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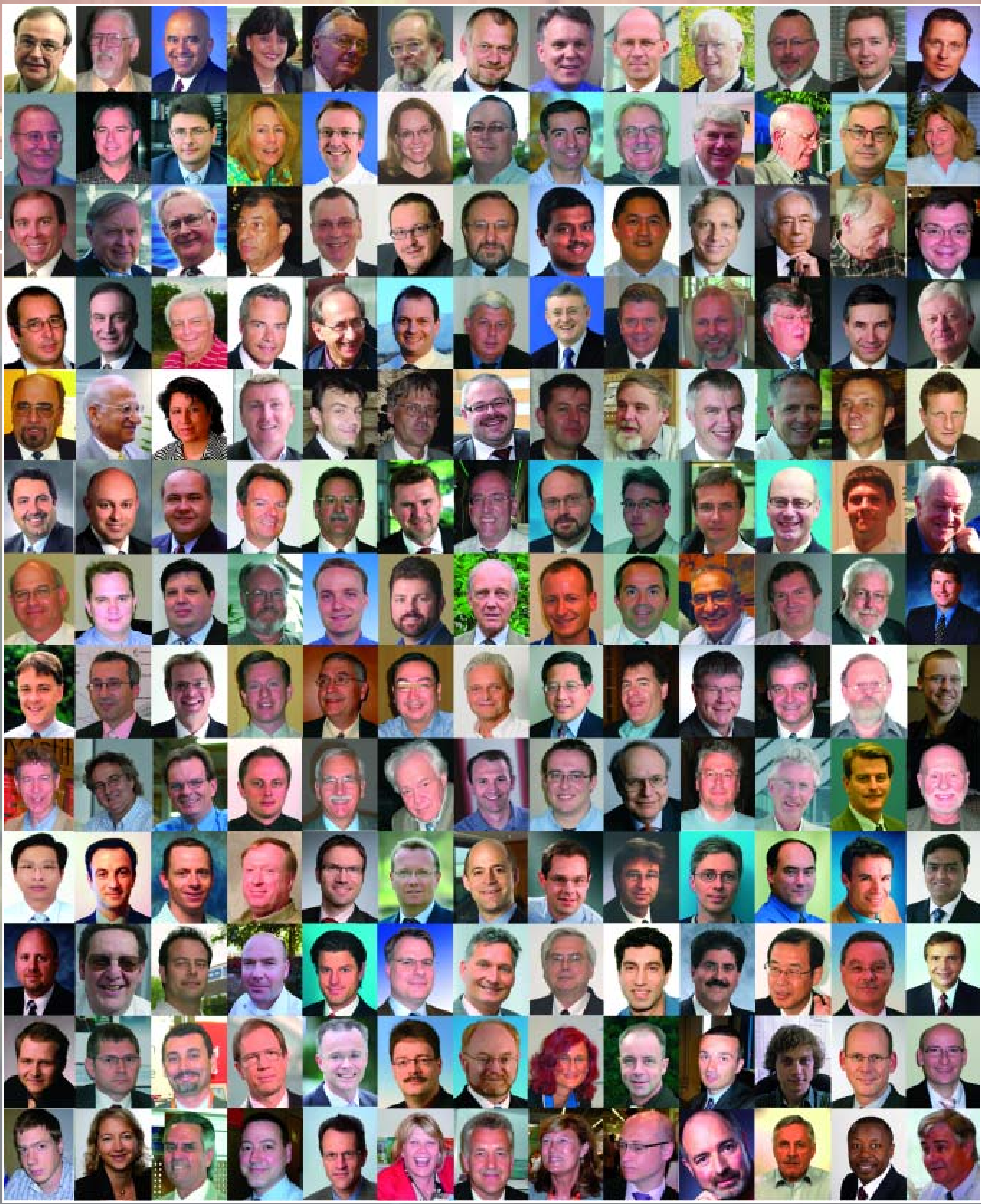
Bodo´s Power Systems®

Electronics in Motion and Conversion

October 2011

Bodo´s Power Systems®

The Gallery



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Events

ESREF,
Bordeaux, France, October 3rd -7th
www.esref.org

Distribution Automation Europe,
London UK October 10th-11th
www.smi-online.co.uk/distributionautomation38.asp

Semicon Europa,
Dresden, Germany October 11th -13th
www.semiconeuropa.org/

eCarTec,
Munich, Germany, October 19th -20th
www.ecartec.de

Smart Grid Electronics Forum,
San Jose, CA Oct. 24th -26th
SmartGrid.Darnell.com

Productronica,
Munich, Nov. 15th -18th
www.productronica.com

SPS/IPC/Drives,
Nuremberg, Nov. 22nd -24th
wwwmesago.de

Power electronics Moscow,
Nov. 29th –Dec. 1st
www.powerelectronics.ru

Serving Comprehensive Information

Our world is flooded with information. How much information can be digested and how efficient are video clips in explaining technology? What amount of time is dedicated to providing the information crucial for progress? Why is printed information so valid and a datasheet, an application note, or a printed magazine so successful?

In print, the reader controls his speed in extracting information and skips common, well known, subjects. This process cannot be matched by rapid mouse clicks or watching videos. An experienced designer has faster ways of gathering information than watching videos. On the other hand, a video is valuable in presenting the strong and unique personality of technology leaders.

But a face-to-face discussion is easily the best way to work out technical questions. Conferences and exhibitions provide a forum for this communication. They overcome the lack of interactivity that watching screens involves and the passive acceptance of what is presented, without qualification. Personal meetings are still the best way to get technology information travelling.

Attending EPE in Birmingham gave me a global view of progress in Power Electronics, especially in the workshop discussing progress in putting Silicon Carbide and Gallium Nitride to work.

The Photovoltaic Conference and show in Hamburg showcased the importance and value of solar power for our future. We need every renewable source of energy to survive the future. Manufacturing and the long-term stability of solar panels are important aspects of their efficiency over decades. The LED symposium in Bregenz, Austria, will convey in a most efficient way, information about lighting applications. Heat was yesterday, light is today. What huge amounts of energy can be saved to help relieve the grid! We must all work to sustain the planet. Reducing energy consumption and enhancing alternative energy are ways to a better future.

October offers SEMICRON Europe in Dresden where semiconductor manufacturing experts will communicate about progress.

The eCarTec Conference in Munich will present developments in electric and hybrid-electric cars and discuss the enormous potential for successful mobility through electric vehicles. Improvements in batteries for extended range have been long-awaited and at the moment, prospects suggest frequent re-charging, a solution that requires many charging stations. We are far away from having that infrastructure in place. This is a challenging subject for all of us.

It is a busy time all over the globe. Just look at the events list in the magazine, on my website, or in my e-newsletter – all ways to access information. Communication is the only way to progress. Bodo's Power Electronics magazine provides information to all, including those for whom travel to relevant trade shows is not possible. We have now delivered ten issues this year, with 650 pages of information - on time, every time. As a media partner, Bodo's Power Systems is internationally positioned and represented at more than two dozen shows and conferences worldwide.

My Green Power Tip for October:
Collect the rain water from your roof drains and use it, instead of drinking water, for watering the garden.

Looking forward to seeing you at one of the next shows!

Best Regards

Light-Weight Durable Lithium Iron Phosphate Motorcycle Batteries

The LBP5500 (Lithium Bike Power) battery from BMZ Batterien-Montage-Zentrum weighs just 2 pounds (900 grams). This battery, specifically designed for powerful motorbikes and quads, has small dimensions of only 95 mm x 80 mm x 80 mm and a rated capacity / voltage of 5500 mAh / 13.2 V.
The LBP5500 battery has a maximum impulse discharge current of 350 A and a maximum continuous discharge current of 300 A. Thanks to state-of-the-art lithium iron phosphate (LiFePO4) technology, the highly safe LBP5500 battery is ideally suited for

use in powerful sports vehicles with 2- or 4-cylinder motors up to 1500 cc capacity. Despite its high performance capability, the LBP5500 battery can be fully charged within 45 minutes at a charge current of 7.5 amps. For 90 percent of the rated capacity, 15 minutes at a charge current of 20 amps is sufficient. The LBP5500 battery has substantially reduced charge times as compared to the usual 7 to 14 hours for conventional lead acid batteries.

www.bmz-gmbh.de

SPS – Industrial Automation Fair Guangzhou 7 – 9 March 2012

To meet industry demand for leaner productivity protocols and advanced measuring methods, SPS – Industrial Automation Fair Guangzhou to be held 7 – 9 March 2012 at the China Import and Export Fair Complex, will include new trend areas for Machine Vision and Measurement and Instrument.
Mr Louis Leung, Deputy General Manager of Guangzhou Guangya Messe Frankfurt Co Ltd, one of the show's organisers said: "The fair will deliver more business and value by offering additional solutions in overall equipment effectiveness and complex measuring processes." Mr Leung expects the 2012 show to be a success. "Interest in the event is high; the number of enquiries received from potential exhibitors and visitors are up compared to the same period last year," he added.
SPS – Industrial Automation Fair Guangzhou is sponsored by the China Foreign Trade Centre and Messe Frankfurt Exhibition GmbH. It is organised by the China Foreign Trade Guangzhou Exhibition General Corporation, Guangzhou Guangya Messe Frankfurt Co Ltd, Guangzhou Overseas Trade Fairs Ltd and Mesago Messe Frankfurt GmbH. The honorary sponsors are the Guangdong Automation Association and Guangzhou Automation Association.
To find out more information about the 2012 show, please visit

www.siaf-china.com

Power Electronics Knowledge Platform Goes Online

Semikron, global leader in power electronic systems, goes live with its new power electronics knowledge platform. The knowledge platform www.powerelectronics-base.com provides basic information on semiconductor physics and power electronics, as well as detailed information on IGBT, MOSFET, diode and thyristor component selection and applications. The knowledge platform is to facilitate and make more efficient the work of development engineers.
The printed version of our application manual opens up the doors to a vast knowledge base that draws upon a wealth of expertise and years of field experience. Now, this vast knowledge base is being opened up to interested parties online, explains Gerlinde Stark, Head of International Communication at SEMIKRON.
For those who would rather have the print version of the Application Manual, this is available for purchase from bookstores (ISBN No. 978-3-938843-56-7) or the Sindopower power electronics eCommerce portal at www.sindopower.com for a price of €9.90.

www.semikron.com

Revision to Standard for Electrostatic Discharge Sensitivity Testing

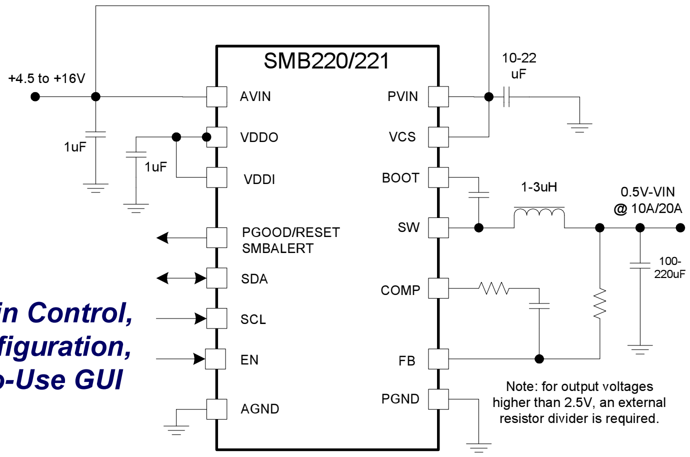
JEDEC Solid State Technology Association and the ESD Association announced the publication of ANSI/ESDA/JEDEC JS-001-2011 for Electrostatic Discharge Sensitivity (ESD) Testing – Human Body Model (HBM) – Component Level. The product of a ESDA /JEDEC agreement to produce joint standards in the field of device ESD sensitivity testing, the new revision represents a significant update over the prior version of the standard. ANSI/ESDA/JEDEC JS-001-2011 may be downloaded free of charge at:

www.ESDA.org

www.JEDEC.org

Programmable Integrated DC-DCs Deliver Big Power and Small Size

10A and 20A Output with Built-in MOSFET's and Digital Control
Advanced Power Management with No Extra Components or Cost



I²C or Pin Control, NV Configuration, Easy-to-Use GUI

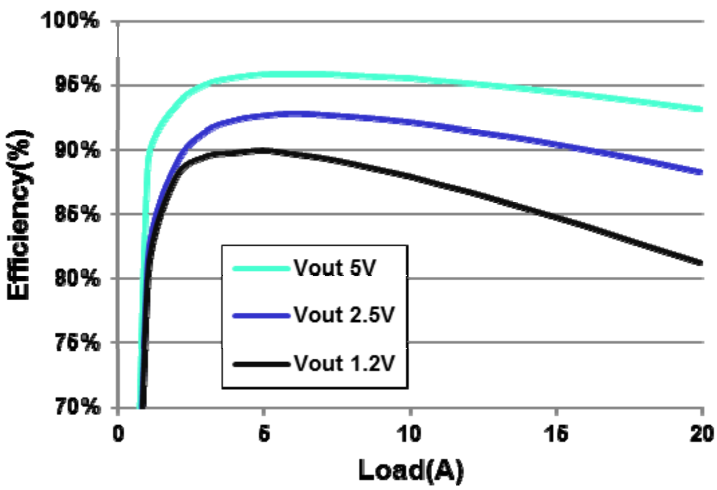
Features

- Integrated MOSFETs up to 10A/20A output
- Digitally Programmable with Non-Volatile OTP Configuration
  - Static/dynamic output voltage/margining
  - Softstart timing/slew rate
  - RESET/PGOOD behavior
- True Current-Mode PWM Control
- Built-in Safety and Protection
  - Cycle-by-cycle current limit
  - Over-temperature protection
- Tiny 5mm x 6mm QFN Package

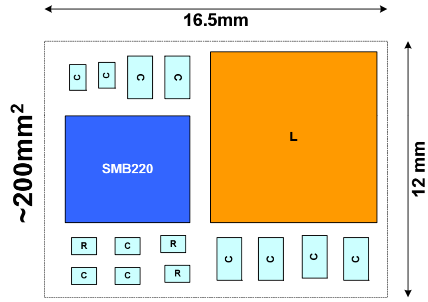
Applications

- Server, Notebook and Tablet Computing
- Enterprise Switches/Telecom Routers
- POL Power Modules
- Digital/IP Set-Top-Box/DTV/Smart TV
- Storage Equipment and Disk Drives

Efficiency with +12V Input



Fewest Components Smallest Footprint



Summit Programmable DC-DC Family

	SMB109/8/6	SMB206/7/8/A	SMB209/10/A	SMB211	SMB220/1
Input Voltage Range (V)	4.5 to 28	4.5 to 16	4.5 to 16	4.5 to 16	4.5 to 16
# of Outputs	2/3/4/8	2	1	1	1
Output Current (A)	>20	1/2/3	4/6	>20	10/20
Switching Frequency (kHz)	300-1200	500/1000	500/1000	250-1000	250-1000
Output Voltage Range (V)	0.5-VIN (Prog)	0.8-VIN (Prog)	0.8-VIN (Prog)	0.5-VIN (Prog)	0.5-VIN (Prog)
Internal/External FETs	External	Internal	Internal	External	Internal
Output Voltage, Seq., Softstart, OCP	Prog	Prog	Prog	Prog	Prog
Output UV/OV Monitor	Prog	√	√	Prog	Prog
RESET/POWER GOOD Output	√	√	√	√	√
I2C/SMBus Interface	√	√	√	√	√
Packages	7x7 QFN-56 5x5 QFN-32	3x3 QFN-20 TSSOP-24	3x3 QFN-20 TSSOP-24	3x3 QFN-20	5x6 QFN-28

For more information see:
www.summitmicro.com/SMB220
www.summitmicro.com/MobileGreen

MobileGreen™ TECHNOLOGIES
SUMMIT MICROELECTRONICS
Programmable Power for a Green Planet℠

The 16th elcomUkraine with a Major Focus on Energy Efficiency and on Renewables in 2012

Energy demand in Ukraine is to double until 2030. As 70% of the energy demand is imported, enormous savings are possible by introducing modern energy efficiency and renewable energy technologies and solutions. The 16th elcomUkraine 2012 therefore focuses on energy efficiency, on renewables and on intelligent solutions for the future's energy mix. Against this backdrop the German trade fair specialists fairtrade Messe and their partners Euroindex of Kiev organize the International Trade Fair on Renewable and Conventional Energy, Energy Efficiency, Electrical Engineering, Lighting and Automation. The event is scheduled for 17 – 20 April 2012 at the KyivExpoPlaza in Kiev, Ukraine.

According to Inogate (the international energy co-operation program between the EU and Ukraine and other Central European countries), Ukraine has an energy saving potential of almost 50% as its energy intensity is extremely high.

ufi Approved Event

elcom Ukraine 2012

Renewables at elcom 2012
The time is right!

April 17 - 20, 2012
KievExpoPlaza, Kiev, Ukraine

www.elcom-ukraine.com

450mm and EUV Linked with Uncertainty

Jonathan Davis

The transition to manufacturing semiconductors on larger wafers continues to be one of the hottest topics in the industry. Some chipmakers have committed to advancing the transition. Intel announced that its D1X fab in Oregon will be 450mm compatible (2013). TSMC announced a 450mm pilot line by 2013-2014. IMEC and ISMI have well-established programs focused on the challenges posed by manufacturing with 450mm wafers and the University of Albany's College of Nanoscale Science and Engineering (CNSE) is expanding facilities to encompass 450 program R&D.

With increasing interest in a near-term 450mm pilot line development, many critical elements need coordination for affordable high-volume 450 manufacturing to occur. At the recent SEMICON West 450 Wafer Transition Forum, panelists from throughout the supply chain grappled with the numerous issues involved. Uncertainty with EUV rollout has exacerbated the 450mm planning challenge and is reinforcing the need for more transparency in planning and funding.

www.semi.org

Electro, Automation, Energy and Renewables

Algeria's leading trade show focuses on renewable energies and energy efficiency 22,000 MW of power generating capacity shall be installed from renewable sources until 2030. This has been announced by the Algerian Government. For 2020, about 60 solar photovoltaic and concentrating solar power plants, wind farms as well as hybrid power plants are planned. As its new brand name indicates electro, automation, energy & renewables focuses on renewable energies and energy efficiency. Algeria's leading trade show is organized by the German trade fair specialists fairtrade Messe and their Algerian daughter company in Algiers. It will be held at the Palais des Expositions in Algiers - Safex from 7 to 10 May, 2012.

ufi Approved Event

electro | automation | energy & renewables

May 7 - 10, 2012
Palais des Expositions d'Alger
Pavilion B

www.electro-automation.info

Smart LED Luminaire Based on Cree XLamp® ML-E LED Solution

FuturoLighting, a new company focused on LED lighting solutions, introduces Aurora a fully autonomous, motion detecting, lighting application which uses Cree's latest XLamp® ML-E LED. Due to its immediate light output and no lifetime limitation due to switching, Aurora offers advantages over traditional incandescent and fluorescent light sources as well as improved reliability due to its solid-state construction.

Aurora has a simple setup using its microcontroller with integrated high resolution control over light output levels, ambient light threshold, dimming functionality, and Gamma correction which improves visual comfort. Once the desired settings are set the Aurora doesn't need to be adjusted again. It can be installed in any location that is dry and has a standard wall outlet. Suggested applications for Aurora are under cabinet lighting (kitchens, shelves, desks, etc.), smart illumination for galleries, museums, cupboards, stair illumination, architectural lighting and many others.

www.futurolighting.com


EV
QUICK CHARGER

Innovative RO-LINX Power Circuit Busbars for Emerging Power Electronics Applications

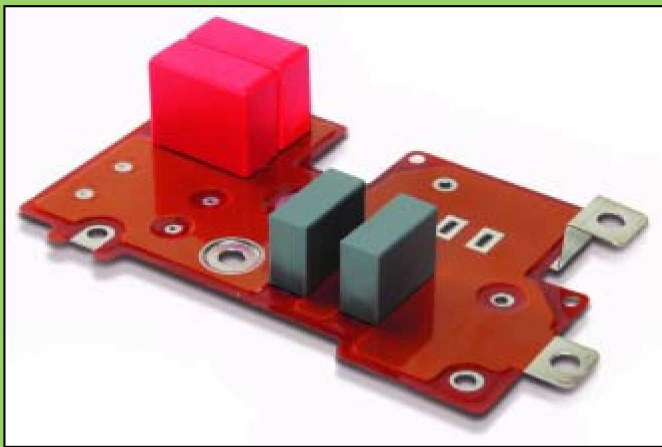
Rogers Corporation's Power Distribution Systems Division has announced an innovative new solution for emerging power electronics applications: RO-LINX® PowerCircuit™ busbars. The PowerCircuit solution was developed to meet the growing power distribution demands in electric vehicle (EV) drives, hybrid electric vehicle (HEV) drives and related charging systems. Other significant applications include solar power inverters, uninterruptable power supplies (UPS) and industrial motor drives. RO-LINX PowerCircuit busbars fill the gap between printed circuit board (PCB) power distribution solutions and higher power laminated busbar systems, such as Rogers' highly regarded RO-LINX laminated busbar products.

RO-LINX PowerCircuit busbars combine the performance features of power PCBs and laminated busbars. RO-LINX PowerCircuit busbars are highly engineered solutions for multilayer power distribution delivering 2optimal thermal management. Unlike two dimensional (2D) power PCBs, PowerCircuit busbars can be made in three dimensions (3D) to reduce weight and footprint and to conform to specific engineering designs to maximize efficiency. In addition, PowerCircuits eliminate assembly steps at the end user reducing complexity and sources of error.

Traditional power PCBs can handle up to 100 A current due to limited conductor layer thickness. Laminated busbars serve much higher power applications, generally at current levels from 500 A to more than 1000 A. RO-LINX PowerCircuit busbars fill the gap in designs for low to medium voltages and current levels. They are subsequently ideal for applications at current levels from 100 to 500 A, such as industrial variable frequency drives and HEV or EV motor drives. Furthermore RO-LINX PowerCircuit busbars can perfectly be combined with industrial mounting of functional components such as capacitors, sensors, and IGBTs.

RO-LINX PowerCircuit busbars draw from Rogers' extensive multi-decade experience in developing laminated busbars and specialty materials, such as their RO-LINX laminated busbars. The new RO-LINX PowerCircuit busbars incorporate a closed mold design, using carefully selected materials engineered for high performance reliability in applications subject to conditions of high vibration and temperature cycling, such as in EV or HEV drives. 3D designs are well suited for medium to high volume assembly and most soldering processes. The RO-LINX PowerCircuit busbars are also compatible with a number of different interconnect systems, including press fit, bolted-on, riveted, and common soldering methods assuring functional compatibility with today's and tomorrows assembly technologies.

RO-LINX PowerCircuit busbars offer excellent thermal management properties and achieve high power efficiencies while minimizing switching losses and reducing dangerous partial discharge and transients. They are ideal for use at lower to medium voltages, to about 690 V, and are compact and lightweight enough to support the latest power electronics designs in EVs and HEVs plus other mobile applications. For more information on RO-LINX PowerCircuit busbars, visit http://www.rogerscorp.com/pds.



Rogers Corporation (NYSE:ROG) is a global technology leader in specialty materials and components that enable high performance and reliability of consumer electronics, power electronics, mass transit, clean technology and telecommunications infrastructure. With more than 179 years of materials science and process engineering knowledge, Rogers provides product designers with solutions to their most demanding challenges. Rogers' products include advanced circuit materials for wireless infrastructure, power amplifiers, radar systems, high speed digital; power electronics for high-voltage rail traction, hybrid-electric vehicles, wind and solar power conversion; and high performance foams for sealing and energy management in smart phones, aircraft and rail interiors, automobiles and apparel; and other advanced materials for diverse markets including defense and consumer products. Headquartered in Connecticut (USA), Rogers operates manufacturing facilities in the United States, Belgium, China, Germany, and South Korea, with joint ventures and sales offices worldwide. For more information, visit

www.rogerscorp.com

Digital Controller Provides Real-Time Adaptive Loop Compensation

Using Real-Time Self-Compensation Technology, Controller Improves System Efficiency while Providing Accurate Telemetry Information and Supporting >50 PMBus™ Commands

Powervation Inc., the pioneer in adaptive digital power management IC solutions that maximize system efficiency and improve field reliability, today announced the PV3012, the company's new dual phase digital controller with Auto-Control®.

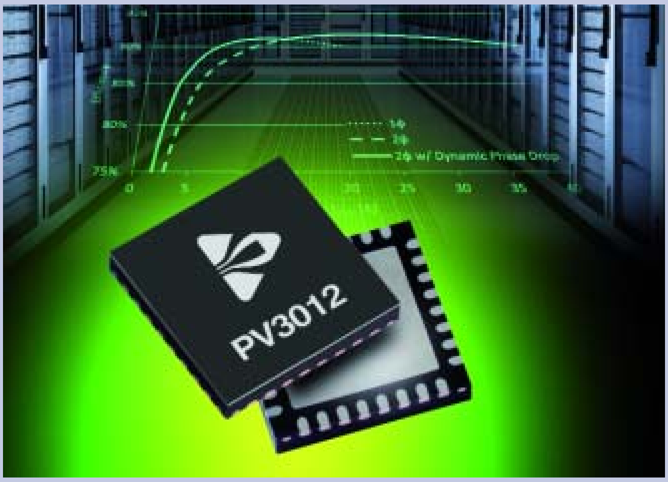
Auto-Control® is the industry's first and only real-time adaptive loop compensation. This real-time, active technique balances the trade-offs between dynamic performance and system stability on a cycle-by-cycle basis and does not rely on determining the compensation during power supply start-up or only occasionally while in use. This is a key advantage for designs that use efficiency maximization techniques like phase add/drop and for applications that continually run with infrequent power cycling. Additionally, since self-compensation occurs on a cycle-by-cycle basis, Auto-Control® is able to continuously adjust according to changes in temperature that occur while the power supply is in use, and account for other factors such as aging and drift.

PV3012 can provide ±0.5% VOUT set-point accuracy and the converter's output can be configured from 0.6 V to 5.5 V using PMBus™ commands or with an external resistor to access standard and DOSA VOUT set-point tables. Phases may be automatically added or removed as the load varies, maximizing efficiency over the load range. Additionally, with Powervation's Digital Stress Share (DSS™), multiple PV3012 devices may be used in parallel to increase the number of phases supporting the application's load.

PV3012 is based on a lean DSP/RISC dual-core architecture with a precision data acquisition system that enables the Auto-Control® algorithm to run in firmware; the result is a high performance voltage regulator that is able to support applications that demand potential load flexibility or use loads that may change over the lifetime of the power supply. PV3012 is designed to work with all leading MOSFET drivers and is a fully protected DC/DC solution. This feature rich solution reduces component count without sacrificing important features.

This PMBus™ compliant controller uses differential measurements and an 11 bit ADC to provide precision system telemetry of current, voltage, and temperature information, as well as fault and warning reporting over the SMBus. Additionally, to maximize system performance and reliability, PV3012 provides advanced digitally mapped temperature compensation of key parameters. PV3012's anti-fuse based non-volatile memory (NVM) is specified from -40 °C to 125 °C with a 20 year data retention rating; using the on-board NVM, users have access to eight configuration tables with each table providing 59 configuration parameters for user adjustment & customization.

Comments Powervation's Director of Product Marketing, David New: "Working with key networking and computing customers, we've been able to tailor the performance of our product to the needs of the applications. As a digital, programmable solution, the PV3012 and our graphical user interface design tool provide our users with a full set of configurable features that most solutions are unable to achieve. Using our DCR sense method with calibration, PV3012 has shown 3% current measurement and reporting accuracy, even under difficult conditions such as light load."



Targeting POL, high current ASIC, and FPGA for networking, communications, server, storage, and advanced power module applications, the RoHS compliant PV3012 is sampling now in 32-lead QFN packaging.

Powervation delivers breakthrough digital power management IC solutions for designers of Communications, Computing, and power Point-of-Load systems. The company's digital power controllers with its patented Auto-Control® technology is the industry's first, and only real-time adaptive compensation for DC/DC controllers, which delivers significant customer benefits in performance, efficiency, reliability, and ease-of-use. Powervation is a private company backed by leading global VCs - SEP, Intel Capital, VentureTech, and Braemar Energy Ventures and is headquartered in Cork, Ireland, with sales/applications offices in San Jose, California and Hong Kong.

www.powervation.com

POWER MADE SIMPLE, MADE FASTER

ZL9117M: 17 Amp Digital Power Module
PowerNavigator™ Configuration Software

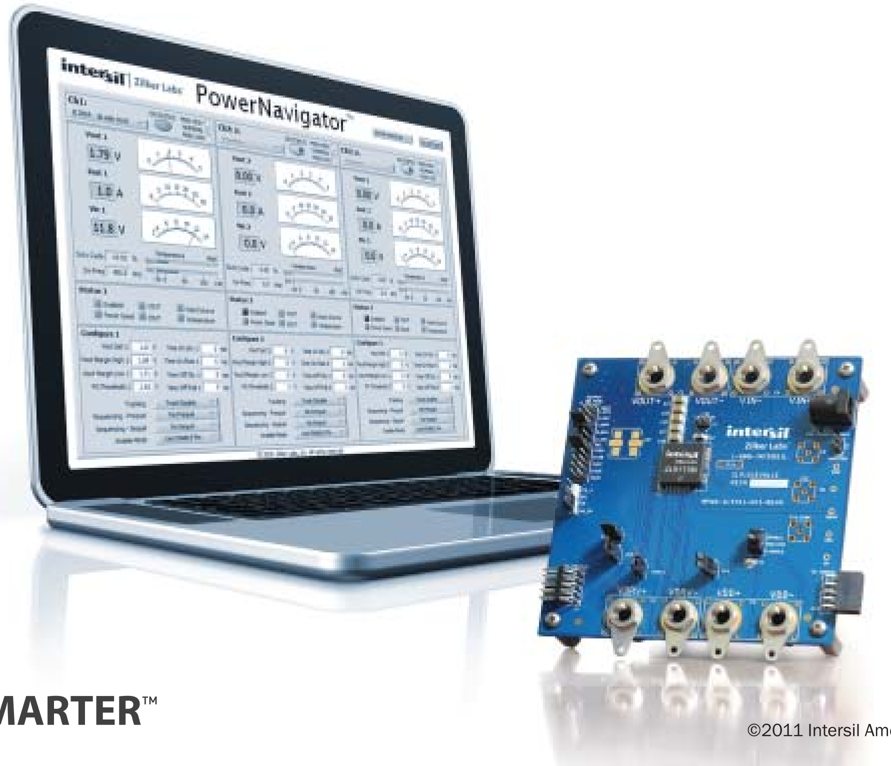
Simplifying design doesn't end with finding room on the board. Intersil's line of digital power modules is also the industry's easiest and quickest to configure. Our PowerNavigator™ GUI connects to your power design through an industry-standard PMBus interface, putting the control you need at your fingertips and delivering real-time status on telemetry, voltage, current, and temperature.

Whether you need analog or digital, the only name in power modules you need to remember is Intersil. That's just one more way we've made your design job easier.

intersil™
Zilker Labs™

Super quick. Point-and-click.

PowerNavigator™ accelerates your design with true code-free digital power configuration. Go to intersil.com/powermodules to download your complete design kit and watch video tutorial.



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New Power Management Solutions Expand Design Choices

By Pete Oaklander and Chris Young, Intersil Corporation

Designers of electronic products ranging from mobile handsets to industrial automation systems have never had as wide a selection of power management solutions as they have today. They can pick and choose from the traditional, proven analog control loop based power conversion, try the rapidly emerging digital power conversion techniques, or even use a hybrid approach.

As veteran designers know, traditional analog power solutions typically have provided the fastest loop for transient response. Lower quiescent currents are also a characteristic of the simpler analog feedback path, which leads to lower power dissipation within the IC, a particularly important feature and a benefit of the analog loop, especially, in light load situations. In addition, analog is proven and popular, and designers are comfortable with it.

But for some applications there are drawbacks. In many newer system architectures, users want to read back what is going on in the regulator, for example, measuring the current, voltage or temperature, or whether the over current protection has tripped or if efficiency is degrading due to discrete component fatigue. External supervisory ICs have been used in these applications, but they add system cost. Also, it is generally not possible to control the analog loop as easily as it can be controlled in the digital domain -- more external components are needed to configure the power supply. Compensation is another issue: most analog solutions require loop compensation, which can be tricky. One exception is Intersil's R4 modulator, a popular and patented scheme that removes that requirement.

Chris Young is Senior Manager, Digital Power Technology, Intersil Corp.

Peter Oaklander is Senior Vice President, Power Management Products, Intersil Corp.

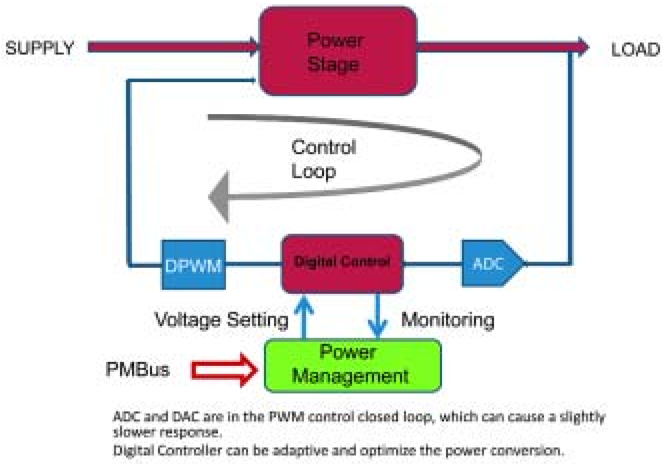

Figure 1: Flow Chart of Power Optimized Digital regulator

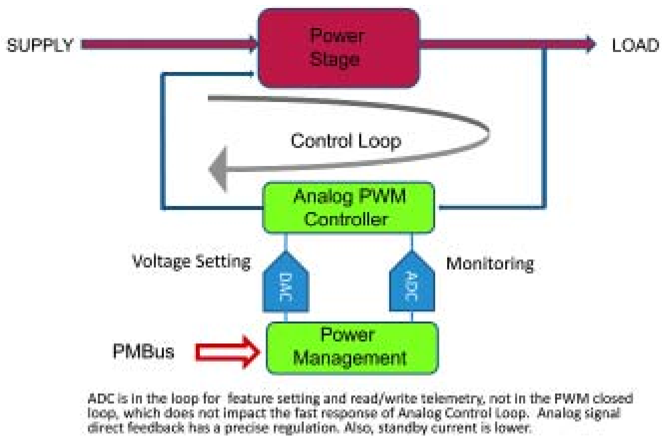

Figure 2: Flow Chart of Hybrid regulator

Compared with analog power solutions, digital power benefits are becoming better understood and put to use in applications such as communications systems. There is 'textbook' digital, which uses catalog DSPs or MCU's in a 'brute force' approach to control the loop effectively using their high processing power. This is a good approach, but the wasted power of the high-speed converter and CPU rob efficiency from the power system. More recently, power optimized digital (Figure 1) has emerged, with a full set of efficient compensation, calibration, and configuration schemes and optimization/adaptation algorithms that deliver best in class stability, transient performance and other performance metrics. It's possible to easily change the parameters such as current or voltage, or reconfigure the regulator by making firmware changes, a simple alternative compared with re-spinning a PCB or bill of materials (BOM) in an analog loop.

The result is improved time to market for a wide range of systems and products. Drawbacks to the full digital loop can include the controller cost, which generally tends to be higher, especially in applications that require significant and precise power management. But in many applications, even with a more expensive digital DC:DC controller the system BOM cost can come in lower by removing the requirement for external sequencing ICs or for discrete components used to configure the IC. Depending on the specifics of the design, full digital power solutions are not automatically higher cost than hybrids or the traditional analog loop.

Also at issue is speed. Up to now the speed of a digital loop has not been quite as fast as the fastest analog loop, because the ADC and DAC reside in the PWM, which slightly slows response time. More output capacitance is often needed to keep Vout within regulation for a load current step. Companies like Intersil continue to work on the cost and speed issues as digital power solutions evolve.

The hybrid power approach is shown in Figure 2. Hybrids are able to perform many of the functions of the full digital solution. They can read back what is going on in the DC/DC conversion and, for example, work with a smaller power budget than full digital power ICs. Hybrids also can control DC parameters such as Vout or margining or turn on/off (sequence) the regulator. In some instances, it's possible to include an on chip MCU for programming with firmware.

Hybrid regulators send commands such as output changes through a digital to analog converter (DAC) that works inside the regulator, with the ability to set current and voltage, turn on and off, and sequence. In many applications, there can be as many as 10 to 20 banks of hybrid regulators all controllable through a serial bus.

Load line is also important for applications such as x86-based systems in computing and other markets. As the load increases, for example, Vout is reduced to provide voltage positioning; it is important to maintain a linear load line. This can be controlled using a hybrid solution.

Among the design tradeoffs of a hybrid solution: a user gets some digital control and monitoring with a lower quiescent current, whereas a full digital solution, with extensive digital control and monitoring tends to require a bit larger quiescent current due to the addition of mixed signal blocks (ADC/DAC) and digital blocks such as MCUs, memory, logic and others.

Memory in digital and hybrid controllers

Full digital solutions usually incorporate memory so they can change settings or configurations, which are stored in EEPROM or Flash memory in a 'set and forget' format. Flash memory can also store measured voltage, current and other parameters, including anything that could be 'going wrong' during system operation. A hybrid tends not to have EEPROM or Flash for retaining setup or data logging.

But controllers can include memory if the application requires it, which will add layers of silicon and, as a result, some additional cost. These typically can be completely preconfigured, or provided with memory that enables the 'set and forget' capability typical of full digital solutions. Or they can be simply configured, without memory.

In many higher volume applications, where there are fewer rails but where the requirement exists for digital control and monitoring while there is less need for the full configurability of full digital solutions, the hybrid controller can prove to be a lower cost choice. However, as process geometries continue to move lower, we are headed to a point at which quiescent power dissipation in full digital regulators will approach the hybrid power dissipation levels.

The bottom line is that hybrid solutions are now coming into their own, for applications like high-end computers and servers, networking products and industrial systems, while at the same time, sophisticated full digital power solutions continue to improve and add value. The result is that designers have a complete set of choices for their system development, based on their specific cost, volume, time to market and power management requirements.

www.intersil.com

Electronics Industry Digest

By Aubrey Dunford, Europartners

GENERAL

The semiconductor industry should continue to grow at a moderate rate for the remainder of 2011 and in 2012, so Semiconductor Intelligence. Despite concerns about the overall economies in the U.S. and Europe, key end markets for semiconductors are continuing to show solid growth.

SEMICONDUCTORS

Worldwide sales of semiconductors were $ 24.9 billion in July 2011, essentially flat from prior month, but 3.2 percent higher than the same period last year on a year to date basis, so the SIA. Sales in the second quarter were down 2 percent compared to the prior quarter.

Maxim has acquired SensorDynamics, a semiconductor company that develops proprietary sensor and MEMS solutions. SensorDynamics is based in Lebring, near Graz, Austria. Maxim is paying approximately $ 130 M plus the assumption of approximately $ 34 M in debt to acquire Sensor Dynamics. According to IHS iSuppli, the total market for MEMS-based sensors is expected to be $ 7.7 billion in 2011, of which SensorDynamics gyroscope inertial sensor technology addresses about $ 900 M.

Cree, a market leader in LED lighting, acquired Ruud Lighting, a leader in LED outdoor lighting, at an estimated cost of $ 525 M. The acquisition allows Cree to increase the adoption of energy-efficient LED lighting.

To become a fabless semiconductor company, IDT intends to sell its Hillsboro, Oregon wafer fabrication facility to Alpha and Omega Semiconductor, a supplier of power semiconductors. Under a foundry service arrangement with IDT, AOS has the option to acquire the wafer fabrication facility and related assets for $ 26 M.

Crocus Technology, a French developer of magnetic semiconductors, announced the acquisition of NXP Semiconductors' MRAM patent portfolio. These patents provide fundamental MRAM intellectual property rights in multiple geographies worldwide.

Worldwide silicon wafer area shipments increased five percent during the second quarter 2011 when compared to first quarter 2011 area shipments, so SEMI.

SEMI projects 2011 semiconductor equipment sales to reach $ 44.33 billion. The forecast indicates that, following a 148 percent market increase in 2010, the equipment market will expand by 12.1 percent in 2011. In 2012, the equipment market is expected to experience a slight decrease of about 1.2 percent.

OPTOELECTRONICS

Hitachi, Sony and Toshiba have signed an agreement to integrate their small- and medium-sized display businesses, in a new company to be established. Innovation Network Corporation of Japan (INCJ), as a public-private partnership that provides financial, technological and management support for next-generation businesses, plans to invest a total of 200 billion yen in NewCo in exchange of 70 percent of the shares with voting rights of NewCo, while Hitachi, Sony and Toshiba each expect to hold 10 percent of such shares.

PASSIVE COMPONENTS

Worldwide production of PCBs grew by 19 percent over 2009 to nearly $ 55 billion, so IPC. Approximately 2,600 PCB fabricators produced an estimated $ 54.772 billion in 2010. Production grew by 6.9 percent in North America, 14.4 percent in Europe and 21.1 percent in Asia, increasing Asia's share of world PCB production to 87 percent. Rigidflex was the highest growth category. Germany's PCB industry continues its growth, with orders and sales remaining at high levels.

OTHER COMPONENTS

For € 130 M (inclusive of assumed debt) Cooper Industries acquired Martek Power, a French manufacturer of power electronic components for the military, heavy-duty transportation, aerospace, medical, telecom and hybrid/electrical vehicle markets.

Robert Bosch is to build a pilot production line in Eisenach, Germany, in order to research into materials and production processes for future generations of lithium-ion cells. It is planed that the line will produce the first samples for trial purposes from 2012, and will then be extended until it reaches an annual production volume of more than 200,000 cells by 2015.

The Electronic Design Automation industry revenue increased 16 percent for Q1 2011 to $ 1446.4 M, compared to $ 1247.0 M in Q1 2010, so the EDA Consortium. Sequential EDA revenue for Q1 2011 decreased 4.1 percent. Revenue in Europe, the Middle East, and Africa (EMEA) was up 7.8 percent in Q1 2011 compared to Q1 2010 on revenues of $ 241.8 M. The EMEA four-quarters moving average increased 7.9 percent.

DISTRIBUTION

The European semiconductor distribution market enjoyed a healthy, although slower growth in Q2/2011. DMASS (Distributors' and Manufacturers' Association of Semiconductor Specialists), reported a 13.2 percent growth to € 1.71 billion compared to Q2/2010. The first half of 2011 ended at € 3.52 billion (+22.8 percent). Eastern Europe again grew strongest, by 31.1 percent to € 241 M. For Germany DMASS reported 21.1 percent growth to € 603 M. Italy grew by 10.3 percent to € 183 M, the UK by 6.3 percent to € 138 M and France by 3.3 percent to € 122 M.

Avnet has acquired J.C. Tally Trading, an interconnect, passive and electromechanical components (IP&E) distributor in Asia with operations in Taiwan and China. J.C. Tally (140 employees) generated revenue of approximately $ 90 M in calendar 2010.

Avnet also acquired Prospect Technology, an electronic components distributor with operations in Taiwan. Prospect Technology provides technical support, module solutions and circuit design support to help customers expedite product development. Prospect Technology generated revenue of approximately $157 M during the 2010 calendar year.

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.

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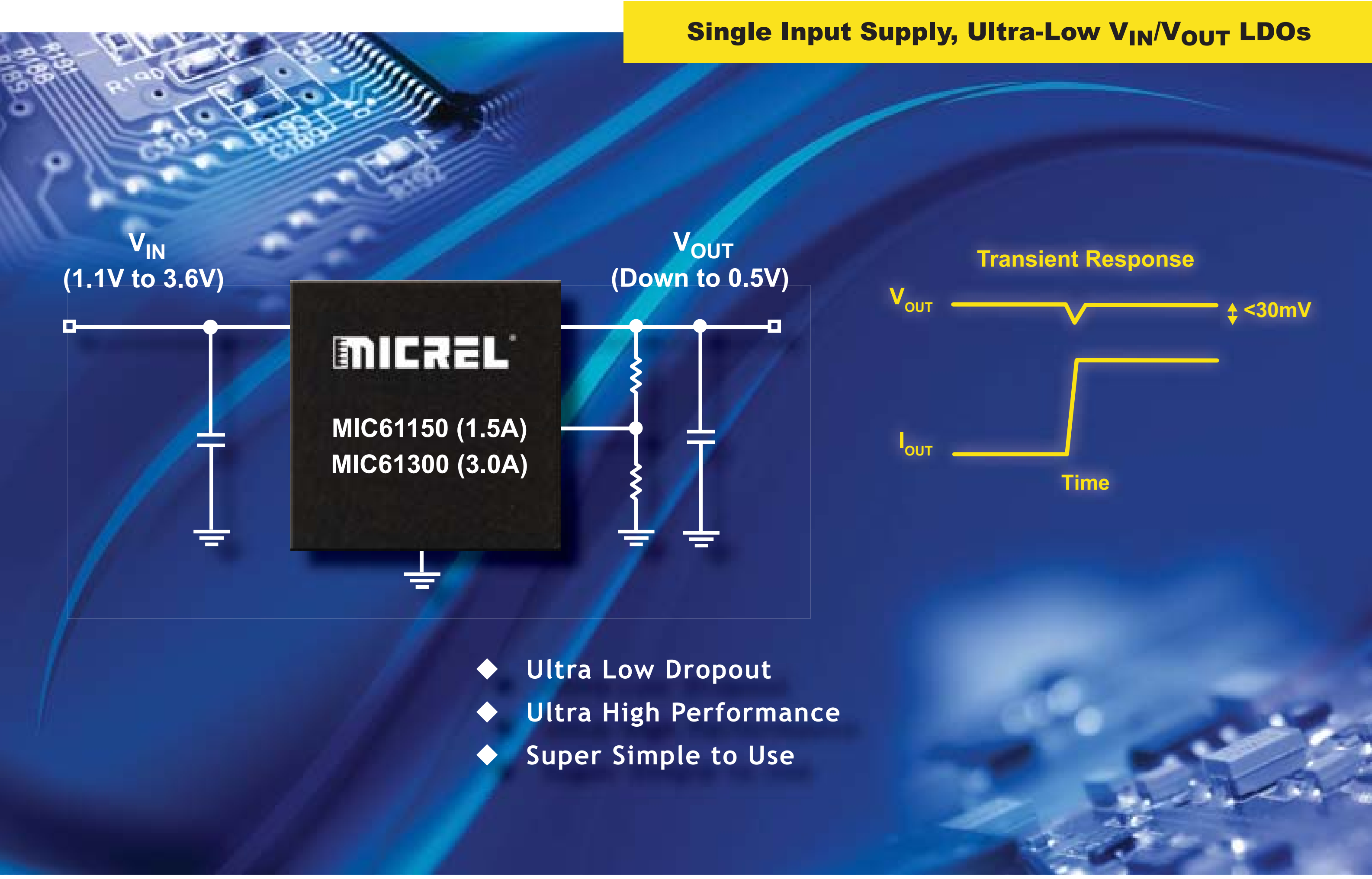
Simple, High-Current LDOs for Powering Next Generation FPGAs, DSPs and ASICs



Powering today's FPGAs, ASICs and DSPs involves the challenge of supplying high currents in very low input-output voltage conditions. This is where Micrel's new family of ultra-low V_{IN}/V_{OUT} LDOs excels. These new Micrel LDOs offer the convenience of adjustable output voltages as low as 0.5V with input voltages as low as 1.1V, while supplying up to 3A of output current.

To further enhance flexibility and reduce overall cost for the power supply designer, Micrel has eliminated the additional bias supply! Unlike other solutions, the MIC61150 and MIC61300 do not require an additional bias supply and hence offer clean and simple single input supply operation.

For more information, contact your local Micrel sales representative or visit Micrel at: www.micrel.com/ad/mic61xxx.

Key Applications

- FPGA/DSP Power Supplies
- ASIC/Microprocessor Power Supplies
- Telecom/Networking Cards
- Point-of-load Applications

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Immediate High Growth Projected for AC-DC Market

By Richard Ruiz, Research Analyst, Darnell

In spite of the current economic slowdown, the global ac-dc power market is projected to grow from $17 billon in 2011 to over $22.3 billion in 2016, a compounded annual growth rate (CAGR) of 5.6%. Not only is the overall market growing, it is undergoing a significant shift in demand characteristics that is expected to result in new product designs and sales opportunities. In fact, emerging applications such as the Smart Grid, Solid-State Lighting (SSL), and Building Automation will surge, with over 18% compound annual growth achieving over $750 million in sales in 2016. This is one of several important findings in the tenth edition of Darnell Group's AC-DC Power Supplies: Worldwide Forecasts.

One of the more important findings is that the emerging applications – Smart Grid, SSL and Building Automation – are growing three times faster than the traditional applications, and are projected to make up an increasing portion of the unit market over the forecast period, growing from 22.0% to 32.0% of the unit market share.

The Smart Grid segment is a new addition to this report and is expected to make an immediate impact, as it is projected to be the fastest-growing segment over the forecast period. Made up of three applications – smart meters, electric vehicle chargers and smart appliances – the Smart Grid segment is expected to be one of the more promising longer-term areas of opportunity. Manufacturers need to know, however, that the power supplies currently used in smart grid applications are primarily captive areas of production.

Although projected growth in the Smart Grid segment is expected to be primarily captive, it does not mean there will be no opportunities for power supply manufacturers. As the smart grid matures and expands, new regulations and standards will be adopted, technologies will change, and new products will be announced. According to a number of smart grid insiders, that is when the opportunities for merchant power supplies will develop, as it will become too complicated and expensive to manufacture a custom power supply for each new application. This is expected to be a longer-term opportunity.

Solid-State Lighting is expected to be one of the beneficiaries of the growing smart grid market. Solid-state lighting specifically refers to the type of lighting that utilizes LEDs, organic light-emitting diodes (OLED), or polymer light-emitting diodes (PLEDs) as sources of illumination rather than electrical filaments, plasma or gas. LEDs are already on the market in a number of applications and are already accepted as a reliable technology.

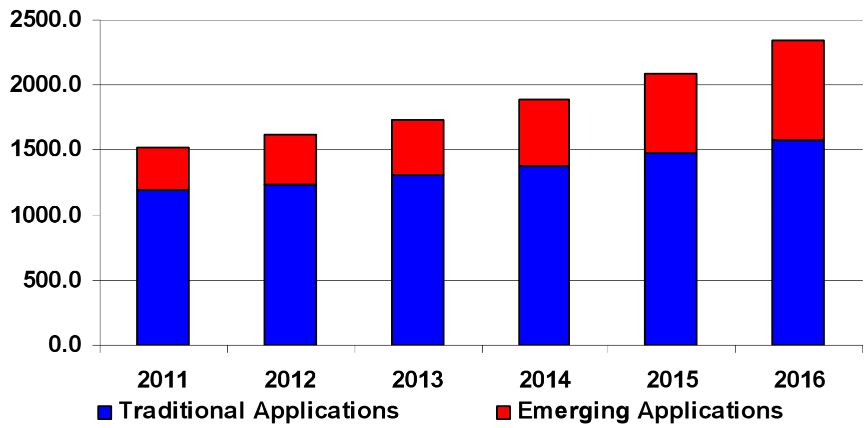

Figure 1: AC-DC Market Shifts, Emerging vs. Traditional Applications (millions of units)

By 2020, LED lighting is anticipated to saturate nearly half of the US commercial, industrial and outdoor lamps market. Over $4.5 billion in US federal grants have already been directed towards funding project development and investment. LED streetlights and smart grid technology have been combined, and systems have been rolled out in a growing number of California cities, providing one of the better opportunities for the embedded ac-dc power supply market. In light of this fact, the emergence of ac-dc power supplies for LEDs will require power manufacturers to focus on designs that are industrial grade, rugged and can be used outdoors.

Billboards are another emerging market with a tremendous amount of potential. Digital LED billboards and large signs along roads and highways and in commercial, sports and entertainment facilities are large and require multiple power supplies. Currently, of the half million billboards in the US, only about 1 in 750 of them use LED lighting solutions. This means the market potential for digital signage has barely been tapped, and a huge market for embedded power supplies exists.

Building Automation Systems (BAS) are another new area of opportunity identified for embedded power supplies. Heating, ventilation and air conditioning (HVAC), lighting and security control systems have traditionally been split, but there is a trend towards merging these systems into a more efficient and cost-effective building management system. In fact, HVAC and lighting control alone comprise more than 70% of a building's energy consumption, making these segments one of the most promising areas of application. Opportunities exist in both new construction and existing facilities. As an example, more than 80% of commercial buildings in the US are more than 10 years old, representing a significant opportunity for energy efficiency retrofits.

Traditional applications will also play a large role in the growth of the embedded power supply market. Both the Communications and Computer segments are expected to see substantial growth and be among the most reliable industries for the power supply market. Driven by desktops, servers, peripherals and a number of other applications, the computer market will see a mix of both high average selling prices (ASPs) and large commoditized unit sales, resulting in the largest overall dollar market of any application between 2011 and 2016. In contrast, the smaller communications segment will be driven by just four applications, including Customer Premises Equipment (CPE), CATV, Set-top-boxes and Power-Over-Ethernet (PoE), which make up not only a large dollar market, but the largest dollar market share increase over the forecast period.

Due to a number of factors, it is expected that pricing will not follow the traditional patterns, which includes a steady annual pricing decline. As a result, the average selling prices (ASPs) of ac-dc power supplies will be much flatter than “normally” expected. In fact, in the first year of the forecasts, the ASPs for a number of applications will see a small increase, while others will see either no increase at all, or will realize a smaller-than-expected decline.

The pricing adjustments will have the most impact on the larger, more established segments in this report – the Communications, Computer and Consumer markets. Many of the applications in these segments rely on large volume, highly commoditized power supplies, and any negative influence in price is more likely to result in shortages and increased material costs for power supply manufacturers. Although the unit projections remain the same, each of the sub-segments will experience either an increasing or flat average selling price in the first year.

Darnell Group does not expect consistent growth over the next five years. Projected growth will be significantly slower over the first several years of the period before returning to normal. Even though the immediate effect might appear negative, it is lessened by the flatter pricing in the first year. In addition, the effect of the slowdown on growth will vary by segment, with some applications showing increased dollar sales, before returning to normal pricing trends.

Over 90 tables and graphs and illustrations are presented in this report covering the embedded power supply market for 41 applications. This comprehensive analysis provides decision makers with a detailed and insightful look at the current and future opportunities available in the embedded ac-dc power supply market.

www.darnell.com/acdc

10th Anniversary of htc-network the Specialist in Hightech Executive Search

Interview with Klaus Nolte, Founder of htc-network by Bodo Arlt, Editor BP

Bodo Arlt: 10 years htc-network – my congratulation Klaus. Let´s start our interview with the changes in executive search over the past 10 years and the major success criteria in recruiting services today.
Klaus Nolte: I observed significant improvements in the experience and knowledge of the recruitment consultants over the past years, especially in the hightech industry. 10 years ago you found in our business generalists as well as 25 year old junior "consultants" with little to no job and industry experience. This isn't acceptable anymore, our business matured. The competence of the consultant and the quality of his service are the major criteria for a successful consulting business today.

Bodo Arlt: How does htc-network approach the high quality expectations of its customers?
Klaus Nolte: Already 10 years ago htc-network and all of its partners had strong expertise and long term experience in the hightech industry. Our consultants cover all important steps in the search process - no delegation - and maintain a long-term relation with our clients. This was, is and will be the base of our success.

Bodo Arlt: How do you start a search with your customers?
Klaus Nolte: As in any business, the first question to your customer should be: "What do you need?" Our recruiting service starts with the definition of the job profile in close cooperation with our customer. The result is sometimes radically different from the original customer brief. The experience of the htc-network consultant helps to match customer´s expectation and reality, short term manpower need and customers long term strategy as well as the future challenges of the industry. So in a short form: It is important to identify, what the customer really needs!

Bodo Arlt: How do you identify suitable candidates?
Klaus Nolte: Most candidates are identified through our network, which is already an excellent reference. We guarantee by our intense qualification process covering the biography, experience, knowledge as well as the personality of the candidates the best possible match of customer´s needs with candidate's expectations.
Also you have to take into consideration, candidates expect more than just a job offer today. Our intense assessment is the solid base for a competent, individual career coaching. This helps us very often to motivate candidates for a move, which they didn't consider when they receive our first call.

Bodo Arlt: Do you see Internet Career Platforms and Job Portals making recruiting consultants redundant?
Klaus Nolte: So called "recruiting services" which simply screen a range of candidates, who might be the right match and supply CV's

Klaus Nolte, MSEE
Professional Experience:

Texas Instruments	- Design- and Process Engineering Positions
National Semiconductor	- Director Mixed Signal Division
Concurrent Computer	- GM Europe
htc-network Executive Search	- Owner

of those, who are currently available are strongly affected. They will become probably medium to long term redundant because of the internet job offering. Professional recruitment consulting on rarely available specialist- and management competencies are not affected at all. Often the candidates we approach haven't even thought about changing their job before they get a first call from us.

Bodo Arlt: What is the mayor challenge in the executive search business today?
Klaus Nolte: This hasn't really changed over the years. The identification of the real customer needs, the real candidate experience, - competence, - personality and the matching of both are the major challenges in our business. The htc-network candidate interview video as well as the hiring manager profile video will be presented to our customers and candidates at an early stage in the process. This transparency helps to match expectations with reality on both sides. The retention rate of candidates placed by htc-network is well above industry average.

Bodo Arlt: What is the industry focus of htc-network?
Klaus Nolte: Over the last years the significant growth of power electronics driven by the automotive-, industrial- and new energy – industries has changed our focus towards this market segment. Europe and especially Germany has developed a strong market position already and a significant need for candidates, who can support the growth. 10 years ago the IT, Internet and Communication Industry had the highest need for hard- and software engineers. Today I would recommend to any student starting an engineering study, that she/he should have a closer look towards the power electronics industry, as we do!
A good example of this trend is an actual project, which we are working on: A Technology Development Centre for High-Voltage Semiconductors in Munich. This was started as a Green Field Project last year. The motivation of our customer to build this Technology R&D Centre in Munich is Germany´s engineering base and strong position in the Power Electronics Industry.

Bodo Arlt: Thanks for this interview Klaus. I wish you all the best, good luck and success for your and htc-network's future.

www.htc-network.com/en/network

Fairchild's Board of Directors announces:

Foundation of Technology Development Centre for High-Voltage Semiconductors in Munich

The mission of this team is to advance Fairchild's Technology and product portfolio for High Voltage applications for Industrial, Automotive and Consumer markets to take over the leading edge position.

This newly formed R&D centre, located in Munich, provides opportunities to their members to closely work with existing global Fairchild Technologists in US, Sweden and Korea, as well as to work in partnerships with Research institutes and hand selected partnership programs with competitors.

The scope of this team includes

- Device and process simulation
- Design and layout experts
- Characterization and testing lab
- Experts for process integration, device architecture, novel materials and module development

For the initial phase, we have opened positions for:

Device Simulation Experts

Job description:

You are responsible to develop and optimize device architecture for Fairchilds next generation IGBT generations, optimize static and dynamic device performance and work with local and Korean process experts to create prototypes.

Job requirement:

We are looking for highly innovative and self-motivated individuals, Master or PhD degree in Electrical engineering, Physics or similar, fluency in English required.
At least 4 years experience in High Voltage Discrete device development, using state of the art simulation software, preferably Synopsis TCAD process and device simulators. Solid knowledge of state-of-the art IGBT device architecture required. 3D simulation, device layout experience and packaging know-how is of advantage but not mandatory.

Device Modelling Experts

Job description:

You will be spearheading a team for device parameter extraction and modelling including behavioural and (semi)-mathematical models for High Voltage devices. Near term emphasis is put on Trench IGBT and Superjunction MOSFET developments.

Job requirement:

We are looking for highly innovative and self-motivated individuals with Master or PhD degree in Electrical engineering, Physics or similar; fluency in English required.
At least 3 years experience in High Voltage device test keys drawings, parameter extraction and device modelling. PSPICE - equivalent circuit and knowledge of electro-thermal behaviour for Power devices is required. Device layout experience would be beneficial.

IGBT Technologist

Job description:

You will be shaping a global team with the distinct focus in IGBT development, focussing on device architecture, new process modules and innovative package solutions for automotive and industrial applications.

Job requirement:

We are looking for a senior technology expert with Master or PhD degree in Electrical engineering, Physics or similar with profound semiconductor background in the field of high-voltage technology.
You need to have at least 10 years experience in IGBT development, wide knowledge of process, device and package topics. Experience with HV-MOSFETS, Superjunction, GTO's or IGCT's as well as experience on specific automotive and industrial applications will be preferred.

We offer:

- Start-up spirit in highly inspirational and expanding team in Muenchen
- Space for fundamental and scientific research
- Very competitive, performance oriented compensation schemes
- High strategic impact and visibility within a global company

Contact:

Dr. Thomas Neyer
Vice President and Fellow of Fairchild Semiconductor
Head of the Fairchild Technology Center in Munich

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eMail.: thomas.neyer@fairchildsemi.com

Performance to Value

The Turning of the Tide in Power Semiconductors

Power semiconductors are not new. Indeed the applications where they are typically used are well established; however what is changing rapidly is the rate of power semiconductor adoption. 15 years ago a power electronics based SMPS for your television, video recorder or laptop computer was considered 'high-end'. A car filled with wafers of silicon to control its electric motor was 'emerging' while a wireless charging system for your iPhone was the stuff of science fiction films!

By Benjamin Jackson, International Rectifier, El Segundo

So what has changed – did the MOSFET and IGBT technology suddenly get markedly better, well not really. For sure the Rds(on) of a MOSFET today is considerably lower than it was 15 years ago but that does that mean that the MOSFET can be used in applications which were previously out of bounds for power semiconductors. So what was the key to take the power semiconductor from niche to main stream? As with so many new technologies the main limitation is not so much the limited capability of the new technology but more the dominance of the incumbent technology. The value of the traditional solutions was just too high. In the last 10 years this has changed and moreover power semiconductors are now the preferred option. But what are the technical steps which are accelerating this change?

$$Value = \frac{Performance}{System\ Cost} \quad (1)$$

For the last 30 years the power semiconductor companies have been chasing along one axis: performance. In order to make the MOSFET easier to drive the gate charge needed to come down. In order to make the heat sinking manageable the Vce(on) and Rds(on) needed to be lower. All this was aimed at increasing the value proposition of the power switch by giving it more performance. Indeed this exercise was necessary to ensure that the power semiconductor was technically competitive against the traditional solution. However there is another axis which is now being pursued – how cost effective the power semiconductor solution is. So how are semiconductor companies addressing the lower half of our value proposition equation? One way would be through further cost effective manufacturing and indeed this has a role to play, but perhaps more important is making the power switch itself more efficient and no better example than the standard MOSFET and its Rds(on).

Remembering that MOSFET is made up of thousands upon thousands of cells, and the more cells that are placed in parallel the lower the Rds(on) it is easy to make the connection between the on resistance and the MOSFET's area, or die size as it is commonly known. Figure 1 shows the difference in current flow between a planar and trench MOSFET it can be seen that with the vertical path in the trench design the structure is inherently more efficient at packing more cells together in a small space than planar structures and thereby reducing the Rds(on).

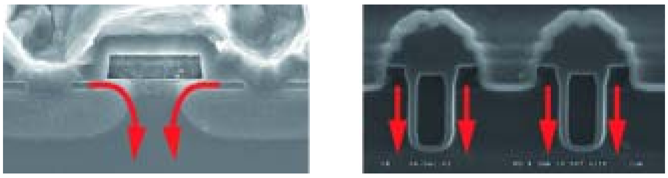

Figure 1. Current flow through planar and trench MOSFETs

This property allowed a smaller die to be used in a trench technology for the same Rds(on) than a planar technology. More commonly known as 'die shrinking' this practice enables successively better silicon technologies to achieve the same on resistance in a smaller die size and thereby at a lower die cost. However there are two limitations of die shrinking. Firstly the finer pitch and increasingly complex trench structures usually cost considerably more to make, so while the die size may go down the per unit area cost of the wafer is going up. Inevitably semiconductor manufactures aim for trade off where the die size reduction more than offsets the extra cost per unit area, but this implies you can carry on making the die smaller and smaller albeit with more costly technologies. And herein is the second and more fundamental limitation which is particularly pronounced in power semiconductors.

Power is the key word and equation 2 shows the factors which limit the power dissipation in a power MOSFET.

$$Pd = \frac{T_j - T_A}{R_{thJA}} \quad (2)$$

Where Pd is the power dissipated in the semiconductor switch, T_j is the junction temperature, T_A the ambient temperature and R_{thJA} is the total thermal resistance from junction to ambient. Linking power dissipation to current through the MOSFET (3) and then substituting 3 into 2 we end up with the relationship in equation 4.

$$P_d = I_D^2 R_{DS(on)} \quad (3)$$

$$I_D = \sqrt{\left(\frac{T_j - T_A}{R_{thJA}}\right) / R_{DS(on)}} \quad (4)$$

Does your digital power-supply design require high performance flexible on-chip peripherals?...

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- Pin range – 18 to 64
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dsPIC33F 'GS' Series Plug-In Module – MA330024

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Equation 4 shows that the power handling capability is limited by the Rds(on) and the junction to case thermal resistance. With the new technologies we have successfully reduced the on resistance, but by going to smaller and smaller die the thermal resistance increases and thereby limits the current handling capability. In addition we must also consider how the current gets in and out of the die – through wire bonds – figure 2 shows a typical arrangement.

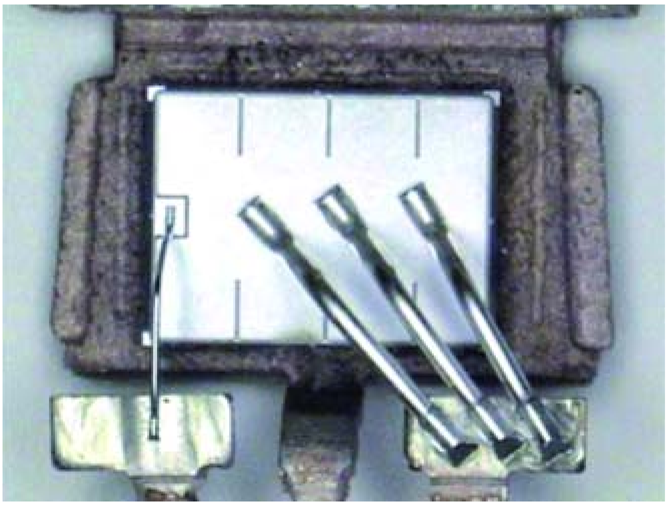

Figure 2:
An example of wire bonding inside a power semiconductor device

Naturally to carry a given current the wires must be of a sufficient diameter to avoid excessive heating and ultimately to prevent fusing. At the same time there must physically be enough room on top of the silicon to attach the bond wires. This combined with the thermal limitations of smaller die mean that the practice of 'die shrinking' for power switches is becoming more and more challenging and perhaps soon to reach a fundamental limit. Investing in incredibly complex semiconductor structures to enable the die shrink is a case of diminishing returns. What is needed now however are simpler and more cost effective semiconductor structures and more scrutiny on refining what we put around the semiconductor namely the packaging which limits both the thermal and on resistance performance of the device.

In the automotive power electronics industry there is no better example of the constraints that a package puts on the silicon by looking at a state of the art 40V D2Pak MOSFET. Today the very best of such devices have a maximum Rds(on) of around 1mOhm however of this value around 50% of the Rds(on) can be attributed to the wire bonding and the package. This is a significant impedance to the value of the device, after all the majority of the expense of such devices is in the silicon and not the package. Indeed when 5mOhm was considered advanced technology 0.5mOhm of extra resistance in the package was not an issue – today the picture has changed dramatically. Therefore it is possible to see some clear examples of how reducing the thermal and electrical resistance of the package can deliver far better value and use of the semiconductor inside.

The TO-262 is a well-established power package (see figure 3) which is widely used in many power applications, particularly those where the power devices are placed on a high performance thermal substrate such as IMS, separate from the control board. The advantage of this assembly is that very good thermal performance can be achieved; the disadvantage is the associated electrical performance of the leads and the mechanical challenges in mass production.

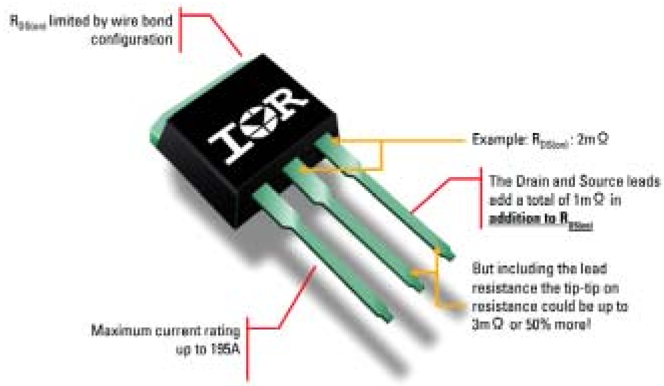

Figure 3. Limitations of the existing TO-262 package.

As shown in figure 3 the leads of the TO-262 actually add around 1mOhm in addition to the RdS(on) max that is specified on the data sheet. When considering a popular 2mOhm MOSFET in such a package this would mean that the total resistance at the end of the leads would be 50% higher. While the electrical impact of this can be accommodated in the design of the system the joule heating of the leads and the associated reliability concerns at high currents is not as easy to asses. Furthermore due to the wire bonding configuration inside the package the maximum current handling capability is limited along with the Rds(on) performance. To this end International Rectifier set about to understand how more value could be achieved with this well established package. The new WideLead is the result and shown in figure 4.

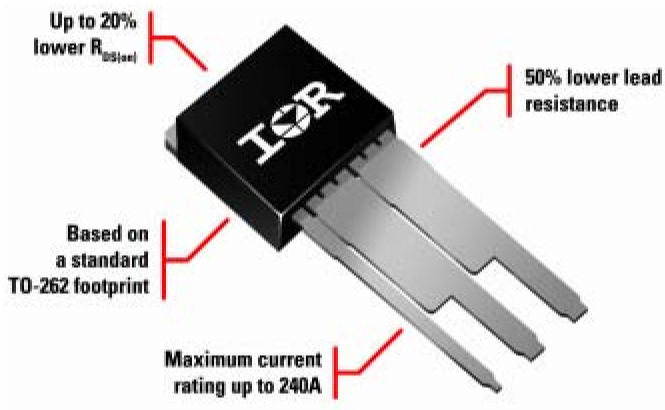

Figure 4.
Enhanced performance with the new WideLead TO-262 Package

As can be clearly seen in in figure 4 while the fundamental footprint, overall form factor and construction of the WideLead remains the same as a traditional TO-262 it has, as the name suggests, significantly wider leads! This might appear to be an obvious or even trivial step, but the results on performance are significant. At a first pass by greatly increasing the cross sectional area of the leads the lead resistance was slashed by 50% to around 0.5mOhm. This instantly allows a customer in a through-hole assembly to access more of the performance of the silicon. At the same time the packaging designers did an overhaul of the internal lead frame design, enabling an improved wire bonding configuration to be accommodated. This has the benefit of firstly increasing the maximum current rating of the package from 195A to 240A and at the same time reducing the electrical resistance between the die and the outside of the package – thereby reducing the Rds(on) by up to 20% for the same MOSFET die! Figure 5 compares and contrasts some of the key data sheet parameters for the standard and WideLead versions of these AEC-Q101 grade components.

Part number	V_{DSS} (V)	$R_{DS(on)}$ Max. (mΩ)	I_D Max. (A)	Packages
1324 Family				
AUIRF1324L	24 V	1.65 mΩ	195 A	Standard TO-262
AUIRF1324WL	24 V	1.3 mΩ	240 A	WideLead TO-262
3004 Family				
AUIRFSL3004	40 V	1.75 mΩ	195 A	Standard TO-262
AUIRF3004WL	40 V	1.4 mΩ	240 A	WideLead TO-262

Figure 5: Comparison of electrical performance between identical die housed in standard TO-262 and the WideLead TO-262 Package

Comparing the performance on paper and in an application setting however are two very different things. To this end the AUIRF1324L (standard TO-262) and AUIRF1324WL (WideLead) – both with identical silicon were put on an identical test. Varying levels of current were run through the parts for extended periods of time and the lead and junction temperatures measured. Figure 6 shows the results of the evaluations. It can be clearly seen that the WideLead part runs cooler, in fact at a 60A current the WideLead was around 39% cooler than the standard TO-262, the lower resistance in the leads and wire bonds generating less heat in the part. At a system level this offers the benefit of either being able to reduce the size, cost and weight of the cooling arrangement or perhaps enable a lower thermal grade of PCB material to be used for a given current while at the same time reducing conduction losses and improving efficiency. Alternatively by playing the graph horizontally it can be seen by taking a fixed operating temperature of say 120°C a 30% higher current can be achieved with the WideLead, again due to the revised wire bonding inside the package and the lower lead resistance courtside of the package. In both cases the silicon is the same so by improving the package the overall value of the existing silicon is greatly improved. The device is more efficient.

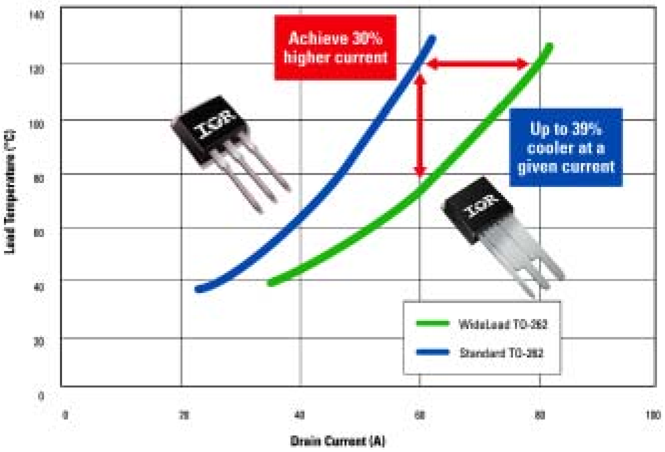

Figure 6: Comparison of performance between two identical MOSFETs accommodated in different packages; the standard TO-262 and the new WideLead TO-262.

At this point it is worth remembering that nowadays an increasing majority of designers choose surface mount components for the easy of manufacture and design. One of the innovations here is the bond wireless Automotive DirectFET package. The benefits of this package have been well documented, but with increasing adoption more system level data for this package is now available in particular comparing it to the standard D2Pak. Be eliminating the bond wires the DirectFET achieves three fundamental system level benefits:

- Very low parasitic inductance
  → reduced ringing and excellent high frequency performance
- Very low package resistance
  → reduced conduction losses and improved efficiency
- Ability to cool the package from top and bottom
  → flexible assembly, reduced thermal resistance

One automotive example of Automotive DirectFET at work is in an inverter such as an electric power steering system, fuel or water pump or cooling fan applications traditionally dominated by the D2Pak and DPak packages. However in the DirectFET by eliminating the wire bonds the value of the silicon is unharnessed. Firstly the 0.5mOhm package resistance of the D2Pak is considerably higher than the 150µΩ which the DirectFET package contributes to the Rds(on) and secondly by freeing up the space on top of the die (traditionally used for wire bonding) the part can be cooled through the top side via thermal interface material directly to a heat sink. This has the benefit of not having to pull the heat through the PCB on the way to the heat sink as is necessary with a D2Pak (see figure 7).

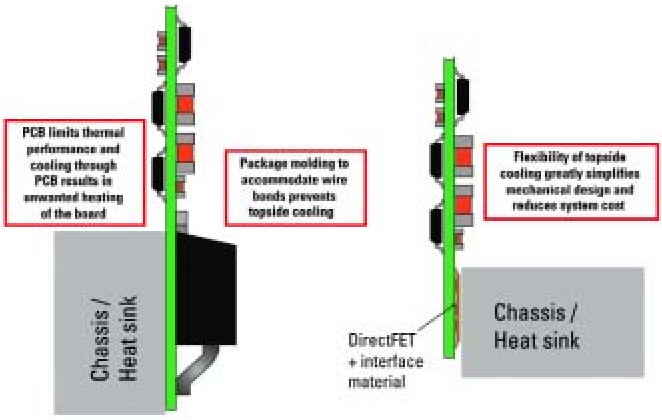

Figure 7:
Comparison of cooling arrangements for a DirectFET and D2Pak

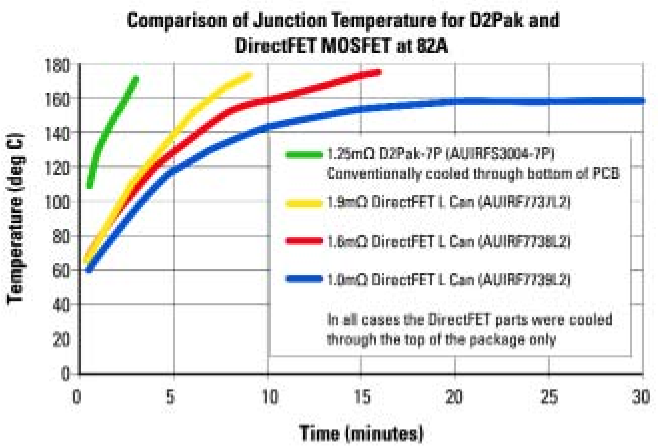

Figure 8 Comparison of junction temperature of inverters based on D2Pak-7P and DirectFET devices

To evaluate the performance of the two configurations two identical 3 phase inverters were constructed, one accommodating various sizes of 40V DirectFET devices from 1.9mOhm to 1mOhm maximum Rds(on) and the other with a 40V 7 pin D2Pak package (AUIRSF3004-7P) with an Rds(on) max of 1.25mOhm. The boards were run at various currents and the junction temperatures of the MOSFETs were measured – figure 8 shows the results of how Tj varied over time.

The difference between the top side cooled DirectFET and the 7 pin D2pak (cooled in the traditional manner through the PCB – see figure 7) is clear. A significant difference in performance attributed purely to the Rds(on) and conduction losses would be expected between the 1.25mOhm D2Pak-7P and the 1mOhm AUIRF7739L2 DirectFET. However the true demonstration of the advantage of cooling through the top side of the part is shown when comparing the AUIRF7737L2 (1.9mOhm max) with the D2pak-7P. Despite the AUIRF7737L2 having an Rds(on) that is over 50% higher than the D2Pak-7P the part runs cooler. This offers several benefits; primarily the higher Rds(on) and therefore the more cost competitive DirectFET can be used in place of the D2Pak-7P. At the same time the DirectFET also has a 60% smaller footprint than the traditional package and by cooling through the top of the package and not through the PCB, both sides of the board can be used for components. Alternatively higher current and power could be achieved for a given operating temperature, this can be hugely beneficial in an automotive environment where space and weight are confined and where the new electric systems are competing with traditional engine driven systems which typically have a very high power densities.

Power semiconductor manufacturers will always strive to improve the performance of the semiconductor, but the examples shown here highlight how what goes around the device can make a huge difference in terms of performance, cost and ultimately value. In the early days of power semiconductors much fanfare was given to the efficiency savings which a power electronic solution could bring against a traditional solution. Today with device performance at a level that satisfies many demanding applications the emphasis must now shift to simplify and refine the semiconductor and packaging technology. Ultimately this will improve the efficiency of the system but more over the goals has to be to deliver better value by improving the efficiency of the of the power semiconductor switch itself.

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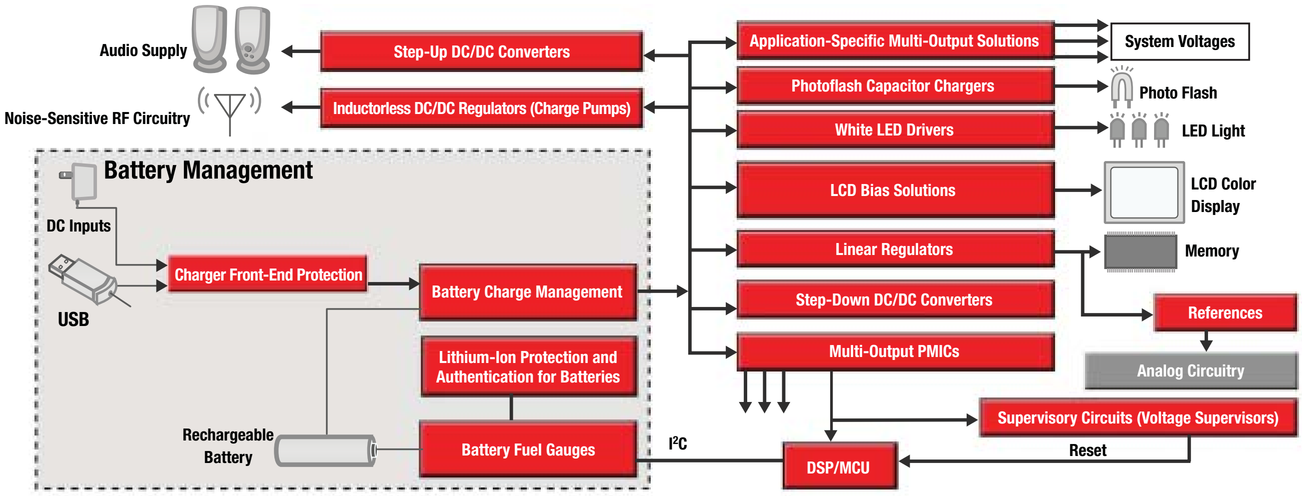

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Device	Description
TPS61220	0.7-V input DC/DC boost converter for solar cells
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TPS61087	3.2-A switch-current, limit-boost converter
TPS62290	1-A buck converter in 2x2 QFN package
TPS62750	Programmable input-current-limit buck converter for USB applications
TPS63030	95%-efficient buck-boost converter in 2.5x2.5 QFN package
TPS61165	High-power boost LED driver in 2x2 QFN package
TPS61500	High-brightness boost LED driver with 3-A switch
TPS65001	3-channel mini PMU with 1 buck converter and 2 LDOs
TPS781xx	1-μA quiescent-current LDO
TPS728xx	200-mA LDO with 2 output options via VSEL pin

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The Grey Area

Access at your own risk

Data sheet specifications for power semiconductors are values which are assured by the manufacturers. But they can only be used to a limited extent for dimensioning and calculation.

By Thomas Schneider (Dipl.Ing.FH), GvA Leistungselektronik GmbH, Mannheim

The development of more and more compact and efficient systems for converting and transmitting electrical energy is dramatically increasing the requirements which are placed on modern power semiconductors. Optimisation of the level of efficiency often comes first on the list of priorities in requirement specifications and functional specifications and regularly presents the development departments that are confronted with these specifications with challenges.

The economic and technical optimisation of topologies for converters, rectifiers or power adapters is not just confined to the active and passive components which are used, but also incorporates the entire manufacturing process including the materials which need to be used. In an era in which commodity prices appear to be the mere plaything of speculators, and in which natural disasters or mishaps caused by human deficiencies are leaving the world economy on the brink of collapse, you cannot afford to integrate a lot of spare design capacity into technical systems. Optimisation to the point is the name of the game and the key thing is to provide the specified data for the systems with the minimum use of raw materials.

Many systems and devices now undergo trials in the virtual environments of development platforms and simulators before the first version of the hardware is actually built. But as good as the electrical, thermal and mechanical models are, the results are always dependent on the starting figures. A close tolerance with the results usually also means that there was a close tolerance with the initial figures and, particularly for key components in power systems such as power semiconductors, this is not always the case.

Technical specifications such as data sheets of IGBTs or thyristors are difficult to draw up as the technical data which at first glance appear to be simple are in fact very complex and have lots of mutual dependencies. Data sheets must achieve a balance between conveying purely technical facts and attempting to distinguish the product from the competition for the purpose of marketing. One consequence of this is that they are then also difficult to read or even compare with those of other manufacturers.

Many parameters which are listed in data sheets of power semiconductors are in turn dependent on one or possibly more other parameters as a result of the technology which is used. One global parameter that influences the characteristics in lots of respects is the temperature. It alters the forward voltage, the blocking behaviour, the dynamics and limits the performance capability of a semiconductor. As it is very complicated to specify all of the temperature dependencies on a data sheet, one limits oneself to specifications of limit values which appear to make technical sense. Some of the most important semiconductor values are therefore specified at room temperature (25°C) and at maximum operating temperature (technology-dependent). The behaviour of the components at a temperature in between the two can only be estimated as only in the rarest cases do the dependencies display a linear profile.

It becomes particularly critical for the exact calculation of a switch if only one limit value specification is provided at a particular temperature. This is often the case, for example, when specifying the maximum reverse current of a power semiconductor. Many manufacturers only specify one limit value here, either at room temperature or at the maximum operating temperature.

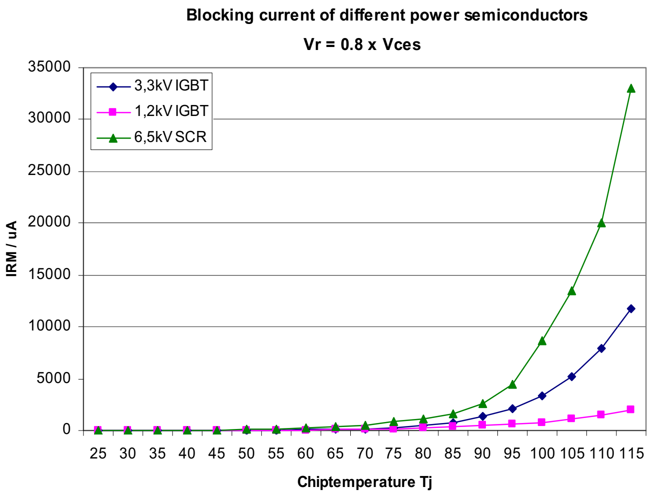

Figure 1: Reverse current profile plotted against temperature for different power semiconductors

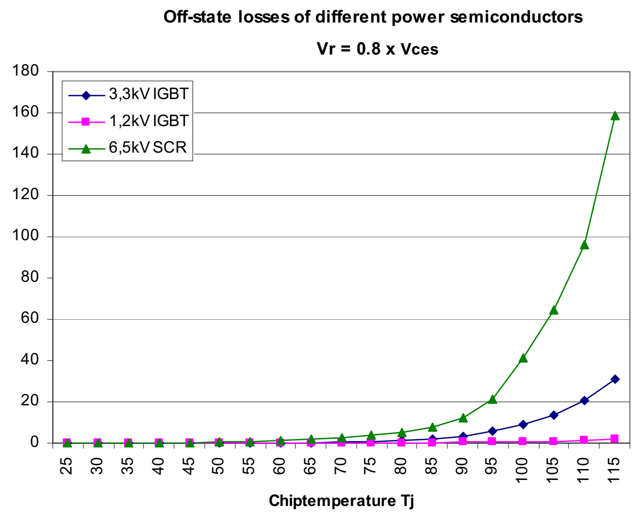

Figure 2: Reverse power loss plotted against temperature for different power semiconductors

But as the semiconductors will later operate in the converter or power adapter neither at 25°C nor permanently at the maximum operating temperature, these specifications cannot be utilised directly. A comparison of the reverse current for different semiconductors is also not much help here because no correlation can be inferred from the data sheet specifications.

Table 1 shows the Ices figures for IGBT modules from different manufacturers for different maximum reverse voltages.

Voltage class	1200V	1700V	3300V	6500V
Manufacturer A Ices@25°C	5mA	5mA	5mA	0.4mA
Manufacturer B Ices@25°C	1mA	1mA	4mA	3 – 24mA
Manufacturer C Ices@25°C	5mA	5mA	8 – 12mA	25mA
Manufacturer D Ices@125°C	120mA	120mA	120mA	120mA

Table 1 IGBT modules from different manufacturers

Reverse current problems

In general, the reverse current of power semiconductors and the associated reverse power loss tends to be regarded as low, often as negligible. As semiconductor technology has now advanced into the medium-voltage range, this attitude can no longer simply be maintained. Since, as was outlined above, the data sheet specifications for the reverse current do not permit precise dimensioning, the real blocking behaviour of semiconductors is often measured. The results which are obtained from this may look similar to the characteristics shown in Fig. 1 and Fig. 2.

As the measurement curves show, the reverse power loss naturally remains very low when viewed in absolute terms against the temperature in the case of the 1200V IGBT. Even at a junction temperature of 115°C, only approx. 2 watt reverse losses are generated. The 3300V IGBT, by contrast, reaches approx. 33 watts with a 115°C junction temperature and the high-blocking thyristor does in fact attain approx. 160 watts. However, Fig. 3 shows that all three reverse current profiles follow the same logarithmic regularity.

The currents measured by way of example are below 1 mA for all three semiconductors up to a temperature of 80°C. In the room temperature range (25-35°C), the reverse current is once again lower by a factor of 100 (!) and this does not allow any further conclusion to be made about how it will respond as the temperature rises.

Few semiconductor manufacturers specify the reverse currents at room temperature and on the data sheet. However, if these two specifications are provided, the big difference between the currents measured by way of example and the limit values of the data sheet is clearly apparent. The area above the red line is guaranteed by the manufacturer, and the real values may be below this line. Here you can now clearly see the problems that occur if components and peripherals (cooling) are dimensioned to be very tight and are based on values which are measured by way of example.

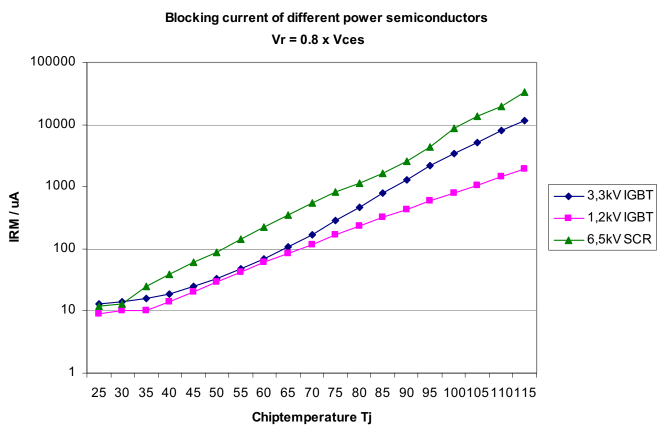

Figure 3: Reverse currents of different power semiconductors (log. representation)

Practical example:
In a sub-synchronous converter cascade, the intention is to use an AC crowbar switch which will short-circuit the generator in 3 phases in the event of a fault in order to prevent overvoltages in the DC intermediate circuit of the mains converter. The maximum DC intermediate circuit voltage was 1250V, and a 2200V component with corresponding surge current resistance was selected as the short-circuit thyristor. Reverse current tests at room temperature as part of the initial sample testing revealed that the reverse losses which occurred were so low that the decision was taken to fit the thyristor module with its insulated base plate directly to the wall of the switchgear cabinet. For reasons of cost, neither heat sink elements nor assembly materials improving heat transfer (heat transfer compound or heat conducting foil) were used. What was not taken into account here was the fact that the switchgear cabinet wall could heat up during operation to over 60°C as a result of heat dissipation and the cooling air from the converters.

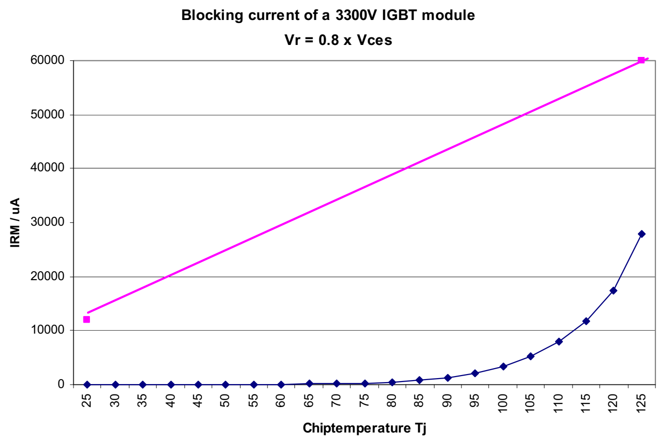

Figure 4: Data sheet specification for a 3300V IGBT module

Once the system was deployed out in the field, the failures of thyristor modules on new systems increased dramatically after around three years of production. In many systems, thyristor faults which shut down the entire system and even led to massive damage occurred just a few weeks after commissioning. As a first response to this, the user questioned the quality of the thyristors and held these responsible for the failures. However, a more detailed investigation by an independent testing institute with responsible cooperation from the semiconductor manufacturer then revealed a different picture. As part of the process of product overhaul and ensuring delivery capacity, the semiconductor manufacturer switched the manufacturer of the passivation coating on the thyristors from a less well-known manufacturer to a global market leader. On the one hand, this switch drastically improved the reverse current stability at high temperature, but on the other hand it led to increased reverse currents in the medium temperature range. Within the framework of the normal process-related fluctuation range, only some of the thyristors produced reverse losses which were so high that the cooling of the modules through the switchgear cabinet wall, which was substandard anyway, was no longer sufficient to dissipate the heat. Although the measured values of all of the semiconductors which were tested were still well within the old data sheet limits which still applied, suddenly a number of the modules failed on account of a „thermal runaway“.

As part of the process of product overhaul and improvement, such changes in the manufacturing process of power semiconductors are carried out repeatedly ensuring that these components work reliably within the assured limits.

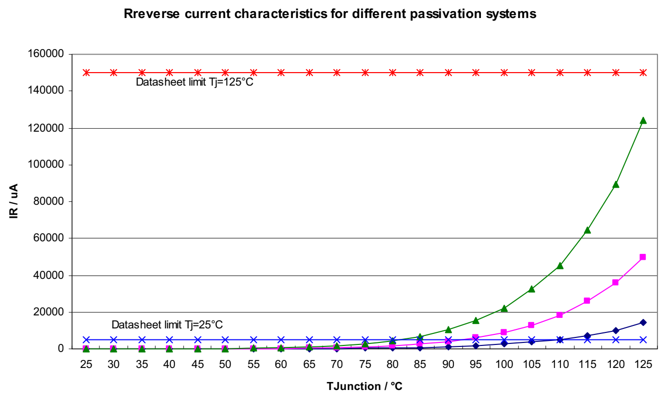

Figure 5: Reverse current profile plotted against temperature for different passivation processes

But the process-related fluctuations of many semiconductor parameters are also significant in a continuously running manufacturing operation. As can be seen from the values in Fig. 6, no general validity can be inferred from a measurement carried out by way of example on individual semiconductors.

Particularly with devices which have tight thermal dimensions and when using high-blocking semiconductors, it is imperative to take account of the reverse losses, which are often considered to be negligible, in order to obtain reliable, thermally stable dimensioning. If the parameters on the data sheet are insufficiently defined, the semiconductor manufacturer or its sales partner must be consulted so that the probability of any nasty surprises is minimised.

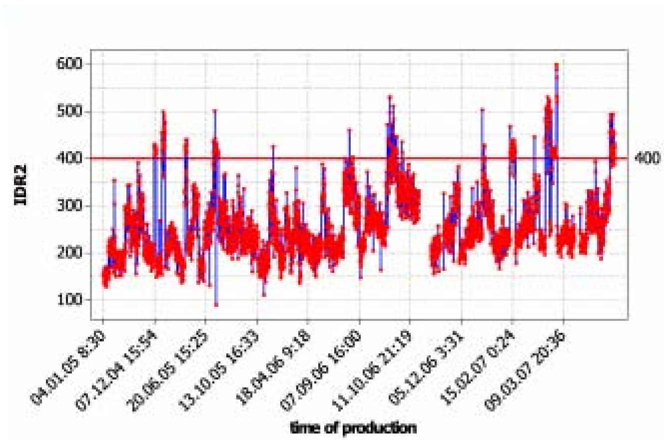

Figure 6: IDR parameter fluctuation (reverse current at 125°C) of a 2800V thyristor over a production period of approx. 2 years

As you can see, even the issue of static blocking behaviour, which is regarded as being relatively trivial, can present problems in certain cases. Further operating parameters which have an even greater influence on the behaviour of power semiconductors - e.g. forward voltage and dynamic response – will be considered later on. Here too, the same holds true for the grey area of data sheet specifications: Access at your own risk.

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Inspecting IGBT Modules

Ultrasound or X-Ray?

An IGBT module that passes electrical tests might contain between-layer defects capable of causing overheating and electrical failure during service. Engineers responsible for long-term reliability have multiple options for determining whether gap-type defects are present. For example, they can physically section the IGBT and use an optical microscope to look for delaminations, voids and similar gaps. One drawback is that they might not section in a plane that intersects a defect. The IGBT, whether defects turn up or not, is destroyed.

By Tom Adams, consultant, Sonoscan, Inc.

Two good nondestructive methods are x-ray and acoustic micro imaging using a Sonoscan C-SAM® system. Both will image the interior of the IGBT module without destroying it, but with very different results. X-ray and acoustic microscopy are rightly considered complementary methods.

An x-ray tube emits photons that, like visible light, are part of the electromagnetic spectrum. X-ray photons have much higher frequencies and much shorter wavelengths than the photons of visible light. “Hard” x-rays (shorter wavelengths, higher energies) are used in imaging. “Soft” x-rays hardly penetrate metal materials at all.

An x-ray beam traveling through a material is absorbed to some extent by that material - which means that eventually, if the material is thick enough or “dense” enough, all of the energy in the beam will have been absorbed and no energy will emerge from the far side of the material for imaging. When an x-ray beam is transmitted through a sample containing multiple materials having different densities, the intensity of the emerging beam at any location depends on what materials it has traveled through.

Unlike x-rays, ultrasound is not part of the electromagnetic spectrum but is mechanical energy. When a C-SAM® system pulses ultrasound into a material, the pulse travels as a wave that causes motion in molecules. Part of pulse may be scattered in a variety of directions. Some of the pulse energy may be absorbed by molecules, especially molecules such as polymers that are long, twisted, and flexible. The ultrasonic energy causes bending of the molecule. Most production materials transmit ultrasound adequately for imaging. Rubber, on the other hand, is an example of a material that absorbs ultrasound rapidly, although thin samples of rubber have been imaged. The least absorbing material is crystalline diamond.

Acoustic images display internal material interfaces - a metal to polymer bond, for example - because material interfaces reflect ultrasound back to the transducer for collection. The reflected pulse reports the amplitude of the echo caused by a material interface, the polarity of the interface, and the travel time. Solid-to-solid interfaces have more or less moderate amplitudes, depending on the properties of the two solid materials.

The result is very different when an ultrasonic pulse strikes a solid-to-gas interface, such as the interface between a metal and an air-filled void, because these interfaces have the highest amplitudes. Typically >99.99% of the energy that has struck the interface is reflected back toward the transducer. Suppose there is a gap <1μ thick between the ceramic layer and the solder in an IGBT module. When the ultrasonic pulse strikes the top of the gap - i.e., the solid-to-gas interface - >99.99% of the pulse energy is reflected. A tiny fraction of the pulse might cross the gap and encounter the gas-to-solid interface at the bottom of the gap, where >99.99% of the the very feeble pulse might be reflected.

The transmission of ultrasound through a given material depends much less on the mass density of the material than does the transmission of an x-ray beam. In some materials such as ceramics, high porosity (i.e., the inclusion of large numbers of microscopic gap-type features) can scatter ultrasound and limit acoustic imaging, but these pores do not alter the inherent density of the solid material.

In the imaging of IGBT modules, there is thus a considerable difference in the information obtained by x-ray and ultrasound: x-ray displays variations in material density, while ultrasound displays differences at internal interfaces.

If there is a delamination, for example, between a ceramic layer and the heat sink, or more precisely between the ceramic layer and the solder that bonds it to the heat sink, here is what each method will see:

- X-ray photons traveling through the delamination will encounter only less overall density than the photons that pass through other areas of the module. The difference is that for a distance of perhaps 0.5mm the beam travels through air instead of solder. This difference is so slight that the delamination will typically be invisible in the x-ray image, and it is not possible to determine that a once bonded interface is now delaminated. For a gap-type defect to be visible to x-ray, the gap needs to be thick enough, and the IGBT module needs to be thin enough, for the gap to cause a visible difference in attenuation of the beam.
- Ultrasound will be almost completely reflected by the initial solid-to-gas interface of the gap. Reflection is nearly total whether the thickness of the gap is 1 cm or considerably less than 1 micron.

Figure 1 shows the x-ray (top) and acoustic (bottom) images of the same IGBT module. The acoustic image was gated to use only the return echo signals from the interface between the round disks and the substrate. The x-ray image encompasses the entire thickness of the module.

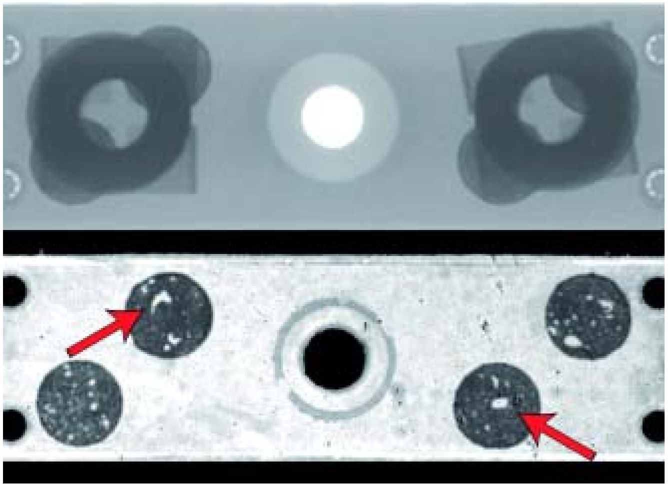

Figure 1: X-ray image (top) and acoustic image (bottom) of an IGBT module. Arrows mark gap-type defects.

The x-ray image therefore shows the square outlines of the chips at the top of the assembly, as well as the circular disks and larger holed disks. The acoustic image, gated on a single significant interface, reveals numerous white gap-type defects between the circular disks and the substrate. Two of the gaps are marked by arrows in Figure 1. These gaps mostly lie directly below the chips and will block thermal dissipation to the heat sink. Probably these gaps are best described as delaminations, since they are very thin. Because they are thin, they represent an insignificant loss of attenuation to the x-ray beam, and do not appear in the x-ray image.

The ways in which ultrasound and heat react when they encounter gaps is important in understanding IGBT modules. A gap such as those in Figure 1 reflects 99.99% of the ultrasonic pulse if the gap is, say, 1 millimeter thick. It reflects the same 99.99% if the gap is 1µ thick, or even less. The reflection occurs at the solid-to-air interface; essentially none of the pulse crosses the gap to be reflected from the air-to-solid interface on the other side of the gap. Laboratories that text plastic-encapsulated microcircuits (PEMs) to determine their Moisture Sensitivity Level routinely cross-section the PEMs in order to view delaminations and the like optically. But they image the PEMs acoustically before cross-sectioning because they know that some gap-type features are too thin to be seen by a light microscope after sectioning.

In some IGBT modules, x-ray is able to image gap-type defects. This is true only if there is missing material and if the gaps are relatively thick - i.e., bubble-like voids rather than delaminations or disbonds a few microns thick. The thickness of the gap needs to be large relative to the whole thickness of the module.

The IGBT module shown in Figure 2 is small and relatively thin - considerably smaller and thinner than a typical high-power industrial IGBT. The entire module is about 5.0mm thick; the die attach layer is about 0.5mm thick, or about one-tenth of the thickness of the module, and the voids in the die attach are also about 0.5mm thick. In the x-ray image at bottom, the voids are visible as lighter areas, but the contrast is poor. X-ray must travel through the entire IGBT, and is not easily restricted to a single depth. In the acoustic image (top), the voids appear bright white because echoes from the specific depth were used to make the image, and because the voids reflect 99.99% of the ultrasonic pulse, just as they would if their thickness were as little as 1µ. Thick voids are sometimes seen in modules where a die is tilted and the die attach is therefore of uneven thickness.

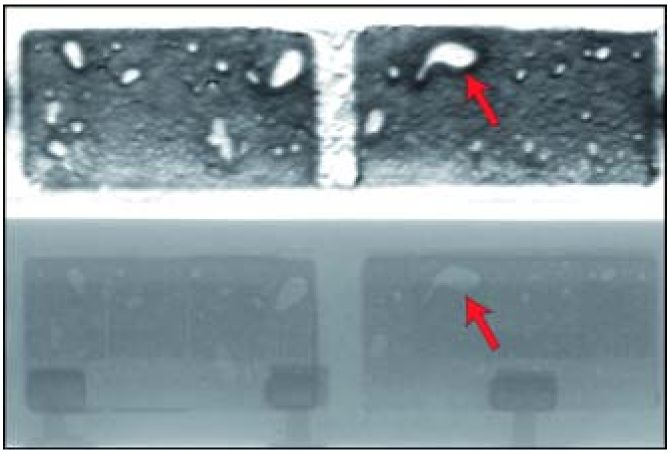

Figure 2: A very thin IGBT module in which relatively thick voids are visible in the acoustic image (top) and, very faintly, in the x-ray image (bottom).

The x-ray image (bottom) shows most of the same gaps because they are thick enough to cause a significant change in attenuation. The contrast is much less than the contrast in the acoustic image, even though the contrast has been enhanced here for publication. Since it incorporates the entire thickness of the module, the x-ray image also displays overlying structures (at the bottom of the image) and, very faintly, the chips above the die attach. Some of these structures effectively lower the local attenuation loss from the voids, and make some of the voids difficult to see.

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DC/DC Converters Boost Reliability in IGBT Applications

The high demand for utilities to move to greener sources of power such as wind-generated and photovoltaic has focused attention to the development of highly efficient power electronics to convert the output of wind and solar systems to voltages suitable for interface to the power grid.

By Jordi Torrebadell, Director of Engineering – Americas, Recom Power Inc.

This article examines the challenges that this demand presents to the DC/DC converter segment of the power electronics industry in terms of converter transformer isolation breakdown in insulated gate bipolar transistor (IGBT) inverters and how a unique Recom solution can improve the efficiency and reliability of power converters in renewable power generation applications.

Background

Wind driven systems and photovoltaic renewable power systems produce electrical power whose magnitudes are variable depending on ambient conditions. Wind driven sources are subject to variations in wind velocity. This variation can be compensated for by varying rotor pitch but the output must still be stabilized to conform to grid waveform requirements or the output must be disconnected from the grid.

Solar panel driven systems are subject to weather conditions, e.g., cloud cover which can reduce electrical output. In addition, solar panel output also varies as the sun rises and sets. The output must then be adjusted to meet grid requirements or be disconnected from the grid as in wind powered systems.

The renewable energy industry requires the ability to convert the output of the renewable energy source to a form and magnitude suitable for interface to the power grid. Since the output can be a DC voltage as in the case of photovoltaic systems or a DC or AC voltage as found in wind powered systems, the inverter needs to convert the input from the renewable voltage source to a voltage that is magnitude and phase matched to the power grid. Such an inverter is commonly referred to as a grid tie inverter since it is connected to the power grid and in a typical residence application the inverter can deliver power to residential loads or to the grid

when the renewable source generates power. Additionally, the renewable source must be isolated from the grid in the event that the grid fails locally to assure the safety of grid repair crews. Consequently, the overall inverter reliability is critical to meet these operational and safety requirements.

Inverters in the renewable energy industry pose challenges that are similar to those seen for electric motor and pump controllers. Our discussion of reliability risks and mitigation strategies can apply to either application.

Inside the Inverter

Within the inverter, DC/DC converters power one or more IGBT drivers which then feed their output to the IGBTs which are being driven in a pulsed mode. The IGBTs and the drivers operating in the pulsed mode are driven at frequencies that can exceed 10 KHz. This operation is represented schematically in the block diagram in Figure 1. The DC-DC converter provides galvanic isolation between its input and output and the isolation voltage is a function of DC/DC converter transformer design.

The DC/DC converter within the inverter employs a transformer to shift voltage and current levels within the device. The transformer isolation, i.e., winding insulation and spacing/separation to prevent electric shock and arcing, is specified in UL 60950 for three isolation classes: basic, supplementary, and reinforced. The separation/spacing is further subclassified into two categories: creepage and clearance. Creepage is defined as the shortest distance measured between two conducting points along a connecting sur-

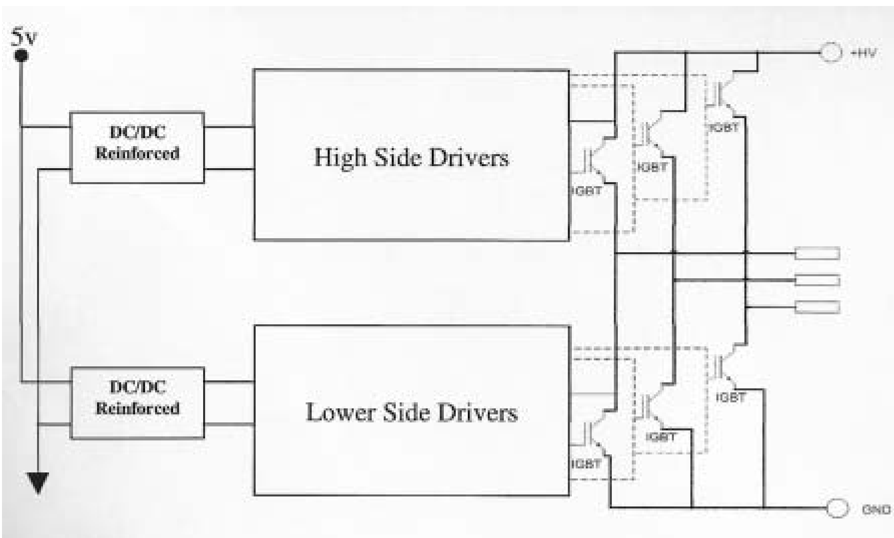

Figure 1: Block diagram of an three phase IGBT Inverter

face, taking into account surface contours and irregularities (tracking distance). Clearance is the shortest distance measured between two conducting points directly (essentially line-of-sight distance).

UL 60950 calls out creepage and clearance distances to meet isolation requirements in transformers. Creepage and clearance dimensions increase with applied voltage and as the isolation classes progress through basic, supplementary, and reinforced. For example, for basic insulation class (lowest class), clearance and creepage for 15 VDC/12VAC (lowest voltage) are 0.4 mm and 0.8 mm respectively. The highest isolation class, reinforced, calls out clearance and creepage distances of 5.0 mm and 8.0 mm for voltages of 300VDC/250VAC. It is clear that to meet higher class and higher voltage isolation requirements transformer physical size must increase unless some alternate methodology can be employed. These UL requirements are detailed in Table 1.

		Input		Voltage		
Isolation	Class	15 VDC	36 VDC	75VDC	150 VDC	300 VDC
		12 VAC	30 VAC	60 VAC	125 VAC	250 VAC
Basic	Creepage	0.4 mm	0.5 mm	0.7 mm	1.0 mm	1.6 mm
	Clearance	0.8 mm	1.0 mm	1.3 mm	2.0 mm	3.0 mm
Supplementary	Creepage	0.8 mm	1.0 mm	1.2 mm	1.6 mm	2.5 mm
	Clearance	1.7 mm	2.0 mm	2.3 mm	3.0 mm	4.0 mm
Reinforced	Creepage	1.6 mm	2.0 mm	2.4 mm	3.2 mm	5.0 mm
	Clearance	3.4 mm	4.0 mm	4.6 mm	6.0 mm	8.0 mm

Table 1: Isolation Class vs. Input Voltage requirements (from UL 60950 2nd Edition, Table XVI).

Sources of Stress in Inverter DC-DC Converters

IGBT controllers can efficiently convert high voltage DC supplies to single or three phase AC outputs and are an integral part of wind and sea turbines and photovoltaic renewable energy systems. The IGBT high side drivers shown in Figure 1 run at the high voltage DC input which is typically a few hundred volts (possibly as high as 300 volts). Opto-couplers are used to achieve isolation voltages of several thousand volts at frequencies up to several megahertz. Consequently, reliability of the DC-DC converter in the high side driver is critical for reliable operation of the inverter. These high side drivers are commonly powered by a DC/DC converter that would require a reinforced isolation transformer to avoid breakdown of the insulating layer due to the high voltage. A DC/DC converter rated at 2 kVDC would seem adequate for this application as it can withstand up to 550 VAC continuous.

However, the high side DC-DC converter is subject to additional stress because the high side IGBT drivers are not designed to function at low frequencies because their efficiency would be greatly reduced. Transformer isolation clearance and creepage distances are specified at 50-60 Hz so additional margin is required to operate at frequencies above 60 Hz. Frequencies of 10 kHz or more are common in inverters. Since transformer emf is directly proportional to frequency for a fixed transformer flux density, increases in operating frequency can cause an increased electric field which can further weaken the insulation.

This high AC voltage (actually a pulse width modulated (PWM) voltage) is accompanied by very fast rise and fall times in the PWM voltage. These rapid changes are referred to as slew rate or dV/dt (change in voltage with respect to time). High slew rate voltages can cause isolation failure over time by generating large voltage differences between adjacent windings that further stress the transformer insulation. Reinforced isolation assures higher reliability of the DC-DC converter at these high-frequency elevated voltages by increasing the clearance/creepage distance in the DC-DC converter transformer which equates to longer life.

The higher the isolation voltage rating for a DC/DC converter is, the lower the coupling (isolation) capacitance and a low coupling capacitance is essential in AC or highly dynamic switched DC usage. This will ensure application safety and avoid a shortened lifetime in such a highly demanding situation.

Voltages can also be boosted by transmission line effects. If the load impedance and the line impedance are mismatched the reflected voltage can be as high as the incident voltage, resulting in voltages within the circuit that are twice the applied (incident) voltage. Circuit layout is critical in minimizing reflected voltage to reduce additional voltage stress. Since the PWM voltage is a series of square waves, the harmonics of the fundamental operating frequency can also be doubled resulting in further stress on the transformer windings.

Insulation on transformer windings, when weakened by elevated voltages, can degrade due to corona effects which lead to partial discharge effects. When a corona discharge forms, ozone is created which can cause localized deterioration of the winding insulation. Once the insulation is compromised, partial discharge causes further breakdown of the insulation and, over time, causes winding failure.

Solution for DC-DC Converter Reliability

Using a patent-pending technology, Recom has successfully integrated reinforced DC-DC converter technology into the casing of standard-insulation converters that deliver up to 10 kVDC insulation and up to 20% more power.

Early attempts to physically increase isolation distance were not successful because the efficiency of the transformer decreases if the electric and magnetic fields of the transformer are not closely coupled. However, Recom engineers have developed a portfolio of DC-DC converters that meet the most stringent isolation requirements and that guarantee at least 2.4 mm clearance between circuits. The insulation is composed of a series of layers and a special plastic film that allows for creeping distances exceeding the required 4.6 mm. This construction assures increased reliability even with the stresses induced by high amplitude, high frequency, high slew rate voltages.

Conclusion

Renewable power systems require inverters that are safe and reliable. DC-DC converters are an integral part of these inverters and are a critical component that contributes to overall system reliability. Recom Power has developed a unique solution to incorporate reinforced transformer technology into their DC-DC converters which fits into a standard insulated converter envelope and this development provides a compact, high-power, efficient solution to renewable energy source inverter requirements. The solution addresses all aspects of DC-DC converter reliability, particularly high side driver stress caused by frequency and slew rate, transmission line effects, harmonics, corona, and partial discharge.

www.recom-power.com

The Thermal Challenge

Benefits of thermal interface materials (TIM) especially dedicated to power electronics

The enhancements of semiconductors throughout the last decades targeted the improvement of reliability, the increase of efficiency, electrical and mechanical robustness as well as economic aspects. Most of the efforts done by semiconductor manufacturers concentrate on fine-tuning the silicon's abilities along with optimization of interconnection technologies. Recently, more work was done to the interconnection between power module and heat think as with the ongoing increase of power densities the thermal interface becomes a larger challenge.

By Dr. Martin Schulz, Infineon Technologies, Warstein, Germany

Power Density vs. Power Density

Computer processors today can be seen as an application with high power densities. A modern CPU can consume as much as 130W of power on an area of 263mm² representing a rectangle of 16mm in width [1] and a power density of about 0.5W/mm². Thermal grease is needed here too to get good thermal connections between the processor core and the heat sink attached. The vast amount of processors sold is the reason for grease manufacturers to tune grease for this application, especially as processors and larger discrete packages have similar footprint sizes. It is often concluded, that grease works under the condition described by thermal swing regardless of the application. However, the demands in power electronic differ from those in personal computer, notebooks or mobile phones, demanding a dedicated solution.

A brief comparison hints out some of the main discrepancies is shown in table 1

	CPU	Power Electronic Application
Chip Area [mm²]	263	190
Power Density [W/cm²]	50	100-200
Force applied to heat sink	Several Newton	Several kilo Newton
Thermal Cycling demand	None	Large
Expected Power Cycles	None	>100.000
Expected Lifetime [Years]	<5	10-30
Cost of replacement [US$]	<200	10^3 to 10^6
Ambient Temperature [°C]	20-40	-50 to 65
Case Temperature [°C]	<75	85 to 110

Table 1: Comparison hints out some of the main discrepancies

Due to these differences, the thermal interface is far more crucial in power electronics than in any other application. It would be short-sighted to conclude that general purpose materials that perform well on a CPU perform equally well in power electronics as both thermal stress and long term issues cannot be compared. Additionally, thermo-mechanical stress applied to thermal grease becomes a topic in power modules and needs to be examined closely to achieve a thermal interface that features excellent thermal transfer in conjunction with the long-term stability demanded.

Thermal Transfer Capabilities

From technical point of view, the thermal resistance or thermal conductivity of a material defines its thermal transfer characteristics. In detail, this is only true if single materials are observed that are considered to be homogenous. Datasheets of thermal interface materials often include values for the so-called bulk resistance. If experimentally investigated, it turns out that in power electronics there is no relation between measured junction temperature of a chip and the thermal conductivity of the TIM in use. The bars in Figure 1 correlate different TIM to the junction temperature achieved, emphasizing the lack of dependency between the datasheet value for thermal conductivity and the thermal results of the experiment.

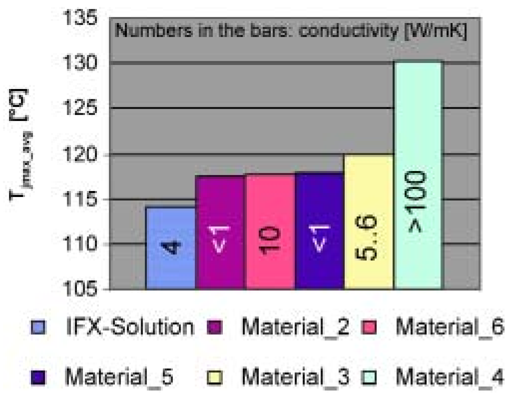

Figure 1: Measured Junction temperatures with different TIM in use; averaged values from a 100k cycle test

The diagram substantiates that this datasheet value is insufficient to compare different products. Particle sizes, particle size distribution and the abilities to wetting surfaces along with forming thinnest possible bond lines are more important, yet partially difficult to quantize in numbers. For an evaluation, extended tests become unavoidable [2].

The most accurate insight into the thermal capabilities can be gained by thermographic imaging as depicted in Figure 2.

The picture was taken in a test setup with two modules connected in series. Both were mounted onto a common heat sink carrying the

identical current. It can clearly be seen that a solution, especially developed for this application outperforms a standard approach. The thermal situation not only improves for the chips inside. Higher temperatures in the power module also lead to increased stress for the components surrounding the power module [3].

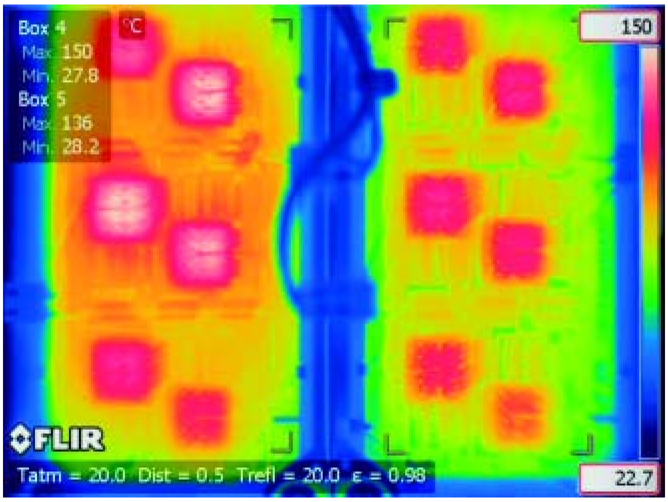

Figure 2: Difference between a common thermal solution to the left and Infineon's TIM dedicated to power electronics to the right, DUT: FF450R12ME4

Longevity

As the expected lifetime in power electronics easily exceeds 10 or even 20 years, the thermal interface has to stay intact and operational for the same period. For power modules, one of the well established reliability tests is High Temperature Storing (HTS) where the module is exposed to 125°C dry heat for 1000 hours.

This test was done for TIM with setups consisting of modules mounted to heat sinks using different thermal solutions. Chip temperatures under given conditions were measured before this test, the measurement was repeated once a week, every 168hours respectively. Six weeks resemble the 1000h test with the results summarized in Figure 3.

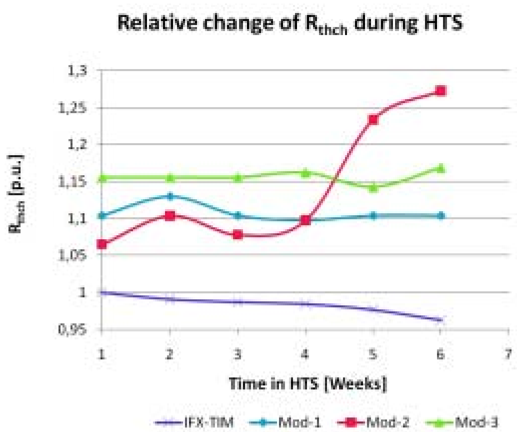

Figure 3: Relative changes of thermal resistances during HTS-Test referenced to IFX-TIM

Multiple conclusions can be drawn from the data gathered:

- As expected, a specially tuned material dedicated to the particular application outperforms those considered general purpose components
- The composition chosen for Infineon's new material achieves the best initial condition. Due to excellent wetting abilities and optimized particle content the bond-lines decrease over time, thus further reducing the thermal resistance
- Though materials like Mod-1 or Mod-3 behave stable, they do not show the best thermal performance
- With Mod-2 it is obvious that a reliable statement regarding longevity cannot be give within days or simple tests; the material performed well for the first four weeks.

One detrimental effect often observed with TIM is pump-out. Here the material gets shifted away from its position by movements of the base plate as a consequence of thermal expansion. To best counteract this effect, a phase-changing base material was chosen at Infineon that changes to a thixotropic state at elevated temperatures. Thus, the TIM's viscosity stays in a range that prevents the material from being pumped out.

Besides the thermal investigation it was also verified that neither retightening of screws nor burn-in for settling was necessary; these are an often observed drawbacks in common phase-changing materials.

Applying TIM

As implied, thermal performance depends on forming the thinnest possible bond lines between the power electronic component and its heat sink. Thus, the amount of material applied becomes a crucial parameter and manually handling of thermal interface material is no longer a preferred option. While manual stencil printing already is a step in the right direction, only automated processes allow for a reliable and reproducible procedure. A stencil-printer to apply TIM is set up to first flood the stencil and removes the excess material in a second step. The two sequential steps can be seen in Figure 4.

Figure 4: Flooding the stencil and removing the excess material afterwards to achieve the best possible printing results

A further step in applying Infineon's new solution is a thermal treatment, transferring the paste-like material into its final phase changing status with a solid appearance at room temperature. This way, the material can safely be handled and transported.

The final step consists of an inspection verifying that every dot of the printed pattern is done properly and the correct amount of TIM has been applied.

Conclusions

As the complete process of design, qualification and application of thermal grease is of complex nature, Infineon has decided to offer power electronic modules with pre-applied thermal interface material to the market. This will improve the thermal behavior, release the customer of the often unwanted process of applying thermal grease and therefore contribute to managing the thermal challenge in power electronics.

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www.infineon.com/highpower

Thermal Management of Boards and Current-Carrying Capacity of Traces

An electrical current creates a local heat source in a trace - but board cooling is non-local

A three-dimensional, spatially detailed and combined simulation of electrical current and temperature in PCBs is the best approach to answer the question: "what is the maximum current for a trace at given temperature?" Board layout based on design rules IPC-2221 or IPC-2152 is merely a rough estimate leading to oversized traces or too conservative designs. We are discussing the effects of local heating and global cooling in a printed board and its consequence for temperature.

By Dr. Johannes Adam, ADAM Research, Germany

Joule Heating

Electrical current in a wire causes deposition of thermal energy. To honour the discoverer of the effect, James Joule, it is called "Joule heating". Nowadays Joule heating also plays an eminent role in electronics, e.g. for copper traces in printed circuit boards (PCBs). The thermal power P can be easily calculated using

$$P = R\, I^2 \qquad (1)$$

where R is the electric resistance of the trace in Ohm and I the DC current in Ampere. R is a combination of geometric data (width *w*, height h and length L) and material properties (specific electric resistance). Given *w* and *h* in mm, *L* in m and a value for copper at 20 deg C called ρ_{20}=0.0175 Ohm*mm²/m

$$R = \frac{L}{w \cdot h} \cdot \rho_{20} \cdot \left(1 + 0.00395 \cdot (T - 20)\right) \qquad (2)$$

Two problems show up immediately:

Problem 1: What should be done, if the trace is geometrically not a wire cable?

Problem 2: How to write down a similar simple formula for the temperature *T*?

The temperature of a trace in a PCB is the *result* of thermal equilibrium between Joule heating, conductive transfer of energy to other parts of the board, and convective / radiative *cooling* by the heat flowing from the board surface to the ambient environment.

Because of technological T-limits, like the glass transition temperature of FR4, the temperature of a copper trace must not exceed a certain value. A typical target used in industry is a maximum additional ΔT_{max} of about 20 K while all other components are off. Moreover the target depends on the ambient temperature.

Simple Trace Temperature Estimates and Simulation

For first estimates the graphs in *IPC-2221* (=MIL-STD-275) are widely used as a 'design rule' for trace geometry (i.e. trace width and height) for a given pair of current and temperature rise. For a reproduction and how to use them we refer to [1]. It may be doubted if this 'standard' is really useful and valid [2] anymore. First, layout experts tell, that usually higher currents can be carried by a trace. Second, the IPC-2221 diagrams for so-called "internal conductors" are derated in current by a factor of two, exactly. These suspicious facts made it necessary to ask for further theoretical and experimental investigations.

While working on a revision of the old design rule, now called *IPC-2152*, the IPC Task Group 1-10b lead by M. Jouppi, found the root of IPC-2221 being experimental work for the National Bureau of Standards back in 1956 [3,4]. The original current vs. cross-section diagrams reproduced in [4] show a wide scatter of data points. This is due to the variety of investigated boards with different structure and coating. The final nomographs (i.e. Figure 1 in [1]) roughly represent the upper limit of the points. The lower limit is in close agreement with the so-called Design-News ('DN') correlations brought to notice by Brooks [2].

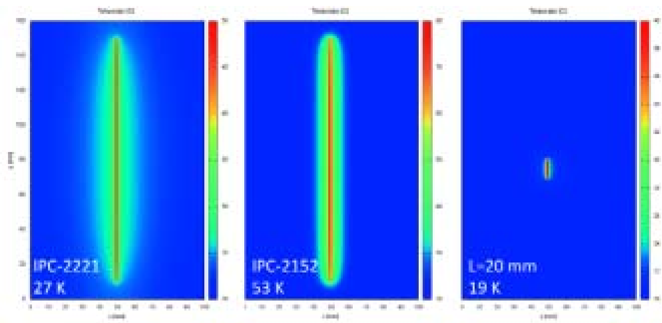
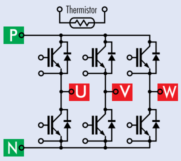


Figure1: Simulated thermographs of test boards with one powered trace (I=5 A). Left: a cladded bilayer PCB rises to ΔT=27 K above ambient, middle: single layer PCB rises to ΔT=53 K, right: a very short trace on a bilayer can be cooler than a long trace because front and end face contribute considerably to cooling (ΔT=19 K).

Questions: is it possible to explain or to reproduce the experimental IPC curves by numerical simulations? What could be learned? Could this technique be extrapolated to other scenarios? To answer the questions, we perform numerical studies on a simple 3-D model of a board using the author's software *TRM* [5] which is primarily designed to calculate complex multilayer layouts. The code is solving

The 6-PACKs



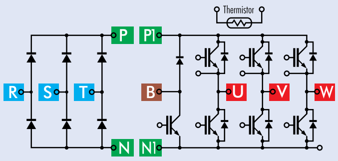
With soldering pins

	I_C	600V	1200V	1700V
45x107,5mm	50A		●	
	75A	●	●	
	100A	●	●	
62 x 122 mm	75A		●	
	100A		●	●
	150A	●	●	●
	180A		●	
	200A		●	

With PressFit contacts

	I_C	600V	1200V
45x107,5mm	50A		●
	75A	●	●
	100A	●	●
62 x 122 mm	100A		●
	150A	●	●
	180A		●
	200A		●

The PIMs



With soldering pins

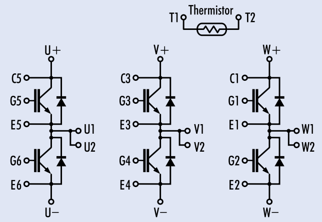
	I_C	600V	1200V
45x107,5mm	25A		●
	35A		●
	50A	●	●
62 x 122 mm	75A	●	●
	100A	●	●
	150A	●	●

With PressFit contacts

	I_C	600V	1200V
45x107,5mm	25A		●
	35A		●
	50A	●	●
62 x 122 mm	75A	●	●
	100A	●	●
	150A	●	●

The High Power 6-PACKs

	I_C	1200V	1700V
150 x 162 mm	225A	●	●
	300A	●	●
	450A	●	●
	550A	●	



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numerically the partial differential equations of Ohm's law and Fourier's law to solve for high-resolution x-y-z distributions of potential U, current density j, Joule heating power density and temperature. Without knowledge of the exact NBS setup, we are assuming a model with a double-sided PCB in Euro-Format, with one copper trace of length L=100 mm and of thickness h=35 µm (=1 oz) on the top face and a coated copper cladding on the back face (also of thickness 35 µm). In "still air" environment (parameterized by a heat exchange coefficient α=10 W/m²K) the result for w=0.055" (=1.4 mm) and I=5 A is shown in Fig. 1. The calculated maximum value of ΔT=26 K matches closely the blue line example in [1]. When the copper cladding on the bottom face is removed, the rise increases to ΔT=53 K, which is now very close to IPC-2152 and Brook's Design News data (59 K).

Heat Spreading is Important

The examples in Fig. 1 show, that heat spreading in FR4 and by copper layers is essentially influencing the trace temperature. Having demonstrated the viability of the method, other layer stacks, although not detailed either, can be investigated. For example, a 4 layer board with 2 internal homogeneous copper planes (e.g. GND and VCC) has a much higher current carrying capacity than the IPC boards (Fig. 2). The calculated results [6,7,8] for other boards can be fitted by Eq. (3)

$$\Delta T \approx B_{PCB} \cdot \left(\frac{w}{\text{mm}}\right)^{-1.45} \cdot \left(\frac{h}{35\mu\text{m}}\right)^{-1} \cdot \left(\frac{I}{\text{Amp}}\right)^{2}, \qquad (3)$$

where B_{PCB} is a characteristic figure for the board layer stack and layer parameters. Some values are given in Table 1.

Layer Stack	B_{PCB}
DN and IPC-2152	3.6
IPC-2221	1.7
2 internal 17mu planes	1.2
2 internal 35 mu planes	1

Table 1: Coefficients for Current- Temperature Correlation Eq (3)

IPC-2221 and IPC-2152 are not Universal

Eq. (3) reveals another drawback in both the old and new IPC charts. The horizontal axis shown there is the cross-section $w*h$ of the trace, which is incorrect. In fact the cross-section is controlling heating, but cooling is controlled by the footprint (width). This brings in another $w^{-0.45}$ term. Simulations also disprove the myth of hot internal traces:

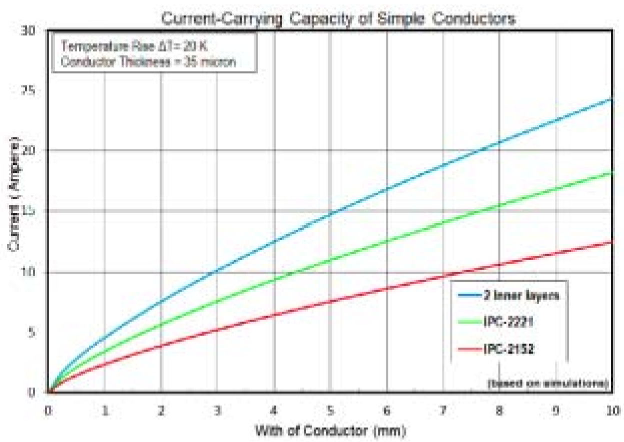

Figure 2: Current carrying capacity of a 35 µm trace at temperature rise of ΔT=20 K. The more heat spreading, the more current can be carried.

an internal trace can be even cooler than an external trace, because of better heat spreading above and below. Finally we should mention that the new IPC-2152 values are close to "DN" correlations and is therefore more conservative than the old 2221.

High-Resolution 3-D Multilayer Simulations

Eq. (3) does not contain the trace length L, because P and the area of left and right cooling wings are proportional to L. However this is true only for long traces. From Fig.1 (left) we can estimate a width of the wings of about 10 to 20 mm. In this model a trace may be called short, if L<20 mm. If we now simulate a trace with L=10 mm (Fig. 1 right) we see that the result ΔT_{max}=19 K does not agree anymore with Eq. (3).

Realistic layouts are more complex and hence are the genuine application for numerical simulation. We can observe current concentrations at *constrictions*, *curvature* effects and *shielding* of current by other conductors. Fig. 3 shows a close-up of results of a calculation with x-y resolution of 0.1 mm. We assume a bilayer PCB like in IPC-2221. Current of 18 A enters each conductor path via 3 pins at 6 A each and leaves by 4 pins terminated to 0 V. Fig. 3 (top) shows the potential (with potential lines), the current density and the temperature in a layout *with thermal reliefs*. The middle conductor has the lowest cross section and thus the highest DC voltage drop (31 mV). It is also the hottest (ΔT_{max}=20 K), because it is surrounded by two other heat sources. The current density is related to the potential gradient and forms characteristic patterns: high values between pins with shortest distance, in constrictions and at inside bends, and low values around "shielded" pins and outside bends. The thermal conductivity is high enough to smear out the local heating effects. Fig 3 (bottom) shows the same situation *without thermal reliefs*. Now, maximum voltage drop is 27 mV and ΔT_{max} is 18 K. Don't try to predict these temperature with design rules!

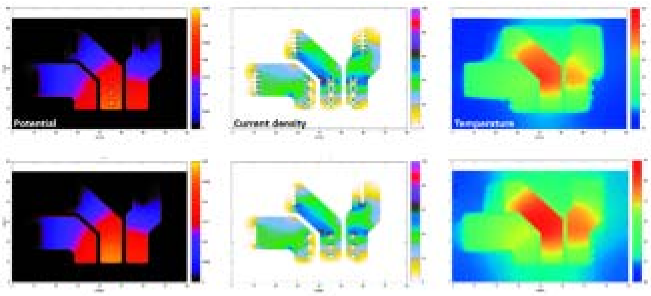

Figure 3: Consistent high-resolution simulations of three conductor paths at 18 A each. Top: with thermal reliefs, bottom: without reliefs (scales are individual).

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EconoPACK™ 4

The world standard for 3-level applications

The EconoPACK™4 is an optimized module for 3-level applications like:

- Uninterruptible Power Supply
- Solar Inverter
- High Speed Drives

where a rugged design, high efficiency and less harmonics are needed.

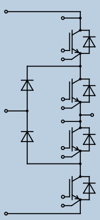
For these applications starting with 50kW up to 125kW, the EconoPACK™ 4 can be used to build up one phase. For higher power ratings modules can be switched in parallel.
All modules are equipped with the state of the art IGBT4.
Further information's are available on request.

The degree of efficiency for two 3-level topologies, NPC1 and NPC2, has to be investigated depending on the switching frequency.

- EconoPACK™ 4 in NPC2 topology for low and medium switching frequencies (approx. $f_{sw} \leq$ 12kHz)
- EconoPACK™ 4 in NPC1 topology for high switching frequencies (approx. $f_{sw} \geq$12kHz)

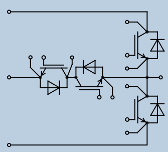
NPC1 topology

- 650V IGBT4
- Optimized for $f_{sw} \geq$12kHz
- Portfolio
  - F3L200R07PE4
  - F3L300R07PE4



NPC2 topology

- 650V/1200V IGBT4
- Optimized for f_{sw}<12kHz
- Portfolio:
  - F3L300R12PT4_B26
  - F3L400R12PT4_B26



[www.infineon.com/highpower]

New High-Voltage Power Thyristor with Built-In Protective Elements in the Semiconductor Structure in Case of Emergency Mode: Excess-Voltage Protection

Despite of the possibility of "outer" protection, usage of thyristors with built-in in the semiconductor structure elements for excess-voltage protection can also be attractive to customers if pricewise such thyristor will be on the same level with the standard one. There are two types of protective elements different in principle of operation.

By Y.M. Loktaev, A.M. Surma, A.A. Chernikov

First of all, it is a voltage suppressor similar to nonlinear resistor (varistor) or avalanche semiconductor voltage suppressor. Such element can be characterized by nonlinear volt-amps diagram where up to certain threshold voltage current through the element has very low value, and exceeding this threshold value it's growing rapidly. Such protective elements can suppress surge discharge applied to thyristor directly and blocking direction as well. Though admissible power of these pulses is low as a rule (up to several joules) because the bigger part of it is dispersed in protective element.

Secondly, this is an element with dynistor characteristics switching at exceeding of some threshold voltage value. As a rule structure of such element is the following: at exceeding of some threshold voltage value initiates the switching of protecting thyristor. With the help of such element only direct excess-voltage protection can be realized, though this protection is also effective for high power pulses. Moreover, such protective elements help to reach very important characteristic, which improves the reliability of thyristors in series connection assemblies of high voltage valves: thyristor in series connection assembly can safely switch if driver fails (absence of standard control signals), i.e. the valve still works after failure of one of thyristor drivers.

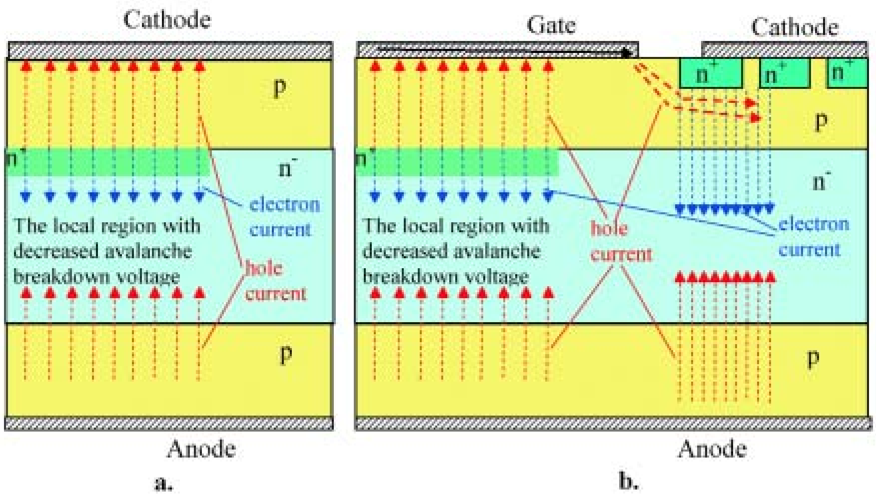


Figure 1:Integrated into semiconductor element of thyristor protective elements: a. –voltage suppressor of p-n-p type, b. – switching limiter of dinistor type.

Rather simple and relatively cheap way of protective elements production of both types integrated in semiconductor element of thyristor is production of local areas with undervoltage of avalanche breakdown as it's shown in figure 1.

Controlled voltage drop of avalanche breakdown in these areas is reached at the expense of n'-layers in n-base with higher dopant concentration.

To have protective elements of the first type p-n-p area of semiconductor element with no n+ of emitter layer is used, where the amplifying electrode is located. In this case avalanche current with limited pulse of direct voltage doesn't lead to switching of thyristor element.

To have protective elements of the second type p-n-p area of semiconductor element is used, located under the amplifying electrode. In this case avalanche current with limited pulse of direct voltage leads to thyristor switching, because this current is similar to control current applied at this electrode.

One of effective technologies, which may be used to create deep hidden n'layers in semiconductor elements of power high voltage thyristors, is proton irradiation. It's well known [1-4] that during proton irradiation of silicon, implanted atoms of hydrogen stimulate appearance of connected to them dopant centers similar to traditional dopants in their characteristics (phosphorus, arseni-

um, stibium). Unlike the atoms of mentioned elements, hydrogen can be easily implanted into silicon at depth of hundreds microns. This allows creating in n’base hidden n’layers with precise regulation of their depth and concentration of additional dopants. As a result high precision of voltage regulation of avalanche breakdown is possible on the level of dozens volts with 4000-8000 V overall voltage.

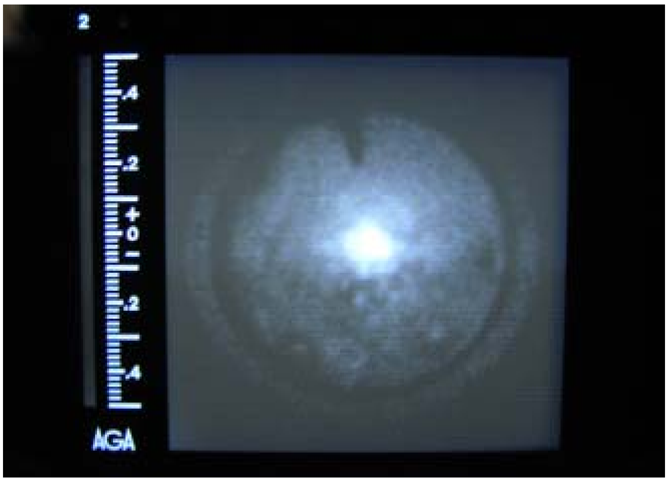


Figure 2: Temperature distribution image during avalanche current through the experimental semiconductor element with area of reduced breakdown voltage in the center.

Similarity of breakdown voltage is achieved as well, even in the relatively big areas. Thus, for example, temperature distribution with current of avalanche breakdown in experimental semiconductor element is shown in figure 2, which was taken with help of infrared image converter. The diameter of element is 56 mm, with help of proton irradiation in the center of it was created a ring-shaped area about 1 cm in diameter with reduced voltage of avalanche breakdown. It’s clear that avalanche current causes relatively even overheat almost within all area with reduced voltage breakdown, i.e. current distribution is close to even.

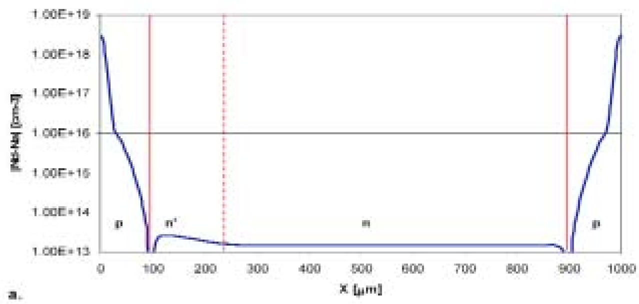


Figure 3a: Typical distribution profile of atoms of acceptor and donor dopants according to the thickness of high-voltage p-n-p element

Thus the technology of proton irradiation allows creating local areas with controlled reduced voltage of avalanche breakdown against big area with rather evenly distributed power with avalanche current, i.e. implanted into thyristor structure protective elements can have quite high power capacity and admissible peak power.

Volt-amps diagram of voltage suppressor on basis of three-layer p-n-p semiconductor element (Figure 1 a) has some peculiarities comparing with characteristics of avalanche diode. Same as in high voltage diode generation of electron-hole pairs during avalanche breakdown happens in relatively thin layer with maximum values of electric field intensity (Figure 3).

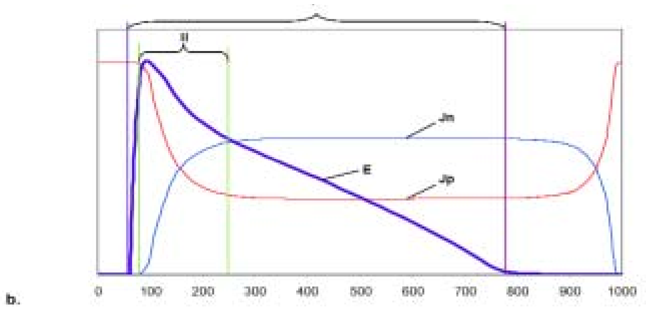


Figure 3b: Electric field intensity distribution (E), electrons (Jn) and holes (Jp) current densities during avalanche breakdown. I – area of volume charge of p-n junction, II – layer with maximum values of electric field intensity, where electron-hole pairs are generated.

In the main part of the area of volume charge of p–n junction located in high-resistivity n-layer avalanche generation of electron-hole pairs doesn’t happen, though in this layer current of electrons is present as well as current of holes, injected with the second p-n junction of p-n-p element as a result of transistance in p-n-p element. Current of electrons as a result of avalanche generation for this p-n-p element is similar to base current, values of current of electrons and holes, transferred to the area of volume charge of reverse-biased p-n junction equal

$$J_p = \alpha \cdot J$$

$$J_n = (1 - \alpha) \cdot J$$

J_p, J_n – holes and electrons current density in the area of volume charge of p-n junction located in high-resistivity n-layer (without layer of avalanche generation),
J – current density through limiter
α – current amplification factor (in the scheme with joint base) of transistored p-n-p element.

Supplementary charge appears with apparent density Qv during current of holes and electrons in the area of volume charge:

$$Q_v = \left(\frac{\alpha}{v_{ps}} - \frac{1-\alpha}{v_{ns}} \right) \cdot J$$

v_{ps}, v_{ns} – rich (maximum) speed of holes and electrons with high electric field intensity.

Presence of this supplementary charge influences the electric-field gradient and as a result the voltage value. Herewith, if

$$\frac{\alpha}{1-\alpha} > \frac{v_{ps}}{v_{ns}} \approx 0.8 ,$$

then Q_v is positive and with increase of J voltage in semiconductor element decreases, i.e. volt-amps diagram has the area with negative dynamic stress. Otherwise voltage of semiconductor element evenly increases with increase of current density, as in avalanche diode, though value of dynamic resistance of volt-amps diagram can be much lower.

The value can be easily regulated changing, for example, life time of carriers in n-layer of semiconductor element. This allows changing the appearance of volt-amps diagram of limiter. In Figure 4 some typical volt-amps diagrams of high voltage suppressor are shown, which can be achieved by the above mentioned method (1). To compare, there is a volt-amps diagram of diode structure with identical parameters of high-resistivity n-layer shown in the same figure.

In case of usage of such elements as protective excess-voltage suppressors it's better to have volt-amps diagram with low dynamic resistance but with no area of negative resistance similar to one shown in figure 4b. It's clear that in comparison with characteristics of diode protective element, dynamic resistance of volt-amps diagram can be significantly decreased.

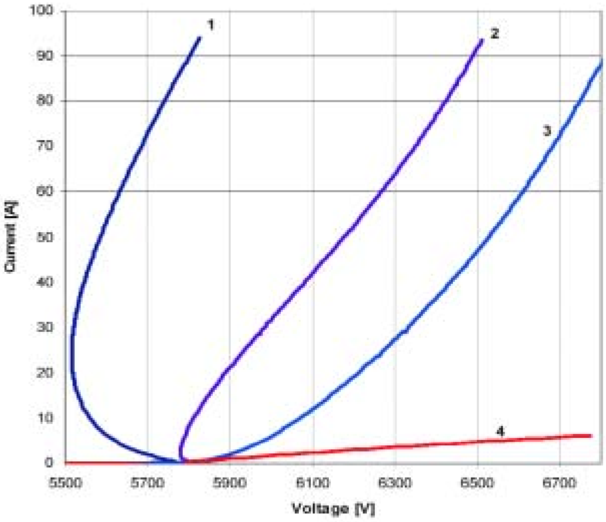


Figure 4: Volt-amps diagram of p-n-p element (1-3) and diode p-n-n+ element (4) during avalanche breakdown. Flat area of semiconductor elements is 1 cm2, thickness of high-resistivity n-layer is 820 μm. 1 – $\alpha/(1-\alpha)>v_{ps}/v_{ns}$, 2 – $\alpha/(1-\alpha)\approx v_{ps}/v_{ns}$, 3 – $\alpha/(1-\alpha)<v_{ps}/v_{ns}$.

Transfer of holes through the base layer of p-n-p element has some persistence, that's why the question of voltage suppressor performance on basis of such element is quite important. Calculations and experiments prove that for limiters meant for voltage up to 8000 V during applying of surge discharges with rate of voltage rise up to

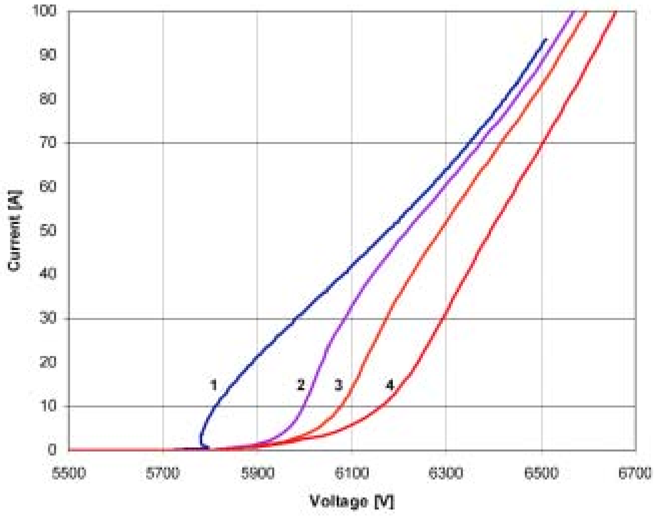


Figure 5: Volt-amps diagram changes of p-n-p type voltage suppressor depending on rate of voltage rise in front of surge discharge. Flat area of semiconductor suppressing element is 1 cm^2, thickness of high-resistivity n-layer is 820 μm. 1 – "quasistatic" characteristic, 2 - dV/dt = 1000 V/μs, 3 – dV/dt = 2000 V/μs, 4 – dV/dt = 4000 V/μs.

1000-2000 V/µs voltage fluctuation in comparison with “quasi static” can be hardly visible. Thus, for example, in figure 5 “dynamic” volt-amps diagrams of limiter with various rate of voltage rise in comparison with “quasi static” volt-amps diagram are shown.

For usage in protective elements of dinistor type (figure 1b) volt-amps diagram of p-n-p element with area of negative dynamic resistance is the most acceptable. Such characteristic allows forming for thyristor part of protective element control current pulse with necessary amplitude and rather high rate of rise, which is very important, if surge discharge applied at protective element has low rate of rise. In figure 6 typical current changes of p-n-p and thyristor elements as well as anode voltage at switching-on of such dinistor protective element with surge discharge with low rate of rise in front.

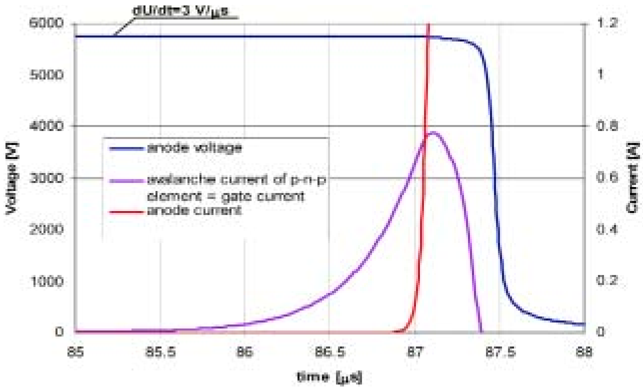


Figure 6: Switching of dinistor protective element with surge discharge with low rate of rise in front. Volt-amps diagram of p-n-p element corresponds (1) in figure 4, flat area of p-n-p element is 0.1 cm^2

At present moment many companies have standard constructive solutions and technologies, which allow optionally or in mass production use integrated into semiconductor structure elements with protection against surge discharge. Proton-Electrotex, using the above described standard structures and proton irradiation technologies [3], apply them optionally in accordance with special requirements of customers for all produced thyristors with voltage from 1200 V up to 6500 V. Typical characteristics of voltage suppressor of p-n-p type are shown in figure 7, integrated dinistor element in figure 8.

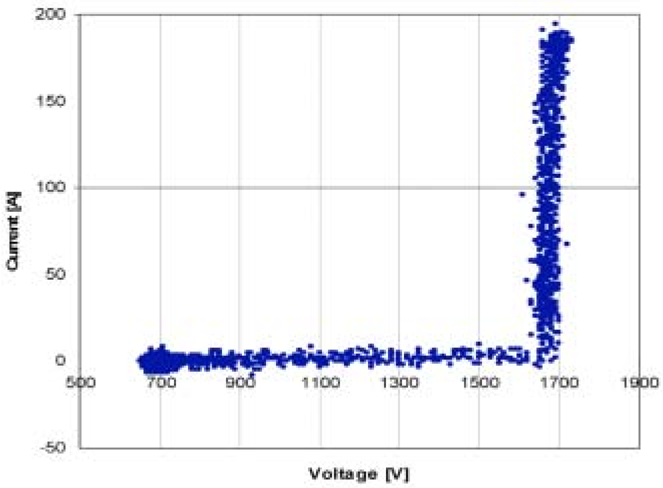


Figure 7: Volt-amps diagram of element - excess-voltage suppressor for thyristors with voltage up to 1800 V

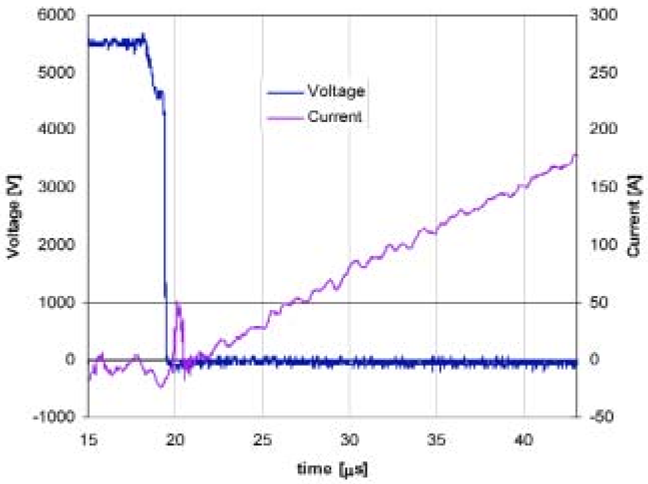


Figure 8a: Switching of thyristor with built-in excess-voltage protection element: a. – with low rate of voltage rise.

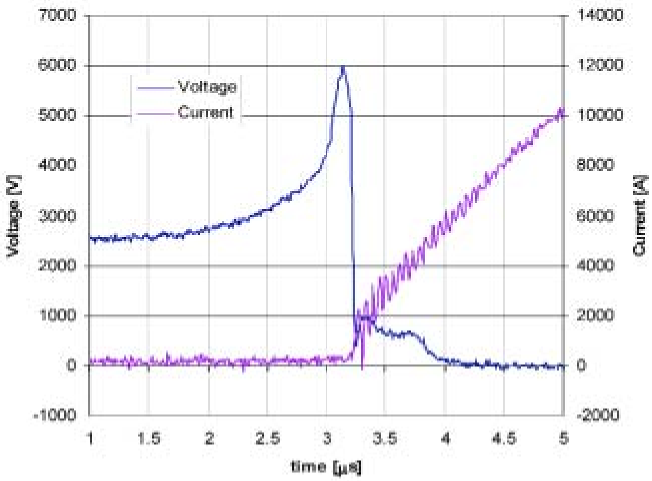


Figure 8b: Switching of thyristor with built-in excess-voltage protection element: b. – with high rate of voltage rise.

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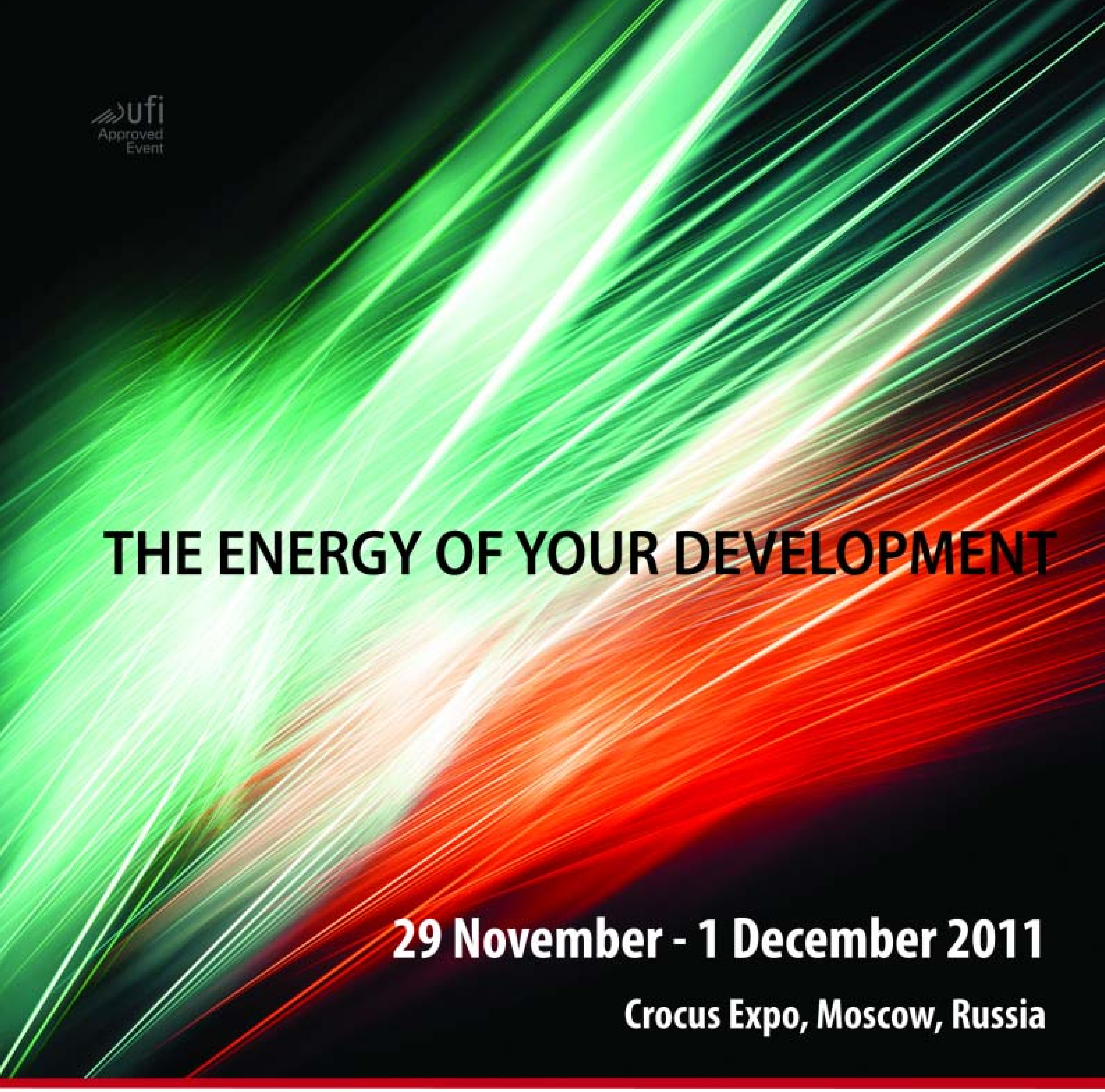
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Silicon Carbide - Taking Efficiency to the Next Level

SiC SBDs maintain a constant trr regardless of temperature

The semiconductor industry has a well-established history of "smaller, faster, and cheaper." Improving performance and reducing device cost while shrinking packaging size is fundamental to virtually every semiconductor product type. For power products, improved performance is measured by increased efficiency and power density, higher power handling capability, and wider operating temperature range.

By Masanori Tanimura, Product Marketing, ROHM Semiconductor GmbH

Such improvements depend largely on the desirable characteristics of power components used, such as low switching and conduction losses, high switching frequency, stable electrical characteristics over a wide temperature range, high operating temperature, and high blocking voltage. As silicon power components approach their theoretical limits, compound semiconductor materials, such as silicon carbide (SiC) and gallium nitride (GaN), provide the capability to dramatically improve these parameters.

Additionally, with the advent of hybrid electric vehicles (HEVs) and electric vehicles (EVs) came an increasing need for power electronics and conversion losses generated in conventional (Si-based) semiconductor devices have become increasingly problematic, prompting a search for a viable alternative as well.

The Advantages of Silicon Carbide

The highest performance silicon power diodes are Schottky barrier diodes. Not only do SBDs have the lowest reverse recovery time (trr) compared to the various types of fast recovery (fast recovery epitaxial), ultra-fast recovery and super-fast recovery diodes, they also have the lowest forward voltage drop (VF). Both of these parameters are essential to high efficiency. Table 1 shows a comparison of breakdown voltage, VF, and trr for commonly available diodes. While Schottky barrier diodes have the advantage of low forward losses and negligible switching losses compared to other diode technologies, the narrow bandgap of silicon limits their use to a maximum voltage of around 200 V. Si diodes that operate above 200 V have higher VF and trr.

Type	VBR (VRRM)	V_F (1)	t_{rr} (1)
Si Schottky Barrier Diode	15 V-200 V	0.3V-0.8 V	<10 ns
Si Super Fast Diode	50 V-600 V	0.8V-1.2 V	25 ns-35 ns
Si Ultra Fast Diode	50 V-1,000 V	1.35V-1.75 V	50 ns-75 ns
Si Fast Recovery (Epitaxial) Diode	50 V-1,000 V	1.2 V	100 ns-500 ns
Si Standard Recovery Diode	50 V-1,000 V	1.0 V	1 µs-2 µs
Silicon Carbide Schottky Barrier Diode	600 V	1.5 V	<15 ns

(1) @25°C. Si-based diodes have a wide increase at higher temperatures and are typically limited to 150°C operation.

Table 1: Comparison of key parameters for silicon and SIC diodes

Silicon carbide is a compound semiconductor with superior power characteristics to silicon, including a bandgap approximately three times greater, a dielectric breakdown field 10 times higher and a thermal coefficient three times larger. These characteristics make it ideal for power electronics applications. Silicon carbide devices have higher breakdown voltage, operating temperature and thermal conductivity, as well as shorter recovery time and lower reverse current than silicon diodes with comparable breakdown voltage. These device characteristics equate to low-loss, high-efficiency power conversion, smaller heat sinks, reduced cooling costs and lower EMI signatures. Continuing progress in raising high (250° C+) operating temperature and high blocking voltage promise exciting new applications such as motor drive in HEV/EV and solid-state transformers.

SiC is certainly not the only compound semiconductor material being considered for next-generation power components. Gallium arsenide (GaAs) Schottky rectifiers have been available since the 1990s but have only found limited acceptance for the most demanding applications due to their higher cost than silicon. GaAs bandgap, breakdown field and thermal conductivity are lower than silicon carbide. More recently, researchers are pursuing gallium nitride (GaN) for power transistors. GaN has similar bandgap and dielectric constant (hence comparable breakdown voltage) to SiC. It has higher electron mobility but only ¼ the thermal conductivity. This technology is early in its development/commercialization phase relative to SiC. Currently there are many more SiC devices and suppliers.

Figure 1 shows the reduction in switching losses compared to fast recovery diodes based on SiC SBD's minimal reverse recovery charge (Qrr) during turn-off.

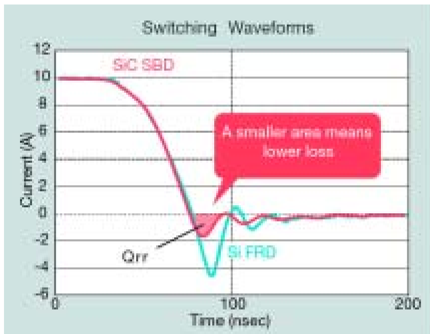

Figure 1: Reduction in switching losses compared to fast recovery diodes

With silicon fast recovery diodes, the trr increases significantly with temperature as shown in Figure 2. In contrast, SiC SBDs maintain a constant trr regardless of temperature. This enables SiC SBD operation at higher temperature without increased switching losses. The numerous SiC SBD performance advantages can result in more compact, lighter power devices with higher efficiency.

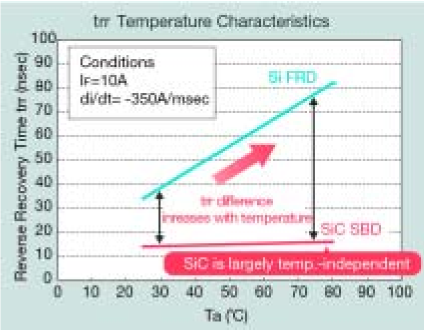

Figure 2: SiC SBDs maintain a constant trr regardless of temperature

SiC has demonstrated temperature stability over a wide operating range (Figure 3). This simplifies the parallel connection of multiple devices and prevents thermal runaway. With all of these benefits, why hasn't SiC had more of an impact in new products? One reason is the continuous improvements of silicon devices, which benefits from having an infrastructure – process, circuit design, production equipment – that has been fine tuned for over fifty years. By contrast, SiC technology is still in its infancy. The higher cost of SiC devices has been a barrier to most applications. This is due in large part to the fact that SiC is a much more difficult material to process than silicon. For example, costly ion implantation is used for doping because of SiC's low diffusion rate. Reactive ion etching (RIE) with a fluorine-based plasma is performed, followed by annealing at high temperature. These processing difficulties increase cost and limit the types of device structures that can be built. As a result, the cost is high and availability limited. However, this is about to change.

The Timing is Right for Silicon Carbide Technology

Though the first commercial SiC SBDs were available in 2001, adoption has been limited until recently. The increase in interest and adoption in many applications are predominantly due to lower production costs, availability of SiC transistors, a wider pool of suppliers and the rise of green energy in general, and power conversion efficiency in particular, driven by legislation and market demands; and last but not least new applications such electric vehicles (EVs) and charging stations. In its report "SiC 2010," Yole Developpement identified the transition to 100-mm SiC wafers as a significant milestone towards reduced cost. The report states, "The total SiC substrate merchant market has reached approximately $48M in 2008. It is expected to exceed $300M in a decade." The coming transition to 150-mmwafers is expected to play a significant role in further cost reduction and market growth. According to the report, "150-mm wafers will definitely accelerate the cost reduction of SiC device manufacturing."

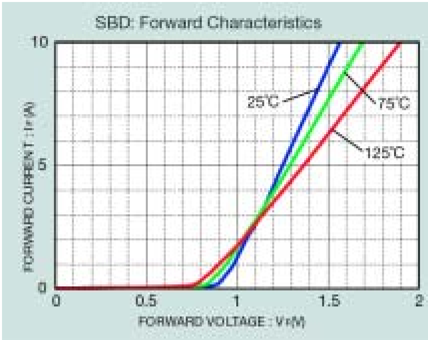

Figure 3: SiC has demonstrated temperature stability over a wide operating range

SiC Transistors

One of the main obstacles to the increased use of SiC has been the lack of an SiC transistor to provide a complete SiC solution. With the ongoing global R&D efforts in this area, Yole expects to see volume production within the next few years. The growth is based on a greater number of suppliers and increased production capacity for both SiC diodes and transistors.

Finally, governments around the globe are pursuing renewable energy sources to reduce the dependence on fossil fuels and reduce CO² emissions. Other applications that are attracting early adopters of SiC technology and seeing early implementation include those where the need for high efficiency is either a major end-product differentiator and/or where legislation and regula-

80 PLUS Test Type	115V Internal Non-Redundant			230V Internal Redundant		
Percent of Rated Load	20%	50%	100%	20%	50%	100%
80 PLUS Basic	80%	80%	80%	Not defined		
Bronze 82%	85%	82%	81%	85%	81%	
Silver 85%	88%	85%	85%	89%	85%	
Gold 87%	90%	87%	88%	92%	88%	
Platinum 90%	92%	89%	90%	94%	91%	

Table 2: 80 Plus Efficiency Levels. Per ENERGY STAR 5.0, desktop computer, laptop computer or server power supplies must comply with the Bronze level. Source Wikipedia

tions dictate a minimum energy efficiency level.

SiC advantages in real-world applications
SMPSs with output power ratings above 300 W typically use active PFC boost converters designed to operate in continuous conduction mode (CCM). The single biggest advantage of using SiC diode in place of Si diode is the former's much lower reverse recovery current, which translates into approximately 60% lower switching loss and elimination (or great simplication) of the snubber circuit to control EMI. Also, the switching transistor no longer has to be derated to accommodate the large reverse current from the silicon blocking diode — a lower amperage, less expensive transistor can be used. With lower loss, the heat sink/cooling system can be made smaller. Lower switching loss allows the circuit to operate at higher frequency giving designers options to further increase efficiency and/or to reduce the choke's size, saving cost and board space. As a practical example, consider the PFC circuit in a 1 KW AC-DC power supply with the following characteristics:

n Input: 100 Vac, 60 Hz
n Output: 400 Vdc, 2.5 A
n Switching frequency: 50 KHz
n Operating temperature: 100º C

Table 3 summarizes the performance comparison between a circuit using a 600V Si FRD and an SiC SBD.

	Si-FRD	ROHM SiC SBD
Peak reverse current	56 A	14 A
Power conversion efficiency	93.13%	95.57%
Harmonic distortion	2.42%	2.38%

Table 3: Performance comparison between circuits using 600 V / 20 A Si-FRD and ROHM 600 V / 10A SBD (SCS110AG)

For example, inverters with SiC SBDs have dramatically reduced recovery losses, resulting in improved efficiency. When used with IGBTs and lower operating frequencies, the lower thermal losses allow for smaller heat sinks.

Other applications for 600 V and lower SiC devices include switching circuits, uninterruptible power supplies (UPS), motor drive circuits, and others where high efficiency is a product differentiator. Figure 4 shows how various application areas are distributed according to blocking voltage and current handling requirements. Though today's SiC devices still trail IGBT in power rating and the types of devices are still limited, in general the higher these requirements are, the more compelling the adoption of SiC technology.

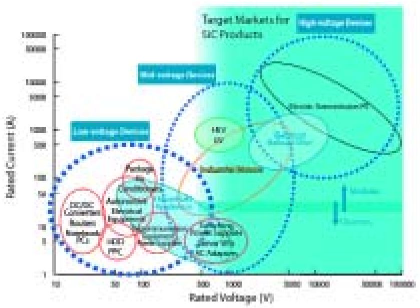

Figure 4: Various application areas are distributed according to blocking voltage and current handling requirements

Challenges to SiC adoption
The main obstacles to widespread adoption of SiC are cost, availability (of different device types as well as a larger supplier pool) and familiarity of the engineering community with this technology.

For SiC components to be widely adopted in power electronics, the premium over Si must come down. As with silicon, lower costs will be realized by improving yield as the technology matures, the use of larger wafers, and an increase in the number of suppliers. In the past few years, more vendors — both small and large, startups and established - have joined the "race." As a result, a variety of SiC devices are or will soon be available, including various flavors of diodes and transistors (MOSFETs, JFETs, BJTs), SiC diodes packaged with Si transistors, SiC module, etc.

A rapidly emerging field that can dramatically accelerate the need for SiC are vehicles with some form of electric propulsion such as hybrid, plug-in hybrid, electric, and fuel cell vehicles. Efficiency, size, and cost are extremely important factors, making SiC devices particularly suitable. These vehicles require the efficiency that SiC can provide and, equally important, they have an operating environment that demands SiC's temperature stability and higher temperature operating capabilities. Cars with SiC SBDs and SiC transistors can potentially eliminate a liquid cooling system to help justify the increased costs of SiC technology. Acceptance in these vehicles will create a high volume damand and push the technology into the mainstream.

While EV usage will occur in the future when SiC transistors are more affordable and widely available, having them as a driving force should encourage engineers with other applications to take a closer look at SiC technology.

SiC can in many cases serve as a drop-in replacement for its Si counterpart. In order to fully realize the performance benefits and potential cost savings, (e.g., no or simplified snubber, using switching transistor with lower current rating), designers must be fully aware of the characteristics of SiC devices. Those who take advantage of SIC's capabilities early, when the diodes are widely available, will be in a much better position to judge, adopt and fully realize the benefits of future SiC components (transistors, modules, etc.) in power applications.

ROHM Semiconductor's Silicon Carbide Solutions
As a leading designer and manufacturer of semiconductor products, from VLSI integrated circuits to discretes and passives to optical electronics, ROHM recognized the potential of and made significant investment in silicon carbide technology many years ago. ROHM's pioneering efforts resulted in the successful development of a silicon carbide double-diffusion metal-oxide-semiconductor field-effect transistor (DMOSFET) prototype in 2004. Schottky barrier diodes and power modules that incorporated SiC transistors and SBDs were developed soon afterwards. Improvements and enhancements were made to the SiC SBDs based on customer feedback in 2005. This led to the development of a uniform production system for SiC devices.

Mass production of SiC transistors has proven particularly challenging to manufacturers worldwide. Therefore, in parallel,

Part No.	Absolute Maximum Ratings (Ta = 25°C)				Electrical Characteristics (Ta = 25°C)				Package
	V_{RM}(V)	V_R(V)	I_O(A)	IFSM(A)	V_F(V)		I_R(µA)		
				60Hz,1	Typ.	I_F(A)	Max.	V_R(V)	
SCS106AGC	600	600	6	24	1.5	6	120	600	TO-220AC [2 pin]
SCS108AGC	600	600	8	32	1.5	8	160	600	TO-220AC [2 pin]
SCS110AGC	600	600	10	40	1.5	10	200	600	TO-220AC [2 pin]
SCS112AGC	600	600	12	48	1.5	12	240	600	TO-220AC [2 pin]
SCS120AGC	600	600	20	80	1.5	20	400	600	TO-220AC [2 pin]

Table 4: Available Schottky barrier diodes range from 6A to 20A-rated 600V products

ROHM partnered with university and industrial partners to develop production processes and equipment. ROHM overcame several significant obstacles and successfully established the industry's first mass production system for SiC transistors. To do this, ROHM developed a proprietary field-weakening architecture and unique screening methods to ensure reliability and technology that limits the degradation in characteristics caused by the high-temperature (up to 1,700° C) processes required in SiC fabrication.

ROHM has also solved the problems associated with mass production of SiC SBD devices, such as uniformity of the Schottky contact barrier and formation of a high-resistance guard ring layer that does not require high temperature processing, making uniform, in-house production possible.

In 2010, ROHM acquired SiCrystal AG, a leading producer and supplier of high-quality, single-crystalline silicon carbide wafers. SiCrystal's capabilities include complete materials processing from crystal growth to wafering. With the acquisition of SiCrystal AG, ROHM possesses total manufacturing capability for SiC semiconductors from ingot formation to power device fabrication. This allows the rapid development of advanced products and complete control of raw materials for industry-leading reliability and quality.

ROHM's R&D activities also include the development of the industry's first SiC Trench MOSFET as well as high power modules using SiC Trench MOSFETs and SBDs compatible with operating temperatures greater than 200° C.

ROHM's SiC offerings include Schottky barrier diodes, MOSFETs, and modules. 600 V SBDs are in mass production and are available as bare die or packaged parts. 1200 V SBDs and MOSFETs are currently sampled to customers in North America. In the pipeline are paired SiC SBD plus Si transistor in a single package as well as all-SiC modules.

ROHM Semiconductor Silicon Carbide Schottky Barrier Diodes
ROHM Semiconductor's SCS1xxAGC series of SiC Schottky barrier diodes has a rated blocking voltage of 600V, is available in 6, 8, 10, 12 and 20 A, and offers industry-leading low forward voltage and fast recovery time. Compared to Si FRD diodes, all SiC diodes incur much lower switching loss. Compared to other SiC diodes, ROHM SiC SBDs feature lower VF and thus comparatively lower conduction loss. Table 3 shows the characteristics at room temperature, but the low VF advantage remains true at high (150ºC) as well. It's worth noting that the 20 A-rated part is achieved with a single die, not by paralleling two die (although the 2-die version is available for sampling for interested customers).

Table 4 presents a more detailed description of ROHM 600 V SBDs. All products have a typical trr of 15 nsec.

At higher temperatures, ROHM Semiconductor SBDs demonstrate a smaller increase in VF than other available products. For example at 150° C, the 10 A/600 V SCS110AGC features a VF of 1.6 V (1.5 V @25° C) compared to 1.6 V (1.4 V@25°C), 1.85 V and 2.2 V for comparably rated SBDs from other suppliers. Initial SBDs are rated at a maximum operating temperature of 150°C. Even though SiC has the capability to perform at much higher temperatures than silicon devices, most engineers will initially design to the 150°C maximum rating they have traditionally used and use the higher operating capability as a safety factor. Initial products are offered in the popular TO-220, 2-pin package with exposed fin. ROHM Semiconductor also utilizes surface mount D2PAK and TO-220 fully isolated packaging technology. These packages may be offered in the future depending on customer interest.

These Schottky barrier diodes are but the first in ROHM's SiC product line-up. And through extensive R&D activites, more products are in the pipeline. In fact, 1200 V SiC SBDs and MOSFETs are already sampling at strategic partners to address higher power applications such as UPS and to develop all-SiC power devices. SiC and Si combination and all-SiC modules are also expected to be part of future offerings.

Silicon Carbide for Today's Designs
ROHM Semiconductor process and device technologies incorporate advancements that address performance and cost aspects of SiC SBDs. The 600 V Schottky barrier diodes in production today provide both low VF for reduced conduction loss with ultra-short reverse recovery time to enable efficient high-speed switching. With its long history and investment in SiC development, including the recent the acquisition of SiCrystal, ROHM Semiconductor is well-positioned to provide leading-edge SiC products in production quantities. Unlike many startups that are taking compound semiconductor research into pilot manufacturing lines, ROHM Semiconductor already possesses high volume manufacturing capability. Furthermore, it has complete control over the entire SiC manufacturing and designing process. ROHM is currently the only supplier capable of offering a complete range of SiC products, from bare die to package parts to modules.

ROHM considers products that enable increased energy efficiency – SiC products in particular – as a key growth driver. ROHM is committed to continue driving SiC technology development and offering a full range of competitive SiC products. Expect more device types, higher-performance and cost-competitive SiC products from ROHM Semiconductor in the near future.

www.rohm.com/eu

Breakthrough High Temperature Electrical Performance of SiC "Super" Junction Transistors

The SiC based 1200 V/220 mΩ Super Junction Transistors (SJTs) feature high temperature (> 300 °C) operation capability, faster switching transitions (< 20 ns), extremely low losses and superior avalanche ruggedness performance (36 mJ). Integration of SiC SJTs with GeneSiC's freewheeling SiC JBS rectifiers will result in a power loss reduction by about 64% than its comparable Si counterpart.

By Siddarth Sundaresan, Director-Device Design & Fabrication, Stoyan Jeliazkov, Process Engineer, Michael Digangi, Chief Business Development Officer and Ranbir Singh, President, GeneSiC Semiconductor, Inc.

With Silicon almost reaching its theoretical limit, alternate semiconductor materials like SiC are sought for power electronic conversion applications [1]. SiC transistors are identified as an attractive alternate solution to the existing Si counterparts in the high voltage regime (1.2 kV-10 kV), particularly for medium and high frequency applications [2]. Though SiC based Schottky diodes were readily available since 2001[3], commercial SiC transistors came into limelight only in the last two to three years [4-5].

GeneSiC has developed an innovative SiC power switch, "Super" Junction Transistor (SJT) in 1.2 kV to 10 kV voltage ratings for high efficiency power conversion in Switched-Mode Power Supply (SMPS), Uninterruptible Power Supply (UPS), aerospace, defense, down-hole oil drilling, geothermal, Hybrid Electric Vehicle (HEV) and inverter applications. The Gate-oxide free, normally-off, current driven, quasi-majority device, SJT is a "Super-High" current gain SiC based BJT that features a square reverse biased safe operating area (RBSOA), high temperature (> 300 °C) operation capability, low $V_{DS(on)}$ and faster switching capability (10's of MHz) than any other competitor SiC switch. The MOS interface reliability related issues and high channel resistance of SiC MOSFETs have limited their temperature capability to 150 °C where as the Gate-oxide and channel free SiC SJTs deliver high temperature performance (> 300 °C). Unlike SiC SJT, SiC MOSFET requires a custom made Gate driver design due to its poor transconductance characteristics. On the other hand, the commercially available SiC normally-off JFET displays a very high positive temperature coefficient of $V_{DS(on)}$ and lower temperature capability as compared to the SiC SJT. GeneSiC's 1200 V/220 mΩ SiC SJTs are packaged in standard TO-220 and high temperature TO-257 packages (see Figure 1). The following three best-in-class Si IGBT co-packs with internally integrated anti-parallel Si FREDs were chosen for comparing their electrical performance with that of 1200 V/220 mΩ SiC SJT:

NPT1: 125 °C/1200 V rated Si Non Punch Through IGBT
NPT2: 150 °C/1200 V rated Si Non Punch Through IGBT
TFS: 175 °C/1200 V rated Si Trench Field Stop IGBT

On-state and Blocking Performance

An almost temperature independent blocking performance of a 1200 V/220 mΩ SJT till 225 °C operating temperature is depicted in Figure 1. The leakage current in a SJT while blocking 1200 V do not change by a large extent up to temperatures as high as 225 °C. Leakage currents of < 100 µA were measured even at 325 °C on a 1200 V/220 mΩ SJT. Figure 2 shows the comparison of the temperature dependent leakage currents of the three Si IGBT co-packs and SiC SJT. Unlike Si IGBTs, the leakage current in SJTs do not show a strong dependence of temperature. Moreover, the operation temperature capability (< 325 °C) of SJTs is solely limited by the power package capability.

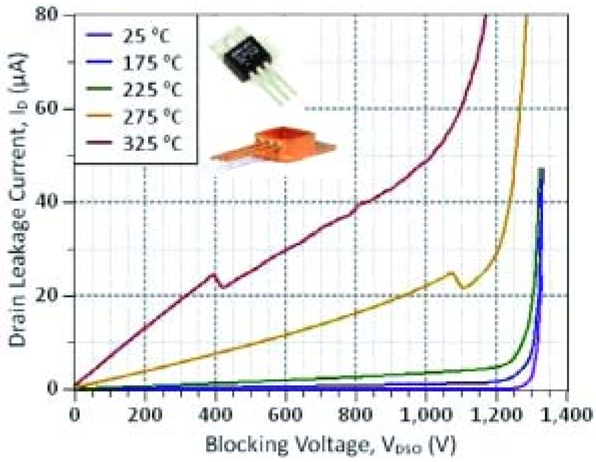

Figure 1:
Temperature variant blocking performance of a 1200 V/220 mΩ SJT

The on state characteristics of a 1200 V/220 mΩ SJT were generated using a curve tracer for operating temperatures up to 250 °C (see Figure 3). The distinct lack of quasi-saturation region and merging of the on state curves for various Gate currents in the saturation region of a SJT indicate the absence of the minority carrier injection and clearly distinguishes it from a Si "BJT". Appropriate metallization schemes and an optimized device design yield low Drain Source saturation voltages. The On-state voltage values of SJT are relatively smaller than the existing same current/voltage rated Si IGBTs with $V_{DS(on)}$ values of 1.5 V at 25 °C and 2.6 V at 125 °C at 7 A of drain current. SJTs display a positive temperature coefficient of $V_{DS(on)}$ that make their paralleling easy for high current configurations. A highest Common Source current gain value of 88 was measured on this batch of SJTs.

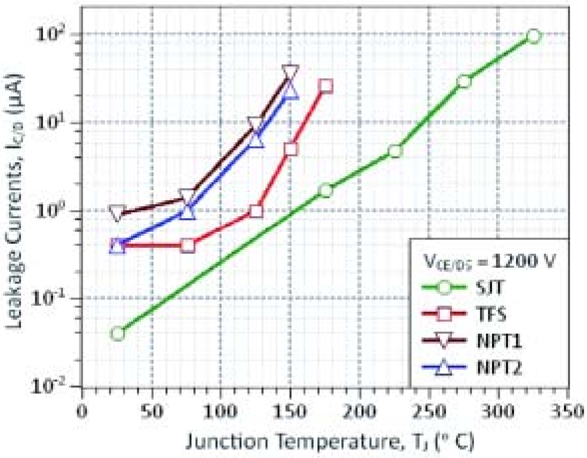

Figure 2: Leakage current comparison of Si IGBTs and 1200 V/220 mΩ SJT as a function of temperature

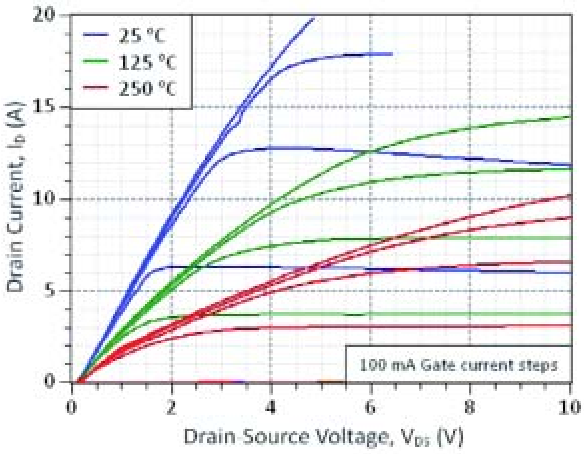

Figure 3 : Temperature variant output characteristics of a 1200 V/220 mΩ SJT

Dynamic Electrical Performance

The dynamic test setup for comparing the switching performance of SiC SJT and Si IGBTs comprises of an inductively loaded chopper circuit configuration. A GeneSiC 1200 V/ 7A SiC Schottky diode [6] and Si IGBT co-packs were used as Free Wheeling Diodes (FWDs) in the switching test circuit. The Gate Source terminals of Si IGBT co-pack (FWD) are tied together (V_{GS} = 0 V) to avoid the IGBT conduction during the dynamic testing. A 1 µF charging capacitor, a 150 µH inductor, 22 Ω Gate resistor and a supply voltage of 800 V were used in the testing process. A commercially available IGBT Gate driver with an output voltage swing from -8 V to 15 V is used for driving all the devices. A 100 nF dynamic capacitor connected in parallel with the Gate resistor generated an initial large dynamic Gate currents of 4 A and -1 A (Figure 4 and Figure 5) during turn-on and turn-off switching respectively, while maintaining a constant Gate current of 0.52 A during its turn-on pulse. The initial dynamic Gate currents charge/discharge the device capacitance rapidly, yielding a superior

switching performance. A Drain current rise time of about 12 ns and a fall time of 14 ns were obtained for 7 A, 800 V SJT switching at a temperature of 250 °C, resulting in extremely low switching energies when compared to the Si IGBT co-packs.

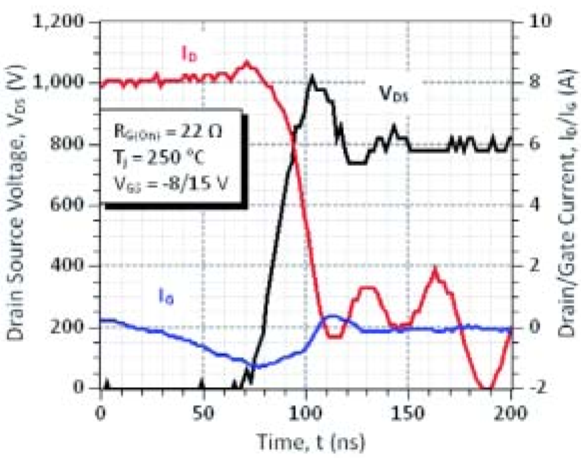

Figure 4:Turn-Off switching transients of a 1200 V/220 mΩ SJT

A comparison of the overall power losses measured on the SJT and Si IGBT co-packs is shown in Figure 6 for a switching frequency of 100 kHz and 0.7 Duty Cycle. Si TFS + SiC FWD represents Si TFS IGBT as the DUT and SiC Schottky diode as FWD respectively where as Si TFS + Si TFS represents Si TFS IGBT as DUT and Si

TFS IGBT co-pack as FWD respectively. The calculated gate drive, conduction and switching losses of SJT are 5.25 W, 26.65 W and 20 W respectively at 250 °C operating temperature. Though the gate driver losses of SJT are higher than Si IGBTs, their contribution to the overall losses is insignificant. The relatively high conduction losses of SJT when compared to the Si IGBT co-packs can be attributed to its high temperature operation (250 °C). An all-SiC solution reduces the overall losses by about 64% when compared to an all-Si solution.

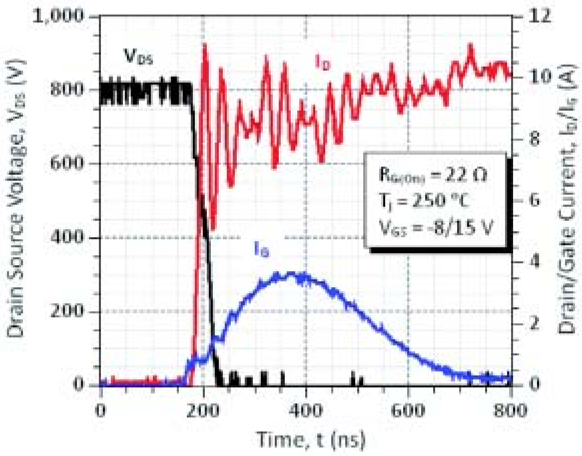

Figure 5: Turn-On switching transients of a 1200 V/220 mΩ SJT

Figure 6 : Power loss comparison of SiC SJT and Si IGBT co-packs at their maximum operating temperature

Avalanche Ruggedness Performance

A single pulse Unclamped Inductive Switching (UIS) [7] setup was used to obtain the nonrepetitive avalanche energy rating on the SiC 1200 V/220 mΩ SJTs. Using a supply voltage of 60 V and 210 µH inductor for the single pulse UIS test, resulted in non-repetitive avalanche energy and current ratings of 36 mJ and 20 A respectively (see Figure 7). The measured avalanche voltage (1650 V) is about 37% larger than the rated blocking voltage (1200 V).

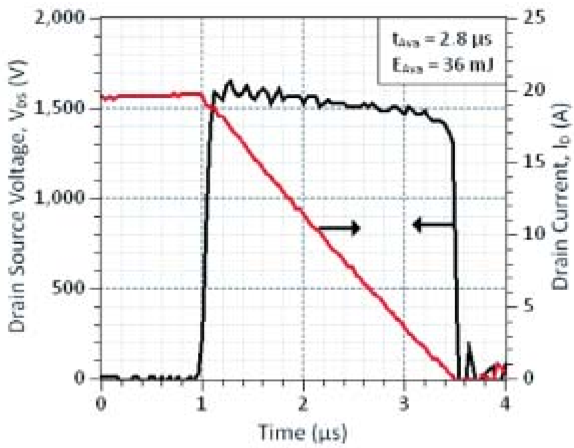

Figure 7 : Unclamped Inductive Switching waveforms of a 1200 V/220 mΩ SJT

Conclusions

GeneSiC highly rugged SJTs offer significant benefits over the Si IGBTs and SiC competitor transistors by reducing the power losses tremendously and delivering high temperature performance respectively. These benefits result in improving the system efficiencies, and reducing its cost and size. As SiC SJTs are direct replacement to the Si IGBTs, they can be driven using the standard IGBT/MOSFET gate drivers.

Beta side sampling of 1200 volt 220 m Ohm SiC SJT is currently under way and the product will be on GeneSiC distributer´s shelves by January 2012.

http://genesicsemi.com

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Powering Smartphone and Tablet PC Application Processors

Step-down converters powering the application processor resulting in a highly efficient system

The Smartphone and tablet segments experience amazing growth. Being a platform for software applications the need for a reasonable battery-on time paired with the required computing power have become dominant differentiators in the market. Both contradictory requirements can be addressed by a smart system design, where the application processor's power saving techniques are properly addressed while resulting requirements for its step-down converters are supported to squeeze highest computing power and longest battery on-time out of the battery.

By Andreas Schaefer, Portable Power Systems Engineer, Advanced Low Power Solutions, Texas Instruments

Starting from a low market share, smartphones, ultrathin laptops and tablets have become the growth engine star within the handheld wireless device category. Form factor and easy-to-handle human-machine interfaces have come to a state of implementation making these devices appealing and affordable not only for businesses but also leisure use. Affordable data transfer rates and high-speed data connections, such as LTE, create the mesh for fast wireless applications.

This has opened a platform for portable social media, gaming, still and motion picture viewing, 3-D applications and ever increasing mobile computing applications where a big portion of the value proposition is created by software applications. With this comes the continuously increasing need for higher performance and enhanced capabilities.

This need is being addressed by exponentially increasing the application processor performance. Smaller submicron nodes allow the system-on-chip (SoC) designer to integrate more features and higher operating performance with higher clock rates.

Since battery technology does not keep pace with the resulting increased processor power consumption, both the application processor itself and the respective power supply are challenged to compensate for that by utilizing an improved, power-efficient architecture.

Power saving technologies in application processors

As SoC's evolved, smaller submicron processes allowed for increasing the number of transistors operating at higher clock rates at the same or less silicon costs. During the past years, the product life cycles have even become shorter. The transition from 65nm to 45nm took place in 2 years and was followed by 28nm after the same amount of time. Thus, 65 nm technologies are now two generations old and effectively obsolete.

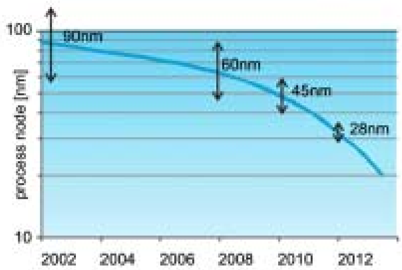

Figure 1: Technology scaling

Technology scaling comes with reduced dynamic losses per transistor due to reduced parasitic gate capacitance, but the number of logic gates is increasing. Despite the decreasing core supply voltage, leakage currents are rising due to smaller structures and lower off-resistances. With smaller logic gates, process variations become higher resulting in higher lot-to-lot and die-to-die variations.

These aspects lead to a continuously increasing power demand in mobile application processors. To address the increasing power demand and benefit from the scaled down technology and still offer the maximum performance, multiple techniques have been implemented to enable power-efficient processor operation. To begin discussing these techniques, Equation 1 gives an overview of where losses are created in an application processor.

$$P = P_{static} + P_{dynamic} \propto n \times V_{DD} + n \times f_{SW} \times V_{DD}^2$$

Equation 1: Power Losses of application processors with: n = number of logic gates, V_{DD} = supply voltage and F_{SW} = clock frequency

Analyzing Equation 1 gives an idea of how to leverage a power-efficient architecture – all variables affecting the losses are allowed to change. Explicitly, this means adaptively changing the number of active logic gates, reducing the supply voltage and regulating the clock frequency.

The techniques for power saving can be categorized into two main areas: Static power saving techniques, addressing losses which are not a function of the required processor performance, and dynamic power saving techniques, adapting to the current operating performance point of the processor.

Figure 2 shows an example of both dynamic and static power saving techniques.

Mobile application processors run at several operating performance points (OPP) to address different use scenarios in application, such as gaming, standby, WIFI access, etc. As an example, figure 2 depicts two OPPs. In OPP A the processor is operating with higher performance, for an application such as gaming, which requires increasing the processor's clock rate (Digital Frequency Scaling, DFS). For OPP B, the frequency is reduced since WIFI access doesn't require as high of a computing power. This also allows it to be operated at a lower supply voltage–V_{DD} will be adapted according to which OPP the processor is currently in (Dynamic Voltage Scaling, DVS). So both scaling down the frequency and reducing the supply voltage VDD saves power.

Figure 2 also depicts static power saving techniques. Semiconductors produced in any process have inherent variations which increase as processors move towards smaller process nodes. To account for this, die-specific supply voltages are applied to cover the variation from weak to strong process corners to meet the performance goals. As a positive side effect, adapting the supply voltage to these process variations accommodates a wider variation in processor performance, increasing yield and thereby reducing costs.

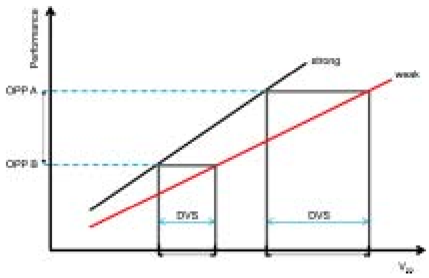

Figure 2: V_{DD} as a function of Operating Performance Points and Process Variation

Moving towards smaller process nodes, leakage power reduction also becomes more significant. To absolutely stop leakage losses of an unused block, power gating puts into practice the idea of disconnecting that block from the supply rail, VDD. Modern processors are equipped with a global power grid. Unused blocks can be cut off from the global power grid, zeroing out leakage for the block not in use, e.g. turning off multi-media blocks while in standby.

Besides the power saving techniques described above, various additional techniques are in place, such as low-Vt and high-Vt logic gate types to either increase performance or lower leakage, back-gate biasing, voltage islands, complex light/ deep sleep retention modes and further techniques.

Requirements for step-down converters as application processor supplies

By analyzing the power saving techniques of state-of-the-art application processors the requirements for the step-down converters, used to supply VDD of the application processor from a battery, can be derived.

High Efficiency over the complete application range

To leverage the dynamic and static power reduction techniques and to achieve a power-efficient processor operation, the conversion from the battery needs to address the processor's voltage domains and support dynamic voltage scaling (DVS) down to lowest output voltages required to support the processor's retention modes.

Moreover, efficiency needs to be kept high over the whole nominal battery voltage range, complete output current and output voltage range going down as low as 0.5V to support retention modes. The application processor's current demands stretch from little over a mA up to peaks in the Ampere range resulting from the power saving techniques described above.

Step-down converters usually feature peak efficiency at a singular output current. This peak needs to be spread over the whole output current range down to lowest output currents to support retention modes and up to highest output currents, both to extend battery run time and to reduce heat generation that would otherwise cause thermal rating limitations in the small device packages. Still,

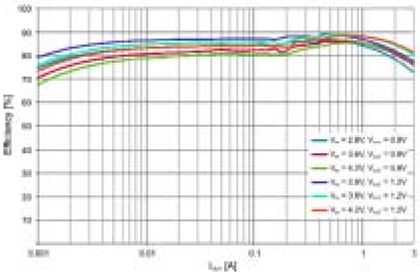

Figure 3: TPS6236x: High Efficiency over the complete output current, output voltage and input voltage range

to achieve tiny overall solution size inductors must be tiny – trading this off, the parasitic inductor resistance DCR is higher and contributes to the power losses. The step-down converter needs to compensate for that having a minimal power loss itself.

Output Voltage Accuracy

A stable output voltage is essential to facilitate reliable processor operation and avoid brown- and black-outs of the processor. A crash user experience definitely needs to be avoided. Still, another bad user experience must be prevented: The battery being drained too quickly with a low battery-on time. Besides tweaking the converter efficiency over the complete output current range, as described above, a highly accurate output voltage helps to keep the system efficient and thereby battery on-time high.

The more accurate output voltage regulation is, the less security margin needs to be factored in. Coming back to Equation 1, this reduces both static and dynamic power losses since V_{DD} can be kept at the lowest required level.

The supply needs to react quickly to the processor's sudden load changes, which are mostly originated by the dynamic power saving techniques described above. Slew rates of several Amps within a microsecond can occur; still the output capacitor needs to remain in a reasonable range for lowest solution size. Figure 4 shows as an example a good reaction to a sudden load change.

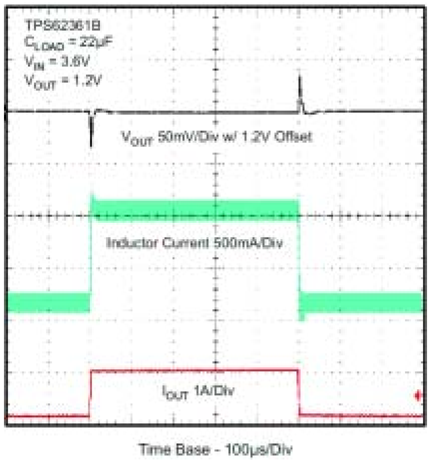

Figure 4: TPS6236x load step behavior

Differential sensing also helps keep output voltage security margins low. Two eyes seeing more than one, both V_{DD} and V_{SS} are sensed to react quickly to sudden load changes. Since the output currents can vary over a wide range, the voltage drop from the PCB power traces varies massively. Instead of factoring in a constant security margin, differential sensing allows for dynamically adjusting the output voltage and thereby compensating for the traces' voltage drop by measuring the output voltage at the power balls of the processor, not at the power supply itself.

The trend for Integration: Power Management ICs vs. stand alone switch-mode power supplies (SMPS)

Among the mobile phone industry, as well as to a certain extend in tablet pc, there is an ongoing trend towards integration. This is based upon the motivation of achieving savings in solution size.

Application processors are typically powered by several voltage rails, e.g. MCU, core or memory – all of them often powered by a single PMIC. However, in particular for the rail with the highest current demand the solution size is dominated by the passives. A single rail supply and a companion PMIC will not necessarily have a larger solution size compared to a single PMIC which has all power rails integrated. This is based on the possibility of placing the passives closer to the single rail supply and the single rail supply closer to the processor. This saves decoupling caps, since traces can be kept short; and it reduces the power loss on the traces, which can be massive at high currents. Finally, the performance of the single rail supply can be increased, since it has lower parasitic inductances in its smaller package, which allows faster switching of the internal power FETs--keeping dynamic switching losses small.

Texas Instruments TPS6236x Application Processor Supply

The TPS6236x devices are a family of step down converters to supply application processors with an output voltage range of 0.5V to 1.77mV, programmable in 10mV steps.

The device features high efficiency conversion over the complete output current range (up to 3A) with static output voltage accuracy of ±0.5%. The DCS-Control™ architecture enables fastest load step response on sudden load changes and achieves precise dynamic output voltage regulation.

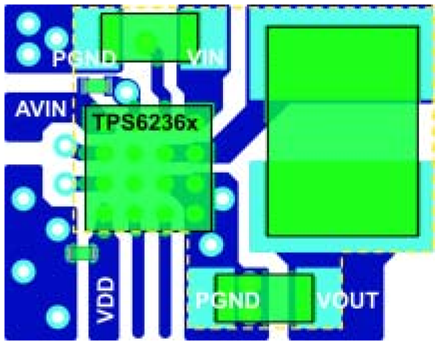

Figure 5: TPS6236x with a tiny solution size of approx 27.5 mm²

Optimized for mobile use, such as in smartphones or tablets, the total solution size is 27.5mm² which includes all required passive components.

The TPS6236x devices come with a dedicated feature set for application processors. The sensing scheme enables monitoring the output voltage differentially at the point of load. Features such as programmable ramp rates at the output voltage transition, OPP and POR support by dedicated hardware pins and highest programming flexibility by I²C interface allow for easy and flexible system integration.

Samples, evaluation boards and demo software are available at TI:

http://www.ti.com/docs/product/tps62360.html


Messe München
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coolRAC™ Boosts Server Power Efficiency 10% in Cloud Computing

Integrated Device Technology, Inc. announced coolRAC technology,

a breakthrough power architecture for enterprise data centers that dramatically increases energy efficiency and lowers operating cost. IDT's technology is the most efficient and cost-effective solution for enterprise data center applications, and does not require a data center re-design or changes to the physical architecture, minimizing the required effort and cost to upgrade.

IDT coolRAC utilizes an innovative approach for converting and distributing the AC input power of an enterprise computing data center to the DC inputs of the servers' electronics. Using low-voltage point-of-load conversion and AC distribution, coolRAC achieves end-to-end power efficiency of nearly 90% – a 10% improvement over traditional solutions, dramatically lowering energy and cooling costs. This solution provides a low-cost and high availability cabinet-level power solution for server, network, and storage products, such as those used in massive cloud computing facilities. The return on investment of coolRAC versus existing power architectures is extremely attractive, since investment costs can be recovered through energy savings.

www.IDT.com

Low-Jitter VCSO Solutions for High-Performance Optical Networking

Integrated Device Technology, Inc. announced the addition of a low-jitter Voltage Controlled Surface Acoustic Wave (SAW) Oscillator (VCSO) for high-end optical networking and telecom applications. The new VCSO clock generator expands IDT's industry-leading portfolio of clock and timing solutions.

The IDT M690SDM low-jitter, low-noise oscillator incorporates an analog frequency multiplier and single-ended RF output with jitter at less than 270 femtoseconds root mean square (rms) integrated across the 20kHz to 20MHz frequency band. It is available with an output frequency in the 1.5GHz to 2.1GHz range, providing customers a high frequency reference clock with low-jitter, low-noise performance. The IDT M690SDM's performance specifications meet the low bit error ratio (BER) requirements for today's high speed 40G and 100G board designs used in telecommunications and optical networking applications, helping to drive the development of next generation cloud computing and 4G wireless infrastructure.

www.IDT.com

Maxwell Ultracapacitors Solution for UPS Systems

Richardson RFPD, Inc. announced that it is delivering 56-volt ultracapacitor modules designed specifically to address the short-term ride-through and bridge power requirements of uninterruptible power supply (UPS) systems. These modules are needed for mission-critical UPS installations including data centers, hospitals, semiconductor fabrication plants, other large industrial power users, and telecommunication facilities.

Maxwell developed its new module to help UPS designers best mitigate the adverse effects of brief power disturbances (<1 second typical duration) on sensitive digital systems, especially those used in medical, financial and manufacturing environments. In the UPS industry, this is known as "ride-through" power capability. For longer term power disturbances or outages, these ultracapacitor modules can be used to provide up to 60 seconds of bridge power, which in turn allows the given UPS system to seamlessly switch-in a generator or other long-term backup power source (ex. fuel cell power generating system), thus keeping power available 100 percent of the time.

www.richardsonrfpd.com

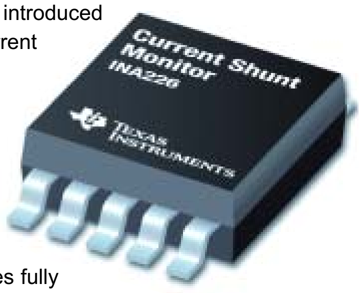
Compact, High-Efficiency RF Power Amplifier for 5 GHz Wi-Fi® Applications

Microchip announces the SST11CP15 RF power amplifier for 5 GHz IEE 802.11a/n WLAN embedded applications. The device operates on the 4.9 to 5.9 GHz band and offers a wide operating voltage range of 3.3V to 5V. The SST11CP15 features a high linear output power of 18 dBm at 2.5 percent EVM, using 802.11a OFDM 54 Mbps at 3.3V, and 20 dBm at 5.0V; and offers an output power of 23 dBm at mask compliance of 6 Mbps, at 3.3V. The compact, 2 mm x 2 mm x .55 mm, 12-pin QFN package makes the SST11CP15 suitable for 5 GHz WLAN applications where small size and high-efficiency operation are required.

The SST11CP15 enables designers to reduce DC current consumption in applications such as wireless multimedia and MIMO for broadband gateway and consumer-electronics equipment. With its high power-added efficiency, the SST11CP15 reduces battery current drain and therefore extends battery life, whilst its 4.9 to 5.9 GHz linear operation enables 802.11a/n operation and increases data rates.

www.microchip.com/get/02DL

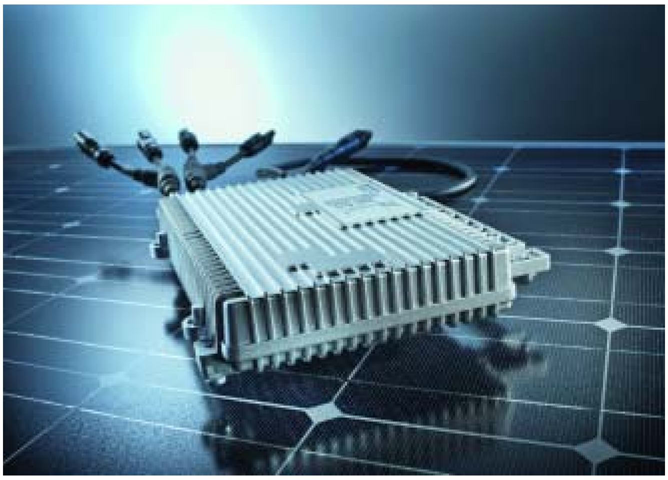
Accurate Current Shunt Monitor



Texas Instruments Incorporated introduced the industry's most accurate current shunt monitor. With a maximum offset voltage of 10-microvolts (uV) and a maximum gain error of 0.1%, the INA226 is 10 times more accurate than leading competitors. The device is a complete 16-bit, single-chip solution, and provides fully programmable measurements for current, voltage and power across a digital I2C interface. The INA226 benefits designers working with servers, telecom equipment, computers, power management devices and testing equipment, where accurate power measurements are crucial. To order samples and learn more, visit:

www.ti.com/ina226-preu

Dual-Input, Long-Life Micro Inverters for Solar PV Systems



Enecsys Limited, a leading provider of reliable solar micro inverter systems, had showcased micro inverter products and solar PV monitoring systems at EU PVSEC in Hamburg, Germany.

The new 480W Enecsys Duo micro inverter that supports fully independent power point tracking of two photovoltaic modules when converting the DC output of the PV modules to grid-compliant AC will be on show. Also on show will be the 360W version of the Enecsys micro inverter that was launched earlier this year. These dual-input micro inverters from Enecsys bring the capital costs of solar PV systems down to those of systems based on string inverters. However, string inverters typically need to be replaced at least once during the lifetime of the system while Enecsys micro inverters are expected to have a service life of over 25 years and come with a 20-year limited warranty, double the reliable operating life of solar PV systems based on string inverters.

www.enecsys.com

Isolated Power, 36V, H-Bridge Transformer Driver for Isolated DC-DC Designs

Maxim Integrated Products introduced the MAX13256, an H-bridge transformer driver with a wide input-voltage range for isolated power supplies. Using this simple solution, engineers can quickly design a highly efficient (up to 90%) isolated DC-DC converter. The MAX13256 drives a transformer's primary coil with up to 300mA of current from an 8V to 36V DC supply which can deliver up to 10W of isolated power. Users can choose their own transformer winding ratio which defines the output voltage, thus allowing the selection of virtually any isolated output voltage. This robust supply range eliminates external voltage regulation. Integrated protection features prevent system-level failures. By eliminating 16 discrete components, the MAX13256 simplifies BOM complexity and reduces footprint with high integration in a tiny TDFN package. With all these capabilities, the MAX13256 driver is a simple way to create isolated power supplies in smart grid metering applications, and industrial and medical equipment.

www.maxim-ic.com

25-Watt LED Lighting Ballast Reference Design for T8 Tubes

Power Integrations published a reference design for a 25-watt LED T8 tube ballast power supply. Notable for industry-leading efficiency of greater than 91%, the design (DER-287) also meets commercial requirements for power factor (PF greater than 0.9) and harmonic distortion (EN61000-3-2 Class C). DER-287 is a single-stage converter built around LNK409EG, a member of the LinkSwitch-PH family of LED driver ICs. Single-stage technology greatly increases product lifetime by eliminating the opto-isolators and large aluminum electrolytic input bulk capacitors required by conventional two-stage solutions.

Explains Andrew Smith, product marketing manager at Power Integrations: "Achieving very high power-conversion efficiency is as critical as LED choice in maximizing overall luminous efficacy of a lighting fixture. Efficiencies above 88% are extremely difficult to achieve cost-effectively in a T8 tube form factor unless a single-stage topology is used; this design easily exceeds 91%." Smith added: "Most regions require either low THD or high PF in commercial and industrial lighting installations – specifications that the LinkSwitch-PH LED driver IC easily meets, enabling designs that can be used worldwide.

www.powerint.com/linkswitch-ph

Low Leakage Current EMC Filters with UL Approval

The EMC filters in the FN 2450 range have successfully passed certification by UL (Underwriters Laboratories, USA). Now equipment intended for export to the USA can also benefit from the functional light-weight construction of the filters and from their greatly reduced leakage current compared to conventional filters.

FN 2450 EMC noise filters are particularly distinguished by their low leakage current of only 0.002 to 0.73 mA, depending on the version. This makes them particularly suitable for use with sensitive residual current circuit breakers for applications where protection of life and limb and/or fire prevention are of paramount concern. FN 2450 also meets the strict requirements of IEC/EN60601-1, which allows use in medical technology without reservations.

www.schaffner.com

350 W Half Brick Dc-Dc Converter

CUI Inc's power line announced the release of a new 350 W dc-dc converter. The VHB350 series is a board mounted solution that comes in an industry standard half brick package. It is designed to provide high levels of isolated power for applications with a limited amount of space.

The VHB350 series accepts a wide 2:1 input and can support either 18-36 Vdc or 36-75 Vdc input voltages. The dc-dc converter is offered in a variety of different regulated output voltage versions: 3.3, 5, 12, 24, and 28 Vdc. With tight regulations and efficiencies up to 92.5%, the converter is useful in many industrial and communications applications.

www.cui.com

eGaN® FET Family with Second Generation 40 Volt, 16 milliohm Power Transistor

Efficient Power Conversion Corporation announced the introduction of the EPC2014 as the member of EPC's second-generation enhanced performance eGaN FET family. The EPC2014 is environmentally friendly; being lead free, RoHS-compliant (Restriction of Hazardous Substances), and halogen free.

The EPC2014 FET is a 1.87 mm2, 40 VDS, 10 A device with a maximum RDS(ON) of 16 milliohms with 5 V applied to the gate. This eGaN FET provides significant performance advantages over the first-generation EPC1014 eGaN device. The EPC2014 has an increase in maximum junction temperature rating to 150 degrees C and is fully enhanced at a lower gate voltage than the predecessor EPC1014.

Compared to a state-of-the-art silicon power MOSFET with similar on-resistance, the EPC2014 is much smaller and has many times superior switching performance. Applications that benefit from eGaN FET performance include high-speed DC-DC power supplies, point-of-load converters, class D audio amplifiers, hard-switched and high frequency circuits.

www.epc-co.com

Three-Phase Brushless Motor Pre-Driver Driving up to 60-A FETs

Texas Instruments Incorporated introduced the first in a new line of integrated three-phase brushless motor pre-drivers. The DRV8301 is the most highly integrated pre-driver available today, reducing board space as much as 60 percent compared to the next closest integrated solution. It can drive sub-10-A to 60-A external FETs, providing current scalability, improved thermal performance and greater efficiency in brushless DC (BLDC) and permanent magnet synchronous motor (PMSM) applications, such as ventilation pumps, medical pumps, commercial refrigeration cooling systems, robotics, power tools, e-bikes and other high-torque industrial motor control applications. For more information or to place an order, visit

www.ti.com/drv8301-preu

Gen 3 PCI Express® Switch for SSD Storage Arrays and Cloud Computing Applications

Integrated Device Technology, Inc. announced that it has released the world's highest performance family of Gen 3 PCI Express (PCIe) switches targeted at solid-state drive (SSD) storage arrays and cloud computing applications. The new family of switches builds upon IDT's leadership in high-performance, scalable PCIe Gen 1 and Gen 2 switches, supporting a capacity up to 64 lanes and 16 ports with additional protocol enhancements for improved efficiency and reduced power consumption.

IDT's 89H64H16G3 is a 64-lane, 16-port Gen 3 PCIe switch, capable of up to 128 Gigabytes per second (GBps) switching capacity – the highest in the industry, making it the most scalable and highest-performance single-chip Gen 3 PCI Express solution on the market. The device conforms to the latest Gen3 PCIe specification providing 8Gbps link speed to enable the fastest PCIe connectivity possible for next generation enterprise server and storage systems. Added Gen 3 protocol enhancements improve overall efficiency and reduce power consumption, a critical factor for energy-conscious enterprise and cloud computing data centers. The device has been sampling to IDT's lead customers for several months.

The new family of IDT switches also includes clock isolation, offering the ability to operate with independent spread spectrum clocks (SSCs), as well as multicast for a significant gain in performance. Moreover, the switch incorporates a multi-root partitioning feature that allows designers to reduce system cost by replacing multiple PCIe switches with a single monolithic solution.

www.IDT.com

Non-Isolated, High-Power 3-Pin DC/DC Converter

ROHM presents its new high voltage resistance, high efficiency DC/DC Converter module BP5277 family which eliminates the need

of external components and thermal design.
Configuring a DC/DC converter used to be complicated and time-consuming, starting with the selection of ICs for the loads and covering circuit design as well as the selection of constants e.g. those for phase compensation, board design for obtaining desired characteristics, and thermal design for heat generation. This new 3-pin DC/DC converter module integrates all required components such as the control circuit, switching element, coil as well as I/O capacitors and also allows for high-power operation. Since the series can be deployed like a module, all necessary characteristics can be obtained without involving circuit and board design which significantly reduces the time, costs and energy required for the power supply design.
Based on an identical configuration, and including pin compatibility to the max. 15V series, the new family features a max. 36V input voltage converter module, which allows for applications with larger equipment.

www.rohm.com/eu

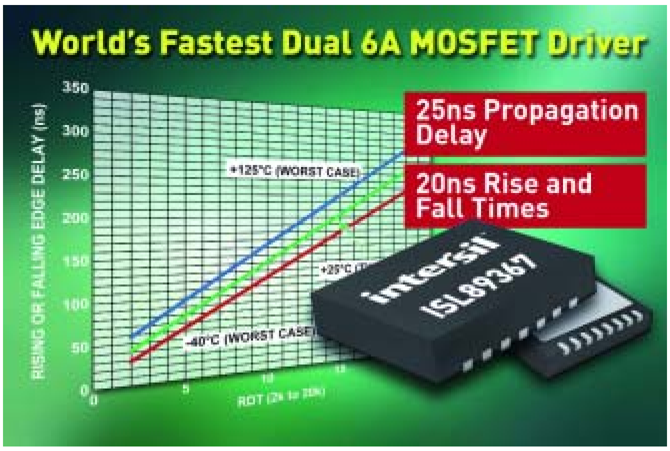
High Power, Low VSWR Chip Attenuators for Signal Sampling

Specialist RF and Microwave component and equipment distributor, Aspen Electronics, has announced the immediate availability of a range of high quality, high power chip attenuators.
Designed for virtually any industry sector using RF technology, these high power chip attenuators feature a power handling capability up to 150W, which makes them ideal for signal sampling applications in circulators and isolators for example.
The RPCA150-20 and RPCA150-30 series offer excellent performance from DC to 3GHz. They feature low VSWR of 1.20:1, impedance of 50ohms and an operating temperature range from -55 °C to 150 °C.
Users can select any attenuation value with accuracy at 20dB of ±1dB (RPCA150-20) or 30dB±1dB (RPCA150-30), and a choice of termination styles. Terminal finish for all devices is electroplated tin over nickel barrier. All devices are fully RoHS compliant.

www.aspen-electronics.com

High Speed, Dual Channel 6A MOSFET Driver

Intersil Corporation introduced the ISL89367, the industry's first dual channel 6A MOSFET driver capable of driving two outputs each with 6A of peak drive current. This unique part provides designers with an integrated solution for high speed driving of large, high current MOSFETs. The device is ideally suited for applications such as switching power supplies, motor drivers and Class-D amplifiers.
The driver's fast rise and fall times assure lower power losses and significant improvements in efficiency over competitive devices with drive voltages ranging from 4.5V to 16V. Programmable switching delay times prevent shoot-through current between MOSFETs, and allow optimization for maximum efficiency and reduced electromagnetic interference.
For isolated applications, the ISL89367's precision logic thresholds simplify the design of synchronous rectification on the secondary side of the transformer. Internal timers can be programmed to provide up to 270ns of drive delay. For applications that require longer times, precision comparator input thresholds allow simple RC circuits to generate longer time delays.



www.intersil.com

Current Transducers HCT´s Families Receives UL Certification

Premo announced that its HCT-xxDS5, HCT-xxDSR5, HCT-xxPT5, HCT-xxPTR5, HCT-xxA05 and HCT-xxSY, devices received UL component certification.

These devices are open type, current transducer that senses an alternating and a direct current in a feed-through wire set up at the through-hole, by a Hall Effect principle through the closed loop magnetic field in the core provided to, and the Hall Effect device generates a signal proportional to it.
A complete list of Premo HCT´s devices UL-certified is available on the UL website "Online Certification Directory". All of devices under UL-certification, will marked according to UL recommendation:
C and US indicate that these products were investigated under the Standard for Industrial Control Equipment, CSA C22.2 No. 14-10 and UL-508 respectively.
PREMO introduced last year in the market, this HCT´s family with a very good reception.

www.grupopremo.com

LinkSwitch™-PH Delivers Flicker-Free TRIAC Dimming for LED Downlights

Power Integrations introduced a new reference design (DER-281) detailing an 85%-efficient, 15 W PAR38 downlight driver that delivers flicker-free dimming without the use of unreliable high-voltage electrolytic bulk capacitors. Based on Power Integrations' LNK405EG, a member of the company's popular LinkSwitch-PH family of LED driver ICs, the design's novel approach to dimming eliminates the need to sacrifice reliability and efficiency in order to achieve flicker-free performance across a broad range of TRIAC dimmers.

Typical TRIAC dimmers were designed for incandescent lights that use an order of magnitude more power than LED lights of equivalent lumen output. The low current requirement of LED lights, especially when dimmed, can cause TRIACs to switch off unexpectedly or oscillate, creating an annoying flickering effect. Early-generation LED lighting designs addressed this problem either by storing energy in an unreliable electrolytic bulk capacitor, adversely affecting bulb lifetime, or by allowing a continuous flow of current into the bulb, wasting energy and thereby defeating the main benefit of LED lighting.

Single-stage LinkSwitch-PH ICs, combined with the innovative active damping and bleeding circuitry employed in DER-281, eliminate these pitfalls, providing flicker-free dimming with high efficiency and long lifetime.

www.powerint.com

Highly Integrated IEEE 1588v2 Over Ethernet Solution

Micrel Inc. introduced the KSZ84xx family of IEEE 1588v2-enabled Ethernet devices for Industrial Ethernet and Power Substation Automation applications. The groundbreaking solution employs Micrel's EtherSynch™ technology, which integrates IEEE 1588v2 distributed synchronization, Ethernet switching, and Precision GPIO in an energy efficient, compact package. The ICs are currently sampling with volume production expected in the first quarter of 2012. For specific pricing, please contact your local Micrel sales office. The KSZ84xx platform is the most compact, highly integrated, and energy efficient IEEE 1588v2 10/100 switch available, supporting both centralized and distributed network topologies. A full complement of Precise Timing Protocol timing modes are provided, including the Transparent Clock (TC) introduced in IEEE 1588v2, along with a range of host interfaces capable of interfacing to a wide range of CPUs.

www.micrel.com

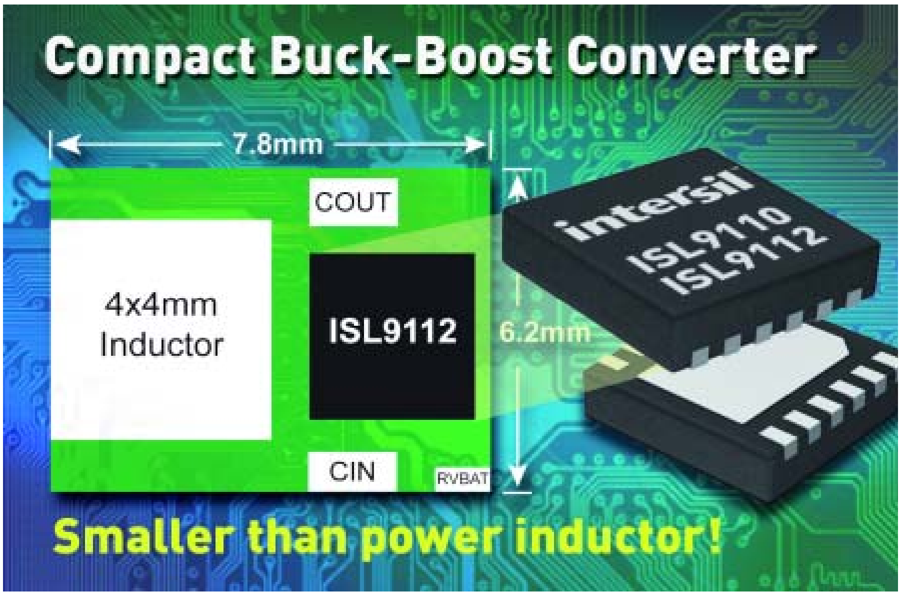
eGaN® FET Family with Second Generation 100 Volt, 30 milliohm Power Transistor

Efficient Power Conversion Corporation announced the introduction of the EPC2007 as the newest member of EPC's second-generation enhanced performance eGaN FET family. The EPC2007 is environmentally friendly; being lead free, RoHS-compliant (Restriction of Hazardous Substances), and halogen free.
The EPC2007 FET is a 1.87 mm2, 100 VDS, 6 A device with a maximum RDS(ON) of 30 milliohms.
This second generation eGaN FET provides significant performance advantages over the first-generation EPC1007 eGaN device. The EPC2007 is fully enhanced at a lower gate voltage and has greater immunity to fast switching transients than the predecessor.
Compared to a state-of-the-art silicon power MOSFET with similar on-resistance, the EPC2007 is much smaller and has many times superior switching performance. Applications that benefit from eGaN FET performance include hard-switched and high frequency circuits such as isolated DC-DC power supplies, point-of-load converters, and class D audio amplifiers.

www.epc-co.com

Industry's First I2C Controlled Buck-Boost Regulator

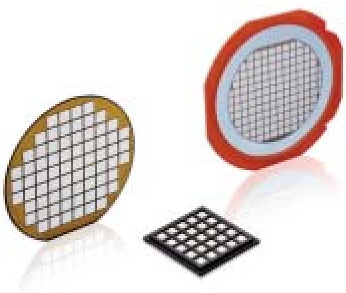
Intersil Corporation introduced the world's first I2C controlled buck-boost regulator, delivering a highly flexible solution for providing a regulated output voltage from a varying input voltage. The ISL9112 is a compact, high efficiency 2.5MHz, 1.2A buck-boost regulator designed for applications that require I2C programmability, and utilizes Intersil's proprietary H-Bridge Buck-Boost architecture. The I2C interface allows output voltages to be changed instantaneously or ramped between two values.

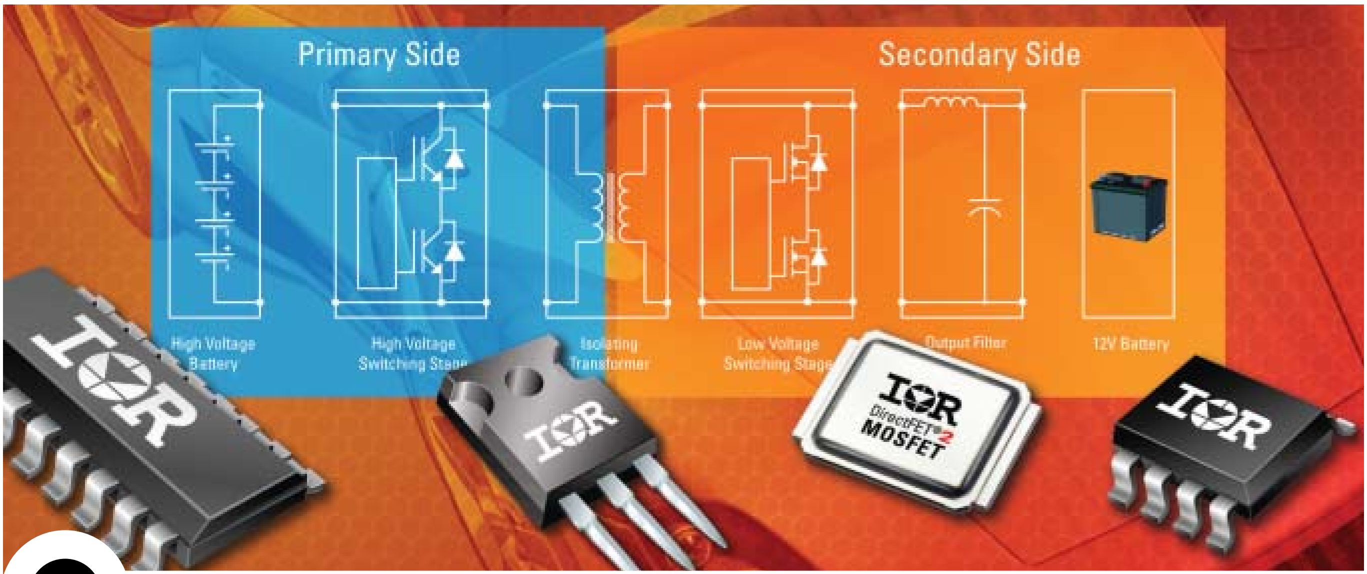


The ISL9112 simplifies design by providing a regulated output voltage from an input that can be either above or below the output voltage. The regulator minimizes external components, requiring just a single inductor and two capacitors. It also features the industry's lowest voltage deviation during transitions between buck and boost modes, providing designers with flexibility in selecting the optimal output voltage. The ISL9112's 2.5MHz switching frequency is also the highest available in a buck-boost regulator, further minimizing external component sizes.

www.intersil.com

ADVERTISING INDEX





IR's Solution for Energy Saving Drive

Automotive DirectFET®2 Power MOSFETs

Part Number	V_{DS}	$R_{DS(on)}$ Max @10V_{GS}	I_D max. @TC = 25°C	Qg typ. @10V_{GS}	Package
AUIRF7669L2	100 V	4.4 mΩ	114 A	81 nC	DirectFET L
AUIRF7759L2	75 V	2.3 mΩ	160 A	200 nC	DirectFET L
AUIRF7739L2	40 V	1 mΩ	270 A	220 nC	DirectFET L
AUIRF7736M2	40 V	3.1 mΩ	141 A	83 nC	DirectFET M

600V High Voltage IC for Switching Stage Drivers

Part Number	Description	Output Current	V_{CC} UVLO	Package
AUIRS2191S	High Speed High and Low Side	+3.5 / -3.5 A	8.2 V	SOIC16N
AUIRS21811S	High Speed High and Low Side	+1.9 / -2.3 A	8.2 V	SOIC8

600V Automotive IGBTs for Switching Stage

Part Number	I_C @TC=100°C	$V_{CE(on)}$ typ.	Package
AUIRGP35B60PD	34 A	1.85 V	TO-247
AUIRGP50B60PD1	45 A	2.00 V	TO-247

25V Low Voltage IC for Switching Stage Drivers

Part Number	Description	Output Current	Package
AUIRS4426S	Dual Channel Low Side	+2.3 / -3.3A	SOIC8
AUIRS4427S	Dual Channel Low Side	+2.3 / -3.3A	SOIC8
AUIRS4428S	Dual Channel Low Side	+2.3 / -3.3A	SOIC8

Features

- Automotive Q101 qualifications
- HVIC with integrated protections
- Optimized copack IGBT for high frequency SMPS operation
- Extremely low $R_{DS(ON)}$ FET and high current ratings for synchronous rectification stage

For more information call +49 (0) 6102 884 311
or visit us at www.irf.com

International IOR Rectifier
THE POWER MANAGEMENT LEADER