POWER ELECTRONICS EUROPE

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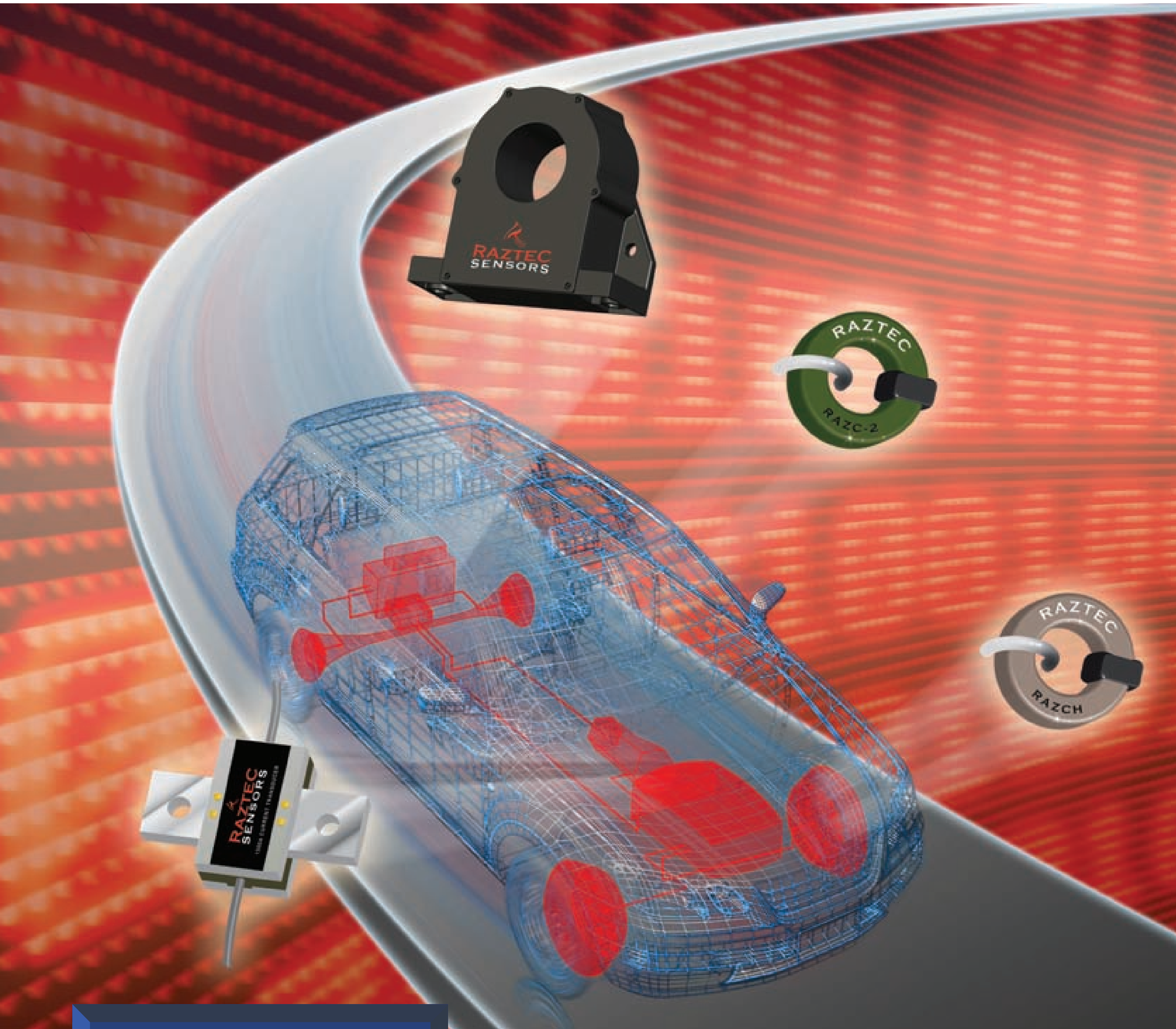
AUTOMOTIVE CURRENT SENSING

Current Sensing Solutions for Hybrid Electric Vehicles



THE EUROPEAN JOURNAL FOR POWER ELECTRONICS AND TECHNOLOGY

Also inside this issue

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Greener Cars Through Power Electronics

The popularity of hybrid electric vehicles (HEVs) is increasing across the world, and the UK is listed as one of the top five global hybrid electric vehicle markets. Increasing demand for gas, price rise and environmental concerns are driving a market that is in need of alternative solutions. The advantage that an HEV offers with regard to construction and design aspects is that the engine designed in an HEV is small, which makes these vehicles more efficient. Electric cars such as G-Wiz, Sakura and NICE, along with hybrid cars including Toyota Prius, Honda Civic, Lexus RX, and GS Hybrids, are exempted from the London Congestion Charges. This exemption would enable commuters to potentially save over £1600 when they drive in and out of the city centre. Such promotional features are likely to boost EV and HEV markets. Hybrids require much less fuel than conventional vehicles, offering greater savings on fuel costs. Another advantage is improved efficiency. In fact, they offer more mileage compared with conventional vehicles, which makes HEVs require minimal gas. They are environment friendly; hybrids have much fewer greenhouse gas emissions, and are therefore capable of reducing the smog-forming pollutants in the atmosphere; tax credits and incentives. Finally, many governments across different countries promote HEVs by offering tax credits and incentives that make HEVs affordable.

These advantages and technical aspects ensure that HEVs are the most compatible next-gen vehicles, which are user-friendly as well as environment friendly.

Mercedes-Benz i.e. will launch an S-Class hybrid next year, equipped with a lithium-ion battery supplied by Continental Automtive Systems. The main advantages of the newly developed lithium-ion battery are its very compact dimensions and far superior performance, relative to conventional nickel-metal hydrid batteries such as those powering the Toyota Prius. The power-to-weight ratio of the battery is 1,900W/l. It has a high ampere-hour efficiency, long service life, and is reliable even at very low temperatures, the company said, adding that its safety is the equal of that provided by today's auto batteries. The S 400 BlueHYBRID, powered by a 299HP engine that enables it to sprint from 0 to 100km/h in 7.3s. It would consume on average 7.9l of petrol per 100km and emit 190g of carbon dioxide per kilometre, compared with 10.3l of petrol and 247g of CO_2 in a comparable conventional S-Class. Conti also supplies an inverter to control the flow of energy between the electric motor and the hybrid battery, as well as a voltage converter that links the hybrid battery to the car's standard electric system, eliminating the need for a conventional generator.

But as the market will not accept premium prices, there is a substantial challenge for designers to provide technologically innovative and cost-effective solutions. This implies the need for a modular automotive-grade power electronic approach which can be manufactured at a resonably low price. To master these challenges, the InGA project was initiated in Germany with industrial partners Continental, Infineon Technologies, Epcos, SiCED and Volkswagen, with the main aim being to reduce system costs by integrating the electronics at the electrical machine for generating hybrid drivetrain units. This means developing generic technology and modular systems, built up from components that can be manufactured essentially with similar configurations, but with different qualities, to meet the specific performance, lifetime and cost requirements of different applications. Based on that approach, scalable mechatronics, high temperature electronics, power electronics, and cooling technologies will be developed and have been presented recently at the CIPS 2008 conference.

Hybrid electric vehicle technology also plays a major role at PCIM Europe in Nuremberg. The first keynote by Reinhold Bayerer, Infineon Technologies/Germany is entitled 'Higher Junction Temperature in Power Modules - a Demand from Hybrid Cars, a Potential for the Next Step Increase of Power Density for Various Variable Speed Drives'. And a special session 'Automotive Power' on May 29, organised by Power Electronics Europe, focuses with four papers on power electronics for efficient hybrid drivetrains.

Thus, mark PCIM Europe (May 27 – 29) in Nuremberg and particularly the session Automotive Power (May 29, 10.00 – 12.00, Room Mailand) in your calendar. See you there!

Achim Scharf
PEE Editor

New Heatsink Materials

The objective of the EU project ExtreMat is to develop novel heat sink composites and to test their performance under extreme loading conditions. At present overheating causes more than 50% failures of electronic devices and the high temperature becomes a limiting factor.

New developments requiring the dissipation of up to 20MW/m^2 will only be possible with heatsinks made of materials possessing extremely high thermal conductivity (~600 W/mK), ability to withstand large temperature changes without disintegration and deterioration of properties and capability to reduce complex thermo-mechanical stresses after bonding to supporting or protecting structures by tailoring of their thermal expansion in the range of 4 to 9ppm/K. "In the first phases of project performance, experimental studies were performed on more than 40 promising material systems in order to evaluate their feasibility for targeted applications. Two main material groups were investigated: copper alloys reinforced with fibres or (nano) particles for heatsinks working mostly in reactors and engines where performance at high temperatures (up to 1000°C) and dimensional stability play primary role; and metal matrix composites based on highly conductive phases such as diamond, highly graphitised carbon fibres and flakes, carbon nanotubes, etc. for use in advanced electronic applications", commented project coordinator Christian Linsmeier.

After systematic assessment performed by industrial partners including Siemens, selected composites were further optimised in phase 3 of the project. For their preparation several advanced technological methods, including gas pressure infiltration of melts, squeeze casting, isostatic pressing, rapid sintering, PVD and plasma coating, were utilised. The development of composites was supported by tailoring of interfaces between constituents at nanoscopic level, in order to stabilise them in the whole range of working temperatures without degradation of thermal conductivity.

A set of (SiC, W, C) fibre reinforced copper matrix composites has been produced and submitted to neutron irradiation testing to evaluate their feasibility for fusion applications. Regarding materials for electronics, thermal conductivities in the range 600 to 700W/mK have already been achieved with diamond and pitch based carbon fibres reinforced metals. The technology for continuous manufacturing of Cu-SiC-fibre mono layers in industrial scale and also industrially applicable technique for gas pressure infiltration of particle/fibrous preforms were developed to support future industrialisation of obtained knowledge. In next phases of the project, the developed materials will undergo a large application oriented testing programme, which should yield data to allow assessment of their behaviour at irradiation, heat flux and thermo-mechanical loading.

Various combinations of heatsink and protection materials will be prepared, in order to demonstrate and test the mutual joinability and performance of joints under extreme loading. Several experiments have already started to evaluate the performance of developed mate rials as heatsinks in electronic packages, power- and optoelectronic devices.

Heatsinks based on copper matrix reinforced with ceramic and intermetallic (nano) particles or fibres for use in high temperature applications (up to 1000°C), where excellent dimensional stability combined with good thermal conductivity play a primary role. The thermal conductivity should be comparable to Cu (300W/mK) with a heat flux removal capability of up to 20MW/m^2. The CTE in plane direction at the interface should be adapted to the CTE of the protection material which is typically 4...9 x 10^{-6} K^{-1}. Secondly, heatsinks based on highly conductive phases (diamond, highly graphitised carbon fibres, carbon nanotubes with theoretical thermal conductivity 800 to 6000W/mK) embedded in appropriate metallic matrix for use in applications, where extreme heat fluxes combined with tailored CTE are the main requirements. The CTE in plane direction at the interface should be adapted to the CTE of the supporting structure, typically 4...9 x 10^{-6} K^{-1}. The limitations of current materials will be overcome by knowledge-based combination of constituents, by optimum architecture of composites based on modelled performance and by tailored interfaces between constituents at nanoscopic level. The main aim will be to develop stable interfaces in the whole range of working temperatures without degradation of thermal conductivity.

"Extremat is a € 35 million EU-funded project for research and development of new materials under extreme thermal conditions including heatsinks for power modules", states project coordinator Christian Linsmeie

Surface tailoring techniques provide compatibility for the joining of ceramic matrix composites to metallic materials, e.g. SiC joined to Cu-based heatsinks. Atomic deposition of thin interface films followed by sophisticated characterisation, like Rutherford back-scattering and sessile drop technique for in-vacuum wetting angle measurements at high temperature, open enhanced operation regimes (temperature, mechanical loads) for compound materials.

Improved matching of the coefficient of thermal expansion (CTE) of different constituents of composites for heatsink applications by interlayers. W and Mo, deposited by thermal spray or chemical vapour deposition or implemented as solid sheets, are the main elements used for interlayers with intermediate CTE. As a highlight, W-Cu layers with tailored CTE and an almost four-times increase of thermal diffusivity could be produced by a combination of plasma spraying and HIPping.

The public outreach of the ExtreMat project will be intensified by the presence at the Hanover Industry Fair 2008 and through the organisation of an "ExtreMat Conference" open for all interested parties in June 2008.

AS

www.extremat.org

Internal Qualification at Semikron Honoured by German President

SEMIKRON's last financial year was particularly good for the company achieving a turnover of €430 million - doubling the figure of four years ago. The main drivers behind this success were new technologies in the area of renewable energy. The global manufacturer of power semiconductors and modules operates 35 subsidiaries in 27 countries and 10 production locations and employs 1,350 people in Germany and 3,000 worldwide.

Over a period of two years, the company will be investing over €100 million into the expansion of its production locations, €65 million of this will go into the company's HQ in Nuremberg, where the main gaols are to double chip production capacity and further expand the New Technologies division.

To achieve this, more engineers with an innovative spirit and the willingness to adopt responsibility are needed immediately. This is the key to design new products for emerging markets such as wind and solar power, hybrid vehicles, frequency converters in electric drives, industrial installations and power supply systems. Thus, programmes involving internal training in machinery and plant engineering have been set up ending with a formal Chamber of Trade and Commerce qualification. For a total of 125 days, 22 employees will be relieved of their normal responsibilities in order to be able to take part in the programme. A second group is to start training in October.

"This programme will raise the level of qualification among our personnel, making them more flexible for different areas of activity", explains Andreas Dauer, Head of Corporate Development at Semikron. Recently, German President Köhler visited Semikron in order to check the outcome of this training programme for semi-skilled and non-skilled personnel carried out in cooperation with the German Employment Agency.

www.semikron.com

CTO Thomas Stockmeier (left) accompanies Mr. Köhler during the production tour at Semikron's plant in Nuremberg

High Growth for Automotive Power Semiconductors

Discrete power semiconductors and microcontrollers will find significant opportunities in automotives as hybrid and electric vehicles gain popularity. End-user market expansion, increased automobile multiplexing, and wider application of vehicle integrated circuits will likely sustain this growth.

Analysis from Frost & Sullivan, World Markets for Discrete Power Semiconductors in Automobiles, reveals that the market earned revenues of $1.76 billion in 2006 and estimates this to reach $2.7 billion in 2010. "Government safety, security, and pollution regulations have encouraged the use of electronic content in automobiles in order to eliminate human error", said Senior Research Analyst Bonnie Varghese. "This has had a direct and positive impact on the automotive power discretes markets". Manufacturers have to ensure that attractive price points and technological superiority back product performance and quality, in order to take advantage of market opportunities. They will also have to determine how to overcome challenges associated with the increased integration of power discretes with application-specific integrated circuits (ASICs).

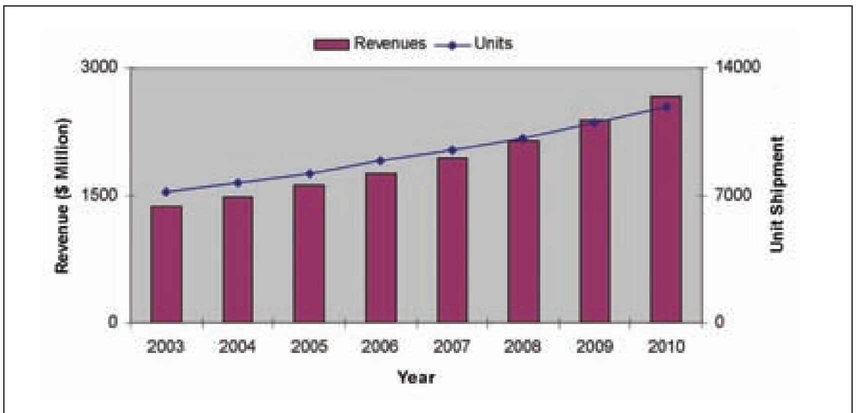
Discretes with higher levels of integration pose numerous problems to manufacturers. The high on-resistance interconnects and complications involved in the isolation of power cause design cycle delays, thereby prolonging the time-to-market. Once discrete power semiconductors resolve issues such as safety, security and telematics, driver information applications will likely grow at a startling pace. The intricate processes required to create an integrated solution often increase the product cost. Therefore, manufacturers should focus on module solutions, particularly within the high-voltage discrete segment. "Having a modular solution that integrates discrete power semiconductors with a small high-performance package enhances the performance at a relatively lower cost", noted Varghese. "Another advantage of using the module is better thermal management, which represents a key concern in the automotive industry". Asia will likely become one of the fastest growing markets due to the increasing sales of automobiles in this region. However, Europe will likely generate the most revenues due to its early technology adoption.

Gaining popularity of HEVs

The popularity of hybrid electric vehicles (HEVs) is increasing dramatically across all the countries in the world, and the UK is listed as one of the top five global hybrid electric vehicle markets. At present, the developed countries are keen on promoting HEVs, while the developing countries are unable to enforce the usage of them. Increasing demand of gas, price rise and environmental concerns are driving a market that is in need of alternative solutions. "The advantage that a HEV offers with regard to construction and design aspects is that the engine designed in a HEV is small, which makes these vehicles more efficient", explained Suba Swaminathan, Frost & Sullivan's Team Leader Power Systems Group. Electric cars such as G-Wiz, Sakura and NICE along with hybrid cars including Toyota Prius, Honda Civic, Lexus RX, and GS Hybrids are exempted from the London Congestion Charges. This exemption would enable commuters to potentially save over £1600 when they drive in and out of the city center. Such promotional features are likely to boost EV and HEV markets. "One of the advantages of HEVs is improved fuel economy. Hybrids require much less fuel than conventional vehicles, offering greater savings on fuel costs. Another advantage is improved efficiency. In fact, they offer more mileage compared with conventional vehicles, which makes HEVs require minimal gas. They are environment friendly; hybrids have much fewer greenhouse gas emissions, and are therefore capable of reducing the smog-forming pollutants in the atmosphere; tax credits and incentives. Finally, many governments across different countries promote HEVs by offering tax credits and incentives that make HEVs affordable", Swaminathan noted.

These advantages and technical aspects ensure that HEVs are the most compatible next-gen vehicles, which are user-friendly as well as environment friendly. With the Asia Pacific countries joining the race, the growth of HEVs is expected to accelerate to a significant extent in the next five years.

Continental Automotive Systems (Germany) announced in March that it will launch first-time volume production of a high-performance lithium-ion battery for hybrid vehicles at the end of 2008. It will be used in the Mercedes S 400 BlueHYBRID. "This marks an important breakthrough for Continental as a supplier of battery systems. In the next few years, we will be launching production of further lithium-ion energy storage devices for mild- and full-hybrid and electric-powered vehicles", stated board member Karl-Thomas Neumann. Aside from the lithium-ion battery, Continental also supplies the inverter and the DC/DC converter for the Mercedes S 400 BlueHYBRID. The inverter controls the flow of energy between the electric motor and the hybrid battery, as well as between the hybrid battery and the vehicle's standard electric system and thus, makes possible the elimination of the conventional generator.



Automotive discrete power semiconductor world market, base year is 2006 Source: Frost&Sullivan

www.semiconductors.frost.com

Greener EcoSmart Technology Enables Compliance

The Energy Independence and Security Act of 2007, passed by both houses of Congress and signed into law by President Bush in December, includes stringent, mandatory energy-efficiency standards on external power supplies (EPS), the AC adapters and chargers that power cellphones, cordless phones, modems and countless other electronic products. Most external power supplies manufactured for sale in the US after July 1, 2008 must comply with the standards. The standards are equivalent to the second, tighter version of the California Energy Commission EPS standards, also scheduled to take effect on July 1.

The energy law also mandates significant improvements in the efficiency of lighting technologies used in general service lamps. The new lighting standards are expected to result in the phase-out of traditional incandescent light bulbs beginning in 2012, in favour of more efficient technologies including compact fluorescent bulbs and light-emitting diodes (LEDs).

"The California efficiency standards touched off a transformation of the external power supply market", said Balu Balakrishnan, CEO of Power Integrations. "Linear transformers are no longer a viable option for most end products. The next phase of the standards, with tighter active-mode and no-load requirements, will now be adopted nationwide as a result of the new energy law, and additional EPS specifications are being developed by ENERGY STAR and the European Union. We are committed to helping manufacturers meet these standards in a timely and cost-effective manner, so that consumers need not pay extra for products with efficient power supplies. The transition to efficient lighting is also part of a worldwide trend, as plans to phase out traditional light bulbs have also been announced in Australia, Canada and Europe", Balakrishnan noted. "Our chips enable simple, energy-efficient off-line LED driver circuits that are compact enough to fit into the base of a standard light bulb".

www.powerint.com

Voltage Regulation Market Weakened in 2007

The global voltage regulation IC market grew by 5% in 2007 to more than $7 billion, according to recent analysis from IMS Research.

The results reveal that the non-isolated regulation market weakened in 2007, following a period of prolonged high growth. However, the isolated market continued to perform well, due to demand for highly efficient controllers for AC/DC power supplies. Despite the relatively low growth seen in the voltage regulation market last year, some pockets of high growth were apparent. "It is clear that the voltage regulation market weakened in 2007, partly due to inventory correction; however, some applications, such as notebook PCs and high-end consumer equipment bucked this trend", commented Research Director Ash Sharma. "Vendors are hoping for a much stronger 2008, but whilst the long-term drivers for power management remain favourable, short-term spending in the consumer and computing sectors looks uncertain due to the current economic climate".

www.imsresearch.com

Green Opportunities for Branding

Strong growth of digital video recorders, digital cameras and portable media players have been and are expected to be significant contributors to the healthy consumer electronics market. In these, and most other consumer electronics products, new features and reductions in size have increased system complexity. This increased complexity, along with lower operating voltages and higher currents, is placing higher demands on power supplies and batteries.

At the same time, consumers are also expecting longer periods between battery charges and electronics that are increasingly efficient in their use of electricity. New Energy Star regulations that went into effect in 2007 place stricter efficiency demands on a wide range of consumer electronic equipment during both operating and standby modes. These regulations and the new features that encourage consumers to upgrade their devices have resulted in semiconductor manufacturers developing new ICs that can support the higher performance demands of consumer electronics and still enable the design of equipment that can meet or exceed Energy Star's specifications.

OEMs have already started to deliver greener products and equipment, in compliance with newly introduced Energy Star guidelines. According to the Environmental Protection Agency (EPA), just by replacing the 180 million computers in use in the United States with computers complying with the Energy Star guidelines, energy savings would total $1.8 billion over the next five years and greenhouse gas emissions would be reduced by the equivalent of 2.7 million cars.

Commercial organisations are also examining their energy usage at the corporate level. Datacenters, massive consumers of electricity for computing and cooling operations, are also becoming larger and more prevalent. Prompted by concerns over electricity consumption, organisations like Google, Intel and HP are reexamining their strategies for designing these facilities and the equipment used in them. These companies realise that they have a responsibility, both to their shareholders and the world, to reduce the electricity usage and carbon footprints of their equipment and facilities. In the home, consumers are being encouraged to look for the Energy Star label on white goods, home entertainment equipment and light bulbs.

OEMs are designing their equipment – PCs, monitors, switches, routers and power supplies – to comply with industry and government standards – and the growing desire of businesses, governments and private citizens to be more socially responsible, whether by mandate or by choice. In research conducted in 2007, VDC found that OEM engineers who specified power management components frequently stated that efficiency was a top factor when specifying components, in some cases more so than price. High efficiency is a differentiator which many power management suppliers are highlighting in product briefs and other marketing collateral. As part of their marketing strategy, several vendors have established brand names to convey their commitment to high efficiency. National Semiconductor's PowerWise brand is attached not just to its power management portfolio, but recently also to its entire analog portfolio, including op amps and data converters. Texas Instruments has established Impedance Track as a brand for its line of highly accurate battery fuel gauge ICs. Branding is a very powerful marketing tool that can create an association between a product and its features and benefits, and it should not be underestimated.

By displaying their brand alongside their like-minded OEM partners, semiconductor vendors can demonstrate their commitment to helping end users reduce their electricity consumption. OEMs also stand to gain, showing that they too care about the environment and are committed to helping consumers reduce their electricity consumption. This additional branding, once recognised by the mass market, can be used to command higher average selling prices, both by the component vendors and the OEMs. Consumers will pay more for higher efficiency products because of the lower cost of ownership, and also because they know they are doing something to help the environment.

Power-One Inverters Selected for Solar-Power Installation in Spain

Aurora PVI-Central inverters have been selected by the Energy Division of Isolux Corsán for use in Spain's largest photovoltaic-power installation, and the second largest renewable-energy facility in the world. One hundred of these 300kW inverters will be installed before September 2008 to process over 34 megawatts of solar power.

"When tested in accordance with IEC 61683 photovoltaic-system standards, these products can provide up to a 2.3% performance-ratio advantage compared to other commercial solutions; resulting in an additional 9,000kWh per year for each inverter. With 100 inverters in this installation, almost 1MWh of added power can be generated annually", commented Paolo Casini, Power-One's Alternative Energy Marketing Director. PVI Central utilizes a modular architecture that enhances flexibility and reliability. Flexibility is improved through incorporation of modules with different power ratings, which facilitates current-distribution optimisation. Aurora PVI-Central inverters are available in configurations from 50 to 300kW.

www.power-one.com/renewable-energy/

Strengthening Europe's Position in Power Electronics

The program for this year's Conference on Integrated Power Electronic Systems (CIPS) from March 11-13 in Nuremberg/Germany included 11 conference sessions with the presentation of 55 technical papers. 84% of them came from nine European Countries, 8% from North America, and 8% from Far East. The program also included 12 invited papers, authored by qualified experts coming from important industrial and academic organisations.

CIPS General Chairman J. Daan van Wyk was proud to announce the participation of more than 180 delegates

General Chairman J. Daan van Wyk was proud to announce the participation of more than 180 delegates for this first stand-alone conference, while in previous years CIPS has been held in conjunction with ISPSD oder PESC. For the first time a Session on 'Technology Roadmaps' for Power Electronics has been organised, and five contributions gave an insight to the ECPE initiative on technology roadmaps.

Projections up to the year 2020

General Chairman Leo Lorenz introduced this roadmap initiative. "Our vision in ECPE is to devise medium to long-term research roadmaps up to 2020 to offer guidelines for power electronic research by universities and research centres, but also to provide an orientation for public research programmes and to help industry to prepare for upcoming technologies. The focus is on power electronics in different key systems and applications, installing system-oriented teams with experts from industry and university".

Basically, the roadmap development process can start from the application or the technology view. The chosen application-oriented approach is focussing on the requirements in different key systems using power electronics. Therefore, seven system-oriented teams have been formed for the power electronics applications of highest strategic importance which are coordinated from the university side. Included are Power Grid Infrastructure (power generation & distribution, energy storage) and Renewable Energy Sources (wind, PV); Large Drives (large industry and traction drives); High Performance Motor Drives; Small Drives for Home Appliances; High Frequency Power Conversion >1kW (e.g. telecom, server, heating, welding); High Frequency Power Supplies <1kW (e.g. stand-alone & integrated power supplies, chargers, lighting); and Automotive Power Electronics (low and high voltage applications).

"Our vision in ECPE is to devise medium to long term research roadmaps up to 2020 to offer guidelines for power electronic research", General Chairman Leo Lorenz explained

"In the vision 2020, the role of power electronics in 2020 is described with special focus on the role of Europe regarding industry position and R&D institutions in power electronics. In the next step, megatrends in society are related to power electronics. Trends and drivers from the customer and end-user side, as well as technology trends and drivers, are investigated. Limiting challenges driven by market needs and major technology gaps to be closed to meet the challenges have to be analysed. Finally, strategic goals are defined answering the key question for the roadmap development process: where do we want to stand in 2020 and what are reasonable intermediate steps in 2010 and 2015, in the powerelectronic systems view?", Lorenz explained.

Bottom-up approach

"The use of technology roadmaps in microelectronics is indispensable, but little has been done so far in power electronics, except the activity of the power supply manufacturers association. For this reason, ECPE has started an own technology roadmap initiative in which all power electronics systems are using common materials, components and technologies", Technical Chairman Eckhard Wolfgang stated. For power semiconductors roadmaps are provided by the manufacturers, i.e. by Infineon Technologies.

Automotive power electronics

The automotive industry has specific requirements for its power electronic systems, such as a compact design, high reliability, long lifetime and an extremely low cost to power ratio. The systems are further required to operate over a wide ambient temperature range and with liquid cooling temperatures of typically 105°C. "In a study from the USA FreedomCAR project, it is projected that the required cost of the power electronic systems has to reduce by a factor of three until the year 2020. The task of the Automotive Roadmap Committee was to clarify which technologies are needed to achieve the performance and cost targets of the automotive industry", Wolfgang said.

"The use of technology roadmaps in microelectronics is indispensable, but little has been done so far in power electronics", Technical Chairman Eckhard Wolfgang stated

Thus, the road mapping effort is focused on three systems such as a non-isolated DC/DC converter in the 40 to 100kW power range, that can be used as a fuel cell interface; an AC/DC inverter that is integrated into the machine housing of a hybrid drive system (since an integrated solution provides the greatest cost reduction potential); and an isolated DC/DC converter to provide bidirectional power flow between the high-voltage bus and the 14V accessory power system, where the required power range is up to 3kW.

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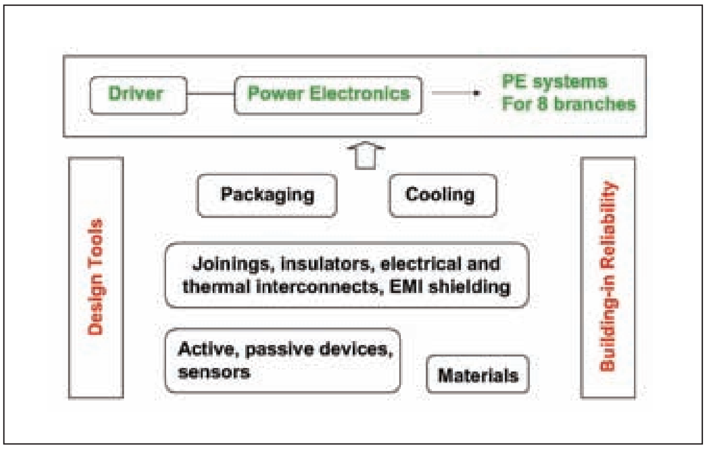
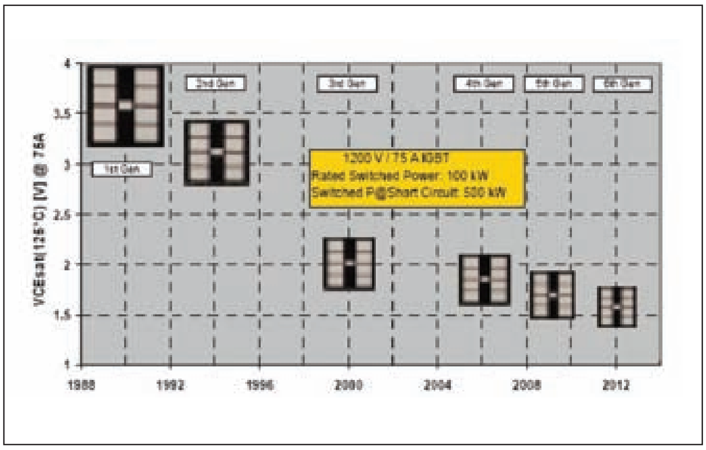


ECPE bottom-up roadmap



Roadmap for 1200V IGBTs – on-state voltage and chipsize

The roadmap utilised the bottom-up approach, here mathematical descriptions for the electrical, thermal, packaging and magnetic components are developed. Using these descriptions a component technology space is formed. By using the specifications, topologies, and operating parameters, the component space can be mapped into a system performance space, which gives system performance measures such as efficiency, power density and costs.

High frequency power supplies

"Europe is in a good position with regard to semiconductor technology and some system level applications, like automotive, medical and lighting, but on the other hand, Europe is in a weak position in power supplies and packaging, especially in the low power range. The proposed strategy for Europe is to use our strengths to improve our weak points", José A. Cobos (Universidad Politécnica de Madrid) pointed out.

Diversity is a keyword in power supplies, since they may be classified from very different perspectives. Different requirements apply from an application viewpoint, ranging from Industrial or Telecom to Lighting or Information Technology. The energy source also makes a difference: typical off-line AC power supplies show different metrics than battery supplied converters, and even greater distance from self-powered or autonomous devices. There is also diversity in the loads, which impose different requiremens to the power supplies. New power management trends are based on the own nature of the load. Some techniques applied to reduce power consumption in digital circuits (voltage scaling) differ from those used in highly efficient non-linear RF amplifiers. They are also different from the requirements of contact-less chargers (i.e. in body implants),and they also differ from the strategy to supply flat panel displays. Power device technology also makes a difference, lateral CMOS devices are more appropriate than standard vertical devices in some low power applications.

Therefore, groups with some commonalities need to be identified, so that the same strategic goals apply to all the possible applications of that group. Pursuing this objective, four different groups (off-line electronics, digital circuits, mobile electronics, and self powered) have been selected, all of them under the umbrella of the Integrated Power Supplies.

High frequency power conversion

"Europe's worldwide market position has a big chance of remaining very strong in the field of industrial high power supplies, because of two important factors - the innovation in high-power supplies is key prerequisite for industrial manufacturing technologies for high-volume goods such as electroplating or induction heating, and the final product is not only the power supply itself, but also the sum of technical quality, cost-performance relation, customer support during the design-in process, application as well as technology specific knowledge, maintenance issues, and much more. Moreover, the power supply is the key-part of a very complex final product", Tobias Reimann from ISLE/Germany stated. "Thus, a completely different added-value sharing situation can be utilised, compared to mass market products, and therefore, it is absolutely necessary to gain the basic R&D activities to defend this position in the future.

Examples for main research topics for the next ten to twenty years include fully digital, self-learning converter to load and converter to grid interfaces; active-passive integration at very high power levels; efficient prototyping platforms including electrical, thermal, EMI, EMF, mechanical, and economical issues; materials for high power density passives; self-protected intelligent high power semiconductor switches with high load and temperature cycling capability; multifunctional materials for impedance-optimised system design and shielding; and high performance systems for remote diagnostics maintenance and service.

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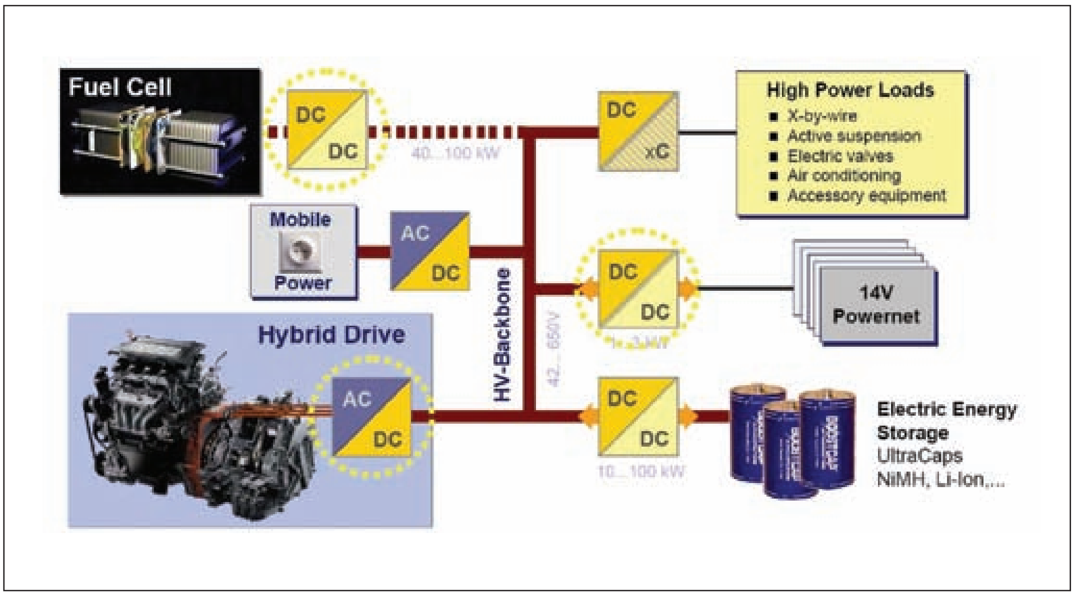

Power electronic key systems for the cars of tomorrow, three considered systems in the automotive roadmap are encircled

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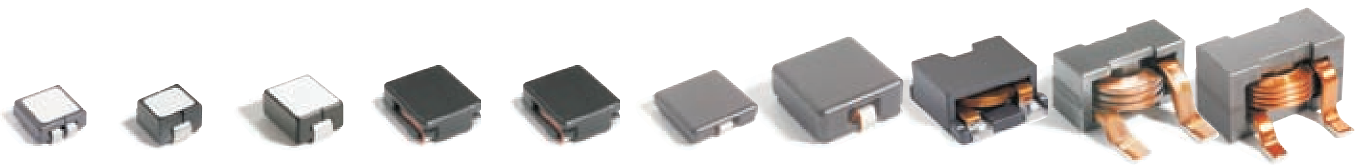

SLC7530	SLC7649	SLC1049	MVRT	MVRC	MLC1200	MLC1500	SER1360	SER1590	SER2000
0.05 - 0.4 µH	0.04 - 0.1 µH	0.08 - 0.15 µH	0.25 -0.56 µH	0.36 - 2.3 µH	0.36 - 4 µH	0.5 - 4.5 µH	0.33 - 10 µH	0.3 - 1 µH	0.3 - 2 µH
Up to 50 A	Up to 100 A	Up to 61 A	Up to 35 A	Up to 36 A	Up to 37 A	Up to 32 A	Up to 48 A	Up to 50 A	Up to 100 A
6.7 x 7.5 mm	7.5 x 7.6 mm	6.9 x 10.2 mm	9.8 x 11.5 mm	9.8 x 11.5 mm	10.5 x 11.2 mm	13.2 x 13.8 mm	13.1 x 12.9 mm	16.3 x 15.8 mm	19.6 x 20.1 mm
3 mm high	5 mm high	5 mm high	5.1 mm high	4.7- 7.8 mm high	4.1 - 6.1 mm high	3.9 - 6.5 mm high	5.8 mm high	10.2 mm high	8.6 - 14 mm high

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A Deeper Focus on Power Electronics

This year's PCIM conference focuses with 12 sessions and 51 papers on power electronics. German speakers will supply 24 papers, 19 papers will come from other European countries, and five papers from Asia and three from the USA round up the internationality of the conference.

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

The 12 sessions are categorised around special topics such as High Voltage Devices, High Freuency Converters, Automotive Systems, Module Reliability, Fast Switching Devices, Advanced Power Management, New Packaging Concepts, Protection Strategies, Power Factor Correction and Compensation, High Efficiency, Advanced IGBT Technology, and last, but not least, a Special Session Automotive Power organised by Power Electronics Europe.

Awards and keynotes

The opening ceremony on May 27 from 9.00 – 9.45 is not only an opportunity to give some welcome addresses, but also for presenting the Young Engineers Award (for 3 authors up to 35 years receiving €1000,00 each) and the Best Paper Award for industrial or automotive applications (flight and accomodation for PCIM China 2009). The latter has been sponsored by Power Electronics Europe.

The following keynote by Reinhold Bayerer, Infineon Technologies/Germany is entitled 'Higher Junction Temperature in Power Modules - a Demand from Hybrid Cars, a Potential for the Next Step Increase of Power Density for Various Variable Speed Drives'.

Though many data sheets of power devices show maximum ratings in junction temperature of up to 175°C, reliable application is mainly limited to junction temperatures of 125 or 150°C. Driven by automotive requirements and hybrid car application, further increase of junction temperatures is on the roadmap. It would simplify power electronics, because the coolant of the combustion engine could be used to cool the power electronics as well. For other drives applications the question arises as to whether they could also benefit from the related increase of power density. 600 and 1200V IGBT and diodes can be operated at up to 200°C in the junction. The results are demonstrated, for example, by blocking characteristics, turn-off and short circuit test results. The limit in junction temperature is therefore not set by the semiconductor, but rather by the lifetime of solder joints and interconnects. Assembly and Interconnection technologies have to change for enabling high temperature operation in the range of 175 to 200°C. As a replacement of solder joints, the low temperature joining technique has been known since 1986 and has been in production for high power thyristors and diodes at Infineon Technologies since then. Power cycling results prove the elimination of fatigue. As this process is not that attractive for power modules from the process point of view, other assembly technologies, which can be considered to meet the target of eliminating the solder fatigue, are investigated too. High voltage applications such as traction may not approach the junction temperature as high as foreseen for the 1200V devices, but such application may take advantage of the extended reliability gained by new packaging technologies.

The second keynote on May 27 in the afternoon by Jacques Laeuffer, Supèlec/France deals with 'Higher Frequencies Power Transformers Designs'.

Increasing power supplies frequencies leads to new issues for transformers and inductances design, related to electromagnetic power propagation delays inside the structure of the windings. When semiconductors commutations times are less than this delay, this leads to strong and noisy HF oscillations. Thus, EMC - including winding insulations and semiconductors safety - requires reduced propagation delays, to be designed through new rules, including analysis of energy densities and power flow density inside the transformer structure. Introduction of very fast switching SiC diodes will reinforce this for transformers such as planar, round wire, or pulse, and last, but not least, windings of electric machines fed by inverters.

The keynote on May 28 morning by Ikuya Sato, Fuji Electric Advanced Technology/ Japan covers 'Technologies for Practical Motor Drive System with Matrix Converters'.

Recently, matrix converter has attracted a lot of attention, because it has bi-directional power flow, has no large electrolytic capacitors, and can make its input current of sinusoidal waveform. Therefore, it is highly efficient, has long life-time, and has lower input harmonic distortion than an inverter system with diode rectifier. And it has a potential of additional energy saving by using a novel IGBT that has reverse blocking capability. This paper describes several technologies to realise practical matrix converter system with nine bi-directional switches.

The final keynote on May 29 morning by Christof Zwyssig, Swiss Federal Institute of Technology is entitled 'Mega Speed Drive Systems: Pushing Beyond 1 Million RPM'.

Research in mesoscale drive systems is targeting rotational speeds up to and beyond one million rpm in a power range from 1W to 1kW. Emerging applications for mega-speed drives are to be found in future turbo compressor systems for fuel cells and heat pumps, generators/starters for portable nano-scale gas turbines, PCB drilling and machining spindles, and electric power generation from pressurised gas flow. The selection of the machine type and the challenges involved in designing a machine for mega-speed operation are presented. Prototypes and experimental results originating from

This year' PCIM conference will feature four keynotes and 50 papers on power electronics, including a special session Automotive Power organised by Power Electronics Europe

MegaNdrive research at ETH Zurich are given.

Special session automotive power

Just after the final keynote, this special session organised by Power Electronics Europe will be held in the room Mailand from 10.00 – 12.00. The focus is on power electronics for hybrid electric vehicles which is also attracting growing interest in Europe as the market increases.

The first paper in this session 'Semiconductors in Hybrid Drives Applications – A survey lecture' by Ingo Graf from Infineon Technologies AG describes the structure and function of the different hybrid drive components, as well as used semiconductors. The latest IGBT, MOSFET and SiC technologies will be shown. According to the special needs in hybrid drive applications, future trends like increased junction temperature or new interconnection technologies will be illustrated.

The second paper 'Resonant Motor Drive Topology with Standard Modules for Electric Vehicles' by Michael Frisch from Tyco Electronics shows that weight and volume reduction of the system have highest priority in electric vehicles, which leads to high motor frequencies. To gain the advantage of high speed drives without the disadvantage of high power losses, resonant switching topologies are required, without becoming too complex and whilst still satisfying the required reliability. A new standard component which supports an innovative switching topology might be an important step forward.

'From vehicle drive cycle to reliability testing of Power Modules for hybrid vehicle inverter' is the third paper given by Markus Thoben from Infineon Technologies. In HEV the battery, motor, and inverter are core elements of the electric drive train. In the inverter power semiconductors are packaged in a module. To qualify such power modules amongst others, extensive power and thermal cycling tests have to be performed, which ensure the reliability over the vehicle lifetime. This paper describes requirements of power modules regarding reliability and lifetime in HEVs. A general approach is presented and applied to evaluate drive cycles and estimate required test cycles.

The final paper, entitled 'Thermal Management in Automotive/HEV and Outlook on Energy Storage' by Claus Peter Kluge from CeramTec, focuses on new ceramic materials. Technological developments are focused on smaller products with tendency to functional ceramics, as well as on the consequences due to miniaturisation. Therefore, future high priority challenges are thermal management, reliability and durability under rough environmental conditions. The primary topic 'energy conversion' will be discussed in the example of light generation. The outlook targets applications for high performance ceramic in energy management, energy storage and energy conversion. CeramTec provides and develops high volume ceramic materials for these challenging applications.

Thus, PCIM 2008 will feature highly interesting topics of the power electronics world.

AS

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Current Sensing Solutions for Hybrid Electric Vehicles

With so much engineering design effort now being invested by so many of the Automotive world's R&D organisations in various forms of electric and hybrid-electric vehicle development, perhaps now is a good time to review a few of the basic needs of the design engineer when dealing with current measurement.

Warren Pettigrew, CTO Raztec Sensors, Christchurch, New Zealand

Good current measurement techniques have long been identified as a basic requirement in the automotive industry. Now, with the advent of EVs (Electric Vehicles), HEVs (Hybrid-Electric Vehicles) and FCEVs (Fuel Cell Electric Vehicles) the idea of 'good current measurement' just isn't good enough any longer – now we need 'excellent current measurement!'

In a previous article [1] we looked at some of the more widely used methods of current measurement and then went on to discuss their various merits, and shortfalls. When we now consider the prospect of accurately measuring current, in some cases from many 100's of Amps through to perhaps a few milliamps, all via the same device, and then couple that with a pretty hostile environment, subject to electrical noise, vibration, mechanical shock, extremes of temperature, ingress of contaminants, etc…whilst also demanding a robust, reliable, galvanic isolation, high speed, yet low-cost device with extreme ease of integration allied with incredibly low power consumption – the open-loop Hall effect current transducer showed itself to be a truly formidable candidate.

Building upon the experience in the development of the current sensing technologies used on the New Zealand entrant for the 2007 Panasonic World Solar Challenge, Raztec engineers have cooperated with automotive industry leaders to develop sensors precisely targeted at some of the more demanding roles HEVs offer. When the design engineer is faced with selecting the correct solution for use in the various areas of electric vehicle design – accurate current measurement really is 'mission critical (see Figure 1).

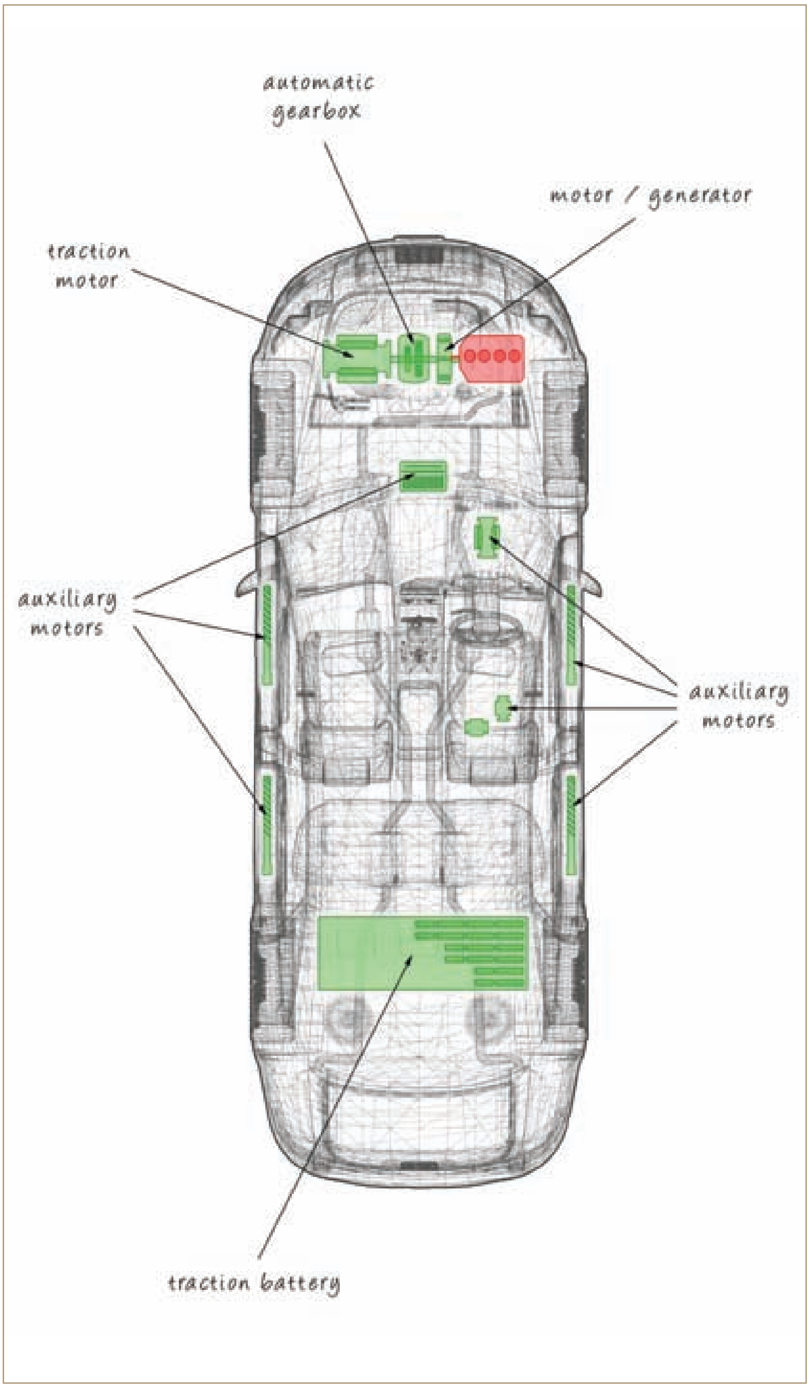


Figure 1: Typical HEV showing major areas requiring accurate current measurement

Traction motor current sensor

The function of the traction motor current sensor is to provide phase

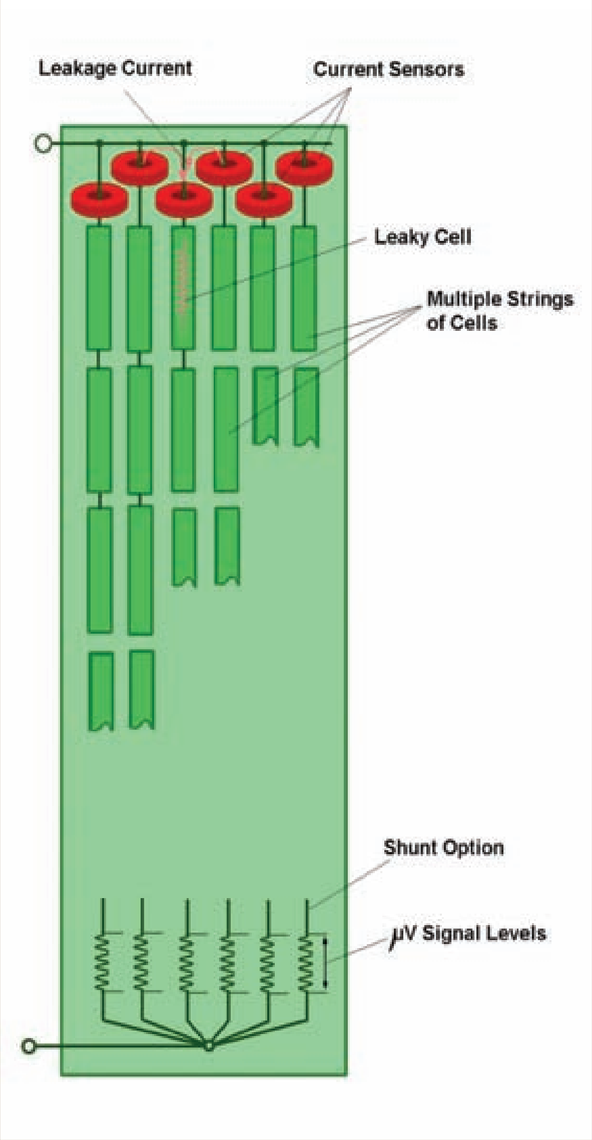


Figure 2: Traction battery string detail with alternative current measurement options

current measurement for the current loop within the traction controller itself. This essential parameter is critical for the stability and dynamic performance of the speed/torque controller. Key requirements are high frequency response (>100kHz), galvanic isolation to avoid issues related to HF common mode voltages, compact size, 5V operation, stable performance over the automotive temperature range, immunity to stray magnetic fields, low quiescent current, and modest price.

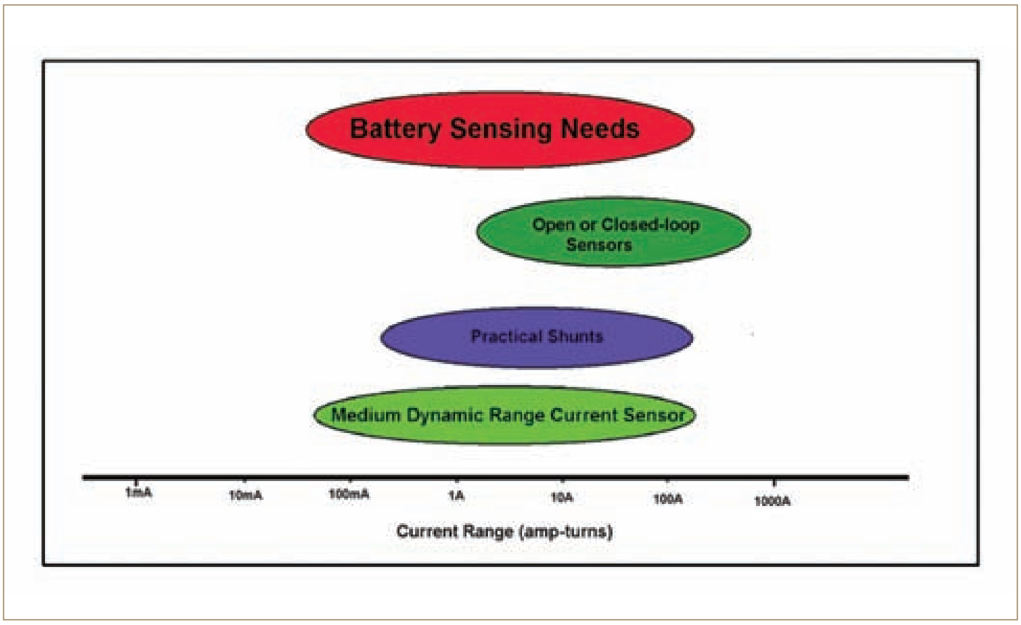
High performance open-loop current sensors that meet all of the above criteria, and additionally can be shaped to fit any tight physical requirements that the controller configuration may demand, will provide hybrid vehicle engineers the freedom to be more creative in their designs.

The drive to optimise efficiency leads to six or more speed gearboxes with electric actuators managing all gear shifts. To assure correct function, it is useful to monitor not only deflection but also the actuation forces or current flow in the actuators. This is a reasonably straightforward task, but again wide temperature range stability is important along with low installed cost, robust trouble-free design and small size.

Traction battery management

One of the most important requirements in hybrid vehicles is also one of the most demanding applications for current sensing; this is the measurement of battery current to determine its state of charge (SOC) and state of health (SOH). Absolutely critical for battery performance and longevity is the strict management of charge and discharge currents. Thorough management involves the measurement of current in each string of cells. With the trend to very small cell sizes, there will almost certainly be a multitude of series/parallel cell combinations which must be kept in equal state of charge. A weak string must be detected

Figure 3: Current sensor types for battery sensing needs



immediately and corrected, before it causes the rest of the battery to be damaged (see Figure 2). This is particularly relevant for Lithium chemistry.

Ideally, we need a sensor that is able to detect a weak cell in a string. This weak cell would cause just a very small increase of float current of some 10's of mA, and at the same time the sensor must be capable of measuring discharge currents of 100's of Amps. No normal sensor based on Hall sensor technology is, at present, capable of doing this. However, this need is currently the matter of intense engineering development that should result in a suitable solution being generally available imminently.

A possible option for sensing string current could be to use shunts in the battery negative line, but their application is not straightforward. There will be common mode voltage differences that the interface amplifiers must cope with. The current waveforms will be noisy with noise levels far exceeding signal levels, and the dynamic range requirements are demanding.

For example, if the current range is 25mA to 150A and we choose a 0.5mΩ shunt, peak power dissipation is 11.25W, signal at 150A = 75mV, and signal at 25mA = 12.5μV. It is quite common to experience thermoelectric voltages of this magnitude resulting in signal corruption, thus a high quality amplifier would definitely be required, there may be volts of noise, and biasing resistors must be very stable as current flow will be both negative and positive.

Typical battery current sensor requirements would be galvanic isolation, easy/flexible application, current range from ~50mA to 150A, excellent performance stability throughout automotive temperature range, compact size, modest price, 5V operation, high immunity to stray fields, and very low quiescent current (Figure 3).

Monitoring of cranking currents

If the cranking currents are monitored, a great deal of diagnostic information becomes available such as the condition of the battery, the condition of the motor/generator, the condition and compression of the engine, and the condition of the starter circuit.

For this application, the sensor must be able to operate reliably and accurately over a wide temperature range. Galvanic isolation makes the monitoring of small signals that are superimposed on PWM voltages much less problematic. Key requirements include high frequency operation, galvanic isolation, compact size, 5V operation, very low quiescent current, stable over a wide range of temperatures, and modest price level.

Auxiliary motor current control includes power steering motors, cooling fans and water pump motors. The needs are very similar as those for traction control, but price and small size is more important.

Overload protection is applicable to protect seat adjust motors, window motors, power locks etc. Some intelligence could be included with current monitoring to help protect against trapping in power windows.

Conclusion

Whilst this article attempts to throw some light on the demands placed upon the design engineer when it comes to the best selection of a particular current sensing technology for HEV applications, it is far from being a comprehensive guide to all options. The intention of the author is to offer 'food for thought' regarding both the sensing needs of successful control design relating to HEVs, and to suggest alternatives to the type of current sensor historically used in the automotive industry. HEVs are going to require a complete re-think regarding those attributes of a current sensor deemed essential for 'excellent' performance. It's obvious that the immense interest now being shown in the development of these type of vehicle is going to continue driving product design and innovation. We already see the absolute need for a current sensor operating in the ~50mA through 150A range, you can be sure that any current sensor manufacturer worth his salt is going to be working on the early release of a device that extends this range – at both ends!

Literature

[1] Selecting the Most Effective Current Sensing Technology, Power Electronics Europe issue 8/2007, pages 27-31

Active Charge Balancing for Li-ion Battery Stacks

Infineon's E-Cart electric vehicle is used to demonstrate the electrical features of a hybrid car. The necessity for battery management with charge balancing is a prerequisite and the simple conventional solution - dissipating power for charge equalisation - was replaced by an active energy shift between the cells. The resulting active system has much better performance at material costs comparable to a passive solution.

Werner Rößler, System Engineer for Safety Applications, Infineon Technologies AG, Neubiberg, Germany

The E-Cart (see Figure 1) is powered by a big Lithium-Ion (Li-Ion) battery stack. Nickel-Cadmium cells and their successors, Nickel-Metal Hydride cells, have been the dominating technology for many years. Recently, new Li-Ion batteries came onto the market. With significantly better performance, their market share has been rising rapidly. These cells have amazing energy-storage capacity. Nevertheless, this capacity is insufficient to support a hybrid motor using a single cell. The voltage and the current are both too low. To increase the current capability, cells may be connected in parallel. Higher voltages can be achieved by connecting cells in series.

Battery assemblers describe their arrangements usually using shorthand terms such as '3 P 50 S', which means 3 cells in parallel and 50 cells in series. A modular architecture is ideal for battery management with many cells in series. A serial connection of up to 12 cells is combined into one block in a 3 P 12 S array, for example. These cells are managed and balanced by an electronic circuit with a microcontroller in its heart. The output voltage of a block depends on the number of cells in series, and the cell voltage. The voltage of Li-ion cells is typically between 3.3 and 3.6V. This leads to block voltages between 30 and 45V. Hybrid drives need a DC supply voltage in the range of 450V. To compensate for variations in cell voltage depending on the charge state, a DC/DC converter is a suitable link between the battery stack and the motor drive. The converter is also able to limit the current. For optimal operation of the DC/DC converter, a stack voltage of 150 to 300V is required. Therefore, 5 to 8 blocks have to be connected in series.

Figure 1: **E-Cart prototype**

Necessity for balancing

Li-Ion cells are very susceptible to damage outside the allowed voltage range (Figure 2). If the upper and lower voltage limits (e.g. 2 and 3.6V for nanophosphate types) are exceeded, the cells may be damaged irreversibly. At a minimum, an extended self-discharge rate is the consequence. Over a wide state-of-charge (SOC) range, the output voltage is stable. The risk of leaving the safe area is low. However, at the beginning and at the end

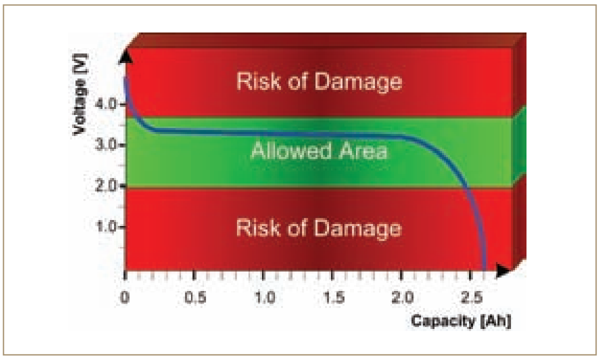


Figure 2: **Li-ion discharge characteristics (nanophosphate type)**

of the safe range, the curve steepens sharply. As a precaution, the voltage has to be monitored carefully.

If the voltage reaches a critical value, the discharge or the charge process has to be stopped immediately. With a strong balancing circuit, the voltage for the affected cells can be driven back into a safe area. To reach this target, energy must be moved among the cells whenever the voltage of any cell in the stack begins to differ from the others.

In the conventional passive method, each cell is connected to a load resistor via a switch. In such a passive circuit, individually selected cells can be discharged. This method is only suitable in the charge mode to suppress a voltage rise in the strongest cells. In order to limit the dissipated power, small currents in the range of 100mA are used, resulting in balancing times that may take several hours.

Various methods for active balancing can be found in the literature. A storage element to move energy is required. Using a capacitor requires a huge array of switching elements to link the storage capacitor to any cell. It is more efficient to store the energy in a magnetic field. The key component of the circuit is a transformer. A prototype was developed in co-operation with VOGT electronic. It is used for moving energy between the cells and multiplexing the single cell voltages to a ground-voltage-based Analog-to-Digital-Conversion (ADC) input.

The construction principle is the flyback converter. This type of transformer can store energy in a magnetic field. An air gap in the ferrite core increases the magnetic resistance to avoid the magnetic saturation of the core material. The primary side of the transformer is connected to the complete battery stack, and each cell is connected to a secondary winding (see Figure 3). A feasible model of the transformer supports up to 12 cells. The limiting factor is the number of possible connections. The prototype transformer described has 28 pins. The switches are realised with OptiMOS3 MOSFETs that have an extremely low on-resistance, so the conducting losses are negligible.

Each block is controlled by an 8bit microcontroller (XC886CLM) featuring a flash and 32kbyte data memory. Two hardware-based CAN interfaces support communication using the common automotive Controller Area Network (CAN) bus protocol with a low processor load. A hardware-based multiplication and division unit (MDU) speeds up the calculation process.

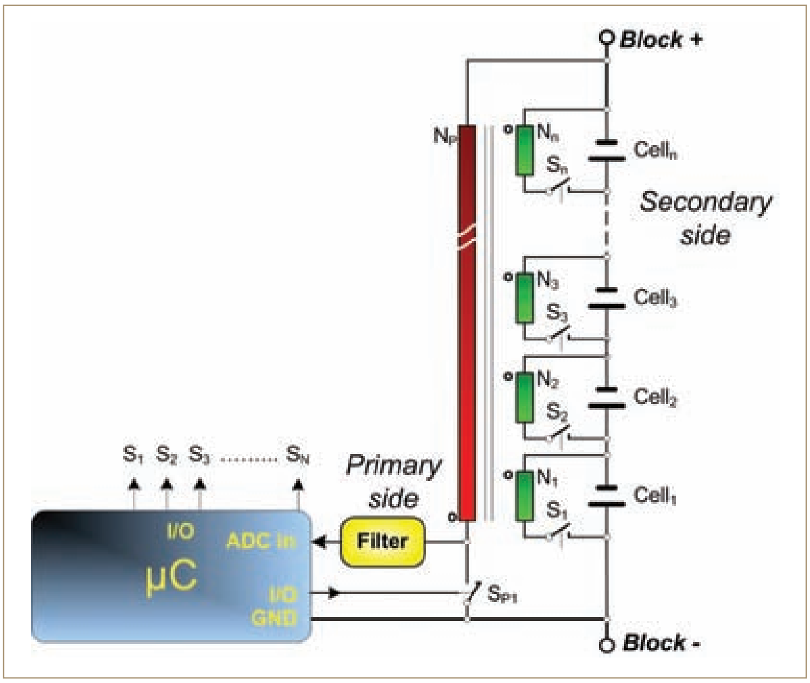


Figure 3: **Principal circuit of a battery-management module**

Balancing methods

The bi-directional use of the transformer allows the application of two different balancing methods, depending on the situation. After a voltage scan of all cells the average value is calculated. Then the cell with the largest deviation from the average is examined. If its voltage is lower than the average, the bottom-balancing method is applied; if it is

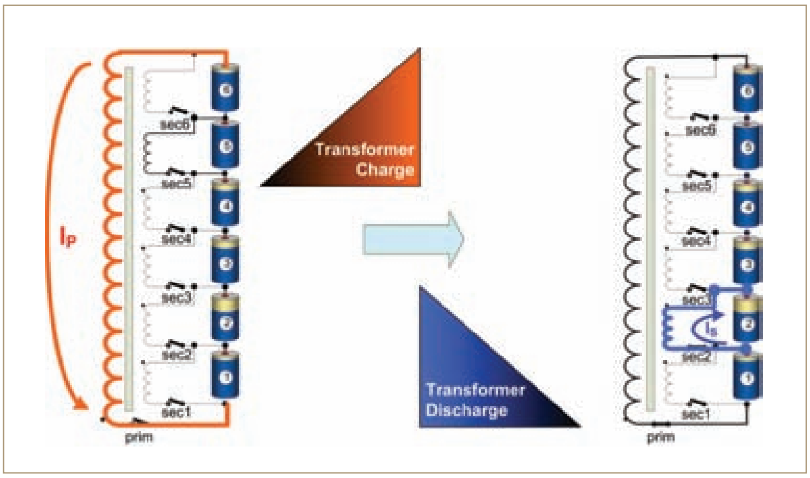


Figure 4: **Bottom-balancing principle**

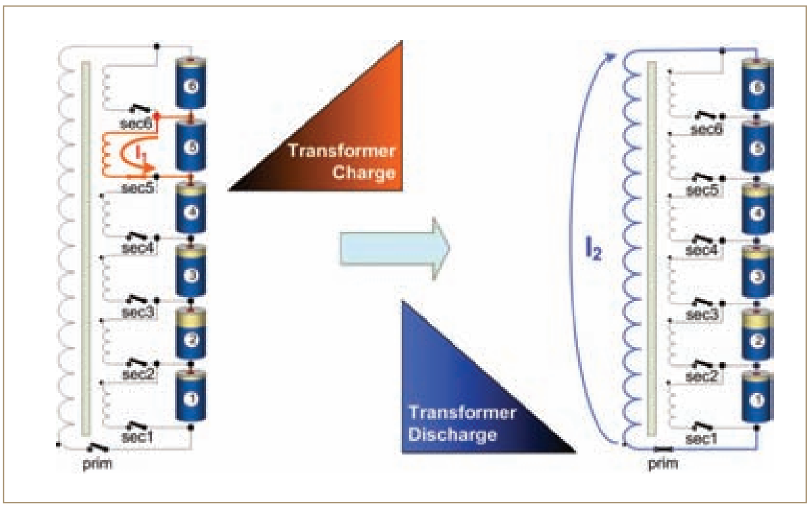


Figure 5: **Top-balancing principle**

higher, the top-balancing variant is applied.

The example in Figure 4 shows a situation in which the bottom-balancing method is required. Cell 2 is recognised as weakest cell which has to be supported. When the primary ('prim') switch is closed, the transformer is charged from the stack. After the primary switch is opened, the stored energy of the transformer can be shifted into a selected cell. This happens if the corresponding secondary ('sec') switch - in this example sec2 - is closed.

A cycle period consists of two active pulses and a pause. In this example, the period of 40µs equates to a frequency of 25kHz. The transformer should be designed for a frequency over 20kHz to avoid a whistling noise in the audible frequency range generated by the magnetostriction of the transformer's ferrite core. Especially where the lower end of the SOC of a cell has been reached, the bottom-balancing method helps to prolong the operational time of the stack. As long as the current drawn from the stack is less than the average balancing current, vehicle operation can be continued until the last cell is empty.

If one cell has a higher voltage than the others, it is useful to draw energy from the cell. In the charge mode, this is absolutely necessary. Without balancing, the charging process has to be stopped immediately when the first cell is full. Balancing will help to avoid this by keeping the cells at the same voltage.

The example in Figure 5 shows the energy flow in the top-balancing mode. After the voltage scan, cell 5 has been detected as the strongest member of the stack. When the switch sec5 is closed, a current flows from the battery into the transformer. Because of the inductance, the current rises linearly over time. As the inductance is a fixed characteristic of the transformer, the on-time of the switch defines the maximum current value. The energy portion out of the cell is stored as a magnetic field. After sec5 is opened, the prim switch has to be closed. The transformer behaviour changes into a generator mode. The energy is fed into the complete stack via the large primary winding. The current and timing conditions are similar to the bottom-balancing example. Only the sequence and current directions are reversed.

With the prototype configuration used in the E-Cart, an average balancing current of 5A is reached. This is 50 times higher compared to the passive method. The power dissipation in the complete block caused by the balancing with 5A is only about 2W. This requires no special cooling effort and improves the energy balance of the system.

Voltage scanning

To manage the charge-state of the individual cells, their individual voltages have to be measured. As only cell 1 is inside the ADC range of the microcontroller, voltages in the remaining cells of the block cannot be measured directly. A possible solution would be an array of differential amplifiers, which would have to sustain the voltage of the complete battery block.

The method described below allows the measurement of all voltages with only a small amount of additional hardware. The transformer, whose main task is the charge balancing, can be used as well as a multiplexer. In the voltage-scanning mode, the flyback mode of the transformer is not used. When one of the switches S1 to SN is closed, the voltage of the connected battery cell is transformed to all windings in the transformer. Simply preprocessed by a discrete filter, the measurement signal is fed into an ADC input of the microcontroller.

The measurement pulses generated when one of the switches S1 to Sn is closed may be very short. A practical on-time is 4µs. Therefore, there is not much energy stored in the transformer. In any case, after the switch is opened, the magnetically stored energy is fed back to the complete battery block via the primary transistor. Consequently, the energy content of the battery block is not affected. After one scanning cycle over all cells, the system returns to the original state.

Conclusion

The benefits of the new Li-ion batteries for vehicle applications can be advantageous only with a capable battery-management system. An active charge-balancing system offers significantly better performance than the conventional passive approach. The ingenious use of a relative simple transformer helps to keep the material costs low.

Simplifying Dual Motor Control in Energy-Efficient Appliances

When permanent magnet brushless motor drives were introduced to the market more than twenty years ago, the control algorithms were implemented using a combination of analog amplifiers and logic components. Today, highly integrated mixed signal controllers enable the implementation of complex control algorithms that maximise the efficiency of permanent magnet AC drives in various applications.

Aengus Murray, International Rectifier, El Segundo, USA

Advances in power and digital control silicon technology over the past few decades have enabled a continuous improvement in motor drive technology. Japanese air conditioning manufacturers recently started switching from sensorless control based on back EMF (electro-magnetic force) sensing to sensorless field oriented control based on current feedback. Field oriented control (FOC) with current angle phase advance maximises the efficiency of interior permanent magnet motors, providing an efficiency gain of almost 5%. The switch from trapezoidal to sinusoidal control also minimises torque ripple to reduce acoustic noise in the fan motor.

A recently introduced mixed signal control IC can simultaneously run both the compressor and fan motors in an air conditioning system. A combination of highly optimised hardware control blocks and a configurable control sequencer enables rapid execution of complex motor control algorithms. The IC is one element in an appliance design platform that includes all the power and control silicon needed to drive the fan and compressor motor in an air conditioning system. The same IC can also be applied to the latest energy efficient laundry systems that use an energy saving heat pump in the drying cycle.

Air conditioning design platform

The circuit schematic in Figure1 includes the major components in the outdoor unit controller for an air conditioning system. The mixed signal motor control IC drives the compressor motor, the fan motor and the power factor correction circuit. The IC integrates three major functions: the Motion Control Engine (MCE), the Analog Signal Engine (ASE) and an 8bit microcontroller. The MCE executes the motor control algorithms, while an independent 8bit microcontroller core implements the application functions.

The sensorless field oriented control algorithm derives all the required motor information from the currents flowing in the DC link shunts. This avoids the need for position sensors on the motor shaft and isolated current transducers in the power inverter circuit. The Analog Signal Engine includes the fast A/D converter, multiple sampling circuits and differential amplifiers needed to extract the motor winding current from the DC link current signal.

The Motion Control Engine executes the sensorless FOC algorithm described by the control schematic in Figure 2. The algorithm includes a reverse rotation function that transforms the measured stator currents into a reference frame synchronised with the angle of the rotor magnet flux. The transformed currents have two quasi DC components: a direct axis current is aligned with the rotor flux and a quadrature axis component that generates motor torque due interaction with the rotor magnet.

The d and q axis current loop compensators calculate the stator voltages to force the currents to track the set point values. The forward rotation function transforms these voltages to sinusoidal AC voltages in the stator reference frame. The space vector PWM generator uses these signals to derive transistor switching signals for the three-phase inverter. When driving a classical permanent magnet synchronous motor with surface mounted rotor magnets,

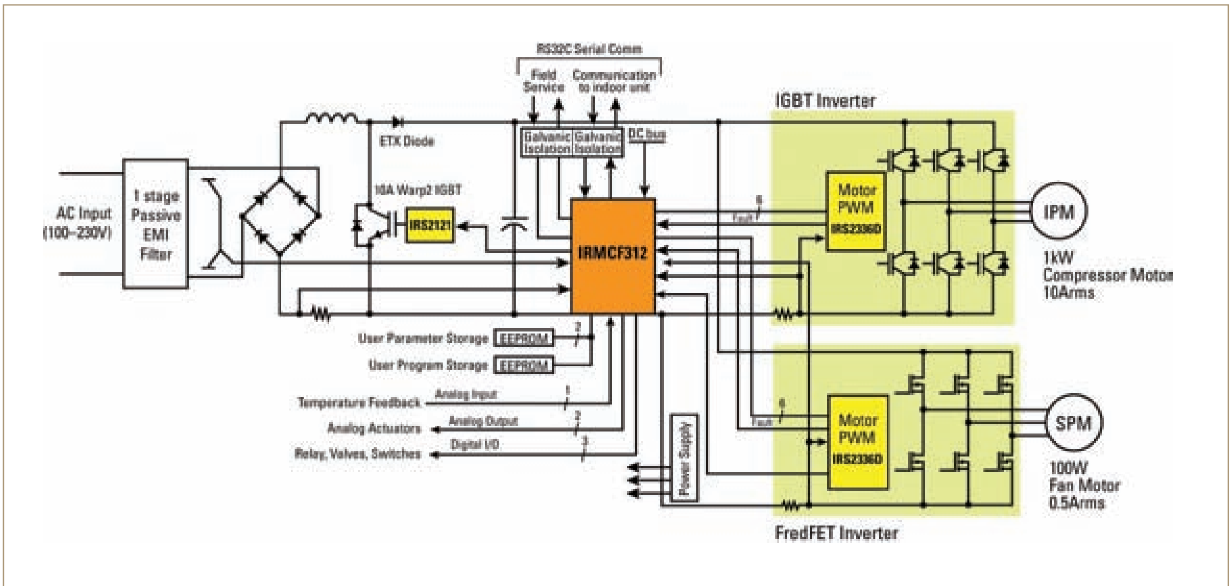


Figure 1: Air conditioning design platform

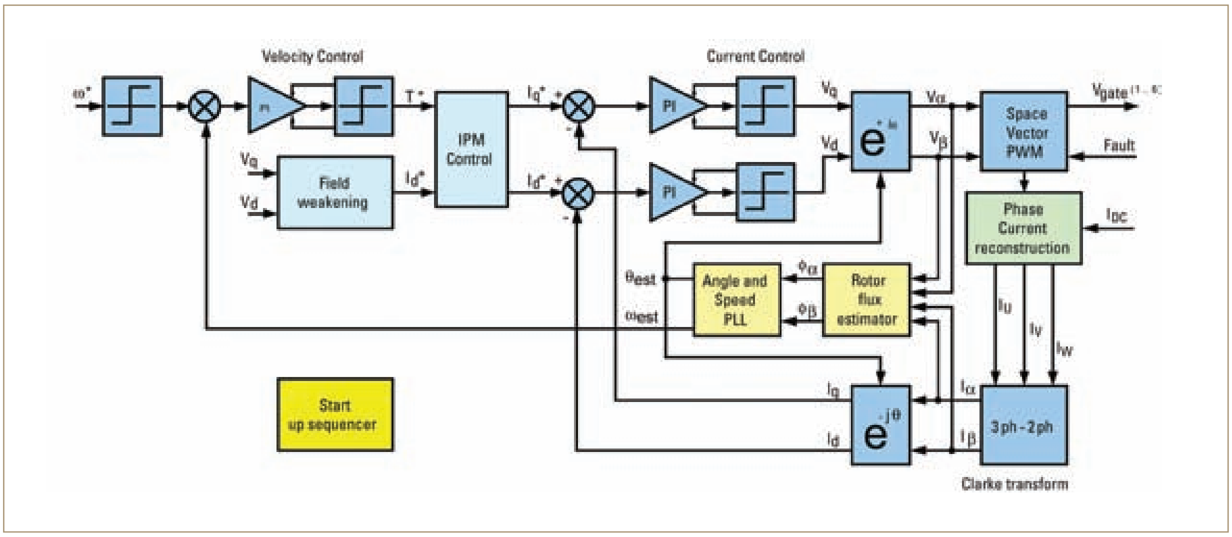


Figure 2: **Sensorless field oriented control algorithm**

the d axis reference current is set to zero to maximise the torque per amp. However, when driving an interior permanent magnet motor, the d axis current will generate a reluctance torque component to augment the torque produced by the rotor magnets. The IPM control function is the key control element that enables the operation at a higher efficiency when driving the IPM motor.

The other key feature of the sensorless FOC algorithm is that it does not require high resolution rotor angle sensors typically found in industrial drive systems. In appliance drives, where low speed performance is not important, the rotor angle can be derived from the winding back EMF signal. In brushless DC drives with a six-step commutation sequence, the back EMF is available directly by sampling the voltage on the unconnected winding. However, when driving the motor with sinusoidal currents the back EMF has to be calculated indirectly from the motor circuit model. The equations 1

$$v_\alpha = R_S.i_\alpha + L_S.\tfrac{di_\alpha}{dt} + \tfrac{d}{dt}\left(-\Psi_r.\cos(\theta_r)\right)$$

and 2

$$v_\beta = R_S.i_\beta + L_S.\tfrac{di_\beta}{dt} + \tfrac{d}{dt}\left(-\Psi_r.\sin(\theta_r)\right)$$

describe the two-phase equivalent circuit for the permanent magnet synchronous motor. The two-phase currents are derived using the Clarke transform that calculates the currents in two quadrature windings that will produce the same field as the currents in the three phase windings. The two-phase winding currents are the outputs of the forward rotation function that drive the space vector PWM generator.

The important aspect of the two-phase circuit model is that the back EMF terms are time derivatives of cosine and sine flux functions, and so they can be determined through integration. The detailed control schematic for angle and speed estimator shown in Figure 3 has two major subsystems. During the first stage, the flux estimator derives the rotor cosine and sine flux functions. The flux integrators include low frequency gain compensation to avoid DC saturation. At the second stage, the rotor angle phase locked loop (PLL) forces the error between the rotor angle and the estimated angle to zero. The error is calculated using a vector rotation function whose quadrature output will be zero when the rotation angle input matches the angle of the cosine and sine flux functions. The second order feedback loop in the PLL generates both angle and velocity signals.

A further feature of the PLL is the start up sequencer that is required at low speeds when the winding back EMF signal is swamped by circuit noise. The first part of the start up sequence is a parking function that drives DC current into the stator windings to align the rotor at a

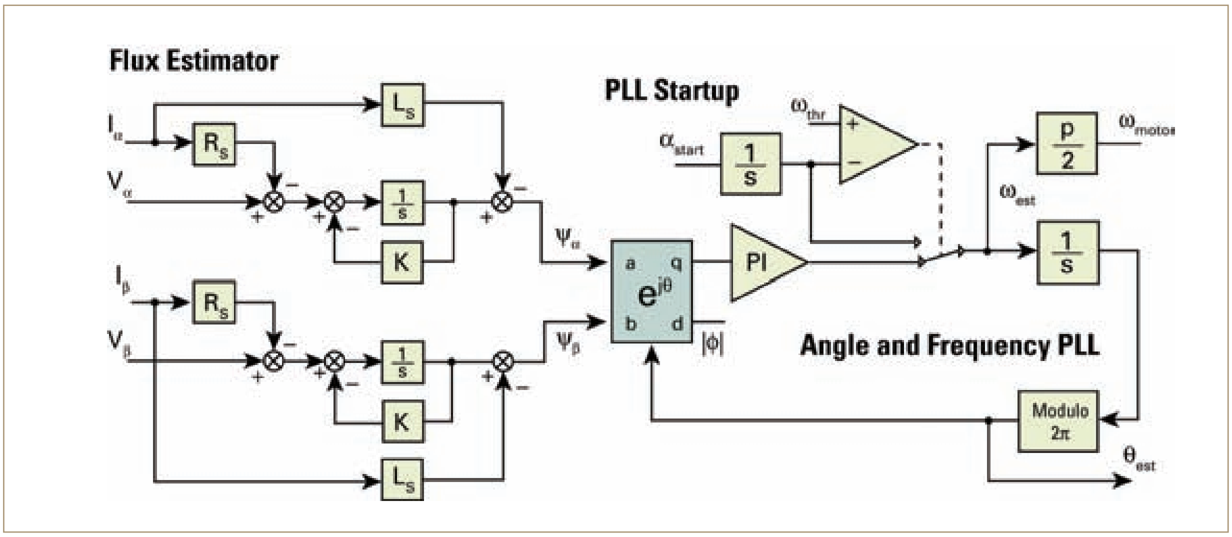
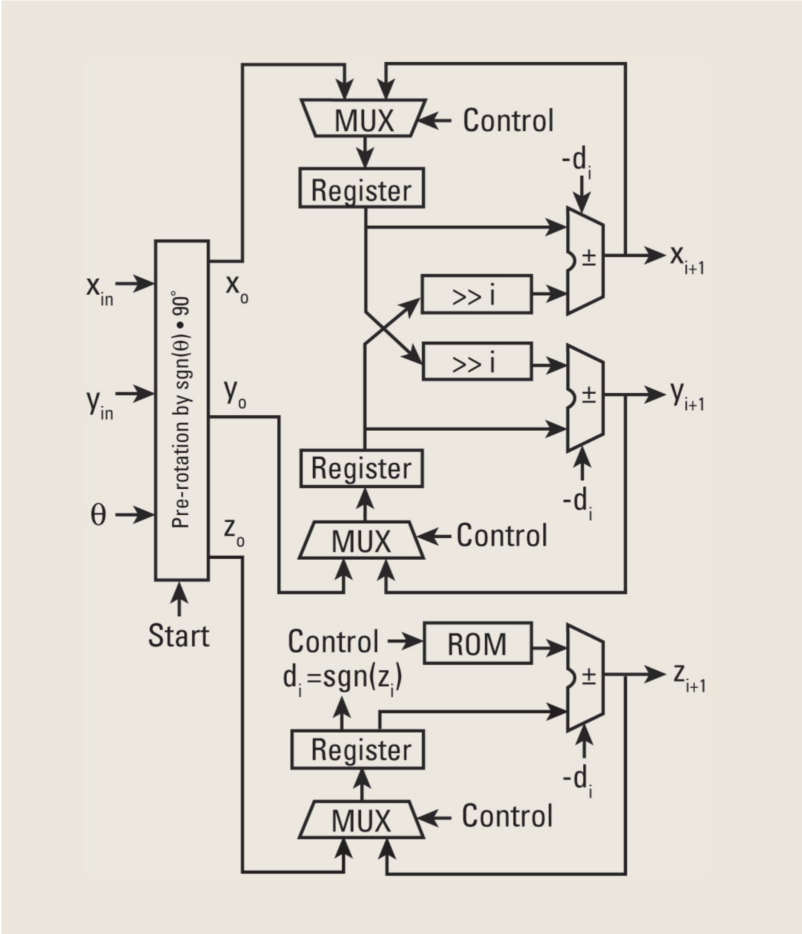


Figure 3: **Rotor angle and speed estimator**

Figure 4: **Vector rotation hardware**



known angle. Then the motor is driven with a constant current to generate a constant torque. The PLL speed integrator is fed by a motor mechanical model that estimates the motor speed from the accelerating torque and system inertia. Once the motor reaches a certain minimum speed, the PLL switches to a closed loop mode and tracks the rotor flux angle.

The motion control engine

When using a traditional DSP or RISC processor, the motor control schematic is first translated into state equations that are written in C code before software development tools can generate machine code for the processor. The motion control engine (MCE) supports a unique approach to motor control algorithm development. The MCE graphical compiler is an algorithm development tool that transforms the control schematic directly to MCE sequencer code avoiding all intermediary steps. This allows the developer to modify the reference algorithm directly, making use of a library of optimised control blocks such as PI compensators and vector rotations.

The reference algorithm includes the basic AC motor control functions, including the FOC current loop with sensorless rotor position estimation and an outer velocity loop. The inner current loop is a well-established FOC algorithm used for PMSM control, and typically does not require modification, but the optimal algorithm for the outer control loops will vary with application. Fan or pump controllers, for example, may need to regulate torque to maintain pressure, while compressor controllers may just regulate speed. In compressor control, a simple velocity loop may not properly regulate at low speeds because of the load torque ripple. A feed forward algorithm can compensate for the load torque to eliminate mechanical vibration at low speeds.

In washing machines, the controller can detect the wash load imbalance by analysing the ripple signature in the motor speed and torque before entering the spin cycle. The appliance designer edits the control algorithm schematic using the Matlab Simulink graphical user interface and can add control blocks such as comparators, summing junctions, switches and integrators. The digital control IC executes the algorithm on the IC using the matching hardware blocks from the MCE control library based on the MCE sequencer code generated by the graphical compiler.

Optimised control blocks enable a significant reduction in execution time relative to software implementations. One example of an optimised control block is the vector rotator shown in Figure 4. The CORDIC vector rotation has been developed specifically for ASIC implementation that relies on a series add, subtract and shift functions that yield 12bit accuracy in only 13 cycles [1]. This calculation is 10 times faster than the calculation using Taylor expansion on a 32bit RISC processor.

The digital timing circuits that generate the inverter PWM signals also generate the sample timing signals that allow the ASE to extract the motor winding current from the inverter DC link. This optimised combination of analog and digital signal processing circuits can simultaneously control two permanent magnet synchronous motors. There is additional signal conditioning and MCE processing capacity to support the execution of a power factor control (PFC) algorithm. Thus, the air conditioning control IC can control the input power factor, the fan and compressor motor, while traditional RISC processor based systems require separate fan and PFC control ICs.

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Power Device Technologies for Sustainable Growth of Power Conversion Applications

PCIM China 2008

Power devices have gone through a rapid technological evolution along with the advancements in power electronics during the last few decades. More recently, the enormous advancement made by MOS-gated power device technologies such as IGBTs, power MOSFETs, and power modules have tremendously helped fast proliferation of power electronics application in industrial, commercial, residential, transportation, utility, aerospace and other emerging fields that include newer power generation systems. The first part of this keynote, given at PCIM China, reviews the state-of-the-art key technologies related to power devices and their contribution in power conversion applications. **Gourab Majumdar, Mitsubishi Electric Corporation, Fukuoka, Japan**

A continuous advancement of power devices is considered to be the key to a sustainable future growth of power conversion application that can adequately cope with the increasing global energy and environmental issues. In the following, requirements from various application fields will be briefly reviewed with an overview of key power semiconductors that have emerged so far. This includes state-of-the-art key technologies related to the advancement of IGBT modules and intelligent power modules (IPMs) as key components for power conversion technologies.

Application environment

As it has been until today, the demand for energy saving and ecological compatibility in power consumption will continue to enforce thrusts for newer consumption equipment and advancements of power electronics as the key enabler for power savings. It is estimated that, presently, a total of 17000TWh of electric power is being consumed globally every year and this number has increased by about three times in the past 30 years. However, only a small percentage of this is being processed by use of efficient conversion methods which can be achieved by application of Power Electronics (PE) engineering. In spite of that, a huge growth rate in applying PE is observed in some specific new areas, such as alternative and renewable energy generation systems and automotive power-train controls. Both of these new fields are growing at a rate higher than 20% per year and are expected to continue growing for many more years to come.

The history of power electronics has been closely allied with advances in electronic devices that provide the capability to handle high-power levels. Although the trend in this growth indicates an 'application-driven' behaviour in specific segments, it still shows a 'device-driven' characteristic. Therefore, the trend followed by power devices and continuous improvement of them is extremely

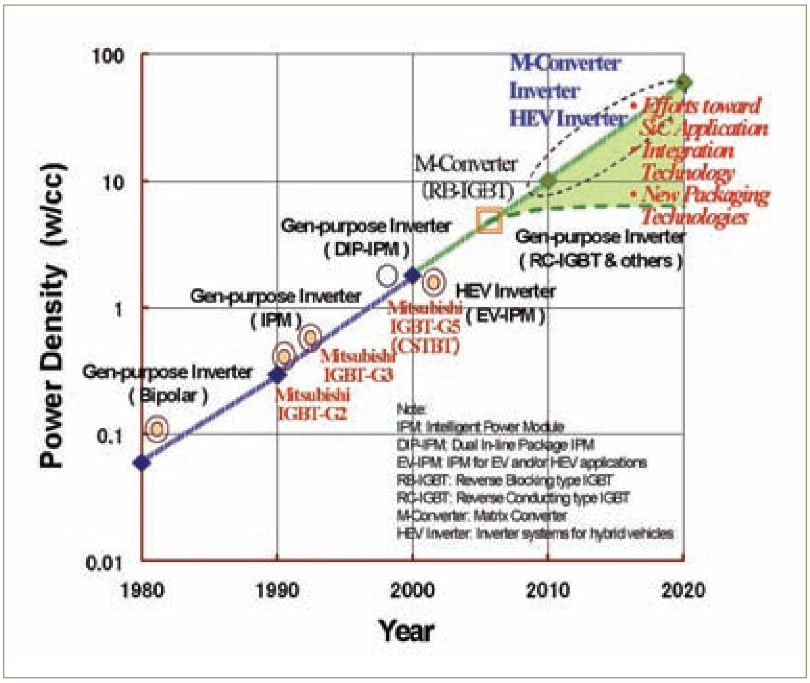


Figure 1: Projected growth of power density in power electronics system designs in relation with the trend in power semiconductors

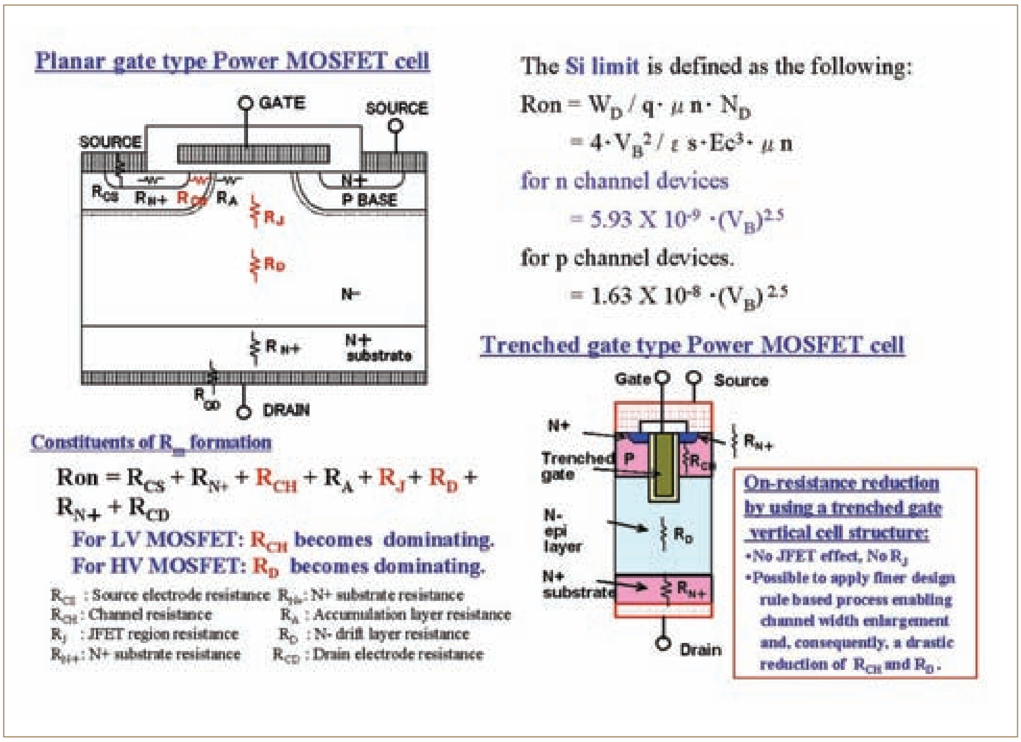


Figure 2: Power MOSFET cell structures and relations with unipolar Si-limit defining scope for specific on-resistance versus breakdown voltage trade-off improvement

important for reaching a sustainable energy structure globally.

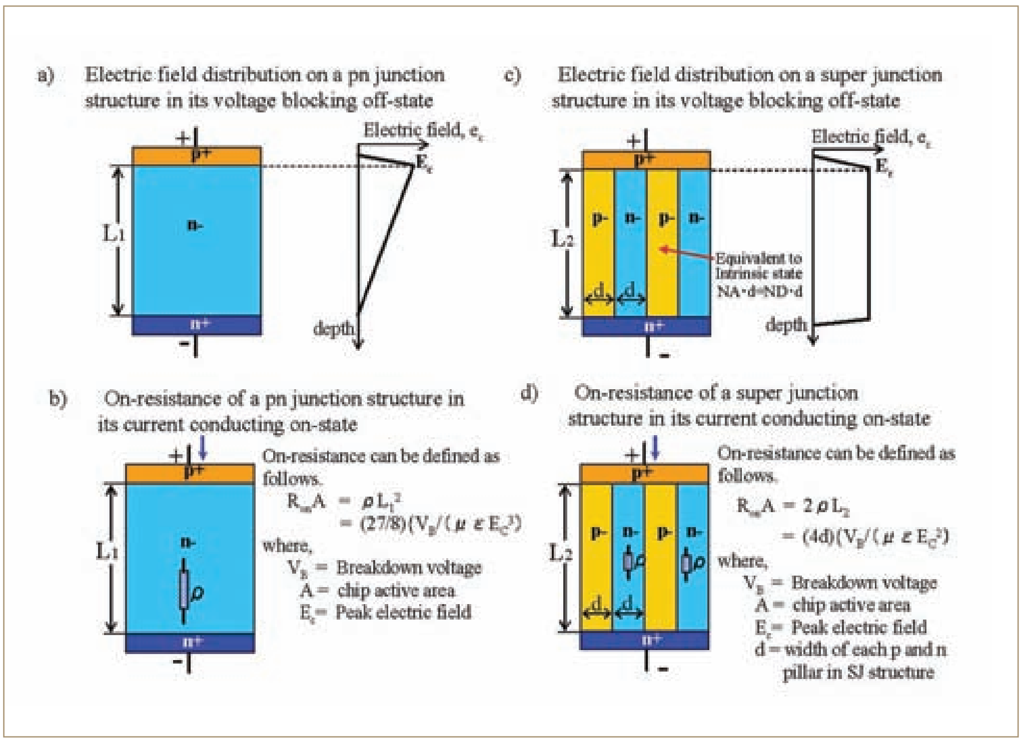
Of the various requirements from power applications of today, one of the key trends followed in the design of newer systems is toward achieving higher 'power-density' in a structural concept. This trend is heavily dependent on evolution of power devices in terms of performance improvement and functional integration. Progress made in 'power-density' improvement and related contributions by various power devices so far, and expectations in the future, is illustrated in Figure 1.

Power MOSFETs

Power MOSFETs appeared in the late '70s. This device became possible by virtue of the development of metal-oxide-semiconductor (MOS) technology for microelectronic applications. Unlike the bipolar junction transistor (BJT) the MOSFET, which belongs to the Field Effect Transistor (FET) family, is a unipolar voltage controlled device, and it operates only by majority carrier transport in the conduction mode requiring very low drive power compared the to current-controlled bipolar BJT.

Out of various categories of power MOSFETs in the FET family, the vertically structured n-channel enhancement mode type is the most popular one for power amplification and conversion applications. Simple cell structures based on a planar gate concept and a trenched gate concept are shown in Figure 2. This figure also illustrates the prime constituents of the device's drain-to-source on-resistance and its specific value related to the device's breakdown voltage in relation with the theoretical silicon limit (Si-limit) for an unipolar

Figure 3: Super-junction concept and operation principle



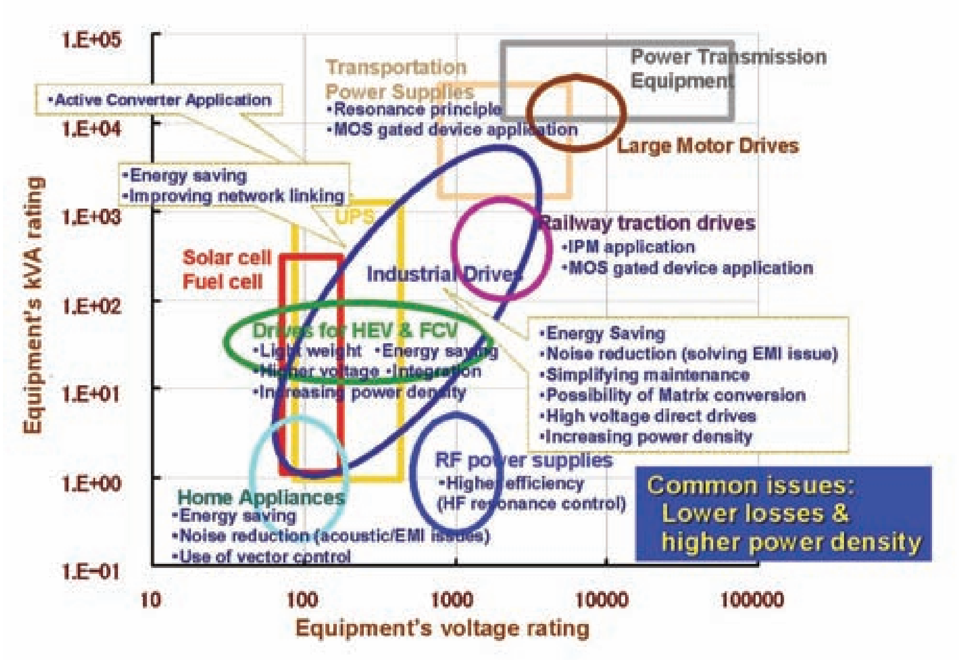


Figure 4: Application map of different power electronics equipment and their major technological requirements

structure. As also described in the figure, a trench-gate cell concept is very effective for reducing R_J and R_{CH} components of the total R_{ON} and, therefore, has been the trend for low voltage (<200V) class devices.

On the other hand, as the resistive component R_D increases exponentially with higher breakdown voltage requirements, which, in turn, requires a thicker N-layer, the power MOSFET has not been an appropriate solution for high voltage applications. Therefore, its application has been mainly concentrated in the low voltage (<200V) range. Here, advanced processes have been used to optimise static on-state resistance versus breakdown voltage trade-off relationships. Today, less than 0.2μm design rule based superfine trenched-gate power MOSFET processes have been made practical for less than 100V class, where specific on-resistance (r_{sp}) values have been reached very close to the theoretical Si-limit [1,2,3].

Also, as only majority carriers contribute to the current flow, a power MOSFET can switch very fast and, therefore, it has been the primary device solution for high-frequency applications. By comparison, bipolar transistors have greater power handling capability, but due to slower switching speed characteristic, these devices have been mostly used for low frequency type applications. Power MOSFETs have lesser power handling capability, but the fast switching speed performance has made these devices particularly suitable for high frequency applications.

Super-junction concept

As discussed, the most important issue throughout the development history of power semiconductor devices has been searching for methods to improve trade-off between on-state voltage drop and breakdown voltage (BV) characteristics with newer devices structures and semiconductor material. In the case of unipolar devices like a power MOSFET, it translates to attaining the best trade-off between r_{sp} and BV, and to shrink the feature size without degrading the device's characteristics.

As discussed before, much effort has been put into the reduction of r_{sp} while maintaining the desired BV. However, the theoretical Si-limit is understood to be the extreme that can be achieved. Recently, a three-dimensional structural concept, named the superjunction (SJ) concept, has been investigated for practical use and has given significant results in terms of r_{sp} and BV trade-off improvement, compared to conventional power MOSFET devices.

Figure 3 summarises some features of the SJ concept, in comparison with the principle of a pn-junction operation mechanism. This SJ principle has been extended to create practical MOS-gated power switching devices in recent years. An SJ power MOSFET, which has a concept similar to a multi-RESURF idea, allows doping levels of its n-region to be typically one order of magnitude higher than that used in standard high-voltage MOSFETs. The additional charge is counter-balanced by the adjacent charges of a p-column. This counter-balancing contributes to a horizontal electrical field without affecting the vertical field distribution. The electric field inside the structure is fixed by the net charge of the two oppositely doped columns. In this way, if both regions counter-balance each other perfectly, a nearly flat field distribution can be achieved.

Practically, the main advantage of an SJ power MOSFET is a drastic reduction of the device area because of the device's low r_{sp} feature. The trade-off between r_{sp} and BV being dependent on the column pitch or width, refined process techniques for column building, can achieve better value in the future. This small chip size of the SJ power MOSFET leads to a low gate charge, which also results in higher switching frequencies, compared to conventional power MOSFETs with comparable voltage and current ratings.

However, this device concept is not very practical for very high voltage ratings (>1000V) because of the process difficulties in achieving a perfectly balanced charge condition. Also, unlike a standard power MOSFET, the integral body diode present in an SJ structure exhibits a very inferior performance in terms of reverse recovery characteristics and avalanche energy rating due to its spaced charged based operation. Therefore, in applications such as power inverters or converters, where the integral body-diode is used for regenerative conduction and, by that, the same diode is required to be low loss type and robust in reverse recovery performance, the SJ device concept is not capable of serving the application adequately [4].

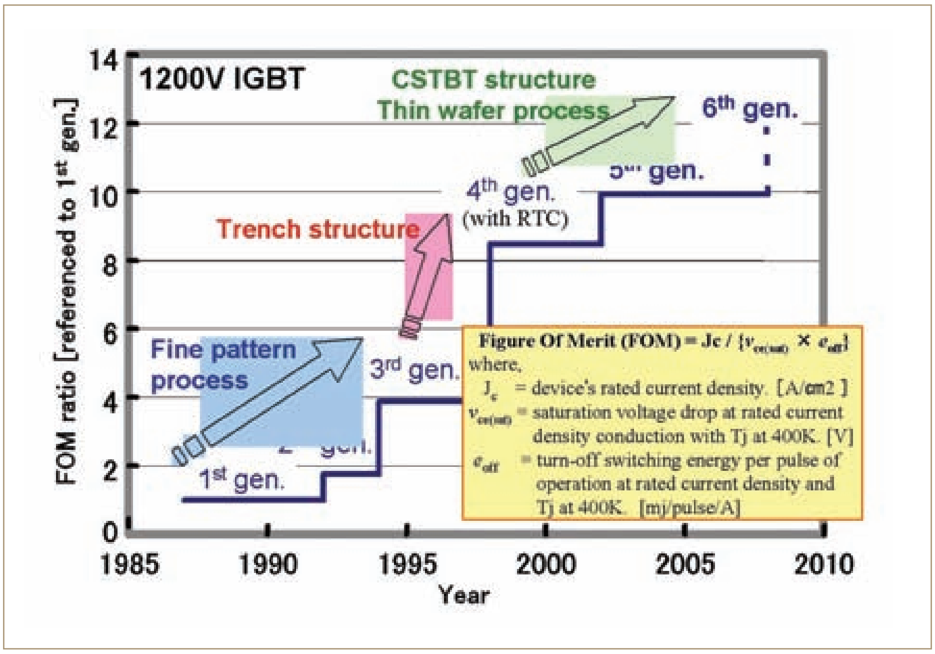


Figure 5: The chronograph of IGBTs FOM improvement

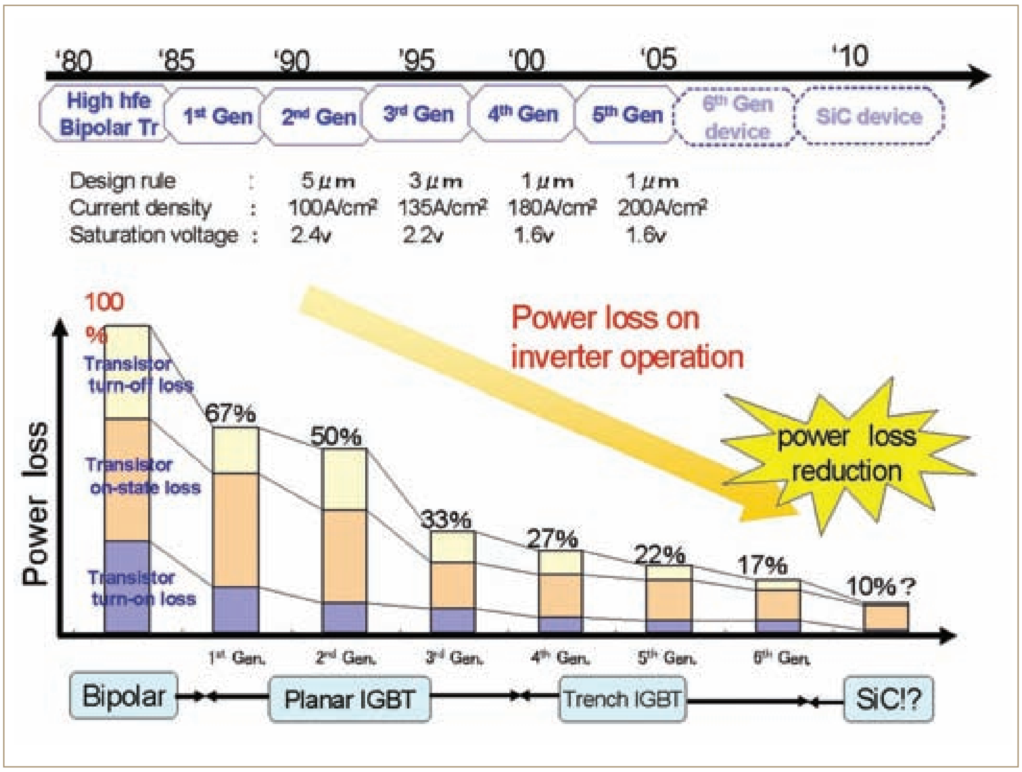
Power module technologies

Power modules, including standard IGBT type and intelligent type (IPM), have been widely used in power systems such as industrial motor drives, power supplies, home appliances, electric vehicles, or traction control for railways. In such applications, system designers have continuously demanded improved device performances regarding loss reduction, higher power density and higher power handling capability, lower electromagnetic noise generation, better switching controllability and wider safe operating area (SOA). Figure 4 depicts a summary of such requirements from various application fields. The two most common thrusts have been the reduction of power losses and improvement of power density.

In order to visualise the performance improvement of IGBTs on a relative basis, a new figure-of-merit (FOM) term relating current density, saturation voltage drop and turn-off switching energy has been proposed by the author. The FOM expression and chronograph of IGBT's performance improvement is given in Figure 5. The key technologies related to the structural aspect of various generations of IGBT devices are also described in the diagram. The Carrier Stored Trench Gate Bipolar Transistor (CSTBT) device cell concept has helped improving the defined FOM greatly since its debut at the 5th generation level of IGBT evolution. Along with the improvement of FOM, the various new generations of IGBT device structures have also contributed greatly in power loss reduction. In Figure 6, this trend has been plotted in comparison with the performance made by an equivalent BJT module in the early '80s.

The latest CSTBT technology based power modules are extensively used today because of low loss characteristic (1/3rd compared to 1st generation IGBT and

Figure 6: Trend of operating losses of various power devices



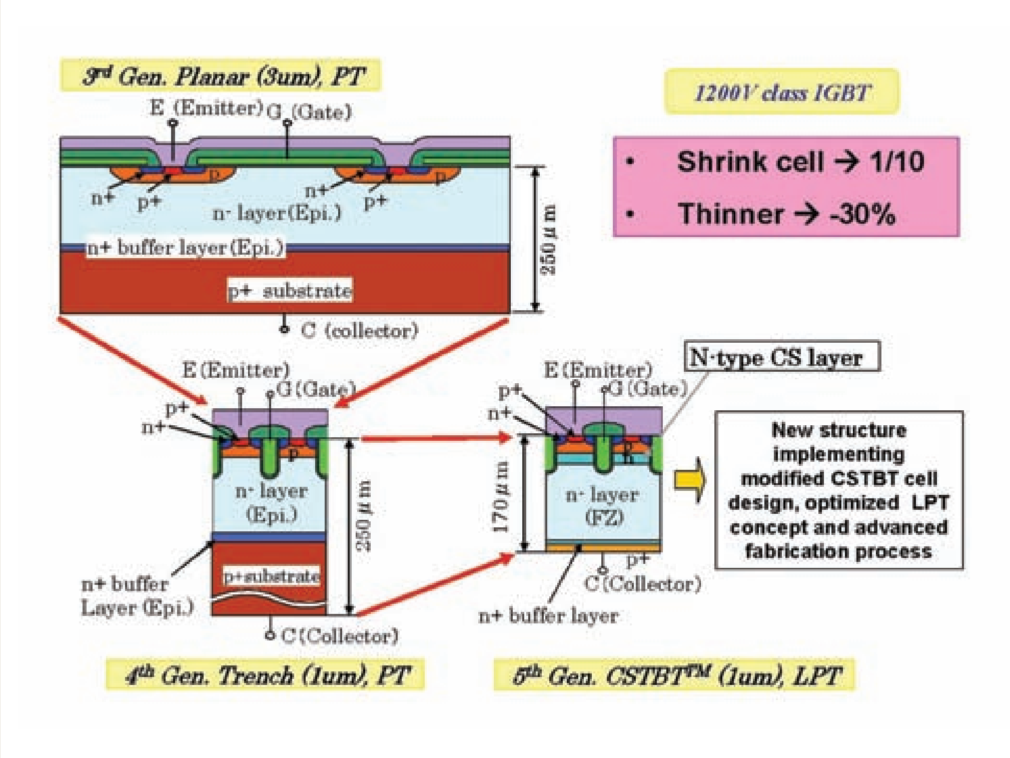


Figure 7: Changes in IGBT cell design from 3rd to 5th generations and trend toward the next step

1/5th compared to the old BJT technology). Another new trend in IGBT device technology is the wafer thinning approach. The main objective was to eliminate the need for any epitaxial active layer in the device's structure. Figure 7 describes briefly how such a structural change has come in play and its optimisation aspect.

An optimised non-epitaxial type device structure works on the principle known as the light-punchthrough (LPT) voltage blocking mechanism, and lately has been combined with the CSTBT cell concept to achieve superior IGBT performance. Figure 8 describes some features of this advanced LPT based CSTBT structure. On this structural innovation line, a new IGBT device concept featuring integrated diode function to create a Reverse-Conducting type of IGBT (RC-IGBT) has become feasible. Such multi-functional new devices have opened up new hopes for power density improvement in future system design.

Figure 6 also projects that the 6th generation in the IGBT trend will bring the loss ratio down by another five points, which is about a 30% reduction, compared to the losses of current 5th generation. This large-step improvement is expected by the introduction of advanced process technologies for fabrication of CSTBT chips. New generation chips are also expected to be based on cell concepts that can reduce terminal capacitances effective for suppressing EMI and improving the dynamic performance of the device. On the other hand, for higher voltage class IGBTs (1700V and above) somewhat different chip technologies are expected to be playing

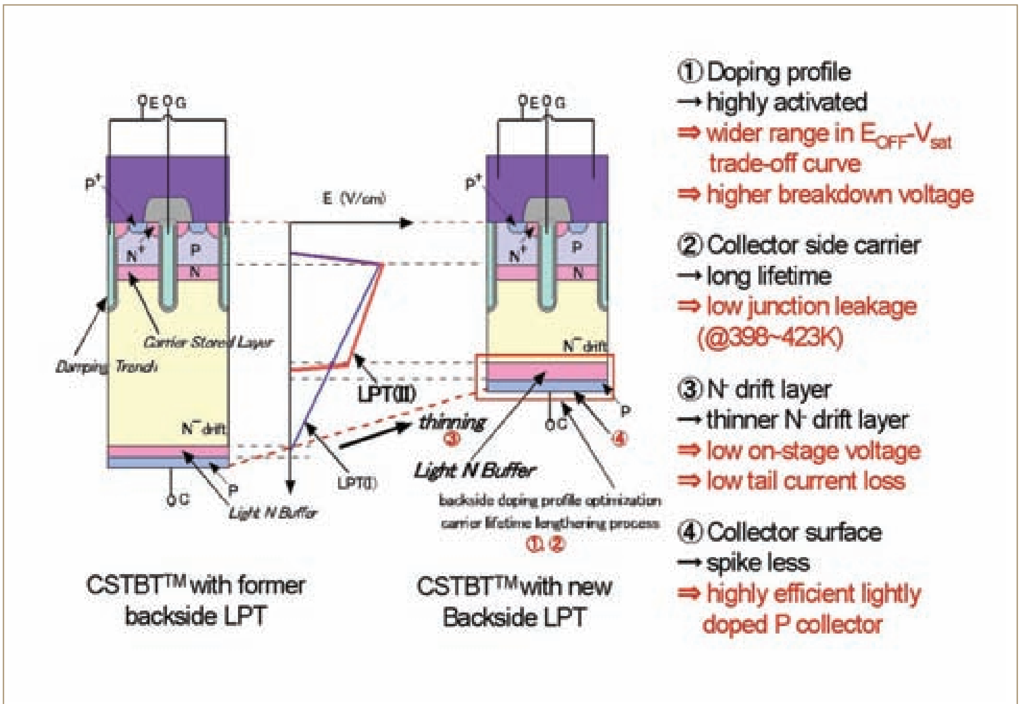


Figure 8: Advancement of CSTBT on wafer thinning

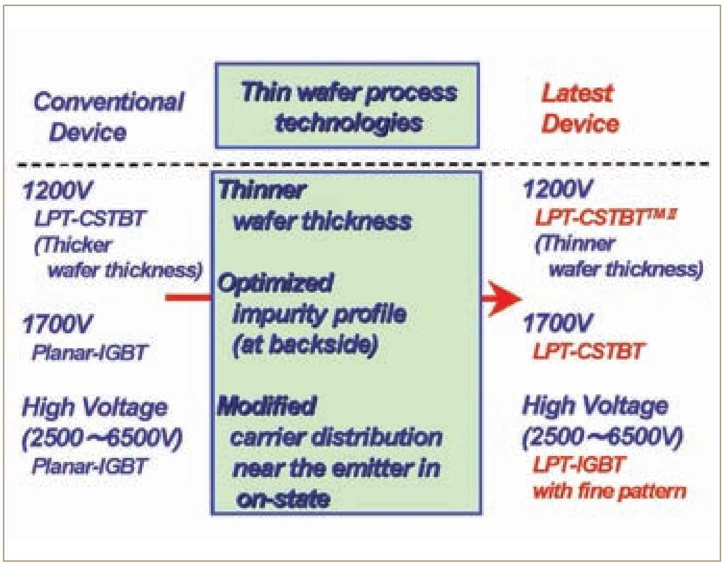


Figure 9: **IGBT chip technologies for high-voltage applications**

the key role for some years in the future.

A planar gate design concept is still going to voltage ratings higher than 2kV. Figure 9 explains structural features adopted in such chip designs [5,6]. See the next part in our May issue!

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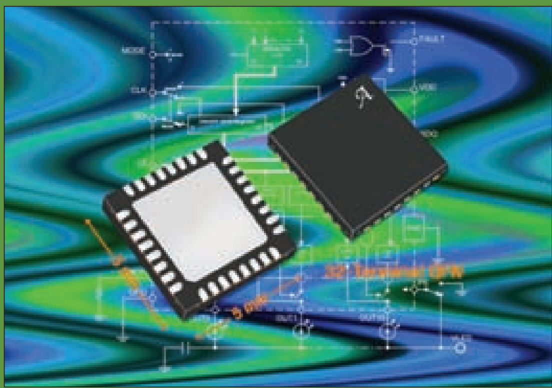
6 Channel Constant-Current LED Driver



The A6285 from Allegro MicroSystems Europe is a 16-channel constant-current LED driver featuring individual channel current adjustment via a 7bit dot correction register. Each channel can sink a constant current up to 80mA, and a single external resistor sets the maximum LED drive current for all channels. Each channel's drive current can be individually adjusted from 0 to 100% of the maximum value via the dot correction register, and the brightness of all the channels may be adjusted simultaneously by pulse-width modulation of the output enable (OE) input.

The A6285's serial interface can interface directly with microprocessor or FPGA-based systems. A serial data output permits cascading of multiple devices in applications requiring more than 16 channels. The A6285's CMOS logic runs on a 3.3 to 5V supply. LED supply voltage can range up to 12V, accommodating a series string of several LEDs on each channel. Applications include large-scale displays and signs in the industrial, communication and office automation markets.

www.allegromicro.com

150mA Dual-Level Output LDOs

Texas Instruments has introduced 150mA, low-dropout linear regulators (LDOs) with dual-level voltage output for MSP430 microcontroller-based, battery-powered devices consuming low quiescent current of 500nA. The TPS780xx LDOs with selectable dual-level output voltages allow to dynamically shift to a lower voltage level in a battery-powered design when the microprocessor is in sleep mode. The two voltage levels are factory preset by an EPROM, which provides multiple output voltage options.

The LDO requires no external parts to implement the device's dynamic voltage scaling (DVS) feature for an 8 or 16bit MSP430 or other microcontroller design. The TPS780xx is stable with any output capacitor greater than 0.1μF. The devices come in a 6pin, 2mm x 2mm SON package, which is targeted at portable applications that require low power, while maintaining a small footprint.

http://power.ti.com

New Power MOSFETs for DC/DC Supplies

STMicroelectronic's STD60N3LH5 and STD85N3LH5 are the first in a new series of STripFET V devices which provide better performance and increased efficiency as a result of low on-resistance and significantly lower total gate charge. Both are 30V (BVDSS) devices. With gate charge (Q_g) of just 8.8nC and on-resistance of 7.2mΩ at 10V, the STD60N3LH5 can applied as a control FET in non-isolated DC/DC step-down converters, whereas the 4.2mΩ on-resistance at 10V and Q_g of 14nC of the STD85N3LH5 can be applied as a synchronous FET.

Both devices are housed in DPAK and IPAK packages and will be soon available in other package options including SO-8, PowerFLAT 3.3 x 3.3, PowerFLAT 6 x 5, and PolarPAK. STripFET technology makes use of very high 'equivalent cell density' and smaller cell features to achieve low on-resistance and losses, while using less silicon area.

STripFET V is the latest generation achieving 35% improvement in the silicon resistance and active area, plus some 25% reduction in total gate charge per active area, compared to the earlier generation.

www.st.com/pmos

4.5kV Rated Asymmetric Blocking GTO

Westcode Semiconductors, an IXYS company, has launched a new asymmetric blocking GTO with nominal current rating of 1000A when used with a 2μF snubber capacitor and suitable for DC link voltages up to 2.8kV. The device has been developed using Westcode's unique cathode design and is encapsulated in a 38mm pole face hermetic pressure contact package.

The device is offered in two voltage grades: G1000QC400 with a repetitive peak off-state voltage of 4kV and G1000QC450 with a repetitive peak off-state voltage of 4.5kV. Target applications for the new GTO thyristor are auxiliary converters in railway applications such as coach hotel facilities, as well as main drives in mass transport systems such as the tram or trolley bus. This device is also suitable for other applications outside traction including all power conversion systems up to 500kW. The industry standard outline makes it a substitute in the maintenance of existing equipment. The new GTO is also a replacement for the now obsolete Westcode GTO thyristor types WG5045S and WG8045S.

www.westcode.com

Digitally Powered DC/DC Converters

Lambda, a unit of TDK Corporation, has expanded its half-brick DC/DC converter with the iHG series. Using the industry standard half-brick footprint with no base plate, these modules are intended for low airflow, high temperature, 48V power architectures in telecom, wireless, industrial and many other applications. The initial offering includes 5V/10A, 5V/20A and 3.3V/30A devices. The 93% efficiency delivers a very high level of useable power in convection cooled environments, particularly where airflow rates are low. Furthermore, the digital control circuitry reduces component count and improves reliability at lower cost. A double ended-power train topology with FET driven synchronous rectification combined with a secondary side auxiliary control rail ensures safe operation under functional and fault conditions.
www.lambda-europe.com

900V Superjunction MOSFETs

Infineon Technologies has introduced its first 900V superjunction MOSFETs specifically intended for high-efficiency SMPS, industrial and renewable energy applications. CoolMOS uses an innovative approach to overcome the silicon limit, a characteristic of MOSFETs in which doubling of voltage blocking capability leads to a five-fold increase in on-state resistance.

In overcoming the silicon limit, the CoolMOS 900V devices achieve on-state resistances of 0.12Ω in a TO-247 package, 0.34Ω in a TO-220 package and 1.2Ω in D-PAK packages, which is at least 75% lower than can be achieved in such packages with conventional 900V MOSFETs.

CoolMOS 900V devices can offer an FOM (figure-of-merit, calculated as on-state resistance times gate charge) as low as 34Ω*nC, which results in low conduction, driving and switching losses, and leads to increased efficiency. Quasi-resonant flyback designs for LCD TV power supplies can benefit from a higher flyback voltage, which provides a longer primary duty cycle with reduced peak current, zero-voltage switching and significantly lower voltage stress on the secondary side. Because of their low on-resistance, a single CoolMOS 900V in a TO-220-FP package can be used in such a design, rather than the two or more TO-220-FP packages that must be used with conventional 900V MOSFETS. Compared to the most common solution today, which uses 600V MOSFETs, a CoolMOS 900V solution gives a premium efficiency of more than 0.5%.

15A Current Sense Transformers

Murata Power Solutions has introduced three new ranges of surface-mount current sense transformers.

The 5300, 5400 and 5500 series can be used to measure or monitor AC currents in high frequency applications such as switched-mode power supplies, motor controllers, and electronic lighting ballasts. Designed to measure AC currents up to 10A, the 5300 series comprises ten different devices with a primary current rating to 10A and between 20 and 200 turns, depending on the resolution of current measurement desired. A primary to secondary isolation of 500Vrms in an industry-standard footprint helps simplify their inclusion into existing product designs.

The 5400 and 5500 series are designed to measure AC currents up to 15A and are available with 50, 100 or 200 turns. The 5400 series features a small footprint package style and provides 1200Vrms primary to secondary isolation. The 5500 series is offered in a low profile package with a primary to secondary isolation of 1000Vrms.

www.murata-ps.com

Power ICs in eSIP Package

Power Integrations has announced the TOPSwitch-HX series of AC/DC power conversion ICs in the new eSIP-7C Eco-Single-Inline-Package.

This package exhibits the same low thermal impedance as the traditional TO-220, yet stands less than 10mm above the PCB - half the height of the 45 year old package.The heatsink attached to the eSIP package is at source potential and therefore electrically quiet without the use of an insulating pad, greatly reducing system EMI and assembly cost.

In addition to thermal and physical size benefits, the new eSIP package also reduces power supply manufacturing costs. A low-cost clip reduces heatsink assembly time and improves package to heatsink contact repeatability, ensuring consistently good thermal performance in contrast to the asymmetrically-mounted screw tab on the older TO-220 package design.

The clip-mounted eSIP passes shock and vibration tests to IEC 60068.

www.powerint.com

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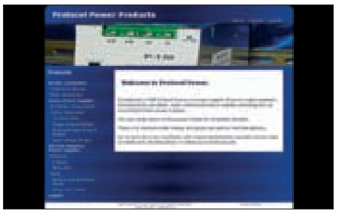

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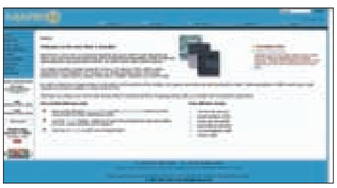

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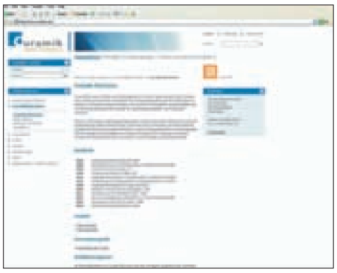

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