POWER ELECTRONICS EUROPE

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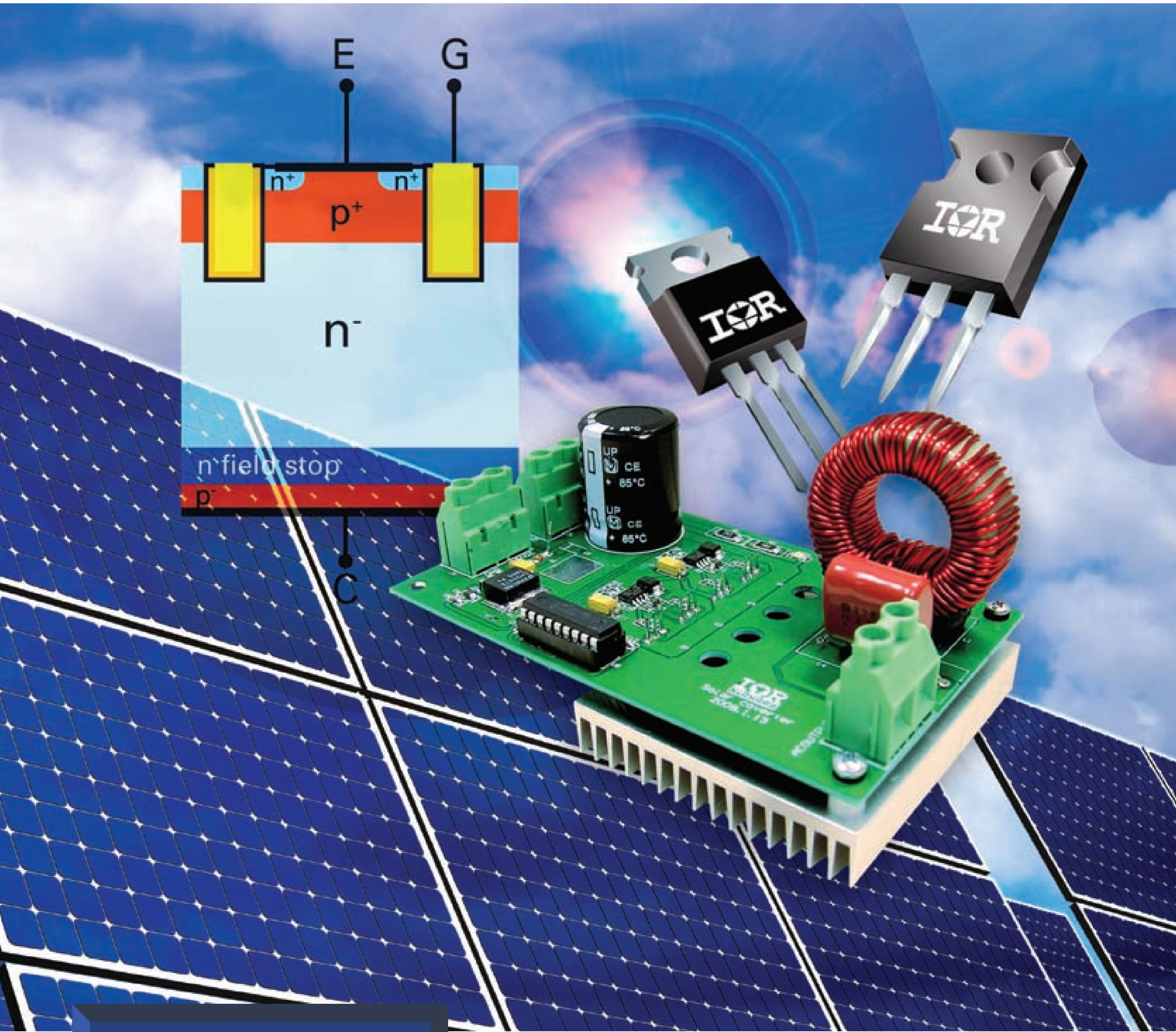
POWER SEMICONDUCTORS

600V Trench IGBTs Reduce Power Loss in DC/AC Inverter Applications



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Also inside this issue

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COVER STORY

600V Trench IGBTs Reduce Power Loss in DC/AC Inverter Applications

Selecting the best IGBT for an application can be confusing and time-consuming, so is it worth the time? In this article, we will attempt to simplify the selection process by providing an explanation for the trade-offs to be considered. To illustrate the benefits, the author will describe the performance improvement possible with a new generation of 600V IGBTs targeted for DC/AC inverter applications. By using optimised trench IGBTs, IR can improve efficiency or reduce system heatsink size or increase current density out of the same board assembly.

The new devices use field stop trench technology to reduce both conduction and switching losses in high frequency switching applications such as UPS and solar inverters enabling higher efficiency power conversion and hav,e been optimised for switching at 20kHz with low short circuit requirements. In order to verify this claim, IR have built a 500W D/AC inverter using similar sized IGBTs and analysed differences in performance. Full story on page 28.

Cover supplied by International Rectifier

Using Energy More Efficiently

The rising demand for energy in all forms and the recent series of dramatic increases in energy prices have made it evident that energy must be used more efficiently. Today, we are in a position where technologies for realising substantial energy savings already exist. Unfortunately, these technologies have not yet been used up to their full potential, although a number of voluntary standards and labels in the field of energy efficiency have been suggested and introduced. To reach these goals, new highly efficient power electronic technologies are needed as an enabling factor to reduce today's massive waste of energy, while keeping the conveniences of technical progress – this will be the focal point of this year's PCIM in Nuremberg. According to the European Commission, about 180 million tons of CO_2, the equivalent output of around 50 power stations, could be saved by 2010 with new and energy-efficient products and appliances alone in Europe.

Pumps are the single largest consumer of electricity with 160TWh per annum in the EU, accounting for 79 million tonnes of CO_2 emissions. With variable speed control through inverterised drives, the duty point of the pump follows an unchanged system curve. Changing the speed moves the pump curves in accordance with the affinity laws, meaning that the pumping capacity is exactly matched to the process requirements. Though the initial cost for an inverterised drive is higher, a payback through energy savings and better process control can be expected in a two year period. It is estimated that lighting amounts to approximately 15% of the world total electricity consumption. Electronic ballast for fluorescent lighting saves up to 25% of the energy compared to magnetic lamp ballast. Further reductions are feasible by using daylight linked dimming systems. Light emitting diodes (LEDs) are the most dynamic light sources with the potential to catch up with high intensity discharge lamps (HIDs) by 2010. LEDs offer benefits such as small size, long life, low heat output and durability. LED converters are based on a current-controlled buck with outputs of 300, 500 and 1050mA supplied to a chain of LEDs. No ignition circuit, filament-heating or observation conditions like end-of-life is necessary. And there are no special requirements regarding the stability of the regulation and dimming is relatively easy – another opportunity for power electronics. Various surveys confirm that, by using state of the art energy efficient technologies, 20% of the current energy consumption in the European Union could be saved, translating into 60 billion Euros per year.

In the absence of committed energy efficiency measures, the International Energy Agency (IEA) predicts that by 2030, the world's energy needs will be almost 60% higher than now. At the same time, supplies of fossil fuels are dwindling. Some of the major economies of the world are having to rely increasingly on imported fuel, sometimes from regions of the world where conflict and political instability threaten the security of that supply. By contrast, wind and also solar energy is a massive indigenous power source in virtually every country in the world. The US market has witnessed a late surge in new wind turbine installations in the past two years, but it still trails Germany in the global ranking. Meanwhile, in wind power production, it is only one notch below Spain, according to the Global Wind Energy Council.

Thus, wind and also photovoltaic energy are changing by means of power electronics from being minor energy sources to important power sources in the energy system.

Approximately a quarter of current CO_2 emissions is known to come from the transport sector. And traffic fatality is still increasing worldwide. In order to create a society that will continue to enjoy the convenience that automobiles bring, in other words, to achieve sustainable mobility, automobile makers must work to reduce automotive CO_2 emissions and to enhance technologies for vehicle safety even further. A hybrid car has an inverter that provides tens of kilowatts of power to drive the motor by converting DC voltage to AC voltage. The power semiconductors that are used to control the current are therefore critical key devices for hybrid technology, and this is the topic of PCIM's session 'Automotive Power' organised by Power Electronics Europe.

Power electronics itself has changed rapidly during the last thirty years and the number of applications has been increasing, mainly due to the developments of the semiconductor devices and the microprocessor technology. In both cases, higher performance is steadily given for the same area of silicon, and at the same time they are continuously reducing in price. The key driver of this development is that the power electronic device technology is still undergoing important progress. MOS-gated devices are preferable in the sense of easy control. The breakdown voltage and/or current carrying capability, as well as the temperature range of the components, are also continuously increasing. Important research is going on to change the material from silicon to silicon carbide (SiC), which may dramatically increase the power density of power converters. Thus, Power Electronics Europe has sponsored PCIM's Best Paper Award which will honour a technology breakthrough and will be handed over at PCIM's opening ceremony on May 27.

You are all invited to attend the PCIM conference in general, the Automotive Power session on May 29, 10.00-12.00, and the exhibition. Stop by our PCIM booth 12-558.

Achim Scharf
PEE Editor

Infineon Acquires Primarion

Infineon Technologies announced that the company has acquired Primarion, Inc. to further strengthen its activities in the field of power management applications, particularly in digital power.

Peter Bauer is strengthening Infineon's position in digital power by the acquisition of Primarion

Digital power is a fast growing emerging market for ICs in power supplies and is increasingly replacing today's traditional analog solutions. Advantages of digital power ICs include the ability to optimise the efficiency and performance of the power supply over all conditions on the fly by adjusting key system parameters with advanced diagnostics, telemetry and non-linear control. This leads to increased density and reduced system cost through the removal of bulky output capacitors and the integration of many passive components required for 'tuning' analog solutions. "Infineon will now be positioned to set the benchmark in system density, efficiency and control by combining the performance of Primarion's digitally controlled power management devices with our power semiconductors portfolio. "The addition of Primarion helps accelerate our access to the potential growth in the digital power segment by providing advanced system solutions for our customers. This investment is also a great complement to our power management activities based in Villach", commented Peter Bauer, Head of Infineon's Automotive, Industrial and Multimarket Business Group.

Infineon's decision to enter the digital power management IC market comes at a time when the relatively undeveloped market is set to expand rapidly over the coming next five years to generate a total of $1.5 billion to the end of 2011, according to latest forecasts from IMS Research. "Although the digital power management IC market is still relatively small, we expect it to grow on average at more than 40% per year. We've seen more suppliers enter the market recently, and of course, prices of digital power ICs will inevitably fall to a comparable price with analog ICs. Infineon's decision to attempt to grab a large chunk of this market while it is still in its infancy is a bold move; but it will reinforce its strong overall position in the voltage regulation market", added Research Director Ash Sharma. "Although Infineon was still ranked behind the leaders Texas Instruments and National Semiconductor in the global voltage regulation market at the end of 2006, its acquisition of the second largest supplier of digital power management ICs will make it a major player in this important segment. Demand for digital power management ICs is expected to increase particularly strongly in applications employing multiple voltage rails and high currents, such as servers and routing equipment".

AS

www.infineon.com
www.imsresearch.com

New Sales Manager at Chomerics Europe

Chomerics Europe has appointed Tiberius Recean as Territory Sales Manager for Germany, Austria and Switzerland.

Based near Munich, Tiberius will provide customers with both technical and commercial support for Chomerics' range of EMI shielding and thermal management products. Key market sectors include automotive and telecoms, plus military and aerospace.

Tiberius has a strong background and experience in communications engineering and electrical/electronic engineering. Prior to joining Chomerics Europe, he spent eight years working in a sales engineering role for a cable manufacturer, and before that, was employed as a Key Account Manager for a leading power supply manufacturer.

www.chomerics.com

Diodes Acquires Zetex

Dallas-based Diodes announced that it will acquire Oldham-based Zetex plc for £91.6m cash.

Under the terms of the recommended proposal, Zetex shareholders will receive 85.45 pence in cash for each Zetex Share, valuing the entire issued and to be issued ordinary share capital of Zetex at approximately £91.6m. The transaction is subject to the approval of Zetex shareholders and following such approval, it would be expected to complete in June 2008. Undertakings to support the transaction have already been received from shareholders representing approximately 56.5% of Zetex's existing issued ordinary share capital. The Zetex and Diodes directors believe that a combination of the two businesses will strengthen the position of the enlarged group as a global provider of analog and discrete semiconductor solutions to the consumer electronics, computing, communications, industrial and automotive markets. "The combined group will be over 4 times the current size of Zetex and will have far greater resources at its disposal", commented Zetex's CEO Hans Rohrer.

www.zetex.com

TI Offers Hot-Swap for ATCA and MicroTCA

Texas Instruments has introduced a single-chip, dual-slot hot swap manager for Advanced Mezzanine Cards (AdvancedMC) used in wireless, telecom and computing systems, including AdvancedTCA (ATCA) and MicroTCA systems.

"With rising energy prices, telecom operators are looking for energy-saving technologies such as digital power, power factor correction and hot swapping", said TI's European Business Development Manager Francois Malléus. "Though MicroTCA is an emerging market, it is necessary to have the appropriate products ready. The TPS2359 and TPS2358 are the only multiple-voltage output hot swap controllers compliant to ATCA and MicroTCA. This achievement will increase our ability to solve this key power design challenges and open the door to allow more rapid adoption". Telecom market projections show great opportunities for digital power and hot swapping in ATCA systems. According to Crystal Cube Consulting the ATCA market accelerated in 2006 and will reach a volume of $50 billion by the year 2009, compared to $200 billion for conventional architectures.

In 2002, the PCI Industrial Computing Manufacturers Group (PICMG) released the industry-wide ATCA as an open standard, which addresses the growth and changes in the communications infrastructure market. MicroTCA was developed as a follow-on standard, further extending the ATCA open platform into applications requiring scalability and redundancy in distributed environments.

The I²C-programmable TPS2359 hot swap controller performs all necessary power interface functions for two AdvancedMCs, while eliminating up to 75% of the components required in other solutions. Enabling seamless 'plug-and-play' insertion and removal of AdvancedMCs during system operation, the device's two integrated 3.3V rails provide inrush control, over-current protection and FET ORing control functionality. In addition, two 12V channels provide the same functions using external FETs and sense resistors. The controller's 3.3V current limits are set at the factory to AdvancedMC-compliant levels and the 12V current limits can be programmed using external resistors. The integrated ORing control capability simplifies power design for MicroTCA power modules or other implementations that manage redundant power in the AdvancedMC slot. When used with a low on-resistance N-channel MOSFET, the controller seamlessly manages power distribution, while protecting the system from potentially dangerous reverse-current or transient events by providing an extremely fast turn-off response of 130 nanoseconds at half the power loss of a conventional ORing diode.

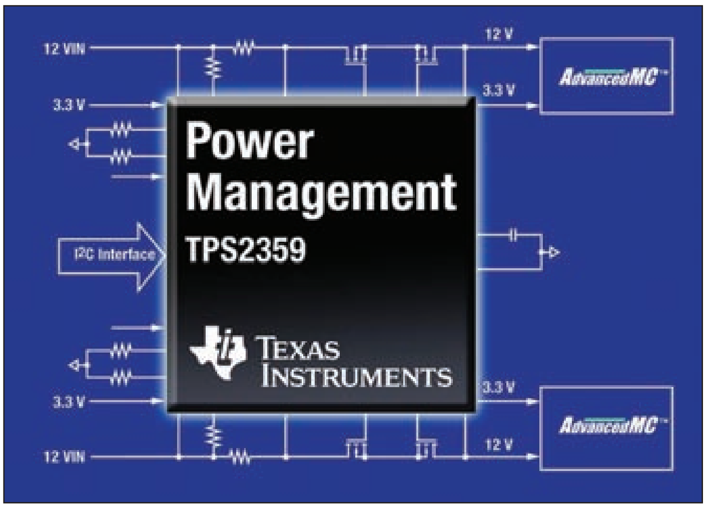
"With rising energy prices telecom operators are looking for energy-saving technologies such as digital power, power factor correction and hot swapping", said TI's Francois

The I²C interface allows a designer to digitally configure and monitor the AdvancedMC hot-swap solution over a two-wire bus, with fewer required external components and pins. This interface programs current limit, fast-trip threshold and fault time. The TPS2359 also features enable or disable of the ORing, multi-channel cross-connect and auto-retry.

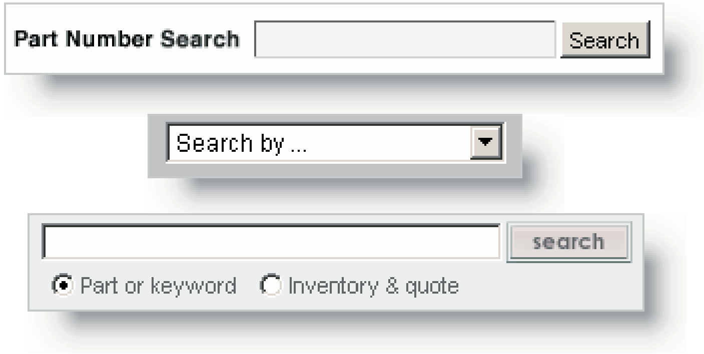
For digital power supply systems, this allows designers to better manage the system's overall performance. For example, a hot-swap solution with the TPS2359 can alert the system of any over-current, fast-trip and current-limit situation. For designers who do not want to use a digital interface, TI offers the TPS2358 controller with dedicated output pins and configuration capability using external components. The devices will be displayed on TI's PCIM booth 12-329.

AS

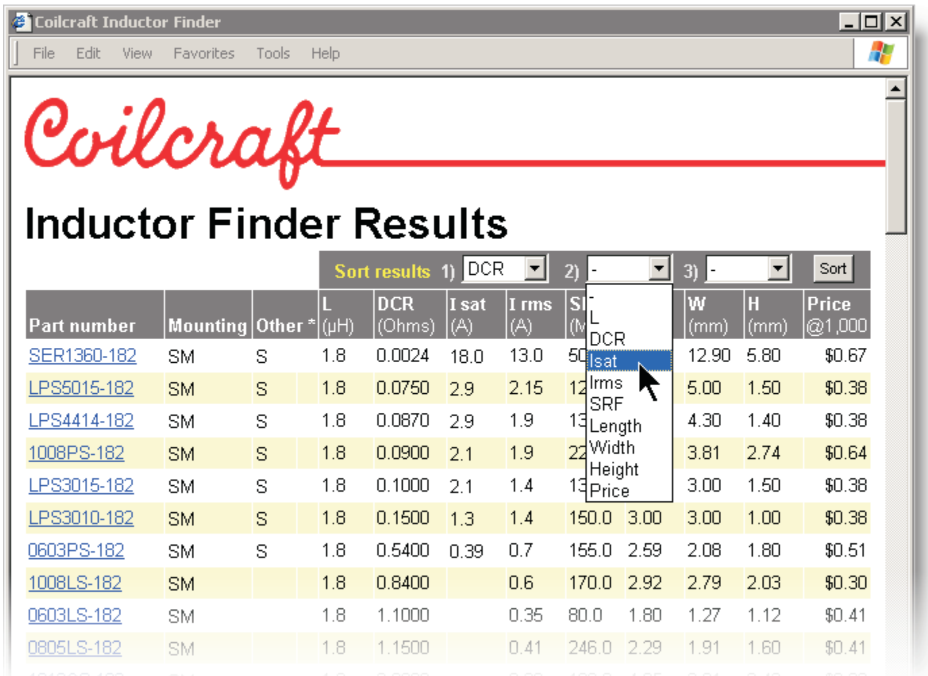
http://power.ti.com



New controller for hot swapping in telecom ATCA systems
Source: TI



Their sites have search engines. Ours has a find engine.



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Energy Harvesting Technologies Offer Low Costs and Low Maintenance

The need to minimise maintenance and replacement costs of battery-powered applications drives energy harvesting technologies that bind renewable and ambient sources of energy. Analysis from Frost & Sullivan 'Advances in Energy Harvesting Technologies', finds that technologies such as piezoelectric, thermoelectric and others will have potential applications in wireless sensor networks and low-power devices.

"Although micro-level energy harvesting technologies are very new compared to batteries, they can initially be used to recharge batteries and gradually replace them as self-sufficient devices", notes Research Analyst Arvind Sankaran. "By replacing batteries, these devices eliminate toxic waste from disposed batteries and provide the perfect solution to many countries that are implementing stringent rules to monitor power consumption and environmental waste". As energy harvesting technologies harness ambient and renewable sources of energy, growing awareness among consumers to use environmental friendly technology further strengthens demand. "Low output power and below-par efficiency of energy harvesting systems currently limit the application scope of energy harvesting technology", says Research Analyst Kasthuri Jagadeesan. "It faces difficulty in penetrating the market as it is still in the early prototyping or early commercialisation stage, as opposed to battery technology".

Along with developments in materials and control electronics, researchers and manufacturers concentrate their efforts on the exploration of various kinds of energy sources and improve the performance characteristics. Starting with low-power sensor applications, they can be gradually used to power portable devices and utilised in buildings for lighting and temperature control. Additionally, improvements in energy harvesting technologies would allow these devices to provide reliable and constant power for industrial, automotive, aerospace, defense and medical applications.

Texas Instruments will present a paper on this technology at PCIM in Nuremberg (see our PCIM preview).

www.technicalinsights.frost.com

New Chairman at International Rectifier

International Rectifier's Founder and Chairman, Eric Lidow, has retired from his position as Chairman and as a member of the Board of Directors effective on May 1, 2008. Mr. Lidow had served as the Company's Chief Executive Officer until 1995, after which time he assumed the position of Chairman.

Eric Lidow founded International Rectifier in 1947. Over the course of more than six decades, he transformed a start-up company that developed selenium photoelectric cells and selenium rectifiers into a world leader in power management technology that today produces thousands of analog, digital, and mixed signal integrated circuits and other power management technologies and products. "As the power management industry continues to evolve, I have great confidence in the IR's technology roadmap and in the management team's ability to execute the strategy established to take the company forward", Lidow stated. The Board of Directors immediatley appointed Richard J. Dahl Chairman of the Board, effective on May 1, 2008. He was already elected to the company's Board of Directors in February 2008. His executive experience includes serving as President and CEO of the Dole Food Company and of the NYSE-listed Bank of Hawaii Corporation. Mr. Dahl, a former CPA with Ernst & Young, has extensive business experience in Asia, the Pacific Basin and Europe.

www.irf.com

CWIEME Berlin – The Largest Coil Winding, Insulation & Electrical Manufacturing Show in the World

This year in Berlin over 6,000 members of the Coil Winding Industry will gather for the Largest Dedicated Coil Winding, Insulation and Electrical Manufacturing Exhibition in the World. CWIEME Berlin has consistently grown year on year and CWIEME Berlin 2008 is no exception.

CWIEME was born 13 years ago from one man's frustration with the quality and quantity of various Coil Winding Shows worldwide. The Managing Director of CWIEME, Timothy House, held the first Coil Winding Show in Berlin in June 1996. At this first Show CWIEME had 80 exhibitors and 1000 Delegates. That has grown over the last 12 years to what now is a Show with over 500 Participating Companies and with over 3600 registered visitors each year. Mr House has worked in the Coil Winding Industry since 1972 and was involved in the very first Coil Winding Show to take place in London in 1972 as well as the Chicago Coil Winding Show in 1973. He has also built up and run the Coil Winding International Magazine for the last 25 years, a magazine that is the market leader in its field.

CWIEME guarantees an exhibition that is purely dedicated to the Coil Winding, Insulation and Electrical Manufacturing industry and has delegates that are purely from companies directly involved in the Coil Winding, Insulation and Electrical Manufacturing industry. People who register for the CWIEME Berlin Show are people from companies whose interest in the Show is on a completely professional level.

At CWIEME Berlin 2007, two new CWIEME Shows were launched, CWIEME Chicago and CWIEME Mumbai. CWIEME Chicago 2008 will be at the Rosemont Centre and is a Show that will be held in the hub of the Industry. Chicago has the largest airport in the World making access to the Show easy for customers right across the USA and North America. CWIEME has no affiliation to any other Show or organisation other than Coil Winding International Magazine and they aim to replicate the success and service that exhibitors in Berlin have enjoyed for the last 12 years.

Autumn 2009 will see the launch of CWIEME Mumbai at the Bombay Exhibition Centre, a Show intended to offer an invaluable tool to Companies from Eastern Asia to meet customers from a part of the World that is swiftly making its presence known in the Coil Winding industry.

CWIEME Berlin takes place on the 10th – 12th June 2008 at the Messe Berlin.

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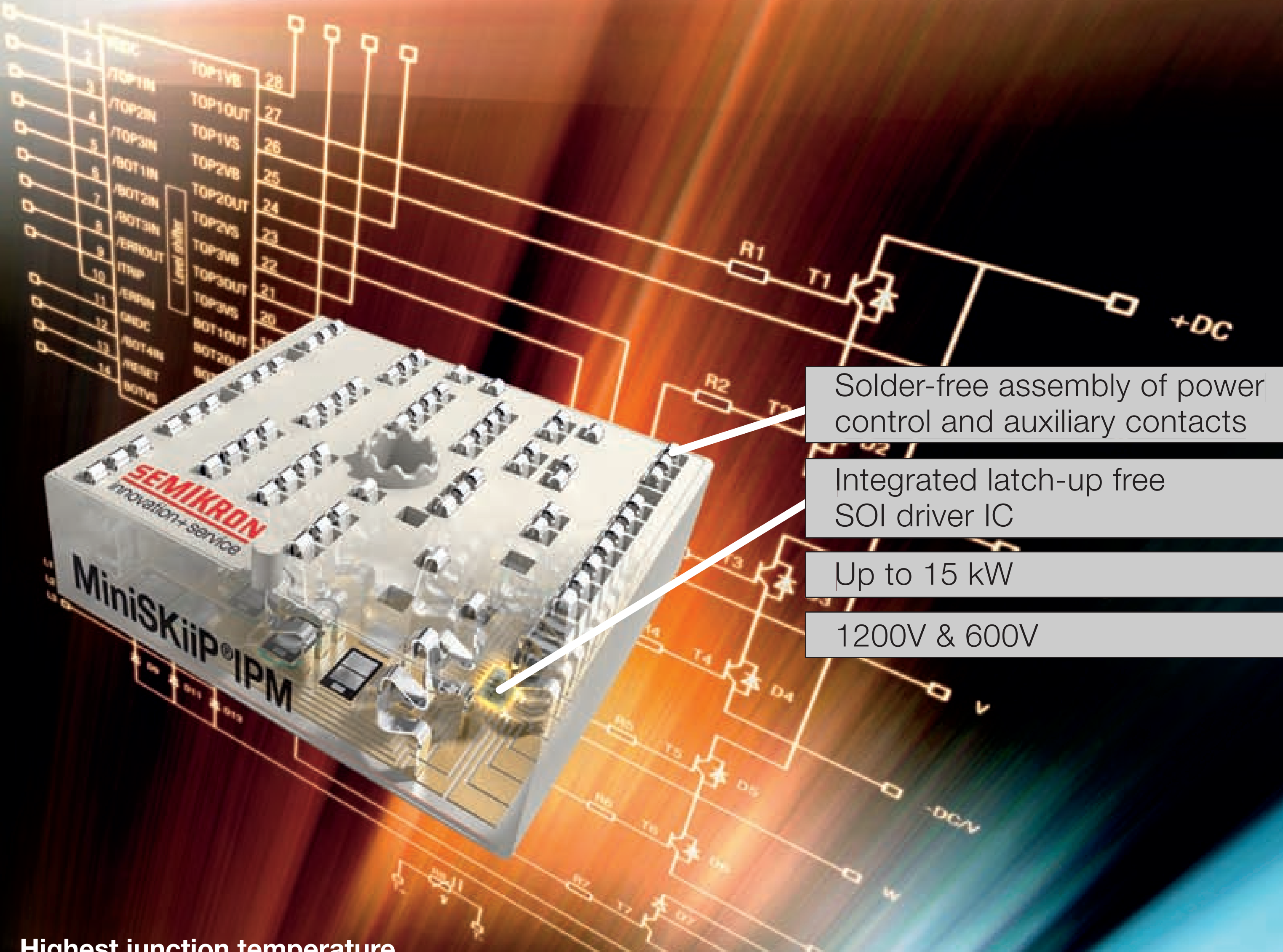

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600V	MiniSKiiP IPM	Competitor A	Competitor B
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Full Programme on Power Electronics

Power electronics along with energy efficiency are the main focus of this year’s PCIM conference. The 12 sessions are categorised around special topics such as High Voltage Devices, High Frequency Converters, Automotive Systems, Module Reliability, Fast Switching Devices, Power Management, Energy Systems, New Packaging Concepts, Protection Strategies, Power Factor Correction and Compensation, High Efficiency, Advanced IGBT Technology and, last but not least, a Special Session Automotive Power organised by Power Electronics Europe.

PCIM Europe 2008
International Exhibition & Conference for
POWER ELECTRONICS
INTELLIGENT MOTION
POWER QUALITY
27 – 29 May 2008
Exhibition Centre Nuremberg

A comprehensive overview on PCIM’s tutorials has already been given in Power Electronics Europe issue March 2008 (pages 13-14) and in the keynotes in April (pages 18-19). Here, we will concentrate on the oral presentations within the power electronics conference programme. The opening ceremony on May 27 from 9.00 – 9.45 is not only an opportunity to give some welcome addresses, but also for presenting the Young Engineers Award (for 3 authors up to 35 years receiving €1000 each) and the Best Paper Award for

As in recent years, PCIM 2008 will attract the power electronics community worldwide

industrial or automotive applications (flight and accomodation for PCIM China 2009). The latter has been sponsored by Power Electronics Europe.

High voltage devices

This session (Tuesday, 27.05.2008, 11:00 – 13:30, Room Paris) chaired by Prof. Josef Lutz from Technical University Chemnitz (Germany) will highlight the advances in 6.5kV IGBTs and free-wheeling diodes, as well as in 4.5 and 3.3kV devices. The session is comprised of five papers entitled '6.5kV IGBT and FWD with Trench and VLD Technology for Reduced Losses and High Dynamic Ruggedness' by Thomas Duetemeyer, 'Robustness Improvement of High-Voltage IGBT by Gate Control', Tao Hong, 'CIBH Diode with Superior Soft Switching Behaviour in 3.3kV Modules for Fast Switching Applications' by Jürgen Biermann, all Infineon Technologies AG (Germany, 12-404), '6500V SPT+ HiPak Modules Rated at 750A' by Arnost Kopta, ABB Schweiz AG (Switzerland, 12-506/408), and 'Test Procedure to Ensure Quality of 4.5kV Very High Current Press-Pack IGBTs' by Gangru Li, Westcode Semiconductors Ltd (United Kingdom, 12-401).

High frequency converters

The converter session (Tuesday, 27.05.2008, 11:00 – 13:30, Room Amsterdam) will be chaired by Prof. Enrique J. Dede from the University of Valencia (Spain) and will introduce various topologies for DC/DC converters particularly in automotive applications. It covers five papers entitled 'Comparative Study of Different Three-Stage DC/DC Converter Solutions in the Power Range up to 3kW' by Ulf Schwalbe, ISLE Steuerungstechnik und Leistungselektronik GmbH (Germany), 'Two-Phase Boost Converter for 14V/42V Automotive Applications using Coupled Tapped Inductors', by Michael Stadler, University of Applied Sciences Ingolstadt (Germany), 'Digital 8bit µP for Harmonic & Output Regulation in AC/DC SMPS' by Alan Rockenbach, VI Chip (USA), 'A Novel Fixed-Frequency Dimming Scheme with Ultra-Wide, High-Frequency Dimming Range', by Sameh Sarhan, National Semiconductor (USA), and 'Modular Voltage Inverter For Induction Heating', by Maciej A. Dzieniakowski, Warsaw University of Technology (Poland).

Automotive systems

This session (Tuesday, 27.05.2008, 11:00 – 13:30, Room London) chaired by Jacques Laeuffer, Supélec (France) assembles five papers on special questions for power electronics in automotive applications, such as the optimum coupling of dual-voltage power nets or converters for hybrid drive systems. In detail these are 'Choosing a Three-Phase PWM Method for Automotive Applications' by Dusan Graovac, Infineon Technologies AG (Germany, 12-404), 'Fuel Cell and Battery Hybridization for Automotive Applications" by Daniel Chatroux, Centre d'Etudes Nucleaires (France), 'Power Electronic Converter for Hybrid-Drive Systems' by Folker Renken, University of Applied Sciences Oldenburg (Germany), 'Analysis and Control of Multiphase DC/DC-Converters for Dual-Voltage Automotive Power-Nets' by Tomas Reiter, BMW AG (Germany), and 'Life time prediction and design for reliability of a Smart Power IC specified for automotive applications' by Romeo Letor, STMicroelectronics (Italy, 12-414).

Module reliability

A high system reliability is possible only by the application of reliable power modules, thus this session (Wednesday, 28.05.2008, 10:00 – 12:00, Room Paris) chaired by Uwe Scheuermann, SEMIKRON International GmbH (Germany) will present four papers on 'Investigations on Ageing of IGBT Transistors under Repetitive Short Circuit Operations' by Stéphane Lefebvre, SATIE (France), 'Reliability of PressFIT Connections' by Thilo Stolze, 'Ultrasonic Metal Welding as Contact Technology for State-of-the-Art Power Modules' by Roman Tschirbs, both Infineon Technologies AG (Germany, 12-404), and 'Power Cycling of IGBT-Modules with

Superimposed Thermal Cycles' by Marco Feller, Chemnitz University of Technology (Germany).

Fast switching devices

This session (Wednesday, 28.05.2008, 10:00 – 12:00, Room London) chaired by Prof. Leo Lorenz, Infineon Technologies China, concentrates on silicon carbide (SiC) devices. SiC Schottky diodes can reach very high current densities, whereas SiC MPS diodes exhibit high surge current capabilities. The four papers of this session start with an overview entitled 'SiC Power Devices Market and Forecasts' by Dr. Philippe Roussel, Yole Développement (France, 12-465), followed with an 'Investigation of Surge Current Capability of SiC MPS Diodes' by Matthias Neumeister, Siemens AG (Germany, 12-357), '1200V SiC SBD Chip Evaluation at Ultra High Current Density' by Katsumi Satoh, Mitsubishi Electric Corporation (Japan, 12-431/421/301), and 'New 900V Voltage Class for Superjunction Devices - A New Horizon for SMPS and Renewable Energy Applications', by Markus Schmitt, Infineon Technologies AG (Germany, 12-404). The market for SiC devices today is stagnating, mainly due to a lack of commercially available SiC switches. Here, the 900V superjunction switch could serve as an alternative.

Energy systems

Prof. Alfred Rufer, EPFL (Switzerland) chairs this session also on Wednesday 10.00-12.00 (Room Amsterdam) covering four papers entitled "2 new Topologies for Transformerless Grid Connected Photovoltaic (PV) Systems with Minimum Number of Switches" by Peter Zacharias, ISET (Germany), "Energy Harvesting For Low Power Microprocessors" by Scot Lester, Texas Instruments (USA, 12-329), "Replacement and Emulation of a Lead-Acid Battery with Supercapacitors for an UPS Application", by Philippe Barrade, Laboratoire d'Electronique Industrielle (Switzerland), and "Survey of Power Management Strategies for Generator-Set with Energy Storage for 4Q-Load" by Pavol Bauer, Delft University of Technology (Netherlands).

Advanced power management

This session (Wednesday, 28.05.2008, 14:00 – 16:00, Room Amsterdam) is chaired by Andreas Müsing, ETH Zürich (Switzerland) and introduces 'A New Family of Enhanced Ripple Regulators For Power-Management Applications' by Richard Redl, ELFI S.A. (Switzerland), 'Generalized Predictive Control Applied to DC/DC converters' by Simon Effler, University of Limerick (Ireland), 'Power Factor Correction Controllers based on Current Rebuilding Technique Implemented on FPGA' by Francisco Javier Azcondo, University of Cantabria (Spain), and 'Accurate Voltage and Current Regulation with only Primary-Side Sensing in Flyback Power Supplies' by David Garner, Cambridge Semiconductor Ltd (United Kingdom).

Automotive power

This special session (Thursday, 29.05.2008, 10:00 – 12:00, Room Mailand) organised by Power Electronics Europe and chaired by Achim Scharf focuses on power electronics for transportation/ automobiles and in particular for (hybrid) electric vehicles (see sidebar).

New packaging concepts

The trend in the IGBT module of increasing the power capacity greatly helps to contribute to the system's downsizing. The optimum combination of the new silicon and new package technologies results the most economical solution for each module ratings. This session (Thursday, 29.05.2008, 10:00 – 12:00, Room Paris) chaired by Reinhold Bayerer, Infineon Technologies AG (Germany) covers the four papers 'Integration of a New SOI Driver into a Medium Power IGBT Module Package' by Thomas Grasshoff, 'A New 3D Module Packaging Technology Without Bondwires' by Christian Göbl, both Semikron Elektronik (Germany, 12-411), 'Extending the Power Capacity of IGBT Modules - Integration of Chip and Package Technologies' by Osamu Ikawa, Fuji Electric Device Technology (Japan, 12-407), and 'Designing an IGBT Module Packaging for High Quality and Reliable Operation' by Daniel Schneider, ABB (Switzerland, 12-408/506).

Protection strategies

The increasing power density requires improved protection strategies which are covered in this session (Thursday, 29.05.2008, 10:00 – 12:00, Room London) chaired by Prof. Johann Walter Kolar, ETH Zürich (Switzerland). The four papers feature 'Temperature Prediction in High-Current and High-Power Applications' by Johannes Adam, Flomerics Ltd. (Germany, 12-131), 'Cooling System Optimization for High Power UPSs' by Marco Piemontesi, GE Enterprise Solutions (Switzerland), 'A Progressive Way to Integrate Current Measurement into Modern Power Electronic Systems' by Martin Schulz, Infineon Technologies AG (Germany, 12-404), and 'A Series IGBT Connection and Gate Control for Auxiliary Converters in Railways' by Benoit Michaud, Adeno (France).

Power factor correction and compensation

Compenstion of reactive power is a major concern. In this session (Thursday, 29.05.2008, 14:00 – 16:00, Room Amsterdam) chaired by Prof. Philippe Ladoux, University of Toulouse (France) covers the four papers "High Efficiency Adapter Using Dual Switch PFC-Flyback Single Stage" by Bogdan Bucheru, Delta Energy Systems (USA), "2nd Generation FL-Ballast Controller Saves System Costs and Energy" by Michael Herfurth, "Line-conducted EMI-behaviour of a high efficient PFC-stage without input rectification" by Manfred Schlenk, both Infineon Technologies AG (Germany, 12-404), and "3 MVAR Single Phase STATCOM based on AC Chopper Topology" by Luc Lowinsky, LAPLACE Research Laboratory (France).

High efficiency

Almost all equipment used in our daily life is supplied from the power line and thus, higher efficiency leads to lower operating cost. This session (Thursday, 29.05.2008, 14:00 – 16:00, Room London) chaired by Prof. Dr. Andreas Lindemann, Otto-von-Guericke-University (Germany) consists of four papers entitled 'A novel, High Efficiency Approach to Input Bridges' by Davide Giacomini, International Rectifier (Italy, 12-202), 'An Asymmetric Half-Bridge Converter with Current Doubler using a New Self-Driven Synchronous Rectifier' by Jin-Tae Kim, Fairchild Korea Semiconductor (Korea, 12-601), 'Low Losses Modulation Algorithm for Dual Cascaded Inverters' by Giuseppe Tomasso, University of Cassino (Italy), and 'Modeling and Analysis of Five-Phase Coupled Buck Converter using Intercell Transformers' by Nadia Bouhalli, LAPLACE Research Laboratory (France).

Advanced IGBT technology

Power semiconductors are the main part of every power electronic system. The optimum balance of the short circuit control and the reduction in the on-state voltage is the most important trade-off for designing IGBTs. This four paper session (Thursday, 29.05.2008, 14:00 – 16:00, Room Paris) chaired by Ulrich Kirchenberger, STMicroelectronics (Germany) starts with a paper 'Short Circuit Design Criteria of Trench FS-IGBTs' by Masahito Otsuki, Fuji Electric Device Technology (Japan, 12-407), followed by '600V Reverse Conducting Trench Field-Stop IGBT for Drives Applications in Thin Wafer Technology' by Holger Rüthing, Infineon Technologies (Germany, 12-404), 'ESBT Technology in Industrial Converters: the Best Way to Cut your Losses' by Simone Buonomo, STMicroelectronics (Italy, 12-414), and 'New Chip Design Technology for Next Generation Power Module' by Manabu Yoshino, Mitsubishi Electric Corporation (Japan, 12-431/421/301).

AS

www.pcim.de

Special Session Automotive Power

This session is organised by Power Electronics Europe and will be chaired by Achim Scharf, a member of PCIM's advisory board. He will give an overview on the market for power semiconductors for automotive applications and for hybrid electric vehicles in particular, as well as on battery technology as an introduction to the topic. The following papers will drill down in this subject.

Semiconductors in Hybrid Drives Applications - A Survey Lecture

With the upcoming importance of energy saving in future cars, as well as CO_2 reduction, today's hybrid cars show the potential for reaching higher efficiency in automotive applications. Hybrid electrical vehicles (HEV) have the potential to save energy in the automobile. Besides the power semiconductor devices used for the main inverter, additional electronic components will be needed in future vehicles. The paper to be given by Ingo Graf from Infineon Munich (12-404) describes the structure and function of the different hybrid drive components, as well as used semiconductors. The latest IGBT, MOSFET and SiC technologies will be shown. According to the special needs in hybrid drives applications, future trends such as increased junction temperature or new interconnection technologies will be illustrated.

Resonant Motor Drive Topology with Standard Modules for Electric Vehicles

Weight and volume reduction of the system have the highest priority in electric vehicles, which leads to high motor frequencies. To gain the advantage of high speed drives without the disadvantage of high power losses, resonant switching topologies are required, without becoming too complex and whilst still satisfying the required reliability. The automotive miracle of increased reliability at reduced cost has to become true again to make this vision real. A new standard component which supports an innovative switching topology might be an important step forward. This paper to be presented by Michael Frisch, Vincotech/Munich (Germany, 12-426) describes the development of an electrical motor drive for a commercial application. Different technical solutions for the building blocks are compared regarding system performance, efficiency, reliability and cost. A frequency converter has been developed, based on the results of this investigation, and is introduced in commercial applications.

From Vehicle Drive Cycle to Reliability Testing of Power Modules for Hybrid Vehicle Inverter

In hybrid electrical vehicles (HEVs) the battery, motor and inverter are the core elements of the electric drive train. In the inverter power semiconductors, usually packaged in a module, are used. To qualify such power modules for the use in HEVs amongst others, Power cycling and Thermal cycling tests have to be performed. These tests mainly ensure the reliability of the module regarding thermal stress conditions over the vehicle lifetime. This paper to be given by Markus Thoben from Infineon Warstein/Germany (12-404) discusses in detail the requirements on such power semiconductor modules in terms of reliability, and lifetime in HEVs. A general approach is presented to evaluate duty cycles and thermal conditions and estimate required test cycles. Based on a water cooled power module, this approach is performed and test cycles are calculated.

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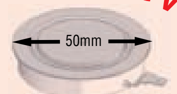

Ø32mm Pole face

V_{DRM}/V_{RRM}	32mm	38mm	50mm	68mm
600V	N2154JK	N3220QK	N4316MK	N6974HK
1.4kV	N1366JK	N2083QK	N3022MK	NX160HK
1.8kV	N1263JK	N1806QK	N2593MK	N4472HK
2.2kV	N1174JK	N1651QK	N2367MK	N3904HK
New Products	1400V, 68mm product in development			

NEW Rectifier Diodes - more silicon, less package

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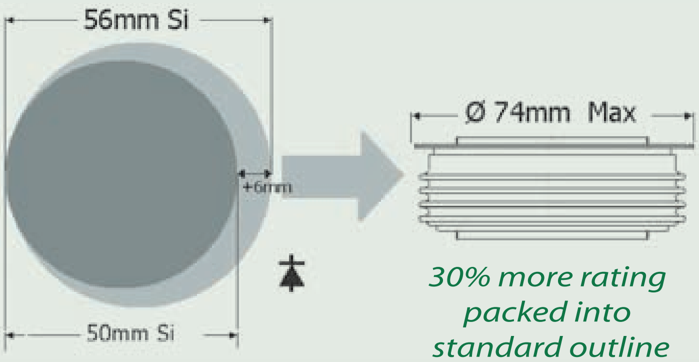

30% more rating packed into standard outline

V_{DRM}/V_{RRM}	Ø50mm
300V-600V	WX248MC030-060
1.2kV-1.5kV	WX249MC120-150
1.6kV-2.8kV	W3842MC160-280
1.8kV-2.2kV	WX250MC180-220
3.2kV-3.5kV	W3708MC320-350
3.2kV-4.8kV	W2899MC320-480
3.6kV-4kV	W3477MC360-400
4.2kV-4.5V	W3082MC420-450
5.2kV-6kV	WX254MC520-600
New Products	Products in Development

Ø50mm Pole face

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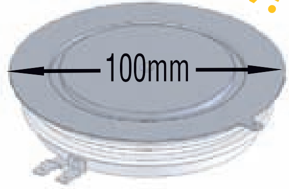
V_{DRM}/V_{RRM}	Ø47mm	Ø63mm	Ø75mm	Ø85mm	Ø125mm
1.7kV	T0500NC17A	T0800VC17G	T1600TC17A		
	T0700NC17E	T1200VC17E	T2100TC17E		
2.5kV	T0360NA25A	T0570VA25G	T1200TA25A		
	T0500NA25E	T0850VA25E	T1500TA25E		
4.5kV	T0160NA45A	T0340VA45G	T0600TA45A	T0900EA45A	T1800GA45A
	T0240NA45E	T0510VA45E	T0800TA45E	T1200EA45E	T2400GA45E
New Products	1700V products in development				

New package size Ø63mm



Ø63mm Pole face

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Power Electronic Innovations

PCIM 2008 will feature up to 250 exhibitors and more than 6000 qualified visitors. Roughly 50% of them came in 2007 from the electrical, electronics and white goods industry, 25% from automotive and 15% from factory automation. The main exhibits range from semiconductors, components and sensors, motors and rectifiers through to power management systems, simulation and design software, as well as many of the latest developments in the power electronics sector. Apart from the conference programme, a selection of new products is listed below.

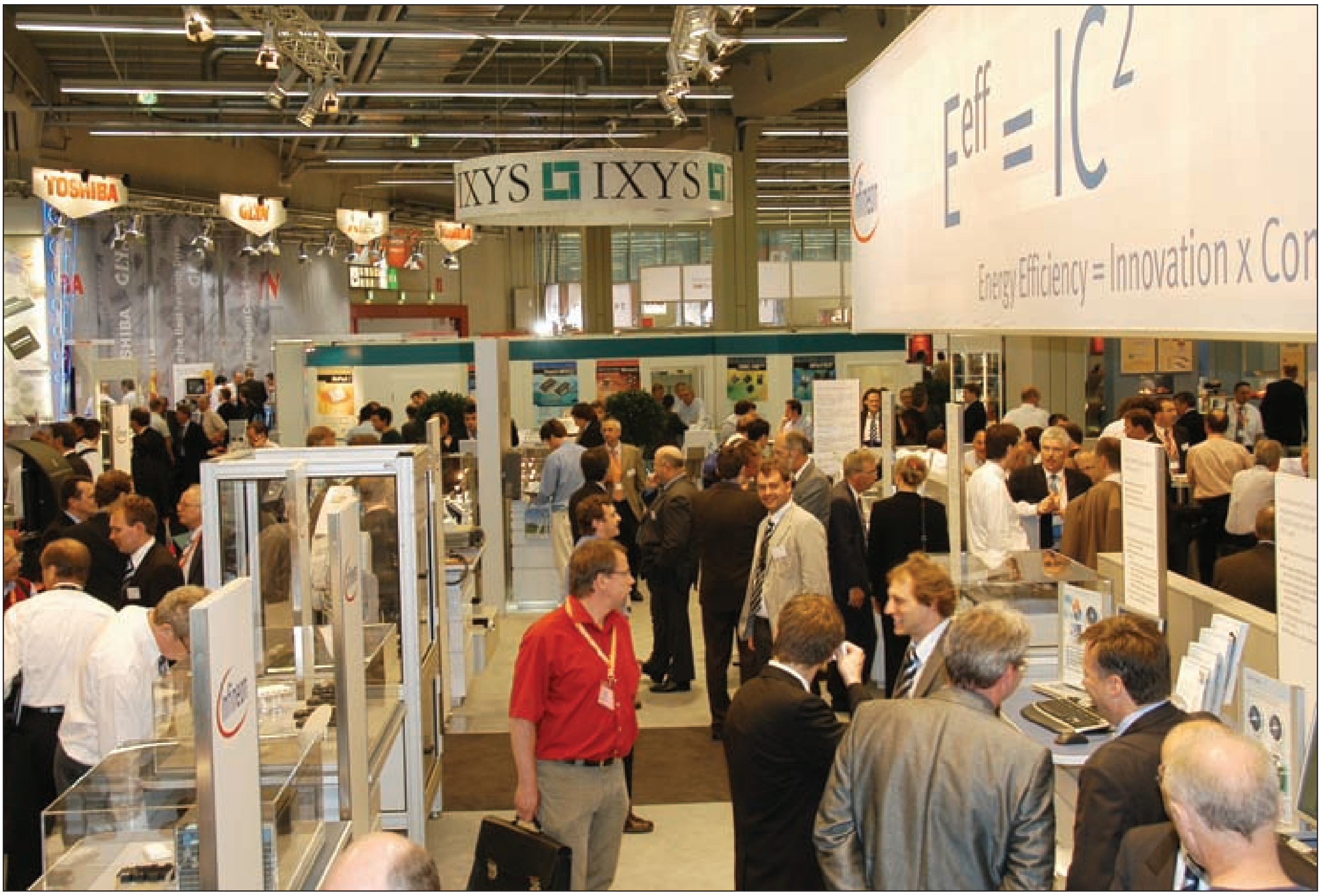
AMS Technologies

AMS Technologies announces a product enhancement at Caddock Electronics: MP820 and MP821 TO-220 Style Metal Tab Resistors are now compliant with the EU RoHS Directive (2002/95/EC). A new EU RoHS Compliant moulding compound has been qualified by Caddock for use in the MP820 and MP821. MP820 and MP821 Series are 20W resistors in a TO-220 style power package with metal heatsink mounting tab. The resistor element is electrically isolated from the mounting surface. MP821 devices feature a resistance from 0.020 to 9.99Ω, MP820 devices from 10Ω to 10kΩ. The non-inductive resistors are especially designed for measurement, high speed switching, snubbers and RF applications.

www.ams.de, *12-512*

Champs Technologies

Founded in 1992, Champs Technologies is a manufacturer and developer of high efficiency, low profile planar magnetics for the European, North & South American, and Asian markets. As a direct manufacturer of OEM planar and supplier to Asian DC/DC converter manufacturers, Champs has established a solid reputation in the power magnetics market.



Again, PCIM 2008 will serve as meeting point for the 6000+ visitors and 250 exhibitors

PL14 & PL18 series are intended for10W-100W forward converter application, wide spread use in 1/8, 1/16 brick footprint; PL40, PP40, PI40 inductor series are designed for telecom applications for power 30 to 200W; PL58, PP58 series are rated to 300W active clamp forward at 250kHz and 600W 250kHz ZVT bridge; and PL58 AC series feature 8mm creepage over 3.750VAC dielectric isolation with power rating 100W to 1kW.
www.champstechnologies.com, *12-658*

Diotec Semiconductor

Diotec Semiconductor introduces a new type of Single in Line (SIL) three-phase bridge rectifiers (DBI25-16A). Featuring 25A/1600V they can be safely soldered to a PCB using standard procedures. The DBI25-16A is a cost-effective device to provide input rectification in lower and medium power industrial applications such as power supplies or motor drives. The product range includes further a 6A and 15A version, with voltages from 400 to 1600V.

A new power Schottky diode in Quad Flat No-leads package (PowerQFN 5x6) measures only 5mm x 6mm and has a profile height of as low as 1mm. In contrast to common SMD power packages, the QFN outline comes without any exposed leads. The connection to the printed circuit board is done with integrated leads on the bottom side of the package. One big lead area forms the cathode and allows for easy dissipating of power losses.
www.diotec.com, *12-539*

ECPE

The European Center for Power Electronics e.V. – the industrial and research network for power electronics in Europe - together with leading European Centres of Excellence (university and research institutes) will be presenting its activities in the field of power electronics.
www.ecpe.org, *12-366*

ELDIS

The company offers liquid cooled high power braking resistors in the range 5 to 150kW which are aimed as brake resistors for fuel cell and hybrid vehicles, but having the capability to be used in various industrial high-power applications wherever liquid cooling is available.The resistor and termination enclosure is constructed in thermal plastic and protected to IP65, allowing the resistor to be mounted externally as well as internally.The LCHP series offers a very compact (sandwich) design and weight considerably less as conventional metal constructions. The enclosure is inherently an electrical insulator providing increased safety. The construction will also overcome the problem of capacitance. Power handling capability is related to the coolant medium and the temperature, as well as the flow rate provided.
www.eldis.de, *12-107*

IDS

The newly introduced Surge Protector (ISP) is a new, patented voltage limiter for protection of IGBT converters in wind turbines, traction and industrial converters with a very flat voltage characteristic (+/- 60V) over the whole load range (from a few mA up to several kA). The limiting voltage of conventional varistors varies up to +50% of the limiting voltage depending on the load. Unlike conventional varistors, the ISP is capable of reliably protecting IGBTs connected to the grid offered for 400 and 690V grid voltages and for higher grid voltages. The energy absorption capability is up to several 10MJ, adaptable to customers requirements. The ISP can be connected between the phases, as well as between phase and earth.
www.idsag.ch, *12-233*

Inductive Systems Europe

Inductive Systems Europe (ISE) designs and produces inductors and transformers according to special requirements of the customers, but catalogue products are also available. ISE has a long term experience and special focus on products for medical applications such as like X-ray and other scanning devices, requiring extra safety (isolation), aerospace and avionics, current sensing, energy systems, wind and solar or switch mode power supplies.
www.ise.be, *12-650*

International Rectifier

Besides new 600V IGBTs (see our cover story) the company introduces the IR3514 and IR3507 XPhase chipset for AMD parallel and serial VID (PVID and SVID) processors. The IR3514 control IC enables to migrate from AMD processors requiring a parallel VID to SVID processors without the need to change the motherboard. Combined with the IR3507 phase IC, the IR3514 provides Power Saving Interface (PSI) capability to turn phases(N-1) on or off depending on CPU load requirements. The IR3514 is designed to receive power savings commands through the SVI serial bus and communicates this information to theIR3507 phase IC to improve efficiency at light loads and MIPS per watt. This new XPhase chipset, co-designed with the latest generation of DirectFET MOSFETs, offers a full-featured and flexible approach to implementing a complete CPU power solution.

The IR3502 is a control IC for Intel VR11.0 and VR11.1 processors providing overall system control and interfaces with any number of IR's XPhase phase ICs, each driving and monitoring a single phase. The IR3502's key features include 0.5% overall system set point accuracy and daisy-chain digital phase timing for accurate phase interleaving without the need for external components. Combined with the IR3507 phase IC, the IR3502 and IR3507 chipset provides the power state indicator (PSI) capability to improve voltage regulator module (VRM) light load efficiency.

Additionally, the IR3721 measures dynamic power at the output/load side of voltage regulators to deliver a significant improvement in dynamic power measurement accuracy compared to competing power monitor ICs. TruePower technology addresses dynamic errors which can account for more than a 30% error.

www.irf.com, *12-202*

IXYS Semiconductor

A new family of 100V to 500V PolarP p-channel Power MOSFETs are designed for 'high side' switching where a simple drive circuit that is referenced to ground can be used. This is more cost-effective than using an n-channel MOSFET. Furthermore, it allows for the design of a complementary power output stage, with a corresponding IXYS n-channel MOSFET, for a power half bridge stage with a simple drive circuit. The voltage ratings of these new MOSFETs are 100, 150, 200 and 500V with current ratings ranging from 10 to 52A.

The new TrenchT2 Power MOSFET family with the voltage ratings of 40 to 75V is designed to meet the high power, thermal and electrical performance of energy and power management systems with low energy losses. Common applications include battery chargers, synchronous rectification, DC/DC converters, power train management, off-line SMPS and UPS, primary switches for 24 and 48V systems, distributed power architecture, power amplifiers and brushless motor control.

A new family of proprietary diodes (DFP32-005) are optimised for solar cell panels and space-sensitive applications, where the devices can withstand radiation levels found in space. The diodes feature low forward voltage drop and typical low leakage current of only 0.01nA. This prevents energy stored in the batteries from leaking back out of the solar panel when in the dark.

Westcode Semiconductors launches a new addition to its rectifier diode range. The new device forms an extension to the Wespack housing, having a maximum voltage rating of 3.5kV with an RMS current of 8678A encapsulated in a 68mm pole face hermetic pressure contact package.

www.ixys.com, *12-401*

LEM

LEM has added to its LTS range of current transducers designed to operate from a single +5V power supply. The LTSP model measures positive and negative AC, DC and pulse currents on printed circuit boards and provides a current output instead of the voltage output provided by the other units in the family. This allows the LTSP to detect currents up to at least 14 times the nominal current. The transducer's multi-range configuration has been designed for nominal currents of 8A, 12A and 25ARMS with galvanic isolation between the primary and output circuits.

www.lem.com, *12-402*

Powersys

PSIM is a simulation package specifically designed for power electronics and motor control. With its capability of simulating any type of power converters and control circuits, PSIM is suited for system-level simulation, control loop design, and motor drive system studies. It can be used for a wide variety of applications, including (but not limited to) switch mode power supplies, AC/DC rectifiers, single-phase and three-phase inverter and UPS systems, battery chargers, power factor correction, active filters, reactive power compensators, grid-link operations, and power IC components.

www.powersys.fr, *12-455*

Ohmite Manufacturing

Ohmite offers the first thin film power resistor in heatsinkable packaging. The TK/TN series offers major advantages over existing TO-220 products, namely low resistance values down to 0.003Ω for current sense applications at low cost. The use of thin film technology enables enhanced performance advantages such as being extremely stable (low TCR), low noise (parasitic capacitance and resistance), excellent high frequency performance and high accuracy (tight tolerances). The wirewound product portfolio has increased following the recent acquisition of both Ultronix and Angstrohm. Using newly manufacturing techniques whereby components are wound on plastic bobbins, rather than on ceramic cores, the new range of wirewound resistors offer tolerances down to 0.001%. Bringing high voltage capabilities to surface mount, MacroChip resistors have a non-inductive design combined with a low voltage coefficient. The resistors are available in precision tolerances, high voltage ratings, and high resistance values. Finally, the new G Series capacitor discharge and symmetry resistor range, is destined for tough assignments. Specially designed to handle repetitive pulse loading, the G Series provides high power dissipation up to 13W at 25°C. Available in 10 and 13W ratings, the components have ohmic range of 1 to 82K and 1 to 120k respectively.

www.ohmite.com,*12-643*

Spoerle

Spoerle addresses the needs of the power electronics segment, offering controllers for ultra-low standby current AC/DC transformers, point-of-load (POL) applications for high-efficiency embedded and automotive power supply scenarios, as well as battery management. The broadline distributor will also focus on drive technology, products from this segment will include controllers, drivers, modules and transistors for dedicated motor control of any kind of electrical drive systems. Also passive components for power management applications are to be offered.

www.spoerle.de/arrowce, *12-625*

Vishay

New for PCIM Europe 2008, the Vishay Beyschlag ACAS 0612 AT automotive precision thin-film chip resistor array is tested according to AEC-Q200 and offers a 1000-V ESD stability rating. The device is optimised to meet new automotive industry requirements for temperature and humidity, while offering high repeatability and stable performance for industrial, telecommunication, and consumer electronics.

A new series of Vishay Siliconix power MOSFETs in the PowerPAK SC-70 features devices with voltage ratings from 8 to 30V with low on-resistance values from 0.011Ω to 0.11Ω at 4.5V. The PowerPAK SC-70, with footprint dimensions of 2mm by 2mm and a low 0.8mm profile, combines the tiny footprint of the SC-70 package with on-resistance comparable to the larger TSOP-6.

A new series of enhanced high-current-density PowerBridge rectifiers with current ratings of 10 to 25A and maximum peak reverse voltage ratings of 600 to 1000V will be introduced. Compared to larger-size bridge rectifiers on the market, the advanced thermal construction of the PowerBridge devices allows heat to dissipate more efficiently. The PowerBridge rectifiers are thus able to provide the same power ratings as larger packages, while requiring smaller heatsinks.

The TJ3-HT, Vishay's new toroidal inductor offers horizontal and vertical mount options to optimize the PCB layout. With 10 standard inductance values to choose from, the inductor features a maximum DCR range from 0.108Ω down to 0.0016Ω when vertically mounted, and 0.118Ω to 0.002Ω when horizontally mounted. The TJ3-HT offers a wide inductance range from 100µH down to 0.39µH, with a high rated current from 2.25A up to 32A, and saturation current from 1.15A up to 23A. The inductor provides low magnetic radiation and is RoHS-compliant. Custom values and current ratings are available upon request.

www.vishay.com, *12-328*

Power Device Technologies for Sustainable Growth of Power Conversion Applications

Power devices have gone through a rapid technological evolution, along with the advancements in power electronics during the last few decades. More recently, the enormous advancement made by MOS-gated power device technologies such as IGBTs, power MOSFETs, and power modules have tremendously helped fast proliferation of power electronics application in industrial, commercial, residential, transportation, utility, aerospace and other emerging fields that include newer power generation systems. The second part of this keynote given at PCIM China deals with new areas of power module advancement including prospects of SiC power devices for future application needs. **Gourab Majumdar, Mitsubishi Electric Corporation, Fukuoka, Japan**

As the trend in almost all power electronics applications based on inverter control continued to be towards higher efficiency, more ruggedness against abnormalities, steadier performance, higher noise immunity, higher frequency operation, down-sizing etc., the initial IGBT modules needed new dimensions towards higher functionality and better performance.

Integration technology IPM

In order to overcome the IGBT's inherent parasitic limitations and maximize its performance, fulfilling the ever-increasing application systems' needs, a concept integrating dedicated drive and protection circuits with the IGBT in an appropriate packaging was introduced by Mitsubishi Electric, based on a new invention in the late 1980s [10]. The resulting module was named 'Intelligent Power Module' or IPM because of its self-drive and self-protection capabilities (Figure 10).

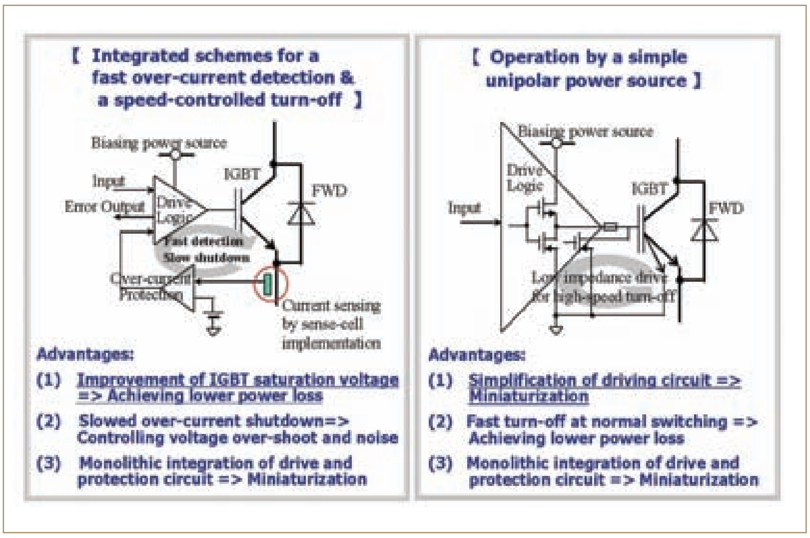


Figure 10: Fundamental concept of IPMs

An integrated sensing and protection circuit scheme detects any over-current situation of an internal IGBT power switch almost instantaneously, and turns off the switching current safely at a subdued shutdown speed to suppress destructive surge voltage. The scheme, thus, effectively enlarges the SOA of the internal IGBT. Secondly, by virtue of a smart integration concept, only positive biasing is required for gate driving and protection circuitry of each integral IGBT of an IPM. With a proper layout design, a low impedance circuit is created across the gate-emitter of each IGBT at its turn-off switching operation and during its turned-off state.

Thus, the conventional need for a negative gate biasing for IGBT's turning-off and off-state operations is eliminated. This feature contributes to downsizing of application system by simplifying IGBT drive circuitry. Also, a fast turn-off type internal gate control scheme reduces switching losses of the IPM and, thereby, it effectively solves the other trade-off issue between on-state loss and turn-off switching loss of a conventional IGBT by making suppression of both losses possible.

Furthermore, simple monolithic integration of IGBT's drive and protection circuitry for IPM use has been made possible and has created many future scopes for higher functionality. Thus, large-scale-integration (LSI) process technologies were utilised to produce dedicated low-voltage ASICs (LVIC), which were later paired with high-voltage ASICs (HVIC) for further functionality enhancements, together with optimised packaging techniques and circuit layout designs. Figure.11 is the basic block diagram of an IPM that also highlights its main advantages. Each IGBT chip integrated in an IPM typically contains an on-chip current sensor, which feeds back collector current information to an internal ASIC for processing and performing over-current and short-circuit protection functions on a real-time basis.

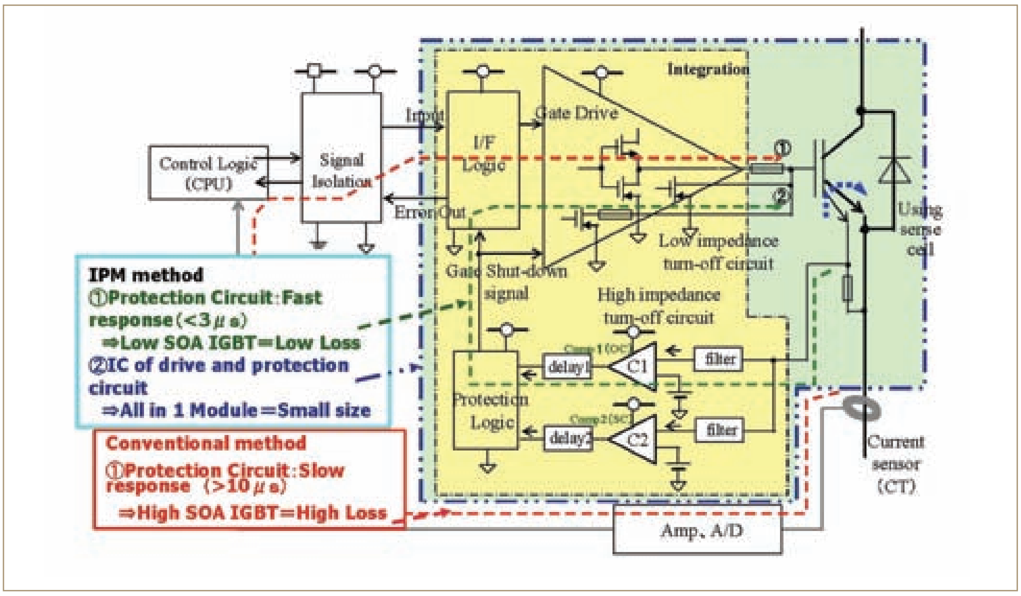


Figure 11: Feature of IGBT drive and protection

The IGBT elements for IPM applications can be designed to have a very low forward voltage drop characteristic close to the ideal level acheivable by the device's theory, without being hindered by the internal parasitic thyristor's latch-up issue.

To protect internal IGBTs more efficiently against over-temperature an on-chip temperature scheme has lately been developed. Figure 10 schematically explains this protection scheme and shows an actual chip architecture depicting the location of such integrated sensing elements (a string of series connected small-signal type poly-silicon diodes) on the chip surface. All IPMs from 5th generation level are featured with this scheme.

Another example of IPM advancement by its intelligent function is a low noise radiation feature achieved by a unique gate control scheme. The main cause of noise radiated from the power module is fast switching operation performed by the internal IGBT power elements. Fast switching characteristics is desirable for reducing switching losses in power conversion applications. However, noise level increases with the dv/dt generated due to speed of switching transients and thus, the trade-off relationship between noise generation and switching losses has been a difficult design issue in the power conversion system applications.

The new feature in the latest 5th generation IPM series solves this issue adequately by changing the gate switching speed at a preset value of switched collector current level, typically 50% of the rated I_C based on information available from on-chip current sensor's feedback as shown in Figure 13. In actual applications, the IPMs from this new series have demonstrated an 8dB average noise reduction without increasing their total power losses.

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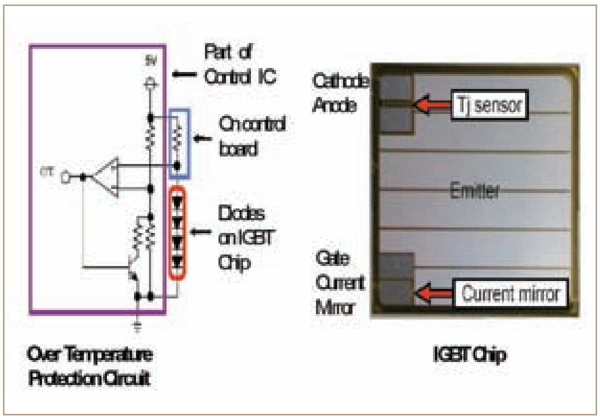

Figure 12: For improving over-temperature protection performance, a new 'on-power chip' diode-sensor scheme is used in the latest 5th generation IPM series

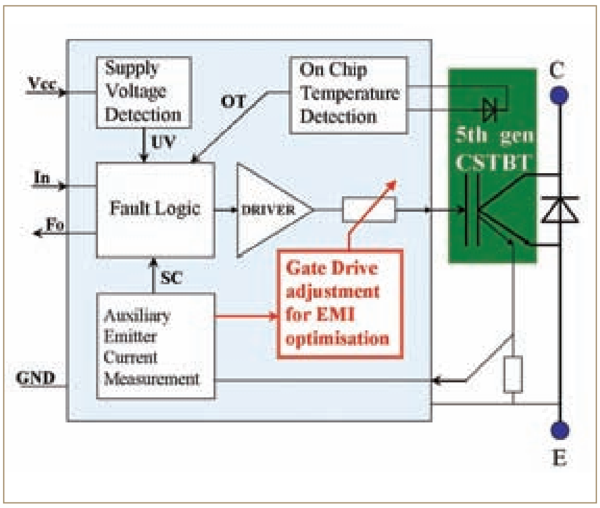

Figure 13: 5th generation IPM's internal block diagram depicting a new gate drive adjustment feature that effectively reduces radiated EMI noise

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Furthermore, a continuous demand for further compactness (hence lower system cost) and high quality performance led to the development of a super compact size IPM named the DIP-IPM (Dual-In-line-Package IPM) using transfer-mould packaging construction, targeted particularly at low power inverter applications for the household appliances (Figure 14).

In the following years, further miniaturised versions of this transfer-molded packaging concept, providing high-density silicon power solutions up to 1200V class through incorporation of 1200V HVIC technology and the latest in the power chip technologies, were successfully developed and commercialised. Thus, IPMs are largely contributing as key components to achieve the energy saving goals of various application systems such as industrial motor drives, high voltage inverters for railway systems, automotive and inverter systems for home appliances, covering fractional horse power to mega-watts applications. The expansion has led to a substantial market share for this smart integrated solution and brought in demand for higher performance, higher power density and more built-in functionality [7, 8, 9, 10].

New power semiconductor material

With achievements made by several generations of IGBT and IPM devices, the Si-Power is considered to be approaching limits in terms of performance improvement. For this reason, extensive research works are being carried out globally to implement a new candidate for material that can replace silicon in this field.

Among several wide-band-gap materials, which are tipped for power semiconductor

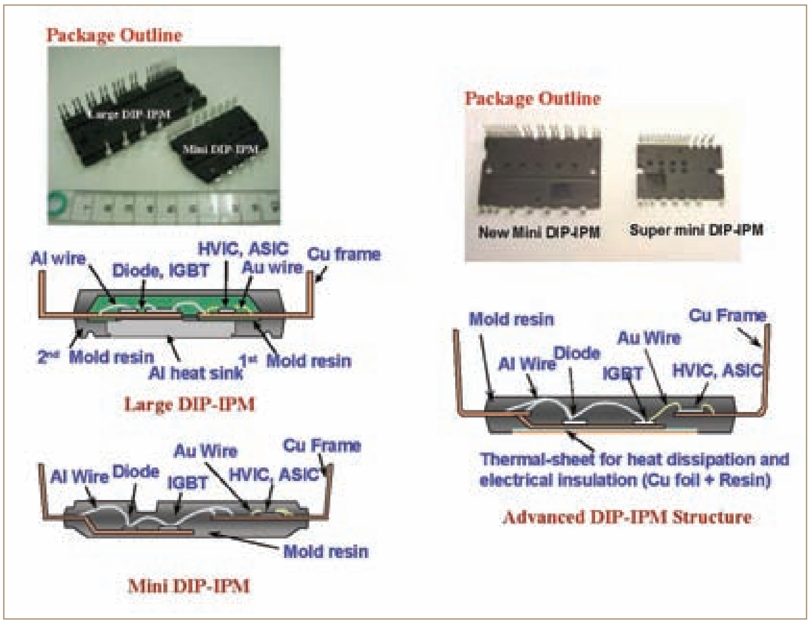
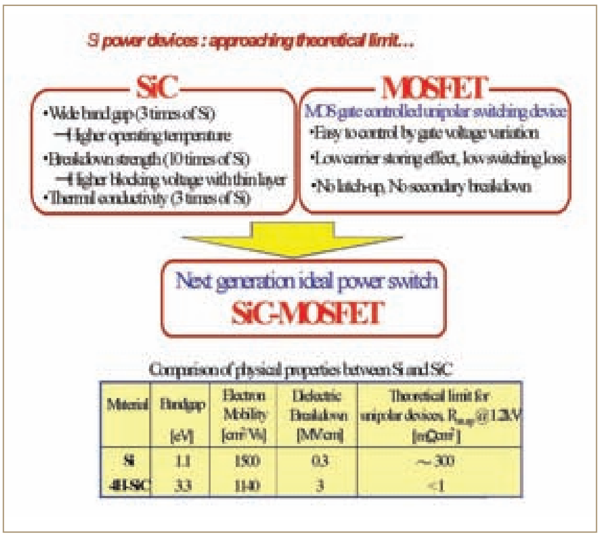


Figure 14: Transfer-mould DIP-IPM package structure

Figure 15: Features of SiC material and SiC-MOSFET for power device application



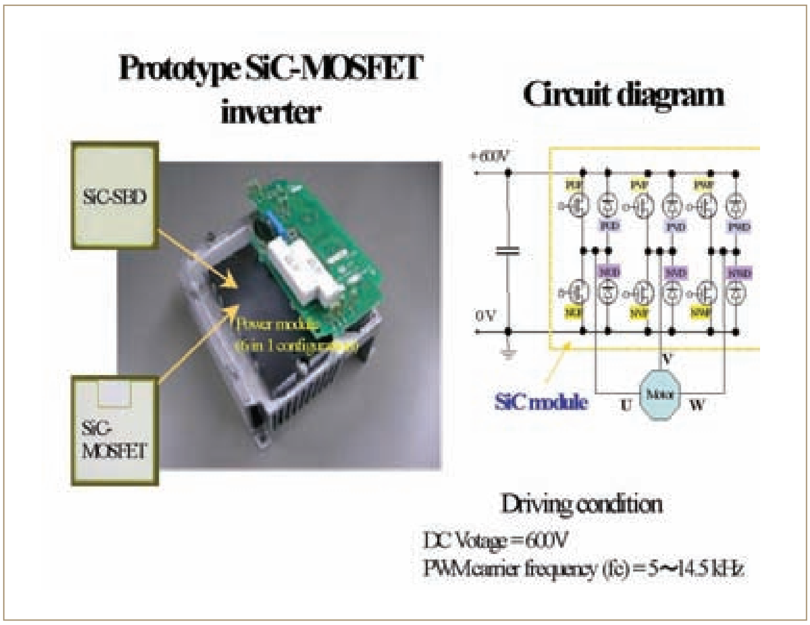


Figure 16: A prototype 3-phase high frequency inverter using an experimental 1.2kV SiC module

applications, 4H-SiC is today considered to be the most suitable one for its overall superiority, not only in terms of physical properties, but also in terms of feasibility of manufacturing both base material and devices from it with minimum complexities. Out of many arguments and analyses to define an optimum power device solution using SiC, the unipolar MOSFET structure has proven to be the best choice for device implementation for future applications up to at least 1200V class.

Figure 15 explains this view in a brief form. To evaluate this prediction quantitatively, a prototype three-phase inverter system was built by fabricating an experimental six-pack SiC module using 1200V class 4H-SiC based MOSFET and SBD chips. Each arm of the three-phase configuration in the module used a MOSFET chip of active area 7.8mm² and an SBD chip of active area 4mm².

In the inverter experiment, a 10A/1200V 5th generation silicon IGBT/FWD based module was also used for comparison purposes. Figures 16 and 17 show a prototype full-SiC module and a test-bench fabricated for evaluating SiC device on an actual inverter system environment. A three-phase/400V/3.7kW rated induction motor drive system was created for this purpose. Figure 17 also presents test waveforms depicting full-load output currents of the SiC module and comparison of its power losses with an equivalent silicon IGBT module of 5th generation level.

Comparing total operation losses in the high power three-phase inverter system, the SiC device based solution avails a large loss-saving advantage over the silicon IGBT based solution, which can be 54% or larger if a carrier frequency of 14.5kHz or higher is used. It has also been found that the SiC based MOSFET and SBD combination can remarkably reduce power losses in actual system applications of switching frequency higher than 20kHz. Thus, SiC unipolar devices have a significant potential to replace bipolar IGBT devices in various application fields, including industrial and consumer motor drives, power supplies, automotive power electronics and very high voltage systems in the near future. However, several critical issues still remain to be overcome to bring SiC devices in full-fledged commercial use. Some of these are improving wafer size and quality, solving device processing hurdles, and reducing wafer and device processing costs.

Among these items, the most critical one is the availability of viable quality low-cost SiC wafers from various sources in the global market [11]. For medium power-ranges, the power devices are expected to grow continuously primarily depending on silicon based chip and module technologies for several more years and SiC is expected to become a material choice for power semiconductors in the future. Figure 18 is a projection of major technological trends that are expected in the future.

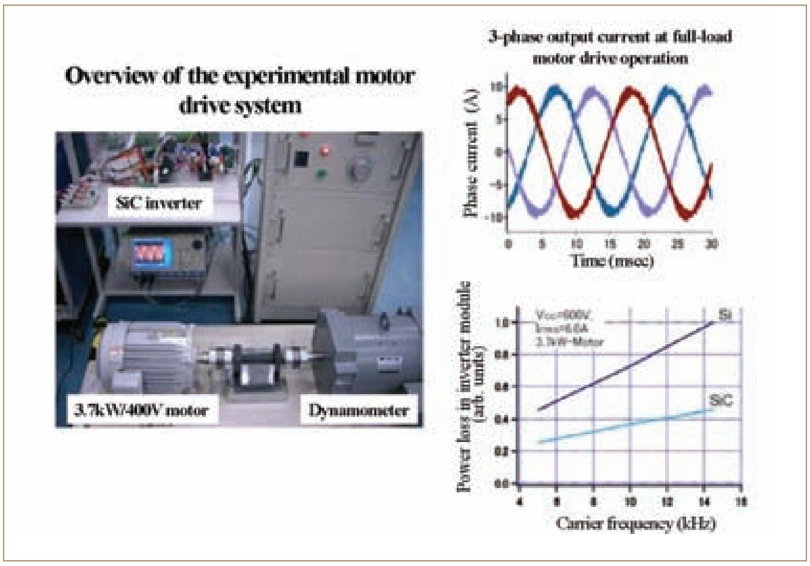


Figure 17: **Test-bench for evaluating SiC MOSFET inverter and a 5th generation silicon IGBT inverter using a three-phase/400V/4.7kW motor drive set-up and test results**

Figure 18: **Projection of technological trends for future power devices and modules**

Conclusion

In this article, the importance of power modules for various power conversion applications and new technologies related to power chips and power module packaging concept have been reviewed. Also, practical demonstration of SiC device performance has been made and analysed. The ever-increasing global energy demand and environmental issues will continue to drive power devices for greater advancement of power electronics in this century. Thus, a sustainable growth in this field is expected to follow.

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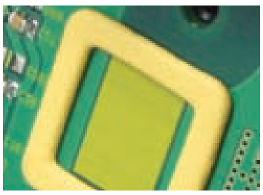

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600V Trench IGBTs Reduce Power Loss in DC/AC Inverter Applications

Selecting the best IGBT for an application can be confusing and time consuming, so is it worth the time? In this article, we will attempt to simplify the selection process by providing an explanation for the trade-offs to be considered. To illustrate the benefits, we will describe the performance improvement possible with a new generation of 600V IGBTs targeted for DC/AC inverter applications. By using optimised trench IGBTs, we can improve efficiency or reduce system heatsink size or increase current density out of the same board assembly. **Wibawa Chou, Application Engineer, International Rectifier, USA**

The new devices use field stop trench technology to reduce both conduction and switching losses in high frequency switching applications, such as UPS and solar inverters enabling higher efficiency power conversion, and have been optimised for switching at 20kHz with low short circuit requirements (Figure 1). In order to verify this claim, we have built a 500W DC/AC inverter using similar sized IGBTs and analysed differences in performance.

Figure 1: New 600V trench IGBTs optimised for 20kHz switching applications

Basic trench IGBT

Recent advancements in IGBT technology have enabled the latest generation of 600V trench IGBTs targeted for 20kHz operation. Figure 2 shows cross-sections of planar and trench IGBTs, respectively. In a planar IGBT, the polysilicon gate is 'planar' or horizontal with respect to the p^+ body region. In a trench IGBT, the polysilicon gate is 'trenched down' into the p^+ body region as shown in Figure 2. This has the benefit of reducing channel resistance to electron flow and eliminating current crowding, since now electrons flow vertically in the channel. In a planar IGBT, electrons enter the channel at an angle creating current crowding which increases resistance for electron flow. Enhancing electron flow in a trench IGBT results in a large reduction of $V_{ce(on)}$.

In addition to reducing $V_{ce(on)}$, switching energy is also reduced by changing the construction of the IGBT to a thinner structure. Thinner structure allows for faster hole/electron recombination which translates into reducing IGBT tail current at turn off. In order to maintain the same breakdown voltage capability, an n-field stop layer is created to stop the electric

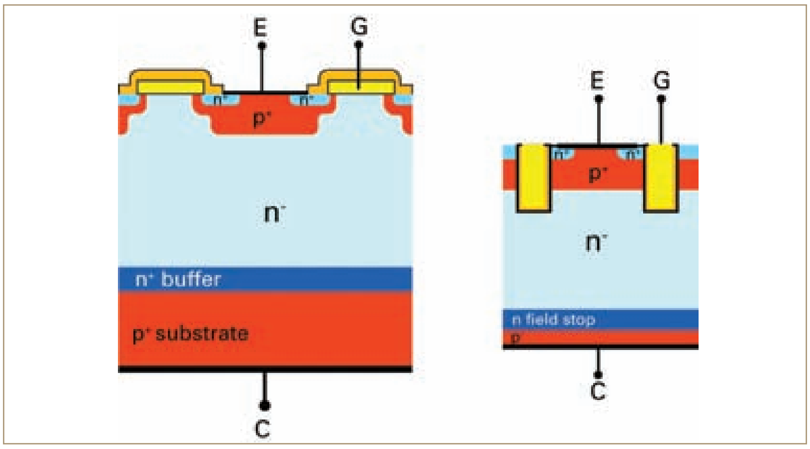

Figure 2: Planar IGBT and trench IGBT construction

field from reaching into the collector region as voltage across the IGBT increases. The combinations of lower conduction and switching energy allows for a smaller inverter size or increase power density out of the same inverter assembly. Table 1 shows parameter comparisons of similar sized planar and trench IGBTs.

From Table 1, the lower $V_{ce(on)}$ and lower switching energy loss of the newest optimised trench IGBT clearly predicts a more efficient inverter design. Comparing the products step by step illustrates the benefits of selecting the optimised part for the design. Comparing column two to four shows the advantage of lower $V_{ce(on)}$ when short circuit rating is not required, both devices are the same generation. Comparing column two to three shows the large improvement achieved when NPT devices were used to achieve improved short circuit rated products. Now comparing column 4 to 5 illustrates how the new optimised parts have improved both $V_{ce(on)}$ and switching losses E_{ts} with lower thermal impedance and lower gate charge. To achieve all these improvements a trade-off was required. The short circuit withstand time was eliminated, consistent with the requirements of the targeted application.

Part Number	IRG4BC20KDPBF	IRG15B60KDPBF	IRG4BC20UDPBF	IRGB4056DPBF
Technology	Planar Gate Punch Through	Planar Gate Non Punch Through	Planar Gate Punch Through	Trench Gate Field Stop
BV_{ces}	600V	600V	600V	600V
$V_{ce(on)}$, I_c=12A, 150°C	3.6V	2.50V	2.30V	1.90V
E_{ts}, I_c=12A, 150°C	1400µJ	580µJ	980µJ	510µJ
Q_g	34nC	36nC	27nC	25nC
R_{th}	2.1°C/W	1.4°C/W	2.1°C/W	1.07°C/W
T_{sc} at 125°C	10µs	10µs	2µs	3µs

Table 1: Planar and trench IGBTs parameter comparisons

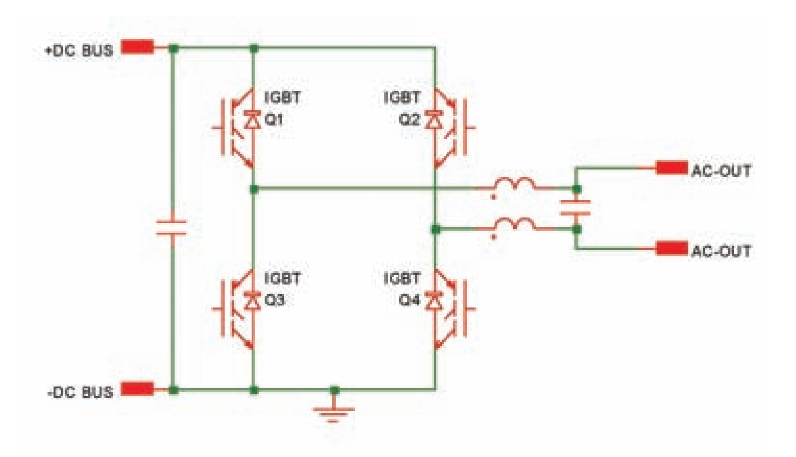

Figure 3: Implementation of a full bridge DC/AC inverter

DC/AC inverter implementation

The DC/AC inverter system discussed here is specific to only a system that requires true sine wave output at 50 or 60Hz. Square wave or quasi sine wave inverters will not be discussed here, as implementations of such inverters usually do not require the power devices to operate at 20kHz switching frequency.

Applications that require true sine wave output can typically be found in uninterruptible power supplies (UPS), solar inverters or frequency converters, just to name a few applications. A typical implementation utilises a full bridge inverter shown in Figure 3. The DC bus voltage can be derived from a bank of batteries in the case of a UPS, a solar panel in the case of a solar inverter, or rectified AC mains in the case of a frequency converter. The output of the inverter is a true sine wave voltage after the LC filter of Figure 3. In this topology, two of the IGBTs (Q1 and Q2) are considered high side devices whose gate voltages are driven 15V above the DC bus voltage. An easy way to achieve this is with a high voltage gate drive IC with bootstrap power supply. A driver IC can typically drive a pair of complementary high and low side IGBTs. Therefore, only two such driver ICs are required to implement a full bridge inverter. The input signals to the driver ICs can come from a microcontroller or can be implemented using analog circuitry.

Using this topology, it is possible to reduce the power dissipation by up to 30%, simply by changing the power devices Q1 to Q4 from an older short

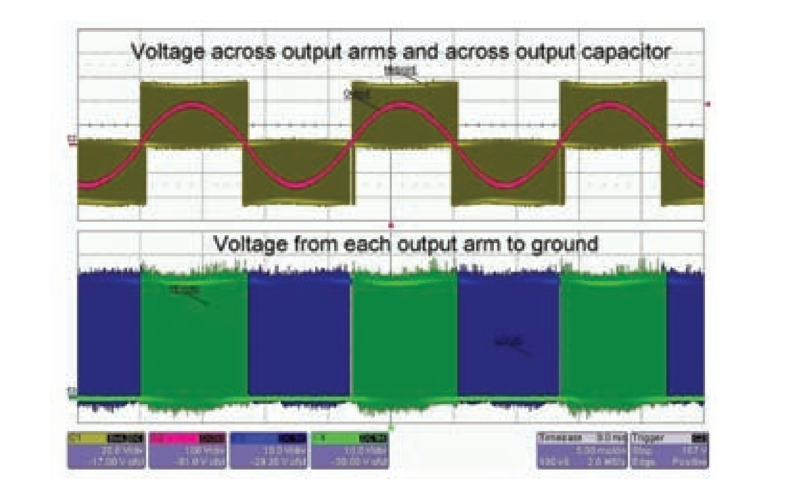

Figure 4: Typical voltage waveforms across the inverter arms and output capacitor

circuit rated planar IGBT to the newer optimised trench IGBTs. The switching frequency of this inverter is selected at 20kHz to prevent the output inductor L1 from generating audible noise. In this topology, Q1 is sine pulse width modulated at 20kHz, while Q4 is kept on during the positive 50 or 60Hz half cycle. Q2 and Q3 are kept off during this positive half cyle. During the negative 50 or 60Hz half cycle, Q2 is sine pulse width modulated at 20kHz while Q3 is kept on. Q1 and Q4 are turned off during this negative half cycle.

The resulting output waveforms are presented in Figure 4 which shows the voltage across the output arms of the full bridge inverter prior to the LC filter. The voltage waveform shows both the 20kHz switching of the IGBTs, as well as the 60Hz commutation. It can be seen that since the power devices operate at both 20kHz and 60Hz, lower conduction and switching losses of trench IGBTs are beneficial in reducing overall power dissipation of the inverter.

Figure 4 also shows the output voltage across the output capacitor after the 20kHz switching artifacts have been removed by the LC filter. The output is a true sine wave voltage. In order to meet total harmonic distortion (THD) requirement of the application, one usually adjusts the value of the output inductor and capacitors appropriately.

DC/AC inverter demo board

Figure 5 shows the demo board that IR built to compare the performance of best planar and trench IGBTs using the scheme discussed previously. This demo board is capable of delivering 500W of output power without requiring forced air cooling. It measures 3in x 5in and is based on the schematic shown in Figure 3. A microcontroller is used to generate appropriate signals for the high voltage gate driver ICs that drive the IGBTs. The IGBTs are soldered on the bottom of the board and are mounted to a 3in x 2.5in x 0.5in heatsink.

The 500W target for this demo board is ideal for a distributed power solar inverter application where the power electronics are integrated with the solar panel. Figure 6 shows the heatsink temperature difference between the best planar IGBT and the optimised trench IGBT at 500W output power. The heatsink temperature of the demo board with planar IGBT and the one with trench IGBT are 101 and 85°C, respectively. Replacing the power devices with trench IGBTs showed a 16% reduction in heatsink temperature. This gives the design engineer an opportunity to increase power density out of the same circuit board assembly simply by swapping out the power devices or reducing the size of the power electronic assembly by reducing the size of the heatsink if the same temperature is to be maintained.

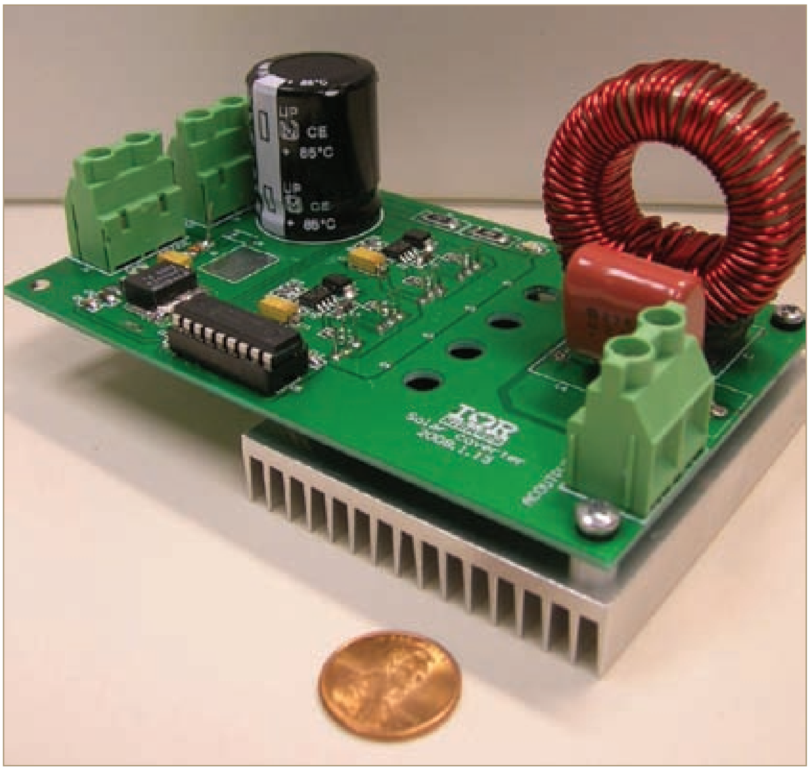

Figure 5: DC/AC inverter demo board

Conclusion

The new optimised family of 600V trench IGBTs have been designed to reduce conduction and switching losses at 20kHz compared to older IGBTs. The target application for these IGBTs is DC/AC inverters typically found in UPS, solar inverter and frequency converter applications where true sine wave output voltage is required. International Rectifier built a 500W DC-AC inverter demo board using a full bridge topology to verify the power loss reduction by measuring heatsink temperature differences. In this experiment, it was shown that replacing the power devices with new optimised trench IGBT devices delivered a 16% reduction in heatsink temperature. The reduced losses provided an efficiency improvement of approximately 30% from previous generation IGBT devices.

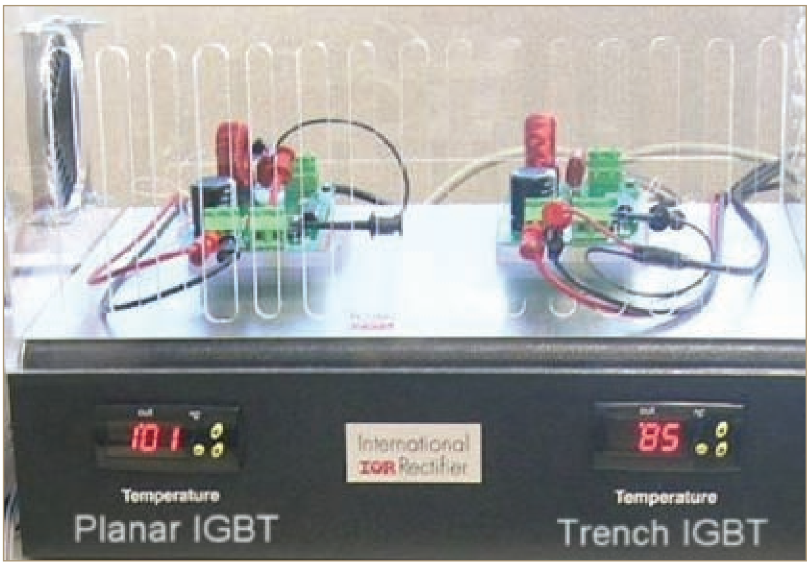

Figure 6: Heatsink temperature differences between trench and planar IGBTs at 500W inverter output power

THERMAL INTERFACE MATERIALS

- Ferrite Film
- Thermally Conductive Films
- Thermal Interface Grease
- Thermally Conductive Insulators
- Graphite Film
- Phase Change Interface Materials
- Insulated Metal Substrates
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Paralleling of IGBTs and Diodes of One Power Module – Pushes Power Capability

The increasing request for motor drives with higher power levels is also driving the demand for power modules providing higher currents. The conventional approach to fulfill this requirement is to look for dedicated high current power modules. This article describes the alternative approach of paralleling IGBTs and diodes within one power module to extend its power capability, for example using a 35A sixpack module as a 100A half-bridge. The conclusion is that this approach provides an advantage due to the improved thermal behaviour of several small chips rather than fewer big ones. **Werner Obermaier, Tyco Electronics/Vincotech, Munich, Germany**

The breakthrough in performance is seen when real life data of parameter variations within one power module are considered, instead of the datasheet values, which suggest a much higher spread than actually seen in real life. Figure 1 shows how a sixpack can be used as a half-bridge.

The following calculations are based on the P700-F sixpack module from Vincotech, which uses Infineon IGBT3 low loss IGBTs and Emcon HE FREDs. Both components feature a positive temperature coefficient for their voltage drop at high junction temperatures. This is important in avoiding thermal runaway of individual components when paralleled.

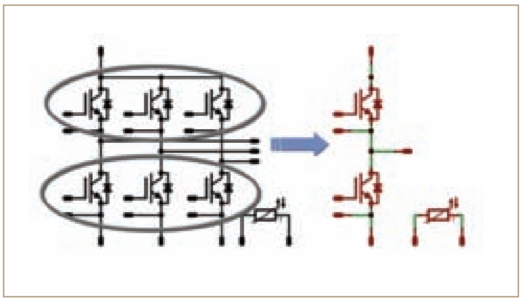


Figure 1: Sixpack used as a half-bridge

Switching behaviour

When paralleling IGBTs, special attention has to be given to the drive circuit. Because of the variation of the gate threshold voltage of the different chips, simply connecting the gates is not adequate. Instead, each gate has to be driven by its own gate resistor and therefore its own current source, in order to ensure that the chip with the lowest threshold voltage does not clamp the voltage for the others and carry all the current. Furthermore, the layout of the emitter circuit has to be very symmetrical in order to minimise differences in emitter inductances and resistances. Even minor, unavoidable differences in the emitter inductances and resistances will generate compensation currents between the gate drive emitter connections. To limit these currents, the introduction of an emitter resistance in the drive circuit is strongly recommended. It is strongly recommended to use a resistor in the range of at least 0.5Ω, but not to exceed approximately 1/3 of the total gate resistance. To ensure real emitter drive sensing, the module needs to provide emitter sense connections with separate bond wires, as do the power modules from Vincotech.

Moreover, any mismatch in the delay, rise and fall times of the driver circuit are to be avoided, as these will also result in a mismatch of switching currents and therefore switching losses of the different devices. Recommended is the use of a single gate drive circuit with individual gate and emitter resistors for the different IGBTs, as shown in Figure 2. If higher drive currents are required, a single driver

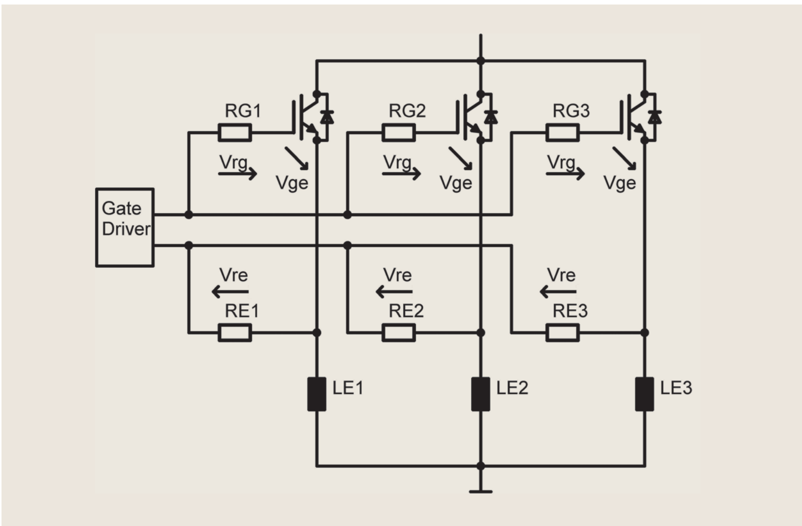


Figure 2: Sixpack low side with drive circuit

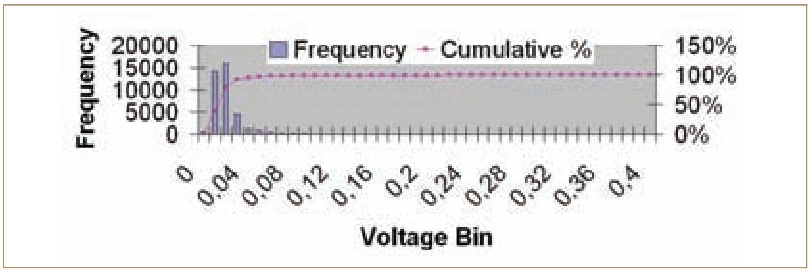


Figure 3: IGBT saturation voltage spread

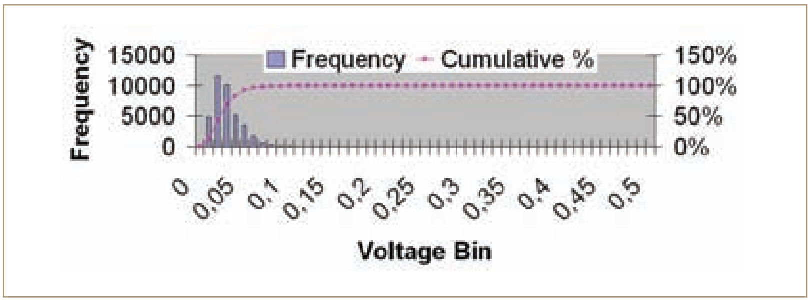


Figure 4: FRED forward voltage spread

Table 1: Voltage spread for different probabilities

	IGBT Voltage		FRED Voltage	
Probability	Voltage spread (min/max) Tj = 25 °C	Voltage spread* (min/max) Tj = 125 °C	Voltage spread (min/max) Tj = 25 °C	Voltage spread* (min/max) Tj = 125 °C
99,1%	≤ 100 mV	≤ 140 mV	≤ 90 mV	≤ 100 mV
99,9%	≤ 240 mV	≤ 350 mV	≤ 200 mV	≤ 240 mV
99,99%	≤ 310 mV	≤ 450 mV	≤ 400 mV	≤ 490 mV

*) values are extrapolated based on 25 °C data

circuit with individual push-pull driver stages is recommended.

Since the switching losses and their mismatch depend on the layout, it is good practice to measure and confirm them in the real application. If the recommendations above are followed, it is fair to assume that the switching losses for the different devices will match to within 10 to 15%.

On-state behaviour

The on-state behaviour is more critical. The datasheet for the P700 sixpack suggests a relatively large variation in IGBT collector-emitter and diode forward voltage. For the IGBT, the collector-emitter saturation voltage at 25°C is given as 1.7V typical and 2.25V maximum. No value is provided for the minimum voltage. Considering this information, the paralleling of chips cannot be recommended, since the current sharing among the individual IGBTs cannot be ensured. The situation is even worse for the diodes.

In reality, however, the actual spread of the devices within one power module is much lower. This is due to the fact that they are picked from locations either exactly next or very close to each other on the same wafer, and will therefore feature extremely similar electrical characteristics. To determine the real voltage variation, Vincotech has collected data from more than 40 thousand modules produced in multiple lots distributed over a period of more than one year. This evaluation shows that the saturation voltage variation for 99.99% of the high side or low side IGBTs does not exceed 310mV at 25°C and 450mV at 125°C respectively. For the FREDs, the value is 400mV at 25°C and 490mV at 125°C. The distribution of the voltage spread within the measured series is shown in Figure 3 for the IGBTs and Figure 4 for the diodes. Table 1 shows the probabilities for different voltage spreads.

When considering current sharing, apart from the low or high side of the voltage variation of the IGBTs and FREDs, it is important to know what value the third device will exhibit. Again, instead of using a worst case view based on the datasheet voltage spread, the actual data collected from the 40 thousand modules can be used. Based on this information, the current sharing can be calculated for each module individually. The device with the lowest voltage drop is used to determine the voltage for the other two devices. By doing so, it is ensured that the best device will run with the maximum current level it is designed for and that the other devices will run at a lower current level well within their design limits. The current of the other devices can be calculated using the dynamic voltage slope of the saturation voltage for the IGBT or the voltage slope of the forward current for the diode. The total current of the module can be calculated according to equation 1:

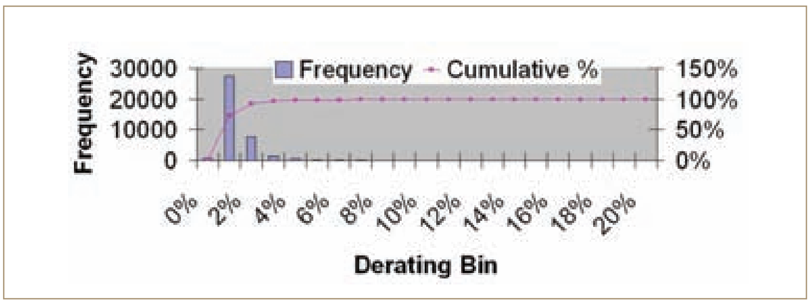


Figure 5: IGBT current de-rating distribution

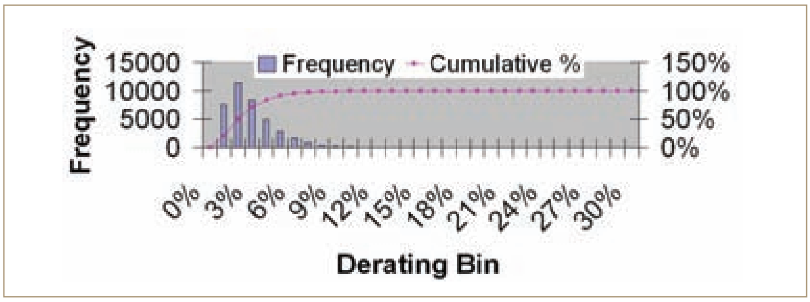


Figure 6: **FRED current de-rating distribution**

IGBT Current Sharing Probability		FRED Current Sharing Probability	
Probability	Required Current Reduction	Probability	Required Current Reduction
99.9%	11%	99.9%	14%
99.99%	13%	99.99%	25%

Table 2: **Current derating for different probabilities**

$$I_{total} = I_{nom\ (best\ device)} + I_2 + I_3 \quad (1)$$

And the current de-rating for the module can be calculated as (2):

$$D = I_{total} / 3 * I_{nom} \quad (2)$$

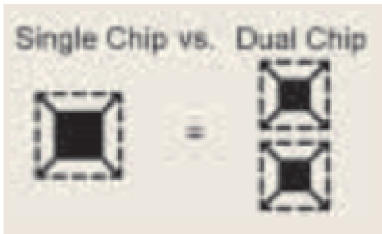
Figures 5 and 6 show the distribution of the de-rating for the paralleled IGBT and FRED section of the module. Table 2 shows the probabilities for the current de-rating.

For a design where the 13% de-rating for the IGBT and 25% de-rating for the diode is used, only 1 device out of 10.000 will exceed the targeted design limit of all devices running lower than the originally targeted current. Due to this fact, this single device out of 10000 devices may exhibit lifetime, which is lower than expected. On the other side, the distribution curves show that, for the IGBTs, 90% of the modules will share the current within 2% and 99% within 6%. For the FREDs, the current sharing for 90% of the devices will be within 5% and for 99% within 9% respectively. With a design made using the 13 and 25% de-rating, the majority of the modules will run with a much better current sharing, thus running at a temperature lower than expected. This will not only compensate for the lower lifetime of the few devices, but also improve the overall lifetime and reliability of the design.

Thermal behaviour

Using multiple smaller chips instead of one larger chip improves the thermal behavior, described by the thermal impedance of a device. This is due to the fact that not only the chip itself, but also a certain area around the chip, will participate in the transfer of heat from the chip to the heatsink. Figure 7 shows the improved thermal spreading when using two small chips instead of one large, with in equal total area in both cases.

Figure 7: **Improved thermal spreading**



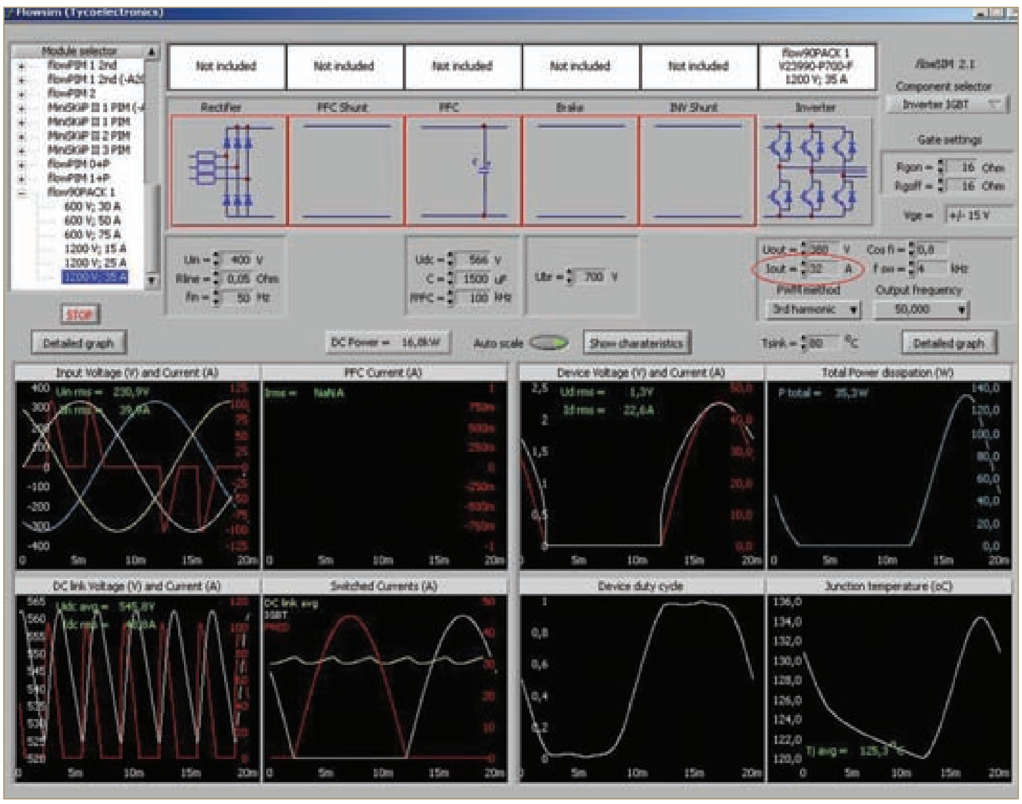


Figure 8: **FlowSIM P700 IGBT phase current determination**

	P700-F		P569-F	
	IGBT	FRED	IGBT	FRED
Simulated phase current	32 A	103 A	74 A	180 A
Required derating	13%	25%	0%	0%
Resulting phase current	**28 A**	**77 A**	**74 A**	**180 A**
Number of devices	3	3	1	1
Total phase current	**84 A**	**232 A**	**74 A**	**180 A**
Limiting value for application	**84 A**		**74 A**	
Improvement	**13%**			

Table 3: **Comparison between single chip P569-F and multi-chip P700-F solution**

This can also be seen when comparing the thermal resistance of the 100A IGBT in the P569-F module with the 35A IGBT in the P700-F module. The thermal resistance junction to heatsink for the 100A device given in the data sheet is 0.57K/W. The resistance for the single 35A IGBT is 1.29K/W, resulting in an overall resistance of 0.43K/W, when three of them are used in parallel. This provides an improvement of about 25% in thermal performance, which compensates for some if not all of the de-rating required due to the non-ideal current sharing.

As an example, the performance of a 35A sixpack module used as a half-bridge is compared to a 100A single chip half-bridge module. The conditions and parameters used for the evaluation are motor frequency 50Hz, cos phi 0.8, PWM frequency 4kHz, heatsink temperature 80°C, $T_{j\,max}$ 125°C.

In the first step, the phase current capability of the individual devices, the IGBT and the FRED are determined for the P700 and P569, using the Vincotech flowSIM simulator. This simulator already takes the improved thermal performance of the smaller chips into account, which does not need to be explicitly considered later on. Figure 8 shows the flowSIM result for one 35A IGBT of the P700-F module.

In the next step, the current de-rating is applied and the result is multiplied by 3 for the 3 paralleled devices. Table 3 shows the result for the IGBT and FRED for both solutions.

The result reveals that the overall performance for the application at hand can be improved by 13% using the P700-F 35 A sixpack instead of the P569-F 100A single chip half-bridge. The actual improvement will vary for different application parameters and therefore needs to be evaluated at the most critical point.

Conclusion

The use of sixpacks as half-bridges can boost the performance and enable the use of preferred modules and packages at higher power levels. Special care has to be taken regarding the drive circuit and current de-rating is to be considered when calculating the current of a single chip used in a multi-chip arrangement. Individual emitter sense down to chip level and symmetrical design are required of the power module, both of which are met by Vincotech modules. With the use of components in parallel, not only can higher current levels be reached, but also the reliability of the design be improved.

Power Cycling Induced Failure Mechanisms in High Temperature Applications

The specific cooling conditions of hybrid electric cars and the trend to higher current densities in power electronic applications demand the operation of semiconductors at junction temperatures above the common level of 125°C. **Thomas Licht, Thomas Schütze, Infineon Technologies AG, Warstein, Germany**

The maximum operation temperature is mainly limited by the reliability of the assembly and interconnection technology to reach the number of required temperature cycles during lifetime. Known weak points are bond wires and solder joints.

Power cycling test

Figure 1 demonstrates the run of dissipated power as well as upper and lower level T_{high} and T_{low} of the die temperature T_j by which a power cycling test can be described.

IGBT forward voltage drop V_{CE}, forward current I_C, virtual junction temperature T_j and heatsink temperature T_h are continuously monitored during the test. The thermal resistance R_{thjh} is calculated from these values. Since both V_{CE} as well

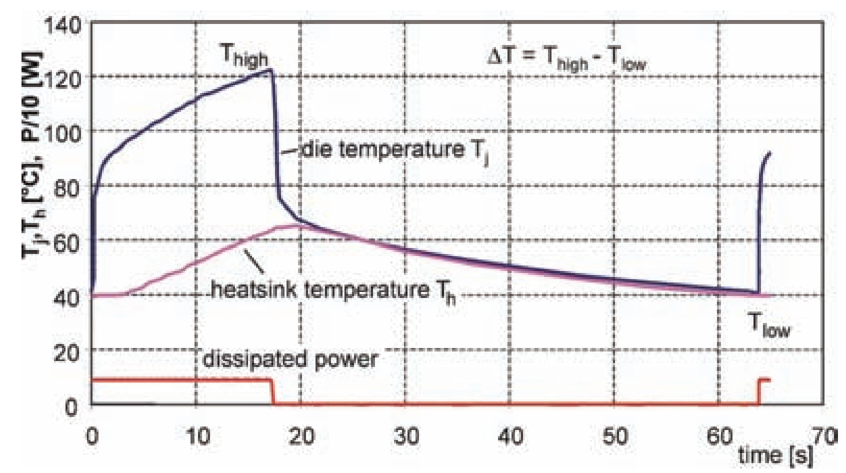


Figure 1: **Characteristic variables of a power cycling test: dissipated power and resulting temperatures of junction and heatsink**

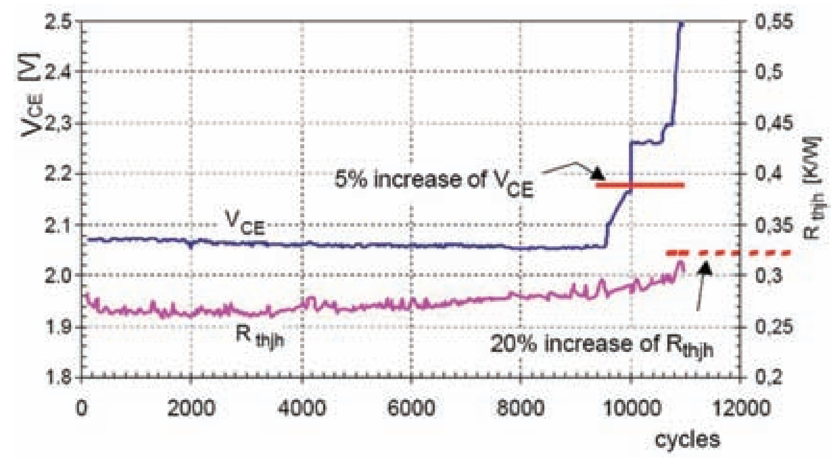


Figure 2: **Recording V_{CE} and R_{thjh} in power cycling test with high ∅T = 123K**

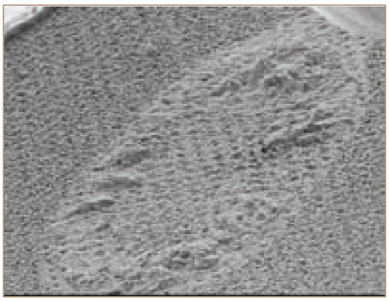


Figure 3: Bond lift-off as a result of power cycling

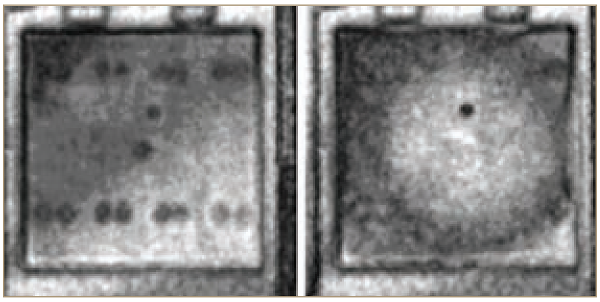


Figure 4: Ultrasonic image of a lead-free unstressed (left) and stressed (right) chip solder layer

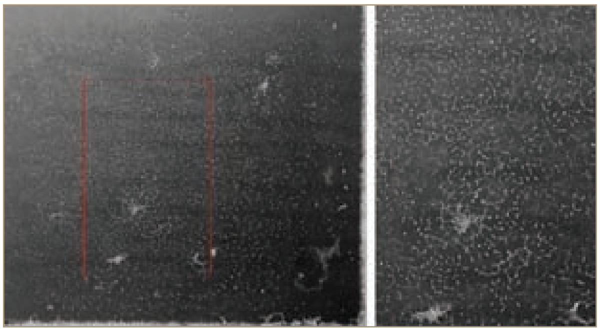


Figure 5: Lead-rich soft solder with damage in centre and zoom of the damage (right)

as R_{thjh} may increase during the test, one must distinguish both factors.Therefore either an increase of V_{CE} by 5% or an increase of R_{thjh} by 20% are defined as failure limits.

In Figure 2, the V_{CE} failure limit is reached after approximately 10,000 cycles. The sudden leaps in the V_{CE} curve indicate lift-off of single bond wires. After 6,000 cycles a slow increase of R_{thjh} can already be observed, a sign of solder fatigue. The failure limit of R_{thjh} would be reached after approximately 11,000 cycles. The progressive increase of R_{thjh} raises the temperature T_{high}, and thus enlarges the thermal stress for the bond wires at the same time. Also, solder fatigue is a significant failure mechanism in this test; it could even be the main failure mechanism.

Bond wires

For a long time bond wires were discussed to be the main weak point for power cycling. Figure 3 shows the typical failure mode, the lift-off of a bond wire. There is no adherence in the centre of the bond area.

The bond wire process could be improved significantly. From the viewpoint of high temperature applications, bond wires seem to be no longer the main weak point, if a proper technology is used. In [1] it was shown, that by the use of Low Temperature Joining Technique (LTJT) the power cycling capability could be raised even for cycles up to ØT = 160K.

Solder layers

By improved bond wire technology, limits of solder layers become more and more visible. Using large area silicon dies (>0.5cm²) the hottest spot is under the centre of the device. Figure 4 demonstrates that the degradation of lead-free solder layer starts in the centre of the device.

Degradation below the device centre is also found, if lead-rich solders are used. This becomes visible only in high-resolution X-ray images. The sample of Figure 5 reached the V_{CE} + 5% limit at 24,800 cycles. The test parameters have been t_{on} = 17s, T_{high} = 156°C, ØT = 120K and the increase of R_{th} between junction and substrate has been 10%.

Degradation at the hottest point is also found for the solder layer between substrate and base plate. The example shown in Figure 6 was executed with an

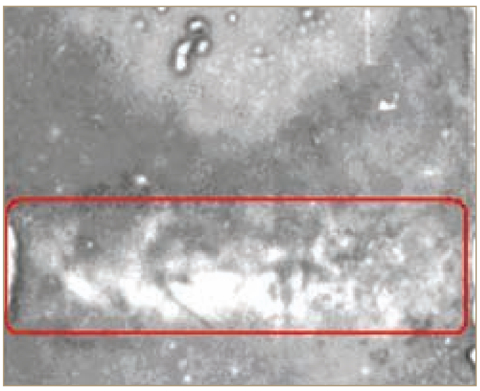


Figure 6: Damage below active power cycled IGBTs in a lead-free substrate solder joint

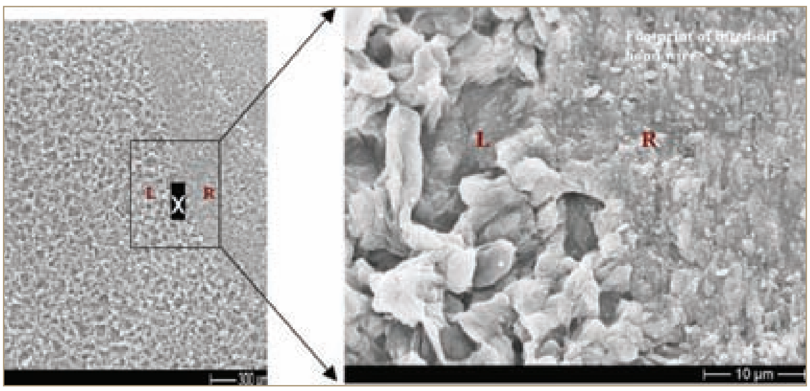


Figure 7: Region adjacent to the footprint of a lifted-off bond

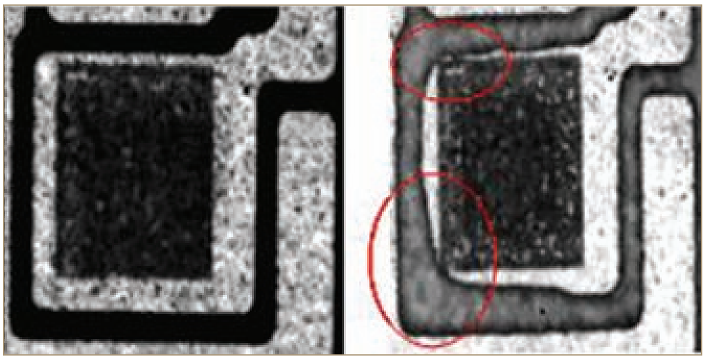


Figure 8: Comparison of unstressed (left) and stressed (right) DCB substrate

AlSiC base plate module at $\varnothing T$ = 70K, T_{high} =150°C, the number of cycles to V_{CE} +5% was 255,000.

It must be noted that these results contradict often used models which assume crack propagation starting at the edges of the devices. These models are valid for temperature cycling tests, in which the module is heated and cooled passively, and where a homogeneous temperature is given. In active power cycling, there are significant temperature gradients appearing between the different layers. On large dies with areas >1cm², temperature differences of up to 20K are possible between the hot centre and the edge of the silicon die.

Reconstruction of metallisation

Besides bond wire lift-off and solder degradation, thermo-mechanical stress can cause reconstruction of the metallisation. Although a resistivity increase of up to 41% for a metallisation with strong reconstruction was found, the effect on the forward voltage drop is rather low.

Figure 7 shows a detail of the metallisation adjacent to the footprint of a lifted-off bond. The device survived 44,500 cycles with $\varnothing T_j$ = 130K, T_{high} = 170°C. The high number of cycles was achieved by applying single-side LTJT technology. From this observation, we do not suppose reconstruction to be a mechanism which leads directly to bond-wire lift-off.

Nevertheless, the effect of reconstruction should be regarded in further investigations, because it may affect the current distribution and may be of negative influence to the surge current capability of free-wheeling diodes.

Substrate delamination

Under same conditions, $\varnothing T$ >130K, LTJ technology, limits of the Direct Copper Bonding (DCB) substrates were found. Figure 8 gives an example of failure analysis after 56,780 cycles.

The devices under test were baseplate-less modules without a substrate solder joint. Substrate delamination was found, which usually only occurs under passive temperature cycles. A possible improvement is e.g. the introduction of so- called dimples which help to reduce mechanical stress in the corners of the Cu pads.

Conclusion

With improved bond wire technology, limits of solder layers become more and more visible. Besides cracks propagating from the centre to the edge, solder fatigue starting from the centre of the devices is also found. In substrate solder joints, fatigue starting at the locations of the dies and therewith the hottest point of the solder interconnection was also found. Additionally, a strong reconstruction of the die metallisation layers occurs. The metallisation below the bond wire is less affected, but the resistivity of the metallisation is increasing significantly.

We would like to thank J. Lutz, T. Herrmann and M. Feller from the Chemnitz University of Technology and Raed Amro from the University of Hebron, Palestine for their contribution to this abridged version of a corresponding paper published at CIPS 08.

Literature

[1] R. Amro, J. Lutz, J. Rudzki, R. Sittig, M. Thoben: 'Power Cycling at High Temperature Swings of Modules with Low Temperature Joining Technique', Proceedings of the ISPSD 2006, Naples, Italy

Forward and Reverse Stable HiPer Fast Recovery Diodes

This article introduces new families of forward and reverse HiPer Fast Recovery Diodes (FREDs) in the 200V to 400V voltage range with different current ratings. The experimental findings are consistent with numerical modelling results and demonstrate that, without using guard rings, it is possible to achieve breakdown voltages of 200 to 400V. The devices show stable blocking characteristics with low reverse current after high temperature reverse bias and humidity testing. **J.V. Subhas Chandra Bose and Peter Ingram, IXYS Semiconductor, Lampertheim, Germany**

To increase the avalanche breakdown voltage and to improve the reliability of a diode, it is necessary to shift the maximum electric field from the surface to the semiconductor interior.

Blocking and breakdown voltage alignment

In a forward planar diode, blocking voltage is limited by the region of junction curvature where maximum electric field occurs. The forward diode consists of phosphorus N-type Si region with low doping concentration. The backside is highly doped phosphorous (N+) substrate, or deep diffused phosphorus wafers in contact with the cathode metal. The front side has a boron-doped region, which is in contact with the anode metal. The blocking voltage of a forward diode can be increased by reducing the curvature effect either by using floating field limiting rings (FLRs), metal field plates or a combination of both. It has been shown that the FLR technique is sensitive to oxide charges and process variations. Optimal field plate designs involve multiple dielectric layers and gaps between metal field plates. Furthermore, using a forward diode it is possible to obtain 85 to 90% of plane parallel breakdown voltage.

In a reverse diode, it is possible to obtain 100% plane parallel breakdown voltage because of absence of junction curvature. The reverse diode consists of an N- type Si region with low doping concentration. The backside is highly doped boron (P) substrate or deep diffused boron wafers in contact with the anode metal. The front side has a phosphorus-doped region, which is in contact with a cathode metal. The 100% blocking voltage is obtained by diffusing aluminium or boron as isolation diffusion. Final passivation layer can be glass or metal field passivation.

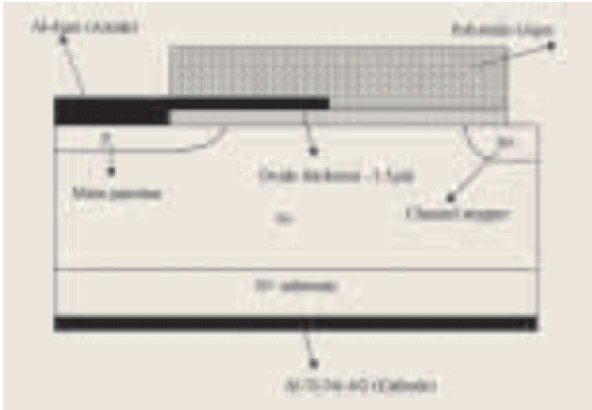


Figure 1: Cross-section of forward HiPer FRED

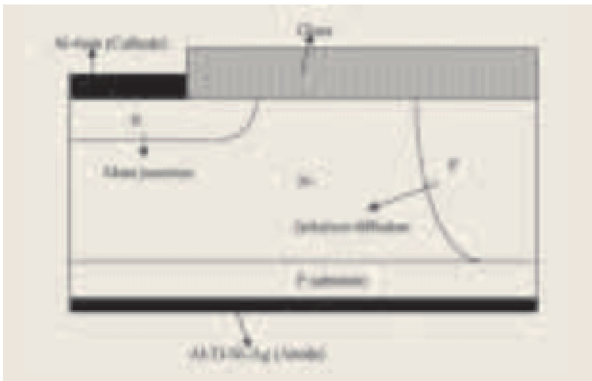


Figure 2: Cross-section of reverse HiPer FRED

Forward and reverse 200 to 400V diode techniques have been investigated which are insensitive to surface charge during processing and after high temperature reverse bias (HTRB) and humidity test. A new technique replaces the diffused guard rings and combination of guard rings with metal field plates. Optimisation of the structure and analysis of the breakdown voltage characteristics is carried out using ISE TCAD software. In the simulation life-time killers are not taken into account.

Numerical computations and results

The forward and reverse 200 to 400V diodes are as shown in Figure 1 and Figure 2. For example N- resistivity and thickness of 300V forward and reverse devices are 8Ω-cm and 31μm respectively. Table 1 and Table 2 show the parameters used for forward and reverse diode simulation. Figure 3 shows simulation results of impact ionisation (left) and the potential contour (right) of forward diode at breakdown voltage. Impact ionisation occurs at the main junction and the device breaks down at 300V, which is 80 to 85% of plane parallel breakdown voltage. Figure 4 shows the simulation results of impact ionisation distribution (left) and potential contours (right) of a reverse diode at breakdown voltage. Impact ionisation occurs at the bulk between PN- and device breakdown at 375V, which is plane parallel breakdown voltage.

Experimental results

For a reverse diode the starting N- thickness is high (51μm) compared to the forward diode (31µm). This is due to the fact that when the boron substrate concentration is high or the resistivity low, during deep isolation diffusion, the substrate will also diffuse into the N- epi. This process can cause a reduction in the N- thickness and consequently, the breakdown voltage is reduced. The substrate resistivity should be chosen to be a high value and isolation diffusion surface concentration or dose should be as high as possible, to reduce substrate diffusion into the N- epi during the isolation diffusion process. The boron substrate resistivity is typically 0.01Ω-cm and the boron isolation surface concentration is typically higher than 1E19cm^{-3}. During the deep boron diffusion process the substrate diffuses less into the N- epi and therefore a reduction in the breakdown voltage would be minimal.

For example, the commercially available 30A forward diode has a chip size of 3.3mm x 3.3mm and an active area of 3mm x 3mm, whereas the reverse diode has a chip size of 3.77mm x 3.25mm and an active area 3.27mm x 2.75mm. The chip size of a reverse diode is comparable to the forward diode because the isolation diffusion area is greater. To obtain fast switching diodes or HiPer FREDs, a heavy metal such as platinum is diffused and yields devices with maximum leakage currents of 1µA at 25°C and 250µA at 125°C.

Reliability

Reliability is defined as the ability of a device to conform to its electrical and visual/mechanical specifications over a specified period of time under specified conditions at a specified confidence level.

Prior to the official release of a new device for mass manufacturing, it must undergo full qualification test. New device qualification most often requires several sets of samples for different reliability tests. The actual reliability of a device cannot be accurately determined with standard visual and electrical measurement techniques. The most important reliability tests for the electrical stability of the chip are high temperature reverse bias (HTRB) and humidity test.

HTRB test checks the ability of the samples to withstand a reverse bias while being subjected to the maximum ambient temperature that the parts are rated to withstand.

Humidity test checks the ability of the package and chip to resist moisture penetration. The sample is loaded into an environmental chamber. The relative humidity is then increased from 85 to 100% and the temperature is also elevated.

HTRB and humidity test samples are randomly selected from 25 processed wafers. The condition used for HTRB test is 80% of rated voltage at 125 or 150°C. The breakdown voltage and leakage current were measured before starting the test. 200, 300 and 400V devices were assembled into the V1-plastic package. The test was conducted for up to 1000hr and readings were taken once every 4hr. 300V Reverse diode HTRB test was carried out for up to 168hr due to a customer request. For all three-voltage classes, leakage currents are below 25µA. Furthermore, there is no increase in leakage current between pre and post measurement results.

The device characteristics are measured before starting the test. The humidity test was conducted at 85°C and at 85% relative humidity for 168hr. The device characteristics are re measured after cooling down for 2 to 3hr. Pre and post measurement results show that there is no increase in leakage current for all 4 types. The maximum leakage current at room temperature is 1µA and at 150°C for 200V 150µA, for 300V 250µA and for 400V 350µA.

By careful analysis of 30A chips of 200, 300 and 400V, we have designed and fabricated different chip sizes for different current ratings (10A/200V to 60A/300V/ 400V). All these HiPer FREDs are commercially available. Furthermore, forward HiPer FREDs are availabe with or without polymide passivation, and the reverse diodes are only available with glass passivation.

N- epi thickness	31µm
Boron junction depth	7µm
N+ substrate	1E19 cm^{-3}
N- epi	8Ω-cm
Boron surface concentration	5E18 cm^{-3}

Table 1: Parameters used for forward diode

N- epi thickness	31µm
Phosphorus junction depth	7µm
P substrate	2E18 cm^{-3}
N- epi	8Ω-cm
Isolation boron surface concentration	1E19 cm^{-3}

Table 2: Parameters used for reverse diode

Conclusion

Simulation analysis and practical results show that using a single field plate, it is possible to obtain breakdown voltages of 200 to 400V for forward diode, and it has been demonstrated for the first time that by using reverse diode, it is possible to get ideal plane parallel breakdown voltage. Single field plate for forward diodes and isolation diffusion techniques for reverse diodes are less process sensitive and requires less chip area. Experimental results show that the device guarantees low leakage current at 25 to 150°C conditions, plus long-term stability of the blocking characteristics, even in plastic packages. Reverse HiPer FREDs with platinum as lifetime killers are a realistic new concept for power semiconductor devices.

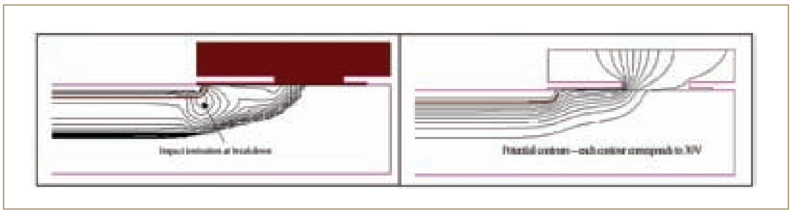


Figure 3: Forward diode impact ionisation (left) and reverse diode potential contour at a breakdown voltage of 300V

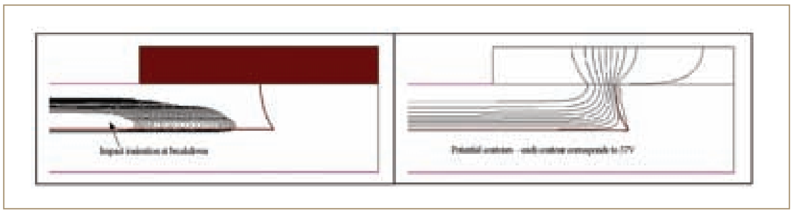


Figure 4: Forward diode impact ionisation (left) and reverse diode potential contour at a breakdown voltage of 375V

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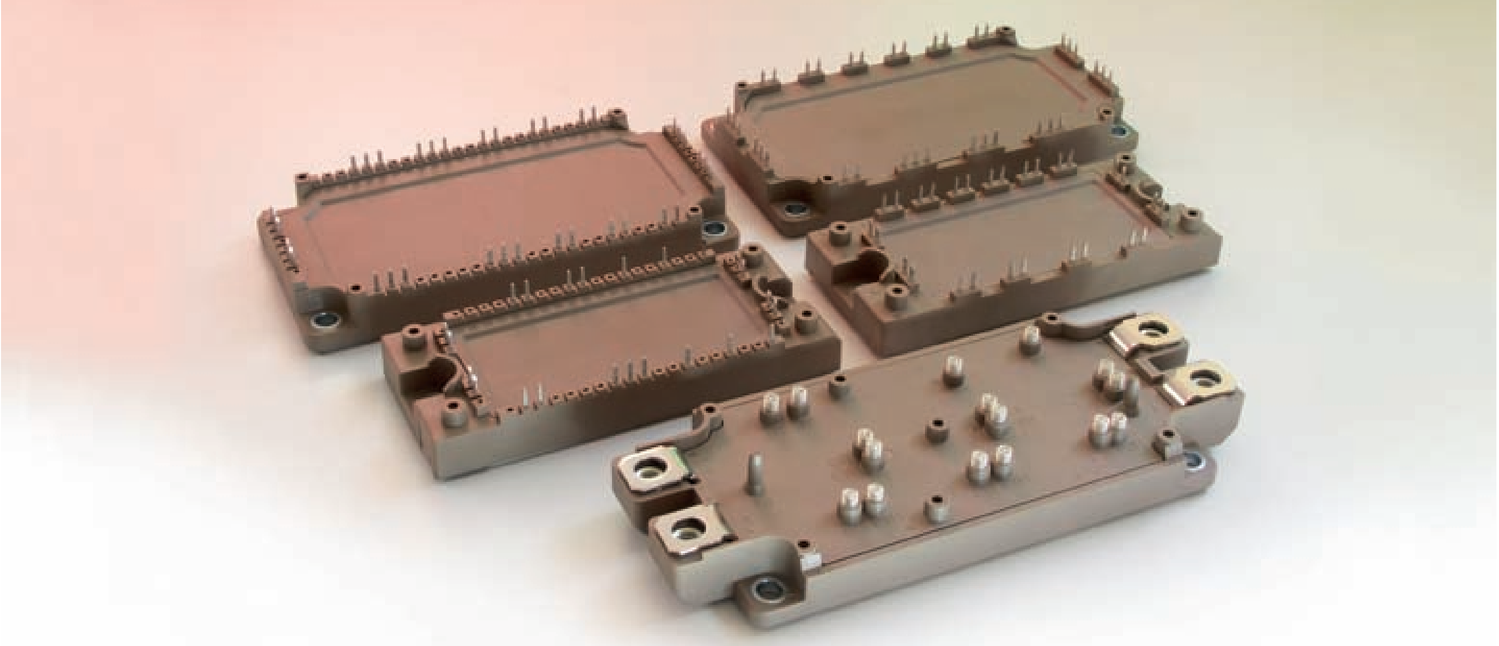

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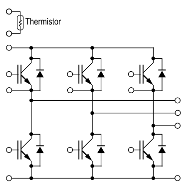
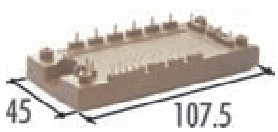
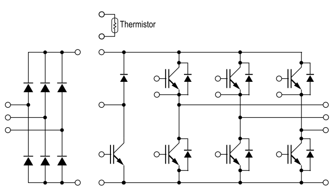




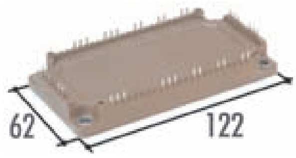
50A
75A
100A

100A
150A
180A

PIM IGBT
1200V

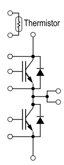


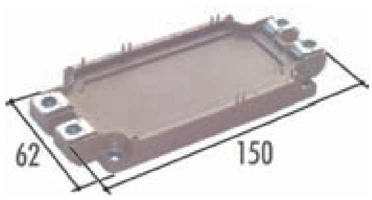
25A
35A
50A



75A
100A
150A

2-Pack IGBT
1200V





225A
300A
450A
600A

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Driving High Power LED Camera Flash

Whilst camera phones continue to improve with greater resolution, better lenses, improved image-processing software, anti hand-shake features and so on, the ability to save power and energy when carrying out flash photography is lagging way behind. Many cell phones have compromised by providing a low-current LED photo light or flash, but this provides insufficient light energy for an acceptable photo in low light conditions. To become a usable flash technology, the light source must be capable of adequate illumination within a target range of around 50lux at 1m distance. This can be achieved by state-of-the art high power, high brightness white LED technology, driven by up to 1500mA per chip. This article discusses LED camera flash challenges including high-power LED driver architecture, battery current and voltage drop considerations. **Christophe Vaucourt, Portable Power Systems Engineer, Texas Instruments, Freising, Germany**

In order to help fulfill the increasing market demand for camera phones, and the consequent need for more miniaturisation and versatility, smaller form factor and shorter time to market, a new family of easy to design in high-power LED flashlight drivers has been introduced (TPS61050/2/4). These devices feature a solution size of less than 25mm² and are capable of supplying up to 5W power to the LED (see Figure 1).

In portable applications with a single-cell lithium-ion (Li-ion) battery, the sum of the voltage drop across the white LED and the headroom voltage across the current regulator can be lower or higher than the battery voltage. This means that the LED driver topology should handle buck and boost operating modes. The easiest way to implement down conversion is by the means of a linear low-side current regulator. The advantages of this method are low-cost and high efficiency as the LED forward voltage is typically slightly lower than the nominal battery voltage.

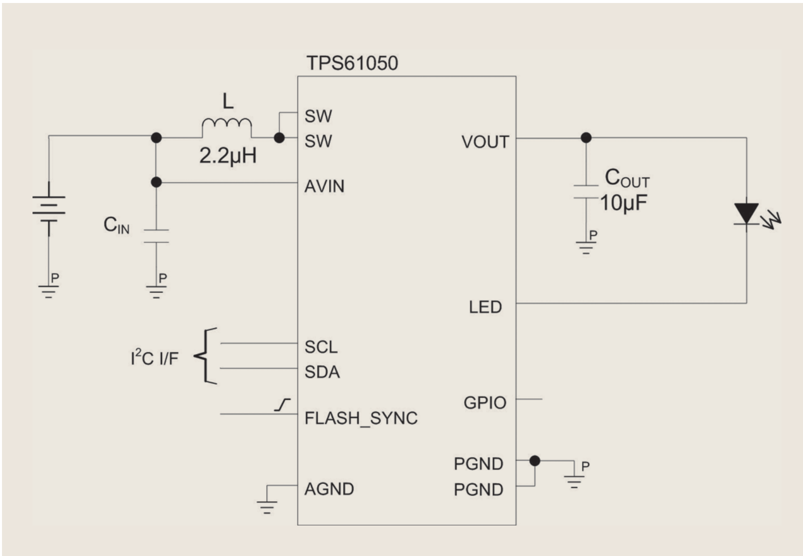

Figure 1: TPS61050 application overview

LED camera flash driver topology

Regardless of the vendor, type, size and power, all LEDs work best when driven at a constant current. Light output, measured in lumens, is proportional to current, and hence LED manufacturers specify the device characteristics (such as Illuminance, colour, temperature) at a specified forward current (I_F). High-power LEDs tend to exhibit a steep I-V curve, therefore driving an LED with a constant voltage can lead to significant and hard to predict forward current variations.

The TPS6105x family employs a 2MHz constant-frequency, current-mode PWM converter to generate the output voltage required to drive high-power LEDs. The device integrates a power stage based on an NMOS switch and a synchronous NMOS rectifier. The device also implements a linear low-side current regulator to control the LED current when the battery voltage is higher than the diode forward voltage.

Low-side sensing has been adopted for simplicity reasons and silicon area utilisation. The current sensing circuit is based on an active current mirror designed to operate in the saturation region. Depending on the voltage drop across the current sink, the device will automatically transition between linear down-mode and inductive boost mode featuring minimum sense voltage of typically 250mV.

The advantage of this architecture is very high efficiency over all LED currents and battery voltage conditions, because the input voltage can be boosted to the sum of the LED forward voltage and current-sink headroom voltage.

The challenge of current sensing is to make it accurate and efficient, two goals which are in direct conflict. The lower the headroom voltage across the current sensing/regulation circuit, the more power saved, but this comes at the expense of noise sensitivity.

As the LED flashlight functionality may not be used that often in camera phone applications, the idea was conceived to use the inductive power stage for an additional

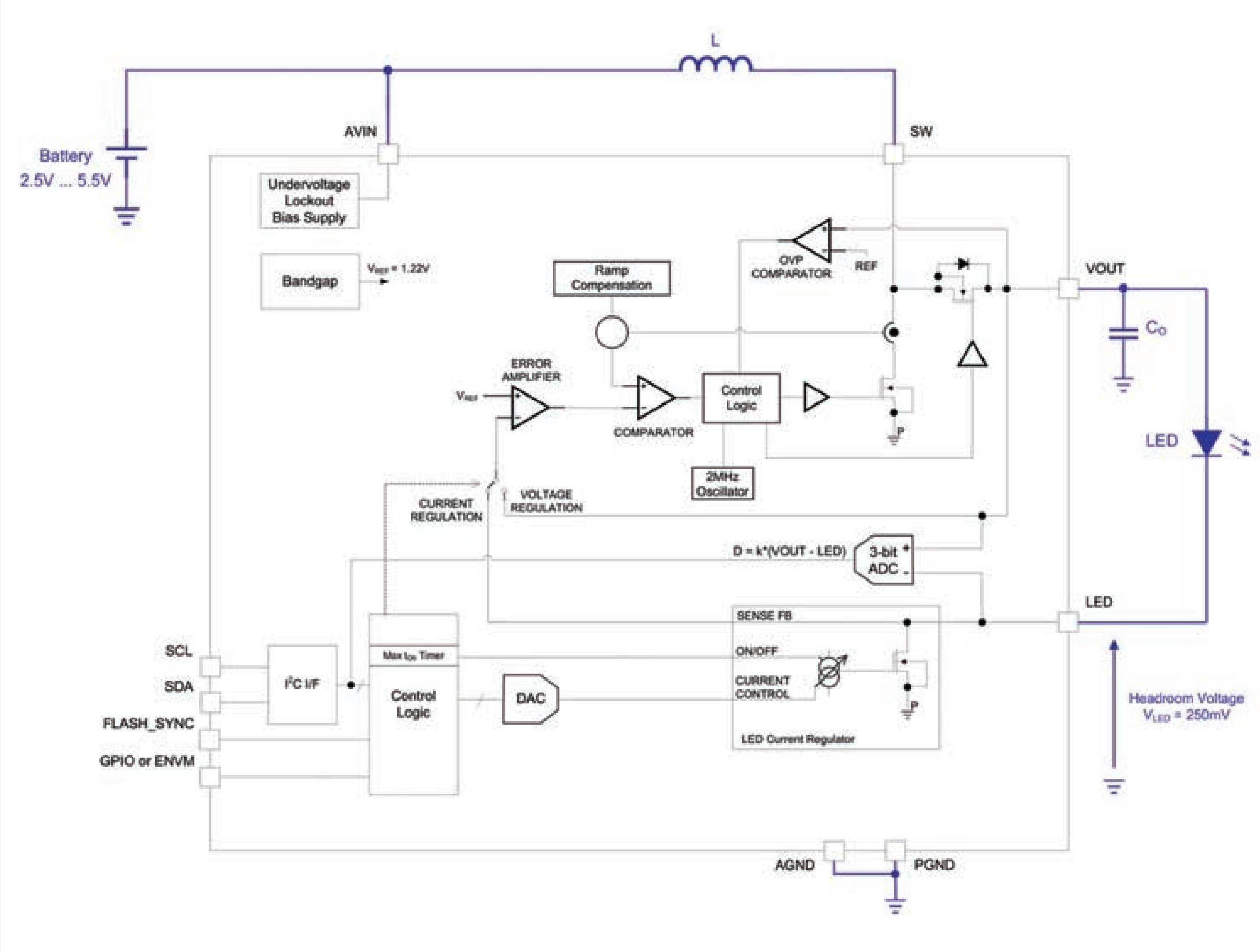

Figure 2: **TPS61050 functional block diagram**

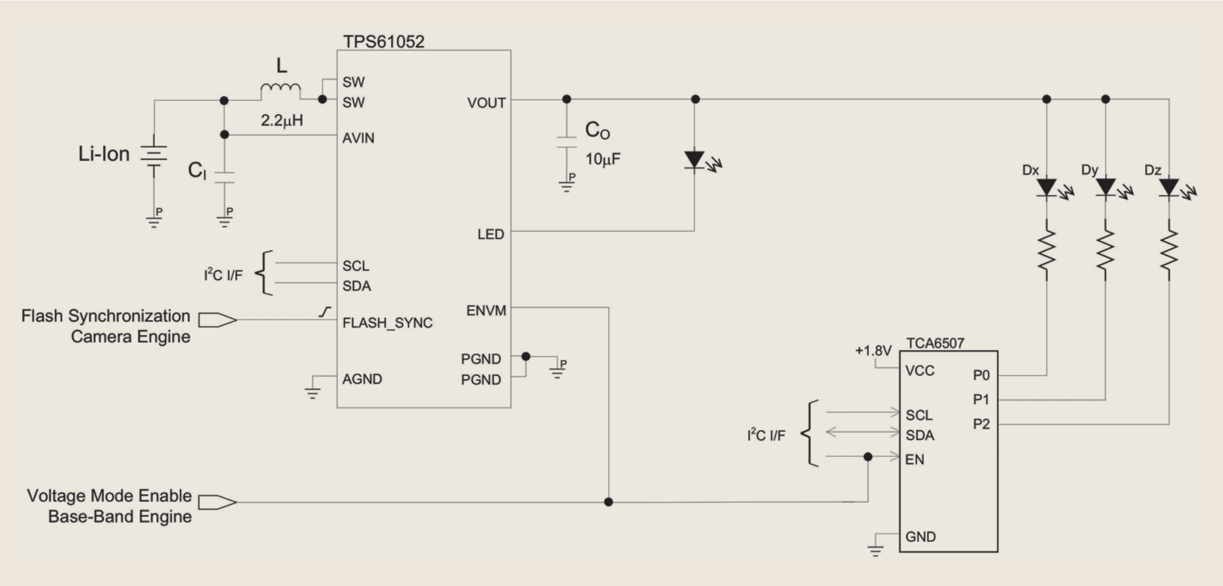

Figure 3: **White LED flashlight driver and auxiliary lighting zone power supply**

role. The TPS6105x device not only operates as a regulated current source, but also as a standard voltage-boost regulator. The voltage-mode operation can be activated either by a software command or by means of a hardware signal (ENVM).

This additional operating mode can be useful to synchronise the converter properly when supplying other high-power devices in the system, such as LED drivers, hands-free audio power amplifiers, or any other components requiring a supply voltage higher than the battery voltage.

To support either LED current regulation or output voltage regulation, the TPS6105x device implements a new multi-purpose regulation scheme (see Figures 2 and 3) providing seamless on-the-fly transition between the two control loops.

LED power, battery current and voltage drop

The output power relation to be used in the efficiency calculation is $P_{LED} = V_F \times I_F$. The LED drive efficiency, i.e. the ratio of electrical LED power over battery power, is equal to:

$$\eta = \frac{V_F \times I_F}{V_{IN} \times I_{IN}}$$

conversely

$$I_{BAT} = \frac{1}{\eta} \times \frac{V_F}{V_{IN}} \times I_F$$

Figure 4 shows efficiency versus input current curves. For a given LED current, the forward voltage can vary with process and temperature. This means that the conversion efficiency from electrical battery power to light output can vary, while still maintaining constant brightness, since the latter depends solely on the current.

Efficiency is, therefore, not an adequate figure of merit to evaluate power consumption. What must be considered is battery current versus LED brightness, i.e.

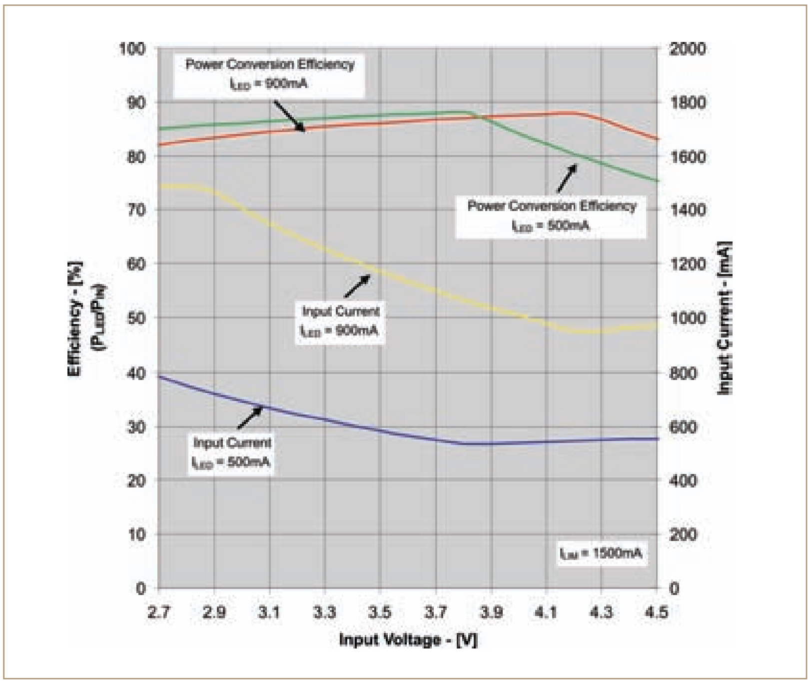

Figure 4: Efficiency versus input current curves

LED current. Input power is the true measure of how much energy is drained out of the battery for a given LED illuminance.

When a heavy load is applied to the battery, the open-circuit battery voltage is distorted by the voltage drop that is due to the internal impedance of the battery pack. The impedance of batteries is largely dominated by a number of parameters. Brand new Li-ion cells show an impedance in the approximate range of 50~70mΩ. The impedance is cell-dependent and can be expected to vary by 15% per production batch. The battery voltage keeps changing after application/ removal of the pulsed load (Relaxation

Figure 5: Battery equivalent circuit

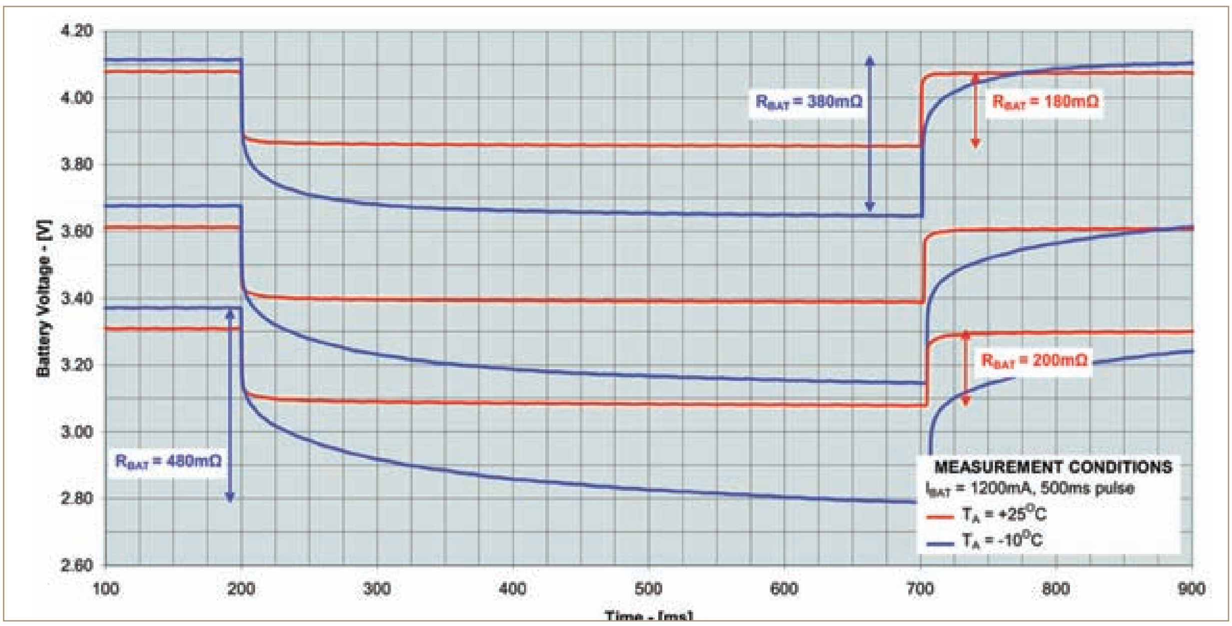

Figure 6: 900mAh, Li-Ion battery transient response versus SOC and temperature

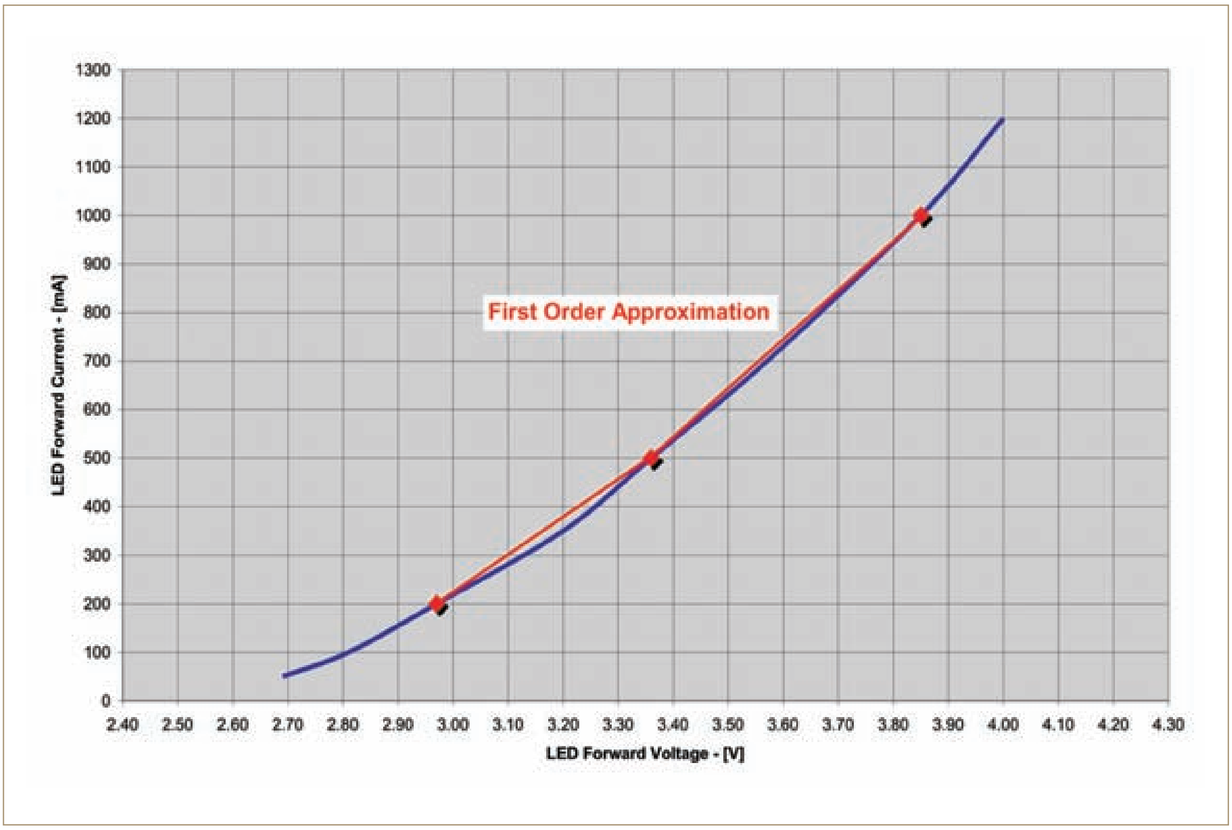

Figure 7: LED forward voltage approximation

Effect). The cell impedance exhibits a strong dependence to temperature and can increase by 50% every 10°C temperature drop. The internal resistance depends on state of charge (SoC) and increases at the end of discharge. Li-ion battery packs feature back-to-back protection MOSFETs that are in series with the cells. Their resistance is in the approximate range of 50~70mΩ. The battery pack is typically to hooked-up to the system via a couple of spring connectors, 25mΩ DC resistance each.

From an electrical point of view, batteries are often represented either as simply a voltage source, or as voltage source connected in series with a resistor representing internal resistance of the battery. To represent battery transient behaviour correctly, we should use an equivalent circuit rather than simple resistance.

When a battery is charged or discharged, its open circuit voltage changes, therefore it can be electrically represented as a capacitor with variable capacitance (C_O).

In Figure 5, R_A and R_C are summary diffusion, conduction and charge transfer resistances for cathode and anode correspondingly. C_A and C_C are surface capacitances. R_{SER} is serial resistance that includes electrolyte, current collectors and wires resistances. Each stage is associated with its own time constants, which causes complex electrical behaviour.

As seen in Figure 6, the battery voltage response to the current step is delayed, but after some time it approaches the behaviour of a capacitor with a serial resistor. After termination of current, the battery voltage does not immediately return to a no current state, but slowly increases until eventually it reaches the level of

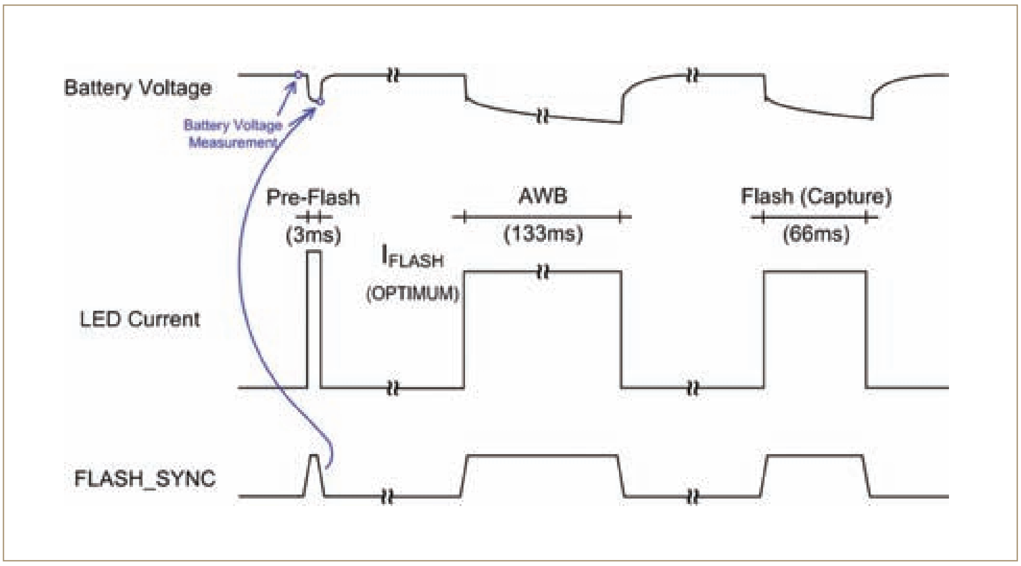

Figure 8: Image capture sequence with pulsed LED operation

equivalent capacitor voltage, which is the open circuit voltage.

Even when the battery holds insufficient capacity, the voltage drop across high internal impedance can cause the system to reach its cut-off voltage and the 'low battery' indicator to trigger. As a consequence, the mobile device is reset and/or stops working. This should be taken into account when calculating the camera engine cut-off voltage and the maximum LED flash current level.

In TDMA based systems like GSM/GPRS phones, the RF power amplifier (PA) also pulls high peak current from the battery. The TPS61050 device integrates a general purpose I/O pin (GPIO) that can be configured either as a standard logic input/output or as a flash masking input (Tx-MASK).

This blanking function turns the LED from flash to torch light, thereby reducing almost instantaneously the peak current loading from the battery. This system-level feature prohibits the phone from shutdown by avoiding two high-power loads (PA and flash LED) to be on at the same time.

LED flash current level optimisation

In cell phone applications, the camera engine is normally specified over an operating temperature range down to 0 or -10°C. In order to achieve a reliable system operation, the LED flash current would need to be rated according to the maximum tolerable battery voltage drop (i.e. highest battery impedance, lowest ambient temperature).

To optimise the LED flash current (i.e. light output) versus battery state-of-charge and temperature dynamically, we could consider the following self-adjustment procedure. This algorithm could be embedded into the auto-exposure, auto white-balance or red-eye reduction pre-flash algorithms.

A first order approximation of the LED forward voltage (V_F) can be achieved with the integrated 3bit A/D converter (see Figure 7). Simply perform three short flash strobes (a couple of tens of ms is enough) for three different flash currents (200mA, 500 and 1000mA). This data can help to estimate more precisely the actual LED electrical power versus flash current.

The battery voltage usually drops by a few hundred milli-volts during a high-power flash strobe. For short durations, this voltage drop should not be subject much to the battery intrinsic capacitance (i.e. relaxation effect) but more to its cell impedance (see Figure 8).

The camera and/or the base-band engines are usually capable of measuring the battery voltage before and at the end of a flash strobe. With this information, the system can compute the estimated battery impedance, defined as:

$$R_{BAT} \approx \frac{\Delta V_{BAT}}{I_{BAT}} ,$$

with

$$I_{BAT} = 1.15 \times I_F ,$$

linear down-mode operation ($V_F < V_{BAT}$)

$$I_{BAT} = \frac{1}{\eta} \times \frac{V_F}{V_{IN}} \times I_F \cong 1.25 \times \frac{V_F}{V_{IN}} \times I_F ,$$

boost-mode operation ($V_F > V_{BAT}$)

Based on the actual LED electrical characteristic, the mid-frequency battery impedance, state-of-charge and temperature information, the camera engine software can dynamically optimise the LED flash current to avoid the battery to collapse dangerously.

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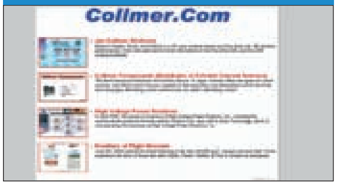

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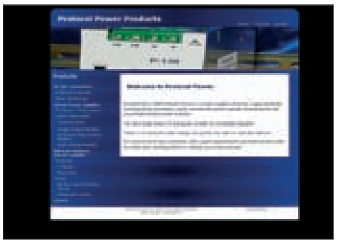

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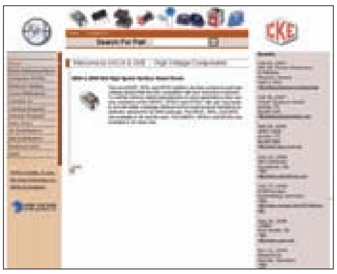

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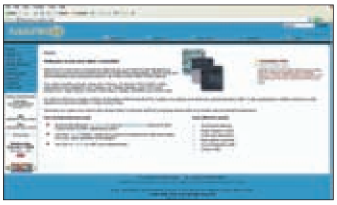

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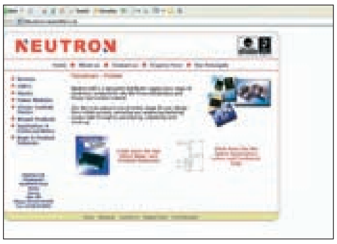

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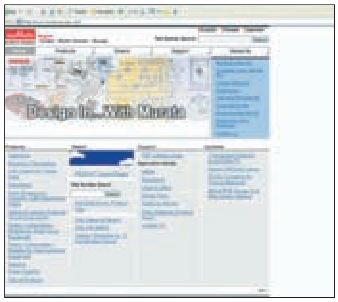

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