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Bodo´s Power Systems®

Electronics in Motion and Conversion

March 2014

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powerguru.org

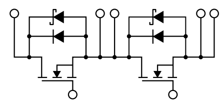
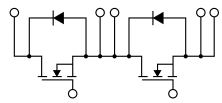
The Gallery

Choose ROHM SiC Products for Your Power Component Needs

Class-leading SiC power components are available in a range of output currents.
From SiC ingots to finished components, we offer a one-stop production and development system that guarantees a stable supply of high-quality SiC power products.

■ Full SiC Power Modules

Specifications: 45.6×122×17mm(Including pins)

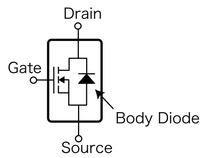
BV_{DSS}	I_D max	Structure: Half-Bridge Circuit
1200V	120A	BSM120D12P2C005 
	180A	BSM180D12P2C101 

■ SiC MOSFETs

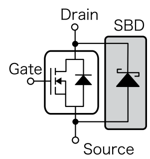
TO-247

BV_{DSS}	$R_{DS(on)}$	I_D max
1200V	80mΩ	35A

SCT Series
SiC-MOSFET



SCH Series
SiC-MOSFET+SiC-SBD
Integrated Package



■ SiC Schottky Diodes

TO-220AC 2L

V_R	I_F
650V	6～20A
1200V	5～20A

TO-220FM 2L

V_R	I_F
650V	6～20A

TO-247

V_R	I_F
650V	10～20A *1 20～40A *2
1200V	5～20A *1 10～40A *2

*1: 1 pin *2: overall package

D2PAK

V_R	I_F
650V	6～10A

■Next-Generation SiC Power Modules (Under Development)

Applications: EV/HEV, industrial equipment, etc.

ROHM Co.,Ltd.
www.rohm.com

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Events

European Smart Grid Cyber and SCADA Security,
London, UK, March 10-11
http://www.smi-online.co.uk/utility/uk/conference/european-smart-grid-cyber-security

EMC 2014,
Duesseldorf, Germany, March 11-13
www.mesago.de/en/EMV/home.htm

APEC 2014,
Fort Worth, Texas, March 16-20
www.apec-conf.org/

battery university,
Aschaffenburg, Germany, March 25-27
www.batteryuniversity.eu

New Energy Husum 1014,
Husum, Germany, March 20-23
www.new-energy.de/

Time for a Texas Steak

We will soon be in Texas, to attend the APEC Advanced Power Electronics Conference once again. Fort Worth was the hosting city for APEC in March 2011.

In that same month, the disaster of Fukushima also took place. As a result, people all over the world realized that nuclear power has risks that must be eliminated for a secure life on Earth. Renewable energies took on a new urgency - wind, solar and hydrogen systems became the preferred solutions. Three years after the Fukushima disaster, officials are correcting the permanent contamination levels to higher levels. A region that had been home was lost forever for human habitation.

Some high-level politicians, remote from reality, still vote for nuclear power, while the population and local politicians are taking action to achieve renewable energy. On January 31st delegates from Fukushima, Japan and further Asian countries, America, Australia and Europe gathered in Fukushima for the International Community Power Conference. After three days of inspiring, encouraging and very interactive exchange of ideas and experiences, they have agreed on the Fukushima Community Power Declaration. You will find more details about this declaration as a news item on page 10 of this issue.

We need to be careful with our world. We have only the one, and it must be kept safe for our children and future generations. Industrialization in the last few centuries was based on fossil energy sources. It moved our standard of living forward, but had unwanted side-effects. We now realize we must be careful with innovations that increase energy consumption. So the challenge is to the engineering community to develop a wide spectrum of energy-efficient solutions.

A broad range of wide band gap semiconductors are now being offered. Not only are manufacturing companies offering standard parts, but distribution channels worldwide have GaN and SiC devices on stock. A generational change from silicon semiconductors to wide band gap semiconductors is underway. These will contribute to continued improvement in energy usage.

I am looking forward seeing you at APEC to discuss progress in new technology. After that, the next big conference will be PCIM Europe, in Nuremberg. While Texas is a

great place for a delicious steak, Nuremberg is the place for white asparagus. So each event has its own culinary highlights to compliment the technology.

To learn more about the capability of batteries, mark your calendar for the Battery University Forum in Aschaffenburg, Germany, at the end of March. The New Energy Conference at Husum, Germany, also in March, presents solutions for "green" power generation. At Husum, small wind power and other green solutions are on the agenda. March is a busy month, but with the help of my editors Marisa and Don, we will attend as many shows as possible during the year, looking for important information to fuel upcoming issues of the magazine.

Communication is the only way to progress. We delivered twelve issues last year, each month, on time, every time. With this March issue we've now published 34 technical articles amongst 188 pages so far this year. As a media partner, Bodo's Power Systems serves readers across the globe. If you speak the language, or just want to have a look, don't miss our Chinese version: www.bodospowerchina.com.

My Green Power Tip for March:
Turn off TV if nobody is watching. Our TV set turns off automatically if nobody has pressed any button on the remote control for 3 hours – a good feature. We may have fallen asleep, while the Watt-hours never do.

See you soon at APEC in Texas, and around the world.

Best Regards

World Summit for Small Wind

For the fifth time, WWEA, in cooperation with New Energy Husum, will hold the 6th World Summit for Small Wind, WSSW2014, from 20-22 March 2014. The WSSW2014 takes place on the occasion of the New Energy Fair Husum, the international trade fair for small wind and decentralized renewable energy.

The WSSW2014 will feature "Small Wind - Success Stories from all over the World", an overview of the benefits and impacts of the small wind industry in different countries and regions.

Stefan Gsänger, WWEA Secretary General: "The World Summit for Small Wind 2014 will highlight what small wind turbines can and do contribute to the energy generation worldwide. We will present a unique global overview of the small wind industry within three days. And small wind companies can meet their potential clients during the summit as well as at the accompanying trade fair, the largest small wind fair in the world, with 50 small wind exhibitors and 15'000 visitors."

A Scientifc Committee comprising experts from Australia, China, Cuba, Ethiopia, Germany, Spain, and USA put together a high-quality program with leading small wind experts from around the world: Speakers from China, Cuba, Germany, India, Italy, Korea, the Netherlands, Spain, Turkey, and USA will present latest achievements and challenges of the small wind sector. Also the International Renewable Energy Agency IRENA will present its activities in the field of small wind turbines.

http://www.new-energy.de/en/conferences

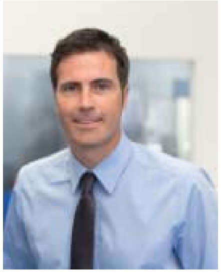
Davos Congress Centre Installs PV System

Just in time for the World Economic Forum's Annual Meeting, Davos Congress Centre and swimming hall launches the first phase of its 340 kWp PV system which includes SolarEdge inverters and power optimizers. The Davos Congress Centre, one of the Alp's most modern congress venues, identified SolarEdge products as next-generation PV technology. The module-based optimization and monitoring offered by SolarEdge provides the Davos Congress Centre increased system uptime, enhances energy yield assurance, and improves visibility into system performance. Not only was SolarEdge

technology simulated to provide an increased energy yield of more than 12% with the initial design, but its module-level MPPT allowed a 10% increase in the amount of modules on the roof in the first phase, further improving energy yield. Specifically, the Davos Congress Center was able to place PV modules on the Atrium roof of the building, which would not have been possible with a traditional inverter.

www.solaredge.com

7th batteryuniversity.eu Rechargeable Battery Developer Forum



From 25th to 27th March 2014 in the Stadthalle Aschaffenburg.
The three-day trade event again kicks off with two half-day intensive seminars on the topics of Battery Packs developed properly and Lithium Ion Rechargeable Battery Technologies/Battery Management Systems on 25th March. Offered for the first time in 2013, each year around 120 participants make use of the opportunity to have their knowledge updated by batteryuniversity.eu experts in just a few hours in the run-up to the developer forum.
Dr. Mählik expects more than 500 participants for the actual expert forum on 26th and 27th March, when around 30 top-class experts will be giving lectures on the latest trends from research and development. This year, Kurt Sigl, President of the Federal Association for Emobility (BEM) and Dr. Reiner Korthauer, Director of the Trade Association for Transformers and Power Supplies at the Central Electrotechnology and Electronics Industry Association (ZVEI) have been engaged as key speakers; they will be opening both morning programs with guest lectures on the topics of Electromobiliy and Stationary Energy Storage. Further key aspects this year are formed by the presentation of current and coming cell generations, the latest battery packaging methods, innovative charging and safety concepts and also problem-solving approaches for OEMs with regard to rechargeable battery storage, fire warning technology, the REACH regulation and much more. In order to also allow interested persons who do not speak German to attend this renowned developer forum, expert lectures in German will be translated simultaneously into English as in 2013.
The developer forum is accompanied by a trade show which is open from 08:30 to 18:00 on the 26th and 27th of March at which more than 30 companies will present their products, solution approaches and services on a total of 2000 m2 of exhibition space again this year.

www.batteryuniversity.eu

www.entwicklerforum-akkutechnologien.de

Among the World's Most Sustainable Companies

Infineon Technologies AG has been listed in the prestigious Sustainability Yearbook by Swiss investment company RobecoSAM for the fourth consecutive year. Hence the German semiconductor manufacturer ranks again among the world's most sustainable companies.
In September 2013, Infineon had been listed in the Dow Jones Sustainability Index – also for the fourth time in a row. The Sustainability Yearbook is based on the index score. The requirements to be listed are more challenging than in the past. This year it was not enough for companies to rank amongst the top 15 percent of their industry to be listed – they also had to achieve a score within the 30 percent of the best-performing companies in their industry.
The Sustainability Yearbook is the world's most comprehensive publication on corporate sustainability. Every year, it assesses and documents the sustainability performance of over 2,000 corporations. This year's edition remarks the increased power of entities such as local authorities, communities and NGOs and how their actions can affect companies' revenues and reputations.
"The renewed inclusion in the Sustainability Yearbook demonstrates that we don't just talk about sustainability, but we practice it through our daily operations. We have built a positive relationship with our stakeholders such as employees, customers, suppliers, investors, communities and the government, and work with them to create a real sustainable business. This has been recognized in the listing of Infineon among the ten best companies in the semiconductor sector," says Dominik Asam, Chief Financial Officer of Infineon Technologies AG and responsible for sustainability.
About Infineon

www.infineon.com

New Version of Component Selector Software

Würth Elektronik eiSos has released a revised and expanded version of the Component Selector. Six modules have been added to the four existing ones, making this selection tool one of the world's most comprehensive component databases to be provided by a single manufacturer.
In the field of EMC components, cable ferrites and common mode chokes are now available in addition to PCB ferrites. These modules allow users to analyse and compare technical values and impedance curves for all products. Within the component characteristic curve, filters help users find the right components quickly and easily.
In the power inductors module, the right inductor for non-insulated DC/DC converters can easily be determined. The Component Selector also calculates wire and core losses and, based on these losses, calculates the temperature increase of the component. In the field of power supplies, there is also a module to help quickly and easily configure flexible transformers for isolated DC/DC converters to suit the relevant input and output values. For use in active PFC circuits, there is now also a module for determining the right PFC choke.
The most significant extension of the software was for signal and communications products. As well as the existing RF inductor module for selecting components according to frequency, for adjusting antenna for example, three further modules have now been introduced. For signal and backlight LEDs, by entering the resistance and input voltage values for every freely definable forward current, the expected brightness of the LED can be displayed.
A particularly practical addition is the module for discrete LAN transformers or integrated RJ45 LAN transformers, which enables users to search and filter components by the internal connections or land pad. This means that the right solutions for existing products can be found in no time at all.
You can install the free Component Selector by downloading the software from:

www.we-online.de/component-selector

www.we-online.com

Innovatively Bridging Supply and Demand

R&D Electronics International Co., Limited, which is a B2B e-commerce portal specialized in online sales and marketing of power electronics, signed a Cooperation Agreement with TECHSEM , the leading Chinese manufacturer of power electronics. Under this agreement, both parties form a strategic partnership in developing international markets.

As an unique publicly listed company that mainly produces power semiconductor devices in China, TECHSEM maintains the leading position in the domestic market. R&D Electronics provides the professional e-commerce platform, which is focusing on the power electronics industry, opening for the world market.

“We are fully prepared for the overseas market by improving product quality and quality management system. Through the cooperation with R&D Electronics, we will be able to serve more overseas customers with our high quality products and excellent services”so Mr. Yan Xing, president of TECHSEM.

“We are very pleased to form the strategic partnership with TECHSEM. Innovatively bridging supply in China and demand on power electronics in the world, that is exactly our mission”said Mr. Lixin Ren, CEO of R&D Electronics International Co., Limited.

Obviously, such cooperation leads to a win-win-win situation. It’s the customers who benefit the most.

Picture Mr. Yan Xing, President of TECHSEM; Right: Mr. Lixin Ren, CEO of R&D Electronics

www.rd-ebusiness.com

Next Generation of the TriQuint GaN Tech Hub

Richardson RFPD, Inc. announced the launch of the next generation of the TriQuint GaN Tech Hub, a micro-website featuring the latest news on gallium nitride (GaN) innovations and product releases from TriQuint. The TriQuint GaN Tech Hub will also feature a robust library of TriQuint GaN technical resources, including white papers and videos, as well as links to online purchasing, the option to sign-up for product updates via email, and personal insights from TriQuint and Richardson RFPD design engineers. It is the second generation of the TriQuint Tech Hub, redesigned to reflect TriQuint’s evolved brand, as well as its latest GaN-based portfolio for commercial and defense applications.

TriQuint continues to be an industry-leader in meeting the demand for GaN technology worldwide. It is closely involved in several research and development programs sponsored predominately by the Defense Advanced Research Projects Agency (DARPA), the Air Force Research Lab, and the Office of Naval Research, and they continue to set the pace for GaN-based standard product releases.

Recent launches include a Ka-band power amplifier (the TGA2595), a broadband low noise amplifier (the TGA2611), and a 285W (P3dB) HEMT (the T1G2028536-FL) that cover a wide range of applications with greater output power at superior efficiency, enabling smaller systems and reduced part counts.

www.richardsonrfpd.com/TriQuint-GaN

Japanese Regions Transition to 100% Renewable Energy

100% RENEWABLES

Local governments across Japan are seeking to supply their regions with 100% renewable energy, three years after the major earthquake which resulted in a nuclear disaster. At the Community Power Conference in Fukushima, the Founding Partners of the Global 100% Renewable Energy Campaign welcome the decision of Fukushima prefecture to be entirely energy self-sufficient by 2040 using only renewable sources. Among them are the Japan-based Institute for Sustainable Energy Policies (ISEP), World Future Council (WFC), World Wind Energy Association (WWEA) and the coordinating organization of the German 100% Renewable Energy region network deENet.

The Great East Japan earthquake, the subsequent tsunami and the disaster at the Fukushima-daiichi nuclear power plant in March 2011 encouraged the people of Fukushima to reassess their energy system and to revitalize industry in the shattered region. “This led to a vision to transition to renewable energy as a pathway forward,” says Tetsunari IIDA, Executive Director of ISEP. Fukushima prefecture now has an official commitment to cover 100% of primary energy demand in Fukushima with renewable resources by 2040.

In the process of revitalizing Fukushima, the authorities have adopted the slogan “Future From Fukushima”. Stefan Gsänger, Secretary General of the World Wind Energy Association, says “In line with the new slogan, it is an important message that Japanese regions are sending from Fukushima when joining the global movement of cities, communities, regions and countries celebrating their recent transition to 100% renewable energy. As we see in an increasing number of places around the world, 100% renewable energy is technically and economically viable.”

www.WWindEA.org

www.go100re.net

European Sales Strategy with Firefly Technology Partnership

Vicor Corporation announced the strategic expansion of its sales and support network in Northern Europe via a partnership with leading manufacturers’ representative Firefly Technology. With this initiative Vicor is strengthening its investment and market reach in this high-value region, establishing and cultivating new customer relationships in close cooperation with its regional distributors.

Founded in 1996 and headquartered in the UK, Firefly Technology will represent Vicor in the UK, Ireland, Denmark, Sweden, Finland and Norway, working in concert with Vicor’s distributors to identify sales opportunities and penetrate new markets. Firefly Technology brings to Vicor keen insight into the Northern European market, and provides its customers with invaluable technical guidance at every stage in the system development cycle, from concept to final design.

www.vicorpower.com

SPICE Models for High Power Gallium Nitride Devices in Automotive Applications

GaN Systems Inc. is presenting a technical paper at APEC describing the application of SPICE models developed for very high power GaN devices and integrated GaN drive circuits in automotive applications.
At present, drive train power requirements of most hybrid vehicles (HVs) and electric vehicles (EVs) are met by using silicon IGBT devices, but it is expected that gallium nitride will take over as the technology of choice for this market in the near future, as GaN power transistors provide greatly enhanced performance in these applications, thanks to lower on-resistance and minimal switching losses compared to silicon-based semiconductors.
GaN Systems' presentation describes the use of advanced thermally augmented SPICE models which were developed to enable large area GaN devices to be simulated in conjunction with an integrated GaN driver, demonstrating how gallium nitride devices can be used in the very wide temperature ranges and high electrical noise environments found in automotive applications. The presentation will be given by John Roberts, Chief Technical Officer, who co-authored the paper with colleague Hughes Lafontaine.
At the exhibition running alongside the conference, GaN Systems' is showcasing its range of gallium nitride power switching solutions for power conversion applications featuring the company's proprietary Island Technology™. GaN Systems' high power devices overcome the limitations of today's silicon-based semiconductors and bring significantly better performance and efficiency to power conversion applications for alternative energy and power supply applications in addition to electric and hybrid vehicles.

www.gansystems.com

$70 Million Energy Power Electronics Development Award

RFMD announced that it will play a key role in developing power electronics to support the next generation of clean energy in the U.S. RFMD is a foundry and product design/development partner to North Carolina State (NC State) University's Next Generation Power Electronics Innovation Institute, which was awarded a 5-year $70 million contract from the Department of Energy to lead next generation power electronics manufacturing. RFMD was one of four institute partners invited to meet U.S. President Barack Obama at a ceremony to announce the contract award at NC State in Raleigh, N.C.
RFMD will offer open foundry services to support the NC State-led program and help accelerate the development of key wide bandgap (WBG) semiconductor products including RFMD's Gallium Nitride- (GaN-) based devices needed to increase the reliability and efficiency of the next generation power grid. Wide bandgap semiconductors offer a new opportunity to jumpstart the next generation of smaller, faster, cheaper and more efficient power electronics for personal devices, electric vehicles, renewable power interconnection, industrial-scale variable speed drive motors and a smarter, more flexible grid.

www.rfmd.com

First ChiP Power Modules

380 VDC input ChiP bus converter modules enable DC distribution with 98% efficient conversion to 48 V at 115 W/cm³ power density

Vicor Corporation unveiled the first module utilizing its Converter housed in Package (ChiP) power component platform. Vicor's new ChiP bus converter modules (BCM®) supply 1.2 kW at 48 V with 98% peak efficiency and 115 W/cm3 power density. Breakthrough performance – 4X the density of competing solutions – enables efficient, high voltage DC distribution infrastructure in datacenter, telecom, and industrial applications.

Converter housed in Package (ChiP) Platform

Vicor's ChiP platform sets best-in-class standards for a new generation of scalable power modules. Leveraging advanced magnetic structures integrated within high density interconnect (HDI) substrates with power semiconductors and control ASICs, ChiPs provide superior thermal management supporting unprecedented power density. Thermally-adept ChiPs enable customers to achieve low cost power system solutions with previously unattainable system size, weight and efficiency attributes, quickly and predictably. The advent of ChiPs embodies a modular power system design methodology enabling designers to achieve high performance, cost-effective power systems from AC or DC sources to the Point of Load using proven building blocks.

"ChiPs will enable power system architects to overcome the power density constraints imposed by conventional power solutions," said Patrizio Vinciarelli, CEO, Vicor. "ChiPs maximize performance while minimizing development cost and time to market, yielding superior solutions with the flexibility and scalability of modular building blocks."

New VI Chip Bus Converter Modules

With a nominal input voltage of 380V and a K-factor of 1/8, Vicor's new ChiP BCM fixed-ratio power converters supply an isolated 48V distribution bus with a peak efficiency of 98%. With its input range of 260 to 410 V, the new BCM supports outputs ranging from 32.5 V to 51.25 V. BCMs are based on Vicor's ZCS/ZVS Sine Amplitude Converter™ topology and operate at a 1.25 MHz switching frequency, providing fast response time and low noise operation.

Offered in the 6123 ChiP package, the new 380 VDC VI Chip BCMs measure 63mm by 23mm, with a height of only 7.3mm. Initially offered as a through-hole device, package options will also include SMD variants. ChiP BCMs may be paralleled to provide multi-kW arrays and are capable of

bi-directional operation to support battery backup and renewable energy applications. Standard BCM features include under-over-voltage lockout, over-current, short circuit and over-temperature protection. ChiP BCMs incorporate digital telemetry and control features that can be configured to meet customer requirements.

"The roll-out of high voltage DC distribution infrastructure is yielding reduced power consumption and operational costs for datacom and industrial facilities," said Stephen Oliver, VP of VI Chip product line, Vicor. "ChiP BCMs provide superior efficiency, density and flexibility – the hallmark benefits of the ChiP platform."

Pricing and Availability

Vicor's new 6123 VI ChiP BCMs are available today. Pricing for OEM quantities is $120.00. Visit the website for more information. To order, email custserv@vicorpower.com or call 00 800 8426 7000.

About Vicor Corporation

Headquartered in Andover, Massachusetts, Vicor Corporation designs, manufactures and markets innovative, high-performance modular power components, from bricks to semiconductor-centric solutions, to enable customers to efficiently convert and manage power from the wall plug to the point of load. Complementing an extensive portfolio of patented innovations in power conversion and power distribution with significant application development expertise, Vicor offers comprehensive product lines addressing a broad range of power conversion and management requirements across all power distribution architectures, including CPA, DPA, IBA, FPA™ and CBA. Vicor focuses on solutions for performance-critical applications in the following markets: enterprise and high performance computing, telecommunications and network infrastructure, industrial equipment and automation, vehicles and transportation and aerospace and defense electronics.

www.vicorpower.com

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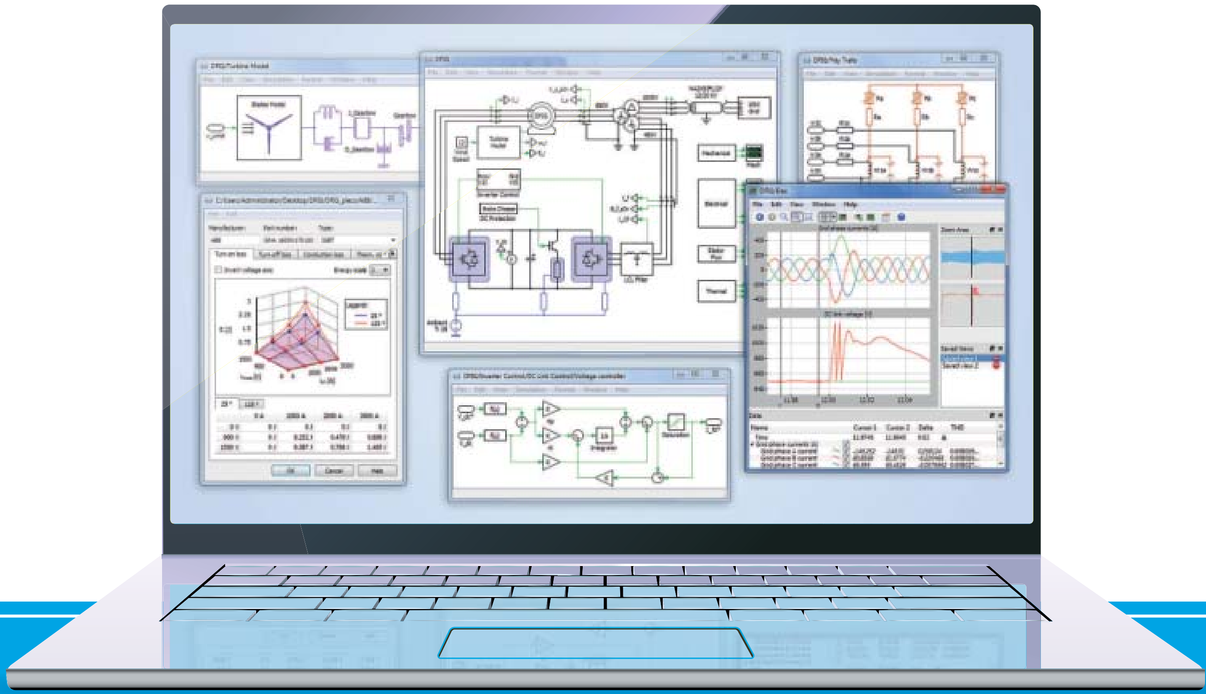

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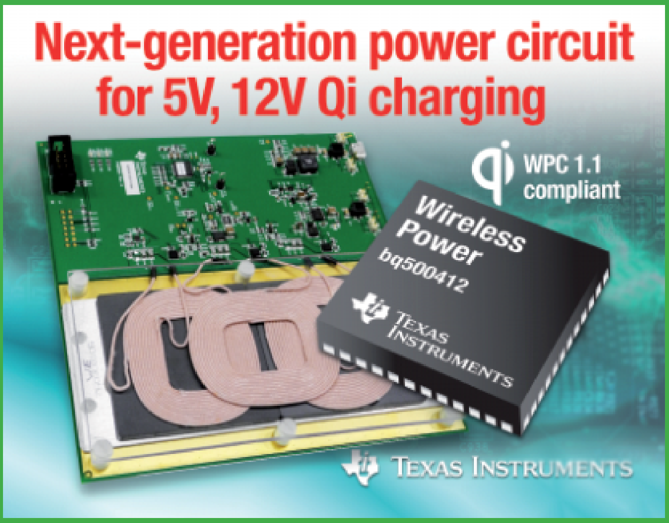
Transmitter Solution with Foreign Object Detection for Qi Wireless Charging Stations

Integrated WPC 1.1-compliant controller cuts component count in half, gives smartphone users greater flexibility to charge from 5-V or 12-V charging stations

Texas Instruments introduced its next-generation wireless power transfer solution with foreign object detection that will allow designers to bring to market 3-coil, 5-V and 12-V A6 charging stations compliant with the Wireless Power Consortium (WPC) 1.1 specification. The bq500412 controller, which is shipping in volume production, requires half the components compared to other solutions.



To order samples and a development kit, visit: www.ti.com/bq500412-pr-eu

Giving smartphone users an improved charging experience, the bq500412 integrates all functions required to control wireless power delivery from the charging station to a receiver circuit used in a Qi-enabled smartphone or other device. In addition to 12-V charging pads, the circuit can be combined with a boost converter to create a 3-coil, 5-V USB charging pad, while taking advantage of a Dynamic Power Limit™ feature to ensure quality operation independent of the power capability of the port. The bq500412 also supports an enhanced foreign object detection scheme, which makes it easier for all designers to implement the requirements of the WPC1.1 specification.

Features and benefits of bq500412:

Complete WPC 1.1 Qi-compliant design for 12-V, A6 charging stations with a minimum 70-mm by 20-mm.

Foreign object detection, as mandated by WPC1.1 specification, comes standard on the controller, which features improved accuracy with intelligent power transfer mechanism.

Intelligent power delivery: TI's Dynamic Power Limit technology allows the transmitter to work from either a USB port or low-power adapter.

TI and wireless power

TI's wireless power management products and support fuel design engineers' imaginations to develop innovative, efficient wireless charging capabilities for smartphones, tablets and other portable electronics, and design wireless power charging transmitters ranging from stand-alone charging pads to those embedded in cars and furniture. The company is the leading developer of power integrated circuits that support WPC's Qi standard. TI also is a member of the Alliance for Wireless Power (A4WP) and Power Matters Alliance (PMA).

Availability and pricing

The new bq500412 wireless power transmitter, which is available in volume production through TI and its worldwide network of authorized distributors, comes in a 48-pin, 7-mm by 7-mm QFN package with a suggested resale price of US$2.93 each in 1,000-unit quantities.

Find out more about TI's wireless power solutions, application notes and evaluation modules:

- Download a white paper to learn about different wireless power design requirements, including the differences between WPC, A4WP and PMA.
- Order the new bq500412EVM-584 evaluation module and download an application schematic to get started on Qi-compliant wireless power transmitter design.
- Video of TI's wireless power demonstrations at CES2014 in Las Vegas.
- Join the TI E2E™ Power Community to ask questions and help solve problems with fellow engineers.

TI analog for consumer electronics

TI's broad range of power management and analog signal chain products offers design engineers the high performance, low power and integration they need to create innovative and differentiated consumer electronics. TI is engineering the future with gesture recognition, touch feedback, advanced battery charging, audio, health technology and more. Learn how analog products improve how we live, work and play with TI Analog Solutions for Consumer.

www.ti.com

The North is in Front

Innovation Cluster Power Electronics for Renewable Energy

By Detlef Friedrich, Fraunhofer-Institut für Siliziumtechnologie ISIT, Germany

In times of globalisation and export oriented economy regional networking between industry and academic institutions is still an element for strengthening innovation and competiveness. A three column model consisting out of applied research at Fraunhofer institutes, basic research at universities and R&D transfer for innovative products by industry is an efficient way to create economic success, knowledge and employment for regional development.

Based on this approach the Fraunhofer society in Germany together with the local governments are funding currently 23 so called Innovation Clusters which are focussed on strategic topics in respective regions. The strategy means: strengthening the strength by regional networking.

novation Cluster focussed on wind energy related topics.

In Schleswig-Holstein the Innovation Cluster Power Electronics for Renewable Energy is already working since January 2013. The Innovation Cluster in Niedersachsen will start soon in 2014.

This activity is fitting well to the successful Competence Center of Power Electronic Schleswig-Holstein (Kompetenzzentrum Leistungselektronik Schleswig-Holstein KLSH) which was founded in 2008 with the same intention to take benefit from regional networking between Fraunhofer ISIT, universities and industry.

Schleswig-Holstein, in between the North- and Baltic See can offer a lot. Next to beautiful landscape and typical northern weather

One of the natural highlights of northern Germany is the renewable energy by wind power.

More than 11 GW nominal power are currently installed in the German federal states Schleswig-Holstein and Niedersachsen which are providing about one third of the total wind energy in Germany. For offshore wind parks no better location will be found than North- and Baltic See offering the highest potential for harvesting wind energy in a continuous mode. Here more than 20 offshore wind parks are projected and approved.

Therefore, many companies, including SMEs, like wind power plant manufacturers, OEM component suppliers up to companies for projecting and operating wind parks are located in Schleswig-Holstein and Niedersachsen.

This economic infrastructure gives the ideal precondition to establish a Fraunhofer In-

we also have power electronics and wind energy in large quantities. More than 80% of the gross electrical power consumption is covered by renewable energy with a wind energy share of 50% in 2012. For comparison the share of the renewables on the total German gross electrical power consumption amounts to 23 % with 8% provided by wind power.

Let's speak about failure rates and correlated down times of wind power plants. Statistics show that 15-20 % of loss rate are due to converter failures. Having in mind lifetime specification of 20 years for electronic components especially for offshore operation under critical maintenance conditions special need for actions becomes obvious.

Hence, the Innovation Cluster Power Electronics for Renewable Energy aims at the improvement of power electronic components for wind power plants in the MW range with regard to increased efficiency, reliability

and lifetime.

New components for wind power converters will be developed and tested all along the industrial value added chain. Application specific Silicon power devices (IGBTs) suitable for innovative assembly techniques, power modules with highest reliability based on sintering and copper wire bonding, efficient converter topologies and driver circuits as well as new mechatronic concepts are the base for an advanced power stack generation. A modular 3-phase power stack demonstrator with a rated power of 1 MW will be developed and tested for the application in back to back full power converter.

The consortium is consisting of the companies Vishay Siliconix Itzehoe GmbH, Danfoss Silicon Power GmbH, Reese & Thies and Senvion Wind Energy Solutions as well as the academic institutions Christian-Albrechts-University of Kiel, University of Applied Sciences Kiel and the University of Applied Sciences Westküste Heide, all located in the federal state of Schleswig-Holstein. The Fraunhofer Institute for Silicon Technology ISIT in Itzehoe is the coordinator of this Innovation Cluster in Schleswig-Holstein.

The political interests of the local government are represented by the "Wirtschaftsförderung und Technologietransfer Schleswig-Holstein GmbH WTSH". A governmental funding is given within the framework of "Zukunftsprogramm Wirtschaft" for European regional development which is supported by the Ministry of Economy of Schleswig Holstein.

In addition to those activities the Innovation Cluster of the German federal state Niedersachsen is addressing complementary tasks such as analysis of failure causes, conditioning monitoring and life time predictions as well as failure tolerant system concepts for power electronics in wind power plants.

This Innovation Cluster of Niedersachsen is coordinated by the Fraunhofer Institute for Wind Energy and Energy System Technology IWES.
Both Innovation Cluster activities complement one another in terms of expertise, technical cooperation and coordination of joint workshops.
With regard to „Energiewende“ in Germany the Innovation Cluster Power Electronics for Renewable Energy is a further technological building block for the successful implementation of this challenging project in the future.
In this context the German Federal Ministry of Economy has launched a call for proposals for the so called “Show Window Intelligent Energies” as demonstrator projects for the “Energiewende”. It is the goal to demonstrate 100% security of energy supply and system stability by means of intelligent grids driven by renewable energy inside so called model regions which one could be the north.

Within the next years Schleswig-Holstein will be the first federal state in Germany which will cover the total electrical energy consumption by renewable energies mainly coming from wind power. The target for the year 2023 is the provision of electrical energy by factor 3 higher than the own consumption. The joint effort of the Ministry of Economy and the Ministry of “Energiewende” in Schleswig-Holstein, as well as the industry, the academic institutions and the Fraunhofer Institute ISIT will give an important contribution for the success of the “Energiewende” in Germany.
The north is in front.

www.isit.fraunhofer.de

Electronics Industry Digest

By Aubrey Dunford, Europartners

Samsung Electronics and Apple, which together consumed $ 53.7 billion of semiconductors in 2013, remained the top semiconductor buyers in 2013, increasing their combined semiconductor demand by 17 per cent, so Gartner. Samsung Electronics and Apple have topped the semiconductor consumption table for three years running, with their share of the design total available market (TAM) rising from 12 per cent in 2011, to 17 per cent in 2013. The top 10 companies bought $ 114.0 billion of semiconductors, to account for 36 per cent of semiconductor vendors' worldwide revenue in 2013.

SEMICONDUCTORS

Texas Instruments announced restructuring charges for cost-saving actions in its Embedded Processing division and in Japan. The company is not exiting any markets or discontinuing any existing products but will reduce investments in markets that do not offer sustainable growth

and returns. The savings will reflect the elimination of about 1,100 jobs worldwide. The charges are expected to be about $ 80 M. The company expects to achieve annualized savings of about $ 130 M by the end of 2014. Texas Instruments reported fourth-quarter revenue of $ 3.03 billion and net income of $ 511 M.

Exar, a provider of high-performance analog mixed-signal and data management solutions has acquired Stretch, a provider of software configurable processors supporting the video surveillance market. Stretch has developed software configurable processors, the first to embed programmable logic within the processor. Stretch devices are used in video processing, machine vision and wireless applications worldwide.

South Korea's Samsung has sold its entire stake in British chip maker CSR shortly after the company said it was retreating from the digital camera market. The Korean company acquired a 4.9 percent stake in CSR at 223p a share in July 2012, as part of a deal to buy the company's mobile phone handset division for £ 198 M.

Renesas Electronics Europe has appointed Michael Hannawald to the position of General Manager of the Industrial & Communications Business Group (ICBG) with immediate effect. Hannawald was previously Senior Director of the ICBG at Renesas Electronics Europe. He moves into the position vacated by Holger Zielke, who will be retiring.

PASSIVE COMPONENTS

Amphenol completed four acquisitions during the fourth quarter of 2013 for a total purchase price of $ 455 M. These include the previously announced acquisitions of the Advanced Sensors Business of General Electric, a manufacturer of sensors and sensor-based instruments primarily for the industrial and automotive markets with annual sales of approximately $ 225 M, and Ionix Aerospace, a UK-based high technology cable assembly company focused primarily on the commercial aerospace market with annual sales of approximately $ 35 M.

Crystal components maker Rakon has announced a proposal to close its manufacturing plant in the United Kingdom which employs 88 persons. Rakon UK is known internationally for its ultra-stable crystal oscillators. Rakon would start consultation within the month on its proposal to shut down the Lincoln plant and shift manufacturing to New Zealand. Rakon would continue to maintain a research and development centre in the UK, based at Harlow which employs 22 people.

Bel Fuse announced the opening of the company's newest R&D centre, located at its TRP Connector division in Changping, China. Bel acquired TRP, formerly the Transpower magnetics business of TE Connectivity, on April 1, 2013. The TRP acquisition solidified Bel's position in integrated connector modules-ICMs.

The German PCB market grew by 2.9 percent in November 2013 compared with November 2012, so the ZVEI. Order intake was down by 8.8 percent compared to the same month. In the period January to November 2013, however, the order grew by 1.7 percent. This growth was particularly strong in the smaller enterprises. The book-to bill ratio reached 1.06. The number of employees in the industry rose by 2.7 percent.

OTHER COMPONENTS

The Electronic Design Automation (EDA) industry revenue increased 6.8 percent for Q3 2013 to $1,729.3 million, compared to Q3 2012, so the EDA Consortium. Sequential EDA revenue for Q3 2013 increased 4.6 percent compared to Q2 2013, while the four-quarters moving average, which compares the most recent four quarters to the prior four quarters, increased by 5.8 percent. The total revenue for the most recent four quarters (Q4 2012 through Q3 2013) was $ 6,830.3 million. Revenue in Europe, the Middle East, and Africa (EMEA) was up 6.7 percent in Q3 2013 compared to Q3 2012 on revenues of $ 285.5 M. The EMEA four-quarters moving average increased 6.8 percent.

Tektronix, a provider of test, measurement and monitoring instrumentation, announced the acquisition of Picosecond Pulse Labs. The move is intended to strengthen the Tektronix portfolio in the growing market for test equipment to support 100G/400G optical data communications research and development. The terms of the transaction were not disclosed.

EMS PROVIDERS

EMS Provider Enics Switzerland, a partner for the development, production, and maintenance of industrial and medical electronics, has disclosed the consultation procedure for planned personnel reductions of 25 persons as of January 22, 2014. The company based in Turgi (canton Aargau), is reacting to the changing market environment and is planning to adapt its structures to the current market trend to secure its medium and long-term competitive capacity.

This is the comprehensive power related extract from the «Electronics Industry Digest», the successor of The Lennox Report. For a full subscription of the report contact: eid@europartners.eu.com

or by fax 44/1494 563503.

www.europartners.eu.com

12th Edition D2D Report Includes Digital Power Analysis

By Richard Ruiz, Analyst, Darnell Group

Darnell has recently completed an extensive analysis of the market for dc-dc converter modules including both isolated and non-isolated converters. Our findings are detailed in “Worldwide DC-DC Converter Module Forecasts: Power Architectures, Product Types, Voltage Trends and Applications” and include extensive analysis of the use of digital power in these markets. While digital power is an established, not an emerging, technology, it is still growing much faster than the overall dc-dc market.

Over 85 tables and graphs are presented in this report covering the dc-dc converter module power supply market for 24 applications. The report details all aspects of the original equipment manufacturer (OEM) market. The focus of this comprehensive analysis is to provide decision makers with a detailed and insightful look at the current and future opportunities available in the dc-dc converter module power supply market. Details can be found at www.Darnell.com

The dc-dc converter module power supply market is projected to see considerable growth over the next five years, with the dollar market increasing from $3.9 billion in 2014 to almost $5.0 billion in 2019, a compounded annual growth rate (CAGR) of 4.9%. Fueled by healthy growth in a number of traditional applications including the communications, computer and industrial sectors as well as the emergence of several new and innovative power architectures, the outlook for the dc-dc converter module power supply market is expected to remain strong over the forecast period.

One of the driving forces in this year’s edition is the emergence of digital power management and control. No longer considered an “emerging” technology, it has entered the mainstream and is now widely considered to be a commercial product and is now used in a growing number of applications. In fact, in one of the more interesting findings in this report, the unit market for dc-dc converter modules with digital capability is projected to grow three and a half times as fast as the overall dc-dc converter module unit market. This higher growth rate varies by application segment and by product type and is detailed in this report.

Another important factor in the growth of the dc-dc converter market over the next several years is the emergence of several new architectures including the Centralized Control Architecture (CCA) and the Dynamic Bus Architecture (DBA), both of which are expected to have a strong impact on the design of dc-dc converters. However, despite the projected growth of these new power architectures, the Intermediate Bus Architecture (IBA) is expected to remain the dominate force driving the sales of dc-dc converter modules over the forecast period.

Specific forecasts presented in this edition are based on a detailed quantitative analysis of 24 applications divided among five categories: communications, computers, industrial, medical and military/aerospace. Additional power supply forecasts are generated for wattage, input/output voltage, amperage, power architecture, digital penetration and product type. The forecasts and analysis presented in this report consider application drivers, technology trends, regulatory considerations, market sizes and other factors for each segment.

The communications power supply segment is expected to have the largest dollar and unit markets over the forecast period. Led by applications in the wireline sector, which will record the largest individual dollar market covered in this report, along with the wireless and consumer premises sectors, the communications segment will make up over one-third of the total dc-dc converter module dollar market over the forecast period.

Combined, the communications and computer segments are projected to make up over 75.0% of the overall dc-dc converter module unit market over the forecast period. In addition, both of these segments are also expected to benefit from the growing trend towards digital power management and control. In fact both of these areas are considered early digital power adopters, as applications in each segment such as telecom and servers both draw lots of power and feature sophisticated and/or complicated power management structures.

Although projected to be the slowest growing dollar market, the industrial segment is expected to grow from $1.0 billion in 2014 to $1.2 billion in 2019, a CAGR of 3.6%. In general, the power supplies used in this section are higher-wattage and more expensive than those found in most of the other sectors covered in this section, resulting in a large dollar market. In order to compete in the industrial power supply market, power supply companies must design products that have long life spans, with reliability an especially important component.

The military/aerospace and medical markets are both projected to maintain small unit markets, as each of them must meet and comply with a number of strict standards and regulations, as well as barriers to entry that do not ordinarily apply to other applications. However, the Mil/aero sector, made up of both COTS and mil/spec applications is expected to see some of the highest average selling prices per unit in this report and will record one of the larger dollar markets over the forecast period.

One of the more clearly defined trends in this report is the continued dominance of the 48V segment over the remainder of the forecast period. Although the use of 12V power buses has increased substantially, the continued use of the intermediate bus architecture (IBA) and to a lesser extent the newer centralized control architecture (CCA), will result in the 48V segment maintaining the largest unit and dollar market over the forecast period.

The largest unit markets for isolated dc-dc converter modules are located in the higher wattage ranges, specifically from 25W to 249W. The sales of isolated dc-dc converter modules are concentrated in both the higher output voltage and higher wattage ranges. Driven by strong growth in the communications, computer and industrial sectors, the three segments included in the 25W to 249W range are expected to account for over 50.0% of all isolated dc-dc converters sold over the forecast period.

Due to the fact that the majority of non-isolated converters drive low-voltage loads, the power levels presented in this report are measured by amps of output current. Due to a combination of strong unit sales and above average selling prices, the >50-≤100A segment will maintain the largest dollar market, as there is still a growing demand for currents up to 100A as the higher levels are often used to feed banks of memory chips.

Another area to watch in the dc-dc converter market are advances in technology, components and materials, in particular advanced semiconductor materials such as Silicon Carbide (SiC) and Gallium Nitride (GaN). In fact, considerable focus in the power industry is on the emergence of these two materials, both of which are expected to have an impact on the dc-dc power supply markets over the coming years. In the short term SiC is expected to be the primary replacement technology for traditional silicon power devices, while GaN seeks initial commercial traction in applications with breakdown voltages of less than < 600V and power requirements of less than 5kW.

Over 85 tables and graphs are presented in this report covering the dc-dc converter module power supply market for 24 applications. The report details all aspects of the original equipment manufacturer (OEM) market. The focus of this comprehensive analysis is to provide decision makers with a detailed and insightful look at the current and future opportunities available in the dc-dc converter module power supply market.

www.Darnell.com

Design, Simulation and Protection

Integrated architecture approach combining power semiconductor components efficient

A constantly growing global population coupled with higher and higher demand for power has led to corresponding growth in needs for power electronics equipment, especially converters and energy storage systems. Those needs are also expressed in key requirements, chief among them better energy efficiency and smaller footprints. To improve their energy efficiency, power electronic converters have to be pushed to maximum performances while ensuring reliability in production and overall purchasing and operating costs.

By Emmanuel Carmier, VP Business Line Manager Power Electronics, Mersen

Today's state-of-the-art power electronics converters require the design engineer to employ an integrated architecture approach combining power semiconductor components, like - but not limited to - IGBTs, with passive components such as heat sinks, capacitors, busbars, resistors and fast acting fuses. Focus on the interfaces and an interaction among those components is key in the search for the best compromise between cost and performance.

Mersen Electrical Power has many years' experience in fuses for semi-conductor protection, cooling, and busbar design. The fusion of three leading brands in those components - Ferraz Shawmut, R-Theta and Eldre - into a single group, Mersen, offers the designers of power electronics equipment much more than a single supplier. They can benefit from Mersen's skills and expertise throughout the process of converter designing. Mersen Electrical Power's position on the market is that of a partner in upgrading the performance of such systems, reducing their footprints, and improving safety and reliability.

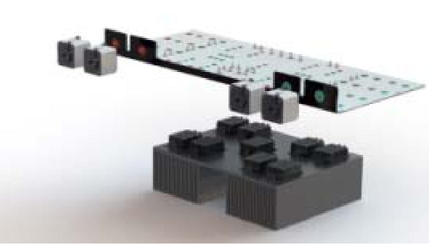


Figure 1: Power electronics integrated architecture

Mersen can guide power electronics designers directly toward the right choices in an integrated architecture approach. We provide our know-how of passive components in the earliest stages of design, giving the customer an opportunity for the best possible discussion of technical issues to ensure their exact needs are met.

Cooling is the foundation of an integrated architecture, since the active semi-conductor components are installed directly on the cooling unit, and therefore defines the dimensional and mechanical outlines of the system. Next, the busbar connects this active heart of the system electrically to all its passive components: resistors, inductors, and capacitors. Finally, fuses are the system's ultimate protection, guaranteeing the safety of both the equipment and the people working in its vicinity.

When the time comes to confirm all the decisions being made, simulation – a crucial complement to full scale tests - is a handy tool that considerably shortens development times.

Mersen and you : straight to the optimized design

The electronic design determines the heat generated by each IGBT, so the cooling device and busbars are the first passives to be selected. The heat sink answers thermal needs but also serves as a base frame for the converter's main power switch. Furthermore, heat sink thermal performance combined with the thermal dissipation of each power semiconductor will influence the converter layout and thus the busbar design.

The first building block of the power converter is the selection of the cooling solution. The challenge is to cool down the semiconductor in a dynamic way. It looks like a thermal issue but in reality it is a trade-off between the thermal performances, the pressure drop

Figure 2: Liquid-cooled cold plate

in the system, the available fluid velocity and the mechanical constraints. Additionally, no two cases are the same and, depending on the customer's design experience, habits and constraints. To answer this challenge, Mersen has developed years of experience customizing each design to the customer application while applying manufacturing processes to drive down the manufacturing cost.

Figure 3: IGBT modules placed onto the heat sink

Once the IGBT modules have been placed onto the heat sink to allow for proper thermal dissipation, the designer is confronted with how to interconnect them with the lowest inductance power distribution path possible.

In high current power electronics applications, low inductance power circuit is a critical element for safe and efficient operation of IGBT modules. If not addressed early in design, the stray inductance on the total DC bus connecting the DC capacitor bank to the inverter devices (commutation loop) can result in several undesirable consequences. For example the hard switching converters' excessive transient overshoots create the potential of increased device heating during switching, leading to unnecessary use of large heat sinks or tuning the converter to lower switching frequency and therefore larger, more expensive, passive components like capacitors. Unnecessary stray inductance is an obstacle for design engineers, who need interconnection distances between switching devices in order to dissipate the heat generated by power electronics semiconductors.

The following will address the different alternatives.

Instead of the use of a wiring harness on DC bus amperages approaching 150 amps and above, the use of multiple interconnect layers is the solution to large current carrying capability, low stray inductance, high frequency applications, smaller space requirements and reliability issues. For the traditional power distribution topology of IGBT modules, the use of side-by-side busbar conductors is still common in today's industry. However, side-by-side conductors do not provide the lowest effective mutual inductance for the distribution path. There is some mutual inductance cancellation along the adjacent edges of the conductors, but to minimize mutual inductance, these busbars would need to be placed directly on top of one another, not side by side.

Designers can further lower the mutual inductance by placing the wide DCplus conductor plate on top of the wide DCminus plate, separating them with a thin dielectric material. This provides the greatest surface area for flux cancellation. Prototyping using this method is frequently done and provides the components in the inverter with enhanced electrical characteristics through lower inductance. Separate bushings can be placed on the bottom contact surface of the top plate to bring the power down to the IGBT module located below the bus. As these types of loose bushings will seldom lie completely flat against a conductor plate, this could result in an increased contact resistance around the bushing.

Figure 4: Lamniated busbar for solar PV inverter application

Mersen custom-designed laminated busbars provide the lowest possible effective inductance for a system. This is made possible by laminating a thin piece of dielectric material between the DCplus and DCminus plates. Laminating the dielectric plates together under heat and pressure keeps the levels consistently close, allowing for maximum mutual inductance cancellation directly along the power distribution path. The closer the plates and the more uniform their separation throughout the length of the bus, the more mutual cancellation can be achieved. To reduce the number of components in the system even further, the AC conductors can also be laminated into the bus assembly. This will not decrease the mutual inductance cancellation of the plus and minus plates but does enhance overall bus design. Once laminated, the resulting rigid structure is capable of withstanding several hundred pounds of cleavage strength and several thousand Volts across the conductor plates. Making the electrical connection to the power components becomes a matter of selecting from a range of metal-forming options: embossments, soldered bushings, press-fit bushings and formed tabs. Permanently incorporating these contact surfaces into the structure permits low contact resistance between the bushing surface and the conductor plate.

Copper alloy is the standard and recommended conductive material in the majority of IGBT laminated busbar applications given its low resistance characteristics and cost, but Aluminum, brass, beryllium copper, or phosphor bronze may also be specified. The accepted value for current carrying capacity of copper is 5A/mm2. To determine the cross-sectional area (in mm2) required to carry the steady state current, divide the steady state current of the DC bus by 5A/mm2. In this scenario the copper's temperature rise will be 30°C above ambient temperature.

Proper selection of dielectric material will ensure the lowest mutual inductance in the laminated structure. A common misconception in laying out a laminated structure is that a very thick dielectric is needed to meet voltage requirements. The laminated structure has materials in a sandwich; designers need to allow sufficient insulation overlap beyond the edges of the conductor to eliminate arcing between the conductors.

Once the conductor size and insulation is specified, the designer must determine how to distribute the power in and out of the IGBT module and what the physical layout will look like. Various methods may be used to interconnect IGBT modules with the laminated busbar. Once the DC conductor plates are laminated into an assembly, the assembler may simply place conductive bushings/spacers under the contact surfaces of the busbar to the IGBT tabs. The different height potentials required for the bushing/spacers may cause an assembler to place the wrong bushing/spacer in the inverter during assembly. The solution to this potential problem is the use of embossments and soldered-in bushings. With the contact surfaces incorporated into the laminated busbar, the designer insures the proper connections to the IGBT tabs while maintaining a low voltage drop contact. The DC bus conductors can be effectively embossed to two times the material thickness, and the embossment slotted if different IGBT terminal spacings are required. The current carrying capacity of the embossment is reduced when the conductor material is stretched beyond two conductor thickness. The soldered-in bushings can extend down and/or up to accommodate the creepage barrier on some IGBT modules and interconnect driver circuits and snubber boards. The use of a tab with slotted holes can also be used to interconnect IGBT modules with built-in creepage barriers. However, the mutual inductance will increase when the DC plates are separated.

Once the basic structure made up of the heatsink, active semiconductor switches, and busbars is defined the integration and optimization of the remaining passive components will take place. Here again, the expertise of the components manufacturer is critical in achieving the best overall performance.

Ultimate protection against excessive damage

Shortcircuit faults in power electronics equipment will cause excessive damage, or in the worst case, explosion. Electronic protection against overloads and shortcircuits is normally embedded in new power electronic semiconductors but backup fuse protection is still needed to ensure safety in the event of failure of these systems or the device itself.

When selecting semiconductor fuses, the designer must reconcile opposite deliverables. During normal operation we want low Watts, unlimited lifetime expectancy, low body and terminal temperatures, and of course low cost but we also need the fuse to operate as fast as possible, with minimum let-through energy and arc voltage when everything else has failed. Many of the requirements (energy let-through by the fuse, commonly known as I2t, life cycle expectancy, connection, fuse opening indicators etc.) conflict with each other, but new fuse designs as well as new manufacturing processes have helped reconcile them. Furthermore, new simulation tools in addition to Mersen's field specification engineers have accelerated fuse selection for demanding power electronic applications like drives and rectifiers.

Figure 5: Typical fuses for the protection of power semiconductors

A typical semiconductor fuse consists of one or more silver or copper or thrulay (series of silver and copper) elements enclosed in a fuse body, either welded or soldered to the fuse contacts/terminal. Sand filler plays a major role in fuse performance. It quenches the arc by absorbing the energy during arcing time and serves as fuse element cooler during normal operation by conducting the heat away from the element, through the fuse body and to the medium surrounding the fuse. Short fuses will transfer more heat through the terminal. Long fuses will transfer heat through the fuse body. Fuse "savoir faire" is how well you manage the fuse element thermal equilibrium. Running with the element hot will make the fuse fast opening but subject to premature opening. Running the element at a lower temperature will lead to a long-lasting fuse, but when needed, will it protect? Fortunately, we current rate fuses to achieve the best trade-off between clearing, operation, and cycle performances.

The fuse is a calibrated current-carrying device designed to open under specific conditions. The numbers of notches in series in the fuse element will define the fuse operating voltage and the total cross section of parallel elements will define the rating of the fuse. The element material, mass, and notch configuration, along with the surrounding materials, all contribute to fuse performance. The narrow path for the current will lead to higher current density and thus to higher heat generated at the notches. The total notches cross section will define the pre-arcing I2t needed to melt the fuse element; in other words the energy needed to melt the narrow path. Under sustained overcurrent, the fuse element generates heat at a faster rate than the filler can conduct it away from the element.

At the end of the pre-arcing time the fuse switches to arcing mode. The fuse will develop an arc voltage higher than the source voltage and this will force the current to go down to zero. This period is call the arcing time. During this period the fuse will have to dissipate the energy supplied by the source as well as the energy stored in the circuit, mainly ½ LI2. The total energy let through by the fuse, known as total I2t, is the result of the sum of the prearcing I2t plus the arcing I2t. Those values are supplied for our fast acting semiconductor fuses. The normal condition for shortcircuit protection is that the total I2t integral let through by the fuse when clearing the fault must be less than the I2t which produces system damage. For example, for IGBTs the appropriate value is the level of I2t which causes case rupture.

Figure 6: Fuses with low inductance for IGBT protection

Increased voltage for IGCT and IEGT protection, demand for lower I2t for IGBT protection and large rectifier protection have led to new fuse ratings and performances. It is not rare anymore to see semiconductor fuses rated at 10kV 1000 A with low inductance. Fault simulation will help to calculate the melting time, and will give the total I2t to be compared with the semiconductor housing's I2t. If needed for demanding applications, our capacitor discharge lab will backup simulation/calculation by actual testing. Also, Mersen's High Power Test Lab can be used to determine the semiconductor's true housing I2t value.

Pre-Applied
Thermal Interface Material (TIM)

The Infineon-qualified solution

With the ongoing increase of power densities in power electronics the thermal interface between power module and heatsink becomes a larger challenge. A thermal interface material, especially developed for and pre-applied to Infineon's modules outperforms the general purpose materials available.

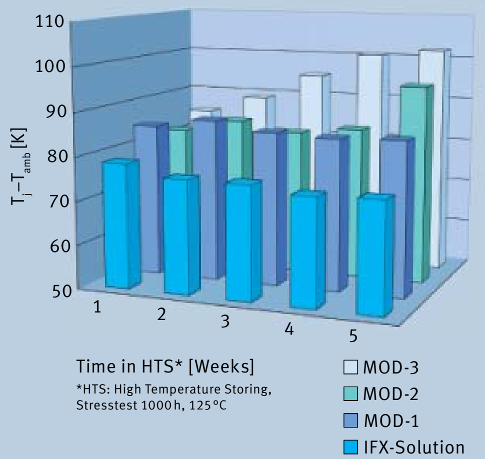
TIM does not only provide the lowest thermal resistance, it also fulfills the highest quality standards given for power modules to achieve the longest lifetime and highest system reliability.

Main Features

- Best in class thermal resistance
- Pre-applied to Infineon Modules
- Dry to the touch
- Optimized for dedicated Infineon Modules

Benefits

- Reduced process time in manufacturing
- Simplified mounting
- Increased system reliability
- Increased system lifetime
- Optimized thermal management
- Improved handling in case of maintenance



www.infineon.com/tim

Simulation to boost development processes

Historically, passive components were developed based on hand calculations and comprehensive know-how. However, as designs grow increasingly complex, analytic calculations become impossible to solve, especially from the thermal standpoint. To shorten time to market thermal simulations are becoming a decisive tool in developing a custom component.

Why use simulation? The most reliable way to make sure that a component respects its specifications is to build a prototype and test it in operating conditions. But as reassuring as this solution would seem, it also presents several drawbacks. Each design is unique: metal cutting and machining operations, surface finishing, tools to bend some intricately shaped products, insulating material layers specially crafted for the tested geometry ... All those additional costs cause the global price to increase for a component that might not be validated by the tests.

Building a prototype is also time-consuming and that's why simulation is a handy tool to boost development processes. By adding pre-test steps in the conception phase, design flaws can be spotted and eliminated before going through the prototype manufacturing process. Overheating areas or overly thick plates are not always easy to determine by calculations. Computer generated temperature maps are very appealing and easy to understand: "a picture is worth 1000 words". It is more encouraging for the customer to get preliminary test results before ordering a prototype, and to have a back and forth exchange to adjust the initial design. However, simulation is not meant to replace tests entirely. The quality of the calculated results is only as good as the input data and understanding of underlying physics.

Mersen uses COMSOL Multiphysics finite element software. The finite element method is based on iteratively solving equations locally until overall stability is reached. To be able to take into account the geometry, we need to divide spatial domains (or surfaces in the case of a 2D problem) into small meshes; for each knot we calculate the value of each studied variable at each iteration (in the case of a stationary study) and each time (in the case of a transient study). A suitable mesh is crucial: too coarse a mesh might hinder the convergence of the simulation, but the number of elements and knots is limited by system memory and computing capacities. In COMSOL the mesh is built automatically, depending on the physics used in the model.

The next step is very important: defining the physics involved. Let's take the busbar example. In the case of our thermal simulations, we are aiming to prevent the busbars from reaching high temperatures caused by Joule heating, 105°C being the typical PET limit, or a limit set by the end customer. The current distribution is determined according to customer specifications. The easiest way to model it is to calculate current r.m.s. values and to treat them as direct currents. With this approach, we can set a stationary model of current repartition.

When currents are more complex, especially currents of different frequencies going through different inputs or outputs, a transient model is required to account accurately for the fact that currents of different frequencies don't add up directly. The electrical phenomena timescale being different from the heat transfer timescale, a transient study must be done to calculate the current density map before the stationary heat transfer study. Current density leads to heating. Cooling is usually accounted for by three phenomena.

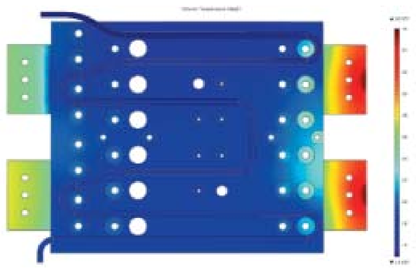


Figure 7: Thermal simulation for a water-cooled busbar

The first is conduction, addressed by solving the heat equation. The second is radiative heat transfers calculated from the Stephan-Boltzmann law. Plastic radiates much more than oxidized metal, which radiates more than polished metal. The third is convection and is less straightforward.

Simulating a complete air volume with fluid mechanics is possible, but memory and computing power can be expensive. Meshing the air is again very difficult, as the air mesh has to be continuous with the busbar mesh. The finite element method is not the best to solve this kind of problem. The best way to address it swiftly is usually to calculate the mean heat transfer coefficient depending on temperature, based on the customer's operating conditions.

Fluid mechanics is, however, used in the case of water-cooled busbars, by modeling laminar water flows in the pipes. Conduction means a water cooled busbar will take the heat away from the circuit. Of course, well defined material properties and current condition are paramount to running an accurate simulation. Simulation can, in fact, vary significantly, depending on environmental conditions (temperature, pressure, etc.) and the metallic alloys and dielectric materials (PET, Nomex, Kapton, etc.) used. To achieve an accurate simulation will require clear understanding of the final application.

As we saw earlier, thermal simulations can be used in numerous situations. The earlier the simulation is integrated into a project the better. Computer calculation can also intervene later in the product life-time, to determine causes for product failure, or to study if a given design could be used for another application and/or higher current rating and/or ambient temperature conditions. The main goal is to validate if the proposed design meets customer specifications.

Simulations are perfect to provide precise information to the customer. Having accurate and detailed information on each available solution is extremely valuable when determining key characteristics for a prototype.

Figure 8: Power electronics assembly with the integrated architecture approach

To conclude, in today's Design for Manufacturability (DFM) environment, both design performance and manufacturing costs come into play when design engineers lay out systems. Component count, assembly time, and system size and performance are all factors that must be taken into consideration. The Mersen cooling, busbar, and fuse expertise support designers to optimize all of the components in a power system in an integrated architecture approach. From the outset and throughout the project, our team of solutions engineers, our product offering, and our simulation and testing capability can provide critical added value to the converter designer.

http://ep-uk.mersen.com/solutions/power-electronics-solutions

PMBus – the Rising Star!

Once upon a time, there was an ugly step-child called "power" that was shoved in a corner where it could be hardly be seen and most definitely not heard. But as applications became more intelligent, the step-child began to grow with it. Now, the world is becoming more energy conscious and more mobile, hence our step-child is emerging into the bright lights of intelligent power management.

By Ramesh Balasubramaniam, Marketing Director, Enterprise Power, International Rectifier Corporation

Active power management in an electronic system is now a central design facet and no longer an afterthought. The challenges of configuring power supplies, sequencing multiple voltage rails, monitoring power supply status, determining faults and reacting to warnings and status are common to all electronic applications regardless of market. From this need, the industry standard Power Management Bus (PMBus™) was conceived. A typical application in a computing system using International Rectifier's PMBus enabled products is shown in Figure 1.

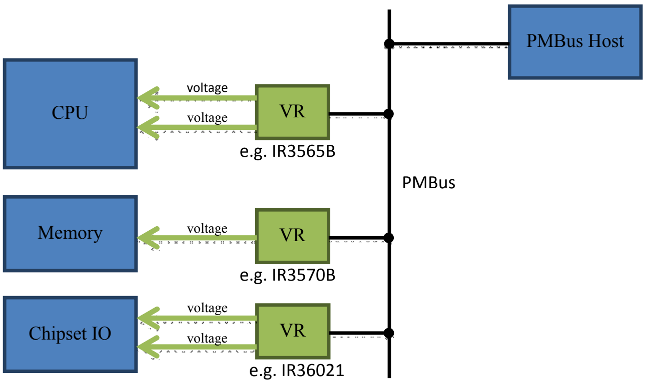


Figure 1: Typical PMBus system

History

The PMBus specification, developed in 2004 and first released at version 1.0 in 2005, is an open standard that is owned and controlled by the System Management interface Forum (SMIF). Adopter companies, such as International Rectifier, bring their market knowledge to these Forums to guide the definition and ratification of the specifications. To minimize implementation cost overhead and to make easy re-use of existing infrastructure, PMBus was conceived as a predefined command set that sits on top of the transport layer protocol of the SMBus™ (System Management Bus). SMBus, first released in 1995 and also owned and controlled by SMIF, is highly adopted in notebook computers and batteries as the industry standard way of controlling and monitoring battery power. SMBus itself, uses the physical and electrical layer protocol of the ubiquitous I2C (Inter integrated Circuit) bus developed by Philips in 1982.

Protocol

I2C is a multipoint, open drain, two wire bus (clock and data). It is generally implemented at low speed (around 100kHz) to ensure compatibility due to its widespread popularity, even though higher speed versions are defined. Multiple masters and multiple slaves may co-exist on the bus, each with their own unique 7-bit address. The I2C protocol consists of a START bit followed by a one byte address (7 bits of address and 1 bit for read/write direction), one or more bytes of data and a STOP bit. Whereas I2C is wide open, SMBus strictly defines the data packets into a few allowable protocols such as "Write Byte/Word", "Block Write/Read" and so on. The advantage is standardization around a few common protocols to ensure compatibility across manufacturers. SMBus also adds robustness to the basic I2C specification with the introduction of a bus timeout and the optional Packet Error Checking (PEC) protocol. A third wire, SALERT#, is added to allow Slaves to quickly signal the Master for faster fault handling. SMBus addresses follow the I2C format, however one address is reserved for an SMBus protocol called Alert Response Address which allows the Master to quickly find out which Slave signaled the SALERT# line.

The current PMBus specification is version 1.2 and was released in 2010. PMBus primarily defines the command set that operates over the SMBus protocol to provide a unified and standardized method of communicating with power management devices (Figure 2). In addition, PMBus adds a further data packet protocol, the "GROUP" command which allows multiple devices to be sent commands in a single large data packet that is the concatenation of address, command and data to each device.

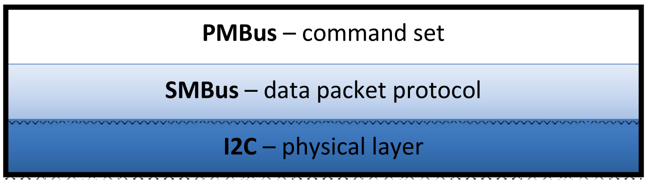


Figure 2: PMBus protocol layers

Command Set

The command set is wide enough to cover a broad range of power management applications such as AC/DC, DC/DC, fan control etc. and the approximately 200 commands can be loosely categorized as:

- Memory related e.g. STORE_DEFAULT_ALL
- On/Off related e.g. OPERATION & ON_OFF_CONFIG
- Output voltage related e.g. VOUT_COMMAND
- Configuration related e.g. FREQUENCY_SWITCH and PHASE

- Warnings and Faults related e.g. IOUT_OC_WARN_LIMIT
- Sequencing related e.g. TON_RISE
- Status related e.g. STATUS_TEMPERATURE
- Telemetry related e.g. READ_VOUT
- Inventory related e.g. MFR_ID
- Manufacturer ratings related e.g. MFR_POUT_MAX

International Rectifier offers products with varying amounts of commands for cost effectiveness as PMBus compliancy does not require all commands to be implemented. As well as standardizing the command set to ensure inter-operatability between manufacturers, an important part of the standardization is to specify the number formats to be used with all values. PMBus version 1.2 allows two universal number formats, Linear mode (most common) and direct mode. The linear data format expresses numbers according to the formula $X = Y.2^N$, where Y is the mantissa and N is the exponent. This is encoded within two bytes of data where the first 5 bits are the exponent (N) and the remaining 11 bits are mantissa (Y). Only VOUT related commands use a higher precision version where the mantissa (Y) is encoded as 16 bits and the 5 bit exponent (N) is set by the VOUT_MODE command. Less commonly used is the Direct mode which has the form $X = 1/m.(Y.10^{-R}-b)$ where m, Y and b are two bytes each and R is one byte.
With power management devices, it is critical that transmission and data errors are handled correctly. To that end, PMBus defines that commands not meeting the correct protocol transmission sequence or reporting a PEC error are flagged and rejected with the appropriate status register bits set. Similarly, invalid data or out-of-range data must be safely rejected, with the proper status bits being set.

Limitations

Although PMBus version 1.2 has been very widely adopted and today provides the backbone for intelligent power management, it is not without its limitations. Wide scale adoption has resulted in increased number of devices on the bus, thus throughput of data (especially telemetry) can be slow. The ALL CALL address can send the same command to every device in a compact form, while the GROUP command can send any command to any device in a long string. However, there is no mechanism to compactly target a small group of devices with the same command. For example, you may only want to turn off the voltage regulators to a particular sub-system and currently the best choice is to use the GROUP command to send the same (turn off) command to the targeted regulators. This requires exactly

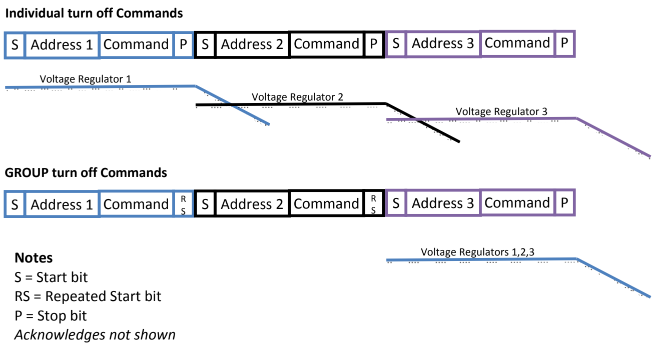


Figure 3: Sending commands to turn off a subset of devices

the same transmission length as sending individual turn off commands with the only advantage being that all regulators will turn off at the same time at the end of the entire transmission (Figure 3). Another common difficulty is deciphering the root cause of a fault on the bus as typically a faulted device causes many other devices on the bus to report faults due to the coupled nature of power components.

Looking Forward to PMBus 1.3

SMIF recognized that the success of PMBus had revealed some limitations, so in early 2013 a Working Group was set up. It was tasked to update the specification to address the limitations and encompass emerging usage models. As silicon processes move towards deep submicron geometries, leading edge processors such as CPUs, FPGAs and ASICs require to dynamically control their own voltages to optimize power and performance. A major update in PMBus 1.3 is the inclusion of Adaptive Voltage Scaling (AVS) through a complementary AVSBus (Figure 4). Further enhancements announced in the draft 1.3 specification in September 2013 include:

- Up to 1MHz bus speed for increased data throughput
- Fast Zone read/write protocol to multiple devices for increased data throughput
- Floating point number format for a wider range with higher precision
- Relative output voltage thresholds to allow warning/fault limits to track the output voltage
- AVSBus up to 50MHz for an ASIC to dynamically control its own voltage

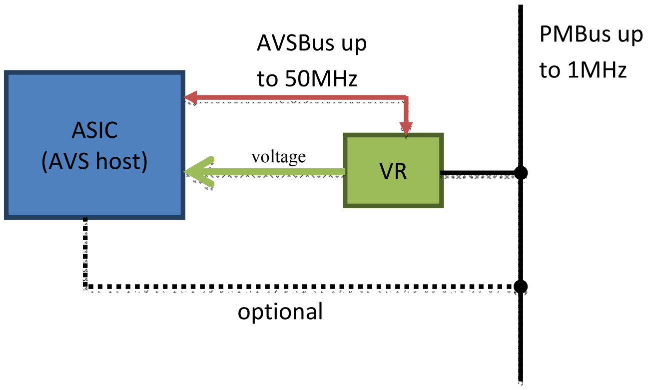


Figure 4: PMBus 1.3 with AVSBus

The final PMBus 1.3 specification is expected to be released around April 2014 and the world waits with bated breath as the little ugly stepchild of long ago finally makes its bow as one of the leading cast.

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PMBus is a registered trademark of SMIF
SMBus is a trademark of Intel
I2C is trademark of Philips semiconductor

Efficiency Improvement in Booster Power Modules with SiC Components

Two factors are shaping the development of advanced power conversion systems - increasingly stringent standards for energy efficiency, especially in solar and UPS applications, and the need to decrease the overall system's costs for the customer.

By Dr. Evangelos Theodossiu, Product Marketing Manager, Vincotech GmbH

These two goals are rather ambitious, at least for power semiconductors based on conventional silicon technology and with limited switching capabilities. The solution is the use of wide band power semiconductors as SiC (silicon carbide). This article compares the efficiency of booster power modules to see how pure silicon components stack up against silicon carbide components. It also discusses the benefits, drawbacks and challenges of using SiC technology.

Introduction

Intrigued by its special properties, researchers have been looking into SiC as a semiconductor material since the early '70s. It offers:

- High breakdown field strength (tenfold that of Si)
- A wide bandgap (threefold that of Si)
- High thermal conductivity (threefold that of Si)

These properties are conducive to applications that demand greater efficiency in a smaller footprint and operate at higher frequencies and temperatures. These properties, however, posed also some obstacles to mass-manufacturing, so it wasn't until the early 2000s where the mass production of single-crystal SiC wafers starts. Although 4" wafers are the standard today and the next step up 6" wafers is becoming apparent, together with the expectation that the costs are sure to drop significantly. In comparison, today 12" Si wafers are commonplace, and if predictions are anything to go by, the next technological leap to 18" wafers will come in four or five years.

Vincotech successfully rolled out the first standard power modules with SiC Schottky diodes ten years ago. SiC Schottky diodes have practically no reverse recovery charge, which reduces switching losses in the diode itself and even in IGBTs when these transistors are used as commutation partners. SiC Schottky diodes are the solution of choice for many of today's applications. However, the cost situation still needs to be improved to fully tap their market potential.

These days, the research and development of active switches, based on SiC components, are mainly in focus. The reverse voltage range below 4kV is the exclusive domain of unipolar switches configured with various types of circuits. The SiC MOSFET has prevailed over the SiC JFET in this arena. SiC MOSFETs exhibit excellent dynamic behavior because of their low tail current and superior static behavior because of their very low specific on-resistance (RDSon). What's inhibiting large-scale commercialization of SiC MOSFETs is the relatively steep cost, which is proving to be an even greater obstacle than for SiC Schottky diodes. However, their impact on the overall system has to be considered when assessing their full potential for reducing costs. The comparisons made in this article between Si and SiC technologies' efficiency, switching losses and switching frequency aim to substantiate this impact.

A comparison of Si and SiC components in a booster power module

The basis for comparison

This assessment is based on a booster topology. One possible point of application is on the DC input side of inverters in photovoltaic systems. Figure 1 shows a schematic diagram of a booster.

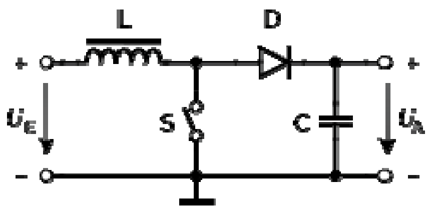

Figure 1: Schematic diagram of a booster

This example looks at a typical operating point of a photovoltaic system with 350 V input voltage and 700 V output voltage. The input current Iin and the switching frequency f are varied. The calculations were performed using the simulation software Vincotech ISE [1]. It uses measurements results obtained during the modules' characterization. This provides a fast, accurate way of comparing heat losses and temperature at various operating points. The best option for the given application may then be chosen.

This comparison examines the following standard Vincotech modules:

IGBT switches and Si diodes

flowBOOST 0 (part no. V23990-P629-F72-PM) with a 40 A/1200 V Ultra Fast IGBT and a 30A/1200V STEALTHTH Diode. Although the flowBOOST 0 contains two parallel booster stages, this comparison looks at just one stage. The same goes for the other modules.

- IGBT switches and SiC diodes
  - flowBOOST 0 (part no. V23990-P629-F62-PM) with an 40 A/1200 V Ultra Fast IGBT and 3x5 A/1200 V SiC diodes
- SiC MOSFET switch and SiC diodes
  - flowBOOST 0 SiC (part no. 10-PZ-12B2A045MR-M330L18Y) with a 45 mΩ/1200 V SiC MOSFET and 4x10 A/1200 V SiC diodes

Efficiency Benchmark

The first step to improve efficiency is to replace the Si diode with a SiC diode. Figure 2 shows the efficiency curve as a function of the input current (power) in a comparison of modules with IGBT switches and Si or SiC diodes. Efficiency increase / losses respectively with the SiC diode even at switching frequencies > 4 kHz. Losses can be reduced to 50% from 1.6% to 0.8% at 16 kHz and 5A input current. Losses can be further reduced by 37% to 0.5% at the same input power and same switching frequency by using a SiC MOSFET in place of an IGBT. This is the second step to increase efficiency (see Figure 3). The benefits of the SiC MOSFET are even more striking at switching frequencies > 32 kHz. Given the same input current and a switching frequency of 64 kHz, efficiency increases and losses are reduced by just under 35%. The effect is even more pronounced at higher input currents, but measures must be taken to ensure good cooling. These simulations were carried out with a constant heat-sink temperature of 80 °C. The physical limitations of Si technology are soon evident in applications demanding great efficiency and high switching frequencies. It is equally evident that SiC components will drive this market.

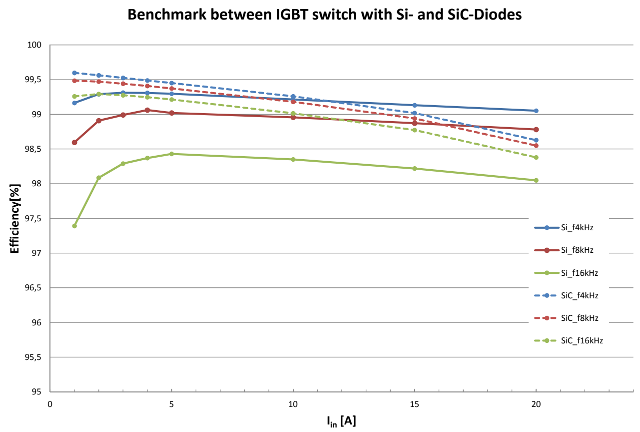

Figure 2: A comparison of the efficiency curves of IGBT switches with Si and SiC diodes as a function of the input current at switching frequencies between 4 kHz and 16 kHz

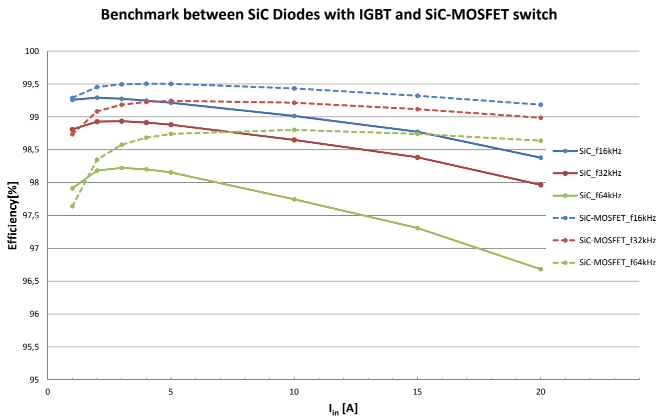

Figure 3: A comparison of the efficiency curves of SiC diodes with an IGBT and a SiC MOSFET as a function of the input current at switching frequencies between 16 kHz and 64 kHz

The following figures also show the benefits of using SiC components rather than Si components in performance-driven applications. Given the same losses – for example, 50W of total dynamic and static losses – and a switching frequency of 16 kHz, output power can be increased by up to 85% when using SiC diodes instead of Si diodes. In this case, output power is commensurate with input current. Refer to

Figure 4 for more on this. Given the same switching frequency, output power can be increased up to 50% by using a SiC MOSFET in place of an Si IGBT as shown in Figure 5. In this case, the combination of IGBT switch and SiC diode outperform the SiC MOSFET and SiC diode pairing because the IGBT's conduction losses are lower than those of the SiC MOSFET.

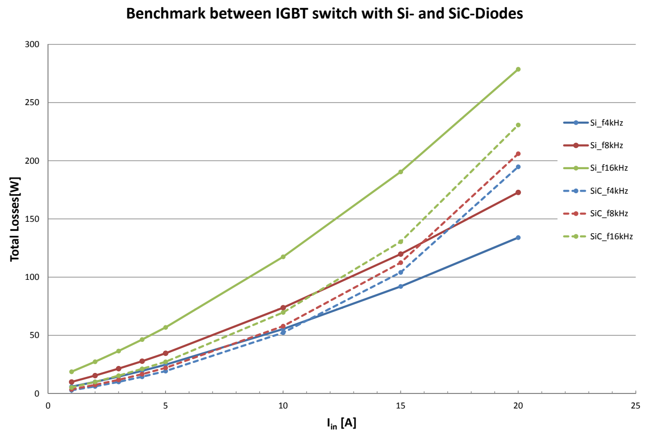

Figure 4: A comparison of the total dynamic and static losses of IGBT switches with Si and SiC diodes as a function of the input current at switching frequencies between 4 kHz and 16 kHz

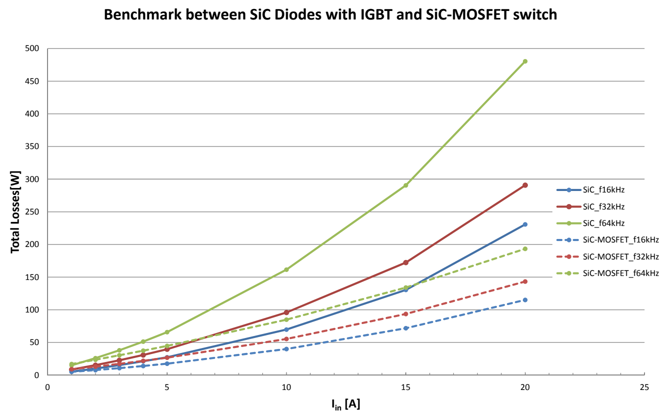

Figure 5: A comparison of the total dynamic and static losses of SiC diodes with IGBTs and SiC MOSFETs as a function of the input current at switching frequencies between 16 kHz and 64 kHz

Another interesting comparison looks at how total losses relate to switching frequencies. Compared to the Si diode with IGBT switch, the SiC-diode-with-IGBT combination's switching frequency can be increased from 16 kHz to > 48 kHz with switching losses remaining the same (at input current 5A), see figure 6. The SiC diode/ SiC MOSFET twosome's switching frequency may even be increased to over 100 kHz, see figure 7. And as the switching frequency rises, the size and cost of the inductance for the overall system can come down. In the final reckoning, losses can be decreased by more than 80% with SiC components rather than Si components. This, in turn, reduces the effort and cost of cooling. The benefits shown here also go a long way in helping engineers miniaturize end products and therefore cut costs. However, a quantitative assessment of the cost reduction also has to consider other factors and the challenges inherent in using SiC technology.

Challenges in using SiC components

In times when cost is the driving force behind new products' development, high price tags make it hard for new technologies to gain market share. This was the greatest barrier to SiC semiconductors' mass rollout. That barrier is gradually eroding as a result of higher unit volumes, generational change and less initial costs. For example, the price of 600 V SiC diodes dropped some 35% to 45% from 2011 to today. It is expected that it will come down another 10% or so in the next three years. The price of SiC MOSFETs is predicted to fall by more than 50% in the next three to four years, for example, for the 1200V/ 80mΩ type. At these prices, SiC components are sure to see widespread use in the years ahead.

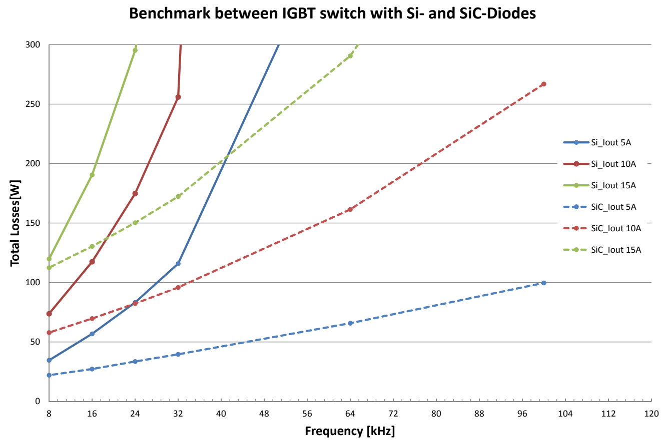

Figure 6: A comparison of the total dynamic and static losses of IGBT switches with Si and SiC diodes as a function of the switching frequency at input current between 5A and 15A

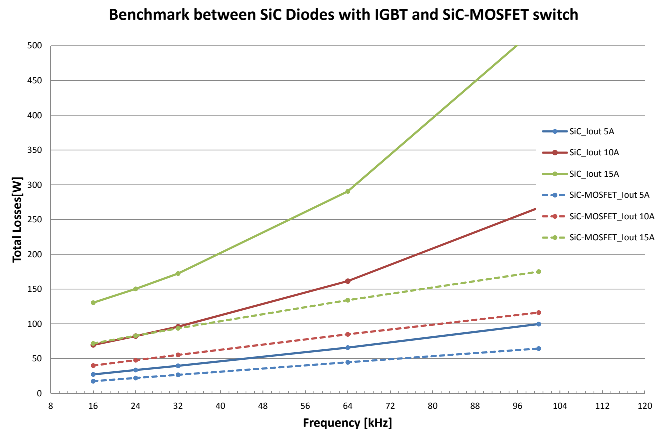

Figure 7: A comparison of the total dynamic and static losses of SiC diodes with IGBTs and SiC MOSFETs as a function of the switching frequency at input current between 5A and 15A

Technical challenges also need to be addressed to make the most of SiC technology's benefits. Above all, assembly and bonding techniques have to be adapted to SiC components' higher performance capabilities. Devices with SiC components can operate at relatively high current densities with the heat-sink temperature remaining the same. This subjects bond wires and solder joints to greater thermo-mechanical stress, which could influence the power module's lifetime. Then again, assembly and bonding techniques such as sintering, pressure sintering with silver powder, optimized bonding compounds, copper braiding or large-area foil contacts could counter such effects. SiC has a greater defect density than Si, which is why chips were kept small to obtain an acceptable yield. Until recently a rated current carrying capacity on the order of 5 to 10 A was typical for SiC diodes, but today the latest generations offer up to 50 A. To learn more about the benefits and challenges of using SiC diodes, read the paper indicated in [2] below.

Summary

This article discussed how the SiC diodes and switches used in Vincotech power semiconductor modules can increase efficiency and switching frequencies, while reducing losses in demanding applications such as solar inverters. These power modules were developed specifically to satisfy such applications' demanding requirements for symmetric control, heat dissipation and low-inductance connections. In addition to the flowBOOST 0 SiC module used for this comparison, Vincotech is gearing up the new flow3xBOOST 0 SiC for mass production. This module contains a three-channel booster topology with SiC diodes and the latest generation of SiC switches. Designed for efficiency-driven applications, it caters to the solar market where companies are eager to reduce device size and cost with passive components such as inductors and transformers. It is also well-suited for inverters in machines that rotate at very high speeds and for applications where noise pollution is a problem.

Additional reading:

[1] http://www.vincotech.com/en/support/simulation-software.html

[2] Advantages of SiC Schottky Diodes in Fast Switching Power Electronics Solutions, Ernö Temesi, Development Engineer, Vincotech Hungary Ltd, Bodo's Power 2008

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200A/600V Silicon Carbide Hybrid Intelligent Power Module for Servo-Inverter Applications

In Multi-Axis Servo-Drives several servo amplifiers are operating from a common DC-link power supply. Mechanically those servo amplifiers usually are mounted in a so called "book-shelf-arrangement" in a common mechanical rack. This specific construction principle is providing a limited space at each inverter's backside for cooling the power semiconductors.

By E.Thal, Mitsubishi Electric

With its S1-Series IPM Mitsubishi Electric was providing a dedicated solution for this specific application (module ratings see Table 1). The baseplate width of S1-IPM is only 50mm (see Figure 1), allowing a narrow housing for each servo amplifier and thus a compact size of the whole multi-axis servo rack.

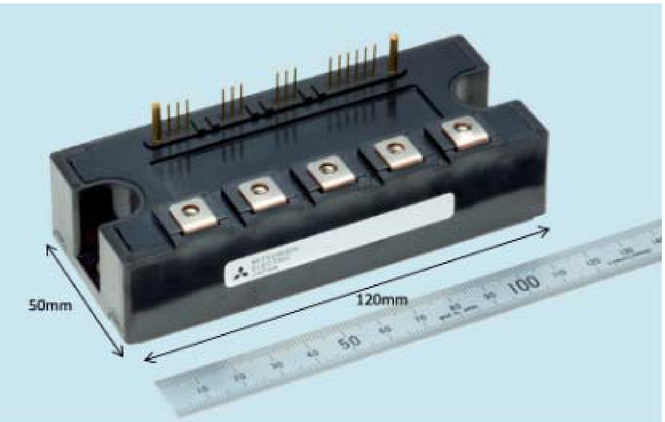

Figure 1: S1-series package outline, Baseplate footprint: 50x120mm

S1-Series IPM	Vces (V)	Ic(A)					
	600	-	50	75	100	150	200
	1200	25	50	75	100	-	-

Table 1:S1-Series line-up

As next step Mitsubishi Electric now is introducing its new Silicon Carbide Chip technology into this proven IPM design. A new 200A/600V 6in1 IPM (type name PMH200CS1D060) was developed by using SiC Schottky Barrier Diodes (SBD). This approach is called "Hybrid SiC" module. For better understanding the used terminology, please refer to Figure 2.

A hybrid SiC module is containing Silicon-based IGBT in combination with SiC-based Schottky barrier diodes. The main benefit of using SiC Schottky barrier diodes as free-wheeling diodes is the drastically reduced switching loss in the diode itself. As shown in Figure 2 this results also in a substantial reduction of IGBT-turn-on loss.

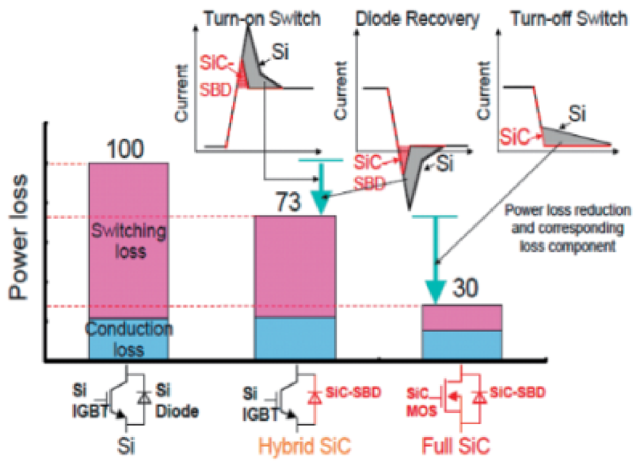

Figure 2: Evolution of SiC technology in power modules

Both effects are very welcome in servo inverter applications which are operating typically at high PWM switching frequencies. This was the motivation and background for developing this new 200A/600V hybrid SiC IPM dedicated for servo inverter applications.

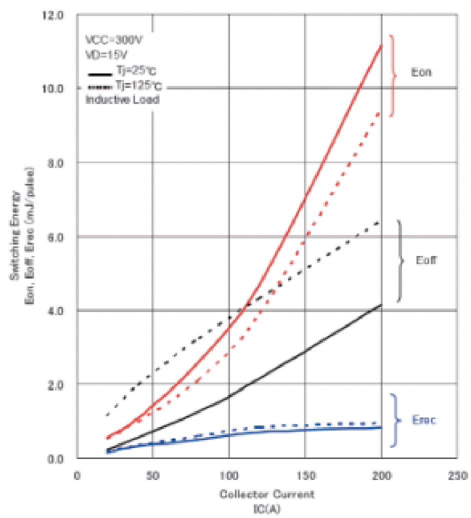

Figure 3: Switching loss of PMH200CS1D060 (Hybrid SiC-Module)

The switching energy characteristics of the new SiC hybrid module PMH200CS1D060 are shown in Figure 3; the switching energy characteristics of its Si-based predecessor type PM200CS1D060 are shown in Figure 4.

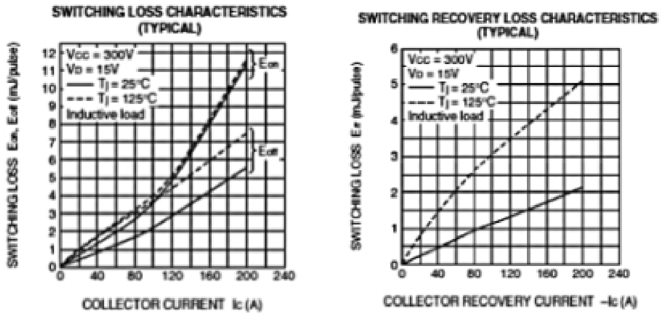

Figure 4: Switching Loss of PM200CS1D060 (Si-Module)

When comparing those characteristic curves (for example at Tj=125°C and rated current 200A) we can find 2 improvements caused by the SiC Schottky barrier diode in PMH200CS1D060:

- FWDi switching loss is reduced from 5mJ to 1mJ
- IGBT turn-on loss Eon is reduced from 11mJ to 9,5mJ
- Carrier life time control of IGBT chip was improved to suit with SiC Schottky barrier diode specification. As a results of improvement, IGBT turn-off loss Eoff was improved from 7.5mJ to 6.5mJ.

A substantial switching loss reduction in PMH200CS1D060 has been obtained. This is helping the inverter designer to overcome the typical for servo applications thermal constrains in high overload situations, particularly at high PWM switching frequency.

All other specific features of S1-series IPM have been preserved. For completeness they will be briefly reviewed as follows (see Figure 5):

- Short circuit protection by current sense emitters in each IGBT chip
- Over temperature protection by monolithically integrated Tj-sensors in each IGBT chip
- Control power supply under voltage protection
- Error output from n-side switches

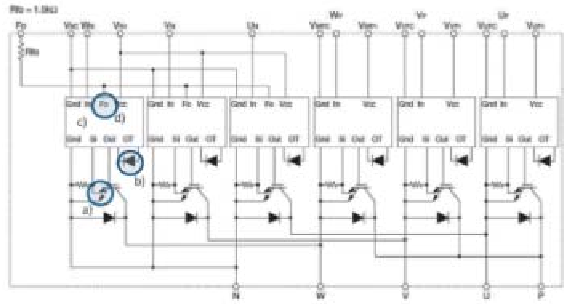

Figure 5: Functional block diagram PMH200CS1D060

Summary

Mitsubishi Electric has developed a new 200A/600V 6in1 Intelligent Power Module with Silicon Carbide (SiC) Schottky barrier diodes and improved Si-IGBTs. This hybrid SiC design approach leads to a substantial reduction of switching losses, particularly in the free-wheeling diode. In combination with the slim module package and the dedicated protection functions of S1-series IPM the newly developed hybrid SiC IPM type PMH200CS1D060 is offering an excellent technical solution for new multi-axis servo inverter designs.

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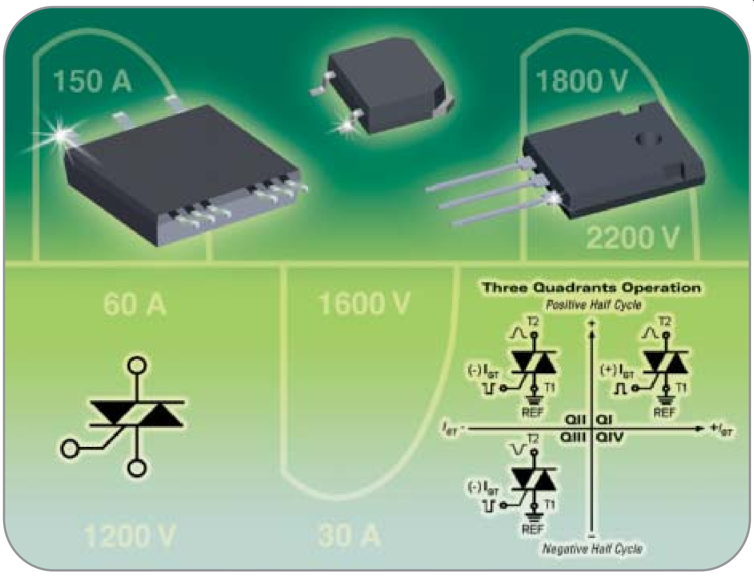

Systems Approach to Server Power Supplies

Supported by New Synchronous MOSFET Driver Family

In an effort to provide better solutions to its customers in the server arena, Infineon Technologies has enlarged its focus from pure MOSFET technology and product to system solutions. This means that Infineon supplies not only the MOSFET for the power converter but also the driver and controller.

By Milko Paolucci, Infineon Technologies

The result is that engineers can achieve higher efficiency and support new features. Being a system solution provider means not only being capable of optimizing each part of the system, but also improving the overall solution. After a short introduction about the system approach, this article guides the reader on the driver portion. In particular it shows which parameters have to be considered for selecting a good driver and the subsequent results that can be achieved with a system solution.

Further optimization with system approach

The level of complexity of the newest server-class CPUs requires a new approach to system design. Furthermore, for some server manufactures it is no longer enough to simply assemble the latest generation component technologies. At every aspect of the design, optimization arises from a system level view. In DC power conversion, for example, looking at controller, driver and MOSFET selection from a system point of view can enable a further step in performance. Combining the right driver technique with a tailored MOSFET technology in a single package will be much better than a general purpose driver with a generic MOSFET.

Infineon Technologies is a well established MOSFET provider in multiple markets and it is now adding to its driver portfolio two new devices, PX3517 and PX3519.

The PX3517 and PX3519 are dual, high speed drivers designed to drive a wide range of High Side and Low Side N-channel power MOSFETs in synchronous rectified buck converters. When combined with the Primarion family of Digital Multi-phase Controller ICs or Digital Point of Load Controller ICs and Infineon N-channel MOSFETs, they form a complete core-voltage regulation solution for advanced micro and graphics processors as well as point-of-load applications. The two devices are very similar in their basic features, with some differences in the package and advanced features.

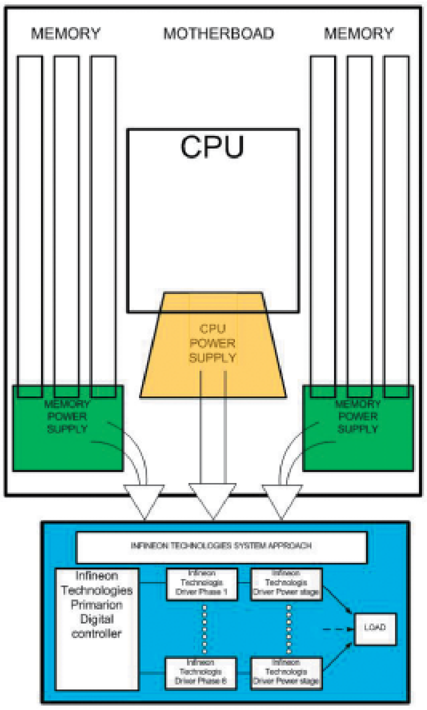

Figure 1: Infineon Technologies system approach

Both devices have an embedded bootstrap diode for the High Side MOSFET floating driver and they have adaptive shoot-through protection integrated into the IC. This prevents both upper and lower MOSFETs from conducting simultaneously and minimizes dead time. They can be synchronized up to 1.2 MHz with an external PWM signal, which also implements a tri-state functionality setting both MOSFETs in OFF state. The PWM pin has a built in resistor divider to set the voltage of the PWM inside the tri-state window, which avoids a fault condition in case the pin is left floating. The value of the divider is selected based on two criteria. On one side, the resistor divider creates a consumption that might affect the low load efficiency or stand by requirements. For this reason that network should be designed with high resistances. On the other side, the reaction time of the PWM can in some cases be influenced by these resistances and the parasitic capacitances associated with the pin/trace from controller to driver. In this case a low value resistance is desirable. The PWM is suitable for controllers with 3.3V. The low thermal resistance junction to solder point (θJS) (bottom exposed pad) secures a good thermal path to the PCB for heat. This good connection to the PCB is very important to decrease the self heating of the driver due to the MOSFET gate charge related losses, which can be significant in cases when multiple Low Side MOSFETs are used.

In the PX3517 a thermal warning function with an adjustable threshold, set by an external resistor, is featured to protect the system from thermal issues. Once the junction temperature of the PX3517 encounters the thermal warning threshold the driver outputs a logic signal through the open drain THW# pin.

To compensate for difficult layouts and noise generation, the PX3517 also offers separated power supplies for the power section (PVCC) and for the logic section (VCC). PVCC and VCC also can be supplied with different voltages, but in this case the appropriate power up sequence has to be implemented. PVCC provides the capability of driving the High Side MOSFET gate and Low Side MOSFET gate with a variable gate driving voltage (between 4.5V and 8V) to tailor efficiency based on customer conditions. The PX3519 presents an enable pin which can be used to put the system in stand by quickly from a different input compared to the PWM.

The PX3517 comes in a TDSON-10 leadless package and is pin to pin compatible with the previous generation of driver from Infineon Technologies (PX3516). The PX3519 comes in a VDSON-8 leadless package and due to the smaller pin count have PVCC and VCC merged in only one pin.

Figure 2: PX3517 TDSON-10 in leadless package

Figure 3: PX3519 VDSON-8 in leadless package

Electrical characteristics

There are many considerations for selection of a driver for power converter applications. This paragraph summarizes key concerns and their importance for the application.

PVCC operating range: 4.5V to 8V:

As described above the possibility to have a variable operating range for the MOSFET driving voltage allows the customer to optimize the efficiency for different levels of load. This is due to the fact that at different levels of load different losses play different roles. At full load for example, conduction losses are more important than dynamic losses. At low load / stand by, the dynamic losses are more important than conduction losses.

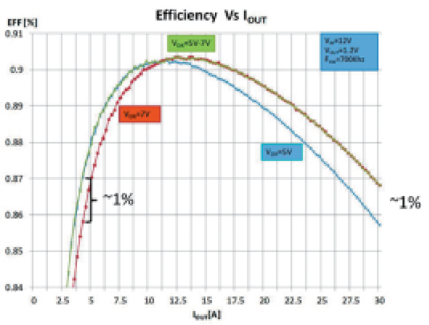

Figure 4: Driving voltage optimization

Figure 4 quantifies the improvements which can be reached with a variable gate driver. For the conditions given in the chart this is in the range of 1%.

Driver consumption: IVCC_O:660uA

At low load, power consumption of the driver itself is very important to overall system efficiency, especially in stand by. In the case of a 5V supply voltage the power dissipation accounted for by the driver is in the range of 3mW.

Timing characteristics:

Timing characteristics are important for two reasons. First, they provide a rough estimation of the dead time in the application and second they affect speed of the system to switch off both MOSFETs. In some particular application conditions the faster the power stage enters into high impedance mode the better.

Figure 5 and Figure 6 show the very small dead times between the two transitions. For the turn on transition (High Side MOSFET turns on) the dead time is in the range of 20ns, while for the opposite transition (Low Side MOSFET turns on) the dead time is in the range of 10ns.

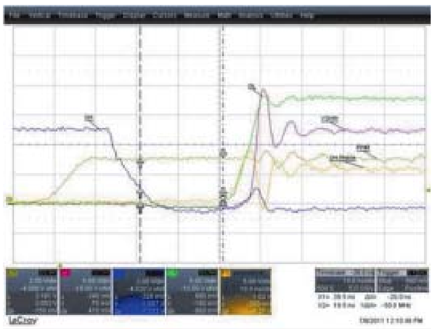

Figure 5: Turn on dead time

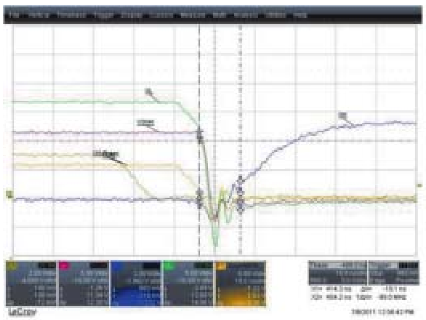

Figure 6 Turn off dead time

Output characteristics

The high sink/source current capability, for both high side and low side sections of the driver, allows the device to switch very low RDS(ON) MOSFETs generally showing a high input capacitance value. This permits the design of a high output current (up to 50A) single phase buck converter. The high side driver, through the high sink/source current capability (ISRC_UG, ISNK_UG), has the capability to switch a relatively high capacitance MOSFET in a few ns, making the device suitable balanced duty ratio applications (for example 5V down to 3.3V). The low side driver sink impedance (RSNK_LG) is designed to be very low in order to ensure the OFF state of the Low Side MOSFET during the turning on of the High Side MOSFET. In fact during this transition high dv/dt on the drain of the Low Side MOSFET can be coupled through the CRSS to the gate of the Low Side MOSFET resulting in an induced turn on. In case low RDS(ON) MOSFETs are used in the low side section, then the capability to turn on the Low Side MOSFET quickly is also extremely important to reduce the dead time. This is the reason for the high current capability of the source section of the low side driver (ISRC_LG).

Propagation delay enable pin

This feature is present only on the PX3519 and it gives an idea, of how fast the EN will switch off the two MOSFETs. It is very important to shorten this time in order to keep the overshoot on the output voltage low during load steps. Furthermore it is important that this functionality will not conflict with the PWM logic.

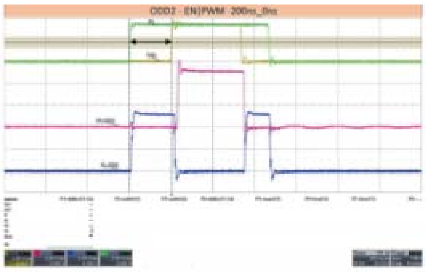

Figure 7: Quick and clean reaction time of the power stage

Figure 7 shows the quick and clean reaction time of the power stage to the toggling of the EN pin.

Thermal accuracy: +/-10°C

This feature is present only on the PX3517. The thermal accuracy is very important in order to prevent an excessive thermal runway which can later on cause damages.

Conclusion

Selecting a good driver for a specific application requires a systematic approach in comparing electrical characteristic designing a good layout and measuring efficiency. In this basic article a simple list of the most important parameters and effects on the application are described. The two new products introduced by Infineon Technologies provide excellent characteristics in most of the parameters considered. Figure 8 shows the typical results of a system level approach in terms of performance and shows a comparison of Infineon's former driver technology PX3516 VS the new PX3517.

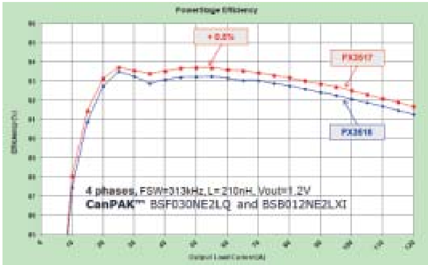

Figure 8: Typical results of a system level approach

References

PX3517, PX3519 datasheets

Application Note AN 2011-02: Buck Converter: Negative Spike at Phase Node.

Application Note AN 2013-06: Synchronous Rectified Buck MOSFET driver IC

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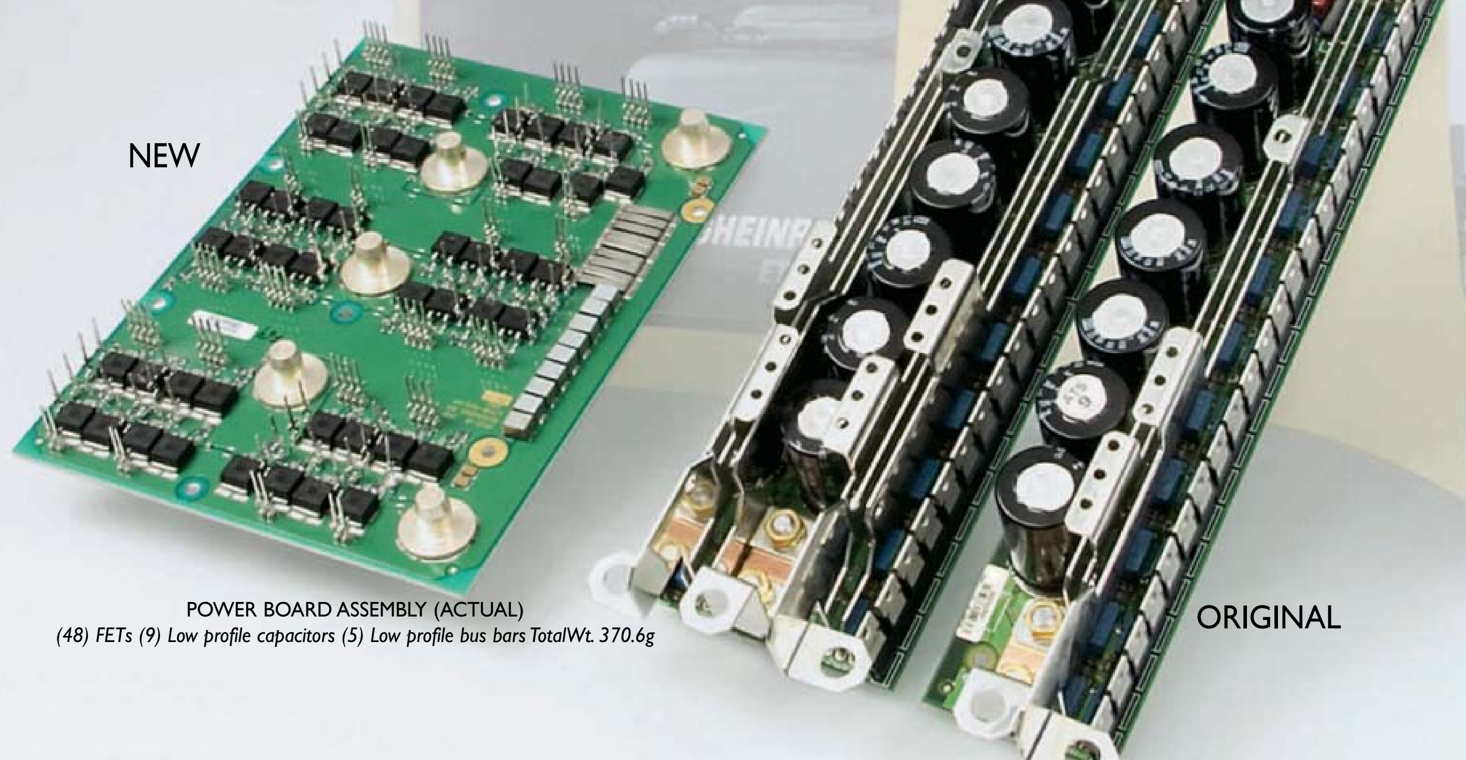

POWER BOARD ASSEMBLY (ACTUAL)
(48) FETs (9) Low profile capacitors (5) Low profile bus bars TotalWt. 370.6g

POWER BOARD ASSEMBLY (ACTUAL)
(66) Thru-hole FETs (15) High profile capacitors (9) High profile bus bars TotalWt. 1543.6 g

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SEPIC-Fed Buck Topology Boosts Performance in Non-Isolated DC-DC Converters

A point-of-load (POL) converter is a step-down dc-dc converter designed to supply constant voltage to a load, (almost) independently of load currents. It has become a popular solution for a wide variety of applications: from networking and telecommunications to data-communications and computing applications.

By Fariborz Musavi, Director of Engineering, CUI

The use of POL converters is rising rapidly for powering FPGAs, ASICs and other devices with a high-performance processing core. Furthermore with the dynamic power consumed by a processor being proportional to processor frequency and to the square of the processor voltage, the trend is towards lower core voltages that reduce power losses and consequently allow faster processing speed.

And it is obvious that the current required from these converters will increase even if the power requirement stays the same.

This has several implications for the power supply circuitry, including the need to route low voltages at high currents around a printed circuit board. This leads to relatively large voltage drops, higher power consumption, and large PCB tracks, which can easily result in poor output regulation.

By placing the point-of-load (POL) converter near to the load, it is possible to eliminate the long wiring between power supply and load found in conventional power supply systems. This enables a precise voltage supply while also meeting the low-voltage and high-current requirements. Additionally, as the power converters are located in physical proximity to the load circuitry, dc distribution losses are minimized and distribution inductance is reduced, enhancing dynamic response performance.

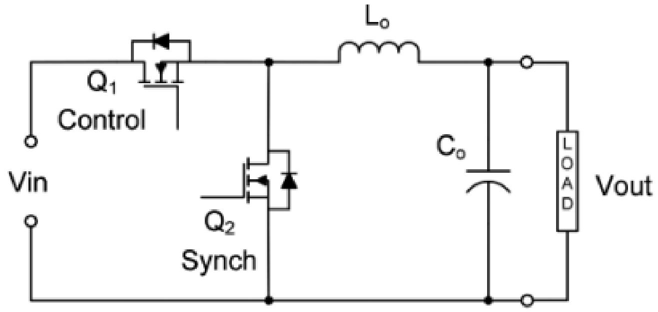

Figure 1: Schematic of a Synchronous Buck Converter

In summary, today's systems demand high levels of current at multiple low-supply voltages, and have tight regulation requirements, with large and fast dynamic currents.

Limitations of Existing POL Topologies

The most common topology used in POL applications is the synchronous buck converter. This replaces a diode with a low-side MOSFET, helping to significantly reduce losses and thereby optimize the overall conversion efficiency compared with a buck converter. Figure 1 illustrates the schematic of a synchronous buck converter.

However, all of this demands a more complicated MOSFET drive circuitry to control both the switches. In addition, care has to be taken to ensure both MOSFETs are not turned on at the same time, which would create a direct short from Vin to ground and cause a catastrophic failure. This short circuit is also called cross-conduction or shoot-through.

While using a MOSFET in place of the catch diode reduces the conduction loss, it also allows bidirectional flow of the inductor current. Thus, the synchronous buck converter maintains operation in its continuous conduction mode (CCM), versus the discontinuous conduction mode (DCM) for a conventional buck converter at light load. So while a synchronous buck converter may yield high efficiencies at high output current, it's anything but efficient under light loading conditions.

This means improving overall efficiency at both light loads and at high output current, a priority in next generation networking equipment, remains a challenge.

Another limitation of existing topologies can be highlighted by the requirement to supply a highly dynamic current with a tightly regulated voltage. This is a critical problem if using a buck converter as significant output voltage variations will occur during large load transients.

The inductor current's inability to vary at the speed of the load current causes the output capacitor to provide the necessary current to supply the load during load transients. This, in turn, will cause the output voltage to vary from its designed nominal voltage due to the capacitor discharging. Conversely, a fast "step-down" load transient would result in a voltage overshoot caused by capacitor charging.

Additionally, the controller cannot immediately react to turn on the control switch following the load current step due to its constant-frequency synchronous operation. The controller must, therefore, wait until the succeeding clock pulse before the control switch is turned on again. And, the finite bandwidth of the linear compensator - designed to be a fraction of the switching frequency for the purpose of system stability - prevents the control voltage from increasing at a sufficient rate. These two factors combined cause the capacitor discharge integral to be much larger than the ideal case.

Since the bandwidth of the compensator is designed based on the switching frequency, an obvious solution to improve the above drawbacks would be to simply increase the switching frequency of the converter. However, as already stated, the frequency-dependent losses of a buck converter (MOSFET gate loss, switching loss, inductor core loss), would lead to significant efficiency decreases for the converter.

Physical limitations of semiconductor devices and their current capabilities also play an important role in physical limitations of POLs. In order to design a higher current POL converter, designers either put several MOSFETs in parallel or they employ a multi-phase converter approach. Either way, the size and component cost would increase significantly.

Enter the SEPIC-Fed Buck Topology

CUI has developed a new topology to counter these problems. The proprietary Solus® Power Topology combines a single-ended primary-inductor converter (SEPIC) with a buck converter to form a SEPIC-fed buck. This patented topology addresses several limitations in the existing POL converter solutions, particularly efficiency and transient response. Figure 2 illustrates the schematic of a SEPIC-fed buck converter.

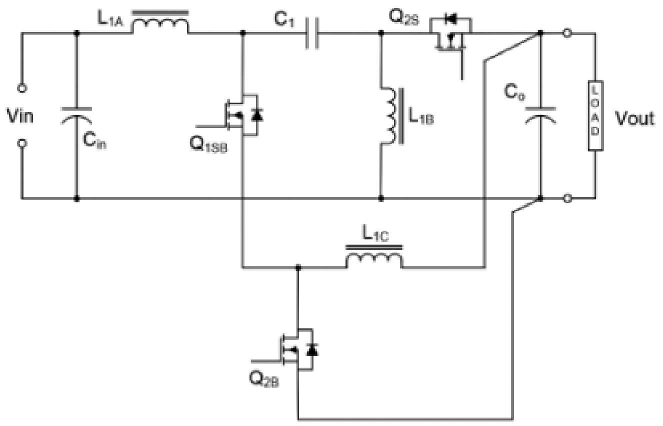

Figure 2: Schematic of a SEPIC-Fed Buck Converter

The ability to reduce power losses is an important aspect of this topology. Increased efficiency is accomplished by reducing both the conduction and switching losses at several critical points within the converter circuit.

At increased switching frequencies, these improvements become even more compelling. The higher the switching frequency could be produced, the higher the power density and the higher bandwidth of the linear compensator, consequently the more cost effective and the better transient response. If we assume that identical switching devices are used in a buck and Solus design, the new topology has the potential to reduce the switching losses by over 90%.

This allows the Solus converter to operate at a higher switching frequency without sacrificing very much efficiency, permitting benchmark power density at very reasonable levels of efficiency. Furthermore, since the topology has a very flat efficiency curve and can operate very efficiently over a wide voltage range, designers can substantially reduce the amount of the bulk hold-up capacitance as well, reducing the total cost of the power supply.

Figure 3 illustrates the converter efficiency versus output current at 12V input and 1V output in a 60 A non-isolated POL designed by CUI. As it can be noted, the converter's efficiency peaks at 30A at 91.28%.

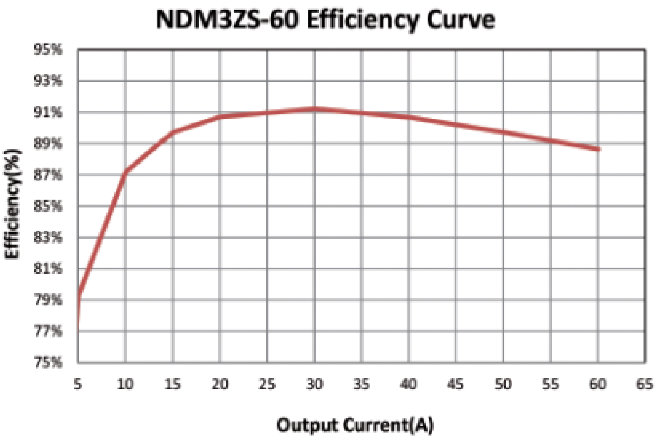

Figure 3: 60A SEPIC-fed buck converter efficiency versus output current at 12V input and 1V output

Figure 4 illustrates the transient response at 12V input and 1V output, to a 30A step change to the load (from 15A to 45A) with 10A/µs slew rate. It is noted that the peak deviation in voltage change is 16 mV, and bulk capacitors used in the board are 10x470 uF PosCAPs with no additional ceramic capacitors.

When comparing to another digital power POLs on the market today, this same solution would require two POLs in a current sharing mode and require more than 11,000 uF PosCAPs, all operating at a much lower overall efficiency.

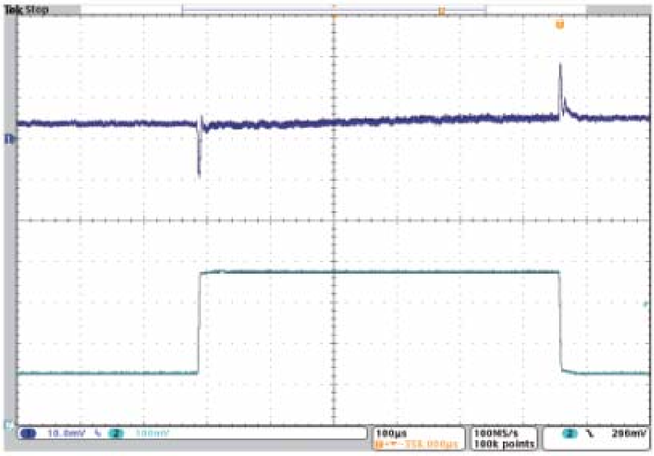

Figure 4: Transient response at 12V input and 1V output, to a 30A step change to the load with 10A/us slew rate. Ch1 (Blue): Vout, 10mV/div. and Ch2 (Green): Iout, 10A/div.

Input current to the SEPIC-fed buck converter is almost straight dc with only slight ripple, so the input capacitors value could be reduced up to 95%. This input characteristic also reduces EMI caused by input current ripple. This is due to presence of an inductor at the converter input side, which also helps to reduce any chance of failure in case of any shoot-through.

The Solus Power Topology includes one magnetic component, one control switch and two commutation switches that are optimally controlled by pulse-width modulation (PWM). The magnetic component consists of four inductively-coupled inductors wound on the same core. This translates to a level simplicity on par with a traditional buck converter.

Summary

Modern systems are demanding higher levels of current at multiple low-supply voltages, and have tight regulation requirements, with large and fast dynamic currents– indeed, 100A + rails are not unheard of – and existing topologies are consequentially reaching the limits of their capabilities.

High performance POL power conversion now demands high power density, high efficiency for greener systems, fast transient response and low EMI.

The SEPIC-fed buck is the first topology to incorporate the characteristics needed to address these new requirements.

Be sure to visit our booth (1233) at the Applied Power Electronics Conference (APEC) in Fort Worth, TX from March 16-20 to learn more about our solutions to the power challenges of next-generation networking applications, including the latest high density modules based on CUI's Solus Power Topology.

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Programmable Power Technology offers Highest-In-Class Power Density and Efficiency with Versatile Programmable Functionality

The increased complexity and sophistication of modern electronics in the field of networking, telecommunications, embedded systems, industrial control systems and automatic test equipment creates an ever increasing demand for advanced high performance power management systems.

By: Alan Elbanhawy, Simo Radovic and Jason Weinstein, Exar Corporation, California, USA

These systems require a host of features from precise programmable control loop parameters, fault monitoring and reporting to high power conversion efficiency and rail sequencing, all in the smallest possible footprint with uncompromising reliability. Devices like Exar's XRP9710 and XRP9711 are changing the power management landscape by meeting all of these requirements plus a large variety of specialized features that deliver fully customizable solutions and a very fast design cycle every time.

The Challenge

The continuous push for smaller electronic equipment and appliances has resulted in power management applications that demand a wide range of specifications that dictate the use of multiple ICs and discrete components to meet all the requirements. Generally, these components are not perfectly matched for the application and hence some compromises must be made in the final design implementation. This also leads to larger PCB real estate to accommodate such designs leading to higher cost and potentially larger EMI due to trace parasitics ringing and ground planes bouncing in a larger size PCB. Achieving good efficiencies is an absolute requirement to achieve higher reliability and lower PCB temp rise; but this necessitates finding, sourcing and testing multiple power components like MOSFETs, MOSFET gate drivers, inductors and capacitors. This process can be a lengthy and costly activity and once successful, next leads to the challenging task of PCB layout of the powertrain which can take several iterations to reach an acceptable design. The lengthy process is a major investment in resources, time and cost that may affect time-to-market and/or the competitive positioning of the product.

XRP9710/XRP9711 Power Management modules

This family of power management modules takes on all of the above challenges head-on and offers an array of features that will meet the most demanding requirements and satisfy the most discriminating power design engineer. Figure 1 shows a simplified application schematic.

Power Conversion Modulation Techniques

In order to maximize the efficiency over the entire load range, the power conversion architecture provides two types of modulation, Pulse Width Modulation (PWM) and a patented Pulse Frequency Modulation (PFM) with ultrasonic mode to guarantee that the lowest switching frequency does not drop down to the audible range. PFM provides very high efficiency at light loads and PWM provides high efficiency at medium to high loads. The control algorithm guarantees fully stable operation before, after and during transition from one mode to the other in both directions to guarantee a seamless operation over the entire load range.

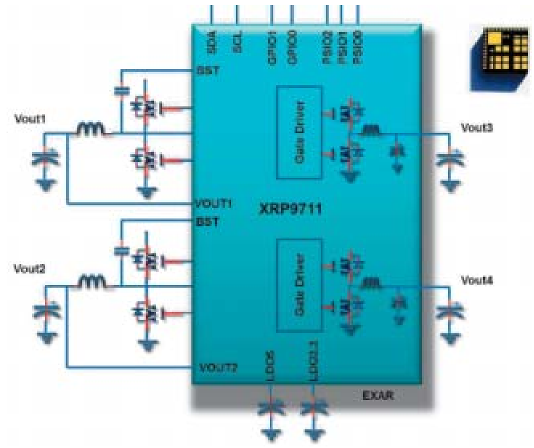

Figure 1: Simplified Application Schematic

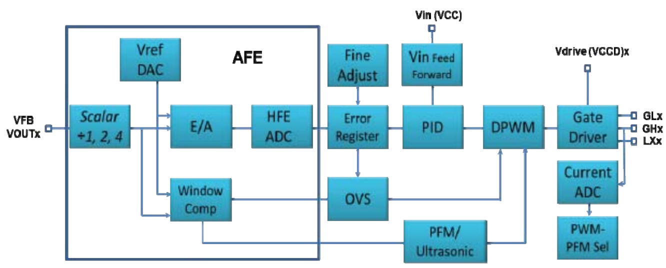

Figure: 2 Block Diagram of Control Architecture

Together with the PFM and PWM modes, the controller provides a patented Over Sampling (OVS) Feedback signal to guarantee excellent transient response.

Fast Transient Response

Figure 2 shows a simplified functional block diagram of the regulation loops for one output channel. There are four separate parallel control loops; PWM, PFM, Ultrasonic, and Over Sampling (OVS). Each of these loops is fed by the Analog Front End (AFE) as shown at the left of the diagram. The AFE consists of an input voltage scalar, a programmable Voltage Reference (Vref) DAC, Error Amplifier, and a window comparator. Figure 3 shows the transient response.

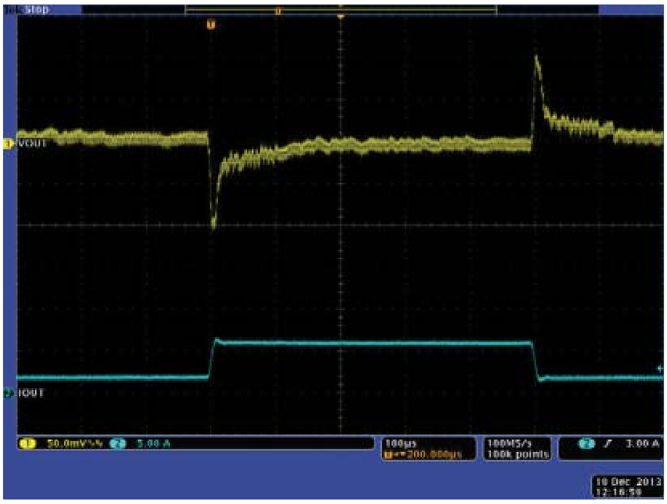

Figure 3: Transient response 2A-6A

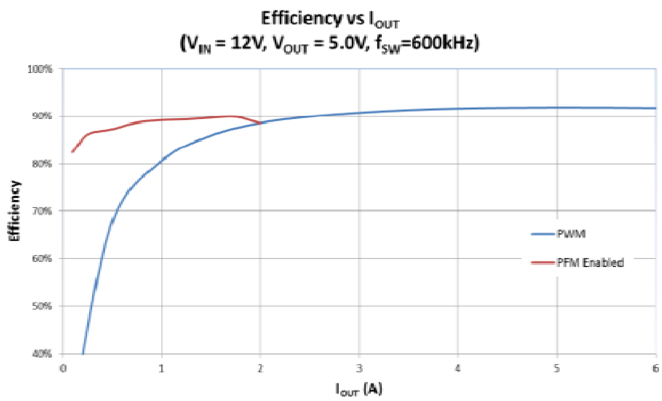

Figure 4: Efficiency measurement, Vin=12V, Vout=5V at 600KHz switching frequency

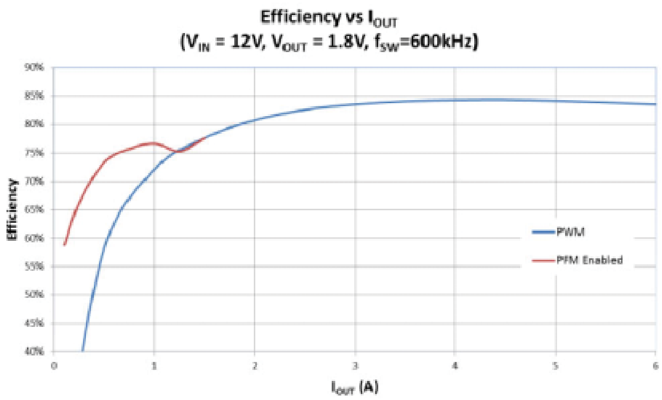

Figure 5: Efficiency measurement, Vin=12V, Vout=1.8V at 600KHz switching frequency

Power conversion efficiency

Figure 4 shows the efficiency for a 12V to 5V step down conversion, a sustained efficiency ≥ 90% over the range of 2.2A-6A and sustained efficiency ≥ 85% over the range of 0.25A-2.2A. Figure 5 shows the efficiency for a 12V to 1.8V step down conversion and figure 6 shows a thermal image of the module running at full power for the 12V to 1.8V case. Needless to say, the maximum module temperature will ultimately depend on the power losses and the available PCB copper area that acts as a heat-sink and helps radiate the heat, mitigating the maximum temperature. Practical PCB layout guidelines can be found in Application Note ANP-32

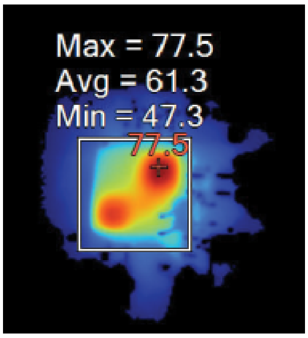

Figure 6: IR camera image, Vin=12V, Vout=1.8V at 600KHz switching frequency

Power Sequencing

Using the programming GUI supplied with all modules, all channels may be grouped together. Within a group, a user can specify the voltage ramp rate, the order in which the channels are powered up and any delays between channels. This applies to both the start-up and shut down allowing for maximum flexibility and total control of the order and the exact rate required for any given applications. Both sequential start-up/shutdown and simultaneous start-up/shutdown are supported, as illustrated in figures 7 and 8.

Fault management and protection

The XRP971x family offers an extensive array of fault reporting while allowing the user complete control over the system response by means of preprogramming or by allowing the host controller/CPU to react in real time to the reported fault through the use of the I2C bus:

- Under Voltage Lockout (UVLO) monitors the input voltage and will cause the controller to shut-down if it drops below the pre-programmed level.
- Over Voltage Protection (OVP) monitors the output voltage of all channels. This is a user defined parameter.

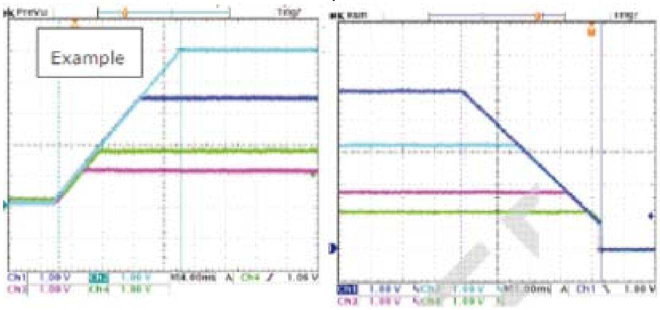

Figure 7 Sequential start-up and shut down

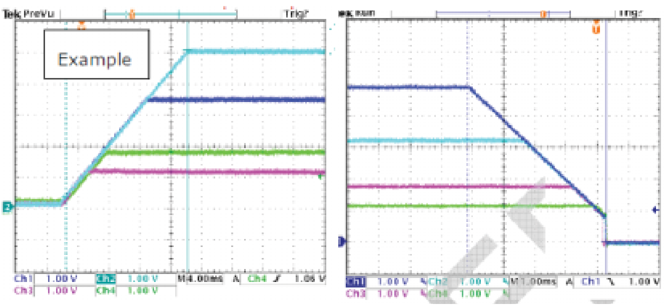

Figure 8: Simultaneous start-up and shut down

- Over Temperature Protection (OTP). The controller will shut-down all channels if maximum temperature limit is exceeded
- Over Current Protection. The limit is user defined and a user can choose one of three options for how to react to an OCP event: to shutdown the faulty channel, to shut down faulty channel and to perform auto restart of the channel, or to restart the chip.

Complete fault management details can be found in the datasheet (URL to be provided).

Advanced Feature Set

To round off the list of impressive performance features and advantages, the following is a brief description of some additional features to note:

- The XRP9710/XRP9711 family of power management modules boasts the highest in-class power density in the industry with excellent package thermal resistance of both junction-to-case (θJC) and junction-to-ambient (θJA) in a 12mmx12mm Land Grid Array (LGA) package.
- Very high reliability due to the fully optimized components with the proper design factor of safety criteria.
- Design once and use multiple times in applications simply by re-configuring the system software. This saves development time and R&D expense and results in optimum time-to-market and maintaining the product competitive positioning.
- I2C and five GPIO ports for reporting and remote control functions by a host controller/CPU.
- Perfect matching of the control IC and the power train components on a very small package outline of 12mm x 12mm:
  * Saves time sourcing, selecting and testing MOSFETs, inductors and capacitors etc.
  * Saves time on PCB layout and potential re-spins to optimize Efficiency, EMI and temperature rise of the application.
  * No need to procure and stock multiple parts, one part does it all.
- Fully programmable parameters such as:
  * Output set point   * Feedback compensation
  * Frequency set point   * Under voltage lock out
- Fully independent two/four channel multi-phase DPWM controllers.
- Full operation and health reporting e.g. input/output voltages, output currents, die temperature etc. Using I2C and GPIOs, a system processor could be configured to log and analyze operating history, perform diagnostics and if required, take the supply off-line after making other system adjustments.
- The module provides voltage tracking among the different channels.
- An internal 5V LDO that can be used by the design engineer for any housekeeping tasks up to 135mA.
- Differential voltage sensing is available in XRP9710. This allows for very precise output voltage set-point accuracy independent of PCB parasitic.

Conclusion

As we have seen, the XRP9710/11 is a family of versatile power management modules from Exar that offers significant advantages over other solutions on the market today. While the turn-around cycle for new products from concept to product release is getting shorter, this line of products takes away the time, expense and worry of power management system design and implementation. This allows design engineers to concentrate on the innovative aspects of their new products, and be free of concerns about the exacting performance specifications of their power management implementation.

Alan Elbanhawy: alan.elbanhawy@exar.com

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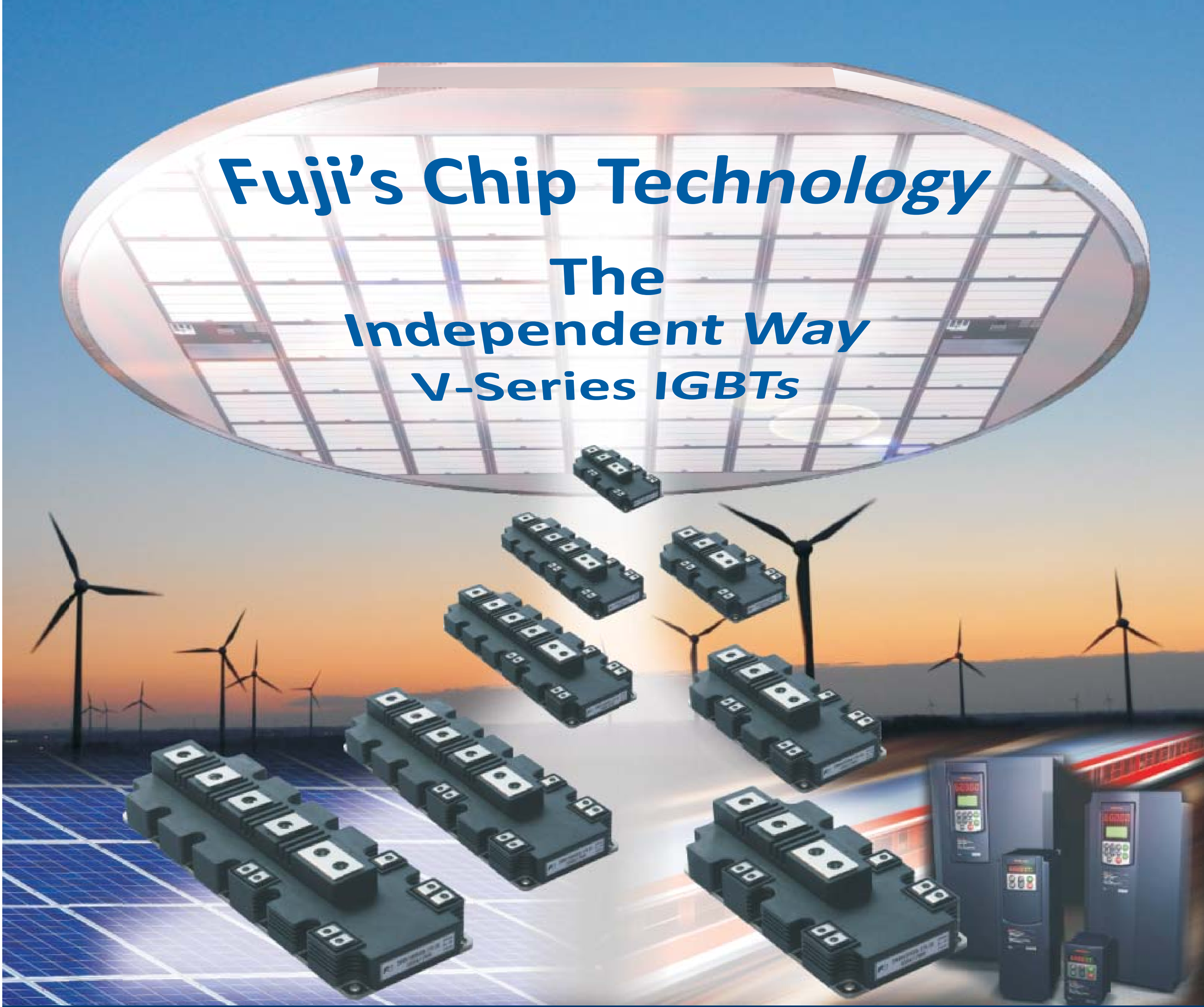

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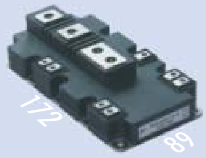
High Power Modules, 2-Pack & Chopper

	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)

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WPC Standard Wireless Charger Receiver Solution Based on FPGA

By Louis Tang, Fairchild Semiconductor

Background

With the vigorous development of wireless charger technology, and as more smartphone users are plagued by various charging cables, the convenience of a wireless charger will be widely accepted and adopted. Currently there are three different wireless charger standards – WPC (Qi), PMA and A4WP. The WPC Qi standard is more popular for use in smartphone applications. Now, many smartphone OEMs have launched wireless charger solutions which support the WPC standard. This paper will focus on the WPC standard's wireless charger receiver system and how it relates to the detailed system architecture based on the FPGA.

WPC Standard Overview

WPC Qi standard provides a detailed description of the wireless charger system, including the communication and transport protocols. Power transfer always takes place from a base station to a mobile device. A base station contains a subsystem—referred to as a power transmitter—that comprises a primary coil, and a mobile device contains a subsystem—referred to as a power receiver—that comprises a secondary coil.

Figure 1 illustrates the basic system configuration. As shown, a power transmitter comprises two main functional units, namely a power conversion unit and a communications and control unit. The control and communications unit regulates the transferred power to the level that the power receiver requests. A power receiver comprises a power pick-up unit and a communications and control unit.

The power receiver is at the side of the mobile phone, so the following will mainly introduce the power receiver system, and give the wireless charger receiver solution based on FPGA.

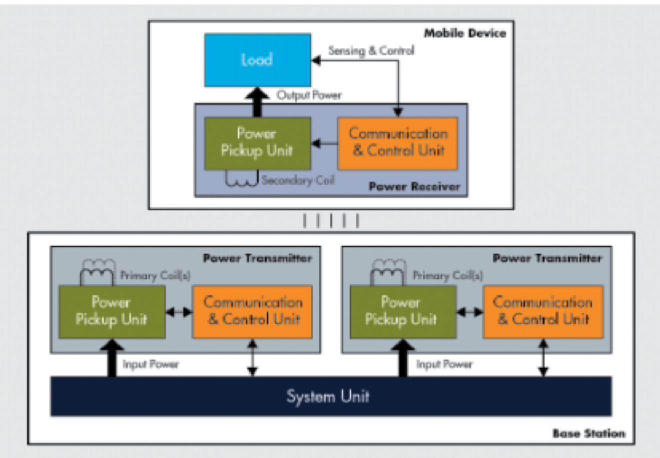

Figure 1: Basic system configuration

Power Receiver System Based on FPGA Overview

According to the WPC Qi standard, the power receiver system will contain a power pick-up unit and a communication and control unit. Examples will provide a detailed receiver solution that fully meets the WPC Qi standard's requirements. Figure 2 shows the architecture of the power receiver system based on a FPGA.

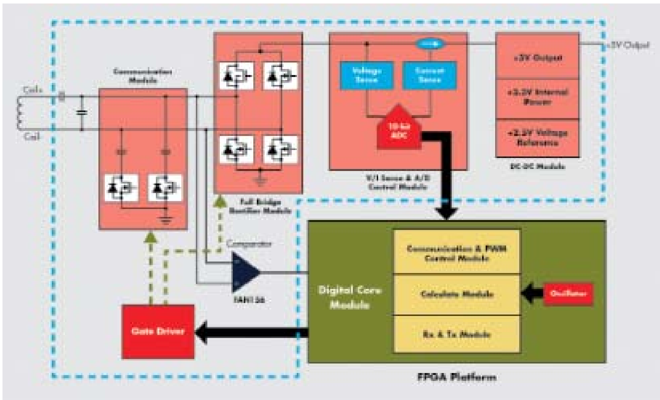

Figure 2: System architecture

As shown in Figure 2, the receiver system contains two subsystems, one is the analog module and another is the digital module. The analog module is composed of discrete components, which includes the full-bridge rectifier module, V/I sense and AD control module, communication module and DC-DC module. The digital module is built into the FPGA, using the Verilog language to write the programs. The digital core module can be divided into three main sub-modules: first is the communication and PWM control module, second is the calculate module, and third is the Rx and Tx (receiver and transmitter) module. These modules are described in more detail below.

Analog Module

The secondary coil is the power source of the analog part; the primary coil and secondary coil form the two halves of a coreless resonant transformer. Through electromagnetic coupling, the alternating magnetic field will generate the AC power at the secondary coil, and then the full-bridge rectifier will convert AC to DC. Figure 3 shows some of the analog module's schematic.

Full-bridge Rectifier

In this solution, the FAN156 (U10) comparator, the FDMA8878 (M1, M2, M3, M4) N-channel MOSFET and the FAN7085 and FAN3180 (U2, U3, U4, U5) MOSFET drivers comprise the full-bridge rectifier. The FAN156 device's output signal feeds directly into the FPGA, and then the FPGA will give the control signal H1, L1, H2 and L2 to the full-bridge rectifier.

The FAN156 comparator is used to detect the polarities on the ends of the coil. As shown in the schematic, if coil + is positive and coil - is negative, then the FAN156 comparator will give a “H” signal to FPGA. In a similar way, if coil + is negative and coil - is positive, then the FAN156 comparator will give a “L” signal to FPGA. The PWM control module will then give its output based on these inputs. From the full-bridge rectifier perspective, if coil + is positive and coil - is negative,

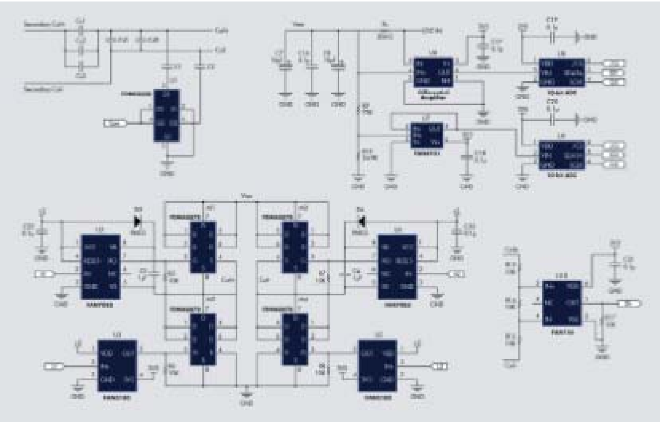

Figure 3 - Part of the analog module’s schematic

then the N-channel MOSFET (M1 and M4) should turn-on and (M2 and M3) should turn-off. Similarly, if coil + is negative and coil - is positive, then the N-channel MOSFET (M2 and M3) should turn-on while the M1 and M4 should turn-off. These form a rectification cycle and there should be dead-time between the M1 and M4 opening and the M2 and M3 closing, or M2 and M3 opening and M1 and M4 closing. This is because there is a potential risk, for example, when the FPGA sends the instruction to let M1 and M4 turn-on, at the same time, M2 and M3 is on and is going to turn-off, so the M1 and M2 will form a low-impedance path. This kind of situation should be avoided. There needs to be dead-time to ensure M2 is turned-off before M1 is turned-on. In this solution, the dead-time can be added in the FPGA PWM control module. Figure 4 illustrates the timing diagram of the PWM control module. Please note that “1” means logic “H”, “0” means logic “L”, and FAN7085 is negative logic.

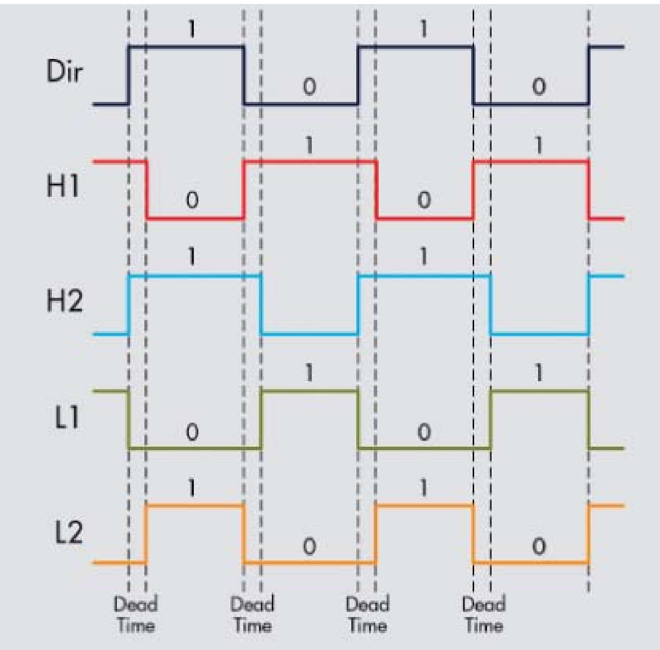

Figure 4: PWM control module timing diagram

V/I Sense and AD Control Module

V/I sense and AD module is in charge of voltage and current data acquisition, these parameters are very important for the FPGA control module. In this solution, 10-bit ADC (U8, U9), differential amplifier (U6) and FAN4931 device (U7) comprise the V/I sense and AD control module. Use a 20 milliohm precise resistor to sense the current, and the differential amplifier will amplify the voltage drop across the precise resistor. For example, set the differential amplifier with a 100V/V gain, and the reference voltage of the ADC is 2.5V, so the maximum current that can be detected is 1.25A, and the theoretical accuracy is less than 2mA.

The precise divider resistors R9 and R10 are used to sense the rectified DC voltage Vrec, if R9=75K and R10=24.9K as show in the schematic, because the ADC’s reference voltage is 2.5V, so the maximum detectable voltage is 10V, and the theoretical accuracy is less than 10mV. The FAN4931 device is used as a voltage follower, and to achieve the impedance matching between the ADC and divider resistors.

The control signal of the ADC, /CS and CLK, comes from the FPGA control module. Their output data will feed into the FPGA, the calculate module will use this data to calculate the received power, and the control module will use this data as the verilog program’s sensitive signal.

Digital Module

The digital core module is built into the FPGA and it is crucial for the power receiver system.

Communication and PWM Control Module

The WPC Qi standard provides a detailed description of the power transfer phases, from a system control perspective. Power transfer from a power transmitter to a power receiver comprises four phases – start (selection), ping, ID & C (identification and configuration), and PT (power transfer). Figure 5 illustrates the relationship between the phases.

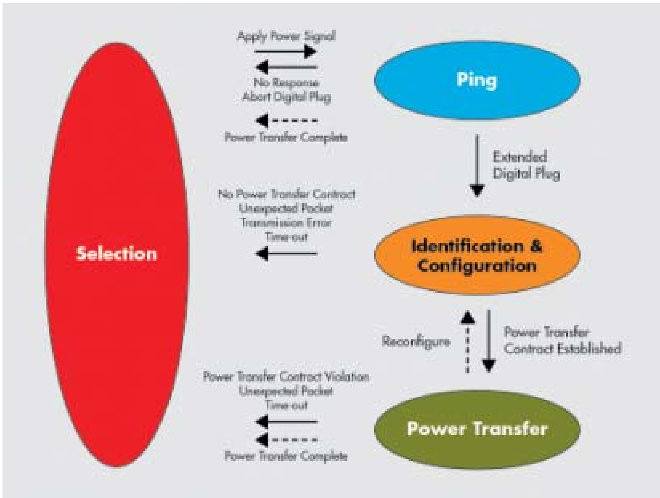

Figure 5 - Power transfer phases

The WPC Qi standard also defines a strict timing requirement during the power transfer phases. According to these requirements, this paper extracts a state machine, including nine different states, and the FPGA control module program will be written based on this state machine. Figure 6 illustrates the control module state machine.

Every time the receiver board is placed on the wireless charger pad, the control programs will enter a state 0. If the connection (ping) is successful, the receiver will go into charging status. Thus the control program will stay on the state 5 and 6, the control module will send out a control error packet to adjust the charging current, and will also send the received power packet to implement the FOD (Foreign Object Detection) function.

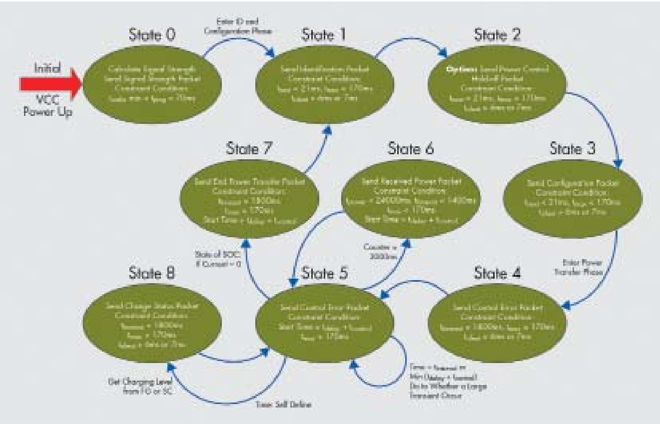

Figure 6 - Control module state machine

Calculate and Rx and Tx Module

The calculate module is used to calculate the signal strength, control error and the receive power. In the analog module, the ADC will give the voltage and current information to the FPGA, and the calculate module will get the signal strength, control error and received power, and send it to the Rx and Tx module.

The Signal Strength value can be calculated with the formula below:

$$\text{Signal } Strength = \frac{U}{U\max} * 256 \quad (1)$$

Where U is the monitored variable, and Umax is the maximum value, which the power receiver expects for that variable during a digital ping. Note that the power receiver shall set the signal strength value to 255 in the case that U Umax. Here use the rectified voltage Vrec as the U, the ADC will give the 10-bit digitized voltage to the FPGA, and the FPGA will use it to calculate the Signal Strength.

The Received Power value is calculated as shown below:

$$\text{Received Power} = \left(\frac{\text{Received Power Value}}{128}\right) * \left(\frac{\text{Maximum Power}}{2}\right) * 10^{\text{Power Class}} \quad (2)$$

Where the maximum power and power class are the values contained in the configuration packet, in a low power wireless charger application, the maximum power should be set as 10. Following the WPC Qi version 1.1.1, the power class should be set to 0, which means the power receiver expects to provide at the output of the rectifier – 5W. Note here that the Received Power value in formula 2 is not the actual value. It should be converted as below:

$$\text{Received Power Value} = \left(\frac{\text{Rectified Voltage} * \text{Rectified Current}}{5W}\right) * 128 \quad (3)$$

Where if the Received Power Value is 128, that means the Received Power is 5W.

All of these algorithms are implemented in the FPGA.

The Rx and Tx module use the data which comes from the calculate module to process the packets, and send these packets to the power transmitter. The WPC Qi standard defines the data format in the communication. In every data transmission, one packet will be transferred. One data packet is formed by a preamble (>11 bit one) for bit synchronization, one byte message head which indicates the packet type, the message information (1..27 byte) and one checksum byte. One data byte is an 11-bit serial format. This format consists of one bit start bit, the eight data bits, one parity bit and one bit stop bit. The start bit is a ZERO. The order of data bits is least significant bit (LSB) first. The parity bit is odd and the stop bit is a ONE. Data bit is encoded in differential bi-phase code and its speed is 2Kbps. The data format is shown in Figure 7.

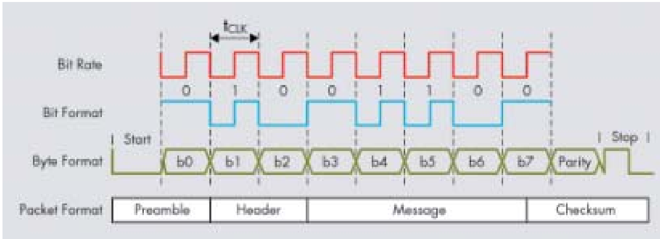

Figure 7 - Data format

Conclusion

Through testing and analyzing, the demo board works well on the major OEM's wireless charger pad. This shows that the system is stable and reliable, which has some practical values. Figure 8 shows this solution being used to charge a handset on a major OEM's wireless charger pad. As portable devices increase in popularity, convenient charging is going to be the growing trend, and wireless charging may be the best choice. This solution adopts a few discrete devices and one FPGA, to verify the design of the Qi standard charger receiver, and has the very high technical reference value to the wireless charger receiver system's architecture and design. With the wireless charger market developing, this method can be very easily integrated into new silicon.

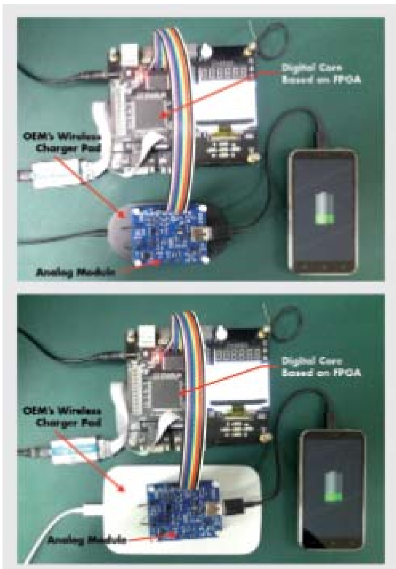

Figure 8: Wireless charging on the wireless charger pad

Reference

[1] "System Description Wireless Power Transfer Volume I: Low Power, Part 1: Interface Definition V1.1.1 July 2012", Wireless Power Consortium.

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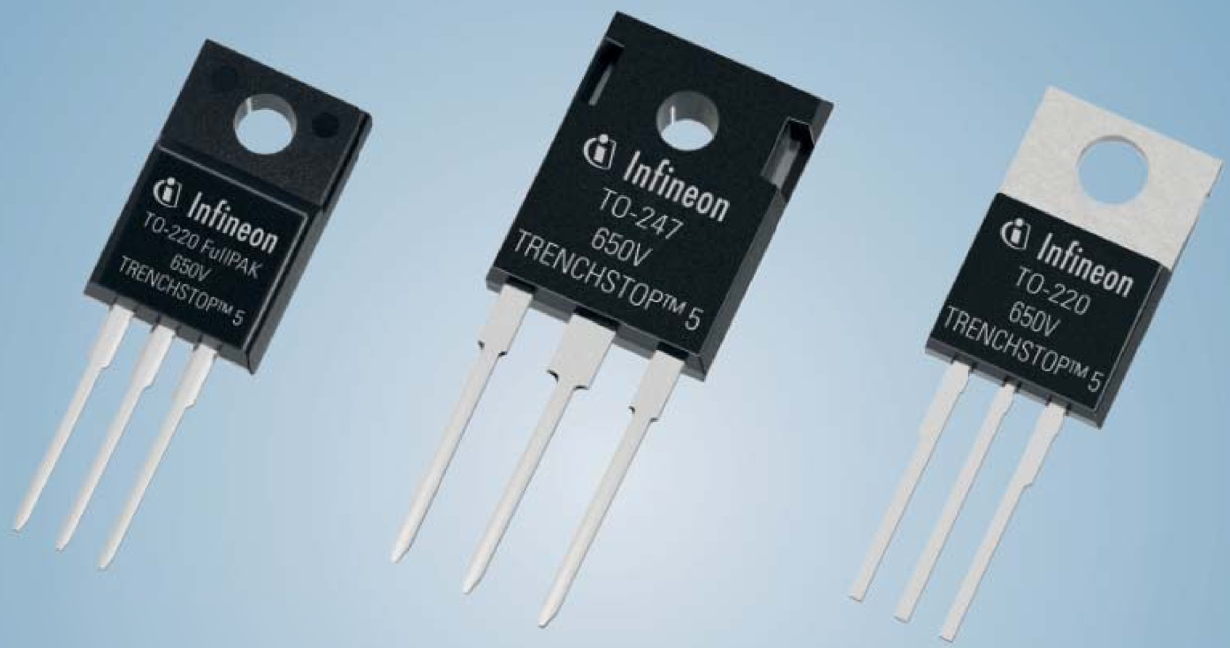

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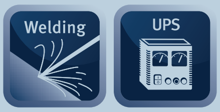

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Watch the video!

Power meets Precision

The PX8000 Precision Power Scope is a mixture of power-analyzer and oscilloscope

DLM4000, WT3000, DL850E – Yokogawa's last year's developments focussed on power measurement in a special way. The new Power Scope PX8000 is supposed to fill a gap in this power measurement solution as it combines power-analyzer and oscilloscope functions.

By Marisa Robles Consée, Corresponding Editor; Bodo's Power Systems

Johann Mathä considers the PX8000 "a logical consequence of Yokogawa's measurement roadmap". Yokogawa Germany's Marketing Manager elaborates: "We have pulled together power meter and oscilloscope functions into a hybrid instrument, because we believe that this is needed to deal with a growing number of designs that either have to meet increasingly stringent energy-usage regulations or deal with often unpredictable renewable-energy systems." The PX8000 precisely captures voltage and current waveforms and may be suitable for various applications and solutions for a wide range of emerging power measurement challenges. "With the launch of this instrument, R&D professionals need no longer compromise on the need for high-accuracy time-based power measurement – something that conventional power analyzers and oscilloscopes were never designed to meet", Mathä states.

Figure1: The power analyzer PX8000 pulls in scope functions for energy-saving designs. (Picture: Yokogawa)

PX8000: Packed like a digital oscilloscope

The PX8000 is packed like a digital oscilloscope and has 12 bit resolution with 100 MSample/s sampling and 20 MHz bandwidth. This means that it 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 a basic accuracy of ±0.1% of reading.

The PX8000 has built-in functions for the direct calculation of derived parameters, such as RMS and mean power values, to enable the identification of cycle-by-cycle trends. It 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 the examination of transient phenomena and 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 modes, from "sleep" to full activity and all the transient states in between.

Figure 2: The PX8000 is the new flagship product for Yokogawa's range of industry-proven power analyzers. (Picture: Yokogawa)

Fast shifts between operating modes

Clive Davis, manager of test and measurement marketing for Yokogawa in Europe and Africa, says: "The PX8000 has a number of innovative features that support the crucial measurement and analysis of transient power profiles." For example, the device provides simultaneous voltage and current multiplication to give real-time power sampling. This supports both transient measurement (as standard) and numerical values averaged across the sample period. The available measurement period will depend on the sample rate and the memory size. "People try to use an oscilloscope to measure power because it feels easy. But oscilloscopes are not designed to be temperature stable," says Davis, leading to problems with drift in measurements. He adds: "A fundamental issue is the transient nature of power. That's where you need integration between the power meter and oscilloscope, because the conventional oscilloscope isn't calibrated." Trend measurements between waveforms can be calculated by mathematical functions (up to four million points). The system provides graphical displays of voltage, current and power readings. The waveforms can be inspected for specific numerical values at any point and averages can be calculated between start and stop cursors. Such capabilities are particularly important when analyzing and optimizing the performance of, for instance, lighting and electric motors at start-up.

"Up to 16 different waveforms – including voltage, current and power – can be displayed side-by-side, giving engineers instant snapshots of performance", claims Hafeez Najumudeen, Product Marketing Manager for Europe and Africa.

The PX8000 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 phenomena and in the design of periodically controlled equipment. To ensure that equipment such as photocopiers complies with energy standards, for instance, 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. Despite this, for certain tasks it is important to be able to display values on an X-Y axis. Motors, for instance, are characterized by an ST-curve that shows the relationship between speed and torque. The PX8000 supports such displays as standard. It can also display Lissajous waveforms of input and output for phase analysis.

Hafeez Najumudeen says the harmonics analysis is a key component, up to surprisingly high orders, for applications that include power supplies and wireless power chargers, where the inductive energy transfer components can lead to high frequencies being injected into the power signal: “The PX8000 makes it possible to simultaneously measure the harmonic components of voltage and current waves as well as the harmonic distortion factor. Harmonic measurements take place in parallel with conventional voltage and current measurement. Harmonics up to the 500th order of the fundamental can be measured.” Additionally, the system features arithmetical, time-shift, FFT and other computations that enable users to display waveforms with offsets and skew corrections. “Users can also define their own computations via equations that combine differentials, integrals, digital filters and many other functions”, he adds.

Choice of Modules

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. Basic accuracy is down to ±0.1 percent. Sensors can introduce phase errors or skew between the current and voltage inputs. The de-skew kit 701936 enables this phase shift to be corrected automatically for each power measuring element individually. Up to three sensor and voltage measurement modules can be installed.

To prevent incompatibilities, the PX8000 detects mismatched current and voltage modules and flags them with an on-screen warning message. The system also comes with a range of dedicated input connectors designed to prevent incorrect or dangerous power connections. Using these connectors, it is not possible, for instance, to connect a current probe to a voltage input terminal. A tie-wrap system prevents accidental current terminal disconnection.

Figure 3: Clive Davis (l.) and Hafeez Najumudeen: “The harmonics analysis up to surprisingly high orders is a key component.” (Picture: Marisa Robles Consée)

This new instrument is powered by Yokogawa’s isoPRO technology, which offers isolation performance at the highest speeds. Designed with energy-saving applications in mind, this delivers the performance needed to evaluate high-efficiency inverters that operate at a high voltage, current, and frequency, while achieving the measurement accuracy, stability, and repeatability. Connection to a PC can be established via standard Ethernet/USB/GP-IB connections. The software displays waveforms in a simple and clear graphical style that is familiar to users of Yokogawa’s Xviewer software. Researchers who want to use their own analysis software can use the LabVIEW driver to establish a connection to the PX8000.

Fit for many applications

Applications for the PX8000 cover various areas from renewable power to advanced robotics. Any situation where power consumption is at a premium – which means almost anywhere power is consumed – can benefit from the introduction of its precision measurement and analysis capabilities. Typical applications include inverter and motor testing, reactor loss measurement for inverter boost circuits, transient response measurement for industrial robots, wireless charger efficiency measurement, and voltage and power measurement for electricity distribution systems.

“The vertical resolution of analog/digital conversion is one of the most important factors in precision measurement”, Hafeez Najumudeen says. A common problem when testing inverter motors is the presence of ambient noise that can mean test values are nonzero 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. Another example is the ability to evaluate motor-driven robots, power consumption of all motors and controllers is measured throughout all operational speeds and action patterns. He adds: “Design engineers need 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 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.”

www.tmi.yokogawa.com/px8000

Methods of Current Measurement in Mid-Frequency Power Circuits

Fast-changing power current precise measurements are very important in modern measuring equipment for power semiconductor devices. It is quite important for converter equipment as well, since improved control algorithms are used there, which require knowledge of instantaneous current value in a certain period of time.

By Alexey Poleshchuk, R&D Center, Proton-Electrotex JSC

There are many methods to measure current, which differ depending on the used physical effect. Electronic components and the chosen technique play a critical part because they set complexity of circuit solution.

The situation is complicated by the fact that current may vary from ten amps up to hundreds kiloamps, and frequency may vary from industrial 50/60 Hz up to hundreds kHz. If it is necessary to run current measurements in a high-voltage pulse cascade which requires increased insulation, additional limitations occur. There is no single way to solve the problem that is why it is necessary to know all pros and cons of certain methods to manage the issue.

Further there is a comparative analysis of the accepted methods to measure current, the areas of their usage and differential peculiarities. At first, the pros and cons of various sensors are described depending on the operational approach. Secondly, analysis of the issues connected with a insertion point of the sensor into scheme and following processing of received data received is described.

Current measurement principles and features

Measurement Transformer

Power current transformer is a device which is widely used in industrial electrical engineering. It is fully described in various literatures. There is no its detailed description in this article since it is used only in industrial frequency networks.

Disadvantages of this device:

- Slow response, determined by core magnetism, which does not let using it at a frequency higher than assigned (60 or 400Hz). At higher or lower frequency its transmission ratio is distorted due to nonlinear characteristics of core magnification;
- Distortion of transmission ratio due to heating-up and core saturation and necessity to apply turns correction;
- High mass-dimensional characteristics and overheat danger of the secondary coil in the case of measuring device disconnection.

General advantages:

- Simple design and low cost comparing to the other solutions;
- Availability of regulatory standards and normative documents for accuracy class index;
- Possibility of high voltage galvanic insulation, no additional power supply requirements.

There are broadband power current transformers, which can operate in the frequency range different from the industrial network range, but such solutions are more expensive and less popular. For example, transformers by Pearson Electronics can register current in the 10Hz-20MHz range with 100A current amplitude. Other models produced by Pearson Electronics allow to measure current flowing in coaxial cable in the 300Hz-200MHz range.

Rogowski Coil

The Rogowski Coil is an alternating-current component sensor in conductor. It is a coreless coil around the current-carrying conductor. Coil design provides with high protection from the external electromagnetic interference and high output linearity to the measured current.

Coil output voltage follows the formula:

$$V = \frac{-AN\mu_0}{l}\frac{dI}{dt}$$

where $A = \pi a^2$ – small area (one coil around the central wire)
l – coil length, N – number of coils around the central wire.

Since the coil registers alternating-current component only, to achieve absolute current value it is necessary to integrate the coil input signal. This process is done by the sensor internal circuit, which is supplied together with the coil (figure 1).

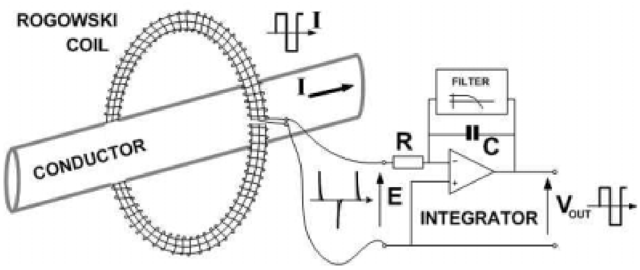

Figure 1: The Rogowski Coil is an alternating-current component sensor in conductor

Since the coil is not closed and sensor output does not depend on the coil path, the sensor can be quickly installed in any conductor line without structural changes.
Due to fast response and high linearity the sensor registers alternating and pulse current with high accuracy, but the integration scheme

generates distortion on direct current linked with the accumulative error during registration of high frequency transient phenomenon and insensitivity to the low frequency current changes.

Since transmission characteristics of each coil vary during production process, typically the sensor, amplifier and integrator are considered as a whole thing calibrated by the manufacturer.

Advantages of the method:
- High linearity and fast response of the sensor which enable it to register high frequency current pulses;
- Lightness and installation simplicity at any circuit location;
- Galvanic isolation of the sensor.

Disadvantages:
- Accumulative error on direct current connected with integration errors and influence of the noises;
- External power supply requirements.

Hall Effect current sensor

Unlike the above described sensors, the ones based on Hall effect measure real current in the circuit. This allows to precisely register processes in the circuit in the range from direct current to high-speed transients.

There are many types of this sensor in different design: for semiconductor mounting and for mounting around the conductor line. According to the principle of operation there are 2 types of sensors: open and closed-loop. Open type sensors use Hall effect to register the flowing current and distribute converted Hall voltage. Unlike the open closed-loop sensors generate current, which compensate magnetic field produced by primary current, and, as a result, provides with zero magnetic flux linkage.

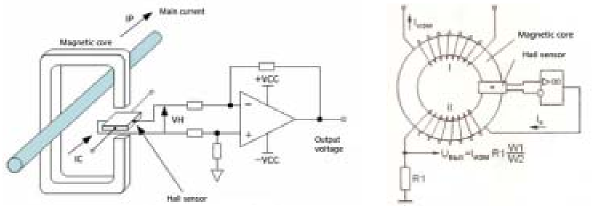

Figure 2: Open type sensors use Hall effect to register the flowing current and distribute converted Hall voltage

The following formula describes connection between coils volume and current: primary coil and control coil.

$$I_P N_P = I_S N_S$$

The main advantage of closed-loop sensors is increased accuracy and wide frequency range. The sensors have current output, which provides increased resistivity to electromagnetic interference.

For the low current range (up to 30A) integrated design sensors are widely used to be mounted on semiconductors produced by Allegro Microsystems, for example. One of the main disadvantages of such microcircuits is output noises related to internal compensation scheme. LF filter used to eliminate the noises decreases system response rate down to 30-40kHz.

Advantages of the method:
- Wide range current measurement including direct current;
- High measurement accuracy, good linearity especially in closed-loop sensors;
- Overcurrent withstand without damage;
- Complete galvanic separation with measured circuit.

Disadvantages:
- Output noise in some kind of sensor;
- Limited frequency range (below 500kHz);
- Saturation mode when measured current exceeds rated range;
- High cost and large dimensions especially for closed-llop sensors designed for high current (from 1kA);
- Additional power supply requirements;

Resistive Sensor

Resistive shunt is one of the most common but in many cases the most complicated device due to the absence of galvanic separation with the operating circuit.

In the low current range film technology SMD-resistor shunts are used, which provide good heat sink and low inductivity. The next power class is represented by the resistors produced with the thick film technology in TO-220 housing for through-hole mounting; these resistors have very good thremal characteristics through the external heatsink and low inductivity.

There are two major problems associated with the usage of resistive shunts with high current - shunt power losses, which require its cooling and internal shunt inductance which distorts voltage with increasing frequency transients. Galvanic insulation between high voltage circuit and control circuit, especially at high nominal and pulse voltage, is another important question.

It is possible to include a compensating element with the transfer function for approximate compensation of reactance into the measurement scheme:

$$W(s) = \frac{R_{Ш}^{-1}}{\frac{L_{Ш}}{R_{Ш}}s+1}$$

$L_ш$ and $R_ш$ – shunt characteristics.

However, frequency band of the whole device is limited by the band of first order filter, and accuracy of measured values doesn't meet the metrological requirements.

To have very accurate measurement of high frequency processes special design coaxial shunts are used, where influence of the internal inductivity is compensated what allows to measure current in the range up to several MHz. Coaxial shunts produced by LEMSYS allow to register peak current up to 100kA in the 200MHz frequency range (figure 3).

Exceptionally high accuracy of current measurement, the possibility to register peak current values beyond the nominal range and wide frequency range make these devices indispensable to use in measurement equipment.

Figure 3: Coaxial shunts produced by LEMSYS allow to register peak current up to 100kA in the 200MHz frequency range

As a result, there are the following major advantages and disadvantages of the resistive shunts.

Advantages:
- Simple design;
- High metrological accuracy and very wide frequency range (for coaxial shunts);
- High overload capability and possibility to measure current peak values;
- Need no power supply;

Disadvantages:
- Need to be directly connected to power bus, power losses during heating-up of the shunt;
- External galvanic isolation is required;

Magnetooptic Sensor
Current sensors based on magnetooptical effect are used for galvanically isolated measurement of high currents (up to 500kA) in high voltage buses.

Advantages:
- Possibility to measure high current values;
- Stability against the influence of the cross-magnetic field;
- Complete galvanic isolation;
- No power losses in the sensor;

Disadvantages:
- High cost and large dimensions;

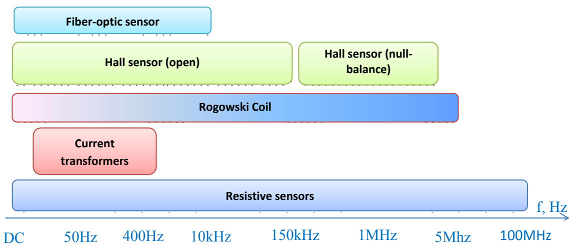

Figure 4: The general application areas of the various current sensors

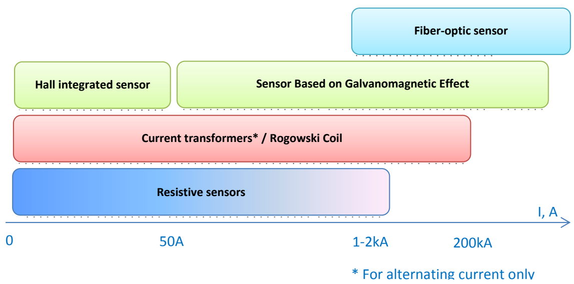

Figure 5: The general application areas of the various current sensors

General Application Areas of Various Sensors
During development of the measuring equipment there are some key questions: the precise measurement of current peak value in the wide frequency range due to high rate transient processes in power circuit and tested elements. Hall effect sensors and resistive shunts correspond to the current value registration accuracy criterion.

In most cases the Hall sensor frequency band is not enough for precise registration of the transient processes, moreover, closed-loop sensors for high current values are very expensive. Coaxial design resistive shunts have very wide passband and high measurement accuracy combined with ability to register very high peak current values limited by shunt heat capacity only (fig. 5). These advantages determine their usage for measurement despite the disadvantages linked to requirement of additional galvanic isolation.

Current measurement in bridge and half-bridge schemes
Shunt connection point
Since the shunt is installed in measured circuit, it is under power circuit operating voltage, where its connection point is very important (figure 6).

Supposing that ground measurement and control design is connected to the common line of the main circuit, there are two ways of measurement shunts connection in any power circuit - between power supply and load (high-side current sensor) and between load and common line (low-side current sensor).

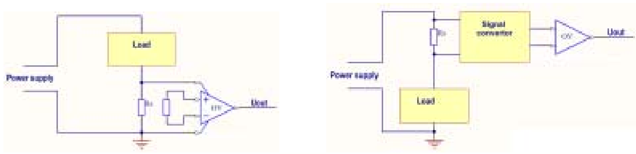

Figure 6: There are two ways of measurement shunts connection

Connecting shunt to the negative load pole we have the following:
- Measurement is done with respect to the control scheme ground;
- Low common mode voltage on the input of the buffering operational amplifier;

Connecting to the positive pole:
- Measurement is done using differential method (since floating shunt connection point potential);
- Adapter scheme is required to transmit and convert input differential signal;
- High common mode voltage on the input of the buffering circuit;

To simplify the implementation of measurement circuits, connection of the shunt between load and common lines has some advantages, but sometimes it is not possible due to different reasons. To implement the scheme a lot of instrumental amplifiers can be used, for example, AD627 produced by Texas Instruments. There are no issues to implement this scheme.
Connection of the shunt to the positive load pole has the one major problem - fast-changing common-mode input voltage.
There is a set of instrumental amplifiers to measure differential-mode signal in shunt at common-mode input voltage out of the scheme supply range. LT1990 and AD629 belong to the set of such amplifiers. AD629 has ±270V common-mode input voltage with bipolar supply, and its maximum is ±500V. Rejection level of common-mode voltage is defined by CMRR characteristic (common-mode rejection ratio), which reaches 90dB in the frequency range up to 1kHz.

In the scheme key switching time is 200ns and supply voltage is 0V and +300V. Then:

$$\frac{dV}{dT} = \frac{\Delta V}{\Delta T} = \frac{300V}{200ns} = 1500V/\mu s$$

Thus, current shunt installed in the scheme changes its potential from 0 up to supply voltage with defined rate (figure 7).

Unfortunately, CMRR characteristic drops with common-mode voltage frequency growth, and usage of this type of amplifiers is impossible at the frequency about several tens of kilohertz, and it also cannot block the noise formed by *dV/dt*.

To implement the scheme considering all issues described above it is necessary to use the methods which guarantee blocking of the common-mode noises through the galvanic separation. Such methods consist of the following: tied part, which makes preliminary signal adjustment, galvanic isolation, untied part, which normalizes output signal. All these parts can be combined in one unit or implemented as separate components and units.

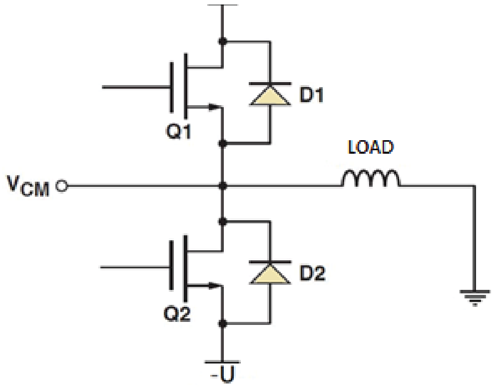

Figure 7: Current shunt installed in the scheme changes its potential from 0 up to supply voltage

Primary areas of this method implementation:

- High-linearity analog optocoupling devices;
- Insulated operational amplifiers;
- Insulated analog-digital converters with digital separation;

Analog optocoupling devices are used for signal separation through highly linear couple LED - 2 photo diodes, where one of the photo diodes is used to make feedback and ensure signal accuracy. An example of such components type is Avago HCNR200. Principle application diagram is shown in the following figure (figure 8):

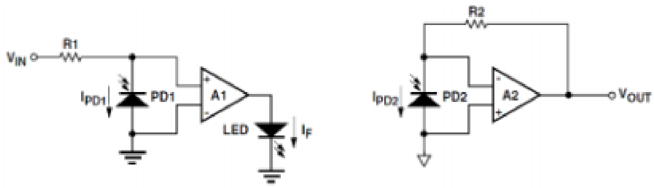

Figure 8: Principle application diagram

Optocoupling devices have very high transmission ratio accuracy and wide dynamic range (over 5MHz). If there are good characteristics to block common-mode interference with 50Hz frequency, its inner structure doesn't provide with high CMTI (common-mode transient immunity), and high frequency common-mode interference goes into the secondary circuit insufficiently filtered.

Isolated operating amplifiers have a wider application area. These are Texas Instruments AMC1200 and Avago ACPL-790x. Avago ACPL-790x provides a wider band pass up to 200kHz. It has the following advantages: integral design, which requires minimum additional elements and high withstand to transient processes up to 15kV/µs.

Major disadvantages: limited band pass, which is not enough for many applications in measurement equipment and high level of interference with frequency over 50kHz (figure 9) related with operation of sigma-delta converter used in this microcircuits. However, these microcircuits are very convenient to use for current measurement in control systems such as drive controllers and power converter controllers, where there is no need in precise current feedback.

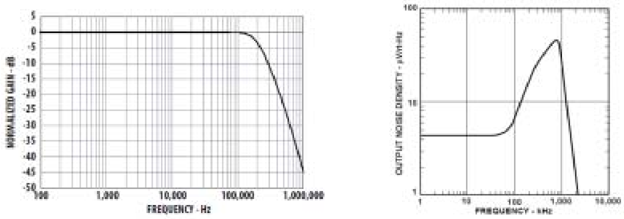

Figure 9: Interference of frequency over 50kHz related by operation of sigma-delta converter

In the case when high resistivity to switching noises is required, wide frequency range and high measurement accuracy with low noise level, it is justified to use analog-digital converter located in unisolated part and further isolation of digital signal through digital isolators. Depending on the application this can be done by analog-digital converter with serial or parallel interface; after digital isolation it is possible to convert signal back to analog from using digital-analog converter, or connect it to the controller input (figure 10).

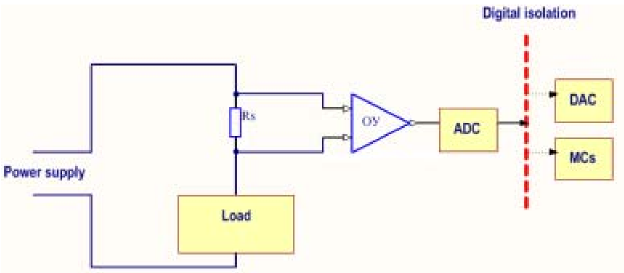

Figure 10: Digital isolation it is possible to convert signal back to analog from using digital-analog converter

Such scheme provides maximum quality of signal measurement, but it is more complicated, expensive and bulky. Simultaneously, it gives an opportunity to measure current in high voltage circuit, because digital signal insulation does not have any major issues and can be done using high voltage optocoupling devices and POF type optical fiber transmission system.

Influence of Power Circuit Parasitic Parameters

Usage of shunt connection scheme in the negative load pole in some cases is complicated by influence of high current flow and fast switching processes of power circuit stray characteristics such as power bus line inductivity.

Such influence leads to the fact that current shunt is getting under floating potential defined by EMF power bus line self-inductance in different moments (figure 11).

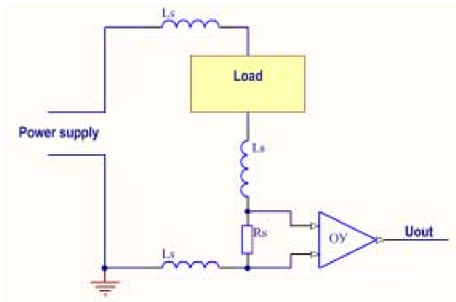

Figure 11: Shunt connection in the negative load pole suffers from stray inductivity

Switching off 1000A current for 500ns the voltage value on short copper bus reaches 100V, and rate of voltage rise equals 200V/µs. This allows treating this situation equal to the first, which occurs during shunt connection to the positive load pole, because the load is distributed.

Current Measurement in Bridge Circuit

During development of the bridge circuits switching low currents (up to 100A) with necessity to precisely control these currents value, it has sense to use current shunts connection into the lower arms of half-bridges instead of using shunt in the load area (figure 12).

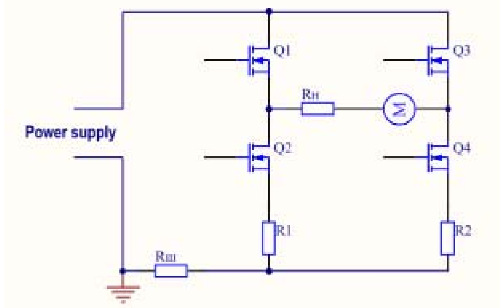

Figure 12: In bridge circuits the current shunts are in the lower arms of half-bridges

Current in the shunt Rh is the real current flowing in the load, but its measurement causes additional problems, especially during high frequency key elements switching (80kHz). Current in the Rw shunt shows general power consumption of the power circuit, but it doesn't reflect the processes, which occur during load short circuiting by keys Q2 and Q4. Current measurement in this resistor is used to define power line short-circuit to an external devices (housing, for example), what cannot be traced by the data from the other circuit points.

Thus, measuring voltage drop on resistors R1 and R2 it is possible to completely restore current flowing in the load in the almost all switching modes.

Summary

Measuring equipment for power semiconductors has very high requirements to the quality of current measurement circuit and its characteristics. These are wide range of the measured current in consideration of peak values measurement necessity, and wide frequency range up to several MHz. Considering the price factor, the coaxial resistive shunts correspond to the above mentioned characteristics. Its usage in fast main circuits is linked to the inevitability to solve some tasks like signal galvanic isolation and switching noises suppression. These tasks can be solved in different ways depending on the required accuracy and passband using integrated solutions like ACPL-790x by Agilent, or using special circuits on discrete elements, which allow to achieve dynamic and precise characteristics.

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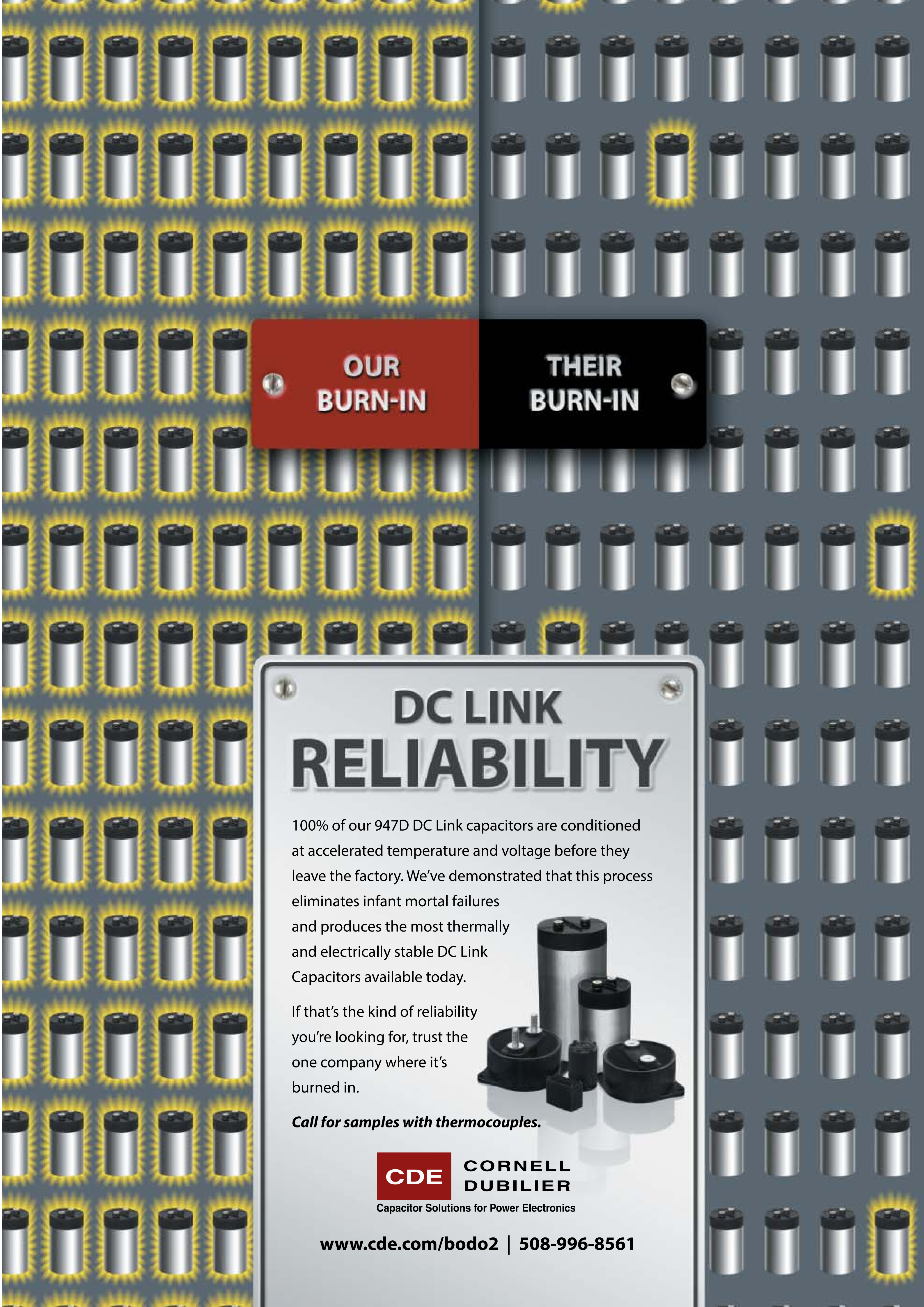

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Comparison of Silicon Versus Gallium Nitride FETs for the Use in Power Inverters for Brushless DC Servo Motors

The Institute of Robotics and Mechatronics of the German Aerospace Centre (DLR) is actually developing a new lightweight robot named SARA, what stands for Safe Robot Assistant. As successor of the LBR III it is the 4th generation of lightweight robots made at the institute. It will feature safe sensor signal supervision to guarantee signal integrity and safe motor and brake control systems to allow secure man machine interaction even with the significant higher dynamics of the new system.

By Robin Gruber, German Aerospace Center (DLR)

SARA consists of seven joints and a flexible gripper, each driven by a brushless DC servo motor from a series of motors, which have also been developed at the institute to get an optimized drive regarding efficiency, space and weight.

Figure 1: SARA Robot

To drive these motors low voltage motor power pulse inverters are being developed to fulfill the constraints regarding output power, control of an electromagnetic brake, efficiency and digital interface.

In the final design the inverters are equipped with an FPGA or DSP riser board that will process the 3-phase current controller that is required for a smooth motor control. Four of these inverters will be placed in a heat spreader plate and connected to a common power supply that also carries the bulk DC-link capacitance and a control board that will read in and preprocess the commutation, joint position, force and torque sensors as well as optional additional sensors resulting in a very compact Drive Control Unit. Each unit supplies and evaluates up to 16 sensors and controls four motors so that two Drive Control Units are sufficient to operate the complete arm.

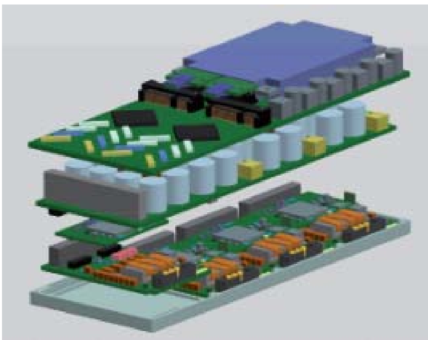


Figure 2: SARA Drive Control unit for 16 Sensors and 4 Motors

This different approach compared to the LBR III where each joint had a dedicated inverter and control board directly attached to the motor, improves the modularity and the thermal design - the heat sources like motor and inverter are distributed over the arm and not concentrated at the joints - as well as the serviceability and allows for a more compact joint design.

Since the Robotics and Mechatronics Institute is highly interested in the improvement of sensor and power electronics we used the opportunity of this new robot development to evaluate the new enhancement mode Gallium Nitride FET technology from EPC and compare it with our up to this time best inverter design. Therefore we designed two inverters with the same form factor and electrical interface as well as similar parameters, one Silicon based and one Gallium Nitride based FETs for the 3-phase bridge.
Both inverters are able to deliver at least 25A continuous (35A peak) at a nominal voltage of 48 to 60V (75V peak) (safety extra low voltage) into a motor with an inductance of as low as 100µH requiring at least 40kHz PWM frequency and a current control loop of the same speed. Additionally both inverters provide a digitally controllable output voltage of up to 12V/2A to actuate an electromagnetic brake with current measurement to implement brake inductance measurement for an open / close detection. Overcurrent protection and some housekeeping measurements like motor and inverter temperature and the surveillance of several voltages are implemented as well. Figure 3 shows the two inverters from the bottom side. The tiny blue parts are the GaN-Power-FETs.

Phase Current Measurement

Our standard approach to phase current measurement is a shunt resistor in the source to ground path of each low side transistor for each of the tree half bridges. The shunt signal is then EMI-filtered (to avoid EMI induced offset effects of the amplifier, also known as EMI rejection ratio), amplified and fed into a 12 bit AD converter (see Figure 5). During the operation of the inverter with a symmetric PWM pattern (that originates from the space vector modulation that we usually implement), there is an instant when all low side transistors are conducting and all three phase currents are fed through the shunt resistors so that they can be measured. Timing is essential here, because the measured decaying current equals the average motor phase current only when the sampling point is exactly in the center of the PWM period.

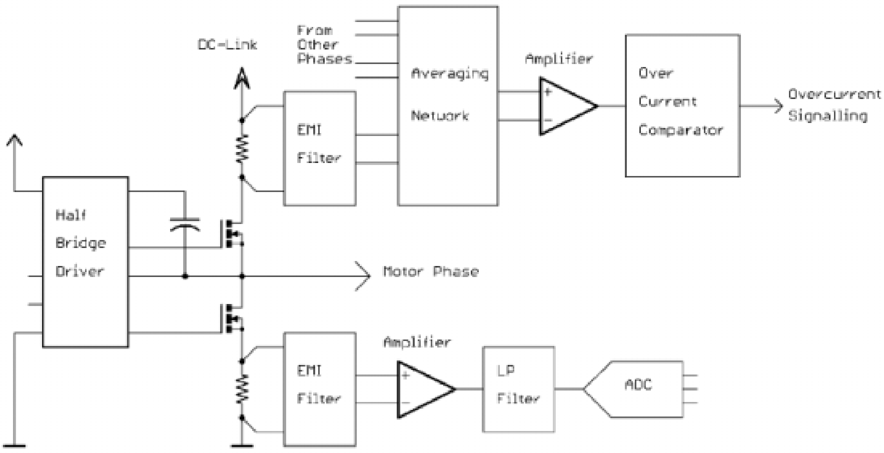


Figure 5: Low Side Source Shunt Current Measurement

The advantages of this technique are its simplicity, the (theoretically) small size of the solution and the possibility to implement an automatic offset and 1/f-noise compensation when two measurements per PWM period are performed and subtracted, one when all low side FETs are conducting and one when all high side FETs are on, resulting in no current flow through the low side shunts.

The drawbacks result from the location of the shunt in a fast switched current path. Even when resistors with a very low inductance are being used, the changing current due to the switching of the half bridge, and even worse, the current change of the low side body diode recovering can result in more than 8A/ns, which then will result in a few volts of voltage drop over the resistor followed by excessive ringing compared to a few millivolts of current sensing. The voltage peak and the ringing have to be filtered out, limiting the corner frequency of the amplifier's bandwidth resulting in more time for the amplifier to

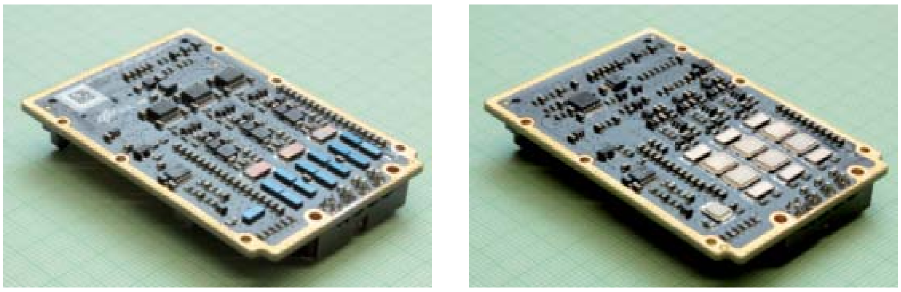


Figure 3: GaN-FET inverter (left) and Si-MOSFET inverter (right)

settle. This settling time limits the minimum pulse width and thus the length of the resulting voltage vector. Figure 6 shows the raw value of the DC current of all three phases as measured by the ADC with current flowing through one phase (only possible on a test setup). For this test the inverter is operated at 50% pulse width for all phases, so current flows for half of the time through the shunt only. The spike on the left originates from the filter's response to the removal of the low side MOSFET's reverse recovery, and the smaller one on the right from discharging the MOSFET's output charge. The decay of the

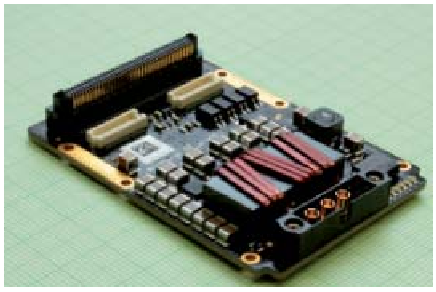


Figure 4: Topside of the Si-Inverter

signal near the center is generated by driving an inductive load.

This effect can be reduced by dynamically taking the measurements from the two half bridges that commutate the widest pulse width only and calculate the third phase current. But the ringing of one half bridge induces noise into the DC-link supply which cannot be built infinitely "stiff" and thus is exciting the other half bridges resonant tank resulting in a crosstalk error between the half bridges. To keep this effect as low as possible, we managed to shift the resonant frequency above 200MHz so it can be separated from the measurement signal more easily, provide a very low inductance DC-link voltage and use low inductance resistors which also reduce the chance of self-conducting of the low side FETs when the ringing pulls the source potential below the gate potential.

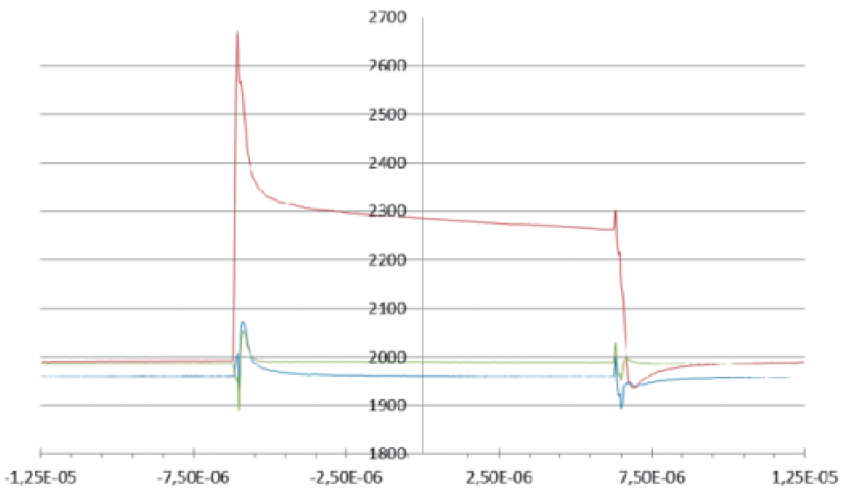


Figure 6: Signal at the ADC of the low side source shunt current measurement

Another disadvantage of the low side source shunt is the limited ability of an overcurrent protection that can detect a short between two phases only. To extend the protection capabilities to include the detection of a short of a phase to ground, additional high side MOSFET drain shunts have been added together with a summing amplifier and comparators to detect the overcurrent thresholds. Current sensing and overcurrent protection for three phases also need an overall board space of approx. 675mm² (1.04inch²) implemented for the inverter with the silicon MOSFETs.

Figure 7 shows a plot of the deviation of the current measurement of each of the three phases (red, green, blue) of one inverter dependent on the measured current and the pulse width that has been set. The dotted lines show the very wide or very small pulse widths, where the filter either after measuring with all high side or all low side FETs conducting, has not enough time to settle after the current change of the switching and reverse recovery of the body diode excites the ringing.

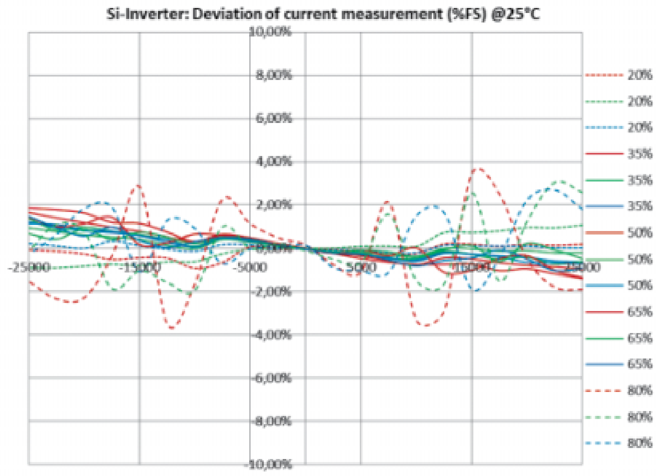


Figure 7: Accuracy of low side shunt measurement

Although we managed to keep the DC-link impedance around 10mOhms up to a frequency of 20MHz, below 100mOhms up to 100MHz and below 1Ohm up to 1GHz (measured, not simulated), the ringing of the half bridge can still be found in the DC-link voltage (see Figure 8), but with moderate amplitude. The resulting crosstalk is up to 2.2% of the current of the adjacent phase.

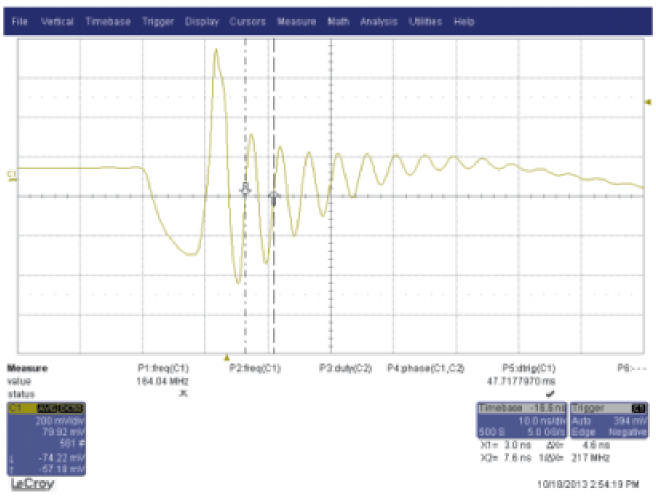


Figure 8: Ringing in the DC-link supply

Because our project's senior electronic engineer cowardly refused to build a low side shunt current sensing for the GaN-inverter where transistors were expected to switch faster and the threshold voltages are half that much so that the same common source inductance is in the range of two times as evil, we used the opportunity to make him try a different current measurement approach for the first time at the institute (see Figure 9).

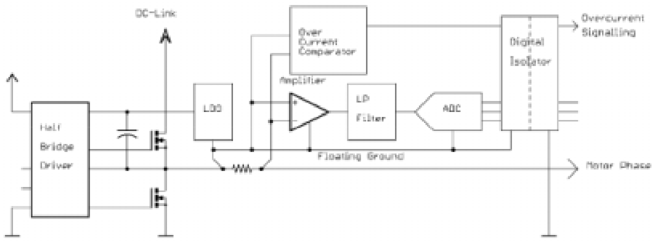


Figure 9: Current measurement with phase shunt

Here we use a shunt resistor in the output path of each half bridge. The shunt voltage is monitored by two comparators for overcurrent sensing in both directions and a chopper amplifier with low pass filter followed by a 12 bit AD converter with a 4-channel bidirectional magnetic signal isolator to level shift the AD converter's SPI and the overcurrent signal down to the inverter's ground reference. The shunt evaluation circuit of each half bridge is supplied by its own low noise voltage regulator which is fed from the bootstrap capacitor of the half bridge driver. It was routed using only one single layer and partial vias on the bottom side of the board with a close local ground area underneath directly connected to one side of the shunt. The required board space for this current measurement is approx. 880mm² (1.4inch²).

Although this circuit is hopping from 0 to 60V within about 8ns (which is not too far from the limit of the digital isolator) 40.000 times a second the measurement results are much better (see Figure 10). In addition the measurement crosstalk between two phases could be reduced to 0.1%.

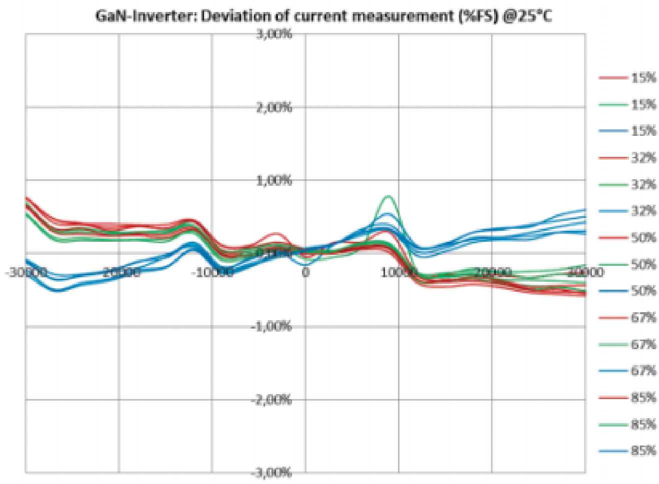


Figure 10: Accuracy of the phase shunt measurement

The corner frequency of the low pass filter could be chosen to be 20kHz in contrast to the 3.5MHz bandwidth of the low side shunt bandwidth. Also in this variant two measurements per PWM period are sampled, but now averaged to get a higher resolution and to eliminate a group delay dependent offset that would otherwise occur when undersampling a DC signal with sinusoidal offset only once per period.

The measurement noise vanishes in both variants behind the last bit, because very low noise amplifiers and resistive networks that equal the noise performance of the amplifiers have been used. This is essential because a noise in the current measurement of a robotic arm produces audible noise from the joints.
In addition it has to be noted, that the output voltage from this type of inverter can be higher because here the pulse width range that still allows the current measurement to operate is from 0 to 95%. The upper limit comes from the topology that the bootstrap capacitor also has to supply both the high side MOSFET driver and the current measurement with the bootstrap diode of the bridge driver being too small to supply this higher amount of current when the charging time becomes too small. This will be optimized in further versions.

Efficiency

First of all it must be emphasized that the efficiency comparison is not absolutely fair because we compare an 80V inverter with a 100V inverter both operated at 75V for the measurement, but we had no choice - there hasn't been such a thing as an 80V GaN-FET.
The inverter was designed to have its maximum efficiency around the typical robot joint operation point of 4 to 8A that is required for static torque control or slow movement of the system. This ensures low power losses when cooling is critical. As soon as the robot starts moving, higher ammounts of heat can be dissipated due to the better cooling of the arm moving through air.

For the silicon inverter we chose an IRF6646 and for the GaN inverter our loss estimation calculation offered two EPC2001 in parallel. The loss calculation was done for an input voltage of 75V, a voltage vector length of 60V, an output current of 6A, and a gate current of 3A for the silicon and 1.6A for the GaN inverter delivering an estimated efficiency for the power stage alone of 99.58% for Si and 99.67% for GaN, so we assume not to be too far from the optimal transistor choice.

Of course the measurement results differ from these theoretical results, because it's not only the losses in the power stage, but also shunt resistance, connector resistances, ESR of DC-link capacitors, copper losses of PCB traces and output filter losses that occur additionally, and that appeared to be the main loss source.
The peak efficiency of the inverters was measured to 97.7% @ 5A for the silicon type and 98.0% @ 6A for the gallium nitride version. That sounds little but is still a reduction of the losses of 13%.

A small drawback is the switching losses without load, where the GaN FETs cannot play out their advantage of having no reverse recovery losses and lower RDSon. Since we paralleled two transistors for better efficiency at higher currents and have an additional charge at the output of the half bridge generated by the floating ground of the current measurement against DC-link ground, the no load losses are slightly higher than the silicon inverter.

We chose 40kHz switching frequency as a good tradeoff between the switching losses within the inverter and the magnetizing losses within the motor that are mainly generated by eddy currents produced by a changing magnetic field due to the pulsed output voltage that uses the motor winding as storage inductor. For brushless DC motors with less inductance like the ones used for our DLR Hand Arm System higher frequencies of up to 100kHz are used to optimize overall efficiency.

EMI

Our project's senior electronic engineer was a little bit worried about the faster switching times of the GaN-FETs in combination with the space (the silicon inverter was first and so the dimensions for the power stage were fixed) and current constrains that didn't allow us to perfectly design as described in the EPC application note for paralleling transistors. Also stealing the restring from poor little vias seemed not to be acceptable for him, so he had to try his own solution.

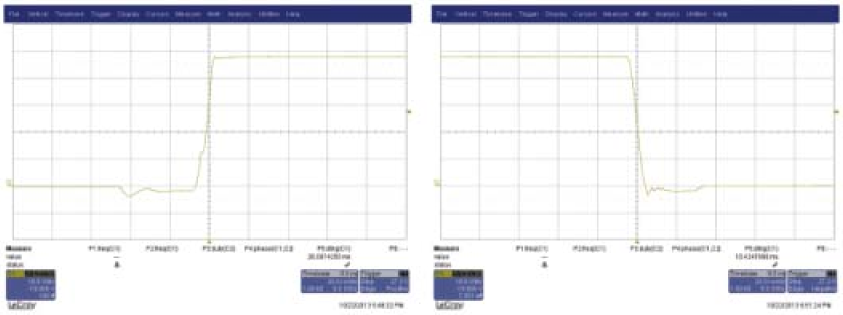


Figure 11: GaN FET rise and fall times

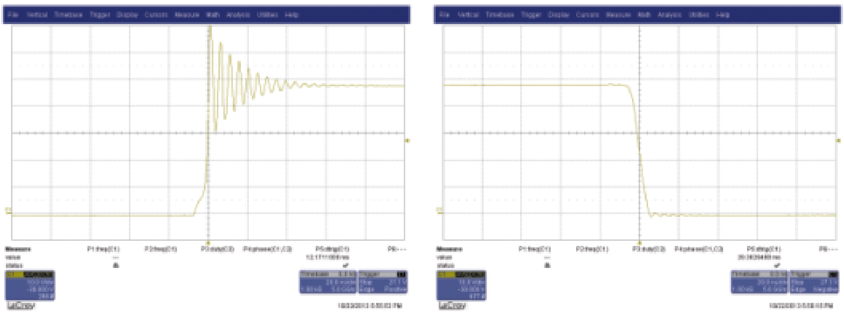


Figure 12: Silicon MOSFET rise and fall times

The ringing at the phase output is even lower with the GaN-FETs than with the Si-Transistors, that of course also results from the different current measurement topologies. Figure 11 and Figure 12 show rise and fall times of the inverters. Note that current is flowing out of the phase so the negative voltage over the FETs during the 30ns (the test setup wasn't able to do it any shorter) dead time can be seen.

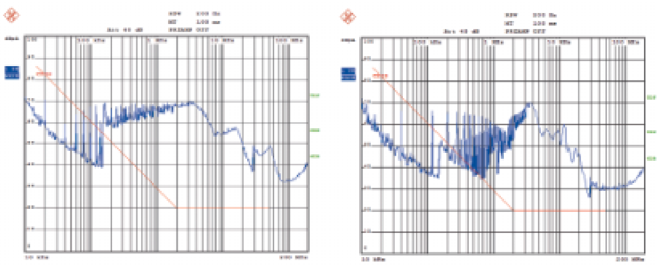


Figure 13: Common mode noise of industrial inverter (left) and GaN inverter with filter (right)

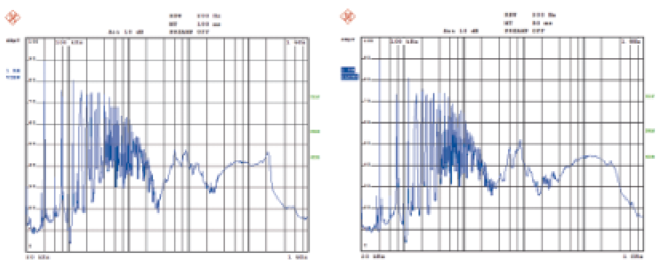


Figure 14: Interference measured in the DC-link voltage (left: Si, right: GaN)

With the silicon FETs, the effect is harder to spot in the plot because the beginning and the end of the 200ns dead time lies outside of the measurement window and the body diode forward voltage is lower. Also notice that ringing occurs only during the rising edge. This is when the low side MOSFET is forced to reverse recover its body diode producing a current rise and decay [1] of approx. 15A/ns which is more than the worst case current change caused by switching the load current of approx. 3.5A/ns.

We are planning to use unshielded motor cables since thick cables with shields and small bending radiuses do not match. The estimated rise and fall times of the inverter's half bridges of less than 10ns for both inverter types and the predicted harmonics thereof resulted in a strong urge to implement an output filter, so there is no measurement of the inverters without filter. Instead we compared the GaN-inverter to a compact industrial low voltage inverter (see Figure 13).

To ensure the internal EMC of the complete Joint Control Block we also compared the amounts of noise in the DC-link voltages. Measurements at 10A phase current and 40kHz PWM show no significant difference between the Si and the GaN inverter (see Figure 14).

This was not really unexpected due to the paralleled GaN-FETs, having 16nC total gate charge driven with 1.6A (sourcing) compared to the Si-FETs having 36nC total gate charge driven with 3A, so similar rise and fall times should result.

	Si	GaN
Nominal (peak) supply voltage	20..60V (75V)	20..80V (95V)
Nominal (peak) output current	25A (35A)	30A (35A)
Nominal output power	1.5kW	2.4kW
Max. efficiency	97.7%[1] @ 5A/75V	98.0%[1] @ 6A/75V
PWM frequency	Up to 40kHz	40 to 100kHz
MOSFETs used	IRF6646	2xEPC2001 parallel
Required board space for power stage (without gate driver)	242mm² (0.37inch²)	
Output for an electromagnetic brake	12V / 2A	
EMI-Filter at Output	included	
PCB	10 layers 70µ (2oz) copper	
Size of PCB	45 x 64mm	
Current measurement range	+/-36A	+/- 38A
Current measurement topology	Low side source & high side drain shunt	Phase shunt with floating supply and digital isolator
Shunt resistance	2 x 1.5mΩ	1.5mΩ
Current measurement resolution	12 bit	
Current measurement error (25°C)	<5% FS	<0.8% FS
Current measurement crosstalk between phases	2.2%	<0.1%
Response time of overcurrent protection	<1µs	<0.5µs
Required board space for current measurement	675mm² (1.04inch²)	880mm² (1.4inch²).

1) Including losses of EMI filter, DC-link capacitor ESR, shunts for current measurement, connector resistances and PCB copper losses, without gate driver losses.

Table 1: Inverter data overview

Summary

The DLR Institute for Robotics and Mechatronics compared silicon with gallium nitride based MOSFET technology for the use in low voltage brushless DC servo motor inverters. It could be demonstrated that it is possible to use GaN-FETs with an increased efficiency and without performance loss regarding output power, EMC and current sensing quality.

http://dlr.de/rm

[1] The value has been obtained from a simulation, but measurements on other inverters at the institute show – having 8V drop over the inductance of a bunch of paralleled vias, that were assumed to have 400pH – that this value is not far from reality

Industry’s Most Accurate and Lowest Power RGB Digital Light Sensor

Intersil Corporation announced the ISL29125 digital light sensor, the industry’s most accurate, lowest power and smallest Red, Green and Blue (RGB) sensor that optimizes the display resolution and color quality of mobile devices and TVs in all lighting environments. The ISL29125 RGB sensor communicates directly with a device’s core processor to enable the automatic adjustment of display brightness based on changing light conditions, providing consumers with a more crisp and color consistent experience while extending battery life. The compact ISL29125 is also the industry’s smallest 6-lead RGB sensor, which minimizes the real estate requirements of the optical sensor aperture, leading to improved industrial device designs.

When moving from one environment to another, lighting conditions invariably change and can affect the clarity and brightness of the device display, sometimes making the display difficult to read and use. With integrated, robust on-chip IR filtering technology and market-leading angular response of a minimum of +/- 35% field of view at 50% light intensity, the ISL29125 RGB sensor eliminates these display fluctuations, whether one is in an incandescent lit classroom, an LED lit store or outdoors in the sun. The ISL29125 works directly with the device’s core processor to continuously adjust the lux range and ensure that the display maintains consistent perceived color and the ideal brightness level based on the current lighting environment.

The ISL29125 works similarly when integrated into a TV display, effectively adjusting the brightness and color consistency of the display as the lighting conditions in a room changes. Specifically, in organic light-emitting diode (OLED) display TV applications, the ISL29125 can be used to adjust the blue organic material ageing profile to maintain consistent contrast and brightness throughout the life of the display.

www.intersil.com

High-Speed Logic IC Coupler

Toshiba Electronics Europe (TEE) has launched two photocouplers housed in ultra-miniature SO6 and SO8 packages that combine high-speed communication with low power consumption. TLP2361 and TLP2161 will find application in factory networking, high-speed

digital interfacing for instrumentation and control devices, as well as in I/O interface boards.

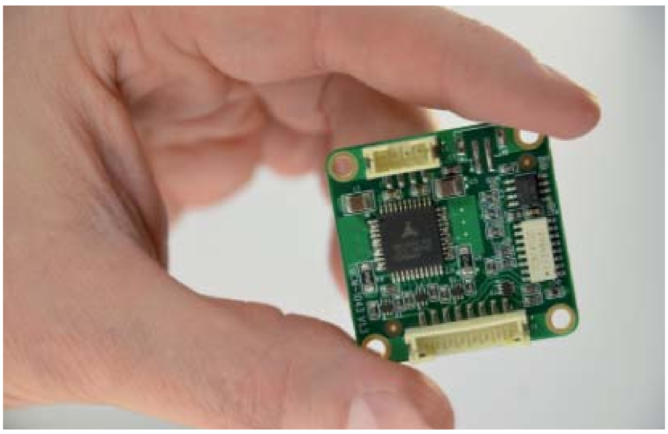
By employing Toshiba’s proprietary high-reliability, high-output GaAlAs (MQW) infrared light-emitting diodes, operation is guaranteed from -40°C to an industry-leading temperature rating of 125°C.

The LED’s high output and reliability enables low threshold input current of just 1.6mA (max.), a reduction of 54% compared with equivalent products such as Toshiba’s TLP2366 and TLP2160. Supply current per channel is reduced to 1.0mA per channel, a reduction of 66% for TLP2361 and 60% for TLP2161 compared to conventional products.

www.toshiba-components.com

Easy-to-Use, Fully Customizable Embedded Driver for NEMA 17 Stepper Motors

TRINAMIC Motion Control announced a smart, energy and cost efficient embedded driver stage custom designed for direct mounting on NEMA17 stepper motors. Pre-programmed and pre-configured with all operating parameters to support standard 1.1A (rms) motors, the



new TMCM-1043 is intended for rapid design-in and off-the-shelf use without any additional programming required.

With its optional programming kit, the TMCM-1043 becomes a fully customizable smart driver stage allowing for adaption to a broad range of embedded motion control and mechatronics requirements. In addition to a desktop programmer kit with an intuitive GUI for evaluation and ideal parameter selection, a volume programmer for quick parameterization of production scale quantities will also be available.

The TMCM-1043 incorporates the TMC2660, TRINAMIC’s latest stepper motor driver IC, which integrates power MOSFETS with the industry’s lowest RDS(on) specification, resulting in minimal power dissipation. The PCB also integrates all required protection circuitry and interface hardware into a compact and robust assembly. The TMCM-1043 is pulse controlled for 16 microsteps per fullstep. TRINAMICs patented proprietary interpolation processor interpolates these steps to a resolution of 256 microsteps per fullstep, allowing for a smooth and noiseless movement.

www.trinamic.com

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Resilient Communications Energy for our Connected World.
INTELEC®, International Telecommunications Energy Conference, is the annual world-class technical forum presenting the latest in communications power systems, energy storage and energy conversion. This year's exciting conference program will include key note and plenary sessions from today's industry leaders as well as technical presentations, continuing educations tutorials and workshops and poster sessions. This leading conference will also include a comprehensive technical tour and social program for networking amongst industry peers.

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- Power systems (High and/or low voltage DC; High and/or low voltage AC) for central offices/data centers
- Power distribution architectures for communications equipment
- Wireless power transfer for handheld communications devices

Energy Storage for Communications Systems

- Architectures for energy storage
- Battery technology (lead, zinc, lithium, sodium)
- Flow battery technology
- New fuel cell technology
- Energy management techniques
- Energy modeling and simulation

Power Conversion for Communications Equipment

- Circuit topologies and control techniques for AC/DC, DC/DC and DC/AC power converters
- Utility interface inverters for energy generation and storage
- AC and DC UPS
- High efficiency and high density power supplies

Site Support Systems

- Disaster recovery and mitigation
- Engine generator technology
- Physical and thermal design
- Grounding and EMC
- Codes, standards and specifications

2014 intelec® VANCOUVER

For more information, please visit www.intelec2014.org

Miniature linear Hall-Effect Sensor IC for Medium-Accuracy Applications

The A1304 from Allegro MicroSystems Europe is a linear Hall-effect sensor IC specifically designed for applications that require

medium accuracy in a very small package. The device is designed for applications in consumer and industrial markets, and supports an industrial temperature range of -40°C to 85°C and a factory trimmed one-time programmable 3.3 V linear sensor that eliminates the need for customers to program the device to compensate for temperature effects on sensor performance. It has a typical programmable sensitivity level of 4 mV/G ± 6%.

The device's high bandwidth and high-speed chopping scheme minimise quiescent voltage output drift across the operating temperature range, yielding a low noise analogue output and ultimately enabling higher accuracy.

The A1304 complements Allegro's existing linear Hall-effect sensors by providing a more cost-effective solution for non-automotive markets, with sensitivity and quiescent voltage output temperature coefficient being trimmed at the factory for improved accuracy relative to other low cost linear IC's from Allegro (A1301/02).

www.allegromicro.com

Op Amp Delivers Industry's Highest Precision Measurements

Texas Instruments introduced the industry's first 36-V rail-to-rail input and output (RRIO) operational amplifier (op amp) to achieve precision offset voltage and drift without using auto-zero techniques. The OPA192 achieves stable offset voltage drift over the full specified temperature range, which eliminates the need for system level calibration. Fast settling and high-output drive, combined with precision, allows designers to use the device to drive analog-to-digital converters (ADCs) in high-voltage, precision data acquisition systems including test and measurement, and industrial sensors and controls.

www.ti.com/opa192-pr-eu

3 Watt Isolated Dc-Dc Converters Reduce Board Space and Cut Power Consumption

CUI Inc announced two isolated dc-dc converter families for industrial, test & measurement, and telecommunication applications. The rugged and compact PQMC3-S and PQM3-M families increase total efficiency across the entire load curve and give improved performance at light and no loads. The converters are ideal for battery-powered applications where power draw under these conditions are a concern.
Rated at 3 W, the PQMC3-S Series is available with input ranges of 4.5~9, 9~18, 18~36, or 36~75 Vdc while the PQM3-M Series offers input ranges of 9~18, 18~36, or 36~75 Vdc. Both families come equipped with an operating temperature range of -40° to + 85°C at 100% load, allowing the dc-dc converters to work reliably in harsh environments.
The PQMC3-S Series is housed in a compact 8 pin SIP package measuring 0.86” x 0.37” x 0.47” (22 mm x 9.5 mm x 12 mm) and the PQM3-M series is housed in a 16 pin SMT package measuring 0.94” x 0.54” x 0.30” (23.86 mm x 13.70 mm x 7.50).
Both families are available in single output voltages of 5, 12, or 15 Vdc while the SIP version PQMC3-S is also available in dual output voltages of ±5, ±12, or ±15 Vdc. Outputs are fully regulated to within ±0.2% (typ.) for all line and load conditions. Input to output isolation of 1,500 Vdc is provided across the range of models.
Protections include continuous short circuit and over current. The dc-dc converters meet CISPR22/EN55022 Class B standards with limited external components.

www.cui.com

LEDrivIR™ Control IC Simplifies Design for High Performance Dimming Applications

International Rectifier has introduced the IRS2983 control IC for single stage Flyback and Buck-Boost topologies used in LED drivers and power supplies.
The IRS2983 employs primary side regulation that reduces component count and simplifies design by eliminating the opto-isolator and other components necessary for isolated feedback for fixed loads. The device also features a rapid startup circuit that drastically reduces the turn on time of the system, also offers high power factor and low THD and operates over a wide input range for many LED lighting applications. Comprehensive protection features including hiccup mode over-voltage protection, cycle-by-cycle over-current protection and open and short circuit protection are also included. The device also supports TRIAC dimming.

As traditional incandescent, halogen, and CFL light sources are rapidly being replaced by LED bulbs, tubes and fixtures, the Flyback converter is the preferred power supply topology for a large segment of the LED driver market. Flyback LED drivers are simple, cost effective and efficient. IR’s IRS2983 helps simplify the design process and reduce part count and can also be configured to work with TRIAC dimmers.

www.irf.com

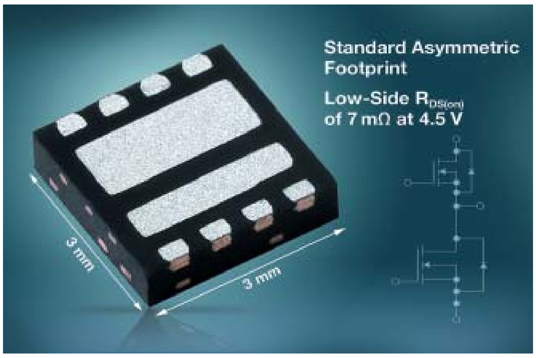
Aaronia Launches Ultra-Broadband Omnidirectional Antenna

Aaronia has launched the ultra-broadband OmniLOG® 70600 small and compact omnidirectional antenna. Despite its small size it covers an extremely wide frequency range of 680 MHz to 6 GHz. Within the most important frequency bands the antenna reaches very high gain up to 6.5 dBi. It fits well with the SPECTRAN handheld spectrum analyzers but can also be used with any other spectrum analyzer brand.
The frequency range covers the following, typical signal sources: GSM, CDMA, LTE, WiFi, ISM, DECT, Bluetooth, 5GHz WLAN, WiMAX. The Antenna offers a heavy-duty 90° knuckle base with SMA connector. The knuckle base is freely adjustable into each position and fixed by two special ball pressure screws.
The OmniLOG antenna offers an omnidirectional measurement of field strength without the need to move the antenna to the source. This allows a direct field strength reading without any hassle, which is very useful for measurements of e.g. exposure limits.
The PC Analysis-Software – MCS – supports the OmniLOG 70600. Using this software, the OmniLOG antenna can also be used with the SPECTRAN V3-series Spectrum Analyzers. It is extremely small size allows measurements without attracting attention or even covert measurements. Every OmniLOG Antenna offers a high-grade SMA male connector and as such can be connected directly to each SPECTRAN Analyzer.

www.aaronia.com

Asymmetric Dual TrenchFET® Gen IV MOSFET in Compact PowerPAIR® Package

Vishay Intertechnology, Inc. introduced a 30 V asymmetric dual TrenchFET® power MOSFET in the PowerPAIR® 3 mm by 3 mm package utilizing TrenchFET Gen IV technology. Providing 57 % lower on-resistance, up to 25 % higher power density, and 5 % higher efficiency than previous-generation devices in this package size, the Vishay Siliconix SiZ340DT helps to save space and simplify the design of highly efficient synchronous buck converters by combining a high-side and low-side MOSFET in one compact package.



The TrenchFET Gen IV technology of the SiZ340DT utilizes a very high-density design to reduce on-resistance without significantly increasing the gate charge, minimizing conduction losses and reducing total power loss for higher power output. As a result, the low-side Channel 2 MOSFET of the SiZ340DT offers a low on-resistance of 5.1 mΩ at a 10 V gate drive and 7.0 mΩ at 4.5 V. The high-side Channel 1 MOSFET features on-resistance of 9.5 mΩ at 10 V and 13.7 mΩ at 4.5 V.

www.vishay.com

SiC Products Brochure

Richardson RFPD, Inc. announces availability of a Silicon Carbide (SiC) Products Brochure featuring the latest products from Cree, Microsemi, Powerex and Vincotech.

The 8-page quick reference guide highlights SiC Schottky diodes (600V, 650V, 1200V and 1700V, 1A – 60A), SiC MOSFETs (1200V and 1700V), full SiC modules (1200V, up to 270A) and Si/SiC hybrid modules (600V – 1200V, up to 116A).

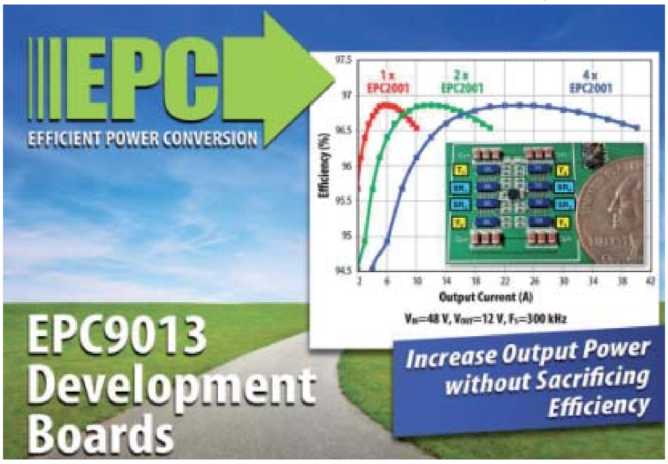
SiC offers significant advantages to systems designers, including improved efficiencies due to decreased thermal dissipation, higher operating junction temperatures, smaller system size, higher power density, higher operating frequency, and reduced overall system cost.

The brochure is Richardson RFPD's latest resource designed to support its energy and power market customers and their design activities with this rapidly-expanding technology

www.richardsonrfpd.com

High Current Development Board Featuring Multiple Half-Bridges in Parallel

Efficient Power Conversion Corporation (EPC) introduces the EPC9013 development board featuring the 100 V EPC2001 enhancement mode (eGaN®) field effect transistor (FET) operating up to a 35



A maximum output current in Buck mode using a four half-bridge configuration in parallel and a single onboard gate drive. This innovative design increases output power without sacrificing efficiency.

The EPC9013 development board is 2" x 2" with eight EPC2001 eGaN FETs in conjunction with the Texas Instruments LM5113 gate driver. The development board can be operated as a Buck, Boost, or bidirectional, as well as a half bridge for motor drives and isolated converter applications. Its parallel configuration is recommended for high current applications. The printed circuit board (PCB) layout is designed for optimal switching performance. There are various probe points to facilitate simple waveform measurement and easily evaluate the eGaN FETs.

This development board simplifies the evaluation process of the EPC2001 eGaN FET for high current operation by including all the critical components on a single board that can be simply connected into any existing converter.

http://epc-co.com/epc/Products/DemoBoards.aspx

Power-Monitoring IC with High-Accuracy Signal Acquisition and Power Calculations

Microchip announced a power-monitoring IC, the MCP39F501. This device is a highly integrated, 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 power-monitoring IC allows designers to add power monitoring to their applications with minimal firmware development. Its performance enables designs capable of 0.1% error over a wider dynamic range and superior light load measurement compared to current competing solutions. 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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Seminars

Sunday, 18 May 2014 from 14.00 – 17.30 hrs

Designing Low Cost Multiple Output DC-DCs
Stefan Klein, Würth Elektronik eiSos GmbH & Co. KG, Germany

Basics of Electromagnetic Compatibility (EMC) of Power Systems
Jacques Laeuffer, Dtalents, France

PCB Layout for Low EMI
Bruce Carsten, Bruce Carsten Associates, USA

Modern Power Supply Design
Ray Ridley, Ridley Engineering Europe, France

Advanced Control Techniques for DC-DC Converters
Richard Redl, ELFI S.A., Switzerland

Wireless Power Technologies
Dan Jitaru, Rompower Inc., USA

Tutorials

Monday, 19 May 2014 from 9.00 – 17.00 hrs

New Trends in Soft Switching Topologies
Dan Jitaru, Rompower Inc., USA

New Developments in Power-Factor Correction
Richard Redl, ELFI S.A., Switzerland

Electromagnetic Design of High Frequency Converters and Drives
Jacques Laeuffer, Dtalents, France

High Performance Control of Power Converters
Jens Onno Krah, Cologne University of Applied Sciences, Germany
Christian P. Dick, RWTH Aachen University, Germany

Advanced Control Design
Ray Ridley, Ridley Engineering Europe, France

Advanced Design with MOSFET and IGBT Power Modules
Tobias Reimann, ISLE Steuerungstechnik und Leistungselektronik GmbH, Germany
Thomas Basler, Chemnitz University of Technology, Germany

Power Electronics and Control for Grid Integration of Renewable Energies and Energy Storage Systems
Mike Meinhardt, SMA Solar Technology, Germany
Siegfried Heier, Peter Zacharias, University of Kassel, Germany

IGBT Gate Drive Technologies – Principles and Applications
Reinhard Herzer, Arendt Wintrich, Semikron Elektronik, Germany

Design Considerations for High Frequency Linear Magnetics
Bruce Carsten, Bruce Carsten Associates, USA

Reliability of IGBT Power Modules
Josef Lutz, Chemnitz University of Technology, Germany

Conference

Registration information and full program with all lectures, posters and speakers on **www.pcim-europe.com/program**

Tuesday, 20 May 2014

Conference Opening and Award Ceremony

KEYNOTE »Progress in Power Semiconductor Devices and Applications«

Module Technologies I	**Special Session** HVDC	Drives for Power Converters	Power Quality Solutions	Control Techniques in Intelligent Motion
New Materials in Packaging	IGBT Improvement	Sensors	Capacitors	Converter Control

Poster/Dialogue Session

Wednesday, 21 May 2014

KEYNOTE »Ultra High Voltage SiC Power Devices and its Impact on Future Power Delivery System«

Power Converters	GaN	High Voltage	Power Electronics in Automotive, Traction and Aerospace	Energy Storage
SiC Devices	Package and Thermal Aspects	Power Electronics in Transmission Systems	High Efficiency Converters I	Passive Inductors

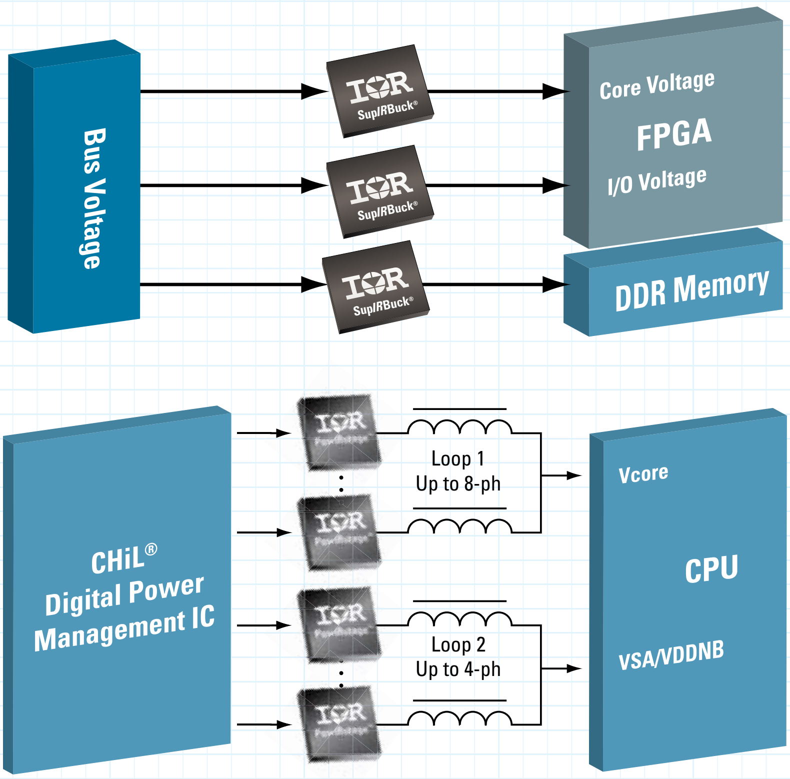
Poster/Dialogue Session

Thursday, 22 May 2014

KEYNOTE »e-Mobility 2020: Power Electronics, a Key Technology for the Effective Deployment of Electric Vehicles in a Low Carbon Society«

Module Technologies II	**Special Session** Designing Packages for Fast Switching	DC/DC Converters I	New and Renewable Energy Systems	
Reliability	SiC Systems	DC/DC Converters II	High Efficiency Converters II	

Complete End-to-End DC-DC Solutions



International Rectifier's PowIRstage® offers the most efficient solution for multi-phase converters. Our Sup*IR*Buck® product offers flexible solutions for all Point-of-Load supply requirements.

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