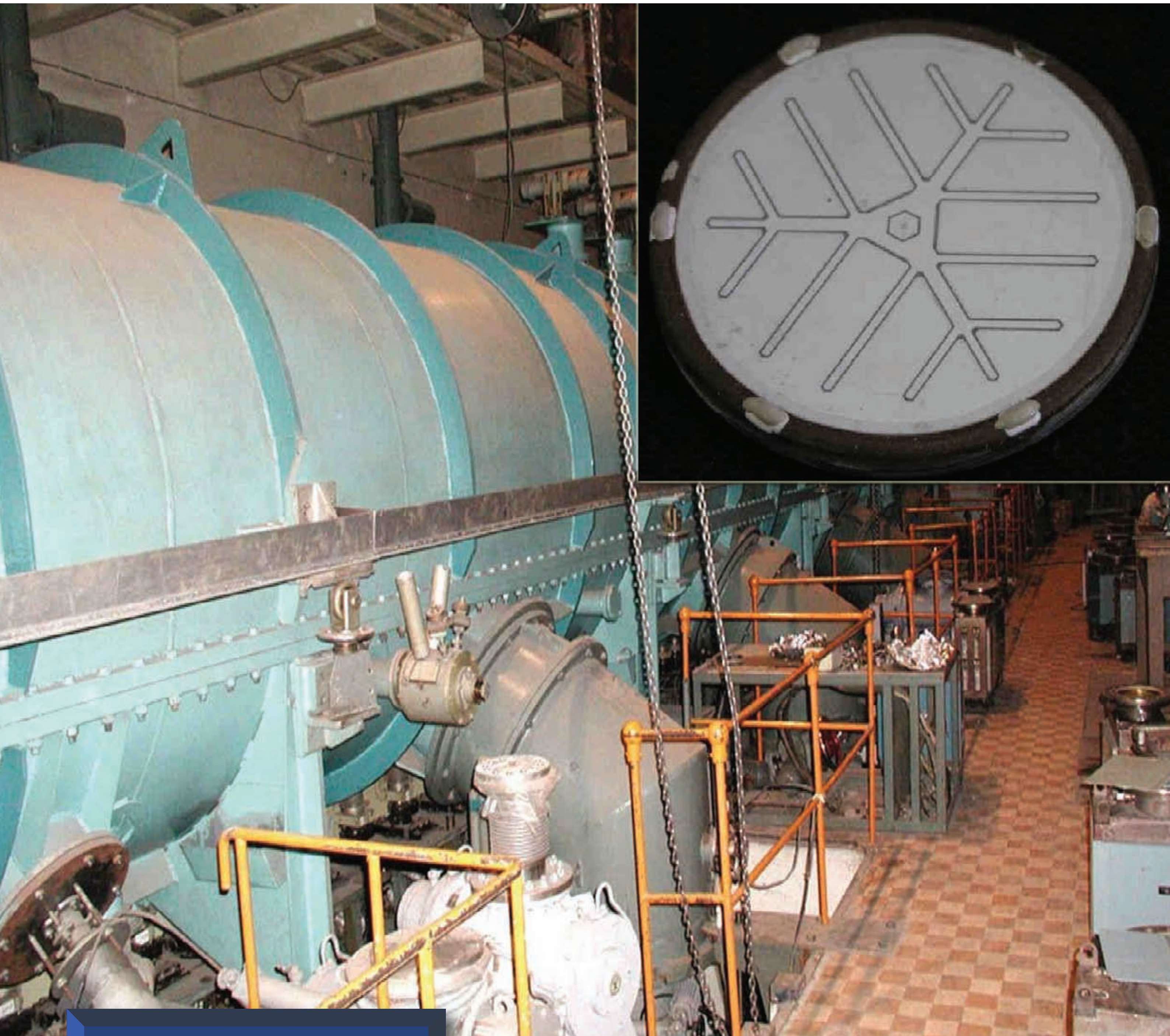
POWER ELECTRONICS EUROPE

ISSUE 7 – Oct/Nov 2011 www.power-mag.com

POWER SEMICONDUCTORS

High Voltage Thyristors for Soft Starters



THE EUROPEAN JOURNAL FOR POWER ELECTRONICS AND TECHNOLOGY

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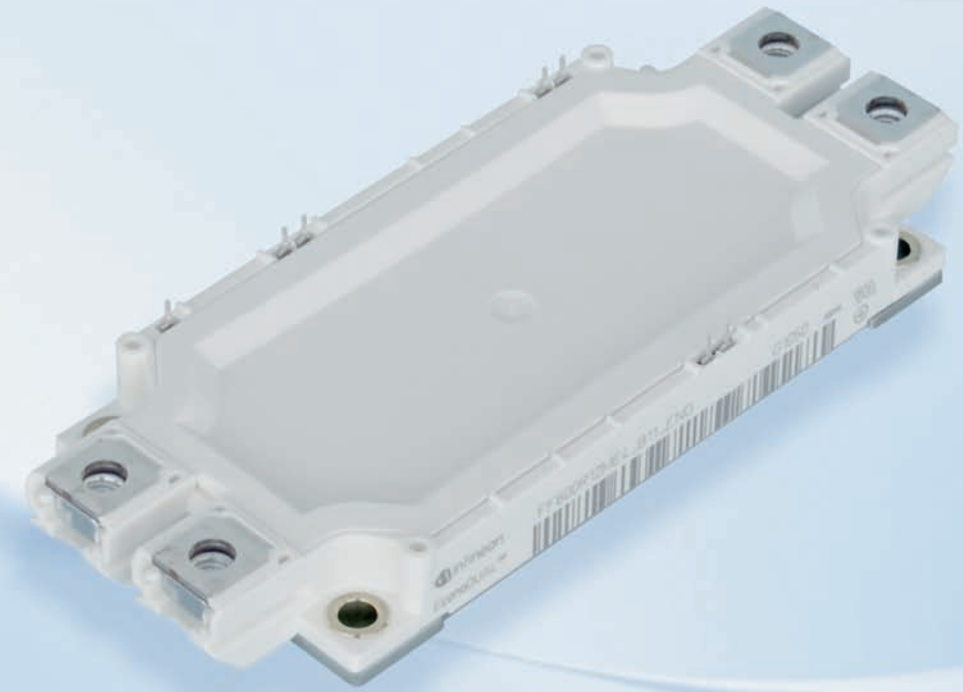

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Circulation and subscription: **Power Electronics Europe** is available for the following subscription charges. **Power Electronics Europe**: annual charge UK/NI £60, overseas $130, EUR 120; single copies UK/NI £10, overseas US$32, EUR 25. Contact: DFA Media, Cape House, 60a Priory Road, Tonbridge, Kent TN9 2BL Great Britain.
Tel: +44 (0)1732 370340. Fax: +44 (0)1732 360034. Refunds on cancelled subscriptions will only be provided at the Publisher's discretion, unless specifically guaranteed within the terms of subscription offer.
Editorial information should be sent to The Editor, **Power Electronics Europe**, PO Box 340131, 80098 Munich, Germany.

Printed by: Garnett Dickinson.
ISSN 1748-3530

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Market News

PEE looks at the latest Market News and company developments

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SMD Power Inductors for Converters

Low Loss SEPIC-Fed Buck Converter Topology

COVER STORY

High Voltage Thyristors for Soft Starters

In spite of significant development of converters on the basis of fully controlled semiconductor stacks (IGBT, GTO, IGCT), today it's still technically legitimate and demandable to use "traditional" high power thyristors in stacks of controlled rectifiers as well as in soft starters for electric motors. Usage of thyristors is especially relevant in case of operating in AC network of 6/10 kV and higher, because the devices produced on the basis of such thyristors have no competition in price and energy efficiency (efficiency coefficient). That's why development and production of high voltage thyristors is of high interest. Fast thyristors produced with help of proton irradiation technology have remarkably small turn-off time, small recovery charge and peak reverse recovery current. Implanting hydrogen atoms during proton irradiation helps to build local hidden n'-layers with low specific resistance inside the n-layer of the semiconductor element. Using such hidden layers can produce power diode-thyristors (dynistors) and semiconductor voltage suppressors with increased power capacity. In collaboration with the Institute of Theoretical and Experimental Physics and All-Russian Electrotechnical Institute, "Proton-Electrotex" has developed a low-cost industrial technology for proton irradiation of semiconductor devices.
Full story on page 22.

Cover supplied by Proton-Electrotex, Russia

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IGBT Press-Packs for the Industrial Market

The standard Press-pack IGBT (PPI) basically uses the same packaging concept as Bipolar high power semiconductor devices. The main difference is that the high power semiconductor content in the package is square IGBT chips arranged on a round molybdenum disc instead of large, round bipolar devices matched in size to the molybdenum disc and ceramic housing. The Press-pack IGBT comes under the name StakPakTM in a pseudo-square frame package that allows for much better utilization of the squared IGBT chips and for a modular platform in power scaling of the device. **Bülent Aydin, Franc Dugal, Evgeny Tsyplakov, Raffael Schnell, Liutauras Storasta and Thomas Clausen, ABB Switzerland Ltd, Semiconductors, Lenzburg, Switzerland**

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Multi-Topology Battery Charging from Milliwatts to Kilowatts

The practice of battery charging spans a wide variety of battery chemistries, voltages and current levels in many market segments. For example, industrial, medical and automotive battery chargers continue to demand higher voltages and currents as new applications are emerging for both existing and new battery chemistries, such as the proliferation of sealed lead acid (SLA) batteries in solar applications. Existing single integrated circuit (IC) based solutions cover just a fraction of the many combinations of input voltage, charge voltage and charge current. A cumbersome combination of ICs and discrete components was routinely used to cover most of these combinations and topologies. A new charger IC overcomes this problem. **Steve Knoth, Senior Product Marketing Engineer Power Products, Linear Technology Corp., USA**

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Inverting Buck Regulator Saves Space and Power

Designers are periodically faced with the requirement to generate a negative voltage rail in order to provide a bias voltage for applications using sensors which read signals both above and below ground. For many engineers, the first thought will be to use inverting regulated charge pumps: in fact, these are ideal for handheld applications where the output voltage required is less than -5V and the input is typically a lithium-ion battery. In applications that require negative voltages greater than -5V, SEPIC inverters and transformer-based designs can also produce a positive-to-negative voltage conversion, but only at the cost of complexity and a high component count. Now the AS7620 IC helps designers to solve these problems. **Mark Shepherd, Field Applications Engineer, Austriamicrosystems, Unterpremstätten, Austria**

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Unique Probe Measures Current in PCB Tracks

Observation and measurement of current in printed circuit board (PCB) tracks has always presented major difficulties. The only practicable way of doing it has been to cut the track and insert either a current shunt, or a loop of wire large enough to attach a conventional closed-loop current probe. In modern high density circuit designs this is normally impracticable. A new type of probe measures the current by placing the insulated tip of the probe directly onto the PCB track without any need to cut it or to surround it by a magnetic loop. **Mark Edwards, Aim-TTi, Huntingdon, Cambridgeshire, UK**

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Product Update

A digest of the latest innovations and new product launches

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Website Product Locator

Time Has Come for Electric Mobility

After more than 100 years of development history of the combustion engine, electric mobility is now ushering in a new worldwide traffic era. The electrification of drives is an important prerequisite for future mobility. It helps us become more independent of oil, to reduce emissions and to integrate vehicles even better in a multimode traffic system.

The federal German government has therefore set a goal to put one million electric vehicles on German roads by 2020. But also the goal of France to have 100,000 vehicles on its roads by 2015 is rather ambitious. Countries such as the US, Japan and China have also recognized the enormous potential of electric mobility and are encouraging their industries with major programs in support of electrically powered traffic.

In its “Inaugural Quadrennial Technology Review Report” the US Department of Energy summarised six key strategies, three of which directly pertains to green transportation. The main weight will be put upon increasing vehicle efficiency. It is by far the cheapest and most widely available improvement that can be implemented by almost any car manufacturer. The super-fuel-efficient petrol and diesel cars that are suddenly starting to crop up here and there is no major breakthrough - it’s just tweaking and tuning the internal combustion engine. The other two points outlined in the DoE strategy is electrification of the fleets and deployment of alternative fuels. It is expected that companies developing electric cars and other alternative fuel vehicles will see a large chunk of DoE’s $3 billion yearly research and development funding coming their way. This move has also suddenly made the electric car sector more appealing for both private and corporate investors.

An intermediate step are hybrid electric vehicles. Here Hyundai Motor Company and Kia Motors Corporation have selected Infineon as supplier of power modules for their current hybrid car generations, the Hyundai Sonata Hybrid and Kia Optima. Hyundai and Kia teamed up with Infineon on the hybrid powertrain design including the HybridPACK1 power module and the related control electronics as part of the electric motor inverter. Hyundai and Kia are ramping up production of their hybrid fleet and plan to increase their presence mainly in the North American and Korean Markets. Infineon has already started to deliver its HybridPACK1 power module which was specifically designed for use in HEV applications for a power range of up to 30 kW. Typically, there are two power modules in use in full hybrid cars. Compared to a combustion engine vehicle a hybrid car with its regenerative braking and boost functionality saves about 15 to 35 % of fuel. The power module has a crucial role in controlling and powering the hybrid electrical motor being the energy bridge between the battery system and the HEV drive. The HybridPACK1 is responsible to translate the direct current from the battery into alternating current, which drives the electric motor, and back to to charge the battery system using braking energy.

The basic technologies regarding electric drives, energy storage and network infrastructure are well-developed. However, there is still a need for further research, optimization and integration within the value added chain, as the fair eCarTec in Munich underlined. Electrical motors and Power Electronics as well as Batteries are the crucial parts within these efforts. Challenges of the future are the reduction or substitution of rare earth materials in motors, optimised cooling methods, and better efficiency. Thus the Friedrich-Alexander-University in Nuremberg/Germany is establishing an E-Drive Center at focusing on the pilot manufacturing of advanced power electronics and electrical motors, funded with Euro 9 million in the time frame 2010 - 2014. The university has organized the first conference on the production of electrical drives, E|DPC-2011. With more than 350 delegates the conference and its associated exhibition was a success, particularly due to its focus on industrial drives including power electronics and electromobility.

The future belongs to electrical drives, that is the opinion of Siemens. The transportation and industrial production are each responsible for producing one third of all the damaging greenhouse gases which jeopardize the global climate. In both of these areas, ground breaking new technologies and sustainable R&D are needed, particularly in the field of drives. In the industrial sector, maximum potential for savings can be leveraged using integral software and IT solutions to ensure the consistent integration of drive components into customer applications. In transportation key is the mechanical integration of the drive solution not only into the vehicle, but primarily also into the topology of the overall solution. Key components are intelligent on-board chargers and power electronics, such as compact inverters. Hand in hand with a suitable charging infrastructure for electric vehicles and integration into the Smart Grid, this process will culminate in system solutions, automated communication and reliable processes. In twenty years mobility will be all-electric, expects Ralf-Michael Franke, CEO Drive Technologies of the Siemens Industry division.

I hope he is right. This will help to increase the use of power electronics and to reduce the emission of greenhouse gases.

Achim Scharf
PEE Editor

Showcase of UK Power Electronics

The "iPower" Technical Conference will bring together specialists in the field of power engineering from Science, Academia, Supply and Industry at The University of Warwick on 30 November and 1st December 2011.

The event, being held in conjunction with the University's Electronics, Power & Microsystems Research Group headed by Professor Phil Mawby, will provide a unique insight into the fields latest developments and technologies, including applications, trends and devices, thermal management and efficiency, device fabrication, packaging, test and reliability, assembly materials and technologies, high reliability and temperature.

In addition to its technical programme comprising sixteen papers across two days, delegates will also get the opportunity to take tours of the SiC & VEF Laboratories on Campus, view EV demonstrators, review posters from academic and industrial researchers, attend a gala dinner and examine exhibits at the supporting tabletop exhibition. The event will conclude with the "Power Factor" panel session, which will debate key elements raised in the forthcoming Department for Business, Innovation and Skills (BIS), "UK Power Electronics Strategy" document.

The conference sessions will cover UK Power Electronics Strategy by NMI; HVDC Technology Roadmap by Alsthom Grid; Future Power Strategy by Converteam; Power Electronics by Emerson; Power Control Devices by International Rectifier; Power Devices by NXP; SiC Developments by Anvil Semi; SiC and New Materials by Univerity of Warwick/WMG; Making Power Devices Perform by Isotron; Solder TIMS for Thermal Management by Indium; Investigating Assembly Process Control by Altus; Power Modules Thermal Management by TT-Semelab; Material Challenges in Packaging by leMRC; Wirebonder Interconnect Aspects by Delvotec; New Technology in High Volume Power Package by ASE; and finally the Power Factor Session.

IMAPS (International Microelectronics And Packaging Society, **www.imaps.org.uk**) is the largest organisation dedicated to the advancement and growth of microelectronics and electronics packaging. The United Kingdom Chapter (IMAPS-UK) provides a forum for its members via seminars, conferences, newsletters, website's etc., to ensure they are kept up to date with the latest news, developments & innovations.

To register online follow **https://nmi/eventwax.com/ipower/register**


EV
QUICK CHARGER

Successful Electric Drives Production Conference

From September 27 - 30 the first conference on the production of electrical drives, E|DPC-2011, was held at the Friedrich-Alexander-University in Nuremberg/Germany. With more than 350 delegates the conference and its associated exhibition (15 stands) was a success, particularly due to its focus on industrial drives including power electronics and electromobility.

Technology center Nuremberg
"The European Metropolitan Area Nuremberg is on the one hand the industrial capital of Bavaria with leading manufacturers of electrical drives, automotive suppliers, and automation experts. Corresponding trade fairs such as the SPS/Drives, PCIM Europe, or SMT/Hybrid underline the importance of this region in the electrical drives industry. Carbon dioxide reduction, growing mobility or progressing automation are not possible without powerful electrical drives. The electrification of the automobile powertrain is considered crucial, thus the focus of the conference is set on the presentation of highly innovative products from various industries as well as manufacturing processes and strategies", underlined Chairman Prof. Jörg Franke. "Challenges of the future are the reduction or substitution of rare earth materials in drives, optimised cooling methods, and better efficiency. Thus we are establishing an E-Drive Center at our university focusing on the pilote manufacturing of advanced power electronics and electrical motors, funded with Euro 9 million in the time frame 2010 - 2014", he added.

The future belongs to electrical drives, that is the opinion of Siemens. "The transportation and industrial production are each responsible for producing one third of all the damaging greenhouse gases which jeopardize the global climate. In both of these areas, ground breaking new technologies and sustainable R&D are needed, particularly in the field of drives. In the industrial sector, maximum potential for savings can be leveraged using integral software and IT solutions to ensure the consistent integration of drive components into customer applications. In transportation key is the mechanical integration of the drive solution not only into the vehicle, but primarily also into the topology of the overall solution. Key components are intelligent on-board chargers and power electronics, such as compact inverters. Hand in hand with a suitable charging infrastructure for electric vehicles and integration into the Smart Grid, this process will culminate in system solutions, automated communication and reliable processes", said Ralf-Michael Franke, CEO Drive Technologies of the Siemens Industry division. "In twenty years mobility will be all-electric", he expects.

Nuremberg-based Semikron presented a new generation of sintered power modules for automotive applications. "Sinter technology substitute all solder connections and also the aluminium bond wires. These are the weak points in a standard power module", explained speaker Jürgen Steger. The thermal and reliability results were shown on the example of a 400 A/600 V Dual IGBT module. Berlin-based Andus Electronic presented a technique to combine high currents and microelectronic control in a single system for powertrain and power supply applications. "The combination is achieved by incorporation of busbars and other massive copper bars into a PCB to obtain high current load capability up to 1000 A as well as heatsink for components with considerable power dissipation", said speaker Christoph Lehnberger. Conti Temic Microelectronic (Nuremberg) described their vision of the Factory of the Future for Power Electronics in Hybrid & Electric Vehicles. "The market potential for electric vehicles will reach a worldwide share of three percent in the year 2020. In combination with HEVs this means a volume of more than four million vehicles in 2016 and around nine million in 2020. Our actual series production power electronics system is a combined HEV DC/DC 3 kW converter and 110 kW inverter consisting of more than 300 components from more than 70 suppliers. It is now time that also material and equipment suppliers besides the manufacturer of power electronic systems are taking their responsibility in finding solutions and setting standards for this special requirements in order to support the idea of a reliable and flexible launch under best cost conditions and finally to enable an optimized factory of the future for automotive power electronic systems", speaker Axel Weber concluded.

Next E|DPC conference will be held October 16 - 17 again in Nuremberg, but on the Fairgrounds. Mesago will organise the exhibition. **AS**

www.edpc.eu

LEFT: "We are establishing an E-Drive Center at our university focusing on the pilote manufacturing of advanced power electronics and electrical motors", E|DPC Chairman Jörg Franke points out

RIGHT: "The future belongs to electrical drives", said Siemens CEO Ralf-Michael Franke

Record Attendance Expected at SPS/IPC/DRIVES 2011

This year's SPS/IPC/DRIVES, the trade fair for electric automation in Nuremberg from November 22 - 24, will be bigger and more international than ever before. For the first time it will cover 12 exhibition halls and more than 100,000 sqm of exhibition space. Almost 1,400 exhibitors are expected to attend, some of them from the power electronics community looking for their customers in electrical automation.

Companies from almost 40 countries will be exhibiting at SPS/IPC/DRIVES 2011, representing an increase of 20 %. With 76 companies registered, Italy is the foreign country providing the most exhibitors, followed by Switzerland (36), China (35) and Austria (27). Following 2010's record total visitor number, more than 50,000 visitors are likely to attend again this year. About 20 % of the visitors are expected to come from abroad and the proportion of international trade visitors continues to increase. With 10,000 m_ of exhibition space, hall 3 which is in use for the first time will accommodate the companies in the "Drive and control technology" sector, hall 8 where "Control technology" is to be found. These halls are of particular interest for power and control electronic applications.

The conference covers the topics plant automation, industrial communication, and electrical drives. Within automation the latter are the main application for power and control electronics and thus of interest for application engineers from this fields as well.

Electrical drives provide for dynamic and precise motion in industrial manufacturing plants and comply with strict requirements on energy and economical efficiency. New components with FPGAs provide a platform for parallel signal processing in control structures and sensor evaluation with short running times and extreme dynamics and resolution. Functional safety and easy integration in mechatronic system concepts are key requirements on modern drive systems. The conference program thus will cover Energy-efficient drives and process management; Motor control and converter technology; Mechatronics and motion control; Project planning and virtual commissioning; Mechatronic modelling and control; Linear and direct drives, special motors; Motor-converter integration and small drives; and Functional safety of networked drives.

www.mesago.com/sps

PV Demand Forecast for 2011 to Over 22 GW

IMS Research has increased its forecast for the full year by more than 1 GW and predicts more than 22 GW of new PV capacity will be added in 2011.The market researcher cited growing demand in all major markets, most notably in Asia and the Americas, as well as a pick-up in the sluggish German market and projects that installations in the second half of the year will be nearly double that seen in the first six months.

Demand will grow rapidly in the second half of 2011 due to rapidly falling module prices, incoming incentives in new markets and planned end of year cuts in existing markets. "Although installations grew just 13 % in Q2 from Q1 the results of our latest report show that there will be a huge surge in installations in the second half of the year. Several mid-sized markets like the USA are growing massively whilst markets like Germany and Italy are starting to pick up too", analyst Ash Sharma commented.

Several European markets, including Germany are predicted for a major slowdown or even a fall in 2011. However, Europe overall will be only 1 % down this year due to geographic diversification, with high demand coming from a number of new countries such as Slovakia and the UK. The report revealed that 11 countries in Europe will install at least 100 MW this year, with 20 countries globally installing this amount or more - up from just 13 the previous year. This increasing diversity in the market is helping to support demand and provide stability to a market that was once dependent for growth on just one or two countries.

One significant factor in IMS's increased forecast is the recently introduced national FIT in China which was revealed by the NDRC. This FIT pays a premium for installations completed this year, but continues past the end of the year and is in addition to the country's Golden Sun scheme, "We earlier predicted the introduction of a PV FIT in China once prices had fallen to an acceptable level and we're forecasting installations of 1.3 GW this year and more than 2 GW in 2012", commented Sharma. In the longer-term, China will become a key player for PV and not just for production, with it becoming one of the top three global markets in 2015. "At the same time, it is important to remember that Europe will still account for close to 70 % of global installations this year and in fact the next five largest markets are all European. Despite many still predicting doom and gloom, our latest research, which analysed more than 60 downstream markets and surveys hundreds of participants through the industry and supply chain, presents a very different picture. The decision by the Chinese Government to introduce a national FIT to boost flagging demand, as well as a diversifying global market and the introduction of new incentive schemes globally presents a much more optimistic, but still very challenging future for the industry", added Sharma.

www.pvmarketresearch.com

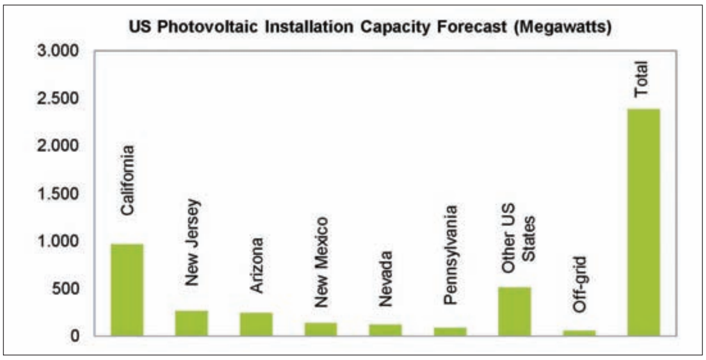
US Photovoltaic Installations Forecast to Soar 160 Percent in 2011

US photovoltaic (PV) installations in 2011 will rise more than 160 % to a total of 2.4 GW, with California leading the country in the amount of power derived from renewable solar energy, according to a new IHS iSuppli report.

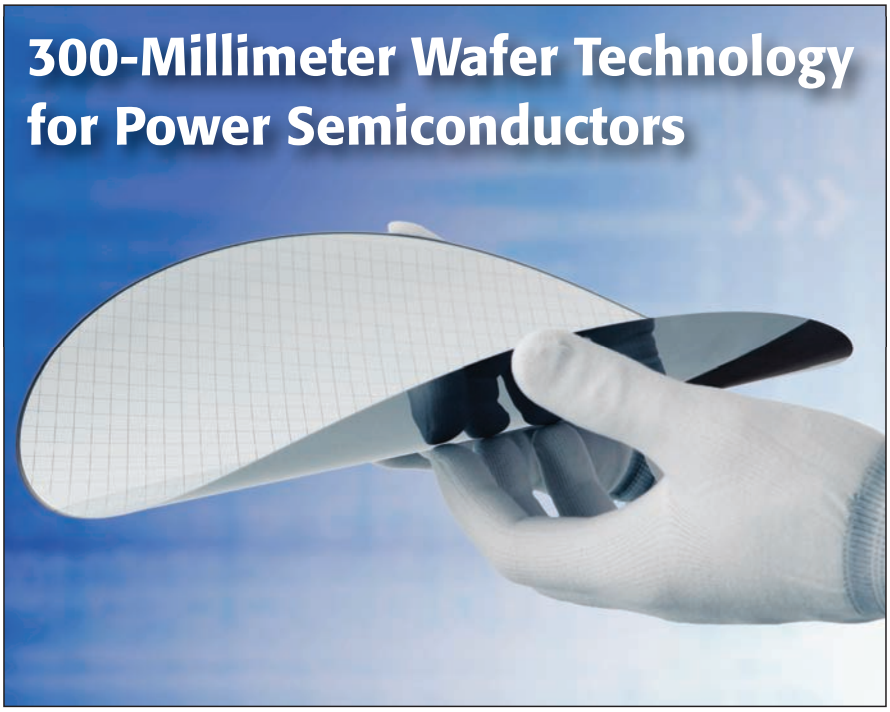
The number of US PV installations this year is projected to climb to approximately 49,000, up from 39,000 in 2010. Of the 2.4 GW in solar power expected to be installed this year, ground installations will contribute approximately 1.4 GW, commercial installations 710 MW and residential installations 270 MW. "Thanks to the implementation of many utility-scale projects this year, the US growth rate in 2011 will be more than double the 80 % expansion level of 2010, when PV installations amounted to just slightly over 900 MW," said analyst Mike Sheppard. "Next year, new solar installations will reach an estimated 3.1 GW, on the way to some 5.5 GW by 2015. And while a downturn next year is forecast for Europe, growth will be good stateside because of healthy support from the US Department of Energy in the form of loan guarantees to help stimulate the market and help secure a lower cost of capital for large projects."

Among US states, California will be the leader by a wide margin in solar power this year, accounting for 967 MW. Tiny New Jersey is expected to be second with 263 MW, followed by Arizona with 243 MW, New Mexico with 139 MW and Nevada with 118 MW. With large projects coming through the year, Nevada will enter the Top 10.

www.ihs.com



300-Millimeter Wafer Technology for Power Semiconductors



Infineon has produced the first chips on a 300-millimeter thin wafer for power semiconductors at the Villach site in Austria. The chips exhibit the same behavior as the ones made on 200-millimeter wafers - as has been demonstrated by application tests using MOSFETs for high voltage applications.

Infineon had embarked on setting up a power semiconductor pilot line for 300-millimeter wafer and thin wafer technology in Villach, Austria, in October 2010. The team today is composed of 50 engineers and physicists from the fields of research and development, manufacturing technology and marketing. "Our engineers' achievement marks a quantum leap in production technology," said Dr. Reinhard Ploss, Operations, Research & Development and Labor Director of Infineon Technologies AG. As part of the investment plans, the company announced end of July this year to set up Dresden as the high volume production site for Power 300 technology. At first up until 2014, Infineon Technologies Dresden GmbH will invest around Euro 250 million for this purpose and will create 250 jobs in Dresden.

www.infineon.com

30 Years Linear Technology

Founded on September 26, 1981, Linear Technology commemorated three decades of innovation in analog ICs. Over these 30 years, the worldwide analog market has grown from $2 billion to over $40 billion.

Fueled by new markets and applications, Linear has brought key innovations to a broad range of markets and applications, and has provided the enabling technology for many. A list of these innovations include first 5A single chip easy-to-use switching regulator (1986); Burst Mode DC/DC converters (1993); multiphase synchronous switching regulators (1999); first buck-boost regulators (2002); µModule DC/DC converters (2006); precision battery monitor device for hybrid/electric vehicles (2008): and digital power management monitors & controllers (2009). Revenue for fiscal year 2011 (ending July 2011) was $1.48 billion, an increase of 27% or $314 million over revenue of $1.17 billion for fiscal year 2010. "Twelve percent of 2011 revenues came from automotive applications, doubling from recent years. We are one of the Class B suppliers outside Japan for Denso", commented Tony Armstrong, Linear's Director of Product Marketing for Power Products.

For the quarter ended October 2, 2011, the company reported revenues of $330 million, a decrease of $28.6 million or 8 % from the previous quarter's revenue of $360 million. "In the beginning of the quarter, we noted that orders had slowed and that global

economic sluggishness appeared to affect the ordering patterns of our customers as they continued to work down inventories. Although cautious given the current economic state, we

"The automotive industry is quickly becoming one of our biggest customers, particularly due to growth of Chinese increasing production", says Linear's Tony Armstrong

were hopeful that this would be temporary and that orders would pick up in the latter half of the quarter as inventories and orders were balanced against end customer demand. This did occur in a few of our markets, notably the automotive market as the efforts we have invested in that business are having positive results. However, business in our core industrial and communications end-markets continued to soften through the quarter as it appears that end-demand has softened. Consequently, we are cautious and we expect many of our customers, particularly in the industrial and communications end-markets to have year-end shutdowns and thereby delay inventory procurement into the new year. Accordingly, we expect another difficult quarter of declining revenues and earnings, with revenues down 9 -13 % sequentially in the second quarter", said CEO Lothar Maier.

Nevertheless, new power products are intended to soften a downturn. Among them is the

LTM8052, a 36 V input constant frequency step-down µModule regulator with an adjustable output current limit up to 5A. The adjustable current limit helps system designers set the maximum power delivered to a load, minimizing the output rating of the upstream AC/DC or DC/DC power supply. The µModule regulator converts an input voltage between 6 V and 36 V to an adjustable output voltage between 1.2 V to 24 V. In a 12 V input to 2.5 V output application, the LTM8052 achieves a peak operating efficiency of 88 % at 2 A. The LTC3115-1 is a synchronous buck-boost converter that delivers up to 2 A of continuous output current from a wide range of power sources from single-cell Li-Ion to 24 V/28 V industrial rails to 40 V automotive inputs. The LTC3115-1's 2.7 V to 40 V input range and 2.7 V to 20 V output range provides a regulated output with inputs above, below or equal to the regulated output. The LTC3115-1's switching frequency is user programmable between 100 kHz and 2 MHz, and can be synchronized to an external clock. Proprietary buck-boost PWM circuitry ensures low noise and high efficiency while minimizing the size of external components. The device incorporates four N-channel MOSFETs to deliver efficiencies of up to 95 %. User-selectable Burst Mode operation lowers quiescent current to 50 _A. For noise-sensitive applications, Burst Mode operation can be disabled. Additional features include internal soft-start, programmable undervoltage protection, short circuit protection and output disconnect. Finally, the LT3798 is an isolated flyback controller with single stage active PFC. A power factor of greater than 0.97% is accomplished by actively modulating the input current eliminating the need for an extra switching power stage and associated components. In addition, no opto-isolator or signal transformer is required for feedback since the output voltage is sensed from the primary-side flyback signal. **AS**

www.linear.com

National Now Part of TI

On April 4 Texas Instruments announced an agreement by which Texas Instruments would purchase National Semiconductor. On September 23 this acquisition was completed.

More than 5,000 National employees will immediately become part of TI. The two companies will integrate National as a unit of TI's Analog business, which will have a combined portfolio of nearly 45,000 products, customer design tools, and a sales force that is ten times larger than National's previous footprint. Also TI's distributors will integrate National Semiconductor products onto their line cards. This will expose National products to a number of new distributors, and will ensure that customers all over the world have an extensive authorized channel. TI also said that all of National's current distribution contracts with Future Electronics will conclude by December 1, 2011.

TI will continue to operate National's manufacturing sites, located in Maine (USA), Scotland and Malaysia, as well as business headquarters in Santa Clara and sales/design support around the world. "The story behind this acquisition was the enhancement of our product portfolio including tools such as Webench. Step by step we will integrate TI's libraries into this tool. Also National's Wafer Fab and headquarters in Santa Clara was one of the motivations purchasing National, in order to have access to the skills of the Silicon Valley", commented TI's EMEA Marketing Manager Power Solutions, Miro Adzan. "With this acquisition we enhanced the share of power semiconductors within our analog product to 30 percent", he added. **AS**

www.ti.com

"Not only the enhancement of our product portfolio, but also also access to the skills in the Silicon Valley were motivation to acquire National Semiconductor", says TI's Miro Adzan

Energy and Safety seminars new at Drives and Controls 2012

Complementing Drives & Controls, Air-Tech, Plant & Asset Management and The International Fluid Power Exhibition (IFPEX) at the NEC, Birmingham between 17-19 April 2012, is a free highly focused seminar programme. New for 2012 is the Energy and Safety seminar theatre, sponsored by CompAir where themed panel discussions and seminar presentations will focus on key energy management topics, ranging from wind turbine maintenance, to the latest legislative debates surrounding health and safety, including machinery safety, and ATEX.

Also new for 2012 is the Motion and Control Industry seminar theatre which will include more technical workshop style presentations, with practical issues being discussed concerning the various sectors that makes up Drives and Controls Exhibition, Air-Tech, and IFPEX.

POL for Telecom Applications

Texas Instruments introduced two 20 V step-down voltage regulators with PMBus digital interface and adaptive voltage scaling capability for non-isolated point-of-load designs. The 2 MHz switching TPS40400 single-channel controller with a 3 V to 20 V input range and the new 1.2 MHz TPS40422 dual-channel or multi-phase controller with 4.5 V to 20 V input voltage range combine high-performance analog voltage regulation with digital control to achieve greater than 90 % efficiency, tight output voltage accuracy and design flexibility. The devices' adaptive voltage scaling capability saves up to 25 % more power than previous solutions, and eliminates the need for up to 12 external components. The controllers achieve even greater power efficiency when paired with TI's NexFET(tm) power MOSFETs, such as the CSD87350Q5D.

The TPS40400 and TPS40422 can be combined with the National 17 V LM25066 system power and hot-swap protection IC as a complete PMBus-compliant solution for 12 V systems with input protection and power conversion. The LM25066 continuously supplies the system management controller with real-time, accurate power measurement including voltage, current, temperature and fault data for each blade subsystem in a telecom or server application. For 48 V systems that generate a 12 V intermediate bus, the National

LM5066 and LM5064 system power and protection circuits measure, protect and control the electrical operating conditions.

Inside the TPS40400

The TPS40400 is a synchronous buck controller that operates from a nominal 3 V to 20 V supply. This analog PWM controller allows programming and monitoring via the PMBus interface. Flexible features include programmable soft-start time, short circuit limit and under-voltage lockout (UVLO).

An adaptive anti-cross conduction scheme is used to prevent shoot through current in the power FETs. Gate drive voltage is 6 V to better enhance the power FETs for reduced losses. Short circuit detection is done by sensing the voltage drop across the inductor or across a resistor placed in series with the inductor. A PMBus programmable threshold is compared to this voltage and is used to detect over-current. When the over-current

threshold is reached, a pulse by pulse current limit scheme is used to limit current to acceptable levels. If the over-current condition persists for more than 7 clock cycles of the converter, a fault condition is declared and the converter shuts down and goes into either a hiccup restart mode or latches off. The behavior is selectable through the PMBus interface. Other PMBus interface features include programmable operating frequency, soft-start time,

over-voltage and under-voltage thresholds and the response to those events, output voltage change including margining as well as status monitoring.

PMBus operation

The TPS40400 supports both the 100 kHz and 400 kHz bus timing requirements. The TPS40400 does not stretch pulses on the PMBus (**see http://pmbus.org**) when communicating with the master device.

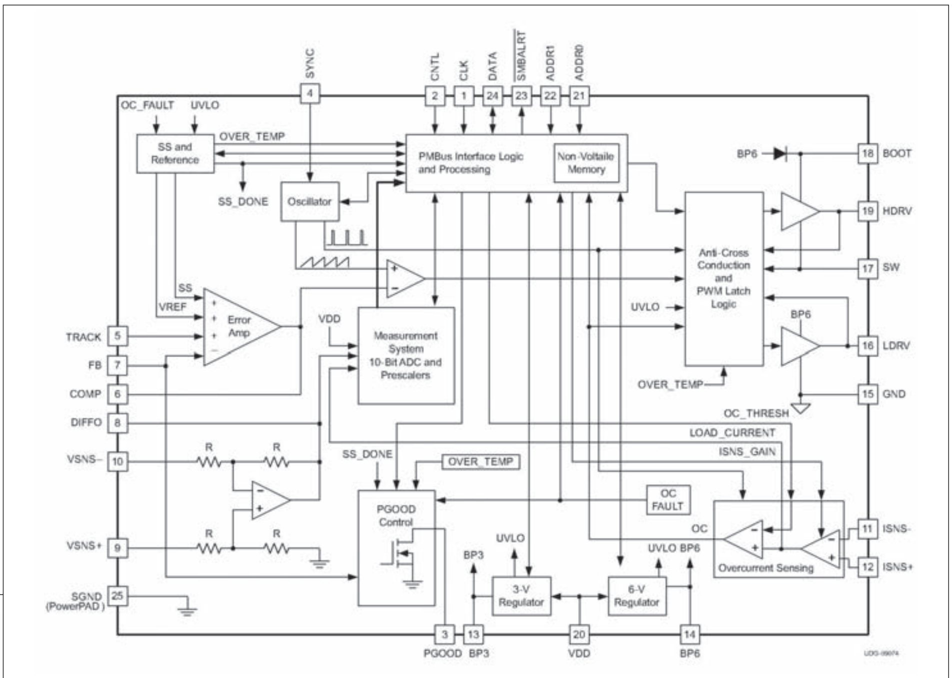
Communication over the TPS40400 device PMBus interface can either support the Packet Error Checking (PEC) scheme or not. If the master supplies CLK pulses for the PEC byte, it is used. If the CLK pulses are not present before a STOP, the PEC is not used.

The TPS40400 supports a subset of the commands in the PMBus 1.1 specification. Most all of the controller parameters can be programmed using the PMBus and stored as defaults for later use. All commands that require data input or output use the literal format. The exponent of the data words is fixed at a reasonable value for the command and altering the exponent is not supported.

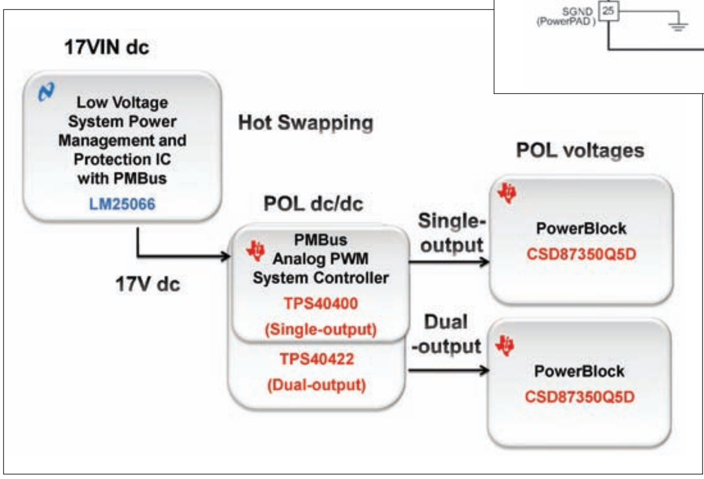
The TPS40400 also supports the SMBALERT response protocol, which is a mechanism by which a slave (the TPS40400) can alert the bus master that it wants to talk. The master

processes this event and simultaneously accesses all slaves on the bus (that support the protocol) through the alert response address. Only the slave that caused the alert acknowledges this request. The host performs a modified receive byte operation to get the slave's address. At this point, the master can use the PMBus status commands to query the slave that caused the alert.

The TPS40400 contains non-volatile memory that is used to store configuration settings and scale factors. The settings programmed into the device are not automatically saved into this non-volatile memory though. The STORE_DEFAULT_ALL command must be used to commit the current



ABOVE: TPS40400 functional block diagram



LEFT: PMBus point-of-load solution with system protection and power conversion settings to non-volatile memory as device defaults. The settings that are capable of being stored in non-volatile memory are noted in their detailed descriptions.

The nominal output voltage of the converter i. e. can be adjusted using the VOUT_TRIM command. The adjustment range is ±25 % from the nominal output voltage. The VOUT_TRIM command is typically used to trim the final output voltage of the converter without relying on high precision resistors.

TPS40400 and TPS40422 analog PMBus controllers and the National system protection ICs extend TI's portfolio of digital power products that meet any non-isolated or isolated power design requirement. The merger of TI and National Semiconductor has recently been completed. The new TPS40400 comes in a thermally enhanced 24 pin, 3.5 mm x 5.5 mm QFN package. Suggested resale pricing is $2.15 in 1,000 unit quantities. The TPS40422 comes in a 40 pin, 6 mm x 6 mm package, and is currently sampling with expected volume production later in the fourth quarter.

www.ti.com/tps40400-preu

SMD Power Inductors for Converters

Power inductors play an important role in voltage conversion applications by yielding lower core losses. They are also used to store energy, filter EMI noise, and provide lower signal loss in system designs. The increased utilization of battery powered miniaturized portable electronics such as mobile phones, notebook PCs, and handheld game devices has led to the added use of small-sized SMD power inductors into system designs.

As a precondition to constructing an outstanding product that is also competitive, electronic product designers must deeply understand the characteristics of each component being considered for the system design. Even further, proper power consumption design is the most vital aspect in battery powered systems. Accurate comprehension of the energy storage feature of power inductors is essential for system designers. The addition of power inductors frees up limited board space while filtering noise and providing a stored energy source.

Understanding SMD power inductors

Surface mount power inductors are used to store energy while also filtering EMI currents with a low-loss inductance for voltage conversion applications. They are also used in DC/DC converters for a wide range of products in a variety of applications. Requiring minimal PCB space, power inductors provide a high-performance, multiphase design that significantly reduces the overall system cost.

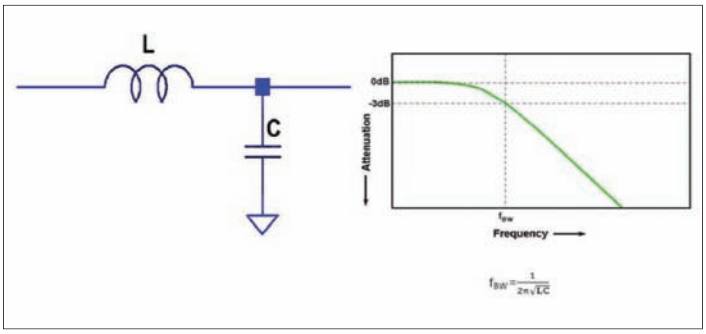
L-Inductance is the primary functional parameter of an inductor. Inductance is the property in an electrical circuit where a change in the electric current through that circuit induces an electromotive force that opposes the change in the current. The unit of inductance is the henry (H). This parameter determines the current output and ripple noise level.

DCR-DC Resistance is the resistance in the power inductor due to the length and diameter of the winding wire that is used. DCR is the key parameter for power efficiency. The power consumption will increase if a larger DCR power inductor is used.

Rated current is the maximum allowable operational current of the inductor. If the applied current exceeds the rated current, the self-temperature rise and the drop of the inductance value will exceed specification, and the performance and reliability will be decreased. For power inductors, there are two different definitions to describe the rated current, which is based on self-temperature rise or on inductance change. Laird Technologies defines the maximum rated current as the maximum amount of current by which inductance will drop by a typical value of 10 % of initial inductance.

Laird Technologies shielded (left) and unshielded power inductors

Self-resonant frequency (SRF) is the frequency where the inductor and parasitic capacitor among coil windings resonates. At a higher frequency than SRF, the inductor appears as capacitive rather than inductive, and is defined as a minimum value in MHz. The higher the SRF, the higher the inductor's effective operational frequency range. So, the operational frequency selected for the inductor should be lower than the SRF.



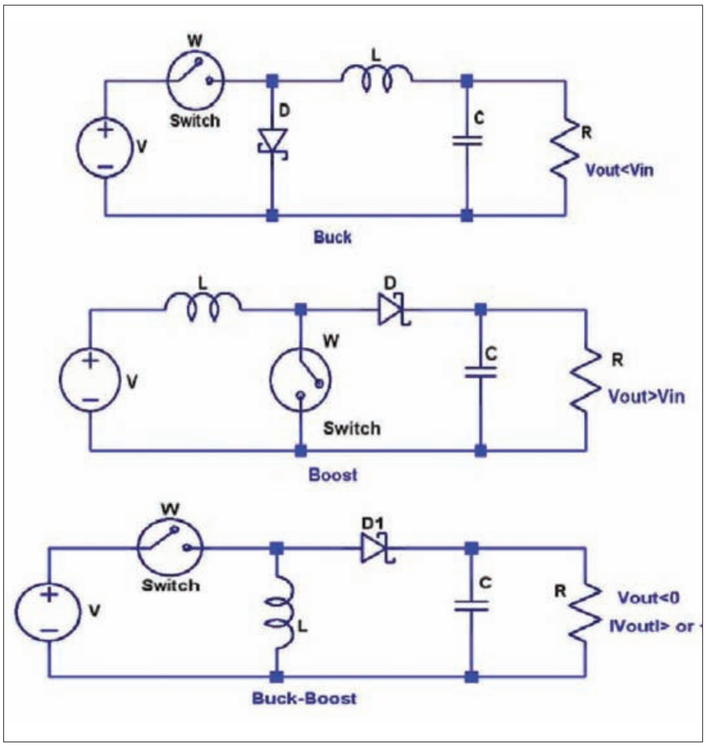
Low pass LC filter

Shielded and unshielded SMD power inductors

First, the magnetic field generated by the shielded power inductor keeps the magnetic field within the inductor. It emits few magnetic fields outside the package and has a less negative effect on others parts that are in close proximity to it, therefore minimizing the coupling to other components or modules. In an unshielded inductor, some of the magnetic flux field is radiated outside. If a sensitive component or module is in close proximity to it, its normal functionality may be affected.

Since the entire magnetic flux field is contained within the inductor, the power efficiency is higher. The inductor also contains less wire turns if it has equal inductance with the unshielded inductor. This results in the DCR being smaller for a shielded inductor, as compared to that of an unshielded one.

If the DCR is the same for both the shielded and unshielded inductors, then this implies that the inductors utilize the same wire and winding turns. The shielded inductor should have a higher inductance value than the unshielded one. However, the inductance change versus the current



Buck (upper), Boost (middle) and Buck-Boost converters featuring power inductors

curve will drop earlier because of saturation characteristics. This determines that the unshielded power inductor is easier to work with in a larger current.

Power inductor applications

Power inductors mainly have three applications:

- Low pass frequency noise filters,
- conducted EMI noise filter,
- energy storage in DC/DC converters.

Low pass frequency filter applications are mostly used in DC power lines in order to filter the low frequency ripple current noise. Larger inductors also can be used in AC inputs as conducted EMI noise filters in order to meet the regulatory requirements.

SMD power inductors are widely used in DC/DC converters as energy storage parts in the circuit. There are typically buck, boost, and buck-boost converters which convert the DC input voltage from high to low or low to high in order to provide the DC power to various circuits in an electronic system.

Summary

As battery devices continue to be designed and produced with slimmer profiles, implementation of convergence components that perform a variety of functions is more important than ever. Power inductors play an important role in voltage conversion applications by yielding lower core losses and are used to store energy, filter EMI noise, and provide lower signal loss and handle higher power capability in system designs. The result is a high-performance, rugged constructed design with a small footprint that requires significantly less total PCB space and a lowered overall system cost.

Laird Technologies can provide a series of SMD power inductors, including shielded and unshielded, which are widely utilized in the electronics market. The inductors cover from 1 to 10 μH, and have a current from 20 mA to 30 A with a constraint size to save space in portable electronic systems.

www.lairdtech.com

Low Loss SEPIC-Fed Buck Converter Topology

CUI's Solus Power Topology combines the single-ended primary-inductor converter (SEPIC) with the conventional buck topology to form the SEPIC-fed buck converter resulting in significant reduction in switching losses within a PWM circuit. SEPIC have a pulsating output current, as well as all buck-boost converters. The similar _uk converter does not have this disadvantage, but it can only have negative output polarity, unless the isolated _uk converter is used. Increased efficiency is achieved with the Solus Topology reducing both the conduction and the switching losses at several critical points within the converter circuit. The loss reduction is so significant that the output current can be increased by 40 % for a given power supply package size. Conversely, the loss reduction enables increased efficiency by several percent for a given output current and package size when compared to the traditional buck topology.

Solus accomplishes the reduction of conduction losses by channeling the operating currents into several paths. As shown in the schematic Q_{1SB} functions as high-side switch for both the SEPIC and buck operation. Q_{2B} functions as the low-side switch in buck operation. Q_{2S} functions as part of the SEPIC operation. As soon as the input current enters the converter at I1, the topology immediately branches that current into several paths, with each circuit path carrying lower instantaneous current than the output current. This reduces the conduction losses by the square of the current reduction. Thus, the conduction losses are significantly less when compared to standard buck converter losses.

The multi-current paths also reduce the voltage stress on components by nearly 50 %. This opens the possibility that, for a given voltage conversion, the design may use lower voltage MOSFETs and capacitors compared to the standard buck converter. This allows substitution of lower $R_{ds(on)}$ MOSFETs in a given device package size.

High switching speed

The topology is suited for implementing the gate-charge-extraction (GCE) circuit, which has the ability to turn off the Silicon MOSFET channel in less than a nanosecond. The first oscilloscope capture shows the voltage and current waveforms for HSS turn-off. In the second shot the red curve shows the instantaneous power during turn-off, which is approximately 50 W peak and lasts 6.4 nanoseconds for a total power loss at 200 kHz of a negligible 68 mW.

At increased switching frequencies, these improvements become even more compelling. The higher the switching frequency, the higher the power density, if converter efficiency is held to a reasonable level. If equivalent switching losses for both turn-on and turn-off of the high-side switch in the buck converter are assumed, the Solus Topology has the potential

to reduce the switching losses by over 90 %. This allows the Solus converter to operate at a higher switching frequency without sacrificing very much efficiency.

The Solus Topology can be used both isolated and non-isolated DC/DC power supply designs. It is an excellent topology for non-isolated DC/DC point-of-load (POL) power supplies due to its ability to provide a wider duty cycle "D" for given output to input voltage ratio "M". This is an especially attractive feature for wide-conversion-ratio POLs.

In the canonical buck converter, the D term, or pulse-width ratio, is equal to the M term or output/input voltage ratio. For the Solus converter, M = D/(2-D). Translating that to an operational advantage, at any given voltage ratio, the pulse width will be wider than for the standard buck converter. Thus, the 12 V intermediate bus voltage is still attractive for

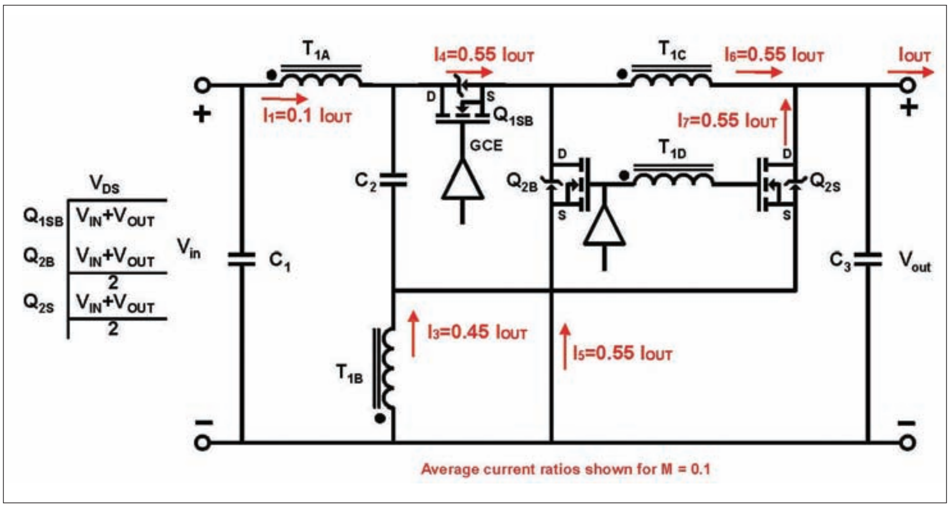
powering chips even down to 0.5 V. The Solus Topology should support continued use of the lower-distributed-current 12 V intermediate bus voltage, rather than yielding prematurely to lower intermediate bus voltage with higher distributed current.

The Solus Topology is independent of the control method, it can operate with analog voltage mode control, analog current mode control, and various digital control profiles. It can also improve the performance of the isolated high-voltage DC/DC section of the AC/DC power supply. Since it can operate very efficiently over a wide voltage range, the amount of the bulk hold-up capacitance can be substantially reduced.

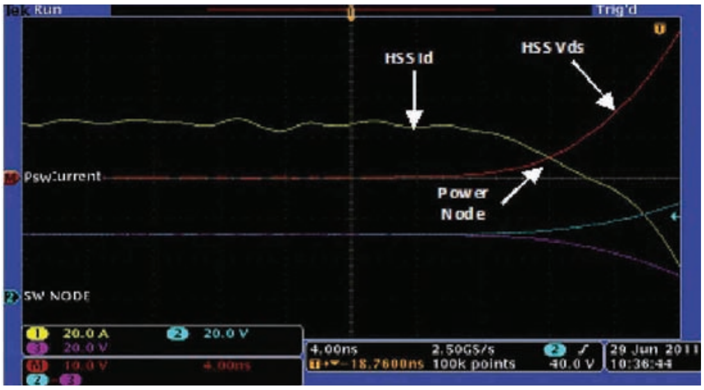
In July CUI introduced the engineering release and initial sampling of the NQB isolated DC/DC quarter brick. The 720 W intermediate bus converter supports an input range of 36-60 V with an output of 12 V and will provide an efficiency greater than 96%. The NQB product will eventually support a wider input range as well as an output of 9.6 V. Additional features include options for DOSA footprint compatibility, remote on/off, and load share capability.

Ericsson second source

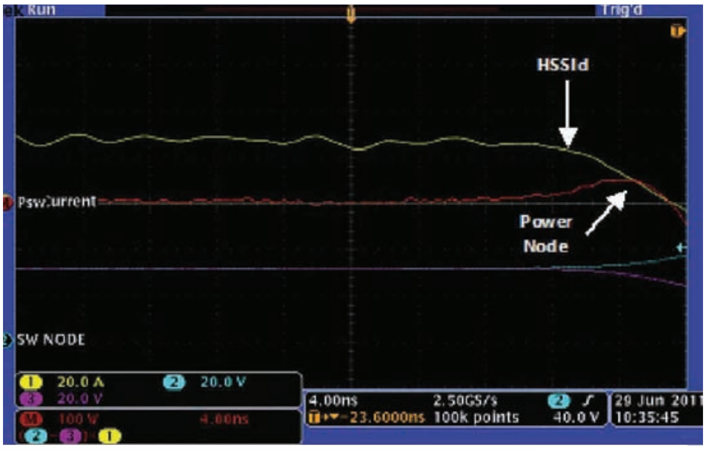
The company will also develop and market multi-source, digital POL power solutions that are based on the Ericsson footprints and designs. The Novum NDM2 series is the first to be designed by CUI as part of the Ericsson cooperation announced in July. The agreement formalizes a plan between the



Solus Topology schematic with relative average internal currents (M = output/input voltage ratio)



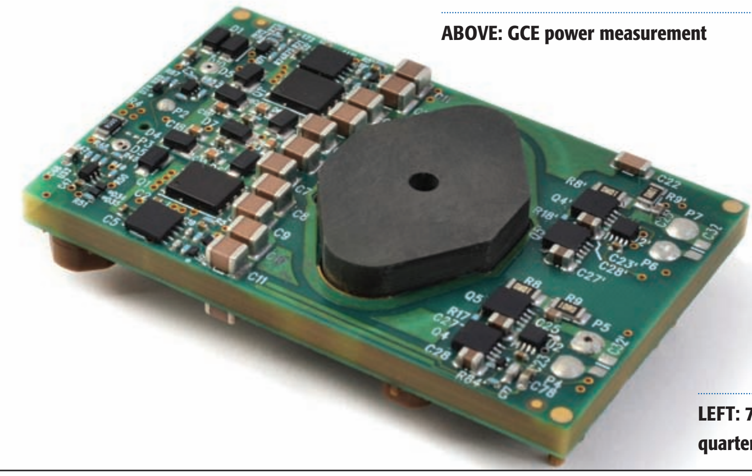
ABOVE: High-Side Switch (HSS) Gate Charge Extraction (GCE) waveforms



ABOVE: GCE power measurement

two companies to offer a multi-source digital POL platform based on the BMR46X series, with future plans to co-develop modules outside the existing range of 12-50 A. The NDM2 series modules are pin and function compatible with Ericsson Power Module's BMR46X series and will initially be available in 12 A, 25 A, and 50 A configurations. Features include programmable output, active current sharing, adjustable compensation settings, voltage sequencing, and voltage tracking. Additionally, the modules are footprint nested, supporting easing transition of dual layout needs.

www.cui.com



LEFT: 720 W NQB isolated quarter brick DC/DC converter

IGBT Press-Packs for the Industrial Market

The standard Press-pack IGBT (PPI) basically uses the same packaging concept as Bipolar high power semiconductor devices. The main difference is that the high power semiconductor content in the package is square IGBT chips arranged on a round molybdenum disc instead of large, round bipolar devices matched in size to the molybdenum disc and ceramic housing. The Press-pack IGBT comes under the name StakPak™ in a pseudo-square frame package that allows for much better utilization of the squared IGBT chips and for a modular platform in power scaling of the device. **Bülent Aydin, Franc Dugal, Evgeny Tsyplakov, Raffael Schnell, Liutauras Storasta and Thomas Clausen, ABB Switzerland Ltd, Semiconductors, Lenzburg, Switzerland**

Originally, it was thought that the PPIs would replace Gate Turn-Off Thyristors (GTOs) in both medium voltage drives and traction drives and be an alternative to the insulated IGBT modules. In 2011, PPIs have become an established part of the high power semiconductor market segment serving the industry in medium voltage drives, but PPIs have only marginally penetrated the traction segment. For propulsion drives, the development of rugged and reliable insulated IGBT high power modules have allowed for new platforms and topologies and virtually all new propulsion drive designs feature insulated IGBT modules.

ABB Semiconductors has many years of experience in manufacturing Press-pack IGBTs for power transmission & distribution applications. For many years, the StakPak has proved its outstanding reliability and ruggedness by serving as the principle switching device in the ABB HVDC light application. In the HVDC transmission link high voltage, direct current is transported either over long distances or via sea cables with very low transmission link losses. More than 15 of the HVDC light transmission links using StakPak devices for valves are currently in operation carrying more than 10 GW of power, and five projects are planned to add an extra 5 GW. The first link began operation in 1997 and, as of today, no field failures related to the StakPak device have been reported. This proves the device's capabilities in ruggedness and reliability.

The StakPak is well suited for series connection. With both 2.5 and 4.5 kV switches, there are a multitude of industrial applications that can benefit from the use of StakPak devices. Static VAR Compensation (SVC) systems and multi-level high power inverters with several devices in series to match industrial line voltages > 6 kV are the most obvious applications. Also, Pulse Power applications requiring high voltage level and fast repetition rates between the pulses will benefit.

Package outline

What makes the StakPak PPI unique as a high power switch is foremost the modularity of the package combined with the flexibility of the IGBT/diode ratio in the module. For high power PPI products the package size increases to support the high amount of chips. As the number of chips per unit operation increases, so does the probability of failures during subsequent device manufacturing steps and early failures in the field. The StakPak PPI consists of a number of standard rectangular sub-units, called submodules. The number of chips per submodule is limited to 12 and each submodule is tested for full functionality before it is inserted into the frame. In this way, power is configured into the switch based on the number of submodules in the frame. The frame is pseudo-square and can hold 2 (Figure 1), 4 or 6 (Figure 2) submodules. Our BiMOS line is designed for high manufacturability and as a result of recent factory expansion, high volume manufacturing is possible.

Each submodule has 12 chip positions and the layout of the IGBT connections to the gate pad allows for at least four different IGBT/diode ratios in the submodule. The ratio can be 1:1, 2:1, 3:1 or even 5:1. The fifth possible configuration with only IGBT chips is currently not possible due to package restraints relating to the maximum current

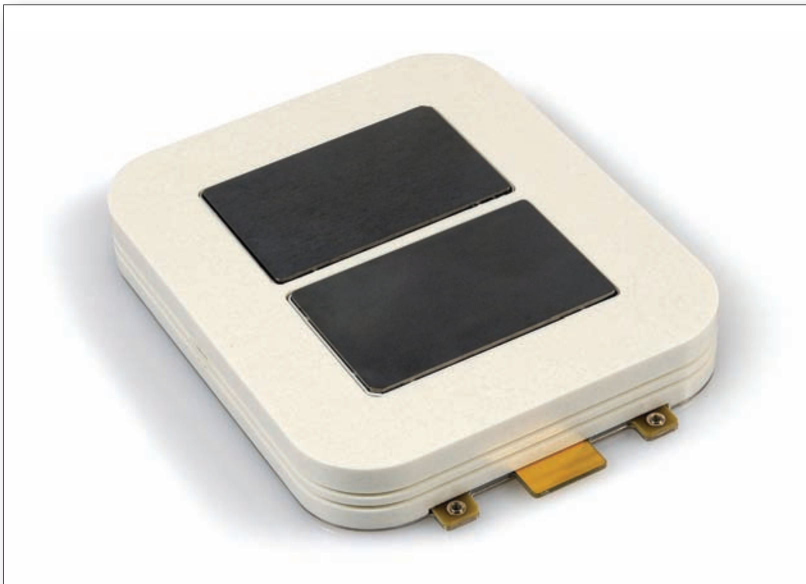


Figure 1: **StakPak™ (4.5 kV) in a pseudo-square frame package with two submodules**

Figure 2: **StakPak™ (4.5 kV) in a pseudo-square frame package with six submodules**

flow through the package. The maximum current flow at present is 2600 A in a 2:1 configuration between IGBT and diodes. The 2600 A maximum rating for the complete switch means that one phase leg of the medium voltage drive can be built from one stack only without special considerations concerning the diode and special design rules with respect to the cooling system and the elimination of parasitics. The fact that only one StakPak compact stack is needed per phase leg is highly beneficial in terms of footprint of the drive and manufacturability of the complete drive. Figure 3 shows the soldering of a StakPak.

The press-pin that contacts the emitter side of the IGBT chip has been designed with two additional goals in mind besides conducting the current when the switch is on. The first of these goals is to make the pin assembly consisting of 12 pins on a carrier independent of each other and the second goal is to bring a failing IGBT chip into short circuit failure rather than open circuit failure as is the case for insulated IGBT modules. The underlying principle in order to achieve the first goal is the independent suspension principle. This principle originates in the automotive industry and is considered to offer the highest quality and load characteristics for the individual pins as well as for the pin assembly. The individual pins are designed for lowest possible unsprung weight and each individual pin spring contacts the carrier without affecting the other pin spring contacts in the submodule (Figure 4).

IGBT and diode technology

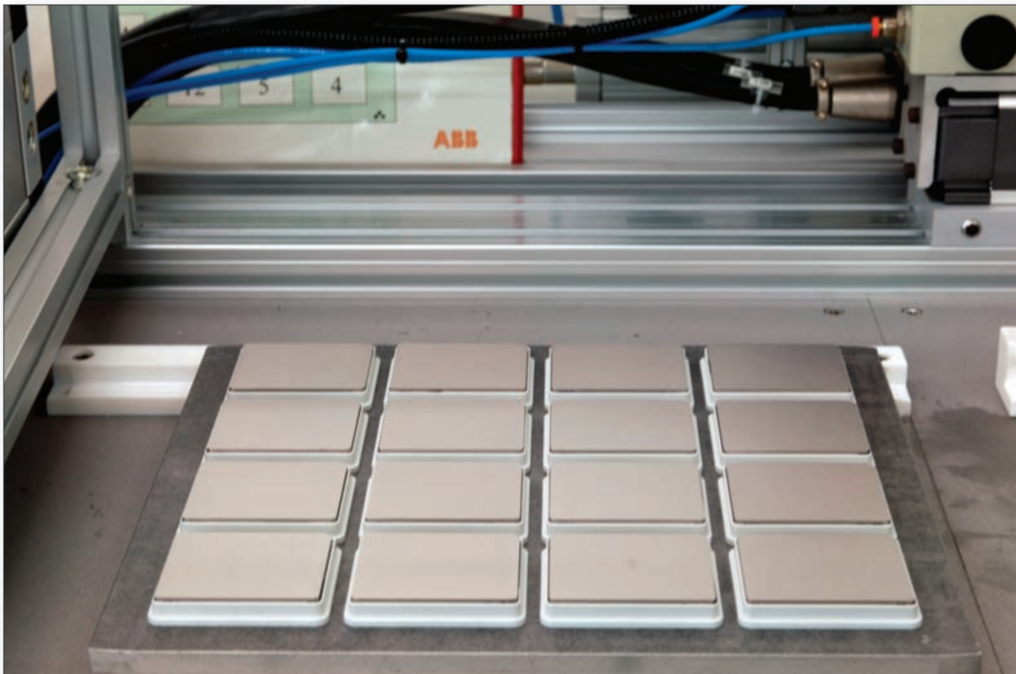
The IGBT chips inside the StakPak are manufactured using the Soft-Punch-Through (SPT™) technology platform that is considered among the best high voltage (HV) chip and which performs excellent in both hard switching and soft switching applications. The HV IGBT SPT+ chips use the same rugged planar cell design as the former SPT chips, but the SPT+ chips have a much lower on-state voltage drop. The lower on-state voltage drop has been achieved by introducing an enhancement layer within the IGBT cell that increases the carrier concentration on the emitter side during turn-on of the device. The SPT+ chips, besides having a much lower on-state voltage in comparison with SPT chips, also show an improved turn-off SOA as a result of the advanced design.

The diode chips inside the StakPak need to have a fast recovery when they go from the conductive state to the blocking state, so that the diode does not become a limiting factor with respect to the overall losses of the switch. In principle, the diode is a simple pin type structure

Figure 4: **Press-pins contact the emitter side of the IGBT chip**

manufactured using the same technology as is used for the SPT+ IGBT chips. In order to match the performance of the IGBT chips, there is a trade-off needed in the on-state voltage versus the switch-off losses. This trade-off curve increases the on-state voltage by placing specially

Figure 3: **Soldering of a StakPak**



designed carrier lifetime control layers in the bulk and close to the pn-junction of the diode, but in turn makes the recovery fast and significantly lowers the diode switching losses. The localized carrier lifetime control technique gives a much better diode performance in comparison with conventional carrier lifetime control techniques, where the carrier lifetime in the whole bulk is lowered by i.e., electron irradiation. With localized carrier lifetime controlling, the minority carrier lifetime is kept high in the bulk, which in turn lowers the leakage current in the device. When switched off, the localized layers act as a carrier recombination drain for fast recovery, and it shapes the tail of the reverse recovery current for optimum softness.

Application benefits

There are several other functional advantages of the StakPak PPI over standard PPIs and insulated IGBT modules. The benefits are all functionalities that make the design of medium voltage drives more straightforward or help to reduce the need for power semiconductor protective circuits in the drive.

Probably the most important parameter that will greatly benefit the designer of medium voltage drives is the unsurpassed thermal properties of the StakPak. Besides the possibility of cooling both the emitter and the collector side, the IGBT and diode thermal resistance (junction to case) is as low as 4 K/kW, but since only ~20% of the heat flows to the emitter side when double side cooling is employed, it is crucial that the main emphasis is on collector side cooling. Cooling only from emitter side must be avoided.

When taking care in the design of the heatsink (mostly the surface roughness), it is possible to achieve a thermal resistance from case to heatsink for both the IGBT and Diode of only 1 K/kW. The thermal resistance from junction to heatsink is up to 50% lower compared to standard PPIs and insulated IGBT modules. The excellent thermal properties are obtained by having the chips soldered directly onto the molybdenum submodule disc. With the chip-to-case alloyed design, the short-time thermal overload capacity, which is another important parameter for the designer of the medium voltage drives, is also much improved in comparison with other types of IGBT module design.

In case of an event outside the safe operating area (SOA) for the switch or a chip in the switch, the press pin alloy to the IGBT chip because of the local temperature increase at the failing point. If the alloyed pin/IGBT is not conductive, the switch fails into open circuit, which is a disaster for series connected devices. The design thus has to be so that the pin/IGBT alloy is conductive in the event of a failure. The current path is thus short circuited by creating a low current path between the collector and emitter. The built-in pin short circuit failure mode (SCFM) is a key feature of the switch.

The trend in medium voltage drives is to move away from bulky protective circuit elements in the design; i.e. reduce the number of passive elements. This basically put the protective control scheme on the semiconductor switch itself or alternatively on the on/off gate control unit. Another important protection feature of the StakPak is the surge current capability, which is up to 27 kA (w/o reapplied voltage) dependant on the diode content in the switch.

Yet another element of built-in protection, which is very difficult to test, but is an important parameter for designing medium voltage drives, is case non-rupture rating. The case non-rupture rating is the highest current in reverse direction that a damaged module can tolerate without emitting plasma that can damage other elements of the drive. The case non-rupture rating is often referred to as an explosion rating for the semiconductor element. For the StakPak there are no high current carrying wire bonds in the module and the module is not a tight capsule type of module. Both of these facts will be beneficial in case reverse voltage is applied to a damaged element. With the StakPak, it is difficult to define a worst case for damage to the module that will cause an explosion. In the event of a damaged module, we do not expect any emission of plasma to occur, because the module is not sealed and therefore a huge pressure build-up inside the module is unlikely.

BiMOS and Bipolar outlook - solutions for industrial drives

With the introduction of the StakPak press-pack IGBT to the industrial market, ABB not only offers the largest variety of high power semiconductor switches in Bipolar and BiMOS, but also the highest power levels available in single switch configurations. ABB manufactures IGCT devices with 4.5, 5.5 and 6.5 kV blocking voltage capabilities with switch-off capability of more than 5 kA of current. For BiMOS switches, ABB has a production line in operation since 2010 capable of producing more than 150'000 modules. ABB Semiconductors offers products in the blocking voltage range from 1.7 kV to 6.5 kV for standard insulated IGBT modules. Because of the built-in isolation, these modules are ideally suited for medium voltage drives, in which the modules are paralleled to achieve high power levels. The StakPak addition to the industrial product platform offers manufacturers of medium voltage drives an opportunity to use the latest IGBT technology in packages suitable for series connection. The midterm roadmap is to achieve higher current ratings in the same package. This is a challenging task, because each press pin must conduct higher current in a potentially more challenging working environment.

High Voltage Thyristors for Soft Starters

In spite of significant development of converters on the basis of fully controlled semiconductor stacks (IGBT, GTO, IGCT), today it's still technically legitimate and demandable to use "traditional" high power thyristors in stacks of controlled rectifiers as well as in soft starters for electric motors. Usage of thyristors is especially relevant in case of operating in AC network of 6/10 kV and higher, because the devices produced on the basis of such thyristors have no competition in price and energy efficiency (efficiency coefficient). That's why development and production of high voltage thyristors is of high interest. **D. A. Presnyakov, I. Yu. Vetrov, A. V. Stavtsev, A. M. Surma, Orel, Russia**

During last several years some manufacturers developed and put into production high power devices with voltage up to 6,5-8,5 kV necessary for high-voltage valves of electric converters operating in AC with 6 kV and higher. The blocking voltage level is still low to allow using only one thyristor in such stacks. That's why the stack consists of several series-connected semiconductor devices which requires operating synchronization of thyristors in such connections.

Unfortunately, along with increase of maximum allowed blocking voltage, reverse recovery voltage increases as well, which is quite typical for high voltage device. It's connected with the necessity to guarantee low voltage in off-state. For devices with 6,5-8,5kV voltage values of reverse recovery voltage and maximum value of reverse recovery current reach very high level, even with low value of current rate of rise.

In Figure 1 typical values for high voltage thyristors manufactured by various companies are shown. These values for thyristors with 6,5-8,5 kV reached the values when it's quite difficult to cross match damping and conforming RC-circuits.

Calculations and experiments show that full power of losses in damping RC-circuit, limiting the pulse spike of reverse voltage at recovery of the typical high voltage thyristor on the level of 0,75-0,8V_{RRM} in circuit with VDC~0,5V_{RRM} voltage is connected with reverse recovery charge by semi-empirical equation 1:

$$E_R \sim 1{,}5 Q_{rr} \cdot V_{DC}$$

where E_R = energy dissipating in resistor of RC-circuit in "turn on - turn off" cycle.

Taking the data shown in Figure 1 it's easy to see that power dissipated by damping circuit of high voltage thyristor can be compared with full power of losses of thyristor, which isn't optimistic at all concerning the complexity of stack cooling system as well as its efficiency coefficient.

Considering this the development of high voltage thyristors designed for series connection assemblies with some specific characteristics at reverse recovery:

- Minimized values of reverse recovery charge and current (on condition of low level of voltage in on-state);
- "soft" character of reverse recovery; usage of thyristors with soft reverse recovery allows to simplify the requirements to RC-circuit in case of providing acceptable level of peak voltage;
- adequacy of reverse recovery charges, as well as reverse recovery current form for thyristors used as series connected assembly; this allows to lower the requirements to conforming RC-circuits, and completely abandon it as perspective.

Let's consider the problems in more details, which may occur when developing

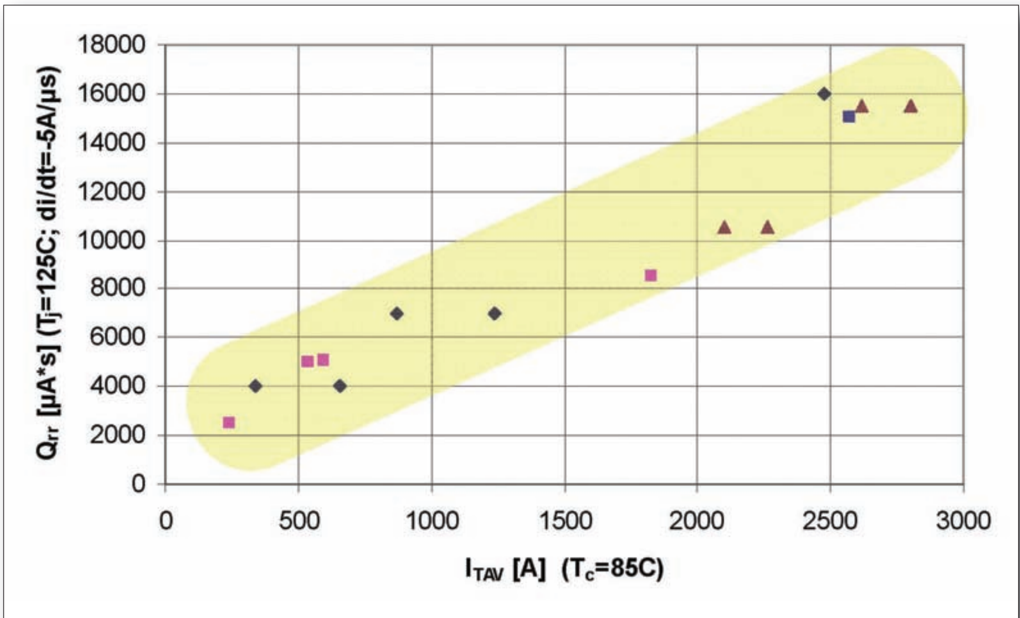


Figure 1: Dependence of average current in on-state and reverse recovery charge for high voltage (6,5-8,5 kV) thyristors manufactured by various companies (average current: pulse waveform - half-wave sine time length 10 µs, 50 Hz frequency, thyristor case temperature 85°C; reverse recovery charge: temperature of semiconductor element 125°C, rate of rise 5 A/µs, reverse voltage $V_{R(DC)}$ ~ 0,5-0,8V_{RRM})

and producing such devices and series connected assemblies on its basis, using the example of thyristors and stacks produced by Proton-Electrotex JSC.

High voltage thyristors adjusted for usage in series assemblies

It's clearly known that value of reverse recovery charge depends on value of accumulated charge of excess electrons and holes in n- base layer of thyristor, and also on recombination rate of this accumulated charge. For high voltage thyristors, which recover at low rate of rise of anode current, the second factor is more crucial. Indeed during rate of rise of anode current the bigger part of excess carriers recombinate. Thus there is some optimum value of effective life time of carriers in n-base of thyristor, which allows achieving low reverse recovery charge with relatively low value of voltage rate of rise in on-state.

To reach the optimum value of carriers' life time in n- base of thyristor the technology of accelerated electrons and protons irradiation of silicon elements is used. However, there are some additional options to lower the value of reverse recovery charge. If we lower the maximum concentration of atoms of acceptor dopant in p- base of thyristor, this will lower reverse recovery charge by means of transferring part of excess electrons accumulated in n- base into n+ emitter, same to the process in diode. In thyristor with highly doped p- base, as a result of transistance, there isn't any electrons transfer from n- base, but excess holes injection into n- base what leads to relative increase of reverse recovery charge.

Thyristors produced by Proton-Electrotex JSC have quite low doped p- base (as a rule maximum concentration of acceptors - (1 or 2)*10^{16} cm^{-3}) [1]. This allows to lower reverse recovery charge without any influence on voltage rate of rise in on-state.

To guarantee the required dU/dt - durability for thyristors with low doped p- base, special configuration of distributed cathodic diversion is used.

"Softness" of reverse recovery S is very significant characteristic, which can be shown as quotient of duration of rate of rise of reverse current (t_f) and time of delay of reverse voltage applying (t_s) in the process of reverse recovery of thyristor according to equation 2:

$$S = t_f / t_s$$

It's known that increase of reverse recovery softness can be reached with lowering of concentration of excess carriers near anode p- emitter. There are two ways to achieve it:

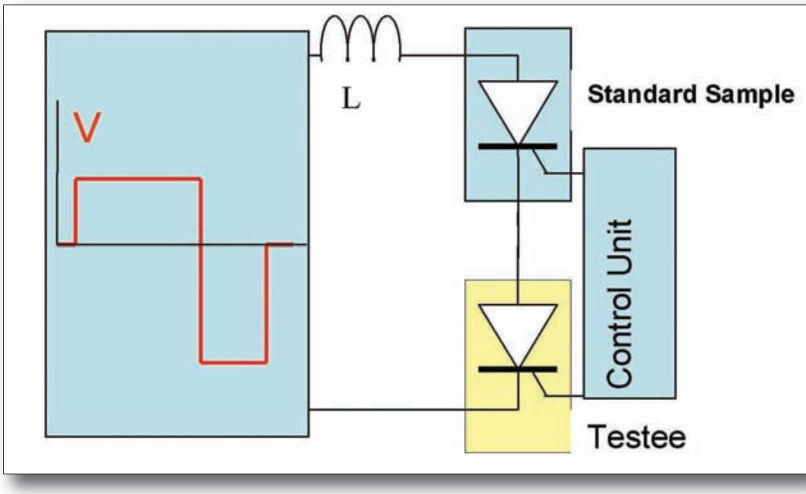


Figure 2: **Basic diagram of equipment for final presorting of thyristors by reverse recovery characteristics**

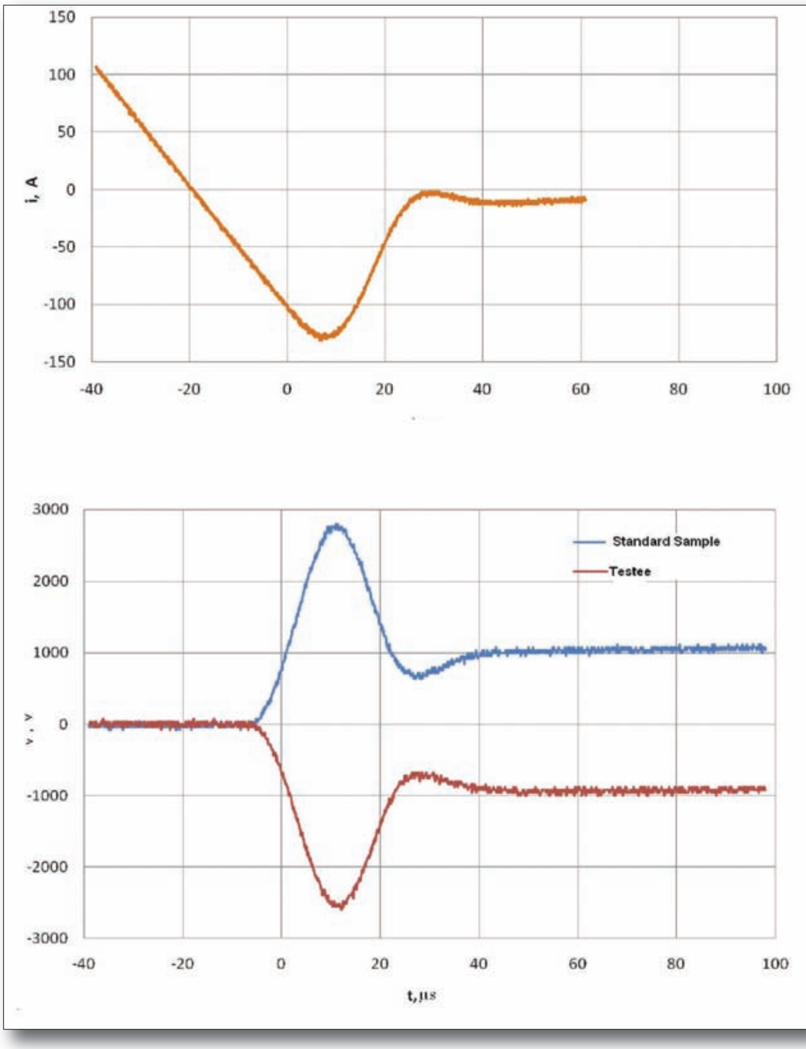


Figure 3: **Typical dependences of reverse recovery current (upper) and voltage of testee (lower graph) and standard sample thyristors using equipment for final presorting by reverse recovery characteristics**

- Lowering of injection efficiency of anode p- emitter; this can be achieved by lowering the maximum concentration of acceptor dopant as well as carriers' life time in highly doped area of p- emitter layer;
- local decrease in life time in the layers of n- base and low doped p- emitter joining anode p-n junction.

Proton-Electrotex JSC uses both ways to achieve the desired results for thyristors.

Firstly, relatively low doped p- emitter layers are used. This allows reducing reverse recovery surge current and increasing softness of reverse recovery. More than that, as proved by calculations and experimentations, for such thyristors low temperature dependence of time and reverse recovery charge is very characteristic. Secondly, when it's necessary to reach soft reverse recovery special technology of carrier life time regulation based on proton irradiation. This technology allows locally decrease carriers' life time in the layers joining the p-n junction.

It's very crucial to have identical reverse recovery characteristics for thyristors. And it's very important to have same surge current and reverse recovery charge, as well as identical characteristic of current dependence on time. This can make it possible to avoid using RC-circuits when assembling thyristors.

In accordance with above mentioned it's clear that to have identical characteristics of reverse recovery it's necessary to provide high precision of doping profile and life time distribution of carriers in semiconductor elements. Identity of dopants distribution is provided by high level of production of semiconductor elements technology, precise control of carriers' life time becomes possible with help of special technology of electron and/or proton irradiation.

To achieve low variation of reverse recovery parameters the following process flowsheet is used:

- Step 1. Presupposition for achieving low variation of reverse recovery characteristics - providing high identity of dopant profiles in produced silicon elements, which is achieved by thoroughly worked-out technology. This step provides the repetition of reverse recovery current form, temperature dependences of reverse recovery characteristics.
- Step 2. Precise control of reverse recovery parameters (reverse recovery time, reverse recovery current, reverse recovery charge, softness) with help of electron and proton irradiation. This step provides additional correction of reverse recovery time and charge to lower the variation of these characteristics in group. Combination of electron and proton irradiation allows simultaneously adjust softness.
- Step 3. Final presorting with equipment that provides the possibility to run tests of reverse recovery of two and more series connected thyristors in mode close to operational.

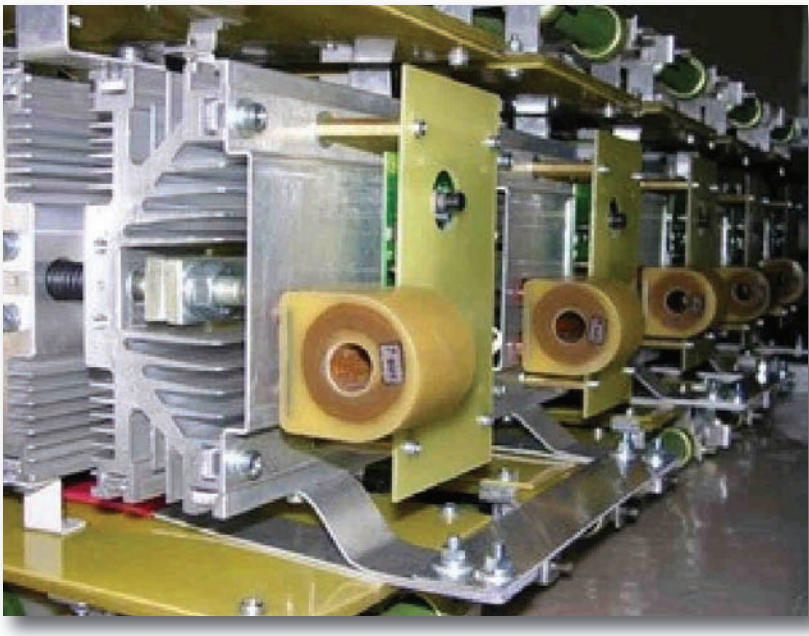
The scheme of equipment necessary for such tests is shown in Figure 2. Presorting is done during test of each and every thyristor in series connection with standard sample. Pulse power supply provides positive voltage distribution to the switched-on thyristors, and current, going through the inductive reactor L, linear reaches the necessary value. Voltage polarity changes and two series connected thyristors reverse recover.

And the fitting criterion of reverse recovery characteristics of device to the standard sample is voltage distribution applied to the thyristors during the whole process of reverse recovery equally between testee and standard sample. Typical dependences of reverse recovery current and voltage of testee and standard sample thyristors are shown in Figure 3.

This equipment can be used for testing the assembled high voltage valves on basis of series connected thyristor stacks. As a result of the above mentioned technologies in production it made it possible to have thyristors with relatively low reverse recovery charge, low temperature dependence, as well as high softness of reverse recovery. Typical

Thyristor Type	T543-250	T653-500/630	T473-1000/1250
Silicon element diameter, mm	40	56	80
Allowed average current, A (current pulses halfwave sine, time length 10 µs, frequency 50 Hz, case temperature 85°C)	250	500-630	1000-1250
Repetitive voltage in off-state, reverse voltage, V	4600-6500	4600-6500	4600-6500
Reverse recovery charge, µC, (semiconductor element temperature 125°C, current rate of rise 5A/µs, reverse voltage $V_{R(DC)}$= 0,5V_{RRM})	2500-3500	4000-6000	6000-8000
Reverse recovery charge variation by group	In accordance with customer's demands from ±5% to less than 1%		
Reverse recovery softness S	1,0-1,3	1,0-1,3	1,0-1,3

LEFT Table 1: Typical characteristics of high voltage thyristors adjusted for usage in series assemblies



BELOW Figure 4: KT5.11-800 stack for usage in soft starters of electric motors operating in AC networks of 6 kV

Voltage & current range

I_C	1200V	1700V
225A	●	●
300A	●	●
450A	●	●
550A		●
600A	●	

↓

SiN-DCB & thicker Cu pattern

↓

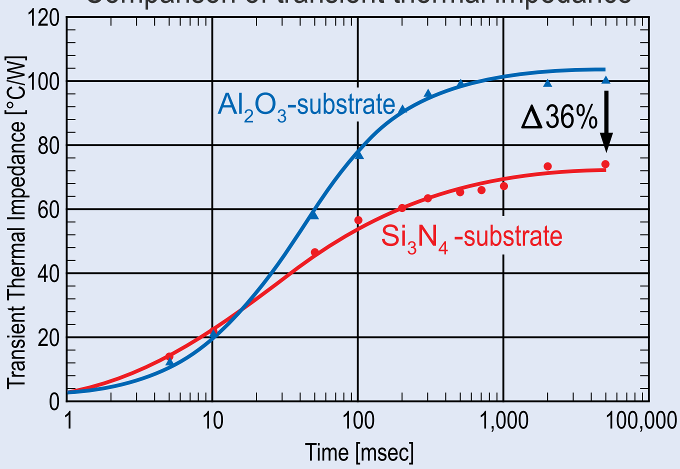
Lower thermal impedance
Higher bending strength & fracture toughness

↓

Higher thermal cycling capability
Higher reliability

- $T_{j\,(op)}$ = 150°C continuous operation
- $T_{j\,(max)}$ = 175°C
- New solder material for higher reliability
- Low switching losses & low over voltage spike

Comparison of transient thermal impedance



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characteristics of high voltage thyristors adjusted for usage in series assemblies are shown in Table 1.

Series stacks for usage in soft starters of electric motors

New high-voltage thyristors adjusted for usage in series connection are used for series connected stacks - KT5.11-800, designed for usage in soft starters of electric motors operating in AC network of 6 kV (see Figure 4). The stack consists of thyristors with 6,5 kV blocking voltage and presents the complete unit - AC stack equipped with drivers, power units, conforming circuits and heat sinks, it's basic diagram is shown in Figure 5. Thyristor groups, forming direct and reverse stacks are controlled separately by fiber optic line.

The stack can be used in AC network of 6 kV, as well as in other networks with peak values of direct and reverse voltages up to 11 kV, and provides maximum starting current of electric motors up to 400 A.

Literature

[1] Applying Proton Irradiation for Performance Improvement of Power Semiconductors, Power Electronics Europe 3/2011, pages 35 - 38

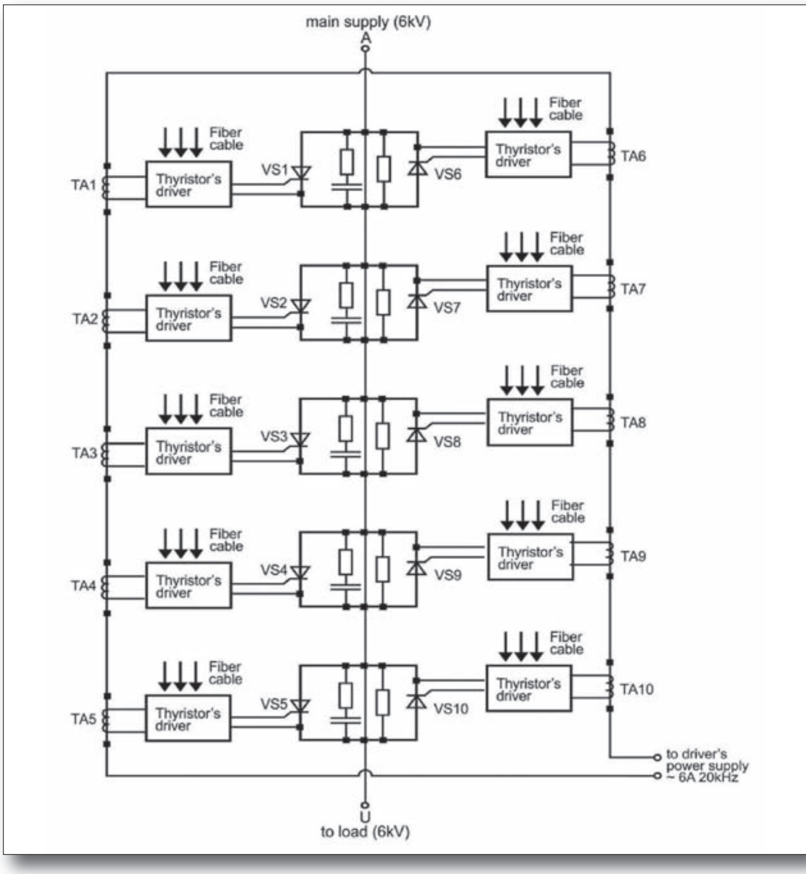

Figure 5: Basic diagram of KT5.11-800

Multi-Topology Battery Charging from Milliwatts to Kilowatts

The practice of battery charging spans a wide variety of battery chemistries, voltages and current levels in many market segments. For example, industrial, medical and automotive battery chargers continue to demand higher voltages and currents as new applications are emerging for both existing and new battery chemistries, such as the proliferation of sealed lead acid (SLA) batteries in solar applications. Existing single integrated circuit (IC) based solutions cover just a fraction of the many combinations of input voltage, charge voltage and charge current. A cumbersome combination of ICs and discrete components was routinely used to cover most of these combinations and topologies. A new charger IC overcomes this problem. **Steve Knoth, Senior Product Marketing Engineer Power Products, Linear Technology Corp., USA**

Current market trends would indicate that there is renewed interest in high capacity SLA battery cells - a revival of sorts - they are not just for cars anymore. Automotive or "starting" SLA cells are inexpensive from a cost/power output standpoint and can deliver high pulse currents for short durations, making them excellent for automotive and other vehicle starter applications. Deep cycle lead-acid batteries are another technology popular in industrial applications. They have thicker plates than automotive batteries and are designed to be discharged to as low as 20% of their full charge. They are normally used where power is required over a longer period of time in such applications as fork lifts and golf carts. Nevertheless, lead-acid batteries are very sensitive to overcharging, so careful charging is very important.

Obviously, solar-powered applications are on the rise. Solar panels of various sizes now power a variety of innovative applications from crosswalk marker lights to trash compactors to marine buoy lights. Batteries used in solar powered applications are a type of deep cycle battery capable of surviving prolonged, repeated charge cycles, in addition to deep discharges. This type of battery is commonly found in "off grid" (i.e. disconnected from the electric utility company) renewable energy systems such as solar- or wind-power generation.

All-in-one charger?

Some of the tougher issues a designer must encounter are the high input voltage requirements, the high capacity batteries needing to be charged, or an input voltage range that spans above and below the battery voltage range. Furthermore, to make matters worse, there are many applications without dedicated, simple battery charging solutions. Examples include:

- High series cell count battery stacks - there are no existing IC solutions for >4 Lithium cells,
- high input voltage applications - there are no existing IC solutions above 30V to 40V,
- buck-boost applications and isolated topologies, e.g. a flyback configuration.

Due to IC design complexity, existing battery charging controllers are primarily limited to step-down or buck architectures. Finally, some existing solutions charge multiple battery chemistries - some with on-board termination; however, up until now no chargers have provided the necessary performance features to solve all of these issues. Popular applications for a device such as this would be high power battery charger systems, portable instruments, industrial battery equipped devices, and general purpose charging.

A new IC solution

An IC charging solution that solves the problems outlined needs to possess many, if not all, of the following attributes:

- Flexibility - it must operate in tandem with various switcher topologies
- Wide input voltage range,
- wide output voltage range to address multiple battery stacks,
- ability to charge multiple battery chemistries,
- autonomous operation (no µP needed),
- high output current,
- low profile solution footprints,
- advanced packaging for improved thermal performance and space efficiency.

A typical convoluted competing solution with PowerPath™ control and input current limiting would consist of a DC/DC switching regulator, a microprocessor plus several ICs and discrete components. However, a simpler solution is with the new LTC4000 battery charging controller at hand.

The LTC4000 is a high voltage controller and power manager that converts virtually any externally compensated DC/DC power supply into a full-featured battery charger (Figure 1). The IC is capable of driving typical DC/DC converter topologies, including buck, boost, buck-boost, SEPIC and flyback. The device offers precision input and charge current regulation and operates across a wide 3 V to 60 V input and output voltage range, making it compatible with a variety of different input voltage sources, battery stacks and chemistries. Typical applications include high power battery charger systems, high performance portable instruments, battery back-up systems, industrial battery-equipped devices and notebook computers.

The LTC4000 features an intelligent PowerPath topology that preferentially provides power to the system load when input power is limited. The IC controls two external PFETs to provide low loss reverse current protection, efficient charging and discharging of the battery, and instant-on operation to ensure that system power is available at plug-in even with a dead or deeply discharged battery. External sense resistors and precision sensing enable

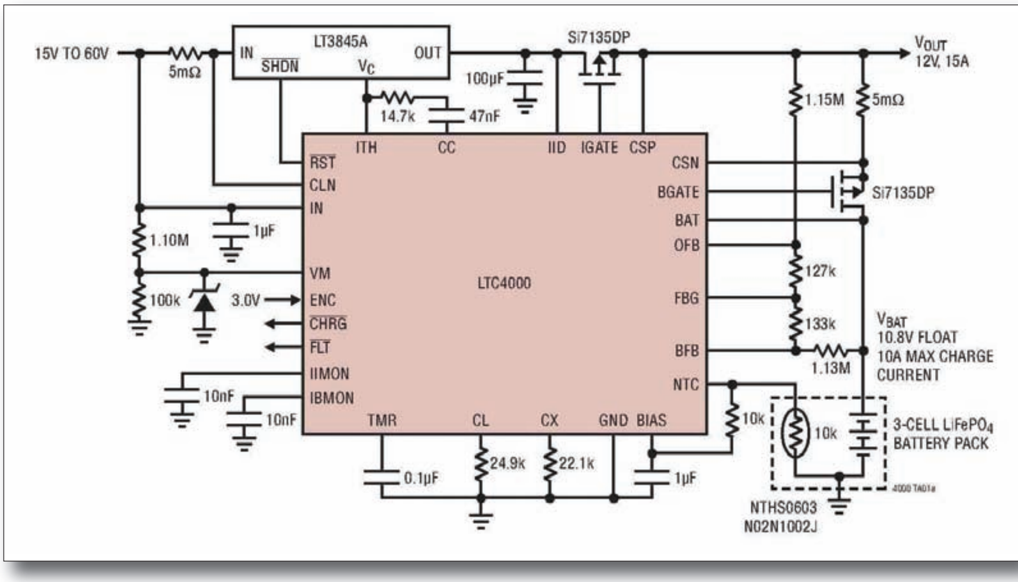

Figure 1: LTC4000 typical application circuit

accurate currents at high efficiency, to work with converters that span the power range from milliwatts to kilowatts.

A variety of battery chemistries including Lithium-ion/polymer/phosphate, sealed lead acid and nickel-based can be charged. The device also provides charge status indicators through its FLT and CHRG pins. Other features of the battery charger include: ±0.25% programmable float voltage, selectable timer or C/X current termination, temperature-qualified charging using an NTC thermistor, automatic recharge, C/10 trickle charge for deeply discharged cells and bad battery detection. The LTC4000 is housed in a low profile (0.75mm) 28-pin 4mm x 5mm QFN package and a 28-lead SSOP package. The device is guaranteed for operation from -40°C to 125°C.

Full control of external DC/DC converter

The LTC4000 requires an externally compensated switching regulator to form a complete battery management solution. System performance will vary based on the type of switching regulator that the LTC4000 is paired with.

The charger IC includes four different regulation loops: input current, charge current, battery float voltage and output voltage (A4-A7), please refer to the block diagram in Figure 2. Whichever loop requires the lowest voltage on the ITH pin for its regulation controls the external DC/DC converter. The input current regulation loop ensures that the

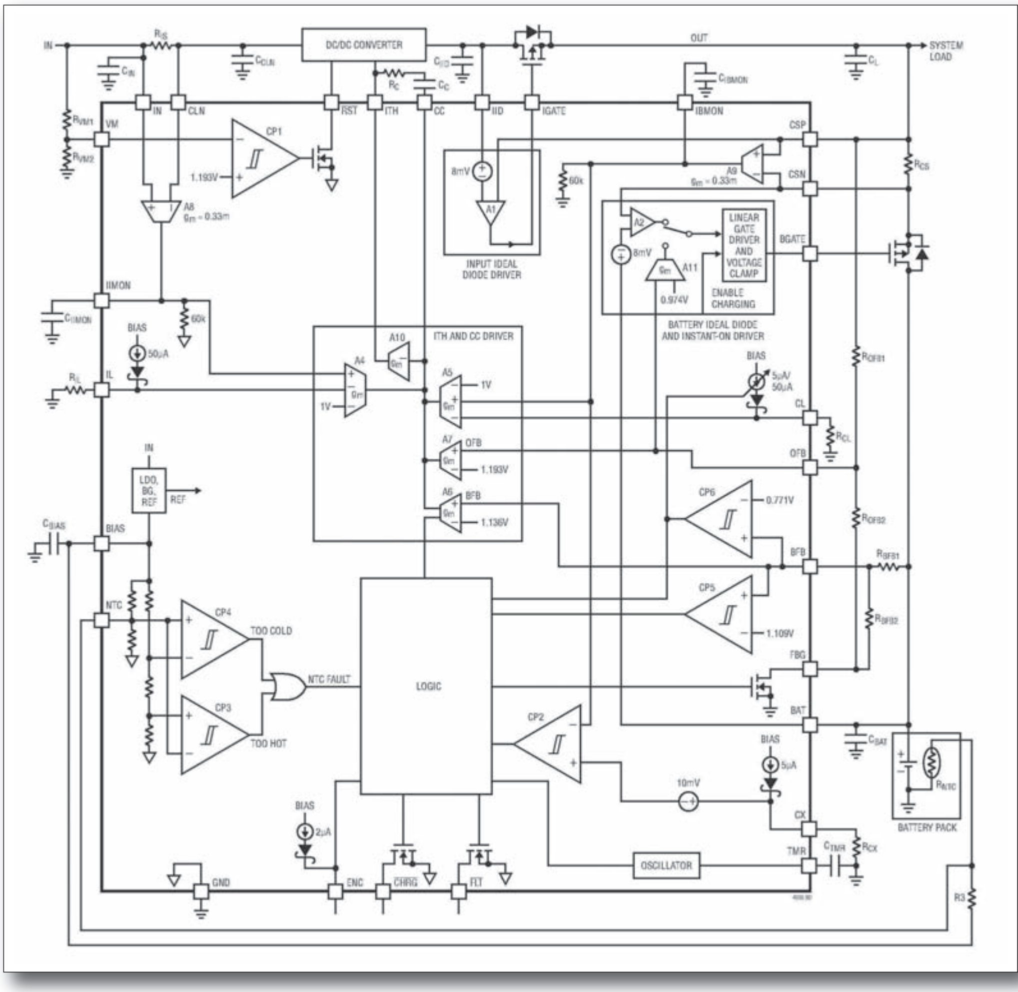

Figure 2: LTC4000 block diagram

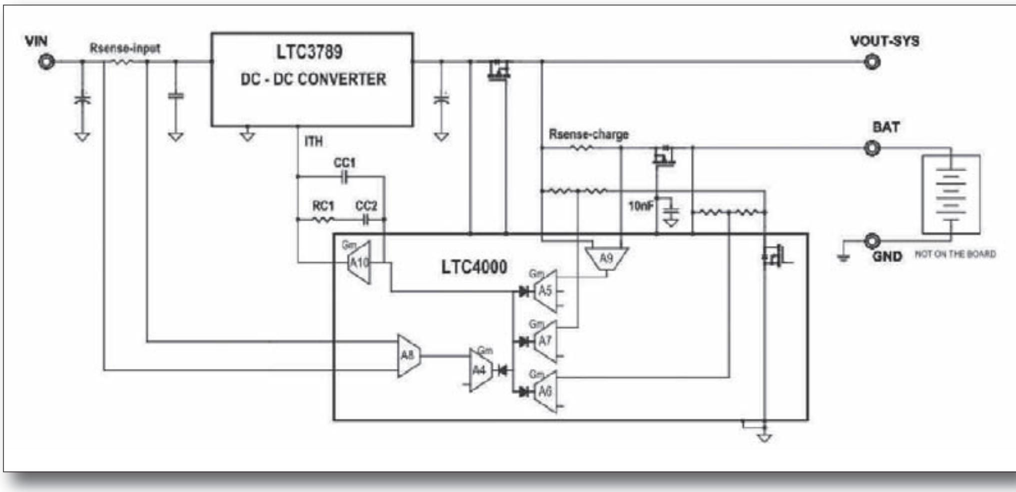

Figure 3: Demo board system block diagram using LTC4000 / LTC3789

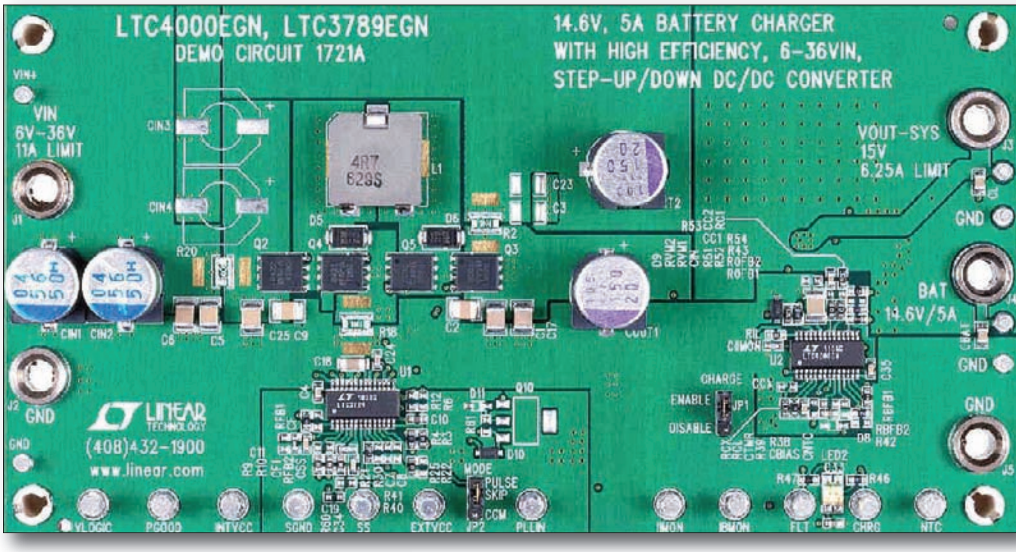

Figure 4: DC1721A demo board

programmed input current limit (using a resistor at IL) is not exceeded at steady state. The charge current regulation loop ensures that the programmed battery charge current limit (using a resistor at CL) is not exceeded.

The float voltage regulation loop ensures that the programmed battery stack voltage (using a resistor divider from BAT to FBG via BFB) is not exceeded. The output voltage regulation loop ensures that the programmed system output voltage (using a resistor divider from CSP to FBG via OFB) is not exceeded. The LTC4000 also provides monitoring pins for the input current and charge current at the IIMON and IBMON pins respectively.

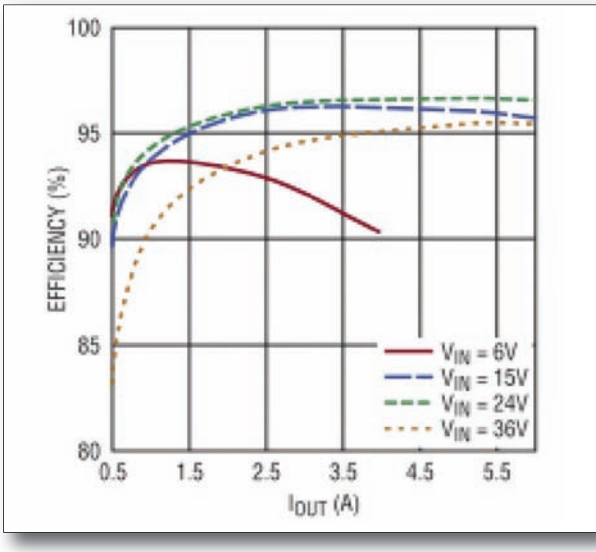

Figure 5: DC1721A efficiency from V_{IN} to V_{OUT_SYS}

Flexible demonstration circuits

The DC1721A-A is a 14.6 V, 5 A battery charger and PowerPath manager with 6 V to 36 V input buck-boost converter featuring the LTC4000/LTC3789, targeted at 4-cell LiFePO4 applications (see Figure 3).

The output of this demo board is specifically tailored for a Tenergy 10 Ah battery. Other voltages can be set by changing external resistors. The desired nominal voltage can be accurately trimmed by using trim resistors. This circuit was designed to demonstrate the high levels of performance, efficiency, and small solution size attainable using these parts in a buck-boost converter battery charger with Intelligent PowerPath manager. It operates at 400 kHz and produces a regulated 5 A/14.6 V battery charger output as well as a system output of up to 6.25 A from an input voltage range of 6 V to 36 V: suitable for a wide variety of portable applications including instruments, industrial equipment, power tools, and computers. It has a total footprint area of 12.4 cm^2 (3.6 cm2 for the LTC4000 circuit only) enabling a very compact solution (see Figure 4). Synchronous rectification helps to attain efficiency exceeding 96% at full load and nominal input (see Figure 5).

For added circuit evaluation and simulation, demonstration circuit DC1830 will soon be released, allowing the LTC4000 board to be interfaced with other compatible DC/DC converter standalone evaluation boards.

Inverting Buck Regulator Saves Space and Power

Designers are periodically faced with the requirement to generate a negative voltage rail in order to provide a bias voltage for applications using sensors which read signals both above and below ground. For many engineers, the first thought will be to use inverting regulated charge pumps: in fact, these are ideal for handheld applications where the output voltage required is less than -5V and the input is typically a lithium-ion battery. In applications that require negative voltages greater than -5V, SEPIC inverters and transformer-based designs can also produce a positive-to-negative voltage conversion, but only at the cost of complexity and a high component count. Now the AS7620 IC helps designers to solve these problems.

Mark Shepherd, Field Applications Engineer, Austriamicrosystems, Unterpremstätten, Austria

Inductor-based switching buck inverters offer the benefits of good efficiency with low component count. Depending on the buck inverter, they can provide high efficiencies over both a wide dynamic load and input range, an area where charge pumps tend to fall down due to their seesaw efficiency curves. The designer must be mindful of the total system power consumption in a scenario in which a -5 V rail must be generated from a 12 V or 24 V system voltage. For instance, a sensor application might require a -5 V bias voltage at a 1-200 mA load range, operating from a 24 V system supply feeding multiple sensors distributed through a building. The designer could connect an inverting charge pump to the 5 V output that has been stepped down from the 24 V system rail to provide the -5 V. The efficiency of such a circuit, however, would be the product of the charge pump's efficiency - typically 70 % - and the efficiency of the step-down regulator - typically 90 %. This gives an overall system efficiency of 63 %. Multiplied across multiple sensors, this loss can add up.

This brings into focus the advantages of implementing an inverting buck regulator circuit, a simple technique that involves exchanging Vout with ground on a buck regulator. Not all buck regulators can be used this way, however, since the inversion of Vout with ground can introduce a right half plane (RHP) zero in its control-to-output transfer function, opening up the regulator to the risk of instability.

Figure 1 shows a -5V negative buck/boost inverter circuit, using the AS7620 positive buck regulator from austriamicrosystems. This IC is specified for a 3.6 V to 32 V input voltage range, uses a 1.2 V feedback voltage and has an internal 500 mA power switch. The switch current is monitored so that the converter always operates in discontinuous current mode (DCM): this means that it is intrinsically stable, and no external compensation circuitry is needed. It also means that it does not have an issue with stability due to the RHP zero, because this only occurs in flyback, boost and Ćuk circuits, and then only in continuous current mode.

As mentioned earlier, by exchanging V_{out} with ground, it is possible to invert the polarity and produce a negative output voltage. Since the circuit topology is now that of a buck/boost circuit, it might in theory seem attractive to use the part in both boost and buck mode. In practice, however, the efficiency of the buck/boost topology when in boost mode barely exceeds 60 %. In buck mode, efficiency is far higher (see Figure 2).

Careful specification of the inverting buck regulator pays dividends in light-load applications in particular. As Figure 2 shows, high efficiency is maintained all the way down to a 1 mA load current, and this is a consequence of the AS7620's low internal quiescent current (37 µA).

Operation of the inverting buck/boost regulator

During the first stage of the switching period, when the switch is on, the inductor is linearly ramped up to store energy (see Figure 1 again). No current passes to the output. In the second stage,

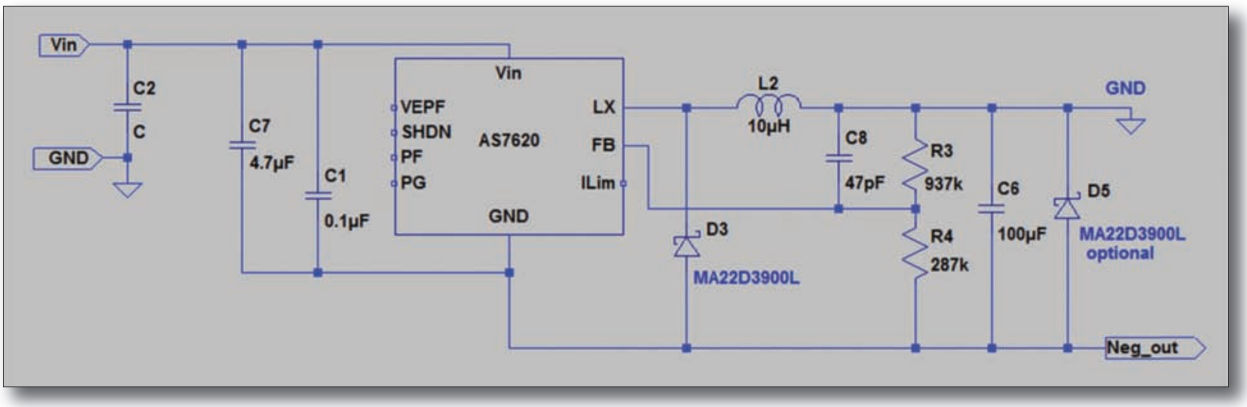

Figure 1: AS7620 connected as a negative buck/boost regulator

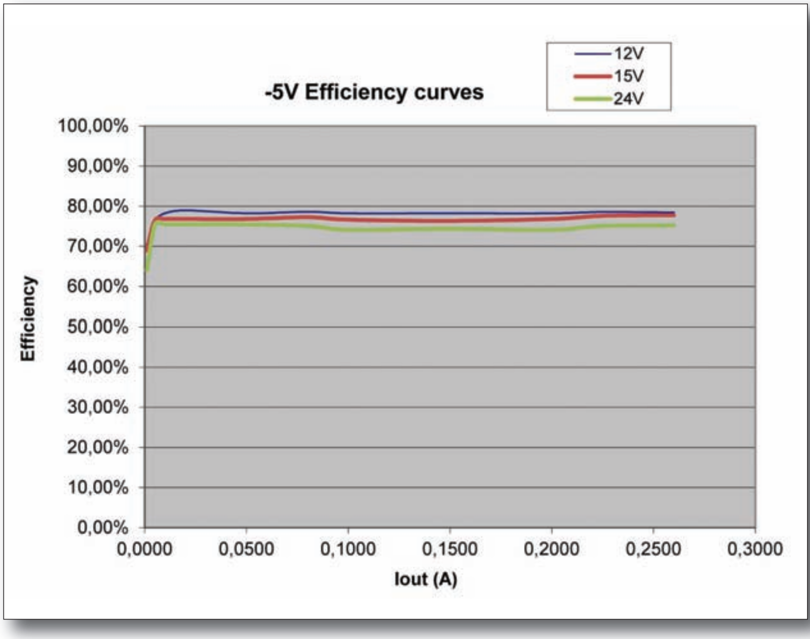

Figure 2: **Efficiency curves of AS7620 in buck mode supplying a -5V output**

when the internal switch in the IC turns off, the inductor will reverse polarity, inducing the freewheeling diode D3 to forward-bias and transfer energy to the load and the output capacitor C6. The only energy to reach the output via the diode is the energy stored in the inductor - none comes directly from the input DC source. The output voltage is negative because the switch node is negative in reference to ground.

This circuit gives rise to a number of characteristics that are not obvious at first glance, and that must be taken into account if the design is to operate effectively.

1) The voltage across the AS7620 is made up not only of V_{in}, but is equal to the input voltage plus the magnitude of the negative output voltage ($V_{in} + |V_{out}|$). Therefore care should be taken to specify an appropriate voltage rating for the input caps (C7 and C1 in Figure 1). In addition, ($V_{in} + |V_{out}|$) must not exceed the maximum voltage rating of the regulator. The AS7620, for instance, has a maximum voltage rating of 40 V. It is feasible to use this part to generate a -12 V output from a +12 V rail, or a -5 V output from a +24 V rail.

2) The switch currents in the buck/boost configuration are necessarily higher than in the buck topology, thus lowering the available output current. The start-up input current of the buck/boost converter is also higher than in the standard buck-mode regulator, and this might overload an input power source that has a current limit set too low. For this reason, the buck/boost circuit employing the AS7620 has an efficiency sweet spot of 1-250 mA at input voltages of 12 V and higher. At voltages below 12 V, the negative output current capability of the part will need to be decreased to 170 mA at most.

3) The circuit's Shutdown pin is left floating. The AS7620 provides an internally regulated pull-up circuit, so the device can be shut down if the SHDN pin is pulled to the GND pin (which is the negative output voltage). Since the GND pin of the AS7620 is the negative output voltage in an inverting application, it will be necessary to use a level-shifting circuit, connected to an open drain, to shut the part down. If Shutdown is not used, the pin should be left floating, and no trace should be connected to it in order to minimise noise injection.

4) The current coming from the input capacitor will be choppy because of the switching operation of the internal FET, so care should be taken to provide enough input capacitance; 4.7-10 µF is sufficient.

The output current will also be choppy because of the diode current transitions.

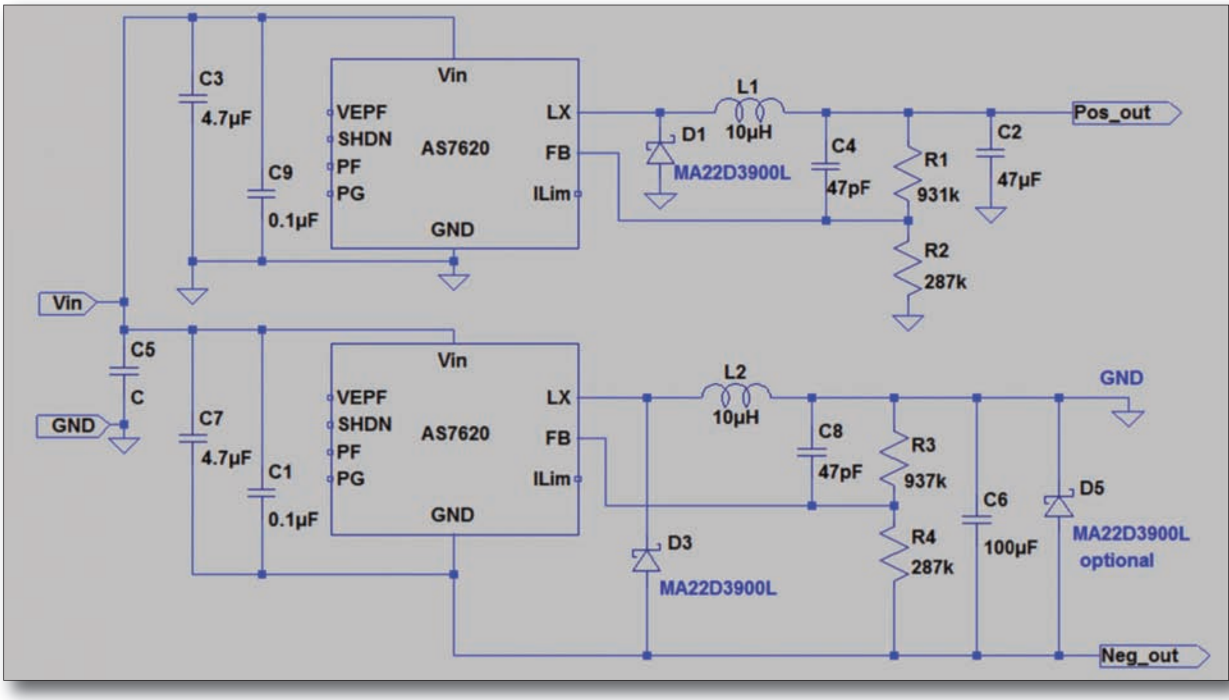

Figure 3: **Two AS7620 buck regulators configured as a positive 5 V/500 mA regulator and a -5 V/250 mA regulator**

So for noise-sensitive applications, additional filtering with a negative low drop-out regulator might be necessary.

Example of a working circuit

Figure 3 shows an example of a tested circuit for providing positive and negative 5 V output rails from a 12-24V supply. The positive 5 V output could generate up to 500 mA, while the -5 V output could safely provide a 250 mA output current while maintaining high efficiency.

When voltage is first applied to this circuit, the negative V_{out} rail will momentarily start to rise by a few hundred mV in the first 10 µs or so, due to the action of the input capacitor. The magnitude of the positive rise on the negative rail will be a function of the size of the input capacitor; an optional Schottky diode across the output (D5 in Figure 3) can be added to clamp this voltage to below 300 mV. The output of this circuit is shown in Figures 4 and 5.

Design resources for implementing an inverting buck regulator circuit using the AS7620, including a datasheet with guidance on best layout practice, and information about a useful evaluation board, can be found at austriamicrosystem's website.

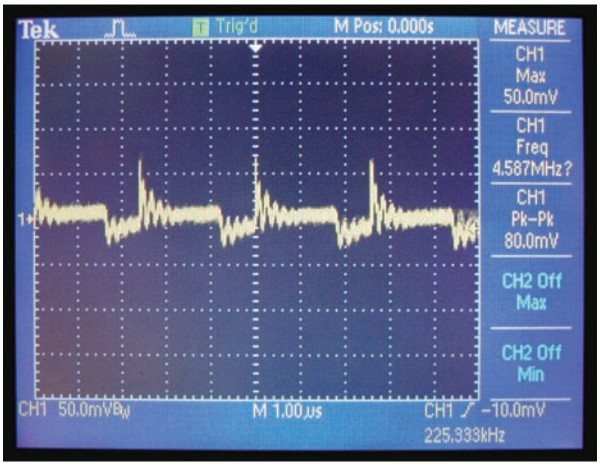

Figure 4: Steady state output voltage with 80 mVpp ripple

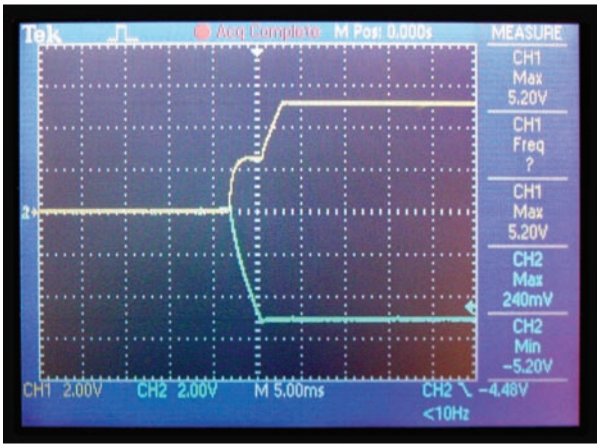

Figure 5: Start-up waveform for the +5 V and -5 V rails

Unique Probe Measures Current in PCB Tracks

Observation and measurement of current in printed circuit board (PCB) tracks has always presented major difficulties. The only practicable way of doing it has been to cut the track and insert either a current shunt, or a loop of wire large enough to attach a conventional closed-loop current probe. In modern high density circuit designs this is normally impracticable. A new type of probe measures the current by placing the insulated tip of the probe directly onto the PCB track without any need to cut it or to surround it by a magnetic loop. **Mark Edwards, Aim-TTi, Huntingdon, Cambridgeshire, UK**

Measuring current in a PCB track presents particular difficulties because it is normally not possible either to break the track or to enclose it within a magnetic circuit. Typically engineers have to guess at the current flowing in a track from voltage measurements made in other parts of the circuit. As electronic design moves towards ever higher densities, development omits the "bread board" stage and goes straight to PCB design. The inability to observe and measure currents in a circuit under development can pose a serious problem for engineers.

Conventional current measurement techniques

True measurement of current requires the circuit to be broken and a current measurement device inserted (e.g. a shunt that converts current to voltage). Conventional DC capable current probes do not measure current, they measure field density. Current flowing through a conductor creates a magnetic (H) field which is directly proportional to the current. If a conductor is surrounded by a closed magnetic circuit the whole of the field is 'captured' by the magnetic circuit and the field density can be scaled to represent current.

Conventional current probes achieve this by concentrating the field into a gap within a loop of high magnetic permeability (Mu) material. The field is then measured by a field sensor inserted into the gap, often a Hall effect device. Alternatively AC current can be measured by transformer action whereby the loop of magnetic material creates a one turn primary from the conductor that is enclosed. Hybrid devices use a field sensor for DC and low frequencies plus a transformer for higher frequencies.

Normally the probe provides a method of mechanically splitting the magnetic circuit to enable the conductor to be inserted. The position of the conductor within the loop has relatively little effect upon the measurement, and a high rejection of external fields can be achieved.

Principle of a positional current probe

To make a quantitative measurement of current from the field that it generates requires that a known proportion of that field is measured. As explained earlier, conventional current probes achieve this by concentrating the whole of the field within a loop of high Mu material, and measuring using transformer action or a field sensor within a gap.

By contrast, the positional current probe, measures a known proportion of the field by positioning the sensor at a known distance from the conductor. This provides the potential to provide a calibrated measurement of current (see Figure 1). However, to be useable with a PCB track, the size of the sensor must be very small as must its distance from the conductor.

Previous positional current probes have been physically large, capable only of measuring high currents at low bandwidth, and totally unsuited to use in the high densities of modern electronic circuits.

The I-prober 520 uses the long

Figure 1: New current probes allow for direct current measurement up to 20 A in PCB tracks of power supplies

Figure 2: Miniature fluxgate magnetometer for the I-prober 520

established principle of a fluxgate magnetometer to measure field. This type of magnetometer uses a magnetically susceptible core surrounded by a coil carrying an AC excitation current which magnetises the core alternately in opposite directions. If there is no external magnetic field, this magnetisation is symmetrical. When an external field is applied, the resulting asymmetry is detected by a feedback loop which applies an opposing current through the coil to restore the net field to zero. The output voltage is proportional to this opposing current, and therefore to the magnitude of the field.

Conventional fluxgate magnetometers are relatively large with bandwidths of a few kHz. They are typically used for precision measurement of fields within geophysics and bio-electromagnetics. By contrast, the sensor within the I-prober 520 uses a patented miniature fluxgate magnetometer of sub-millimetre size incorporating a highly advanced core material (see Figure 2). This enables it to use an excitation frequency of several tens of MHz resulting in a sensor with a bandwidth of DC to 5 MHz combined with low noise and wide dynamic range.

This miniature sensor is fitted within a double insulated probe tip (see Figure 3) which is just 1.8 mm wide with the sensor spaced 0.7 mm from the surface of the tip. Because the field reduces with the square of the distance (to a first order approximation), this spacing is critical to the operation of the probe giving it both high sensitivity and reduced susceptibility to fields from adjacent conductors. In consequence, the Aim I-prober 520 is the first and only probe that can be used to measure currents from amps (20 A) down to milliamps (20 mA) at frequencies from DC up to 5 MHz, making practical measurement of PCB track currents a reality.

The I-prober 520 in use

The magnitude of the signal from a positional current probe (see Figure 4) is critically related to its position relative to the conductor. The size of the conductor (e.g. the width of a PCB track) also has a significant effect.

This means that the sensitivity of the I-prober has to be adjusted to match the track width when quantitative measurements are required. A calibrator within the control box enables sensitivity adjustment in conjunction with a calibration graph. The output from the control box is scaled to 1 V per A and is intended for connection to a conventional oscilloscope.

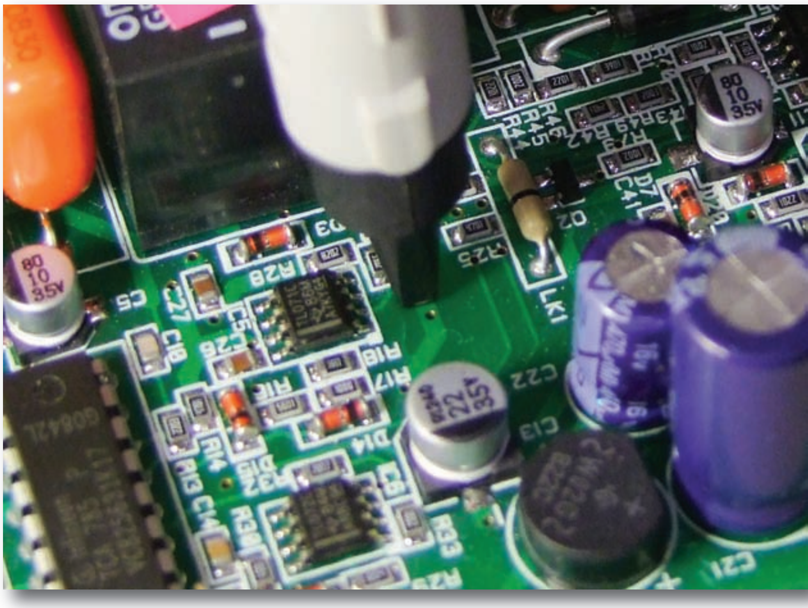

Figure 3: Probe tip which is just 1.8 mm wide in use

The measurement result will also include other field effects present at the tip of the probe and not just that coming from the current through the conductor. This may include DC effects from adjacent magnetised components and from the earths magnetic field, plus AC effects from transformers and other field radiating sources. Current in adjacent tracks, or tracks on the opposite side of the PCB will also affect the measurement.

There are potential solutions to these problems. The unwanted DC can be nulled out by observing the measurement without power to the circuit, whilst AC interference can be attenuated using bandwidth filters. The I-prober control box includes a wide range DC offset control and switchable filters.

Nevertheless, the use of the I-prober 520 requires interpretation based upon a proper understanding of circuits and systems, and is a tool for the professional engineer.

A useful analogy might be with an ultrasound probe. Whereas the layman will just see a blur of indeterminate images, the skilled professional can use it to make valuable qualitative and quantitative measurements. Similarly the experienced user can learn the techniques needed to distinguish the wanted from the unwanted and make observations and measurements that were previously impossible.

The probe bandwidth of DC to 5 MHz encompasses a wide range of applications including most power switching circuits. The maximum current that can be measured is 20 Apk-pk in a track of up to 3.5 mm, or 40 Apk-pk in a wider track. The minimum visible current is limited by the noise figure which, for a 0.5 mm track, is equivalent to around 6 mArms at full bandwidth reducing to 1.5 mA at lower bandwidths. In practise this enables AC signals as low as 10 mApk-pk to be usefully observed.

It should be understood, however, that accurate measurement of very small DC currents is likely to be impracticable in most situations. The effect of the earths magnetic field is equivalent to up to 180 mA flowing through a 0.5 mm track. Whereas this can be nulled out within the control box, the effects of small changes in orientation can cause variations that would invalidate mA level measurements. Similarly the effect of magnetised components and high Mu materials close to the probe can cause significant offsets.

One of the most interesting applications

Figure 4: **Clip-on toroid assembly for measuring current in a wire**

of the I-prober is the observation of currents flowing within ground planes. Whereas quantitative measurements are not possible (because the current density can not be inferred) it is easy to see whether and where circulating currents are flowing and to find their injection points. Many circuit designs are adversely affected by power and ground connecti on schemes which fail to provide a true zero impedance connection allowing unexpected interfering signals to appear.

Further measurement modes

Whereas the primary purpose of the I-prober 520 is as a positional current probe, there are many circumstances where current measurements can be made in the conventional way by enclosing the conductor. To increase its overall usefulness, the I-prober 520 is supplied with a clip-on toroid assembly (Figure 4) which converts it into a closed magnetic circuit probe for measuring current in a wire (Figure 5). The wide bandwidth, dynamic range and low noise of the probe are retained but higher accuracy; repeatability and unwanted field rejection are achieved.

The very small size of the field sensor within the I-prober 520 gives it some unique capabilities when used to measure magnetic fields. The variation of field with position can be accurately determined enabling the precise source of fields to be located and their variation in space measured A switch on the control box re-scales the output voltage to measure in Teslas or in amps per metre.

Figure 5: **Measuring wire current**

Three-Phase Bridge Driver IC

Based on Intersil's HIP4086 N-channel MOSFET driver IC, the new HIP4086A integrates three half-bridge gate drivers in one package that can replace larger discrete circuits. It drives 1000 pF loads, and rise time is only 50 ns (maximum over temperature). The six N-channel MOSFET drivers can be driven independently so users can configure any switch combination and use the HIP4086A either in brushless DC (BLDC) or switched reluctance motors. The HIP4086A requires no gate drive charge pump, improving EMI performance. Programmable dead time of 0.25 to 4.5 µs avoids cross-conduction or 'shoot-through' current, also helping reduce EMI. Other configurable features include programmable UVLO, bootstrap refresh, an optional charge pump (available in the HIP4086ABZ and HIP4086APZ versions) and a disable input override feature - all programmable using small external components. The HIP4086A is built using a TS16949 automotive quality level process in a TS16949-qualified fabrication facility. It is suited for battery-powered tools, light electric vehicles and consumer products.

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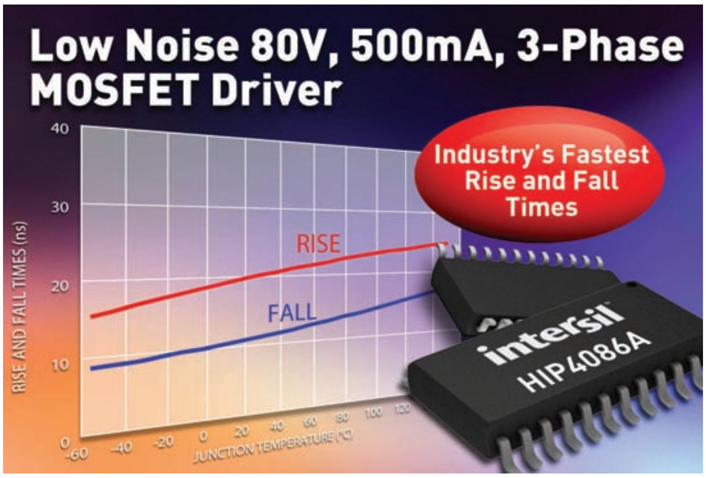

Small Hermetic Surface Mount Package for Transistors and Diodes

Microsemi introduced the industry's smallest hermetic surface mount package for power transistors and diodes. The new industry-standard U4 package has achieved Defense Logistics Agency (DLA) qualification for a range of products. The devices assembled as vehicles for this package qualification included medium power NPN and PNP bipolar transistors. Microsemi will also pursue qualifications for additional device types to support customer-specific requirements. The compact U4 is 70 % smaller than its U3 predecessor and is constructed with aluminum nitride ceramic, which provides excellent heat dissipation. This is particularly important for small products such as power supplies, converters and regulators which operate at high current rates that can cause overheating issues. The U4 has a typical power rating of 5 to 15 W (case temperature 25°C). Packaged parts are compatible with current pick-and-place assembly processes and are offered in tape-and-reel format.

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SJ HV MOSFETs

Vishay released a new series of 600 V and 650 V N-channel power MOSFETs with maximum on-resistance from 64 mΩ to 190 mΩ at 10 V and with a wide range of current ratings from 22 A to 47 A. Based on Vishay's next generation of Super Junction Technology, the E Series MOSFETs offer ultra-low gate charge and low gate charge times on-resistance, a key figure of merit (FOM) for MOSFETs used in power conversion applications. With the new E Series technology, on-resistance is reduced by 30 % compared with previous-generation S Series devices. Depending on the application, these products can deliver higher power density and achieve new levels of efficiency. Gate drive losses are also reduced due to the lower input capacitance. The twelve new E Series devices include four 22 A MOSFETs and four 30 A MOSFETs with on-resistance of 190 mΩ and 125 mΩ, respectively, at 10 V. The 22 A and 30 A MOSFETs are available in the TO-220, TO-220 FullPAK, TO-247, and TO-263 (D^2PAK) packages. In addition, one 47 A device with on-resistance of 64 mΩ at 10 V is offered in the TO-247, and a 24 A, 650 V MOSFET with an on-resistance of 150 mΩ is offered in the TO-220, TO-263 (D2PAK), and TO-247 packages. The MOSFETs are compliant to RoHS Directive 2002/95/EC.

www.vishay.com

Tantalum Stack Polymer Capacitors

KEMET has introduced new Tantalum Stack Polymer (TSP) Series capacitors. The TSP Series is the first stack solution that utilises organic conductive polymer as the cathode plate of the capacitor. The TSP Series is targeted at applications requiring high capacitance and very low ESR, but with limited board space. The new TSP Series surface mountable devices can be specified with a variety of capacitance and performance characteristics by stacking two, three, four, or six standard EIA case size discrete components into just one device, resulting in high capacitance, very low ESR and high ripple current capability in a single footprint, which makes them an ideal solution for power supplies. Capacitance values range from 66 to 4080 µF, voltage from 3 to 35 VDC with operating temperature range of -55 to +125°C.

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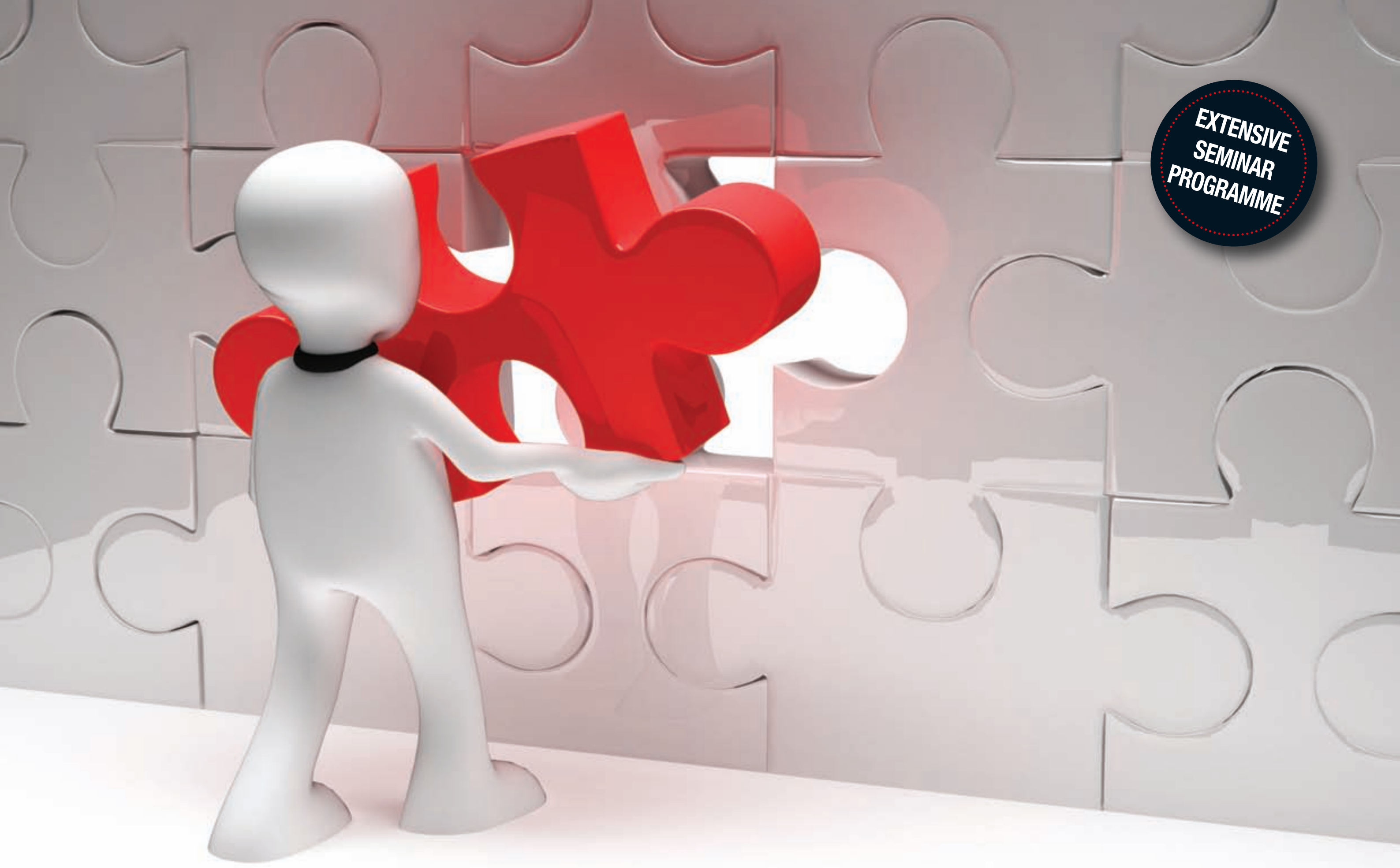

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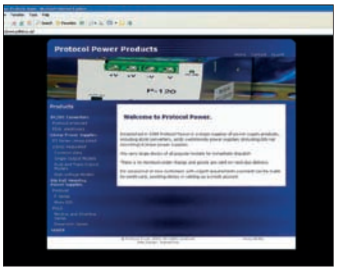

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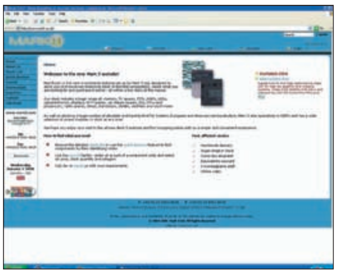

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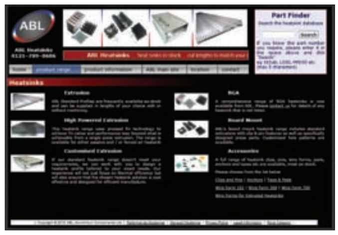

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	SOT-23	24	41	IRFML8244
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