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UNINTERRUPTIBLE POWER
New Sensor Technology for Total Battery Management

THE EUROPEAN JOURNAL
FOR POWER ELECTRONICS
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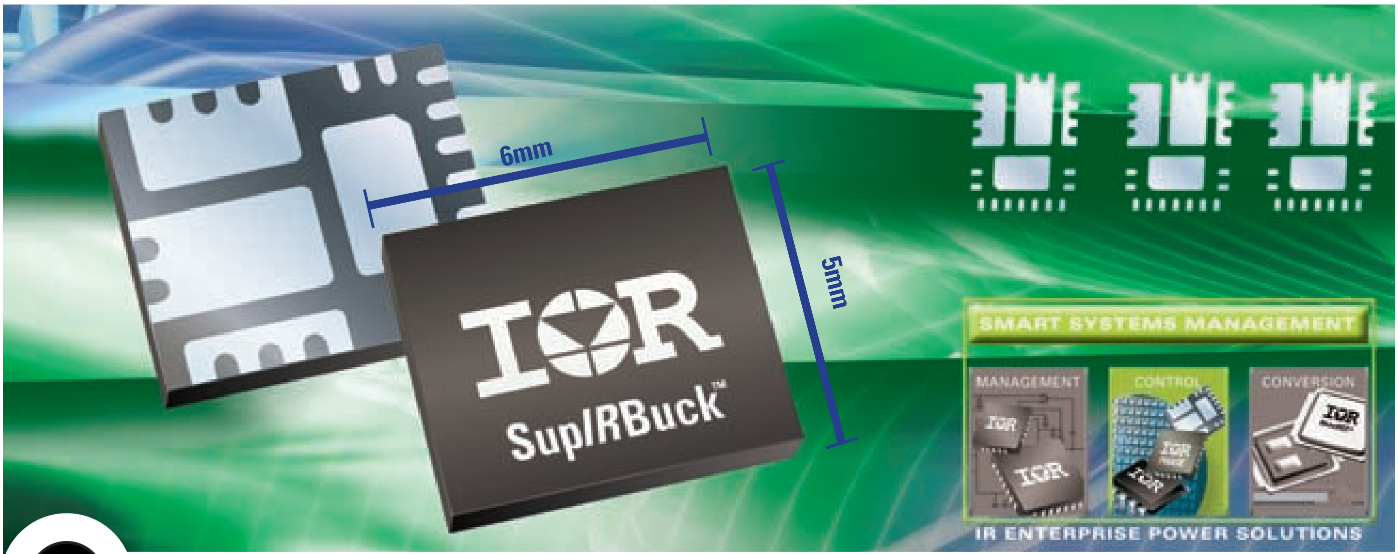

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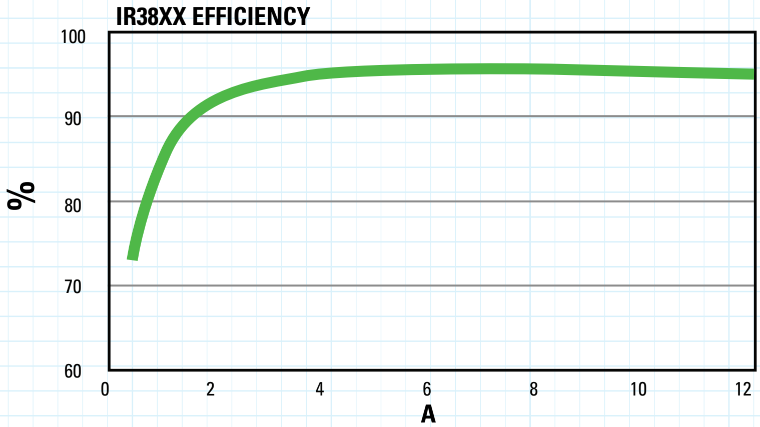

The SupIRBuck™ family of versatile point-of-load (POL) voltage regulators shrink silicon footprint 70% compared to discrete solutions and offer up to 10% higher full-load efficiency than monolithic power ICs.

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- Programmable over-current protection
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- Wide input voltage range
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- Fewer discrete components

Part Number	V_{IN} Max/Min	V_{OUT} Max/Min	Max Current	F_{SW}	Package	Features
IR3812MPBF	21 / 2.5	12 / 0.6	4A	600KHz	5mm x 6mm QFN	OCP; OTP; Tracking
IR3822MPBF	21 / 2.5	12 / 0.6	4A	600KHz	5mm x 6mm QFN	OCP; OTP; PGood
IR3822AMPBF	21 / 2.5	12 / 0.6	6A	300KHz	5mm x 6mm QFN	OCP; OTP; PGood
IR3811MPBF	21 / 2.5	12 / 0.6	7A	600KHz	5mm x 6mm QFN	OCP; OTP; Tracking
IR3821MPBF	21 / 2.5	12 / 0.6	7A	600KHz	5mm x 6mm QFN	OCP; OTP; PGood
IR3821AMPBF	21 / 2.5	12 / 0.6	9A	300KHz	5mm x 6mm QFN	OCP; OTP; PGood
IR3810MPBF	21 / 2.5	12 / 0.6	12A	600KHz	5mm x 6mm QFN	OCP; OTP; Tracking
IR3820MPBF	21 / 2.5	12 / 0.6	12A	600KHz	5mm x 6mm QFN	OCP; OTP; PGood
IR3820AMPBF	21 / 2.5	12 / 0.6	14A	300KHz	5mm x 6mm QFN	OCP; OTP; PGood

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COVER STORY

New Sensor Technology for Total Battery Management

Whenever a battery is used as a critical source of energy such as with uninterruptible power supplies (UPS), electric vehicles (EV), hybrid electric vehicles (HEV) and mobile life support equipment, it is essential that the user has complete confidence in the battery's ability to deliver its expected amount of energy. It is also important that the user can have faith in the battery status display. Raztec recognised this gap in current sensing technology some years back and have recently developed a device specifically tailored for measuring battery current for battery management purposes. These feature wide dynamic range of current measurement and automated degaussing eliminating hysteresis issues. Full story on page 23.

Cover supplied by Raztec Sensors

More than just Doom and Gloom

The financial crisis has impacted various industries and markets relevant to (power) semiconductors.

Worldwide semiconductor industry revenue is set to decrease by 9.4% in 2009 to $241.5 billion, down from $266.6 billion in 2008, according to iSuppli. In the fourth quarter of 2008, many industries have reset their inventory target levels in anticipation of a long economic downturn, expecting that the reduced stockpile goals will help their cash balances. These new targets mean that even if semiconductor revenues were anticipated to remain flat, inventory levels would need to drop in proportion to the new lowered DOI targets (Days-Of-Inventory) in order not to have any 'excess' inventory at that node of the supply chain.

The second factor is that semiconductor demand has fallen in the fourth quarter, and it declined much faster than expected at the end of the third quarter, as shown by a rash of lowered guidance announcements. This means that initial fourth-quarter production schedules were set too high. Production schedules have been ratcheted down during the quarter in what are mainly reactive moves, resulting in excess inventory build-up. Third, OEMs have not been able to cut production as fast as they would like to, due to supply chain rigidities, mostly because of workforce rules in some parts of the globe and cancellation windows at subcontractors and component suppliers. The near-tripling of excess semiconductor inventory throughout the electronics supply chain in the fourth quarter will significantly extend the time necessary for the semiconductor industry and contract manufacturers to benefit from any recovery in demand. It also will wipe out several additional percentage points of growth from the semiconductor industry in 2009. While there is a wide range of predictions, it appears that most economists are projecting the economy will recover in one year. Based on this outlook for an improved economy in late 2009 or in early 2010, iSuppli is projecting the semiconductor industry will recover to grow by 6.4% in 2010. This will be followed by growth of more than 10% in 2011, the first year to show a double-digit gain since 2004.

Market researcher IMS predicts a fall in revenues of around 3% in 2009 for the global power management and driver IC market, owing mainly to the current slowdown in consumer spending. After a healthy growth year in 2008 with total revenues reaching almost $13 billion, the market for power management and driver ICs is forecast to fall by nearly $400 million in 2009. It is anticipated that the sectors worst hit will be automotive, portable consumer and desktop PCs with an average decline of around 10%. Power semiconductor discrete and module revenues are forecast to shrink by over $1 billion in 2009, with power MOSFETs anticipated to take most of the hit, reported IMS. The power semiconductor market is estimated to have expanded by 2% in 2008, bolstered by a project 9.5% growth in revenues from power modules. In the current recession, the markets in computer and office, consumer and automotive applications are envisaged to be worst hit, and will spend $0.9 billion less in 2009 in power discrete components alone. But there are also some positive figures: the power module market's renewable energy segment is estimate to grow 51% in 2008 and continue with strong growth for the next five years. Overall, power module revenues are forecast not to fall as hard as discretes in 2009, and to recover faster in 2010.

Some companies are more optimistic than pessimistic in face of these figures and will invest in manufacturing capacities, such as ABB. The company will expand its high-power semiconductor manufacturing plant in Lenzburg, Switzerland. The 150 million Swiss Francs investment plan includes construction of new buildings and installation of additional manufacturing lines at the existing plant. ABB's Lenzburg plant is its leading manufacturing unit for high-power semiconductors found at the heart of many ABB technologies such as High Voltage Direct Current (HVDC) transmission systems and variable speed drives.

So not all is doom and gloom. Have a good year 2009 and enjoy reading this issue.

Achim Scharf
PEE Editor

New PI Power ICs and Power Supply Design Software

Power Integrations has launched the HiperPLC (High Power, Power factor corrected, LLC, Controller) power supply controller IC, additions to its LinkSwitch family of AC/DC switched-mode power conversion ICs, and a new version of its power supply design software PI Expert. The software now supports the LinkSwitch-CV and LinkSwitch-II primary-side-control switcher ICs, and includes comprehensive design functionality for offline LED drivers.

PI's Doug Bailey introduces a 280W Reference Design and PI Expert Suite v7.1 adding design support for offline LED lighting
Photo: AS

The new LinkSwitch-CV series includes the LNK626PG, a constant voltage integrated switcher IC with primary-side control targeting applications requiring +/-5% voltage accuracy, such as AC/DC adapters up to 10W, auxiliary power supplies for appliances up to 17W and multiple-output supplies for consumer products.

HiperPLC combines a continuous conduction mode PFC controller, a LLC resonant converter and high voltage (800V) half-bridge drivers in a single IC package targeting offline converters in the power range of 200 to 600W such as flat-panel TVs, so-called 80%+ efficiency Bronze, 85%+ efficiency Silver and 90%+ efficiency Gold PC main power and workstation power supplies, and the latest generations of high-brightness LED streetlights. "The new device saves costs by combining the Power Factor Correction control, high voltage drive functions and a substantial amount of supporting circuitry into a single IC package. Further savings are achieved by leveraging the communication between the PFC and LLC controllers, reducing external component count, the cost of magnetic components and the size of the expensive high-voltage bulk-storage capacitors. The combined PFC and LLC control also ensures a single switching frequency for the entire power supply, reducing differential mode noise and EMI harmonic spectrum components to reduce input filter cost", explains Doug Bailey, VP of marketing. "To simplify the design process, we are also offering downloadable design tools which considerably reduce LLC transformer iterations and development time, as well as Reference Design Kit for a 300W power supply".

PI Expert Suite v7.1 consists of three components. PI Expert is an interactive program that takes a designer's power supply specifications and automatically generates the electrical design and selects the critical components required to build a cost-effective switched mode power supply. The tool also provides a detailed electrical and mechanical transformer design using PI's proprietary eShield EMI reduction techniques. Optimisation choices stressing cost and efficiency are included to help designers target specific needs. The program reduces design time from days to minutes. PI Xls Designer is a hands-on approach to power supply design for advanced users and those who prefer a spreadsheet interface, along with support for recently introduced products not yet included in PI Expert. The tool generates detailed engineering and mechanical designs to assist users in prototyping the transformer. PI Viewer finally is a tool for viewing design files created with older versions of PI Expert. "Power Integrations focuses on making it easier for designers to create highly efficient power supplies. Typically, system developers go through a make/buy decision for their power supply needs - trading additional unit cost against development cost and risk. PI Expert arms system designers with the tools they need to take advantage of lower production costs by designing and building a custom power solution. The new version 7.1 software simplifies the design process, guiding the designer to a predictable and successful project outcome. The design of LED drivers poses a unique challenge, in that LEDs must be driven with a constant current, rather than a constant voltage. PI Expert Suite v7.1 adds full design support for offline LED lighting applications", comments Bailey. PI Expert Suite v7.1 is available for free download.

www.powerint.com/

Avnet Memec and COILCRAFT Extend Distribution

Avnet Memec, the semiconductor distributor of Avnet Electronics Marketing EMEA, has announced the extension of its distribution agreement with Coilcraft to Austria, Switzerland, Benelux, the Baltic States, East Europe, Turkey and Greece. Avnet Memec already distributes Coilcraft into Germany, Italy, France and Scandinavia.

Coilcraft was founded in 1945 as a custom coil maker for the television set manufacturers clustered around the Chicago area. Today, inductors for a long list of customers in telecommunications, computers, instrumentation and consumer electronics are produced. Many are standard, off-the-shelf products. Basic product lines include surface mount inductors and power inductors, xDSL magnetics, tunable and fixed RF inductors, EMI filters and high frequency power magnetics. "The products are optimised for Power and RF applications, and their on-line design tools enable customers to achieve very tangible time-to-market and cost reductions. Coilcraft have also worked hard to embed themselves with many of our semiconductor partners as the coil of choice, and our customers across Europe will appreciate the delivery of proven technical solutions. Avnet Memec is already very well positioned in all of the markets for which Coilcraft products have been designed, and the combination of our forces across Europe and industry segments will help both Avnet Memec and Coilcraft to drive their advantage", commented Jon Ellis, Vice President Technical Marketing, Avnet Memec.

www.coilcraft.com, www.avnet-memec.eu

ABB Expands Power Semiconductor Manufacturing Capacity

ABB will expand its high-power semiconductor manufacturing plant in Lenzburg, Switzerland. The 150 million Swiss Francs investment plan includes construction of new buildings and installation of additional manufacturing lines at the existing plant.

The expansion will substantially increase the production capacity to help meet market needs, at the same time maintaining the company's high standards of quality and delivery. The expansion of the facility at the present site will help harness synergies and ensure the optimised utilization of the specific infrastructure required for the production of these high technology products, including clean room technology and research and test laboratories. "This upgrade is part of our ongoing commitment to technology and innovation and will enable the introduction of a new generation of high-power semiconductors with significantly better performance characteristics", said Peter Leupp, head of Power Systems, ABB Group. "It will also widen the scope of application of high-power semiconductors across a range of products, resulting in greater energy efficiency". ABB's Lenzburg plant is its leading manufacturing unit for high-power semiconductors found at the heart of many ABB technologies such as High Voltage Direct Current (HVDC) transmission systems and variable speed drives.

ABB's Peter Leupp will expand Lenzburg's power semiconductor manufacturing capacity

www.abb.com/semiconductors

New Managing Director at

Joachim Fietz is new managing director at Vincotech

Vincotech, a Munich-based provider of power modules and other technologies used in industrial, solar, automotive and GPS applications, has named Joachim Fietz as managing director. Vincotech is owned by The Gores Group, a Los Angeles-based private equity firm.

Fietz replaces Rainer Sendrowski, who has announced his decision to leave the company. Over the next few months, Fietz and Sendrowski will work closely together to ensure a smooth transition of responsibilities. Fietz has held various senior-level leadership positions in engineering, sales and operations. He most recently served as chief executive officer of Innominate Security Technologies AG, a Berlin-based venture capital funded company which develops and sells advanced network security products to global customers. He also served as managing director for Storage Technology GmbH. Fietz received a master's degree in mechanical engineering from the University of Hannover, graduating Summa Cum Laude. "In spite of the challenging economic outlook ahead, I believe the business is well positioned to capitalize on current market opportunities", Fietz stated.

In November 2008, the company celebrated the dedication of their new offices in Unterhaching near Munich together with customers and business partners. After the divestiture of the former Electronics Modules division from Tyco Electronics to The Gores Group end of 2007, it was necessary for Vincotech to move to a new location as well. The new offices include a laboratory to design GPS modules and telematics platforms, adding up to about 2000m², which offers plenty of room for 70 employees and the possibility of further expansion. Production sites are still in Shenzen (China) and Bicske (Hungary).

www.vincotech.com

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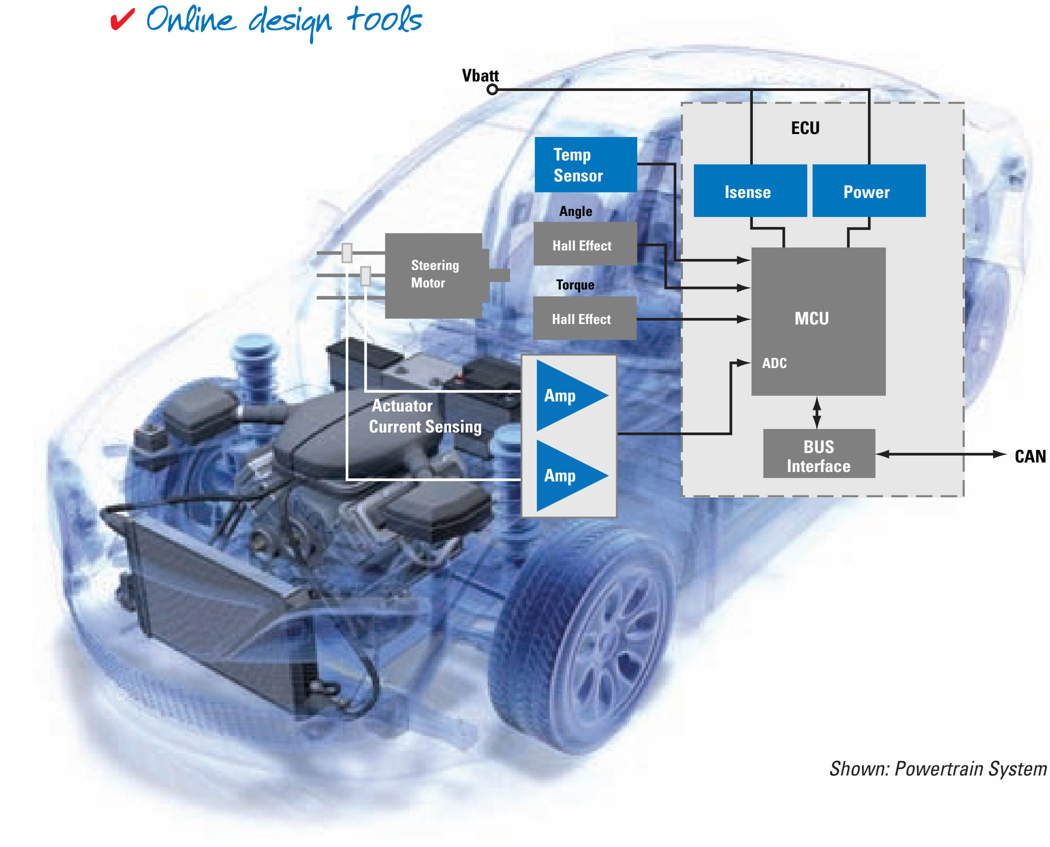
Energy-Efficient Automotive Powertrain Solutions

National Semiconductor offers a wide portfolio of Power Management and Signal-Path products for wide temperature ranges up to 175°C, in small package sizes with efficient power consumption, for applications including electrical power steering, turbo-charge control or automatic gearboxes.

- ✔ AEC-Q100 qualified products
- ✔ System solutions
- ✔ Online design tools



Shown: Powertrain System

Signal Path

National's precision amplifiers, data converters and thermal management products, designed for Powertrain applications with wide temperature ranges, are offered as bare die or in small packages.

Power Management

National's PowerWise® power management products for automotive applications feature wide operating voltage range, wide operating temperature range, low Iq and small solution size.

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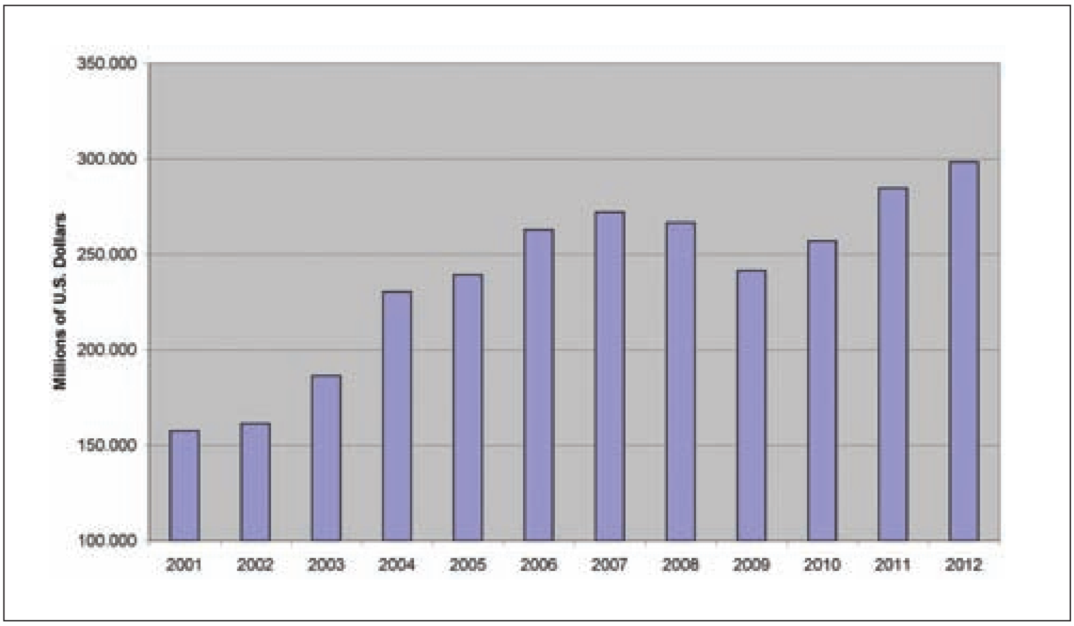
National's host of online tools, including parametric selection guides, reference designs, and WEBENCH® online design and simulation software, application notes and online seminars make design easy.

national.com/automotive

National Semiconductor

Downturn Expected for (Power) Semiconductors in 2009

The deck appears to be stacked against the global semiconductor industry including power semiconductors, with six separate market forces conspiring to cause revenue to decline by nearly a double-digit margin in 2009, according to market researchers iSuppli and IMS.



The semiconductor market is very cyclic, as the worldwide revenue forecast illustrates Source: iSuppli December 2008

Worldwide semiconductor industry revenue is set to decrease by 9.4% in 2009 to $241.5 billion, down from $266.6 billion in 2008. iSuppli previously predicted 6.8% growth. "The semiconductor industry's growth cycle is shaped by six primary, interrelated forces: global economic health, electronic equipment production, chip supply/demand balance, capital investment, industry and individual company profitability and competition", said Dale Ford, senior vice president for iSuppli. "All six of these areas will present challenges for the semiconductor industry in 2009, but the global economic crisis is obviously the most significant factor pushing chip revenue growth into sharply negative territory. Given our assessment of the current status of the key forces that shape the semiconductor cycle, we are projecting semiconductor revenues will decline by 9.4% in 2009. However, there is strong downward pressure on this forecast and there is a possibility that the market decline could be even worse than expected".

Limp consumer spending will result in weak to declining electronics factory revenues across the industry. While some key segments such as mobile PCs and LCD TVs will show low single-digit growth, other segments such as mobile handsets and automotive electronics will suffer notable declines. "Amid this broad-based decline, almost every semiconductor category is expected to contract in 2009", Ford warned. "Optoelectronics are expected to show minor growth on the basis of strength in Light Emitting Diodes due to their ongoing penetration of important applications such as display backlighting. Among other major semiconductor categories, microprocessors and DRAM are forecast to fare relatively better than other markets due to the marginal growth still projected for PCs in 2009. However, these product segments also will decline by around 4% in 2009 compared to 2008".

While there is a wide range of predictions, it appears that most economists are projecting the economy will recover in one year. Based on this outlook for an improved economy in late 2009 or in early 2010, iSuppli is projecting the semiconductor industry will recover to grow by 6.4% in 2010, this will be followed by growth of more than 10% in 2011, the first year to show a double-digit gain since 2004.

Power discrete and module revenues to fall 9%

Power semiconductor discrete and module revenues are forecast to shrink by over $1 billion in 2009 with power MOSFETs anticipated to take most of the hit. The power semiconductor market is estimated to have expanded by 2% in 2008, bolstered by a project 9.5% growth in revenues from power modules. In the current recession, the markets in computer and office, consumer and automotive applications are envisaged to be worst hit, and will spend $0.9 billion less in 2009 in power discrete components alone. "We expect the economic trading conditions to worsen in 2009, with even the fastest growing economies, China and India will start to feel the pinch. We do not expect the power semiconductor market to recover to its 2008 revenues until 2011. However, all is not doom and gloom; the power module market's renewable energy segment is estimate to grow 51% in 2008 and continue with strong growth for the next five years. Overall, power module revenues are forecast not to fall as hard as discretes in 2009, and to recover faster in 2010", adds IMS Analyst Josh Flood.

Decline of 3% for power IC market

Market researcher IMS predicts a fall in revenues of around 3% in 2009 for the global power management and driver IC market, owing mainly to the current slowdown in consumer spending.

After a healthy growth year in 2008 with total revenues reaching almost $13 billion, the market for power management and driver ICs is forecast to fall by nearly $400 million in 2009. It is anticipated that the sectors worst hit will be automotive, portable consumer and desktop PCs with an average decline of around 10%. "The power IC market is fairly resilient due to the emphasis placed on greater power efficiency within many applications. This tends to demand a higher quality IC with a higher average selling price and hence drives market growth. However, with automotive and portable consumer applications being two of the largest markets for power ICs, it is inevitable that

New Agilent Technologies B1505A Power Device Analyzer/Curve Tracer.

The B1505A is an integrated solution that provides researchers and device/process development engineers of power devices with high-voltage and high-current source and measurement capabilities. The fully integrated curve tracer mode makes it easy for users to take advantage of its PC-based EasyEXPERT software.

Key Features of the Agilent B1505A Power Device Analyzer/Curve Tracer:

- Accurate measurement of breakdown voltage and leakage currents at high voltage.
- Evaluation of low on-resistance of power devices at high current.
- Quick troubleshooting, evaluation and failure analysis of power electronic circuitry.
- Device characterization at up to 3,000 volts or 20 amps in a single instrument
- Sub picoamp measurement capability at high voltage.
- 50 microsecond high current pulse width. The shortest current pulse width in the industry.
- Capacitance-Voltage (CV) measurement with up to 3,000V DC bias.
- Quick device-check capability enabled by curve tracer mode.
- Easy operation and data management control with PC-based EasyEXPERT software.
- On-wafer testing and prober control.
- Standard device test fixture with interlocks for a safe measurement environment.

Power devices, including power management ICs (PMIC), power MOSFETs and engine management motor control ICs are a growing device category that requires both high-power and high-accuracy test capabilities. In order to meet emerging standards for improved energy efficiencies, power devices must function ever more efficiently even as they continue to become more complex, smaller and faster. New devices using wide band gap materials such as silicon carbide (SiC) or gallium nitride (GaN) have been widely studied in order to achieve higher efficiencies. To meet performance and safety requirements these studies require high-voltage on wafer measurement capabilities of greater than 1,000 volts to reduce development and qualification times.

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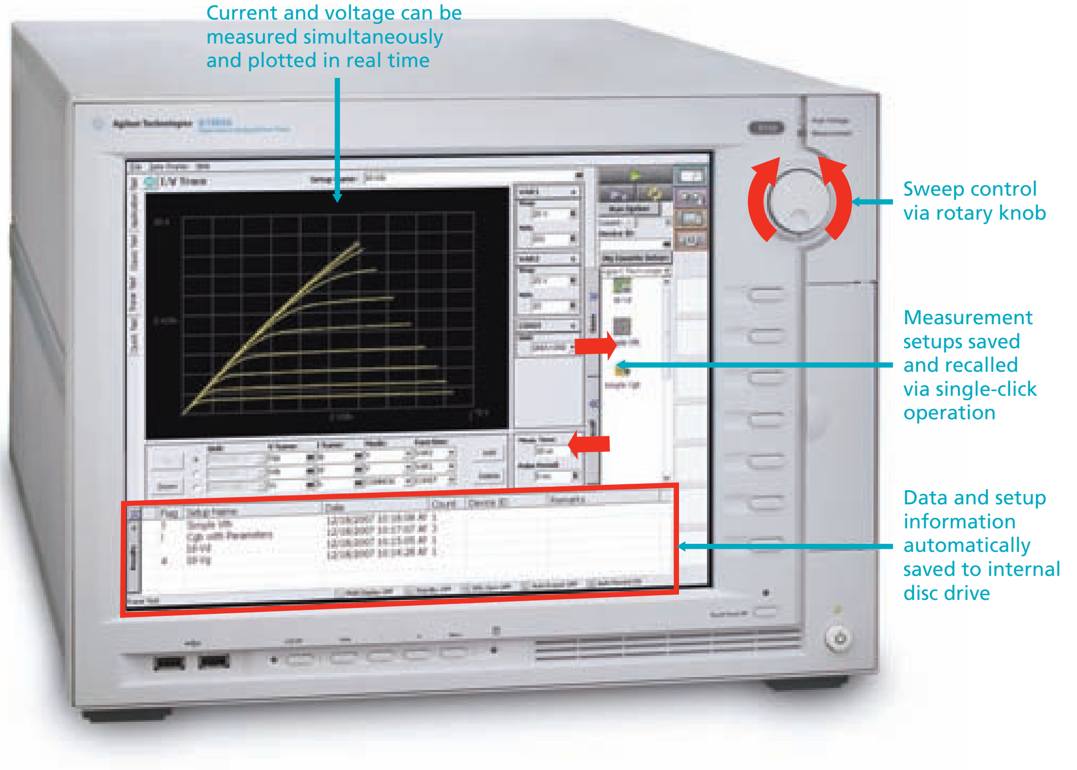


National's CEO Brian Halla expects new business opportunities particularly for renewable energies in the next cycle Photo: AS

revenues will suffer as consumer spending slows. In the mid-term, we expect the market to remain strong with a steady recovery in 2010 and growth of around 10% for 2011 and 2012", comments IMS Analyst Ryan Sanderson.

IMS Research's analysis showed that the top five suppliers in the power management and driver ICs market are Texas Instruments, Infineon Technologies, National Semiconductor, Maxim Integrated Products and Linear Technology. Collectively, they are estimated to account for almost 40% of the total market.

Impact on industry

Of course, these market trends have hit already power semiconductor manufacturers.

National Semiconductor i.e. reported sales of $422 million and net income of $34 million for the second quarter of fiscal 2009, which ended November 2008. First quarter results were $466 million in sales and $80 million in net income. Compared to last year, sales decreased approximately 15% from the $499.0 million reported in the second quarter of fiscal 2008. The company anticipates that sales in the third quarter of fiscal 2009 will be down sequentially by 30%, depending on turns orders received in the quarter. The sales outlook is being impacted by significantly lower-than-usual demand levels in the post-holiday season, especially for personal mobile devices. In addition, the company expects gross margins to decline as the company plans to significantly lower its manufacturing activity in the third quarter of fiscal 2009. Nevertheless, National's CEO Brian Halla expects some growth in renewable energies. "Penetration of solar energy generation is only 0.4% in the USA, this represents a great opportunity in light of Obama's proposal for spending $150 billion in renewable energies. Our recently introduced solar magic concept recupes electrical energy by 50% and thus leads to huge energy savings. An other opportunity is our concept of instant charging, a backup technology for Lithium Ion batteries with supercaps in (hybrid) electric vehicles. And, history has shown that the following cycle leads to a broader market for semiconductors due to new applications", Halla predicts.

Infineon's Automotive, Industrial & Multimarket segment reported revenues of Euro 767 million for the fourth quarter of fiscal year 2008, up 8% sequentially and down 6% year-over-year. The sequential increase was mainly due to the seasonal pattern in the company's industrial business. Excluding the effects of currency fluctuations, primarily between the US dollar and the Euro, and acquisitions and divestitures, segment revenues increased 5% sequentially and decreased one percent year-over-year. Results in the automotive business were stable compared to the prior quarter, as solid demand in the Asian automotive market offset further declines at US car manufacturers and the start of a weakening of the car business in Europe. In the Industrial and Multimarket business, results increased strongly compared to the prior quarter, mainly due to seasonally strong demand for both low and high-voltage MOSFETs in consumer, computing, and telecom products. Demand for high-power products remained strong. "The Semiconductor Industry is driven by energy savings through power electronics. We see a conversion of technologies which may open a new cycle beyond 2009", states Infineon's CEO Peter Bauer.

AS

www.isuppli.com
www.imsresearch.com
www.national.com
www.infineon.com

LG Chem and STMicroelectronics Improve High-Power Battery Technologies

STMicroelectronics and LG Chem have unveiled details of a new automotive battery pack that significantly extends the potential of electric and hybrid electric vehicles. The new battery pack combines LG Chem's lithium ion battery technology with a battery management chip manufactured by ST.

Today's HEVs use batteries based on Nickel Metal Hydride (NiMH) technology. Li-ion batteries are widely used in portable consumer electronic equipment, because they offer one of the best energy-to-weight ratios - more than twice that of NiMH batteries - with a very low self-discharge while not in use. However, their use in higher power applications has so far been limited because the charge/discharge cycle of Li-ion batteries must be carefully managed to protect the batteries from abuse condition. For this reason, Li-ion batteries must be combined with sophisticated and highly reliable electronic battery-management circuits in high-power applications. The new Li-ion battery pack from LG Chem manages the charge/ discharge cycle by incorporating SWT's battery-management chip, which enables safe and long-term reliability of Li-ion battery technology at affordable cost, even in demanding applications such as automotive powertrain systems.

The battery-management chip is manufactured in BCD (Bipolar-CMOS-DMOS) technology, which combines digital logic circuits, analog measurement circuits and power transistors in one chip. Each chip can handle up to 10 Li-ion cells, and also includes an interface for communicating with other battery-management chips in a system. With this communication capability, as many as 32 battery-management chips can be connected in cascade to manage batteries that deliver up to 1600V to the electric motors. "We've been able to adapt our power management and analog expertise with LG Chem to create a new solution that will enable Li-ion batteries to address increasingly higher power applications, from e-bikes to the most demanding public transport vehicles", commented Marco Monti, General Manager, Power Train and Safety Division, Automotive Product Group, STMicroelectronics.

www.st.com

Towards (Hybrid) Electric Vehicles

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

The introductory presentation was given by Peter Lück, head of VW's powertrain development in Wolfsburg/Germany, outlining the requirements on batteries and power electronics for future (hybrid) electric vehicles. Ten years ago, exhaust emission had been the most important criterion for powertrain development, but now the CO_2 debate and shortage of fossile fuels become more and more dominant. Thus, VW will move away from fossile fuels towards renewable energies including biofuels, as well as hydrogen and electricity in the longer-term.

Hybrid electric vehicles are an intermediate step to reduce CO_2 emissions, but the forecasts in terms of worldwide shipments differ significantly, from 1 million units up to roughly 5 million in the year 2015. The key market is in the US, particularly due to legislations in California. Plug-in hybrids and EVs are forecasted to ship between a few 100,000s and 4 million by 2015; this market is a long-term business case in contrast to mid-term HEVs, a meaningful bridging technology. But to make it successful, significant cost reductions have to be achieved.

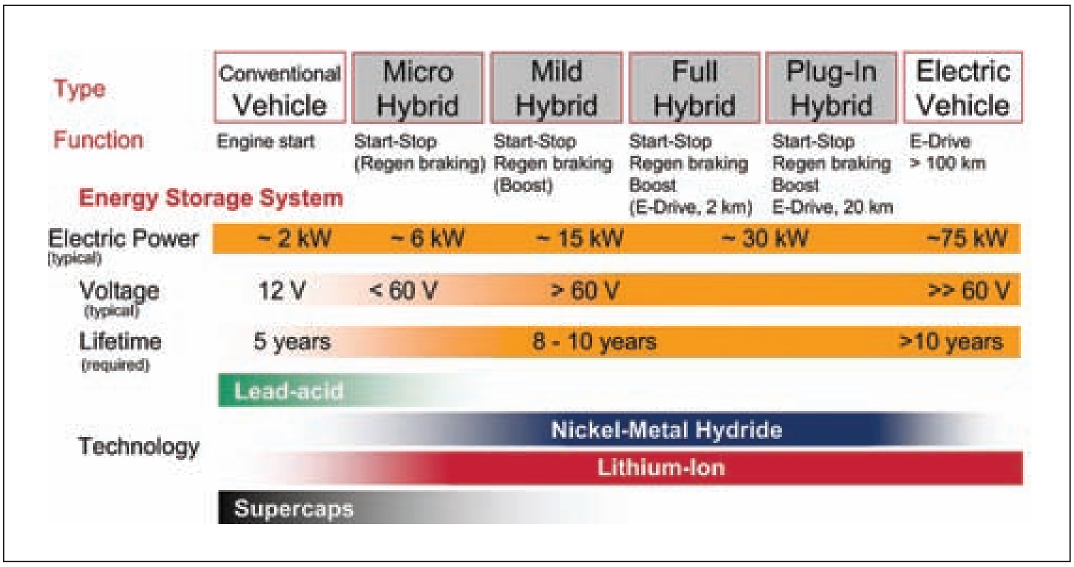
VW already has a long tradition in (hybrid) electric vehicles; in the early 1970s a Typ2 Electric Bus was launched, followed by a T2 City Taxi HEV a few years later. In the 1990s, VW launched the Golf II Hybrid, the EV Golf III CitySTROMer and the HEV Audi Duo, followed by various other models. A full hybrid should be able to drive electrically a distance of 2km, a plug-in hybrid 20km, and an EV more than 100km. Here, the main challenge is electrical energy storage. For plug-in hybrids and pure EVs, VW envisions LiIon batteries due to their storage capabilities and lifetime requirements. Also, the electrical motor must fit the type of vehicle, from simple maintenance-free induction machines to disc/compact-shaped PSM (permanent synchoronous motors).

Battery requirements

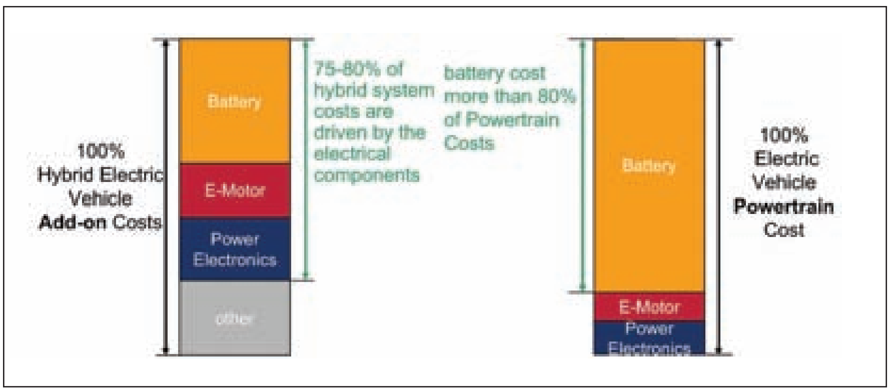
The most critical component in a (H)EV is the high-power battery, here there is a significant development breakthrough in size, durability, packaging and power/weight ratio. In HEVs, up to 80% of the powertrain cost comes from the electrical components. In plug-in hybrids and pure EVs, this adds up to 100% with a battery portion of 80%. While HEVs are targeting CO_2 emissions, they require high-power batteries. Plug-ins and EVs can be considered for energy diversification and thus, require high-energy batteries. Safety and lifetime are the main challenges here.

In the evaluation process for

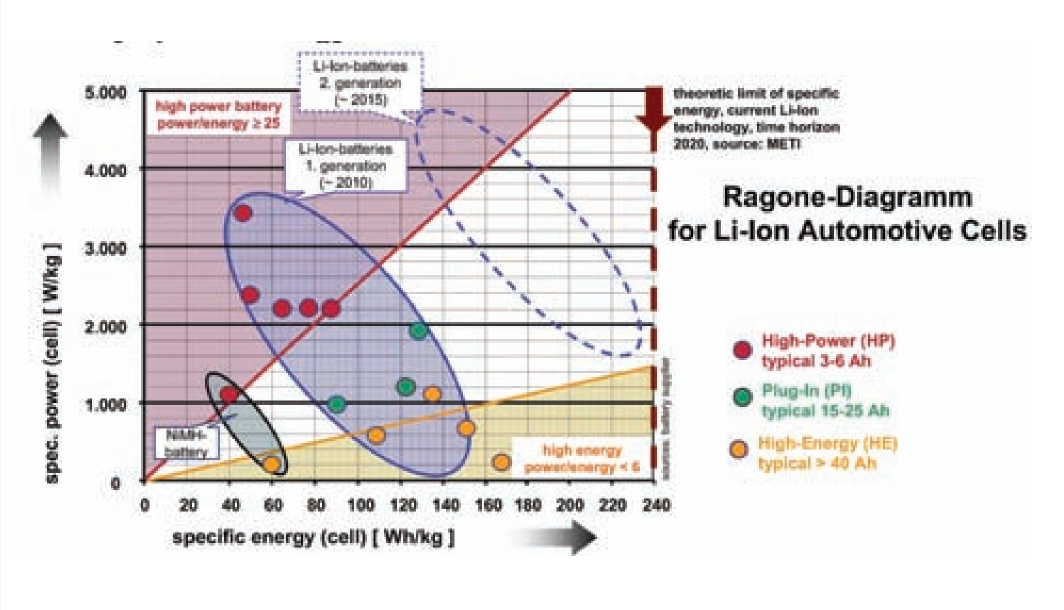
VW's Peter Lück outlined the requirements on batteries and power electronics for future (hybrid) electric vehicles Photo: AS



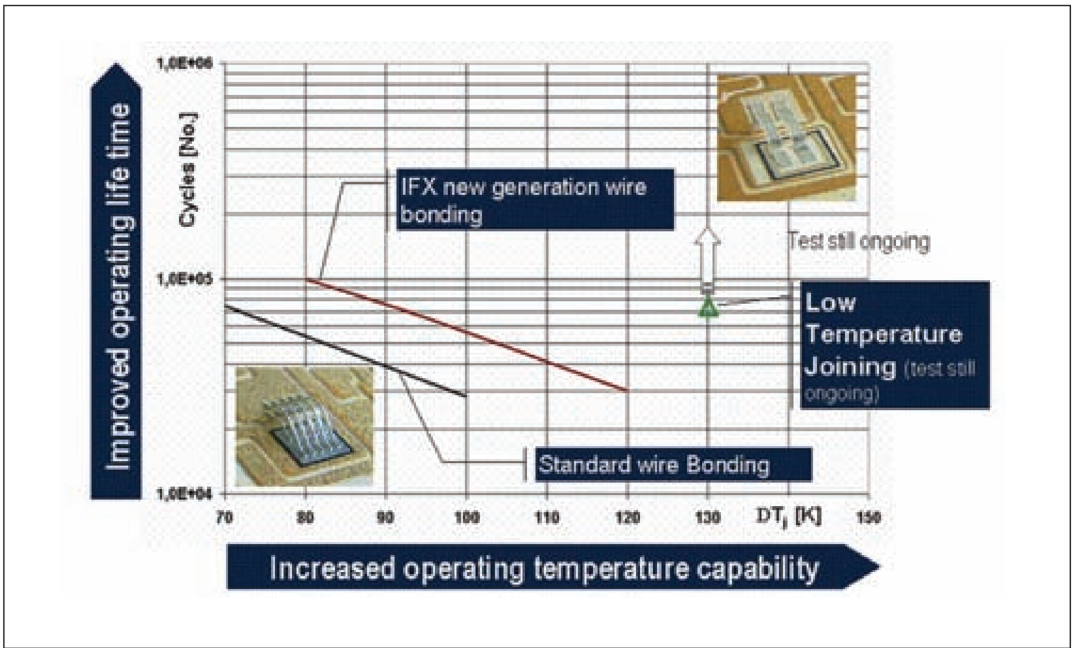
Requirements and technologies for electrical energy storage in (hybrid) electric vehicles Source: VW



Battery and power electronics costs ratio in (hybrid) electric vehicles Source: VW

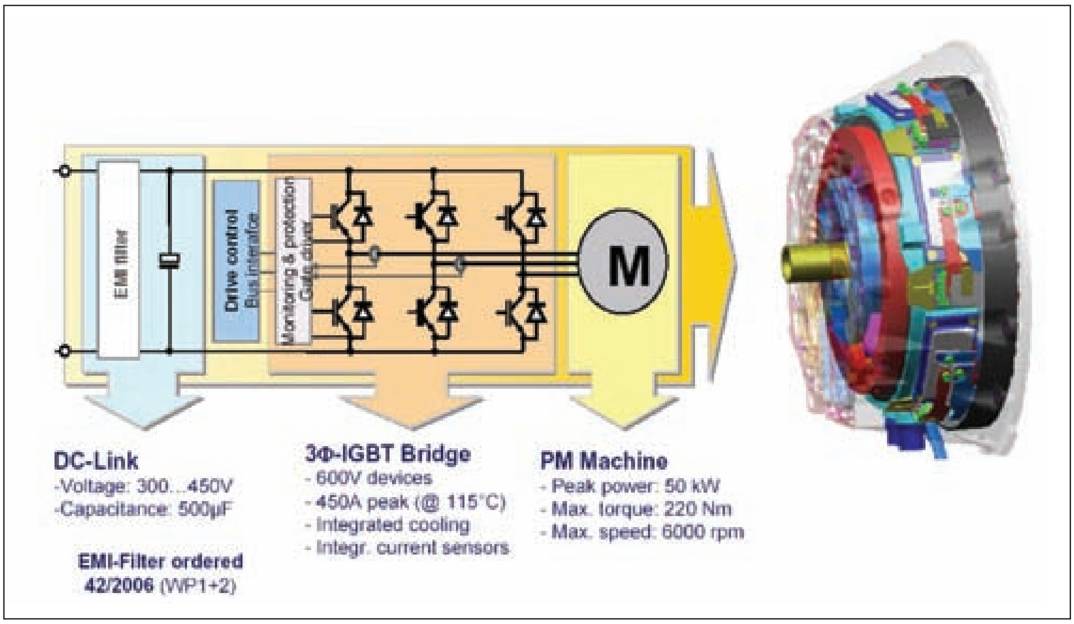


Development of battery technologies with regards to energy and power density
Source: VW



New interconnection technologies will increase temperature capability and operating lifetime
Source: Infineon

Concept of a system integrated inverter with 50kW output power
Source: Infineon



batteries energy, power, lifetime and safety have to be considered. VW views the NiMH battery used in some HEV types and even first generation LiIon batteries not sufficient for pure EVs; here, the second generation to be introduced by the year 2016 with 200Wh/kg specific energy will come into play. For HEVs 4000W/kg are required.

Besides cost, battery safety is a very important aspect, and this has to be considered at each design level from cells (chemistry, vent, rupture disk, shut-down separator, current interrupting) to modules (package, controller, thermalisation), systems (battery and thermal management, self-diagnosis, fuses, current and cras sensing) up to the vehicle (package, communication, drive strategy). Main drivers in cost reduction for batteries are i.e. lower margins for suppliers through increased competition, lower costs for battery management electronics and battery grade materials with no significant change in costs for raw materials. With that VW expects significant cost reductions over the coming 10 to 15 years.

Power electronics requirements

Power electronics have to be adopted to the electric motor and the battery. Main design parameters are increased maximum current and operating temperature at overall lowest cost. Cooling system size is dependent on these parameters, and lower operating temperatures lead to more complex cooling systems and thus, drive costs. Decreasing losses will increase power density, allowing for smaller power semiconductor size and therefore costs.

The necessary cost reduction will be achieved through a modular design and standardisation including batteries, electric motors, and power electronics. This will lead to scaling effects and increased applications over various platforms. VW has already developed a modular powertrain kit with electrification as part of it. Electrification of vehicles is a key development and a chance for the supplier industry, Lück concluded.

Power modules for (H)EVs

Continental and Infineon focused on the role of power electronics. In summary, the message was to improve the efficiency of a hybrid drive, as it is important to reduce the losses in the power semiconductor.

MOSFET and IGBT are the predominant power semiconductors in HEV applications. Due to the uni-polar characteristic, the switching losses of a MOSFET are significantly lower than those of an IGBT. As a result, applications with high switching frequency (>100kHz) are the domain of MOSFETs, while applications with low switching frequencies (<10kHz) are typically dominated by IGBTs. To minimise the cooling effort, it is of interest to increase the maximum allowable junction temperature. With the introduction of 600V IGBT[3], the allowable junction temperature has been raised by 25°C to 150°C operational and 175°C maximum, according to Infineon's speaker Mark Münzer.

Besides cost and performance, quality is a major topic for HEV power electronics. Although expected quality level and lifetime are same for all components, the environmental stress that determines the requirements for each component might be very different. As with most automotive components, the requirements for power semiconductors vary between different mounting places and cooling conditions. A power semiconductor module that is mounted on a forced air-cooled heatsink in the trunk will experience less vibration and thermal cycles over the expected lifetime than a transmission mounted power semiconductor module that is cooled by the transmission oil.

Changing the maximum allowable junction temperature of the power semiconductor will directly change the thermal stress on the interconnection of the chip surface. A typical wear-out effect at the chip surface is the wire bond lift-off. To test this interconnection power, cycling tests are performed. The number of cycles that a device survives is related to the temperature swing, the maximum temperature and the slopes. For the introduction of a maximum junction temperature of 175°C, the wire bonding process has already been improved. Improved thermal performance of the components and interconnection technologies can lead to a system integrated inverter with peak power of 50kW for HEV applications, Münzer concluded.

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Focus on Practical and Applied Aspects of Power Electronics

The 'Applied Power Electronics Conference' was first held in April of 1986, initially sponsored by the IEEE Power Electronics Council and then the Power Electronics Society (PELS). At APEC '90, the fledgling Power Sources Manufacturers Association (PSMA) approached APEC which was already sponsoring its own conference, the Power Electronics Conference (PEC) with modest success. The PSMA proposed that APEC and PEC merge. The conference has enjoyed growing success throughout the years. APEC is now considered to be one of the leading conferences for practicing power electronics professionals. The program addresses a broad range of topics in the use, design, manufacture and marketing of all kinds of power electronics equipment. It combines education seminars, refereed papers and an exhibit hall. An important part of the APEC program is the Exposition, it has grown from about 30 exhibitors in 1991, to more than 120 exhibitors today.

A look at the APEC 2008 exhibition

APEC 2009 starts with Professional Education Seminars (February 15 and 16) covering the sections Control (Feedforward Control of Switching Regulators; Multiphase Voltage Regulator Control and Design Considerations; Stability Analysis and Loop Control in Switching Power Supplies), Design (Microcontrollers for Power Supply Engineers; Maximizing the Effect of Modern Low Voltage Power MOSFETs; Control and Modeling of DC-DC Converters), Integration (EMI Causes, Measurements, and Reduction Techniques for Switch-Mode Power Converters; Advanced Thermal Management Materials for Power Electronics; Integrated Packaging Techniques), Issues and Trends (Understanding Derating-Reliability-Risk Connection; Energy Efficiency Specifications and Standards Activity for Power Supplies; New Trends in Power Conversion Technologies), Topology (Hybrid Power Converters; Analysis and Comparison of Voltage-Mode PWM, Current-Mode PWM, Hysteretic, Constant-On Time, and Constant-Off Time DC-DC Converters; Switched Capacitors Converters) and Motion Control (Permanent Magnet Machines - Design, Modeling, and Control; Design Path for a Typical Digital Motor Control Project; Hybrid Electric and Plug-In Hybrid Electric Vehicles).

The Opening Plenary covers six papers entitled 'PSMA Power Technology Roadmap' by Carl Blake, VP marketing at Transphorm and co-chair at PSMA; 'A Power Electronics Industry Blueprint to Demonstrate Leadership in the Global Energy Debate' by Andrew Fanara, United States Environment Protection Agency Climate Protection Partnership Division; 'Opportunities and Challenges in Very High Frequency Power Conversion' by David Perreault, MIT; 'Energy Efficient System Design. It's more than a power budget…' by John Weil, Freescale Semiconductor; 'Lithium Ion Battery Technology For Automotive Applications' by Jack Waggner, A123 Systems; and 'Power Supply on Chip – Has the Ship Come In?' by Cian O'Mathuna, Tyndall National Institute.

The Technical Sessions start on February 17 and will cover in 35 sessions almost every aspect of modern power electronics and its applications. These sessions are divided into Advances in DC-DC Converters; Modeling and Control of DC-DC Converters; Advances in DC-AC Converters; System Integration Issues and Vehicular Applications of Power Converters; Control of Adjustable Speed Motor Drives; Advances in Simulation, Modeling, and Control of Power Converters; Modeling of Power Electronic Converters; Power Electronics Applications in Renewable Energy Systems; High Efficiency DC-AC Power Converters; Power Electronic Applications in Fuel cell and energy storge system; Advances in SiC devices; Power Electronics Applications in Renewable Energy Harvesting; Power Quality Enhancement Techniques; or Fault Management in Adjustable Speed Motor Drives.

In parallel, Special Presentations will cover Market Trends, System Design, Future of DC-DC Conversion, Power Electronics for a Greener World, and Current Topics for Power Electronics Research. A Wednesday Evening Social Event will round up the program.

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DualPack
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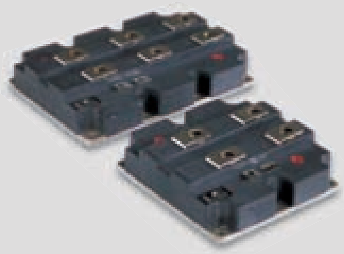
1200V : 225A - 450A

6-Pack IGBT
600V : 15A - 150A
1200V : 10A - 150A
1700V : 100A - 150A

PIM IGBT
600V : 30A - 100A
1200V : 10A - 75A

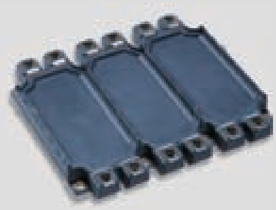


1-Pack
1200V : 1200A - 3600A
1700V : 1200A - 3600A

2-Pack
1200V : 800A & 1200A
1700V : 600A & 1200A

2-Pack IGBT
600V : 50A - 600A
1200V : 50A - 450A
1700V : 150A - 400A

1-Pack IGBT
600V : 600A
1200V : 200A - 800A



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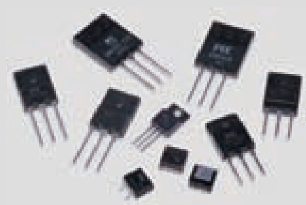
1200V : 225A - 450A
1700V : 225A - 450A

Special version available
for rough environments

IPM-IGBT
600V : 15A - 300A
1200V : 15A - 150A



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Charging for Ultracapacitors

To meet the needs of a growing number of functions that continue to work during engine start in automotive start/stop systems, a high-performance energy storage device to overcome the voltage drop is needed. Ultracapacitors can be used in combination with batteries to provide the additional power. They require high constant current during the charging cycle and, for this reason, a DC/DC converter interface is needed between the ultracapacitor and the battery. The high current ultracapacitor charger is highly complex. This article describes the design of a DC/DC converter for ultracapacitors using National Semiconductor's Synchronous Buck Controller LM5116. **Mariangela de Martino, Product Application Engineer, and Kamal Najmi, Power Design Engineer, Europe, National Semiconductor**

In recent years, ultracapacitors have become accepted for industrial and transportation applications as high power buffers in combination with conventional batteries. The merits of ultracapacitors in such applications results from their high power capability based on ultra low internal resistance, wide operating temperature -40 to 65°C, and high cycling capability. Automotive manufacturers, in particular, are very keen to use this new technology. The characteristics of ultracapacitors can be used in combination with normal electrochemical batteries to improve the transient performance of the main voltage rail in a vehicle, and to increase the lifetime of the battery. Ultracapacitors' cycle life is quite substantial and their internal low resistance makes the cycle (discharge/ charge) efficiency high (from 90 to 98%).

This article shows the design of a charger for an ultracapacitor using a DC/DC synchronous buck-converter (LM5116) with emulated current mode (ECM) control.

The emulated current mode control and its advantages in this specific case will be described in more detail in the next section. The converter, which has to work as a current source, transforms the energy coming from the battery to a value suitable for the charge of the ultracapacitor. The charger utilises CC/CV (constant current/ constant voltage) charging. The CC/CV charger starts the charge cycle by forcing the maximum charge current safely permitted, while accurately clamping the ultracapacitor voltage to its maximum voltage. When the ultracapacitor voltage reaches the maximum voltage, the voltage remains regulated but the charging current starts to back off.

The ultracapacitor used in this application has a capacity of 650 Farad and a rated maximum cell voltage of 2.7VDC (Maxwell BCAP0650). The system can handle more elements in series, but would require an additional balancing circuit which is not part of this article.

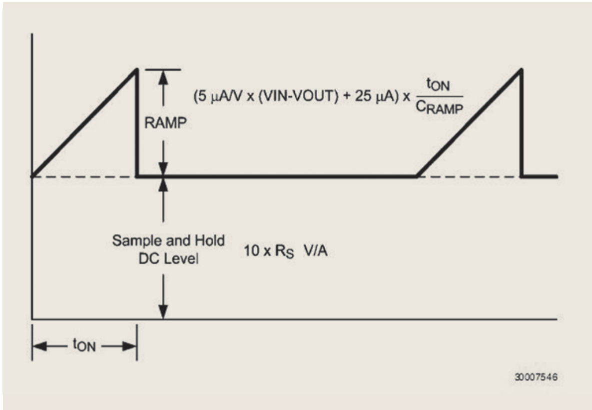


Figure 1: Composition of the current sense signal

Power Conversion Stage

The DC/DC converter, which represents the interface between the battery and ultracapacitor, is a dual phase converter based on two LM5116. The LM5116 is a synchronous buck controller intended for step-down regulator applications from a high voltage or widely varying input supply.

In particular, this application requires an output current up to 50A, which is too high for a single stage. The solution uses two converters in parallel operating 180° out of phase. The benefit of this so-called interleaved converter is to reduce the RMS ripple current in the input capacitors by almost a factor 2. The stress on the active components decreases significantly by using two phases. The dual phase solution is designed to convert an input voltage of typically 12 down to a maximum 2.7V with current limited at 50A.

The LM5116 utilises the emulated current mode control technique. This is a key feature for this particular application. This method of control does not actually measure the buck switch current, but rather reconstructs the inductor current signal. The current reconstruction comprises two elements, a sample and hold DC level and an emulated current ramp. The sample-and-hold DC level is derived from a measurement of the recirculating current through either the low-side MOSFET or current sense resistor. The voltage level across the MOSFET or sense resistor is sampled and held just prior to the onset of the next conduction interval of the buck switch (see Figure 1).

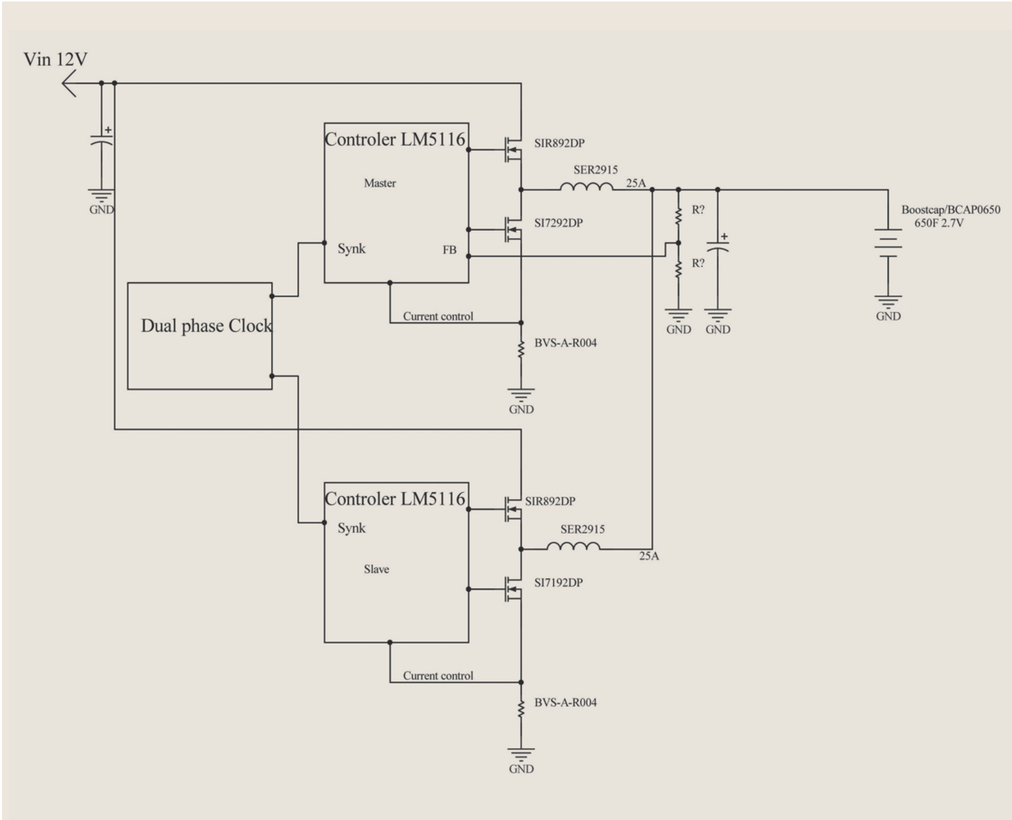
The current sensing and sample-and-hold provide the DC level of the reconstructed current signal. The positive slope inductor current ramp is emulated by an external capacitor connected from the RAMP pin to the AGND and an internal voltage controlled current source. The ramp current source that emulates the inductor current is a function of the V_{IN} and V_{OUT} voltages per equation 1.

$$I_R = 5\mu A/V \bullet (Vin - Vout) + 25\mu A \quad (1)$$

Proper selection of the RAMP capacitor (C_{RAMP}) depends upon the value of the output inductor (L) and the current sense resistor (R_S). For proper current emulation, the DC sample and hold value and the ramp amplitude must have the same dependence on the load current. According to equation 2 that is:

$$Rs \bullet A = \frac{g_m \bullet L}{Cramp} \quad (2a)$$

Figure 2: Architecture of the dual phase Boostcap charger



$$Cramp = \frac{g_m \bullet L}{A \bullet R_S} \qquad (2b)$$

Where g_m is the ramp generator transconductance (5μA/V) and A is the current sense amplifier gain (10V/V). The ramp capacitor should be located very close to the device and connected directly to the pins of the IC (RAMP and AGND).

This unique current mode control samples the buck switch current just prior to the onset of the next conduction interval of the high-side FET. As a result of this, the next cycle can be skipped completely if the current exceeds the current limit threshold.

This is one of the main reasons why the LM5116 has been chosen. Due to the ECM (emulated current mode), the current is measured during the turn-off time of the High Side Switch, and therefore the duty cycle can be modulated to a value close to 0%, in order to avoid high peak current into the inductor. The current never exceeds the current limit threshold when the output voltage is in short circuit, which is exactly the same situation. When the converter's load is an ultracapacitor starting from zero volt, the output is in short-circuit, nevertheless a current runaway situation will not occur, thanks to the ECM mode.

Current sense resistor and MOSFET selection

Using a current sense resistor in the source of the low-side MOSFET provides superiour current limit accuracy compared to $R_{DS(ON)}$ sensing. $R_{DS(ON)}$ sensing is far less accurate due to the large variation of MOSFET $R_{DS(ON)}$ with temperature and part-to-part variation.

The current limit is set by the current sense resistor value (R_S).

For a 2.7V output, the maximum current sense signal occurs at the minimum input voltage, so R_S is calculated according to equation 3:

$$R_S \le \frac{V_{CS(TH)}}{Io + \frac{Vout}{2 \bullet L \bullet Fsw} \bullet \left(1 + \frac{Vout}{Vin(MIN)}\right)} \qquad (3)$$

The current sense resistor is calculated using the above formula and the value chosen is equal to 4mΩ.

Selection of the power MOSFETs is governed by the same trade-offs as switching frequency. Breaking down the losses in the high-side and low-side MOSFETs is one way to determine relative efficiencies between different devices. Losses in the power MOSFETs can be broken down into conduction loss, gate charging loss, and switching loss.

Conduction (P_{DC}) is according to equation 4 approximately

$$P_{DC(HO-MOSFET)} = D \bullet \left(Io^2 \bullet R_{DS(ON)} \bullet 1.3\right) \qquad (4a)$$

$$P_{DC(LO-MOSFET)} = (1-D) \bullet \left(Io^2 \bullet R_{DS(ON)} \bullet 1.3\right) \qquad (4b)$$

where D is the duty cycle. The factor 1.3 accounts for the increase in MOSFET on-resistance due to heating. Alternatively, the factor of 1.3 can be ignored and the on-resistance of the MOSFET can be estimated using the $R_{DS(ON)}$ versus temperature curves in the MOSFET datasheet. Gate charging loss, P_{GC}, results from the current driving the gate capacitance of the power MOSFETs and is approximated as

$$P_{GC} = n \bullet V_{CC} \bullet Q_g \bullet Fsw \qquad (5)$$

where

Q_g refers to the total gate charge of an individual MOSFET, and 'n' is the number of MOSFETs. If different types of MOSFETs are used, the 'n' term can be ignored and their gate charges summed to form a cumulative Q_g. The switching frequency (FSW) chosen in this particular case is 130kHz. Gate charge loss differs from conduction and switching losses in that the actual dissipation occurs in the LM5116 and not in the MOSFET itself. Further loss in the LM5116 is incurred as the gate driving current is supplied by the internal linear regulator. Switching loss occurs during the brief transition period as the MOSFET turns on and off. During the transition period both current and voltage are present in the channel of the MOSFET.

The switching loss can be approximated as

$$P_{SW} = 0.5 \bullet Vin \bullet Io \bullet (t_R + t_F) \bullet Fsw \qquad (6)$$

where t_R and t_F are the rise and fall times

Figure 3: Constant short circuit at 10A. CHANNEL 2 (blue) shows the UVLO pin that is pulled down after 256 cycles; CHANNEL 4 (green) shows the output current equal to the current limit 10A; CHANNEL 1 (yellow) shows the drain voltage

Figure 4: Switch nodes signal (Channel 2 and Channel 3) and current (Channel 1) at the beginning of the charging phase voltage

Figure 5: Switch nodes signal (Channel 2 and Channel 3) and current (Channel 1) when the voltage across the Boostcap is 2.5V

Figure 6: Switch nodes signal (Channel 2 and Channel 3) and current (Channel 1) at the end of the charging cycle

of the MOSFET. Switching loss is calculated for the high-side MOSFET only. Switching loss in the low-side MOSFET is negligible because the body diode of the low-side MOSFET turns on before the MOSFET itself, minimising the voltage from drain to source before turn-on.

For this example, the maximum drain-to-source voltage applied to either MOSFET is 10V. V_{CC} provides the drive voltage at the gate of the MOSFETs. The selected MOSFETs must be able to withstand 10V plus any ringing from drain to source, and be able to handle at least V_{CC} plus ringing from gate to source. A good choice of high-side MOSFET for the design example is the SIR892DP featuring a $R_{DS(ON)}$ of 3.2mΩ, total gate charge of 40nC, and rise and fall times of 9ns. For the low-side MOSFET a good choice is the SI7192DP with $R_{DS(ON)}$ of 1.9mΩ, total gate charge of 90nC, and rise and fall times of 10 and 9ns respectively. In this application two devices are used in parallel.

Once the MOSFET and the sense resistor are selected, it is possible to obtain the rest of the BOM just following the calculation suggestions available on the datasheet online.

The external clock (see Figure 2) is used to apply two out of phase signals to the two ICs (each of them provided with an external pin for the synchronisation) in order to obtain 180° out of phase outputs.

Measurement results

The LM5116 contains a current limit monitoring scheme to protect the circuit from possible over-current conditions. Since the ramp amplitude is proportional to V_{IN} - V_{OUT}, if V_{OUT} is shorted, there is an immediate reduction in duty cycle. An internal counter counts clock pulses when in current limit. When the counter detects 256 consecutive clock cycles in current limit condition, the regulator enters a low power dissipation hiccup mode. The regulator is shut down by momentarily pulling UVLO low, and the soft-start capacitor discharged. The regulator is restarted with a full soft-start cycle once UVLO charges back to 1.215V. This process is repeated until the fault is removed (Figure 3).

For an ultracapacitor charger this feature is not required, since the LM5116 needs to provide the maximum current; for this reason the soft start pin is left at high impedance (no soft start capacitor) and no capacitor is used on the under voltage lockout pin. Figure 4 shows a plot of the output current and the two switching nodes 180°out of phase. As the output voltage ramps from 0 up to 2.7V the duty cycle has to follow the relation $D = V_{out}/V_{in}$ and therefore start from 0% up to D max

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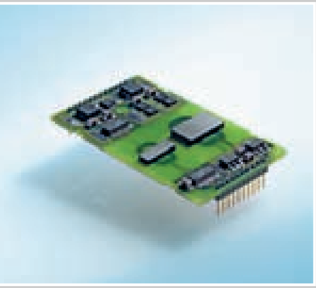

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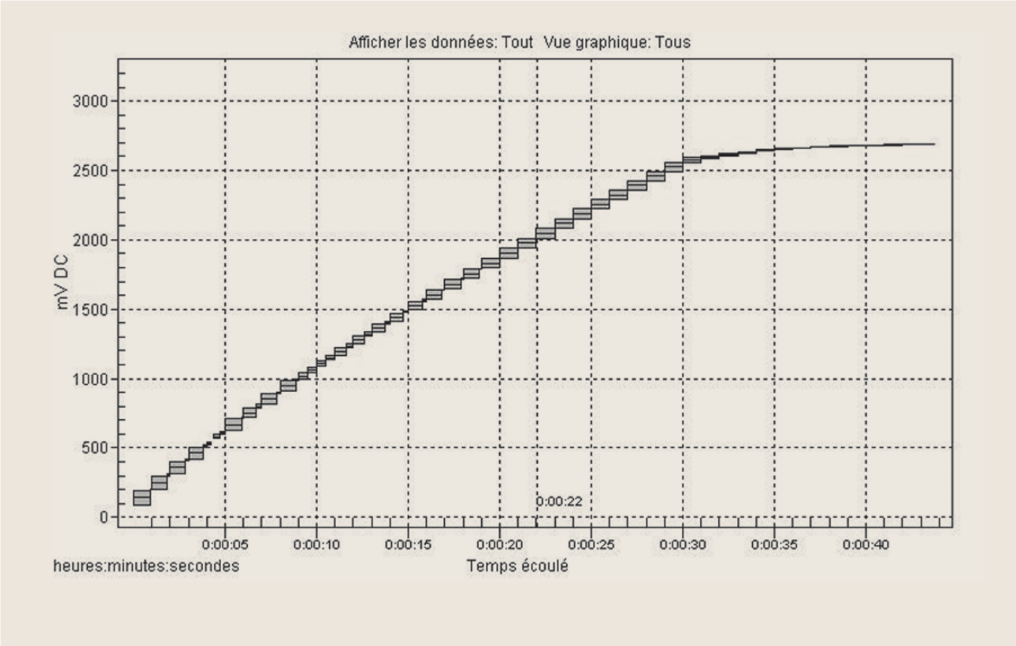

Figure 7: Charge cycle of the Maxwell 650F Boostcap Capacitor

($2.7V/V_{in}$) without runaway current at low duty cycle due to the ECM. The device works in current limit mode providing maximum current equal to 50A.

In the next phase, the voltage across the capacitance is at 2.5V and the current starts to decrease as shown in Figure 5. This is due to the voltage drop across the cable which has a length of 60mm. In the last phase, the ultracapacitor is completely charged at 2.7V and the current supplied by the ultracapacitor charger drops (Figure 6). The plot in Figure 7 shows the voltage across the ultracapacitor during the charging cycle. The charging time of a 650F capacitor takes a little more than 30s (0 to 2.7V at 50A).

The ultracapacitor charger is shown in Figure 8; this is a four-layer board with 70µm thickness. The main components are the LM5116, MOSFETs (SIR892DP, Si7192DP) from Vishay, current sense BVS-A-R0004 from Isabellenhuette, Inductor SER2915 from Coilcraft, electrolytic capacitor 16SVPC270M from Sanyo and ceramic capacitor C4550X5R1A686M, C4532X7R1E226M from TDK.

Conclusion

In this article, the design of a high power charger for an ultracapacitor has been presented highlighting the advantages and the high performance of National Semiconductor's LM5116 with emulated current mode control. Ultracapacitors are ideal for applications that require additional high power for a few seconds. For this reason, they represent a good fit in automotive systems as they can help to overcome the voltage drop in start/stop systems where the engine has to be started on a regular base. The ultracapacitor today represents an energy buffer which helps to extend battery life tremendously. In the future, DC/DC converters like the LM5116 will be fundamentally important in the development of advanced systems such as the power electronic interface with ultracapacitor for fuel cell electric vehicles.

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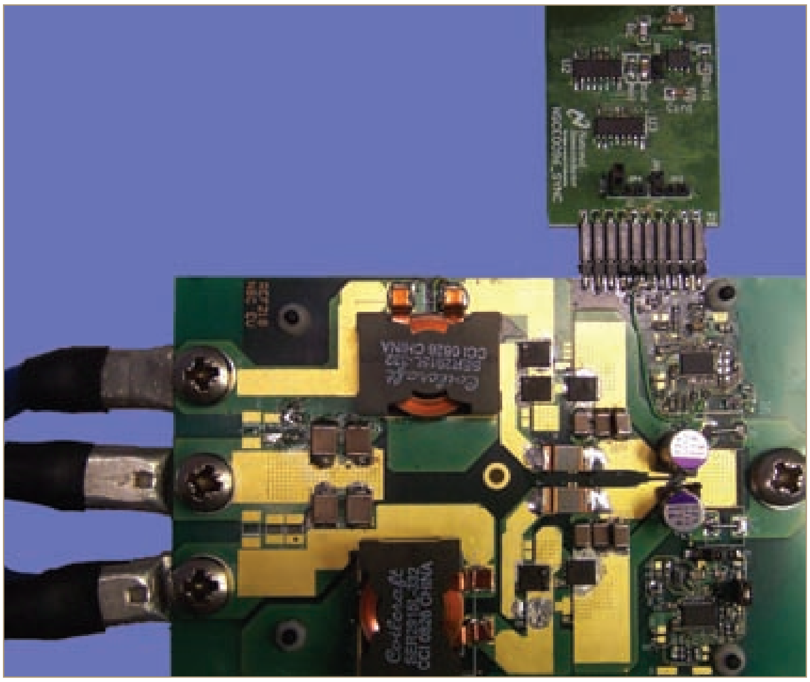


Figure 8: Final layout of the dual phase Boostcap charger

New Sensor Technology for Total Battery Management

Whenever a battery is used as a critical source of energy such as with uninterruptible power supplies (UPS), electric vehicles (EV), hybrid electric vehicles (HEV) and mobile life support equipment, it is essential that the user has complete confidence in the battery's ability to deliver its expected amount of energy. It is also important that the user can have faith in the battery status display. Raztec recognised this gap in current sensing technology some years back, and have recently developed a device specifically tailored for measuring battery current for battery management purposes. **Warren Pettigrew, CTO Raztec Sensors, Christchurch, New Zealand**

In practice it has been remarkably difficult to accurately determine the state of health (SOH) and the true state of charge (SOC) of a battery. There is just such a big stack-up of variables. However, with good and appropriate sensing technology and the use of refined algorithms appropriate for the chemistry, it is now possible to compute reliably the SOH and SOC of a battery.

With most battery applications, the fundamental issue is simply the minimisation of the cost of operation. So much the better if battery life can be extended by predictive maintenance and the charging programme monitored to assure correctness (very commonly batteries are destroyed through incorrect charging techniques). Cost of operation is very much linked to the cost of failure – failure for the battery to deliver its power when vitally needed. It is much better to replace or repair the battery before it fails when the SOH monitor predicts the need.

Additionally, the battery management system may be required to protect the battery or its load from overload, as well as to generate alarms if parameters fall outside prescribed safety windows.

Variables for SOC determination

Monitoring the cell/battery voltage is a common, simple, but inaccurate method. Many variables overlay the voltage/capacity relationship:

- If it is to be measured during discharge, then battery resistance must be considered - but resistance is capacity, time and temperature dependant.
- Cell voltage is temperature dependant.
- There is a memory/hysteresis effect after charge/discharge with a logarithmic approach to a settling voltage.
- Newer high performance batteries such as Lithium Ion have a very flat charge discharge characteristic such that temperature effects dominate cell voltage changes.
- Battery voltage changes as a battery ages and its cycle count increases.
- Generally, there is inequality of individual cell performance.

Net coulomb count: One may believe that a battery will give up the ampere-hours (Ah) that are put into it. But this is far from the case. Many batteries will give up less than half their capacity under fast discharge - with some chemistries and structures behaving worse or better than others. This effect also applies for charging. You never get out the Ah that are put in. Again, temperature is a dominate variable with many batteries performing very poorly indeed at low temperature.

Battery impedance: There is a reasonably consistent relationship between SOC and battery impedance. The impedance measurement may be a steady-state DC impedance or an impedance measured under AC conditions. The algorithm has to be calibrated for a particular chemistry, structure, capacity and manufacturer and is still affected by the usual gambit of variables.

Specific gravity measurement: This is only applicable for batteries that have a free electrolyte. This method can give reasonable results provided the system is pre-calibrated and temperature is considered. It is also important that the electrolyte is stirred, with stratification being a common problem.

Variables for SOH determination

Capacity: Rarely possible to measure this during normal usage.

Cycle count: When used according to specification, batteries have a design discharge/charge cycle count with the depth of discharge thrown in as a modifier. For a battery subjected to cyclic usage this method may be appropriate but it does not accommodate abuse or faulty cells.

Impedance measurement/ripple voltage: As a battery ages, its DC and AC impedance rises in a fairly predictable manner so a number of SOH measurement products are based on this means. The product has to be calibrated for a particular battery and indications are diluted if only one cell of a long string begins to fail.

Float/leakage current: The float current for a particular voltage and temperature is a good indicator of SOH. This parameter increases as the battery ages and also increases as the result of a number of failure mechanisms. The challenge is its actual measurement.

Individual cell temperature: A battery which has all its cells at equal temperature during charge and discharge is probably in good health. Again this technique is more appropriate for cyclic usage.

Individual cell voltage: A battery without a cell equalisation strategy which has good equality of voltage down the string is likely to be in good health. Effectively though, this is a measure of leakage or float current for each cell.

Electrolyte monitoring: Where a battery has free electrolyte, specific gravity and electrolyte level trends can be monitored to give an indication of battery and cell SOH. This technology being more appropriate for larger battery sets and where cost of failure is high such as in nuclear power stations.

How do battery monitors operate?

Because of the seemingly impossible number of variables, the best approach is

to build a mathematical model of the battery based on parameter measurement and real life experience. The model then operates by sensing as a very minimum:
- Battery voltage including ripple voltage
- Battery current including ripple current
- Battery temperature
- Real time.

Additionally, it could also sense:
- Cell voltage
- Cell temperature
- Ambient temperature
- Cycle count
- Specific gravity and electrolyte level
- Connection resistance
- Ground fault current.

The model must accommodate:
- Battery chemistry and structure
- Capacity
- Cell count
- Temperature dependencies
- Affect on capacity of charge/discharge current
- Self-discharge parameters
- Charge/float voltages.

This all adds up to a very complex machine, highly dependant on software algorithms rather than hardware, but there are some measurement issues particularly of current.

Measurement issues

In order to assure reliability of a battery which has more than about 10 cells in series, it is desirable to monitor cell voltage and also force cell equalisation. This adds significantly to hardware costs but can greatly improve battery reliability and life.

Cell equalisation can be via cell current extraction or addition. Subtraction being the easier to manage. This is effectively forcing equal cell self discharge.

Individual cell temperature monitoring is also worthwhile, as one hot cell indicates conclusively a problem. Again, all this is hardware intensive.

Finally, we have battery current sensing. With reliable current sensing it is possible to measure the following parameters:
- Coulomb count
- Ripple current
- Float current
- Charging current
- Discharge current
- Earth leakage current
- Ohmic resistance
- Connection resistance.

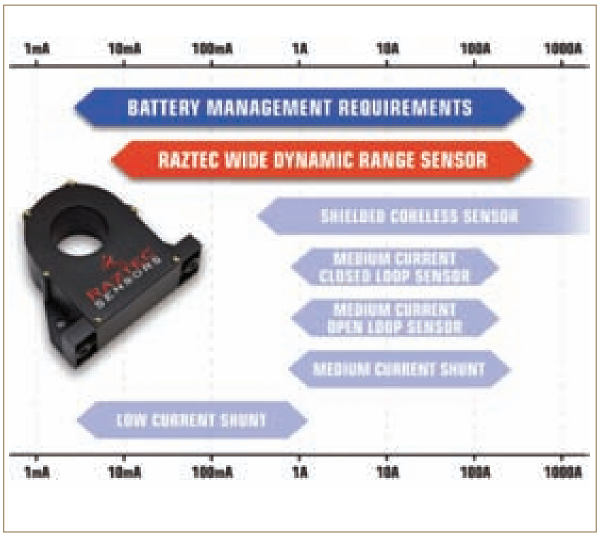


Figure 1: Current range and appropriate sensors for battery management

Current measurement techniques

Figure 1 outlines the current range and appropriate sensors for battery management. The simplest way to measure current is by using a shunt, however, shunts have a number of shortcomings: A shunt that is required to measure both high and low currents will generate considerable heat at high current levels. A shunt has to break the battery circuit. In other words, an intrusive connection which is often not desirable. Shunt output voltage often has a very poor signal to noise ratio. Shunts are incapable of measuring the dynamic range of float currents and discharge currents.

Another method is to use Hall-effect current sensors – either open or closed-loop. These sensors are non-intrusive, so don't have the noise issues of shunts, but traditionally don't give the dynamic range as they can't accurately measure currents much less

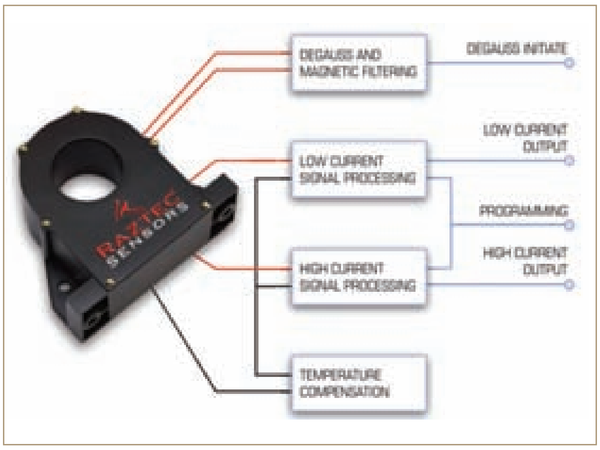


Figure 2: Wide dynamic range current sensor basis structure

PRELIMINARY SPECIFICATION	DIGITAL SENSOR	ANALOGUE SENSOR
Current range[1]	<10mA – 400A+	<10mA – 600A+
Resolution	1mA	N/A
Frequency Response	DC – 400Hz	DC – 25kHz
Accuracy	<+/-2% +/-5mA over 0-+80C	<+/-2% +/-5mA over 0-+80C
Interface	Serial/Digital Data Stream	Dual Channel Analogue
Power Supply Requirement	5V+/-0.1VDC @ 200mA	5V+/-0.1VDC @ 50mA
Aperture Diameter	32mm	32mm
Overload Rating	Limited only by conductor	Limited only by conductor

NOTE – Excellent immunity to stray magnetic fields and conductor position within aperture
[1] Higher current ratings available in subsequent production releases

Table 1: Raztec Wide Range digital and analogue current sensor properties

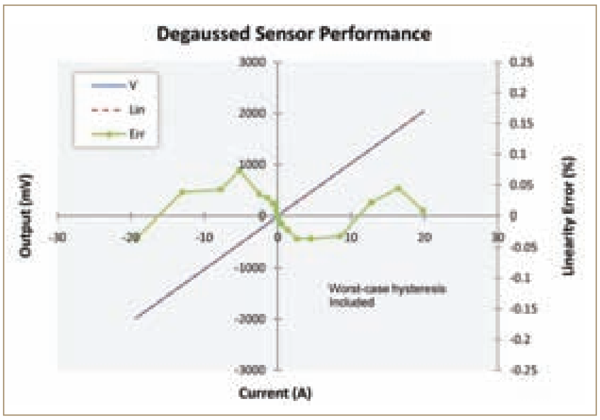


Figure 3: Automated degaussing eliminates hysteresis issues

than 0.5 of an ampere.

Sophisticated sensors based on flux-gate technology may work, but they are expensive and there are practical issues with the dynamic range of the output signal. There are presently two offerings:

- An analogue sensor with separate low and high current outputs. The low current output being heavily filtered to allow the extraction of float current in the presence of a high ripple current as is typical in double conversion UPS systems.
- A sensor with a very high bit count digital output to give 1mA resolution which also exhibits good precision and stability in the mA float current region. This sensor avoids the noise issues typical associated with measuring sub-millivolt DC signals.

Raztec offers a choice of current sensors to address the measuring challenges outlined above.

Non-intrusive:

- Assures no common mode voltage and noise issues
- No extra heat generated from the primary conductor
- Complete flexibility with the mounting position
- Excellent signal to noise ratio.

Wide dynamic range of current measurement (Figure 2 and Table 1):

- Achieved from dual range analogue circuits
- Or from a very high bit count A/D with floating point and sophisticated noise filtering techniques.

Hysteresis cancelling (Figure 3):

- Automated degaussing eliminates hysteresis issues.

Thermal drifts often associated with hall magnetic field sensors:

- Minimised by the use of very high performance sensors which exhibit minimal drift
- Performance further enhanced by drift cancelling techniques which use thermal mapping.

Environmental immunity:

- Comprehensive shielding protects against stray electric and magnetic fields.

Cost management:

- The power of modern microcomputers allows extensive circuit integration thereby reducing cost and improving reliability.

Literature

Current Sensing Solutions for Hybrid Electric Vehicles, Power Electronics Europe 3/2008

Current Sensor Selection for Demanding Applications, Power Electronics Europe 2/2008

Selecting the Most Effective Current Sensing Technology, Power Electronics Europe 8/2007

Guide for Selection and Use of Battery Monitoring Equipment in Stationary Applications, Standard IEEE1491

Silicon for Mini-Ballasts Illuminates the Way

Manufacturers of energy-saving fluorescent lighting for industrial and commercial installations are under pressure to deliver advanced capabilities and target smaller fitment sizes. With smaller form factors, light fixtures are become more numerous, allowing greater control over ambient light settings while operating at lower power. Also, by keeping power low – below 26W – they are excluded from the power factor correction requirements applied to larger installations. This has further increased the appeal of small fixtures and is promoting developments in the mini-ballasts used to drive them. And one of those developments, typically found in fluorescent lighting, is the ability to dim the light output. New ballast devices well-suited for thin lamps including the increasingly popular T5 lamp reduce part count and simplify design. **Tom Ribarich, Director Lighting Design Center, International Rectifier, El Segundo, USA**

The IRS2530D DIM8 is a linear dimming ballast control IC with half-bridge driver in a compact 8pin form factor. The new device provides a competitive solution to replace inefficient incandescent bulbs in multi-level and three-way compact fluorescent lighting (CFL) applications. The IRS2158D 16pin fluorescent dimming ballast control IC with half-bridge driver is designed for applications requiring dimming performance below 10%. Comprehensive protection features such as protection from failure of a lamp to strike, filament failures and end-of-life protection are offered, making the device well-suited for thin lamps including the increasingly popular T5 lamp (Figure 1 and Table 1).

Traditional ballasts require a noise blocking input filter, rectifier and smoothing capacitor for converting the AC voltage input to a DC supply. They also require a sub-circuit to produce the high frequency square-wave voltage. This circuit comprises a control IC and half-bridge, as well as a resonant output stage for preheating, igniting and running the fluorescent lamp. Adding a dimming control requires a further isolated input with a current sensing sub-circuit to measure the lamp current, and a closed loop feedback circuit to compensate for the lamp's non-linear characteristics. This adds significantly to the component count, cost and space of the solution (Figure 2).

Reducing component count and cost

Now, however, the situation is changing with the advent of increasingly integrated

Figure 1: IRS2530D and IRS2158D 600V control ICs for energy-efficient dimming fluorescent lighting ballast applications

Programmability	IRS2530D	IRS2158D
Preheat Time	Yes	Yes
Preheat Frequency	-	Yes
Closed Loop Ignition Current	-	Yes
Run Frequency	Yes	Yes
Deadtime	-	Yes
Features	IRS2530D	IRS2158D
Fixed Deadtime	2.0 µs	Programmable
Failure to Strike	On Over Current	Yes
Open Filament	On Over Current	Yes
Brownout Protection	with non-ZVS	Yes
Shutdown Pin	-	Yes
Fault Counter	-	Yes
End-of-Life Protection	-	Yes
Integration	IRS2530D	IRS2158D
Bootstrap Diode	Yes	Yes
Crest Factor Over Current Protection	Yes	-
Adaptive Non-ZVS Protection	Yes	-
Dimming	IRS2530D	IRS2158D
Minimum Dimming Level	10%	< 10%
Package	IRS2530D	IRS2158D
DIP & SOIC	8 pin	16 pin

Table 1: Specifications of IRS2530D and IRS2158D

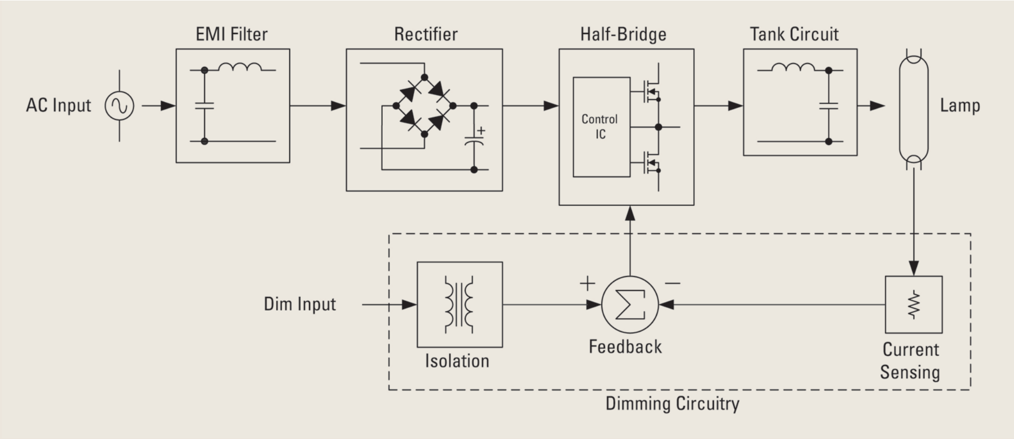
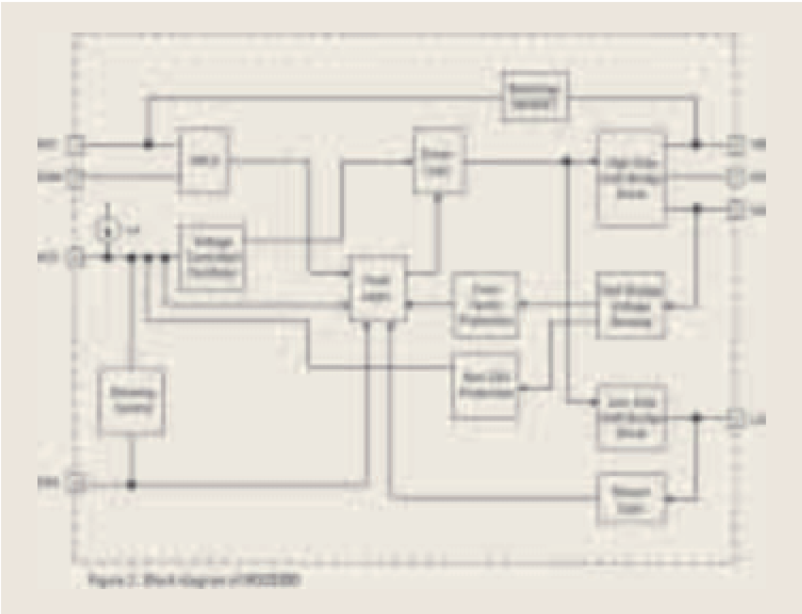


Figure 2: Adding dimmable circuitry to a mini-ballast

Figure 3: Block diagram of IRS2530D



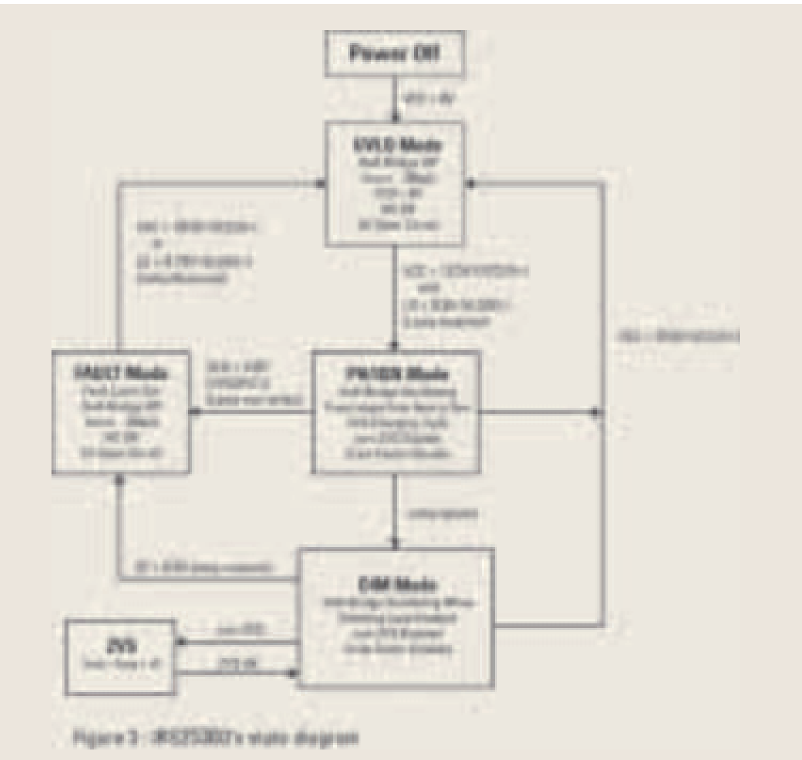


Figure 4: State diagram for IRS2530D

IC solutions. And the latest development in this arena is a single highly-integrated device that enables mini-ballasts to incorporate dimming functionality without increasing the overall form factor. The IRS2530D DIM8 dimming ballast control IC brings together the company's patented High Voltage IC process (HVIC) and a proprietary approach to dimming, allowing the entire ballast and dimming circuitry to reside within a single 8pin SO8 package.

A block diagram of the new device is shown in Figure 3. Conventional ballast operation already requires six of the available eight pins; four are needed for the high- and low-side gate driver alone (VB, HO, VS, LO). Adding the dimming functionality required some innovation, which IR achieved by combining the DC reference with the AC lamp current, to provide both reference and feedback functions for closed-loop dimming, through a single pin. The result is that, using the new IC, it is now possible to create dimmable mini-ballast that requires less than 50 components.

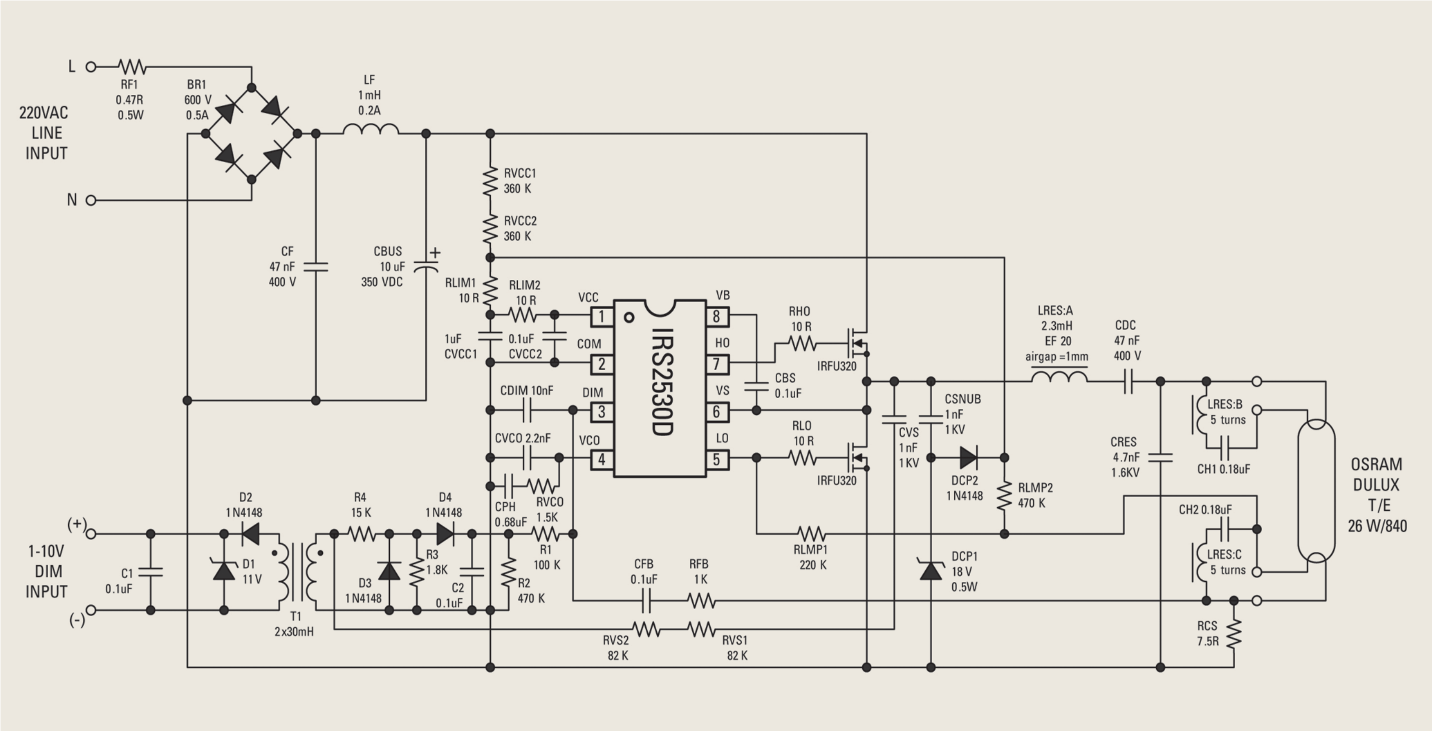


Figure 5: Typical application schematic

Operation and design

The state diagram in Figure 4 shows that when V_{CC} is first applied the IC moves from UVLO mode to the Preheat/Ignition mode. The internal current source at the VCO pin begins charging an external capacitor, as the integrated half-bridge oscillator starts at its maximum frequency. The lamp filaments are preheated by secondary windings from a resonant tank inductor as the frequency decreases towards the resonance frequency of the tank circuit, and the output voltage across the lamp increases. The lamp ignites as the voltage passes the ignition threshold voltage, and as the lamp current begins to flow the IC enters DIM mode.

When implementing a design based on the new IC it is important to observe relevant precautions in the development the PCB layout. For instance, in order to maintain the best performance good noise immunity must be achieved; failure can occur in an otherwise correctly connected circuit if poor component layout is applied. Best practice techniques include maintaining the proper creepage and clearance distances between high and low voltage components; keeping decoupling capacitors close to their respective supplies; placing critical components as close to their IC pins as possible to achieve good noise filtering, and keeping the dimming feedback components as far away as possible from the high voltage switching components.

Other recommendations include using a double filter at the supply to isolate high current spikes that could be generated by the charge pump. The use of gate resistors is also recommended, to avoid Miller currents flowing back in to the gate drive outputs. It is also important to ensure the recommendations for connecting the COM node are observed.

Typical application

A typical schematic is shown in Figure 5. The AC input voltage is full-wave rectified and passes through an EMI filter, before being smoothed by the DC bus capacitor. Thanks to IR's HVIC process, the IRS2530D is able to control the preheat, ignition and lamp dimming voltage by directly driving the half-bridge formed by MHS and MLS.

As the schematic also shows, the resistors RVCC1 and RVCC2 provide the IC's start-up current, which is replaced by the charge pump formed by CSNUB, DCP1 and DCP2, once the half-bridge starts oscillating. The supply filter, as outlined in the recommendations above, is provided by CVCC1, CVCC2, RLIM1 and RLIM2. The high voltages needed for lamp ignition are achieved through the resonant tank circuit (LRES and CRES), which also provide the low pass filtering necessary for lamp dimming. The DC blocking capacitor, CDC, protects the lamp against mercury migration, a cause of lamp end blackening and a shortened lamp life.

The galvanically isolated 10VDC reference voltage applied to the DIM input is provided by T1 and its associated components, which is biased on its secondary side through CVS, RVS1 and RVS2, in order that its input and output track each other. The AC lamp current measurement across the current sensing resistor, RCS, is coupled to the DIM pin through the feedback circuit CFB and RFB. Further components are present to provide protection against strike failure, power outage or filament faults.

Additional design support

Through its HVIC process and some innovative design, a single-chip solution has been developed that will speed the development of low power dimmable mini-ballasts. In order to further simplify the design process for applications based on the IRS2530D, a Ballast Design Assistant software application has also been developed. Freely downloadable from the IR website, this allows engineers to quickly target applications with different line input voltage ranges, lamp types and lamp configurations. The software package then generates the necessary ballast output data, IC programmable component values and inductor specifications along with schematics and a complete bill of materials.

The IRPLDIM4E, IRPLDIM5E, IRPLCFL8U reference designs, featuring the IRS2530D, are also available, in addition to the IRPLDIM3 reference design which features the IRS2158D.

Digital Power Control Benefits Fluorescent Lighting Applications

Lighting is responsible for around 20% of the world's energy consumption and there are number of initiatives being implemented to reduce this demand. Around the globe legislation is being enforced to outlaw inefficient lamp types, whilst the development of norms and standards is helping to improve the performance of others. Enabling this trend are the introduction of better lamp technologies and the development of enhanced lamp control electronics that convert power more efficiently and control it more effectively. David Compton, Michael Herfurth, Infineon Technologies, Munich/Neubiberg, Germany

The ICB2FL01G is a fluorescent lamp (FL) ballast controller designed for T5/T8 Linear and Compact FL Ballasts (Figure 1). It comes in a standard lead-free DSO package with 19 pins. The device integrates the functions of lamp inverter and power factor correction (PFC) circuits. Digital/ mixed-signal power control was chosen as it offers a number of advantages in this application. Operating time constants and the handling of abnormal operation modes can be programmed using only resistors. This has the dual benefit of simplifying some elements of ballast design whilst increasing design flexibility. The elimination of capacitors for programming functions has been found to improve ballast stability and to offer a useful reduction in system cost.

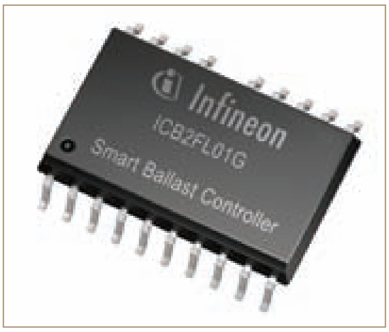


Figure 1: Controller for T5/T8 Linear and Compact FL ballasts in standard lead-free DSO package with 19 pins

Circuit start-up

During pre-start, lamp fault and under-voltage lockout (UVLO) conditions, the supply current is held below 200µA. Control currents flowing in the high-side and low-side lamp filaments allow the presence of up to four lamps to be detected by the two lamp voltage sense (LVS) input pins (Figure 2).

Having ensured that the PFC bus voltage is above start-up threshold (12.5% of nominal), The Inverter and PFC stages are started. PFC start-up is delayed slightly to allow the V_{CC} charge pump supply to stabilise. A detected bus voltage lower than 12.5% and higher than 105% of nominal value inhibits Gate drive to all MOSFETs.

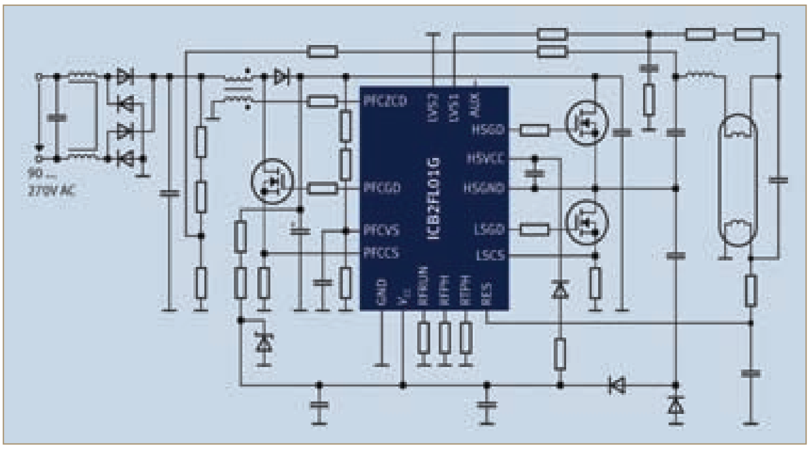


Figure 2: Typical application schematic of ICB2FL01G ballast controller for up to four lamps to be detected by the two lamp voltage sense (LVS) input pins

Half-bridge inverter

The inverter operates with a start-up frequency of 135kHz which is maintained until the PFC bus voltage has reached 95% of its nominal value. This measure provides improved start-up behaviour, especially in universal input voltage designs. Inverter frequency is then decreased to the pre-heating frequency over 10ms to provide soft-start. Pre-heating frequency, run frequency and pre-heating time can all

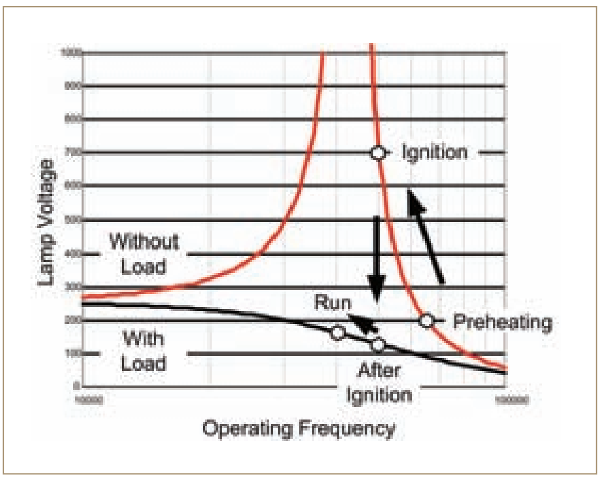


Figure 3: Ignition of fluorescent lamp by frequency shift towards resonant frequency

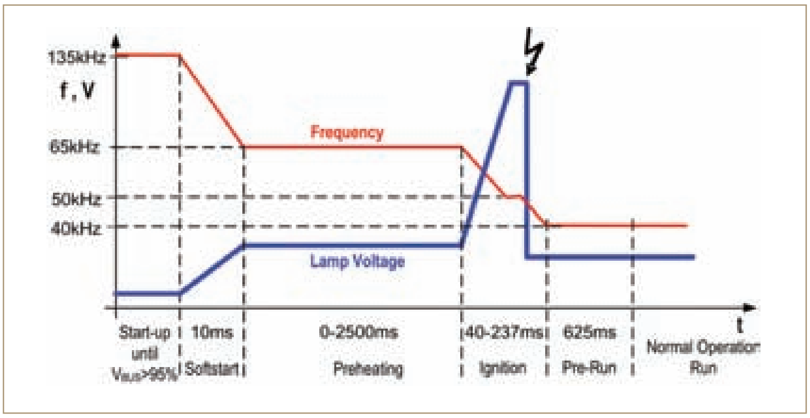


Figure 4: **Operating modes and typical frequency variation during start-up**

be programmed using only resistors.

Following pre-heating time, the inverter frequency is further reduced to the resonant frequency of the series resonant circuit (Figure 3). Because the FL is connected in parallel with the resonance capacitor, their voltages increase in unison. As soon as the ignition voltage of the lamp is achieved, the lamp voltage breaks down and the controller transitions to pre-run mode for 600ms. During this time the range of monitoring functions is reduced. After this period run-mode is adopted and all monitoring functions are enabled. (Figure 4).

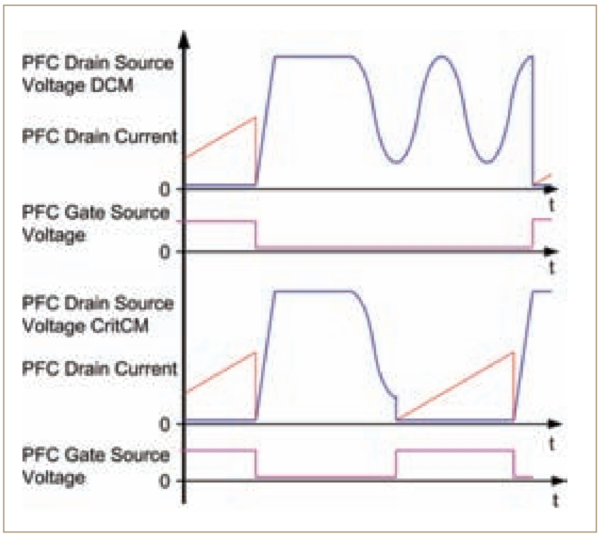
The current in the low-side MOSFET of the inverter is measured via the shunt resistor at pin LSCS. As soon as the programmed level is reached, the ignition control becomes active and maintains the current at this peak level. This measure ensures that the ignition voltage is held within pre-set limits should the lamp fail to ignite. In this case, the frequency shift is stopped either until the lamp ignites or the maximum ignition time is exceeded, whereupon the IC adopts the fault protection mode.

Monitoring features

Over-current protection of the inverter is active during all operating modes. During run mode all monitoring features are enabled: lamp overvoltage leads to a shut down when the condition lasts longer than 620µs; capacitive mode operation is sensed via the shape of the current at the shunt resistor and is handled in the same way; rectifier effect of the lamp is detected via a DC level at the two LVS pins and halts operation when the effect lasts longer than 2500ms. The timing is controlled by a multiple counters in order to ensure effective capture of the failure events.

A state machine manages controller operation including the detection and handling of failure modes and lamp removal. The state machine features an in-circuit test mode which accelerates start-up and fault detection sequences. This feature can be used during ballast production to reduce test times. Pre-heating can be skipped after a breakdown of the line voltage shorter than 500ms, which enables com-pliancy with emergency lighting requirements according to VDE 0108.

Figure 5: **Change of operating mode from CritCM to DCM during light load**



DCM PFC preconverter

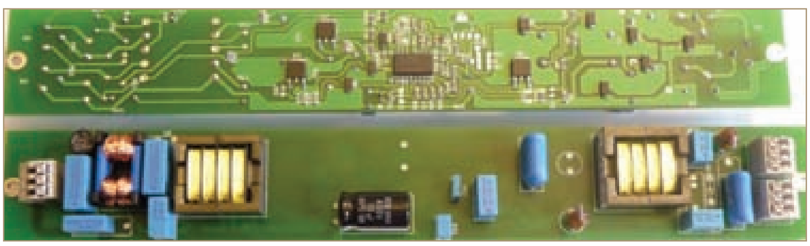
The PFC stage starts in fixed operating frequency mode with increasing on-time and switches to critical conduction mode (CritCM) operation as soon a preset threshold is exceeded at pin PFCZCD. During CritCM operation, the end of the demagnetisation phase of the boost inductor is sensed via the detector winding. The current limiting resistor connecting the detector winding to pin PFCZCD is also used to tune the increase of on-time at low input voltage levels. This measure improves the THD of the AC input current.

The PFC section features an integrated digital control loop which removes the need for external components for loop compensation and synchronisation to the AC input voltage. The digital control allows fast dynamic response and high rejection of superimposed ripple on the bus voltage. During light load conditions the PFC control changes the operating mode from CritCM to discontinuous conduction mode (DCM), which allows stable operation down to zero load (Figure 5).

Conclusion

Lighting offers tremendous scope for electronics to help reduce wasted energy; electronic fluorescent ballasts, for example, use up to 25% less energy than their magnetic counterparts. High performance analogue blocks can ensure efficient conversion of power whilst the judicious application of digital control can ensure its effective use. The described ICB2FL01G lamp ballast controller is supported by comprehensive application documentation including a fully featured demo board (Figure 6).

Figure 6: **Bottom and top side of fully featured demo board for ICB2FL01G lamp ballast controller**



Enhanced Performance with Digital DC/DC Converters

Newly designed DC/DC converters can provide measurable benefits to the user in terms of the design, manufacturing and utilisation phases of the product lifecycle. The internal design of these 3E DC/DC converters uses digital power control techniques, and some of the optional user implementations of these products can benefit from utilisation of system level digital power and energy management approaches. The digital power management concept can be a powerful tool. While saving a few milliwatts in one small subassembly may not seem terribly important, the cumulative power savings in a system of even moderate size can quickly add up. **Patrick Le Fèvre, Ericsson Power Modules, Stockholm, Sweden**

Conventional analog DC/DC converters use a Pulse Width Modulation (PWM) control chip in conjunction with a multitude of external resistors, capacitors, inductors and active discrete semiconductor devices to achieve the feedback and control functions needed by the board mounted power supply (BMPS). The required time constants are formed with linear analog component networks. Ericsson Power Modules uses the term 'digital power control' to describe a power converter or regulator design in which much of the analog control functionality is replaced with digital circuitry (Figure 1).

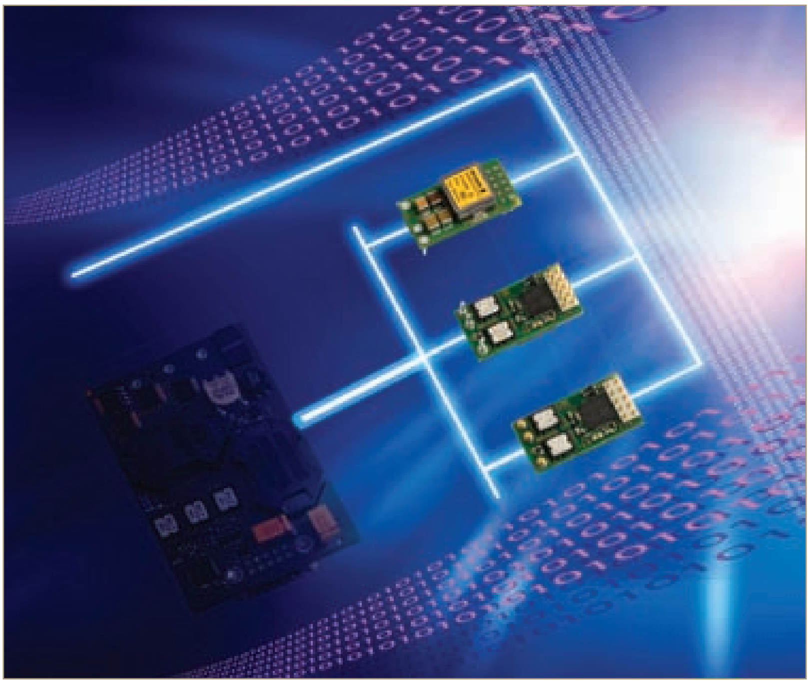


Figure 1: **In an Intermediate Bus Architecture (IBA) a board-level Intermediate Bus Converter (IBC) feeds multiple POL regulators, which are located in proximity to the load circuitry and supply the final operating voltages**

Digital versus analog

Typically, the digital content will include the feedback loops, MOSFET gate drive generation, stability control, and fault detection. The MOSFET switches and the main output LC filter are often quite similar to those in an analog DC/DC converter. The main point to be made here is that digital power control can be transparent to the end-user of the BMPS. Two devices, one implemented digitally and one with analog circuitry, can be plug-compatible, and may even be indistinguishable as far as the end-user is concerned. However, using digital techniques internal to a DC/DC converter can offer significant density and performance advantages, as well as drastically increase the DC/DC converter's flexibility and configurability.

While digital power control only applies to circuitry contained within a power supply and is designed and controlled by the BMPS manufacturer, digital power management and energy management extends beyond the physical boundaries of a DC/DC converter or POL regulator and into the end-use system. This extension significantly increases the capabilities of the end-use system, but will also require the power system designer to participate in the implementation of the digital communications structure. The term 'digital power management' is used by Ericsson Power Modules to describe a system in which DC/DC converters and/or POL regulators communicate digitally with each other and/or other elements in the system for the purposes of monitoring and controlling the behaviour of the power supplies. This digital communication is typically used for the functions of power monitoring, fault handling, power sequencing, and efficiency optimisation, and is facilitated by a digital interface referred to as the power management bus (PMBus).

While digital power control must operate on a cycle-by-cycle basis at the power supply's operating frequency to control the energy flow, digital power management usually operates on a slower time scale to react to changes within the system.

The efficiency of DC/DC converters and POL regulators has always been a key performance criterion. It is receiving even more attention as more emphasis is placed on energy consumption and the environmental impacts of large scale data processing and telecom installations. A fortuitous synergy results when digital power control and digital power management are combined. Digital power control allows for 'on-the-fly' reconfiguration of operating

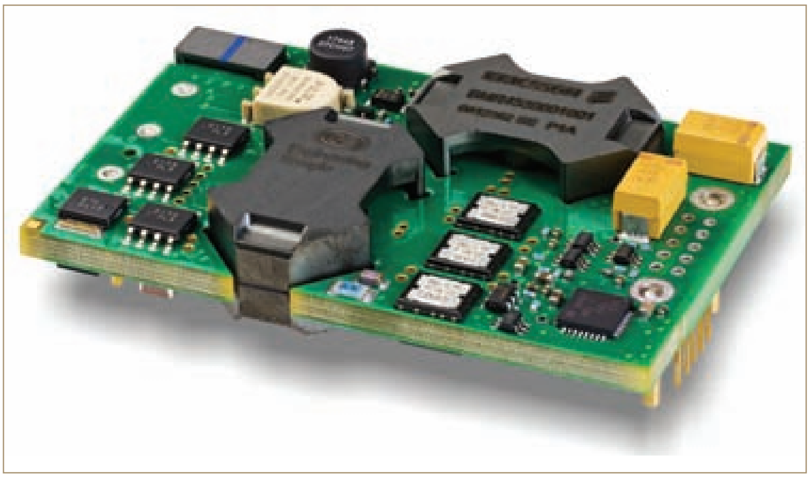


Figure 2: **The first 3E DC/DC converter product is the BMR453 series, an isolated DC/DC converter capable of 33A or 400W of output power in a quarter brick form factor, which combines the tight output tolerance of the traditional DC/DC converter and the high power density and efficiency of the IBC, along with the benefits of digital power control and power management**

parameters within a power supply as a function of system operating conditions.

If a digitally controlled DC/DC converter is operated in a system with digital power management, the system status can be used to dynamically program the operating conditions of the power supply. For example, the power transistor dead-time could be varied as a function of the DC/DC converter's input and output voltage and output current to optimise the real-time efficiency over a broad variety of operating conditions.

Similarly, the intermediate bus voltage provided by an IBC can be dynamically varied to optimise the overall efficiency of the combination of IBC and POL losses as a function of the current system operating condition. Ericsson Power Modules refers to this combined usage of digital power management and digital power control as 'digital energy management'. Impressive savings in total energy consumption can be achieved in this way. In effect, digital energy management replaces compromise with optimisation.

3E DC/DC product overview

The first 3E DC/DC converter product is the BMR453 series, an isolated DC/DC converter capable of 400W or 33A of output in a quarter brick form factor (see Figure 2). These converters are designed to complement the 3E POL regulators, and provide outstanding levels of efficiency, power density, flexibility and performance. Unlike other quarter brick DC/DC converters, the BMR453 achieves this power density while providing tight 2% output voltage regulation over an input voltage range of 36 to 75V at efficiency levels in excess of 96%. The output voltage is variable from 8.5 to 13.5V.

The importance of the BMR453 introduction can best be understood by taking a broader view of the DC/DC converter and IBC market. In recent years, this market has been somewhat segmented. Traditional DC/DC converters were considered 'high performance' products with tight output voltage regulation. The trade-off for this more precise regulation was lower power density and lower efficiency when compared with IBCs. The IBC eliminated the output voltage regulation function in order to achieve better power density, efficiency and cost than was available with DC/DC converter products. The BMR453 combines the best attributes of the traditional DC/DC converter and the IBC, along with the benefits of digital power control and digital power/energy management.

3E DC/DC benefits

The BMR453 converters are available both with and without a baseplate. A communications pin header is used for connection to the PMBus. For users who elect to not use the PMBus interface, an optional version of the converter is available without the communications pin header. While eliminating the opportunity for system level digital power management, this option will still provide the benefits of digital power control internal to the DC/DC converter.

For the normal DC/DC converter power input and output pins carrying large amount of current, thick low resistance pins are used. For other interfaces, such as remote sensing and clock/data lines that conduct minimal current, an industry standard connector header is selected. This selection, in addition to reducing the PCB area needed for interconnection, results in cost savings to the end user. The low current connector header is widely used in the industry with high production volumes and low cost. This selection also eliminates the technical risk of developing a new pin design.

Figure 3 shows the typical efficiency characteristics of the BMR453 as a function of input voltage and output current. Note that the curve is relatively flat over a wide range of output current and extends above 96% for output currents from 10 to 25A with the most common 48V input voltage. This is outstanding efficiency performance. Even though it is a fully regulated DC/DC converter, the efficiency is higher than that of most IBCs without load regulation. BMR453 DC/DC converters can be directly connected without external components in an automatic current sharing configuration, even in systems that do not utilise the PMBus for digital power management purposes. The current sharing is balanced within a maximum of 10% between the

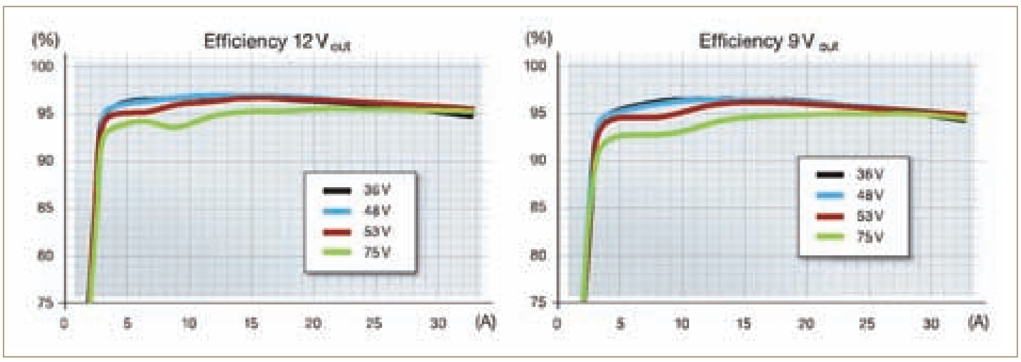


Figure 3: **Typical efficiency characteristics of the BMR453 as a function of input voltage and output current for both 12 and 9V output**

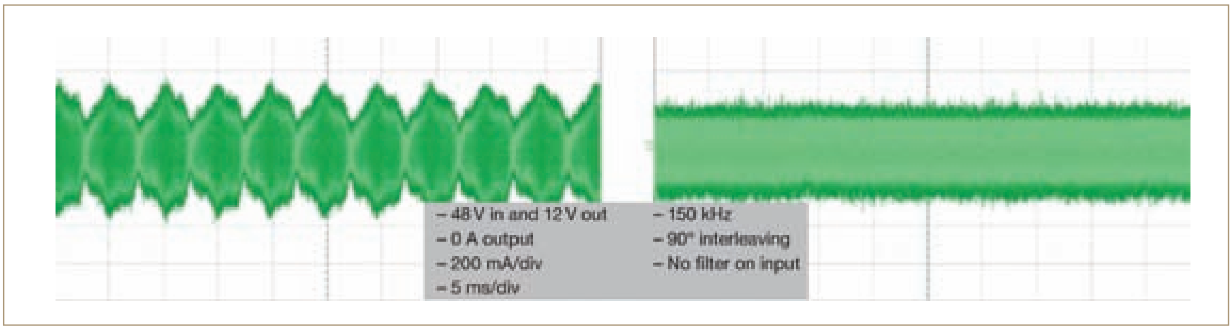


Figure 4: **The synchronisation feature of the BMR453 may be used to attenuate input ripple current, thus facilitating EMI filter design**

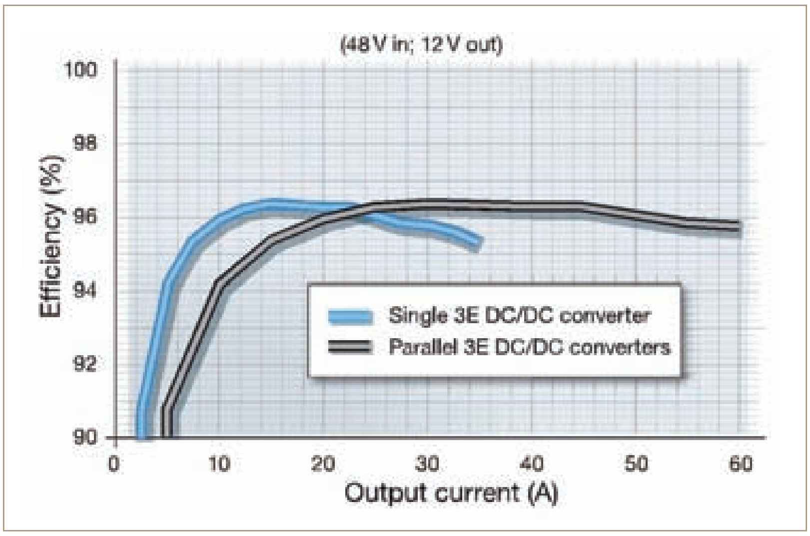


Figure 5: **Active utilisation of parallel versus single DC/DC converter operation is a powerful tool that reduces energy consumption by optimisation of the efficiency over the full load range**

converters resulting in a maximum output power of up to 720W for two units. Two paralleled units will have a typical efficiency of over 96% over an output load range of 25 to 55A. The ability to share current under dynamic load conditions is also important. These converters are directly connected without any ORing diodes and communicate inbetween each other to actively balance the load without further need for external control supervision.

Almost all DC/DC converters are deployed in a system environment that requires an EMI filter between them and the input power source so that the appropriate regulatory requirements can be met. One of the design objectives of the BMR453 was to minimise the input ripple current so that the size and complexity of the EMI filter could be minimized.

This was achieved by automatically synchronising the operation of paralleled DC/DC converters. The synchronisation is done in a 'master-slave' implementation. The slave converter assumes the same operating frequency as the master, but with a 90° phase shift between them. This phase shift is critical for minimising the input ripple current of the combined converters with the interleaved full-bridge topology. The effect of this approach is shown in Figure 4. The maximum ripple current (and most stringent EMI criteria) for this topology actually occurs at light load, so the testing was done with no load on the output.

Optimisation using energy management

Using the PMBus together with a host controller in the ATE during the manufacturing process provides fast and reliable setting of power sequencing routines. This represents a vast improvement in complexity relative to traditional systems that used analog-based power controllers for this purpose.

The BMR453 series is particularly flexible in this regard. It has a 'power good' output signal to indicate when it is in its regulation band and operating normally, which is useful for event-based power sequencing. The voltage tracking feature can be used to create custom user-defined output voltage ramp-up profiles based on a control voltage ramp. It is also easy to implement voltage margin testing during manufacturing to verify system operation over the extremes of the design space. Fault detection and handling can be easily optimised. The host controller can be programmed to set customised limits on each of the fault sensors (temperature, voltage and current), not only for absolute limits, but also for 'warning' conditions.

The wide output voltage adjustment range of the converter can be used to optimise overall efficiency and energy consumption in a system by means of digital power management via the PMBus. Conventional analog DC/DC converters and POL regulators are designed for maximum efficiency under the most commonly expected system operating conditions. But each system application is unique, and any individual system will experience different operating conditions as a function of installed features and operating mode. Consequently, the output current of each BMPS will vary with time, as will its efficiency. The converter's output voltage can be dynamically programmed via the PMBus to optimise either its own efficiency or that of the entire power system. POL regulators, especially at light loads, are generally most efficient at lower values of input voltage (DC/DC converter output voltage). The total system would then be optimised by using a low value of BMR453 output voltage – perhaps in the range of 9 to 10V.

But during conditions of high output current, the system power demand may require a higher intermediate bus voltage in order to increase the power output available from the DC/DC converter. In this scenario, the converter's output voltage could be automatically increased to 12V or above by sensing the system current demand and programming the BMR453 via the PMBus. The host controller, knowing the efficiency curves of the POL regulators and the DC/DC converter, can select the optimal intermediate bus voltage to maximise the total system efficiency. This technique can be very useful for system energy management and can have significant impact on the cumulative energy usage and power utility costs.

Figure 5 shows the combined efficiency of two paralleled DC/DC converters, as well as the efficiency curve of a single unit. As noted earlier, the efficiency curve of the paralleled units is exceptionally broad, exceeding 96% from 25 to 55A. Output current values of less than 25A means the single DC/DC converter will be more efficient than a paralleled pair. For systems in which there is a very wide range of current demand combined with a high priority on operating efficiency, digital power management can be used for efficiency optimisation.

The host power controller can automatically switch the DC/DC converter function from a current shared paralleled connection to a single converter when the system current requirements are low. This communication would be done via the PMBus. The negotiated switching point would need to contain a fair amount of 'overlap' or hysteresis, so that a single converter would not be operated near its maximum current rating to avoid over-current conditions. With this type of automated converter changeover capability, the composite efficiency curve of the BMR453 is truly impressive, with 96% efficiency achieved from10 to 55A. The efficiency is above 90% even at loads down to 2.5A. This approach results in significant savings in power losses, since at light system loads the switching losses of a single converter will be about half those of two paralleled converters.

Practical implementation will require seamless switchover without disruption of the system intermediate bus voltage load or generation of any fault conditions.

A more demanding condition occurs when switching from one converter to a paralleled connection. Synchronous rectification is used in the converters to maximise efficiency with the output rectification via MOSFETs, which can conduct current in either direction. This can create difficulties when starting up into a pre-biased load, which is exactly the scenario presented with the start-up of the second converter in the paralleled configuration. Without proper management of the start-up, the converter could be over-stressed by a reversecurrent and there could be a significant dip in the output voltage. ORing diodes could be used as a solution, but were rejected due to their negative impact on efficiency and packaging density. Instead, the ORing function is implemented with intelligent control of the output transistors. This approach would normally require the addition of a specialised controller IC, but with the digital control the start-up is handled by the existing self-contained microcontroller without the need for any additional components.

Another possible extension of this capability, which could be useful in some high availability systems, would be to automatically disable a failed paralleled converter to permit the system to continue operation at a reduced power level in 'limp along' fashion until a repair action could be accomplished.

Conclusion

The PMBus offers increased functionality, flexibility and opportunity for system optimisation by using it as an interface during system development, manufacturing testing or in the field environment. One of Ericsson Power Modules' goals is to make the transition from analog to digital power management systems as convenient as possible for the end-user, by supporting the new products with a wide variety of applications assistance. An evaluation kit consisting of a demonstration board with provision for hosting two BMR453 3E DC/DC converters, up to six 3E POL regulators, USB cable, CMM software on CD, device drivers, sample configuration files and complete documentation can be used as a development platform. This evaluation kit is highly recommended as a first step for users who may be considering exploring usage of the 3E products or designing a power system configured with a PMBus.

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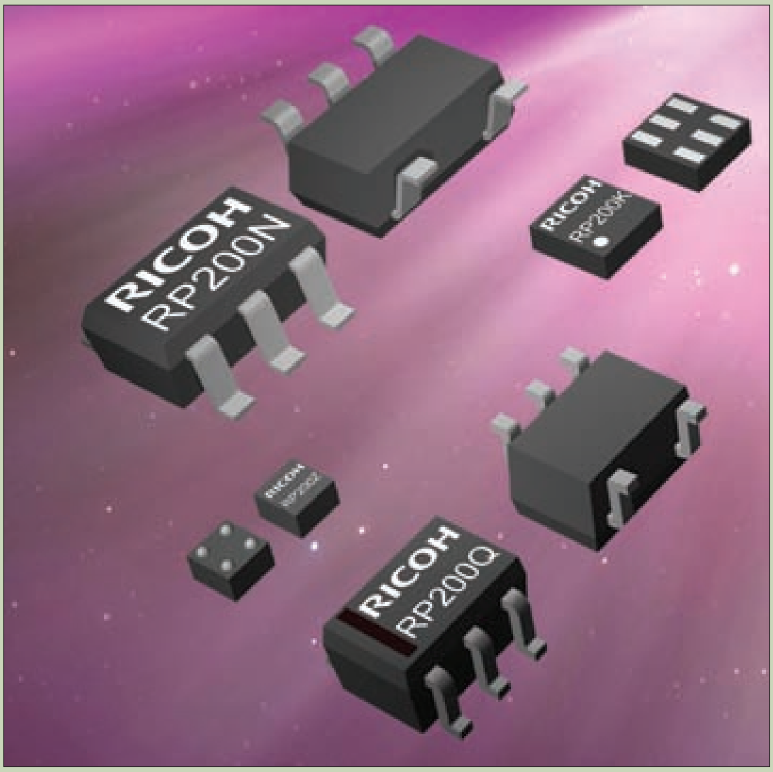
LDO with Three Operating Modes



Ricoh's new 300mA LDO RP200 with three operating modes is designed for applications which require the specifications of the LDO to adapt to their different modes of operation. It has a new additional Automatic Eco mode control pin to select manually between either a continuous Fast Transient mode (when required), or an Automatic Mode Shift operation.

The Automatic Mode Shift feature allows the LDO to switch automatically between Fast Transient and Low Current Consumption mode, depending on the current demand of the application. In particular, the LDO supply current in low current consumption mode (compared with previous products) improved significantly (5.5 to 1µA), as well as the output voltage accuracy and the temperature drift coefficient.

As for protection, an embedded fold-back current limit circuit decreases the output current in case of a short-circuit to approximately 50mA, thus protecting the LDO and other electronic parts of the application from damage. An optional feature is the auto-discharge function, which discharges the output capacitor fast once the LDO is disabled, avoiding odd behaviour of the application during the power-down sequence.

For stable operation, small ceramic capacitors with low ESR and a minimum value of 1.0µF can be used. RP200 is available in a regular SOT23-5 and SC-88A packages.

www.ricoh.com/LSI/

High Current PWM ICs

Cirrus Logic has introduced the Apex Precision Power SA306-IHZ and SA57-IHZ, high current PWM ICs targeted at fractional horsepower DC motor drive applications in the 9V to 60V supply range.

The SA306-IHZ and SA57-IHZ feature of up to 5A of continuous output current (8A with A Grade versions), and PEAK output of 17A and is housed in a 64pin Power Quad package with a footprint measuring less than 2cm². Inside the package, the SA306-IHZ and SA57-IHZ deliver cycle-by-cycle current limit, which provides the unique ability to precisely control motor current in real time for each motor phase.

With this ability the SA306-IHZ and SA57-IHZ allow the power system structure to 'partner' with the processor or DSP to control current in real time for each motor phase, rather than just settle for limiting the overall current to a safe value.

These devices implement current mirrors in each leg of the driver to continuously monitor and regulate motor current in all phases, and compare these levels to a pre-determined 'safe' limit. Should current exceed the limit, the drivers will shut down all outputs for the remainder of the switching cycle and re-set the outputs with the start of the next cycle. An extended benefit of cycle-by-cycle current limit is the ability to soft start the motor by allowing the driver to handle the inrush of start-up current.

In terms of digital interface, the SA306-IHZ and the SA57-IHZ are designed to provide customers with a seamless interface to either a digital microcontroller (MCU) or a DSP. The top side and bottom side output FETs on these PWM drivers can be individually controlled via direct signals from the processor. This communication includes current sensing for each phase.

www.cirrus.com

DC/DC µModule Regulator

ACAL Technology offers the LTM8021, a complete DC/DC regulator for point-of-load (POL) applications from Linear Technology with on-board inductor and power components in a package that resembles a surface-mount IC.

The LTM8021 operates from input supplies from 3 to 36V (40V maximum) and delivers up to 500mA. The LTM8021's tiny footprint (6.25mm x 11.25mm), low profile (2.8mm) and light weight (0.49g), enable system designers to solder the device on the backside of the circuit board. It includes a DC/DC controller IC, power switch, inductor, compensation circuitry and input and output bypass capacitors. Its design is as simple as a linear regulator and has the advantage of less heat dissipation and smaller size.

Target applications are systems with 5V, 12, 24 and 28V input supply rails such as medical, industrial, avionics and after-market automotive.

www.acaltechnology.com

1000W AC/DC Power Bricks

TDK-Lambda adds more functionality to its PFE range of AC-DC MEGA-brick power supplies with the introduction of the 1000W PFE-F Series.

Like the existing lower power PFE modules, PFE1000F combines the AC to HVDC front-end with DC/DC converter into a single module. In addition, the baseplate cooled design satisfy the increasing requirement for fanless high power, especially for outdoor electronics when suitably enclosed. Up to six PFE1000F units can be operated in parallel, achieving outputs of up to 5.1kW.

For use in high reliability equipment, N+1 redundant parallel operation is possible. Space savings of 25% are possible with PFE applications compared to previous generation solutions that utilised a two stage AC/DC front end module and DC/DC backend module. Models in the fully-regulated PFE1000F series are available in 12, 28 and 48V nominal outputs and can be adjusted ±20%.

The 12V versions deliver 720W with a maximum baseplate temperature of 100°C, while the 28 and 48V models provide 1008W.

www.emea.tdk-lambda.com

Low ESR MLCC

AVX's new MH Series provides a ceramic capacitor that combines the attributes of ceramic devices, low ESR, non-polar construction, high frequency behaviour, voltage stress capabilities and wide temperature range, with the enhanced mechanical protection of a molded case.

In addition, the MH Series provides a lead free, RoHS compliant solution for customers who have previously been unable to use large case size ceramic capacitors, or stacked ceramic capacitor solutions because of thermal, mechanical, or environmental concerns.

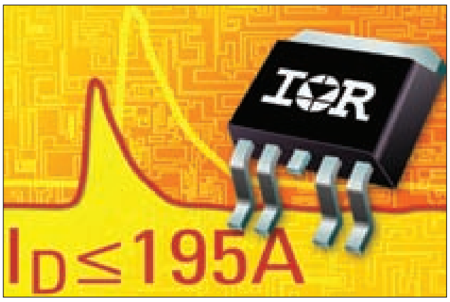
The MH Series is rated at up to 100V with a maximum capacitance of 22µF. The operating temperature is -55 to 125°C. Applications include, input /output capacitors for industrial and telecoms applications, smoothing circuits, HID, and automotive high CV applications previously impossible due to case size limitations.

www.avx.com

High Current Package Power MOSFETs

International Rectifier's new power MOSFETs provide a package current rating of up to 195A, delivering a 60% improvement over typical package current ratings. These MOSFETs also provide improved on-state resistance compared to previous offerings and are available in the TO-220, D2PAK and TO-262 packages. Moreover, the 7pin D2PAK achieves a package current rating of 240A and reduced on-resistance making it one of the most rugged surface mount packages available. The higher current rating from these packages can provide more guard band from unwanted transients and help reduce part count in parallel-type topologies where several MOSFETs share high current. The N-channel MOSFETs provide a voltage range of 60 to 200V and are qualified to industrial grade and moisture sensitivity level 1 (MSL1).

www.irf.com



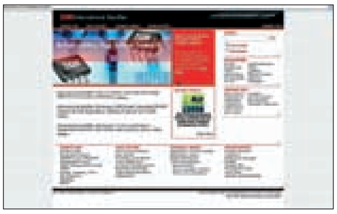
Eight-Channel Power Sequencer

Texas Instruments offers a new eight-channel sequencer and monitor with non-volatile error logging. The device supports the latest generation microprocessors, ASICs and DSPs, to improve system reliability and ease sequencing on boards with multiple points of load. The sequencer operates from a 3.3V supply and does not require external memory or a clock, to help reduce board space in a variety of equipment, including telecommunication switches, servers, industrial, networking and test equipment. The UCD9081 allows to constantly monitor the health of the power supply system and manage the increasing number of power supply rails.

The device's non-volatile error logging stores any system failure to flash memory, which allows for further diagnostics of any power supply failures. The UCD9081 independently monitors eight voltage rails with 3.5mV resolution. In addition, the flexible rail start-up and shutdown sequence and fault response options add further system and load protection. The UCD9081 also provides up to four additional general-purpose outputs for other board-level functions such as power good or reset signals. A GUI allows to configure the UCD9081 via an I²C interface.

www.ti.com/ucd9081-pr

AC/DC Connverters



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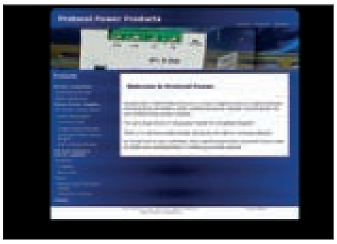

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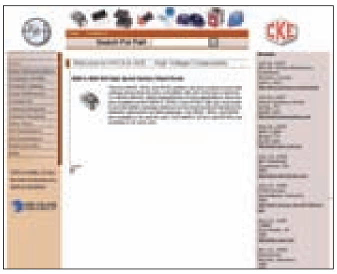

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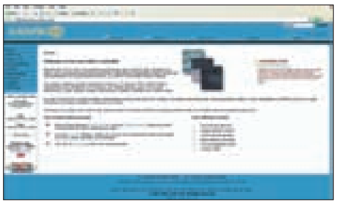

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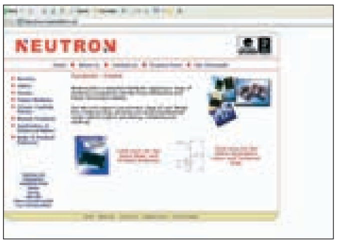

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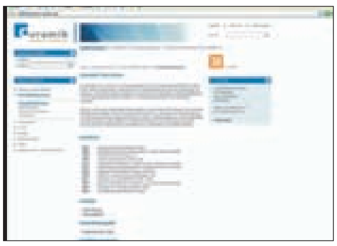

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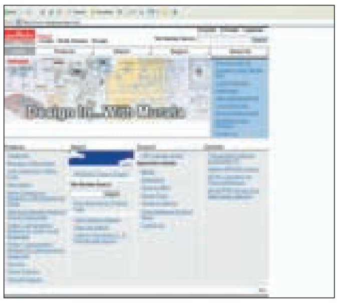

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