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Bodo´s Power Systems®

Electronics in Motion and Conversion

April 2010

New Dimension in Cool Power

The cool way of Power electronics

Current technologies:
Planar module assembly
Typically, power electronics face the following restrictive requirements:

- Stringent cost targets
- Limited packaging dimensions
- Outstanding reliability targets (temperature, vibration, …)

A way to solve all these issues is an optimized thermal resistance and a highly performing cooling of semiconductors.

Traditional traction inverter designs comprise frame-based power modules (e.g. Toyota "Camry"). The metal base plate is coupled to a closed loop heat sink via thermal interface material TIM ("thermal grease"). The key advantage of this design is its ease of assembly, and the separation of high voltage electronics and cooling liquid.

On the other hand, the thermal grease with its low thermal conductivity must be considered non-optimal and contributes a large share of the overall RTH. Furthermore, planar assemblies require a lot of space and therefore, power density is limited.

Next Generation:
Stacked Molded Power Modules with ShowerPower® liquid cooling
Utilising the latest power module technology may contribute to optimising inverter designs. A promising manufacturing technology is transfer moulding, offering compact and robust power modules. Such modules are well suited for the harsh conditions in under-the-hood environments of modern cars. Molded power modules are planar with low building heights. The power- and control terminals are very rugged and may withstand high mechanical pressure needed to ensure a proper thermal contact to the heat sink. Being concentrated on one side of the module block, the terminals allow for a low-inductance and compact busbar. Small signal terminals are concentrated on the opposite side, allowing for a clear separation of drivers and control electronics, and reducing risk of electromagnetic interference.

But still, planar arrangements of power electronics require a lot of space. 3D arrangements of stacked power modules are much more compact and offer a number of benefits compared to standard planar assemblies.

ShowerPower® plasticbaffle ensures homogenous cooling and allows for the elimination of hot spots. The meandering cells may be tailored to each individual product´s requirements.

Danfoss' ShowerPower® technology is perfectly suited to cool stacked assemblies of transfer molded power modules, even if the modules become considerably large. Stacking the ShowerPower® coolers transfers this total thermal design freedom into the third dimension.

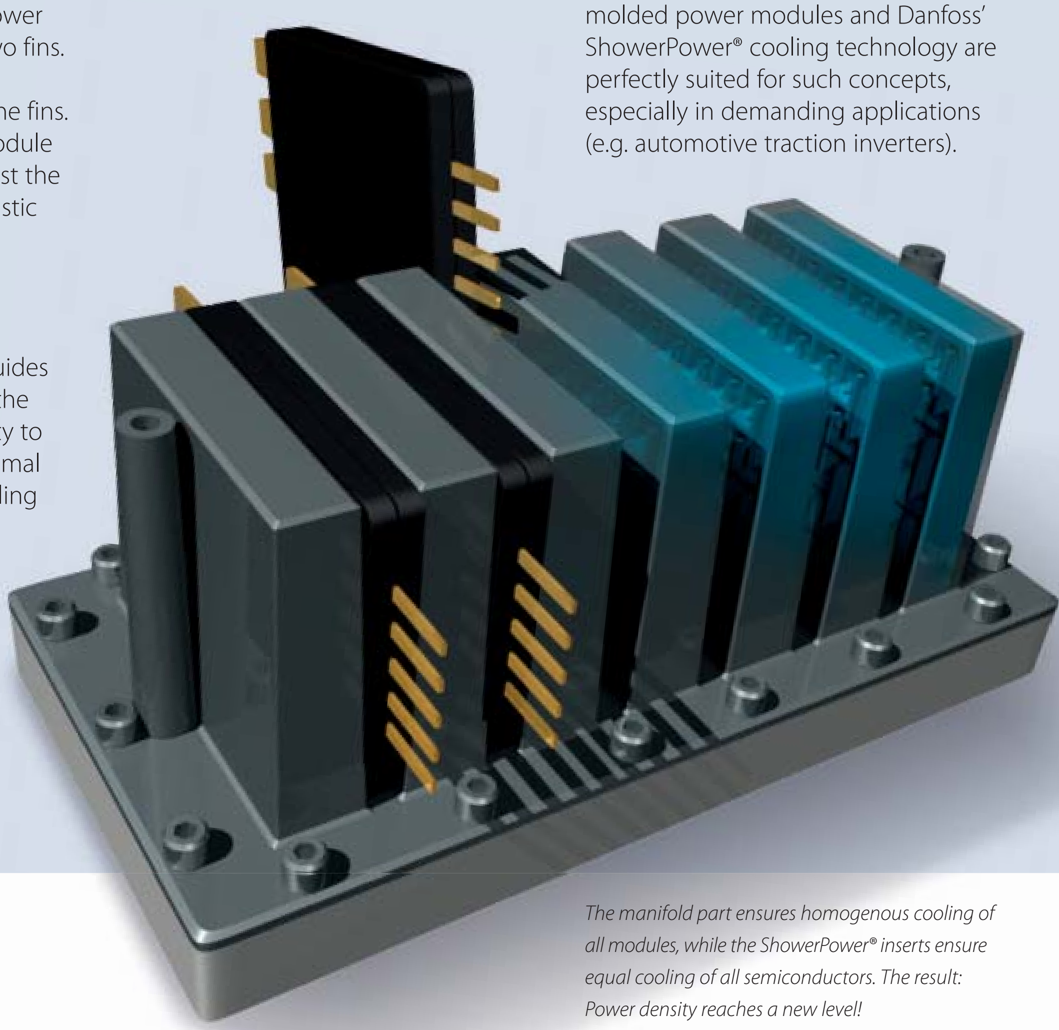
Danfoss proposes to implement a heat sink with hollow fins, which are arranged in such way that the power modules can slide in between two fins. A plastic wedge ensures proper thermal/mechanical contact to the fins. Thus, the fins cool one power module and press the next module against the next fin, etc. A ShowerPower® plastic baffle is inserted into each of the hollow fins of the heat sink.

The ShowerPower® insert acts as turbulator and homogenously guides the coolant directly underneath the power semiconductors. The ability to tailor the cooling enables an optimal thermal design of the whole cooling system.

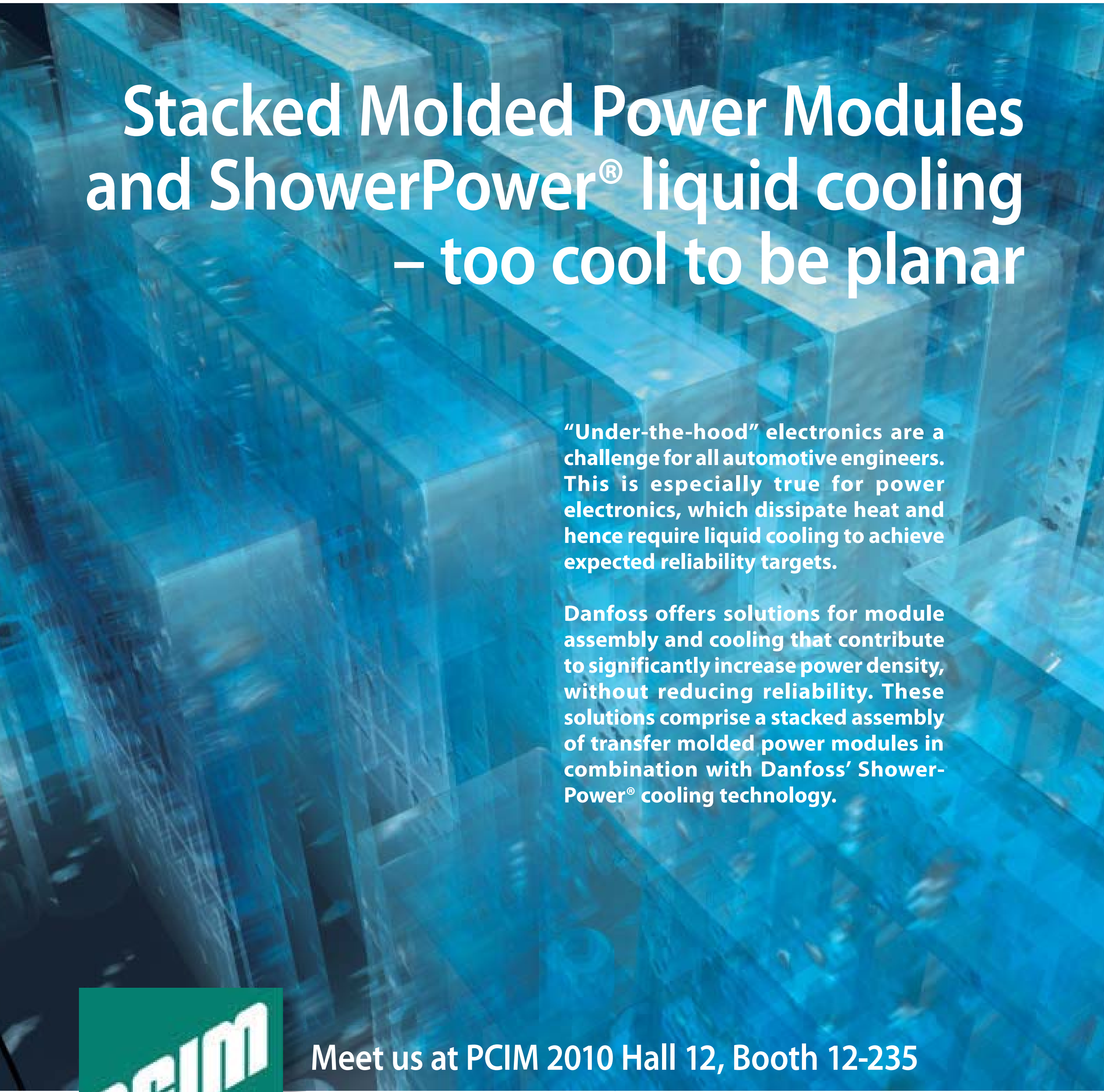
Due to the simplicity of the Shower-Power® insert, the manifold structure may be integrated into an aluminium housing. It ensures all modules to be cooled equally, while the Shower-Power® inserts ensure all semiconductors to be cooled homogenously. Alternatively, ShowerPower® offers a total design freedom in 3D that allows for tailoring the cooling of all chips in all modules individually. Hence, hot spots may easily be eliminated.

Conclusion

Finally, a stacked power module assembly can significantly increase power density in an inverter. Such a 3D-concept is cost-efficient, compact, robust, and reliable. It offers excellent thermal transfer capabilities and provides any degree of freedom to tailor dimension, partitioning, or the circuit topology of the modules to the application's requirements. Transfer molded power modules and Danfoss' ShowerPower® cooling technology are perfectly suited for such concepts, especially in demanding applications (e.g. automotive traction inverters).



The manifold part ensures homogenous cooling of all modules, while the ShowerPower® inserts ensure equal cooling of all semiconductors. The result: Power density reaches a new level!


Stacked Molded Power Modules and ShowerPower® liquid cooling – too cool to be planar
"Under-the-hood" electronics are a challenge for all automotive engineers. This is especially true for power electronics, which dissipate heat and hence require liquid cooling to achieve expected reliability targets.
Danfoss offers solutions for module assembly and cooling that contribute to significantly increase power density, without reducing reliability. These solutions comprise a stacked assembly of transfer molded power modules in combination with Danfoss' Shower-Power® cooling technology.
Meet us at PCIM 2010 Hall 12, Booth 12-235

Bodo´s Power Systems®

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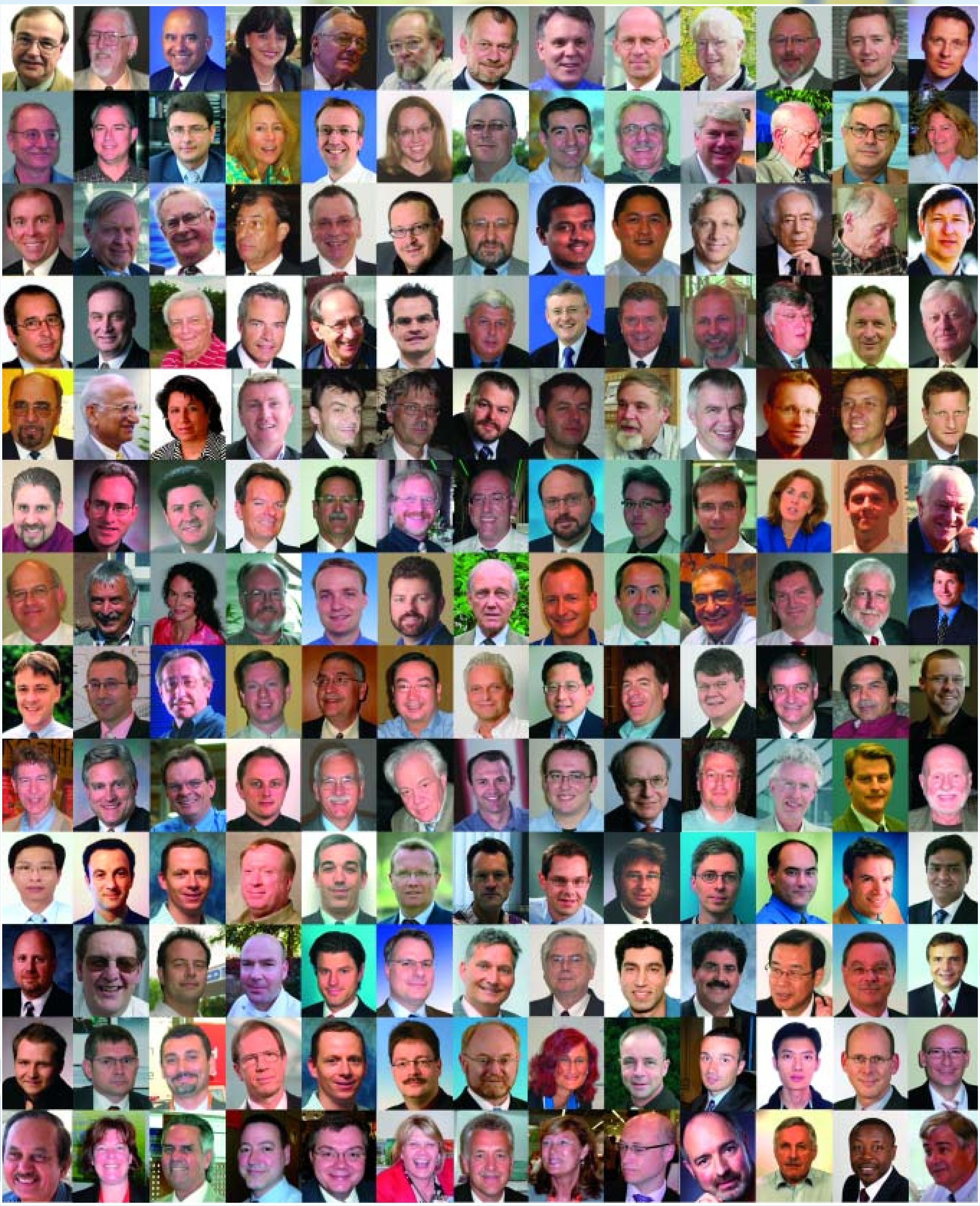


PCIM 2010
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Booth 506

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Events

Digital Power Forum Europe
Nuremberg Ger April 6-7
www.dpfeurope.darnell.com

Battery University
Aschaffenburg Ger April 13-15
www.batteryuniversity.eu

PEMD
Brighton UK April 19- 23
www.theiet.org/pemd

PCIM Europe
Nuremberg Ger. May 4-6
www.mesago.de

Sensor+Test
Nuremberg, May 18-20
www.sensor-test.de

SMT Hybrid
Nuremberg Ger. June 8-10
http://www.mesago.de

Intersolar Europe 2010
Munich Ger June 9 to 11
www.intersolar.de

SEMICON West
San Francisco USA July 14-16
www.semiconwest.org

Technology is Moving Fast

We are seeing positive signs that all areas of the electronic industry are making progress in technology. Renewable energy and efficiency are strong motivators of change. APEC, in Palm Springs, demonstrated design improvements in all kinds of power supply and lighting applications which will have a significant impact on reduced electrical consumption. In addition to the environmentally friendly power sources - whether wind, solar or water - presentations showed reduced consumption through smart power management. Smart grid management will avoid high peak demands. All these approaches are options for our future that do not generate more pollution. Overall, APEC was a well attended exhibition and conference and a good indication of where our industry is headed.

New materials such as SIC and GaN provide very promising potential for more efficient designs. Last year at my PCIM Podium, we learned a lot about the capabilities of these materials and International Rectifier just announced its first commercial GaN power transistor at the APEC. Not only are semiconductors challenged to improve but passive components are the bread and butter of the industry. Without optimized passives solutions will not reach their full potential.

So mark the following date in your calendar, Wednesday, the 5th of May, 12:20 to 13:20 at booth 377, for the Forum discussion at the PCIM Europe that highlights:

"Passive Components for System Efficiency"

Passives need to accompany semiconductors in moving to new materials and higher temperature limits. System solutions must build on these developments.

You will meet experts in passive capacitor and inductor components sharing their competence in discussion with you.

The PCIM is the leading edge Power Electronics show and conference, both in Europe and in China. The April issue is a preview of what to expect in Nuremberg in May and in China in June. In addition to the PCIM, there is much interest in the upcoming Sensor and Test show in May, also in Nuremberg. June will be highlighted by the SMT/Hybrid conference in Nuremberg and the Intersolar Europe show in Munich. All these events are strong showcases of power electronics. This summer will be a busy one and the autumn as well, with the Electronica in Munich.

For all of the busy engineers that have no time to read the magazine, I will be launching a new audio book service on April 1st. Instead of reading the magazine you'll be able to listen to it! Details coming soon on my web-site.

My Green Power Tip for April:
Drive carefully and watch the red lights. Accelerating before a red light only requires extra braking. That is wasted energy - as long as you are not driving a hybrid that recovers energy while braking.

See you at the PCIM conference

Best regards

ECPE received the Award Competence Network 2010

ECPE received from the German Federal Ministry of Economics and Technology the award Competence Network 2010. The competition „Strategy-making and strategic Communication" was targeting at more than 100 innovative and powerful Networks in Germany. ECPE was highest awarded for the contribution „Power Electronics – Key Technology for efficient and sustainable Energy Use". The prize is worth 15.000 Euros. The Parlamentary State Secretary in the Federal Ministry of Economics, Hans-Joachim Otto, handed over the award in the frame of the annual meeting of the initiative Competence Networks Germany held on March 02 in Berlin.
We are very pleased and honoured receiving this award which will boost our efforts to promote power electronics as key technology for energy efficiency and sustainability.

PCIM Booth 12/569

www.ecpe.org

PCIM at its Best

Once again this year Professor Rufer has the great pleasure in welcoming you to our annual event. Indisputably established as the leading event of its kind, it offers unrivalled synergy between conference and exhibition. The increase in the number and quality of the submitted papers is a mark of the success of the new Best Paper and Young Engineer Awards, and I am convinced that you will enjoy and appreciate this year's event.
In last year's welcome address, I spoke about the economic situation; whilst we are now seeing recovery in many fields, the global picture is still uncertain. Nevertheless, there remain a considerable number of major economic and technological challenges, which will only be met through development and investment. For example, energy efficiency and the reliability of systems and components are increasingly driving development.
Two key topics this year provide power electronics developers with clear direction. The first is the increasing focus on the development of electric and hybrid cars. With batteries being the key element of electric cars, the Power Electronics field is faced with a number of challenges. These include how to increase power density and develop efficient cooling systems, through global system efficiencies and inevitably high reliability.
The second area is the generation of electric power, from traditional to renewable sources. As an opportunity for the world to come together and reflect on the problem, the Copenhagen conference was a major event, despite its failure to reach a significant agreement. Global warming is a real problem and will not disappear. Its indirect consequences will include, I hope, some societal support for the development of public transportation, low emission systems, and renewable energy solutions and policies at individual, global/public and political levels.
In many areas of Power Electronics application, particularly those relating to energy supply and use, therefore, the sector is just coming into its own. Existing companies with new ideas, but also new companies offering innovative products are the principal players at our PCIM event.

PCIM Booth 12/638

www.pcim.de

HC Power Series Ultracapacitors

Richardson Electronics supplies the HC Power Series Ultracapacitor product family (from Maxwell Technologies) is helping circuit designers meet growing demands for pulse power capability and short term backup power in consumer electronics, rechargeable power tools, and wireless communication systems. Maxwell's industry-leading technology is now available in the form factors that are most suitable for a broad range of electronic applications. The newest members of the HC series include 5, 10, and 100 Farad cells. These join the previous HC cells: 25, 50, and 150 Farad. All are rated at 2.7 volts. These ultracapacitor products have

a two-pin radial design, are resistant to reverse polarity, are scalable to higher voltages (via multi-cell configurations), and, like all Maxwell Technologies BOOSTCAP® Ultracapacitors, are capable of being recharged at the identical rate of discharge. For datasheet, sample delivery and design-in support contact Richardson Electronics, 1-800-737-6937 (North America); or find your local (International) sales engineer at:

PCIM Booth 12/235

www.rell.com

Powerful Products For Powerful Electronics.

Learn more about our power electronics solutions by visiting us at PCIM Europe Booth #12-439

PDS

Power Distribution Systems specializes in the design and manufacture of custom designed busbars. RO-LINX® busbars serve as power distribution highways. Rogers laminated busbars provide a customized liaison between IGBT modules, capacitors and the power source.

- Low Inductance
- Design for Controlling Partial Discharge
- Compact Design
- UL Rating

TMS

Rogers' HEATWAVE™ high performance AlSiC materials combine excellent thermal conductivity and controlled thermal expansion with low density and high stiffness to match the performance characteristics of modern power semiconductor device packaging solutions and systems.

- Improves Longterm Reliability
- Reliable Thermal Performance
- Ease of Integration into Applications
- High Stiffness & High Mechanical Stress

Empowering your energy.

ROGERS CORPORATION

For more information on our Thermal Management Solutions (TMS), visit us at **www.rogerscorp.com/tms.** You can find more information on our Power Distribution Systems (PDS) at **www.rogerscorp.com/pds.**

The world runs better with Rogers.®

USA +1-480-917-6137 EUROPE +32-9-235-3611 ASIA + 65-6747-3521

Full PMBus Read and Write Capability to Voltage Regulators

In a major product update, Ericsson Power Modules' BMR450 and BMR451 point-of-load voltage regulators are now able to write as well as read data via the power management bus; PMBus. Customers buying these revision 2A products will have access to the internal memory of Ericsson's 3E* point-of-load voltage regulators, providing high flexibility to program functional parameters to match specific profiles required by FPGA, ASIC, memories and other components. Revision 2A complies with PMBus read & write modes. Read-back offered end-users a large range of monitoring options such as output-voltage and current, temperature, power-good. Now with added write-mode it is possible to program the output voltage to a very specific voltage, and to modify this voltage as a function of load condition. It is also possible to sequence modules, and to modify sequencing to account for new configurations that some processors may require. Further, it enables one to adjust current limits and warning levels, to remotely turn modules into sleep-mode, plus many other dynamic features. At its most intimate level, write-mode makes it possible to optimize the compensation loop and many other internal parameters that ultimately contribute to reduce the amount of filtering capacitors and improve dynamic response.

www.ericsson.com/powermodules

Batteryuniversity.eu Developer Forum

The third Entwicklerforum Akkutechnologien (Developer Forum Battery Technologies), hosted by the batteryuniversity.eu, takes place from April 13 to 15, 2010 in the "Stadthalle Aschaffenburg", Germany. Attendees are offered a comprehensive two-day congress program with 24 technical presentations (mainly in German), a one-day Light Electric Vehicle (LEV) Workshop with focus on battery standardization, a half-day seminar on the topic of United Nations transportation regulations for lithium batteries and a lithium-ion introductory course for newcomers.

During the first two days (April 13 and 14), specialists from leading manufacturers and institutions - including A 123 Systems, Akasol Engineering, BaSyTec Batterie System Technik, BMZ Batterien-Montage-Zentrum, Boston Power, Cham Battery Technology, Digatron, enertech International, ESG Elektroniksysteme- und Logistik, Fraunhofer IIS Institut für Integrierte Schaltungen, Fraunhofer ISC Institut für Silikatforschung, Fraunhofer ISE Institut für solare Energiesysteme, LION Smart, Maxell Deutschland, Maxim Integrated Products, Panasonic Industrial Europe, Panasonic Electronic Devices Europe, RRC Power Solutions, Saft Batterien, Samsung SDI, Sanyo, Sony, Texas Instruments, Texsys and ZSW - Zentrum für Sonnenenergie- und Wasserstoffforschung Baden-Württemberg - will present the latest technology trends and solutions.

The detailed program of events and registration form can be downloaded from the homepage

www.batteryuniversity.eu

Power Electronics Markets in Green-Tech

Yole Developpement will share a vision of new trends in PV, Wind, smart grid and EV/HEV.

So mark the following date in your calendar, Thursday the 6th of May from 1PM to 3PM at booth 377, for the Forum discussion at the PCIM Europe that highlights:

Power electronics is currently facing a huge mutation as the demand for efficient power conversion systems is increasing along with the "Green-Tech" introduction.

The Green revolution is now impacting all the application fields of the power electronics, pushed by severe regulations, from low power with the need for improved cell-phone battery chargers, to mid-range where motor control, home appliances, PV inverters, EV/HEV and white goods may consume less energy to higher power in which train traction, wind turbines or energy T&D are expecting new solutions to reduce the conversion losses.

This battle for an efficient world starts at in the heart of every system where power devices lay. Those devices are mainly based on a silicon technology as of now. Silicon diodes and silicon transistors (MOSFET, IGBT, Thyristors…) are the key components since many years and are constantly improving their characteristics, reliability, life-time, efficiency…and so on. However, new materials have emerged these last years and pretend being able to displace part of the silicon devices by exhibiting enhanced characteristics, less loss, higher operation T°, longer life-time, robustness to cycles… SiC has been the first technology commercially introduced early 2000's and GaN is now coming on the market place as well.

PCIM Booth 12/257

www.yole.fr

United Technologies Closes on Clipper Windpower Investment

United Technologies Corp. announced it successfully closing its subscription and partial tender offer to acquire an aggregate 49.5 percent stake in Clipper Windpower Plc (CWP.L), a California-based wind turbine manufacturer that trades on the London Stock Exchange Alternative Investment Market.

United Technologies Corp., based in Hartford, Connecticut, is a diversified company that provides a broad range of high technology products and support services to the building systems and aerospace industries.

www.utc.com

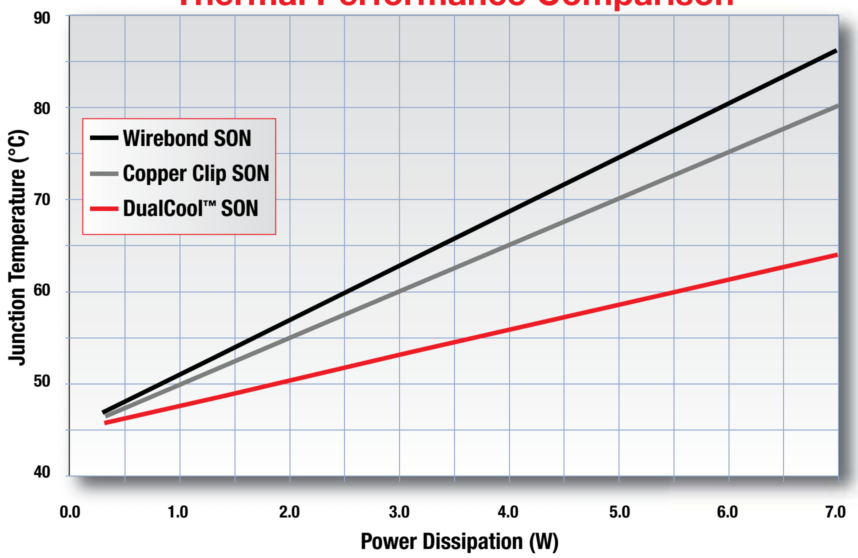
Cool Power

DualCool™ NexFET™ Power MOSFETs

High-Performance Analog>>Your Way™

Key Benefits

- Enables top side cooling
- 80% higher power dissipation
- 50% more current in standard footprints
- Energy efficient POL design



The **DualCool™ NexFET™ family** of power MOSFETs delivers an industry standard footprint, while enabling thermally efficient cooling through the top and bottom of the package. This package allows power system designers to effectively direct heat away from the PCB in high-current DC/DC applications. TI's DualCool NexFET power MOSFETs allow the heat generated by power conversion to be removed from the top side through convection cooling resulting in improved power density, higher current capability and improved system reliability.

Device	Size	V_{DS} (V)	V_{GS} (V)	R at 10 V (mΩ)	R at 4.5 V (mΩ)	Qg (nC)	Qgd (nC)
CSD16407Q5C	5x6	25	16	1.8	2.5	13.3	3.5
CSD16408Q5C	5x6	25	16	3.7	5.4	6.5	1.9
CSD16325Q5C	5x6	25	10	–	1.7	18	2.9
CSD16321Q5C	5x6	25	10	–	2.1	14	2.5
CSD16322Q5C	5x6	25	10	–	4.5	6.5	1.2

www.ti.com/dualcool
Get evaluation modules, samples and datasheets

Texas Instruments

FDK the 13th Member of DOSA

The Distributed-power Open Standards Alliance (DOSA), a global association dedicated to bringing compatibility and standardization to the DC-DC board mounted power conversion market, added FDK Corporation to its membership roster. FDK is a global electronic component and battery manufacturer, cultivating and using cutting-edge technologies in areas such as material engineering and high-density mounting.

Akira Kamada, corporate senior executive vice president of FDK, commented, "The DC-DC converter industry in Japan, while serving a substantial domestic market, has evolved in relative isolation from the global mainstream, with little standardization. As a member of DOSA, FDK looks forward to leveraging its extensive domestic experience to promote platform standardization in Japan for the benefit of both customers and members of the alliance."

www.fdk.com

www.dosapower.com

Senior Management Appointments

Michael Liedtke

Van M. Andrews

Jeremy Cowperthwaite

Maxwell Technologies, Inc. has expanded the scope of Vice President Michael Liedtke's responsibilities to include business development, market intelligence and strategic planning, appointed Van M. Andrews vice president, ultracapacitor sales and marketing and promoted Jeremy Cowperthwaite to the newly created position of vice president, ultracapacitor engineering.

Liedtke joined Maxwell's executive team in 2006. Previously, he spent eight years with BMW's California-based DesignworksUSA, and before that held a series of auto, truck and bus design project management positions with Mercedes Benz and its Freightliner truck division. Andrews most recently was vice president of North American sales with D-Link Corp. and previously was president & CEO of U.S. Robotics, general manager of Gateway Computers' Business-to-Business unit and general manager of Toshiba America Information Systems' Computer Systems Division. Cowperthwaite joined Maxwell in 2007 as senior director of engineering for BOOSTCAP® products. Previously he had held a series of senior engineering and product development positions with Maxtor Corp., and Quantum Corp.

"This realignment and expansion of our executive team reflects the increased focus we are placing on product development, marketing and business development to strengthen and expand our presence in the marketplace and realize the full potential of our ultracapacitor technology, " said David Schramm, president and chief executive officer. "Michael, Van and Jeremy bring solid experience, high energy and proven leadership to these key positions."

Maxwell is a leading developer and manufacturer of innovative, cost-effective energy storage and power delivery solutions.

www.maxwell.com

PCIM China 2010 International Exhibition & Conference

PCIM China 2010

International Exhibition & Conference for
POWER ELECTRONICS
INTELLIGENT MOTION
POWER QUALITY
1 – 3 June 2010
Shanghai, China

PCIM China – the international exhibition and conference – is the leading meeting place for all fields of Power Electronics, Intelligent Motion and Power Quality / Energy Management and will take place from 1 – 3 June 2010 in the Everbright Exhibition Centre Shanghai. The program includes more than 50 first-time presentations and three keynote papers.

The three keynote papers will be among the highlights and see renowned speakers addressing different trends within the power electronic industry.

Developments of Wide Bandgap Power Semiconductor Device, Kuang Sheng, Zhejiang University, China

Pareto-Optimal Design and Performance Mapping of Telecom Rectifier Concepts, Jürgen Biela, ETH Zurich, Switzerland

High-Performance Power Conversion for More-Electric Aircraft, Jian Sun, Rensselaer Polytechnic Institute, USA

- Main conference topics during the three conference days are
- Fast switching devices MOSFET/IGBT's
- Converters for Motor Drives & Motion Control
- High Efficient Lighting Control Units
- IGBT – Integrated Power Modules
- Advanced Concepts for Power Quality
- New Power Converter Systems
- Converters for Renewable

Infineon, Fairchild, Delta Electronics, STMircoelectronics, International Rectifier, Emerson Network Power, Mitsubishi, Semikron, Texas Instruments and Fuji Electric are just some of the companies presenting their solutions within these conference sessions.

At PCIM China 2010, product and system developers, R&D managers, executive directors and buyers will meet to discuss these and other topics. In combination with the conference, the PCIM exhibition offers a whole range of opportunities for obtaining latest information about trends and developments in the sectors of industrial electronics, motor vehicle electronics, office and data technology, medical technology, telecommunications and energy management.

For outstanding contributions two awards will be granted: a "Young Engineer Award" (for authors no older than 35 years of age) and a "Best Paper Award, PCIM China 2010". The winning papers will be selected from amongst all the submitted conference contributions.

All accepted papers will be included in the official PCIM proceedings and the IET Inspec database.

PCIM Booth 12/638

www.pcimchina.com

Fully-Integrated Fusion Digital Power™ Dual Power Driver with Onboard Power MOSFETs

Texas Instruments Incorporated introduced a digital power dual synchronous-buck driver with integrated power MOSFETs, protection blocks and monitoring features, which helps save board space and reduce component count by as much as 80 percent compared to industry standards. The UCD7242 provides designers the flexibility of two independent 10-A rails or one 20-A rail in a small package. The highly accurate on-die current sensing element eliminates the need for calibration or temperature compensation. The UCD7242's input voltage range of 2.2 V to 18 V supports a variety of applications, such as testing and instrumentation, telecommunications, merchant power supplies, and motherboards with multiple points of load. To order samples see: www.ti.com/ucd7242-preu.

TI's easy-to-use Fusion Digital Power Designer Graphical User Interface (GUI) allows the designer to easily enable the UCD7242's features when paired with a UCD9xxx controller. The free, downloadable tool simplifies the development process and speeds time-to-market by allowing the designer to configure all device parameters in minutes. To download the Fusion Digital Power Designer see: www.ti.com/fdpd-pr.

Key features and benefits of the UCD7242:

- Matched drivers and MOSFETs are capable of driving either two outputs at 10 A each or one 20-A output, ranging from 2.2 V to 18 V, and 300 kHz to 2 MHz, providing design flexibility.
- Saves space, component count, and design time by integrating high-side MOSFETs, low-side MOSFETs, drivers, current sensing circuitry, temperature sensing circuitry, and necessary protection functions into a small 6-mm x 6-mm QFN package.
- The UCD7242's advanced monitoring, including accurate current monitoring outputs (+/-5%) and a temperature monitoring output, reduces part count, increases reliability and speeds time to market.
- The accurate current limit (+/-3.3%), thermal shutdown, and separate flag per channel protect the power stage system.
- A dedicated control signal for switching off the low-side MOSFET of each channel makes the UCD7242 highly efficient, even under low load conditions.

Availability and pricing:

The UCD7242 is available now in a QFN-32 package and is priced at $2.65 in quantities of 1,000.

Find out more about TI's Fusion Digital Power portfolio at the links below:

- TI's complete digital power portfolio: www.ti.com/digitalpower-pr
- TI's complete power management portfolio: www.ti.com/power-pr
- TI's digital power E2E online community: www.ti.com/digitalpowerforum-pr

Texas Instruments helps customers solve problems and develop new electronics that make the world smarter, healthier, safer, greener and more fun. A global semiconductor company, TI innovates through manufacturing, design and sales operations in more than 30 countries. For more information, go to:

www.ti.com

Integrated PSU Controller and 725 V MOSFET Deliver 20 mW Output Power for 100 mW Input Power in Standby Mode

Power Integrations, the leader in high-voltage integrated circuits for energy-efficient power conversion, launched TOPSwitch-JX, a highly integrated family of 16 power conversion ICs incorporating a 725 V power MOSFET for use in flyback power supplies. The novel TOPSwitch-JX multi-mode control algorithm maximizes power efficiency across the entire load range. High efficiency at full power minimizes power wasted during normal operation and reduces the complexity and expense of thermal management on the system. At low power levels, high efficiency enables adapters with extremely low no-load consumption and maximizes power available to the system in standby mode for applications constrained by standards and regulatory controls.

Excellent light-load efficiency and low power consumption in the no-load condition are facilitated by a novel multi-cycle modulation mode, which reduces the average switching frequency while minimizing output ripple and audible noise. This allows designs to easily meet stringent new efficiency specifications, such as ENERGY STAR® and the EC EuP Ecodesign Directive, while maintaining a stable output voltage. Standby power consumption below 100 mW (for a 20 mW load) at 264 VAC is easily achieved using TOPSwitch-JX.

David New, product marketing manager at Power Integrations, comments: "In addition to enhancing light-load operating efficiency, we have also increased the breakdown voltage to 725 V in this latest generation TOPSwitch device. This improves system reliability and allows operation with a high reflected voltage, which reduces the secondary diode cost in many designs. The new IC also incorporates a fast AC-reset circuit, which significantly reduces the number of primary-side components required."

TOPSwitch-JX is available in the new low-profile eDIPä package, which is optimized for outstanding heat dissipation in slim-form-factor applications such as LCD monitors, TVs, and netbook/notebook adapters. The device is also well suited for printers, PC and TV standby, set-top boxes, and other consumer audio/video equipment requiring up to 177 W of power with a universal input voltage range.

The TOPSwitch-JX family is available now, priced between $0.78 and $1.69 each for 10,000-piece quantities. In addition to the thermally efficient eDIP package, the device is also available in PI's popular eSIP®-7C heatsink-mounted TO-220 replacement package. Comprehensive safety features include over-temperature, over-current, over-power, line over-voltage, line under-voltage, and user-selectable latching/non-latching output over-voltage protection with fast AC reset.

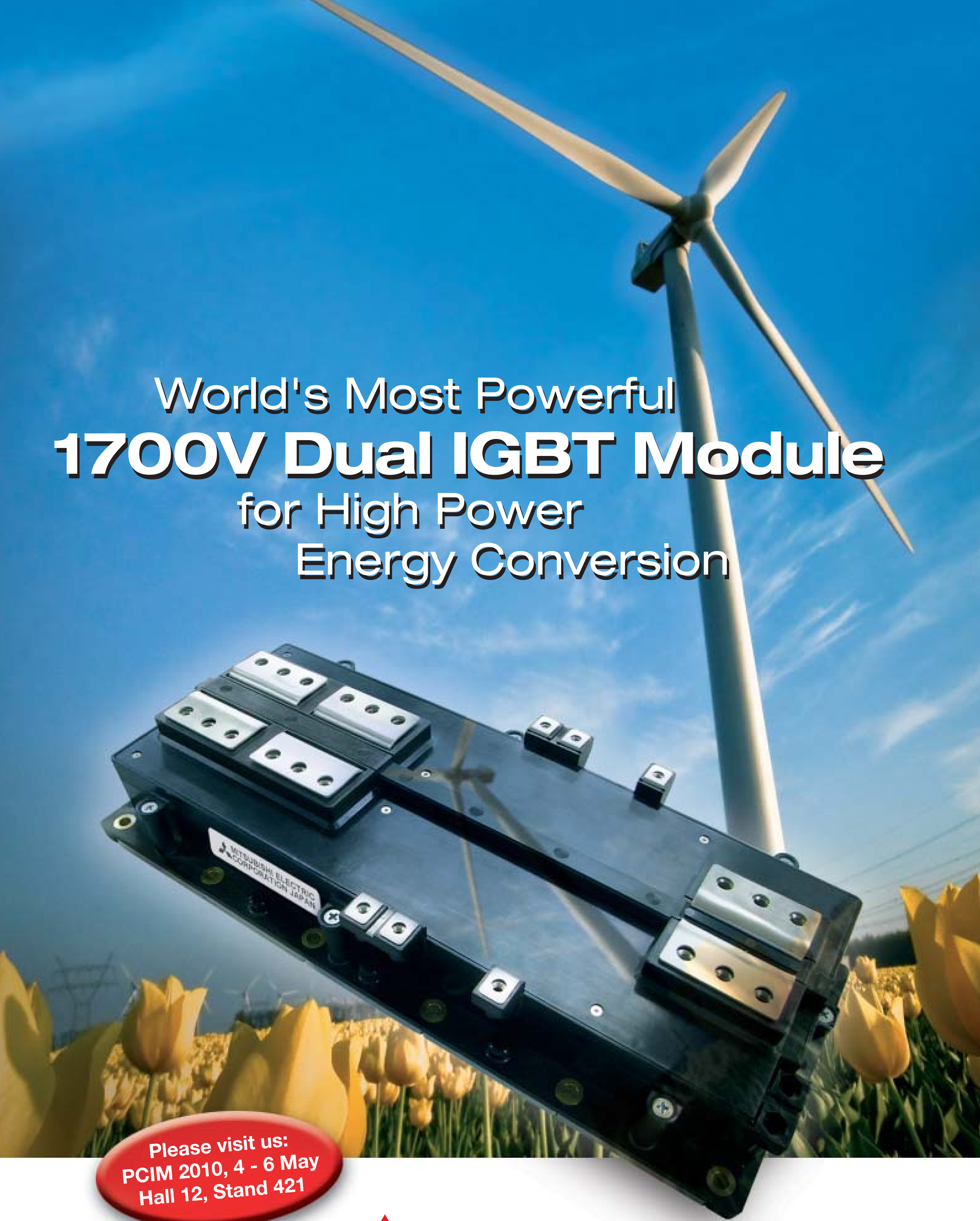
The product datasheet, design ideas, and introductory video are available now on the Power Integrations website at www.powerint.com/en/topswitch-jx.

About Power Integrations

Power Integrations is the leading supplier of high-voltage integrated circuits used in energy-efficient power conversion. The company's innovative technology enables compact, energy-efficient power supplies in a wide range of electronic products, in AC-DC, DC-DC and LED lighting applications. Since its introduction in 1998, Power Integrations' EcoSmart® energy-efficiency technology has saved an estimated $3.9 billion of standby energy waste and prevented millions of tons of CO_2 emissions. The company's Green Room web site provides a wealth of information about "energy vampires" and the issue of standby energy waste, along with a comprehensive guide to energy-efficiency standards around the world. Reflecting the environmental benefits of EcoSmart technology, Power Integrations is included in clean-technology stock indices sponsored by the Cleantech Group (Amex: CTIUS) and Clean Edge (Nasdaq: CELS).

For more information, please visit

www.powerint.com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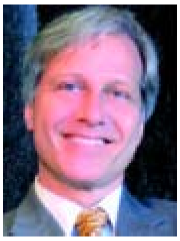
How Fast Will GaN Take Over Silicon in Power Management

By Alex Lidow – CEO of Efficient Power Conversion Corporation



In June 2009 Efficient Power Conversion Corporation (EPC) introduced the first enhancement-mode GaN on silicon power transistors designed specifically as power MOSFET replacements. These products were designed to be produced in high-volume at low cost using standard silicon manufacturing technology and facilities.

Our 30 year silicon power MOSFET journey taught us there were four key variables controlling the adoption rate of a superior technology.

- Does it enable new capabilities?
- Is it easy to use?
- Is it cost effective to the user?
- Is it reliable?

New Capability: The most significant new capabilities enabled by enhancement mode GaN HEMT devices stem from the quantum improvement in switching performance and overall device bandwidth. GaN also has a much higher critical electric field than silicon which enables this new class of devices to withstand greater voltage with less penalty in on-resistance. Expect end products using GaN transistors to appear shortly with greater battery life, less power consumption, smaller size, and lower costs.

Easy To Use: How easy a device is to use depends on the skill of the user, how different the device is compared with devices within the experience of the user, and the tools available to help the user apply the device

The new generation of GaN transistor is very similar in behavior to existing power MOSFETs and therefore users can leverage their past design experience. Two areas stand out as requiring special attention: relatively low gate dielectric strength and relatively high frequency response. The first of these two differences, relatively low maximum gate voltage, can be improved as the technology matures. The second difference, relatively high frequency response, is both a step function improvement over any silicon device, and an added consideration for the user when laying out circuits. For example, small amounts of stray inductance can cause large overshoot in the gate-to-source voltage that could potentially damage devices.

On the other hand, there are several characteristics that render these devices easier to use than their silicon predecessors. For example, the threshold voltage is virtually independent of temperature over a wide range, and the on-resistance has a significantly lower temperature coefficient.

User-friendly tools can also make a big difference in how easy it is to apply a new type of device. EPC has developed a complete set of SPICE device models and a library of applications notes and reference designs available at www.ecp-co.com.

Cost Effective: Since EPC's transistors are built in a standard silicon foundry and the technology allows for a significant die "shrink" compared with silicon MOSFETs, cost comparisons should quickly favor the new technology. As we progress down the learning curve, GaN will be able to dramatically outperform silicon in cost effectiveness to the average user.

Reliable: The cumulative reliability information on power MOSFETs is staggering. Many years of work has gone into understanding failure mechanisms, controlling and refining processes, and designing products that have distinguished themselves as the highly-reliable backbone of any power conversion system.

GaN on silicon transistors are just beginning this journey. Preliminary results, however, are encouraging. As of the date of this writing, EPC has established the basic capability of enhancement mode GaN on silicon transistors. A full reliability report with greater statistics has been published in March 2010.

The power MOSFET is not dead, but is nearing the end of the road of major improvements in performance and cost. GaN is destined to become the dominant technology over the next decade due to its large advantages in both performance and cost; advantage gaps that promise to widen as we quickly climb the learning curve.

www.epc-co.com

Ascending the Final Slope in Ac-Dc Power Supply Efficiency

By Arnold Elderman, Anagenesis

In September 2007, at the Digital Power Forum (DPF 2007), both Google, via Climate Savers, and IBM threw down the gauntlet challenging the industry to provide much more efficient power supplies for data centers. IBM's Randy Malik set the most challenging goal of 90% efficiency from "plug to processor." Ten percent (10%) losses sounds like a slam/dunk until you realize that the most advanced data centers use the widely adopted distributed power architecture (DPA) first created by AT&T Bell Labs in the 1970s. Figure 1 shows that this ancient architecture consists of at least three cascaded power supplies, each losing a disproportionate share of power when compared with all of the other post-generation power losses.

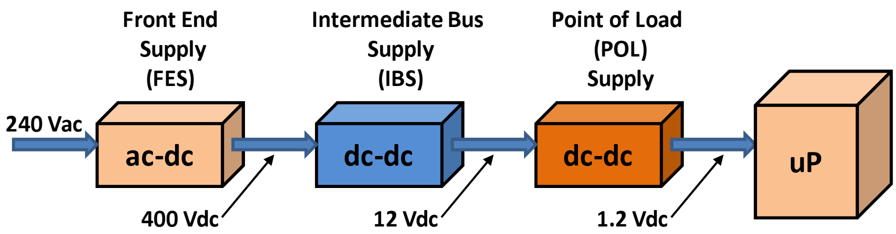


Figure 1 – The distributed power architecture (PDA)

What's the BIG deal?...

Let's take a closer look at what it will take to achieve that 90% efficiency for the whole power conversion train from 240 Vac plug voltage to 1.2 V processor voltage. Table 1 shows that best immediate figures do not "multiply up" to 90%. To achieve the 90% overall efficiency, the ac-dc power supply must have 98% efficiency.

	FES	IBS	POL	Plug-to-Processor
Recent	93%	95%	88%	78%
Best Immediate	95%	98%	90%	84%
	IBM Challenge			***90%***
Needed	98%	98%	94%	***90%***

Table 1 – Efficiency Landscape and the IBM Challenge

DC Partners, the ad hoc group that is advocating data center dc power distribution, will argue that the task is much easier using 380 Vdc power distribution. They have no argument from me on that point. Yet I offer that the adoption of dc distribution will be a long arduous journey with ac distribution never being totally displaced, so we must still cope with ac distribution.

Although most industry stakeholders focused on point-of-load (POL) power supply efficiency improvement, the ac-dc power supplies have also made significant progress. They started the decade exhibiting a nominal 88% efficiency. Eltek Valere introduced their 96.6% efficient power supply in late 2008, causing a design dust storm. Yet I expect the majority of present new designs to fall slightly short of the Eltek Valere benchmark. A CTO recently advised me, "When adjustments are made for a good balance between performance and cost, we feel that 95% efficiency will be very competitive." So, we are not to the summit yet. Ascending the final 3% from 95% to 98%, will be like climbing K2.

How do we get there?

Fairchild Semiconductor's Laslo Balogh gave us the answer at DPF2007 when he said, "Topology and component selection defines the baseline efficiency of a power supply." I believe the last efficiency ascent will require a two-fold attack — new topologies, and new power semiconductor technologies. For a 98% efficient ac-dc power supply, present technologies present sub-optimal-performance-and-cost answers — it will take a paradigm shift. Where will the paradigm shift come from? We are getting glimpses…

The quest for new topologies is the power supply designer's relentless task. For many, it is the essence of their career. As we survey the topology landscape for ac-dc power supplies in the 500 watt to 5 kW range, we find an inordinate amount of effort in the past few years focused on fine-tuning and perfecting the soft or zero voltage switching (ZVS) and zero current switching (ZIS) topologies. To this foundation, topology designers such as Eltek Valere have married a high-voltage version of the dc-dc the synchronous rectifier. Voila! — we have the optimum present. I offer that these approaches are now resulting in diminished incremental improvements.

Some would say that there are no new topologies. That is not true. Recent topological offerings look promising. Designers offer reports of progress from several corners of the industry. These reports show some limited viability for the bridgeless power factor correction (PFC) circuit. One development group proposes that the optimum solution utilizes their topological technology in the balanced-boost bridgeless power factor correction circuit, providing less EMI generation than the present traditional PFC. Another approach offered in a recent Japanese conference announcement claims a completely new topology comprised of fewer components and less parametric stress than today's traditional designs. These two possibilities even claim lower cost than today's designs. Imagine that! Higher efficiency may not mean higher cost. It will certainly be very interesting to see what develops.

The quest for new power semiconductor devices…

The second half of the pincer attack is addressing the power semiconductors. Since ac-dc power supplies convert 120/240 Vac line power to more useable forms, designers must use power semiconductors that are rated for 600 volts and above. At these voltages, the silicon MOSFET runs out of steam with the Rds(on) and intrinsic parasitic elements becoming inefficiently large. The super junction silicon MOSFET has provided an apparent relief solution up to 900 V for some designs.

However, highly efficient converter designs utilize super junction MOSFETs at the expense of lower switching frequency resulting in lower power density. For the phase-modulated soft-switching full bridge converters, the primary power semiconductor transistor losses are directly related to Rds(on) for conduction losses and Coss for switching losses.[1] So the switch figure-of-merit (FOM_2) derived from the product of the transistor "on" resistance, Rds(on), and output capacitance, Coss, indicates the relative losses in a selected device. Although the super junction MOSFET achieves significant FOM_1 = ohm X area improvement, its FOM_2 is almost twice that of the standard silicon MOSFET as shown in Table 2. Thus designers achieve high efficiency designs at lower switching frequencies, adversely affecting the size of the magnetic elements. This inhibits sufficient power density improvements. I also discovered that many designers are not using this device because its cost is still too high.

Therefore, I believe that ascending the final efficiency slope will require more than squeezing the last watt of loss from silicon devices. Their performance improvement is running out of steam. We should not despair because alternatives are appearing on the horizon. I offer that compound semiconductors may well be the answer.

As we consider these new devices, I hope that semiconductor manufacturers will learn from painful past mistakes. Early compound semiconductor attempts at serving the power electronics industry have been less than stellar. Leading off with the gallium arsenide (GaAs) power diode fiasco of the mid 90's, this material was used by the metric ton in rf applications. Born of excess Fab capacity during a mobile phone downturn, the supplier initially offered the GaAs diode as a viable low-EMI, high-efficiency diode solution at below-cost prices. It met a disastrous end when the manufacturer discontinued the devices due to limited Fab capacity when the mobile phone market had an upturn. This left power supply manufacturers high and dry. We certainly don't want a repeat of that scenario. Therefore, to be successful, the compound semiconductor supplier's business model must focus on the power semiconductor market.

Looking at the more recent compound semiconductor devices introduced, the Silicon Carbide (SiC) diode offers a high-efficiency solution with lower recovery current losses and less EMI generation. It has had some success during a painfully long gestation period. The barriers to SiC diode growth include perceived high cost and being void of a partner SiC transistor to complete the design-in solution. Now the SiC transistors are starting to appear.
The question remains — will ramping both of these devices to high volume yield competitive cost structures?

	Rds(on) (Ohms)	Coss (Farads)	FOM = Rds(on) X Coss	Relative FOM_2 Value
Typical super junction silicon transistor	4.50E-02	3.20E-07	1.44E-08	1.89
Typical silicon transistor	3.80E-02	2.00E-07	7.60E-09	1

Table 2 – Comparative FOM2 – Silicon Transistor vs. Super Junction Silicon Transistor

Semiconductor device suppliers are telling us that there are lower-cost compound devices on the horizon. One supplier introduced low voltage (below 200 V) gallium nitride or GaN experimental devices in the fall of 2008. Their 20-volt production product was highly touted at APEC 2010. They also demonstrated some experimental higher voltage devices. Is high voltage GaN the answer for ac-dc power supplies? Time will provide us the answer.

In summary…

Will it be topology or power semiconductor technology that will carry the ac-dc power supply to 98% efficiency in a cost effect way? Perhaps it will be both. My experience has been that new power semiconductor technology begets new topologies as engineers find clever ways to apply these new devices. Perhaps it will be a series of steps commencing with new topologies, moving to new devices, then moving to even better topologies. Some would say this is a pipe dream. Yet I remain confident that ac-dc power supplies will cost-effectively achieve 98% efficiency, thus meeting industry demand.

1 "Exploring the Pareto Front of Multi-Objective Single Phase PFC Rectifier Design Optimization – 99.2% Efficiency vs. 7 kW/dm³ Power Density", by J.W. Kolar, J. Belia, and J. Minibock, ETH Zurich, Power Electrnic Systems Laboratory, IEEE Power Electronics and Motion Control Conference, May 2009, page 7

2 "Exploring the Pareto Front of Multi-Objective Single Phase PFC Rectifier Design Optimization – 99.2% Efficiency vs. 7 kW/dm3 Power Density", by J.W. Kolar, J. Belia, and J. Minibock, ETH Zurich, Power Electrnic Systems Laboratory, IEEE Power Electronics and Motion Control Conference, May 2009, page 7

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Electronics Industry Digest

By Aubrey Dunford, Europartners

GENERAL

Shipments of consumer devices that can be powered or charged wirelessly are forecast to grow from just 1.5 million in 2009 to almost one billion in 2019, so IMS Research. Activity in the wireless power industry has increased significantly over the last two years and the market is now poised for explosive growth. There are numerous start-ups offering solutions using conductive, inductive, magnetic resonance, RF and infrared wireless power technologies and although their shipments were very low last year; this is forecast to grow rapidly driven by the adoption in high volume applications such as cell phones. Mass adoption will occur as major cell phone and notebook OEMs are intending to integrate the technology into their products.

SEMICONDUCTORS

IBM Research announced its collaboration with companies and universities in the European Union to improve the productivity and reliability of semiconductor and electronic systems design. By providing a systematic methodology and an integrated environment for the diagnosis and correction of errors, the EU-funded DIAMOND consortium expects to slash design time and enable significant savings per chip. According to estimates, fault localization and correction for each chip is expected to cost $ 34.5 M per chip by 2010. With DIAMOND aiming to reduce this time by 50 percent, it has the potential to cut design costs by an estimated $ 17.25 M per chip. The Diamond consortium launched a three-year project this month. The consortium partners include the IBM Research -Haifa, Israel; Ericsson, Sweden; Tallinna Tehnikaulikool, Estonia; Linkopings Universitet, Sweden; Universitat Bremen, Germany; Technische Universitat Graz, Austria; TransEDA Systems, Hungary; Testonica Lab, Estonia.

Following the annual general meeting of Infineon Technologies, the new supervisory board unanimously elected Prof. Dr. Klaus Wucherer as its chairman at its constituting meeting. Gerd Schmidt became vice chairman. In the 2009 fiscal year (ending September), Infineon reported sales of €3.03 billion with approximately 25,650 employees worldwide.

Ixys announced the closing of its acquisition of Zilog. Ixys offers a diversified product base that addresses worldwide needs for power control, electrical efficiencies, renewable energy, telecommunications, medical devices, flexible displays and RF power.

Exar will acquire Neterion -a Californian supplier in 10 Gigabit Ethernet network adapter solutions optimized for virtualized data centres with an array of top-tier enterprise server and storage customers. Their product portfolio represents a complement to Exar's solutions for hardware accelerated data encryption, compression and deduplication. The purchase price is estimated to be between$ 10 M and$ 11 M.

DCG Systems, a provider of semiconductor debug and characterization solutions for the semiconductor industry, has acquired Zyvex Instruments, a provider of nanoprobing characterization solutions for the semiconductor industry.

SEMI announced that Martin van den Brink, Executive Vice President of Technology and Marketing for ASML, is the recipient of the eleventh annual Bob Graham Award for outstanding contributions in semiconductor equipment and materials marketing.

PASSIVE COMPONENTS

Revenue growth for the PCB market in Germany was flat in November 2009, so the ZVEI/VdL. Amid the global financial crisis, which has affected the region's PCB market until May 2009, the first 11 months of last year saw a combined revenue of just about a third compared to the same period in the previous year. Incoming orders, however, saw a slight increase-the first in 13 months.

Wire Systems Technology to a South African group. The consideration for the Sale, payable in cash on completion, is £ 5.0 million. WST is a manufacturer and supplier of winding wire, electrical motor components, electrical insulation and related products.

OTHER COMPONENTS

JDSU, a provider of communications test and measurement solutions and optical products has entered into a definitive agreement to acquire the Network Solutions communications test business of Agilent, including the unit's innovative Long Term Evolution (LTE), or 4G, network verification and deployment products, for $ 165 M in cash.

DISTRIBUTION

The distribution electronic components market in Europe has suffered five quarters of declining revenue, followed by two quarters of growth, so the IDEA (International Distribution of Electronics Association).

Premo Group announced the appointment of Power Products International (PPI) as their exclusive distributor for the UK and Ireland. With this agreement, the Spanish company expects to increase its sales volume in these areas up to € 2 M in the next two years.

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

CTO Power Summit Highlights Smart Grid Opportunities

By Linnea Brush, Senior Research Analyst, Darnell Group

Darnell Group's first-annual CTO Power Summit, held February 15-16 in San Diego, California, gave Chief Technology Officers and engineering executives at global power conversion equipment companies a forum for addressing diverse customer demands and providing the tools needed to drive future success in a number of emerging technology areas. Keeping up with the latest technology trends and getting advanced information for next-generation products is important, but it is only part of what CTOs must have for strategic planning. A clear vision of medium- and longer-term market trends is critical. The CTO Power Summit was designed to help CTOs identify product differentiation opportunities and keep up with changing market conditions. Complementing the improved margins enabled by product differentiation is the drive for reduced costs in product development and manufacturing.

Europe was well-represented at this meeting, which was an invited audience of decision-makers from around the world. One of the sponsors, the EMerge Alliance, includes Philips, ROAL, Zumtobel, Configura and the EnOcean Alliance among its members. TÜV Rheinland of North America, which is a part of the TÜV Rheinland Group, presented a paper in the "super session" titled, Impact of the Emerging Smart Grid.

Indeed, one of the areas that the CTO Power Summit addressed was the impact of the "smart grid" on standards, utility communications, energy systems and interoperability. The smart grid is expected to provide a "dynamic systems infrastructure," including intelligent control that will communicate with utilities. This infrastructure will incorporate efficient building systems, Internet access, advanced metering, distributed generation and storage, smart end-use devices, and renewable energy technologies, such as photovoltaics. Based on recent reports, smart meters and supporting networking infrastructure technologies are seeing the earliest growth, with revenue expected to reach $5 billion (about €3.7 billion) by 2015.

In Europe, Greenpeace and the European Union (EU) produced a joint study stating that smart grids will play a large role in the goal of meeting 20% of the EU's energy demand with renewable energy by 2020. A European Union-backed research consortium known as SmartGrids has published a blueprint for a power system that is said to be reliable, flexible, accessible and cost- effective. Sophisticated software in the system that accurately measures demand will monitor the network. According to SmartGrids, the smart grid can be compared to an "energy internet," with user-generated electricity feeding into it from every direction and from multiple sources, including large-scale installations like off-shore wind farms and small-scale installations such as solar panels and rooftop mini wind turbines.

The European Commission (EC) recently allocated over €903 million to electricity interconnection projects as part of its broader European Economic Recovery Plan. The EC states that its plan will promote renewable sources of energy and present an initiative to upgrade Europe's networks, including smart grids.

But building a business case for smart grid investments is a challenging task. According to some reports, "Future progress … will depend on predictable levels of operational and financial risk associated with smart grid investments." The US National Association of Regulatory Utility Commissioners has stated that the benefits of the smart grid are obvious, but "we must be sure that we move deliberately and in stages so that the costs of rolling out the necessary infrastructure are borne by those who will benefit."

So, how real are the opportunities to make money from the smart grid? A super session at the Summit brought together several stakeholders in the smart grid concept. These groups have a legitimate chance of launching a smart grid, although a unified infrastructure is still years away. These groups agreed that the smart grid "isn't here yet, and there is still a lot of hype and not a lot of commercial technology." And it needs more investment and coordination to make it work.

A potential, but provocative, direction came from Intel's Tomm Aldredge, Director, Energy Systems Research, who discussed the "Intel Labs Energy Systems Research Agenda." This agenda proposes an "open smart grid" with distributed control and low-cost energy storage. The operative term is "open system." These smart, local microgrids, dubbed the "Enernet," could enable entrepreneurial change agents to rapidly transform electricity service, quality and value. A user-centered, utility-driven open system can work with the microgrid model, and Intel stressed that such a system would not work independently of the utility grid. Both types of systems are needed, but it should be a utility-driven open system that is based on user needs.

New power architectures were a main focus of the CTO Summit, and future opportunities for power supply companies are found when these architectures evolve or change. Intel's Microgrid Architecture is one such potential shift, and the company claims its strategy can "accelerate the Smart Grid by decades." The company says it can capitalize on its years of experience in building information systems, giving them the ability to create an "open eco-system." The model includes an intelligent control plane, a microgrid architecture, interconnection to plug-in hybrid vehicles and nanotechnology-based ultracapacitors. Intel expects to build an industry around the intelligent control plane "within three years."

More traditionally, utilities have the best opportunity to get the ball rolling, which they have done through such projects as the IntelliGridSM Initiative in the US. These projects will be instrumental in determining the challenges of the smart grid, but they are still considered "closed" as far as players outside the utility industry are concerned.

The utility perspective came through in the Electric Power Research Institute (EPRI) Smart Grid Communications & Cyber Security presentation. This paper provided a "Theoretical Discussion of Smart Grid

Trends." EPRI is on the forefront of smart grid implementation. Their agenda includes the ***IntelliGrid*** Architecture, a Smart Grid Demonstration, and Accelerating the Adoption of Demand Response Ready Appliances. The IntelliGrid™ is based on: a methodology for gathering smart grid requirements; a standards assessment and contribution; an information model to facilitate systems integration; a communications technology assessment; and a security policy for smart grid applications.

One of the main points to come out of the CTO Summit is that cost is not always the driver behind new technology adoption. When large companies, like Intel, get behind an idea money and resources are going to follow. Such emerging technologies now have a solid base from which to launch commercial products. The smart grid is nascent, and it still has many issues to hammer out. Both the utilities and companies like Intel are working seriously on these issues, however.

The impact of "Utility Communications, EMC and Related Smart Grid Issues" was given by Jerry Ramie from ARC Technical Resources, who is a Senior Member of the IEEE and works with the Standards Association and the P1775 Committee. Ramie also espoused the IntelliGrid, which links communications and the power grid using basic technologies available today. Integration (interoperation) is the challenge, and ARC proposed deploying automatic meter reading, SCADA, and remote-controlled distribution devices – in that order. Ramie also emphasized the need for mandating both emissions and immunity testing.

TÜV Rhineland is an international service group that documents the safety and quality of new and existing products, systems and services, along with relevant standards and meaningful performance measures. Dr. Farouk Zanaty's presentation, "Certification Considerations for Smart Grid Compatible Designs: Necessity and Sufficiency of Interoperability Measures," stressed the need for both interoperability and performance testing to ensure operations of different equipment built by different manufacturers, and gave the prerequisites: conformance to a protocol; consistency of configuration parameters; and consistency of modes of operation.

The CTO Power Summit made two critical points: (1) new power architectures are coming out that will drive traditional power products – but not in traditional areas, and not in traditional designs; and (2) opportunities will be found in alternative power solutions, such as the smart grid. CTO Power Summit 2011 will identify more trends that are likely to keep power supply companies profitable for years to come.

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On the Pulse of Power Electronics

The desaturation behaviour of the IGBT allows to turn them off by the IGBT driver

Just about 30 years ago, fast thyristors, RCTs, GATTs as well as GTO and BJT were the best components available at the time for power electronics. Each 100V reverse voltage upwards was keenly fought over, each microsecond reduction in recovery time reduced the effort required for the commutation circuits, and a higher turn-off amplification in the case of the GTOs resulted in smaller gate units.

By Werner Bresch, GvA Leistungselektronik

Current-source inverters, DC choppers, resonant inverters, pulse width modulated inverters etc. switched rather slowly at a rate of a few 100Hz, the current rise shaped by di/dt limiting chokes were comparatively slow in the range of a few 10A/us, the voltage rise limited by large RC circuits were in the range of a few 100V/us. These limitations were due to the power semiconductors with their physical properties which were available at the time and they resulted in what were, from today's point of view, large, heavy, circuitous structures which seemed rather outdated.

In retrospect, it can be stated today that, with the availability of IGBTs, power electronics has taken a quantum leap forward, very much comparable with the development in microprocessor technology. It was the advent of the IGBT that allowed the widespread use of inverters at all customary voltage levels down to the lower medium-voltage level with a pulse width modulated inverter and three-level inverter systems. IGBTs can even be found today in network couplings and HVDC transmission systems. A similar situation is true with the IGCTs in the maximum power range as the successor to the GTOs. It can be assumed today that, with the availability of power semiconductors that can be turned off with blocking voltages of up to 10kV and semiconductor materials with permitted barrier layer temperatures of up to 350°C, further interesting application windows will be opened up. This is therefore an exciting time!

However, in the broad field of power electronics with its very wide-ranging requirements profiles for the power components, the IGBT is just one of many possible components. But to be able to realise customised solutions based on the customer's requirements, it is just as important to be aware of the old approaches to solving problems as it is to be familiar with the new modern power semiconductor components, as the following examples demonstrate.

Figure 1: GvA work shop for high power units

Figure 2: DC Chopper with RCT`s before the conversion

"Old-fashioned" solution

Based on the description provided by the customer, it was to be assumed that so-called RCTs (**R**everse **C**onducting **T**hyristors, monolithic integration of thyristor and antiparallel freewheeling diode on a chip) are used as both, the main and the turn-off thyristors in the existing DC chopper drive. In each case two RCTs were connected in series here in order to achieve the required blocking voltage. The entire drive design was coordinated in terms of the intrinsic dynamics (di/dt and dv/dt) using external components such as chokes and RCD circuits.

Measured figures show that the overall system and all secondary facilities such as cooling, sensors, drivers and controllers work with one another and without interference and they should continue to be used.

In principle, the drive described previously could be converted to IGBT technology. To achieve this, the trigger signals of the main thyristors and those of the turn-of thyristors must be logically linked to one another so that long trigger pulses are produced if the old analogue control system should continue to be used. The principle of forced commutation thyristor turn-off would be obviated, as would all of the turn-off circuits and the protective circuits. Further interfaces for monitoring the IGBT would probably be required, but they cannot be processed with the existing control system.

This would be associated with extensive interference with the structure of the drive, especially if old secondary facilities and functions should and must continue to be used or operated.

IGBTs display entirely different operating characteristics and allow much higher di/dt values (several 1000A/us depending on the size of the IGBT). The same applies to the generated dv/dt values when turning off the IGBT and as a result of the turn-off characteristics of the freewheeling diode (up to more than 10 kV/us).

Figure 3: DC Copper converted with fast thyristors

It is almost certain that this would result in a number of problems and incalculable technical risks. A number of these are listed below by way of example:

- Thermal dimensioning:
  IGBTs generate higher losses and usually have a modular design. This means that only unilateral cooling which is thermally unfavourable is possible. IGBTs should therefore be chosen which have considerably bigger silicon surface area than the thyristors which are used today.
- Current routing:
  Today's current routing is axial. With IGBT modules, the current routing is lateral. This generally results in extensive mechanical changes.
- Short-circuit current control:
  When short-circuits occur, IGBTs must be turned off within their SCSOA limits. This does not work with today's control system.
- Plasma control:
  IGBT modules are non-hermetically sealed components. In the event of a non-controllable short-circuit situation, plasma can escape. This is not the case with thyristors.
- Life expectancy and load cycles:
  IGBT modules naturally have a significantly lower life expectancy compared with thyristors. In the case of an IGBT with an application-level temperature lift, we are talking about a life expectancy of a few 100,000 load cycles (depending on the level of the temperature lift), and with thyristors of a few million. IGBT modules must be generously oversized so that they attain an acceptable life expectancy.
- Parasitic effects:
  On account of the high di/dt, dv/dt values, the probability is high that there will be interference in the secondary facilities, as has already been described. Moreover, there may be parasitic effects such as, for example, capacitive discharge currents, isolation problems in the traction motor (dv/dt), radio emission and conducted interference which may entail additional unforeseeable expenditure.

- Approvals:
  Railway approval etc. must be newly obtained.
- Operational radio
  There may be interference with the operational radio frequency.

Figure 4: Laboratory power supply unit

This list does not claim to be exhaustive, but it does show the high technical risk associated with IGBT conversion using peripherals which are not intended for this. This will also be reflected in the costs.
Following long discussion and a subsequent weighing up of the risks and costs, it was decided to use fast thyristors instead of IGBTs as a replacement for the RCT. At the same time, the entire protective circuitry was renewed.
The replacements used for both the main and the turn-off thyristors were a fast high-blocking thyristor and a fast high-blocking diode in order to replace the RCT function. The DC chopper drives which have been overhauled in this way run reliably and without any interference.

“State-of-the-art” system solution
A requirements specification from a customer for a large “laboratory power supply unit” was of a very different nature. Here it was essential to use the very latest IGBTs.
With a development such as this, it is possible right from the very outset to take optimum account of the highly dynamic behaviour and the advantageous operating characteristics of the IGBT in the design. The lateral current routing of the IGBT modules favours compact inverter structures with short commutation paths and low stray induction. This in turn allows the IGBTs to be turned on and off quickly with minimal switching losses on the one hand and safe control of the switching surge voltage spikes even in the event of an over current and short-circuit current shut-off on the other. The desaturation behaviour of the IGBT allows reliable identification of the short-circuit situation and allows the IGBT to be turned off by the IGBT driver. The identification of a short-circuit and over current as well as turn-off is relatively simple in IGBT inverters compared with all other power semiconductors provided that the inverter is a 2-pulse inverter. However, the delay times which are set on the drivers must be correct. It must be ensured that activation is flawless without any EMC interference. In the case of high-performance inverters, optical transmission routes have proved to be advantageous both for activation and for error acknowledgement, as has the positioning of the IGBT driver board in close proximity to the IGBT.
The emitter efficiency in the case of IGBTs is significantly worse compared with bipolar components (thyristors, GTOs, IGCTs). IGBT modules which can only be cooled on one side (lateral current routing) are mostly also used for the inverter designs. The result of this is that, when there is a demand for higher performance, either complete inverters must be operated in a parallel circuit or IGBTs must be connected in parallel directly. Each of these two options has specific advantages and disadvantages. What the two options definitely have in common is that the current distribution within the parallel circuit must be checked and safeguarded at all operating points.

The cooling method itself is not as significant for the mechanical structure of the inverter when using IGBT modules. As the IGBT modules favour lateral current routing, cooling with natural convection, cooling with forced ventilation and cooling by liquid cooling are possible with the same basic mechanical structure. The fact that IGBT modules have an electrically isolated baseplate means that several IGBT modules can be fitted on a cooler without any problems and there are no potential problems (electrical corrosion) when using liquid cooling. However, material compatibility within the liquid-cooling system must be safeguarded.

Figure 5: IGBT 3-Level Inverter

The realised “laboratory power supply unit” should be capable of being operated in monophase and three phases on the output side. This power supply unit was realised with three monophase inverters which can be operated both in parallel and in three phases. In monophase parallel mode, an output power of approx. 1,5MVA is achieved and the sine output frequency is up to 200Hz. Particular attention needed to be paid to the parallel connection of two IGBT Primepak modules per switching function which was required to be able to achieve the necessary output power at the necessarily high modulation frequency. The parallel IGBT modules are activated jointly by one IGBT driver. All of the power electronics are liquid-cooled. To meet the required EMC levels specially designed filters are provided on both the input and the output side. Software developed specifically for this “laboratory power supply unit” and visualisation round off this development to produce a complete system development.

Summary
In order to be able to offer optimum customised solutions, there needs to be knowledge of the component-specific qualities and characteristics, not just for the new but also for the old power semiconductors. IGBTs are not GTOs, GTOs are not thyristors, thyristors are not IGCTs, diodes, bipolar transistors or MOSFETs. Different design criteria apply to series circuits than apply to parallel circuits. Air cooling results in different performance levels than liquid cooling. Traction requirements are entirely different to steady-state requirements.
This is what makes working “on the pulse of power electronics” so interesting and varied!

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Wide Input, Low Output POL Regulators

Delivery of Benchmark Efficiency With High Density

Capable of handling input voltages as wide as 1.5V to 16V, the second generation integrated point-of-load (POL) regulators are designed to deliver output voltages from 0.7V to 12V at peak efficiency greater than 96%. Thanks to programmable switching frequencies up to 1.5 MHz, this voltage regulator shrinks size and cost as well to achieve a new high in power density.

By Cecilia Contenti, International Rectifier, El Segundo, California

Whether it is servers, data storage facilities or Netcom applications, the need to save power in these equipments is surging vigorously. Because lower dissipation means simpler thermal management and lesser infrastructure cost, the efficiency bar in these products has been further raised by international regulatory agencies and OEMs alike.

While there are many sources that contribute to power consumption in these products, DC-DC converters and voltage regulators used to power various electronic loads in these applications consume about 25-30% of the total power dissipation. Hence, the pressure to build more efficient power supplies with high density is even greater.

Consequently, new and advanced power management solutions are needed to cope with the new challenges. As a result, to overcome the limitations of traditional discrete and monolithic designs, a novel integrated solution has been developed that combines the best of both the worlds. While it simultaneously improves efficiency and cuts size and board space dramatically, it also offers a single rail design to convert a wide input voltage range into a low voltage output. Traditionally, high input to low output DC-DC voltage converters require two stages.

To raise the efficiency bar, this integrated solution incorporates three optimized power components-synchronous buck controller, control FET and sync FET- to minimize conduction and switching losses. In addition, the three power components are cleverly co-packed to eliminate interconnect and packaging parasitic for higher frequency of operation. Plus, it uses pulse-width modulated (PWM) voltage mode control with external compensation to provide good noise immunity and flexibility in selecting inductor values and capacitor types. And, lastly, the design is scalable.

Labeled SupIRBuck, the integrated point-of-load (POL) voltage regulators were first released in November 2007 (SupIRBuck Gen1 family). Ongoing improvements and enhancements have resulted in a second generation family or SupIRBuck Gen 2 integrated POL regulators that surpass the efficiency and density of first generation to set a new performance benchmark. And, thereby, promises to boost efficiency in servers, data storage equipments or similar products by about 5 to 6% with increased density over previous solutions. Gen2.1 devices represent an upgrade to Gen2 parts launched early last year (Figure 1)

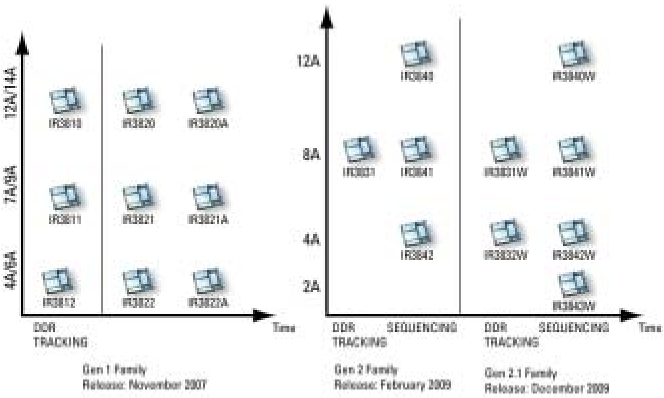

Figure 1. Second generation Gen2.1 POL regulators provide an upgrade path to Gen2 parts launched in early 2009.

To achieve dramatic improvements in efficiency and density simultaneously across light and heavy loads, the integrated Gen2 POL regulators have been redesigned with new advanced CMOS engine capable of handling switching frequencies up to 1.5MHz, high performance floating gate drivers and integrated bootstrap synchronous MOSFET such as mono-FETKY (Figure 2). For improved transient response, high bandwidth (25MHz) high gain error amplifier is used in this design. In addition, circuit techniques have been incorporated to improve the accuracy for current limit and reference voltage, while the standby current has been reduced significantly. For instance, maximum stand-by current is specified at 500 µA.

For higher density and easy upgrade, all members of the second generation family are housed in the same thermally enhanced low profile 5 x 6 mm QFN package. Additionally, to lower the overall on-resistance (RDS(on)) of the sync FET, the interconnect resistance of the package has been minimized.

New Efficiency Benchmark and More

The second generation SupIRBuck Gen.2.1 POL regulators offer output currents up to 12A with efficiency as high as 96% from low to high load range. In essence, these new generation POL regulators are designed to provide a flat efficiency curve across a wide load variation. At the low end, it can deliver output current as low as 2A without compromising performance. While optimized for 12V input voltage, the high electrical performance is maintained at input voltages like 9.6V, 5V and 3.3V. Also, since the footprint is common for all members in this family, it provides design flexibility that permits easy cut-and-paste layout for fast time to market.

Besides providing pin compatible current options from 2A to 12A, the Gen2.1 integrated POL regulators also bring new functions like power good (PGOOD) output for over voltage and under voltage detection, shorter dead-time to reduce power losses and more precise over current (OC) limit. The PGOOD output detects over voltage and under voltage conditions and provides a feedback that can be used by appropriate control logic to shutdown the system or control a second rail. In addition, the PGOOD signal for trackers devices offer tracking capability. And the lower maximum RDS(on) of the sync FET improves OC limit accuracy.

The maximum RDS(on) is 6.9mOhms for IR3840W LFET, which is about 14% lower than the previous generation. Similarly, other members like IR3841W and IR3842W offer 10.7 mOhm and 19 mOhm, respectively. Additional features include pin compatible solutions for 2A, 4A, 8A and 12A units, small footprint (5 x 6mm) and low height

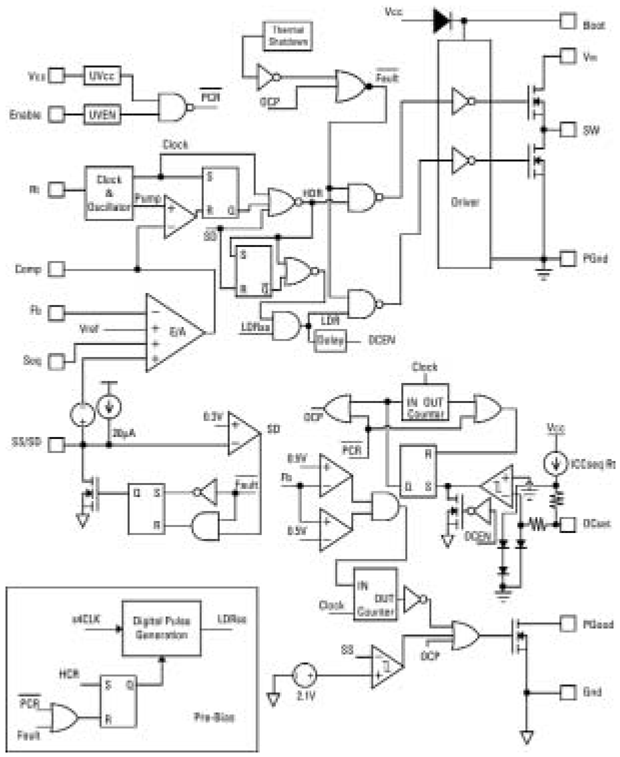

Figure 2: Block diagram for Gen2 SupIRBuck family

(0.9mm), 1% accurate 0.7V reference voltage, programmable hiccup current limit, programmable soft start, enhanced pre-bias start up, thermal protection, enable pin with voltage monitoring capability, and -40°C to 125°C operating junction temperature range.

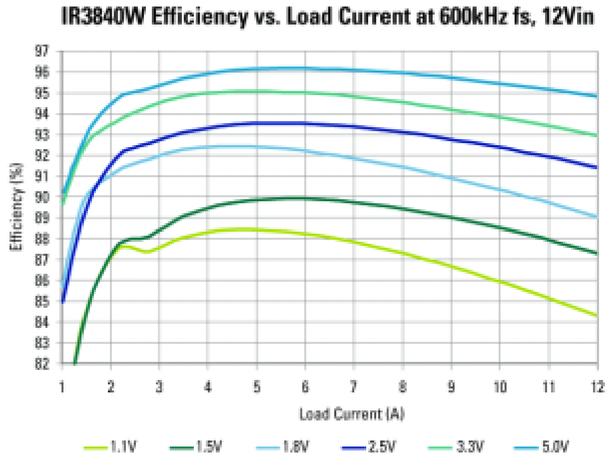

Figure 3: The SupIRBuck Gen2.1 POL regulator efficiency is high and remains flat across a wide load range.

To illustrate high efficiency capability of this new POL family, measured efficiency results over wide load variations for a 12A unit (IR3840W) are depicted in Figure 3. The switching frequency used here is 600kHz, while the input voltage is 12V. The test data shows that for 5V output the peak efficiency is greater than 96% for load current variations from 4A to about 9A. And drops to 95% at 12A load current. Similarly, on the lower side, the efficiency is 95% at 2A output current. In short, the efficiency curve is flat, which is an important factor in applications that require high efficiency across a wide current range rather than at a single point. Even as the output voltage drops below 2V, the efficiency performance remains over 90% across a wide load range. The end result is energy savings and a lower operating temperature requiring a very simple thermal management solution. In other words, Gen2.1 POL regulators are designed to deliver full current rating with no airflow and without a heat sink. All this translates into high reliability levels for the second generation SupIRBuck regulators.

By comparison, at 600kHz operating frequency, the Gen2.1 efficiency is about 5% to 7% higher than Gen1 devices. However, Gen2.1 devices offer programmable switching frequencies up to 1.5MHz. Hence, for applications where density matters, Gen2.1 POL regulators can be switched at frequencies as high as 1.2MHz. to cut the size of external passive components while maintaining high efficiency. This is demonstrated in Figure 4, where Gen2.1 unit IR3841W switching at 1.2MHz is compared with similar device operating at 600kHz, as well as a Gen1 member (IR3821). Here, the input voltage is 12V and the output is 1.8V for all the three regulators. It is observed from this figure that designers have the flexibility to either achieve benchmark efficiency at 600kHz or to operate at 1.2MHz or above and shrink the size by about 20% without trading off efficiency performance.

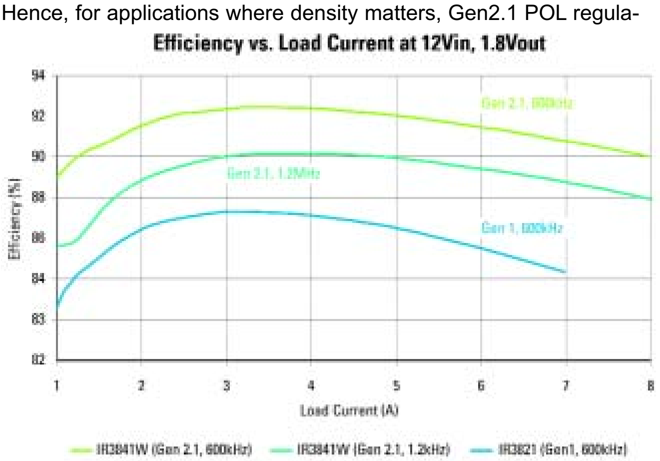

Figure 4: Comparing efficiency performance between Gen 2.1 and Gen 1 devices at operating frequencies of 600kHz and 1.2MHz.

Design Flexibility

Often current or power requirements change during the design process. Traditionally, these changes require new parts with new layout and design. To simplify such implementation, SupIRBuck Gen2.1 offers pin compatible common footprint for 2A (IR3843W), 4A (IR3842W), 8A (IR3841W) and 12A (IR3840W) devices. Thus, by simply changing the part number (PN), Gen2.1 units adapt quickly to changing current or power requirements. In short, the flexibility afforded enables easy upgrade and cut and paste layout for fast time to market.

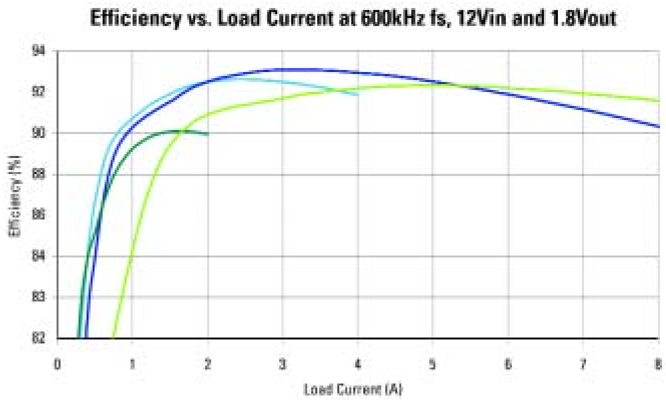

Figure 5: Efficiency versus load Current for 2A, 4A, 8A and 12A SupIRBuck Gen2.1 POL regulators

Figure 5 presents efficiency performance for four different devices of the Gen2.1 family; namely IR3840W, IR3841W, IR3842W and IR3843W. For the same input and output voltages and load current, it is seen that the efficiency performance for the four parts varies slightly. Consequently, by exploiting the pin compatibility and the common footprint of these devices, the user can optimize performance versus cost for current levels up to 8A. Also, since most of the design parameters are programmable, including frequency, soft start time and hiccup current limit, it permits the designer to customize the design parameters based on specific applications.

In summary, the efficiency of second generation SupIRBuck POL regulators has been significantly enhanced with simultaneous reduction in size. In addition, Gen2.1 regulators offer more features and programmability. Plus, for easy upgrade and fast turn around, these devices maintain the same 5 x 6 mm QFN package of Gen1.

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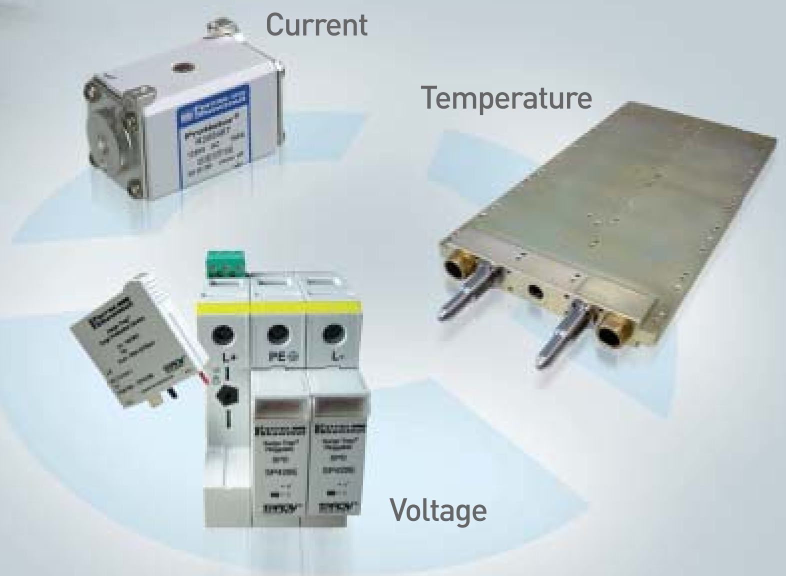

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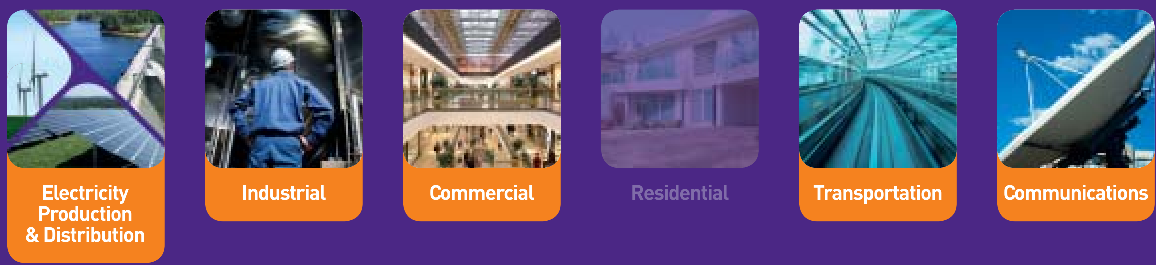

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A New Generation of Lower Power Consumption Power ICs

Reducing switching frequency at no load for lower power consumption

Today's environmental concerns are more complex, far-reaching and interconnected than in the past, and using energy more efficiently has become a global mandate. In recent years, consumer power supplies are encouraged to abide by energy-saving specifications, such as California Energy Commission (CEC) energy-saving specifications, ENERGY STAR®, etc.

By Peter Hsieh, Wesley Hsu; Fairchild Semiconductor

Meanwhile, lower standby power consumption is also becoming an area of focus. According to industry research, the overall standby power consumption of electronic devices was about 3% to 13% of global energy usage; making it even more important to regulate standby power consumption. Leading mobile phone makers already announced a new cell phone charger standby specification in year 2009 with asterisk marking to identify different level of standby power consumption. For this requirement Fairchild Semiconductor has developed a new PSR controller, the FSEZ1317 with new features such as high-voltage startup circuitry, low operating frequency, low operating voltage and current at no-load and a primary side regulation (PSR) method for reducing the secondary-side feedback circuitry. By using these methods FSEZ1317 not only meets CEC and Energy Star energy-efficiency specifications but also provides less than 30mW standby power consumption. This solution meets the five star rating for power-savings requirements in cell phone chargers.

Introduction

Last year's high oil prices and economic crisis has once again brought the need for energy efficiency in all aspects of electronics as a key focus for global sustainability., In recent years, consumer power supplies must abide by energy-saving specifications, such as California Energy Commission (CEC) energy-saving specifications, ENERGY STAR®, etc., especially in terms of standby losses. Power consumption starts once an electronic is plugged in, even if most of the time, they are in the standby mode. Overall standby power consumption of electronic devices was about 3% to 13% of the total global energy usage. From July 2001 the United States government agencies established a specification for electrical products in that they must not exceed 1W standby consumption for electrical appliances. These new energy-saving standards not only regulate the power supply at different loads outside of the required average efficiency but also defined the minimum standby losses. Table 1 shows the efficiency specifications of ENERGY STAR standards and the acceptable standby losses. One of the most remarkable is that this year leading phone manufacturers announced a new cell phone charger standby specification, a clear definition of a different stand-by loss of a different mark an asterisk. Table 2 shows that for a new cell phone chargers standby losses must be reduced to 30mW below and low standby power converter losses will be an essential requirement for power supply designs in the future.

No-load consumption score chart

Five stars = most energy efficient

★★★★★	≤0.03W
★★★★	>0.03W to 0.15W
★★★	>0.15W to 0.25W
★★	>0.25W to 0.35W
★	>0.35W to 0.5W
No stars	>0.5W

Table 2: New Power Consumption Regulation for charger

Analysis the Source of standby losses and New Lower Power Consumption Solution by using Primary Side Regulation Controller FSEZ1317

Based on the current power system, how to achieve lower power consumption from 0.3W to 30mW could be analyzed from conversional flyback topology of each component in terms of standby losses. Figure 1 shows a 40W flyback topology. For this converter, power consumption is 110mW at 230Vac input. The result is shown as Figure 2.

	Energy Star EPS V2-Energy Efficiency Criteria for AC-DC External Power Supplies in Active Mode	
	Standard Models	Low Voltage Models (Vo <6V I_O>550mA)
≦1 Watt	≧0.480*Pno+0.14	≧0.497*Pno+0.067
> 1 to≦ 49 Watts	≧[0.0626*Ln(Pno)]+0.622	≧[0.0750*Ln(Pno)]+0.561
> 49Watts	≧0.87	≧0.87
	No-Load Power	No-Load Power
≦ 50 Watts	0.3 Watts	
> 50 to≦250 Watts	0.5 Watts	

Table1: Energy Start requirement (Energy Star EPS V2.0, 2008)

From this result; standby power loss can be divided into:
Start-up resistor loss (56%): because of start-up resistor for PWM IC turn-on
In order to get a proper start-up for PWM IC from AC line, usually using start-up technology for PWM IC, once PWM IC powered-up, internal start-up circuitry will be disabled. However, there still exist a voltage on start-up resistor and this causes power losses during standby. How to reduce power consumption with high-voltage startup circuit becomes more and more important for the PWM IC.

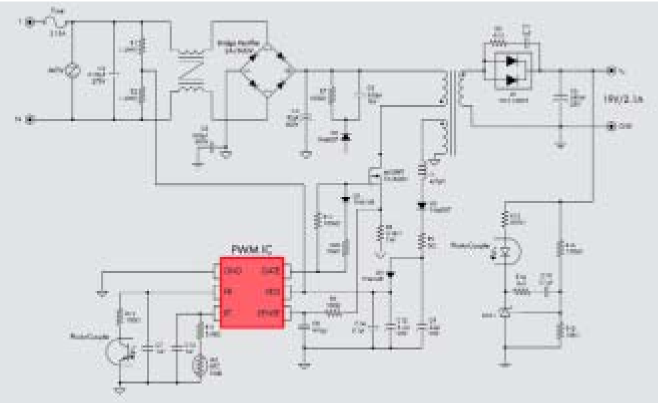

Figure 1: 40W flyback converter schematic

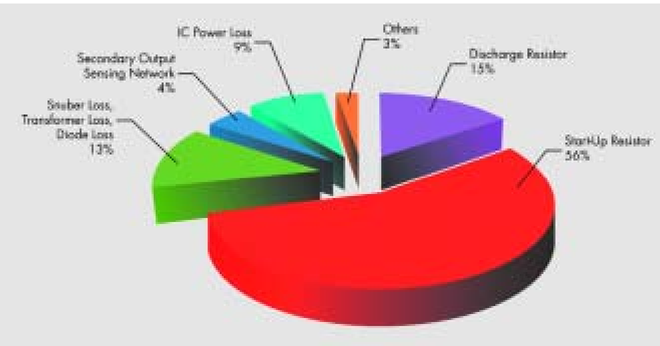

Figure 2: Each components power loss at no load

2. EMI filter capacitor discharge resistor (15%): In order to quick discharge EMI filter capacitor voltage, in case of high-Wattage application usually adds extra discharge resistor parallel to EMI filter capacitor, but for small-watt application the EMI filter capacitor usually no in use.

3. Device switching losses of main loop (13%): In order to stabilize the output voltage, PWM IC must control the duty cycle and frequency, but in standby mode in order to reduce the losses on MOSFET, transformer, secondary side output rectifier and dummy load. PWM IC also reduces duty cycle and frequency in standby mode .Therefore, how to design PWM signal in standby time is also one of the functions for PWM IC.

4. PWM IC's standby consumption (9%): During standby mode, in order to keep PWM IC working, a proper voltage on auxiliary power is necessary. How to work at a lower voltage and operating current for PWM IC during standby mode to reduce power consumption must also be considered.

5. Standby losses of secondary side feedback circuitry (4%): A proper voltage divider at secondary side for feedback loop is necessary but power losses were about 4% of standby losses. For low wattage application by using primary-side regulator technology could help to reduce power consumption.

From above descriptions, some of these challenges could be improved by IC it self. Therefore, improving power IC performance for efficiency, lower cost and power consumption becomes a new milestone for green energy.

A 5W (5V/0.7A) charger using Fairchild Semiconductor's FSEZ1317 integrated with 700V MOSFET could provide extra low power consumption at charger application. Due to the built-in 500V high-voltage start-up circuit, When the power IC reach the turn-on voltage, this HV start-up circuit will disable and hence, reduce power losses on the start-up circuit. To minimize standby power losses, the green-mode function provides off-time modulation to decrease the PWM frequency linearly at light-load and the minimum frequency is 370Hz at no load condition, while reduce the operation current and permit lower operation voltage, which through using the new technology can easily meet the most of power consumption requirement.

In addition, this new innovative technology uses a Primary Side Regulation (PSR) control method, the use of detection of the voltage waveform from the auxiliary winding, to control the output of a constant voltage and constant current, it cannot only provide a substantial reduction in secondary-side feedback circuit but also reduce the secondary side of the power losses and cost. Since this chip is packaged in SOP8 with a built-in 700V rating MOSFET, the layout for the MOSFET can be eliminated, the device count can be reduced, and the layout space can be greatly saved. Protection to adopt auto-restart function includes Output Short Protection (OSP), VDD over-voltage protection (OVP) and Over Thermal Protection (OTP). A built-in frequency hopping function further improves EMI performance. Furthermore, a cable compensation function compensates the voltage drop at the output cable significantly improves the load regulation. Figure 3 is a circuit diagram 3.75W

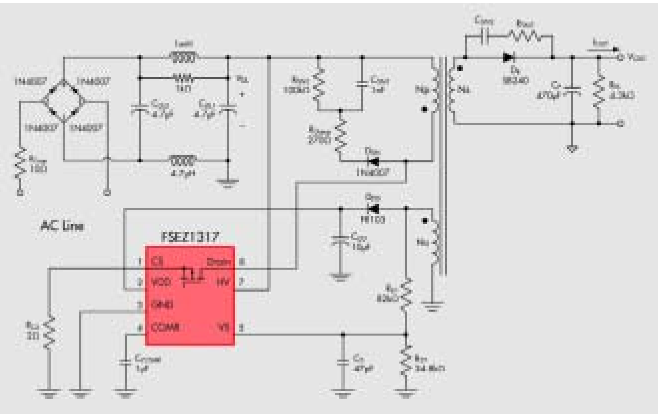

Figure 3: Application circuit of 3.75W charger by using FSEZ1317

All the experimentation results are shown in Figure 4~6, the Figure 4 shows the no load power consumption at different AC input voltage. From these results one can see even in the 264VAC AC line, the no load standby power consumption still can be less than 30mW, meet

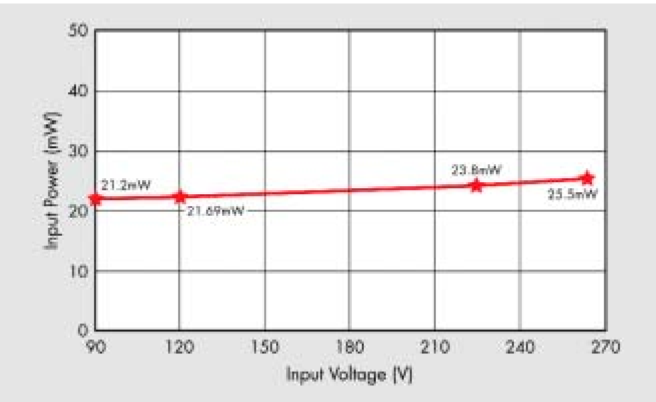

Figure 4: Standby mode power consumption at 90Vac~264VAC

the best five star level of ENERGY STAR's new power consumption regulation for chargers. Figure 5 shows the output voltage and current characteristic curve. From the result, CV regulation achieves 1.38% @ 90V VAC – 264 VAC input and no load to full load. The CC regulation can achieve 3.6% with fold-back voltage @ 1.5V. The CC regulation range is controlled by 5V~24V VDD range. This CC output performance prevents an unregulated output current when the output voltage is low. The average efficiency is 71.61%@115V and 70.01%@230V that meets Energy Star 2.0 Level V specification (65.5% average efficiency). It offers an enough margin for the mass production tolerances.

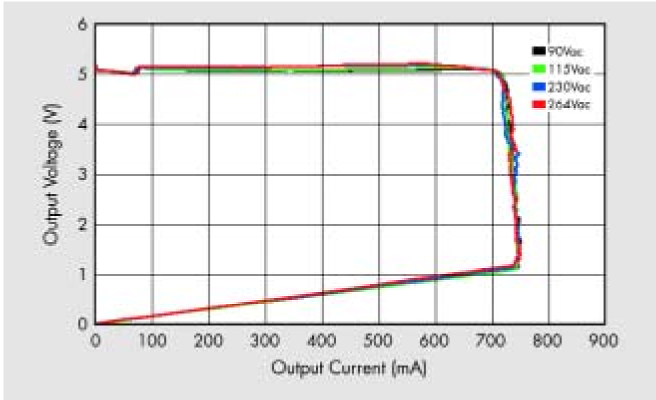

Figure 5: out voltage and output current characteristic

New challenge of Power IC: Lower Power consumption

For green energy, the efficiency usage improvement could help to reduce power losses. An integrated power IC becomes a key feature for efficiency improvements in power management. This could help to reduce total costs, switching losses and improve EMI performance for 'light, slim and smaller' power supply designs. This article shows how the FSEZ1317 with internal high-voltage startup circuitry reduces switching frequency at no load for lower power consumption. A novel primary side regulation (PSR) technology could help to reduce the losses at secondary side feedback loop. The alternative method, the Ringing Choke Convertor (RCC) method, has more components, higher cost and a more complex design. Fairchild's FSEZ1317 reduces components, has lower Bill of Material (BOM) costs, easier design and could become the best solution for charger applications.

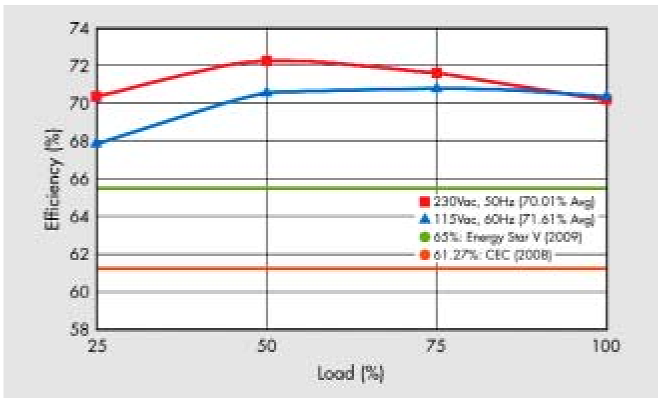

Figure 6: Efficiency at 115Vac and 230Vac

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Time Resolved in Situ Chip Temperature Measurements during Inverter Operation

The IR camera is the best choice for temperature measurements at lower voltages

The device temperature is one of the most critical parameters in the dimensioning of an inverter. However, experimental studies focusing on the virtual junction temperature Tvj in running inverters are scarcely found. The feasibility of four different practical methods will be compared. Special focus is set on routines with high time resolution that enable tracking of the time-dependent temperature during one period of the sinusoidal output current. Details of the procedures are explained and compared with simulations.

By Waleri Brekel, Thomas Dütemeyer, Gunnar Puk, Oliver Schilling, Thomas Schütze, Infineon Technologies

The dimensioning of an inverter application requires qualified knowledge of the stress imposed on the semiconductor devices. All electrical parameters are easily accessible by current and voltage probes and standard oscilloscope data recording while the chip temperature during inverter operation at the moment is seldom determined. The thermal dimensioning is normally done using typical or worst case values specified by the supplier (e.g. thermal resistances of IGBT module and cooler) in combination with simulations of the generated losses. In this work theoretical predictions for the junction temperature are compared with four different methods to measure the T_{vj} during inverter operation:

❶ Infrared camera
❷ Thermocouple
❸ Infrared sensor
❹ Internal IGBT gate resistor (R_{GINT})

Test conditions

The temperature measurements are performed on a 3-phase pulse-controlled inverter using water cooled 6.5kV IGBTs. To measure the temperature with the IR sensor or IR camera, the surface of the IGBT must be uncovered. Therefore the dielectric, that is necessary to assure high insulation capability, has been removed from the module. To avoid a flashover, the applied DC-link voltage for the measurements has been limited to V_{CC}=2kV. Operating conditions are: I_{Cmax}=980A; f_0=20Hz; f_{SW}=400Hz; cosφ=0.01; T_a=30°C.

Figure 1. shows the black coated DUT whose IGBT chips are investigated by different methods. IGBT a) is measured with thermocouple, b) with IR sensor and c) with R_{GINT} method.

Temperature calculation with IPOSIM

IPOSIM is an Infineon simulation tool for power loss and thermal calculations of IGBT modules [1]. It provides switching and conduction losses of IGBTs and free-wheeling diodes operated in several circuit configurations, e.g. for three-phase inverters with sinusoidal output current. The corresponding T_{vj} under defined operating condition which can be set by user (e.g. V_{CC}, I_C, f_{SW}, f_0…) is calculated as well. For best comparison, thermal values Z_{th} acquired by experiment are used for the calculation. Figure 2. illustrates the time depended power losses p(t) within one period and the corresponding IGBT junction temperature.

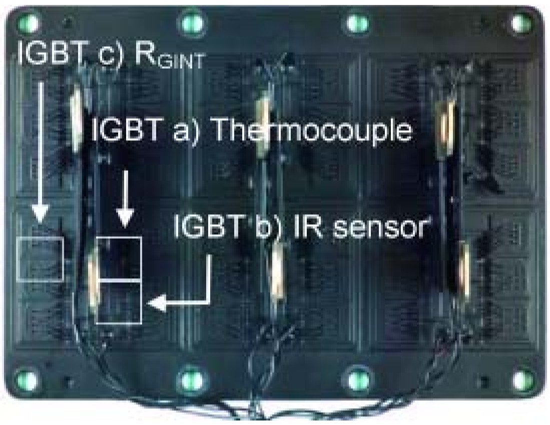


Figure 1: Black coated 6.5kV module (DUT) with marked IGBTs measured by different methods

Infrared camera

The temperature dependent intensity of the emitted electromagnetic radiation of a body is given by Planck's equation. This can be used to determine the surface temperature of an IGBT chip. To achieve an emissivity close to one, the surface has to be coated with a suited material. The respective wavelength maximum of the emitted radiation is in the infrared spectral region. Infrared cameras allow to get the temperature distribution of the module and measure the tempera-

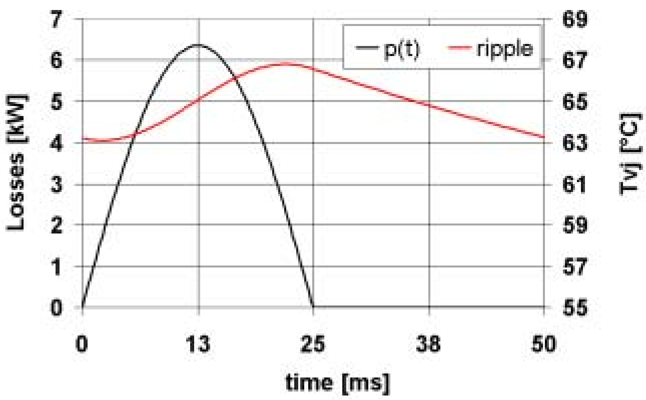


Figure 2: Power losses and T_{vj} as calculated with IPOSIM (T_{vjmax}=66.8°C; $\Delta T_{vjRipple}$=3.7K; T_{vjav}=65°C)

ture of all IGBT chips in parallel. A picture of the temperature distribution is shown in the table ❶B.

The prerequisite for high time resolution with IR camera is its low integration time of the focal pane area. A compromise has to be made between required time resolution and the necessary intensity to measure the temperature itself. An integration time of 0.6ms is chosen to achieve a fine resolution of the 50ms period of the output current. The sample rate of the IR camera is set to 19.5Hz in contrast to f_0=20Hz load current. The small difference between the two frequencies leads to sequentially sampling of the temperature over many periods under steady state conditions. In this case the time between two sampling point is 1.28ms, resulting in 39 sampling points for a 50ms period.

The temperature of IGTB a) and b) is analyzed over their chip area, whereas IGBT c) is investigated in the middle of the die where R_{GINT} is positioned. The result is presented in table ❶C.

The mean temperature of IGBT a) with ~64°C fits very well to the simulated value of 65°C. It is noticeable that T_{vjav} of chip a) which is located near the centre of the module is higher about 3K than the chip b) with T_{vjav}~61°C. This is a well known effect caused by lateral temperature spreading in the module and taken into account in the module characteristics and specification.

Thermocouple

A common way to measure the temperature is given by the thermo electric effect. To record T_{vj} a thermocouple of type K is glued on the surface of a single IGBT chip position a). The applied glue is characterized by low thermal impedance. The picture of an IGBT chip with a glued thermocouple close to the center of the emitter area is shown in ❷A.

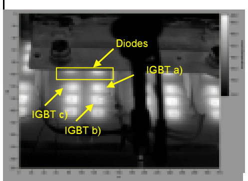
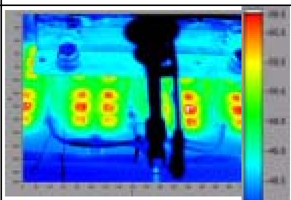
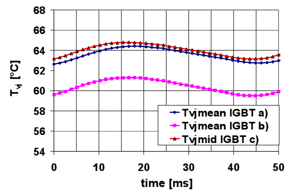
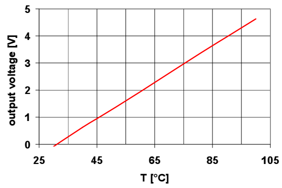
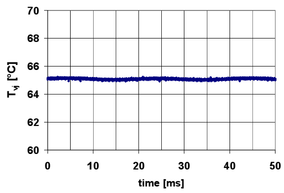
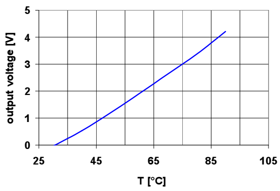
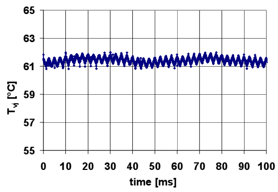
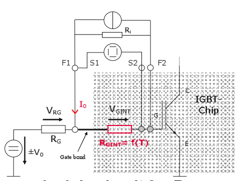
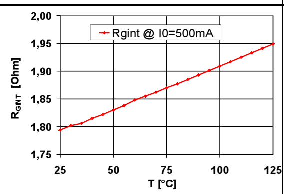
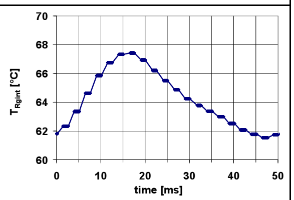
method	A set-up	B characteristic	C measured IGBT temperature
❶ IR camera		 IR camera scale: 34°C – 68°C	 temperatures of positions a) to c)
❷ Thermo-couple	 glued thermocouple on top of the IGBT chip	 amplified thermo voltage with respect to temperature	 temperature measured with thermocouple
❸ IR sensor	 IR sensor over covered IGBT chip	 IR sensor amplified by a transducer	 surface temperature of the IGBT
❹ R_{GINT} sensor	 principle circuit for R_{GINT} measurement	 R_{GINT} calibration line	 temperature measured over one period of the inverter output

Table 1. Overview of all investigated methods

The advantage of the thermocouple is its linearity in the usual chip temperature range. To use the thermo voltage as a temperature proportional signal, it needs to be amplified. The calibrated characteristic line of the thermo voltage amplified by a transducer is shown in ❷B. As the time constant of the thermocouple is in the range of ~200ms, the 20Hz temperature ripple can not be resolved. In ❷C the measured temperature of ~65 °C matches well with the T_{vjav} of the simulation and IR camera.

Infrared sensor

Infrared sensors covering a defined solid angle are commercially available. The infrared sensor allows a contact free determination of the chip surface temperature. ❸A shows the mounted infrared sensor on top of a 6.5kV IGBT chip. The sensor has a ratio of 1:2 between the distance to the surface and the diameter of the measured area. The distance is chosen to limit the investigated area to the active area of the chip. The sensor generates a voltage that corresponds to a thermocouple of type K. This allows to utilize the same transducer and data acquisition as used for the thermocouple measurement. The corresponding calibration line is shown in ❸B.

The output of the sensor is fairly linear correlated to the temperature in the relevant range. Due to the time constant of the sensor (~50ms) only an averaged chip temperature can be determined. ❸C shows the surface temperature of the IGBT over two periods of the load current.

The measured mean temperature is ~61.4 °C. The observed small waviness with a frequency of 20Hz corresponds to the load current. Due to high time constant of the measurement the amplitude of the temperature swing is expected to be damped to a large extent. The high frequency ripple correlates to the switching frequency of 400Hz. As this frequency is far too high to be recorded with this method, it is generated by interferences between the thermoelectric voltage and the module switching operation.

Internal gate resistor

The investigated 6.5kV IGBT chip contains an internal gate resistor (R_{GINT}) in the centre of the die. As this resistance has a well known temperature dependency it can be used to determine the chip temperature. A major advantage of this resistor is the absence of an additional heat capacitance and its immediate vicinity to the semiconductor junction inside the same die. The accurate measurement of the resistance in presence of transient high voltage and current in the IGBT module is a major challenge. A sophisticated circuitry is developed for data recognition and safe data transfer from the measurement point inside of the inverter to the external laboratory periphery. A sketch of the measurement system is shown in figure 3.

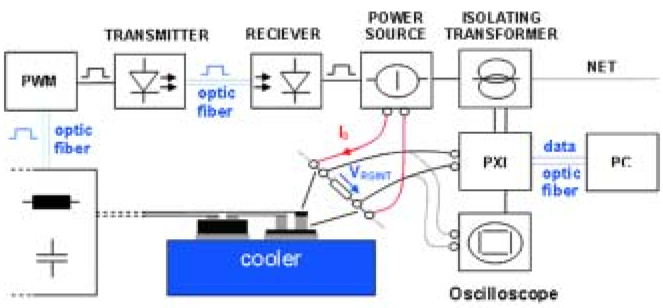


Figure 3: Temperature measuring system for the R_{GINT} method

The evaluation shows that it is possible to achieve high temperature and time resolution at the same time. The principle of the measurement is shown in ❹A. A constant test current of I_0=500mA is applied at the force connections F1 and F2 which generates a temperature dependent voltage drop across R_{GINT}. This voltage is used as temperature indicator and is measured by sense contacts S1 and S2. The temperature dependence of the resistor is determined to be $\Delta R_{GINT} / \Delta T \sim 1.5m\Omega/K$. The voltage resolution of $500mA \cdot 1.5m\Omega/K = 0.75mV/K$ allows to resolve temperature variations down to ~1K accuracy. Since the internal gate resistor of each IGBT chip varies within the specified tolerance, an exact calibration line is needed.

The temperature measured by R_{GINT} is presented in ❹C. The maximum of temperature is about 67.4°C with a ripple of 5.9K and average value of 64.5°C. Thus the temperature of an IGBT in inverter operation can be well resolved. The course over time is in excellent agreement with the simulated results. The $\Delta T_{vjRipple}$ is about 2K higher than expected by simulation. The average temperature of IGBT c) measured with IR camera matches perfectly to the R_{GINT} value. The resistor is placed in the middle of the die at the gate pad. According to the IR measurement there is no hot spot at this position. Therefore the R_{GINT} method provides a local temperature which is approximately the mean chip temperature of the IGBT.

	IGBT a)		IGBT b)		IGBT c)	
method	T_{vjav} [°C]	$\Delta T_{vjRipple}$ [K]	T_{vjav} [°C]	$\Delta T_{vjRipple}$ [K]	T_{vjav} [°C]	$\Delta T_{vjRipple}$ [K]
IR camera	63.7	1.7	60.4	1.8	64.3	1.7
thermocouple	65.0	-	-	-	-	-
IR sensor	-	-	61.3	-	-	-
R_{GINT}	-	-	-	-	64.5	5.9

Table 2. Overview of all measured value. Simulated temperatures are: T_{vjav}=65°C and $\Delta T_{vjRipple}$=3.7K.

Conclusion

To determine the junction temperature of an IGBT during inverter operation, four different measurement methods are applied and compared. Two of these methods (R_{GINT} and IR camera) are capable to resolve the temperature ripple of the IGBT caused by the periodic alternating output current in inverter applications. Due to their high time constants, thermocouple and IR sensor achieve the mean temperature but are not able to resolve the temperature ripple itself.

The measurements are most valuable as a complimentary method to check simulation results. This can help to improve the careful design of an inverter application. Table 2. gives an overview of all measurement methods in comparison with simulation.

The measurement with the IR camera is the best choice for temperature measurements at lower voltages. The R_{GINT} method is a reliable way to achieve time resolved temperature informations where no optical access to the module is possible or measurements at high voltages are requested.

References

Th. Schütze, Th. Barucki, U. Knorr: IPOSIM Web-based Design Support Tool for IGBT Applications; Bodos Power Systems 12.09

PCIM Booth 12/404

www.infineon.com/power

Simple Digital

The Novum Digital family has focused on ease of use

It is nearly impossible to miss an article about the growing digital power market. Engineering publications are loaded with market analysts' comments on the potential of digital power and announcements regarding new digital power products from leading IC companies.   These serve to highlight the intense interest in the marketplace and the optimism for the future of digital power.

By Mark Adams, VP of Worldwide Sales CUI Inc

Analysts collectively agree that the market is growing, to what level, however, is debatable. For example, the Darnell Group in August 2009 announced that the digital power IC market would experience market growth of 19.8% compounded annually from 2009 and 2014. The Petrov Group, on the other hand, six months later announced that the same market would grow 34% compounded over that same period of time. Regardless of which report you read, it is clear that digital power will far outpace the rest of the market.

Who is driving this growth for digital power?

One of the current debates calls into question where the industry lies on the "Technology Adoption Lifecycle" curve. Understanding the level of adoption drives how quickly the market will grow. If the market is still in its infancy, exponential growth will not see fruition for some time. However, if the market has moved through an early adopter phase, near term market acceptance is more likely.

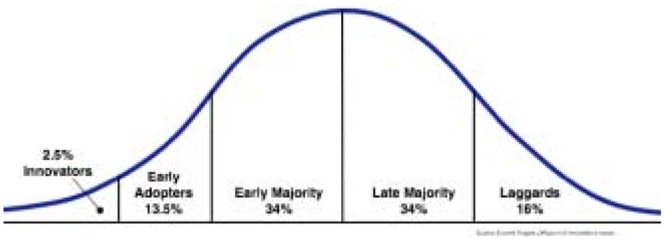


Figure 1: Market adoptions

Today's implementation of digital power is dominated by the Tier One computing, storage, networking, and telecom Original Equipment Manufacturers (OEMs). These large OEMs see the additional value of digital power and have set their future directions accordingly. Some of these OEMs even claim that the vast majority of all new designs going forward will utilize digital power. Since these companies drive a large percentage of sales, the semiconductor and power supply vendors in this market have been driven to develop solutions to support their future requirements.

These OEMs have pushed the IC market to include a wide variety of features in their digital product offerings, and with that complexity comes the difficult task of implementation. This push by the Tier One's has caused a clear divide between the large companies that have resources to support these designs and those that do not. The required application design support has limited the ability for smaller, resource-constrained companies to implement digital solutions. Due to the amount of business from the Tier One companies, the IC and power supply vendors typically provide dedicated support teams for their products. These resources are in addition to the dedicated power designers that these OEMs already have internally on staff.

Unfortunately, the power requirements of today's designs are not tied to just the large OEMs. Similar design issues are common across all companies, regardless of size. These include:

- Power management
- Sequencing and ramp rates, monitoring, and margining
- Fault detection and response
- Greater densities in board design
- Thermal management
- Lower voltages and tighter tolerances
- Higher currents
- Shorter design cycles

The same FPGAs, DSPs, and ASSPs are being used by all companies. However, the available technical resources to solve those requirements are geared towards only a portion of the market.

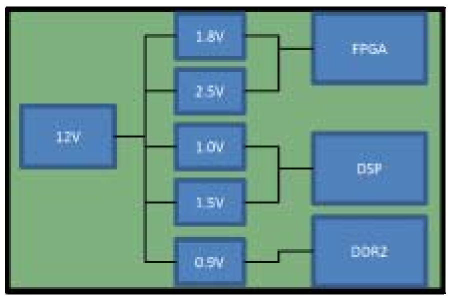


Figure 2: Distributed Power Architecture

In order for digital power to move along the technology adoption lifecycle, the industry must therefore focus on "ease of use".   Products must be usable with minimal support in order for widespread adoption to occur. Digital power providers are already trying to focus on the concept of ease of use. They provide numerous documents to assist with component selection, board layout, and in depth compensation guidelines. These are in addition to numerous tools that support the design effort. Others offer a 4-Day Digital Power Design course to educate the end user. Since ease of use is defined differently by all companies, the true definition in the end will actually come from the customer.

What is Ease of Use?

Today's digital power solutions do not lack available features. It is the ease of implementing those features and prioritizing their use that has caused the biggest challenge for end users. There is always a fine line between required features and those that are optional in a solution. On the surface, it appears that the industry has been leaning more towards solving the "would like to have" rather than focusing on what is truly needed.

There is one basic fundamental that always needs to be kept in mind; the reward for change must be significantly greater than the learning curve to implement something new, otherwise the change is not worth it.

With the shift to digital, software tools have become a part of the design process, and the ease of using these tools must be taken into consideration. The FPGA and Microcontroller companies learned long ago that design tools can win or lose designs regardless of the feature set within the silicon solution. If it takes too much time to implement the features, then the reward to the customer is not worth the effort. These vendors have thus developed tools and support for all levels of customers within their respective markets. Engineers don't necessarily have the time to attend 4-Day classes or to scour through pages of documents looking for an answer. If the answer is not there, they need to get support from the vendor to solve the problem.

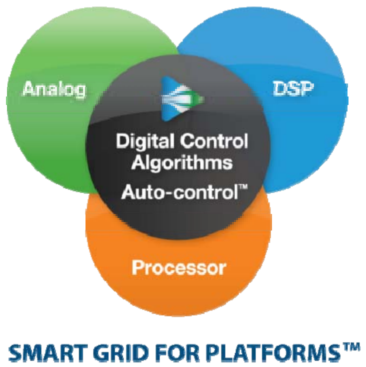


Figure 3: Smart Grid Platforms

Power is the necessary evil

When speaking with engineers and managers at companies outside of the largest OEMs, a common theme continues to surface: "Power is a necessary evil." Engineers are leveraged on the IP they create for their company, not necessarily for the power supply design. The reduction in engineering staffs has forced engineers to not only create company IP, but to then figure out how to power the design. Because of this and the continuously shortening design cycles, the power architecture is one of the last items to be addressed. Unfortunately, time to market is even more crucial for smaller OEMs, as this can make or break a product and even potentially a company. Today's design engineers need a solution that can be truly "cut and paste" to solve the continually shifting demands of power.

Simple Digital

CUI's Novum Digital Family is targeted directly at the engineer that needs to solve today's issues in a simple plug and play manner.

The fundamental philosophy of this product family is "simple digital." It is built around Powervation's Auto-controlTM technology and an intuitive, easy to use design tool. Auto-control greatly simplifies what was once the time consuming "black art" of designing analog compensation loops. These control loops were suboptimal by necessity and designed for worst-case conditions. The automatic compensation feature gives an engineer the ability to layout the circuit and then let the module perform its own compensation calculations. It essentially eliminates the 20+ page compensation application notes and tools from other vendors and incorporates the compensation into the IC directly. In addition, Auto-control will continue to compensate the circuit throughout the life of the product on a cycle-by-cycle basis so the circuit is always in an optimal state. This feature dramatically reduces the design cycle and increases the reliability of the circuit when compared to an analog solution.

As the first pure play module vendor to sign a license agreement with Power One, it has been CUI's intent to remove the barriers to digital power implementation for all customers. The easy to use V-Infinity Intelligent Center (VIC) is a push button driven design tool that allows you to dynamically set output voltage, timing parameters, margining limits, and fault parameters—all the must haves in a digital module.

The first two products in the Novum Digital family include 12A and 25A modules that are footprint compatible for greater overall solution flexibility. Even though the Novum Digital family has focused on ease of use, the modules also provide a smaller overall board footprint and outstanding efficiencies and transient response compared to other solutions on the market.

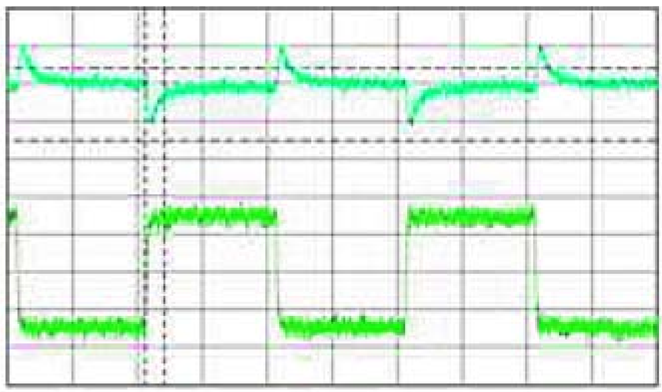


Figure 4: Transient Response 25A Module

The 25A module comes in a compact 0.50" x 1.07" package and provides excellent efficiency and superior transient response. Figure 4 above shows the 25A module operating with a load step of 5-15-5. The recovery time is 150uS, with a undershoot of +35mV and overshoot of -33mV, giving a peak-to-peak of only 78mV. This performance is achieved with only 470uF of ceramic capacitance on the output, thus reducing your total board space and solution cost. The efficiency of the 25A is 90% @ 12Vin/2.5Vout, full load.The Novum Digital Power family is currently sampling to select customers and will be in full production in Q2 2010. Complete demo boards will be also available through Digi-Key beginning in Q2.

Additional information resources

novum simple digital

www.novumdigital.com

www.powervation.com

Power Modules in High-End Market Segments

A low output ripple is mandatory as well when supplying analogue systems

The new SIMPLE SWITCHER® Power Modules from National Semiconductor reach the highest possible level of "Ease of Use" by integrating an inductor and a monolithic synchronous regulator within one power package. Professional power designers have far more requirements than "Ease of Use" related to design efforts, including: high ambient temperatures, requiring guaranteed performance and electrical specs; electrical emission (EMI) within international standards, reliable soldering; and vibration robustness.

By Ralf Regenhold, Technical Marketing Manager Power Management Europe, National Semiconductor

This article describes how these high performance targets can be achieved in the following market segments: Industrial, medical, avionics and military, broadcast video and communication infrastructure. All the market segments mentioned above are targeting highly reliable applications. The requirements for the power supplies are similar. The following sections focus on performance aspects which are specifically critical in those segments but are actually applicable for all high-end systems.

Industrial Market

Power supplies for industrial applications use nominal input voltages of 24V but require full functionality during transients up to 36V or 42V. National's new power modules are designed to support full operation up to those voltages. The loads often require several different voltages from 5V down to 0.8V. The best approach to find the optimum solution for such requirements is to use a two stage converter. National Semiconductor's WEBENCH® Power Architect enables the analysis of the total system efficiency using different interim bus voltages.

Several combinations of regulators can be compared based on total efficiency, footprint size and solution cost. The initial list of combinations is limited and shows the best compromise between cost and efficiency. Additional solutions are offered if the optimisation tuning dial is moved.

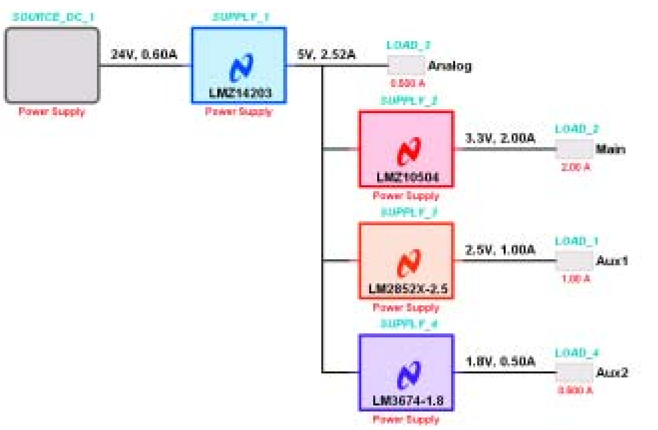


Figure 1: Block Diagram

A specific solution is chosen, using only one regulator to generate the 5V bus voltage. All second stage regulators work from the 5V, generating several point of load voltages. In a project optimisation step alternative devices for the low load currents are selected in order to reduce the solution cost. The final design is displayed in Fig.1 (Block Diagram). A total efficiency of 82% is achieved.

Industrial applications need to work up to an ambient temperature of 85°C without an external heatsink or fan. This capability of National's power modules is demonstrated at the LMZ14203 in the first stage of the design and represents a very common requirement. Vin=24V, Vout=5V, Iout=2.52A.

Under these conditions the LMZ14203 can perform with 87.7% of efficiency. This generates a power loss of PIC=1.75W. The package of the power module has been optimised for very low thermal resistance and evenly distributed heat flow on the PCB by using a solid exposed pad on the back of the module (see Fig.2).

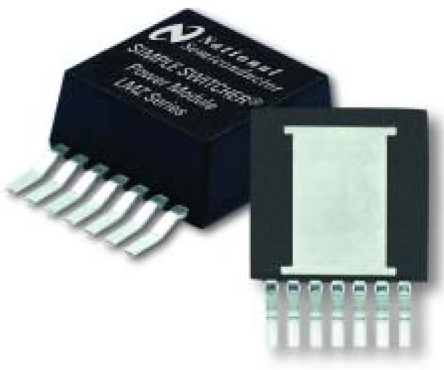


Figure 2: Heat flow on PCB

With the thermal resistance Θ_{JA}=19.3°C/W the rise of the junction temperature can be calculated as $\Delta T_J = \Theta_{JA} \times P_{IC}$ = 33.8°C. This means that at an ambient temperature of 85°C the junction reaches a maximum temperature of $T_{J\ operating}$ =119°C. This is fully within the maximum rating of $T_{J\ max}$ =125°C specified in the datasheet. The actual distribution of the heat on a realistic PCB can be simulated with WEBENCH "Thermal simulations", see Fig.3 (Thermal Image).

During the selection phase, the module datasheets help the designer to estimate the maximum output current versus ambient temperature by providing derating curves. Only modules designed for the industrial market offer full load current at ambient temperatures of 85°C and higher, see Fig.4 (Derating Curves). The LMZ10504 is capable of supplying full load of 4A at up to 106°C ambient temperature at Vin=5V and Vout=3.3V.

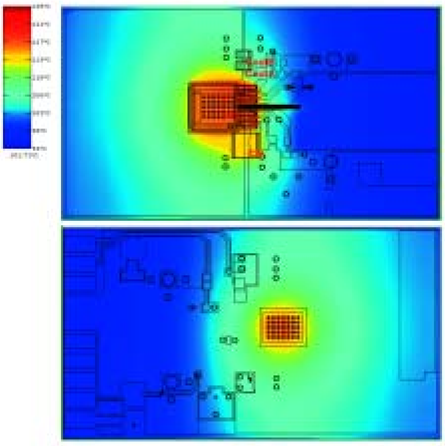


Figure 3: Thermal Image

Electro Static Discharge (ESD), burst and surge, current injection requirements according to IEC 61132 PLC are not discussed here. The design of the power supply can be done independently of the protection circuitry needed for the system ruggedness towards above mentioned tests.

Medical and Telecommunication Markets

Applications in these segments require a high system integrity. Sensitive signal path electronics need to be immune to Electromagnetic Emission (EMI) from the power supply. Linear regulators are usually used to supply analogue amplifiers and A/D converters. In addition to this, higher power for digital processing units is also required. Only switching regulators are able to support these as high efficiency and low heat generation are mandatory.

National's Power Modules are specifically designed for minimum possible emission by the integration of all switching power elements and the fully shielded inductor. Fig.5 shows the critical paths. Switching regulators have paths with high dI/dt switched currents. These act like an antenna and cause high electromagnetic emissions so they must be kept as small as possible.

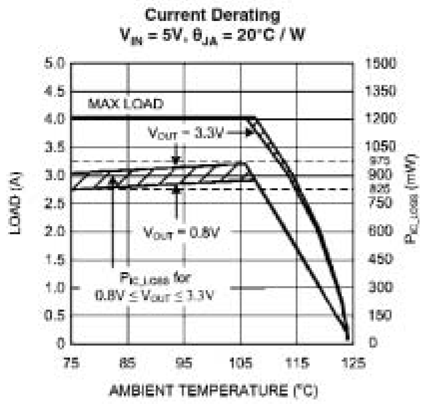


Figure 4: LMZ10504 Power Derating Curves

They can be identified by two steps:

1. Draw the current loop during ON (Loop 1) and OFF-Time (Loop 2). Note that both loops on their own are NOT the critical paths and are NOT the ones to be minimised.
2. The branches of Loop 1 and Loop 2 which do NOT overlap contain the critical high di/dt current. Branches that carry currents during both cycles are considered as DC currents (with a small ripple on top) and do not create EMI. So only the area indicated in yellow as high dI/dt must be minimised for lowest radiation. Therefore the input capacitor (Cin1) is placed as close as possible to the LMZ10504 V_{IN} pin and GND exposed pad.

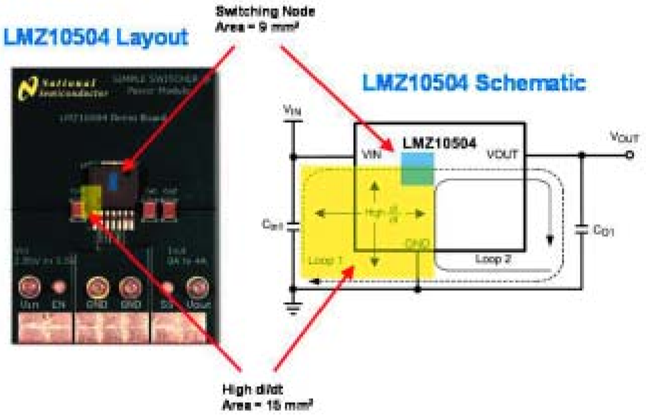


Figure 5: Sensitive Noise Paths

The switching node area is critical as well and is minimised by the integration of the inductor in the regulator package.
With all these design optimisations the complete family of National Semiconductor Power Modules can guarantee within the datasheets the compliance to the international norm CISPR22 (Class B) and EN55022, see Fig.6 (EMI graph LMZ10504 radiated emission).

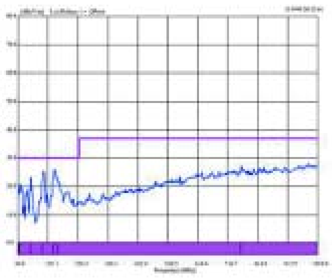


Figure 6: LMZ10504 Radiated Emission

Avionics and Military Markets
These market segments gain the most advantage from the integration of the regulator, the inductor and even capacitors at critical nodes. Device and system failures are reduced to a minimum. In addition this offers the best thermal protection against over-temperature of each Point-of-Load regulator. The RoHS compliant TO263 package has been designed to have standard leads and a single exposed pad in order to guarantee high vibration ruggedness. Certifications of compliance to international standards are in progress.

High efficiency is a key for low heat generation and reliability and can only be achieved by synchronous regulators. Nevertheless, efficiency is heavily dependent of the difference between Vin and Vout. National's Power Modules reach efficiencies of 90% and above.

Examples:
LMZ10504 Vin=5V and Vout=3.3V Iout=3A Efficiency(η)=95%
LMZ10504 Vin=5V and Vout=1.8V Iout=2A Efficiency(η)=93%
LMZ14203 Vin=24V and Vout=5.0V Iout=1.5A Efficiency(η)=90%

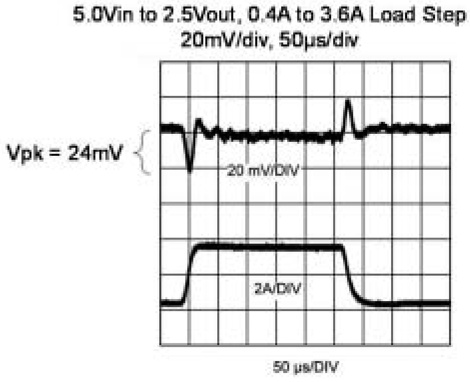


Figure 7: LMZ10504 Transient Response

Fast transient response is needed to supply high end digital processing units like FPGAs or DSPs as they can unpredictably change their processing mode. This requires special care of the regulation loop inside the module. Fig.7 (LMZ10504 Transient Response) shows the deviation of the 2.5V output during a huge load transient from 0.4A to 3.6A.

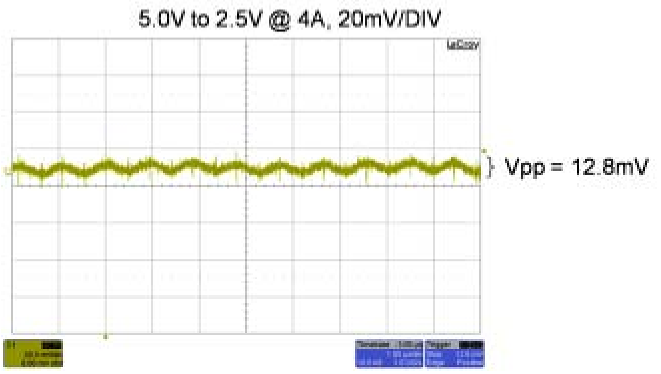


Figure 8: LMZ10504 Output Voltage Ripple

A low output ripple is mandatory as well when supplying analogue systems. All National Semiconductor Power Modules work stably with ceramic as well as low ESR electrolytic or tantalum output capacitors.

The high switching frequency of up to 1MHz and the low capacitor ESR leads to a very low output ripple in the range of only a few mV - see Fig.8 (LMZ10504 Output Voltage Ripple)

Summary
Several features of the new SIMPLE SWITCHER Power Modules from National Semiconductor address specific high performance markets. The company is in the process of releasing more voltage and power options of the modules including additional features that will significantly add more design flexibility.

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Wideband High Temperature Optocoupler

Serving isolated AC/DC and DC/DC converters in HEV and PHEV

Isolated AC/DC and DC/DC converters for onboard charger and power supply in HEV and PHEV require careful examination of popular phototransistor optocouplers as error amplifier feedback. Various performance challenges surface to meet high temperature environment up to 125°C, long operating life time and predictable CTR at extreme operating conditions.

By Zhang Bin, Harold Tisbe, Isolation Products Division, Avago Technologies

Avago's automotive grade wideband analog optocoupler, ACPL-M43T, is designed and manufactured to meet the new challenges. Certified by major safety standards, e.g. UL 1577, IEC 60747-5-5 and CSA as well as complied with automotive qualification standard AECQ100, ACPL-M43T has stable CTR at high temperature and over long operating life time. With typical bandwidth around 1MHz ACPL-M43T readily surpasses the performance of existing phototransistor optocoupler and is the choice of isolator for AC/DC and DC/DC converters in HEV and PHEV.

This article will discuss safety regulatory requirements for HEV, design considerations of feedback loop and extreme operating corners for loop stability. Limitations of phototransistor optocoupler are given and key features of ACPL-M43T are presented to overcome the limitations.

Introduction

The number of electronic components in hybrid fuel efficient vehicles increased tremendously due to the inclusion of high voltage battery, high power electric motors and associated control and communication circuits. AC/DC and DC/DC converters are the key building blocks delivering the required power to circuits and components with high efficiency. For example in '04 and later Prius the main battery voltage is about 200V. DC/DC converters are required to step down the main battery voltage from 200V to 12V to charge the auxiliary battery and power the auxiliary circuits. Further voltage conversions to 5V, 15V and 24V for various circuit operations are necessary. In EVs and Plug-in HEVs both on-board and off-board chargers are AC/DC converters which take power from power grid to charge the battery. These chargers are typically high power converters ranging from a few hundred watts up to 2 kilo watts with output voltage between 48V and 300V. As severe high voltages are present safety insulation against shock hazard must be designed to meet various safety standards and government regulations.

Regulatory Requirements for Isolation

Galvanic isolation between primary and secondary circuits is required for both AC/DC and DC/DC converters due to the presence of hazardous high voltage (above 25Vac or 60Vdc). Although the standards and regulations for HEV are still works in progress there is already handful of international/national standards available. Following is a list of relevant standards and regulations.

- FMVSS 305, Electric Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection
- ECE-R 100 Battery electric vehicles with regard to specific requirements for construction and functional safety
- ISO 6469-3:2001 Electric road vehicles – Safety specifications – Part 3: Protection of persons against electric hazards.
- IEC 61851-21:2001 Electric vehicle conductive charging system – Part 21: Electric vehicle requirements for conductive connection to an a.c./d.c. supply.
- UL 2202:1998 Electric Vehicle (EV) Charging System Equipment
- SAE J2344 – Guidelines for Electric Vehicle Safety

FMVSS 305 is the Federal Motor Vehicle Safety Standard for vehicles that use more than 48V of electricity as propulsion power and enforced by National Highway Traffic Safety Administration of U.S. Department of Transportation. Its purpose is to reduce deaths and injuries during a crash due to electrolyte spillage from propulsion batteries, intrusion of propulsion battery system components into the occupant compartment, and electric shock. The isolation barrier between battery and exposed conductive part should maintain 500 Ohm/V before and after the crash impact.

ECE-R 100 is the regulation set forth by United Nations Economic Commission of Europe (UNECE) and widely adopted by European countries. Its scope covers electric road vehicles with maximum design speed exceeding 25km/h. Isolation resistance between any exposed conductive part and each polarity of the battery shall have minimum value of 500 Ohm/V under normal operation and post impact condition.

ISO 6469-3 and IEC 61851-21 are international electric vehicle safety standards for protection against electrical shock. IEC concerns with electrical devices and equipments and ISO deals with all other technologies. Hybrid electrical vehicles, having both combustion engines and electrical motors, are related to both standards. According to ISO 6469-3 insulation resistance should be greater than 5kOhm/V for double/reinforced insulation. In addition dielectric breakdown test should be performed and passed at 2X working voltage + 3250Vrms or 3750kVrms (which ever higher) for 1 minute, of a frequency between 50Hz and 60Hz.

UL 2202 and SAE J2344 are U.S. national standards but widely followed by many automotive manufacturers for U.S market. UL (Underwriters Laboratories) is an independent product safety certification organization established in 1894, while SAE was formed in 1905 by professional engineers in automotive industry.

UL 2202 has detailed specifications on insulation between primary and secondary circuits, hence is often followed by electrical designers for chargers and DC/DC converters in electrical vehicles.

AC Mains Voltage	Clearance			Creepage		
	UL 2202	UL 840		UL 2202	UL 840	
	Overvoltage Cat			Pollution Degree - Material Group		
	NA	III	IV	NA - NA	3 - IIIa/b	4 - IIIa
150Vrms	3.2 mm	1.5 mm	3.0 mm	6.4 mm	2.5 mm	5.0 mm
300Vrms	6.4 mm	3.0 mm	5.5 mm	9.5 mm	4.71 mm*	9.4 mm*

* Linear interpolation is permitted and applied per Table 9.1 of UL 840.

Table: 1 Comparing clearances and creepage requirements of UL 2202 and UL 840

Isolation Requirements from UL 2202

UL 2202 is the standard for both on-board and off-board charging systems connected to mains voltage of 600Vac or less for recharging the storage batteries in over-the-road electric vehicles (EV). Insulation spacing, e.g. through air (clearance) and over surface (creepage), are given in section 21. However alternative spacing in accordance to UL 840, Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, is permitted. The difference lies that UL 2202 has single spacing specification for intended voltage range regardless micro environment while UL 840 allows reduced spacing given controlled over voltage category, pollution degree and material tracking property. As a result the spacing required by UL 840 is smaller than that of UL 2202, as shown in Table 1.

It is interesting to note, for clearance, UL 2202 meets UL 840's requirement for overvoltage Cat IV, and doubles the spacing requirement for Cat III. Similarly the creepage distance of UL 2202 is about the same to that of UL 840 for pollution degree 4, and meets twice the distance for pollution degree 3. Essentially insulation spacing provided by UL 2202 meets double insulation requirement of UL 840 for overvoltage category III, pollution degree 3 with material group IIIa/b, a condition that satisfy most of the applications for on-board and off-board chargers.

Optimizing the insulation spacing to the application condition is always desirable to reduce total size for on-board application. For mains voltage rated at 110Vac and 220Vac reduced spacing provided by UL 840 are listed in Table 2. For reinforced/double insulation spacing listed in Table 2 should be doubled.

AC Mains Voltage	Clearance		Creepage	
	UL 840		UL 840	
	Overvoltage Category		Pollution Degree - Material Group	
	II	III	2 - IIIa	3 - IIIa
150Vrms	0.8 mm	1.5 mm	1.6 mm	2.5 mm
250Vrms	1.3 mm*	2.5 mm*	2.5 mm	4.0 mm

* Linear interpolation is permitted and applied per Table 8.1 of UL 840.

Table 2 Alternative spacing provided by UL 840

Additional dielectrics withstand voltage test in production is required by UL 2202. The test voltages and conditions are summarized in Table 3.

Voltage Rating V	Test Duration = 60s		Test Duration = 1s	
	AC Test Potential Vac	DC Test Potential Vdc	AC Test Potential Vac	DC Test Potential Vdc
< = 250Vrms	1000	1400	1200	1700
250 < V <= 600Vrms	1000 + 2 * V	1400 + 2.8 * V	1200 + 2.4 * V	1700 + 3.4 * V
600Vrms	2200	3080	2640	3740

* Derived from Table 76.1 of UL 840.

Table 3 UL 2202 Production Test Condition for Insulation Breakdown*

Meeting Regulatory Requirements with ACPL-M43T

Designing with right isolation components meeting all the regulatory requirements at early stage of design is critical for successful regulatory approval. Avago Technologies R2Coupler series of optocouplers are designed to meet the insulation requirements for automotive application. Table 4 summarized the insulation characteristics of ACPL-M43T against the most stringent safety insulation specifications.

Parameters	Requirements	R2Coupler ACPL-M43T	Remarks
Package Size	small	SO5	
Isolation Resistance	> 1.25 MegOhm	10^6 MegOhm	ISO 6469-3
Insulation Breakdown (60s)	> 3750 Vrms	> 3750 Vrms	ISO 6469-3
Clearance (Through Air)	> 2.5 mm	> 5 mm	UL 840, alternative spacing for UL 2202
Creepage (Over Surface)	> 2.5 mm	> 5 mm	

Table 4 Insulation Requirements for mains voltage up to 250Vrms, overvoltage category III, pollution Degree 2

Maximize Converter's Close Loop Bandwidth with Wideband Analog Optocoupler

In isolated AC/DC and DC/DC converters optocouplers are often used for error amplifier feedback due to its low cost, smaller size and ability to transmit DC signal as shown in figure 1. Transformers could be used however complex signal conditioning circuits are required for DC transmission.

For closed loop control system loop transfer function should meet Nyquist criteria for stability, where loop gain rolls off to 0dB at the cut-off frequency, f_c. Phase delay at f_c should be less than 45 degree for good phase margin and well behaved dynamic response.

For sampling system the close loop bandwidth, which is also the loop cut-off frequency, should be bounded and not greater than $f_s/(2\pi D)$, where D is the maximum duty cycle and f_s is the PWM switching frequency. At $f_c = f_s/(2\pi D)$ error amplifier gain may be high enough to cause the amplified output ripple voltage to drive the error amplifier into saturation, necessitating a further reduction in f_c. [6] In practice cut-off frequency up to $f_s/4$ is attempted but much lower values are common, often due to the bandwidth limitation of both error amplifier and phototransistor optocoupler.

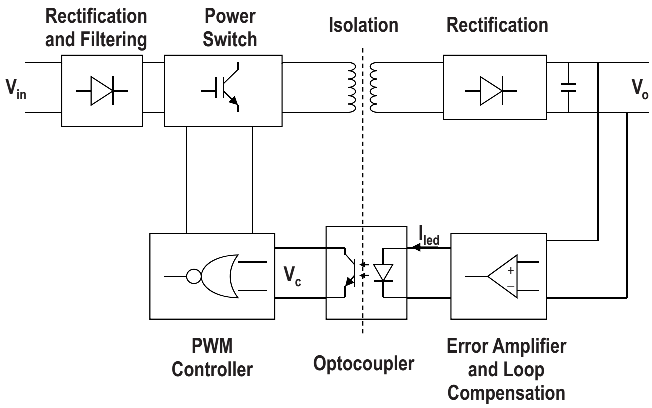

Figure 1 Isolated AC/DC Converter Block Diagram

High PWM frequency is preferred for HEV application in order to reduce the size and weight of power transformer. At typical PWM switching frequency of 200 kHz cut-off frequency between 10kHz and 50kHz are possible and is the frequency of interest.

Closing the loop requires a good understanding of loop transfer function, which includes signal transfer path from V_o to I_{led}, I_{led} to V_c and V_c to V_o. Transfer function from V_c to V_o is determined by the PWM control methodology and circuit topology, which is well explained in many literatures. Transfer function from I_{led} to V_c needs to be analyzed in order to design the compensation network to achieve Nyquist criteria for the loop in most unfavorable operating condition.

Common emitter topology shown in figure 2 is used for the analysis as it is more popular due to its inverting logic required by start-up of PWM controller. LED pole related to LED input capacitance, approximately 100pf – 200pF including both depletion and diffusion capacitance, is neglected in the small signal model shown in figure 3. At relatively low bias current of 1mA (v_T/I_{led}) the small signal input resistance of LED is on the order of 25 Ohm, resulting a pole at about 60MHz, therefore not a dominant pole. Neither the output impedance

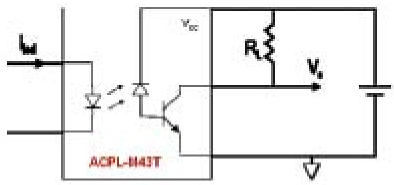

Figure 2 Feedback using ACPL-M43T

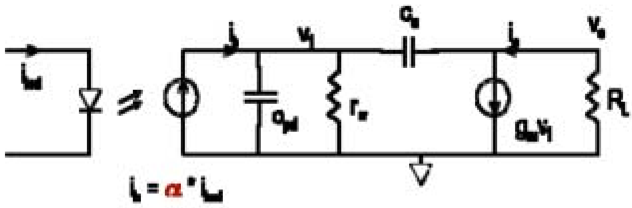

Figure 3 Small signal model of figure 2

of error amplifier nor the external driving resistor could affect the pole as the LED input resistance appeared in parallel with its capacitance.

Based on the small signal model in figure 3 the I_{led} to V_c transfer function can be written as:

$$\frac{v_c}{i_{led}} = \frac{-(\alpha g_m r_\pi R_L)(1 - s c_u/g_m)}{1+s(c_u(g_m R_L + 1 + R_L/r_\pi)+c_{pd})r_\pi + s^2 c_u c_{pd} R_L r_\pi} \qquad (1)$$

where

i_c = collector current
i_b = photodiode current driving into base
α = i_b / i_{led} , photodiode responsivity
c_{pd} = photodiode junction capacitance,
g_m = transistor transconductance
c_u = collector to base capacitance,
r_π = transistor base small signal input resistance,
R_L = optocoupler pull-up resistance

Given

$$\beta = g_m r_\pi \qquad (2)$$

$$CTR = i_c/i_{led} = (i_c/i_b)(i_b/i_{led}) = \beta\alpha = \alpha g_m r_\pi \qquad (3)$$

we have

$$\frac{v_c}{i_{led}} = \frac{-(CTR * R_L)(1 - s c_u/g_m)}{1+s(c_u(g_m R_L + 1 + R_L/r_\pi)+c_{pd})r_\pi + s^2 c_u c_{pd} R_L r_\pi} \qquad (4)$$

The transfer function (4) has DC transimpedance gain, CTR * R_L, 1 zero at much higher frequency than the frequency of interest thus ignored, and 2 poles.

Assuming 2 poles in (4) are widely separated we have

$$p_1 = -1/(r_\pi(c_u(g_m R_L + 1 + R_L/r_\pi) + c_{pd})) \qquad (5)$$

$$p_2 = -(1/(R_L c_u) + 1/(r_\pi c_{pd}) + 1/(R_L c_{pd}) + g_m/c_{pd}) \qquad (6)$$

Equation (5) tells that dominant pole of ACPL-M43T, p_1, is inversely proportional to small signal base-emitter junction resistance $r\pi$ as well as the sum of miller capacitance, $c_u(g_m R_L + 1 + R_L/r\pi)$, and photodiode capacitance c_{pd}. Due to the large area of photodiode c_{pd} is on the same order of magnitude of miller capacitance.

Base-emitter junction resistance $r\pi$ decreases with increasing collector current according to characteristic equation (7).

$$r_\pi = v_T/i_b = \beta v_T/i_c \qquad (7)$$

where v_T is the thermal voltage.

Base-collector junction capacitance c_u increases with decreasing collector voltage, v_c, due to the reduced biasing voltage across the collector and base junction. As a result c_u increases with increasing collector current in common emitter configuration. Compounded effect of collector current to dominant pole, p_1, is shown in figure 4 where R_L=1kOhm, v_{cc} =5V and Ta=25°C. The bandwidth reduction at low bias current is due to the reduction of $r\pi$. At high biasing current the increase of c_u is dominant due to the lower base-collector bias voltage (~ 0.2V at 4.5mA for R_L=1kOhm, v_{cc}=5V).
Bandwidth across temperature is shown in figure 5, which indicates the worst case condition occurring at high temperature with typical bandwidth of 600kHz. At high temperature both current gain, β, and thermal voltage, v_T, in equation (7) increase resulting increased $r\pi$ and reduced bandwidth. Considering â variation up to +/-30% the

resulted worst case bandwidth is above 400kHz, which is still a decade away from the frequency of interest. Hence the optocoupler pole can be ignored for loop compensation.

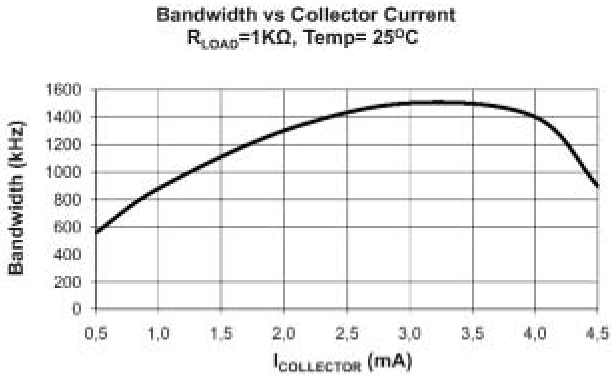

Figure 4. ACPL-M43T Bandwidth vs Collector Current

On the contrary a 4-pin phototransistor found in many consumer power supplies is much slower due to the large photodiode capacitance located between base and collector, multiplied by large voltage gain as miller capacitance.

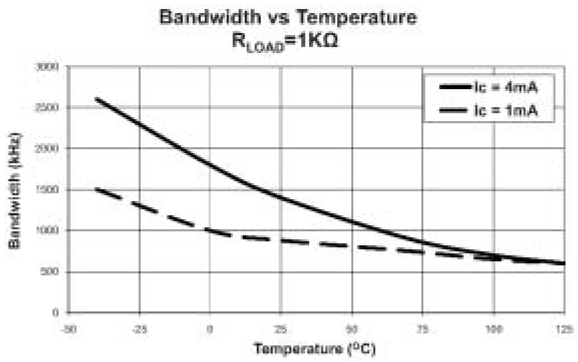

Figure 5. ACPL-M43T Bandwidth vs Temperature

As a result the typical bandwidth of a phototransistor is on the order of 10 kHz. Significant phase delay is introduced at the frequency of interest and zero compensation must be designed to cancel the phototransistor pole in order to achieve larger bandwidth and good dynamic performance.

However the pole location changes with temperature, biasing current and from part to part. A zero implemented by passive component can hardly track the pole position at all conditions. Compromise in loop compensation to ensure good phase margin has to be made, resulted in much lower close loop bandwidth and poorer dynamic performance.

CTR Characteristics across Temperature, Biasing and Life Time

As indicated in equation (4) and figure 6 CTR directly affect DC loop gain and cut-off frequency. The worst case phase margin occurs at high CTR where 2nd loop pole, p_{2_loop}, is getting close to the cut-off frequency, f_{c_high}. When CTR is low both DC gain and loop bandwidth reduce, deteriorating the static and dynamic loop regulation. It is important for CTR variation to be small and well bounded so that power converters are well behaved at worst case conditions.

For optocoupler CTR is the product of light output (LOP) generated form light emitting diode (LED), photodiode current caused by incident light and β of transistor. Although LOP and β varies from part to part Avago's ACPL-M43T can achieve max to min CTR span ratio less than 2, well within 1 CTR bin of a typical phototransistor. When temperature increases LOP of LED decreases but transistor β increases. Opposite temperature coefficient of LOP and β helps to narrow the CTR variation across temperature and is shown in figure 7, where temperature coefficient of β dominates at cold resulting decrease of CTR. At hot temperature LOP coefficient dominates resulting CTR bending lower as well.

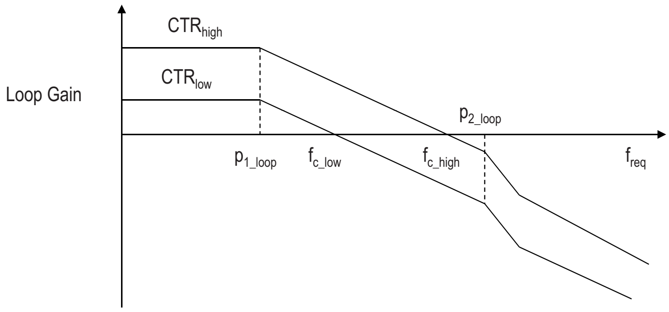

Figure 6 Example of loop gain and loop bandwidth variation vs CTR variation

A typical CTR dependency on collector current is shown in figure 8. For a common emitter configuration a load resistor of 1kOhm will limit the collector current to less than 5mA. Between 0.5mA and 5mA CTR variation is relatively flat.

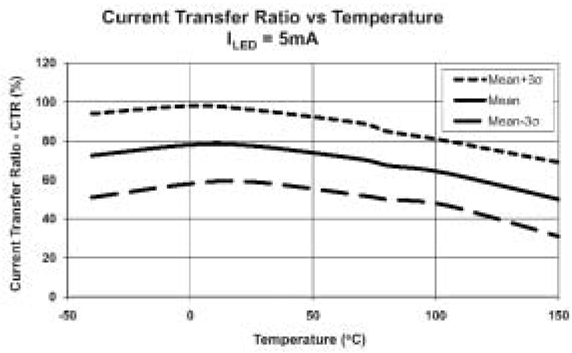

Figure 7 CTR vs Temperature (Iled = 5mA)

Another common concern for optocoupler is the CTR degradation over life time as seen in many phototransistor type of optocoupler. However less than 10% CTR drift was observed (figure 9) after 5000 hours of accelerated life time stress under 150°C and 20mA of LED driving current for ACPL-M43T, thanks to the technology advancement of Avago's LED fabrication and assembly process over past 35 years [8].

Although phototransistors for many consumer power supplies have tight binning at room temperature its variation across temperature, biasing current and life time is not characterized hence unpredicted. While this uncertainty is acceptable for many consumer applications, e.g. hand phone chargers, computer power supplies and etc it should be a concern for automotive application, where performance degradation of power supplies in electrical vehicles could potentially cause system malfunction and road accident.

Conclusion

AC/DC and DC/DC converters are the key building blocks for fast growing HEV market. Although existing power supply's circuit and topology can be used, high reliability, robust performance at high temperature and extreme operating conditions require careful examination of the existing components against the system requirements. Designed and manufactured specifically for automotive application Avago's ACPL-M43T features:

Isolation Resistance: 10^{12} Ohm
Isolation Voltage: 3750Vrms for 1minute with UL1577, IEC60747-5-5 and CSA certification
Clearance and creepage: > 5mm
Operating temperature range: -40°C to 125°C
Wide bandwidth: 1MHz typical
Well characterized CTR at all operating conditions and across parts
Low CTR drift over life time: < 10%
Qualified per AECQ100.

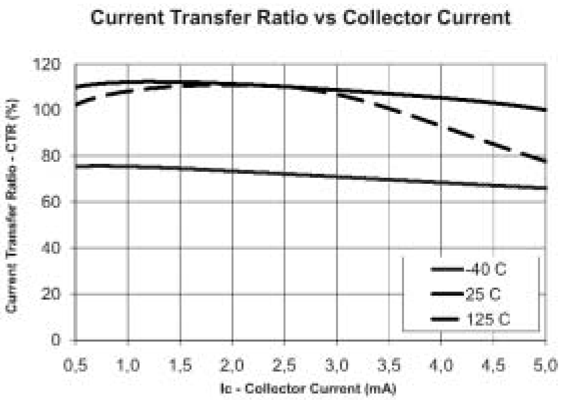

Figure 8 CTR vs collector current (Vce=1V)

Avago Technologies offers R2Coupler (Reinforced and Reliable insulation) series of optocoupler, providing isolated solutions for variety of automotive applications, e.g. power supply analog feedback, power switch gate driver, isolation amplifier for precision voltage/current sensing, high speed digital communication, low power status feedback and etc. Leveraging 35 years of expertise and quality track record in LED, photodiode, IC and high voltage assembly technology Avago's automotive optocouplers meet the new challenges for high temperature and long operating life requirements and are the choice of isolators for the emerging HEV.

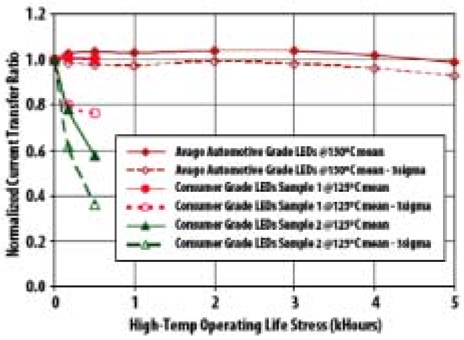

Figure 9 CTR drift over life time stress

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Electrolytic Capacitor Lifetime Estimation

Key parameters are necessary to predict lifetime

Aluminum Electrolytic Capacitors ("elcaps") are essential for the function of many electronic devices. Frequently, the lifetime of these devices is directly linked to the lifetime of the elcaps [9].

By Dr. Arne Albertsen, JIANGHAI EUROPE GmbH

This article reviews the construction of elcaps and highlights related terms like ESR, ripple current, self-heating, chemical stability, and reliability. Two estimation tools for obtaining elcap lifetime approximations are illustrated.

Construction of Elcaps
Aluminum electrolytic capacitors consist of a highly roughened anode foil covered by a thin dielectric layer and an exact-fitting cathode, the electrolyte liquid (Fig. 1).

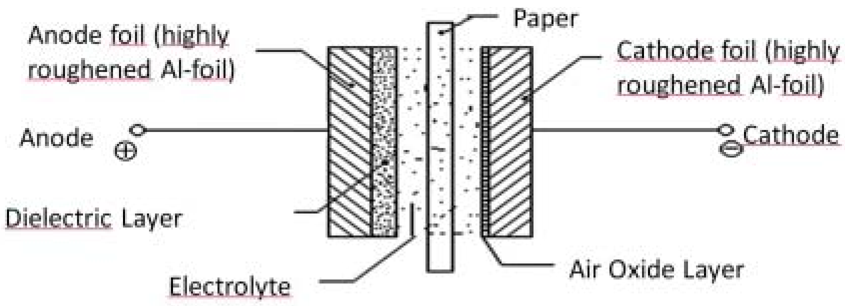

Figure 1: Electrolytic capacitor construction

The liquid electrolyte makes the construction of electrolytic capacitors special:

The current flow is mediated by moving ions. Temperature rise decreases the viscosity and lowers the electrical resistance (ESR).

The electrolyte's boiling point limits the maximum permissible self-heating caused by the ripple current and ambient temperature.

Electrolyte loss caused by electrochemical self-healing and drying out limit the lifetime of electrolytic capacitors [7].

Equivalent Series Resistance ESR
The ESR (Equivalent Series Resistance) allows for an easy calculation of the thermal losses that occur during the operation of elcaps [1].

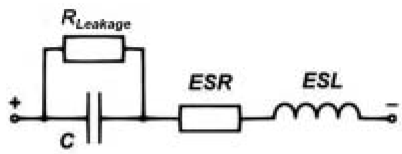

Figure 2: Equivalent circuit of an elcap

The ESR (Figure 2) is the sum of an approximately constant, a frequency dependent and a temperature dependent part [2]:

$$ESR = R_o + R_d + R_e$$

R_o designates the ohmic (foil, connecting tabs and solder terminals), R_d the frequency dependent (dielectric layer (Figure 3 (a) [3])), and R_e the temperature dependent resistance (electrolyte and spacer paper (Figure 3 (b))).

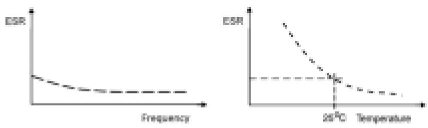

Figure 3(a): ESR vs. Frequency ;
(b): ESR vs. Temperature

To obtain reliable designs, maximum rather than typical ESR-values should be used when selecting electrolytic capacitors.

Ripple current
Usually, an a.c. or ripple voltage exists on top of a d.c. voltage and causes a ripple current and a self-heating of the elcap. As currents of any frequency contribute to the self-heating [8], RMS (root mean square) values of the rated ripple currents need to be considered:

$$I_a = \sqrt{\left(\frac{I_{f1}}{F_{f1}}\right)^2 + \left(\frac{I_{f2}}{F_{f2}}\right)^2 + \cdots + \left(\frac{I_{fn}}{F_{fn}}\right)^2}$$

I_a	RMS value of the rated ripple currents
$I_{f1} \ldots I_{fn}$	RMS Values of ripple currents at frequencies *f1…fn*
$F_{f1} \ldots F_{fn}$	current correction factor at frequencies *f1…fn*
$F_{fi} = \sqrt{\frac{ESR(f_0)}{ESR(f_i)}}$	where f_0= reference frequency of the nominal ripple current

The correction factors for the currents originate from the frequency dependency of ESR and are given in the datasheets.

Self-heating of elcaps
During operation, the elcap's temperature rises above ambient. In the steady state, the applied electrical power P_{el} matches the heat power P_{th} dissipated to the ambient.

$$P_{el} = P_{th}$$

The main cooling mechanisms for elcaps are radiation and convection. Heat conduction is usually very small. The capability to radiate heat depends on the elcap's surface material. The visible sleeve color does not matter, though.

The contribution of convection to the total cooling effect can be improved by forced cooling [5].

The individual equivalent thermal resistances of each cooling mechanism may be lumped together into a single thermal resistance R_{th}.

The core temperature T_c can be expressed by:

$$T_c = \Delta T \cdot \frac{R_{th}^{inside}}{R_{th}} + T_s$$

where $\Delta T = I^2 \cdot ESR \cdot R_{th}$

The combined internal thermal resistances range in the order of $R_{th}^{inside} \cong 1{\sim}3\frac{K}{W}$.

The measurement of the surface temperature T_s at the can bottom provides a good approximation of the core temperature T_c for radial and small snap-in elcaps (can diameters ≤ 25 mm). For larger can sizes, a direct measurement of the core temperature is recommended. Jianghai supplies elcaps with assembled thermocouples on request.

	Useful Life		Load Life	Endurance Test	Shelf Life	
Lifetime	7000h	>200000h	5000h	5000h	1000h	
Leakage Current	Not more than specified value		Not more than specified value	Not more than specified value	Not more than specified value	
Capacity Change	Within ± 30% of initial value		Within ± 20% of initial value	Within ± 20% of initial value	Within ± 20% of initial value	
Dissipation Factor	Not more than 300% of specified value		Not more than 200% of specified value	Not more than 130% of specified value	Not more than 200% of specified value	
Condition: Applied Voltage Applied Current Applied Temperature Failure Rate Level	U_R I_R 105°C ≤ 1% Failure Rate	U_R $1.8 \times I_R$ 40°C ≤ 1% Failure Rate	U_R I_R 105°C guaranteed	U_R $I_R = 0$ 105°C	$U_R = 0$ $I_R = 0$ 105°C	After test: U_R to be applied for 30min 24h before measurement

Table 1: Full definition of test conditions and allowed ranges

Chemical Stability

Electrolyte systems are multi-compound mixtures, and their chemical stability is a must. A good indicator for chemical stability is the "shelf life" (Table 1, right column). As opposed to the regular storage of elcaps at moderate temperatures, the shelf life test is a demanding accelerated life test that subjects the test specimens to their upper category temperature without any voltage applied.

A high shelf life figure is a good indicator for chemical stability, high purity of materials and advanced production quality. The results of this test are shown on the datasheets of all Jianghai series.

Reliability and lifetime

The related concepts of reliability and lifetime provide answers to the questions of "How many elcaps may fail during the usage of my application?" and "How long will the elcaps survive in my application?"

The typical time course of reliability density for elcaps follows the so-called "bathtub curve" [6]. The failure rate ("FIT rate") λ designates the number of failures per unit time (FIT = "Failures in Time" in $\frac{10^{-9} failures}{h}$).

The bathtub curve in Figure 4 shows three distinct consecutive segments:

- The early failure period (decaying FIT rate λ)
- The period within the normal lifetime describes the occurrence of random failures (constant FIT rate λ)
- The final segment originates from wear-out and changes beyond acceptable limits at the end or after the end of the regular lifetime (increasing FIT rate λ)

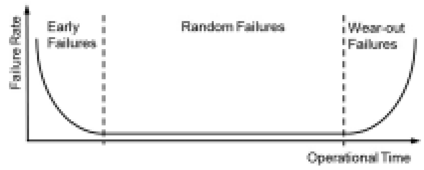

Figure 4: FIT rate vs. time

Towards the end of the production process, all elcaps are subject to post-forming (similar to a "burn-in"). Early failures in the application are thus a rare exemption [1].

For the further proceeding, we consider the elcap is operated during the random failure period of the bathtub curve.

The end of the lifetime is reached when certain parameters exceed pre-defined limits. It is common practice to allow a certain portion of species to be outside of these limits.

When comparing databooks of different elcap manufacturers, an inconsistent use of terms becomes obvious. The range of terminology comprises terms like „load life", "useful life", "endurance", "life expectancy", "operational life", and "service life". In addition to different limits that define the end of the lifetime, some manufacturers even use differing standards to allow for a certain amount of test items to be out of the specified range – this makes a comparison of the various lifetime values between suppliers very difficult.

Today, there exist no valid uniform standards that could be used to obtain an exact definition of the terms and their meaning. Jianghai resolves to list all relevant definitions and test conditions in the datasheet (Table 1).

Elcap lifetime diagram and lifetime model

To provide the users of their products with some tools for the lifetime estimation of elcaps, Jianghai has devised lifetime diagrams and a lifetime model. While the lifetime diagrams consider the most important parameters (temperature, ripple current) and show permissible combinations of these parameters graphically, the lifetime model also takes the influence of the actual operating voltage on lifetime into account. For each application, the results obtained by any tool need to be confirmed by the supplier.

Jianghai lifetime diagrams (Figure 5) exclude combinations of ripple current and ambient temperatures that may lead to temperatures too close to or even exceeding the boiling point of the electrolyte. These load conditions may only be applied if confirmed by Jianghai.

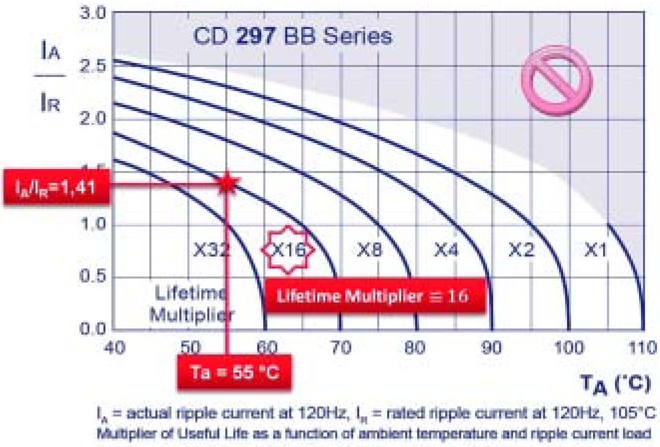

Figure 5: The lifetime multiplier is found at the intersection of the actual operating parameters

The input of the lifetime model are some elcap type specific parameters from the datasheet along with application-specific parameters like ambient temperature, ripple current load and the actually applied voltage during operation [4]. In case of forced cooling the ripple current load capability needs to be adjusted accordingly.

Example lifetime estimation

The following example is supposed to serve the illustration of a practical application of the lifetime diagram and of the lifetime model.

Let a 105 °C elcap, type 390 µF, 400 V, 35x45 mm from the snap-in series CD_297_BB from Jianghai be operated at ambient T_a = 55 °C and a ripple current of 2.51 A_{rms} at 20 kHz. The actual operating voltage equals the rated voltage of 400 V, hence only ambient temperature and ripple current load enter the lifetime estimate. The cooling is supposedly done by free convection and radiation.

The datasheet indicates a nominal ripple current of I_R= 1.27 A_{rms} at 120 Hz and 105 °C and a frequency correction factor of 1.4 for frequencies beyond 10 kHz and rated voltages 315 ~ 450 V. The lifetime („useful life“) is specified to be L_0= 7,000 h at nominal load conditions.

The ratio of the actual, frequency-rated ripple and the nominal ripple current is computed as

$$\frac{I_A}{I_R} = \frac{\frac{2{,}51 A_{rms}}{1{,}4}}{1{,}27 A_{rms}} = 1.41$$

From the lifetime diagram (Figure 5), we obtain an approximate value for the lifetime multiplier of 16 at the intersection of ambient temperature and ripple current ratio. The estimate for the “useful life” of the elcap in this application under the mentioned operating conditions is:

$$L_x = L_0 \cdot 16 = 7{,}000\ h \cdot 16 = 112{,}000\ h \cong 13\ years$$

Alternatively, the lifetime can also be estimated by using the numerical lifetime model:

$$L_X = L_0 \cdot K_T \cdot K_R \cdot K_V$$

$$= L_0 \cdot 2^{\frac{T_0 - T_a}{10K}} \cdot K_i^{\left[1-\left(\frac{I_a}{I_0}\right)^2\right]\cdot\frac{\Delta T_0}{10K}} \cdot \left(\frac{U_a}{U_r}\right)^{-n}$$

Inserting the values of

L_0 = 7,000 h, T_0 = 105 °C, $T_a = 55\ °C$, K_i = 4

$I_A = \frac{2.51 A_{rms}}{1.4} = 1.79\ A_{rms}$, $I_R = 1.27\ A_{rms}$, $\Delta T_0 = 5\ K$

$U_r = U_a$: $0.8 \le \frac{U_a}{U_r} \le 1 \rightarrow n = 5$

yields

$$L_X = 7{,}000h \cdot 32 \cdot 0.5 \cdot 1$$
$$= 7{,}000\ h \cdot 16 = 112{,}000\ h \cong 13\ years$$

The result of the numerical estimate matches the result obtained from the graphical solution that utilized the lifetime diagram.

Summary

Aluminum electrolytic capacitors often determine the lifetime of electronic devices. A thorough knowledge of some of the key parameters and aging concepts of these components are necessary to ensure the reliable design of electronic devices with a predictable lifetime.

Typical electrical and thermal properties of elcaps as well as the definitions for reliability and lifetime are elucidated. Two methods are available for obtaining lifetime estimates: a graphical approach (lifetime diagram) and a numerical computation (lifetime model).

The applicability of the models and their results depend on the specific product type and the particular application. Consultations with the supplier are key to get guidance throughout the design project and to confirm any estimates.

A practical example shows how the methods presented here can be applied to obtain application specific elcap lifetime estimates.

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www.jianghai-europe.com

Integrated Voltage Regulators Deliver Benchmark Efficiency

International Rectifier has announced the expansion of its SupIRBuck™ family of integrated point-of-load (POL) voltage regulators for energy-efficient high performance server, storage and netcom applications.

The Gen2.1 SupIRBuck family features IR's latest advances in control IC, MOSFET and package integration technologies to deliver up to 12A output current in a low profile, thermally enhanced 5x6mm Power QFN package. Capable of handling input voltages as wide as 1.5V to 16V, the new family of integrated voltage regulators is designed to deliver output voltages from 0.7V to 90% of the input voltage with benchmark efficiency over the entire load range and peak efficiency greater than 96%. As a result of delivering programmable switching frequencies up to 1.5MHz, the devices shrink board size as

well as achieving high power density.

The Gen2.1 family eliminates the need for traditional dual stage POL conversion by operating directly from 12V, and while optimized for 12V input voltage, superior efficiencies are also achieved in applications with 9.6V, 5V or 3.3V input voltages. In addition to providing pin compatible current options from 2A to 12A, the Gen2.1 SupIRBuck devices offer new power good (PGOOD) output window comparator for over-voltage and under-voltage detection, shorter deadtime to reduce power losses and more precise over-current (OC) limit. Additional features include 1% accurate 0.7V reference voltage, programmable hiccup current limit, programmable soft start, enhanced pre-bias start up, thermal protection, enable pin with voltage monitoring capability, sequencing (IR384xW), DDR memory tracking (IR383xW), and -40oC to 125oC operating junction temperature (Tj).

PCIM Booth 12/202

www.irf.com

Miniature High Power White LEDs

Toshiba Electronics Europe has announced three high-brightness, miniature white LEDs that will allow designers to deliver high-efficiency solid-state solutions for a wide range of commercial, residential and industrial lighting.

With a drive current of 350mA, the new TL12W03-D white, TL12W03-L warm white and TL12W03-N neutral white LEDs deliver high typical luminous flux ratings of 90 lumens, 75 lumens and 100 lumens respectively. As a result they offer high-efficiency, high-reliability alternatives to incandescent, fluorescent and halogen bulb technologies in general lighting designs.

The LEDs are supplied in miniature surface mount packages with dimensions of just 10.5mm x 5mm x 2.1mm. All of the devices will operate at temperatures between -40ºC and 100ºC, making them suitable for both indoor and outdoor lighting applications.

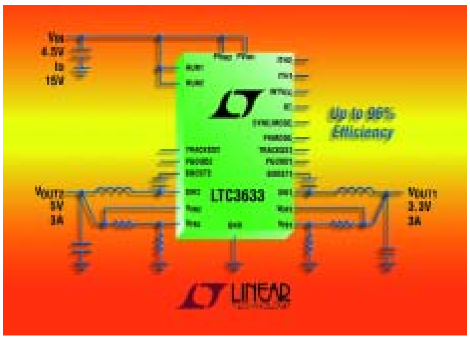
As with other models in Toshiba's LED family, the package technology has been designed to ensure a low thermal resistance. This ensures improved heat dissipation characteristics, which simplifies thermal management in the target lighting design.

All of the new LEDs are rated for a maximum forward current (IF) of 500mA and a typical forward voltage (VF) at 350mA of 3.3V. Maximum power dissipation for the LEDs is rated at 1.95W.

PCIM Booth 12/301

www.toshiba-components.com

15V, 4MHz, Synchronous Dual 3A Step-Down Regulator



The LTC3633 is a high efficiency, 4MHz synchronous dual output buck regulator that incorporates a unique constant frequency/controlled on-time, current mode architecture. It can deliver up to 3A of continuous output current from each channel at output voltages as low as 0.6V from a 4mm x 5mm QFN package. The LTC3633 operates from an input voltage of 3.6V to 15V, making it ideal for dual-cell Li-Ion applications as well as 5V and 12V intermediate bus systems. Its switching frequency is user programmable from 800kHz to 4MHz, enabling the use of tiny, low cost capacitors and inductors.

Each channel of the LTC3633 uses internal switches with RDS(ON) of only 50mOhms and 80mOhms to deliver efficiencies as high as 96%. Its unique control architecture enables it to achieve duty cycles as low as 5% while maintaining switching frequencies as high as 2.25MHz, making it ideal for high step-down ratio applications such as 12VIN to 1.2VOUT conversions. The two channels run 180 degrees out of phase, minimizing the size of both input and output capacitance. Burst Mode® operation is used to maximize light load efficiency, requiring only 500µA at no load, making it well suited for applications demanding maximum battery run time.

www.linear.com

Broadest Selection of PSR PWM Controllers

Fairchild Semiconductor's industry-leading portfolio of primary side regulation (PSR) PWM controllers offers designers of mobile chargers, adapters and LED lighting applications multiple solutions to meet the stringent power and regulatory specifications such as ENERGY STAR® Level V.

In charger and adapter applications, designers have been challenged to lower standby power and achieve higher efficiency, all while reducing the form factor of their designs. Currently in these applications, RCC or other IC solutions are used with varying degrees of success. With the broadest portfolio of PSR PWM controllers in the industry, including the FSEZ1307 PSR controller with high voltage (HV) startup and an integrated MOSFET, Fairchild devices simplify designs, save board space and meet today's demands for power savings.

Key features available in the Fairchild portfolio are 30mW standby power, HV start up and an integrated power MOSFET for ease of design, primary side regulation without secondary side feedback and a universal AC input range. Unlike competitive solutions, Fairchild's PSR PWM controllers achieve constant voltage (CV) (±5%), constant current (CC) (±7%), 30mW standby power and ENERGY STAR Level V efficiency, all with a competitive bill of materials (BOM) cost and component count.

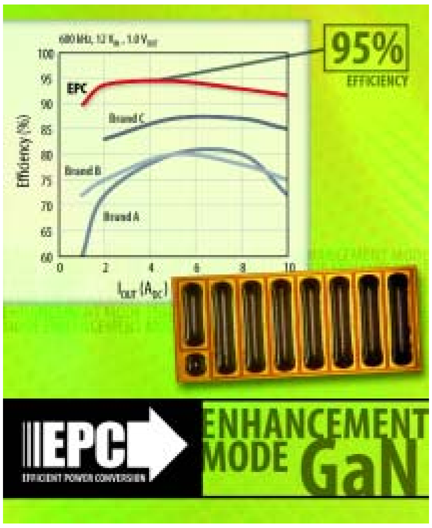
For LED lighting applications, Fairchild's PSR PWM controllers achieve the most accurate CC through built-in, proprietary TRUECURRENT™ technology and tight CV without secondary-side feedback circuitry. Constant current allows the device to accommodate different numbers of LED units in a string, increasing design flexibility, stretching the lifetime of HB LEDs and reducing time-to-market.

PCIM Booth 12/601

www.fairchildsemi.com

Availability of 40 V to 200V Enhancement Mode GaN Power Transistors

Efficient Power Conversion Corporation (EPC) introduced a family of enhancement mode power transistors based on its proprietary Gallium Nitride on Silicon technology. Spanning a range of 40 Volts to 200 Volts, and 4 milliohms to 100 milliohms, these power transistors demonstrate significant performance advantages over state-of-the-art silicon-based power MOSFETs. EPC's technology produces devices that are smaller than similar resistance silicon devices and have many times superior switching performance. Applications that benefit from this newly available performance are DC-DC power supplies, point-of-load converters, class D audio amplifiers, notebook and netbook computers, LED drive circuits, telecom base stations, and cell phones, to name just a few.



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

www.epc-co.com

Power Film Capacitors up to 1300 Vdc

For power electronics design engineers looking for bulk energy storage and ripple current filtering for DC link applications, Cornell Dubilier recently expanded its high current power film capacitor series to include more than 120 different ratings with extended voltages up to 1300 Vdc and capacitance values up to 1500 µF Designated the Type 947C, the metallized polypropylene film capacitors deliver higher bus capacitance with the enhanced ripple current handling capabilities required for inverters in wind, solar and fuel cell applications connected to the power grid.

"The extended voltage ratings and case sizes provide design engineers with more options for power film capacitors in inverter applications where higher ripple current ratings are required," said Laird Macomber, technology manager at Cornell Dubilier. "These higher voltage and current ratings eliminate the need for multiple aluminum electrolytics across the bus and greatly improve reliability and lower cost."

www.cde.com/catalogs/947C.pdf

Intelligent IGBT Gate Drivers for High Power Applications

InPower Systems GmbH will introduce a new range of intelligent gate drivers at PCIM 2010. These were developed for high-power IGBT modules with blocking voltages up to 6.5kV. The IPS- drivers reduce IGBT switching losses and offer reliable protection. Adapting the software makes custom applications a simple task.
The smart IPS-drivers may be used both in dual- and multilevel topologies and in parallel operation. They are very flexible and can be easily adapted to special applications. The IPS drivers are supplied "plug-and-play", they do not need any further components and are optimized for the IGBT module used. The other advantage of these drivers is: customers are not required to have either programming skills or additional equipment.
Protection of the IGBT-module is provided by the digital multi-step desaturation and the di/dt protection features, the feedback clamping and digitally controlled soft shut-down. All protection characteristics are controlled by the software and guarantee a reliable safeguard for the IGBT-module. Based on the variable gate resistors with up to seven different values RON and ROFF, the IPS drivers reduce the turn-on losses by up to 20 per cent and, therefore, improve the efficiency of the entire system.
Adaptable timing constants and delay times, short signal transition times, wide supply voltage range from +14V up to +30V, high peak output current of 70A, high switching frequency up to 120kHz and isolation testing voltage up to 10,000V are also key features of the IPS gate drivers and make it possible to implement these drivers in various high power applications such as industrial drives, power-supplies, transportation, renewable energies and induction heating.
Visit us at PCIM 2010 in Nuremberg and find out about the latest of intelligent digital drivers to make your inverter design more efficient and reliable.

PCIM Booth 12/602

www.inpower-sys.com

High-Voltage COTS Filters Perform in Extended Temperature Range

LCR Electronics offers a line of single phase 300 VAC 50/60Hz COTS filters ideal for high reliability applications as found in the lighting, military and medical industries.
Operating over an ambient temperature range of -40°C to +85°C (-40°F to +185°F), the new RoHS-compliant Single Stage 0913 Filters and Double Stage 0923 Filters are used where higher voltages and operating temperature ranges than standard off the shelf filters are required.
The 300 VAC 50/60 Hz EMI filters are available with rated current from 1 A to 40 A for the 0913 filters and 1 A to 30 A for the 0923 filters in both general purpose and low leakage current versions. High potential voltage

for both series is 1,450 VDC line-to-line and 2,250 VDC line-to-ground.
Depending on the current rating, insertion loss for the 0913 filters measured in a 50 ohm system for frequencies starting at 50 kHz up to 30 MHz ranges from 5 dB to 52 dB in common mode and 5 dB to 35 dB in differential mode. Insertion loss for the 0923 filters ranges from 5 dB to 80 dB in common mode and 10 dB to 75 dB in differential mode under the same conditions.

www.lcr-inc.com

Low-loss Inductive Components for Solar Power Inverters

SMP Sintermetalle Prometheus (SMP) is presenting chokes for inverters in photovoltaic systems at this year's Intersolar trade show in Munich this June. These inductive components feature low losses, very low stray fields and a highly compact design, which significantly increases the chokes' – and therefore the inverters' – energy efficiency. SMP uses core materials made of powder composites with low magnetostriction that have been purpose-designed specifically for this application.
A photovoltaic inverter converts the direct current output from the solar cells into alternating current before it is fed into the mains grid. To be able to modulate current with as close to sinusoidal a waveform as possible, so-called filters, consisting of capacitors and

filter chokes, are required. For this purpose, SMP has developed high-performance, low-loss chokes that meet the requirement for solar power inverters with an ever increasing efficiency.
For use in wind turbines, railway engineering, drives, power electronics, power generation, and instrumentation and control, SMP supplies inductive components for frequencies up to 200 kHz and current ratings up to 1000 amperes. Depending on their application, they are constructed either as single-conductor chokes for high-current applications, single-phase individual chokes, three-phase choke modules or LC filters. These components offer a high energy storage capacity in a compact and cost-conscious design as well as reduced losses and good EMC characteristics.
SMP at Intersolar 2010, 9 to 11 June 2010, Neue Messe München, Munich, Germany: Hall B3, Stand 733

www.smp.de

Breakthrough in Linearization Technology for RF Power Amplifiers

Richardson Electronics, announced it has teamed with Scintera, Inc. to bring Scintera's recently announced SC1887 to the worldwide market. The SC1887 delivers critically needed power amplifier linearity improvements without requiring access to the I/Q baseband signals. This digitally controlled analog technology works at the RF signal level, can be brought to market quickly, and requires only the addition of a few standard RF components to implement. Scintera's SC1887 Adaptive RF Power Amplifier Linearizer is a practical, cost-effective solution that satisfies today's needs for reduced amplifier distortion, increased power efficiency, and higher output power.

Benefits of this technology for RF Power Amplifier (PA) designers include:

Access to I/Q baseband signals is not required

No software development required (reduced time-to-market)

No digital R&D team required (lower development cost)

No training algorithm development or special control required – the SC1887 automatically calibrates and adjusts to the signal and the existing PA environment

Up to 26 dB ACLR (Adjacent Channel Leakage Ratio) improvement

Increase power output levels while maintaining linearity requirements

Low cost – no A/D or D/A converters needed

Minimal part count – less than 15 additional passive components needed

www.rell.com

www.scintera.com

PCIM Booth 12/235

Industry's Thinnest High-bright RGB LEDs

ROHM Semiconductor GmbH has recently announced the development of two types of high-bright RGB LEDs: SMLV56RGB1W1, featuring a height of only 0.6mm, and the standard-type SMLW56RGB1W1, featuring a height of 1.1mm. Both units are capable of 1.8cd (white).

RGB LEDs are convenient because they can emit virtually any color, including white, while taking up very little space since the three elements are integrated into a single, compact form factor without reducing reliability. This makes them for instance the preferred choice in portable gaming devices and applications requiring high brightness and multiple colors in a small area (display blocks, LED spotlights, illumination devices, and more).

One drawback to high brightness LEDs is the small distance between the LED and target object, often due to the relatively large package height of conventional LEDs (at least 1.4mm). This often results in non-uniform light distribution or LED see-through, where the LED is visible through the object itself.

www.rohmeurope.com

First Commercially Available GaN-based Integrated Power Stage Devices

International Rectifier introduced the industry's first family of commercial integrated power stage products utilizing IR's revolutionary Gallium Nitride (GaN)-based power device technology platform. The iP2010 and iP2011 family of devices is designed for multiphase and point-of-load (POL) applications including servers, routers, switches and general purpose POL DC-DC converters.

The iP2010 and iP2011 integrate a highly sophisticated, ultra fast PowIRtuneTM driver IC matched to a multi-switch monolithic GaN-based power device. These devices are mounted in a flip chip package platform to deliver higher efficiency and more than double the switching frequency of state-of-the-art silicon-based integrated power stage devices.

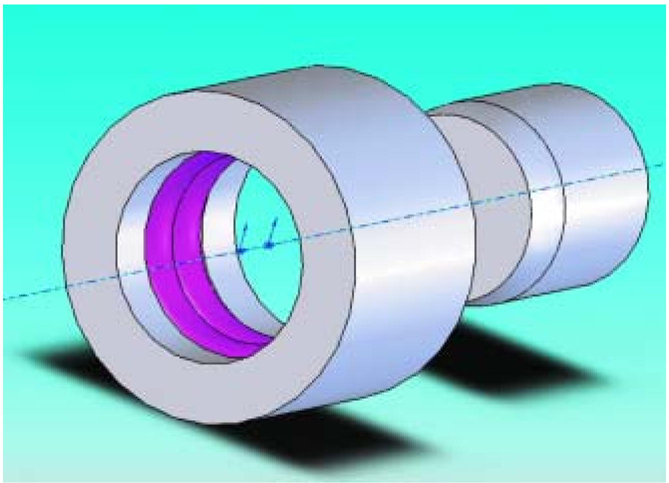
The iP2010 features an input voltage range of 7V to 13.2V and output voltage range of 0.6V to 5.5V with an output current up to 30A. The device operates up to 3MHz. Operating up to 5MHz, the pin-compatible iP2011 features the same input and output voltage range but is optimized for an output current up to 20A. By offering multiple current rating devices in a common footprint, IR provides flexibility for meeting different customer requirements in terms of current level, performance and cost.

PCIM Booth 12/202

www.irf.com/product-info/ganpowir/

Springs in Wind Power Generators

Bal Seal springs distributed by CMS Kontakt und Dichtungstechnologie in Bocholt Germany, provide excellent electrical and mechanical performance in industrial connectors. The patented canted-coil spring provides near-constant spring contact force over a wide range of working deflection. Bal Seal springs provide long life and superior service in shock, vibration, and harsh environments.



In a wind turbine, the force of the wind turns two or three blades around a rotor. A shaft extending from the rotating blades drives the generator, converting mechanical motion into electric power. Electricity flows through high-capacity cables to a nearby substation, where voltage is stepped up and delivered to the power grid.

The Advantages of Bal Seal are:

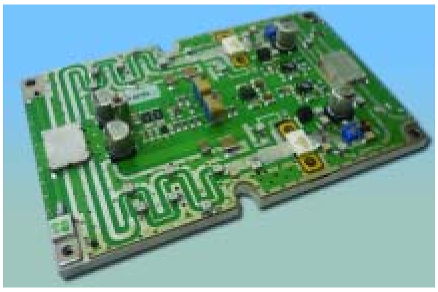
- Well suited for shock, vibration and other harsh environments.
- Multiple point contacts; minimal contact resistance
- Available in small diameters and cross sections
- Near constant spring contact force
- High current carrying capability with high contact density
- Minimal heat buildup
- Easy installation and assembly
- Small space requirements
- Wide tolerances permitted on mating parts for low production cost

For more information and technical assistance, consult:

www.cmscontact.eu

500 – 1000 MHz, 50W Pallet Amplifier

Richardson Electronics recommends the new LDU50-CW (RES-INGENIUM) is a 500 – 1000 MHz Class AB pallet amplifier designed for heavy duty operation in military and law-enforcement jamming applications (50W, CW). This rugged RoHS-compliant amplifier, features two FreescaleTM MRF9030LR1 power transistors (LDMOS), achieves 15dB gain, maintains impressive gain-flatness of +/- 0.5dB across the operating frequency band (500 - 1000 MHz), and can handle a load mismatch of 2:1 VSWR (over all phase angles). Connectorized versions are available upon request. For datasheet, price, delivery and design-in support contact Richardson Electronics, 1-800-737-6937 (North America); or find your local (International) sales engineer at



www.rell.com

CUI Inc's 3D Catalog Now Available

CUI Inc announced that their 3D catalog is now available on Digi-Key's website for the majority of their 1000+ stocked line items. CUI is the first Digi-Key partner to make this service available to Digi-Key customers. CUI's VP of Marketing, Jeff Schnabel explained, "We are very excited to be the first partner to offer free 3D drawings through Digi-Key. This service has already proved to be a valuable tool for our direct customer base, and I think engineers visiting Digi-Key.com will also find this service extremely helpful as their design cycles continue to shorten."

Users are able to configure, view, and download 2D and 3D drawings in any of the major mechanical CAD formats for free, eliminating unnecessary data conversion costs and delays. Available formats include SolidWorks®, Pro/Engineer®, AutoCAD®, and Mechanical Desktop®, among others. The models can be dropped directly into a product's design to check compatibility in just a few mouse clicks, enabling the engineer to specify components quicker and reduce the design cycle.

CUI designs, manufactures, and markets electro-mechanical components for the OEM manufacturer in the fields of power electronics, motion control, interconnect, and acoustic technologies.

www.cui.com

First PMBus System Power Management and Protection IC

National Semiconductor announced the industry's first system monitoring, protection and control integrated circuit with on-chip power management bus (PMBus) support. The LM25066 provides designers of blade servers, storage networking systems, routers/switches and modular subsystems with a solution that improves system reliability and reduces operating expenses in data centers.

National's LM25066 integrates high-performance monitoring, protection and control blocks that precisely control and manage the electrical operating conditions of each blade in the chassis. It also provides accurate monitoring of critical system power consumption and fault conditions.

The LM25066 continuously supplies the system management host with real-time power, voltage, current, temperature and fault data for each blade subsystem. The LM25066's system management bus (SMBus) communications interface delivers this data using the PMBus protocol. The host's system diagnostic and optimization routines use the data to increase system reliability and minimize the data center's total power consumption.

Key Features - LM25066 PMBus System Power Management and Protection IC

The LM25066 features a voltage input range of 2.9V to 17V and a selectable 25 mV/50 mV current limit threshold for addressing a wide range of intermediate bus voltages and load currents. The LM25066 monitoring block measures both current and voltage at 1,000 times per second with a current measurement accuracy of three percent over the full temperature range of -40 degrees C to 125 degrees C. Additionally, its simultaneous sampling of current and voltage provides a true power measurement of the server blade power consumption. The monitoring block also captures the peak current and peak power and computes the average of subsystem operating parameters (Vin, Iin, Pin and Vout).

A temperature monitoring block on the LM25066 interfaces with a low-cost external diode for monitoring the temperature of the external MOSFET or other critical temperature source. The LM25066 reports the status of all system parameters and fault conditions through the SMBus interface and offers individually programmable warning thresholds for all faults. This feature provides design flexibility and dynamic system protection.

The LM25066 control and protection blocks include National's unique hot-swap architecture that provides both current and power limiting to protect sensitive circuitry during insertion of boards from a live system backplane or any other "hot" power source. The LM25066 protection block also provides adjustable under/overvoltage and hysteresis.

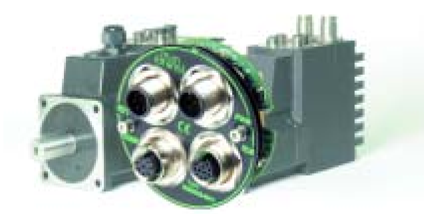
National supports the LM25066 with a suite of powerful development tools that simplify application design and system verification. System designers may also use these tools to create value-added features for their subsystems.

www.national.com

Option Module for MAC Servo Motors

MAC00-B41 is a new module intended to be used for the integrated MAC servo motors type MAC400 and MAC800. The module offers the following extended I/O functions: 6 digital I/O (24V tolerant); 2 analogue 12 bit inputs; 2 multi function RS422 channels; Dual supply feature for safe motor stop: Galvanically isolated RS232 and RS485; New simple and robust internal connector and M12 industrial connectors for simple and safe connection

The module is primarily intended for dispenser applications where a very fast motor start and stop function is needed. The start and stop jitter is les than 50µs and syncronization with an external encoder is possible.



In addition the module contains a galvanically isolated RS232 and RS485 interface to be used for setup and diagnosis or permanent connection in a network.

www.jvl.dk

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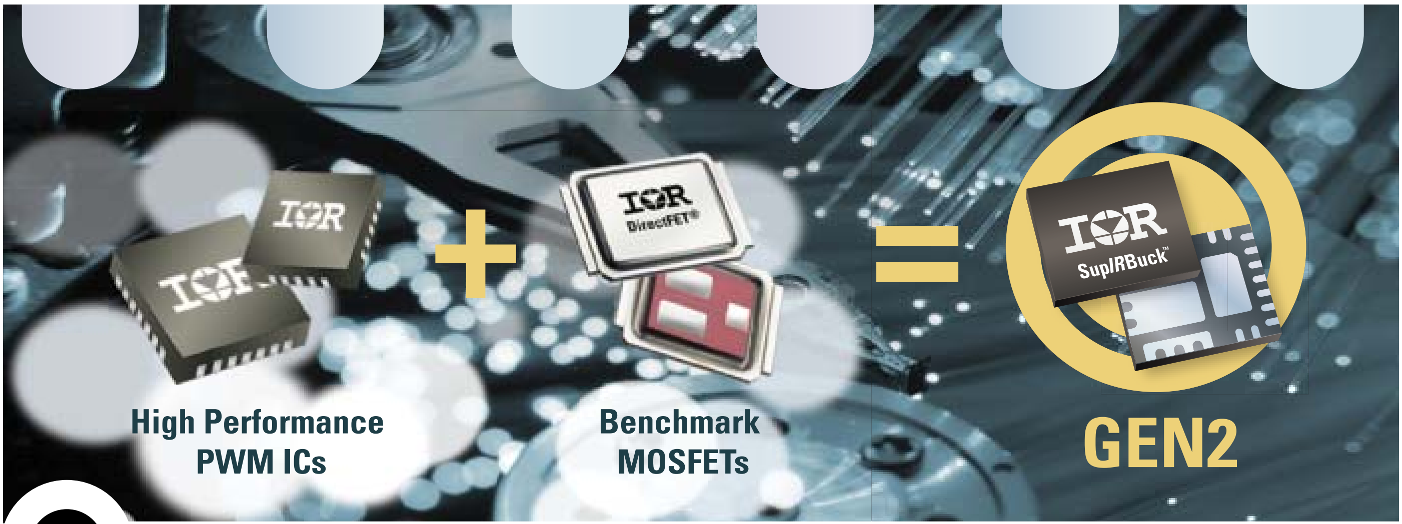
Fuji Electric	17	PCIM China	59		
GVA	3	PCIM Europe	39		



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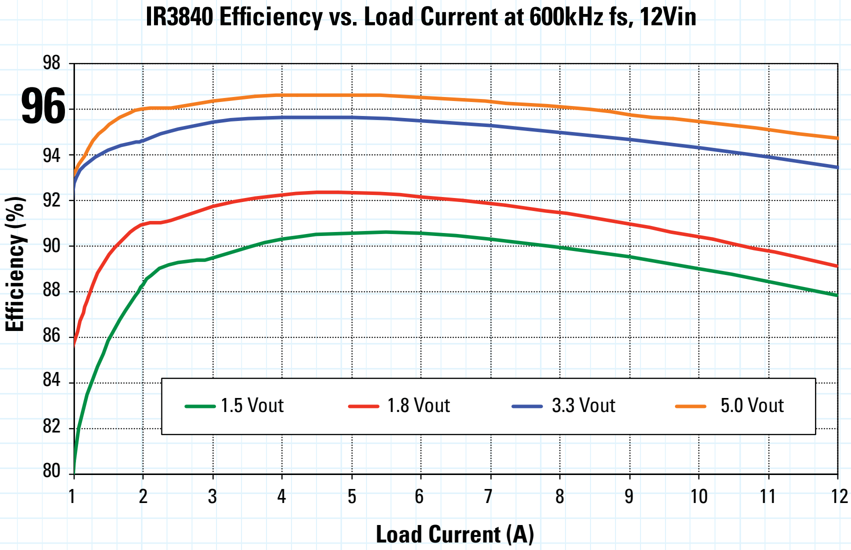

Features:

- Wide input voltage range (1.5V to 16V with 5V bias)
- Pin compatible solutions for 4A, 8A and 12A
- Small footprint (5x6mm)
- Low height (0.9mm)
- Programmable frequency up to 1.5MHz
- 1% accurate 0.7V reference voltage
- Programmable hiccup current limit
- Programmable soft start
- Enhanced pre-bias start up
- Thermal protection
- Enable pin with voltage monitoring capability
- Power Good output
- -40°C to 125°C operating junction temperature

Part Number	V_{IN} Range (V)	V_{OUT} Range (V)	Iout (A)	Switching Frequency (kHz)	Special Features
IR3831MPbF	1.5 - 16	0.7 - 0.9*V_{IN}	8	250KHz - 1.5MHz	DDR Tracking
IR3840MPbF	1.5 - 16	0.7 - 0.9*V_{IN}	12	250KHz - 1.5MHz	SEQ input
IR3841MPbF	1.5 - 16	0.7 - 0.9*V_{IN}	8	250KHz - 1.5MHz	SEQ input
IR3842MPbF	1.5 - 16	0.7 - 0.9*V_{IN}	4	250KHz - 1.5MHz	SEQ input

Reference Designs Available

For more information call +49 (0) 6102 884 311
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