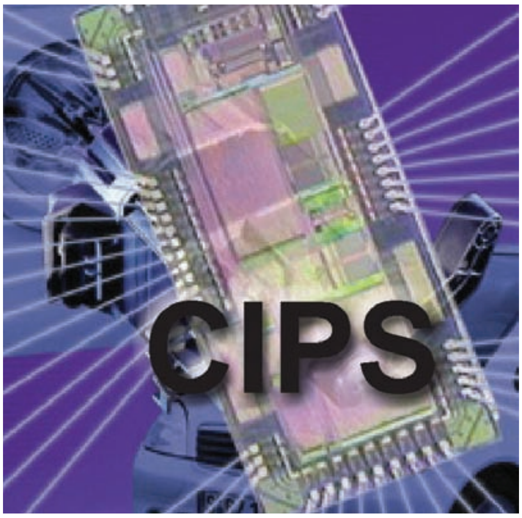
The project HI-LEVEL, is running from September 2011 – August 2014 with the aim to develop planar power modules for 50 kW motor inverters. With height down to 10 mm, with cost efficient production without expensive packaging, incorporating the integration of control electronics and with the capability of double sided cooling. Topics of current investigations include low-pressure sintering on large panels, application of 5 µm Cu bumps on thin IGBT wafers, and high voltage isolation of thermally conductive dielectric.

The embedding of power components offers new opportunities in terms of integration, cost and electromagnetic performance. It relies on existing manufacturing processes and can even be combined with ceramic substrates for high-power applications. It is an emerging technology where not all questions have been answered thus far, such as reliability and lifetime for higher power, and thermally conducting safety isolation. But embedding technology offers one large-area manufacturing technology for many different types of power applications.

http://www.ilt.fraunhofer.de, http://projekt-hilevel.de/



HI-LEVEL packaging construction



Packaging of SiC and GaN

The 8th Conference on Integrated Power Systems (CIPS 2014) from February 25 – 27 in Nuremberg attracted 282 delegates (2012: 235) and featured 102 regular papers and 29 posters. The conference focused on wide bandgap devices, applications and packaging, a main challenge for squeezing out the potential of Gallium Nitride (GaN) and Silicon Carbide (SiC) in terms of switching frequencies and operating temperatures.

The role of power electronics in our society sketched Johann W. Kolar from ETH Zurich in his keynote 'What are the big Challenges in PE'.

According to Kolar power density is approaching 3 kW / l, in solar inverters losses have been cut by 50 % every five years and efficiency is rising up to 99 % and beyond. Also cost reduction of 50 % have been observed over the last ten years. In Silicon Superjunction MOSFETs (CoolMOS) have made a disruptive change, on-resistance has been decreased significantly also in other MOSFET technologies and IGBTs. GaN will drive the future of power electronics, Kolar is confident. An examples for that is a 3 x 3 matrix converter in 25 mm x 18 mm footprint. GaN will move towards 600 V breakdown voltage, SiC will be located above this level.

"Moore's law is also valid in power electronics with upcoming GaN/SiC technologies, but here the challenge is still in low-inductive and high-temperature packaging in order to realize the benefits of these materials", Kolar stated. Examples how to solve this are the works of Berlin-based Fraunhofer IZM (see PEE June 2013, pages 13-16) or Semikron's SKiN packaging technology. Planar power chip packaging in printed circuit boards could be a solution for this challenges in high-speed switching GaN/SiC applications. Also US president Obama has realized the potential of packaging, as Kolar demonstrated in a video clip within his keynote (laughter in audience). Main challenges for modules are electrically quiet packages and integrated gate drivers. "Wide bandgap technologies and digital power are the drivers of future power electronics, but we also have to move from a component to a system approach – from power to energy – that is the way", Kolar concluded.

Packaging and reliability

Prof. Josef Lutz from Chemnitz University detailled in his invited paper 'Packaging and Reliability of Power Modules' the above mentioned aspects.

After a general introduction on the problems of bond wires (lift-off) and solder layers (solder fatigue) including power cycling tests which are discussed for decades he introduced some new developments.

In power modules the weakest point is soldered die attach. One alternative is silver sintering. The quality of a silver sinter layer depends on its porosity, which depends on process parameters pressure (typ. 30 MPa), temperature (around 230°C) and process time. One can get very stable layers. However, the reliability is not unlimited. After 2,000 cycles from -55 to 150°C, perimeter fracturing reached 11 % to 21 %. This is far above the temperature cycling capability of usual Sn-Ag solder layers. A further alternative is diffusion soldering. Intermetallic compounds Cu3Sn and CU6Sn5 have much higher melting points and higher mechanical strengths than the Sn-based soft solder base materials. Both diffusion soldering and silver sintering do not longer limit the power cycling capability. If one of these technologies are used, the lifetime is determined by the bond wires. Thus the bond wire limit is found if the die attach is improved.

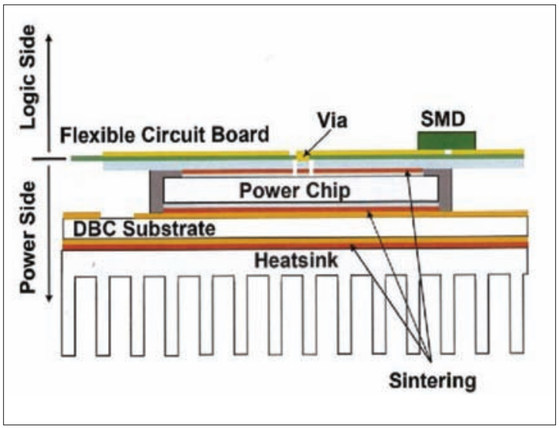
Power module manufacturers have spent more than 20 years of work in improving the ultrasonic Al bond wire process. Usually the process is part of the protected technology and not published. Nevertheless, Al bond wires come to a limit. Copper (Cu) bond wires need a new die metallization with a thick Cu layer as top layer. Cu bond wires in combination with silver sintering or diffusion soldering (Infineon's .XT technology) lead to increased lifetime by a factor of 30. This is a strong progress. Both interconnections are hard to destroy. A possible alternative to Cu wires are Al-coated Cu wires. The Cu core of 230-250 µm diameter is coated with an Al layer of 25-35 µm. An improvement by a factor of four and more was found, depending on the used Cu characteristic (hard or soft) and on the conditions.

With the SKiN technology bond wires are replaced by a flexible PCB whose bottom is connected to the topside Chip metallization. All interconnections are executed with silver sintering. Additional, the weak point thermal grease layer is eliminated by sintering the module on the base plate. All weak points are addressed, and the system reaches an extremely huge power cycling capability.

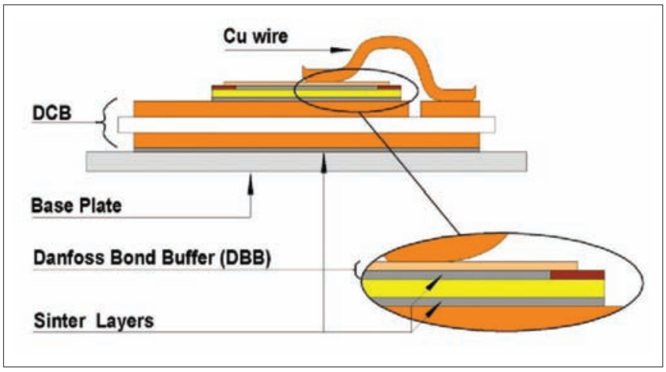
The bond buffer technology, invented by Danfoss Silicon Power, applies a thin Cu plate (bond buffer) attached on the topside of the die with silver sintering. This layer absorbs the high mechanical load during Cu wire bonding and prevents the die from damage. The technology leads to a homogeneous current distribution across the die. The interconnections from die to substrate and from substrate to base plate are executed with silver sintering. The technology promises also a very high lifetime.

Now the substrate was found to become the

Johann W. Kolar referred in his CIPS keynote on Barack Obama who talked about packaging in a video clip Photo: AS



LEFT: With Semikron's SkiN-technology all interconnections are done by silver sintering



ABOVE: Danfoss' bond buffer interconnect technology

limiting factor. But here also some progress is visible. The 0.32 mm thin HPS substrate introduced by Curamik consists of Al203 with 9 % Zr02. It offers a higher tensile strength compared to Al203 and AlN. However, the highest tensile strength is achieved with Si3N4. A special coated material is presented which allows a direct Cu-bonding (DCB) process. The progress to other substrates is more than a factor of 10. For Si3N4 active metal brazing (AMB) substrates no failures occurred up to 5000 cycles, were the test was stopped.

Thus the power cycling capability shows potential for use of power modules with maximum junction temperature of 200°C. This can strongly increase the power density and enables to use the higher temperature capability of wide-bandgap semiconductor materials up to some extent.

Power GaN semiconductors for PV inverters

Experiences gained with SiC and GaN in PV inverter applications have been presented by SMA Technology.

GaN in comparison to state-of-the-art Silicon have been analyzed during the German BMBF founded project 'NeuLand'. The determined 600V GaN High Electron Mobility Transistors (HEMTs) were fabricated by MicroGaN and packed by Infineon. At SMA a 1.2 kW, 200 kHz PV boost converter has been developed reaching a peak efficiency of 99.2 % using a tremendously shrunken choke. The project was targeted until mid 2013 on the development of new highly efficient devices made from compound semiconductor materials and evaluation in application related tests. Members were Aixtron SE, Azzurro Semiconductors AG, SiCrystal AG, MicroGaN GmbH, Infineon Technologies AG as project leader and SMA Solar Technology AG. MicroGaN and Infineon provided GaN, SiC and Si transistors as well as SiC diodes. Another partner allocated GaN engineering samples. SMA has found out, that the switching behavior of SiC and GaN devices is quite similar. Due to the expected lower price of GaN-on-Si compared to SiC devices the GaN HEMT is able to gain appreciable market shares, which has to be proven in future.

SMA's job in 'NeuLand' was the application-oriented test of the GaN devices, which included the steps investigation of slopes and package influence on switching and cooling, studies on drivers, normally-off and cascode operation, etc.

Another relevant result came from the boost converter test, in which several WBG devices are compared to each other and to a fast Silicon reference. The state-of-the-art normally-off Silicon transistor (Infineon C7) was just 0.1 % behind the best in test device.

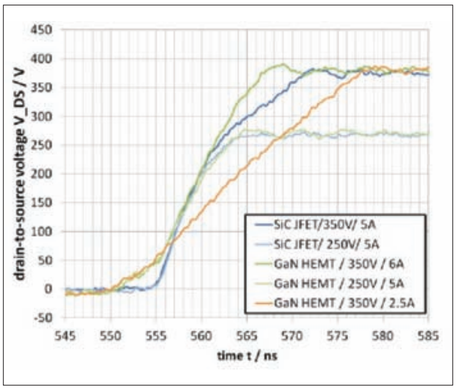
Besides the used transistor the choke design has a likewise big effect on the loses. Thus the efficiency of the converter was reduced by 0.1 % when a choke optimized for 100 kHz was used instead the 200 kHz choke.

To operate GaN devices in solar inverters (just as inverters for electric vehicles), that are deployed outdoors, in most climate zones and from sea level to high mountain ranges, a lot of qualification work has to be done. The short drift region length, which is the quintessence of WBG devices, leads to higher field strength and thus to much higher stress for the semiconductor device. The inhomogeneous field distribution in GaN devices with their lateral structure could exacerbate this adverse the vertical configuration of SiC and Si devices. "But it is possible to cut system costs by using reasonable priced GaN or SiC devices, even if a lot of attention on package, layout, cooling, etc. is required. It is expected that GaN-on-Si technology will help to reach a suitable and competitive pricing within the next few years", SMA's Thorsten Stubbe pointed out.

Market trends in WBG power modules

"Emergence of new wide bandgap technologies such as SiC and GaN will definitely reshape part of the established power electronics industry, especially on the high and very high-voltage side", Philippe Roussel from Yole Dèveloppement pointed out. "Up to now, the incumbent packaging solution does not fit SiC/GaN specifications. In particular, Only a tiny part of the WBG added-value could be captured by using current approaches. Some companies offer a new enhanced package strategy that can help addressing the demand for improved performance, in line with SiC and GaN specifications At midterm, these new power modules could create a $200 million market in 2016, exceeding $1 billion in the longer term".

According to Yole PV inverters have proven their desire for SiC devices in 2012. They are the biggest consumer of SiC devices together with PFCs. SiC device (bare-dies or packaged discretes) market reached about $75 million in 2012, dominated by Infineon and CREE. However the competition is gradually taking market share with STMicro and Rohm leading the way. All together, SiC and GaN devices and modules market is expected to top $1.4 billion by 2020. There are now more than 50 companies worldwide which have established a dedicated SiC or GaN device manufacturing capability with related commercial and promotional



Turn-off transients of SiC JFET and GaN HEMT according to SMA's evaluation

activities. Virtually, all other existing Silicon-based power device makers are also more or less active in the SiC or GaN market at different stages. "We now sec the WBG industry reshaping, especially SiC, starting from a discrete device business and now evolving into a power module business. Originally, this was initiated by Powerex, Microsemi, Vincotech or GeneSiC with hybrid Si/SiC products, then other players such as Mitsubishi, GPE and more recently Rohm have reached the market with full SiC modules", Roussel underlined. **AS**

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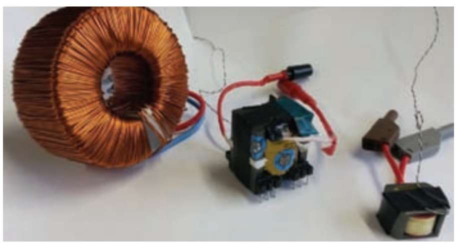

Choke dimensions for SMA's 2 kW boost converter and different switching frequencies of 16 kHz (left), 100 kHz and 200 kHz (right)

Focus on Power SiC and GaN

APEC 2014 offers a comprehensive program including the Plenary and Rap Sessions, Industry and Dialog Sessions and last but not least the Technical Sessions. The latter will cover 35 sessions up to ten papers each, the majority is coming from the academia dealing with novel power semiconductor devices and technologies.

The **DC-DC Converter Applications** Session covers nine papers. One of the papers featuring novel power semiconductors "A Hybrid Resonant Converter Utilizing a Bidirectional GaN AC Switch for High-Efficiency PV Applications" will be presented by the Virginia Polytechnic Institute and State University. This paper introduces a novel isolated hybrid resonant converter with smooth transition between multiple operating modes to obtain high efficiency over a wide input-voltage and output-power operating range. The proposed converter achieves high efficiency through low circulating losses, ZVS and near ZCS of the primary-side switching devices, and ZCS of the output diodes regardless of input voltage and output power. Closed-loop input-voltage controllers are designed for the different operating modes and a smooth transition between operating modes is achieved using a two-carrier modulation scheme. Experimental results verify the proposed system using a 300 W prototype that achieved 97.5 % CEC efficiency at 30 V input including all auxiliary and control losses.

The **Single-Phase AC-DC Converters** Session also features nine papers, notable is the Ohio State University's contribution "A GaN Transistor Based 90W AC/DC Adapter with a Buck-PFC Stage and an Isolated Quasi-Switched-Capacitor DC/DC Stage". This paper presents a GaN Transistor based 90 W AC/DC adapter with a Buck-PFC stage and an isolated Quasi-Switched-Capacitor DC/DC stage. In the DC/DC stage, two different QSC converters are proposed. Compared to Flyback and LLC resonant converters, the QSC converters feature: 1) reduced voltage stress on the primary-side switches to 2/3 of the input voltage; 2) reduced voltage stress on the transformer to 1/3 of the input voltage and a lower transformer turns ratio; 3) a wide range for soft-switching operation and high efficiency; 4) a simple control strategy. The operation principles and simulation results are presented. A 90 W, 85 V/19 V, 1 MHz QSC resonant converter is built, using 100 V EPC eGaN FETs for all switches. This prototype achieves: 1) a high power density of 10.5 W/cm^3; 2) wide-range soft switching and a peak efficiency of 92.8 % at 900 kHz in preliminary test results. A Buck-PFC evaluation module from TI is tested with a GaN HEMT and a SiC Schottky diode. The peak efficiency reached 97.1 %, and the experimental results are compared with those from the Si based version.

Within the **High Speed Devices & Gate Drives** Session (nine papers) the University of Tennessee presents an "Investigation of 600 V GaN HEMTs for High Efficiency and High Temperature Applications". This paper investigates the fast switching characteristics and high temperature performance of the 600 V GaN HEMT for high efficiency applications. First, the inherent switching performance of the GaN HEMT is demonstrated in the double pulse test. The GaN HEMT exhibits superior switching capability, with a di/dt reaching 9.6 A/ns and dv/dt reaching 140 V/ns. Then, the limitations of the fast switching capability by the device packaging and application circuit are analyzed. The inference between the current and gate thorough common source inductance limits the inherent switching speed. Packaging and circuit layout with small parasitics is critical in achieving fast switching. Finally, the high temperature static and switching characteristics up to 200°C are also tested and given. The switching performance of the device is independent of temperatures.

The Nanjing Aeronautics and Astronautics University presents "A High Efficiency Inverter Based on SiC MOSFET Without Externally Anti-Paralleled Diodes". This paper analyzes a highly efficient SiC MOSFET based inverter without externally antiparalleled diodes. Steady-state performances of MOSFET channel and its body diode are demonstrated; proper control and modulation technique is applied to realize synchronous rectification of the inverter and to minimize the conduction loss of body diodes. Power loss analysis of the inverter under various junction temperatures is performed. Calculated results show it is unnecessary to antiparallel external diodes for the less than 0.15 % efficiency improvement since external diodes will inevitably increase the system volume and harm the power density. At last, a 10 kW SiC MOSFET based prototype is built. A full load efficiency greater than 98 % is achieved. Experimental results show that the three-phase inverter exhibits high efficiency under various working conditions even without antiparalleled diodes. By removing the external diodes, system volume and cost of the inverter can be reduced and power density improved. This paper shows the possibility of utilizing body diodes and provides references for trade-off making between power efficiency and power density of the inverter.

The Virginia Polytechnic Institute and State University presents an "Evaluation of High-Voltage Cascode GaN HEMT in Different Packages" which evaluates high-voltage cascode GaN HEMTs in different packages. The GaN HEMT in traditional package has high turn-on loss in hard-switching turn-on condition, and severe parasitic ringing in hard-switching turn-off condition, due to package related parasitics. To solve this problem a stack-die package is introduced, which is able to eliminate all the critical common-source inductances in traditional package, avoiding side effects caused by the package, and thus could be more suitable for MHz high frequency operation. A prototype of this stack-die package is fabricated in the lab, experimental results are shown to verify the analysis and to demonstrate the strength of the stack-die package.

Fujitsu Laboratories will analyze "Dynamic Performances of GaN-HEMT on Si in Cascode Configuration". This paper describes dynamic characteristics and power loss analysis of a high-voltage GaN-HEMT in cascode. The GaN-HEMT is "normally-on" and fabricated on 6-inch Si substrate using a Si mass-production line. Simple switching characteristics with resistive load and power efficiency measurements with a power factor correction (PFC) circuit driven from 100

kHz to 800 kHz were performed for the evaluation. The switching times are about 4 times faster than those of conventional Si-MOSFET. An analytical method of power losses including temperature dependence of component parameters is also demonstrated.

In Session **Multilevel Converter Modulation & Control Strategy** Aalborg University shows how a "Reduction of DC-Link Capacitor in Case of Cascade Multilevel Converters by Means of Reactive Power Control" will be possible. A new method to selectively control the amount of DC-link voltage ripple by processing the desired reactive power by a DC/DC converter in an isolated AC/DC or AC/DC/AC system is proposed. The concept can reduce the DC-link capacitors used for balancing the input and output power and thereby limiting the voltage ripple. It allows the use of a smaller DC-link capacitor and hence a longer lifetime and at the same time high power density and low cost can be achieved. The isolated DC/DC converter is controlled to process the desired reactive power in addition to the active power. The control system to achieve this selective degree of compensation is proposed and verified by simulations.

Marquette University/General Motors will present in Session **Multilevel Inverters** "Loss Balancing SVPWM for Active NPC Converters". This paper presents a novel loss balancing modulation method for more evenly distributing semiconductor losses in multilevel active neutral-point-clamped (ANPC) converters. The presented method is achieved by optimally utilizing the redundant switching states of space vector pulse width modulation (SVPWM) in ANPC converters. A comparison of the effect of losses distribution between the proposed loss balancing SVPWM (LB-SVPWM) method and the conventional phase-shifted PWM (PS-PWM) methods is carried out in simulation. The effectiveness of the presented LB-SVPWM method is also verified in ANPC converters based on all-SiC MOSFETs. The results show that the proposed method can distribute the device losses more evenly, especially for all-SiC based ANPC converters, which can in turn improve the output power capacity and switching frequency. In addition, with utilization of the introduced loss balancing SVPWM method in ANPC converters, 15 % higher output voltage and lower harmonic distortion can be achieved compared to PS-PWM modulated ANPC converters.

Within the **Utility Interface Converters** Session Aalborg University will present "Loss Comparison of Different Nine-Switch and Twelve-Switch Energy Conversion Systems". Nine-switch converter is a recently proposed reduced-switch equivalence of the twelve-switch back-to-back converter. The usual expectation is thus for the nine-switch converter to face some switching constraints and hence performance trade-offs. However, this might not always be the case with an answer only available after performing a thorough analysis. For that, it is the intention now to compare the nine-switch and twelve-switch converters when they are used in AC/AC, AC/DC, DC/AC or DC/DC energy conversion systems. Their losses will be compared to identify when the nine-switch converter will have an advantage or face only a slight constraint, which can hence better justify its usage to save switches. Simulation results are presented, while experimental loss measurements are presently ongoing.

The University of Tennessee introduces in **Renewable Energy System Integration** Session "An Active Damping Method Based on Biquad Digital Filter for Parallel Grid-Interfacing Inverters with LCL Filters". In this paper, the resonance phenomenon involved by the multiple LCL-filtered interfacing inverters in a distributed renewable energy system is studied. The frequency domain characteristics of the parallel LCL-filtered inverters are presented. It is shown that additional resonance peak appears compared to the single inverter system, which further challenges the system stability. In order to facilitate efficient damping of the above multiple resonance peaks, the biquad filter based active damping method is proposed. The biquad filter based active damping method does not require additional sensors and control loops. Meanwhile, the multiple instable closed-loop poles of the parallel inverter system can be moved to the stable region simultaneously. Real-time simulation based on dSPACE 1103 and the preliminary experimental test based on 2?2.2 kW prototype are performed to validate the proposed

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damping approaches. Further experimental results will be shown in the final paper.

Texas Instruments and Virginia Polytechnic Institute and State University will introduce in session **Non-isolated DC-DC Converters** an "Adaptive Ripple-Based Constant on-Time Control with Internal Ramp Compensations for Buck Converters". This paper presents an adaptive ripple-based constant on-time control architecture for buck converter ICs with wide applications. An internal ramp compensation with emulating inductor current ripple is implemented to solve the ripple oscillation instability issue when using low-ESR output capacitors in buck converters. However, in order to guarantee the stability margin and the jitter performance for wide duty-ratio applications with different switching frequencies, a large internal ramp is normally applied, but it may not be optimal for all different applications. Hence, the internal ramp must be carefully designed to guarantee the stability margin while maintaining fast load transients and adequate phase margins for wide duty-ratio applications. In this paper, an adaptive ripple tuning algorithm is proposed to fine tune the internal ramp compensation automatically based on the duty ratio, output voltage, and the switching frequency.

Session **Wide Bandgap Devices in DC-DC Converters** focuses on the application of GaN/SiC devices.

Efficient Power Conversion Corporation will present an "Evaluation of Gallium Nitride Transistors in High Frequency Resonant and Soft-Switching DC-DC Converters". The emergence of GaN power devices offers the potential to achieve performance not possible with Si power MOSFETs. This paper will demonstrate the ability of GaN to improve performance in resonant and soft-switching applications. A figure of merit is proposed to compare the critical device parameters between GaN and Si technologies that influence the in-circuit performance of resonant and soft-switching applications. The benefits of GaN transistors are experimentally verified in high frequency 48 V to 12 V resonant bus converter prototypes with Si and GaN power devices operating at 1.2 MHz and output power up to 400 W.

The University of Texas at Dallas introduces "A 130 W 95 %-Efficiency 1 MHz Non-Isolated Boost Converter Using PWM Zero-Voltage Switching and Enhancement-Mode GaN FETs". A PWM zero-voltage-switching (ZVS) non-isolated boost converter using enhancement-mode GaN (eGaN) FETs is proposed in this paper. The new converter topology requires small number of passive components, minimizes the capacitive switching loss under high-voltage high-frequency operation, and offers low-voltage stress across power transistors. A transformer-based floating gate driver with 30 ns propagation delay and 3 ns rising/falling time enables high-speed high-side gate driving of the eGaN power FET and thus high-frequency operation of the proposed ZVS converter. A 1 MHz switching frequency 130 W output power prototype circuit of the proposed boost converter has been implemented and the measured peak power efficiency achieves 95 %.

Texas Instruments will present "Advantages of GaN in a High-Voltage Resonant LLC Converter".

LLC Resonant converters have been popular in recent years by providing highly-efficient, compact isolated power conversion for numerous applications. 48 V to 12 V and 400 V to 12 V step-down isolated converters are often required in server, telecom and automotive applications. While the switching losses in LLC converters are eliminated due to zero-voltage switching, the primary-side switch output capacitance limits switching frequency and thus places a lower-bound on the converter size. This switch-node capacitance can be significantly reduced by the use of high-voltage GaN power transistors. This paper demonstrates a 500 W, 380 V to 12 V LLC converter which achieves 97.85 % efficiency.

HRL Laboratories LLC introduces a "Normally-Off GaN-on-Si Multi-Chip Module Boost Converter with 96% Efficiency and Low Gate and Drain

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Overshoot”. A normally-off GaN synchronous half-bridge boost converter is designed with fast switching and low overshoot. A half-bridge Multi-Chip Module is designed with a power-loop inductance of ~4 nH using transmission-line techniques to minimize inductance. The gate circuit inductance is reduced to 1 nH using bare MOSFET die for driving the GaN gates and a 0.5 mil flexible substrate gate transmission-line. Critically damping the gate turn-on reduces overshoot to safe levels of 1 V gate overshoot and ~20 V drain overshoot. The resulting synchronous boost converter has an efficiency of 96 %, switching 300 V at 1MHz with 50 % duty cycle and an output power of 2.4 kW.

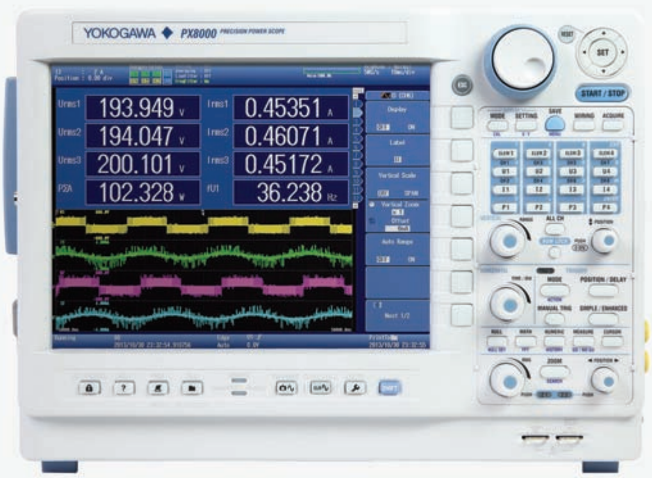
Zhejiang University presents “Experimental Analysis of a 1 kW, 800 kHz All-SiC Boost DC-DC Converter”. This paper presents the design, prototype development, operation and testing of a 1 kW, 800 V output all-SiC boost DC-DC converter module utilizing SiC MOSFET and SiC Shottky diode chips. The switching frequency is raised up to as high as 800 kHz and a 230°C SiC MOSFET junction temperature has been reached by switching-loss dominant self-heating. High frequency switching operation of the proposed converter is evaluated in detail and a Critical Conduction Mode (CrCM) Zero Voltage Switching (ZVS) soft-switched control method is experimentally proposed to reduce the switching loss of SiC MOSFET.

In session **Device and Thermal Modeling** GaN Systems Inc. introduces “Advanced SPICE Models Applied to High Power GaN Devices and Integrated GaN Drive Circuits”. The paper describes SPICE models and the use of SPICE models that have been developed for a CMOS/GaN cascode. The device is compared to a conventional discrete MOSFET/GaN cascode and a Super Junction MOSFET. The GaN devices provide a high speed 650V/50 A switching capability. The DC and AC simulations of the high power structures use the new SPICE models which produce accurate simulations over a wide temperature range and width load currents ranging from 2-47 A. Measured results are compared to the SPICE simulations and show that the high speed performance is maintained at the higher operating currents.

In session **Packaging for Higher Performance** Toyota introduces “Double-Sided Nickel-Tin Transient Liquid Phase Bonding for Double-Sided Cooling”. This paper is the first time presentation of double-sided nickel-tin transient liquid phase (Ni-Sn TLP) bonding and its application to double-sided cooling structures used in automotive power modules. Double-sided cooling is an emerging solution for heat dissipation problems inside compact power modules (used in electrified vehicles) and requires high-level reliability. This requirement is satisfied by the high re-melting temperature of Ni-Sn TLP bonding technology. Double-sided Ni-Sn TLP bonded (conventional) power diodes exhibited 1) consistent and reproducible bonding quality and 2) excellent high temperature reliability, demonstrated by electrical characterizations, high temperature storage (at 300°C), and thermal cycling (-40 to 200°C) evaluations.

Virginia Polytechnic Institute and State University will discuss “Design Considerations for GaN HEMT MultiChip Half-Bridge Module for High-Frequency Power Converters”. The module is designed with HRL 600 V GaN enhancement mode device. To unleash the capability of fast switching with low loss from high-voltage GaN devices, different layout structures have been analyzed to reduce power loop parasitic inductance and improve switching performance. The approach investigated is based on a multi-chip module where small current rated dies are placed in parallel to achieve higher current handling capability. Moreover, a transmission-line type gate structure has been proposed to minimize the gate loop inductance and reduce the gate voltage ringing. Finite-Element-Analysis (FEA) simulation and switching circuit simulation show that the multi-layer power loop design can effectively reduce the gate loop inductance and voltage overshoot on the devices.

In session **Multilevel/Matrix Converter** the University of Arkansas



presents a "SiC Module-Based Indirect Matrix Converter with Minimum Parasitic Inductances". The use of new SiC power semiconductor devices for different power converter applications is becoming more prevalent due to advantages realized at the system level when compared to conventional Si devices. The small footprint and low switching losses of SiC devices allow an increase in the power density of power converters, but packaging them into a module is a challenge. As power converters with higher volumetric densities are being pursued, an IMC based on SiC semiconductor devices provides a more than viable solution for exceeding current power density limits. The development of a 10 kVA, 480 Vrms IMC module based on SiC 1200V, 40A MOSFETs and 1200V, 20A Schottky diodes to achieve a power density of 15 kW/l is presented in this paper. The power converter is implemented in an interleaved input/output phase leg arrangement to reduce parasitic inductances in the critical DC-bus path by 30 %. Experimental results of the IMC prototype are given to demonstrate the advantages and functionality of the proposed IMC system.

Samsung and the University of California introduce a "1200 V Cascaded HVIC Gate Driver for Three-Level Neutral-Point-Clamped Inverter IPM" by proposing a new 1200 V cascaded high voltage IC (HVIC) gate drive circuit for a 1200 V three-level NPC inverter intelligent power module (IPM). The proposed single-ground IGBT gate driver of the 1200 V three-level NPC inverter is based on a bootstrap capacitor charging method and a cascaded 600V HVIC configuration which can dramatically improve its integration for practical use, especially system air conditioner application. The proposed approach possibly enables high-volume production, low cost, and increased reliability of the 1200 V three-phase inverter IPMs. Simulation and experimental results of a 1200 V 30A three-level NPC inverter prototype and its IPM are provided to verify the effectiveness of the proposed 1200 V cascaded HVIC gate driver for the three-level NPC inverter IPM.

The **Dialog Session** comprises 20 sessions and thus also numerous papers.

STMicroelectronics will present a "Fully SiC Based High Efficiency Boost Converter". Wide band-gap semiconductors (WBG) have recently drawn a lot of interest as main switches for power conversion processes. Owing to their inherent properties, materials such as Silicon Carbide (SiC) offer some advantages over silicon in the 1200V voltage range representing a solution to the quest for increased power density, safer thermal operation, better efficiency and reduced system form factor. In this paper the main benefits of ST 1200V SiC MOSFETs as an "ideal" high voltage switch through the results found in a 5 kW boost converter will be shown. The most relevant aspect of this work consists in exploiting the SiC MOSFET reverse mode capability through its extremely fast intrinsic body diode as well as with the synchronous rectification technique.

The University of Tennessee demonstrates "A 10-MHz Resonant Gate Driver Design for LLC Resonant DC-DC Converters Using GaN Devices". A new high frequency resonant gate driver for commercial GaN devices with off-chip inductor is derived. Simulation shows as much as 40 % gate driving loss saving. A LLC DC-DC converter using a conventional gate driver is designed and tested. The designed high frequency gate driver design is in progress. The complete testing and comparison will be carried after the fabrication of the designed gate driver.

The North Carolina State University evaluates the "Control and Performance of a Single-Phase Dual Active Half Bridge Converter Based on 15 kV SiC IGBT and 1200V SiC MOSFET". A single-phase Dual Active Half Bridge (DAHB) DC-DC converter topology is evaluated for medium voltage (MV) application. A 15 kV SiC-IGBT based three-level half-bridge is connected to the high voltage (HV) primary side of a high frequency (HF) transformer operating at 10 kHz link-frequency. A 1200 V SiC-MOSFET based two-level H-bridge is connected on the low voltage (LV) secondary side. This topology requires fewer switches and is suitable for MV application particularly with high step-down ratio where HF transformer may have considerable parasitics. It offers advantage of half blocking voltage requirement per device on the HV side and a simpler transformer saturation protection implementation. This paper also presents a robust D-Q based inner current control technique for the single phase DAB. The converters on both HV and LV side of the DAHB can also be switched in 60 degree zero quasi-square mode to eliminate third harmonic voltage. The square and 60 degree modes of operation are compared. The DAHB converter topology and controls are validated with simulation results followed by experimental results.

Also the University of Wisconsin-Madison will present "Efficiency Characterization and Thermal Study of GaN Based 1 kW Inverter". Rapid advancement of GaN based device technologies enables the possibility to design inverters that have superior performance capabilities compared to Si based inverters. It is prevalently acknowledged that GaN-based switching devices outperformed the Si-based counterparts in many aspects such as lower power consumption, faster switching frequencies, and higher operating temperatures. GaN devices will benefit many applications such as hybrid and plug-in electric vehicles, solar power inverters, industrial motor drives. Nevertheless, the superiorities of GaN devices in inverter design have not been fully explored by researchers, and the purpose of this paper is to evaluate the high efficiency capabilities that can be achieved using these new devices and the resulting benefits on the thermal side. As a case study, 1 kW GaN FETs inverter is considered. Loss and efficiency analysis is performed under various load conditions, and the requirements on heat sink for various ambient temperatures are specified according to the loss values obtained. Analysis results are compared with conventional Si-based inverters.

Cree Inc. will propose a "1000 V Wide Input Auxiliary Power Supply Design with 1700 V SiC MOSFET for Three-Phase Applications". The paper proposes a single end Flyback design with 1700 V SiC MOSFET to replace conventional two-switch Flyback converter. An active start-up circuit with 1700 V SiC MOSFET is implemented to optimize the converter design with wide input voltage to 1000 VDC and lower power losses. A 60 W auxiliary power supply is developed to demonstrate higher performance and lower component count to support wide input voltage range with this new 1700 V SiC MOSFET device.

The Nanjing Aeronautics and Astronautics University proposes a "Three-Level Driving Method for GaN Transistor with Improved Efficiency and Reliability Within Whole Load Range". Compared with Si MOSFET, GaN power transistor has higher reverse conduction voltage drop due to the absence of body-diode, which will result in higher reverse conduction loss. Furthermore, the oscillation on the driving voltage is quite severe when the GaN transistor operates in high frequency condition, which is critical for GaN transistor because of its relatively narrow driving voltage range. To guarantee GaN transistor operating reliably, driving voltage can't be set high enough to have lower conduction resistance, thus reducing the forward conduction loss. The three-level driving method for GaN transistor solves the issue of high reverse conduction voltage drop in some extent, but not completely, and the problem of driving voltage ringing still exists. This paper proposes an improved three-level driving method for GaN transistor in synchronous Buck converter. The method can reduce the reverse conduction loss in the whole load range and effectively decrease the ringing of the driving voltage. The mechanism for the reduction of the driving voltage ringing is presented and simulation results are given.

United Silicon Carbide, Inc. will present a "Study of SiC Vertical JFET Behavior During Unclamped Inductive Switching". The unclamped inductive switching (UIS) testing and simulations are performed to investigate the SiC JFET behavior and failure mode. A record high UIS energy density dissipated in the SiC JFET has been measured. Uniform channel openings and gate bias of the cells are critical for JFET ruggedness because the major portion of the UIS current flow through the vertical channels.

ABB Switzerland Ltd. and the Universidade Federal de Santa Catarina designed a "Propulsion and Battery Charging Systems of an All-Electric Boat Fully Constructed with Interleaved Converters Employing Interphase Transformers and GaN Power FET Semiconductors". This work presents a Power Electronics solution for an all-electric passenger boat. The proposed system is constructed with building blocks comprising interleaved half-bridge converters employing interphase transformer and Gallium Nitride FET semiconductors. The system employs two multi-level drives and an integrated harbor and onboard PV system. The PV battery charger has two stages. One converter per PV panel and a second based on cascaded buck-boost

converters that control the battery current and adapts the voltage levels. The operation, control and design expressions are presented. Experimental results verify the feasibility of the proposed system.

Industry Sessions

The PSMA-sponsored (Power Sources Manufacturers Association) Industry Session is entitled "Breakthrough Technologies Driving Successful Energy Harvesting-Powered Products" on March 18. Drawing on their expertise in the commercial and research institute sectors, including Cymbet, the Fraunhofer Institute, Linear Technology, NXP, Texas Instruments and IDTechEX, the six speakers will discuss the latest technologies integrated into innovative energy harvesting-powered systems by an overview of energy harvesting market requirements, economics and technology drivers; a look at the latest advancements in transducers; a discussion on how to design minimal-footprint, high-efficiency circuits; a description of new ultra low-power sensors, sub-microamp controllers and wireless transceivers; as well as a look at products that have been deployed in several different applications areas. The session will show how real-life, commercially successful energy harvesting-powered products are using new and innovative technologies to drive their successful commercialization in the areas of: transducers, energy conversion, energy storage, power management, ultra-low power microcontrollers, sensors and wireless radio solutions. At the conclusion of the presentations, hands-on, table- top examples of energy harvesting-powered products will be on display in the room for audience inspection.

Additionally, APEC attendees are invited to participate in the PSMA Energy Harvesting Technical

Committee meeting on March 18 for a two-hour workshop entitled "Integrating Energy Harvesting Eco-System Solutions". This mini-workshop will address one of the key impediments to creating energy harvesting-powered systems: putting all the pieces together effectively. At this meeting, energy harvesting eco-system companies who provide various parts of system solutions will create end-to-end reference designs.

The PSMA Energy Efficiency Committee is also sponsoring an Industry Session on March 20 "Energy Storage and the Power Converters that Control Energy Storage" which will explore various energy storage devices and applications, with an emphasis on the power electronics and controls that interface with them. Featured at the session will be six experts from industry, research and government, including Xtreme Power, Ioxus, Stem, Hyxos Innovations and EMerge Alliance. Designed to provide an overview of the current applications and insights into current markets, the presentations will help attendees identify potential opportunities so that their companies can participate in this important segment of technology. The topics in the session are: The Role of Energy Storage in Power Management; Batteries and Their Control; Using Super Capacitors for Frequency Regulation; Other Energy Devices (water, compressed air, thermal, rotating, flow batteries, etc.) Using DC Microgrids for Energy Storage Integration in Zero-Net Energy Buildings; and Energy Storage and Its Control in the Smart Grid.

Also on March 20 the Industry Session Wide Band Gap Devices will feature six contributions, namely Wide Band Gap Power Devices for High-Density Power Converters – Excitement and Reality by Krishna Shenai – Argonne National Laboratory; Moving Beyond Qualification to Verify the Long-Term Reliability of GaN Devices by Carl Blake – Transphorm; GaN: Raising the Bar for Power Conversion Performance by David Reusch – Efficient Power Conversion; GaAs-based Power Stages for Granular Power by Greg J. Miller, Robert Conner – Sarda Technologies;

Normally-Off GaN-on-Si Bi-Directional Automobile Battery-to -Grid 6.6 kW Charger

Switching at 500 kHz by Brian Hughes – HRL Laboratories; and finally Next-Generation Power SiC Devices for High-Volume Applications – Trench Schottky Barrier Diode and Trench MOSFET by David Doan – Rohm Semiconductor. **AS**

Literature

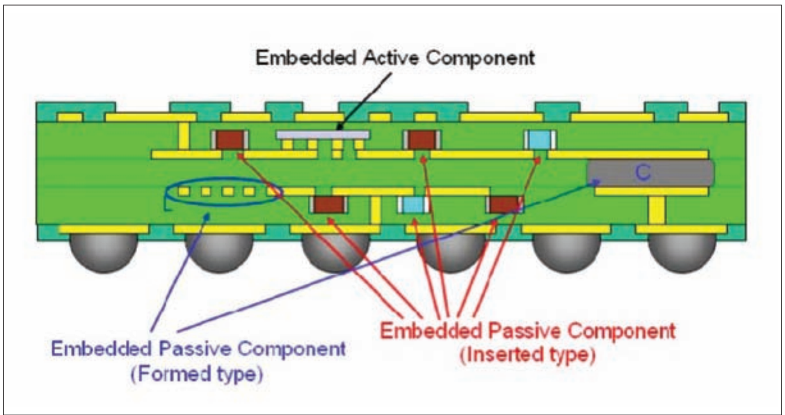
"More Power in 2014", Power Electronics Europe 1/2014, pages 10-11.

Packaging Technologies for Electronics

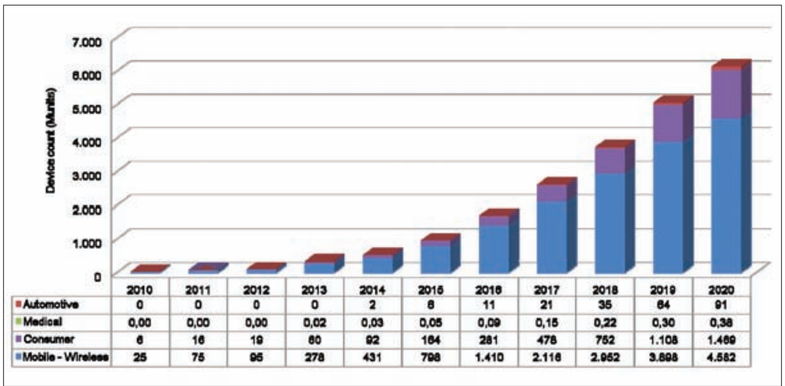
Ahead of PCIM 2014 at Nuremberg Fairgrounds SMT 2014 and and ECWC13 will take place, an exhibition and also a conference on innovative (power) electronic packaging technologies. This year, the SMT Hybrid Packaging, taking place from 6 - 8 May 2014, is on the way to reach last year's result (500 + ehibitors). Many new exhibitors and long-time exhibitors will participate to present the latest developments in the fields of PCB manufacturing, surface mount, micro-assembly or testing strategies.

The worldwide production of PCBs is around $60 billion, with a share of 90 % in Asia and only 5 % in Europe, but the market (consumption) is mainly in Europe and the USA. Looking specifically at the PCB market in Europe, Germany has 43 % market share, followed by Austria/Switzerland, and then Italy. Overall the market was down 5 % in 2013. The major players are still AT&S, Würth and Schweizer. The market is valued at € 1820 million. In the European PCB market sectors, automotive is strong, as are industrial electronics, with process equipment and laminate sales all back to growth. Europe is continuing to grow, and 2014 will be a positive year, with 2.5 % growth in the PCB world.

The current trend in PCBs is towards embedded components in a multilayer PCB, in other words the integration of passive components (resistors, capacitors, inductors) in a first step and in a second step the integration of passive and active devices such as power MOSFETs and controllers. The advantages are obvious: On a comperatively cheap substrate complete subsystems can be manufactured by using multiple interconnect and isolation layers and embedded devices between them. Double-siding cooling is ensured since the thermal resistance even of epoxy is much less compared to air. Market researcher Yole (**www.yole.fr**) predicts in 2014 more than 500 Million embedded die packages to be shipped worldwide, and this number could increase up to 6 billion by the year 2020. An extension to that are multi-functional packages including thermal management, etched planar coils and printed or discrete resistors.

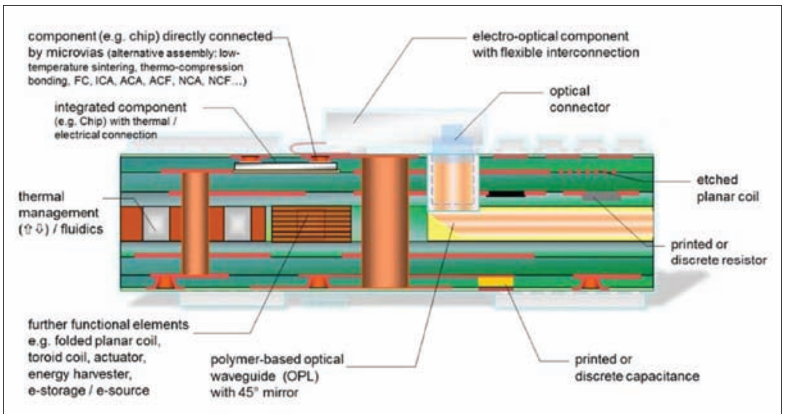


Cross section of a PCB with embedded components



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Automotive	0	0	0	0	2	6	11	21	35	64	91
Medical	0,00	0,00	0,00	0,02	0,03	0,05	0,09	0,15	0,22	0,30	0,38
Consumer	6	16	19	60	92	164	281	478	752	1.108	1.469
Mobile - Wireless	25	75	95	278	431	798	1.410	2.116	2.952	3.898	4.582

Embedded die package unit (millions) shipment forecast



Cross section of multi-functional package

Parallel to the exhibition, the 13th Electronic Circuits World Convention (ECWC13) will take place from 7- 9 May 2014. On three conference days, in 26 sessions with 123 presentations, ECWC13 examines new processes, current technologies and changing market dynamics of the printed circuit board industry. The organizer is the European Institute of Printed Circuits (EIPC) as a member of the World Electronic Circuits Council (WECC). Its members have been holding the ECWC for more than 35 years, every three years alternately in Asia, Europe and the USA. The conference will start on Wednesday, 7 May 2014.

The Electronic Circuits World Convention was founded in 1978. During the last 35 years the ECWC teams have organized 12 PCBs and PCBA world convention events, with the primary aim of demonstrating leadership in electronic equipment and PCB manufacturing, set against a background of knowledge of the global demand, new processes and technologies required, and the changing market dynamics.

One of the papers within the numerous sessions are of particular interest in the above mentioned context: Ultra-thin Silicon Chips in Flexible Microsystems by Jürgen Wolf, Würth Elektronik, Germany. With the growing demand for mechanically flexible electrical systems and the increasing level of integration of electrical assemblies, hybrid build-ups combining polymer substrates and ultra-thin flexible silicon chips (system-in-foil) are getting more and more important. These systems need thin chips which maintain their functionality even in bent condition as well as reliable handling and assembly processes. A consortium composed of companies and research institutes has researched and tested novel technologies within the framework of a leading-edge cluster called MicroTEC Südwest in Germany.

www.smt-exhibition.com

PCIM
EUROPE

Nuremberg, 20 – 22 May 2014

European Power Electronics Meeting Point

The PCIM Europe 2014 conference (Nuremberg, 20 – 22 May) presents a diversified program. From 269 abstracts in total the conference directors have put together a comprehensive program on the latest technological trends in power electronics components and systems.

On the two days before the conference, well known experts will share their knowledge on topics such as “New Trends in Soft Switching Topologies”, “Reliability of IGBT Power Modules” or “High Performance Control of Power Converters” in six half-day seminars and ten full day tutorials.

Keynotes on current trends

The highlights include, amongst others, 3 keynote speeches on the morning of all three days. On the Tuesday (May 20), after the official opening and handing-over of the Best Paper and Young Engineer Awards the first keynote on “Progress in Power Semiconductor Devices and Applications“ by Dan Kinzer, CTO Fairchild Semiconductor, will be given.

Advances in power semiconductors are enabling major steps forward in energy efficiency, power density, system size, and cost. Breakthroughs continue to happen in the areas of power devices and drivers, power topologies and controllers, and integrated power packaging. Some of the most important areas to reduce energy waste are in energy generation, automotive transportation, industrial and commercial HVAC, consumer appliances and lighting, and the cloud. In each of these areas, advances in technologies like superjunction MOSFETs, shielded gate trench MOSFETs, trench field stop IGBTs, and Silicon Carbide switches are cutting losses substantially. Of course, none of that can happen without the right drivers, sensors, control, diagnostic, and protection functions. These elements need to be combined in the right packages and assemblies that enable the highly interactive parts of the solution to be optimized and function reliably together. The intention of this talk is to take a few of the critical applications for power semiconductors, and show how these new power devices work in solutions that enable new levels of electronic system performance. Specific design examples will be included.

The keynote on the second day (May 21) entitled “Ultra High Voltage SiC Power Devices and its Impact on Future Power Delivery System” will be presented by Prof. Alex Huang, NSF FREEDM Systems Center North Carolina State University.

The Future Electric Energy Delivery and Management (FREEDM) System is a novel power delivery architecture suitable for plug-and-play of distributed renewable energy and distributed energy storage devices. Motivated by the success of the Information Internet, the architecture was put forward by the NSF FREEDM Systems Center as a possible roadmap for an automated and flexible electric power distribution system. In the Information Internet, people share information in a plug and play manner. In the envisioned 'Energy Internet', a vision for sharing of the energy is proposed for ordinary citizen and home owners. Key technologies required to achieve such a vision are discussed. In this talk the author will provide an overview of the research conducted at the NSF funded FREEDM Systems Center. Among many of the key technologies, the development of ultra high voltage SiC power semiconductor devices and power electronics systems will be shown and their impact to future power delivery system such as the FREEDM System will be discussed.

The third keynote on the Thursday morning (May 22) covers e-mobility with the title "Power Electronics, a Key Technology for the Effective Deployment of Electric Vehicles in a Low Carbon Society" given by Enrique J. Dede, ETSE University Valencia, Burjassot Valencia, Spain.

The presentation aims to give an overview on different aspects of the e- mobility, especially in charging Electric Vehicles, starting with the current Megatrends in the actual Society and corresponding EU regulations. EV s charging modes and corresponding applicable standards are presented and the current power converter topologies for DC chargers are discussed including advantages and disadvantages of the different structures. A short discussion on wireless EV chargers and applicable standards is also in the scope of the presentation. The integration of chargers is smart grids is extensible described, as well as the actual ICT services for the smart charging of Evs.

Special sessions on: "HVDC" and "Designing Packages for Fast Switching" plus 28 oral sessions as well as two poster sessions will round up the program.

The PCIM Europe international conference and trade fair is the meeting point for experts from industry and industry related sciences. About 8,000 professionals from the power electronics, intelligent motion, and renewable energies sectors annually visit this leading exhibition for power electronics in Nuremberg.

www.pcim-europe.com

SEMIKRON Awards at PCIM Europe

The SEMIKRON Innovation Award and the Young Engineer Award is given for outstanding innovations in projects, prototypes, services or novel concepts in the field of power electronics in Europe, combined with notable societal benefits in form of supporting environmental protection and sustainability by improving energy efficiency and conservation of resources.

Both prizes have been initiated and are donated by the SEMIKRON Foundation which is awarding the prizes in cooperation with the European ECPE Network.

With the award the SEMIKRON Foundation wants to motivate people of all ages and organisations of any legal status to deal with innovations in power electronics, a key technology of the 21 century, in order to improve environmental protection and sustainability by energy efficiency and conservation of resources.

A single person or a team of researchers can be awarded with a prize money of EUR 10.000,00. The Young Engineer Award for researchers who have not yet completed their 30 year of age includes prize money of EUR 3.000,00.

The award targets at projects, prototypes, services and novel concepts developed in Europe, which did not yet appear on the market, which are used in a novel application, or which form an absolute novelty, and therewith fulfil the requirement to be extraordinary and remarkable.

Sole project proposals are not in the scope of the call, the innovation should have been verified by experiment or simulation. The degree of innovation has to conform to international standards.

The selection procedure is organised in cooperation with ECPE European Center for Power Electronics. The submitted proposals will be passed to an independent and neutral evaluation committee of experts for discussion and assessment. To apply for the SEMIKRON Awards own applications as well as proposals from third parties are welcomed. Proposals comprising 3-5 pages resp. applications with the reference 'SEMIKRON Innovation Award' should be e-mailed to Thomas Harder, General Manager of ECPE e.V., thomas.harder@ecpe.org.

Deadline for submission is 07.04.2014!

Power Management IC for Automotive Instrumentation

Maxim new Integrated's automotive PMIC combines three high-current DC/DC converters, saving over 50 % board space compared to discrete solutions. Automotive OEMs often limit instrument cluster module consumption to less than 100 µA in standby mode. Given all the functions that the instrument cluster performs, the power supply itself must consume only a tiny portion of the power budget. Under no-load conditions, the MAX16993 is the only 3-channel solution that consumes just 25µA of quiescent current. This makes the PMIC more efficient than traditional DC/DC converters

The MAX16993 power-management IC (PMIC) is a 2.1 MHz, multichannel, DC/DC converter designed for automotive applications. The device includes one high-voltage step-down controller (OUT1) designed to run directly from a car battery and two low-voltage step-down converters (OUT2/OUT3) cascaded from OUT1.

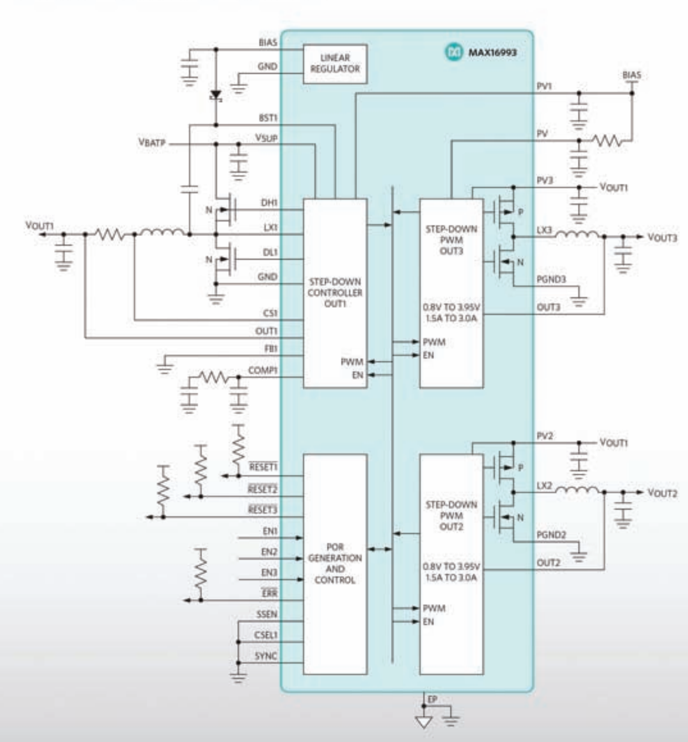
Buck controller details

The 2.1 MHz, high-voltage buck controller operates with a 3.5 V to 36 V input voltage range and is protected from load-dump transients up to 42 V. The high-frequency operation eliminates AM band interference and reduces the solution footprint. It can provide an output voltage between 3.0 V and 5.5 V set at the factory or with external resistors. Each device has two frequency options that are pin selectable: 2.1 MHz or a lower frequency based on factory setting. Available factory-set frequencies are 1.05 MHz, 525 kHz, 420 kHz, or 350 kHz. Under no-load conditions, the device consumes only 30 ?A of quiescent current with OUT1 enabled.

The dual buck converters can deliver 1.5 A or 3.0 A of load current per output. They operate directly from OUT1 and provide 0.8 V to 3.95 V output voltage range. Factory trimmed output voltages achieve ±3 % output error over load, line, and temperature without using expensive ±0.1 % resistors. In addition, adjustable output-voltage versions can be set to any desired values between 0.8 V and 3.6V using an external resistive divider. On-board low on-resistance switches help minimize efficiency losses at heavy loads and reduce critical/parasitic inductance, making the layout a much simpler task with respect to discrete solutions.

All three regulators have their own enable input. When EN1 exceeds the EN1 high threshold, the internal linear regulator is switched on. When VSUP exceeds the VSUP,STARTUP threshold, Buck 1 is enabled and OUT1 starts to ramp up with a 4 ms soft-start. Once the Buck 1 soft-start is complete, Buck 2 and Buck 3 can be enabled. When either Buck 2 or Buck 3 is enabled, the corresponding output ramps up with a 2.5 ms soft-start. When an enable input is pulled low, the converter is switched off.

Highly integrated automotive step-down controller



MAX16993 block diagram

Buck 1

Buck controller 1 uses a PWM current-mode control scheme. An internal transconductance amplifier establishes an integrated error voltage. The heart of the PWM controller is an open-loop comparator that compares the integrated voltage-feedback signal against the amplified current-sense signal plus the slope-compensation ramp, which are summed into the main PWM comparator to preserve inner-loop stability and eliminate inductor staircasing. At each rising edge of the internal clock, the high-side MOSFET turns on until the PWM comparator trips or the maximum duty cycle is reached, or the peak current limit is reached.

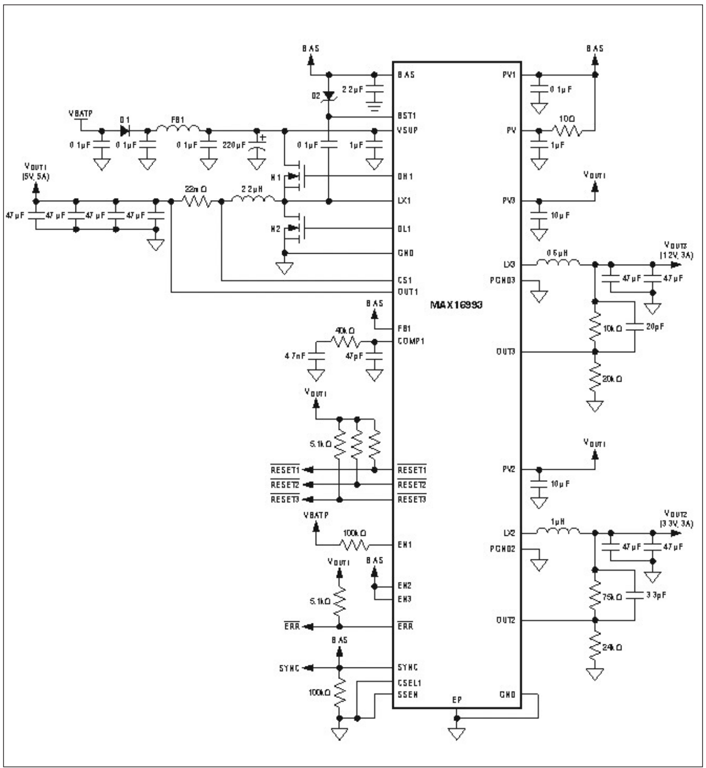
During this on-time, current ramps up through the inductor, storing energy in a magnetic field and sourcing current to the output. The current-mode feedback system regulates the peak inductor current as a function of the output-voltage error signal. The circuit acts as a switch-mode transconductance amplifier and pushes the output LC filter pole normally found in a voltage-mode PWM to a higher frequency.

During the second half of the cycle, the high-side MOSFET turns off and the low-side MOSFET turns on. The inductor releases the stored energy as the current ramps down, providing current to the output. The output capacitor stores charge when the inductor current exceeds the required load current and discharges when the inductor current is lower, smoothing the voltage across the load. Under soft-overload conditions, when the peak inductor current exceeds the selected current limit, the high-side MOSFET is turned off immediately and the low-side MOSFET is turned on and remains on to let the inductor current ramp down until the next clock cycle.

Buck 1 drives two external logic-level n-channel MOSFETs as the circuit switch elements. The key selection parameters to choose these MOSFETs are on-resistance (RDS(ON)), maximum drain-to-source voltage (VDS(MAX)), minimum threshold voltage (VTH(MIN)), total gate charge (QG), reverse transfer capacitance (CRSS), and power dissipation.

Both n-channel MOSFETs must be logic-level types with guaranteed on-resistance specifications at VGS = 4.5 V when VOUT1 is set to 5 V or VGS = 3 V when VOUT1 is set to 3.3 V. The conduction losses at minimum input voltage should not exceed MOSFET package thermal limits or violate the overall thermal budget. Also, it must be ensured that the conduction losses plus switching losses at the maximum input voltage do not exceed package ratings or violate the overall thermal budget. In particular, it must be checked that the dV/dt caused by DH1 turning on does not pull up the DL1 gate through its drain-to-gate capacitance. This is the most frequent cause of cross-conduction problems.

Gate-charge losses are dissipated by the driver and do not heat the MOSFET. Therefore, the power dissipation in the device due to drive losses must be checked. Both MOSFETs must be selected so that their total gate charge is low enough. The n-channel MOSFETs must deliver the average current to the load and the peak current during switching. Dual MOSFETs in a single package can be an economical solution. To reduce switching noise for smaller MOSFETs, a series resistor in the DH1 path and additional gate



MAX16993 typical application diagram

MAX16993 automotive instrumentation application example

capacitance can be used.

The high-side gate driver for Buck 1 has a minimum on-time of 75 ns (max). This helps ensure no skipped pulses when operating the device in PWM mode at 2.1 MHz with supply voltage up to 18 V and output voltage down to 3.3 V. Pulse skipping can occur if the on-time falls below the minimum allowed.

Buck 2 and 3

Buck converters 2 and 3 are high-efficiency, low-voltage converters with integrated FETs. They use a PWM current- mode control scheme that is operated also at 2.1MHz. The buck converters can be configured to deliver 1.5 A or 3.0 A per channel. They operate directly from OUT1 and have either fixed or resistor-programmable output voltages that range from 0.8 V to 3.95 V. Buck 2 and Buck 3 feature low on-resistance internal FETs that contribute tohigh efficiency and smaller system cost and board space.

Integration of the p-channel high-side FET enables both channels to operate with 100 % duty cycle when the input voltage falls to near the output voltage. They feature a programmable active timeout period that adds a fixed delay before the corresponding RESET_ can go high.

Compensation network

The device uses a current-mode-control scheme that regulates the output voltage by forcing the required current through the external inductor, so the controller uses the voltage drop across the DC resistance of the inductor or the alternate series current-sense resistor to measure the inductor current. Current-mode control eliminates the double pole in the feedback loop caused by the inductor and output capacitor, resulting in a smaller phase shift and requiring less elaborate error-amplifier compensation than voltage-mode control.

Evaluation kit

The MAX16993 evaluation kit (EV kit) is a fully assembled and tested surface-mount PCB that contains all the components necessary to evaluate the MAX16993 PMIC. The EV kit can operate from 3.5 V to 36 V input voltages and is optimized for automotive infotainment applications. The high-voltage controller is configured for a 5 V output that provides at least 5 A. The low-voltage step-down converters are configured for 3.3 V and 1.2 V, each providing up to 3 A. The EV kit can be easily reconfigured to operate in continuous PWM mode, skip mode, or external synchronization operation.

www.maximintegrated.com

Precision Power Scope

Yokogawa's new PX8000 brings oscilloscope-style time-based measurement to the world of power measurement. It can capture voltage and current waveforms precisely, opening up applications and solutions for a huge variety of emerging power measurement problems.

The new instrument has 12-bit resolution with 100 MS/s sampling and 20 MHz bandwidth. This means that the PX8000 can be used for accurate measurement of inverter pulse shapes, which can then be used to fine-tune inverter efficiency. A choice of input modules covers voltage, current and sensor measurements at voltages up to 1000 V RMS and currents up to 5 A RMS (higher values are possible with external current sensors), with basic accuracy down to ±0.1%.

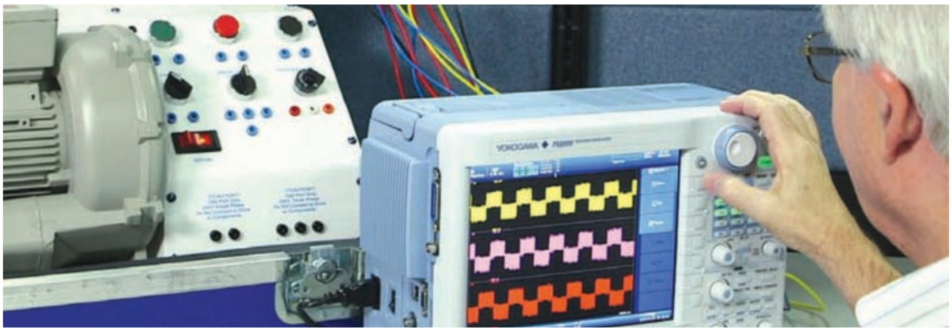
To evaluate three-phase electrical systems, at least three power measurement inputs are required. The PX8000 not only has four inputs but also enables the simultaneous capture and display of voltage and current across all three phases.

In addition to delivering precision power measurement to give insight into energy consumption and performance, the PX8000 incorporates a number of features that support the crucial measurement and analysis of transient power profiles. It provides simultaneous voltage and current multiplication to give real-time power sampling, supporting both transient measurement (as standard) and numerical values averaged across the sample period. Up to 16 different waveforms – including voltage, current and power – can be displayed side-by-side, giving engineers instant "snapshots" of performance.

Numerous built-in functions

The PX8000 has built-in functions for the direct calculation of derived parameters, such as root mean square (RMS) and mean power values, to enable the identification of cycle-by-cycle trends.

The PX8000 provides graphical displays of voltage, current and power readings which can be inspected for specific numerical values at any point or for calculating of average values over a specific period. The instrument also supports the capture of power waveforms over specific periods of time through the definition of start and stop "cursors". This is particularly useful for examining transient



Yokogawa's PX8000 brings oscilloscope-style time-based measurement to power applications such as inverters

phenomena and in the design of periodically controlled equipment. To ensure that such equipment complies with energy standards, it is vital to measure power consumption across a range of different modes from "sleep" to full activity – and all the transient states in between. The PX8000 offers X/Y display capabilities which can be used, for example, to show the speed/torque characteristics of motors. It can also display Lissajous waveforms of input and output for phase analysis.

Like digital oscilloscopes the PX8000 incorporates a history memory function that automatically records up to 1000 historical waveforms which can be recalled and redisplayed at any time. Recorded waveforms can also used to redefine trigger conditions. Historical waveforms are explored via condition-based searches to locate specific hard-to-isolate abnormal phenomena during repeated high-frequency measurements.

A variety of functions including arithmetical calculations, time shifting and Fast Fourier Transforms enable users to display waveforms with offsets and skew corrections. An automatic de-skewing function eliminates offsets between current and voltage signals that may be caused by sensor or input characteristics. Users can also define their own computations via equations that combine differentials, integrals, digital filters and a wealth of other functions.

The PX8000 makes it possible to simultaneously measure the harmonic components of voltage and current waveforms as well as the harmonic distortion factor. Harmonic measurements take place in parallel with conventional voltage and current measurements. Harmonics up to the 500th order of the fundamental can be measured.

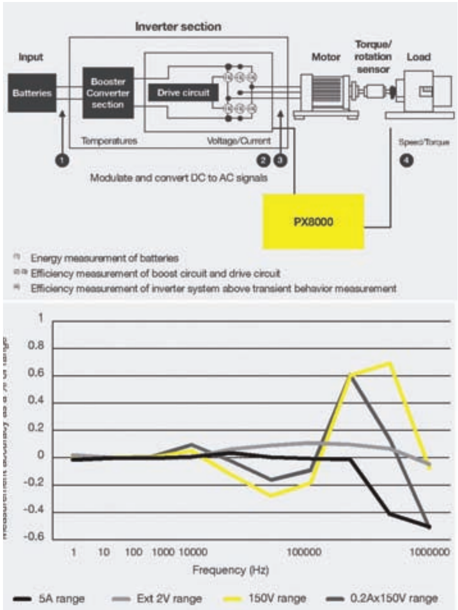
The PX8000 comes with an accompanying PC software application called PowerViewerPlus that can be used to capture waveform data for further analysis. This dramatically extends the number of data points it is possible to analyse, making the PX8000 ideal for capturing and analysing longer-term performance. PC connection is via standard Ethernet/USB/GP-IB connections. The software displays waveforms in a simple and clear graphical style that will be familiar to users of Yokogawa's Xviewer software. Researchers who want to use their own analysis software will be able to establish a connection to the PX8000 via the LabVIEW driver.

Application examples

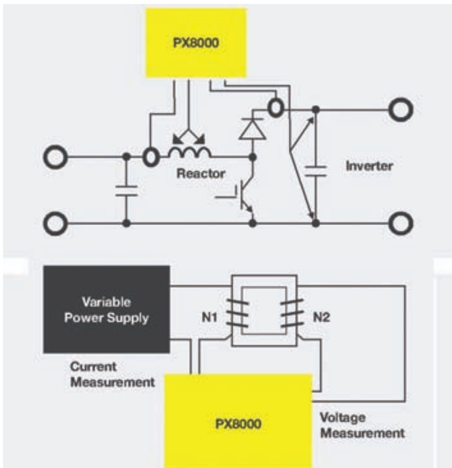
Applications for the PX8000 cover everything from sustainable power to advanced robotics. Typical application sectors include inverter and motor testing, reactor loss measurement of inverter boost circuits, transient responses of industrial robots, wireless charger efficiency measurement, and voltage and power measurements in electricity distribution systems.

Electric and hybrid vehicles have many electrical and mechanical components, and overall performance evaluation requires measuring the efficiency of both. The vertical resolution of analog/digital conversion is one of the most important factors in precision measurement. The PX8000 has 12-bit resolution with 100 MS/s sampling and 20 MHz bandwidth. This means the PX8000 can be used for accurate measurement of inverter pulse shapes, which can then be used to fine-tune inverter efficiency. The PX8000's ability to analyze cycle-by-cycle trends makes it ideal for the measurement of transient effects. During the start-up phase of an inverter and motor, for example, current increases can be analyzed in each cycle. And when the load changes rapidly, the engineers can gain insights that will enable them to improve the control of the inverter. A common problem when testing inverter motors is the presence of ambient noise that can mean test values are non-zero even before testing begins. The PX8000's offset capabilities mean such effects can be nullified and specific inputs can be isolated for testing and analysis.

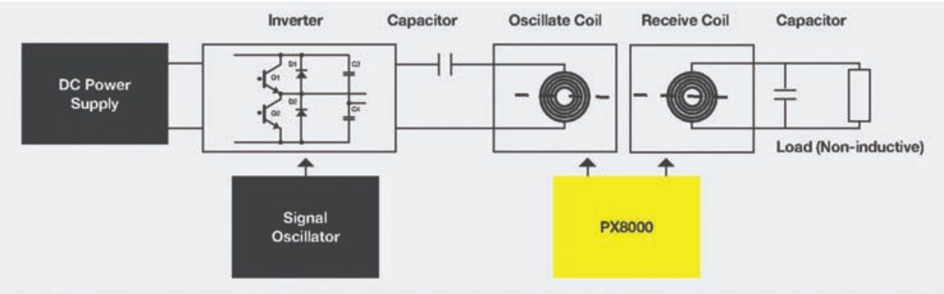
A reactor is used to filter out noise and boost voltage levels prior to the use of an inverter. It consists of an electromagnetic material core and a coil. A main focus is to reduce power loss across the total inverter system, and reactor performance is of particular interest. There are two potential evaluation methods: direct loss measurement of the reactor and iron loss measurement. The PX8000 supports either methodology because it can accommodate both high frequency measurement and low power factor conditions. Higher sampling rates and broad bandwidth make the PX8000 particularly useful for testing devices, such as transformers and reactors, that have lower power factors. It is particularly important to measure the precise power consumption of such devices at high frequency. To analyze power consumption in low power factor devices it is particularly important to minimize any time differences between voltage and current caused by sensor input characteristics. The PX8000 provides precise de-skew adjustment to compensate for this time difference. Core loss is calculated based on



Inverter and motor testing scheme



Reactor loss measurement of inverter boost circuits



Wireless charger efficiency measuremts

primary coil current and secondary coil voltage (using readings from an Epstein device), while magnetic flux density (B) and magnetic field (H) are calculated by factoring in input frequency, cross-sectional area and other parameters. All values can be displayed directly by the PX8000.

To evaluate motor-driven robots, power consumption of all motors and controllers are measured throughout all operational speeds and action patterns. It is useful to measure inrush voltage, current and power over the pattern of repeated actions. Efficiency is calculated by comparing mechanical output with input power. During actual operating conditions, the time to accelerate and decelerate such motors can range from several hundred milliseconds to several seconds. As a PWM-driven motor rotates from the reset position to the top speed, the drive frequency changes from DC to several hundred Hz. The PX8000 gives design engineers insight into power consumption and efficiency throughout a robot's operational performance.

The development of wireless charging technology for mobile devices is a focus for research. Automotive manufacturers are looking into the possibilities of charging electric vehicles wirelessly too. Wireless charging depends on two electromagnetic coils being configured to support particular frequency profiles. Efficient power transfer and the prevention of power loss are naturally particularly important. The PX8000 is suited for measuring such systems because of its ability to operate at high frequencies and low power factors. The PX8000's higher sampling rates and broad bandwidth make it suited for wireless power transfer systems. Crucially, this means the PX8000 supports the measurement of low power factor systems operating at very high frequencies.

Power distribution systems have to maintain constant voltage and constant power during load switching or in the case of a short circuit. Distribution protectors or circuit breakers for three-phase electricity systems must therefore be tested at transient voltage and power levels. The PX8000 can capture fluctuating voltage and current waveform, calculate power parameters (including voltage and current values), determine an average over a specified period and display all values. To evaluate three-phase electrical systems, at least three power measurement inputs are required. The PX8000 not only has four inputs but also enables the simultaneous capture and display of voltage and current across all three phases. For a true evaluation of distribution protection, it is necessary to measure a full cycle of voltage, current and power values half a cycle after the recovery from a short circuit. The PX8000 can easily be set up to focus on such a specific period. The instrument has capabilities for both harmonic measurement and FFT for frequency analysis. The harmonic function can measure fundamental frequencies from 20 Hz to 6.4 kHz, and FFT has 1 k to 100 k points calculation across up to two channels. Such measurements are vital for identifying harmonic currents and identifying sources of noise.

www.tmi.yokogawa.com/px8000

On the Transition from Silicon to GaN-Based Drive Inverters

The recent announcement by several well established suppliers, notably Panasonic and International Rectifier of the near term availability of 600 V rated GaN based devices to the power electronics market, has prompted significant interest in the nature of the resulting transition from Silicon to GaN based inverters for motor drives. Several inherent advantages of GaN based HEMTs, including one to two orders of magnitude reduction in reverse recovery charge, as well as significantly higher current handling capability and lower equivalent on resistance for a given device active area, have already been shown to reduce power losses in actual use conditions of applications such as appliances and electric vehicle drive trains by more than a factor of 2. **Michael A Briere, ACOO Enterprises LLC (under contract to International Rectifier), USA**

The linear I-V behavior of the GaN (Gallium Nitride) based HEMTs (High Electron Mobility Transistors) is particularly advantageous at lighter loads, where the significant overhead of the Si based bipolar device results in large power losses. Inverter densities for these same applications have been shown to be improved from between a factor of 2 to 3 for electric vehicle systems and over a factor of 10 for appliance motor drives. Despite these overwhelming advantages, the adoption rate will be determined by the design cycles of the power electronic system suppliers, which are typically two to four years.

IGBTs versus GaN

In typical offline motor drive circuits today, the switch function is accomplished by a Silicon based insulated gate bipolar transistor (IGBT). The same bipolar effect that provides for relatively low equivalent on-resistance at higher loads, compared to Silicon based unipolar MOSFETs, would add too much reverse recovery charge (Q_{rr}) to be practically useful in switching applications.

Together with the fact that the motor drive application requires a recirculating path for back EMF (electro-magnetic force) induced current from the inductive load, that is the motor windings, when the associated switch is turned off, an external diode is usually co-packaged with the IGBT. This diode is often about half the die size of the IGBT switch and adds significantly to the footprint of the packaged solution. In addition, the significant reverse recovery charge characteristics of this recirculating diode creates significant noise and adds to the power loss of the switching circuit. Although there have been some recent efforts to use SiC-based diodes to eliminate this reverse recovery charge, the cost of such a solution makes it practically prohibited. Another characteristic of the IGBT based solution is that the inherent built in potential of the bipolar transistor produces a large voltage drop across the switch, typically more than 1 V, even for relatively light load currents, for instance of a few hundred mA.

As many motor drive applications, such as refrigerator compressors, spend most time in such light load conditions, this effect has a significant impact on achievable efficiencies in these applications. In addition, as state of the art IGBTs are vertical channel devices, integration is impractical. This makes the IGBT based solution for low power motor drive applications relatively large and expensive to implement. Each of these drawbacks are addressed by the use of commercially viable GaN based power devices as switches in motor drive applications.

In the case of a commercially viable GaN based power device, such as a

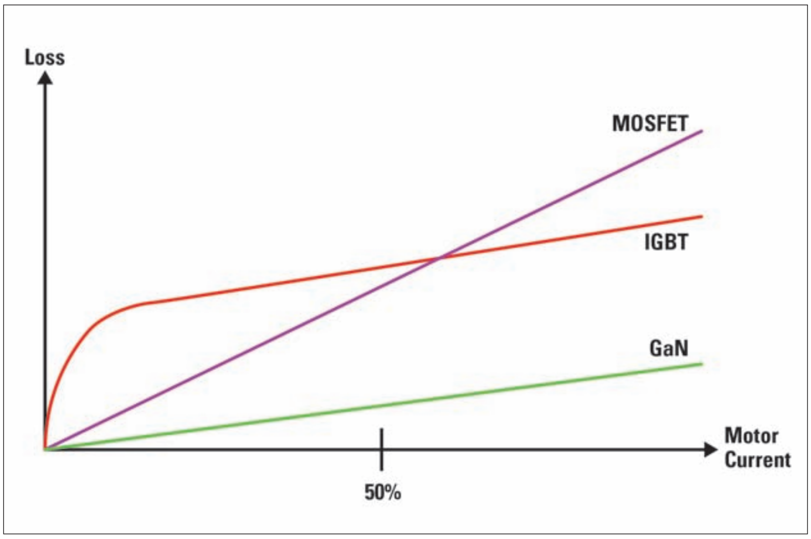


Figure 1: A representation of the voltage vs current output characteristics of Silicon based IGBTs and MOSFETs compared to that of GaN based switches

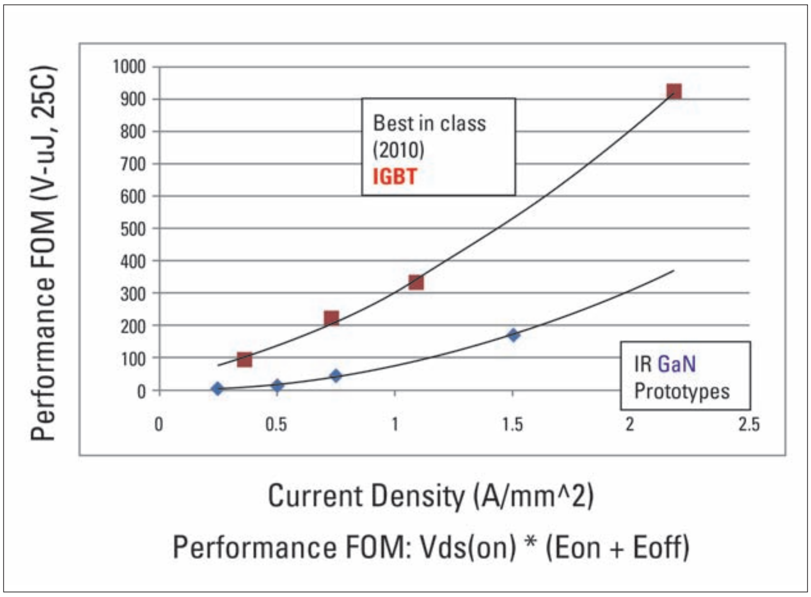


Figure 2: Measured forward voltage drop * switching energy for state of the art IGBTs and early prototype GaN based cascoded switches vs current density

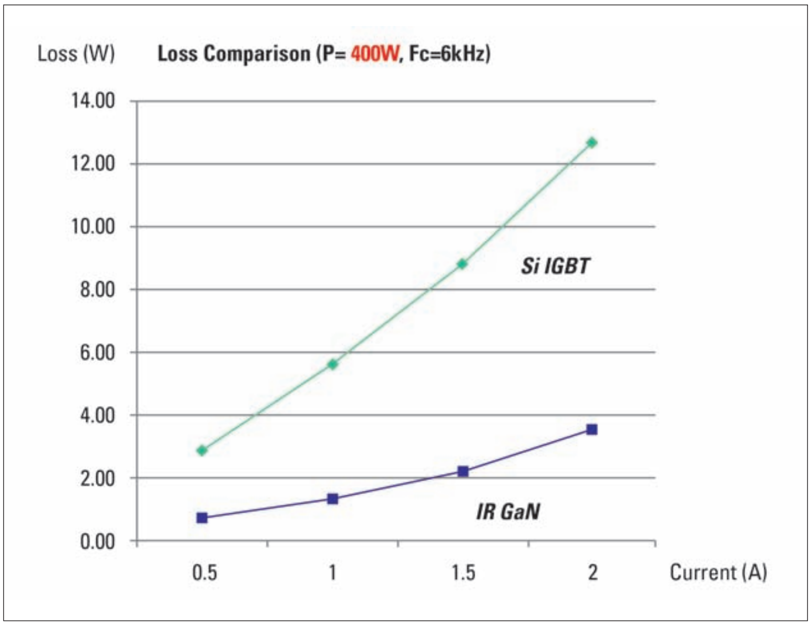


Figure 3: Comparison of power loss in nominal 400 W motor drive inverter using Silicon based IGBTs or GaN based cascoded switches

cascoded GaN HEMT from International Rectifier's GaNpowIR® technology platform, the performance to cost advantage in comparison to state of the art Silicon based IGBTs is quite remarkable. The recirculating function is provided by the body diode of the low voltage Silicon FET cascoded with the high voltage GaN based HEMT. This low voltage diode exhibits a small fraction, e.g. less than 10 %, of the reverse recovery charge characteristics of the high voltage diode used with the IGBT. This leads to much cleaner switching waveforms and less circuit noise. In addition the cascoded LV FET is much smaller, e.g. less than 10 %, than the GaN based HEMT, representing little extra area or cost.

The on resistance of the current first generation GaN based cascoded switch is much less, e.g. a factor of 2 to 3, per active area, than state of the art 6th and 7th generation Silicon based IGBTs. In addition, it has been shown that GaN based cascoded switches can process more than 2 times the current density, per active area, (> 900 A/cm^{-2}) as state of the art Silicon based IGBTs. In this way, the inherent die size required for a given application at full power can be significantly smaller for the GaN based switches. Alternatively, the maximum full power that can be processed for a given inherent die size, or package size, can be significantly greater when using GaN based switches.

Perhaps more strikingly, the unipolar nature of the GaN based device causes the output characteristics to be linear through light load, in contrast to the significant overhead of the built in potential of the bipolar device, as shown in Figure 1.

The combination of lower on-state forward voltage drop and simultaneously significantly reduced switching charge leads to a 3 to 4 fold improvement in power processing performance, in the form of reduced conduction loss multiplied by switching loss, as shown in Figure 2. This improved device performance translates directly into improved efficiency in a motor drive inverter application. As seen in Figure 3, the power loss associated with the motor drive inverter in a typical appliance application at a nominal 400 W, shows more than a 3 fold reduction in power loss when using IR's 600 V rated GaNpowIR® devices compared to state of the art Silicon based trench IGBTs. In particular the light load efficiency is dramatically improved, in agreement with device physics based expectations. In addition, as can be seen in Figure 4, the density of the GaN based solution is 10 times that of the Silicon solution. Most impressively, the GaN based solution does not require a heat sink as the Silicon based solution does, making the practical density advantage a factor of 100.

These impressive results are even more remarkable considering the relative immaturity of the GaN based power device technology compared to the well established and mature Silicon based IGBT technology. It is expected that future engineering efforts will hone the GaN based technology to close to its physically determined performance limits, an expected improvement of at least a factor of ten, over the coming decade. As astounding as this situation appears for enabling advances in future power electronic systems, it represents only a small fraction of the nascent potential present in GaN based power electronics.

Novel architectures on the horizon

One great avenue of innovation involves the development of new circuit topologies that take a full advantage of the inherent benefits and capabilities associated with GaN based power devices, whereas the previous discussion only involved the drop in replacement of GaN based devices into circuits designed explicitly for Silicon based switches. An example of such a topology change would be the replacement of the half bridge, phase leg, approach using

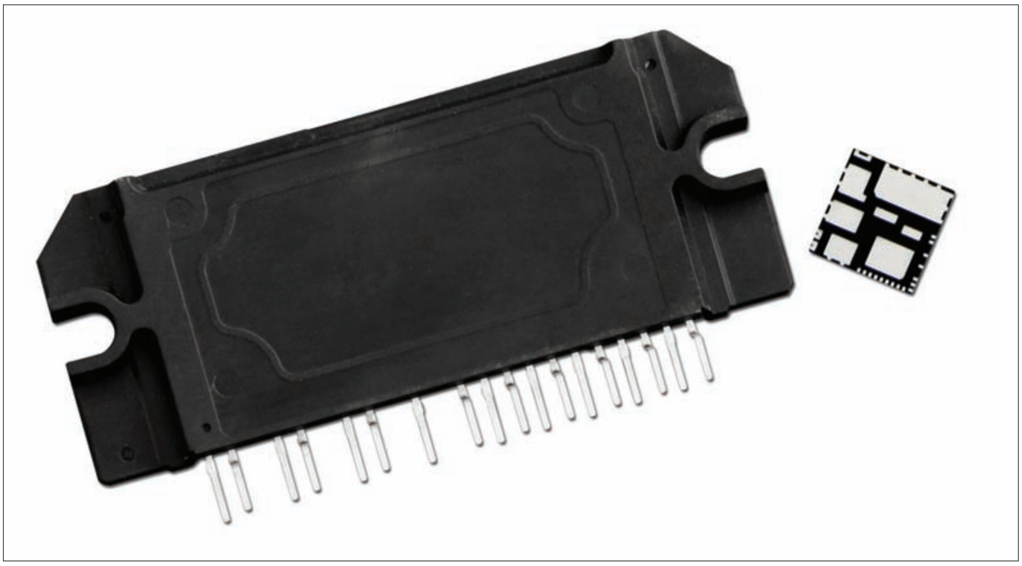


Figure 4: Picture of actual IGBT based (left) and GaN cascade based (right) nominal packaged 400 W inverters used in measurements of Figure 3

IGBTs for motor drive with a 3-switch approach of a matrix converter. Though the advantages of matrix converter topologies have been extensively discussed for at least 20 years, implementation has been hampered by the lack of an adequate bi-directional power switch. GaN based HEMTs are inherently bi-directional capable, enabling the realization of commercially viable matrix converters.

Perhaps the greatest potential innovation for power electronics using GaN based devices is in the field of integration. As GaN HEMTs are inherently integratable, as opposed to state of the art Silicon based power devices, a great revolution in performance, cost, reliability and novel functionality is now made possible. Exciting!

Despite these overwhelming advantages, the adoption rate for GaN based devices will naturally be determined by the design cycles of the power electronic system suppliers, which are typically two to four years. Of course, it is possible that compelling competitive advantages may drive more rapid design cycles as economic factors become more evident.

Programmable Power Management for Small Networks

Modern electronic systems require a large number of rails for DSP, Core, RF PA, IO and Memory. A case in point is Smaller Communications Networks such as Small Cells, Picocells and Femtocells.

Alan Elbanhawy, Exar Corp., Fremont, USA

Exar offers universal PMICs that offer multi-rail DC/DC converters in a small package. These converters are synchronized to minimize board noise and EMI. PMICs offer a host of advanced features from precisely programmable control loop parameters and fault monitoring and reporting to high power conversion efficiency and rail sequencing.

System solution

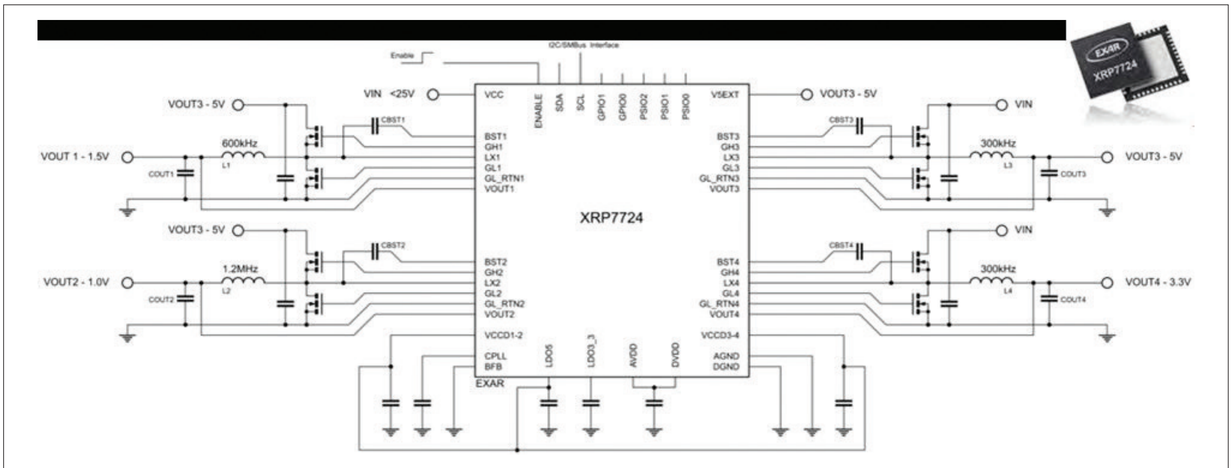
To address all of the above requirements in one elegant and complete solution, the universal PMIC P/N XRP7724 that packs four complete and independent PWM controllers in a TQFN package measuring 7mm x7 mm that feature a patented light load mode for low power dissipation and high efficiency at low output currents (see Figure 1). It provides a number of critical safety features, such as Over-Current Protection (OCP), Over-Voltage Protection (OVP), Over Temperature Protection (OTP) plus input Under Voltage Lockout (UVLO). In addition, a number of key health monitoring features such as warning level flags for the safety functions, Power Good (PGOOD), etc., plus full monitoring of system voltages and currents. The above are all programmable and/or readable from the SMBus and many are steerable to the GPIOs for hardware monitoring by the system controller.

Functional overview

Within the Quad Synchronous Buck controllers integrated MOSFET Drivers with 17 ns and 11 ns rise and fall times will help achieve very low switching losses resulting in higher efficiency allowing the system PCB to operate at lower temperature and hence higher reliability. Figure 2 shows very high efficiency at both low and high end of the load current due to the utilization of light load mode at low output current and PWM at higher loads.

Patented Over-Sampling (OVS) mode guarantees fast transient responses under demanding load conditions. In OVS mode the output voltage is sampled four times per switching cycle. If the voltage goes outside the set high or low limits, the OVS control electronics can immediately modify the pulse width of the GH or GL drivers to respond accordingly, without having to wait for the next cycle to start.

Power supply designers are often faced with limited PCB real estate allocation for the power system forcing them to use all the tools in their arsenal to shrink the size



ABOVE Figure 1: XRP7724 offers four complete PWM controllers

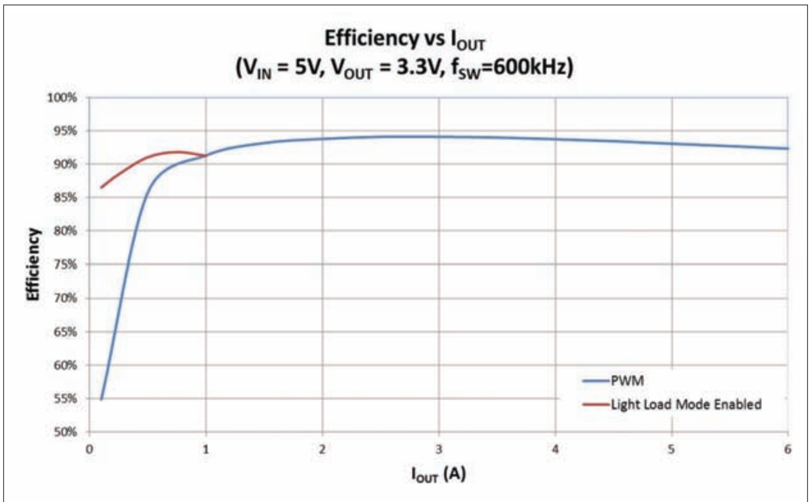


Figure 2: Efficiency at 5 V input to 3.3 V output

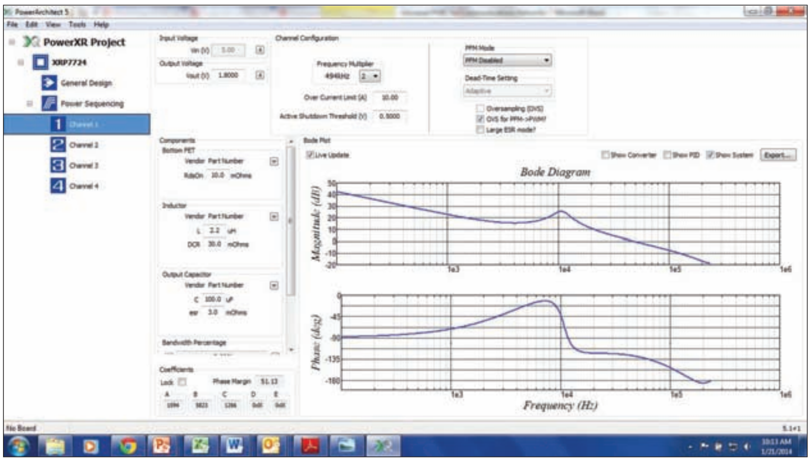


Figure 3: Final PA5.1 screen showing all the selected and calculated parameters

of any converter. To that end, this device allows for setting the switching frequency independently for each channel using Digital PWM 105kHz-1.23MHz Operations with guaranteed synchronous operation between all four channels. Furthermore, since the choice of the switching frequency affects the EMI spectrum of complex system with multiple of rails hence, the final choice will support the design objectives in efficiency, size and EMI.

For maximum flexibility and to allow the system designer total control over the implementation and performance, a sophisticated design tool PowerArchitect^{TM} 5.1 is available. This GUI-based wizard helps with the power train components selection like the output inductors and capacitors as well as the control loop design. XRP7724 offers a programmable 5 coefficient PID control and depending on the user's choice of switching frequency, output voltage and current a Bode Plot will be generated. The user can either accepts it or the PID parameters can be modifed to suit the exact requirements.

Figure 3 depicts the final screen with the selected switching frequency, output filter inductance and capacitance. Also shown are, the PID coefficients, Bode plot, phase margin and the control loop bandwidth for channel 1. All the related parameters are under the user's control to fine tune or completely change. This is the ideal environment for "What if?" scenarios where the response is a mouse click away.

I²C communication

The SMBus Compliant - I²C interface is a valuable tool to enable communication with a System Controller or other Power Management devices for optimized system function. This is achieved through a number of functionalities.

Measurements of per channel input and output voltages and output current allows the controller to gauge the system power demand at any time and implement fine tuning on the fly adjustments to individual rails. This includes voltage margining i.e. incrementally ramp up or down the output voltage for optimum performance like in the case of CPU sleep mode.

Measurement of part temperature is a most valuable reading from the reliability and continuous operation point of view. The system controller can implement software routines to manage power consumption on an overall system basis by allowing consecutive sequencing of power demand when possible rather than simultaneous demand.

At times of low activities, a standby and sleep modes may be implemented by enable and/or disable individual rails or by voltage margining bringing the power consumption to a minimum and reducing the overall demand on the system. Additionally reporting of fault conditions: over voltage, over current and over temperature the system controller can on a dynamic basis adjust all fault limits as well as disabling/enabling faults.

The XRP7724 has two internal Low Dropout (LDO) linear regulators that generate 5.0 V at 130 mA and 3.3 V at 50 mA for both internal and external use.

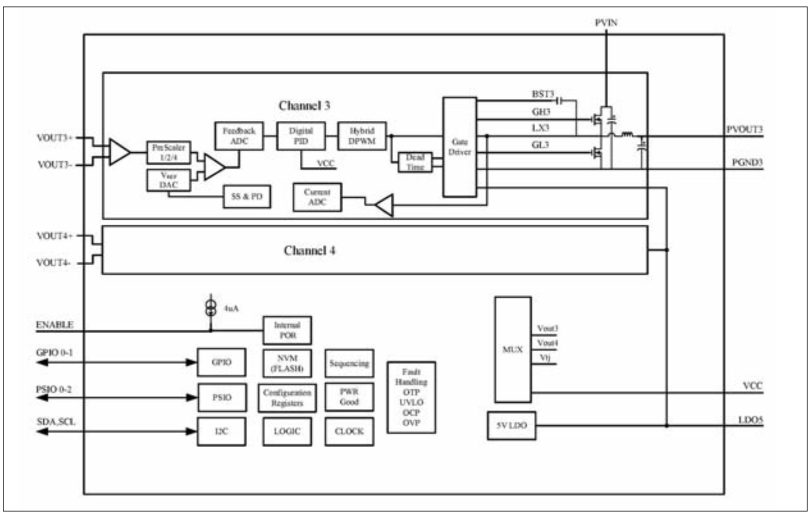
Building block for power modules

The XRP7724 has been used as the quad controller in Exar's XRP9710/11 family of power modules.

The XRP9710 (see Figure 4) and XRP9711 are multi-output, synchronous step-down, programmable power modules that offer high power density and low profile at 2.75 mm with 5 – 22 V inputs. Both devices provide two fully integrated regulators with MOSFETs, inductors, and internal input and output capacitors in a compact 12x12x2.75mm package that support loads up to 6 A each. The XRP9711 also offers two controller outputs that are each capable of driving loads up to 30 A, making it the first module to offer two fully integrated channels and two controller outputs.

These new power modules offer full control via the I²C interface allowing for advanced local- and remote-reconfiguration, full performance monitoring and reporting, as well as fault handling. The output voltages can be programmed from 0.6 V up to 5.5 V without requiring any external components. The XRP9710 and XRP9711 come also with the newly released PowerArchitect 5.1 design tool.

BELOW Figure 4: Block diagram of XRP9710 power module



Conclusion

XRP7724 is an advanced quad channel Power Management IC (PMIC) that is designed to address all the major requirements of the modern power delivery systems in telecommunications products like Small Cells, Picocells and Femtocells. They are the ideal choice for this application with their quad channel synchronous buck controllers with PWM/ light load mode modulation for high efficiency to its comprehensive fault detection and reporting and very small footprints which all translate to high reliability and uncompromising performance

Powering Planet Earth in the 21st Century

In today's society with a "greener and leaner" focus on one's lifestyle, most would agree that increasing energy efficiency is a good thing; in fact, the general consensus seems to be that reducing global energy usage is more than a personal choice, it has become a worldwide priority. While each region of the world is driven by differing needs and requirements, ultimately everyone benefits from increased energy efficiency.

Miguel Mendoza, Micrel, San Jose, USA

The benefits of energy efficiency are far reaching - lower energy bills, improved air quality; reduced greenhouse gases, energy security, more efficient use of dwindling natural resources and deferred infrastructure costs. Numerous studies document the prevalence of economically attractive opportunities for energy savings. The failure to implement these opportunities indicates persistent market and other barriers to efficiency. Government policies are designed to target these barriers and enable the benefits of energy efficiency to be realized [1].

Government activities to accelerate energy efficiency

As the number of electronic devices continues to grow exponentially and as infrastructure and advances in technology bring electricity and electronic products to more and more corners of the globe, ensuring maximum efficiency truly becomes a global imperative. Benefits range from individually focused in that using less electricity saves money on utility bills – to entire governments reaping benefits; including reducing demand on the grid and a reduction in greenhouse gases. In fact, according to the US Department of Energy, Building Technologies Office – Appliance and Equipment Standards states: The cumulative energy savings of standards phased in through 2012 will be about 70 quadrillion British thermal units (quads) of energy through 2020, and will amount to 120 quads through 2030. (The US consumes a total of about 100 quads of energy per year.) The cumulative utility bill savings to consumers of these standards are estimated to be over $900 billion by 2020, growing to over $1.6 trillion through 2030 [2].

To ensure that citizens of the world meet or exceed these projections, governments worldwide are pursuing policies and standards to warrant that the next generation of products both maximize efficiency and reduce energy use as much as possible. Such standards and policies also make it easier for device manufacturers and product designers to meet new requirements. As always, innovation is critical and necessary to achieve ever-more-stringent efficiency targets.

As an example: As of 16 June 2011, only motors that meet or exceed the IE2 level are permitted to be sold and installed within the European Union. From January 2015 onward, all motors will need to meet IE3 specs (IE2 motors can be used if they are controlled by variable-speed drives). The European Union MEPS (Minimum Energy Performance Standard) scheme, which mandates compliance with the IEC 60034-30 energy-efficiency classes, covers most two-, four- and six-pole motors rated from 0.75 to 375kW for power supplies at 50 and 60Hz. It is predicted that some 30 million existing industrial motors in Europe alone will gradually need to be replaced under the MEPS scheme; resulting in energy savings in the order of 5.5 billion kilowatt-hours of electricity each year and a corresponding reduction in carbon dioxide emissions of 3.4 million tonnes [3].

EU at the forefront

One area of emerging technology that is covered by the European Union MEPS policy and that stands to have a significant impact on overall energy usage is the brushless DC (BLDC) motors. A 3-phase BLDC motor is synchronous, it has permanent magnets residing on the rotor and coil windings. These produce electrical magnets on the stator of the motor. Electrical terminals are directly connected to the stator windings; hence there are no brushes or mechanical contacts to the rotor such as in brushed motors. This in turn reduces the energy required to run the motor, all while maintaining the same or greater power output as alternating current (AC) or brushed DC motors.

The use of brushless motors in household appliances alone would lead to enormous savings based on economies-of-scale, which is further increased by its adoption in industrial systems, white goods and even automotive applications. These applications are all related in that they all use relatively high amounts of electricity and offer numerous opportunities for significant energy savings through the adoption of brushless motors (see Table 1).

Brushless DC motors can replace AC motors or mechanical pumps and movements. Key benefits of using brushless motors include: higher efficiency, less heat generated, higher reliability and longer life (because there is no direct

Segments	Policies & Mandates	End Products
White Goods	Europe: Drive Towards Clean Energy & Power Efficiency	Washers Dryers Refrigerators
Industrial	Europe: 3-Phase "Inverter Drive" Power Efficiency Mandate	Pumps Fans Air conditioners Mixers HVAC
Home Appliance	Clean Energy & Power Efficiency Government Subsidies	Pumps Fans Air conditioners Blenders Hand power tools Kitchen appliances

Table 1. **Products benefiting from brushless motor technology**

Parameter	AC Motors	Brushless Motors
Size and Weight	100 Percent	55 Percent
Efficiency	40 Percent - 50 Percent	70 Percent -75 Percent
Speed Control	Difficult	Easy & Linear
Accuracy and Speed	3 Percent - 5 Percent	0.5 Percent
Torque Control	Poor	Excellent
Reliability	Parts Wear	No Wear
Safety	Brush Dust is a Hazard in Dangerous Environments	No Brush Dust

Table 2. Advantages of brushless DC motors

contact from the commutator and electrical terminals such as is found in the brushed motors), safer operation in a dangerous environment (no brush dust generated as in brushed motors), and reduction in overall system weight. Finally, since brushless motors are commutated electronically, it is much easier to control the torque and RPM of the motor and at much higher speeds. Ultimately, the benefits of longer operational lifetime and minimized maintenance translate into lower cost (see Table 2).

Today's engineers use both digital and analog technologies to overcome challenges like motor speed control, rotation direction, drift and motor fatigue. Implementing MCUs provides the ability to dynamically control motor actions so that they respond to environmental stresses and conditions. Brushless motor control does add additional complexity compared to brushed DC or AC motors and the collaboration between digital and analog components becomes very important. For this reason, it is important to work with suppliers who understand the complexities and can work with customers to optimize brushless motor design for each and every target application.

It is a scientifically recognized fact that earth's fossil fuel energy resources are finite and therefore limited. While great progress is being made to identify, harness and make alternative energy sources available and affordable, the very design of tomorrow's electricity-using products will go far towards minimizing their impact on the planet. Just imagine the reduction in energy usage if all of the motors in use today, in every appliance, heating and air conditioning system, and automotive components were replaced with ones that are 25 to 30 percent more efficient. It just goes to show that even a seemingly "small" technology can have a major impact on powering planet earth in the 21st century.

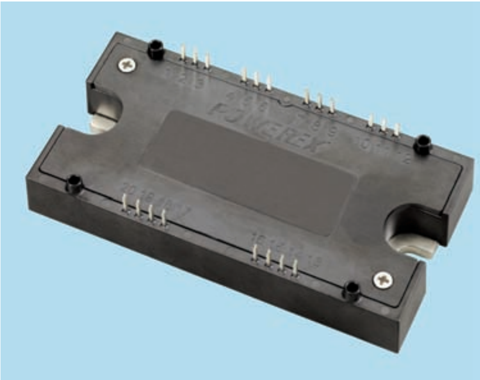
Literature

[1] Energy Efficiency Policy in the United States: Overview of Trends at Different Levels of Government. Elizabeth Doris, Jaquelin Cochran, and Martin Vorum.

[2] US Department of Energy, Building Technologies Office – Appliance and Equipment Standards; http://www1.eere.energy.gov/buildings/appliance_standards/m/history_and_impact.html

[3] Looking ahead to the next generation of energy efficient motors, Alistair Rae, EngineerLive.com.

Powerex SiC Modules Attain RoHS Compliance



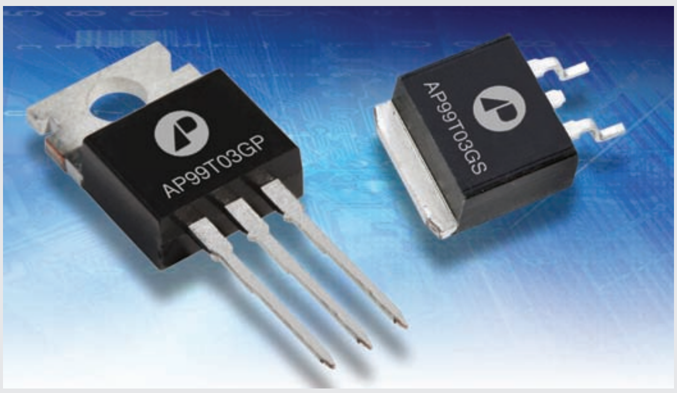
Several Powerex SiC Modules have now been certified RoHS (Restriction of Use of Hazardous Substances) compliant including QJD1210010 and QJD1210011 (Split Dual SiC MOSFET Modules) and QID1210005 and QID1210006 (Split Dual Si/SiC Hybrid IGBT Modules) RoHS regulations ban new electrical or electronic equipment containing more than agreed upon levels of specific substances, including lead, cadmium, polybrominated biphenyl (PBB), mercury, hexavalent chromium, and polybrominated diphenyl ether (PBDE) flame retardants. All four modules are rated at 100A/1200V. These modules can be used in various high frequency applications, including energy saving power systems (fans, pumps and consumer appliances), high-frequency type power systems (UPS, high speed motor drives, induction heating, welding and robotics), and high-temperature power systems (power electronics in electric vehicle and aviation systems).

www.pwrx.com

N-Channel Enhancement-Mode Power MOSFETs

Advanced Power Electronics Corp. (USA) has recently launched new cost-effective N-channel enhancement-mode power MOSFETs offering a fast switching performance and very low on-resistance. The AP99T03GS-HF-3 MOSFET comes in a TO-263 package, which is widely used for commercial and industrial surface-mount applications. Devices are well-suited for low voltage applications such as DC/DC converters, and are also available as the AP99T03GP-HF-3 in a TO-220 through-hole package which is intended for applications where a small PCB footprint or an attached heatsink is required. Both new MOSFETs benefit from simple drive requirements and offer a fast switching performance, very low on-resistance of 2.5 mΩ, a breakdown voltage of 30 V, and a continuous drain current of 120 A. The components are halogen-free and fully RoHS-compliant.

www.a-powerusa.com



650/800 V MOSFETs

STMicroelectronics is expanding three of its advanced high-voltage power MOSFET families with the introduction of two new power packages. The PowerFLAT™ 5x6 HV and PowerFLAT 5x6 VHV packages provide the large insulation path lengths and clearances required for operation at up to 650 V or 800 V, within the same 5 mm x 6 mm footprint of a standard 100 V PowerFLAT 5x6. This is 52 % smaller than the popular DPAK footprint. In addition, the package is only 1 mm high and features a large exposed metal drain pad that maximizes heat dissipation into PCB thermal vias.

This combination of features simultaneously increases high-voltage capability, ruggedness, reliability, and system power density. In addition, ST has started sampling two new 600 V fast-switching MDmesh II Plus low gate charge MOSFETs in PowerFLAT 5x6 HV.

www.st.com/mosfet

Power-Monitoring IC

Microchip announced a new power-monitoring IC, the MCP39F501. This device is a single-phase power-monitoring IC designed for real-time measurement of AC power. It includes two 24-bit delta-sigma ADCs, a 16-bit calculation engine, EEPROM and a flexible two-wire interface. An integrated low-drift voltage reference in addition to 94.5 dB of SINAD performance on each measurement channel allows accurate designs with just 0.1 % error across a 4000:1 dynamic range.

The MCP39F501 allows designers to add power monitoring to their applications with minimal firmware development. In an effort to improve power-management schemes in power-hungry applications, such as data centers, lighting and heating systems, industrial equipment and consumer appliances, power-system designers are driving the need for enhanced power monitoring solutions. This includes requirements for better accuracy across current loads, additional power calculations and event monitoring of various power conditions. The built-in calculations include active, reactive and apparent power, RMS current and RMS voltage, line frequency, power factor as well as programmable event notifications.

www.microchip.com/get/G8CX

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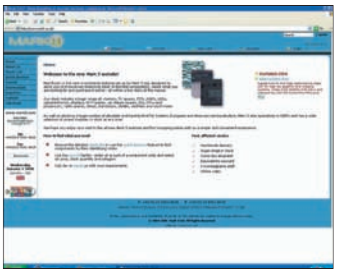

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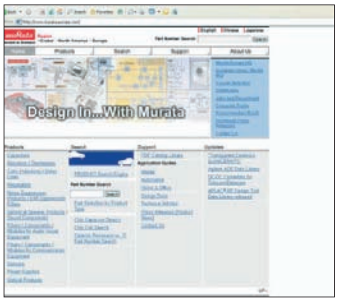

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