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2009 Year of Energy Efficiency

Global semiconductor industry revenue is expected to rise to $280.1 billion this year, up 3.5% from $270.6 billion in 2007. Signs appeared in September that the semiconductor market may be feeling the impact of the credit crisis and economic downturn. Will the financial crisis have the same impact as the 2001 slowdown? This was triggered by a simultaneous collapse of the dot-com inflated demand euphoria, the 9-11 driven economic slowdown and a massive inventory burn just as a huge amount of excess capacity was coming on stream. Everything that could have gone wrong did go wrong, the so-called perfect storm. This time around, aside from the economy, all the other underlying industry trends are good. Inventories are not seriously bloated, wafer fab capacity utilisation levels are high, capital expenditure is very low and decreasing. All of these factors will help cushion the economic slowdown, analysts say.

But Electronica 2008 attracted around 2,800 exhibitors and 73,000 trade visitors, that were roughly the same numbers as in 2006. As expected, there was a great deal of discussion in the exhibition halls regarding economic developments over the last few weeks and months. Exhibitors and visitors are expecting a downturn in this cyclic business and the economy in general during next year. Green electronics and automobile electronics were among the most important topics, including technologies and solutions for increasing energy efficiency of electronic devices and for power-saving applications, but also energy generation components and systems which conserve resources.

The basics for power electronics are promising, even in the near term. The market for power supply solutions is enormous since, ultimately, no electrically driven system can be operated without power. Market researchers are anticipating an annual growth rate of 10% alone for integrated circuits (ICs) used in power supply systems during the next five years. In particular, the rising demand in the area of consumer electronics, the increasingly complex design of power management systems and growing interest in energy-efficient products will catapult the world market for voltage-regulating systems to a volume of $15 billion by 2011. In the area of complete systems, the submarket for uninterruptible power supply systems actually grew by 20% last year. The global volume currently amounts to around $7.4 billion. High-performance electronics for solar electricity generation is placing increasingly higher demands on suppliers of high-performance electronics in regard to power density, efficiency, lowest possible footprint, and reliability. The market for photovoltaics is currently experiencing growth rates of between 30 and 50%. In 2007 alone, solar systems with a total output of between 3 and 4GW were installed. The total capacity of the systems installed throughout the world (2007) corresponds to 10GW. One interesting subaspect: around 40 different types of power supply ICs are used to convert solar energy into electricity. They include, in particular, ICs with low-frequency converters (50 or 60Hz), high-frequency converters (16 to 100kHz) and transformer-less ICs. Transformer-less ICs attain an efficiency of 97% (with bipolar switching) or 98% (with unipolar switching) whereas low-frequency and high-frequency converters have a maximum efficiency of up to 95%. The future standard target will be at least 98%. The trend among high-performance semiconductors in solar electricity generation is also towards the replacement of the traditional basic material of silicon by silicon carbide (SiC) and gallium nitride (GaN) for the benefit of reduced on-resistance and lower conduction voltage drop. Looking forward, this will also be a subject at next year's PCIM, where PEE will host a special session on these new materials and power devices.

From 25 to 27 November 2008, the electric automation industry also met in Nuremberg. At SPS/IPC/DRIVES 1,386 companies (2007: 1,321) showed their range of electric automation to the 48,100 (+2100) trade visitors. No sign of crisis! Some power electronic companies, such as Avago, Infineon, Mitsubishi and Semikron, took the chance to exhibit among their customer base. As with Electronica 2008, energy efficiency was a key topic, but at a higher level. Trade and industry require electrical drives worldwide. Motor-driven systems consume about 70% of all electricity used in industry. Here, there is also great potential for improved efficiencies. Only about 12% of the motor capacity installed in Germany today is operated with energy-saving electronic speed controls. It is estimated, however, that it would be beneficial for over 50% of this motor capacity to be equipped with electronic speed control. Efficiency is much more than saving energy through energy-efficient components such as motors and converters. According to Siemens' numbers within 20 years energy costs account for up to 99% of a motor's lifecycle cost. With innovative drives energy savings of 40% can be realised, leading to savings potential of 43TWh/a equivalent of €3 billion and a payback time of 12 to 18 month per drive. Here, the higher power electronics will play a major part. Thus, the 2009 prospects for our industry look good.

Achim Scharf
PEE Editor

Sustained Growth for Major PE Applications Expected

After several excellent years, with a strong expansion for European engineering, prospects for the coming year are somewhat bleak. Apart from the expected and usual cyclical slowdown that started in the last year, the recent global financial turbulence is beginning to have an impact on the demand of both capital goods and consumer durables manufactured by the industry, and this situation has implications for power electronics as well.

The European machinery and equipment industry has benefited from several years of strong worldwide demand for investment goods and, as a result, growth has been impressive. Unfortunately, 2008 has seen a drop in this growth and in demand. The production volume is expected to grow by a 'mere' 4.5% in 2008, a figure that is nearly half that of the year before. Strong extra-EU exports growth of 7.8% is expected in 2008, with intra trade volumes also growing briskly by about 6%. A number of sectors of machinery are still doing well at present, especially agricultural machinery and machine tools. Lower growth or even contraction in 2008 has, however, affected other sectors of the machinery industry, which is a reflection of low or even declining growth in other parts of manufacturing industry.

Activity in the machinery sector is expected to continue to slow down in 2009. The investment outlook in the engineering industry itself is not positive: many key customers and key industries that are important for the sector have invested heavily in the past three years, and a cyclical slowdown is therefore considered as inevitable. Moreover, the financial turbulence that has arisen over recent months is beginning to limit access to credit, with banks still showing signs of hesitation to provide credit, in spite of the massive injections of liquidity into the financial system. The drop in stock prices, lower capacity utilisation in many customer industries, and the uncertainties in the investment climate in Europe have led to undermining industrial confidence and therefore to the outlook for the investment goods industry. The volume of production for the European machinery sector is, therefore, expected to grow at a very low rate in 2009 by some 0.6%. However, a contraction in output next year cannot be ruled out completely, in spite of sustained demand outside the EU leading to an expected growth in extra trade of some 4.8%.

Preliminary growth forecasts for electrical, instrument and ICT engineering in 2008 are expected to reach some 3.5%. This is lower than the year before. The reason for the slowdown in the sector, as a whole, is mainly the contribution from the telecommunication sector, where growth of output is expected to decrease. With falling prices in this sector, turnover has been affected negatively. On the other hand, the sub-sector of electronic components has grown briskly, as has the office equipment and computers sector. Growth of traditional electrical machinery and apparatus has continued at the healthy pace that started in early 2006. Sub sectors in electrical machinery and apparatus such as traditional generators, motors and transformers, and distribution and control apparatus are showing signs of sustained growth. This is, however, not the case for the wire and cables, accumulators and lighting equipment which have seen signs of a sharp contraction in 2008.

Prospects for 2009 are still rather positive for the sector as a whole, and volume of production is expected to expand further, but falling slightly compared to 2008 or to a growth rate of 2,1%.

"It is high time that that the European institutions and national governments appreciate the fundamental contribution that our industry - the EU's major manufacturing sector - provides to the European economy. The goods and services that our companies provide create real jobs and real wealth: this is particularly important at a time when the financial sector has shown its limitations, and is no longer providing the support that the economy, including manufacturing industry, has come to expect of it", comments Orgalime's president, Robert Mahler. Orgalime is the European Engineering Industries Association representing some 130,000 companies in the mechanical, electrical, electronic and metalworking industries of 22 European countries.

www.orgalime.org

Shipments of Low-Power UPS to Exceed $6 Billion in 2012

In a recently published multi-volume study 2008 Power Protection Analysis, VDC Research Group found that worldwide shipments of 20kVA and under UPS were $4.0 billion in 2007 and will reach $6.1 billion in 2012.

As small- and medium-sized businesses continue to upgrade their IT infrastructure to include voice over IP, wireless LANs and server-based applications, VDC expects shipments of UPS in the 10 to 20kVA segment to outpace the rest of segment. "Due to the key role IT plays in day-to-day operations, business owners look for back-up power solutions that are reliable, easy to maintain and, at the same time, offer the best performance for their investment", said Analyst Brian Greenberg.

VDC's coverage of the 20kVA and under UPS market also includes lower power UPSs used in homes and small offices.

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Chip Market in Eleventh Industry Recession

Despite the fact the first half of 2008 was stronger than many predicted, the relentless deterioration in the global financial markets has finally tipped the global economy into recession. Not surprisingly, it has taken the chip market with it says Malcolm Penn, CEO of industry analyst house Future Horizons, in the November report.

"We now expect Q4-08 to be down 6% on Q3-08, making 2008's growth just 2.2% on 2007 - the fourth consecutive year of single digit market value growth. Staring a global economic recession in the face, a chip market contraction in 2009 is unavoidable; the only big question is how bad will it be? The concern on everyone's mind is if 2009 will be a re-run of 2001?" stated Penn. The 2001 slowdown was triggered by a simultaneous collapse of the dot-com inflated demand euphoria, the 9-11 driven economic slowdown and a massive inventory burn, just as a huge amount of excess capacity was coming on stream. Everything that could have gone wrong did go wrong, the so-called perfect storm. This time around, aside from the economy, all the other underlying industry trends are good. Inventories are not seriously bloated, wafer fab capacity utilisation levels are high, capital expenditure is very low and decreasing. All of these factors will help cushion the economic slowdown. "That said, we expect the first half of 2009 to be bad, down 8.7% on the second half of 2008, with the recovery starting to kick in Q3-09, making the full year's market down just 2% on 2008. 2010 should then see a strong market rebound, driven by seasonality and the green shoots of a recovering world economy", Penn continued. He further reasons that because the 2011 improving economic momentum will be taking place against a parallel capacity undershoot, it is highly likely that 2011-12 will be the next industry double-digit growth years.

www.futurehorizons.com

CamSemi Ships 10 Millionth Chip for Power Supplies

UK-based CamSemi announced at the end of October the shipment of its 10 millionth C2470 RDFC controller chip, confirming that the company's breakthrough approach for low cost, more energy-efficient power supplies is now being rapidly adopted by major manufacturers. "Our shipping of 10 million units is a strong endorsement for our first product family, our unique power supply topology and our overall approach. We have secured major wins from multiple manufacturers and their customers in some of the market's fastest growing sectors such as network adapters and set-top boxes. Although initially most of the interest was from Greater China, we are now getting design-wins with major European and US brands and have started shipping into Japan", said John Miller, VP of sales at CamSemi.

The company's C2470 family of controllers and Resonant Discontinuous Forward Converter (RDFC) topology was launched in late 2007 to help manufacturers replace bulky embedded or external linear power supplies with low cost, energy-efficient alternatives. This innovative approach offers the performance of premium-priced switched-mode topologies, but at the price of a linear or less. Previously, manufacturers would have had no choice but to accept the cost penalty in using flyback SMPS designs in order to meet the Energy Star V2 regulations that come into force next month. Whereas, with CamSemi's new topology, they can substitute linears in consumer applications rated up to 60W with solutions that are lower cost, simpler and offering very low levels of EMI. The C2470 family of RDFC controllers is also suited for manufacturers targeting maximum energy-efficiency at minimum cost.

www.camsemi.com

Embedded DC/DC Converters are Poised for Growth

The tenth Edition of Darnell's 'Worldwide DC-DC Converter Modules and ICs Forecasts' quantifies the changes that are occurring in the market. This analysis finds slowing growth, even shrinking markets, for various categories of DC/DC converter modules and identifies growing opportunities for makers of embedded DC/DC converter components.

One of the primary factors driving change in the DC/DC market has been the growing number of power rails in a typical piece of electronic equipment. For example, there are about 20 in mid-range servers, 30 in high-end servers, and 40 or more in an Ethernet router, each with a dedicated DC/DC converter. This represents a dramatic increase in the need for distributed DC/DC converters in many systems. "While this sounds like good news for makers of DC/DC converters, it is just the opposite", stated Jeff Shepard, president of Darnell Group. "System makers always have a power budget, the percentage of the system cost that can go to powering it. Let's say the power budget is 8%. This doesn't change just because the number of voltage rails has increased. If the number of rails doubles, the power budget does not. The cost of power has to be cut in half just to stay within budget". Since it is not generally possible to cut the cost of DC/DC converter modules by 50%, the solution has been the replacement of almost all modules in high-end equipment with so-called embedded solutions. The emergence of integrated DC/DC components such as DrMOS devices and improved on-line DC/DC converter design software tools from power semiconductor makers have been two of the major developments enabling the replacement of converter modules with embedded designs.

Application dynamics are also playing a key role in the evolution of the DC/DC converter module market. Darnell Group has identified several significant segments in the Communications, Industrial, Medical and Aerospace segments that present significant growth opportunities for such modules.

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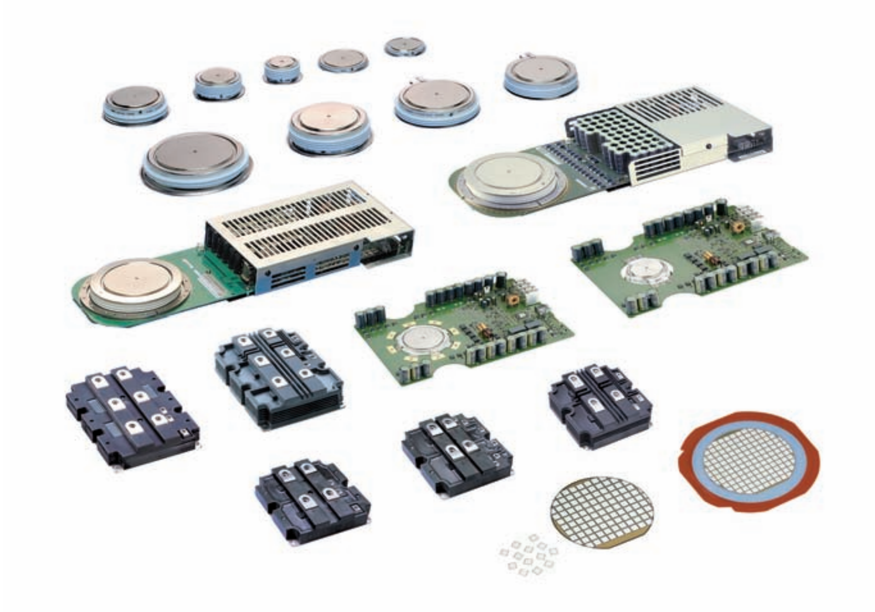

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Fuji Electric and Semikron Team Up

Fuji Electric Device Technology Co., Ltd. of Japan and Semikron International GmbH of Germany signed a supply and licence agreement in November 2008. Fuji Electric will supply IGBT semiconductor chips; in return Semikron will supply Fuji Electric with freewheeling and rectifier diode chips, and module cases in spring contact technology. Power modules with spring contacts will be manufactured by Fuji Electric under licence.

Fuji is a global manufacturer of power semiconductor components ranking in position three in terms of worldwide IGBT module supplier market share, while Semikron is a market leader for diodes and thyristor modules with a 37% market share (Source: Worldwide market for power semiconductor discretes and modules 2008, IMS-Research). Under this co-operation, the two companies are forging the basis for mutual supply of power semiconductor chips. With the new freewheeling diode and rectifier diode chips from SEMIKRON and the IGBT chips from Fuji Electric, both companies are expanding their product range to offer customers the optimum chip/module combination for a given application. By using the same spring contact technology, both companies are able to increase the market penetration for industrial drives, power supplies and home appliances. This matches the second source policy of customers. "This venture opens up new horizons for both parties. The MiniSKiiP and SEMiX concept, which allows for solder-free connection to the controller, reduces the production costs incurred in inverter production", states Dirk Heidenreich (left), CEO of Semikron International. "With modules in spring contact technology, we will be able to conquer new segments in the power electronics market, not only for industrial drives, but also for power supplies and home appliances", added Dr. Hisao Shigekane, President and Representative Director of Fuji Electric Device Technology.

Spring contacts allow for electrical connection without the use of solders. No solders, in turn, means no aging in solder joints. Spring contacts are therefore highly resistant to shock, vibration and corrosion, and boast excellent thermal cycling properties, even in harsh ambient conditions. The controller can be easily screwed onto the module, as electrical connection is established through the pressure applied by the spring contacts.

www.fujielectric.com/device/semi
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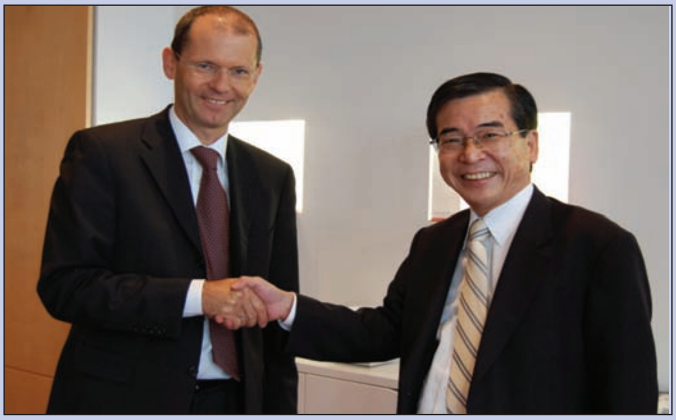

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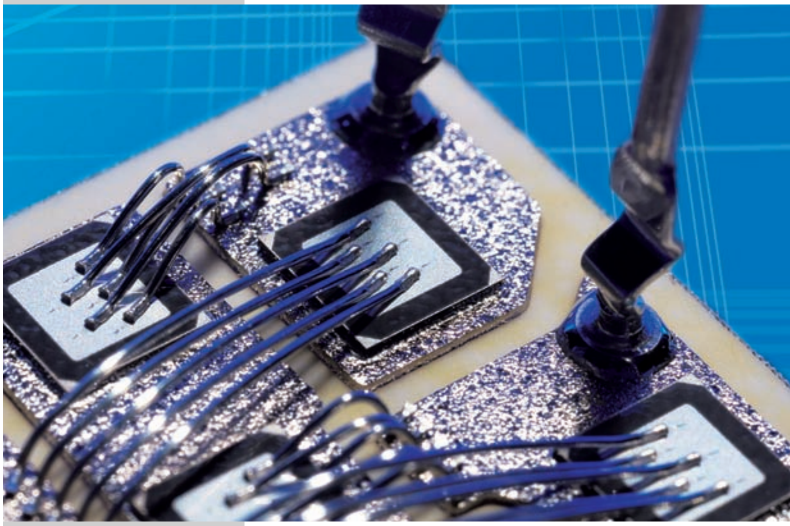

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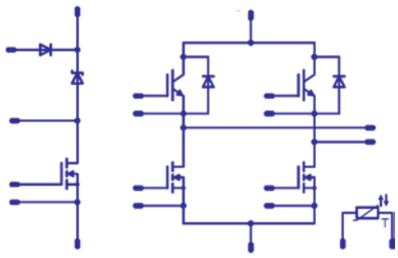

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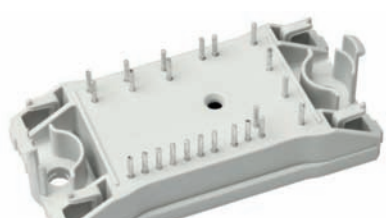

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Green Electronics for a Better Place

Electronica 2008 attracted around 2,800 exhibitors and 73,000 trade visitors. As expected, there was a great deal of discussion in the exhibition halls regarding economic developments over the last few weeks and months. Exhibitors and visitors are expecting a downturn in this cyclic business and the economy in general during next year.

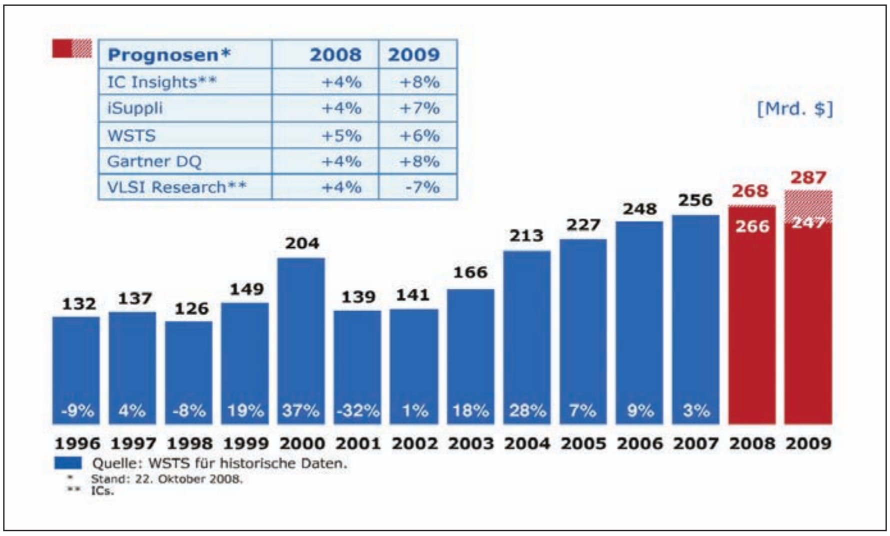
The CEOs of leading semiconductor manufacturers discussed the problems and opportunities of their industry – with energy savings as an ultimate goal in the short and near-term Photo: MMG

According to the German Industry Association ZVEI Electronic Components and Systems, the German market for electronic components will decline in 2008 by 4% down to €16.4 billion, after -1.4% in 2007. For the year 2009 ZVEI expects a further slowdown in the range of 1%. The decline is mainly due to semiconductors (-8%) which have a share of 60% of the overall components market. For the EMEA markets, ZVEI predicts a decline of 5% down to €48 billion and in 2009, a further decline of 0.5%.

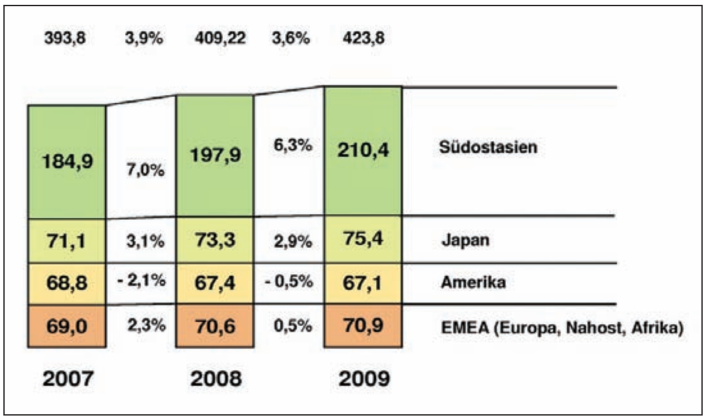
Green electronics and automobile electronics were among the most important topics, including technologies and solutions for increasing energy efficiency of electronic devices and for power-saving applications, but also energy generation components and systems which conserve resources.

CEOs demand energy savings

Environmental protection was also the focal point of the traditional CEO Round Table. Under the chairmanship of Jürgen Gromer, the former President of Tyco Electronics, the CEOs of Infineon Technologies (Peter Bauer, left in picture), Freescale Semiconductor (Rich Beyer), STMicroelectronics (Carlo Bozotti), National Semiconductor (Brian Halla) and Osram Opto



Market cycles in semiconductors between 1996 and 2009; despite downturns the market size has more than doubled during this period Source: ZVEI



Market trends in electronic components between 2007 and 2009 Source: ZVEI

Semiconductors (Rüdiger Müller) discussed the 'contribution of the semiconductor industry to climate protection'.

"The semiconductor industry is driven by energy savings through power electronics. We are facing a downturn in the year 2009; nevertheless, we see a conversion of technologies which may open a new cycle in this cyclic business. By using power electronics to their full extent, we can save electrical energy by 50%, and 23g of CO_2 can be saved if all the electrical consumers in a car are intelligently managed and switched on at demand", explained Peter Bauer during the course of this discussion. "Clearly, we are in a downturn, but we hope that the new US administration will raise some new ideas. Our attempt at increasing intelligence in semiconductors is reducing CO_2 emissions in automobiles in particular", added Rich Beyer. "With the financial crisis the €/$ ratio is much better for us; this has been a big problem for a European manufacturer of semiconductors", stated Carlo Bozotti. "Roughly 50 billion tons of CO_2 are exhausted annually; 10 billion tons come from the use of electricity, and this is where the savings potential comes from". "Obama's proposal for spending billions of dollars in renewable energies and electrical cars is a step in the right direction", commented Brian Halla. "With our newly developed solar magic electrical energy can be recuped by 50%". The final participant in this round-table discussion, Rüdiger Müller, stated: "We manufacture LEDs with the smallest wafers of 4in, but we gain the brightest light. Around 20% of electricity is used for lighting and, by using LEDs, a lot of energy can be saved. LEDs have progressed over the past 15 years by 50%; the light intensity has reached the level of compact fluorescent lamps. But LEDs need control circuitry because they do not operate normally under full load; this opens opportunities for power semiconductors. Off-grid lighting with solar cells and LEDs will become a huge market, particularly in developed countries".

In summary, all speakers agreed that the use of intelligent semiconductors, and in particular power semiconductors, can lead to a considerable increase in the efficiency of electronic systems and thus lowering losses. The semiconductor industry regards the attainment of this goal as one of its most important tasks in the next few years, not least because it will also ensure the economic future of the industry.

A key factor in the current climate discussion is also the automobile – along with the technologies which will help to reduce CO_2 emissions. The electronica automotive conference examined the forward-looking automobile electronics sector and attracted 250 delegates from 23 countries. A comprehensive report will follow in our next issue.

New power semiconductors ahead

International Rectifier took the chance to present its newly developed GaN technology (see PEE Oct/Nov 2008, pages 26-31) along with demonstrations in applications such as drives and multiphase DC/DC converters. The results were very impressive at first sight, in comparison to what can be gained with silicon.

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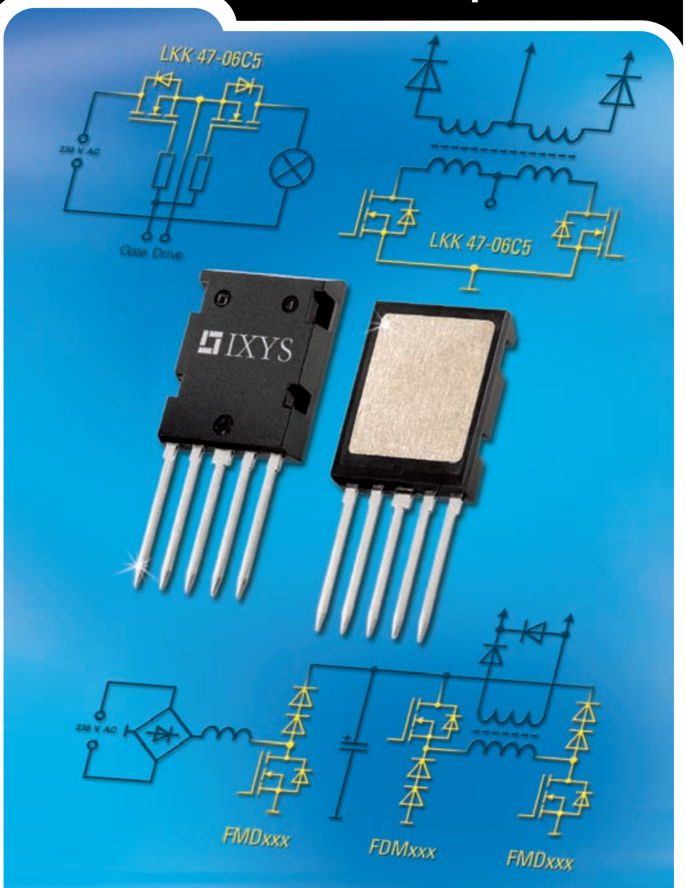

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- AC switch

Benefits
- More compact
- Very low weight
- Highest reliability
- Lowest conduction and switching losses
- Low gate drive power

TYPE	V_{DS} Max V	I_{D25} T_c=25°C A	$R_{DS(ON)typ}$ T_c=25°C Ω	$Q_{G(ON)}$ typ nC	Package	Circuit
IXKR 47N60C5	600	47	0,045	150	ISOPLUS 247	Single
FMD 15-06KC5	600	15	0,165	40	ISOPLUS i4	Boost
FMD 47-06KC5	600	47	0,045	150	ISOPLUS i4	Boost
FDM 15-06KC5	600	15	0,165	40	ISOPLUS i4	Buck
FDM 47-06KC5	600	47	0,045	150	ISOPLUS i4	Buck
LKK 47-06C5	600	2 x 47	0,045	2 x 150	ISOPLUS 264	Dual
IXKT 70N60C5	600	66	0,045	150	TO-268AA	Single

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Efficiency Through Technology

IXYS

IR's CEO Oleg Khaykin presented first GaN wafers for efficient power semiconductor s processed in its UK-based fab

have been prohibitively high-priced, requiring the use of hetero-epitaxial films. However, major substrates used for GaN epitaxy until now, such as SiC or sapphire, have also been relatively expensive. While silicon was a very attractive low cost alternative, it remained difficult because of defects and deformations due to intrinsic mismatch in lattice constants and thermal expansion coefficients. Recently, solutions to these epitaxial process difficulties have been developed. This program has leveraged the extensive experience in GaN epitaxy and devices that has been achieved through the efforts of a wide community of investigators, focused mainly in the fields of GaN RF devices and LEDs. This hetero-epitaxial process allows for volume deposition of GaN based material on low cost silicon wafers, costing about 100 times less than SiC.

"Internal studies show that GaN based power devices can offer performance that is comparable to SiC but at much lower cost. Prototype tests conducted show that reverse recovery characteristics for high voltage GaN diode function is same as for commercially available SiC diodes, both being significantly better than state of the art silicon fast recovery diodes", said Michael A. Briere, a consultant in charge of IR's GaN activities. "We have also overcome the problems of different thermal expansion coefficients through a flexible intermedient compensation layer. Our initial prototypes switch efficiently at 4 to 5MHz, commercial products introduced over the next few years will support switching frequencies of 10 to 60MHz".

Not the last attempt

Vishay Intertechnology completed the third quarter of 2008 with net revenues of $739 million. Compared with the second quarter of 2008, this represents a decrease of 4% and, compared to the third quarter of 2007, growth of around 2%. For the current quarter, sales are expected to range between $640 and 670 million, attributed to the impact of a weaker Euro.

"Overall, the last quarter for Vishay and the entire industry has been difficult. Sales and profits have remained lower than expected. The low order intake in October points to a further economic slowdown. In the meantime, the automotive industry in Europe has also suffered from the economic slowdown, as have mobile telephones, computers and consumer goods, which remain below expectations. Conversely, industrial automation is relatively stable, as is military/aerospace. However, orders from global distributors are decreasing rapidly. Should the recession become deeper and longer, we will take all necessary measures to maintain our free cash flow of $90 million", commented CEO Gerald Paul. The company serves industrial automation with 39% of the gross income, computing with 19% and automotive with 16 to 20%.

"Our attempt to acquire IR in total has failed, but perhaps we will try again at a later stage", said Vishay's founder Felix Zandman

Capital investment in the current financial year is at a high level, with some $150 to 160 million US. The acquisition of KEMET's wet tantalum capacitor line in September marked a further step in the extension of Vishay's specialty capacitor product portfolio, which is used in military, aerospace and medical applications. "Any takeover offers new synergies and opportunities for growth. It supports our basic principle of being a one-stop-shop, because we offer developers a wide choice of discrete semiconductors and passive components. By creating new products, we can address new markets and drive our vertical growth", Paul said. The Company is still committed to the development of its production sites in Germany. It has invested large sums in the development and optimisation of its German capacity (e.g. conversion of wafer production in Itzehoe for the manufacture of standard 200mm MOSFETs). "And we will continue our acquisitions and drive organic growth by focused R&D activities", added Felix Zandman, Founder and Executive Chairman of the Board.

Vishay acquired in 2006 for $290 million IR's Power Control Systems business, and recently made an unexpected $1.6 billion bid to acquire IR's remaining business in a deal that dwarves its previous acquisitions. But IR's Board of Directors has unanimously determined that the unsolicited, non-binding proposal by Vishay to acquire all of the outstanding shares of International Rectifier for $23.00 per share in cash (around $1 billion) is not in the best interests of IR and its shareholders. "This was an attempt to acquire IR in total to complete our product portfolio particularly in high-voltage ICs, this has failed. Perhaps we will try it again at a later stage, in the meantime we are looking for other candidates in the HVIC arena, and here are more than one company of interest for us", Zandman stated.

Concentration on power management

Texas Instruments responded to the growing power management IC market with the formation of a new Power Business Unit headed by Steve Anderson, who also initiated the Point-of-Load Alliance (POLA) some years ago. The new business unit focuses on portable and line-power system designs, including the former Unitrode products including digital power.

"According to market researcher Databeans, the power management IC market will reach $8 billion this year and $10 billion by 2010. We have a market share of around 15%, and this justifies the formation of this new business unit", Anderson commented.

At Electronica the company introduced a 60V input, 1.5A output step-down switcher with integrated FET that achieves significant energy savings in light-load efficiency through Eco-mode light-load switching technique. The converter operates in a pulse skip mode at light load currents to improve efficiency. The peak switch current during the pulse skip mode will be the greater value of 50mA or the peak inductor current that is a function of the minimum on-time, input voltage, output voltage and inductance value. When the load current is low and the output voltage is within regulation the device will enter a sleep mode and draw only 116mA input quiescent current. While the device is in sleep mode, the output power is delivered by the output capacitor. As the load current decreases, the time the output capacitor supplies the load current increases and the switching frequency decreases, reducing gate drive and switching losses. As the output voltage drops, the TPS54160 wakes up from the sleep mode and the power switch turns on to recharge the output capacitor. The internal PLL remains operating when in sleep mode. When operating at light load currents in the pulse skip mode, the switching transitions occur synchronously with the external clock signal. In addition, the converter's high switching frequency range of 300kHz to 2.5MHz reduces the size of the output inductors. TI's SWIFT DC/DC converters are intended for applications such as telecom, computing, industrial and consumer point of load applications with input voltage ranges of 60V and output currents up to 14A. According to Anderson, new POLA compatible design will be introduced in 2009.

On the other hand the company introduced a 2MHz DC/DC boost converter (TPS61220) that operates at 5µA of quiescent current, while maintaining a high efficiency at light load conditions. The IC supports an input voltage of 0.7 to 5.5V and an output voltage range of 1.8 to 5.5V, extending battery life in low-power microcontroller-based designs, such as single AA or coin-cell alkaline applications.

"We also work with Michigan-based Fulton Innovation to co-develop wireless power IC solutions based on eCoupled wireless power technology. The goal is to design an universal power source that charges multiple devices at the same time even at different charging voltages. Users will be able to charge their cell phones, headsets and laptops in new and convenient ways that previously were not possible", Anderson said. Research from the US Department of Energy determined that 75% of all electricity used to power electronics is consumed when products are not in use. Fulton's eCoupled technology addresses this problem by using an profiling protocol that identifies eCoupled-enabled devices to be powered. At the same time, the profiling protocol also assesses power needs and individual battery lifecycles to provide only the necessary amount of power for any given device. The technology is designed to be used anywhere traditional power needs exist. It supplies power and communication through an inductively coupled power circuit that dynamically seeks resonance, allowing the primary supply circuit to adapt its operation to match the needs of the eCoupled-enabled devices it recognises. The goal is to have end-equipment designs with a combination of TI semiconductors and eCoupled technology available in the market in 2009.

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www.electronica.de
www.zvei.org
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"The power management IC market will reach $8 billion this year and $10 billion by 2010. Our new business unit is well positioned for growth", commented TI's Steve Anderson

Towards More Efficient Drives

From 25 – 27 November 2008, the electric automation industry met in Nuremberg once again. At SPS/IPC/DRIVES 1,386 companies (2007: 1,321) showed their range of electric automation to the trade visitors. Some power electronic companies such as Avago, Infineon, Mitsubishi and Semikron took the chance to exhibit among their customer base. As with Electronica 2008, energy efficiency was a key topic, but at a higher level.

Energy efficiency in industrial applications with power electronics here at Infineon's booth was a major concern at SPS/IPC/Drives

Trade and industry require electrical drives worldwide. Motor-driven systems consume about 70% of all electricity used in industry. Here, there is also great potential for improved efficiencies. Only about 12% of the motor capacity installed in Germany today is operated with energy-saving electronic speed controls. It is estimated, however, that it would be beneficial for over 50% of this motor capacity to be equipped with electronic speed control. "It is hard to convince our potential customer base to spend a surplus for energy-efficient variable drives, but with high energy prices a change will come sooner or later", commented Roland Bent, Member of the ZVEI Automation Board. "We view the current crisis as chance to take better care of our resources, we are the right industry to realise energy efficiency". In 2008 the German production of electrical drives will increase by 6% up to €7.5 billion, but incoming orders are slightly decreasing leading to slower growth in 2009.

"We view the current crisis as a chance to take better care of our resources", said Roland Bent, Member of the ZVEI Automation Board

Energy efficiency becomes mainstream

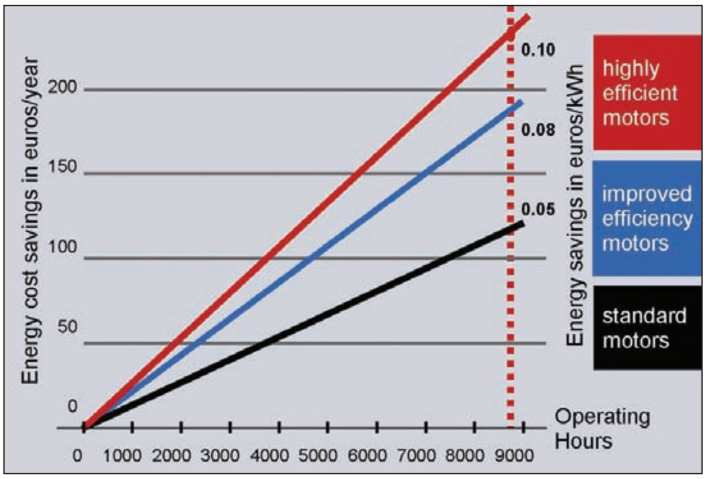
"Meanwhile, the discussion surrounding energy efficiency has arrived in many OEM industries. As suppliers of automation and drives we have a wide range of energy-efficient technologies available and – the message can't be repeated often enough – this technology is available, tested and proven and ready to work", added Jürgen Amedick, CEO of the Siemens Business Unit Standard Drives. "The main focus here is on energy-efficient motors. These are backed by efficient converters, made more compact through the use of new components, which achieve higher levels of efficiency and which are equally an integral part of the efficiency cycle, for instance through the use of intelligent heat management inside switch cabinets. Such components also include cold-plate technologies and water cooling systems. Efficiency is much more than saving energy through energy-efficient components such as motors and converters. 2009 will be the year when, prompted by the need to reduce operating outlay, the highlight will be on life-cycle costs".

According to Siemens' numbers, within 20 years energy costs account for up to 99% of a motor's lifecycle cost. With innovative drives energy savings of 40% can be realised, leading to savings potential of 43Twh/a equivalent of €3 billion and a payback time of 12 to 18 month per drive.

Regarding higher efficiency of converters, two years ago Siemens introduced a 690V inverter (power range from 7.5 to 37kW) with sinusoidal output voltage using SiC freewheeling schottky diodes for the first time in a commercial drive. With these diodes, the switching frequency of the inverter can be increased significantly compared to standard converters, making it possible to integrate the sine wave output filter into the inverter housing. With sinusoidal output voltage, operation with long motor cables is possible. The losses in the motor can be reduced. The insulation of the motor can be reduced compared to standard solutions.

The turn-on losses of the IGBT are strongly influenced by the switching behaviour of the freewheeling diodes and can be reduced to 30% compared to a Si pn freewheeling diode. This reduction is due to the following differences: "As the SiC schottky diode does not show any recovery charge, the current in the turning on IGBT is reduced. The Si diode can take blocking voltage after the reverse recovery peak current. The time interval from the zero crossing of the diode current to the maximum of the reverse recovery current is absent for the SiC diode, as there is no recovery charge. This reduces the switching time. The maximum turn on switching speed is limited by the snap off of the diode. Without recovery charge, there is no snap off due to abrupt changes in the reverse current even at high switching speed. For the SiC schottky diode, the turn-on switching speed can therefore be increased. Furthermore, the SiC diode does not create any switching losses in the diode itself, as there flows no negative current through it", explained Siemens' expert Benno Weis the advantages of SiC technology. This helps to reduce

"The discussion surrounding energy efficiency has arrived in many OEM industries", added Jürgen Amedick, CEO of the Siemens Business Unit Standard Drives



Energy cost savings over lifetime of various drive technologies Source: Siemens

New highly integrated electrical drive for (hybrid) electric vehicles driving directly front wheels

dynamic losses also in the Silicon IGBTs and thus permits to increase switching frequency to 16kHz. Answering to the question of installations and further developments Amedick said that Siemens has been able to fit 200 applications since one year and is working on improved designs.

Improving fuel efficiency

The integration of the power electronic inverter with an electrical machine in the automotive powertrain is in the focus of the ECPE automotive demonstrator programme where the existing cooling circuit from the internal combustion engine is used also for the direct liquid cooling of the power electronics. The mechatronic integration of motor and power electronics led to an ultra-high power density of 75kVA/l for the inverter in a first step, developed by Fraunhofer Institute of Integrated Systems and Device Technology (IISB). Here, the electric drive with the power electronics were both integrated into the clutch-box screwed at the gear-box. At the fair ECPE showed the successor, here the electrical drive of 2 x 20kW along with the power electronics is mounted directly on the axes providing torque and recuperation.

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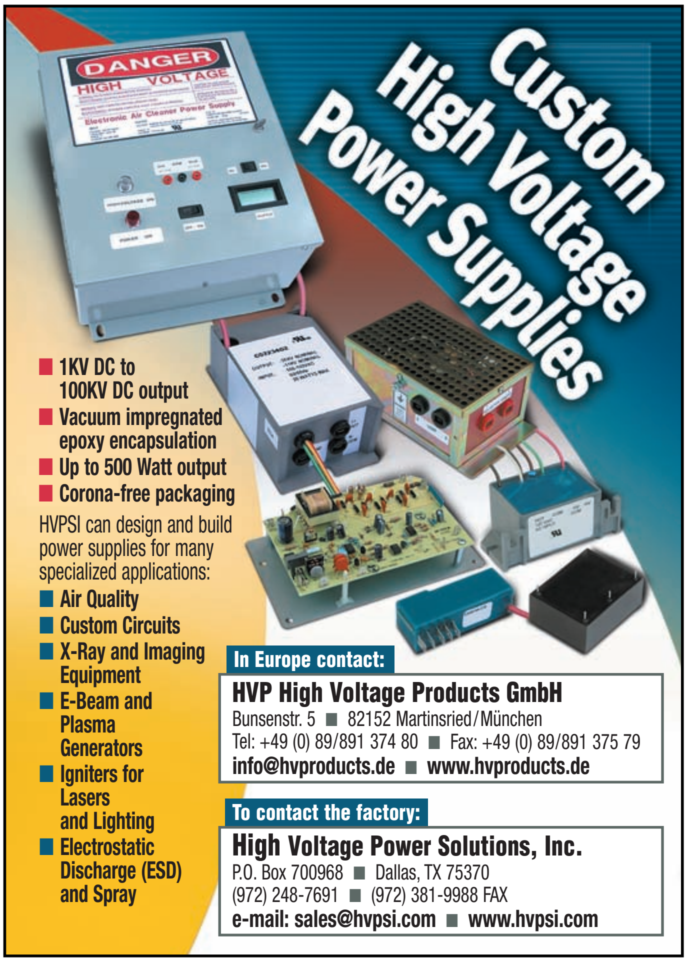


The New Standard for High Power Semiconductors

The physical and electronic properties of silicon carbide (SiC) make it the foremost semiconductor material for high power, high temperature electronic devices. In addition to its inherent chemical inertness, SiC is an excellent thermal conductor. Beyond its thermal advantages, SiC enjoys a high intrinsic electric field breakdown. Recent advances coupled with the proven track record in the field has made the SiC Schottky diode an excellent choice for any high power application requiring fast switching and near zero reverse recovery losses. Pending SiC switches promise complete SiC power solutions and multiply the advantages of SiC technology for power electronic designers. **Jason Henning, Allan Ward, and Paul Kierstead, Cree, Durham, USA**

At room temperature, SiC has a higher thermal conductivity than most commonly used metals. This property enables SiC devices to operate at extremely high power levels and dissipate the large amounts of excess heat generated. In addition to silicon carbide's ability to dissipate heat, SiC material and the active devices are inherently able to withstand much higher temperatures than their silicon counterparts. The wide energy bandgap of SiC reduces thermally generated leakage currents, and the strong bonding structure prevents dopant diffusion and interaction with contact metals at those high temperatures.

Beyond its thermal advantages, SiC enjoys a high intrinsic electric field breakdown. The critical field of SiC is nearly nine times that of silicon. This allows fabrication of very high voltage devices, while simultaneously providing low electrical resistance at reduced die size. Table 1 summarises some of the properties of silicon carbide, and how they compare to silicon. The resulting advantages make SiC an ideal material on which to build power semiconductor devices.

SiC Schottky rectifiers

Schottky rectifiers of any material have the advantages of fast switching times and no reverse recovery current. Limited metal barrier heights restrict silicon Schottky diodes from high voltage applications. For this reason, the industry generally depends on silicon PiN diodes despite their poor reverse recovery performance. The end result is loss of power efficiency in application.

SiC Schottky contacts have been shown to have a barrier height with dependence on the metal work function. Therefore, metallisation choices can be used to enhance device performance. At elevated temperatures, the reverse leakage currents of a SiC Schottky can be somewhat higher than silicon devices if not addressed, with the dominant leakage mechanism being surface emission. Ion implantation of a Junction Barrier Schottky (JBS) diodes provide improved reverse leakage performance, with virtually no impact on forward or switching performance.

The JBS design provides reverse bias performance significantly better than a silicon PiN diode through the use of P-type implanted islands. These P-wells deplete during reverse bias operation and limit the field at the Schottky surface, resulting in the reduced reverse leakage currents. Cree SiC Schottky diodes have always employed JBS design techniques and demonstrate its performance advantages and low leakage.

A consideration for SiC Schottky diodes in some applications is surge current handling. A prime example is surge related to power-on or interruption recovery in switch mode power supplies. The design of SiC Schottky diodes allow for a relatively small die size. This, along with the uni-polar conduction of Schottky structures, limits surge current handling capability versus larger area PiN diodes. However, the use of a Merged PiN Schottky (MPS) design can overcome SiC forward surge limitations by allowing the PN junction to turn on during surge current events. The MPS structure injects minority carriers into the drift layer, greatly improving the conductivity of the diode.

Figure 1 shows the forward conduction of an MPS diode compared to a non-MPS design. While the MPS design offers an advantage for short, non-repetitive surge conditions, it does inject minority carriers and increases the reverse recovery current by a small amount. Therefore, the diode should be designed such that the P-N junction of the MPS does not turn on at too low a voltage, causing injection of holes during normal operation.

Commonly, a boost diode in PFC applications experiences surge conditions resulting in currents of three to four times the rated value. A properly designed MPS avoids minority carrier injection during these repetitive surging events without generating significant recovery current. With proper device design choices, SiC JBS diodes provide suitable surge handling and vastly improved system power efficiency versus silicon diodes.

Reliability of SiC devices

The life cycle of a semiconductor device has three phases: early-life, constant

Parameter	SiC (4H)	Silicon	Units
Energy Bandgap (E_g)	3.26	1.12	eV
Critical Electric Field	2.2E6	2.5E5	V/cm
Thermal Conductivity	3.4	1.5	W/cmK @RT

Table 1: Summary of key material properties for silicon carbide and silicon

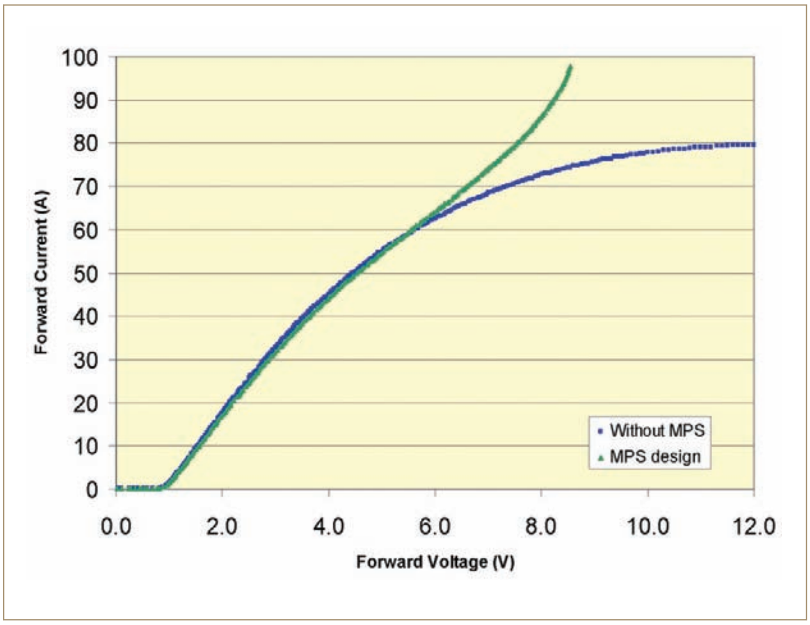


Figure 1: Plot of forward current versus voltage into surge regime for MPS and non-MPS designs

failure rate, and wear-out. For a high quality manufacturing operation, the probability of failure during early life is only slightly higher than the constant failure-rate period. Wear-out failures occur at the end of the device life due to degradation inherent to the material used in the technology.

In terms of reliability metrics, failure-unit (FIT) values describe the average failures per unit time in the early and constant-failure-rate portions of the life cycle. Median-time-to-failure (MTTF) describes the time at which 50% of the devices are expected to reach the wear-out phase of the lifecycle.

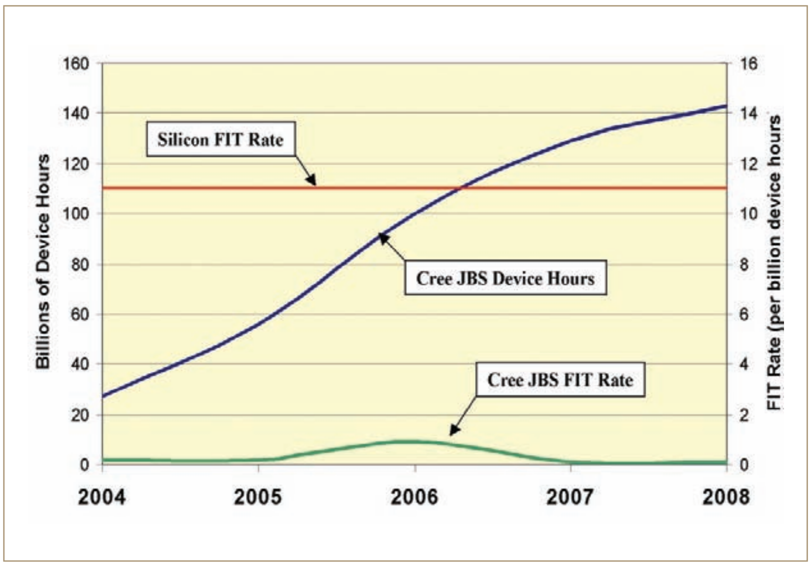
Cree introduced its Zero Recovery SiC Schottky rectifiers more than five years ago. During that time, the devices have accumulated over 140 billion device-hours in fielded industrial and consumer applications. Across those device hours, the FIT value (expressed as failures per billion device hours) is 0.3, which exceeds the FIT value performance for traditional silicon power diodes. In addition, year after year fit rate has been consistent. This demonstrates that the early-life failure rate is comparable to the constant-failure-rate, indicating a high-quality, highly reliable manufacturing process. Figure 2 shows the cumulative device hours and FIT rate for Cree's SiC Schottky diodes and a comparative FIT rate for silicon power diodes.

The final portion of the semiconductor lifecycle is wear-out, which is indicative of the inherent reliability characteristic of the materials used to construct the device. The material set used in Cree Schottky diodes has been studied extensively on various Cree products including the JBS Diodes, SiC MESFET and MOSFET. Test structures have indicated that the dominate failure mechanism for Cee's SiC Schottky-based technology predicts an MTTF of 250 years with an operating junction temperature of 225°C. The inherent reliability assures operation far beyond expected end-system life.

Conclusion

Recent advances coupled with the proven track record in the field has made the SiC Schottky diode an excellent choice for any high power application requiring fast switching and near zero reverse recovery losses. Applications such as switched mode power supplies and solar power inverters have benefited greatly from Cree's JBS parts. Adoption in both areas is accelerating and new applications in hybrid vehicles, motor controls, power converters and medical equipment are emerging, as the portfolio of parts increases and cost reductions occur. Recent news of pending SiC switches from Cree and others promises complete SiC power solutions and multiply the advantages of SiC technology for power electronic designers.

Figure 2: Cumulative Cree JBS diode end-system device hours and FIT rate



High Voltage Reverse Conducting IGBTs

Future high power IGBT modules with Reverse Conducting (RC) IGBT technology incorporating an integrated freewheeling diode in the same silicon volume will be capable of providing exceptional electrical performance in terms of the maximum allowable output current capability. In this article, a fully functional high voltage and high current IGBT module rated at 3300V consisting solely of RC-IGBT chips under hard switching conditions and under heavy paralleling in high current modules is demonstrated.

Munaf Rahimo, ABB Switzerland Ltd, Semiconductors

Recent development trends are targeting RC-IGBT structures (IGBT with integrated anti-parallel diode) as a means for providing higher power for a defined area (i.e. module footprint). In order to obtain the maximum advantage of this Bi-Mode technology, it is essential to utilise the same silicon volume when operating in IGBT or diode mode.

Reverse conducting IGBT concept

The RC-IGBT concept is not new and is basically derived from the concept of the MOSFET's integrated body diode. RC-IGBT developments started in the early nineties with a basic design which consisted of a shorted anode/collector structure with overlapping p+ and n+ regions to provide an anti-parallel diode within the IGBT as shown in the top structure of Figure 1. With the advancements of modern IGBT and diode structures, more development effort is being aimed at reviving the RC-IGBT concept, since the potentials that could arise from such a technological step are great.

Recent efforts were mainly concentrated on lower voltage devices rated at 1200V or below for special applications. However, in the high voltage range, a functional high voltage RC-IGBT is yet to challenge the standard IGBT/Diode approach in practical hard switching applications, due to a number of technological design and process barriers which are: The conflicting requirement for plasma enhancement near the IGBT Cathode (emitter) against plasma reduction for the integrated diode (i.e. doping profiles and lifetime control); the shorted anode P and N regions design in terms of doping concentrations (injection efficiency) for minimising the on-state snap-back phenomenon associated with RC-IGBTs; the shorted anode P and N regions layout design regarding alignment to the front side for controlled and minimum non-uniform charge distributions during IGBT and diode operation; and matching the silicon and buffer design parameters (thickness and dopings) for both the IGBT and diode with regard to turn-off and reverse recovery softness respectively.

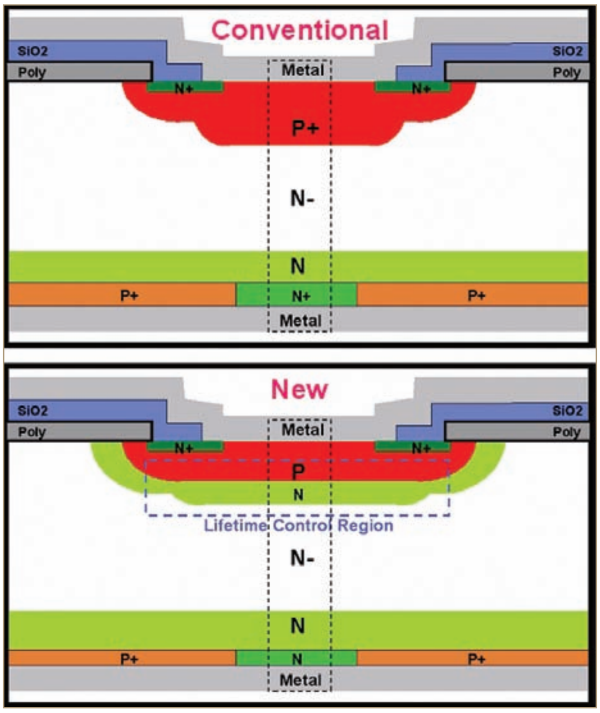
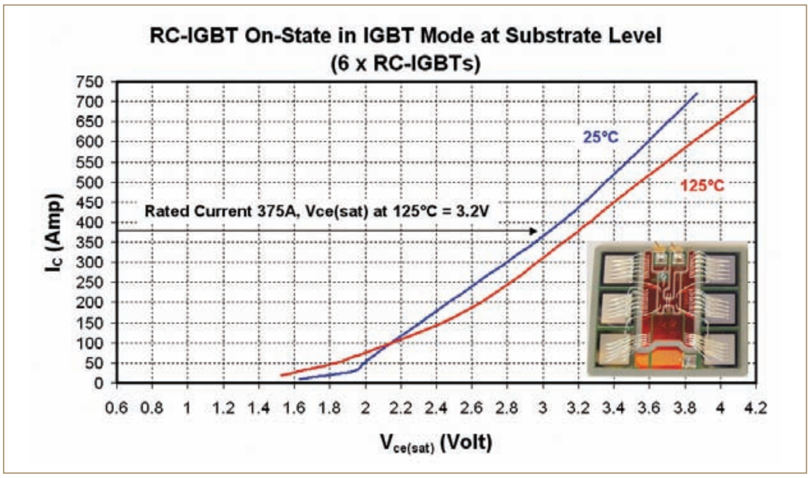


Figure 1: RC-IGBT with conventional technology (top) and new EP technology with local lifetime control (bottom)

3300V RC-IGBT design features

This work mainly tackles the issues mentioned especially for a high voltage device. The recent work carried out on Enhanced Planar EP-IGBTs and diode concepts having low losses, soft characteristics and very high robustness provided compatible technologies for exploitation in a functional RC-IGBT rated at 3300V. Devices were manufactured with a 1cm² active area chip rated at 62.5A with a standard EP cell design and Soft-Punch-Through (SPT) buffer.

For tackling the first issue regarding the conflicting plasma distribution requirements for both IGBT and diode modes of operation in an RC-IGBT, a number of options were considered. The emitter P-wells of the IGBT also represent the main anode regions for the diode, thus reducing the plasma concentration near these well is the main target to be achieved, but without sacrificing the on-state of the IGBT. The favourable EP cell structure with optimum low injection efficiency P-wells have aided the optimisation of the integrated diodes reverse recovery performance by providing low injection efficiency for the diode anode. In addition, controlled lifetime reduction near the RC-IGBT P-well area provided the means to improve the diode recovery behaviour without influencing the IGBT performance, as shown in the new structure of Figure 1.



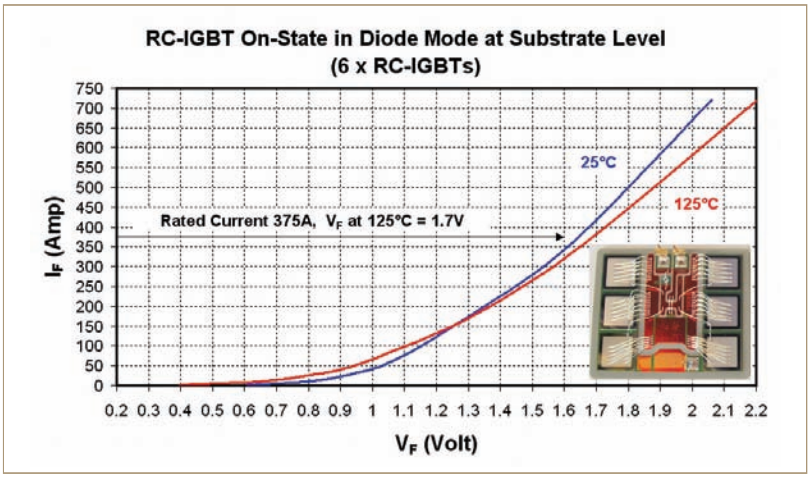


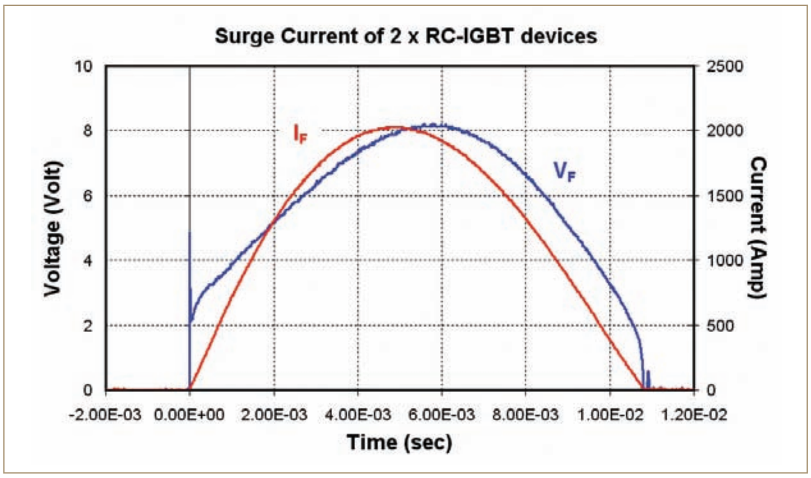
Figure 2: **On-state characteristics of the 3300V RC-IGBT substrates in IGBT mode (a) and diode mode (b)**

The remaining three points are mainly associated with the device shorted anode and buffer design. In order to further optimise the diode recovery behaviour without influencing the IGBT performance, it is necessary to be able to reduce the injection efficiency of the device anode short N-regions and SPT buffer. Hence, a low-doped N-type short was implemented in combination with a low concentration SPT buffer. On the other hand, highly doped P+ anode regions were provided for the IGBT while targeting diode performance for soft recovery, especially since the silicon design is optimised from an IGBT standpoint. In addition to the doping concentrations, a number of anode short layouts, area ratios were also explored to further improve the device performance. The snap-back behaviour in the IGBT on-state curve was minimised by the precise control of the highly doped P+ anode regions and low doped N+ shorts and SPT buffer, in combination with an optimum anode short layout and area ratio. An important target of the RC-IGBT design was to enable good performance without any need for aligning the anode shorted regions to any front side IGBT cathode features, while eliminating any charge non-uniformities that could arise during device operation.

RC-IGBT electrical characteristics

The static and dynamic characteristics of optimised 3300V RC-IGBT devices were obtained. The electrical measurements were carried out on substrate and module level. The substrates employed in the module consist normally of four IGBTs and teo anti-parallel diodes. Hence, the approach here was to substitute the two diodes with RC-IGBTs resulting in a total of six

Figure 3: **Surge current capability of the 3300V RC-IGBT**



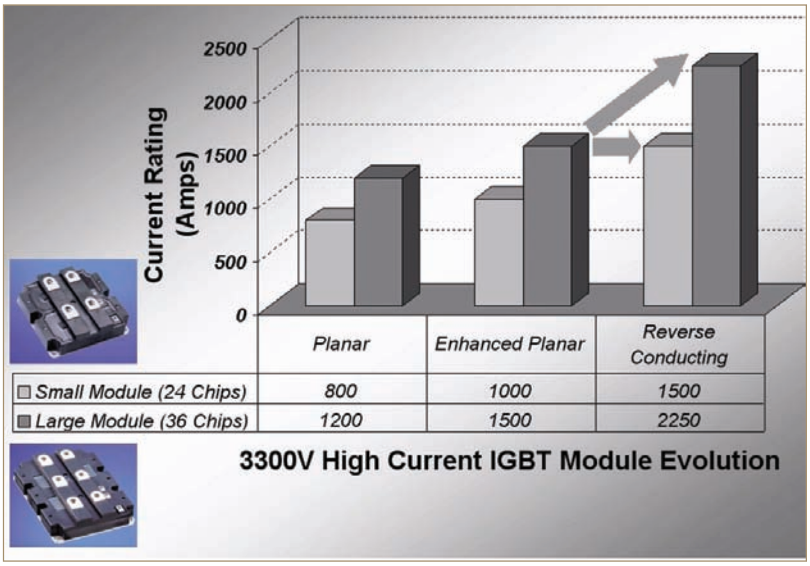


Figure 4: Current rating evolution of 3300V modules

RC-IGBTs connected in parallel, as shown in Figure 2 along with the on-state losses curves.

It is important to note that the substrate design and wire-bond layout does note represent an optimum solution for an RC-IGBT module, but rather a worst-case scenario. The standard substrate is normally rated at 250A; hence this will translate to a 375A RC-IGBT substrate rating.

The static on-state characteristics measured at substrate levels are presented in Figure 2 in both (a) IGBT and (b) diode mode with the given $V_{ce(sat)}$ and V_F values at rated current and 125°C indicated on the chart. The IGBT mode on-state curve at 25°C shows a small snap-back at current levels below 50A. A positive temperature coefficient is achieved in both modes, even at low current densities for safe paralleling, which is preferable since the diode mode is expected to function at much lower current densities due to an increased diode area (200%). On the other hand, the much lower thermal resistance will provide the diode mode with favourable thermal and electrical properties when compared to the standard approach with only two diodes on a substrate. This was demonstrated by a good surge current capability in diode mode with a two chip measured capability exceeding 2000A at 125°C as shown in Figure 3, which translates to 36kA for a full 36 chip IGBT module.

For measuring the dynamic characteristics two sets of RC-IGBT modules

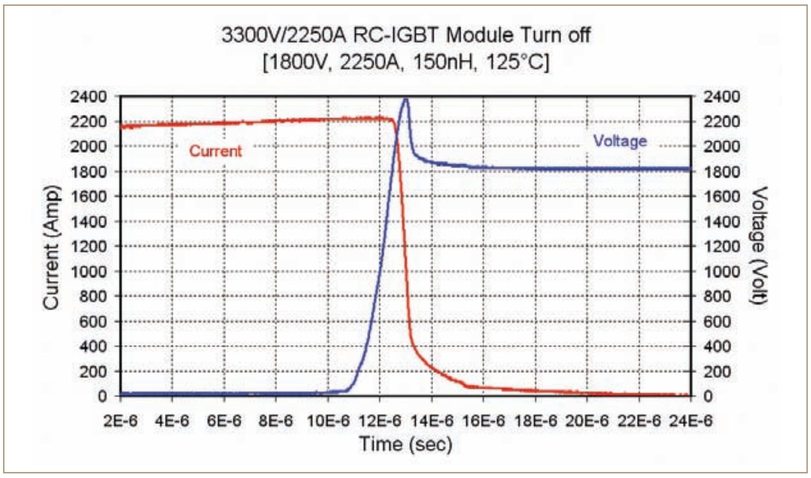


Figure 5: 2250A/3300V RC-IGBT module during IGBT turn-off

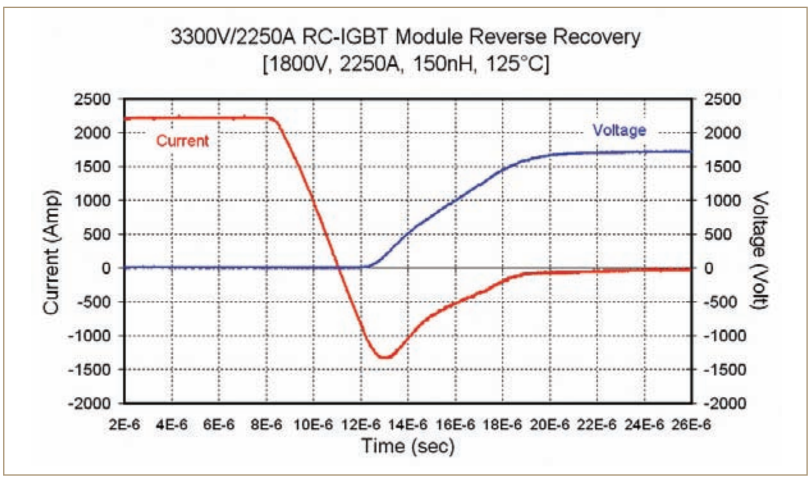


Figure 6: 2250A/3300V RC-IGBT module during reverse recovery

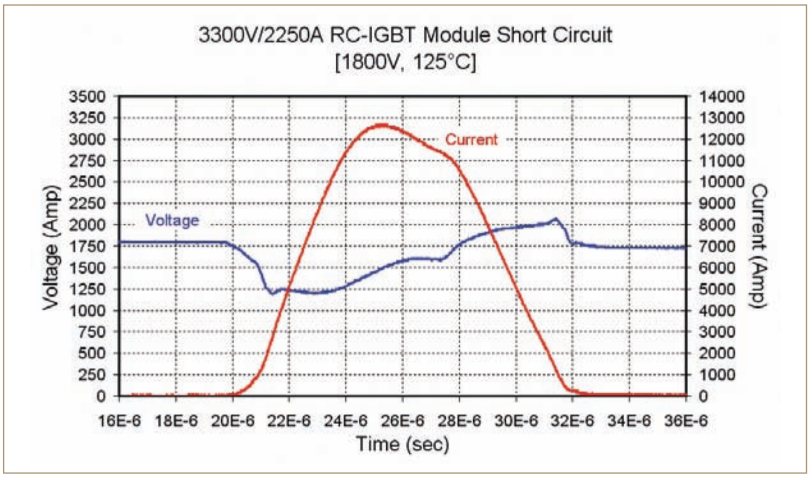


Figure 7: **2250A/3300V RC-IGBT module during short circuit**

in a single configuration were fabricated based on two standard footprint designs. The smaller module (140mm x 130mm) contained four substrates in parallel giving a total current rating of 1500A, while a larger module (140mm x 190mm) consisting of six substrates resulted in a 2250A module as shown in Figure 4. The chart presents the potential of employing RC-IGBT technology and its impact on the module rating when compared to previous and current generation of devices.

The switching characteristics of the RC-IGBT modules were obtained under nominal conditions at 125°C. The turn-off switching behaviour of the large RC-IGBT 2250A/3300V module is shown in Figure 5. The turn-off losses E_{off} under these conditions had a value of 6J while employing a relatively large gate resistance of 10Ω. In addition, the RC-IGBT reverse recovery behaviour is shown in Figure 6. The reverse recovery losses E_{rec} were measured with a value of 3J. The short circuit behaviour of the RC-IGBT module is shown in Figure 7. The short circuit peak current reached values above 12kA due to the large number of devices employed in the modules.

Conclusion

More development effort is currently underway to further improve the RC-IGBT performance in order to allow the new technology to exhibit excellent electrical characteristics in terms of loss reduction and increased SOA in both IGBT and diode mode of operation. The realisation of the new Bi-Mode IGBT technology will provide a potential solution for future high voltage applications demanding compact systems with higher output power capability.

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Modular and Powerful Inverters up to 1MW

Over the last few years, the call for a faster time-to-market for industrial products has become increasingly urgent, causing developers to combine existing subsystems to create a final product. The main aim in doing so is to save time and money in the development stage. To meet the increasing demand for qualified, tried and tested subsystems to be used in product development, SEMIKRON has created a modular IGBT stack platform based on standard 62mm modules. **Daniel Seng, Product Manager, SEMIKRON France**

The SEMIKUBE platform is a solution that meets the market demand for a cost-effective, flexible, compact and easy maintainable power electronic system. It can be used for drives across a wide power range of 75kW to 1MW by simply paralleling several blocks, depending on the power required (Figures 1 and 2).

The total stack consists of a highly efficient heatsink and comes as an air or water-cooled version. The power electronic modules inside the cube are standard 62mm IGBT modules with two switches per housing. To operate the IGBT switches, a driver developed in-house and based on the features of the Skyper 32 Pro is used. For the DC link, capacitors, either electrolytic or polypropylene, are placed just above the power modules. The number can vary, depending on the customer needs. Finally, a sturdy metal frame protects the complete stack and gives it the cubic shape. To interconnect several cubes for higher power applications, a patented, fast-mount clamp connection is available. In combination with the special busbar design, a very low inductive stack solution can thus be achieved.

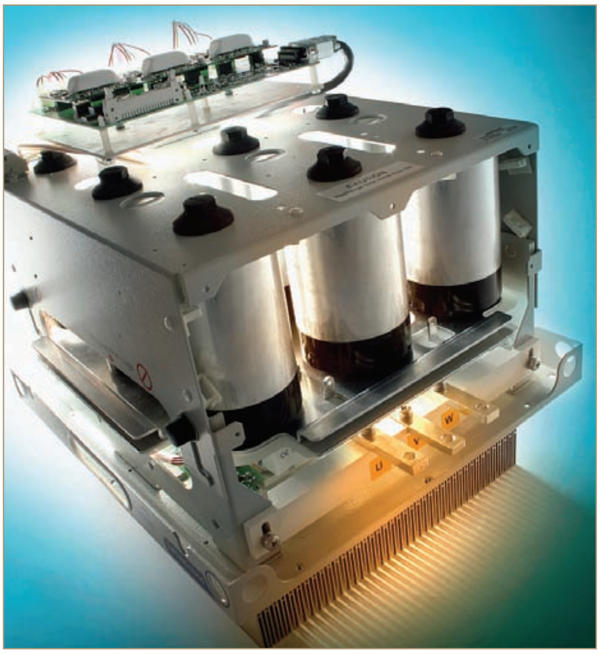


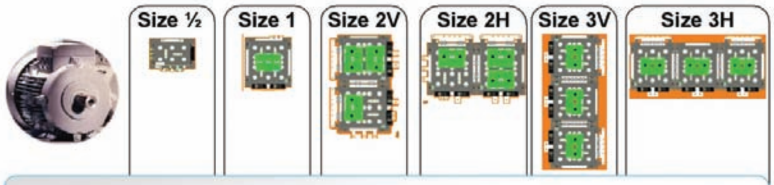
Figure 1: Modular and powerful SEMIKUBE arrangement

High-performance heatsink

To achieve the compact size a highly efficient heatsink is a must. When power electronic modules are used, heat is produced which needs to be transferred from the point of occurrence to the ambient. For this reason, thorough investigations and tests were performed, the purpose of which was to find a suitable compact heatsink that boasts an excellent performance, also in terms of the cost-to-performance ratio. Additional thermal simulations for numerous possible module configurations are performed to ensure that the right choice of heatsink is made.

As an example, a 10-year-old design of eight standard 62mm IGBT modules on one heatsink was compared with a SEMIKUBE size 1 featuring the same power modules. The set-up included the same power loss for each module. The resulting temperature profiles show the difference in the performance of the heatsink (Figure 3).

The hottest point on the heatsink is



	Size ½	Size 1	Size 2V	Size 2H	Size 3V	Size 3H
400 V Ovl 110%, 60s	110 kW 200A	220 kW 385A	375 kW 655A	400 kW 760A	560 kW 1040A	900 kW 1500A
400 V Ovl 150%, 60s	90 kW 160A	160 kW 305A	300 kW 525A	355 kW 600A	500 kW 850A	710 kW 1200A
690 V Ovl 110%, 60s	150 kW 150A	270 kW 270A	450 kW 450A	520 kW 520A	700 kW 700A	1100 kW 1090A
690 V Ovl 150%, 60s	120 kW 120A	220 kW 220 A	370 kW 380 A	400 kW 400A	600 kW 600A	860 kW 860A

Figure 2: Power range of the SEMIKUBE family

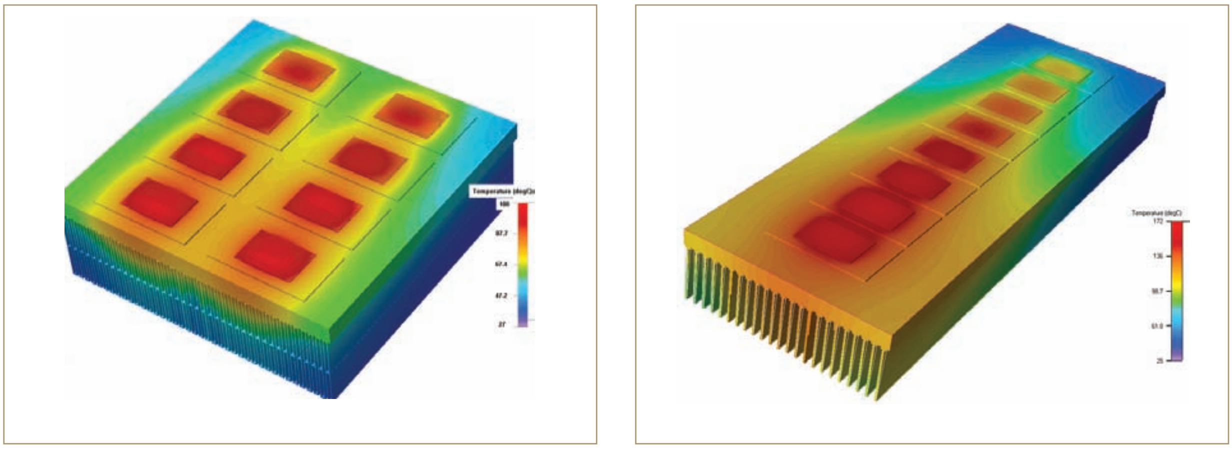


Figure 3: Thermal simulation of the heatsink for a SEMIKUBE size 1 with forced air cooling (a), compared to an older design with the same standard 62mm power modules (b)

108°C, which is still within an acceptable range when compared to 172°C on the old design. The temperature gradient between the hottest point and the coolest spot on the heatsink surface is approx. 130°C compared to around 45°C on the SEMIKUBE heatsink. A closer look also shows that separating the modules by a minimum distance of 20mm is an effective way of increasing the thermal spreading on the heatsink. The further optimisation of the module position on the heatsink (two rows instead of 8 modules in a row) results in a more efficient overall design (SEMIKUBE size 1) as the heatsink needs 75% less surface space.

To ensure heatsink efficiency fans are required, suitable ventilation with the right power to compensate the pressure drop is also available. This fan (230V 50/60Hz) boasts a low-noise design at a maximum of 72dBA. The fan performance curve has to be adapted, both to suit the design of the load to be cooled, and to allow for a little power margin in order to take into account possible additional pressure drops from other devices in the air channel (air filter, choke, mechanical obstacles…). This kind of fan is designed for zero maintenance and includes thermoswitch protection.

For even higher performance, the stack also comes in a water-cooled heatsink version.

Thanks to the heatsink and stack design, compliance with the IP54 standard is ensured, as is the clear separation of the internal atmosphere where the electronics are and external cooling air. This can significantly reduce the pollution around sensitive devices and hence increase reliability.

Low inductive busbar

SEMIKUBE features standard 62mm modules, so up to eight half-bridge IGBT modules can be used in parallel. With paralleled power modules, derating is normally required due to non-homogenous current sharing between modules connected in parallel.

To keep the current derating at a very low level, a special busbar design is used inside the stack. Generally, a good compromise in terms of performance-to-losses ratio can be obtained at a switching speed of around 3kHz, as the difference between the fundamental frequency and the switching frequency results in a relatively low level of losses of typically 1 to 2%.

On the AC side, the busbars are made of tin-plated copper. The optimised structure and identical length of the busbars between the modules result in very low and identical resistance and inductance values. The outcome is excellent paralleling, as well as a reduction in power losses. Likewise, for the DC busbar a purpose-developed design provides the optimal low-inductance current path, guaranteeing smooth switching behaviour.

Additionally, the design is suitable for interconnecting the DC blocks of several cubes. This allows for very compact arrangements inside a control cabinet. To connect several DC links special patented DC clamps are available. The cubes can be connected on any of the four sides. This provides a maximum of flexibility for the final arrangement on the customer side and allows for easy integration into the customer's final application. These clamps provide a reliable and very fast connection for the different metal sheets. Only two screws have to be tightened to ensure safe and long-lasting contact between two SEMIKUBES (Figure 4). Depending on the power between the cubes, several DC clamps can be used in parallel.

The inductance of one clamp is in the range of just 10nH. Qualification tests verify the reliability of this connection technology. Dynamic tests with three clamps in parallel show a homogenous current sharing between the clamps. This results in homogenous heat transfer on the DC link level, which in turn

Figure 4: Patented DC-clamp for the DC-interconnection of the cubes

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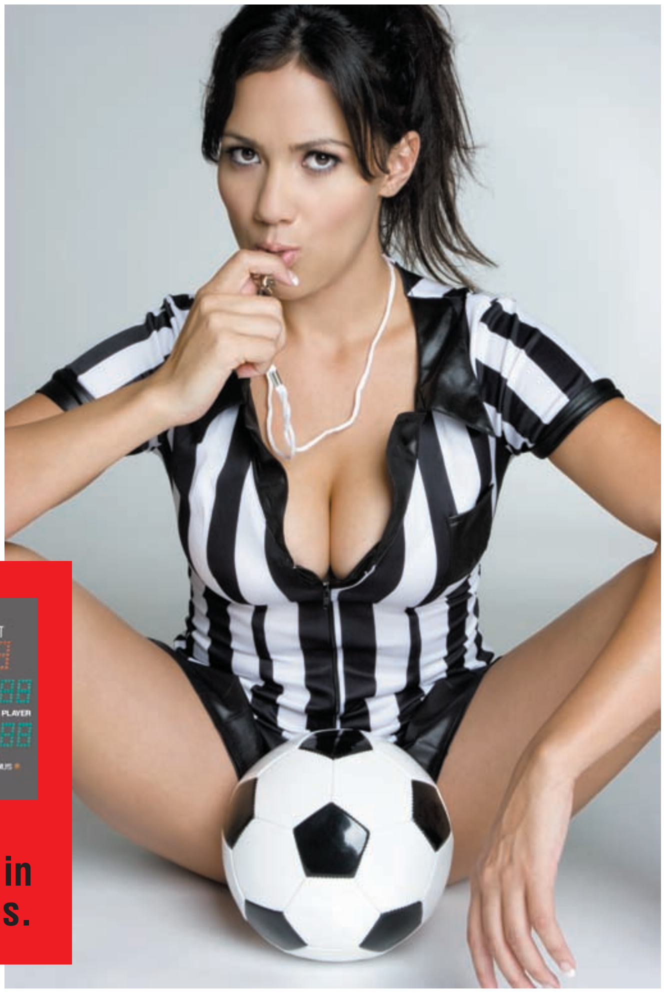

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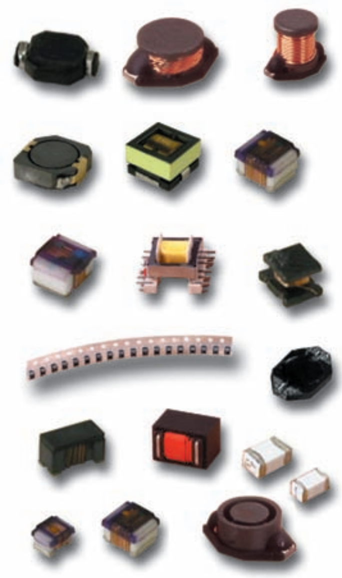

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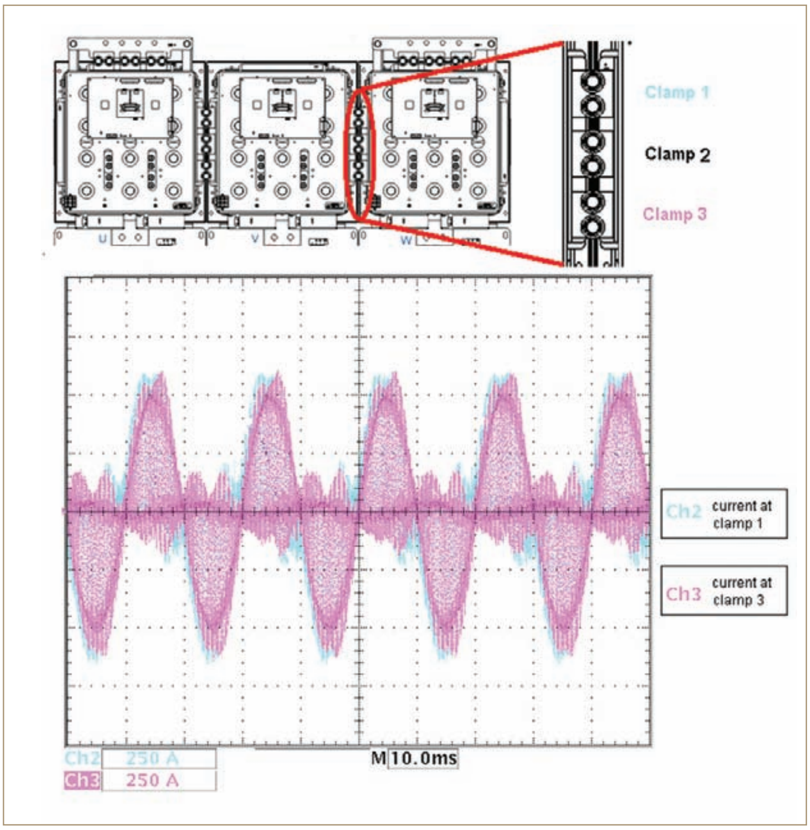

Figure 5: Homogenous current sharing at the patented interconnection DC clamps

improves the overall reliability of the stack (Figure 5).

Long-life DC link capacitors

Depending on the power required for the inverter, up to 12 capacitors can be integrated into one cube. The standard capacitors are long-life electrolytic types with screw terminals. The sizing of the capacitors depends mainly on the inverter current and the necessary capacitance; the SEMIKRON standard provides a minimum service life expectancy of 60kHr. For some applications where higher DC-link voltages are needed (>750V), polypropylene capacitors are also available. To boost the reliability of DC-link capacitors, active cooling is the standard cooling method. Even in the event of fan failure, the hot spot temperatures would never reach critical values. Ultimately, this means that fan failure is a non-critical risk. Here again, the positioning and the interconnection method for the capacitors inside the stack are optimised to achieve symmetry, which translates into greater reliability thanks to homogenous current sharing ensuring a balanced current flow in all connected capacitors.

Driver and sensors

The driver is based on the existing Skyper 32 Pro design. Several adjustments carried out on this platform have resulted in the current SEMIKUBE GB (for Size 2 and 3) and SEMIKUBE GD (Size ½ and 1) drivers. Each cube is fitted with its own driver that operates independently; all of the cubes, however, have a common user interface for connection to the customer's controller. In terms of safety, all of the drivers are fitted with protection and monitoring features. Short-circuit protection, temperature monitoring, galvanic isolation, a safe extra-low voltage interface are just a few of the driver characteristics. Additionally, several LEDs indicate the last fault detected by the driver. This is definitively a big plus in that it provides a quick explanation of unexpected inverter shut down. To ensure a balanced current flow, Hall Effect current sensors are integrated in the stack. The driver will

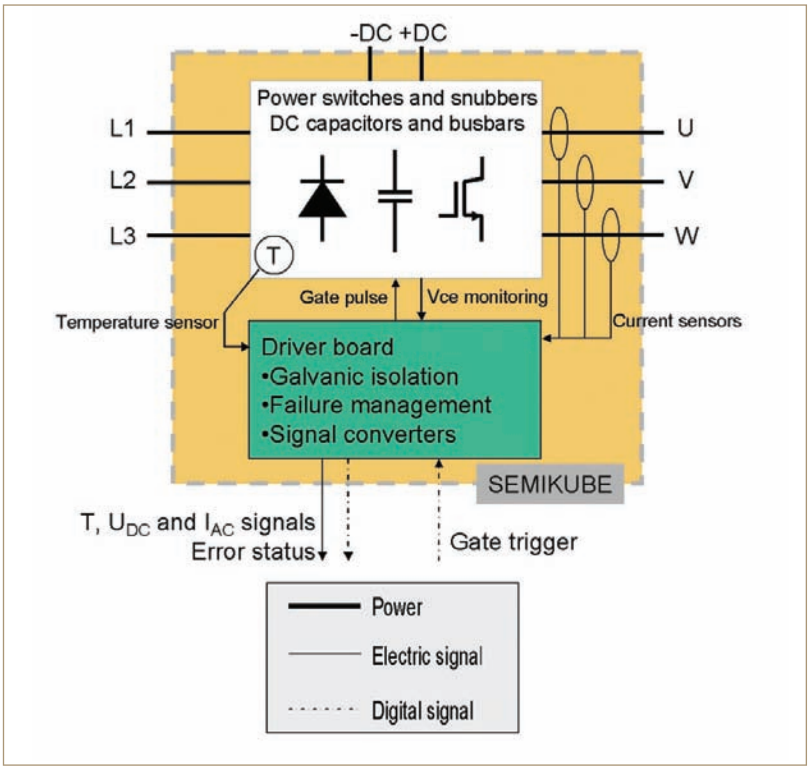

Figure 6: General SEMIKUBE interfacing

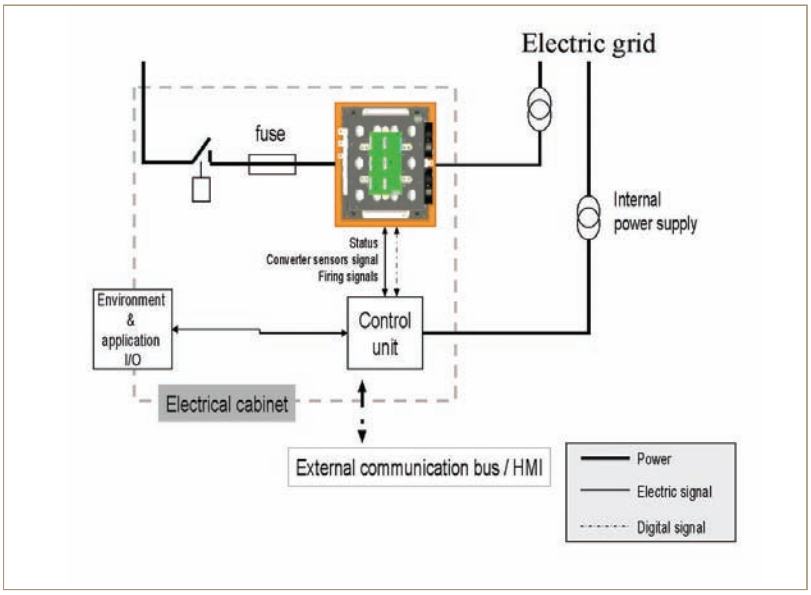

Figure 7: SEMIKUBE in a solar cell inverter application

detect a current imbalance or over-current incident, and will ensure safe turn-off.

Normally, the stack features a three-phase rectifier part and a three-phase inverter. The rectifier can be designed in uncontrolled (B6U), half-controlled (B6HK) or fully controlled (B6C) versions, depending on the customers' needs. On the inverter side, the three-phase topology (GD) is the typical version, although H-bridge configurations (GH) or even single-arm versions (GB) can also be used as a buck or boost chopper (Figure 6).

Applications

The main application for SEMIKUBE stacks can be found in standard industrial variable-speed drives. A new application that has appeared in the last few years is usage in central photovoltaic inverters (Figure 7).

This application shows the major advantage of the SEMIKUBE: fast time-to-market is ensured because the inverter is a pre-tested device and is even available in UR (UL recognized) versions. Another major point for the adoption of this platform in photovoltaic inverters is the overall efficiency, which has to be as high as possible in such applications. The platform explained here boasts an efficiency of more than 98% in terms of losses.

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Renewed Focus on Power Converter Efficiency for Green Applications

High density power converters have transformed the wind energy business from being a mere provider of an energy resource to a provider of an active power source integral to national grids. In particular, the current generation of power electronics technologies has lowered per-watt converter costs, improved efficiency and provided capabilities such as reactive power compensation and low voltage ride through for grid interconnection. **Perry Schugart, Director, Power Converter Business, AMSC Power Systems, New Berlin, USA**

The electric power efficiency of the converter system has become a threshold design criteria for wind turbines. Even a small improvement in converter power efficiency translates to improved profitability of the investment in wind turbines due to increased power production. The reliability of the converter system has also become a key industry focus. Improved reliability of the converter system increases the reliability of the wind turbine, thus increasing the mean-time-between-failure (MTBF) of the wind turbine. And, improved mean-time-between-failures decreases service costs and increases power production over time, which is important for the profitability of the investment in wind turbines.

Converters benefit from progress in power semiconductors

Prior power electronics for variable speed wind turbines have required complicated and expensive circuitry to perform power conversion and to control the turbine. But, the development of higher power IGBTs has made the power electronic converter requirements of a wind generator less problematic. In particular, over the last 10 years, the trend has been toward lower switching and conduction losses in wind power converters, which has meant less costly heat removal hardware.

Lower switching losses have been achieved due to faster, cleaner turn-on/turn-off characteristics of IGBT components – with higher output efficiency gained from lower losses. And more robust, higher temperature rated IGBTs are possible, over 125°C as typified by a new approach employed in a dedicated wind power converter, developed by American Superconductor. Overall, power converters now exhibit greater ruggedness, reliability, and have much higher power density.

The real key in translating the technical trends in power electronics into success for wind energy has been the development of the dedicated, or application specific, power converter. For example, the PowerModule PM3000W, which is a programmable and modular power converter, was developed specifically for wind power applications. As such, it can be rapidly integrated into wind turbines with power ratings from 750kW up to 6MW and has been engineered to withstand severe climatic changes and poor power grid conditions encountered at remote wind farms around the world. This technology also supports low voltage ride through (LVRT) and provides ground fault protection directly inside the wind turbine and can be used with the vast majority of wind turbine generators – synchronous, asynchronous, induction, permanent magnet, doubly-fed, and full conversion, operating on a 50 or 60Hz line.

The converter utilises thermally and mechanically enhanced IGBTs and features wind power specific controls, interfaces and application modules; and with its

Figure 1: **Construction of the programmable and modular power converter PM3000W specifically for wind power applications**

Figure 2: The PM3000 converter is configured to support AC/DC/AC power conversion. Integration of two dual-DSP embedded controllers allows implementation of two separate control functions with independent software for each

mono-frame construction with integrated slide mounts (combining two power converters into a single package) offers versatility (Figure 1). Rated at 850kW, the converter's topology features two embedded dual-DSP controllers, two four-quadrant power processors and a dynamic brake (Figure 2). The two embedded controllers (one for each power processor) allow implementation of two separate control functions with independent software for each, giving the customer the ability to program certain PLC functions (customer's proprietary controls). The power converter is liquid cooled and incorporates a double conversion architecture with a common laminated DC bus (AC/DC/AC). A dynamic brake is included and provides DC bus protection against over-voltage. This compact design yields a power density of up to 130W/in³ (7.9W/cm³). Multiple power converters can additionally be configured in parallel to create higher power-rated converter systems up to 6MW.

The wind-specific PM3000W converter additionally incorporates algorithms and external communication protocols to enable universal generator connectivity and is the first power converter building block developed specifically to bridge the needs of both wind turbine generators and wind farm grid interconnection directly inside the wind turbine through integrated low voltage ride through (LVRT) and proprietary D-VAR technology. Because it can be utilised across multiple wind energy applications, this solution streamlines manufacturing processes, thereby reducing time to market for wind energy converter systems.

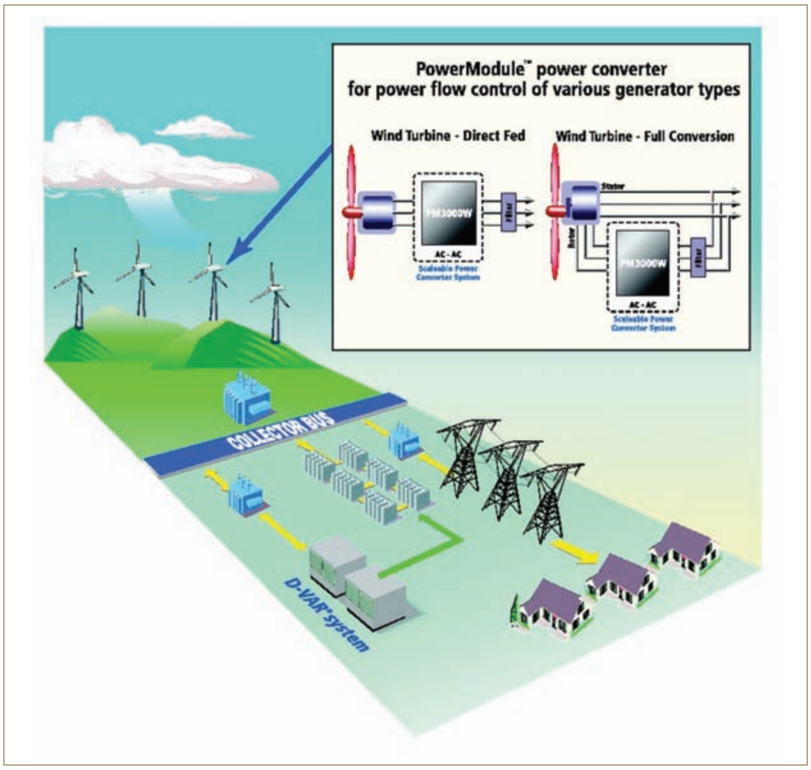
SiC-based converters provide new possibilities

Wind generator power converter electronics are a key building block in the wind industry. Research and development efforts seek to develop more capable power modules incorporating localised intelligence with higher operating voltage (e.g. SiC-based converters) for use in multi-megawatt wind turbines. Switching losses are expected to be reduced by 30 to 50%. That would translate to about a one half of a percent increase in average efficiency and turbine energy production, a modest but still valuable improvement.

Conclusion

Future power converters must be specialised and designed to meet the unique challenges of variable speed wind power applications. Permanent-magnet generators that allow lighter rotor designs and have lower losses will play a role, as will power converters that have even higher efficiencies below rated power. Reliability will always be a key issue, because the generator and power converter are the main power processing components in converting energy from wind to useable electricity.

Figure 3: PM3000W converters incorporate algorithms and external communication protocols to enable universal generator connectivity. Integrated low voltage ride through (LVRT) and proprietary D-VAR technology enables wind farms to meet grid interconnection requirements



Monitoring Multicell Li-Ion Battery Stacks

With high energy density, Lithium-Ion batteries are poised to be the power source of choice for applications such as electric and hybrid electric vehicles, scooters, motorcycles or uninterruptible power supplies. However, designing a large, highly reliable and long-lasting Li-Ion battery stack is a very complex problem. Li-Ion cells are sensitive to over-charging or over-discharging, requiring that each cell in a stack is carefully managed. A new battery stack monitor makes this possible with quick and accurate measurements of all cell voltages, even in the presence of stack voltages over 1000V. **Mike Kultgen, Erik Soule, Linear Technology, Milpitas, USA**

Gasoline and other fossil fuels are the most viable energy sources for use in portable and non-grid applications, since they offer outstanding energy density at a relatively low cost. However, the growing direct and indirect cost of these fuels, combined with major advances in battery technology, is changing these metrics. Nearly all energy sources (solar, wind, geothermal, nuclear, oil, natural gas, etc) can be converted to electrical energy. If battery technology continues to progress such that significant electrical energy can be reliably and economically stored, all of these energy sources can be used interchangeably.

Stamina — Size

Technology	Energy Density	Power Density	No. of cycles
Lead Acid	35 Wh/kg	150 W/kg	200
VRLA	45	250	500
NaNiCl	125	150	1000
NiMH	70	150-300	1000
Li-ion	85-150	400-1300	600-10000
Supercap.	12	3000	500,000

Figure 1: Li-Ion offers the best combination of specifications with cost coming down

Li-Ion battery characteristics

The Lithium-ion battery is poised to be the battery of choice for high power battery applications, primarily for its high energy density; Li-Ion offers nearly twice the energy density of nickel-metal hydride (NiMH), which is the battery used in many of today's hybrid electric vehicles (Figure 1). However, for Li-Ion batteries to be reliable, over thousands of cycles, the battery design must overcome a number of significant challenges.

Li-Ion battery performance depends on battery temperature and age, battery charge and discharge rates, and the state of charge (SOC). These factors are not independent. For example, Li-Ion batteries generate heat when discharged, which can increase discharge current. This has the potential of creating a thermal runaway condition and catastrophic failure. Also, charging a Li-Ion battery to 100% SOC or discharging to 0% SOC will quickly degrade its capacity. As a result, Li-Ion battery SOC is typically restricted to a range between 20% and 90%, effectively providing a usable capacity of 70% of the specified capacity.

The method for configuring multiple Li-Ion batteries is also a very important consideration. To deliver significant power from an electrical system, such as that needed to accelerate a vehicle, up to hundreds of volts are required. To understand, consider that to deliver 1kW at 1V requires 1000A; to deliver 1kW at 100V requires only 10A. Inherent resistance in system wiring and interconnects translates to I x R loss, so designers use the highest voltage/lowest current that's practical. For a battery-based system, where the typical Li-Ion cell has a fully charged voltage of 4.2V, many battery cells must be connected in long strings of series-connected cells. Keep in mind, as part of a long string, any single cell failure will disable the entire stack and each additional cell increases this risk.

Combining the challenges of a high voltage battery stack with the nuances of Li-Ion batteries is a very complex problem. A Li-Ion battery stack cannot be charged and discharged as if it were a single power source. For those cells with slightly less capacity than the others, their SOC will gradually deviate from the others over multiple charge and discharge cycles. If the SOC for each cell is not periodically equalised, or balanced, some cells will eventually be driven into deep discharge, leading to damage, and eventually complete battery stack failure.

Monitoring Li-Ion batteries

As a result, a battery control system must carefully monitor and control each battery cell's condition. This problem can be divided into two separate tasks: the control task and the data acquisition task. The control task refers to the algorithms and techniques devised to charge and discharge each cell in the system. This is highly dependent on the application and often involves highly protected intellectual property.

The data acquisition task refers to the battery stack interface. This interface must quickly and accurately measure each single-cell voltage along the high voltage stack. This requires the ability to extract a small differential voltage from a common mode voltage ranging from 0 to more than 1000V (as you move up the stack). This is a tough challenge, requiring the combination of a number of high performance analog devices. Linear Technology has applied its analog expertise to develop a single IC to meet this challenge.

The LTC6802 is a highly integrated multicell battery monitoring IC (Figure 2), capable of measuring up to 12 individual

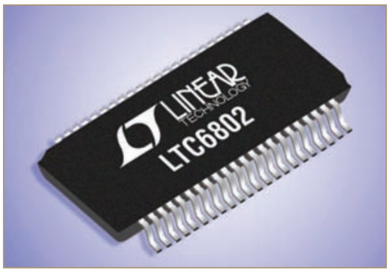


Figure 2: **Highly integrated multicell battery monitoring IC**

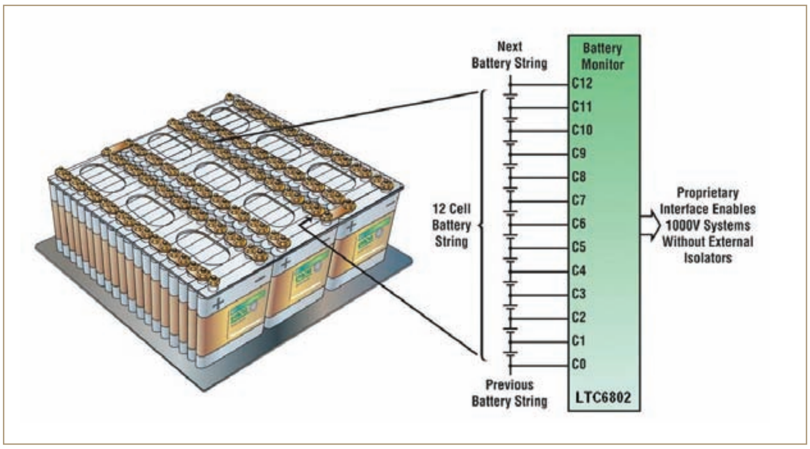


Figure 3: **The LTC6802 is capable of measuring up to 12 individual battery cells**

battery cells (Figure 3). Using a unique level shifting serial interface, multiple LTC6802s can be stacked in series without opto-couplers or isolators, allowing precision voltage monitoring of every cell in long strings of series-connected batteries. The maximum total measurement error is guaranteed at 0.25% from -40 to 85°C and all cell voltages in a battery stack can be measured within 13ms. Each cell is monitored for under-voltage and over-voltage conditions, and an associated MOSFET switch is available to discharge overcharged cells. An input multiplexer connects the batteries to a 12bit delta-sigma analog to digital converter (ADC). An internal 10ppm voltage reference combined with the ADC give the LTC6802-1 its outstanding measurement accuracy (Figure 4).

With the delta-sigma ADC the input is sampled many times over the course of a conversion and then fi ltered or averaged to produce the digital output code. In contrast, a SAR converter takes a single snapshot of the input voltage and then performs the conversion on this single sample. For measurements in a noisy environment, a delta-sigma converter provides distinct advantages over a SAR converter.

Communication between the LTC6802-1 and a host processor is handled by a SPI compatible serial interface. The device can pass data up and down a stack of devices using simple diodes for isolation. The LTC6802-1 also contains circuitry to balance cell voltages. Internal MOSFETs can be used to discharge cells. These internal MOSFETs can also be used to control external balancing circuits.

The device makes no decisions about turning on/off the internal MOSFETs. This is completely controlled by the host processor. The host processor writes values to a configuration register inside the IC to control the switches. The watchdog timer can be used to turn off the discharge switches if communication with the host processor is interrupted.

The LTC6802-1 can be used with as few as four cells. The minimum number of cells is governed by the supply voltage requirements of the device. The sum of the cell voltages must be 10V to guarantee that all electrical specifications are met.

The LTC6802-1 has three modes of operation: standby, measure, and monitor. Standby mode is a power saving state where all circuits except the serial interface are turned off. In measure mode it measures cell voltages and store the results in memory. Measure mode will also monitor each cell voltage for overvoltage (OV) and undervoltage (UV) conditions. In monitor mode, the device will only monitor cells for UV and OV conditions.

The FMEA scenarios involving a break in the stack of battery cells are potentially the most damaging. In the case where the battery stack has a discontinuity between groupings of cells monitored, any load will force a large reverse potential on the daisy-chain connection. This situation might occur in a modular battery system during initial installation or a service procedure. The daisy-chain ports are protected from the reverse potential in this scenario by external series high-voltage diodes required in the upper-port data connections. Each pin of the LTC6802-1 has protection diodes to help prevent damage to the internal device structures caused by external application of voltages beyond the supply rails.

Conclusion

The first, most clearly defined market for the LTC6802, is the electric vehicle (EV) and hybrid electric vehicle (HEV). Automotive applications combine traditional automotive demands (high reliability, safety, long life) with the need for a high performance, high power battery system. In addition to EV/HEV applications, traditional battery applications and entirely new applications are being enabled by Li-Ion battery technology. The same drivers for the EV/HEV revolution are at play, the demand for green technology and the relative cost of petroleum-based fuel, as compared to other fuel sources.

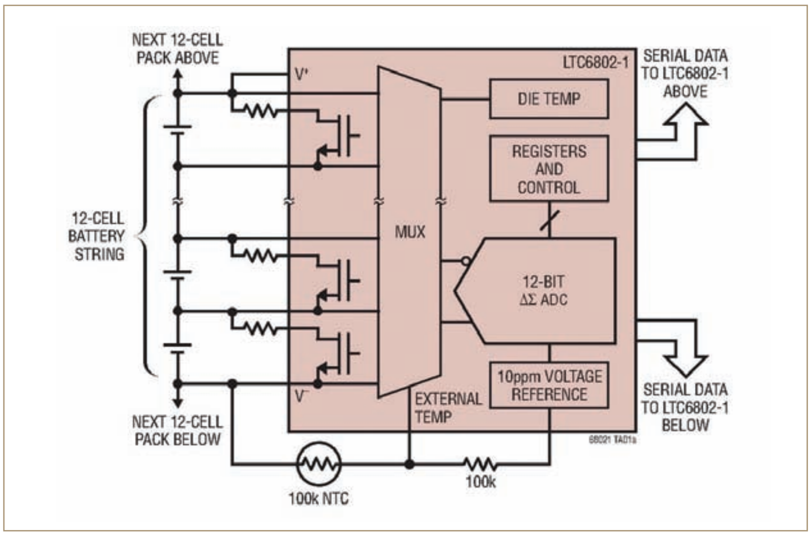


Figure 4: **Typical application of the LTC6802**

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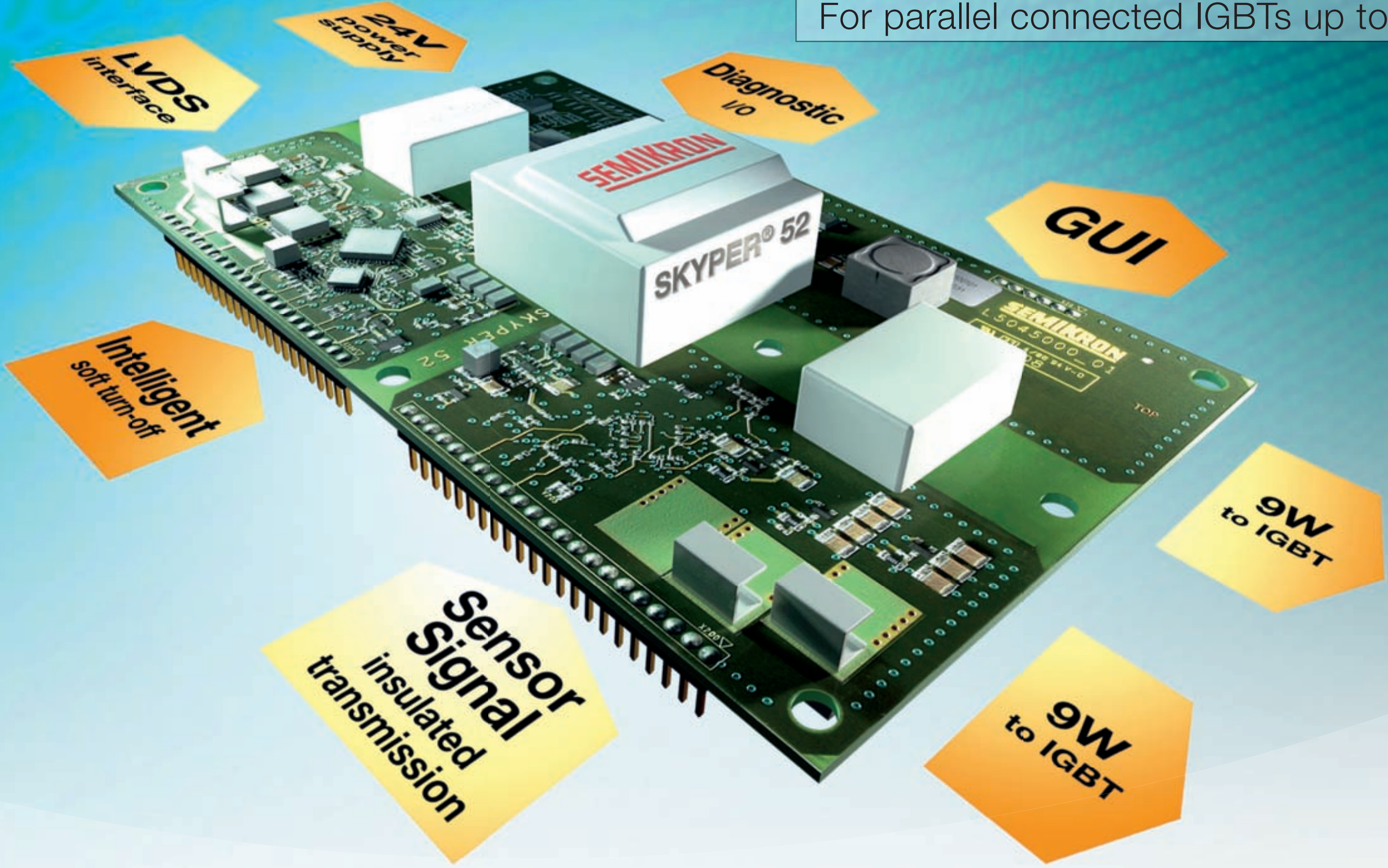

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ULP Meets Energy Harvesting: A Game-Changing Combination

Macro-scale energy harvesting technologies in the form of windmills, watermills and passive solar power systems have been around for centuries. Microenergy harvesting systems that scavenge milliwatts from solar, vibrational, thermal and biological sources. However, understanding ultra-low power from the sourcing side brings challenges as harvested power derived from ambient sources tends to be unregulated, intermittent and small. **Murugavel Raju, MCU Strategic Marketing, Texas Instruments, USA**

Macro-scale harvesting technologies differ in many ways but have one thing in common: they 'feed the grid', typically adding kilowatts or megawatts to the power distribution system. As such, they are not game changers for electronic designers whose mission in life is to snip the wires – including power cords and even battery-powered systems where the perpetual device is the ultimate design goal.

For this second goal, micro-energy harvesting systems are the answer. Energy harvesting's new frontier is an array of micro-scale technologies that scavenge milliwatts from solar, vibrational, thermal and biological sources. A few years ago, micro-harvesting could have been called a scientific curiosity. But the design community's long march to ultra-low-power (ULP) technology has had the unexpected result of pushing micro-scale energy harvesting out of the lab and onto the designer's bench (Figure 1).

Macro vs. Micro	Energy Source	Solutions	Ultimate Goal
Macro	Renewable Energies (Solar, Wind)	Energy Management	Reduce Oil Dependency
Micro	Energy from the Environment (Vibration, Body Heat)	Ultra-Low Power	Perpetual Devices

Figure 1: Macro versus micro energy harvesting comparison

Now, designers are sizing up ULP, not just from the consumption side, but from the production perspective as well. Understanding ULP from the sourcing side will be every bit as challenging as it was from the consumption side not that many years ago. Primary reason: harvested power is derived from ambient sources so it tends to be unregulated, intermittent and small.

ULP sets targets

While there is no widely accepted definition of ULP, it's helpful to consider it in the context of batteries because they are easily the most common energy source for ULP designs today. Medical applications in which electronic devices are implanted in or attached to the body are good examples of ULP designs that run on batteries. Examples are implanted medical devices. Size and battery life are primary considerations. Power dissipation of 10µW and battery life of 15,000 hours would be typical. In-ear devices are another example. Size becomes more important than life, which indicates button cell. Typical power dissipation is 1mW with 1,500hr life. Thirdly surface-of-skin devices. The limiting factor is the ability of the skin's surface to dissipate heat. Typical power dissipation is 10mW with 150hr life.

Medical applications that consume milliwatts set the energy-production bar for harvesting devices. The good news is that milliwatts are the same order of magnitude that micro-harvesters can generate. Some non-medical products already use micro-harvesting sources. These include calculators, watches, radios and Bluetooth headsets. There are also applications that consume in the order of milliwatts as well, but have not yet been adapted to micro-harvesting, the most promising being remote sensors.

Harvester technologies

The most promising micro-harvesting technologies extract energy from vibration, temperature differentials and light. A fourth possibility – scavenging energy from RF emissions – is interesting, but the energy availability is at least an order of magnitude less than that of the first three. Estimates vary, but Figure 2 shows the approximate amount of energy per unit available from four micro-harvesting sources.

Micro-harvesting provides power at the same order of magnitude that carefully designed ULP circuits typically consume. The three most promising technologies – based on light, motion and thermal scavenging – have different

Energy Source	Harvested Power
Vibration/Motion	
Human	4 µW/cm²
Industry	100 µW/cm²
Temperature Difference	
Human	25 µW/cm²
Industry	1 – 10 mW/cm²
Light	
Indoor	10 µW/cm²
Outdoor	10 mW/cm²

Figure 2: Energy harvesting estimates

characteristics. Large solar panels have made photovoltaic harvesting a well characterised technology. Approximately 1mW of average power can be harvesting from each 100mm² photovoltaic cell. Typical efficiency is roughly 10% and the capacity factor of photovoltaic sources (the ratio of average power produced to power that would be produced if the sun was always shining) is about 15 to 20%. Commercially available kinetic energy systems also produce power in the milliwatt range. Energy is most likely to be generated by an oscillating mass (vibration). But electrostatic energy harvested by piezoelectric cells or flexible elastomers is also classified as kinetic energy. Vibrational energy is available from structures such as bridges and in many industrial and automotive scenarios.

Basic kinetic harvester technologies include (1) a mass on a spring; (2) devices that convert linear to rotary motion; and (3) piezoelectric cells. An advantage of (1) and (2) is that voltage is not determined by the source itself, but by the conversion design. Electrostatic conversion produces voltages as high as 1,000V or more. Thermoelectric harvesters exploit the Seebeck effect, which states that voltage is created in the presence of a temperature difference between two different metals or semiconductors. A thermoelectric generator (TEG) consists of thermopiles connected thermally in parallel and electrically in series. The latest TEGs are characterised by an output voltage of 0.7V at matched load, which is a familiar voltage for designing ultra-low-power applications. Generated power depends on the size of the TEG, the ambient temperature, and (in the case of harvesting heat energy from humans), the level of metabolic activity.

According to the Belgian-based research corporation IMEC, at 22°C a wrist-watch type TEG delivers useful power of 0.2 to 0.3mW on average for normal activity. Typically, a TEG continuously charges a battery or super-capacitor and requires advanced power management to optimise efficiency.

Despite their differences, photovoltaic, motion and thermal harvesting also have a few things in common: they generate erratic voltages instead of the steady 3.3 or 1.8V design engineers sometimes take for granted; they also provide intermittent power and sometimes no power at all.

Conversion technology is only part of the solution. Since micro-harvesters tend to generate intermittent power, the most common system architectures are called hybrids because they include energy storage in thin-film batteries.

A typical energy-harvesting system includes conversion, temporary storage and a heavy dose of sophisticated power management circuits, analog converters and ULP MCUs. To take ULP to the next level, it is highly desirable to integrate as many of these circuits as possible on a single chip.

Best practices

Energy harvesting doesn't exactly rewrite the rules of realising the best power efficiency in circuit design, but some of its best practices may be counter-intuitive to many engineers.

The key design goal is to match the power circuits to the application circuits for the best overall performance. Applications can then be developed knowing that technology will support that product.

Several techniques that solve the unfamiliar power management problems that micro-harvesters present include optimising switched power supplies because they can boost very small source voltages. By chopping the input signal, switchers allow designers to control its magnitude and frequency. Switching topologies also dissipate very little power but introduce unwanted frequencies that must be normalised. Since tasks such as charging the gate capacitance of a MOSFET could consume a large percentage of the harvested energy, a current-source gate charge rather and a voltage-source gate charge will often make sense. Another technique is to use more than one power converter circuit. The first circuit could be unregulated but capable of charging a capacitor. Once sufficient energy is stored in the capacitor, it can be discharged and the signal conditioned by a more sophisticated power converter circuit.

Silicon implications

What are the implications of micro-harvesting for ICs? The most common system component would be an MCU. Because MCUs have more to do than just be stingy with energy, other criteria have to weigh in, including wake up time (which also has an impact on energy consumption), operating voltage, frequency and code density.

A system powered by a small battery – or micro-energy harvesting device – will need to communicate information to another system or to a central collection point. Supplying power to a network of sensor-transmitters has traditionally required expensive wiring installation or routine battery changes. Gathering data from difficult or dangerous-to-reach locations using wired sensors may be impossible and or even compromise the safety of personnel installing wiring and replacing batteries.

Low power, wireless communication for energy-harvesting applications is the clear alternative. Low-power RF transceivers are designed to operate in the ISM bands (315, 433, 868 and 915MHz), but can be easily programmed for frequencies in the 300 to 348MHz, 387 to 464MHz and 779 to 928MHz bands. These transceivers also offer leading noise immunity, selectivity and blocking to ensure reliable communications, even in noisy environments.

With TI's CC430 platform, the combination of the power-effi cient, highly functional MSP430F5xx MCU and a TI low-power RF transceiver on a single chip offers a low-power/performance mix and high integration to help break down barriers to RF implementation such as stringent power, performance, size and cost requirements helping bring wireless connectivity to new applications (Figure 3).

Integration adds value

From an IC architecture perspective, integration is almost always a good thing. With ULP designs, the benefits are particularly helpful. Of the five important components of a harvesting system – conversion, temporary storage, power management circuits, analog converters and ULP MCUs – the last four are the most likely first step toward high integration.

The MSP430 MCU family already integrates many high-performance analog and controller functions needed for energy-harvesting applications. The addition of power management and the radio circuits are all that is required – and that is what the new CC430 platform will deliver. The full MSP430 MCU peripheral set will be available on the CC430 devices, including digital and analog peripherals like a 12bit ADC, and comparators that provide high performance even during RF transmissions and consume no power when not in operation. These peripherals also speed design by integrating functions such as an integrated Advanced Encryption Standard (AES) accelerator that encrypts and decrypts data sent wirelessly for more secure alarm and industrial monitoring systems.

With a 50% reduction in printed circuit board (PCB) space, CC430-based devices help enable smaller devices in a wide variety of wireless applications. Examples may include smart hospital tracking that can communicate patient or medical equipment information to a central location or personal area networking between sports watches, pedometers, chest-strap heart-rate monitors and PC-based health and fi tness analysis programs. Smaller board space and reduced complexity also help shrink the size of heat-cost allocators and AMI smart metering systems, which are expected to make up 28% of all electric meters by 2013.

In addition to delivering low-power advantages, integration also reduces package size and cost which is a high priority for small sensor applications that might be deployed, for example, in a mesh network or some other 'network of things' – for example, RF sensor networks that report data to a central collection to analyse and regulate information such as smoke in the atmosphere to detect forest fires, moisture or pesticide information in crop fields, or even humidity levels in a winery.

A major stumbling block to date in deploying wireless technology in industrial settings has always been powering the radio and the application circuits. Both installation and periodic maintenance have been identified as being problematic. If line power has to be extended to the application, the value of wireless communication is reduced. If batteries are used, they have to be replaced from time to time.

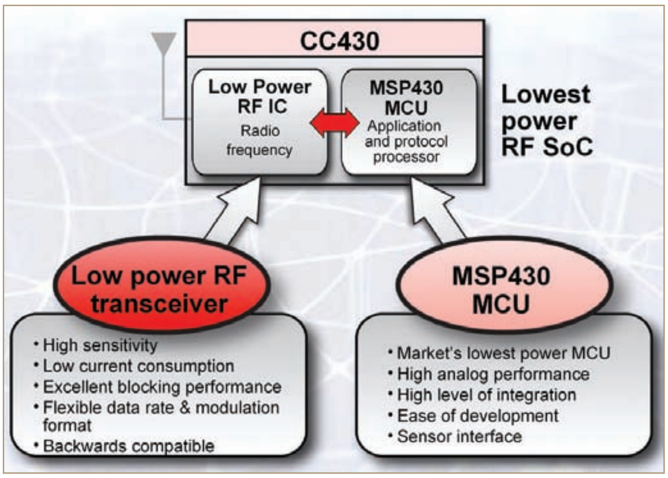

Figure 3: **CC430 devices including digital and analog peripherals consuming no power when not in operation**

Conclusion

The combination of ULP and micro-harvesting is likely to be the most cost-sensitive, sensible approach to addressing the above described challenges; the CC430 technology platform is a solution to provide the microharvesting and ULP needed for these applications. Sensing applications are limitless, power supplies are not; solutions like the CC430 platform that combine low power and high functionality with the know-how to take the mystery out of RF design help bridge this gap to help usher in a new age of energy solutions.

Literature

'Power Management and Energy Harvesting' and 'Powering Microcontrollers from Ambient Energy Sources', Power Electronics Europe Oct/Nov 2008, pages 22 and 32-34.

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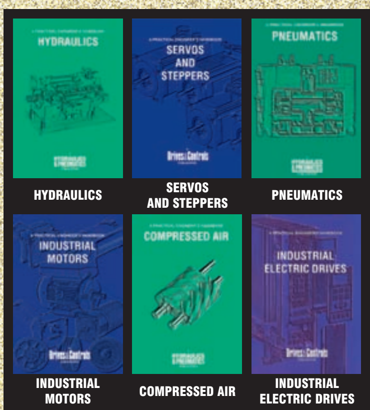

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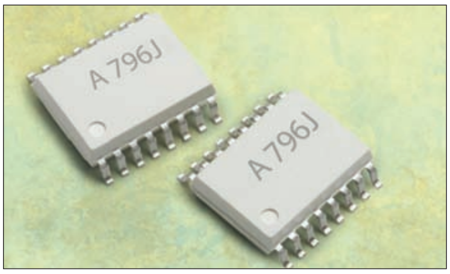
The C2141PX2 and C2142PX2 are rated at 4W and 8W respectively, packaged in SOT23-6 and are available in volume now. The devices completely eliminates the need for optocouplers and all secondary-side feedback circuitry, as well as any additional components that designers may need to specify to improve the current regulation from a typical PSS flyback design. The controllers use patented algorithms combined with digital techniques enabling quasi zero voltage switching, which drives up operating efficiencies and delivers improved current regulation to maintain the optimum lifetime of lithium ion batteries. The controllers are designed for use with low cost bipolar transistors and have protection features such as over-temperature, input over-voltage and output short-circuit included as standard to further simplify designs and reduce system costs.

www.camsemi.com

Optically Isolated Sigma-Delta Modulators



Avago has announced one of the industry's first optically isolated sigma-delta modulator using an external clock to provide direct measurement of motor phase currents in power inverters. Based on a low power CMOS process, the ACPL-796J uses an external clock that allows synchronised data conversion between the current sensor and controller to eliminate complex design processes in data and clock reading.

With 0.5mm minimum distance through insulation, the ACPL-796J provides reliable double protection and high working insulation voltage, which is suitable for fail-safe designs. Offered in a 16-lead small outline package, the isolated A/D converter delivers the reliability, small size, superior isolation and over-temperature performance motor drive designers need to accurately measure current with qualification for industrial safety approvals such as IEC/EN/DIN EN 60747-5-2, UL 1577 and CSA.

www.avagotech.com/optocouplers

17mm Three-Phase Bridge Rectifier Modules

POWERSEM has launched two new bridge rectifier modules PSDS 62 (63A at 110°C, 800 to 1800V) and PSDS 82 (88A at 110°C, 800 to 1800V) with a profile height of 17mm, both with screw connections.

These new modules expand the company's family of single and three-phase rectifier modules with screw, solder and fast-on connectors. The 17mm height modules are following the trend in power modules, gradually replacing the old 30mm profile height standard. The mechanical, electrical and thermal parameters of the new PSDS 62 and PSDS 82 are the same as 30mm PSD 62 and PSD 82. POWERSEM is a German manufacturer of Power Semiconductor Modules with more than 20 years experience.

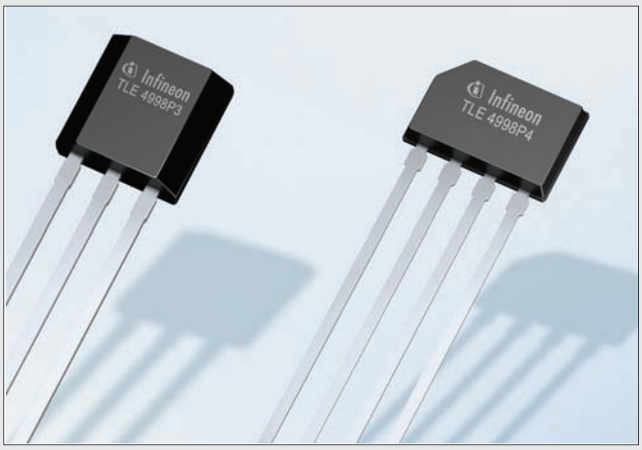
Major products are Bridge Rectifiers, Standard and Fast Recovery Diode Modules, Thyristor Modules, MOSFET and IGBT Modules.

www.powersem.com

Current Measurement Hall Sensors

Infineon introduced two programmable linear Hall sensors designed for use in automotive and industrial applications requiring highly accurate rotation and position detection.

The new TLE4997 and TLE4998 sensors are fully automotive qualified. Additionally, the TLE4997 sensor provides temperature compensation and the new TLE4998 sensor adds compensation of stress over lifetime. Both sensors are suited for a wide range of applications. Automotive applications include pedal and throttle positioning, suspension control, torque sensing and gear stick position detection. In the industrial area, the sensors are for use in robotics and automation applications, medical equipment and high-current sensing applications, such as UPS. The TLE4997 and TLE4998 sensors both feature EEPROM-programmable parameters including offset, bandwidth, polarity, output clamping, coefficients for compensation of a magnet's temperature drifts and memory lock, making them highly versatile in a broad spectrum of linear and angle position sensing applications.



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Software Tool for Power Analysis

MELCOSIM 4.0 from Mitsubishi Electric helps design engineers selecting the best-fitting power semiconductor modules for their individual application. The software tool takes into account such important issues like the power loss occurring in power modules under specific user application conditions, as well as junction temperature rises as a consequence of power loss.

In addition to version 3.0 the new MELCOSIM version 4.0 offers the possibility to calculate the maximum junction temperature – an essential feature for determining the junction temperature at relatively low output inverter frequencies of less then 30Hz, as the temperature swing caused by power losses and thermally equivalent RC elements of the power module is a significant issue in this low-frequency range. Like the previous versions the new MELCOSIM 4.0 operates with fast algorithms, structured input/output windows and the possibility to generate graphical outputs for further analyses and successive changes of individual application condition parameters within the specification limits.

Furthermore, all calculation results can be exported into a text format file. MELCOSIM's graphical user interface ensures that the software tool is easy to use. MELCOSIM instantaneously provides information about the average power loss of the IGBT and the free-wheeling diode (divided into static and dynamic parts), the total power loss for the power module, case temperature, as well as the average and maximum junction temperatures in the transistor and in the free-wheeling diode.

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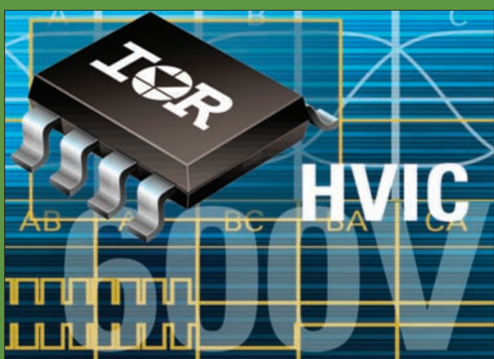
Single-Phase HVICs for Motor Control



International Rectifier offers the IRS260xD family of single-phase high-voltage ICs (HVICs) for motor drive applications including air conditioners, fans, pumps, and general purpose inverter drives. This new family of high speed power MOSFET and IGBT drivers features optional dependent or independent high- and low-side referenced output channels with a gate drive supply range from 10 to 20V.

The output drivers feature a high-pulse current buffer stage designed for minimum driver cross-conduction while the floating channel can be used to drive N-channel power MOSFETs or IGBTs in the high-side configuration operating up to 600V. The devices provide matched propagation delay for both channels and an advanced input filter to improve noise immunity in addition to negative voltage spike immunity to protect the system. The IRS2608D and IRS2609D half-bridge drivers feature internal 540ns dead-time. The IRS2608D provides high-side output in phase with HIN input and low-side output out of phase with LIN input and is also suitable for both trapezoidal and sinusoidal motor control. The IRS2609D features high-side output in phase with IN input, and a shut down input to turn off both channels.

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Murata Power Solutions has added a new series of eighth-brick DC/DC converters to its existing range of brick converter products.

The fully isolated (2250VDC) UCE series is available with fixed output voltages from 1.5 to 12V, output current to 40A and output power up to 100W. The open-frame design uses an interleaved synchronous rectifier topology to achieve efficiency levels of over 90%.

The modules accept an input voltage range of 36 to 75VDC. Compact overall dimensions of 58.4mm x 22.9mm, a low profile of 10.16mm and maximum 85°C operating temperature allow the UCE series to be incorporated in designs for distributed power architectures, servers, telecoms, wireless and information technology equipment.

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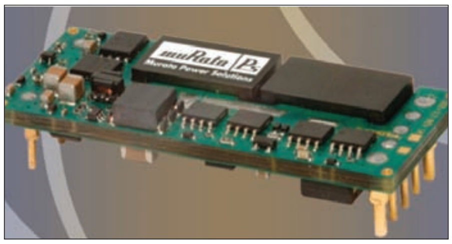

Power Management ICs for Automotive Applications

Diodes qualified a series of its Zetex power management ICs to the AEC-Q100 Grade 1 automotive quality specification for operation in automotive environments at temperatures up to 125°C including monitors, regulators and references.

The ZXCT1008 and ZXCT1080 current and voltage output current monitors, the ZTL431 and TLV431 shunt regulators, and the LM4040 precision micropower voltage reference devices support measurement and protection duties in a wide range of reliability-critical subsystems, including window motor control, air conditioning and courtesy lighting.

The Zetex range of bipolars and MOSFETs has long been qualified to the AEC-Q101 specification. The AEC-Q100 compliant monitors, regulators and references are a complement to the automotive sector.

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