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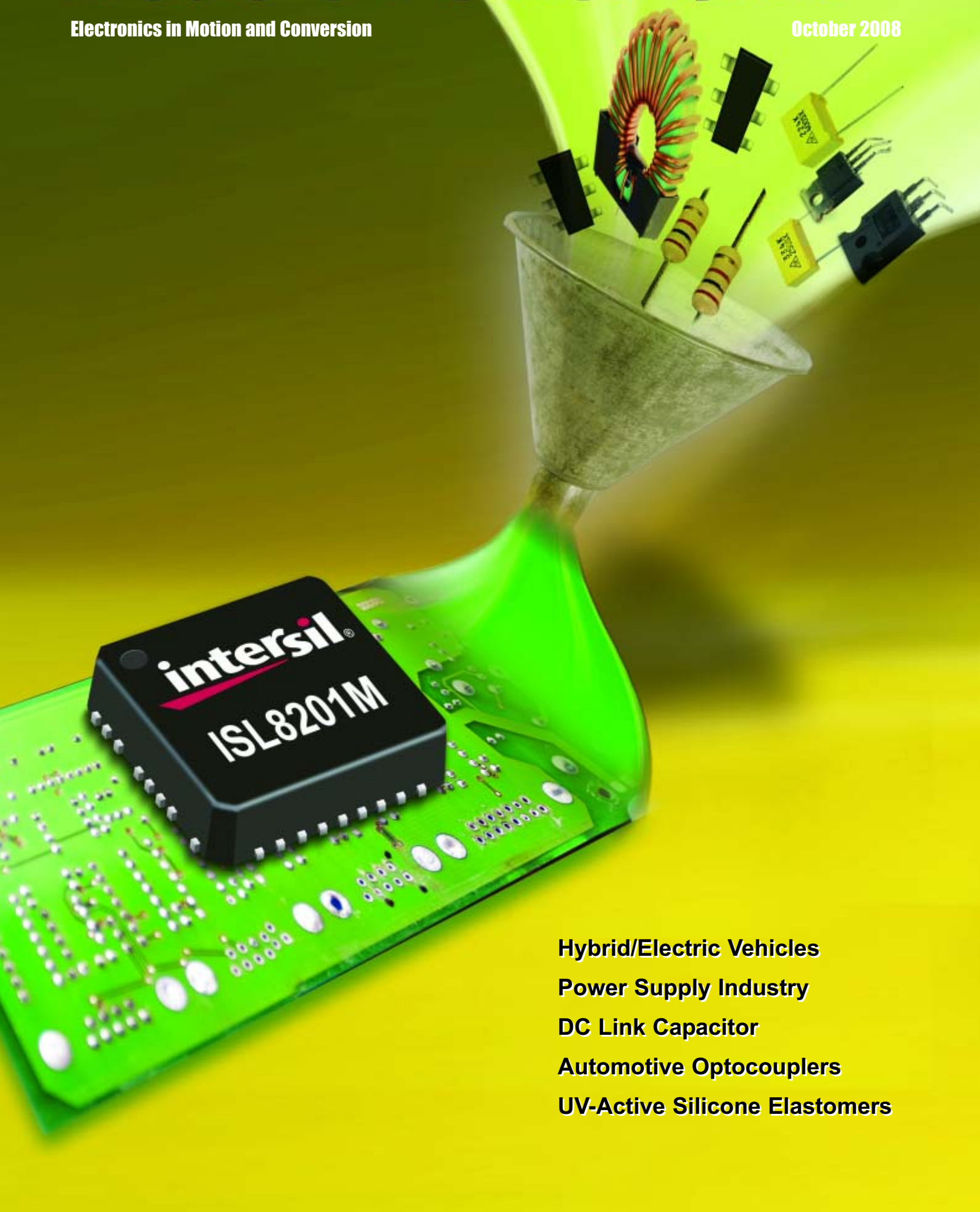
Electronics in Motion and Conversion

October 2008

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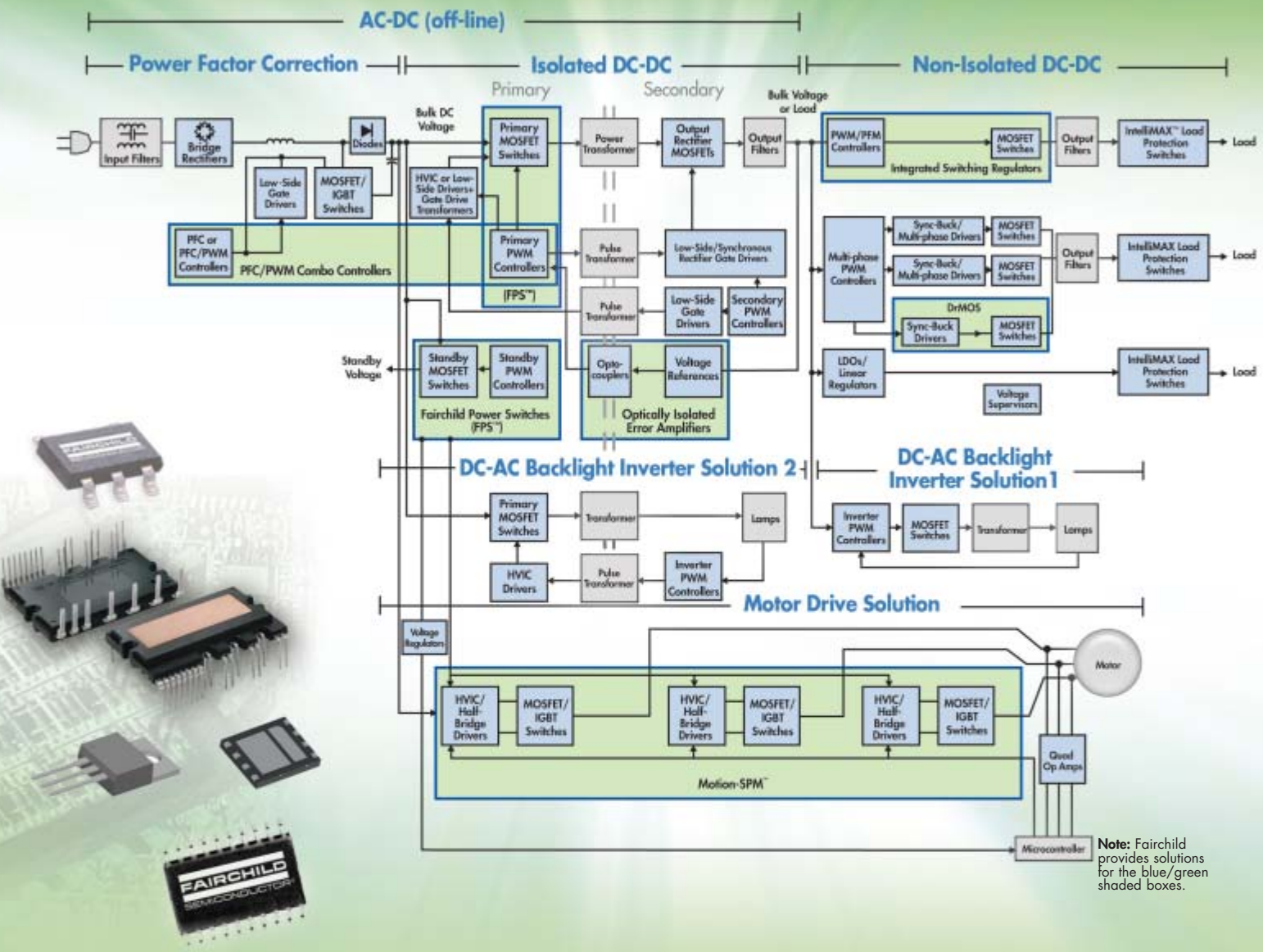




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Analog Applications Journal

DESIGN BRIEF

# Cascading of Input Serializers Boosts Channel Density for Digital Inputs

**By Frank Dehmelt**
Systems Engineer Analog Products

## Introduction

Programmable logic controllers (PLCs) play an integral role in industrial automation. They allow inputs from digital as well as analog sensors and provide outputs to drive actuators. The digital inputs represent a significant share of those I/Os, accepting inputs from end switches, proximity switches, fuel sensors, light barriers, over-temperature sensors and many others.

## The Traditional Approach

There are several types of digital inputs; the IEC-61131-2-standard defines those most commonly used. We will first discuss traditional solutions, and then look at a new approach by TI.

Traditionally, digital inputs used discrete components and required a parallel processor interface. Current limitation was achieved by a series of high-power resistors. Resistor-capacitor (RC) filters reduced bouncing of mechanical switches, while a per-channel optocoupler connected to the parallel processor interface. This design, however, requires bulky components, many isolation channels, and a large footprint host controller to allow for the parallel inputs. It also creates significant power dissipation.

With a typical resistor chain providing about 2.2 kΩ, the current at the nominal 24 V rises to 11 mA and results in power consumptions of 260 mW or 400 mW at 30 V. Considering that this dissipation may occur simultaneously for all input channels — along with the bulky components and the processor interface — it severely limits channel density.

## A New Approach

TI's SN65HVS88x product family addresses these limitations and more. The digital input serializer (as the name implies) serializes the inputs into a single SPI data stream and reduces the number of isolators by 50%.

The resistors and LEDs shown in Figure 1 are required by the IEC-61131-2-standard; they can be omitted for inputs that do not require conformance with this standard. Regardless, the integrated current limit allows use of a lower power resistor.

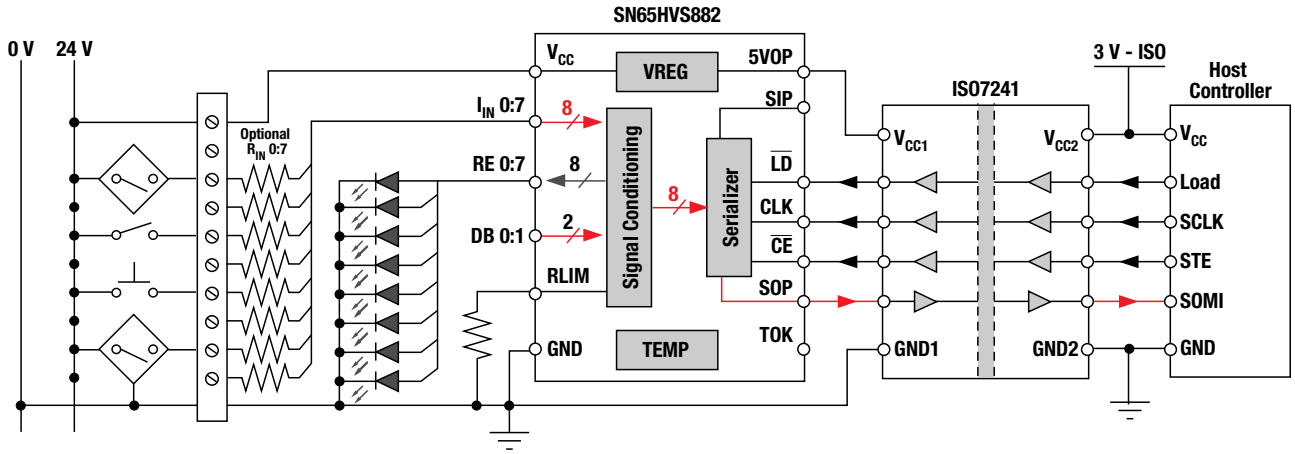


*Figure 1. 8-channel digital input using HVS882 and ISO7241*

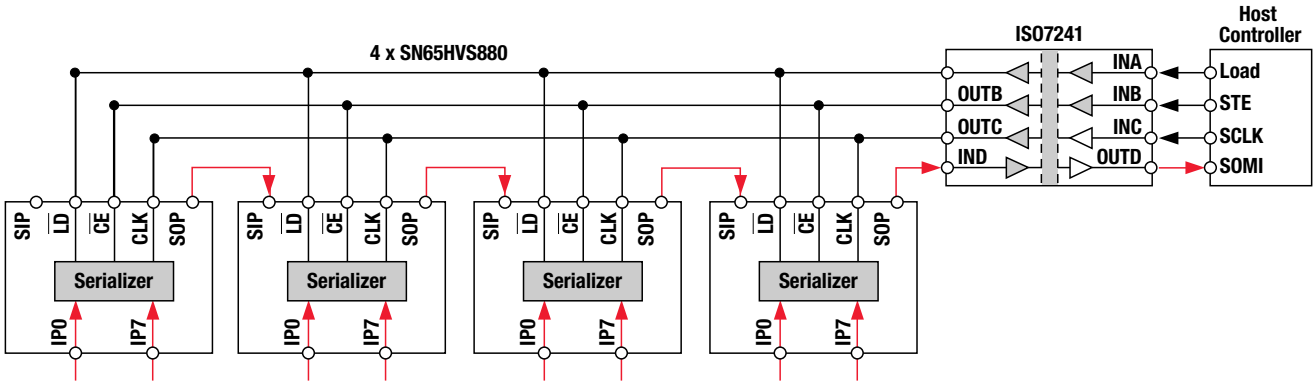


*Figure 2. Simplified 32-channel digital input with cascading, using four HVS88x serializers and one ISO7241 digital isolator*

The input current is fed to an output pin, which allows it to drive an external LED to indicate the current state of the input. Without the LED, this pin simply connects to ground.

The HVS88x family allows for the cascading of several devices, all sharing the same SPI interface, as shown in Figure 2. For a 32-channel input, it still provides a four-channel isolation, saving 87% of ISO channels.

And what about power dissipation with a 32-channel interface? We previously calculated a worst-case dissipation of 400 mW/channel totaling almost 13 W: this is too much for a PLC slice which is about the size of a deck of cards. The HVS88x family allows the designer to set current limitation anywhere between 200 µA and 5.2 mA. For a type-1 or type-3 switch, choose a limit in the 3-mA range, limiting the per-channel dissipation to 90 mW at 30 V. This reduces power dissipation by more than 75% vs. a discrete approach.

The designer can further reduce the number of external components by using the integrated debounce filter, set to filter pulses of less than 3 ms or 1 ms in duration. For the fastest acquisition of glitch-free switches, bypass the filter as well.



The parts operate from the 24-V nominal field supply and generate the internally used 5 V themselves. This supply is also available to drive external circuitry such as the field side of the isolation barrier on the SPI interface.

The HVS88x family allows high-density digital inputs by serialization, cascading, a significant reduction of power dissipation, and elimination of external components. Production material, samples, and evaluation boards are available. Table 1 presents specifications for the SN65HVS88x devices.

| Parameter | SN65HVS880 | SN65HVS882 |
|---|---|---|
| Serialization | Yes | Yes |
| Cascading | Yes | Yes |
| Current limitation | Yes (0.2 to 5.2 mA) | Yes (0.2 to 5.2 mA) |
| Debounce filter | Yes (0 ms, 1 ms, 3 ms) | Yes (0 ms, 1 ms, 3 ms) |
| $V_{CC}$ | 18 V to 30 V | 10 V to 34 V |
| Undervoltage indicator | Yes (~15 V) | No |
| 5-V output | Yes | Yes |
| Input voltage range | 0 V to 30 V | 0 V to 34 V |
| Temperature range | –40°C to 85°C | –40°C to 125°C |
| Over-temperature protection | Yes | Yes |

*Table 1. The SN65HVS88x digital input serializer family digital isolator*

## Reference


1. www.ti.com/sn65hvs882


## Related Device

www.ti.com/iso721

For more information, visit:
**www.ti.com/interface**

# The Gallery

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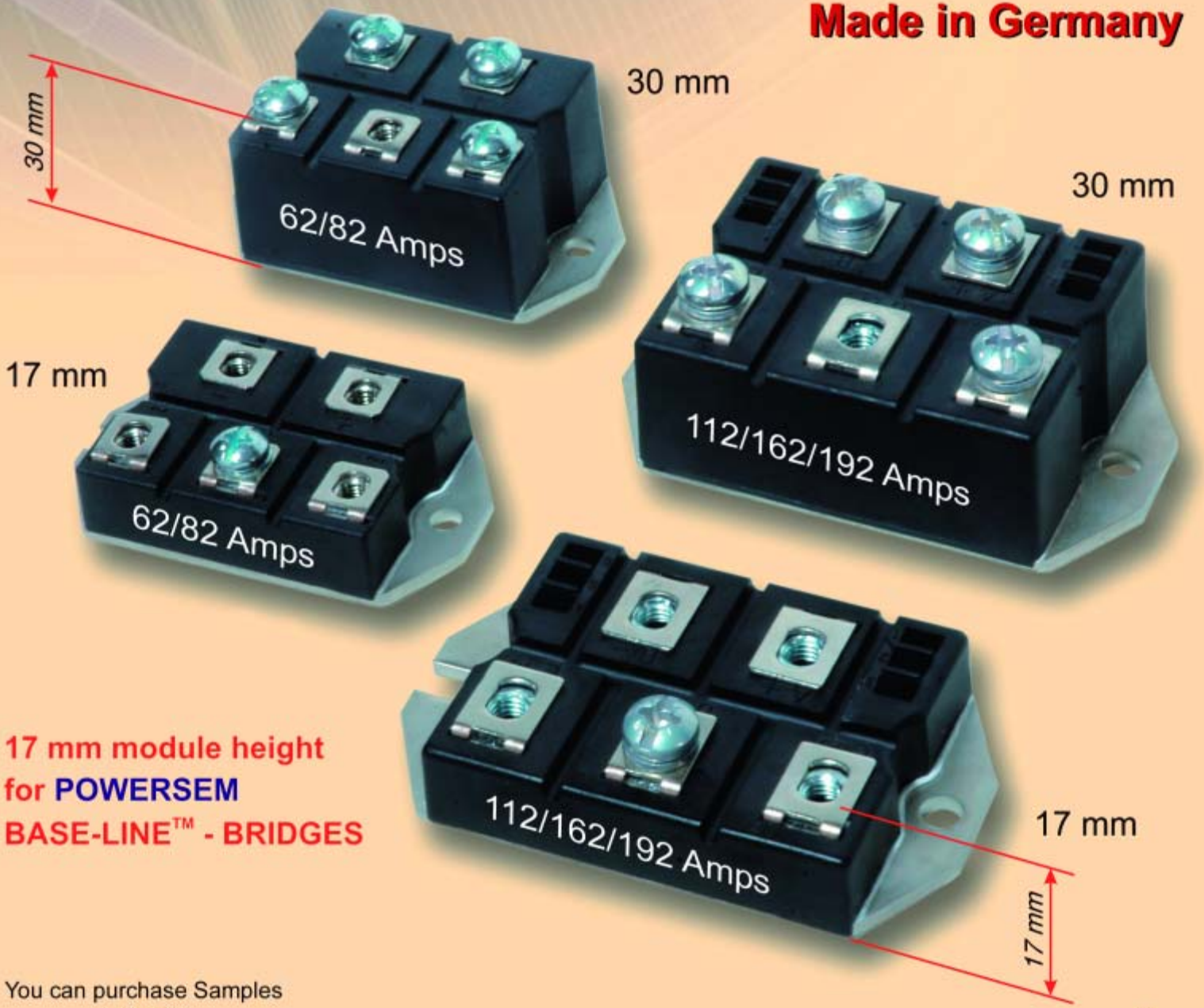


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**Events**

**SEMICON Europe**
Stuttgart Germany October 7-9
www.semiconeuropa.org

**H2expo 2008**
Hamburg, Germany October 22-23
http://h2expo.com

**electronica 2008**
Munich November 11-14
http://www.global-electronics.net

**SPS/IPC/DRIVES 2008**
Nuremberg November 25-27
http://www.mesago.de

**Power Electronics 2008**
Moscow December 2-4
http://www.powerelectronics.ru

# The World Needs Young Engineers

Progress and innovation need engineers to make them happen. As a little boy, I learned basic physics by playing. One experience as a three year old was in trying to turn on the music. Pushing banana jacks from the extra speaker into the main outlet for the line voltage had a major impact. It blew the main fuse for our whole apartment, I was scared to death and we were all left sitting in the dark.

My parents then wisely gave me my older brother's train set and the seed for a career as an electronics engineer was sown. My suggestion for having enough engineers in two decades is simple - let the kids play with electric trains.

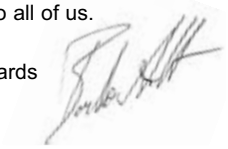
Giving away Marklin train starter-sets has become a much-loved tradition at PCIM shows in Nuremberg and starting this year I am going to raffle customised Bodo's Power Marklin starter-sets for the Christmas Tombola. I will draw the winner from all subscribers who either confirm their subscription or subscribe by using my fax form. Participants must also provide a hand-drawn or painted picture of Locomotive by a child who might aspire to become an engineer. Santa will be on the lookout for full contact details and the fax by November 28th at the latest. The drawing will take place on November 30th and the lucky winners will be notified immediately and will have their trains delivered to them before Christmas Eve.

By the way, in supporting such activities my publication does well and we continue to grow. With the October issue we will have exceeded 600 pages, outperforming any magazine in this area and by the end of 2008 we will have published over 700 pages of crucial information for engineers - a 20 percent increase over 2007. About 60 percent of the magazine consists of technical articles, always delivered on time. Our circulation is audited quarterly by the Advertiser Steering Committee. To help you plan for 2009, detailed media information and the editorial calendar can be downloaded from our website.

I am looking forward to the upcoming shows that boost innovation in electronics and hope to see you again for a chat. Semicon Europa is focused on manufacturing and there we'll also see what is being done in assembly techniques to reduce losses and optimize cooling. All that counts in the end is the right junction temperature during operation. Very soon, in November, Electronica will open its doors and the world of electronics will meet in Munich. A few weeks later, Nuremberg will host the SPS/IPC/DRIVES. These all depend on the ac power being on.

**My Green Power tip for this month:**
Nicola Tesla and George Westinghouse built a Green Power generation plant more than 100 years ago at Niagara Falls. This principle is still a good one for clean power. If we don't have a waterfall of our own, what can we do to contribute to clean power? Consider putting solar panels on your roof - we can all build a future with a clean environment. Solar has a bright future – and the sun belongs to all of us.

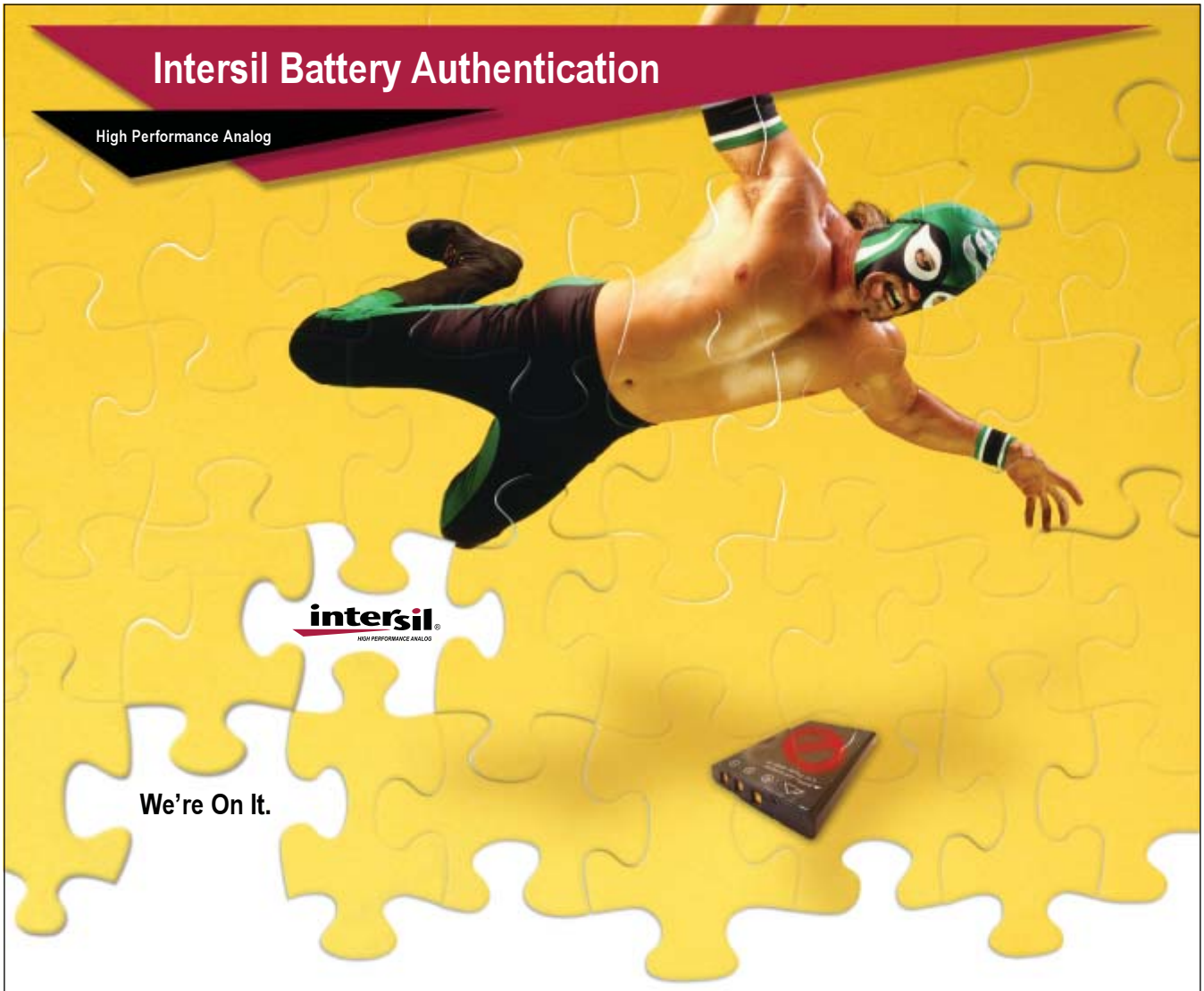
Best Regards



Bodo Arlt

# Intersil Battery Authentication

High Performance Analog

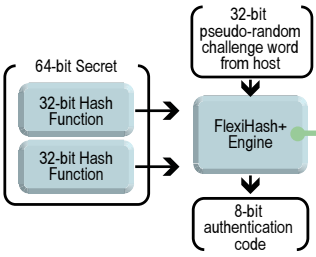



## Intersil's **ISL9206 FlexiHash+™ Engine delivers high-security battery authentication** at a low cost.

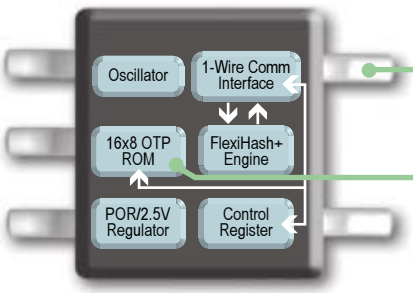
Intersil's ISL9206 is an easy-to-use, robust, and inexpensive battery authentication solution for 1-cell Li-Ion/Li-Polymer or 3-cell NiMH series battery packs.

**ISL9206 Key Features:**

- Challenge/response-based authentication scheme using 32-bit challenge code and 8-bit authentication code.
- FlexiHash+ engine uses two sets of 32-bit secrets for authentication code generation.
- 16x8 one-time programmable ROM memory.
- Additional programmable memory for storage.




Patent pending FlexiHash+ engine consists of four separate programmable CRC calculators. Two sets of 32-bit secret codes are used for authentication code generation.




XSD single-wire host bus interface communicates with all 8250-compatible UARTs or a single GPIO pin. Supports CRC on read data and transfer bit-rate up to 23Kbps.

16 bytes of one-time programmable ROM memory for storage of pack information and ID, device authentication secrets, device default settings, and factory-programmed trim parameters.

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HIGH PERFORMANCE ANALOG

# CT-Concept presents the Winner of the PCIM 2008 Raffle

The CT-Concept Team is pleased to announce the winner of a Tag-Heuer Swiss watch of this year's raffle during the PCIM 2008 in Nuremberg.
On the 17th of July, the happy winner David Ortega Rodriguez, R&D engineer at Ingeteam Traction, was handed out the first price, an exclusive Carrera Automatic Chronograph watch from TAG-Heuer.
Ingeteam is headquartered in Zamudio, Spain, and produces power electronics systems for renewable energy and traction applications. The price was handed out by Michael Reckhard, director sales & marketing at CT-Concept Technology AG.
The lucky winner has taken part in the CT-Concept raffle at this year's PCIM 2008 exhibition in Nuremberg and has been drawn out from more than 500 participants.

**www.ct-concept.com**

# Power Semis Motor Ahead

Of all the semiconductors and components used in industrial motor drives, the power semiconductor segment is the biggest revenue opportunity, according to a new report by IMS Research.
The market for power semiconductors in industrial motor drives was forecast to grow from $1 billion in 2007 to $1.3 billion in 2010, with the growth mainly driven by an increasing fraction of motors using drives. This market size is about twice the size of the combined market for micro and analog based components. "IGBT modules are used in the large majority of industrial motor drives," explained IMS Research analyst Jamie Fox. "As well as standard IGBT modules, Intelligent Power Modules and Power Integrated Modules are also used. Power Integrated Modules have the highest growth forecast, of 10.8% annually."
Most of the market is for modules; however there is also a small market for discretes and power ICs. Significant changes in the basic bill of materials are not expected in the next few years. Performance trends for power semiconductors include a demand for reduced heat losses, better temperature tolerance and higher power densities.

**www.imsresearch.com**

# IRIS Certification for LEM Production Sites

LEM announces IRIS certification for its production sites in Geneva, which has been in place since September 2007 and Beijing which achieved this status in July 2008.
IRIS, the International Railway Industry Standard is a globally recognized standard for the railway industry for the evaluation of management systems. It is an initiative led by the Association of European Railway Industries (UNIFE), supported by system integrators and equipment manufacturers.
IRIS is unique to the railway industry and an extension of the internationally recognized quality standard ISO 9001.

LEM is very proud to be one of the first companies to achieve this certification, especially for its two main production sites. For LEM it is the extension of their Automotive Industry Standard ISO 16949 certification already held for both sites for Automotive. The IRIS standard will become increasingly important because it ensures higher quality across the complete supply chain and simplifies the evaluation and approval process for equipment manufacturers.
LEM implements the IRIS standard together with the Six Sigma method for the entire process from R&D to the final delivery of its products. All LEM industrial and traction transducers have a five year warranty.
Innotrans, Hall 10.2 Stand no: 115

**www.lem.com**

# Continue Education Without Career Interruption

The online Master's Degree in Systems Engineering program from Penn State's World Campus has attracted students from the world's most successful firms and is now accepting applications for a second student group.
Dr. James Nemes, lead faculty for the online systems engineering master's degree program and the director of the Penn State Great Valley's System Engineering program, said students in the first group of the online systems engineering master's program are employed by firms including: Lockheed Martin, Westinghouse, Merck, Motorola, Verizon Wireless, Nucor Steel and Raytheon.
Several branches of the military were also represented in the first online systems engineering master's cohort, Nemes pointed out. Members of the Air Force, Army, and Navy are among the systems engineering students.

**http://www.worldcampus.psu.edu/**

# 2008 Europartners Distribution Report

The 2008 Europartners Distribution Report is in the final stages of compilation!
This will be the 18th Year of publication, and these reports have become the accepted tracking documents for the Electronic Component Distribution Industry World-Wide.
Last year we sold over 160 reports across the world. As a result we have been able to maintain the quality of the reports once again this year. The Worldwide report this year includes 21 Countries.
The reports are widely used by Component Distributors, Component Manufacturers and the Financial Community to verify the current status of this important channel to market.

**www.europartners.eu.com**

# EPCOS Shareholders to Accept Cash Offer from TDK

In a joint statement issued today, the Management Board and Supervisory Board of EPCOS AG announced their support for the public tender offer submitted by TDK on August 25, 2008. Thorough examination of the submitted offer has confirmed the view of EPCOS' governing bodies that TDK's offer meets the interests of the company, its customers, its shareholders and its employees. The Management Board and Supervisory Board therefore recommend that EPCOS' shareholders accept the offer.

Among other reasons, the Management Board and Supervisory Board base their decision on the following considerations:

The cash consideration of EUR 17.85 per EPCOS share offered by TDK includes an attractive premium in comparison to the company's share price both immediately before publication of TDK's intention to make a tender offer1) and in comparison to the historic share prices of EPCOS AG2). The fact that the offered consideration is adequate in financial terms has been confirmed in the fairness opinion submitted by UBS Investment Bank.

In the Business Combination Agreement signed on July 31, 2008, TDK and EPCOS committed themselves to establishing a strong and comprehensive partnership.

**www.epcos.com**

# Edward Lam as VP of Marketing and Engineering

AnalogicTech, a developer of power management semiconductors for mobile consumer electronic devices, has announced that Edward Lam has joined the Company as its Vice President of Marketing and Engineering. Effective immediately, Mr. Lam will oversee global marketing and engineering operations, reporting directly to the President, CEO and CTO of AnalogicTech, Richard K. Williams.
"Edward comes to us with an impressive background in marketing, engineering and business management from some of the industry's most well-regarded companies," stated Richard K. Williams, President, CEO and CTO of AnalogicTech. "Edward has a proven track record of leading focused, successful marketing and engineering teams in analog and power management semiconductors. We are excited to have someone with Edwards' qualifications and expertise to lead our product development and non-handset diversification efforts. We are pleased to have him join the team at AnalogicTech."

**www.analogictech.com**

# From Zemship to A320, H2Expo Hamburg, 22 to 23 October 2008

Zemship, the world's first fuel cell powered passenger vessel, will take tourists on excursions on Hamburg's Lake Alster starting in late summer this year. It is completely emission-free – hence the name Zemship (Zero-Emission ship) – and nearly twice as efficient as a conventional diesel vessel. It is the spearhead in a whole programme of development, reflecting the innovative spirit and the perspectives of the hydrogen and fuel cell industry. If environment friendliness is to be a key factor in future assessment of mobility, fuel cell applications will have fantastic opportunities – in shipbuilding, the automotive industry and aviation. H2Expo, 7th International Conference and Trade Fair on Hydrogen and Fuel Cell Technologies, brings together scientists and manufacturers from all over the world to discuss current projects, new developments and the latest state of the art, at the CCH-Congress Center Hamburg from 22 to 23 October 2008.
The Zemships project, funded by the EU and coordinated by the City of Hamburg, will be the subject of a specialist conference on the second day of H2Expo. It will present first reports on operation of the ship and of the new hydrogen fuel station set up by Linde AG for this purpose. "This ship is a prime example of innovation," says Anno Mertens, Zemships Project Manager at Proton Motor (based in Puchheim). Following special-purpose submarine applications, this is the first FC system for propulsion of a vessel in this power class. The Zemship is operated by ATG Alster-Touristik, cruising the Alster (the lake at the centre of Hamburg, with an area of 1.8 square kilometres) with 100 passengers. Its PEM-FC hybrid system (Polymer Electrolyte Membrane fuel cell) is characterised by low noise and zero emissions.

**www.h2expo.com**

# High-efficiency Reproducible Organic Solar Cells

IMEC, Europe's leading independent nano-electronics research institute and Plextronics, Inc., an international technology company specializing in printed solar, lighting and other organic electronics, signed an agreement to collaborate on state-of-the-art materials and inks for organic solar cells.
With this collaboration, IMEC aims to develop a reproducible process for high-efficiency organic solar cells using Plextronics' Plexcore® branded materials and inks.
IMEC aims to develop organic multi-junction solar cells with efficiency of 10% by 2012. The company's focus is also on up-scaling of the process to achieve a large-area industrial manufacturing technology with an average efficiency of 7% (+/- 0.5%) and solar cell lifetime of 5 years.

To realize these goals, high-quality, highly reproducible commercial materials are essential. In the first phase, IMEC will investigate Plexcore® OS, which is a regioregular poly-3-hexylthiophene (P3HT) polymer with a high absorption coefficient close to the maximum photon flux in the solar spectrum and high mobility. Plexcore® OS materials will be processed using spin coating and validated on film morphology, carrier mobility and reproducibility. Solar cells will be processed on different substrates using spin-coated films of the material.

"Plextronics' materials look very promising for high-efficiency reproducible organic solar cells;" said Jef Poortmans, Program Director Solar at IMEC. "With their focus on materials, inks, and process technology for organic solar cells, we expect that our work with Plextronics will help accelerate our optimization and development of an industrial large-area process."

**www.imec.be**

# July 2008 Book-to-Bill Ratio of 0.83

North America-based manufacturers of semiconductor equipment posted $905 million in orders in July 2008 (three-month average basis) and a book-to-bill ratio of 0.83 according tothe July 2008 Book-to-Bill Report published today by SEMI. A book-to-bill of 0.83 means that $83 worth of orders were received for every $100 of product billed for the month.

The three-month average of worldwide bookings in July 2008 was $905 million. The bookings figure is three percent less than the final June 2008 level of $934 billion, and about 36 percent less than the $1.41 billion in orders posted in July 2007.

The three-month average of worldwide billings in July 2008 was $1.09 billion. The billings figure is about six percent less than the final June 2008 level of $1.16 billion, and about 36 percent less than the July 2007 billings level of $1.69 billion.

**www.semi.org**

# International Rectifier Rejects Vishay's Unsolicited Proposal

International Rectifier Corporation announced that its Board of Directors has unanimously determined that the unsolicited, non-binding proposal by Vishay Intertechnology, Inc. to acquire all of the outstanding shares of International Rectifier for $23 per share in cash is not in the best interests of IR and its shareholders.

The Board reviewed the proposal with the assistance of its financial and legal advisers Goldman, Sachs & Co. and Fried, Frank, Harris, Shriver & Jacobson LLP, respectively. Richard J. Dahl, Chairman of the Board of International Rectifier said: "Vishay's proposal significantly undervalues the Company and its future prospects when compared to the shareholder value realizable under our recently adopted strategic plan. On August 1, we announced that the Company had successfully completed the restatement process of prior financial periods. The Company has also added considerable strength and depth to its senior management team during the past year and is poised to enhance its competitive position in the marketplace.

"The Board believes that the proposal by Vishay does not value the Company and its future prospects appropriately. In our judgment, IR shareholders will be better served by allowing management to move forward with its strategic plan. We believe that IR's valuation is still under the cloud of legacy issues. The Board and our management team look forward to executing the exciting opportunities available to our Company and to delivering this value to our shareholders," concluded Mr. Dahl.

Oleg Khaykin, Chief Executive Officer of the Company added: "We look forward to fulfilling our potential as we continue to follow our strategic plan and focus on long term value creation for our shareholders."

**www.irf.com**

# Environmental Impact Statement on Landmark Wyoming Wind Project

ENSR has been selected by the Bureau of Land Management (BLM) to prepare the environmental impact statement (EIS) for a major new wind energy project proposed by the Power Company of Wyoming. ENSR, a leading environmental services firm, is part of AECOM, a global provider of professional technical and management support services.

The Power Company of Wyoming filed right-of-way applications with the BLM Rawlins Field Office to develop two wind farms on 98,000 acres in the Rawlins and Carbon County areas of Wyoming. The projects would be located partially on federal lands administered by BLM, and on interspersed private lands. Livestock grazing (the current land use) would continue after the project is developed.

The proposed 1,000 turbine wind energy project on the two sites would provide 2,000 megawatts of power to the national electric power grid, establishing Wyoming as the third-largest wind energy generation state, behind Texas and California.

**www.ensr.aecom.com**

# Chris Meaney Global VP of OEM Sales

Lineage Power Corporation, a Gores Group affiliate and a trusted provider of energy-efficient AC/DC and DC/DC switching technologies, announced today that Chris Meaney has been named global vice president of OEM sales. Meaney will be responsible for driving the global sales strategy for the OEM (original equipment manufacturers) market.

"Meaney brings nearly 25 years of general management and sales experience to our team," said Niklas Fallgren, vice president, MicroPower business unit. "He has exceptional leadership skills and a proven track record of success in growing revenue streams and advising national and global customers on solutions that best meet their needs. We're looking forward to him working with our sales teams to take Lineage Power's solutions into new markets, accelerating our growth and expanding our leadership position."

Most recently, Meaney served as vice president of sales at IntraLinks, a leading provider of virtual data room workspaces and other online workflow management solutions. Primarily responsible for the regional direct sales team, Meaney played a key role in generating a $14 million revenue stream. Before IntraLinks, Meaney held multiple sales positions for Siemens Enterprise Communications, where he managed regional and global accounts, such as Coca-Cola, IBM, UPS and Ford Motor Company. Meaney also served as multi-services regional manager at Cisco Systems.

Meaney earned his bachelor's degree in electrical engineering from the University of Vermont. He will be based in Atlanta.

**www.lineagepower.com**

# Industry's Thinnest 500-mA Power Converter Solution

*Tiny 6-MHz step-down DC/DC converter supports ultra-thin, feature-rich smart phones, wireless modules and portable electronics*

Giving portable designers the ability to add more features and functions on a handheld device, Texas Instruments announced today the industry's smallest and thinnest 500-mA, step-down DC/DC converter solution for space-constrained applications. The high-efficiency power management integrated circuit (IC) is the first 6-MHz, 500-mA converter to achieve a 13-mm2 solution size with an ultra-thin 0.6-mm total height. See: www.ti.com/tps62601-pr.


Leveraging TI's analog manufacturing technology, the new TPS62601 converter achieves up to 89-percent power efficiency and only 30-uA typical operating quiescent current – all from a 0.9 mm x 1.3 mm chip scale package roughly the size of a flake of pepper. The synchronous, switch-mode device's fixed frequency of 6 MHz allows the use of only one 0.47-uH inductor with a height of 0.6 mm and two low-cost ceramic capacitors, without compromising performance and efficiency.

"Portable system designers continue to desire more features on their devices, which require smaller, efficient DC/DC converters to maintain long battery life and system runtimes," said Steve Anderson, senior vice president of Power Management, TI. "The TPS62601 gives portable designers access to the smallest, thinnest 500-mA DC/DC solution, which simplifies design and reduces board space and time-to-market."

The TPS62601 can deliver DC voltage regulation accuracy of +/- 1.5 percent. In addition, the device's excellent load transient response, wide input voltage range of 2.3 V to 5.5 V and 1.8 V of output allows it to effectively support single-rail voltage requirements as designers add new features and functionality. The TPS62601 supports many applications, such as memory modules, GPS modules, Bluetooth and Wi-Fi modules or other wireless micro-modules used in ultra-thin smart phones, digital still cameras, portable disk drives and media players.

The converter also applies energy-saving techniques to help maximize battery runtime.

For example, the converter automatically enters a power save mode during light-load operating conditions via an automatic pulse frequency modulation and pulse width modulation switching feature. In shutdown mode, the device's current consumption is reduced to less than 1 uA.

The TPS62601 is available in volume from TI and its authorized distributors. The device comes in a highly reliable, six-pin, wafer chip scale (0.9 mm x 1.3 mm) package and has a suggested resale price of $1.45 each in quantities of 1,000 units. The TPS62601EVM-327 evaluation module, application notes and TI's online Power Management selection tool are available through power.ti.com.

**Innovative power management for portable electronics**

In addition to the TPS62601, TI provides a broad range of power management

battery management solutions for handheld devices. Examples include the new 3-MHz bq24150, switch-mode battery charger integrated circuit, the system-side bq27500 battery fuel gauges, and TI's DC/DC converters that support RF power amplifiers and core supply voltages. Complete system block diagrams with analog and digital solutions for OMAP™ 3 processor-based applications can be found at:

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- Mobile internet devices
- Portable media players and digital cameras

### Features

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- Negative output voltage down to -7 V
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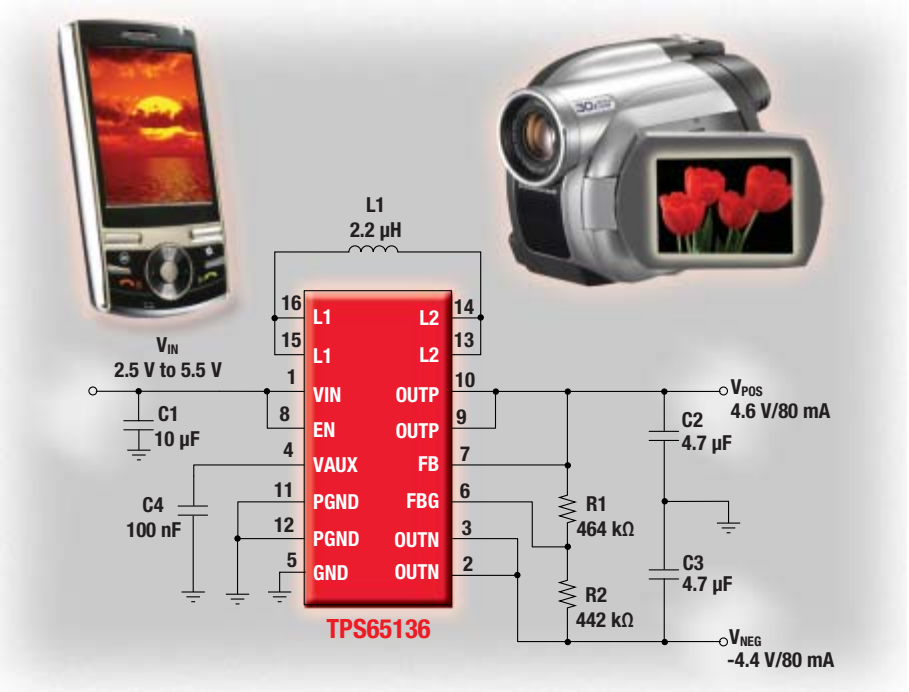
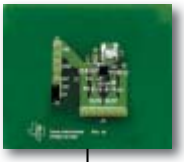
- Superior line regulation
- Buck-boost mode for both outputs
- Supports new batteries with input voltages up to 4.8 V




The **TPS65136**, part of TI’s OLED driver portfolio, enhances the image quality for Active Matrix OLED displays used in portable applications. Based on TI’s single-inductor output regulator technology, the OLED driver supports positive and negative voltages, and achieves the smallest solution size using a single inductor.

| Device | $V_{IN}$ (V) | $V_{OUT}$ (V) | $I_{OUT}$ (A) (typ) | Output Efficiency (%) | Package |
|---|---|---|---|---|---|
| TPS65130 | 2.7 to 5.5 | –15 to 15 | 0.8 | 89 | 24-pin QFN |
| TPS65131 | 2.7 to 5.5 | –15 to 15 | 1.95 | 89 | 24-pin QFN |
| TPS65136 | 2.3 to 5.5 | –6 to 4.6 | 0.7 | 70 | 16-pin QFN |



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Get Datasheets, Evaluation Modules, Samples and the Power Management Selection Guide

Texas Instruments

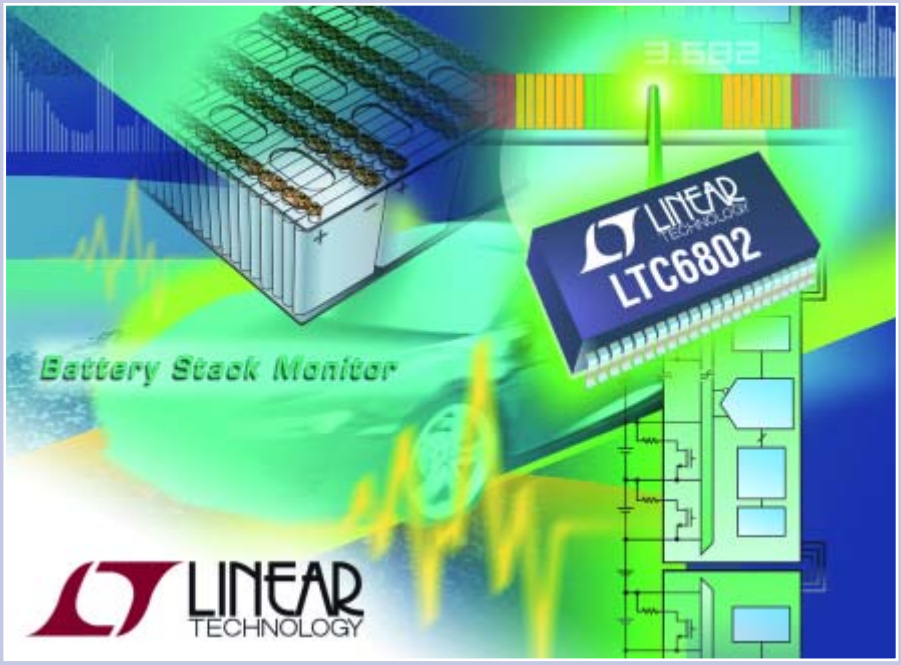
# Battery Stack Monitor Supports Hybrid/Electric Vehicles & Battery Backup Systems

Linear Technology announced the LTC6802, a highly integrated multicell battery monitoring IC capable of measuring up to 12 individual battery cells. The device's proprietary design allows multiple LTC6802s to be stacked in series without optocouplers or isolators, for precision voltage monitoring of every cell in long strings of series-connected batteries. Long battery strings enable high power, rechargeable applications, such as electric and hybrid electric vehicles, scooters, motorcycles, golf carts, wheelchairs, boats, forklifts, robotics, portable medical equipment, and uninterruptible power supply (UPS) systems.

With superior energy density, Lithium-Ion batteries are poised to be the power source of choice for these applications. However, designing a large, highly reliable and long-lasting Li-Ion battery stack is a very complex problem. Li-Ion cells are sensitive to overcharging or over-discharging, requiring that each cell in a stack is carefully managed. The LTC6802 makes this possible with quick and accurate measurements of all cell voltages, even in the presence of stack voltages over 1000V.

The maximum total measurement error is guaranteed at less than 0.25% from -40°C to 85°C and all cell voltages in a battery stack can be measured within 13ms. Each cell is monitored for undervoltage and overvoltage conditions, and an associated MOSFET switch is available to discharge overcharged cells. Each LTC6802 communicates via a 1MHz serial interface, and includes temperature sensor inputs, GPIO lines and a precision voltage reference.

The LTC6802 was designed for the environmental and reliability challenges of automotive and industrial applications. It is fully specified for operation from -40°C to 85°C and offers diagnostics and fault detection. The LTC6802 is a small 8mm x 12mm surface mount device. The combined robustness, exceptional precision and tiny package directly address the critical requirements of emerging and advanced battery technologies.




"The LTC6802 provides a precision analog interface for high performance battery stacks," says Mike Kultgen, design manager for Linear Technology. "By handling the data acquisition task, the LTC6802 enables designers to implement state-of-the-art battery management techniques."

Priced at $9.95 each in 1,000-piece quantities, samples, demonstration boards and the data sheet are now available at www.linear.com. The product will be available in production quantities in the fourth calendar quarter 2008.

**Summary of Features: LTC6802**

- 0.25% Maximum Total Measurement Error from -40°C to 85°C
- Stackable Architecture Enables 1000V+ Systems
- ??? ADC with Inherent FIR Filtering
- 1MHz Serial Interface with Packet Error Checking
- Onboard FETs for Cell Discharge
- Temperature Sensor Inputs
- Built-In Precision 3V Reference & 5V Regulator
- Diagnostics & Fault Detection
- AEC-Q100
- 44-Lead SSOP Package
- Fully Specified for -40°C to 85°C Operation

Linear Technology Corporation, a manufacturer of high performance linear integrated circuits, was founded in 1981, became a public company in 1986 and joined the S&P 500 index of major public companies in 2000. Linear Technology products include high performance amplifiers, comparators, voltage references, monolithic filters, linear regulators, DC-DC converters, battery chargers, data converters, communications interface circuits, RF signal conditioning circuits, uModule™ products, and many other analog functions. Applications for Linear Technology's high performance circuits include telecommunications, cellular telephones, networking products such as optical switches, notebook and desktop computers, computer peripherals, video/multimedia, industrial instrumentation, security monitoring devices, high-end consumer products such as digital cameras and MP3 players, complex medical devices, automotive electronics, factory automation, process control, and military and space systems.

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[ www.infineon.com/optimos ]

# Chip my Ride – Silicon and Vehicle Efficiency

*By Oleg Khaykin, President and CEO of International Rectifier*

*Semiconductor technology is absolutely essential in delivering efficiency improvements for conventional, hybrid and electric vehicle designs.*

With the first 'electric carriage' invented at some point between 1832 and 1839 by Scottish pioneer Robert Anderson, the electric car has a significantly longer history than that of the internal combustion engine (which didn't make its debut until 1883). Powered by non-rechargeable cells Anderson's crude vehicle may have had limited commercial potential, but it was the start of over 170 years of interest in the viability of battery-powered vehicles. Since then, many electric vehicles have come and gone - including International Rectifier's own prototype, which was developed in 1958 for the purpose of demonstrating the viability of silicon controlled rectifiers (SCRs) in electric vehicle drives and which can be seen on display at IR's Temecula, US facility.

Fast forward to today and the electric vehicle has come a long way, as demonstrated by the recent launch of the Tesla Roadster. A true sports car (with a price tag to match), this fully electrical vehicle is capable of 0 to 100kph in four seconds and claims a top speed of over 200kph. At the same time, there has been tremendous investment and progress in the development of hybrid vehicles, illustrated by the popularity of the Toyota Prius - many of which can be found gliding around the same Los Angeles streets that IR's electric vehicle travelled forty years previously.

Right now, interest in hybrid and electric vehicles is at a peak thanks to the pressure to cut carbon emissions and concerns regarding the stability of supply and the cost of oil. These same concerns are also fuelling demands to make conventional petrol-, diesel- and (increasingly bio-fuel-) powered automobiles more efficient. And, while we may have moved on from the SCRs of the 1960s, semiconductor technology remains at the heart of this search for automotive efficiency.

**Semiconductor content**

According to a recent report from industry analyst iSuppli, the semiconductor content of the conventional automobile will double in the five years from 2007. Some of this growth will come from replacing heavy mechanical systems with lighter and more efficient electronic/electrical technologies such as power steering systems and brake-by-wire designs. Power semiconductors are a vital element of such systems and almost all other vehicle electronics - from control of pumps, fans and blowers to driving HID and LED headlamps and powering MCUs, peripherals and other silicon in safety, security, comfort and infotainment applications.

According to iSuppli, a mid-sized petrol engine car uses around 430 semiconductor devices, split between MCUs, memory, ASICs, power ICs, analogue ICs, LEDs and CCDs (with the MCU making up the greatest proportion of the semiconductor cost). In the case of a similarly sized hybrid, however, there is likely to be around 730 semiconductor devices, with the majority of this total being dedicated to the power transistors and power discretes related to inverter and battery circuits.

Finally, it is reasonable to suggest that the semiconductor content of fully electric vehicles is going to be even higher than that of their hybrid counterparts. Critical to the performance of the Tesla Roadster mentioned earlier, for instance, is the Power Electronics Module (PEM) which contains high voltage electronics and performs functions such as motor torque control, regenerative braking control, and charging. Then there is the ESS (Energy Storage System) that uses the same lithium ion cells commonly used in laptops. Tesla has built its battery pack with 11 individual sheets of 621 cells, with each sheet requiring a semiconductor device to evaluate and monitor the cells for charge balancing, cooling, and safety.

**Powering the future of automotive design**

What is clear is that, as we move forwards, semiconductors will play a key role in the development of ever-more efficient vehicles. It is for this reason that companies such as International Rectifier are investing considerable resources in developing new technologies – including mixed-signal processes that meet automotive reliability requirements and allow high voltage analogue electronics to be integrated onto the same IC as digital control - that will meet the rapidly evolving needs of designers, irrespective of the underlying power train architecture.

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**Let experts drive your power devices**

# It Still All Comes Down to Cost

*By Werner Obermaier, Head of Product Marketing Industrial Products, Vincotech*

Since the first oil crisis in the early 80s, the discussions regarding our responsibility to reduce energy consumption, conserve the environment and protect the globe for the generations to come have been raging. Reality, however, is still a long way from the motto “think global act local”.

In Germany, industry amounts to approximately 50 % of the total electrical energy consumption, with 2/3rds of it used for electrical drives. According to the European SAVE study, roughly 22 Billion kWh per year could be saved by the use of variable speed drives and an additional 5,5 Billion kWh by the use of motors with higher efficiency in Germany. These energy savings alone would amount to the electrical energy required to drive 1/3rd of all cars in Germany, were they all battery powered.

Approximately 12 % of the already installed and about 30 % of the newly installed drives in Germany are variable speed drives. Considering energy savings, variable speed would actually make sense already for about 50 % of the drives. Despite the ‘green’ discussions and projections within the European community, only about 9 % of the currently sold motors are considered of high efficiency according to the efficiency standard IEC 60034-30, compared to 50 % high efficiency and 20 % premium efficiency motors sold in North America.

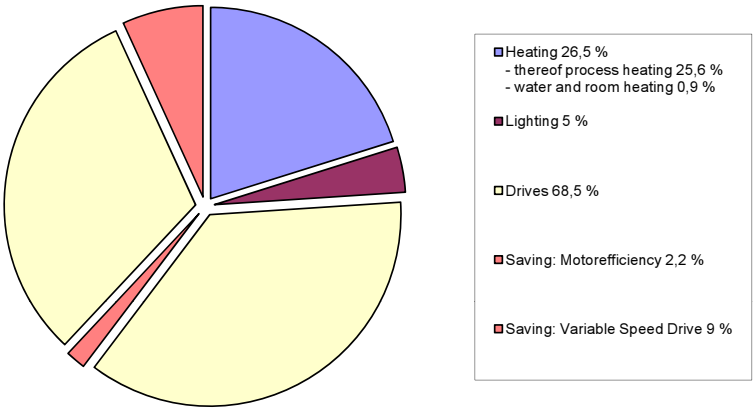
One of the reasons behind the relatively slow implementation of energy saving drives in new applications is the way investment decisions are made. Common business practice is to target a maximum investment payback period of 3 years. With the relatively low energy costs of the past, this target was extremely hard to reach. Furthermore, contracts for production lines or complete factories have so far been agreed mainly on the basis of the investment cost, not taking into account the energy cost. According to studies, energy costs on average amount to no more than 2% of the total cost of production.

With the recent explosion in energy and particularly oil cost, the scenery has shifted. Cries for energy-saving and efficient solutions are resounding throughout the land. The payback time for highly efficient variable speed drives has dropped from several years to almost 2 years, depending on the application. The dramatic rise in energy costs has led to decisions based on lifetime cost calculations. Indeed, the times when decisions were made taking into account energy costs at the time of investment and targeting a 3 year payback seem a thing of the past, particularly considering the fact that a factory lifetime is seldom less than 10 years and that energy prices can be expected to multiply within this timeframe.

The high energy costs and the change in mindset will boost the demand for energy-efficient solutions, leading to intensified activities in this area. This will impact existing applications, such as drives, as well as emerging areas, like renewable power generation and electrical vehicles.

**Conclusion**

The hope for the future lies in the slowly evolving knowledge that our resources are final; in the increasing awareness that what might be a good solution today may not be for the lifetime of the investment; and in the unavoidable increase in energy costs, already taking place today! With this in mind, I am looking forward to the future, with its increasing demand for efficient solutions and the thrilling prospects and demands this implies for the area of power electronics. To put it simply-I cannot imagine a better place to work during these exciting times.




*100 %: 248 Billion kWh*
*Source: ZVEI/VDEW*
*Picture: Electrical Energy Consumption and possible Savings for the German Industry 2004*

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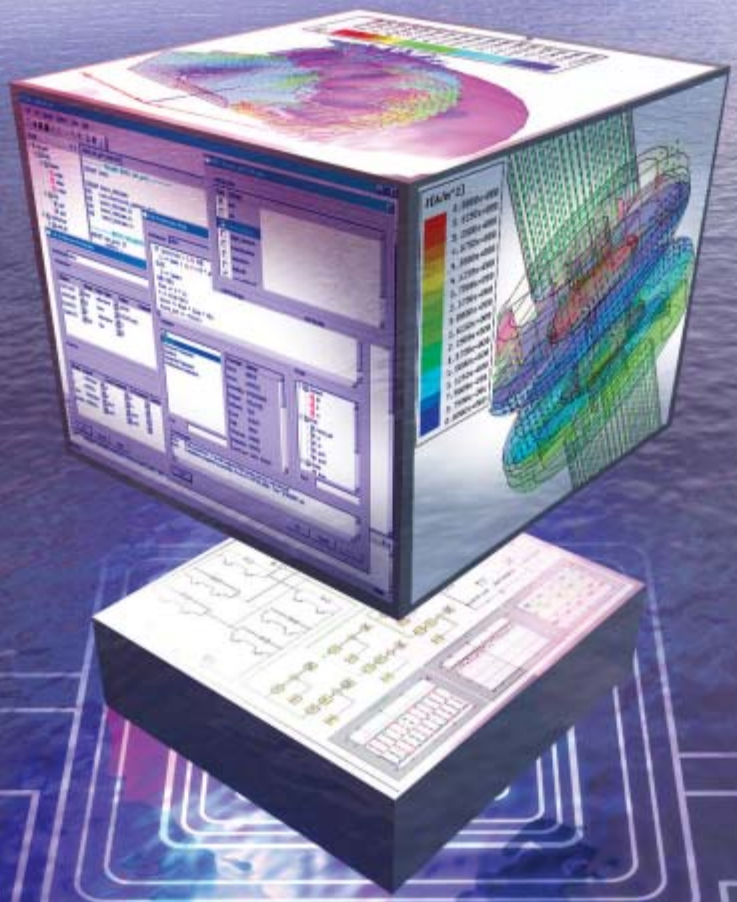

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# Electronics Industry Digest

*By Aubrey Dunford, Europartners*

**SEMICONDUCTORS**

Global sales of semiconductors for the first half of 2008 grew to $ 127.5 billion, an increase of 5.4 percent over the first half of 2007, so the SIA. Second-quarter sales of $ 64.7 billion increased by 3 percent over first-quarter sales of $ 62.8 billion. The main driver for the increase of the semiconductor market in Q2-08 compared with Q2-07 on a three month rolling average is the strong increase of the Average Selling Price (ASP) (5,3 percent world, 4,3 percent Europe). Measured in Euro, semiconductor sales in June 2008 were € 2.156 billion, up 1.0 percent on previous month and down 9.3 percent versus the same month a year ago. On a YTD basis semiconductor sales showed a decline of 11.4 percent versus the same period in the year 2007.

To adapt its size to today's market conditions, Infineon has implemented its cost-reduction program "IFX10+" in the third quarter of the 2008 fiscal year. In the course of the implementation of these measures, it will be necessary to reduce headcount by a gross figure of approximately 3,000 employees.

ON Semiconductor announced the signing of a definitive merger agreement for the acquisition of Catalyst Semiconductor for an equity value of approximately $ 115 M and an enterprise value of approximately $ 85 M.

TT electronics, a British supplier in sensor and electronic component technology, has acquired assets comprising the majority of the business of Semelab, which designs
specialised radio frequency and power semiconductors, optoelectronic components and power microcircuits and modules, primarily for the UK and European markets. The
purchase consideration is £ 9.8 M.

Intersil, specialized in high-performance analog solutions, has signed a definitive agreement to acquire D2Audio Corporation, a supplier of digital audio power amplifiers for consumer, commercial, automotive and professional audio applications.
Microsemi, a manufacturer of analog mixed signal integrated circuits, announced the acquisition for approximately $ 25 M in cash of Semicoa. Founded in 1968, Semicoa designs, semiconductors and smart munitions optoelectronics for the high reliability military,
commercial aerospace and satellite markets.

Silicon Laboratories has completed the acquisition of Silicon Valley-based Integration Associates, an innovator in analog-intensive, highly integrated ICs, for $ 80 M.

Kulicke & Soffa Industries has entered into definitive agreements to acquire substantially all of the assets of Orthodyne Electronics, a supplier of wedge bonders, and sell its wire business unit to Heraeus, a precious metals and technology group. Heraeus will pay $ 155 M in cash to K&S for its wire business unit.

**PASSIVE COMPONENTS**

TDK and Epcos have signed an agreement to combine Epcos with TDK's activities in the electronic components field. The combination will create an industry-leading electronic components company with a strong presence across customer sectors and regions. As a first step, TDK will launch a public tender offer for all outstanding shares of Epcos. Based on the number of Epcos shares outstanding, this offer would value Epcos at approx. € 1.2 billion equity value. The new company will be provisionally named TDK EP Components KK. In fiscal 2007, Epcos posted sales of € 1.44 billion.

ZF Friedrichshafen is further expanding its worldwide automotive supplier position by acquiring Cherry, a US company with production locations in Germany, the Czech Republic, Mexico, Hong Kong, China, and India. Cherry develops and produces among others switch systems, sensors, and control units for the automotive industry. In 2007, Cherry had sales of approximately $ 400 M with 3,100 employees worldwide. Half of the workforce is located in Germany.

**DISTRIBUTION**

EMEA semiconductor distribution sales declined 3.6 percent in Q2/2008 to € 1.34 billion compared to Q2/2007, so DMASS. Sequentially, sales were down by 3.3 percent. On a cumulative basis, the first six months of 2008 so far brought a decline of 5.8 percent. Of the bigger sales regions, Germany stayed flat with -0.5 percent (€ 437 M). Italy (€ 174 M), France (€ 111 M), Nordic, Iberia and Switzerland ended with a relatively soft decline between -3.51 percent (Iberia) and -5.2 percent (Switzerland). Benelux again recorded a decline in the -14 percent to -15 percent range, while the UK dropped 16.3 percent to € 116 M. Eastern Europe continued to grow by double digits (11 percent) to € 170 M. Russia and the emerging countries drove the growth with 23 percent and 24.9 percent respectively. A double-digit weakness seems to have befallen the logic sector, while discretes, analog
and MOS Micro, who together represent 70 percent of the DMASS total, ended between -0.2 percent and -2.1 percent down compared to Q2/2007.

Avnet Memec, the highly specialised semiconductor distributor of Avnet Electronics Marketing EMEA, announced that Chris Shipway has recently been appointed as Country Director UK. He will be responsible for all sales activities in the UK and will directly report to Bill Walker, Regional Vice President Sales Northern Europe.

The German component distributors achieved sales of € 627 M in the 2nd quarter of 2008, which, compared to the same period of the previous year, was a marginal reduction of 0.8 percent, so the FBDi.

This is the comprehensive power related extract from the « Electronics IndustryDigest », the successor of The Lennox Report. For a full subscription of the report contact: eid@europartners.eu.com or by fax 44/1494 563503.

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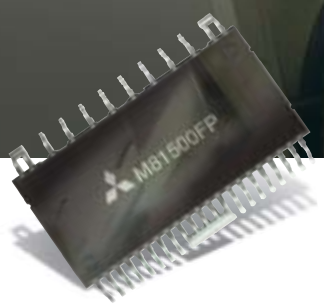


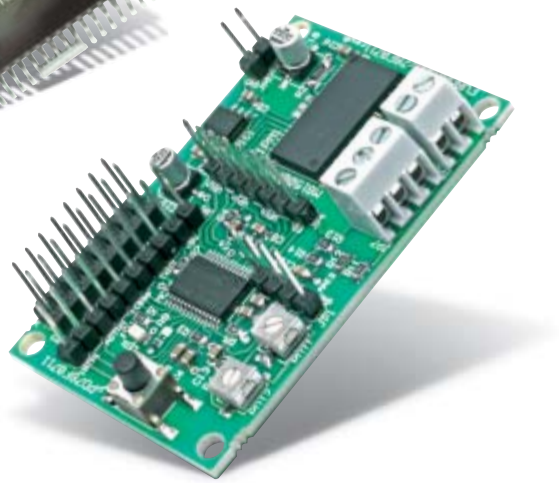

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# New Techniques Challenge the Power Supply Industry

*By Linnea Brush, Senior Research Analyst, Darnell Group*

Several new technologies were debuted at last month's Digital Power Forum (DPF) in San Francisco that could continue the debate of how quickly digital power control will become a "mainstream" solution in product designs. These debates center around the value that digital power management brings to the system – and how important it is to the customer. In some ways, the arguments are coming full circle to where they began: at the engineering and design level.

Powervation sums this up by saying that the "It's just like analogue" view hinders digital adoption by providing users with what they already have, but in digital form. In reality, analogue and digital processing are mathematically similar, but fundamentally different. In fact, algorithms are the differentiating factor in Powervation's new Auto-control™ power conversion technology, which produces "optimal partitioning." Digital control gives accurate knowledge of loop signals, duty-cycle and control error, and the company claims a 50% improvement in transient response.

The digital control algorithm, implemented in firmware, provides a "true adaptive adjustment of the converter to take into account all system variations, while guaranteeing stability of the converter." The Auto-control capability regulates controller behavior on a cycle-by-cycle basis, searching for any modification in the system operation. This means that the power converter is "truly self-contained," according to the company. It can be plugged directly into the motherboard and immediately operate at peak performance without user intervention.

Customers like the idea of controllability, observability and monitoring, and meeting the needs of customers is the main goal for digital power management right now. Original equipment manufacturer (OEM) power system designers need evidence of quality and demonstrated reliability, which requires cooperation with IC suppliers to promote more efficient and cost-effective testing.

This is one of the goals of Ericsson Power Modules. The company has been conducting reliability tests of digital power generation of board-mounted power supplies. Areas of concern have included memory content (EEPROM, ROM and RAM), along with unlimited use. Ericsson's testing showed "equal or better reliability than the corresponding analogue product."

Ericsson also discussed the configurability of digital power supplies from a user and supply point of view. The use of non-volatile memories and configuration files, along with "design-in tracks," mean that a common power supply could be shipped to a customer with application software that configures the power supply for a given use. Configuration files can be downloaded on-board by the user or OEM, allowing the power supply manufacturer to reduce proliferation of part numbers and letting the user have more direct control of the features they want.

The question is whether there is any real threat to the inevitable digital encroachment. A highly publicized announcement from International Rectifier centers around GaN-based power devices, which the company says will be a "revolution in highly efficient, cost-effective, high power density power conversion," and a "challenge to digital regulation." I.R. does not actually have commercially available GaN products, and they admit that their technology is "opening the way" for GaN to be used in power supplies (where little effort has been focused, primarily due to problems with reliability). Indeed, the challenges to GaN being adopted include cost, performance, volume production, quality, robustness, along with reliability. With that many caveats, does GaN pose a true "challenge to digital regulation," as claimed?

I.R. indicated that two of GaN's advantages were smaller size and faster response – 20 MHz in their example. The company says that this switching frequency precludes the use of digital control, but this is not true. In fact, it can actually complement digital control. First, many systems do not need this response time. But even if they do, it is not always necessary to control 20 cycle. The main core could switch at 20 MHz, for example, while the control loop works at 1 MHz. In other words, the control loop can be slower than the switching frequency. In this case, digital control would work alongside GaN technology.

Unlike GaN, SiC technology is being positioned to enable new digital designs, although its use is specialized. For example, Cree offers SiC rectifiers for power factor correction (PFC) in switchmode power supplies. PFC greatly benefits from non-linear programming, which improves efficiency.

Infineon is also looking at new generations of SiC technology to advance switch and diode capabilities for various applications, including PFC. The company believes that device capabilities are being hampered by conventional package fabrication techniques developed for silicon semiconductors. A key issue is the solder die attach process, which adds significantly to the effective thermal impedance and diminishes the benefit of SiC's bulk thermal conductivity.

To improve this situation, Infineon developed a diffusion attachment process, where the conventional solder is replaced by a very thin metal layer on the chip backside. Heating up the chip-leadframe junction leads to an inter-metallic diffusion process. The resulting die attach is very stable under thermo-mechanical stress.

Like GaN, the use of SiC in systems can allow for higher switching frequencies for dc-dc converters and less need for cooling. This results in smaller, lighter and more robust system designs. TranSiC offers SiC bipolar junction power transistors for drilling, aerospace, wind turbine and hybrid electric vehicle applications.

Finally, the added benefits that mixed-signal controllers provide also present a new area of technology for many engineers. According to Infineon, mixed-signal controllers are becoming more popular at lower power levels due to the reduction of cost and the improved functionality and feature sets that have a positive effect on overall system performance.

Infineon introduced a digital controller that includes a driver and the power stage MOSFETs in one package. An “all-in-one” IC such as this provides integration and minimizes board space requirements. Computer analysis tools aid the power supply designer, especially in converting from the continuous-time to discrete-time frequency domain models and back again. A simplified model enables a fast design approach, and all the non-linear behavior can be checked in the laboratory when the converter is running. Infineon says, “The digital controllers on the market today are easy to use in applications once the models are understood.”

The value of digital power management is only beginning to be exploited. As noted previously, digital control is traditionally compared with existing analogue solutions. Cost can be a deciding factor, and the cost of digital control is just now reaching parity with the cost of analogue. As Powervation observed, however, customers (and the power supply industry) are still providing solutions based on traditional analogue capabilities.

The future of digital control will lie outside the capabilities of analogue. For example, digital data can be collected, analyzed and used for predictive modeling, not only in an existing system, but for any number of other, potential system scenarios. Companies will no longer market digital as “doing what analogue does, only better”; it will provide value that analogue cannot provide at all.

Implementing digital techniques produces resources and data that few users have exploited yet. This is the “new frontier” of digital power supply design that will eventually bring the technology into the mainstream.

**http://digitalpower.darnell.com/**

# Interview with Robert Wiatr from Mitsubishi on Wind Power Electronics Applications

*By Bodo Arlt, Editor BP*

**Bodo Arlt:** What influence does the growing wind energy market have on the development of power semiconductors at Mitsubishi?

**Robert Wiatr:** The fast growth of the wind energy market confirms our development strategy which we have been following since years. Customised solutions which fit exactly to end customer's requirements have a huge influence on our development strategy.

**Bodo Arlt:** What are the challenges/alternatives in this market?

**Robert Wiatr:** High growth rates, very innovative designs as well as a strong trend towards consolidation of the key wind turbine manufacturers are characteristic for this application field.
Same trend is shown in other renewable energies such as photovoltaics. In future, also fuel cells and power distribution will become more and more important where energy savings are the key.

**Bodo Arlt:** Which solutions does Mitsubishi offer to be competitive in the wind market?

**Robert Wiatr:** With our Mega Power Dual IGBT Module (MPD) which is well accepted in the market we are well prepared for this application segment. Mitsubishi will follow this concept consistently. However, with Mitsubishi's wide product portfolio we can also follow customers' requirements for alternative solutions.

**Bodo Arlt:** What is the semiconductor voltage class that you would recommend for variable-speed wind turbines?

**Robert Wiatr:** For today's and the next generation of variable-speed wind turbines, we clearly see the 1200V and 1700V class as the most frequently used solution for this application. In the long run, we see a trend towards higher voltages like 3300V and 4500V based on the requirements for future megawatt solutions. Compared to other suppliers to the wind energy market, Mitsubishi have state-of the-art products from 600V up to 6500V, incl. 4500V.

**Bodo Arlt:** What sets Mitsubishi apart from other module suppliers in the world?

**Robert Wiatr:** As the world leader for Power Semiconductor Modules, we are located at all places were our customers are producing. This gives us the possibility to communicate face-to-face directly at the production and developments centres and react to customer's requirements in short time.
Moreover, our well known high quality, based on leading-edge technologies and state-of-the-art production facilities and the high integration of our production processes, is the key for our leadership.
Mitsubishi possess all key technologies for power module design such as state-of-the-art IGBT and diode chip technology, HVIC and package technology for "All the Power You Need" starting from 0.1 kW home appliances up to 4 MW wind mills and even higher in future. Also production facilities and processes are in-house designs exactly dedicated to our needs.
Our expertise in high voltage modules and our key supplier position in the transportation market prove this strong demand for highest quality & reliability standards once more.

**Bodo Arlt:** How much gets Mitsubishi involved in the end customer's wind power applications?

**Robert Wiatr:** Most of our customers involve us directly from the beginning of the development of wind turbines. Especially if we should develop a customised module, close communication will create win-win situation, providing customer with a tailor-made solution and shortening the time to market.

**Bodo Arlt:** How do you see the future in IGBTs and the mandatory gate driver technology for use in wind power applications?

**Robert Wiatr:** Gate drive technology is an essential part of the design to optimise the overall system characteristics, especially in the field of renewable energies where efficiency counts. Gate drive technology is one core competence of Mitsubishi Electric which has been incorporated into our Intelligent Power Module (IPM) concept for a variety of application fields from white goods up to traction systems. Herewith, Mitsubishi have followed the market trend towards more and more compact modules with high efficiency and high integration. However, also in future Mitsubishi will continue to offer both concepts: IGBTs for customers who prefer the flexibility to design their own system and IPMs for those who are looking for an integrated solution.

**Bodo Arlt:** Can we expect to see more silicon carbide devices from Mitsubishi for wind power solutions?

**Robert Wiatr:** Yes. But it still takes time to develop silicon carbide devices for wind power application. The research of silicon carbide devices has a very high priority within Mitsubishi. However, it is not only the development of the silicon carbide devices self but also the provision of appropriate production processes, bonding and package technologies to realise a cost competitive product for a variety of applications.

**Bodo Arlt:** Who of your competitors do you believe will fuel the race for leadership?

**Robert Wiatr:** All of our competitors have strong products for this application, but I believe that the leadership will be at Mitsubishi at the end of the day. With more than 25 years of experience in power electronics, continuous investments into R&D and production capacities and a comprehensive product portfolio we are well prepared for the challenges to come.
Specifically, with the recent acquisition of the chip manufacturing facilities of Renesas' Kumamoto factory and the implementation of an 8-inch wafer production, Mitsubishi Electric have been working to increase the production capability significantly. The capacity of our HV production lines has been increased by 60% in the second quarter of this year.
Together with our highest quality and reliability standards and strong customer orientation we feel well equipped to meet the market requirements.

**Bodo Arlt:** Dear Robert thank you very much for your time. We are looking forward to a bright future for wind power

**www.mitsubishichips.com**

# Selecting a Power Module for Your Application

## *Excellent efficiency and thermal performance in a compact QFN package*

*Recently, a new option has emerged: the point-of-load DC-DC power module. These modules combine most or all of the components necessary to deliver a plug-and-play solution that can replace up to 40 different components. This integration simplifies and speeds designs while reducing the power management footprint.*

*By Zaki Moussaoui, Applications Engineering Manager, Intersil Corporation and Sarika Arora, Product Marketing Manager, Automotive/Industrial & Communications Group, Intersil Corporation*

Many of today's telecommunication, data communication, electronic data processing and wireless network systems are powered with distributed power architectures. These complex systems require power management solutions that are capable of monitoring and controlling the power supply to very precise parameters. To achieve this level of performance, most designs utilize an FPGA, microprocessor, microcontroller or memory block.

This level of design sophistication has placed a heavy burden on application designers serving these communication infrastructure companies. Their choice is simple: either invest significantly to improve their in-house power management proficiency or rely on the expertise of outside design companies. Neither of these options are particularly desirable.

Recently, a new option has emerged: the point-of-load DC-DC power module. These modules combine most or all of the components necessary to deliver a plug-and-play solution that can replace up to 40 different components. This integration simplifies and speeds designs while reducing the power management footprint.

The key to getting the performance you need from these modules – while staying within your budget and space requirements – requires a firm grasp of the different technologies available.

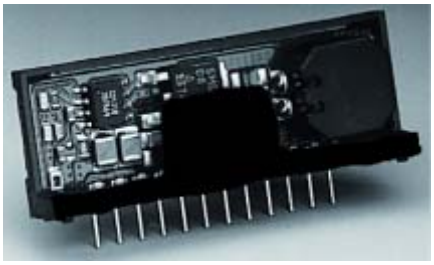
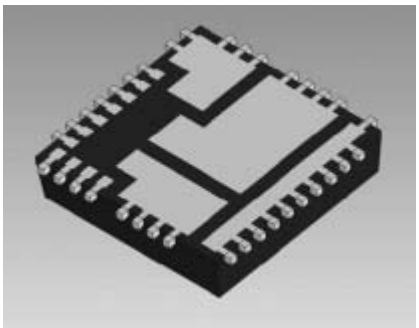


*Figure1:*
*Traditional SIP Open Frame Module*

The most traditional and common of the non-isolated DC-DC power modules are still the single in-line packages (SIP); see Figure 1. These open frame solutions certainly made progress in minimizing design complexity. However, most simply employ standard packaged parts on a printed circuit board. They are typically lower frequency designs (around 300kHz) and their power density is not stellar. Thus, their size makes them a poor choice for many space-constrained applications. The next generation of power modules needed to make significant progress in reducing the form factor to improve design flexibility.

To achieve the higher power density designers need, power management providers must push up the switching frequency to reduce the size of the energy storage elements. But increasing the switching frequency with standard components yields lower efficiency, predominantly due to MOSFET switching losses. This has driven the industry to find ways to cost-effectively reduce parasitic impedances in the driving and



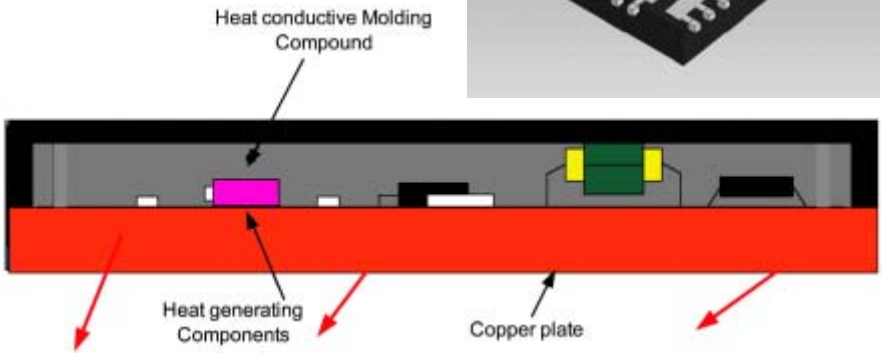



*Figure 2: ISL8201M Conceptual Package Drawings*

power path of the MOSFETs in a DC-DC module, producing molded modules about the size of a single integrated circuit.

**ISL8201M DC-DC Module**

The ISL8201M module from Intersil integrates most of the components required for a complete DC-DC converter, including the PWM controller, MOSFETs, and inductor. Its input voltage range is 3-20V, and it has 10A current capability. It achieves much higher switching frequencies than the traditional SIP DC-DC modules, with good efficiency and thermal performance, by eliminating the MOSFET packages and co-packing the parts in a compact 15x15x3.5mm QFN package (see Figure 2). The ISL8201M is the first in a family of modules; further size and performance improvements are in development.

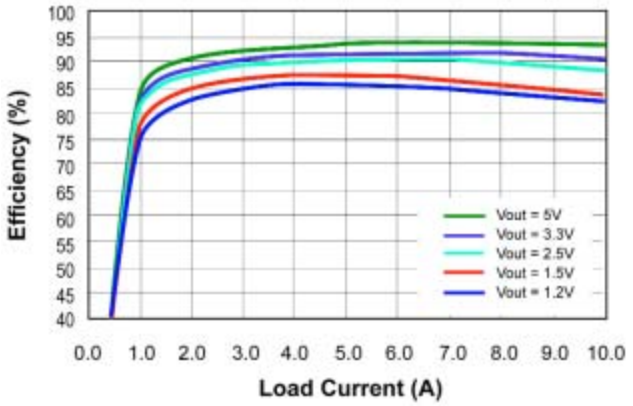



*Figure 3: ISL8201M Efficiency Curves (Vin = 12V)*

The ISL8201M achieves very good performance from an efficiency perspective. Additionally, the excellent thermal performance of the QFN package allows for very compact designs that do not require a heatsink. This allows the ISL8201M to achieve a power density of approximately 200W/in3, roughly 4 times that of conventional open-frame modules.

When evaluating solutions for a specific application, size and cost are two major considerations. But other factors can be equally or more important in the end application. Some of these additional considerations are now examined.

**Reliability**

One major issue that all system designers have to deal with is reliability. Many distributed power architecture applications need to be fully operational for many years with little downtime. Reliability plays an important role in total-system ownership costs. Reliability issues are important when dealing with power modules due to the number of co-packaged parts, heat-fatigue phenomenon due to high power density and, finally, the attachment mechanism failure.

The failure rate of electrical systems and parts follows the bathtub curve shape (see Figure 4). The steepness and sharpness of transition from one state to the other in this curve depends upon the choice of the components used, the rating of those components and their compatibility with the rest of the components in the module. For

example, using a 30V MOSFET in a 20V input capable DC-DC module would be acceptable as long as care was taken in the choice of the driver, the Schottky diode and the snubber circuit.

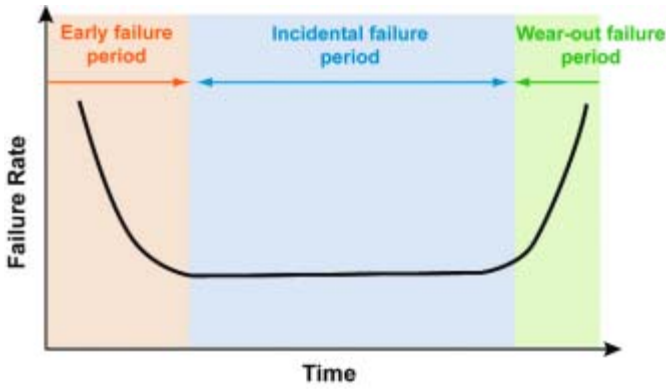



*Figure 4: Life cycle Failure Rate*

Heat-fatigue phenomenon in power modules is caused by inefficiencies in the power conversion and the limited available space to dissipate it. This can ultimately increase the rate of temperature rise and consequently reduce the life of the product. In order to minimize the effect of temperature on the Mean Time Before Failure (MTBF), the system designer should take into consideration heat sinking, available airflow, and derating curves based upon the power losses of the module.

One other phenomenon that causes a major failure is temperature runway caused by a solder joint crack. If the module is subject to mechanical vibration or several temperature cycle shocks, a crack is likely to develop in the solder joint which can eventually separate the component from the substrate. This will cause an increase in the electrical resistance, which in turn increases the temperature stress. These events may repeat until the cycle reaches wire-shear mode and results in catastrophic failures.

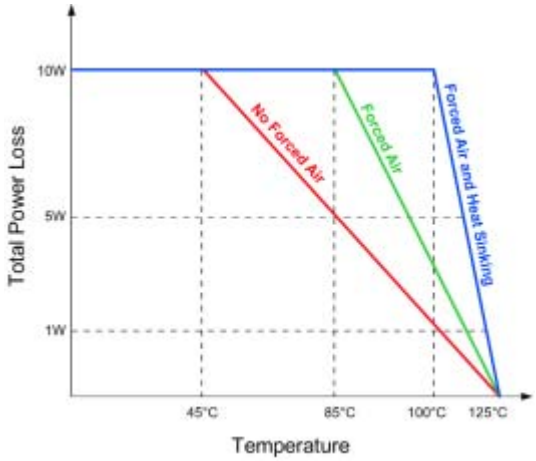



*Figure 5: Typical Derating Power Loss Curve*

In the ISL8201M, system designers receive an extensively qualified and tested solution for the aforementioned reliability benchmarks.

**Electrical Performance**

One of the major difficulties that a system designer faces when choosing the best module is to find the delicate balance between performance, reliability and affordability. The difficulty of this task is amplified by a lack of standardized test conditions and measurement results, especially regarding some of the main parameters published in datasheets, such as power capability, efficiency and transient response.

When comparing efficiency, one has to take into consideration input voltage, output voltage and current level at the point where the efficiency is being compared. Transient response is another parameter that needs some analysis in order to have a valid comparison. One has to make sure that the input and the output voltages are identical, the output capacitors have the same values and similar parameters (ESR, ESL, etc.) and, finally, that the transient current steps applied are of the same magnitude and rate.

**Thermal Performance**

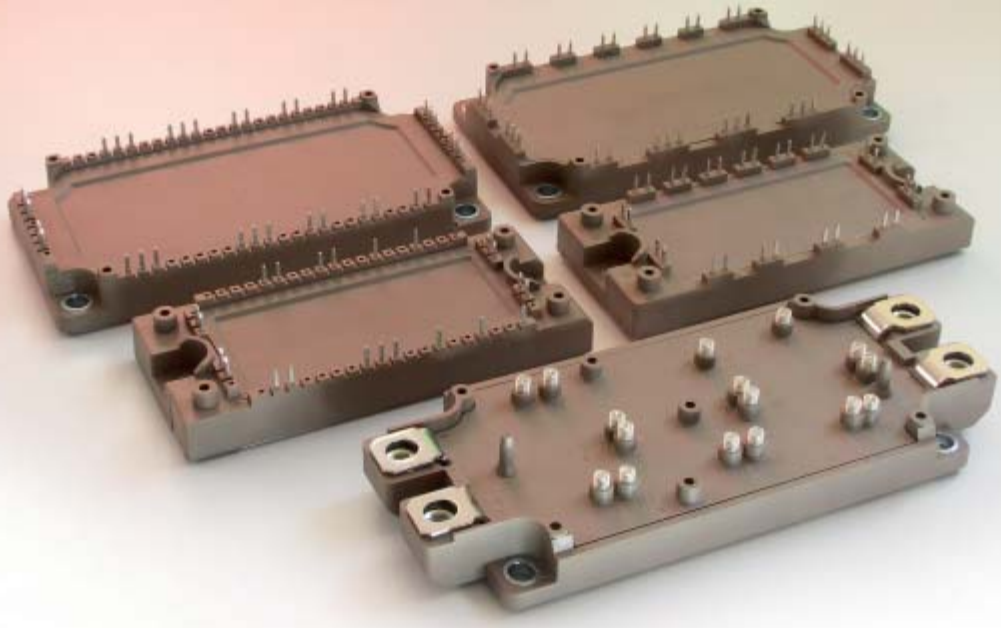
In many applications, power modules are required to operate in challenging environments. When comparing the power capability of a module, one should not only look at the electrical capability at 25°C but also consider the system ambient temperature, air flow and the method of heat transfer away from the module. For example the QFN package used in the ISL820xM series from Intersil is designed to offer an optimum heat transfer through the PCB so the large copper plate under the module will improve the overall power performance.

In conclusion, new, higher power density options are coming to market in the non-isolated point-of-load DC-DC converter space. The Intersil ISL8201M DC-DC module is one such example. It offers excellent efficiency and thermal performance in a compact 15x15mm QFN package. When evaluating DC-DC power modules for a specific application, care must be taken to fully examine the capabilities of the various options. The designer should go through the selection process by comparing their electrical and thermal performance, physical dimensions, and reliability specifications with the application requirements.

**www.intersil.com**

# The new IGBT Generation

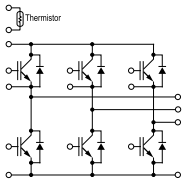
## with improved switching characteristics & thermal management

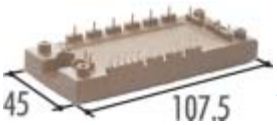


- V-series: New Trench-FS Structure
- Reduced turn-on $dV/dt$
- Lower spike voltage & oscillation
- Excellent turn-on $dIc/dt$ control by $R_G$
- Extended temperature range: $T_{j,\,max}$ = 175°C
- Extended package capacity

### 6-Pack IGBT

1200V



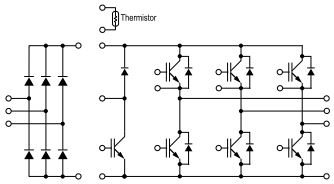



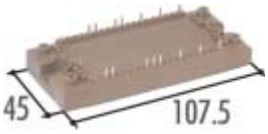

50A
75A
100A


100A
150A
**180A**

### PIM IGBT

1200V



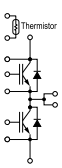




25A
35A
50A

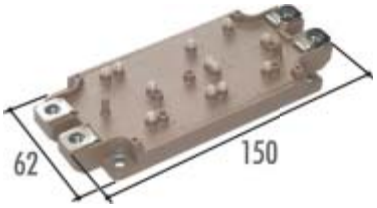

75A
100A
**150A**

### 2-Pack IGBT

1200V








225A
300A
450A
600A

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# The Application-Specific Power Semiconductors

## *All about IGBTs, Planar, Trench and Fieldstop*

*Application-specific IGBTs are taking a major change in direction like any other power devices and adopting distinct bifurcated approaches. The first pertains to innovations improving the silicon and process technologies to overcome the limitations of the current technology and the other approach is towards packaging and the driving of these devices. These IGBTs are targeted for induction heating (IH), motion control, uninterruptible power supplies(UPS), welding, steel cutting, switched mode power supplies (SMPS) and renewable energy (wind power & solar inverter) market,etc.*

*By Sampat Shekhawat and Bob Brockway, Fairchild Semiconductor*

The demand for electricity is increasing and at the same time, the cost of power generation is also going up. There is increasing pressure from governmental agencies to reduce the emission of harmful gases. This is forcing equipment designers to increase efficiency and performance. Governmental agencies will set new minimum efficiency limits. Just one IGBT technology is not suitable for all of the above applications. Each application needs to use its own application-specific IGBT. This is forcing device designers to design application-specific IGBTs. Each application needs its own unique topology variation. In all these topologies, device parameters play a vital role to improve circuit efficiency and performance. Fairchild Semiconductor provides application-specific IGBTs for many types applications.

**Introduction:**

The insulated gate bipolar transistor (IGBT), is one of the most commonly available advanced switching power device. This IGBT structure is very similar to that of MOSFET, as an IGBT is also a voltage-controlled device. One difference between these two devices is the starting material. The starting material for a MOSFET is N+ whereas for IGBT it is often P+. Generally the MOSFET has high resistive n-epi region so conduction losses are high. For IGBT the n-epi region is placed on P+ substrate forming a p-n junction where conductivity modulation takes place and conduction losses are reduced. This is shown as variable resistance $R_{DRIFT}$ in figure1. IGBT is available right from 300V voltage rating to several kilo-volts. The IGBT has high forward conduction current density and very low drive since it is a voltage-controlled device like a MOSFET. It has significantly superior characteristics for low and medium switching frequency and some of the Fairchild Semiconductor 300V & 600V IGBTs are even being used up to 100 kHz applications. Generally, a 600V IGBT has lower conduction losses compared to a 600V MOSFET at high current operating condition. The IGBT is an ambipolar, meaning both majority and minority carrier, device compared to a MOSFET which is a majority carrier device. The recombination of minority carriers at turn-off accounts for the current tail and increases turn-off losses. Due to this, there is a tradeoff between IGBT and MOSFET applications. Generally at low frequency the turn-off losses become less of an issue so it is better to choose a device that has lower conduction losses for applications such as motor drives, UPS, welding and low frequency PFC applications, etc. IGBT is ideal for these applications.

An IGBT is made up of thousands and thousands of small cells connected in parallel like a MOSFET. The equivalent circuit model of this cell is shown in Figure 1. This circuit consists of P-N-P and N-P-N bipolar transistor connected like a four layer parasitic thyristor. The N-P-N transistor is shunted by MOSFET structure. The resistance between MOSFET and base of the P-N-P transistor represents the N- drift region of IGBT. The shorting resistance Rsc shunts the base and emitter of the parasitic N-P-N transistor. This resistance is so small that the base-emitter junction of this transistor does not turn-on even when very high current flows through it. One can assume that for all practical purposes this N-P-N parasitic transistor remains inactive. When an IGBT is fully on the $V_{CE(SAT)}$ voltage across it is given by Equation 1. The drift resistance of IGBT is much less than MOSFET drift resistance because an IGBT is a conductivity-modulated device.

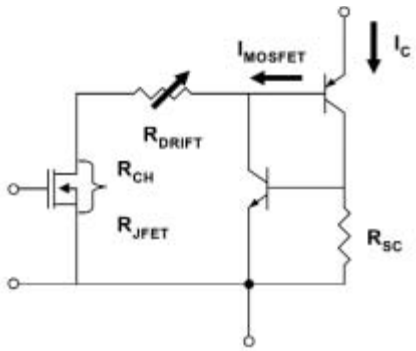


*Figure1: Equivalent circuit of IGBT*

$$Vcesat = V_{BE(pnp)} + I_{MOSFET}(R_{CH} + R_{JFET} + R_{DRIFT})$$

$$I_{MOSFET} = \frac{I_C}{h_{FE} + 1}$$

Fairchild's IGBT technologies have been optimized to reduce $V_{CE(SAT)}$. The trench gate eliminates the parasitic JFET resistance ($R_{JFET}$) of the MOSFET part of the structure. This results in reduced $V_{CE(SAT)}$. In case of field stop IGBT $R_{DRIFT}$ is reduced reducing

$V_{CE(SAT)}$. where as for trench field stop IGBT the JFET resistance is eliminated and also $R_{DRIFT}$ is reduced reducing $V_{CE(SAT)}$. The transconductance of the IGBT is very high compared to the MOSFET. This increases the short circuit current through the IGBT and one has to take action to protect IGBT under short circuit or fault conditions.

Basically, two types of planar IGBT exists, which are punch-through (PT) and non-punch-through (NPT). Both of them normally have similar top cell structures. The main difference between the two is in the vertical device structure as shown in figure 2.

The PT has a thick P+ substrate injector and an N-buffer layer that controls the injection in to the N- region (base of the PNP transistor). The switching speed and $V_{CE(SAT)}$. of this device is controlled by controlling the buffer charge (doping) and the minority carrier lifetime (~0.25us) in the N- region.

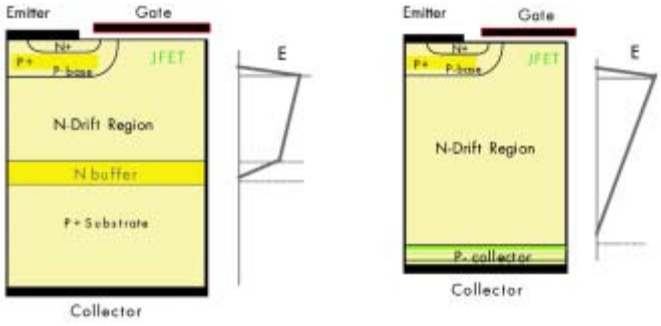


*Figure2: Planar IGBT cell configuration*

The NPT has no buffer and has a thicker N- region. The switching speed and $V_{CE(SAT)}$. of this device is controlled by controlling the injection efficiency of the P-emitter. This is done by making the P-emitter very shallow (<0.5um) and also by limited activation of the P-type atoms in the emitter. The NPT typically does not use lifetime control and hence the minority carrier life times in the N- region are quite long. No epitaxial process is needed where as PT IGBT needs an epitaxial process.

**Basic differences in characteristics with brief explanations:**

1. $V_{CE(SAT)}$. vs $E_{OFF}$ trade off: PT has better trade off due to thinner N- region.

2. $V_{CE(SAT)}$. temperature coefficient: NPT will always have a positive temperature coefficient. This is due to the lack of any lifetime killers resulting in long life times. So NPT is good for paralleling. PT may or may not have positive temperature coefficient depending on the type of lifetime killer used and also the absolute value of the lifetime. Typically, fast devices will have negative temperature coefficient and slow parts will have positive temperature coefficient.

3. $E_{OFF}$ vs. temperature: With increase in temperature there is a small increase in $E_{OFF}$ for NPT, since lifetime remains constant with temperature. For PT, Eoff increases rapidly (~2x from 25°C to 150°C) due to increase in lifetime with temperature. This effect is more pronounced on the fast PT parts.

4. $T_{FALL}$: NPT have high fall times due to the long tail current. This is because of the high lifetimes in the NPT. PT has extremely short fall times and therefore low $E_{OFF}$ losses. But in some cases, this may cause voltage and current ringing problems.

5. Eon vs. temperature: Remains almost constant for both.

6. UIS: NPT are inherently more rugged than PT for the same cell structure. This is because they have reasonable N- resistivities and have very thick N- layers. They normally have UIS capability close to that of a MOSFET. PT has poor UIS unless specifically designed for UIS. The UIS capability of PT devices decreases as you make them faster.

7. SCWT: NPT generally have better SCWT capability due to thicker N- layer. The extra thickness at the bottom adds resistance which helps in limiting the SC current. PT could be easily designed to have high SCWT by changing the top cell structure.

8. Both have JFET resistance.

Fairchild 300V, 450V and 600V SMPS IGBTs are the fastest IGBT available in the market for high frequency applications. Fairchild has recently released new planar field stop IGBT using almost similar cell structure as SMPS IGBT. Again two different types of these IGBT have been released. The switching energy versus on-state voltage drop trade-off curve for these IGBTs is the same. UF/D series planar field stop is for low frequency application where conduction loss has been reduced for moderate switching speed and soft switching IH applications. The other one is SF/D series planar field stop IGBT for high frequency applications where conduction loss has been compromised for low switching loss. This SF series IGBT can replace Fairchild SMPS IGBT and is good for high frequency hard-switching applications such as solar and UPS inverters, PFC and other SMPS topologies. Efficiency is one of the most important parameters for solar inverters. Increase in efficiency helps the cost of PV solar panels for same power output. SFD series being the fastest IGBT will improve efficiency of solar inverter.

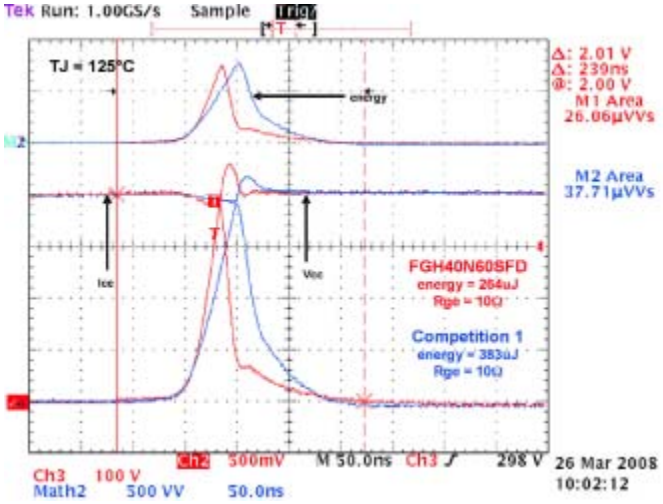


*Figure3: Turn-off switching energy comparison of SFD and next best Trench Field Stop IGBT at same gate resistance*

Fairchild 600V planar SFD version IGBT has been compared in Figure 3. In this case, the same gate resistance was used for both the IGBT and it is clear that both turn-off dv/dt and di/dt are faster for FSD-series IGBT and there is a big savings in turn-off energy when Fairchild's IGBT is used. The energy is the area under the top waveforms. At turn-off both the dv/dt and di/dt are faster, so both are helping in reducing turn-off energy. In this case turn-off energy was reduced above 30%. Again in Figure 4 these IGBT were compared at same turn-off dv/dt but different gate resistances. From this figure it is clear that SFD IGBT has low turn-off loss since its turn-off di/dt is faster. The selection of gate resistance is very important for dynamic performance of the IGBT. The switching dv/dt can be controlled by gate resistance depending on the application.

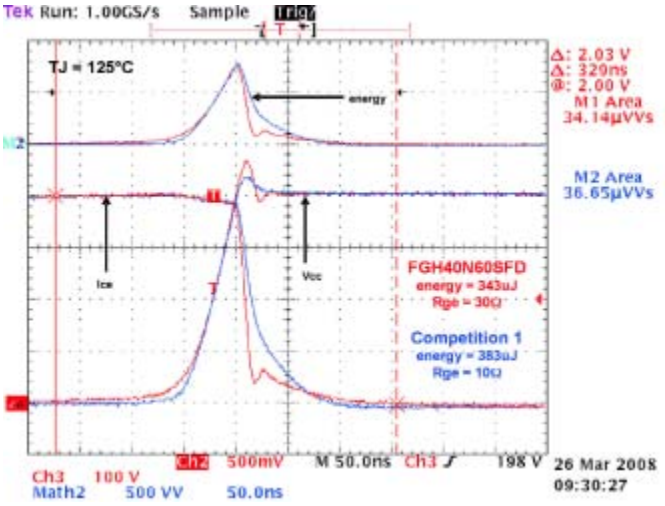


*Figure 4: Turn-off switching energy comparison of SFD and next best Trench Field Stop IGBT at same turn-off dv/dt*

Figure 5 shows another comparision of FGH40N60SFD against competition IKW30N60T at same gate resistance and Ice of 20A. The turn-off loss of FGH40N60SFD was measured against IKW30N60T, another low $V_{CE(SAT)}$ IGBT. The turn-off energy of FGH40N60SFD is 267 µJ whereas this turn-off energy for competition is 530µJ as shown in Figure 5. This means turn-off loss of FGH40N60SFD is 50% less compared to IKW30N60T Even though $V_{CE(SAT)}$ of FGH40N60SFD is higher than IKW30N60T the overall loss will be less for FGH40N60SFD and it will perform better at high frequency for solar and UPS inverters and mid frequency DC/DC converters such as welding customers. In all these applications the selection of free wheeling diode (co-pack) is very important to reduce turn-on loss as well as EMI. The free wheeling diodes for these IGBTs have been optimized for these applications. These Trr and Qrr of these diode has been reduced while at the same time the diodes are soft.

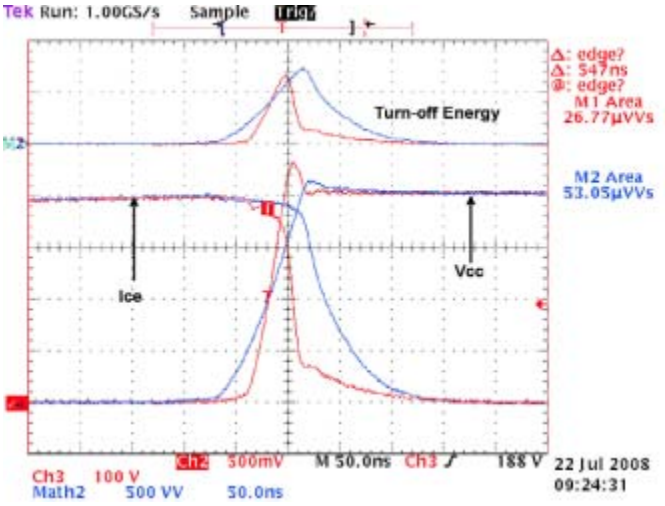


*Figure 5: Turn-off switching energy comparison of SFD and another competition trench FS IGBT at same Rg*

Motor drive applications preferably need different type of IGBT. This IGBT is preferred to have following key features:

- Low $V_{CE(SAT)}$ to reduce conduction loss
- Smooth turn-on and turn-off to reduce EMI
- Short-circuit rated preferably greater then 10 micro-seconds at least above 15 volts
- Lower transconductance will reduce short-circuit current and improve reliability
- Latch-up free operation with square RBSOA > Five to six times rated current
- Positive temperature co-efficient for $V_{CE(SAT)}$ for easy paralleling
- $V_{CE(SAT)}$ and turn-off loss tradeoffs should be optimized at frequency of interest.
- Low turn-on loss: Co-packed should have low Trr and Qrr with soft recovery.
- Moderate Miller capacitance: Low Qgd/Qgs ratio to avoid shoot through.
- VGE(th) >6V for better noise immunity and paralleling of IGBTs
- To reduce voltage stress on motor windings, the IGBT switching dv/dt should be <7KV/µsec.

For UPS and solar inverters the same key parameters are needed except switching speed has to be increased by compromising $V_{CE(SAT)}$. In some of these topologies the low frequency (fundamental frequency) operating leg needs very low $V_{CE(SAT)}$ IGBTs. Fairchild offers LSD series IGBT where $V_{CE(SAT)}$ has been reduced to low value by compromising switching speed. On the other hand in the same inverter topology some of the switches are operated at high frequency (modulating frequency). SFD series planar field stop IGBT has been optimized for high frequency application and when used in these topologies will improve efficiency.

Fairchild's present RUF/C3 600V series IGBTs are good for motor drive applications. In near future these IGBTs can be replaced by new planar field stop RUF series IGBTs under development. Fairchild new 600V planar field stop RUF IGBT will replace C-speed IGBT for most of the low frequency applications and also for motor drive applications too. These are 10 micro-second SCWT rated IGBT at 400V, $V_{GE}$=15V and $T_j$=1000C. At room temperature, SCWT will be 30~40uS. These three different IGBT on same trade-off curve will cover applications such as SMPS, UPS, solar inverters, welding and motor drive market.

**1200V IGBT**

Some applications need 1200V IGBTs. UPS and solar inverters are operated at high frequency to reduce filter size. Some of these inverter topologies are operated in such a way that short-circuit-rated IGBT are not needed. On the other hand, high performance motor drives need short circuit-rated IGBTs. The demand of solar inverters and UPS systems are growing at about 30% a year. IGBTs are the heart and soul of UPS systems and solar inverters. Efficiency of these inverters is very important. The cost of a solar cell is very high and if the solar inverter efficiency is low, it increases system cost to some extent. The datacenter market is the biggest market for UPS and is about $55 billion market. UPS system efficiency is very important for these data centers. The lower the efficiency, the greater will be the power losses and power costs and the lower the power density.

Power density and efficiency both are very important for inverters used in UPS and PV solar systems. High speed IGBTs that are specifically designed for inverters can increase efficiency of these inverters. Fairchild 1200V NPT II technology has been optimized for these applications. The turn-off loss and $V_{CE(SAT)}$ for this IGBT technology has been optimized to offer high efficiency by reducing turn-off energy. This presents an option to reduce heat sink size and cost while maintaining same output or more output power for same heat sink size. This can also help in increasing power density. These devices have become very popular for PV solar and UPS inverters. At higher bus voltage such as 600V and above, switching loss reduction is very important since it starts dominating over conduction losses at frequencies where these inverters are operated. The turn-off loss of this NPTII is about 40 µJ/A at 600V bus voltage and 125°C junction temperature. This makes this IGBT as the fastest 1200V IGBT in the market. The comparison of NPT II, NPT Trench and Field Stop Trench is given here. For most of the solar inverters and UPS inverters NPT II is best. The following table summarizes the 1200V NPT II, trench and field stop IGBT.

| Technology | $V_{CE(sat)}$ (V) @25°C | $V_{CE(sat)}$ (V) @125°C | $E_{off}$ (µJ/A) @25°C | $E_{off}$ (µJ/A) @125°C | SCWT (µs) @125°C | UIS (mJ) @25°C |
|---|---|---|---|---|---|---|
| NPT2 planar | 2.3 | 3.0 | 25 | 36 | >10 | >600 |
| NPT trench | 2.0 | 2.2 | 32 | 60 | <1 | >250 |
| Field stop trench | 1.7 | 2.0 | 81 | 130 | >10 | <5 |

*Table 1: Comparison of IGBT technologies*

For PV solar HV DC/DC applications where the bus voltage is above 600V and PS FB-ZVS DC/DC topology is chosen for high frequency isolation, this NPT II IGBT is very efficient. This also helps in improving power density. The NPT II IGBT (FGH40N120AN) turn-off loss has been reduced drastically over other 1200V IGBT including present Field Stop IGBT. The turn-off switching losses were reduced by 40-60% compared to previous generation IGBTs. Conduction losses were also reduced compared to MOSFETs and some other NPT IGBTs. NPT II is the most rugged 1200V IGBT available in the market since it has highest UIS & SCWT That makes it an excellent device for solar inverter market because these inverters have to have very high mean time between failures. This can be used for high power low frequency PFC where output bus voltage is about 800V volts.

**Trench NPT**

In order to reduce $V_{CE(SAT)}$ and turn-off loss NPT trench-gate IGBT were developed. This technology increases the operating current density and thereby reduces cost. The trench-gate technology has made it possible to improve trade-off curve or trade-off relationship between $V_{CE(SAT)}$ and turn-off energy. This is a maturing technology, with no epi, which lowers cost. However it is a thinner wafer, hence more breakage, which lowers yield and this also adds to cost. On the other hand, it has no life time control which reduces cost. There is a trade-off between $V_{CE(SAT)}$ and SCWT. No JFET resistance means Vcesat is reduced, so Eoff can be reduced by doing $V_{CE(SAT)}$ and Eoff trade-off.

- Maturing technology
- No epi lower cost
- Thinner wafer breakage lowers yield: cost adder
- No life time killing
- Trade-off between $V_{CE(SAT)}$ & SCWT
- NO JFET resistance
- Lower $V_{CE(SAT)}$ & $E_{OFF}$

**Field Stop Trench**

By implanting additional low doped field stop N layer, N– base thickness is reduced drastically while maintaining same breakdown voltage. The reduced N- base or drift layer reduces conduction losses. This further improves the trade-off relation between VCE(SAT) and turn-off energy. The current density also increases compared to trench-gate IGBT. Following are some other key points.

- Emerging technology
- Complex back side process
- No epi so it lowers the cost
- Thinner wafer so low yield
- High cost of processing but die size is reduced so cost can be managed.
- Life time killing is optional
- Trade-off between VCE(SAT) & SCWT
- NO JFET resistance and reduced epi resistance
- Best performance
- Low Vcesat like PT technology
- Low UIS
- Less paralleling is required because current density is increased
- Cell structure of trench IGBT and trench FS IGBT are shown in figure6.

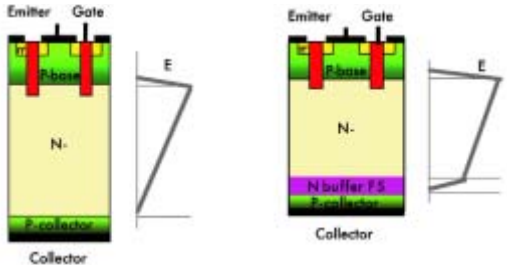


*Figure 6: Trench and Trench FS IGBT cell structure*

Fairchild's 1200V trench IGBT FGA20N120FTD is good and efficient IGBT for IH market where it has been optimized for soft switching. Under ZVS switching current bump at turn-off is reduced and at the same time Vcesat has been reduced.

Snappy co-pack diodes will increase the EMI in the circuit and also can destroy themselves as well as their co-pack IGBT switch in inverters (motor drive, UPS and solar inverter) during reverse recovery. The performance of P-i-N diodes has been continually improving as a result of new simulation tools to optimize structure. Maximizing operating frequency requires faster and faster diodes. In silicon technology, diodes have been optimized for different applications and these minority carrier silicon diodes are categorized as follows.

# Low $V_F$ with high $Q_{RR}$ and $T_{RR}$
# Moderate $V_F$ and moderate $T_{RR}$
# High $V_F$ and low $T_{RR}$
# Moderate $V_F$ but snappy diode

**Conclusion**

From above discussion, it is clear that one IGBT technology is not suited for all applications even though the name IGBT sounds very simple. For best performance, one has to choose right IGBT since each applications has different needs. To meet the need of the customers, Fairchild has developed different type of IGBT technologies for a wide range of applications.

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# Interview on Power Technology with Dan Kinzer, Senior VP of Analog, MOSFET, and Packaging Technology

*By Bodo Arlt, Editor BP*

**Bodo Arlt:** What end markets will drive power semiconductor technology?

**Dan Kinzer:** Power device technology is largely driven by the mobile, computing, communications, and industrial markets. Each market drives different portions of the entire range of devices. Mobile applications drive highly integrated solutions and very low voltage device technologies. Computing and communications drive low and medium voltage FET technology for DC-DC and high voltage FET technology for AC-DC. Industrial applications drive IGBT technology for higher power levels.
Each of these markets also drives power semiconductor packaging in different aspects. Mobile applications require ultra-thin, tiny pitch and small footprint packages such as MicroPak™ and MicroFET ™ as well as BGA and wafer-level CSP. Computing and communications require larger power packages with low resistance and better thermals such as the PQFN Power56 and Power33, as well as integrated System-in-Package products like DrMOS and Tiny Buck™. Industrial applications favor integrated solutions as well, such as Smart Power Modules (SPM™).

**Bodo Arlt:** How do you see Fairchild's market position?

**Dan Kinzer:** Fairchild is extremely well-positioned in the market. We are number one in power transistors in terms of market share, and we are generating advanced technology solutions faster than our competition. We have a great line-up of integrated solutions, which include world class applications and design know-how. Fairchild is the Power Franchise®, and we have solutions for the vast majority of power electronic system requirements. And in these power electronic systems, these solutions enable energy-efficient applications to meet existing or emerging energy efficiency specifications.

**BodoArlt:** What are the technologies that can offer innovation for leadership?

**Dan Kinzer:** There is quite a long list. Analog and mixed signal IC technology such as we have in high frequency DC-DC converters, analog switches, filters, transceivers, and serializers-deserializers for mobile applications; analog and digital controllers, drivers, FETs, and multi-chip assemblies for computing and communications; power factor correction(PFC) devices, primary side control ICs, integrated Fairchild Power Switches(FPS™) with advanced superjunction devices and hyperfast diodes, and synchronous rectification for high efficiency power supplies; Field Stop Trench and non-punch through (NPT) IGBTs, high voltage control ICs, and SPM devices for appliance and industrial brushless DC inverters for high efficiency motor applications. The list goes on and on.

**Bodo Arlt:** Is it more in silicon, or is it part of packaging technology?

**Dan Kinzer:** One cannot perform without the other, and both are fertile ground for innovation. Packaging innovation is the major enabler of overall system size reduction, and enables efficient heat transfer and interconnection to the system environment. On the other hand, ever-improving devices are continuously raising the bar for system efficiency. Both need to be combined with clever topology selection and control methodology to offer the best overall cost and performance.

**Bodo Arlt:** What makes Fairchild different from traditional discrete suppliers?

**Dan Kinzer:** I'm not sure what you mean by traditional. There are some suppliers who have never really advanced beyond the early days of power semiconductors, offering little other than outdated diode and transistor technology. Others attempt to follow the leaders and come up with similar technology to offer at low commodity prices. Still others attempt to offer value-added system solutions, but can only do this across a narrow spectrum of the power electronics industry and lack the manufacturing footprint to do this effectively. Fairchild has the latest technology across a wide application spectrum, and can provide complete solutions that fit the application requirement. Our combination of focus and scale allows us to offer the best products and the best value.

**Bodo Arlt:** How much is Fairchild involved in the end customer's application?

**Dan Kinzer:** That depends on the application. We think about all the aspects of our customer's application of our products, and about how our solutions affect their customers. If you consider a complicated end product such as an automobile, we think about specific aspects such as how our engine control or steering system products affect fuel economy, performance, and handling. With our display or audio products, we have to concern ourselves with the perception of the end user, eliminating distortion, flicker, unintended audible noise, etc. We need to offer convenience, reduced size and weight, energy efficiency, and reliable operation to all of our users.

**Bodo Arlt:** How much is Fairchild involved in motion applications using the advantage of IGBTs?

**Dan Kinzer:** We are quite involved. Motion is the top application for our Smart Power Modules. We are actively working on complete motion control solutions in powers ranging from less than 100W up to several kilowatts. This will include the motion control mixed signal ASIC as well as the high voltage drivers, fast recover rectifiers and IGBTs. In recent years, we have introduced multiple IGBT technologies, including Trench, non-punchthough (NPT), and a unique type of Field Stop IGBT. The new Fairchild IGBTs and rectifiers have the right combination of low on-state voltage, fast and soft switching, and short-circuit withstand capability to meet current and future 600V and 1200V design requirements. We will continue to enhance and optimize our designs for our appliance, HVAC, automotive, and industrial customers.

**Bodo Arlt:** What will be the target to introduce new power module products?

**Dan Kinzer:** We are continuously introducing new power modules, not just in motion but in power conversion, automotive, lighting, and display applications as well. The SPM family ranges in size from our new Power-SPM™ product FPP06R001 , a compact half bridge or synchronous rectifier with control and drive to the SPIM module, a full inverter power stage targeted at >5 KWatt applications. The modules are built in direct bonded copper (DBC), insulated metal substrate (IMS), ceramic, and fully encapsulated lead frame versions. We build applications understanding into all of our modules, with sense, diagnostic, and protection features and careful design to maximize system value. Each module design gives foremost consideration to effective thermal management, ruggedness, quality, and reliability.

**Bodo Arlt:** What will be the future for modules at high voltage and for driver technology?

**Dan Kinzer:** High voltage has different meanings to different applications. For utility and traction applications, it may mean 6.5KV. For us, high voltage means 600-1200V, with some solutions up to 1.7KV. The old style cap and fill modules with heavy baseplates that are standard in the industry today are gradually being replaced with lower profile, transfer molded types that are more convenient to use and much more cost-effective. Better encapsulation, interconnection, and die attach materials will greatly improve operating temperatures, power cycling capability, parasitic package inductance, and thermal resistance. The new modules will include drive, sense, and protection features, more often than not. In some cases, part or all of the control function will also be included.

**Bodo Arlt:** Do you expect to introduce monolithic solutions for power modules?

**Dan Kinzer:** Monolithic solutions are always limited in power by practical cost considerations. We offer highly cost-effective SiP module products for low voltage DC-DC and off-line AC-DC applications. These range up to 30A for 12V input DC-DC DriverMOS and up to 15A in stacked die assembly for universal line AC-DC. We also offer monolithic power and control solutions that range from WL-CSP buck regulators at 5V input and 2 Watts to TO220f green Fairchild Power Switches (green FPS™) at universal line input up to 16 Watts. In the future we will offer monolithic regulator ICs with integrated passives in tiny modules.

**Bodo Arlt:** Do you expect to see high voltage IC technology in the high voltage range?



**Dan Kinzer:** High voltage driver technology is gaining nearly universal acceptance at 600V, because of the design simplicity, availability of supply, and improving cost-effectiveness. 1200V and higher applications still predominantly use optical, transformer, capacitive, or other coupling methods together with low voltage drivers. Fairchild offers all these solutions. In the future, more designers will transition to high voltage ICs at 1200V, with the improved robustness and noise immunity these ICs can now offer.

**Bodo Arlt:** Who are your competitors, who you believe will stimulate the race for leadership?

**Dan Kinzer:** I don't want to bolster anyone's confidence or cause offense. Because of our size and breadth, we compete with every one of the power semiconductor and most of the analog players. You know who they are. Let me just say that there are many intelligent competitors that keep this field interesting, to the benefit of everyone.

**Bodo Arlt:** Are you ready for the future?

**Dan Kinzer:** If you mean personally, I have always tried to live wholeheartedly to accomplish things in the present that more rapidly achieve the vision I have for the future. This vision is one of abundant energy in all kinds of applications delivered ever more efficiently and cost-effectively with minimum unwanted environmental impact. I believe that Fairchild is very well-positioned to lead in delivering to that vision.

**Bodo Arlt:** Thank you Dan for your time and we look forward to a successful future for power semiconductors in discrete and modules.

**www.fairchildsemi.com**

# DSCs Bring DC Control to AC Induction Motors

*Using a digital signal controller (DSC) for field-oriented control (FOC) allows DC control techniques to be used to improve the performance of AC induction motors (ACIM).*

*In the real world, the motor selection process can be complex and the decision must balance the ease of control with other system-related variables such as the ease of maintenance, system response to failure, the operating environment, thermal management and cost.*

*By Steve Bowling, Application Segments Engineer at Microchip Technology, Inc.*

Synchronous DC motors dominate high-performance motor control because they are easy to control. This is especially true if the application requires controlled motor torque, velocity, or position. As the motor torque of a DC motor is an approximately linear function of the input current, it a relatively easy to derive solid performance out of a DC motor with proportional-integral-derivative (PID) controllers.

AC induction motors (ACIM) have distinct advantages over other types of motors and are used when applications need a robust, fixed-speed solution and the evolution of microcontrollers (MCU) and power electronic devices means inexpensive variable-speed control of an ACIM is a viable option.

Whilst ACIM cannot match the performance of DC motors using basic control methods, field-oriented control (FOC) using a digital signal controller (DSC) brings DC control techniques to AC motors and simplifies the motor-selection process.

**How a Motor Works**

An electric motor produces a mechanical force when current flows in proximity to a magnetic field. A synchronous motor has magnetic field source which can be provided by permanent magnets or by windings that are energised with a source of current. Within limits, the torque response of the motor is a linear function of the current and the magnetic field strength. The linear response makes these motors easy to control in high-performance applications. A PID controller can be used to control the motor current and the resulting motor torque. If needed, secondary PID controllers can be used to control position or velocity.

Whilst synchronous motors with field windings or permanent magnets provide good control the motor selection process is more complex than control alone. Using a motor with rotor and stator windings can deliver high power but would mean replacing brushes and keeping the rotor cool. Using a brushless motor with permanent magnets could be an alternative, but the cost of the magnets could be prohibitive.

**AC Induction Motors**

ACIMs eliminate the disadvantages associated with synchronous motors because the ACIM has windings on the outside of the motor, which makes it easy to provide cooling. The rotor is a simple steel cage which is both durable and able to withstand high temperatures, and the ACIM has no brushes to wear out.

Since AC power is widely available, the ACIM is usually designed for a specific line voltage and frequency. As an example, the plate on the side of an ACIM could show that it is rated for the following performance parameters: voltage of 230V AC, frequency of 60 HZ. full load amperes (FLA) of 1.4 A, 1/3 horse-power (HP) and 3450 revolutions per minute (RPM).

The stator windings of the motor are arranged so that a rotating magnetic field is created when energised with AC currents. The rotor of an ACIM must turn at a lower speed than the rotating field. The difference between the field speed and the rotor speed is called slip. Slip can be expressed as a ratio or a frequency, but it is helpful to consider the slip frequency. For the motor in the example above, the rotating field speed would be 60 rev/s, or 3,600 RPM whilst the stated RPM under load is only 3,450 RPM, or 57.5 rev/s. The slip frequency therefore is 60 Hz – 57.5 Hz, or 2.5 Hz.

In this example, the 2.5 Hz slip frequency can be considered as a source of AC power that supplies energy to the rotor via transformer coupling. The rotor becomes energised with AC currents that produce a rotor magnetic field, allowing the motor to produce torque. The ACIM slip gives the motor the ability, to some extent, to self-regulate its own speed. As the motor load is increased, the rotor speed will decrease. The slip frequency will then increase which, in turn, increases the rotor currents and the motor torque.

**Variable-Speed ACIM Control**

An ACIM can be operated at different speeds and torque levels by varying the frequency and voltage supplied to the motor. Supposing that the example motor needed to operate at half the rated speed. To accomplish this, the frequency input to the motor would need to be reduced to one half, or 30 Hz. To operate the motor at one quarter speed, the frequency would need to be reduced to 15 Hz.

The stator field also needs to be maintained at a relatively constant level by keeping the stator currents constant. The ACIM motor is inductive and the stator currents will increase as the input frequency is decreased. Therefore, the input voltage needs to be reduced by a proportionate amount when the frequency is decreased. A constant V/Hz profile is often used to provide variable-speed operation of an ACIM. The V/Hz constant for the motor in the example above can be calculated by dividing the

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operating frequency into the operating voltage:

K = V/Hz = 230/60 = 3.83

Therefore, required drive voltage can be calculated for the required input frequency:

Voltage = K* Frequency

The result is called the Volts-Hertz profile and can be plotted as shown in Figure 1. There is no fixed rule that says the drive voltage has to maintain a fixed linear relationship to frequency. In fact, the shape of the V/Hz profile is often altered in specific frequency ranges to optimise the drive performance in a particular speed range. For example, the shape of the profile shown in Figure 1 has been adjusted to provide higher voltages in the low frequency range. This modification provides a boost to the motor torque when the motor starts from rest to help overcome load friction and inertia. Within the mechanical limits of the motor, the drive frequency can also be increased beyond the stated value to achieve a higher speed. However, the available voltage may be limited, so motor torque will also be lower.

For applications that do not require frequent speed or load variations, the V/Hz method of ACIM control works well. This is especially true when control loops are used to regulate speed or motor current. A typical system block diagram that can be used for a V/Hz application is shown in Figure 2. The PIC® microcontroller used in this circuit has a specialised PWM peripheral to drive a 6-transistor inverter circuit. The MCU measures the frequency of the motor tachometer, calculates the speed error, and generates a drive demand using a PID control loop. The drive demand is translated into a required voltage and frequency using the V/Hz profile. Finally, the PWM modulation code varies the duty cycle over time to generate sinusoidal drive signals with the proper amplitude and frequency.

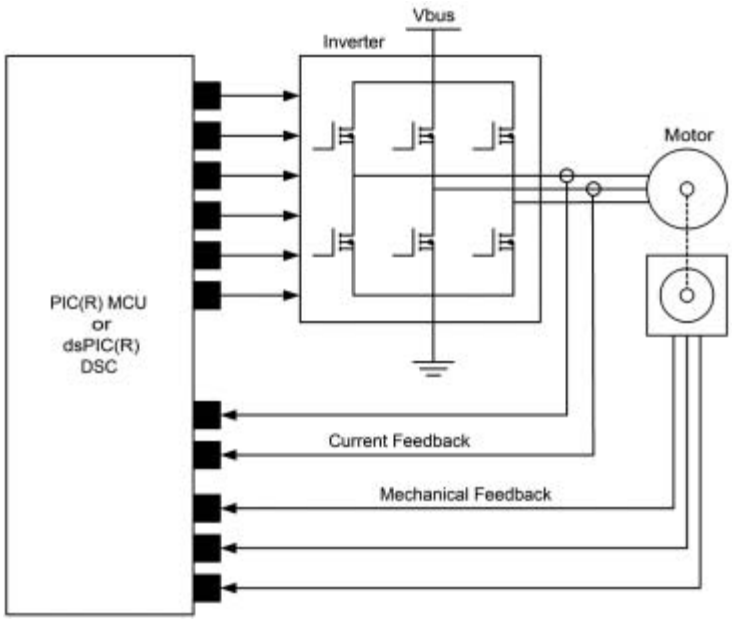


*Figure 2: Typical system block diagram used for variable-speed ACIM control*

The response provided by the V/Hz control method will be too sluggish for applications that require a fast dynamic response and, furthermore, the motor currents will be very high during load or speed changes. The sluggish response occurs because the components of the stator current that control motor torque and the rotor field cannot be separated. A change in drive voltage or frequency will cause a change in both torque and rotor currents.

Ideally, the algorithm should control motor torque independently of other motor variables, and the FOC algorithm accomplishes this goal. Whilst the V/Hz method controls the speed, it does not does not control the phase, whereas FOC controls the voltage, frequency and instantaneous phase of the motor voltage to produce the desired stator currents. This delivers the best motor efficiency and dynamic response for a given application.

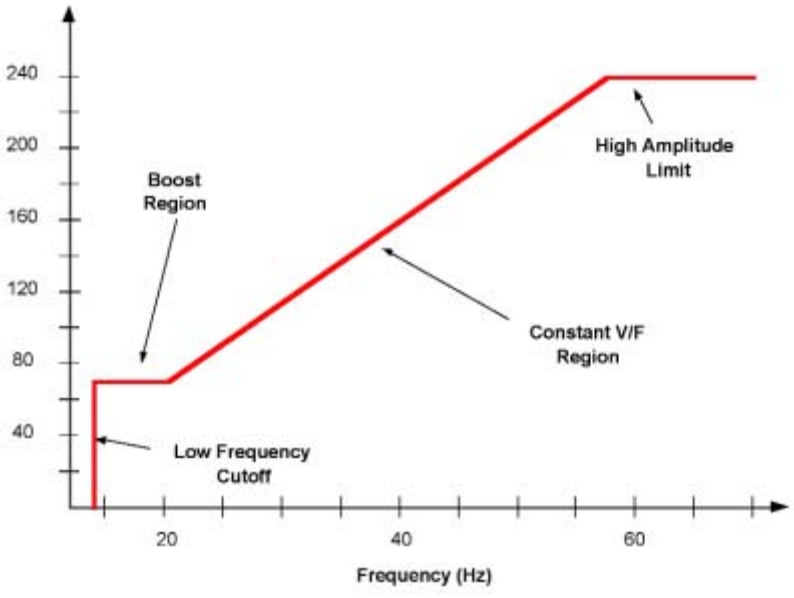


*Figure 1: Typical V/Hz Profile for a Variable Speed ACIM Application*

**FOC - A matter of perspective**

If the motor is observed electrically from the perspective of the input terminals, all signals inside the motor will appear sinusoidal. Sinusoidal signals can be difficult to process in software, especially if PID controllers are used to regulate motor currents. However, by changing the point of reference used in the calculations, the signals inside the AC motor can be made to look mathematically like DC values under steady-state conditions.

Specifically, FOC measures the AC motor currents. In a stationary reference plane, the 3-phase stator currents can be combined to form a single rotating current vector in time. Instead of using a stationary reference, a rotating reference plane that turns synchronously with the motor can be used. With the rotating reference plane, steady-state AC quantities look stationary.

A race-track provides a useful analogy: Imagine standing on the side of a circular car-race track. From a stationary perspective, all of the cars seem to be moving around the track at a very high speed making it hard to see which car is winning the race because the pack of cars goes by so quickly.

Now, instead of watching the cars from the side of the track, imagine driving next to the lead car. From this perspective, the pack of cars becomes more or less stationary. The only thing that changes over time is the relative position of all the other cars to the lead position, which is the moving reference point. The actual speed of the cars moving around the track becomes irrelevant.

To apply this analogy to the motor, the speed of the cars moving around the track is comparable to the motor drive frequency. The relative position of the cars is comparable to the phase of the stator current vector.

**FOC coordinate system transformations**
FOC uses a pair of conversions called the Clarke and Park Transforms to get from the stationary reference plane to the rotating reference plane. First, two of the three phase currents are measured. The value of the third phase current does not need to be known or measured because the sum of the 3-phase currents should be 0. The measured currents represent the vector components of the current in a 3-axis coordinate system with each axis separated by 120 degrees.

It is easier to represent the rotating current vector in a 2-axis orthogonal coordinate system, so the Clarke Transform just converts the measured currents so that the current vector is represented with two vector components instead of three. The two vector components calculated using the Clarke Transform still vary with time.

**Clarke Transform Equations:**
$I\alpha = Ia$
$I\beta = 0.577(Ia + 2Ib)$

Next, the Park Transform is used to rotate the 2-axis coordinate system so that is aligned with the rotating motor:

**Park Transform Equations**
$Id = I\alpha*\cos\theta + I\beta*\sin\theta$
$Iq = -I\alpha*\cos\theta + I\beta*\sin\theta$

The rotation angle is represented by $\theta$. When using FOC for a synchronous 3-phase motor, the rotating reference plane would always be aligned with the rotor and $\theta$ could be obtained directly from the rotor position using a sensor. However, an ACIM is an asynchronous machine that requires slip to operate.

One method that can be used to calculate $\theta$ is to use equations that model the rotor currents. The rotor-current model calculates the required slip frequency from the measured stator currents. The rotor-current model also requires knowledge of the rotor resistance and inductance. These values form a time constant that adjusts the motor slip to the correct value during transient current events. After a slip frequency has been calculated, a value of q can be calculated using the rotor velocity, which will align the reference plane ahead of the rotor to provide the slip. So, the rotating reference plane is aligned with the applied stator current vector, which spins faster than the rotor.

**DC Current ?**
The key to FOC is that the Clarke and Park transformations provide DC representations of the stator phase currents under steady state conditions. But, the motor current is really an AC signal represented as a rotating current vector and it is only because the coordinate system is synchronously rotating with the current vector that the transformed current components appear as DC values. If the value of either current component changes over time, this means that the amplitude and phase of the motor current vector has changed.

Most importantly, one component of the transformed stator current vector determines the amount of motor torque. The other component determines the rotor field. With FOC, the component of current responsible for motor torque can be isolated and controlled separately. This is why FOC lets an AC motor be controlled like a DC motor. Figure 3 shows a time history of the transformed torque current component, taken from an actual FOC application during a 2x speed increase. This is the signal that the FOC algorithm sees, instead of the AC current signal that was measured at the motor terminals. This signal represents the current required to accelerate the motor to the new speed.

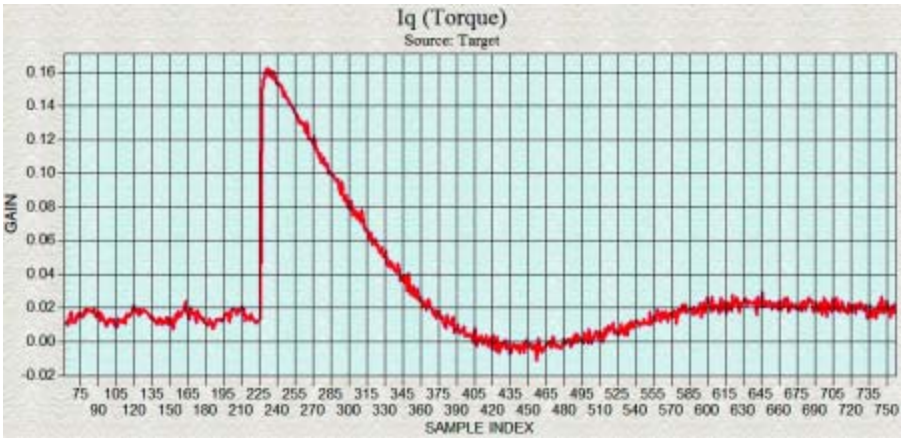


*Figure 3: Time history of the transformed stator current component representing motor torque during a 2X motor speed change*

**The FOC Control Loops**
In practice, the two transformed current components are separately regulated using PID controllers in software. The outputs of the two PID controllers provide two voltage vector components that determine how the motor phases need to be energised to produce the desired stator currents. The reference input for one PID controller is set to a constant value so that the rotor will generate a constant field. The reference input to the other PID controller determines the amount of motor torque. The reference torque level is usually supplied from a third PID control loop that regulates the motor speed.

The last step in the FOC process is to unwind the voltage vector components that were generated in the rotating reference plane. The value of q that was calculated in the rotor current model equations is used, along with inverse Clarke and Park Transforms which are very similar to the forward transforms shown above.

**FOC Summary**
FOC controls the amplitude, frequency and phase of the voltage vector to produce the desired amplitude, frequency and phase of the motor currents, and offers the best efficiency and dynamic response from an ACIM.

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# Ultrasonic Metal Welding

## *A new robust and reliable contact for the next generation of power modules*

*For the ever-growing market of applications with its state-of-the-art compact and efficient inverters, an optimised and reliable system with power semiconductors is needed. As a result of more and more compact inverter designs power module packaging is striving for higher power, density and increased operation temperatures. Robustness and reliability is coming more and more into the focus.*

*By Wilhelm Rusche, Roman Tschirbs, Infineon Technologies AG*

IGBTs and their Power Cycling (PC) capability have improved a lot during the last decade [1, 2, 3]. The upcoming challenges in modern power module design will be a further increase of the operating temperatures with further comprehensively increased lifetime of the complete power module. Among other things one aim to achieve is a robust and highly reliable power contact technology within the power module.

The most commonly used technology today is soft soldering, which is one of the first metal joining inventions made by mankind. For power modules, soft soldering and the related processes have been continuous improved since around 1975.

In 1962, ultrasonic energy was used by the founders of Orthodyne Electronic to form interconnections by wire loops [4]. Since than, aluminum wire bonding was widely used for contacting silicon dies and power connections. Similar to soft soldering, wire bonding requires additional material (like solder or wire) through which the electric current is passed to a power connection leading to the external surface of the housing. Various technical solutions have been presented - one representative is Infineon's Econo DUAL™ 3 (see Fig. 1).

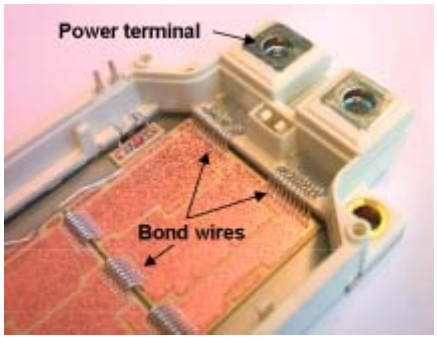


*Figure 1: Wire bonding connections from DBC to DBC and from DBC substrate to power terminal driven by the ongoing increase of the power density of silicon dies combined with rising junction operating temperatures $T_{vjop}$ [1, 2, 3], engineers strive for other joining technologies*

What is the next step to archive the future requirements of interconnection technologies?

**US-welded joints as Substance-to-substance bonds**

One promising candidate is ultrasonic metal welding for the internal contact within power modules.

Ultrasonic (US) welding is a kind of large-scale bonding. A welding tool induces ultrasonic energy and pressure on the movable joining partner. No consumables like solder or bond wire are needed. Even plating or additional cleaning is not required, therefore US welding bare copper is the best possible technology from environmental point of view. By US welding of two identical partners i.e. copper, one gets a true metallurgical bond with the highest possible conductivity connection. As both partners have the same Coefficient of Thermal Expansion (CTE), no delamination of the joint itself has to be expected.

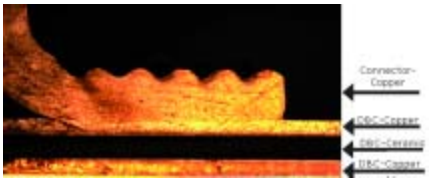

*Figure 2: Cross section through US-welded terminal*

**US-welded joints in high current applications**

In high current applications, the limitations of aluminum bond wires become obvious. Paralleling multiple wires is needed to manage the temperature as a result of the current density (see Fig. 1). To illustrate the electro-thermal advantages of ultrasonic welded contacts compared to commonly used wire bond technology, numerical simulations have been carried out on the basis of the material parameters for a power terminal similar to that shown in Fig. 1. Also, temperature dependencies are considered.

The used boundary conditions are set equally for every simulation run at 100°C for the upper DBC-layer and 110°C at the external bus bar contact area.

The chosen constant DC current of 400 Amps leads to a maximum temperature exceeding 200°C in the setup with aluminium bond wires (see Fig. 3).

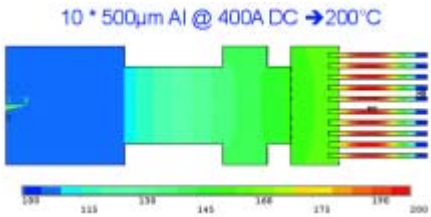


*Figure 3: Simulated temperature equilibrium with aluminum bond wires*

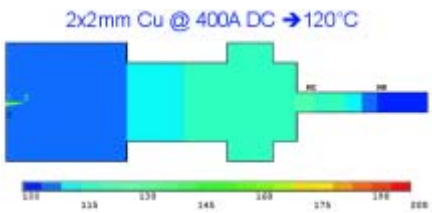


*Figure 4: Simulated temperature equilibrium with US-welded terminal*

Simulating a setup with US-welded contacts, the maximum temperature is lowered to 120°C (see Fig. 4).

This boundary condition leads to a possible increase of terminal current of 62% with lowered terminal temperatures of 31%. These values impressively show the opportunities of US metal welded terminals by reducing the resistive losses in high current power modules.
Soldered connections show similar capabilities due to the negligible thickness of the solder layer and the equivalent contact surface area.

**Investigation on reliability of ultrasonically welded joints**
Fatigue life affecting main factors are the magnitude of stress (geometric design), surface conditioning, material grain size and operating temperature. Due to the ten times higher fatigue strength of copper, even more mechanical robustness can be designed into module packages.
Reliability under vibration load is getting more into focus, not just for transportation applications. Vibrations within the inverter may also be a result of the mounting place and the mounting conditions.
Beside other more application related tests, accelerated life cycle test according to IEC 60068-2-64 are done with US-welded copper-to-copper joints to determine the abilities to withstand specified severities of broadband random vibration. The standard originally applies to specimens that may be subjected to vibration of a stochastic nature by transportation or operational environments, for example in aircraft, space vehicles or land vehicles. The accelerated profile applies 94 h of random vibration in a frequency range between 10 and 2000 Hz at an r.m.s. acceleration of 177 m/s², which is 18 times the acceleration of gravity and three times the acceleration of a manned space-flight launch.

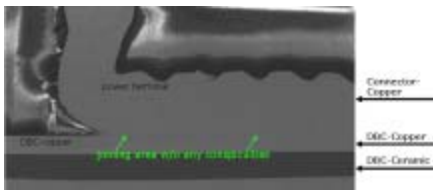


*Figure 5: SEM picture w/o sign of cracks after accelerated lifetime test with random vibration load*

The highly accelerated test produced no failure in the US-welded joint. The quality of all the 24 joints of the test vehicle (Fig. 6.) is investigated by scanning electron microscopy (SEM) where no conspicuities were detected. One of the 24 joints is exemplary shown in Fig. 5.

**Thermal Shock Test (TST)**
Special focus is set on thermal shock stress as the second important lifetime limiting factor.
The applied temperature has been changed between Tmin=-40°C and Tmax=125°C. The left part of Fig. 6 shows the test vehicle. Ultrasonic microscopy (USM) is used to assess the quality of the connection technology before and after the test. The b/w picture on the right side shows the USM analysis after 100 cycles. No delamination of the US welded joint is visible.


*Figure 6: US-welded structures; USM pictures after 100 cycles TST*

This setup as well as others was also assessed by correlation of contact resistance with the result that no change in contact resistance could be observed.

As a summary of all the tests one can say that US-welded terminals show no sign of fatigue in the joint.

**Transfer to a real product - EconoPACK™4**
Summarizing the preceding benefits, the integration of the ultrasonic welding technology into the new package EconoPACK™4 (see Fig. 7) has been started.
The EconoPACK™ 4 is based on the well-known Econo housing principle [5] which is characterized by its flat geometry. Power terminals up to 200Arms are realized within the module by US welding. The auxiliary terminals are also US-welded.

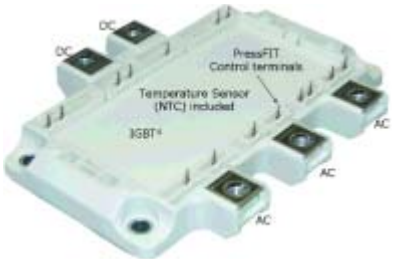


*Figure 7: EconoPACK™ 4*

The consequent implementation of US welding in combination with an “in-frame-bus bar” provides significantly low parasitic stray inductance which is essential to utilize the full advantages of the state of the art silicon devices, the Infineon’s IGBT4 and Emitter Controlled 4 Diode [1, 2, 3].

The innovative designs also takes care of the inverter system costs by providing reliable and solder less press in contact with PressFIT [6] auxiliary terminals. The PressFIT contacts also provide the flexibility for a solder process, if required by the user. The next step with a higher integration level of the EconoPACK™4 is already started with the MIPAQ™serve module. The MIPAQ™ serve provides all the advantages of the EconoPACK™4 in addition with an adapted optimized and galvanically isolated driver electronic on top.

New products like EconoPACK™4, MIPAQ™serve, PrimePACK™ and the future IHM-B share the US welding technology and all these products are well prepared for the next future trends.

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# UV-Active Silicone Elastomers: Fast, Flexible and Cost-Effective

## *UV systems offer very short curing times, maximum processing flexibility, and almost unlimited pot lives*

*A new generation of UV-active silicones enables manufacturers to encapsulate electronic components faster and more economically. This benefits many applications in automotive and power electronics, as well as in sensor technology.*

*By Peter Jerschow and Markus Jandke, WACKER SILICONES, Germany*

High-performance electronics are vital to the increasing pace of technological change in the communications sector. Quality and precision, short innovation cycles and a high savings potential are key features of technological progress in microelectronics. The number of electronic control units used, for example, in automotive electronics, sensor technology and industrial process control, is increasing significantly. Whether for business or private applications – reliability is the key to success.

To resist environmental impact, the ever smaller and increasingly powerful electronic components must be reliably and securely protected – from moisture, dirt and chemicals, as well as from thermal and mechanical stress. Thus, the key to a long working life for electronic components is professional sealing. This requires the components that need protection to be suitably encapsulated.

**UV Silicones: Completely New Processing Properties**

WACKER's SEMICOSIL® range supplies the industry with addition-curing silicone elastomers that vulcanize at room and elevated temperature, and have a wide range of mechanical and rheological properties.

Building on this, the Munich-based chemicals company has succeeded in developing UV-active silicones with entirely new processing properties. These silicones are easy-to-handle and fast-processing one- and two-component systems based on polyorganosiloxanes. They feature long shelf lives and can be stored for over six months in light-excluding, tightly closed containers. Furthermore, they are harmless have a low order of toxicity and do not produce by-products on curing. These properties are particularly interesting for automotive and power electronics, where mass production is involved (Figs. 1 + 2).

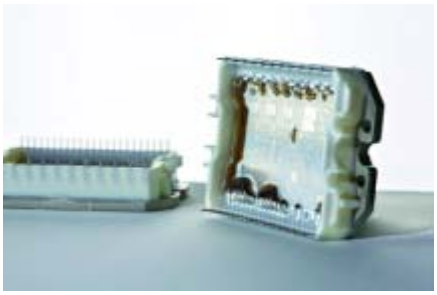

*Figure 1 and 2: Using UV-active silicone gel from WACKER SILICONES to encapsulate an electronic component.*

Until now, UV-curing epoxy- or acrylate-based polymers were used to protect electronic components. These potting compounds are easily processed and cure rapidly, allowing short cycle times. However, in both cases, curing requires the addition of photoinitiators – based on cationic systems for epoxides, and on free-radical systems for acrylates. They leave either ions or free-radical decomposition products in the material, and this can considerably impair the quality, especially in electronic applications. Inhibition by oxygen, which is common for acrylate systems, also doesn't occur with the novel UV systems.

**Curing by Means of a Special Catalyst**

These drawbacks need not be feared when UV-active silicones are used, since theythe they cure without the need for photoinitiators. Instead, the process relies on addition-curing: polymer chains bind to the hydrogen-containing crosslinker via the hydrosilylation of vinyl groups, with the aid of a noble metal catalyst. The crosslinking is activated solely by exposure to UV light. (Figs. 3 + 4)

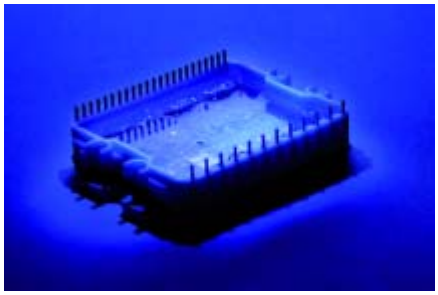

*Figure 3: An electronic component encapsulated with SEMICOSIL® UV. Addition-curing is activated by UV light and completed in a matter of seconds. This rapid curing enables short cycle times and higher processing productivity.*

*Figure 4: With the aid of a special UV-exposure chamber, WACKER engineers in Burghausen can test the novel UV silicone gels' properties, such as rapid curing and variable control of curing times.*

SEMICOSIL® UV has typical silicone properties: excellent stability at - 50 to + 200 °C, outstanding resistance to weathering, radiation and chemicals, as well as superb water repellency. Silicones have dielectric properties that remain almost constant over a wide temperature and frequency range, are of low environmental impact and have a low elasticity modulus. The latter counteracts thermal stress caused by temperature fluctuations. Thus, a low elasticity modulus provides additional protection for sensitive electronic components, which are prone to be damaged by these kinds of forces.

**Shorter Production Cycle Times**

For the first time, and unlike conventional addition-curing two-component silicone compounds, UV-active silicones can drastically shorten production cycle times without the need to observe processing windows and pot lives. This is illustrated in the following component manufacture example:

SEMICOSIL® UV SAVES TIME AND PROCESS COSTS FOR ENCAPSULATING ELECTRONIC POWER COMPONENTS

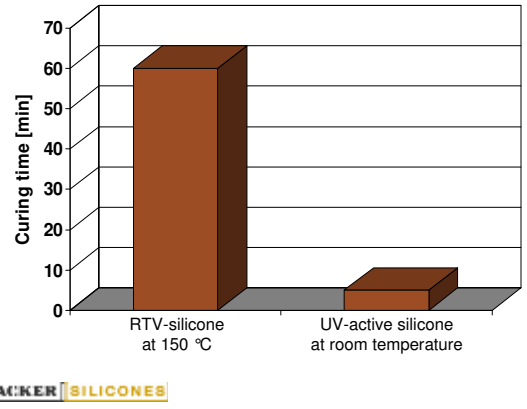


*Figure 5: SEMICOSIL® UV cures much faster at room temperature than conventional potting compounds. This increases productivity and reduces process costs. Thus, SEMICOSIL® UV is ideal for mass production.*

Encapsulating electronic components with conventional silicone used to involve two batch processes requiring 30 minutes oven curing at 150 °C. UV-active silicones can significantly increase the efficiency of this production process. The components are exposed to UV light for five seconds – the silicone rubber is fully cured five minutes later. For the manufacturer this means shorter cycle times of nine seconds, compared to the former 30 minutes (Fig. 5). But that's not all: thanks to the extremely fast curing, the production process now runs continuously, without interruption. This allows significantly increased productivity in production capacity and throughput.

**Customized Manufacture**

The multitude of advantages is by no means exhausted yet. Another important aspect of UV silicones is that they are easily adapted to customers' production requirements. Curing times range from a few seconds to several minutes, depending on the silicone grade and UV dose. This gives processors maximum flexibility (Fig. 6).

Combined with the proven SEMICOSIL® technology, UV-active silicones cover a variety of material properties. Provided that the filler is UV-transparent, filled systems, for example, can be realized. Compact layers, up to several centimeters thick, are possible as well. This is especially important for potting applications. Since curing occurs at room temperature, expensive and time-consuming oven processes are eliminated. Unlike "dual-cure" products, curing is also considerably more uniform, since there is only one curing mechanism.

NOVEL UV-ACTIVE SILICONE TECHNOLOGY
SHORT CURING TIMES AT ROOM TEMPERATURE

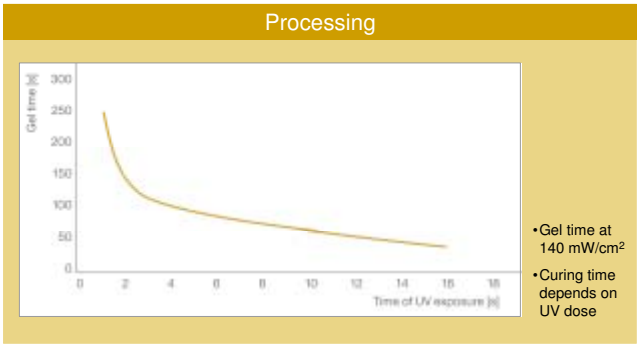


*Figure 6: Curing of SEMICOSIL® UV depends on the UV dose. It can thus be readily adapted to the process parameters.*

Last but not least, UV-active silicones' energy-saving potential should not be underestimated. Unlike HTV silicones, SEMICOSIL® UV also cures at room temperature. This saves a lot of energy, especially in processing large components. The curing process can be further accelerated by a minimal temperature increase, but room temperature is fully sufficient for most applications – a property that is not just appreciated by suppliers to the automotive industry.

**Summary**

Important future markets are accessible with UV-active silicones. This particularly applies to sensor technology, which is always receiving new impetus from the automotive technology sector. Compared to conventional addition-curing systems, UV systems offer very short curing times, maximum processing flexibility, and almost unlimited pot lives. These properties offer significant processing, productivity and cost benefits for manufacturers of electronic and photovoltaic components.

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# Highly Reliable Optocouplers

## *High Temperature Automotive Applications*

*The needs for new isolation devices for automotive applications are rapidly expanding, most notable with the adoption of hybrid vehicle technologies.*

*By Patrick Sullivan, Leong Yik Loong, Andy Poh from Avago Technologies*

Although Avago´s automotive optocouplers are quite a new market addition, in reality Avago´s optocouplers have been successfully used in hybrid automotive projects for more than ten years, albeit in the form of industrial grade products.

However in today's market, it is no longer sufficient to address all emerging automotive isolation applications with industrial grade products, in particular applications requiring reliable long term operation at high ambient temperatures up to 125°C (Figure 1).

Of course there are already well proven hermetic optocoupler products for use in aeronautical and space readily able to meet these high temperature requirements, unfortunately these are not often able to meet automotive price expectations.

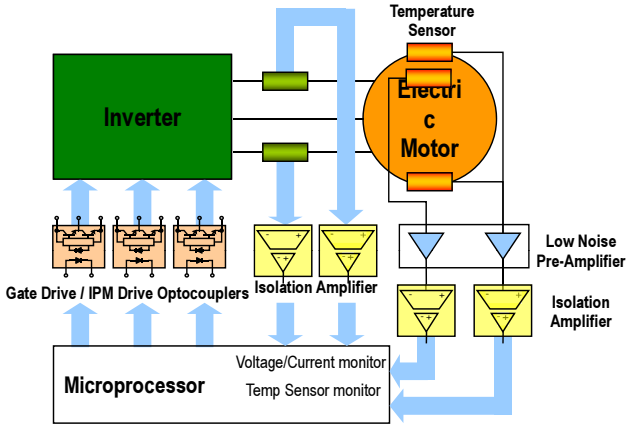



*Figure 1: HEV Electric Motor Drive System*

**Optocoupler Technology**

The primary piece parts of an optocoupler consist of a photodetector IC and an LED (Figure 2).

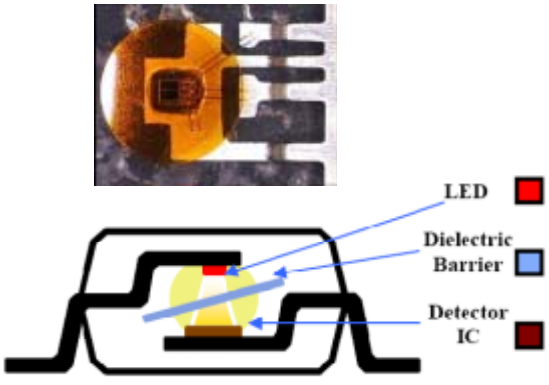



*Figure 2: Optocoupler Construction*

In practice the photodetector IC can sometimes be re-qualified for high temperature automotive use with little or no design changes. The LED however requires more careful consideration. Some technological competitors or even customers might express concern or prejudice against the use of optocoupler LEDs at such high ambient temperatures.

To be fair some of this opinion has at least some grounding, in that LEDs have the potential to suffer from significant light output degradation and aging when operated at high ambient temperatures. But the key operative word here is: potential.

Since the advent of the LED, continuous and rapid development in LED design and processing (see Figure 3) has resulted in a massive divergence in the intrinsic aging and temperature drift performance of LEDs used in optocouplers.

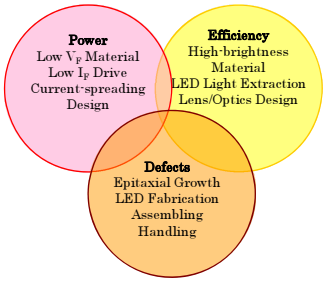



*Figure 3: LED Design and Process Improvements*

In terms of delivering a high quality optocoupler LED, there are two important criteria, the LED design and the manufacturing process. In this regard, in-house III/V R&D and manufacturing capabilities can provide a significant technical advantages when designing and manufacturing LEDs for innovative next generation optocoupler products.

Avago´s latest generation of automotive grade optocoupler LEDs benefit from a number of product enhancements in the areas of:

1. Higher internal quantum efficiency
2. Lower forward voltage
3. Enhanced current spreading design

These product enhancements not only have a direct influence on the intrinsic properties of the LED, they also facilitate secondary benefits e.g reducing the input If current requirement, in turn reducing the internal power dissipation and subsequent junction temperature.

**LED Operating Lifetime**

The combination of the product improvement factors results in the reliability performance shown in Figure 4.

There are no fixed rules for translating this data into an automotive mission lifetime expectation.

However if we take 2K hours as a bench mark, it is interesting to note that the overall current transfer efficiency of the automotive optocoupler remains remarkably unchanged.

The next point of note, is that this data was obtained from LEDs manufactured from a range of wafer lots, so this extremely tight distribution is indicative of a very well controlled manufacturing process.

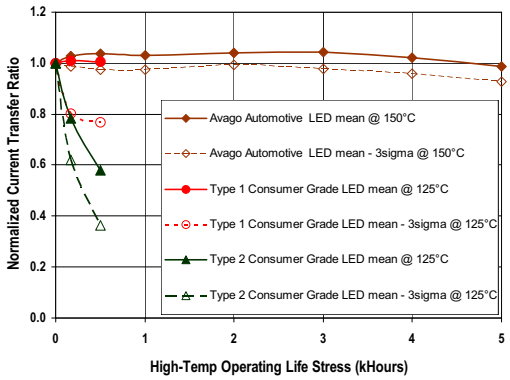



*Figure 4: High temperature Operating Life test*

**Parametric Temperature Drift**

It is not just LED aging which can be considered potentially problematic for optocouplers operated at high ambient temperatures. Light output drift over an extended temperature range can also indirectly influence important parametric values such as propagation delay.

It is not unusual to find optocouplers with current transfer drifts as high as 60% over a 100°C range.

This is another area in which the intrinsic LED design reaps benefits, Avago's automotive LEDs achieve better than a 20% light output drift over the same 100°C temperature range. In fact, this is not the end of the story. Since the forward voltage of the LED has a negative temperature coefficient, driving the LED from a fixed voltage source (normal method) results in an additional 10% compensation factor, giving an overall current transfer drift of less than 10% over a 100°C range.

**High Voltage Safety**

Many emerging automotive isolation applications require safe high voltage insulation as well as simple voltage level shifting capabilities. It is generally considered necessary to provide safety-related insulation for any voltages above 50Vac or 70Vdc. When user safety comes into the equation, the design margins adjust upwards accordingly.

When talking about safe insulation, the commonly used mantra is reinforced insulation. Reinforced insulation is widely synopsized with the use of double insulation. In fact many well established IEC safety standards do not accept single layer thin sheet insulation for reinforced insulation between high voltage circuits and safe low voltage circuits. If multilayer thin sheet material is used, the initial test voltage should be 150% (3 or more layers) or 200% (2 layers) of the test voltage.
Avago Technologies meets the requirement for double insulation in its automotive range of optocouplers using a double insulation composite construction of polyimide tape and silicone.

Additional two basic production safety tests are applied to Avago automotive optocouplers. First test is the UL1577 dielectric test, which involves applying up to 5000Vrms across the device and sensing the leakage current as a pass or fail criteria. The second test is the IEC60747-5-5 optocoupler partial discharge test, which involves applying 1.875 times the rated working voltage and detecting partial discharges as a pass or fail criteria.

Strictly speaking these production tests only give a reliable indication of the capabilities of the isolator when it is new.

It is of course desirable to have an isolator which can provide definitive safe performance over the life time of the end product, this is even more of a concern with the presence of significant aging factors such as high temperature.

Good high voltage lifetime is not achieved by default. On the contrary, it is possible to build an isolator device capable of passing both UL1577 and IEC60747-5-5 testing, but still end up with an isolator with poor immunity to high voltage degradation. Although it should be noted this is more applicable to non optocoupler technology isolators employing very thin insulation materials such as micro magnetic coil based isolators.

**Insulation Degradation**

A widely acknowledged cause of insulation degradation is the combination of injected space charge acting on micro-voids. By reducing injected space charge or micro-voids, or even better both, you can very effectively reduce this cause of high voltage aging.

"Micro voids" are unavoidable in any insulation material, but the number and size of the "micro voids" can be significantly reduced by careful choice of insulation material. Other than the material content, the process in which the insulation material is fabricated is also very important. For instance, spin on polyimide coating processes generates more micro voids than a preformed homogenous sheet polyimide; snow versus sheet ice. There are test methods for detectable voids in insulation materials, e.g. partial discharge testing. But unfortunately the sensitivity of these test methods is only able to detect larger voids. "Micro voids" involved in the high voltage degradation process are undetectable using conventional measurement equipment.

The second aggravation element in the high voltage aging process is space charge injection. Space charge is injected into the insulation material when under high voltage duress. In terms of the quantity of space charge injected, the principle determining factor is the thickness of the material and the applied electric field, resulting in a KV/mm stress factor. Other significant factors include operating temperature and the type and frequency of the applied high voltage stress.

To ensure continued safe insulation at high operating temperatures, all Avago automotive optocouplers use thick homogenous polyimide insulation materials to simultaneously minimize both "micro voids" and space charge injection.

**Conclusion**

To conclude plastic-based optocouplers can meet the requirements of high temperature automotive applications.

# Optimizing the Selection of Optocouplers

## *Surface Mount Devices in DC/DC Converter Designs*

*Optimized design with the latest generation of SSOP-packaged optocouplers takes into account four important parameters like the package height, breakdown voltage, operating temperature and isolation voltage.*

*By Krish Ramdass, Everlight Electronics Co.Ltd*

The driving force towards increased miniaturization to accommodate more compact end products means that designers of DC/DC converters must determine the right optocoupler to optimize their application. Key mechanical specifications have been forced to keep up with the miniaturization trend, as exemplified by the evolution of through-hole to surface lead-form optocouplers in dual-inline packages (DIP) to small-outline-package (SOP and SSOP) options. At the same time, optocouplers must meet other key parameters to preserve the integrity of insulation and isolation characteristics.

**The Challenge**

Applications like DC/DC bricks, lacking the real estate of earlier designs, must provide more useable output power in lower profile and thinner converters, while improving conversion efficiencies, maximizing thermal performance and offering higher useable power density.

Conventional optocoupler packages are susceptible to thermal mismatch between the various materials during high temperature exposure, leading to potential package crack, lifted chip, broken or lifted wire bonds or bleeding of inner materials. The combination of using a higher efficiency LED with an optimized transistor has presented another significant contributor for the need of an optocoupler with improved performance over time and temperature. In these designs, the LED must operate efficiently at low currents and, coupled with a high gain transistor, should provide a high typical Current Transfer Ratios, or CTR, at room temperature. As case temperatures increase beyond 100 °C, the LED output should be marginally affected and the CTR roll off should be minimized.

With all the other on-board components capable of operating at higher temperatures, optocouplers traditionally have been considered the “weak link” on the DC/DC converter board. Designers using conventional optocouplers were limited to derating their board over a narrower temperature range. On the upper end of the range, they would typically derate to 85 °C or even 100 °C, desperate to squeeze as much power out of their designs to gain a competitive advantage.

Until recent improvements in optocouplers emerged, DC/DC converter designers were so constrained by the optocoupler’s limited operating temperature, they started to embrace the idea of eliminating the optocoupler altogether in favor of pulse transformers or magnetic couplers. However, these alternative solutions presented their own set of design problems, such as inconvenient package sizes, insufficient isolation characteristics or potential EMI noise.

Since DC/DC converters dissipate a large amount of heat, designers also have traditionally employed bulky heatsinks or other methods of external cooling to keep component temperatures within safe operating limits. But today, new design methodologies seeking to lower heat dissipation have given way to modular dc/dc converters which abandon the heatsink.

Advancements in optocoupler technology has made the optocoupler a vital component for end products. However, designers of modular DC/DC converters are still faced with the challenge offering a space-saving, reliable solution while meeting the requirements of the major safety certification bodies.

**The Solution**

Today’s new SSOP optocouplers address many of the design community’s concerns. In choosing an optocoupler for a DC/DC converter, designers should consider a number of device attributes that will enable them to optimize their designs based on the performance they are trying to achieve.

Here are some parameters that should be considered when choosing an optocoupler:

Does the optocoupler have a small form factor?

New SSOP optocouplers, some with package heights as small as 2mm and a 1.27mm lead pitch, offer designers the very low standoff height component necessary for ultra-low profile applications.

Does the device have a wide operating temperature range?

The ultimate goal of achieving good thermal performance in DC/DC converter designs depends on selecting electronic components that can operate under higher operating temperatures. Advancements in SSOP optocouplers allow some devices to achieve very wide operating temperature ranges that allow designers to derate their boards up to 110 °C.

In addition to enabling DC/DC converters to achieve higher efficiencies and higher power ratings for system reliability, this improved thermal performance means that designers are not constrained by where they place the optocoupler on the board. Rather than placing the device on the outer edges of the board to shield it from high-temperature components, optocouplers that operate at

110 °C can be placed in the center of the pc board, which in turn, means shorter copper trances can be used.

Does the device family or series offer a choice of CTR ranges?

To increase design flexibility, designers should choose SSOP optocouplers with selectable CTR ranges that are characterized at low LED currents. Having a choice of tightly controlled CTR bins for parts results in a better design margin and increased stability — and provides designers with one less concern to worry about.

Designers can choose from optocouplers that offer different parts based on CTR bins. Some recent device families include optocouplers that combine a high-efficiency LED that can be driven at low currents and a high-voltage phototransistor silicon detector. These optocouplers offer the benefit of consistently delivering a stable current output over time and temperature.

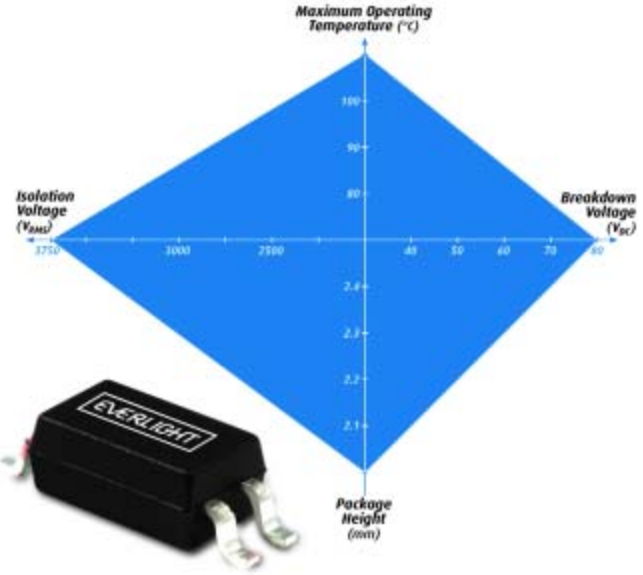



*Figure 1: Everlight Optocoupler capability*

Does the optocoupler feature high isolation voltage?

Higher voltage conditions such as voltage spikes can cause eventual break down in DC/DC converter designs. From a safety perspective, designers need to decide if their design requires a wider margin of insulation.

Many optocouplers provide output isolation voltage of 2500, but best-in-class devices can reach as high as 3750Vrms over 1 minute.

As a corollary to the high isolation voltage, it is important to recognize that smaller form-factor optocouplers must also address creepage distance. Best-in-class devices spec creepage at 5mm minimum.

Is a device with high breakdown voltage needed?

Especially in industrial and control designs, it is important for designers to choose an optocoupler with high collector-emitter breakdown voltage. Recent SSOP optocouplers provide up to 80 V breakdown voltages. Higher breakdown voltage provides the designer with added safety margin and can result in improved reliability.



Does the optocoupler meet environmental standards?

In addition to meeting well-known RoHS initiative, designers must be aware of increasingly strict “green” requirements. New advancements in optocoupler packaging offers them the choice of devices that are not only Pb-free but halogen-free as well.

**Conclusion**

DC/DC converter designers must be able to predict the performance requirements of their designs. To do this, they need to consider key performance specifications whether the optocoupler will help optimize system reliability and stability while also saving board space. Advanced SSOP optocouplers now meet the key parameters of low package height, wide operating temperature range, a choice of tightly binned devices based on CTR, high isolation voltage, high breakdown voltage, and environmentally safe packaging.

**www.everlight.com**

# A 105°C Cooled DC Link Capacitor for Advanced Inverter Applications

## *A Breakthrough in DC Link Capacitor Design*

*SBE Inc. has introduced its new Power Ring Film CapacitorTM to industry. The Annular Form Factor already provides the opportunity for a 35% increase in capacitor volume density vs. the traditional array of Film Capacitor Units currently used and has significantly lower temp rise under power (10°C in many cases), but can it be used with only 105°C engine coolant and remain reliable? SBE is investigating it with the help of the US Department of Energy and shares a status report of the technology for Bodo's Power Systems magazine.*

*By Ed Sawyer, President & CEO, SBE*

**A Disruptive Design**

SBE introduced its Power Ring Film Capacitor Technology in 2005. Originally conceived as an Extreme Pulse Power dry film capacitor, it was soon discovered by HEV, PHEV, EV inverter engineers that it also had a very desirable feature: The capacitor runs very cool while under the heavy ripple current loads typically seen in Automotive Powertrain Inverter systems. These systems typically run 100 – 250 Arms ripple current, some even approach short term ripple current needs approaching 400 Arms.

The typical film capacitor solution in use today is to assemble a bank of film capacitors with each capacitor taking 25 – 50Arms of the current load. Even at these levels, the standard film capacitor design will generate 20 - 30°C temperature rise due to dissipated heat from ESR losses. So not only does it require a bank of 4 – 8 film capacitors, or as many as 24 capacitor sections in an array, but the resulting assembly will still need to be cooled by 50 - 80°C coolant to remain reliable for any period of time approaching automotive standards.

The SBE Power Ring Film Capacitor changes this accepted engineering design practice in a number of very desirable ways:

1) The large surface area of the single ring capacitor provides enough electrode area to handle the entire 100 – 400 Arms.
2) A very low temperature rise resulting from very narrow film, which reduces the ESR.
3) The very low temperature rise while under this current load allows for much more reliable operation when cooled with the existing 50 – 80°C coolant lines.
4) If the existing 50 - 80°C coolant lines are cooling the Inverter IGBTs, a much denser inverter topology can be utilized, even allowing stacking of the Power Ring Film Capacitor above the IGBTs if appropriately rated. Up to a 50% increase in overall inverter power density could be achieved.
5) It could possibly allow for an elimination of the entire extra cooling line and allow for 105°C cooling of the inverter yet remain reliable to automotive standards when appropriately rated in the system.

*Figure 1: Power Rings*

**What makes it work?**

Why does this capacitor run so cool while more traditional capacitors heat up so significantly more under the same ripple current load? It is because of the advantageous geometry: a short path for the generated heat to escape, a very large conducting surface area vs. dielectric volume ratio, extremely low ESR, and optimized distribution of current across the device. The dielectrics used are the same Metallized Polypropylene (MPP) used in the rest of the automotive industry's current capacitor solutions therefore no new reliability issues are introduced based on the materials employed. This is the most reliable capacitor dielectric available today and widely accepted as the most desired solution from a quality perspective in the automotive industry.

Unlike the traditional capacitor shapes used today, the Power Ring Film Capacitor annular shape provides for single digit temperature rise for many inverter applications. A design point of 10°C maximum temperature rise is significant because, as will be seen later on, it is this 0 - 10°C rise range which has the greatest chance of success for long term automotive use with only 105°C coolant.

The geometry is helpful in another way as well. You can fit up to 35% more capacitance in a given volume when the capacitor is wound up into one continuous ring vs. an array of various flattened or cylindrical shapes as employed by most systems fielded today. This is critically important in PHEV, HEV, and EV systems as every cubic inch which can be dedicated to battery volume is extremely valuable. Of course, the

round geometry must be utilized efficiently to get all of this advantage, however, compared to efforts to squeeze energy out of cubic inches of battery space, this task should be considered considerably easier.

How does the Power Ring Film Capacitor compare to other typical arrays while under a number of different current loads? The following graph compares the temperature rise of a typical film capacitor array in use today for an HEV powertrain with that of the Power Ring Film Capacitor under currents ranging from 0 – 300Arms.

As you can see, the more power expected from inverters in the next generation PHEV, HEV, and EVs, the worse the temperature problem becomes for the typical array of film capacitors. This is not a good thing for today's inverter designer being asked to "make it smaller, lighter, and less expensive". Because of the greatly increased temperature rise exhibited under increased current load, the cooling requirements become much greater for the larger motor expectations of these vehicles.

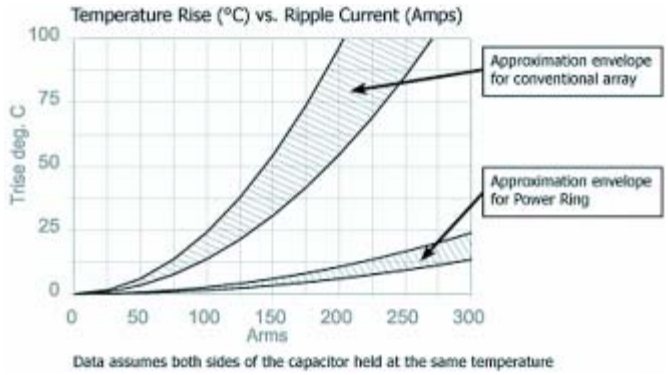



*Figure 3: Temperature Rise of Annular DC Link vs. Conventional Film Capacitor Array for a 25°C ambient example.*

**The 105°C Coolant Breakthrough – Possible?**

But an additional breakthrough in the inverter industry for the DC Link capacitor solution will come if such improved performance was also available with no additional cooling required beyond the already available 105°C engine coolant in an HEV or PHEV. There is so much interest in this possibility that the US Department of Energy is sponsoring research to enable SBE to answer this very question: Is 105°C coolant possible under expected inverter loads of 150 – 250 Arms and still provide the 10 – 15 year lifetime expected for today's automobiles?

In order to provide this answer, we are approaching the reliability assessment 2 ways:

What are the combined affects of current load, temperature cycling, vibration, and shock on the larger annular shape and connection methodology? We want to be sure that the complete automotive environment is demonstrated reliably under the extreme load conditions presented.

What is the affect of MPP while operating on a 105°C cooling plate which will establish capacitor operating hot spot regions of 110 - 125°C? Accepted reliability acceleration tests will be performed to understand the 90% confidence factor MTBFs and to establish a reasonable ripple current rating for the industry which will still comply with the desired lifetime. And is there any advantage to using the available High Crystallinity structures which are now available? This

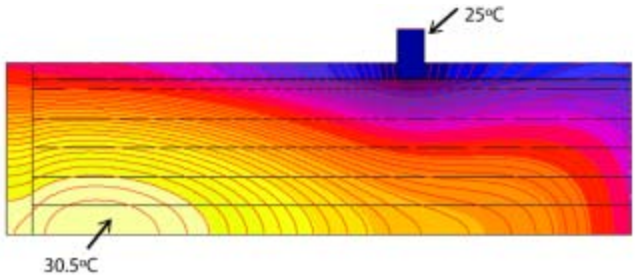



*Figure 2: Thermal profile for an early prototype annular form factor capacitor with a symmetric contact located outside the mean radius and under 100 Arms load*

film has some desired higher temperature characteristics however; SBE's early research has shown that some characteristics may make it unusable as a reliable automotive inverter dielectric. Our DoE sponsored research will allow for a conclusive decision to be made on this material choice as well.

One of the things that will become an issue with any design approaching the 105°C design goal will be DC leakage as a function of voltage at the extremely elevated temperature and what the usage profile is of the inverter in this region. If the demand of the application becomes too strenuous from a high voltage transient standpoint, or the bus voltage is increased upwards of 400V, some trade-off may need to be made to maintain the needed reliability, usable Bus Voltage, acceptable DC Leakage, and total capacitance density. But regardless of this final outcome, an option could become available to eliminate the additional cooling loop and any reduction in ultimate capacitance efficiency should be more than offset by the system efficiencies gained.

**The Future for Inverter Designs**

SBE has demonstrated that the Power Ring Film Capacitor can already greatly exceed traditional film capacitor solutions using the expected cooling systems. Therefore, inverter designers are already incorporating the solution into new leading edge designs. Like any traditional MPP film capacitor DC Link solution, when cooled within expected norms, the Power Ring Film Capacitor is already the most reliable solutions available. It brings along the lowest temperature rise for inverter integration flexibility and the potential for a much greater use of volume for desired capacitance density.

Those systems designers working with the Power Ring Film Capacitor who have elected to truly integrate the new DC Link solution into their inverter bus structure have really reaped the most benefit from what this technology has to offer.

Current designs of any level using this technology can migrate to lesser cooling requirements in the future as the reliability data and resulting MTBF predictions become available in 2009/2010 with the DoE sponsored research.

If SBE is successful in proving automotive reliability expectations of 10 – 15 year life using only 105°C engine coolant, it will open up a whole new world of possibilities for the automotive inverter designer in the future.

**www.SBElectronics.com**

# Reducing Inductance in Power Distribution Systems

## *The Features and Benefits of Laminated Busbars*

*The laminated bus construction is ideal for high power distribution. The interleaved conductors are thin and flat making excellent low magnetic flux emitting conduits. The dielectric materials used provide high voltage isolation with minimal distance between conductive materials.*

*By Michael Stibgen, Methode Electronics*

**Cable Harnessing**

The traditional solution for distributing power within an electronic system has been with cables or cable harnesses. The standard wiring solutions are fabricated with individual conductors or conductors bundled together to make an assembly. The high frequency switching applications (IGBT technology) require that special magnet wire called "LITZ" be used to reduce inductance. These bundles can be large and difficult to assemble due to the varnishing of individual strands.

The laminated bus construction is ideal for high power distribution. The interleaved conductors are thin and flat making excellent low magnetic flux emitting conduits. The dielectric materials used provide high voltage isolation with minimal distance between conductive materials. This combination of thin flat conductors with thin high dielectric insulation creates a low inductance power distribution system ideal for high frequency switching applications utilizing IGBT technology.

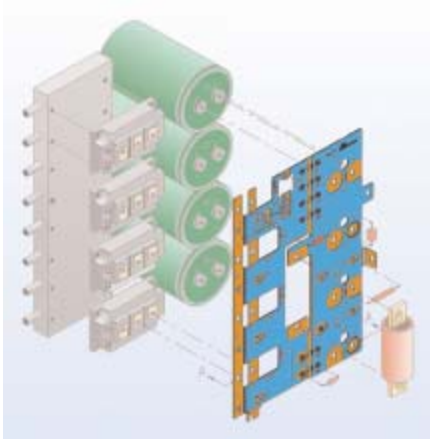


*Figure 1: Inverter application for a motor drive*

**Optimizing Design**

In this example, figure 1 shows an inverter application for a motor drive. Utilizing the low inductance of a busbar, the customer was able to eliminate the snubber capacitors from the assembly. This resulted in a direct cost savings through both the reduction of components and the labor to install them. The laminated conductor assembly resulted in a component reduction of 40% by eliminating the cabling required and mechanical hardware used originally to locate the individual cables.

**Low Inductance Design**

The section view in figure 2, illustrates the construction of the busbar.

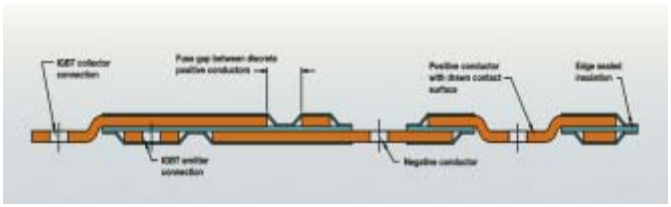


*Figure 2: Construction of the busbar*

The ability of the insulation to have a high dielectric breakdown resistance enables the conductor plates to be interleaved with a minimal spacing between plates, resulting in low inductance. This is very advantageous in systems using IGBT's.

The laminated conductors are fused together with Nomex® insulation coated with a flame retardant epoxy adhesive. The composite system is UL flame rated at 94 V-0 and meets all the requirements of UL 508c.

The insulation material was selected to enable the customer to wave solder discreet radial lead components to the assembly, further compacting the motor drive.

The drawn conductor (embossed) area eliminates the use of bushings to have coplanar contact surfaces for the component attachment. This is both a cost savings in the manufacture of the busbar and an electrical benefit. The bushing is attached using a filler metal that does not have the electrical conductivity of copper, resulting in a voltage loss at the joint.

The customer was able to reduce cost and space by edge sealing the conductor layers. This method optimizes the processing of the assembly, as it is created during the lamination sequence and not as a secondary process. The space is reduced by having the edges sealed electrically. The customer is able to place components in closer proximity and reduce the size of the enclosure.

As evidenced by the above statements, the utilization of a laminated busbar has many benefits. The electrical performance of the system is optimized resulting in fewer components. This directly correlates to cost reductions in both component and assembly time for the customer. The insulation material and conductor isolation reduces the footprint of the motor drive. This all produces a system design that allows the customer to market the drive more competitively with a higher profit margin.

**www.methode.com**

# Metal Oxide Resistors for High Power

Tyco Electronics has a new range of highly stable and reliable metal oxide resistors providing high power in a small package. New RR series resistors are ideal for pulse applications in adverse conditions and are available in three different sizes with power ratings of 1, 2 and 3W for a voltage range from 350 up to 750Volts. Highly temperature resistant the devices feature a resistance range from 0.22Ù up to 1MOhm.

RR series resistors are available in various forming styles and provide defined interruption behaviour (fusing time) and different leads for different applications like power supplies, amplifiers, household appliances and ballasts.

Manufactured by depositing a homogeneous film of metal alloy onto a high-grade ceramic body, the metal oxide resistors are coated with a non-flammable lacquer providing mechanical, electrical and climatic protection. The coating is resistant to all cleaning solvents in accordance with MIL-STD-202, method 215 and IEC 60068-2-45.

**www.tycoelectronics.com**

# Flyback Transformer Drives Loads Up To 2,000 Vdc

The new Model 4283-1200 Series Hi-Voltage Flyback Transformers from Datatronics provide a cost-effective means of driving high impedance loads requiring up to 2,000 Vdc. They are application-specific devices, which can be custom configured to meet a wide variety of medical, military or commercial applications.
Offering primary-to-secondary isolation of up to 7 KVdc, the 4283-1200 Series is ideal for applications requiring a high-voltage, low-power signal. Typical applications include line and portable medical devices such as defibrillators as well as industrial lasers, ion generators for powder coating and painting equipment, cathode ray tube transformers, traveling wave tube transformers and more.

Like other Datatronics transformers, the 4283-1200 Series is particularly reliable in unstable or harsh environments. The 4283-1200 meets or exceeds the
performance, safety and quality standards of a variety of U.S., European and Asian specifications.
The 4283-1200 Series is competitively priced beginning at $12.00 in low volume quantities. It is delivered in a variety of customer-specified packaging.

**www.datatronicsromoland.com**

# 300% Peak Power Capability

Lambda has extended its successful HWS family of single output power supplies with the introduction of the 300W and 600W versions with a 300% peak power capability for 5 seconds. Coming with a lifetime warranty, the new HWS300P and HWS600P series are designed for industrial applications, such as factory automation, process control, and motor and pump drives and provide a very cost and space efficient solution compared to oversizing conventional power supplies just to handle the peak current.

Both HWS-P units from Lambda are available with nominal outputs of 24, 36 and 48V, and each model can be adjusted locally by -20/+10% to accommodate non-standard system voltages. The HWS300P series has a peak output power of 1008W and the HWS600P reaches 1992W. The power supplies have a high-quality internal fan and can be operated in a -10 to +70°C ambient. Overcurrent and overvoltage protection is standard, as is a power good signal and remote on/off.

Immunity compliance is in accordance with all relevant parts of IEC61000 and hold up meets SEMI F47 requirements at high line input. All models meet EN55011/EN55022, FCC VCCI curve B conducted and radiated EMI. Lambda's HWS300P and HWS600P series are approved to UL/CSA/EN 60950-1 and EN50178, CE marked, and operate from 85 to 265Vac.

**www.lambda-germany.com**

# Single-Pole Solid State Relays

Clare, Inc. an IXYS company announces the immediate production release of the LCB716, a 1-Form-B solid state relay, and the dual-pole combination LBA716, which integrates independent 1-Form-A and 1-Form-B relays into a single package. Both are 60V devices, with 0.5 and 1.0A of load current, respectively.

These devices use optically coupled relay technology to provide an enhanced 3750Vrms isolation barrier between the input and the output of the relays. The efficient MOSFET switches use Clare's patented OptoMOS architecture and the optically coupled output is controlled by highly efficient GaAlAs infrared LEDs. The 60V LCB716 and LBA716 relays are in addition to the previously released LCA710 and LCA715 (60V, 1.0 and 1.8A load current) 1-Form-A devices.

This family of 60V SSRs offers the highest load current capability in 6- and 8-pin surface mount and DIP packaging and very low on-resistances, ranging from 0.25 to 2.0 Ohms. These low voltage relays specifically target high current electronic switching applications, industrial power distribution, sensor circuitry, and medical equipment (patient/equipment isolation).

**www.clare.com**

# SMD Aluminum Electrolytic Capacitors

The new SMD aluminum electrolytic capacitors from EPCOS cover a capacitance range from 0.1 µF to 1500 µF and are designed for voltages from 4 V DC to 100 V DC. Versions are available for temperature ranges from -40 °C to +85 °C and from -40 °C to +105 °C. Depending on the CV value, the case sizes vary between 4 mm x 5.4 mm and 10 mm x 10 mm (d x l). The B41142* series with ESR values from a minimum of 0.8 Ù is particularly suitable for applications requiring high ripple current capability. The operating life of the capacitors of this series is 3000 hours (105 °C). All types are RoHS-compatible. The new capacitors are suitable for applications in consumer and industrial electronics. They are an attractively priced alternative to tantalum capacitors.

The updated range is shown in the new Alu-X® 2008 Data Book (ordering code EPC:27017-7600). The data sheets may also be downloaded from the Internet. In addition, more than 5000 competitor ordering codes for SMD aluminum electrolytic capacitors have been added to the X-Reference database in order to facilitate the search for EPCOS types.

**www.epcos.com/xref**

# 600V MOSFETs Feature High Robustness

Alpha & Omega Semiconductor announced the release of ten 600V-rated MOSFETs. The new 600V devices are ideally suited for use in AC-DC power supplies and adapters used for desktop and notebook PCs, LCD TVs, and handheld devices such as cellular phones and PDAs.


The new MOSFETs allow high efficiency power conversion with reduced switching losses by offering an optimized combination of low $R_{DS(ON)}$ and Crss. A wide range of applications can be supported with current ratings from 1A, in the form of AOD1N60, to 12A in the forms of AOT12N60 and AOTF12N60.

The high voltage MOSFETs were developed to reduce switching losses through lowering the Crss. In addition, robustness was "designed in" with high avalanche energy capability that is also guaranteed through 100% final testing.

The devices are available in three industry-standard packages: DPAK, TO-220 and the electrically isolated TO-220F.

**www.aosmd.com**

# High Current Planar Inductors

Payton announced series 50002 of SMT planar inductors for use in the output filter of low profile power modules. The demand for low profile, high efficiency, and high current output DC-DC converters is driving the need for high performance planar inductors.

The inductors in this package, L: 20mm W: 20mm H: 8.2mm, are available up to 40 amps, 0.9uH or 90 Ampere turns with resistance as low as 0.6 milliohms. One to 8 turns are available for inductances up to 25uH/5Amps.

P/N 50002 is a 1.55uH at 30Amps inductor with 1.2mOhms max resistance. The operating frequency is 100 to 300 kHz, the peak current of ripple is 3Apeak, and the peak of total current is 33Apeak. The short-term overload current is 40Amps. The total losses at 80?C heat sink are 1.6 Watts with a hot spot of 100?C..

**www.paytongroup.com**

# Energy Harvesting based on TI Utra-Low Power Technology

Demonstrating the advantages of energy harvesting and radio frequency (RF) technology for wireless sensing, monitoring or ambient intelligence, AdaptivEnergy has developed a demonstration kit using Joule-Thief™ technology to harvest energy and power Texas Instruments Incorporated's (TI) (NYSE: TXN) ultra-low power MSP430 microcontroller (MCU) and RF technology to collect data, control the operation of a system or send sensed data to central collection sites. The Joule-Thief energy harvesting device is based on AdaptivEnergy's Ruggedized Laminated Piezo (RLP®) technology, which enables compact energy harvesting modules to power applications such as wireless sensors. These wireless sensors could be used to gather ambient intelligence to detect and report critical conditions in factories, automobiles, office buildings, homes and other environments – all without wiring or batteries.

**www.ti.com/msp430**

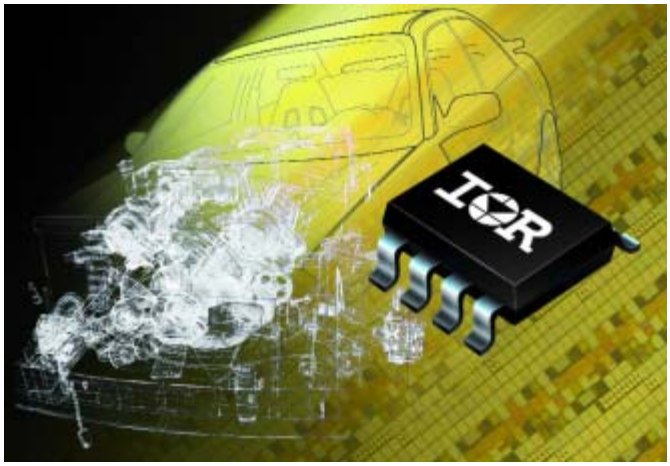
# Rugged, Reliable Automotive-Qualified 600V ICs

International Rectifier has introduced the AUIRS212xS family of rugged 600V, single channel high-side driver ICs for low-, mid-, and high-voltage automotive applications including general purpose automotive drives, high-voltage actuators and fuel-efficient direct injection systems.

Qualified to AEC-Q100 standards, the AUIRS2123S and AUIRS2124S high speed power MOSFET and IGBT drivers offer a gate drive supply range from 10V to 20V. The output drivers feature a high-pulse current buffer stage designed for minimum driver cross-conduction while the floating channel can be used to drive N-channel power MOSFETs or IGBTs in the high-side configuration operating up to 600V. Both devices feature negative voltage spike (Vs) immunity to protect the system against catastrophic events during high-current switching and short circuit conditions.

Designed specifically for automotive applications, the new ICs use a proprietary latch immune CMOS technology featuring exceptional negative Vs immunity to deliver the ruggedness and reliability essential for harsh environments and automotive under-the-hood applications.

The AUIRS2123S features output signals in phase with the input signal while the AUIRS2124S features output signals out of phase with the input signal. Both devices provide under-voltage lockout and CMOS Schmitt-triggered inputs with pull-down.




The new ICs utilize IR's advanced high-voltage IC process which incorporates next-generation high-voltage level-shifting and termination technology to deliver superior electrical over-stress protection and higher field reliability.

**Electronica, Hall A5 Stand 560**

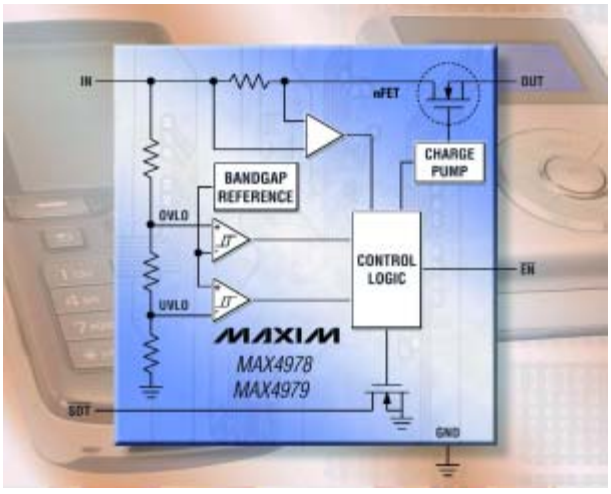
**www.irf.com**

# Accurate Overvoltage Protectors with Active Current Limiting

Maxim Integrated Products introduces the MAX4978-MAX4981overvoltage protectors (OVPs) with active current limiting. They protect low-voltage systems against voltage faults up to 28V with 5.7V and 6.8V threshold options. The active current limiter provides a second layer of defense for the protected device and is available in 0.9A and 1.95A threshold options. Designed to protect the charger input port of portable devices, these OVPs are ideal for cell phones, MP3 players, digital still cameras (DSCs), and PDAs.

The MAX4978-MAX4981 provide ±15kV ESD input protection when a 1microfarad ceramic capacitor is connected from Vin to ground. Additionally, the MAX4980/MAX4981 include battery-overcharge protection that monitors the voltage on the Li-ion battery being charged. Once this monitored voltage reaches 4.4V, the switch is disconnected to avoid overcharging.

Packaged in a lead-free, 2mm x 3mm, 8-pin TDFN with an exposed pad, the MAX4978-MAX4981 are fully specified over the -40 degrees Celsius to +85 degrees Celsius extended temperature range. Prices start at $1.47 (1000-up, FOB USA).




**www.maxim-ic.com**

# Constant Power with new Productline

UltraVolt, announced it has developed a constant power high-voltage power supply..

The new “CP” Series of power supplies has the unique capability of operating in constant-voltage, constant-current, or constant-power modes. The “CP” Series is optimized for this “tri-mode” operation in bias, charging, and pulsed power applications, while providing excellent line regulation, load regulation, dynamic response, and stability. Each high-voltage power supply in the “CP” Series has 0 to +10V buffered and nulled monitors for voltage, current, or power, with automatic crossover from mode to mode. Each mode also has 0 to +10V remote programming. In addition, each mode has an open collector indicator which is an active low. Currently, the “CP” Series can supply 10W with a 10:1 range in output voltage with maximum outputs as high as 15kV.

"The “CP” Series product line offers customers constant output power capability over a broad range of voltages and currents with a high level of accuracy,” said James Morrison, Co-Founder & CEO. “This new high-voltage power supply is a perfect fit for customers with designs sensitive to voltage or current fluctuations.”

**www.ultravolt.com.**



# 500W Medical Grade Power Supply

SynQor continues its successful entrance into the AC/DC marketplace with the introduction of its latest product designed specifically for Medical Applications. The ACuQor® AQ0500M series of off line Power Supplies packs 500W of useable power into just 3.5” x 5.25” x 1.63”, which is the World’s smallest cardiac care, medical grade AC/DC converter for this power level. SynQor continues to bring to the design of its ACuQor series of AC/DC products the same level of technical innovation that has made it a leader in the DC/DC marketplace, achieving an efficiency level of 91%. Single outputs of 48V, 36V, 24V or 12V are available to facilitate the use of Distributed Power Architectures and battery backup, and to directly drive components such as fans, motors, pumps, lamps and actuators.

The AcuQor family operates over a universal input range of 85-264Vrms and 47-63Hz making it suitable for World-Wide deployment. Through the use of SynQor’s “QorCool” thermal conduction techniques, full output power is available when attached to a cold plate maintained at 50oC. It has a transient power rating of 700W for up to 15 seconds. Active Power Factor Correction is incorporated to a level >0.98 enabling compliance with IEC/EN61000-3-2. Both Line and Neutral are internally fused.

**www.synqor.com**

# Protection of Photovoltaic Applications

Ferraz Shawmut commits to the development of solar power, offering made-to-measure solutions. At Ferraz Shawmut, the global specialist in protection for power generation and distribution systems, we have designed electrical protection solutions specifically for grid-connected PV powered systems. Helio Protection is the new brand name for solar power protection developed by Ferraz Shawmut.

Any installation, whether it's a stand-alone solar array with a back-up generator set or a grid-connected one, is vulnerable to fault currents or lightning. In today's technology, fuses and lightning arresters are the most effective ways of protecting both the wiring and all the electrical equipment involved. But those protection systems must still be studied, dimensioned, tested and adapted to the specific features of solar applications. At Ferraz Shawmut, the specialist in protection specially designed for power generation and distribution, we are showing our commitment to the development of solar power with a dedicated range of products: junction boxes, fuses and surge arresters.

Fuses to meet the specific requirements of photovoltaics, Fuses shield the cables between strings of modules from damage. The faulty circuits are isolated and the system can keep on generating power.

**www.ferrazshawmut.com**

# Amplifier Family Eliminates EMI-Induced Errors in Analog Systems

National Semiconductor introduced three new operational amplifiers (op amps) with integrated electromagnetic interference (EMI) filters that maintain the accuracy of analog systems by reducing the effects of radio frequency (RF) interference. The LMV83x op amps deliver the industry's highest EMI rejection ratio (EMIRR) of 120 dB, thereby eliminating EMI-induced errors. They also feature 3 MHz unity gain bandwidth while operating on only 240 uA of supply current. This yields a power-to-performance ratio of 80 uA per MHz, which places these devices among National's PowerWise® family of energy-efficient products.


The LMV831 single, LMV832 dual and LMV834 quad EMI-hardened op amps reduce development time and board size by minimizing the need for metal shielding, filters and extra components. They are well-suited for use in phone accessories, medical instruments, precision weigh scales and other industrial electronic equipment that are sensitive to electromagnetic disturbances in noisy environments. For example, an injected RF signal in a weigh scale can result in as much as 1V of output offset, which would diminish a 10-bit analog-to-digital converter's (ADC's) resolution (1024 codes) to the equivalent of only 3-bits. Using an LMV83x op amp would only reduce resolution by 0.2-bits. A wide range of applications can benefit from EMI protection, including filters/buffers, photodiode preamp and piezoelectric sensors.

**www.national.com**

## ADVERTISING INDEX

# POWER ELECTRONICS

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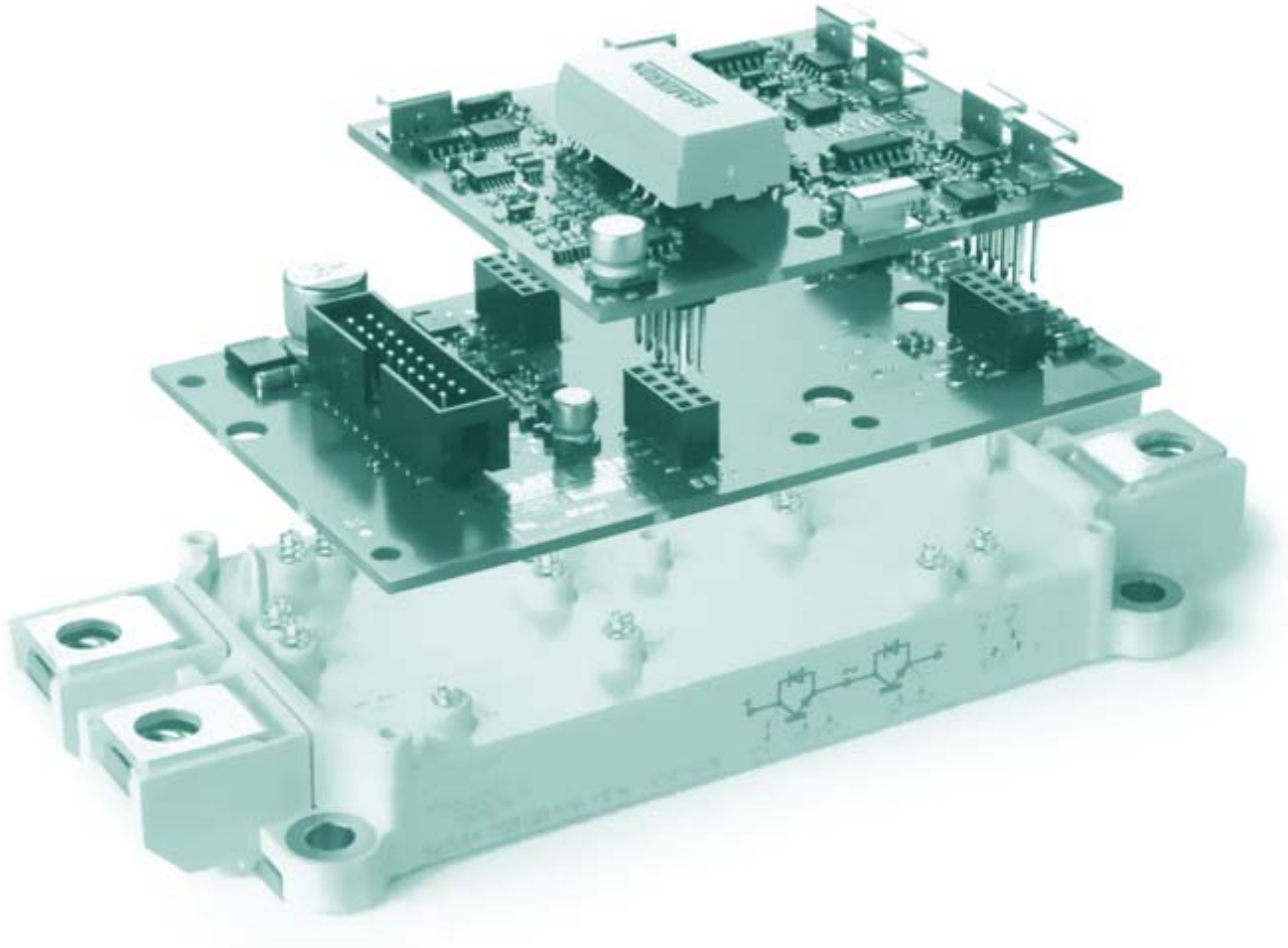

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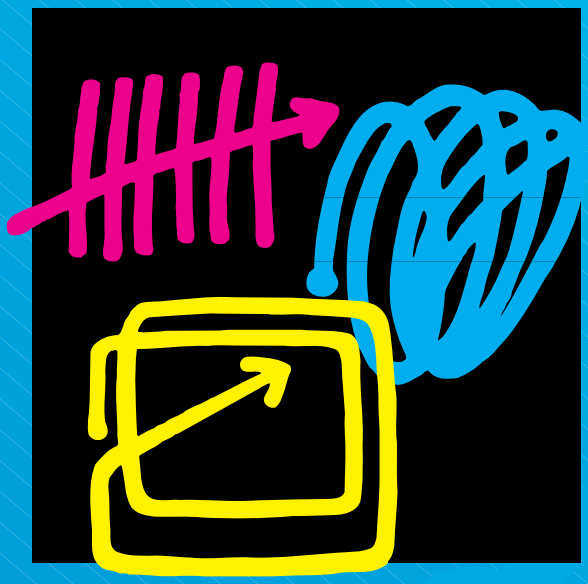

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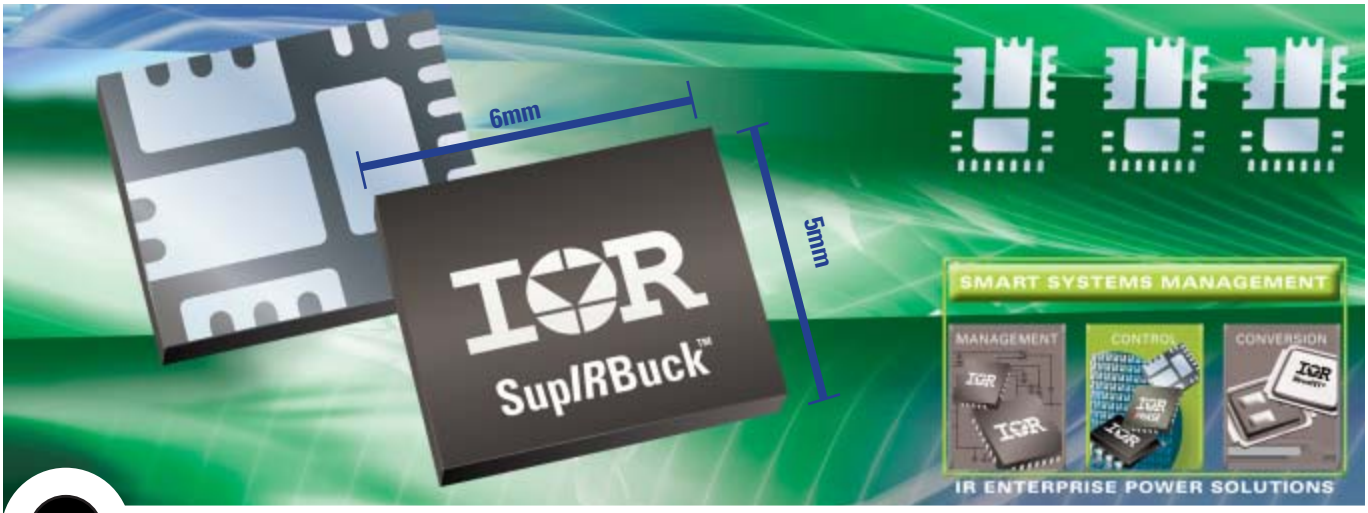
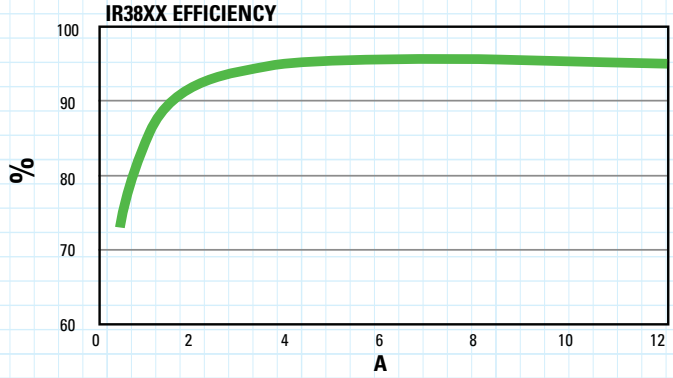



# SupIRBuck™ Integrated Regulators: Simply Smaller, Cooler

## Save Energy, Accelerate POL Design, Shrink Footprint 70%




| 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 |

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.

### Features

- 600kHz switching frequency
- 4A/7A/12A output options
- Programmable soft start with enable
- Programmable over-current protection
- 0.6V reference voltage with 1.5% accuracy
- 2.5V to 21V conversion Input
- Pre-Bias protection
- Integrates rugged control and sync FETs with control IC in one simple 5mm x 6mm power QFN package
- Optional 300kHz, DDR memory tracking, programmable PGOOD

### Benefits

- Ease of implementation
- Enables single input voltage rail
- Wide input voltage range
- Common footprint for 4A, 7A and 12A power regulators
- Fewer discrete components

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