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Power Systems Design EUROPE

Power Control Intelligent Motion

December 2005

Thermal Management Made Simple

PowerLine

PowerPlayer

Marketwatch

ISSN : 1613-6365

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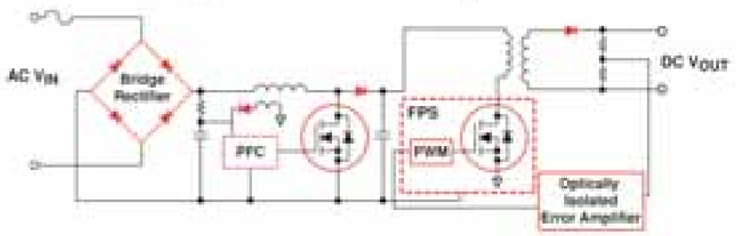
FSCQ1265RT	140	7	0.9
FSCQ1465RT	160	8	0.8
FSCQ1565RT	170	8	0.7
FSCQ1565RP	210	11.5	0.7

Green FPS for quasi-resonant switching converter



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For more information on our AC/DC solutions, design tools or to order an evaluation board, visit www.fairchildsemi.com/acdc/11.

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Volume 2, Issue 10

It Is Toy Train Time

Winter has shown up and the holidays are upon us, this marks my annual ritual to pull out the toy trains and run them throughout the house. My grand nephew enjoys helping me, this is a good start to get them interested in engineering and encourage them to one day perhaps learn a technical profession.

The last events have shown a positive indication for the upcoming year. SPS/IPC/DRIVES in Nuremberg has reported a very positive increase in exhibitors and visitors. Therefore, SPS/IPC/DRIVES show has clearly reached an international high acceptance. Not only was the Drives and Control manufacturing industry represented but the device manufactures have also started to participate in this show.

Mr. Rath from Mesago can be proud of the well-established SPS/IPC/DRIVES show in Nuremberg. I remember the early days of SPS/IPC/DRIVES in Sindelfingen. I had given a paper for Harris on power switches and their areas of application. At that time a device called MCT was very popular. There was talk that it would become the ideal switch. The MOS Controlled Thyristor had got a lot of credit and most of the analysts had not been able to see the technical limits in the device characteristics and behaviour.

It is like today, I hear that SiC switches will be ready next year. We will have to wait and see. Time had shown that MOSFETs and the IGBTs serve the majority of tasks in electrical motor drives and as well in power supply applications.

So SPS/IPC/DRIVES complement in a certain way PCIM perfectly. The thought that device and system manufactures are different animals has changed. An example is Semikron with its move to inverters as we reported in the October cover story. Historically Semikron had been a module manufacture.

Japanese companies, such as Toshiba and Mitsubishi, are examples of the synergy between the semiconductors and the inverters for drives in one systems approach. Also in Europe are ABB drives and ABB semiconductors as well as Danfoss Drives and Danfoss Silicon Power.

Productronica in Munich had a lot of activity, which indicates a sign of positive development for our economy.

This month's cover story is on Bergquist's Thermal Clad Insulated Metal Substrate (IMS) on the cooling benefits for LED lighting applications.

Some of the other technical features in this issue includes the University of Bremen which has taken today's state of the art MOSFET Components and evolved their switching speed and low conduction losses.

Texas Instruments has a solution for sequencing and margining capability to simplify power management.

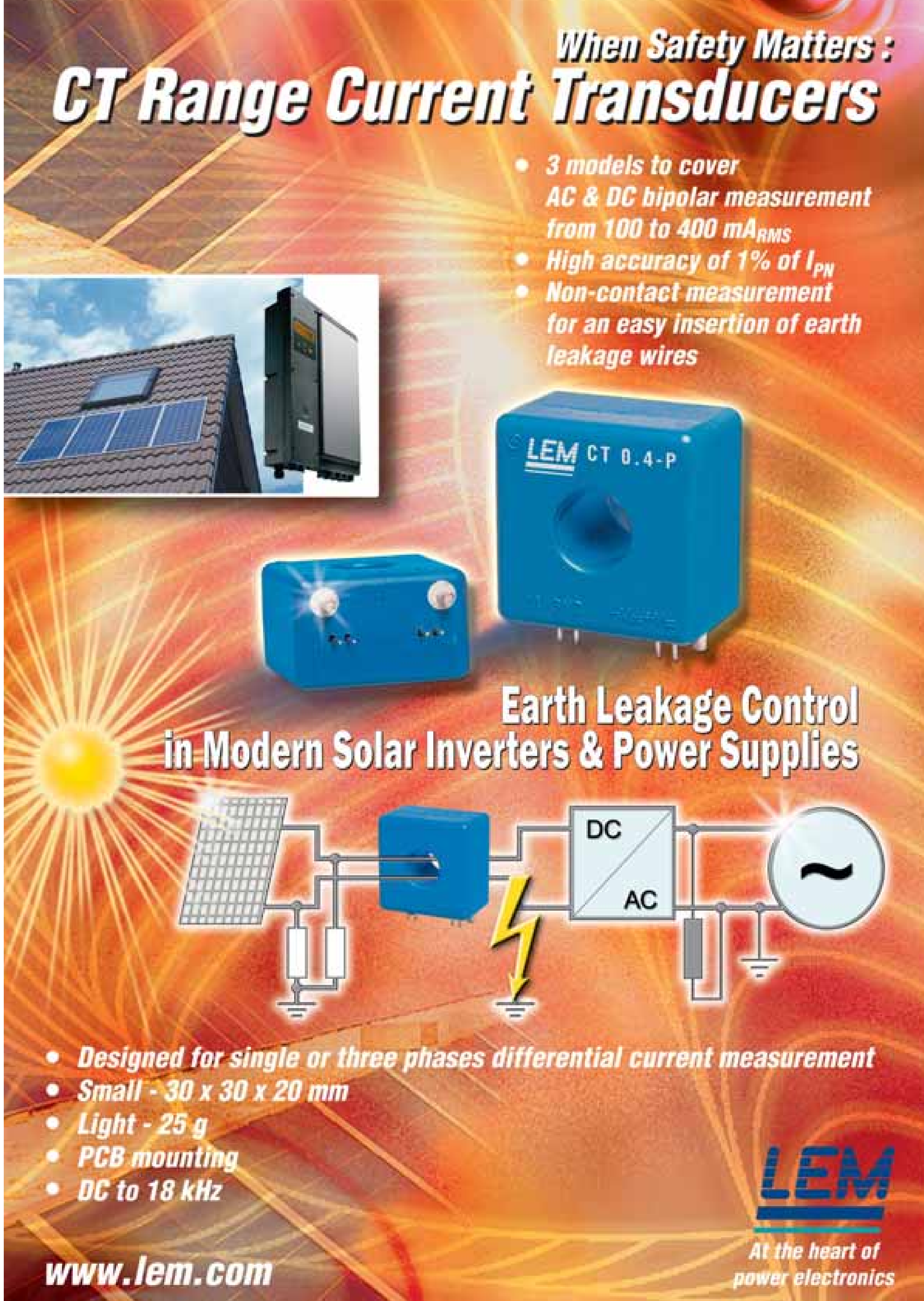
STMicroelectronics takes a closer look at the safe operating area in MOSFETs for anomalous failure mode which limits the ability to operate in linear mode.

Infineon introduces a software to have proper modules selected for the individual conditions regarding DC input and AC output voltage, switching and output frequency, inverter power rating, overcurrent and overload capability as well as the influence of different cooling conditions.

We wish for a peaceful holiday season for all.

Merry Christmas and a Happy New Year!

Bodo Arlt
Editorial Director
The Power Systems Design Franchise



Danfoss Strengthens its Research Activities

As of January 1, 2006 Dr. Frank Osterwald will take over the management of the research and development activities of Danfoss Silicon Power, Germany.

From 1988-1995 Dr. Frank Osterwald studied electrical engineering specializing in control engineering, electronics, microelectronics and semiconductor technologies at the technical University Berlin. As part of a project regarding the reliability of power semiconductors at Fraunhofer IZM, he earned a doctors degree in 1999 and thereafter took up leading positions within industry responsible for the design of microelectronic solutions.

Dr. Ronald Eisele, presently Director of R&D for Danfoss Silicon Power, Germany, has been appointed Professor of Mechatronics at the University of Applied Science in Kiel, Germany. The collaboration with the Department of Mechatronics in Kiel enables Danfoss to continue and further develop its activities within fluid cooling of power modules, assembly and interconnection technologies as well as integration of sensors.

Danfoss Silicon Power situated in Schleswig, Germany, develops and produces electronic power modules for various applications, such as frequency converters, power supplies and electric vehicles. The competences of the company include lead-free soldering of large surfaces and thermal design methods. The company is part of the Danfoss Group and has 100 employees who develop and produce customer specific electronic power modules. Plans have been made for new investments of 30 percent in extensions of clean-room capacity for the production of components for the automotive industry; it will result in 50 new permanent workplaces.

www.danfoss.com/siliconpower

Fairchild Reiterates Guidance for Q4

Fairchild Semiconductor reiterated guidance for fourth quarter 2005 revenue to increase about 5% and for gross margins to increase 200 – 300 basis points sequentially.

"I'm very pleased with the broad-based strength in order rates so far in the fourth quarter," said Mark Thompson, Fairchild's president and CEO. "We've booked and scheduled enough demand within the quarter to approximately meet our guided revenues and are now working to take advantage of quick turn opportunities for potential upsides in December. Demand continues to be seasonally strong for our products serving the computing and consumer end markets, especially for notebooks, televisions, DVD's and other consumer electronics. Bookings have also increased for products supporting power supply and battery charger applications within our industrial end market segment. Our blended lead times have gradually increased during the quarter, and now range from 8 – 10 weeks, so most of the demand we're booking today is for deliveries in the first half of 2006.

"From a product perspective, order rates have been up across virtually all of our product lines," continued Thompson. "Demand has increased for our system regulators and power conversion analog products supporting the computing, consumer and industrial end markets. We have steadily increased backlog for our low power and high power switches supporting a wide range of applications in these same end markets. We're building on our successful efforts to increase distribution re-sales and improve the inventory mix at our distributors, while further reducing channel and internal inventories," stated Thompson. "The seasonally strong demand through the first two months of the fourth quarter has provided a nice tailwind to this inventory reduction process while improving our backlog position for the first half of 2006."

www.fairchildsemi.com

Intersil Online Design Tool for Op Amps

Already Successful with its iSim Tool for Power Management Devices, Intersil Adds Op Amps to its Suite of Online Tools. Intersil Corporation announced a free, interactive, Web-based tool for selecting and simulating devices from Intersil's broad operational amplifier portfolio. Based on input and output specifications provided by the user, the iSim for operational amplifiers tool will find all suitable Intersil devices for a given application. In many cases, simulation is also available for immediate feedback on circuit performance.

Intersil's iSim simulator tool has an applications-based Intersil analog signal processing solution selector with dynamic input fields to match a designer's input and output requirements. Options include inverting and non-inverting gain, transimpedance, differential, and low and high pass filter configurations. All applicable Intersil devices are listed, with many of them available for simulation. When available for simulation, a reference schematic is generated for simulation, based on the designer's specifications.

Making a Designer's Life Easier in Two Simple Steps iSim for operational amplifiers is a two-part tool. First, it contains a dynamic "solution selector" to sort Intersil's portfolio based on the specifications of the application rather than the specifications of the devices themselves. This saves the user a step in determining which Intersil product would best suit the end application. This search function is independent of the simulation side of the tool. Once application specifications are loaded, the sorted devices are displayed with icons indicating which are available for simulation.

The second part of iSim for operational amplifiers is the simulator itself. The simulations run on the well-established SIMetrix/SIMPLIS platform, which is based on SPICE. The simulator builds a circuit using the application specifications loaded into the selector, as well as the basic SPICE model for the following analyses: AC analysis (bode plot), transient pulse and transient sine. In addition, the circuit can be downloaded to iSim: PE (personal edition) for offline editing and AC analysis.

Intersil's iSim for operational amplifiers tool is free to registered users. To register, go to www.intersil.com/isim.

www.intersil.com/isim

We Take the Heat

100% Tested 150°C Analog ICs

"Under-the-hood" environmental conditions present significant challenges to semiconductors due to temperature extremes, especially in high power devices. Thankfully, Linear's growing family of 150°C junction temperature-capable ICs are tested and guaranteed to perform in this environment. Our products include high voltage monolithic switching regulators, controllers and linear regulators. See the table below for our current offering.

High Junction Temperature Capable ICs

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LT®3012/3	4V to 80V	250mA	LDO	150	TSSOP-16E
LT3437	3.3V to 80V	400mA	Buck Converter	140	TSSOP-16E
LT1766	5.5V to 60V	1.25A	Buck Converter	140	TSSOP-16E
LT1976	3.3V to 60V	1.25A	Buck Converter	140	TSSOP-16E
LT1936	3.6V to 36V	1.4A	Buck Converter	150	MSOP-8E
LTC®3803-5	6V to 72V	3A	Flyback Controller	150	ThinSOT™
LTC1772	2.5V to 9.8V	5A	Buck Controller	140	ThinSOT
LTC3731	4.5V to 36V	60A	Sync Buck Controller	140	SSOP-36

Info & Free Samples

www.linear.com/automotive

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LINEAR TECHNOLOGY

Tyco Launches New Website

Tyco Electronics Power Systems announced the launch of its new customer-friendly website. Supported by a powerful content management system, the website provides users with the most up-to-date information on Tyco Electronics' world-class power systems products.

The homepage of the new website is designed to make searching for power products easier and faster by offering easy navigation menus with recognizable industry standard category names. Users can click on these names and be linked to product family pages, where thumbnail images of product families, detailed product descriptions, and product documentation links are easily located. Product documentation sub-categories for application notes and product manuals are especially helpful to users seeking specific product information.

Also included are cutting-edge features such as our interactive Product Viewer that makes it easy to find our most popular DC-DC and Energy Systems products. The Featured Products and Innovations sections will allow users to view the most current products and services that appeal to and benefit a wide variety of customers. Additional website elements designed to enhance user experience include online video, which will include instructional segments for product demonstrations, design tools such as product configurators and designers, as well as product assessment tools.

www.power.tycoelectronics.com

ON Semi Expands Development Center

As part of its continuing commitment to develop efficient power management components for use in consumer, computing and office electronics, ON Semiconductor announced plans to double both the staff and the square footage of its Power Conversion Integrated Circuit Development Center in Chandler, Arizona.

By the end of the year, the Chandler facility will be expanded to 16,000 square feet and up to 20 new power integrated circuit engineering positions will be added. Work at the Chandler center - one of 8 design centers ON Semiconductor operates worldwide - is focused on the research, design and testing of power-efficient integrated circuits and power supply solutions used in the conversion of both AC and DC power. The devices designed at the Arizona facility utilize unique and often proprietary technology to convert power from a wall outlet or battery to digital consumer or computer electronics with minimal energy loss.

ON Semiconductor's proprietary power management devices have been implemented into a wide range of products, including computers, LCD monitors, printers, flat screen televisions, set top boxes and battery chargers for cell phones. Additionally, ON Semiconductor products support ENERGY STAR® qualified consumer products. Recently, the company introduced a unique dual-edge PWM controller that will facilitate the industry-wide development of DC-DC power supplies with highly efficient "active mode" performance for computing and consumer electronics applications. For three consecutive years, the China Energy Commission (CEC) has honored ON Semiconductor with its "Top 10 DC-DC" award for development of energy-saving DC-DC conversion components. Earlier this summer, ON Semiconductor unveiled its GreenPoint portfolio with the introduction of the industry's first open ATX Power Supply Reference Design certified to meet 80 PLUS performance requirements. Additional GreenPoint introductions are planned.

www.onsemi.com

Microsemi to Acquire Advanced Power Technology, Inc.

Irvine, CA Microsemi Corporation and and Bend, OR Advanced Power Technology announced the signing of a definitive agreement for Microsemi to acquire APT. With this acquisition, Microsemi expands its portfolio of analog mixed signal offering in the RF marketplace and also its high reliability offering in the defense/aerospace and medical marketplace.

The transaction combines two strong high performance analog companies offering both differentiated RF product into niche end markets as well as high reliability product addressing a strong defense/aerospace and medical market. APT is a leading designer, manufacturer and marketer of high-performance RF and switching power semiconductors. With APT's strong focus on the high-power, high-speed segment of the power semiconductor market, APT's RF and power switches will greatly expand Microsemi's product offering within its existing channels. Additionally, APT has an advanced development effort in silicon carbide that offers significant advantages in future systems ranging from military to notebook applications.

In addition to the strategic opportunity that this acquisition provides, the combined company should have a profitable operating model that should generate significant cash. The combined entity has potential consolidation opportunities inline with previous restructuring efforts at both companies to improve efficiencies. Together, the companies should in time perform at greater than our 50% gross margin and 27% operating margins goals. Microsemi expects the transaction to be accretive to its third quarter fiscal year 2006 results.

www.microsemi.com

www.advancedpower.com

Power Events

- ***EMV 2006,*** *March 7-9, Düsseldorf www.mesago.de*
- ***ECPE 2006 SiC User Forum,*** *March 14-16, Nuremberg, www.ecpe.org/news/news_e.php*
- ***APEC 2006,*** *March, 19-23, Dallas TX, www.apec-conf.org*
- ***PCIM China 2006,*** *Mar. 21 - 23, Shanghai www.pcimchina.com*
- ***PCIM Europe 2006,*** *May 30 - June 1, Nuremberg, www.pcim.de*
- ***SMT/HYBRID 2006,*** *May 30-June1, Nuremberg, www.mesago.de*
- ***SENSOR/TEST 2006,*** *May 30-June1, Nuremberg, www.sensor-test.de*
- ***MICROSYSTEM,*** *October 5 –6 , Munich, www.mesago.de*
- ***ELECTRONICA 2006,*** *Nov. 14 – 17, Munich, www.electronica.de*
- ***SPS/IPC/DRIVES 2006,*** *Nov. 28 - 30, Nuremberg, www.mesago.de*

Puzzled by Transformer Design?

Get The Solution – *PI Transformer Designer*

PI Transformer Designer, a new design software tool from Power Integrations, makes creating transformers for switching power supply designs easy. Advanced algorithms generate detailed instructions to help you build transformers that work – the first time!

- Complete specs with step-by-step winding instructions
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- Three easy steps to generate your design
- Optimization for low cost or high efficiency
- Supports AC-DC and DC-DC cost-effective, energy-efficient designs with Power Integrations ICs

EcoSmart®

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POWER INTEGRATIONS®

INNOVATION IN POWER CONVERSION™

World's First Mixed-Signal FPGA Designed for the Power Sensitive Applications

Unprecedented integration of analog peripherals, Flash memory and FPGA fabric in a monolithic programmable system chip redefines how products are designed

Satisfying a strong demand from system architects for a device that simplifies design and unleashes their creativity, the leading vendor of single-chip programmable solutions Actel Corporation recently has held a press conference in Beijing, China to announce the immediate availability of the Actel Fusion™ Programmable System Chip (PSC), the world's first mixed-signal FPGA family.

Replacing the high-cost discrete devices

By integrating mixed-signal analog, flash memory and FPGA fabric in a monolithic PSC, the Actel Fusion devices enable designers to quickly move from concept to completed design and deliver feature-rich systems to market. The Actel Fusion PSCs bring the benefits of programmable logic to application areas, including; power management, smart battery charging, clock generation and management and motor control, that until now have only been served by either costly and space-consuming discrete analog components or mixed-signal ASIC solutions.

The Actel Fusion PSCs present new capabilities for system development by allowing designers to integrate a wide range of functionality into a single device while at the same time offering the flexibility of upgrades in the field or deep in the production cycle. The Actel Fusion devices provide an excellent alternative to costly and time-consuming mixed-signal ASIC design. In addition, when used in conjunction with Actel's ARM7 and 8051-based soft MCU cores, the Actel Fusion technology represents the definitive PSC platform.

Designed for power sensitive applications

The Actel Fusion devices integrate a configurable 12-bit successive approximation register (SAR) analog to digital converter (ADC) with frequencies up to 600 ksps. The flexible analog block supports MOSFET gate driver output and multiple analog inputs from -12 volts to up to +12 volts with optional prescaler, thus enabling direct connection and control of a wide variety of analog systems such as a voltage, differential current or temperature monitor.

The Actel Fusion PSC family is the only programmable logic solution to include embedded flash memory—up to 1 Mbyte per device. The flash memory offers 60-nanosecond random access and a very fast 100MHz access in read-ahead mode. The high performance flash memory offers a user configurable data bus supporting x8, x16 and x32 bit widths. The memory also offers error correction circuitry (ECC) with single-bit error fix and two-bit error-detect capabilities. Pseudo EEPROM can be achieved with an available endurance extender IP available from Actel. Further, the Actel Fusion PSCs give designers unprecedented levels of flexibility by allowing them to easily reconfigure analog block settings to perform widely different functions by simply downloading data from embedded flash memory.

Actel's Fusion PSCs extend the core benefits of the company's flash FPGA technology—live at power-up (LAPU), single-chip, firm-error immunity and low total system cost—to the world's only mixed-signal FPGAs. The new Actel Fusion PSCs deliver the core analog blocks required for applications in the industrial, medical, military/aerospace, communications, consumer and automotive markets.

For power sensitive applications, the Actel Fusion PSCs offer ultra low-power sleep and stand-by modes and are specifically designed to handle Level 0 LAPU system supervisory activities, such as system board power-up sequencing and configuration.

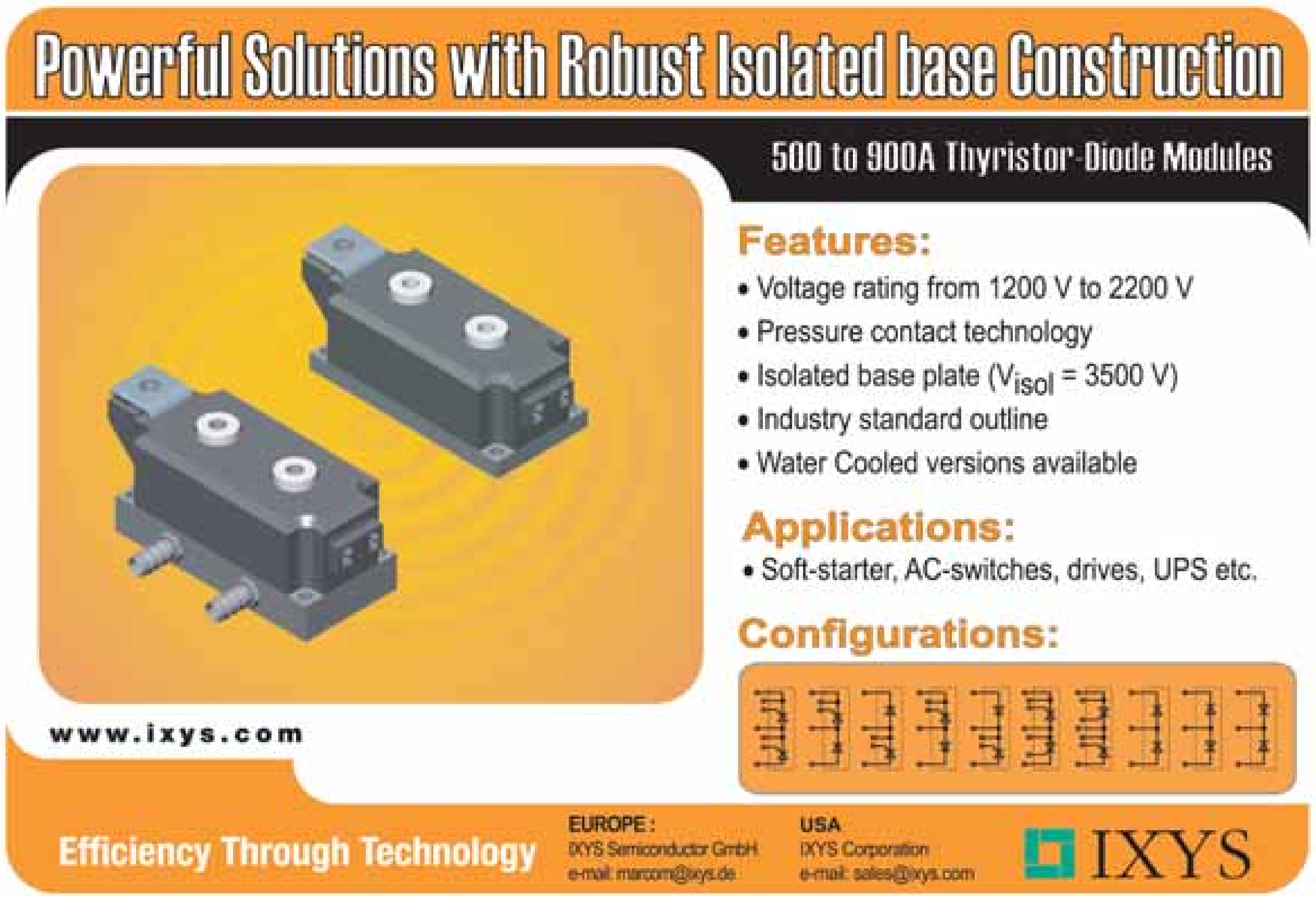
Fusion innovation

The Actel Fusion technology and devices enable designers to design at both very high and very low levels of abstraction. Fusion peripherals include hard analog IP and hard and/or soft digital IP. Peripherals communicate across the FPGA fabric via a layer of soft gates æ the Smart Backbone. Much more than a bus interface, the Smart Backbone integrates a micro-sequencer within the FPGA fabric and will configure the individual peripherals and support low-level processing of peripheral data.

"With the Actel Fusion PSC we are removing the handcuffs from system architects and allowing them to focus on adding unique features and enhancing end-product value," said John East, president and CEO of Actel. "Designers will be able to treat the Fusion PSCs like a mixed signal ASIC without all the ASIC penalties of long design cycles and high costs."

To support these new devices and help maximize designer productivity, Actel has developed a comprehensive design environment that includes software tools, intellectual property (IP) and reference designs.

www.actel.com



Power Player

Saving Energy Needs to Be Price/Performance Neutral

By Dr. Alex Lidow, International Rectifier's CEO

New developments and a system-based approach to design can save energy in motion control applications and vehicles without changing the price/performance ratio.

Our standard of living is increasingly defined by how efficiently we use the energy we extract from oil, coal, wood, nuclear power, hydroelectric power schemes, and other energy sources. The more efficiently use of this 'energy budget', the better we live.

According to the Energy Information Administration, our global energy budget in 2002 was 412 quadrillion BTUs. This figure is set to get much bigger, with predictions that by 2025, it will grow to an even more staggering 645 quadrillion BTUs. The big problem here is not so much finding energy, but consuming it in such a way that we minimise harmful effects on the environment while maintaining or raising our standard of living. And this means more efficient energy use.

Unfortunately, while the need to improve efficiency is clearly recognised, very few governments, organisations or individuals want to pay extra for efficiency improvements. This means that such improvements must be 'price/performance neutral' when compared to existing solutions. Take motion control—inside products that are part of daily life such as home appliances, air conditioning systems, fans, pumps, elevators, and conveyor belts in factories. In total, these motion control applications account for over half of global electricity consumption. Analysis shows that over 85% of these motors are cheap, inefficient 'click on, click off' single-phase AC induction motors. It is estimated that, simply by combining variable speed motors with intelligent controls in all of these applications, we could reduce global electricity consumption by 50%.

But how can this be done without increasing the price/performance ratio?

International Rectifier's experience with washing machines provides a good illustration. Ten years ago, we created a $250 variable speed motor drive system for a washing machine. Now that's a big slice of the cost of a washing machine, and clearly few people were willing to pay a premium just for greater energy efficiency. However, the variable speed motor improved functionality—it was silent and washed clothes better so they lasted longer—functionality for which retailers could demand a premium. The price may have increased but the price/performance equation was essentially neutral and the consumer was getting energy savings as part of the bargain. Furthermore, as mixed-signal and analogue power semiconductor technologies and packaging have evolved, so too has evermore sophisticated control products and methodologies. In the intervening ten years, we have been able to create true system-level solutions that can use much lower cost motors while significantly reducing overall component count. The result? High efficiency, high performance washing machines that are now nearly equal to the cost of a purely mechanically-actuated alternative. With transportation representing 20 – 25% of global energy needs, and with car ownership growing rapidly, improving vehicle efficiency will have a significant impact on global energy consumption.

The starting point is in cutting fuel consumption without compromising cost or performance. To help achieve this, International Rectifier has concentrated on three key automotive systems which include the Integrated Starter Alternator (ISA), the Electric Power Steering (EPS) system, and the climate control and cooling systems with associated blowers, pumps and fans. By combining advanced power semiconductor devices with proprietary analogue, digital and mixed-signal solutions, it will soon be possible to implement all three of these systems in a mid-range vehicle for only a slight cost premium. Again, there is almost no excuse not to pursue the more energy efficient option. It is anticipated that by 2013, costs will be within a few percent for a car with fuel economy that is up to 60% better.

The imperative to save energy and the impact of energy conservation has on our standard of living cannot be underestimated. Only the most conscientious consumers or organisations, however, will buy something simply because it uses less energy. They will buy it if they are comfortable with the price/performance ratio. This means that implementing more efficient systems should either be a 'cost neutral' exercise, or should lead to added functionality and performance that can legitimately demand a premium. And this requires companies such as International Rectifier to take an integrated system-orientated approach to design – to understand the real requirements of the system in terms of cost, performance, features and function.

www.irf.com

MARKETWATCH

Powering Next Year's Data Center

By Chris Ambarian, Senior Analyst, iSuppli Corporation

A lot of us in the power industry have for years felt that while power wasn't as James Bond sexy as some of the more visible chips out there, power management is surely much more important than people realize. Maybe this is because we've really marketed ourselves badly—or maybe it's because we've been doing our jobs so well to date that we haven't really been a headache to the industry.

As most of you know by now, however, this is all changing. We are now in fact being seen alternately as a really important area of design challenge, or as a major headache, depending on whom you talk to. Power management is now a primary and up-front design consideration in product designs in nearly every corner of the equipment industry. Power management is often the pacing, edge-of-the-envelope consideration that determines product capabilities (or limitations). And nowhere is the importance of power management being made clearer than in today's network facilities and data centers.

The Wall Street Journal recently reported (thanks to Astec's Bharat Shah for this story) on the saga of the State University of New York at Buffalo. [Please note: Power management, front page, Wall Street Journal. How far we have come!] It seems that the University bought a $2.3M Dell supercomputer, in an effort to increase its ranking in the world supercomputer standings. But when they went to plug it in, they found that they didn't have enough electrical power to the building to run it (at least not all of it). They needed to do a substantial upgrade to their electrical systems to be able to use their new boxes.

This also presumes that once they upgrade their electrical supply, they can still afford to pay their electrical bills! Operators of data centers and switching facilities are reporting that their electrical requirements are ramping upward at an exponential rate that simply cannot continue. Even moderately-sized users such as hospitals are talking about megawatts.

And the Buffalo story is just the tip of the iceberg. It pales in comparison to the scale of the challenges faced by folks designing new (or worse, trying to retrofit existing) data centers. The power densities of these facilities are now running around 1kW/m2—with some exotic ones running at a staggering 5kW/m2. Individual pieces of equipment are pushing the envelope at 40kW/m2. One false move in any of the power supply or power removal, and you have a dead, multi-million-dollar piece of equipment on your hands.

And yet, I have heard it said among power management people that we're doing everything that they can to increase efficiency, but to some extent it's out of our hands. The logic goes like this: "We can improve another 2 or 3% in efficiency of that converter brick—but what about all the power being dissipated by the micros and the memory and the fans and… So really, whatever we're working on really isn't the pacing item in reducing the losses in the room." This seems like a pretty good line of thinking, but nonetheless I'm here to argue with it. (Sorry, Mom, a guy can change only so much.)

I think that in order to understand our part in the challenge as semiconductor and power supply folks, it is helpful to take a look at the facility level, to see where the power is going.

According to numbers from Intel and from iSuppli's own calculations and conversations with system designers, here's an overall view of where the power supplied to a modern server room is going:

As you can see from Figure 1, half of the power needed goes right to the infrastructure of the room—cooling and continuity of power. As mature as the motor drives and HVAC industries are, there is still much room for improvement in the efficiency of HVAC systems. Unless a sophisticated motor control with communications capability is being used and actively adjusted to the room needs on a real-time, proactive basis, chances are that significant amounts of energy are being wasted in the chiller/air handler loop. These technologies are available—the question is: is anyone minding the switch? The operating point of the system needs to be adjusted to its optimum—which presumes a system to determine what that point is, and to adjust the system to that point (preferably proactively, based on system events). More on this later.

Figure 1. Power dissipation in a modern server facility (source: Intel, iSuppli).

Still in infrastructure, there's the UPS. A typical UPS can dissipate 265 BTU/hr per kVA—which translates to about 89% efficiency. Appropriately, a lot of work is being done to improve on UPS efficiency; of all the dissipaters around the system, this one is the most stand-alone. Efficiency gains here will be direct, and more or less independent of the rest of the system.

Which brings us at last to the reason we're here: the equipment itself. Let's take a look at a typical server system. We'll consider an average configuration, somewhere between a typical 1U (around 900W) and 2U (around 1100W). For such a 988W system, the dissipations at rated capacity look like in Table 1.

The potentials for reduction I'm tossing in there are a best estimate as an interested, more or less objective observer of what's going on in these areas. All of the processor players (both large and small) are introducing new ideas for lower leakage and lower in-use dissipation, and some of the technologies hold tremendous promise relative to today's solutions. Some of that 80% number has already been significantly chipped away at by recent introductions and announcements such as those by AMD And I threw 20% in there for memory because, frankly, I don't know a damned thing about memory but there must be something that they can do to improve on the situation, and I didn't burden them too badly with that. Power conversion gets a big chunk of the work: I figure that with anticipated improvements in magnetics and in digitalization of the PWM controls so that operation can be optimized at multiple points, we ought to be able to gain another couple of percent. Throw in some MOSFET and diode improvements, and AC/DC can be brought up another couple of percent. We can argue the exact amounts of these numbers, but broad side of a barn, we can see a path to about 40% reduction in full-throttle dissipation. Which not only enables us to pack the racks in even more densely—it saves a lot of energy and money. Hey, 40% or so isn't small change. But that's only part of the story.

	Dissipation (typ.)	% of total	Potential for Reduction	Potential for Reduction
Processors	274 W	27.7%	80%	219 W
AC/DC conversion	245 W	24.8%	40%	98 W
Cooling fans	104 W	10.5%	30%	31 W
Memory chips	96 W	9.7%	20%	19 W
DC/DC conversion	89 W	9.0%	20%	18 W
Disk drives	80 W	8.1%	0	0 W
PCI, planar, standby	100 W	10.1%	0	0 W
Total	988 W	100.0%	39%	385 W

Table1. Power dissipations and potential improvements (sources: Intel, iSuppli).

The requirements on the data center are anything but constant. There are very well documented time-load profiles, and then of course there's the unpredictable load that comes up (like that humorous old story about the big flush that overwhelmed the sewage plant after the commercial break of the Super Bowl broadcast). But leaving everything running full-throttle all the time independent of demand is obviously not a smart solution. The smart solution will be the ability to eke the maximum amount of efficiency out of the system at any given time—and as we've seen from this facility-level view, that means scaling back on that expensive air conditioner at the same time that you're scaling back 62% of your server racks. Real time. If we're able to do that, then not only are we saving that 40%, but we're saving a significant portion more than that by idling unneeded capacity all around the system.

This idea begins to provide a glimpse into what we see as a critical need for a power operating system to manage all of the parts of a complex power system for maximum efficiency, while still maintaining the ability to bring the whole system up to full capacity more or less instantly. In data centers in particular, this need must be met within the next 12-18 months. In order to be able to manage all of the pieces of a system like this, we need to be able to not merely sense (e.g., via thermostats), but to digitally predict what's happening or going to happen throughout the system, and then direct the system to operate in the most efficient mode for that condition. This requirement is facilitated by the digitalization of power conversion. In fact, this is what we believe to be the punch line of digitalized power: as a component-level phenomenon, it's an important development, but at a system level, it's a REALLY important development. Digitalized power converters will be able to communicate useful information to a power operating system, which can then use the information to determine the best state for every level of the system to be operating at—whether that level is the adjustment of the speed of a variable speed drive on the air handling unit, or the level of setting the operating point of the control loop in a thousand DC/DC converters.

Of course, this will have some very significant implications on the software side. That will perhaps be the subject of a future editorial.

So to bring us full circle, for us semiconductor and power supply people, it's not out of our hands. In fact, the only way that we're going to get to the next level of meeting our users' needs will be to stop thinking at the component level, and to figure out how we'll fit in at the system level. When we begin to do that, the first thing that we realize is that we'll either be driving that choice, or we'll have to take what we get.

The system awaits…

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High Brightness LED Thermal Management Made Simple

Use similar techniques as with power transistors

Bergquist's Thermal Clad Insulated Metal Substrate (IMS) offers many of the same cooling benefits for LED lighting applications as it does for power electronics.

By Rick Samuelson, Market Development Manager and Justin Kolbe, Sr. R&D Engineer, The Bergquist Company

Like surface mounted power transistors, High-Brightness Light Emitting Diodes (HB-LEDs) require cost effective thermal management for long-term reliability. Consistent color and power magnitude are directly affected by the thermal management solution as well. Generally, as the light output of HB-LEDs increase, so does power dissipation or watts per HB-LED.

Currently, three- and five-watt LEDs are commonplace and many industry experts are predicting 10-watt LEDs availability in the next few years. Packaging and thermal management solutions for HB-LEDs are paralleling surface mounted power devices.

HB-LED of greater than one watt are almost always surface mounted devices. This is because the axial leads to the die in a leaded package do not conduct enough heat away from the LED. Chip-on-board (COB), flip chips and thermally efficient packages are emerging as the standard thermal management packaging solution for HB-LED.

The Effect of Temperature

HB-LED die have several temperature dependent properties. The color, or wavelength will change with temperature. As die temperature increases, the wavelength of the color gets longer.

$$\frac{\Delta\lambda}{\Delta T} = K$$

$\Delta\lambda$ = Change in dominant wavelength (nm)

ΔT = Change in die junction temperature (∞ C)

The temperature effect on wavelength is depicted in Figure 1.

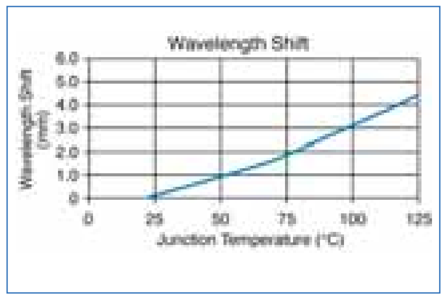
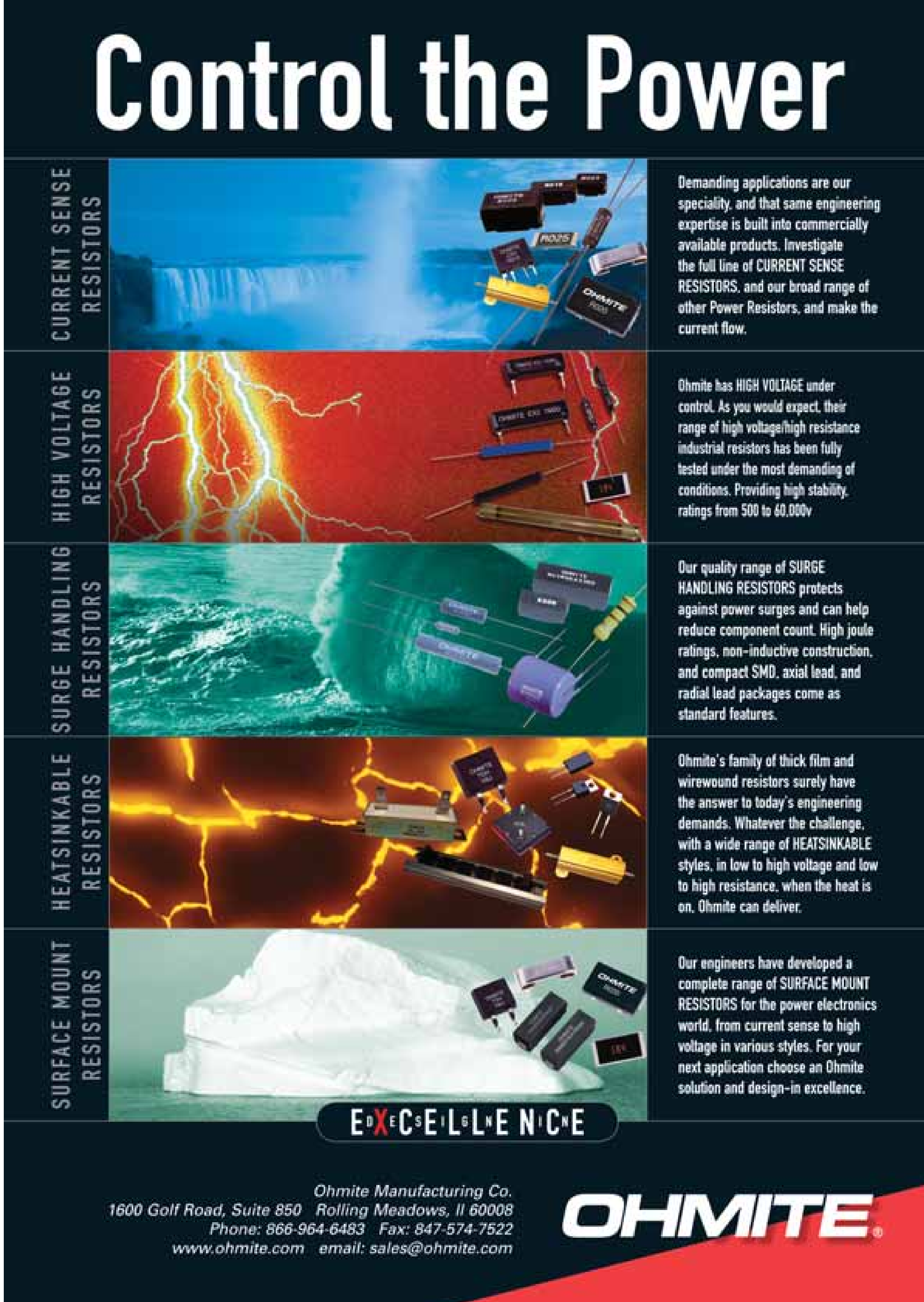


Figure 1. The temperature effect on wavelength.

An area in which this is of particular importance is with white light. The human eye can differentiate small color changes in white light. When HB-LEDs are populated in an array, consistent thermal resistance from one die to the next assures consistent color. Because of the comparatively low thermal resistance Thermal Clad offers as compared to FR-4, die temperature is less affected by slight variances in junction-to-case thermal resistance that occurs with tin eutectic or epoxy-die mounting techniques.

Power magnitude, or watt density, is directly related to light output. The more power that is applied to the HB-LED while maintaining the desired die temperature, the higher the light output will be. It may also be possible to pack the die more closely in an assembly that utilizes good thermal management techniques, thereby reducing the effects of temperature.

The following graph shows the dramatic change in relative light intensity based on the forward current applied to the LED.



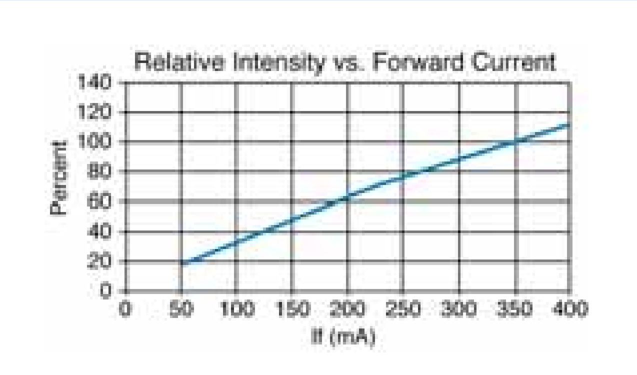


Figure 2. Relative Intensity vs. Forward Current.

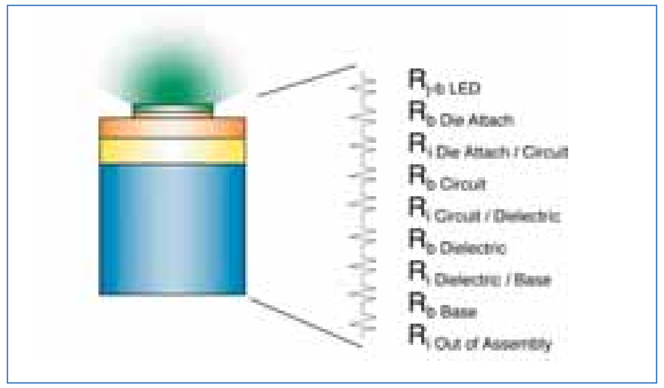


Figure 3. Several thermal resistance interfaces.

Finally, the junction temperature determines HB-LED lifetime. The heat rise in LEDs is due to the energy that is not turned into light energy.

$$P = I^2R$$

Generally, a 50 percent drop in light output for a constant-forward current indicates end-of-life for HB-LEDs. With proper thermal management, HB-LED lifetimes can exceed 100,000 hours. In addition to long life, other factors that make LEDs viable as compared to incandescent or fluorescent lighting are: Versatility, safety factors (low voltage), total cost of ownership.

Although the initial cost of HB-LEDs is higher, many applications such as traffic signals, architectural and display lighting have demonstrated HB-LED lighting is the most cost effective solution.

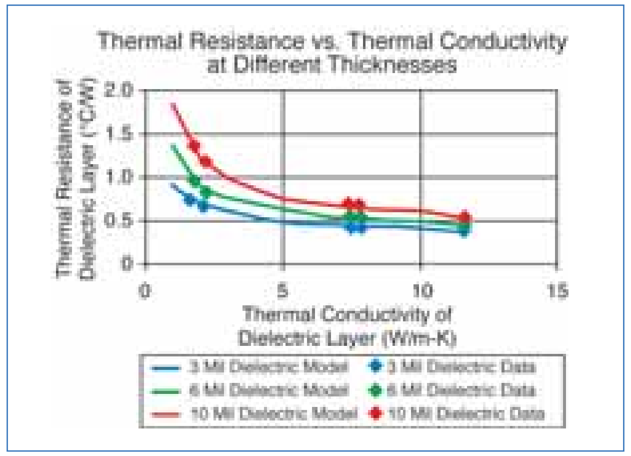


Figure 4. Thermal impedance versus thermal conductivity at different thicknesses.

Cost of Heat Summary

Better thermal management allows for more forward current applied to the LED, which means more light and possibly reducing the number of LED required for the desired light output. Maintaining a cooler assembly at an equivalent power equates to more light per die. Ninety percent of the electrical energy in a red AllnGaP LED will be converted into visible light. Only part of this light energy can be ejected from the chip. The remaining energy, which cannot leave the chip, will be converted into heat.

Heat Transport Methods

Determining the exit path for thermal energy is important. Conduction, convection and radiation are the primary paths for the removal of heat from the HB-LED die. Conduction, or heat transfer through a solid body, is the most efficient thermal path, followed by convection, which is usually the final thermal path to ambient. Radiation is generally negligible in managing the temperature of HB-LEDs.

The following calculation is used for the stack's conductive heat transfer for the stack, from the heat source to the air.

$$\frac{q}{A} = -k\frac{dT}{dx}$$

Power that can be dissipated under a given temperature constraint is then influenced by:

area of the layer [A],
the thermal conductivity [K],
the thickness of the layer [dx] and
the power [q].

In the case of a typical HB-LED application, several thermal resistance interfaces are present in Figure 3.

Moving through the stack, thermal impedance depends on thermal conductivity and thickness. Figure 4 depicts thermal impedance versus thermal conductivity at different thicknesses for the dielectric layer.

Note that as the dielectric thickness gets thinner, thermal conductivity has less affect on thermal resistance. As this relates to heat removal from the assembly, the total thermal resistance of each component in the stack is considered, and then assembly-to-ambient. Thermal Clad has a 75-micron dielectric with relatively high thermal conductivity. This insulation layer is critical in the thermal management of HB-LEDs because the isolation layer is potentially one of the highest thermal resistance interfaces in the stack.

For the assembly-to-ambient interface, different options include an infinite heat sink (such as the chassis of an automobile or metal enclosure), forced air, or a dynamically cooled assembly (such as a fan or thermal electric cooler), often modeled as an infinite heat sink.

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The driver is equipped with the award-winning CONCEPT SCALE driver chipset, consisting of the gate driver ASIC IGD001 and the logic-to-driver interface ASIC LDI001.

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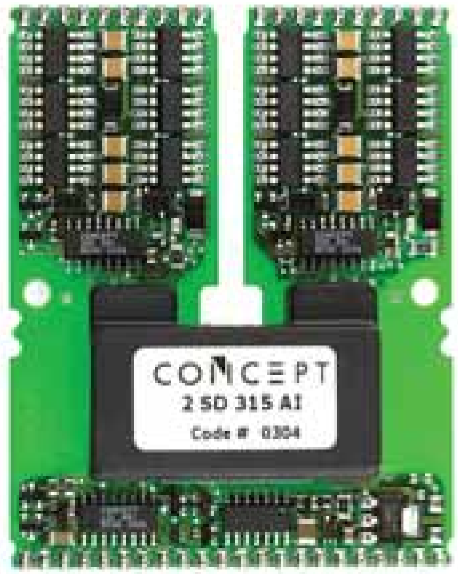
- Duty cycle 0...100%
- Delay time typ. 325ns



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Key product families include plug-and-play drivers and universal driver cores for medium- and high-voltage IGBTs, application-specific driver boards and integrated driver circuits (ASICs).

By providing leading-edge solutions and expert professional services, CONCEPT is an essential partner to companies that design systems for power conversion and motion. From custom-specific integrated circuit expertise to the design of megawatt-converters, CONCEPT provides solutions to the toughest challenges confronting engineers who are pushing power to the limits.

As an ideas factory, we set new standards with respect to gate driving powers up to 15W per channel, short transit times of less than 100ns, plug-and play functionality and unmatched field-proven reliability.
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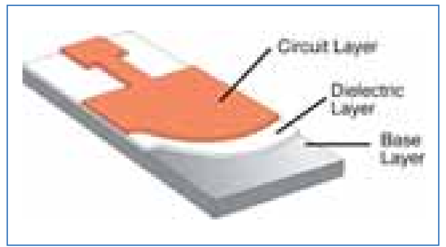

Figure 5. The Bergquist Company's Thermal Clad IMS.

Removing the heat from the die is only effective if it can also be removed from the assembly. An infinite heat sink is the most effective solution thermally, but often impractical or too expensive.

Therefore, when using an infinite heat sink approximation, the problem becomes one of conduction only. This assumption is generally valid if the removal of heat from assembly is greater then the generation of heat, assembly is mounted to a large heat sink and assembly is being cooled dynamically.

Still air (or natural convection) is probably the most common method of cooling but still requires air flow (e.g. holes in a cover or enclosure). Otherwise, air is just a good thermal insulator.

Use the following equation as a rule of thumb when figuring heat dissipation in still air.

$$q = hA\Delta T$$

$$h = a\left(\frac{\Delta T}{L}\right)^{1/4}$$

q = dissipated power (W)
A = area (m²)
ΔT = (temperature plate – temperature ambient) (K)
L = plate length (m)
h = convective heat transfer coefficient (W/m²-K)
a = coefficient 1.32 for top of plate, 0.59 for bottom, dependent on shape and orientation

Use the following equation as a rule of thumb when you have moving air.

$$q = hA\Delta T$$

$$h = a\left(\frac{LV\rho}{\mu}\right)^{B} N_{Pr}^{1/3}\frac{k}{L}$$

q = dissipated power (W)
A = area (m²)
ΔT = (temperature plate – temperature ambient) (K)
L = plate length (m)
h = convective heat transfer coefficient (W/m²-K)
a = coefficient 0.0366 for turbulent flow, 0.59 for laminar flow
B = 0.8 for turbulent flow, 0.5 for laminar flow
V = velocity of fluid (m/s)
ρ = density of air (kg/m³)
μ = viscosity of air (Poise)
N_{Pr} = Prandtl Number = C_p m / k
C_p = heat capacity of air (J/kg K)
k = thermal conductivity of air (W/m-K)

Overall thermal resistance of the build is:

$$R_{Total} = \sum_i R_i$$

Ri is bulk or interfacial resistance
-Conduction R_b = L/k A
Interfacial resistance must be determined empirically (generally small, but not always)
-Convection R = 1/h A

Overall power dissipation in a given temperature rise is:

$$q = \frac{T_2 - T_1}{R_{Total}}$$

Overall temperature rise for given power dissipation is:

$T_2 = T_1 + qR_{Total}$

or the overall temperature rise for the given power dissipation is:

$T_2 = T_1 + qR_{Total}$

These simple equations are good for first approximations of temperature rise in HB-LED designs. However, bench top testing and data confirmation are advisable to verify the design.

Circuit Board Comparison Models

Insulated Metal Substrate (IMS) and standard FR-4 are commonly used circuit board materials in conjunction with HB-LEDs. The Bergquist Company's Thermal Clad IMS is a thin, thermally conductive layer bonded to aluminum or copper substrate for heat dissipation (see Figure 5).

Thermal Clad circuit board materials are available from The Bergquist Company in two different thermal conductivities. Multi-Purpose (MP) and Low Thermal Impedance (LTI). Figure 6 illustrates the modeling results of a Cree XB900 die mounted on each of these circuit board materials, along side an FR-4 board. This thermal model shows the temperature of the die when a constant current is applied to the die on different circuit board materials. The Cree die is modeled on two-ounce circuit foil, .020" square. Tin gold eutectic die attach was utilized with gold wire bonds to complete the circuit. Power dissipation was set at one watt. The resulting die temperature for the FR-4 is 63.7∞C, MP is 36.9∞C and LTI is 34.2∞C.

Bench Test Results

A bench test setup is used to verify the thermal model. The test is adapted from Voltage from Base to Emitter (VBE) testing used in power electronics. The die is calibrated by measuring voltage at different temperatures using a sense current small enough so as to cause negligible heat rise. In this case, one milliamp was used. Following are all of the test parameters common in power electronics to determine junction temperature.

- Sense current - 1 mA
- Heating current and heating voltage from power supply
- Electrical resistance dependent on temperature
- Know V and I, can get T as a function of R
- Thermal resistance of the system is Tj-Ts/(V*I)

Once the LED die was calibrated using the described set up, the forward current to the die was adjusted in order to regulate the die temperature. Figure 7 illustrates the light output of the same LED die on different circuit board materials the die temperature was maintained at 50°C. This bench test shows the thermal advantages of Thermal Clad versus FR-4, resulting in higher light output.

The thermal resistance is both a function of the thermal conductivity of the dielectric and the pad size. As the

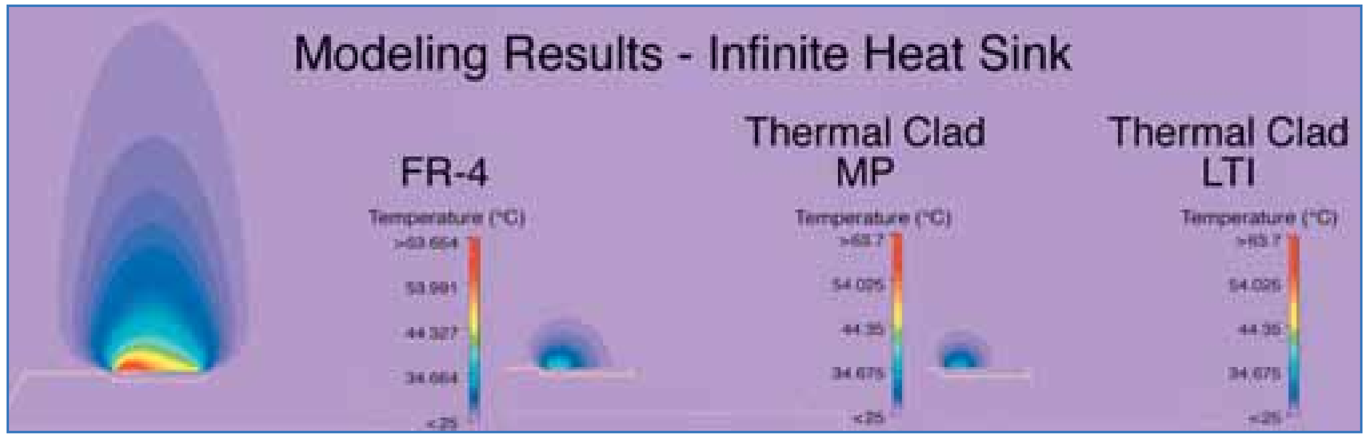

Figure 6. Modeling Results – Infinite Heat Sink.

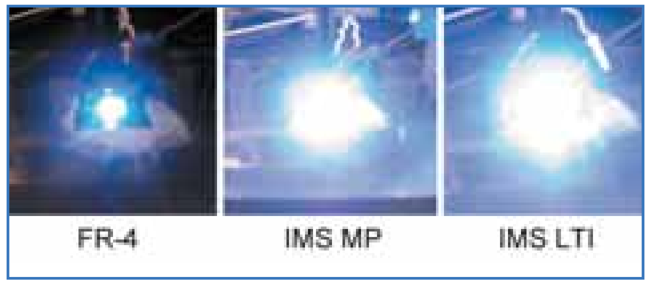

Figure 7. Light Output of Die on Different Dielectric Materials @ 50°C.

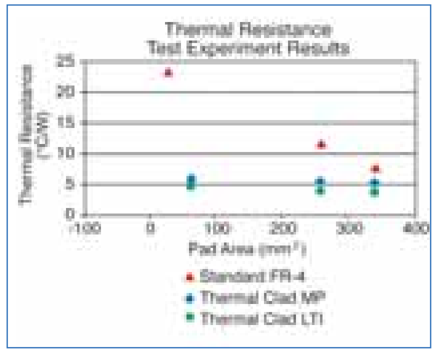

Figure 8. Thermal Resistance Test Experiment Results.

conductor area that the LED is mounted on gets smaller, thermally conductive materials become more valuable. Building the mounting conductor larger, the LED improves thermal resistance as shown in the following graph.

Packaging Conclusion

Several options are available for thermal management of HB-LEDs. Most common are packaged die from the manufacturer and direct-die-attach to the circuit board or substrate by the HB-LED integrator. The most critical thermal path in the stack is the one with the highest thermal resistance. Good practice suggests that you reduce the thermal resistance of that layer with Thermal Clad instead of FR-4. Typically, HB-LED packages from the manufacturer have a thermal resistance of > 15∞C p/Watt. When HB-LED packaging has thermal resistance this high, the circuit board choice has less of an impact on thermal management. When the opportunity exists to use tin eutectic gold die attach methods, as was the case in the model and bench test described earlier, the circuit board material greatly affects HB-LED thermal management. Bergquist's Thermal Clad material is a cost effective option for the thermal management of HB-LEDs thereby improving heat transfer as compared to emitters. However, thermal management of HB-LED emitters is also improved on Thermal Clad as compared to FR-4, though the impact on thermal management is less than COB packaging.

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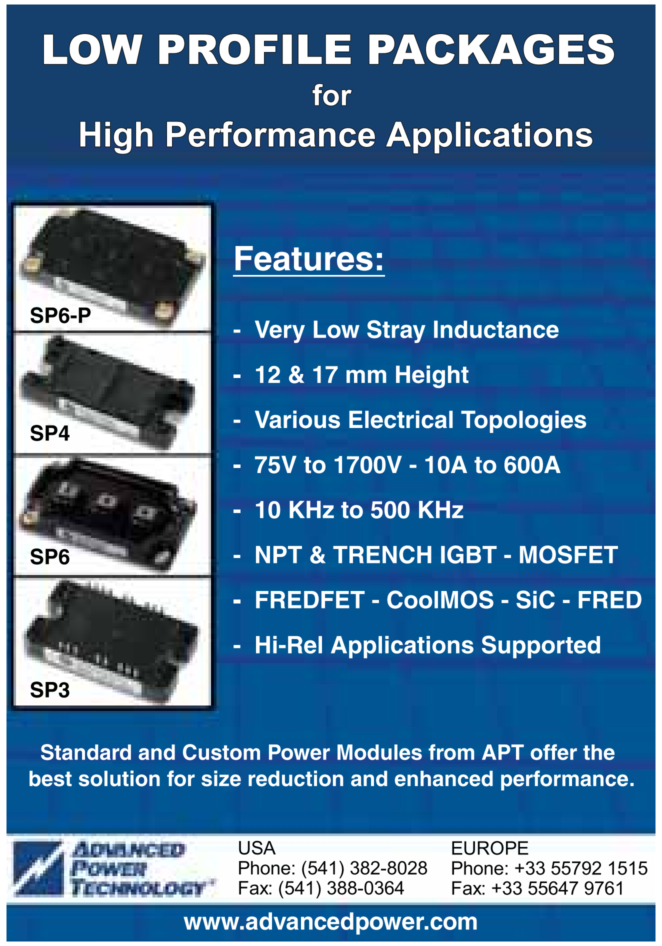


Three Level, Four Quadrant Power Converter

600V CoolMOS devices in 400VAC motion control application

Today's state of the art MOSFET Components offer compelling advantages in switching speed and low conduction losses. These devices have a maximum voltage rating of 600V but they can be employed in standard 400VAC power systems in multi-level topologies.

By Timo Christ, Uwe Werner and Bernd Orlik, IALB University of Bremen, Germany

Frequency converters generate an output voltage by switching between at least two DC voltage levels. The average in time of these pulses is the desired output. A converter with more than two connections to the DC link is regarded as a multi-level converter. The industry standard two-level converter switches the output node either to the positive or the negative potential of the DC link. In a three-level converter, an additional voltage level is introduced. The diode clamped configuration takes this voltage from a tap in the DC link energy storage capacitor. Many converters employ series connection of DC link capacitors in any case to achieve the required voltage rating.

Multi-level converters feature a number of advantages and some disadvantages over two-level converters. The switches in a multi-level converter only need to withstand the voltage of one level, in other words the blocking voltage requirement is cut in half for a three-level converter with the same total DC link voltage as a two-level converter. This allows lower voltage and potentially faster or lower conduction loss devices

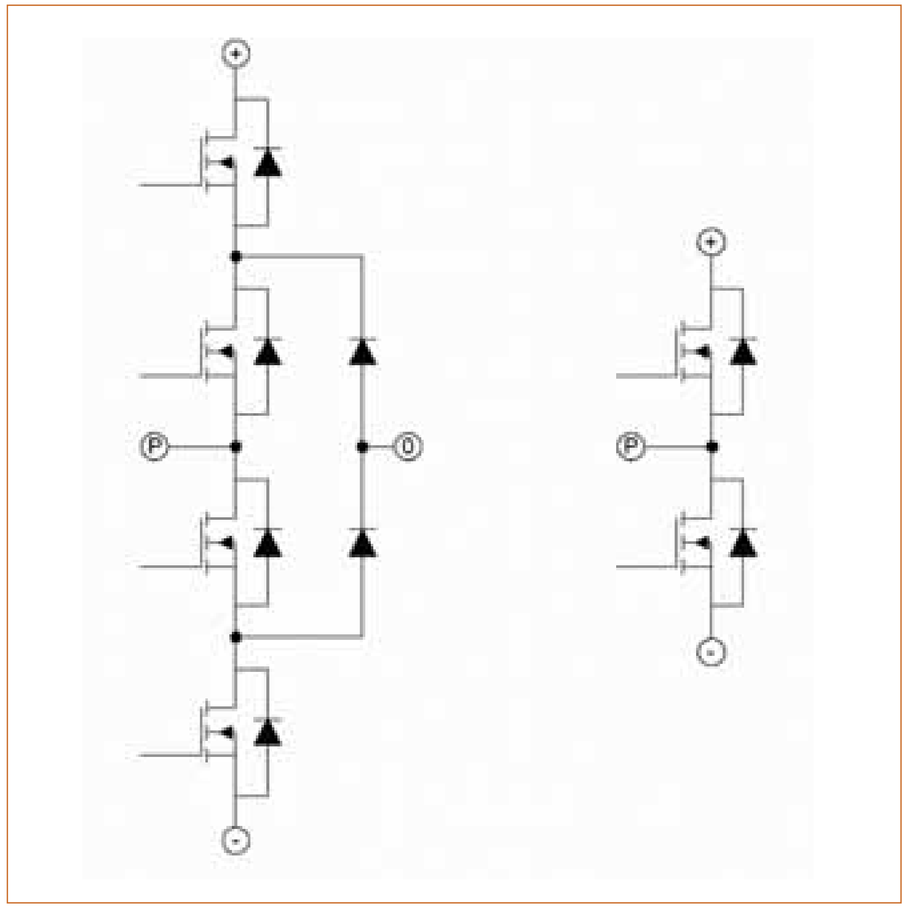
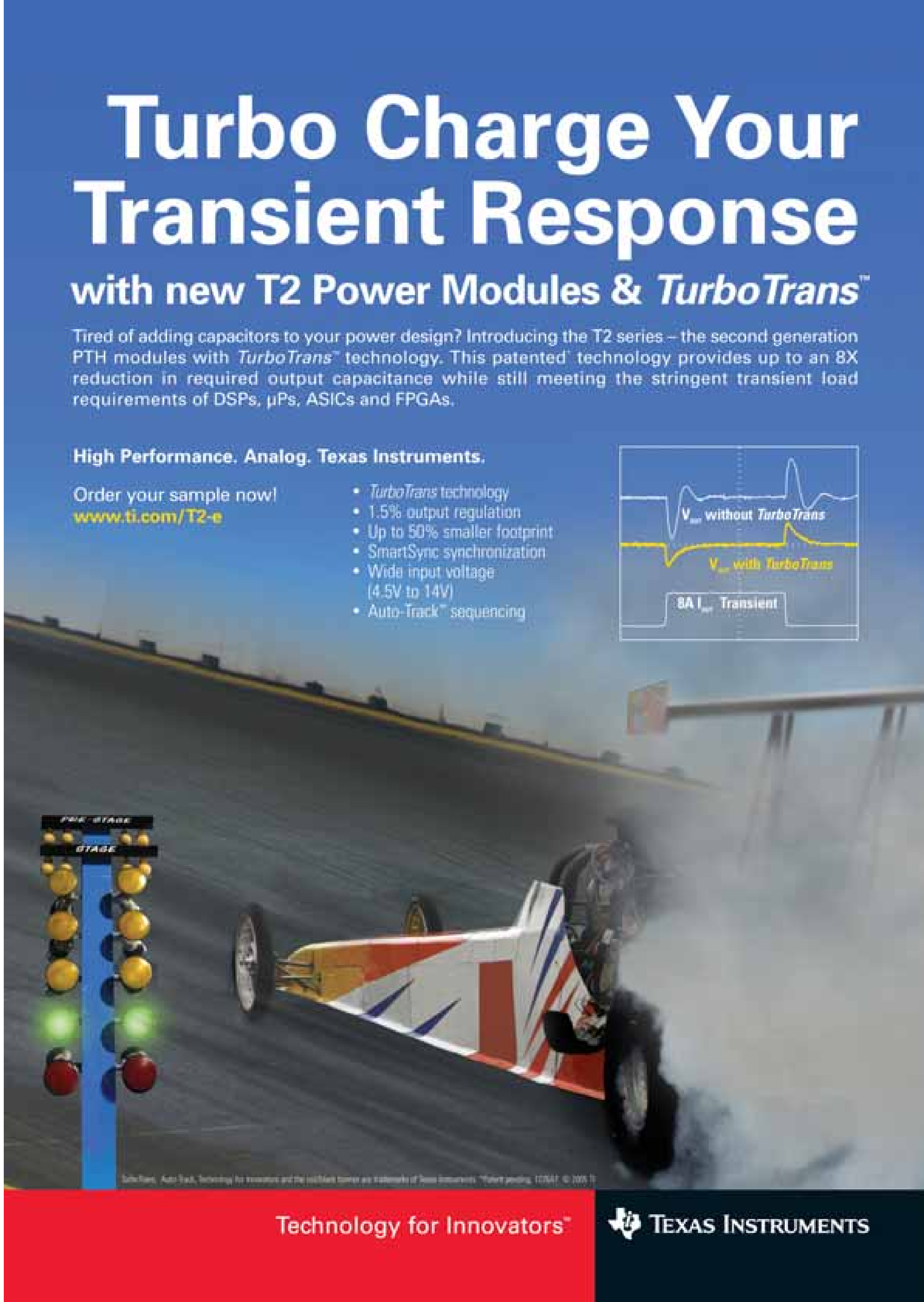


Figure 1. Half-Bridge Structures.



to be used. Switching only half the total DC link potential also cuts the voltage gradient dv/dt in half for the same switching speed. This can ease EMC problems and reduce cost for screening and filtering. Alternatively, switching speed may be increased to reduce switching loss. Approximating the output voltage with three instead of two levels also reduces harmonic distortion significantly, allowing reduction of switching frequency or less filtering for the same quality of output. Switching loss is the same in two- and three-level converters. This is because the average switching frequency of each switch is halved, but the number of switches is doubled. The switching losses are distributed in a greater number of switches. This raises the opportunity to double switching frequency for the same losses per device.

Multi-level converters consist of significantly more parts than two-level converters. The three-level converter needs two additional switches and two diodes per half bridge, and system cost is driven up because additional gate drivers and a more powerful controller are required. More parts also bring about inferior reliability. System cost increase for a three-level converter of 20kVA output power was estimated as 60% over an equivalent two-level converter. Presently, no half-bridge drivers with integrated protection functions are available for three-level converters. These drivers make it easy to build a robust two-level converter, three-level drivers must be custom designed. Half bridge power modules are not available either. Today's digital signal processors designed for motor control are aimed at two-level PWM and contain corresponding peripherals. Making these components work in a three-level converter is an additional engineering effort.

To balance the voltages of the DC-link capacitors a simple regulator is used. It consists of an IGBT half bridge whose output node is connected to the neutral point of the DC link via an inductor. The half bridge is controlled with a hysteresis controller which consists of voltage dividers, high speed comparators and a small microcontroller. When the neutral point voltage sags to below half of the total DC link voltage minus the hysteresis, the upper IGBT is turned on. Accordingly, the lower IGBT is turned on when the neutral point voltages rises above half of the total DC link voltage plus the hysteresis. In this way, the controller keeps the neutral point always centered between the positive and negative DC link potentials. This ensures equal voltage sharing on the CoolMOS devices. With this regulator, the modulation algorithm of the inverter does not need to take charge balancing of the capacitors into account.

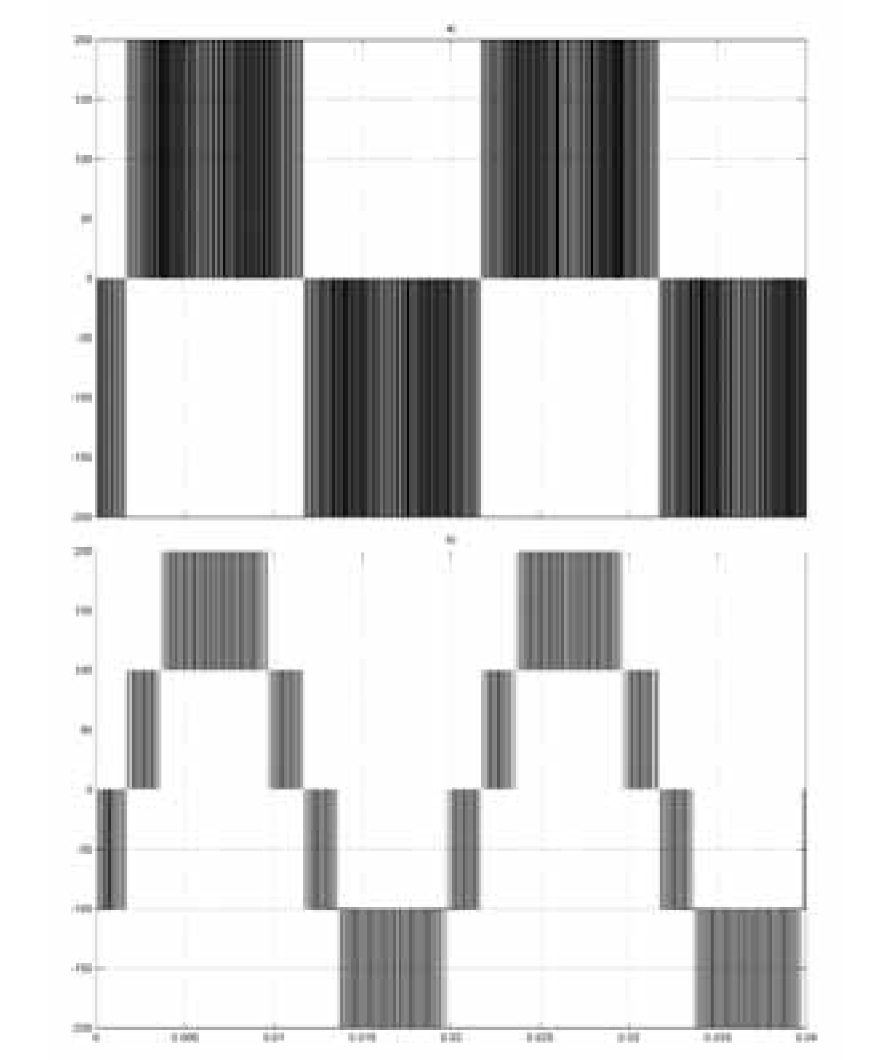


Figure 2. a) Two-Level and b) Three-Level Phase-to-Phase Output Voltages.

Fiber optical signal transfer has the distinct advantage over copper wiring of immunity against electro magnetic interference (EMI), which can be a major asset in a power electronic environment. The attained galvanic isolation between signal and power processing is also of a quality which cannot be matched by other technologies presently. Disadvantageous is the high cost of all fiber optic components. The Versatile Link fiber optic system from Agilent Technologies was employed, using the transmitter component HFBR-1524 and receiver component HFBR-2524 and an interconnection of 1mm plastic fiber of 1m length. Twelve channels are required to control the inverter. The transmitters with their drivers are mounted on a PCB which can be connected to the DSP system directly. Receivers are integrated on the gate driver PCBs.

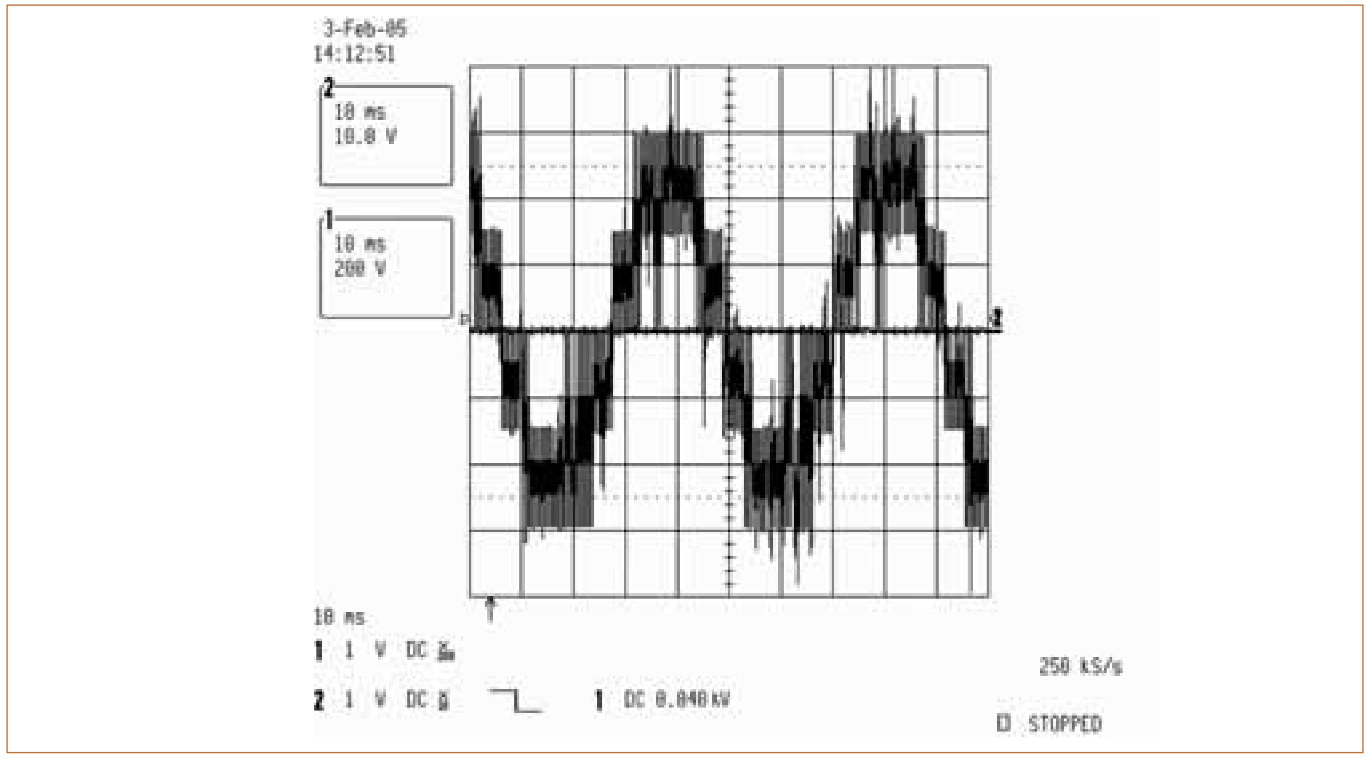


Figure 3. Output of Experimental Converter.

The digital signal processor (DSP) employed is TMS320F2812 by Texas Instruments. This is a device with two integrated peripheral blocks designed to produce two-level PWM output for three phase systems. These blocks are called Event Managers and contain counters, comparators and auxiliary logic circuits to make control of two-level converters easy. Unfortunately, these blocks don't help much at all in controlling a multi-level converter. This problem was solved by having each Event Manager care for only one half wave. Event Manager A only generates switching pulses during the positive half cycle and is switched off during the negative half cycle, for Event Manager B the reverse is true. An external logic circuit constructs the twelve pulse control signals for the three-level inverter from the signals generated by the DSP and provides additional protective functions such as shoot through protection and dead time.

An experimental converter which features active rectifier and inverter stages was built in our laboratory and initial operative testing was conducted with this device. The main PCB, which contains four 70μm copper layers, holds all power components. That is, 24 CoolMOS devices and 12 clamping diodes in TO-247 packages are mounted underneath the board in contact with a substantial heatsink, the DC-Link capacitors and gate interface components are mounted on top of the board. Low parasitic inductance is of extraordinary importance with these very fast switching power devices. The gate drivers are constructed on separate PCBs which are mounted close to the main board. They are implemented basically with the fiber optic receiver and a MOSFET gate driver IC, namely the MC33151D by ON Semiconductor. This modular approach allows experimentation with different gate drivers and easier exchange of power components, however at the disadvantage of longer gate wiring. The converter was successfully tested with DC link voltages of up to 680V.

This experimental multi level converter demonstrates the serviceability of CoolMOS Devices in 400VAC motion control applications. The converter is able to drive up to 15kVA loads with highly dynamic performance and low voltage gradients compared to industry standard two level converters. The use of fast power devices and the multi level topology allow high switching frequencies—the border is set by the speed of the controller. Active rectifier stage allows regenerative braking, power factor control and DC-Link voltage control. An independent charge balancing regulator keeps the voltage levels synchronised without interfering with the input or output stage modulation. The optical link between signal and power processing stages provides a fast, safe, reliable and EMI-immune interface. The system presented in this article is merely a research platform, but commercial implementations of the same technology are completely feasible.

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POWER MANAGEMENT

Design Challenge for Synchronous Buck Controller

Sequencing- and margining-capability simplifies power management

Many applications require multiple voltage rails (e.g. a DSP with different core and I/O voltages), and depending on the part and manufacturer used, there are different guidelines specifying how to control two or more voltage rails to minimize the possibility of latch-up or excessive current draw during power-up and power-down.

By Dirk Gehrke, Texas Instruments

The TPS40100 controller from Texas Instruments features a sequencing capability that simplifies the external circuitry required to implement these sequencing scenarios, as well as offering many other additional benefits over existing controllers. The device is a synchronous buck controller targeted at applications requiring supply sequencing and output voltage margining features, and is targeted at applications with bus voltages in the range of 4.5V to 18V.

Three main schemes are commonly used to power-up multi-rail power supplies: Sequential Sequencing, Ratiometric Sequencing and Simultaneous Sequencing, and the most appropriate scheme for a given application depends on the requirements of the device(s) used. Manufacturer's data sheets often do not specify which power sequencing scheme to implement, but instead outline the voltage and timing conditions to be observed. (Note: Some devices allow out-of-bounds conditions for a short period of time.) Using the pin conditions and waveforms presented below, a sequencing methodology can be chosen to meet the various processor requirements.

Sequential Sequencing requires that one power supply rail ramps up and settles at its final regulation voltage before the second power supply rail ramps up (after a predefined delay). This method can be used to initialize certain parts of the circuit to a known state before activating the rest. An example, in which the core supply is applied before the I/O supply, is shown in Figure 1. Such a scheme can be easily implemented with the TPS40100 by using the power good function of the core converter to enable the I/O converter: the I/O supply will be only enabled once the core supply is within regulation. An RC network could also be included to add some delay between these transitions.

With a Ratiometric Sequencing implementation, both power supply outputs ramp at the same time—and in proportion—until regulation is reached,

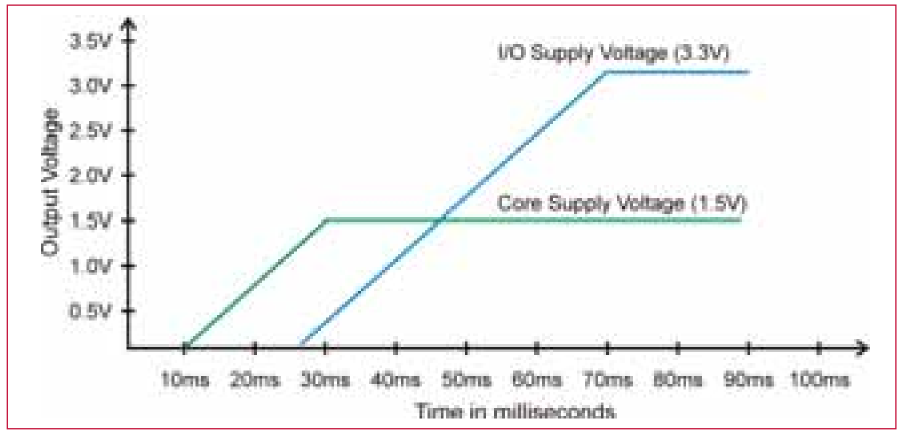

Figure 1. Sequential Sequencing.

as shown in Figure 2. This sequencing scenario can be implemented with the TPS40100 controller by using a common soft-start capacitor for multiple controllers. In the drawing shown, three separate controllers share a common soft-start capacitor.

Simultaneous Sequencing is similar to Ratiometric Sequencing, in that both power supply outputs ramp at the same time. However, with Simultaneous Sequencing, the objective is to minimize the voltage difference between the two supply rails during power-up, as shown in Figure 3. This sequencing method is useful for devices that have "sneak paths" between supply pins, or draw excessive current during start-up if internal logic is not in a stable state. Simultaneous Sequencing can be implemented by using an uncommitted amplifier included in the TPS40100: this can be used to implement a separate control loop that regulates the output according to a reference voltage applied to the TRKIN pin. Typically, a master voltage ramp such as the I/O supply is used to act as the reference for the ramp up voltage, however, an RC network (which generates a voltage ramp as its capacitor charges up) could also be used. Figure 3 shows what such a ramp up situation looks like.

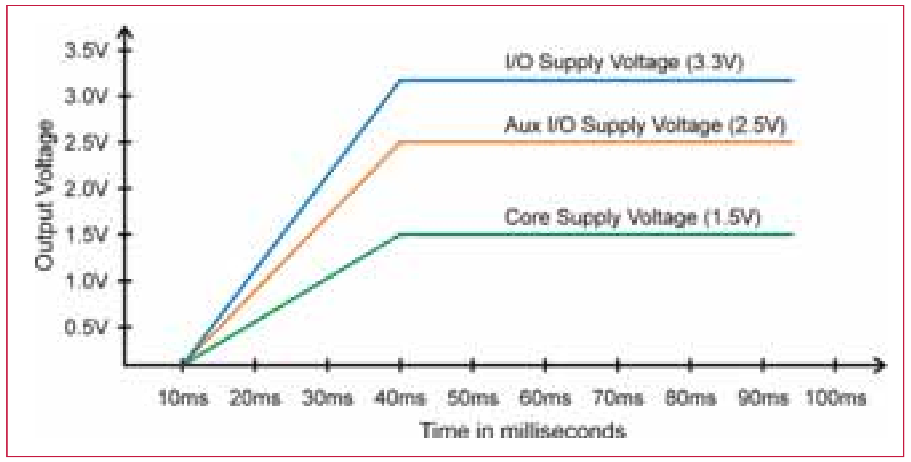

Figure 2. Ratiometric Sequencing.

Since all of these sequencing scenarios can be implemented using the TPS40100, in general it is recommended that placeholders for configuration components are included during the design phase, so that changes to the sequencing scheme can be implemented by adding or replacing components, rather than redesigning the complete

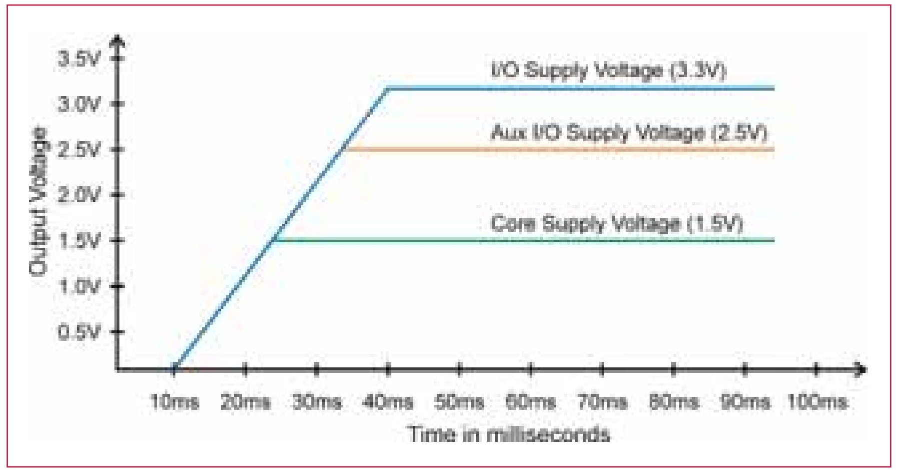

Figure 3. Simultaneous Sequencing.

system. Such an approach can save time during development, and often saves money during mass production (e.g. if the power supply sequencing requirements change because the processor or FPGA used is changed).

Margining Control

In addition to the various sequencing implementations, the TPS40100 incorporates a so-called Margining Control function. This feature allows the user temporarily to adjust the output voltage about its nominal value by a small amount. This feature is useful during automated testing of the final PCB during production because it allows the manufacturer to verify the board's correct operation at the limits of the power supply tolerance. A voltage tolerance level of ±5% is common for a supply voltage like 3.3V, however, in systems using lower core voltages such as 1.5V, a tolerance of ±3% is more typical. This feature can also be used to troubleshoot customer-returned boards exhibiting marginal performance, thereby reducing the risk of sending them back with the description 'failure not found'.

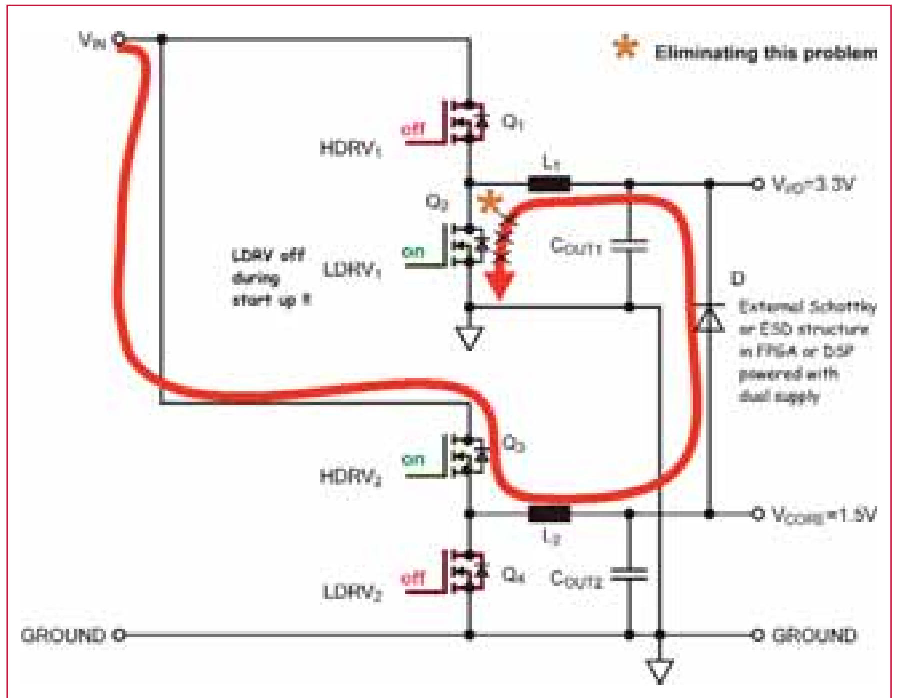

Figure 4. Two converter Output Stages shown during a Pre-Bias Start-Up.

The hardware required to implement this margining feature consists of an inexpensive N-Channel MOSFET connected between either the MGD (Margining Down) or the MGU (Margining Up) pins and GND, like shown in Figure 5. In this case, the supply output voltage will change by about ±5%, relative to its nominal value. If a resistor in the range 25_ to 37_ is included in the GND path the part changes the supply output voltage by ±3%.

Pre-Bias Start-Up

The TPS40100 employs synchronous rectification to improve efficiency, as illustrated by the simplified circuit shown in Figure 4. During power up, some applications require that the converter does not sink current during startup if a pre-existing voltage exists at the output. In this drawn example, the core voltage comes up first and applies I/O voltage through the external series diode (or ESD diodes in the connected load) before the converter stage generating the I/O voltage is enabled. This is defined as a pre-bias condition, in which voltage is applied to the I/O converter's output before the converter is enabled. When the converter's PWM controller is enabled, it soft-starts the high-side FET, and its duty cycle (D) ramps gradually from zero to that required for regulation. However, if, during soft-start, the synchronous rectifier (Q_2) FET is on when the high-side FET is off (synchronous rectifier FET duty cycle = 1-D), the synchronous rectifier FET (Q_2) sinks current from the output (through the inductor), tending to cause both the I/O and core voltages to drop.

Since synchronous buck converters inherently sink current some method of overcoming this characteristic must be employed. The method used in this controller, is to not allow the synchronous rectifier FET (Q_2) to turn on until there the output voltage commanded by the soft start up ramp is higher than the pre-existing output voltage. This is detected by monitoring the internal pulse width modulator (PWM) for its first output pulse. Since this controller uses a closed loop startup, the first output pulse from the PWM will not occur until

POWER MANAGEMENT

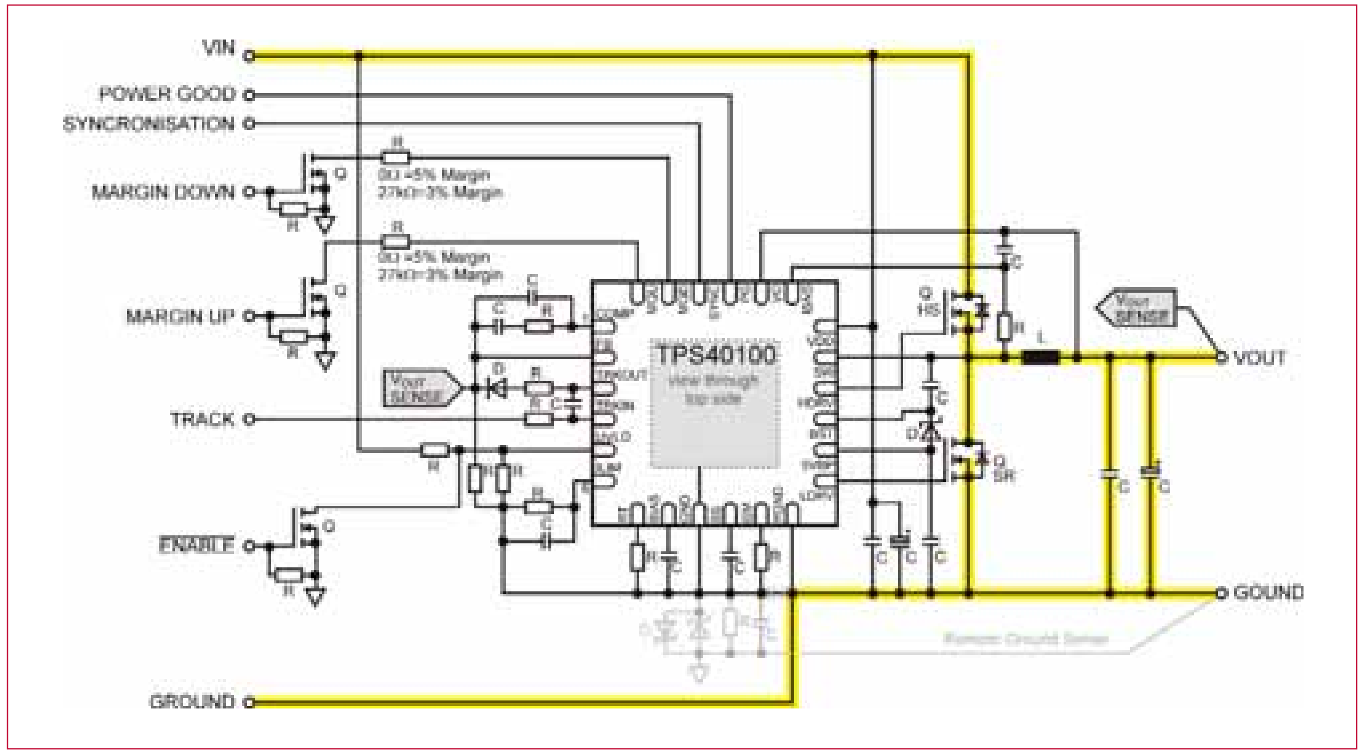

Figure 5. Schematic of typical implementation with all features.

the output voltage is commanded to be higher than the pre-existing voltage. This effectively limits the controller to sourcing current only during the startup sequence. During this phase inductor current flows through the parasitic body diode of the synchronous rectifier FET, rather than through its channel.

If the pre-existing voltage is higher than the intended regulation point for the output of the converter, when the soft start time has completed, the converter will start and sink current.

The need for this pre-bias start-up feature also arises when using sequential sequencing with certain ASICs, in which a leakage path within the device causes some I/O voltage to appear on the core before the core converter is enabled.

Figure 5 shows a typical implementation of the TPS40100, using all its features. The shaded section shows the optional implementation of the remote sensing feature, which allows the analog ground and the power ground pins to be separated. All analog circuitry is connected to the signal ground pin, with a separate trace connected to the ground terminal of the load in order to compensate for losses in the power ground path. The positive Vout terminal is sensed directly at the load and fed back to the error amplifier section of the TPS40100, marked 'Vout Sense'. If the remote sensing feature is not used, the PGND and GND pins should be connected together using a single point scheme (i.e. not routed via a ground plane).

The controller uses a current feedback mechanism to make loop compensation easier for loads that have wide capacitance variations. Current sensing is used for current feedback and over current detection. The measurement is truly differential and can be implemented using the inductor's DC resistance. This approach requires only a resistor and filter capacitor in parallel with the output inductor. The overcurrent level is programmable via the network connected to the ILIM pin, and is independent from the amount of current feedback. This function provides protection against short-circuits and power supply overloads. The implementation in the TPS40100 uses a hiccup overcurrent recovery implementation, that periodically attempts to recover after an overcurrent condition has occurred.

The UVLO (Under Voltage Lockout Voltage) and hysteresis thresholds are programmed independently via a resistor divider connected to the UVLO pin. This function allows the controller to start only after the input voltage has risen above a certain threshold; the hysteresis ensures that there is a voltage difference between turn on and turn off, preventing oscillation if the input voltage is around the UVLO threshold voltage.

The optimum power supply implementation depends not only on voltage, current, size and efficiency, but also on meeting the complete power management objectives for reliability, availability and maintenance. This requires intelligent power management, rather than just simple power conversion. The TPS40100 includes these much-needed system-level features, simplifying design and bringing real benefits to the system it is used in.

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Robust Discrete AC Protection Power Semiconductors

Packages with choice of connections and electrical isolation

As part of our continuing strategy to deliver the most complete line of circuit protection solutions, Littelfuse acquired Teccor Electronics, a reputable producer of thyristor products that includes over voltage protection device, SIDACtor.

By Richard Norris, Littelfuse Inc.

A thyristor is any semiconductor switch with a bi-stable action depending on p-n-p-n regenerative feedback. Thyristors are normally two or three terminal components for either unidirectional or bidirectional circuit configurations. Thyristors can have many forms, but they have certain commonalities. All thyristors are solid state switches that are normally open circuits (very high impedance), capable of withstanding rated blocking/off-state voltage until triggered/gated to on state. When triggered to on state, thyristors become a low-impedance current path until principle/main current either stops or drops below a minimum holding level. Once thyristor triggered to on state, the trigger/gate current can be removed without turning off until main current drops below holding current of thyristor.

Littelfuse thyristor line includes components that range from 0.8Arms to 70Arms. These components are produced in surface mount packages as well as heat sinkable through-hole packages.

The heat sinkable devices are also available in isolated mounting tab packages that are UL recognized. The higher amperage devices are offered in TO220 package, “industry workhorse”, plus larger TO218 package.

Conventional TO220 and TO218 packages are available, but where very robust component leads are required, Littelfuse offers a TO218X package variation that has eyelet leads capable of accepting #8 gauge stranded wire. The high volume production line TO218X products are viable replacement device for similar amperage older Press-Fit and Stud products.

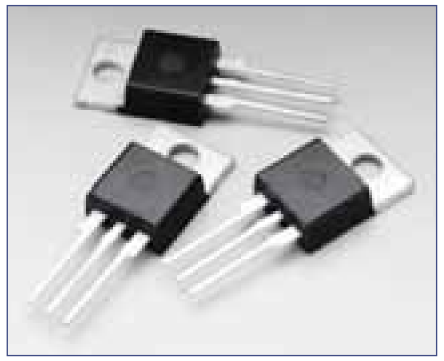

Figure 1. Photo of Standard TO-220.

Figure 2. Photo of TO-218.

Figure 3. Photo of more robust TO-218X.

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From October 1, 2005, eupec GmbH, a 100% subsidiary of Infineon with headquarters in Warstein, has been fully integrated into Infineon Technologies AG. It is an essential part of the new business unit Power Management and Drives (PMD). Within Infineon's Automotive, Industrial and Multimarket Business Group, PMD focuses on the development, manufacturing and sales of semiconductor products for industrial applications.

We would like to thank you for your confidence in eupec in the past and look forward to continuing our successful collaboration in the future.

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Never stop thinking

Internal construction of Littelfuse TO220 and TO218 thyristor switching devices include robust copper alloy connections/contacts from external leads/pins to semiconductor die. This provides best thyristor surge current capabilities for wide variation of loads, such as, locked rotor currents in motor loads and initiating current for tungsten loads and end of life lamp burn-out. Also Littelfuse TO220 and TO218 thyristor components are RoHS compliant.

Bidirectional Triac variations are offered in the TO220 package with up to 35A rating. Triacs are also available in TO218 package variations with rating up through 40Arms. These higher current devices are offered with excellent commutating and static dv/dt ratings are known as alternistor triacs. The alternistor triac die design used by Teccor for many years has gate region located in center of die offering excellent propagation allowing current to spread quickly for good turn-on and excellent surge current capabilities. Alternistor triacs are excellent solid state switches used to control a wide variety of loads.

The Alternistor triac was designed with difficult inductive loads in mind. Its die design effectively offers the same performance as two Silicon Controlled Rectifiers (SCRs) connected inverse parallel (back to back). The die construction provides the equivalent of two electrically separated SCR structures, but in a single die. The alternistor triac is offered from 6Arms to 40Arms ratings.

Blocking voltage ratings for these triacs range from 200 to 1000Volts. For AC loads requiring greater than 40Arms, inverse parallel SCRs such as 65Amp in isolated TO218X package may be used producing 92Arms full wave triac.

Typical full wave AC applications using triacs are home and commercial lighting controls, motor controls (including Permanent Magnet motors), heating controls, AC solenoid controls in appliances such as washing machines and lawn water sprinkler systems plus many other AC solid state switch controls.

For unidirectional thyristor requirements, Littelfuse offers up to 70Arms SCRs with excellent characteristics to control a wide variation of loads with voltage capability up to 1000Volts. As triacs, SCRs are offered in TO220 package (to 55Arms) and up to 70Arms in TO218 package. Because of its unidirectional switching capability, the SCR is used in circuits where high surge currents are present or where latching action is required. SCRs also used in circuits where half-wave gate controlled rectification is required.

Typical SCR applications include crowbars for power supplies, capacitive discharge control, motor controls, battery chargers, welding machines, tankless hot water heaters, electrical tool controls and many other solid state switch applications.

To compliment the SCRs with isolated mounting tabs, Littelfuse also offers rectifiers with isolated mounting tab in TO220 package for full wave bridge controlled loads.

Typical applications for SCRs and rectifiers in a bridge configuration are tool controls for maximum motor torque capability, in exercise equipment such as treadmills, in conveyors, in food processing equipment and other specialty machinery.

Littelfuse isolated TO220 and TO218 packages are very robust for isolated mounting protection. Unlike over molded products (mounting tab covered with epoxy), each isolated Littelfuse part has an isolation element that is totally enclosed and sealed with high pressure transfer molded epoxy with no internal package metal singularization points exposed on package surface. This ensures voltage breakdown well beyond 2500Vrms rating that is UL recognized. The isolation element also has good thermal characteristics to allow heat to be removed from the thyristor package. The high-pressure transfer molding epoxy/compound also has best UL 94V0 flammability ratings and insures best operating and storage temperatures.

Detailed product information can be found at Rectifiers:
http://www.littelfuse.com/cgi-bin/r.cgi/prod_series.html?LFSESSION=GKmXmvDBzZ&SeriesID=434

SCRs
http://www.littelfuse.com/cgi-bin/r.cgi/prod_series.html?LFSESSION=GKmXmvDBzZ&SeriesID=433

Sensitive SCR datasheet
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Alternistor Triac
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The Littelfuse portfolio is backed by industry leading technical support, design and manufacturing expertise. The products are vital components in virtually every product that uses electrical energy, including automobiles, computers, consumer electronics, handheld devices, industrial equipment, and telecom/datacom circuits. Littelfuse offers Teccor, Wickmann, Pudenz and Efen brand circuit protection products.

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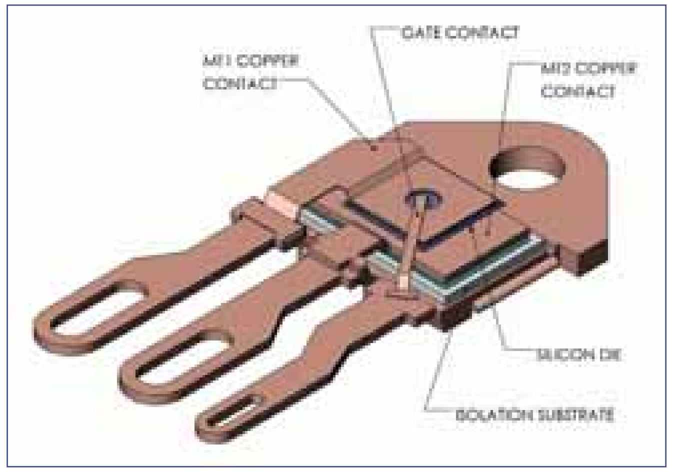


Figure 4. Isolated TO-218 construction.

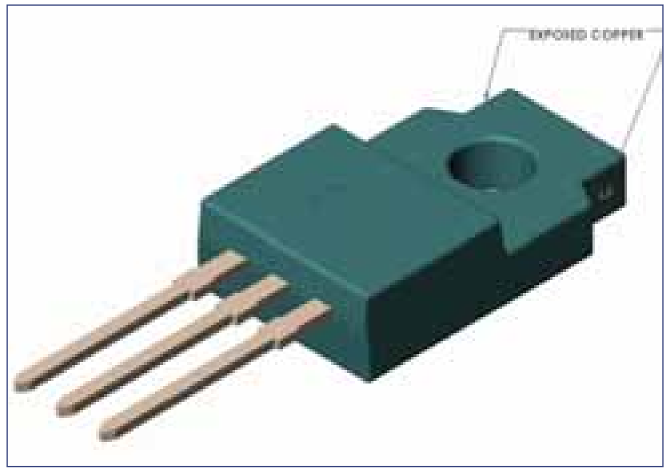


Figure 5. Typical TO-220 Overmolded Device.

Ultracapacitors in Industrial Design

Improving reliability and power consumption

With ever increasing demands for cost competitiveness and conservation of resources, industrial companies and public facilities are looking for improved power consumption and reliable power systems.

By John Dispennette, Maxwell, Application Engineer

Depending on the response time and duration required, a variety of technologies are suitable for meeting power quality and reliability needs. Ultracapacitors are ideally suited for power needs from tenths of seconds up to as much as one minute—including uninterruptible power supply (UPS), voltage stabilization and energy recapture.

Ultracapacitors in UPS

For many years batteries have played a major role in the design of industrial UPS systems, mainly due to their relatively low cost. Batteries have historically required significant maintenance, frequent replacement and have proven unreliable. Reliability concerns have prompted alternative technologies such as ultracapacitors to be considered for UPS applications.

Ultracapacitors have proven capable for maintenance-free operating lives in excess of twenty years. For applications requiring seconds to minutes of backup power, ultracapacitors have proven to be cost competitive. For backup times in excess of minutes, ultracapacitors have been coupled with generators and fuel cells to provide seamless power transition during start up of the primary power source.

A newer use of ultracapacitors within UPS has been for diesel generator starting applications. In this example batteries have been either replaced or significantly downsized depending on the application needs. This has been especially successful for cold weather applications where batteries are less reliable. The ultracapacitor is used to provide the cold cranking amps, while the now smaller battery supports longer duration sustaining power, to keep the engine rpm maintained during sluggish cranks.

Voltage stabilization and energy recapture

Voltage stabilization and energy recapture are two proven applications where ultracapacitors help the reliability of power, as demonstrated by several successful deployments at railway stations.

These systems operate in either a voltage stabilization or energy savings mode. In the voltage stabilization mode the energy storage unit prevents a minimum line voltage on the system as trains enter and leave the station. In the energy savings mode, braking energy is stored and utilized for accelerating trains away from the station. One installation has reported an annual energy saving of 320,000 kWh with a potential of 500,000 kWh.

Another example of voltage stabilization is windmill farms. Sudden changes in wind speed cause significant voltage fluctuations leading into the main power grid. To smooth out these fluctuations, ultracapacitor energy storage systems are being deployed and evaluated.

Power conditioning and control

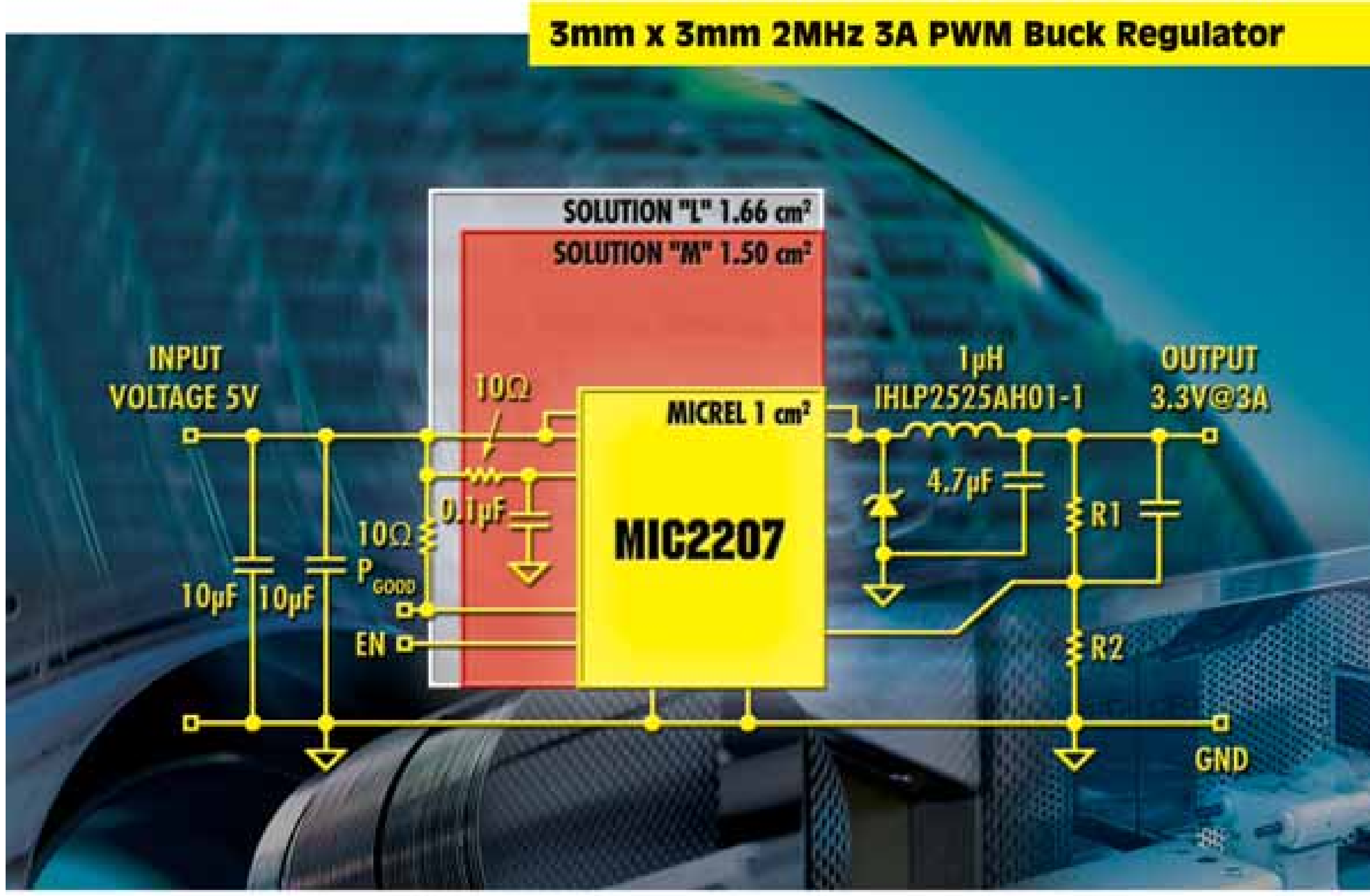
For most applications, additional power conditioning may be necessary on the input/output of the ultracapacitors. Ultracapacitors are DC devices with time constants of approximately one second. High frequency AC or dirty DC waveforms will require filtering to avoid overheating the ultracapacitors. This may be accomplished utilizing standard electrolytics in parallel with the ultracapacitors. Proper converters may be required to either boost or buck regulate for providing proper voltage to the system if constant output voltage is required.

Consideration should be made for the frequency of charge/discharge and the rate of recharge required.

For the voltage stabilization examples at the rail stations, the ultracapacitors prevent low voltage sags which may require quick discharge capability. The ultracapacitors are then able to be

Micrel's MIC2207 3A Solution Buck Regulator Over 33% Smaller At 1 cm²

3mm x 3mm 2MHz 3A PWM Buck Regulator



Micrel's MIC2207 is a high efficiency PWM buck (step-down) regulator that provides up to 3A of output current. The MIC2207 operates at 2MHz and has proprietary internal compensation that allows a closed loop bandwidth of over 200KHz.

The low on-resistance internal p-channel MOSFET of the MIC2207 allows efficiencies of more than 94%, reduces external components count and eliminates the need for an expensive current sense resistor. The MIC2207 operates from 2.7V to 5.5V input and the output can be adjusted down to 1V. The device can operate with a maximum duty cycle of 100% for use in low-dropout conditions.

For more information, contact your local Micrel sales representative or visit us at www.micrel.com/ad/mic2207.

The Good Stuff:

- 2.7 to 5.5V supply voltage
- 2MHz PWM mode
- Output current to 3A
- >94% efficiency
- 100% maximum duty cycle
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slowly recharged with a DC source, see figure 1.

Other applications may need additional control to be maintained between the ultracapacitors and the grid interface. This may be due to differences in voltage between the ultracapacitor and the main line.

An example of this circuit is provided in figure 2. The first step takes the ultracapacitor voltage to an intermediate DC voltage through a reversible boost converter. The second stage employs a DC buck converter to a high level DC voltage to the main line. This topology allows complete control of the ultracapacitor currents and the main line independent of the voltages.

Charging ultracapacitors from an AC or DC source

Ultracapacitors may be linked to either a DC or AC source. To understand how ultracapacitors may be integrated into an industrial design, let's look at example charging circuitries for both sources.

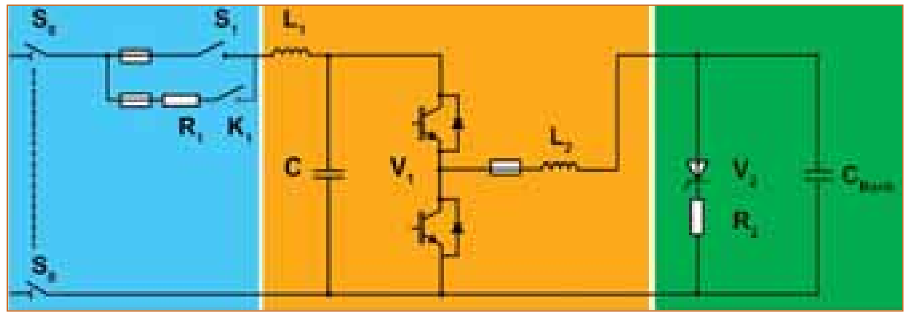

Figure 1. Railway circuit interface example.

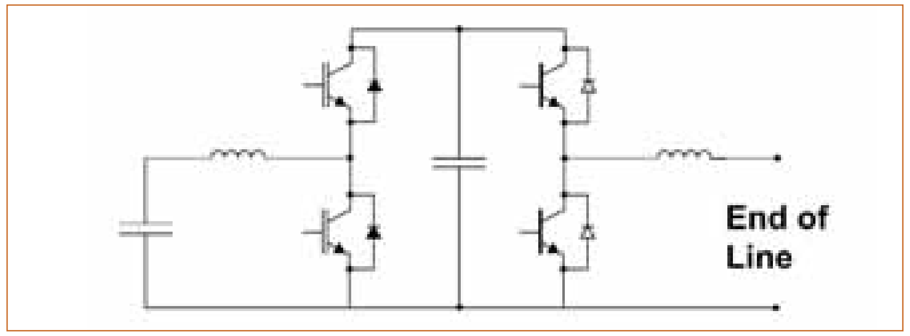

Figure 2. Two stage power converter.

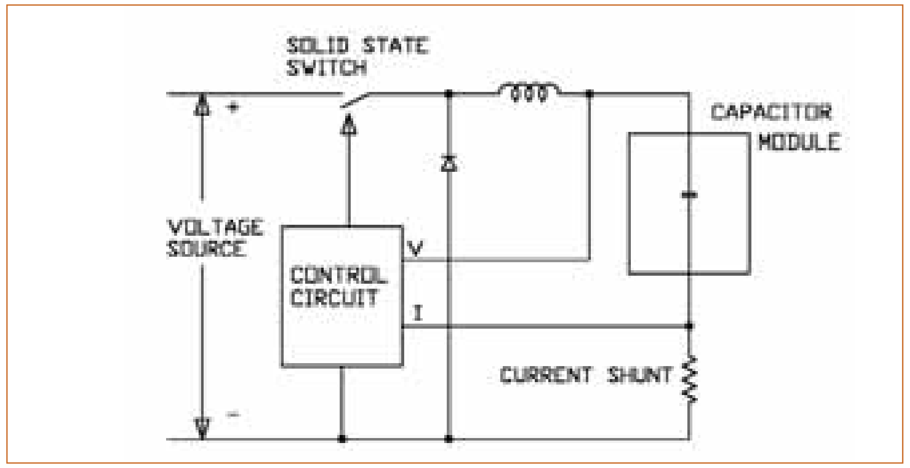

Figure 3. Constant current charging circuit.

A DC/DC constant current regulator is the simplest form of active charging. It can be operated as either a buck or boost regulator depending on the application. The buck regulator is the preferred topology for larger fast charge, high duty cycle applications due to the continuous charge current. An example circuit is provided in figure 3 representing a constant current charging scenario. A simple constant current charger may be built with standard power supply ICs. The current limit is set to the required charge current and the voltage limit would be set to the maximum required voltage.

When charge time is critical, constant power charging provides the fastest method. It can transfer all the available power from the charge source into the energy storage capacitors. Drawing a constant current from the source at a constant voltage is a simple implementation of constant power charging. This usually requires a maximum switching current of 2.5 times the nominal to prevent overloading the switching circuitry when the ultracapacitor voltage is below 40% of maximum. An example is shown in figure 4 (Patent pending).

If a device is to be directly charged from an AC source it is often difficult to cover the wide dynamic range requirements for charging ultracapacitors from a varying AC power line. An example circuit is provided in figure 5 (U.S Patent 6,912,136) for AC charging scenarios. The circuit uses the L/V characteristics of the switching transformer to set the switching frequency. Full output current at zero volts is capable with this design with no risk of saturating the magnetics.

The switch, Q1, turns on charging the primary of T1 to a preset current limit. Q1 then turns off, permitting the energy stored in T1 to discharge through D1 into the ultracapacitor, C1. When the secondary current has discharged to a preset lower limit then Q1 will turn on again repeating the cycle. The time required to charge T1 is inversely proportional to the instantaneous line voltage and the ultracapacitor voltage at C1. The combination of low line voltage

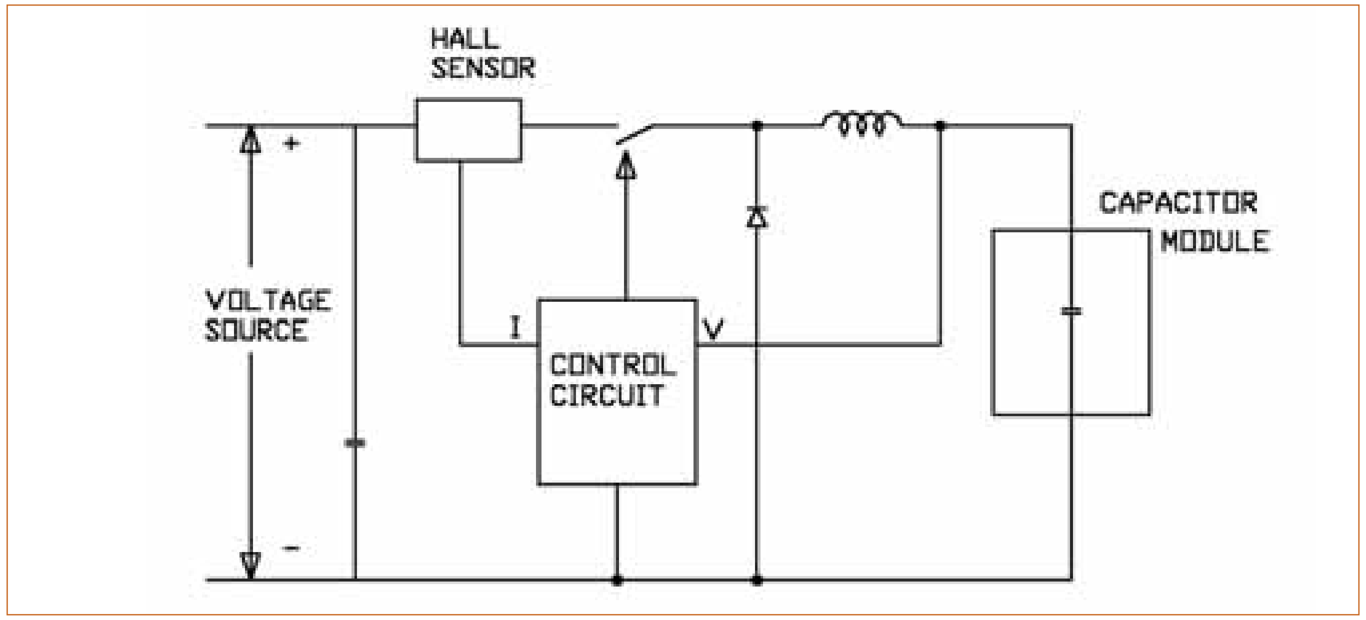

Figure 4. Constant power charging circuit.

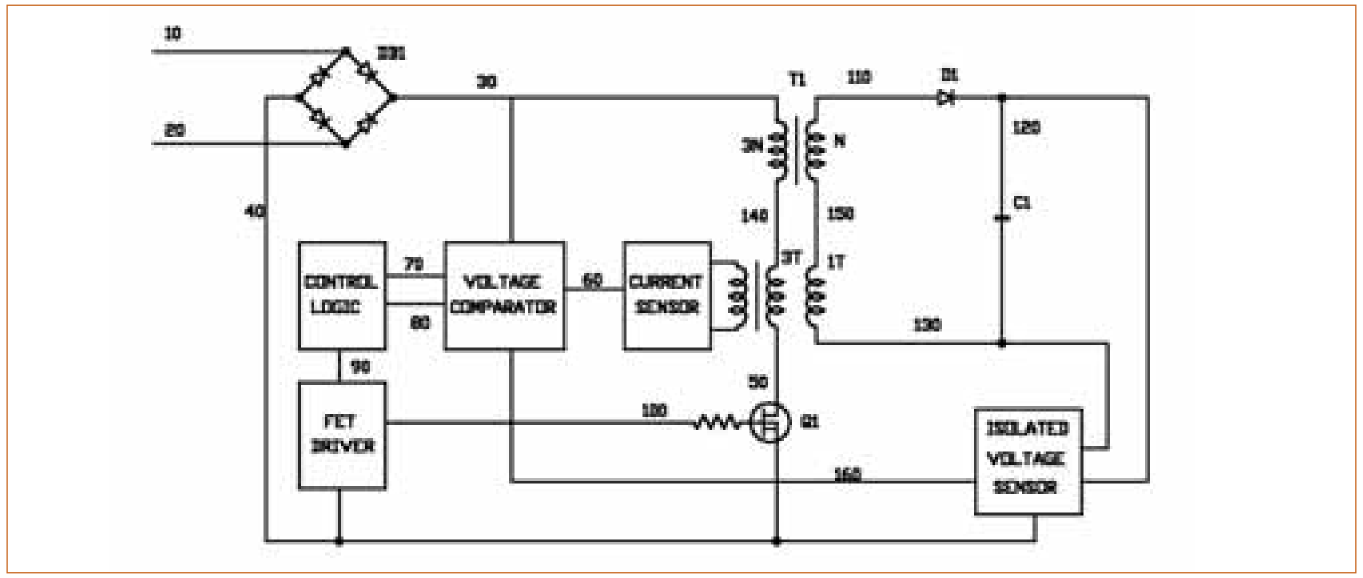

Figure 5. AC charging circuit.

and low ultracapacitor voltage produces the lowest switching frequency. The highest switching frequency occurs at the peak of the AC power line at maximum voltage and full charge voltage on the ultracapacitor. Depending on the application the switching frequency can cover a range of 20:1. When C1 reaches its maximum voltage, then the voltage sensor will drive the control circuit into discontinuous operation.

The output voltage of the ultracapacitor to supply the required electronic application will vary as current is drawn from the capacitor module. As previously mentioned if the device is voltage sensitive a DC/DC boost converter may be added enabling a constant input voltage to the device.

If the ultracapacitor module is allowed to operate between its full rated voltage and half rated voltage the module can supply 75% of its available energy.

Selection of an appropriate DC/DC converter is dependent on the operating voltage range of the system and the wattage requirement for the application.

The example charging circuits and applications show how ultracapacitors have been designed or could be used in industrial applications. Specific circuitry is dependent on the needs of each application.

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Safe Operating Limits in Linear Mode

Latest generation of low voltage power MOSFETs

The forward-biased safe operating area (FBSOA) in a MOSFET defines the permissible and safety operation locus in terms of drain current (I_D) and drain-to-source voltage (V_{DS}). This area is limited by maximum allowable voltage, current and power dissipation. In modern low voltage power MOSFETs, experimental data have shown an anomalous failure mode which limits the theoretical FBSOA at low drain current and its ability to operate in linear mode.

By G. Consentino and G. Bazzano, STMicroelectronics

A Mathematical Model and Experimental Results

The parameter identifying such thermal instability is the thermal coefficient T.C. is mathematically defined as the derivative of the drain current versus temperature. A positive value of the thermal coefficient means that as temperature rises, due to power dissipation in linear operation, drain current also rises. Every low voltage MOSFET exhibits ranges of drain current ID where the thermal coefficient can be either positive or negative but in general safety operation in linear mode depends on the current range over which the coefficient is positive and also on its peak value. Sometimes, even if the thermal coefficient is positive no failure occurs in the device because the junction- ambient thermal resistance R_{thja} can be sufficiently low to avoid thermal runaway. The failure mechanism observed depends on certain intrinsic device parameters and its structure.

Theoretical derivation of the thermal coefficient

Id in the linear zone can be written as:

(1.1)

$$I_D = \frac{1}{2}\mu \cdot \frac{W}{L} C_{ox}(V_{GS} - V_{TH})^2$$

μ is the carriers' mobility, C_{OX} the oxide capacitance, V_{TH} the threshold voltage, W the channel perimeter, L the channel length and V_{GS} the applied gate-to-source voltage. In subsequent calculations we will define K=1/2_W/L so we can re-write as:

(1.2)

$$I_D = K(V_{GS} - V_{TH})^2$$

Under these conditions, the T.C. has the following general expression:

(1.2)

$$\frac{\partial I_D}{\partial T} = \frac{I_D}{K}\frac{\partial K}{\partial T} - 2\sqrt{K}\sqrt{I_D}\frac{\partial V_{TH}}{\partial T}.$$

The terms $\frac{\partial K}{\partial T}, \frac{\partial V_{TH}}{\partial T}$ calculated for constant V_{DS} are both negative.

In order to compare the performance of different MOSFET devices, the T.C. is normalized versus active area or channel perimeter as:

(1.3)

$$J_D = \frac{I_D}{W}, \; J_D = \frac{I_D}{A}$$

We can calculate now the maximum value of the T.C.:

(1.4)

$$\left.\frac{\partial I_D}{\partial T}\right|_{max} = -K^2\left(\frac{\partial K}{\partial T}\right)^{-1}\left(\frac{\partial V_{TH}}{\partial T}\right)^2.$$

The drain current range for which the coefficient is positive is expressed by:

(1.5)

$$\left.\Delta I_D\right|_{pos} = 4K\left(\frac{\partial K}{\partial T}\right)^{-1}\left.\frac{\partial I_D}{\partial T}\right|_{max}$$

Now, we will take into account the effect on the thermal coefficient by the carriers' saturation velocity when a high electric field is applied across the channel,see figure 1.

Two models can approximate the curve of figure 1, the former being

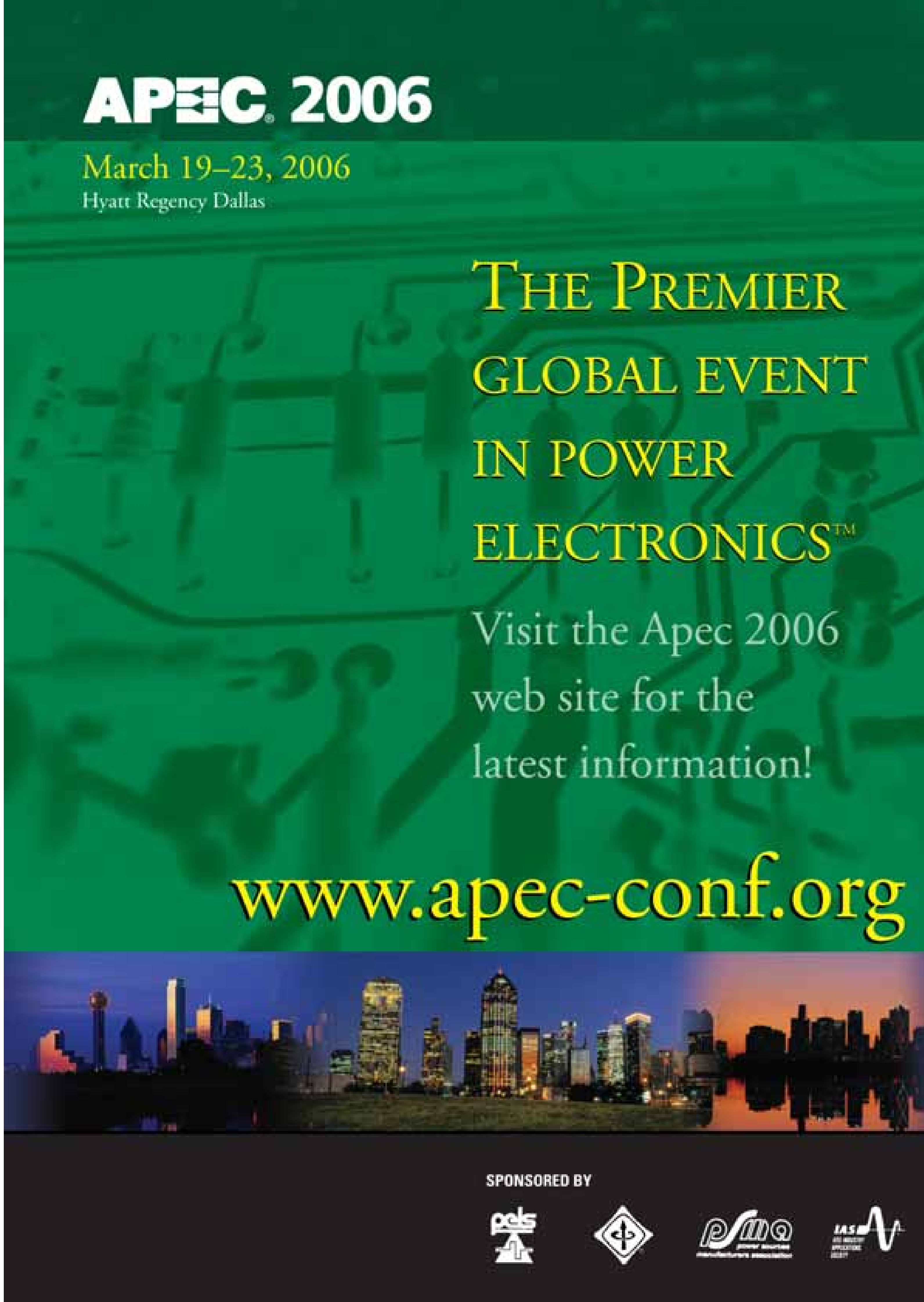
(1.7a)

$$V_{drift} = V_{sat}\frac{\frac{E}{E_C}}{1+\frac{E}{E_C}}$$

and the latter

(1.7b)

$$V_{drift} = V_{sat}\frac{\frac{E}{E_C}}{\left[1+\left(\frac{E}{E_C}\right)^2\right]^{\frac{1}{2}}}$$



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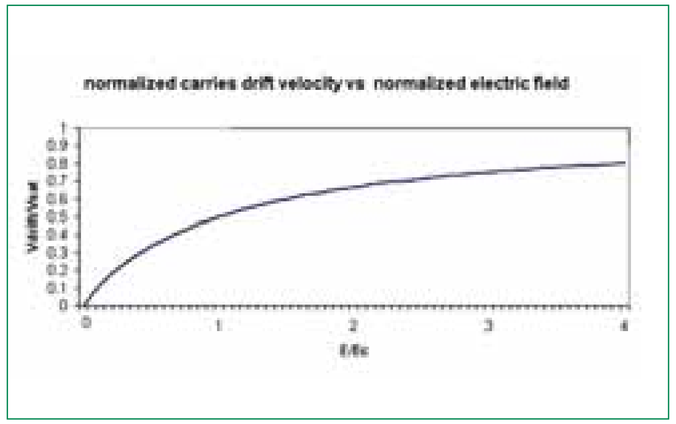

Figure 1. Normalized Carriers Drift Velocity vs Normalized Electric Field.

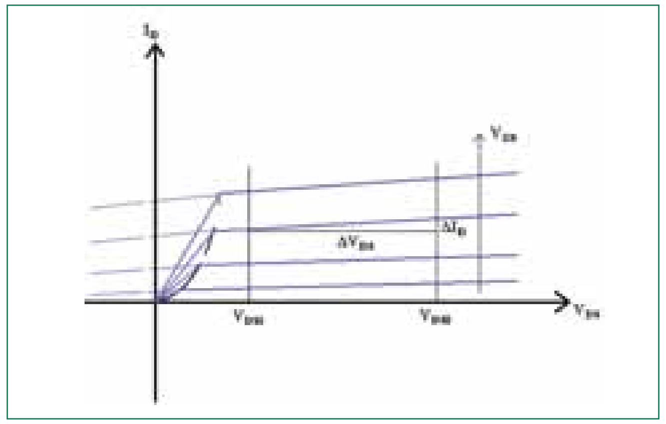

Figure 2. Channel Length Modulation.

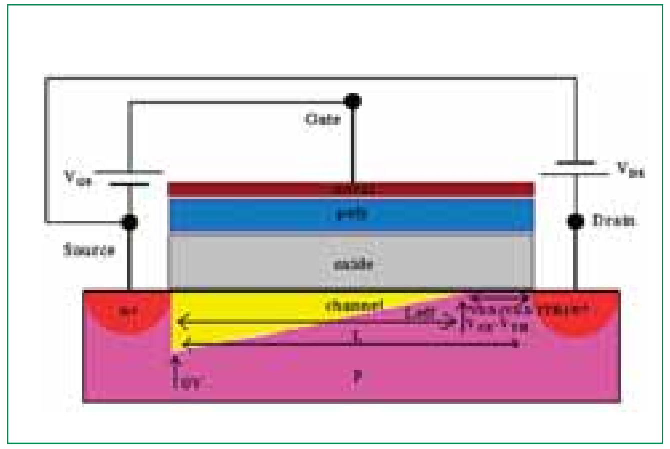

Figure 3. Cross Section.

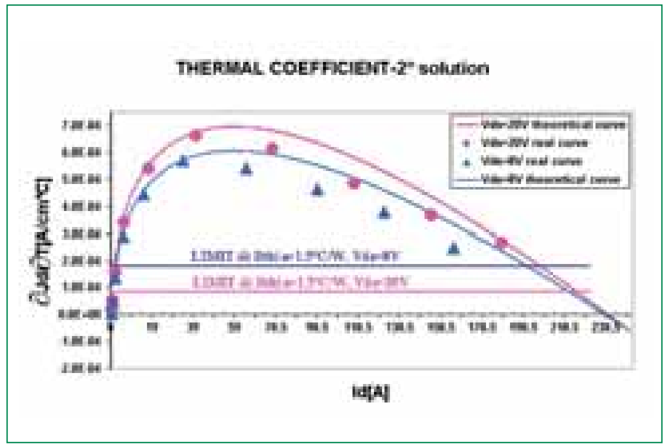

Figure 4. Normalized Thermal Coefficient Curves.

so the T.C. in case of (1.7b) can be written
(1.8)

$$\frac{\partial I_{mat}}{\partial T}=\frac{I_D}{K\left(1+\frac{I_D}{KE_c^{\,2}L^2}\right)^{\frac{1}{2}}}\frac{\partial K}{\partial T}+\left[\frac{I_D}{\left(\frac{I_D}{KE_c^{\,2}L^2}+1\right)\sqrt{K}E_c^{\,2}L^2}-2\sqrt{K}\right]\frac{\sqrt{I_D}}{\left(1+\frac{I_D}{KE_c^{\,2}L^2}\right)^{\frac{1}{2}}}\frac{\partial V_{TH}}{\partial T}$$

Impact on the T.C. induced by channel length

When VDS increases, with VGS constant, the device works in the linear zone and channel length modulation occurs. In particular, the electrical effective channel length becomes shorter compared to the physical channel length involving a little rise on ID (see figure 2).

When VDS exceeds (VGS-VTH), the effective channel length, Leff, becomes shorter compared to L; the voltage applied across the channel remains fixed to V_{GS}-V_{TH}, while, across (L-L_{eff}) a voltage equal to V_{DS}-(V_{GS}-V_{TH}) is applied

From (1.1) after some manipulations we can obtain:
(2.1)

$$\frac{\partial L}{\partial V_{DS}}=-\frac{L}{I_D}\frac{\partial I_D}{\partial V_{DS}}$$

$I_D(L_{eff})$ and _L can be written as:
(2.2)

$$I_D(L_{eff})=\frac{L}{L+\Delta L}I_D(L)$$

Parameters	Values
BVDSS (V)	55
R_{DSON} (mΩ)	8
Vth @ 25°C (V) @ 250µA	2.70
Vth/ T (mV/°C)	-7.20
K @ 25°C (A/V²)	30.5
K/ T (A/V² °C)	-0.1400
L/ Vds (µm/V)	-0.0050
Vth/ Vds (mV/V)	-3.3

Table 1. Device Characteristics

(2.3)

$$\Delta L=\frac{\partial L}{\partial V_{DS}}[V_{DS}-(V_{GS}-V_{TH})]$$

Considering that the threshold voltage depends on temperature also ΔL depends on this parameter as:
(2.4)

$$\frac{\partial(\Delta L)}{\partial T}=\frac{\partial L}{\partial V_{DS}}\frac{\partial V_{TH}}{\partial T}$$

Thus
(2.5)

$$\frac{\partial I_{DSAT}(L_{eff})}{\partial T}=\frac{L}{L+\frac{\partial L}{\partial V_{DS}}[V_{DS}-(V_{GS}-V_{TH})]}\frac{\partial I_{DSAT}(L)}{\partial T}-\frac{L\frac{\partial L}{\partial V_{DS}}\frac{\partial V_{TH}}{\partial T}I_{DSAT}(L)}{\left\{L+\frac{\partial L}{\partial V_{DS}}[V_{DS}-(V_{GS}-V_{TH})]\right\}^2}$$

In other words, we also have a further reduction of the threshold voltage caused by an increase in V_{DS}.

Another factor to consider is the effect of the short channel (0.6µm and less) because the junction depletion width becomes comparable with the electrical channel length. Such effects show up with a further decrease in threshold voltage as V_{DS} increases.

Conditions for thermal stability

The heat generated inside the silicon junction is due to the electrical power generated during the device's linear operation, thus:
(3.1)

$$V_{DS}I_D=\frac{\Delta T}{R_{thja}}$$

When an electrical power impulse is applied to the device, the temperature rises and the drain current changes its values depending on the thermal coefficient. The electrical power variation will be written as:
(3.2)

$$V_{DS}\frac{\partial I_D}{\partial T}$$

Such electrical power pulse due to the temperature rise can be supported from the device if:
(3.3)

$$V_{DS}\frac{\partial I_D}{\partial T}<\frac{\partial(\Delta T)}{\partial TR_{thja}}=\frac{1}{R_{thja}}$$

Instead, if the following condition occurs, the electrical flux exceeds the maximum thermal flux involving the failure mechanism of the device.
(3.4)

$$\frac{\partial I_D}{\partial T}\geq\frac{1}{V_{DS}R_{thja}}$$

By equaling the left-hand side term of (4.5) to the right-hand term, (4.5) can be written as below and it establishes exactly the maximum value of the thermal coefficient where the failure of the device is avoided.
(3.5)

$$\left|\frac{\partial I_D}{\partial T}\right|_{I_D=const}=\frac{1}{V_{DS}R_{thja}}$$

A real example will be taken into consideration. The main characteristics of the device tested are shown in table I.

Figure 4 depicts the normalized thermal coefficient curves versus I_D for the second model shown earlier considering V_{DS} equal to 8V and 20V, respectively. From (3.5) we can establish the right I_D positive range where the device could fail considering Rthja equal to 1.5°C/W.

Technology comparison between planar and Trench structures

In this section we will show a real example which compares one of ST's planar MOSFET (STripFET) versus one of the competitor's trench. The main difference between planar and trench stands essentially in the gate electrode structure. In fact, in the planar technology, the gate electrode is placed on the silicon surface while in the others the gate is placed inside the epitaxial layer.

Due to trench gate shape, the oxide thickness in the trench device is higher compared to the planar technology. In order to fix the right threshold voltage, considering that the trench technology has a higher gate oxide thickness, it is therefore necessary to decrease the carrier concentrations in the channel.

In table 2 are summarized the main parameters of the two devices under test, the ST part being planar.

The T.C.s, considering V_{DS} of 15V, for both devices are shown in figure 6.

From this graphs it is possible to see that, even if the positive thermal coefficient range is equal in the two devices, its peak value in the trench device is around three times higher than that of the planar device. Such behavior involves the best operation mode in linear zone for the planar device.

Pspice Simulation

To validate the empirical results, the Pspice simulator has been used. In fact, the T.C. and electrical characterists has been obtained by Pspice simulator creating an model that include also the suitable thermal coefficients. The graphs shown in figure 7, figure 8 and figure 9 compare the real and the simulated data.

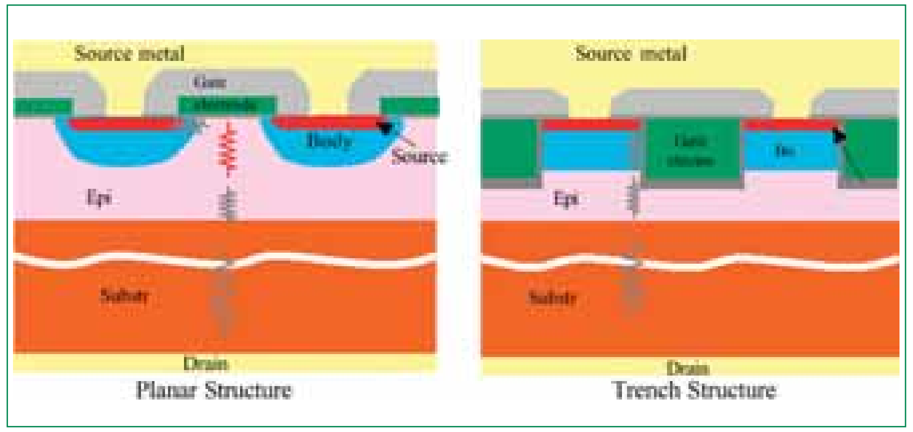

Figure 5.

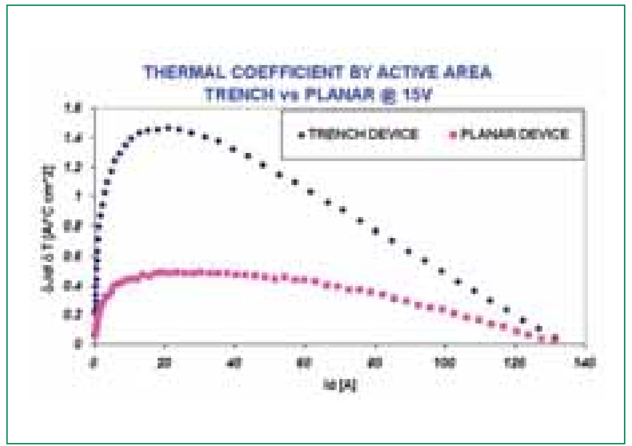

Figure 6. Therma Coefficient by Active Area Trench vs Planar @ 15V.

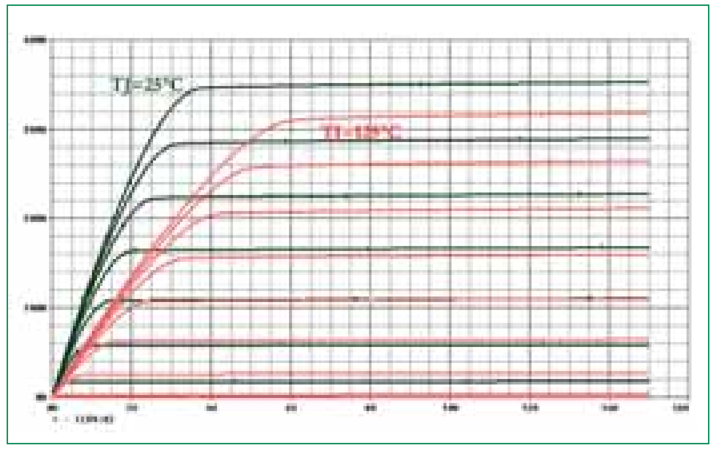

Figure 7. Drain Current vs Gate Drain Voltage @ Tj 25 °C and @ Tj 125 °C.

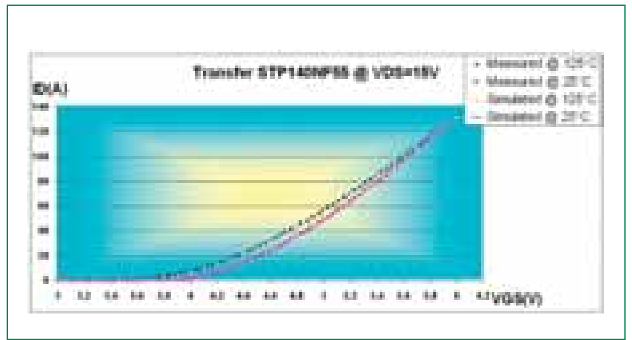

Figure 8. Drain Current vs Gate Source Voltage @ Tj 25 °C and @ Tj 125 °C.

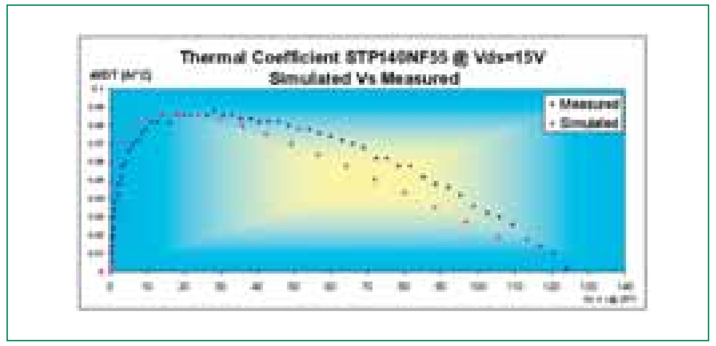

Figure 9. Thermal Coefficient Simulated vs measured.

	ST STripFET (PLANAR)	DEVICE #2 (TRENCH)
BV_{DSS} (V)	70	88
$R_{DS(on)}$ (mΩ)	6.8	5.8
V_{TH} @ 25°C (V) @ 250µA	2.90	2.97
$\Delta V_{TH}/\Delta T$ (mV/°C)	-5.78	-11.68
K @ 25°C (A/V²)	18.5	12.5
Normalized W	1	0.82
Normalized t_{ox}	0.51	1
Normalized L	0.62	1
Normalized C_{ox}	1	0.67
Normalized active area	1	1
$\Delta K/\Delta T$ (A/V²°C)	-0.035	-0.095
$\Delta L/\Delta V_{DS}$ (µm/V)	-0.014	-0.033
$\Delta V_{TH}/\Delta VDS$ (mV/V) [V_{DS}=10-60V]	-3.3	Range: -1.8 ... -6.8

Table 2.

Conclusions

This paper has analyzed the anomalous failure mechanism encountered on the latest generation of low voltage low on-resistance power MOSFET devices considering a detailed mathematical model of the thermal coefficient. Experimental results have also been associated to theory showing a good matching.

Furthermore, this article has performed a comparison between two different MOSFET structures, competition's trench and ST's planar technologies, in order to understand which one exhibits the best performance in linear operation. To this purpose two devices with similar electrical characteristics have been chosen. Results confirm that the planar STripFET is the most suitable device to operate in linear mode owing to lowest thermal gradient of V_{TH} and lowest oxide thickness t_{OX}.

Finally, a Pspice simulation of the electrical characteristics and TC were performed. The comparison between the real and simulated curves shows a good matching.

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Photocoupler for High Speed and Isolated Switching

Fast, safe and efficient solutions

Safety, performance and power consumption criteria are driving the development of highly efficient photocoupler devices. Electrical isolation is a familiar requirement in the design of many systems. Motor controllers, power supply electronics, data communications and general-purpose switching-type applications all require components that form a reliable, controllable electrical barrier between two parts of a circuit.

By Josef Abels, Toshiba

Isolation serves a number of purposes. For instance, the intrinsic function of devices such as relays and switches is to toggle between on- and off-states as part of a control system. Transistor couplers and triac couplers, in contrast, can more often be regarded as signal conversion devices that allow logic-level electronics to control higher currents and voltages. At the same time, these devices may also protect the sensitive electronic portion of the system from the potential damage that can be caused by accidental contact with power circuitry. Just as important is their role in protecting the human user of the equipment from injury, and in preventing the transmission of noise from one part of a circuit to another—in effect to protect the two parts of the circuit from “injuring” the signals of the other.

Optical coupling

Designers are increasingly choosing to implement many of these isolation tasks, which have traditionally been performed by electromechanical or wound components, using optically coupled devices. This move is fuelled not only by the increase in the sheer number of systems—from refrigerators to factory automation—that are electronically controlled. It is also driven by the ability of optical devices to provide better performance, in terms of switching speed, isolation voltage, and power consumption, in ever-smaller packages.

The principle of operation of photocoupler components is simple. They accept an electrical input, which drives a light-generating device—typically an LED. The photons produced travel within the component packaging across a physical gap (hence providing the electrical isolation), to a photodetector, which can be used to drive a range of output circuitry, also integrated within the package. Component manufacturers such as Toshiba Electronics offer a broad range of such devices whose outputs are able to drive a variety of circuits, including inverters, medium or high-power IGBTs, MOSFETs or intelligent power modules (IPMs).

The widening variety of components on the market today makes it increasingly possible for designers to choose a device that will directly drive their required output circuitry and, therefore, eliminate the need for external components. Nevertheless, straightforward transistor couplers remain an important element in the product mix and continue to develop in terms of performance, for applications as wide-ranging as modems, air conditioning units, and PLC control in factory automation. Toshiba's TLP283 exemplifies the typical trend: it features an input current as low as 2mA - half that of previous generations – and has a switching time that is less than 100µs. The devices contribute to system size reductions as they are available in an SOP package, with an option of one or four couplers in a single package. The combination of fast and reliable switching with small size and low power make the TLP283 couplers suitable for applications such as on-board power supplies, programmable controllers, I/O interface boards and AC adapters for PDAs.

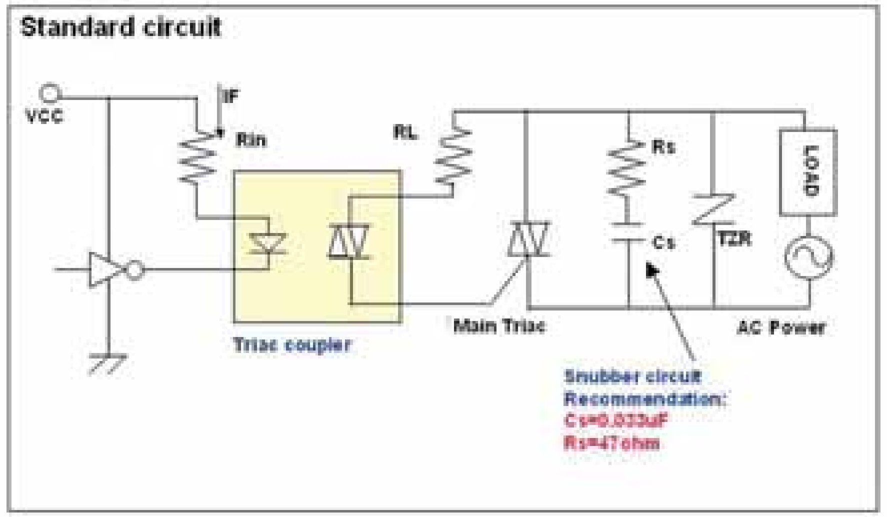

Figure 1.Typical application of triac couplers.

Triac couplers

For AC systems, triac couplers are increasingly used, as illustrated in the typical application circuit shown in Figure 1.

Devices such as Toshiba's TLP36x couplers use a gallium-arsenide (GaAs) infrared LED, which optically couples to a phototriac. Again the need for miniaturisation is a key driver in this area. However, it is also balanced with cost-sensitivity and the need for standards compliance via reliable isolation in applications such as office automation, in which the isolator provides safety protection for the human user. The TLP36x devices provide 5kV of isolation in 4-pin DIP packages, 35% smaller than the space previously required to achieve this level of isolation. Furthermore, at just 20V, the inhibit voltage of these devices is up to 50% lower than previous generations of triac couplers, leading to significant reductions in turn-on noise.

Some of the advances in the phototriac field have been made possible by the development of new methods of device

Figure 2. TLP70x and TLP71x series of photo-IC output couplers.

construction. As its name suggests, the traditional "face-to-face" topology puts the light-emitting device opposite the output circuit within the package. In "single-mould" construction the two elements are sited face-to-face, separated by a single dielectric, whilst "double-mould" fabrication sees both parts given their own moulded insulation (although they remain face-on).

The most recent space-saving alternative, however, is reflective-type coupling, which uses a single transparent resin to achieve optical coupling. The LED and phototriac are actually side-by-side in the package, but optical coupling is still achieved because the devices are encapsulated in the same resin moulding, which is reflective at its boundaries. This allows components such as Toshiba's TLP263 to offer up to 3kV of isolation in small, cost-effective surface mount packages, with full UL and VDE safety approvals.

IC Couplers

Like most components today, higher levels of integration are being required of photocoupler devices, leading to the development of photo-IC couplers that can be used to drive IPMs, IGBTs and FETs. Applications such as communications network equipment and driving motors or flat-panel displays require advanced functionality: for instance high-speed operation in the Megahertz range or undervoltage lock-out (UVLO). Designers also require flexible options, for instance the choice of open-collector or totem pole operation, depending on the nature of the load and whether current sinking and sourcing is required.

All of these requirements, naturally, come along with the increasing expectations now familiar in the semiconductor industry: reduction in power consumption (and supply voltage); smaller size; and higher drive currents, sometimes reaching several Amps.

Pressures such as these have led Toshiba to develop its TLP70x and TLP71x series of photo-IC output couplers, which are the industry's smallest such devices with 5kV isolation. They are aimed at applications from IGBT

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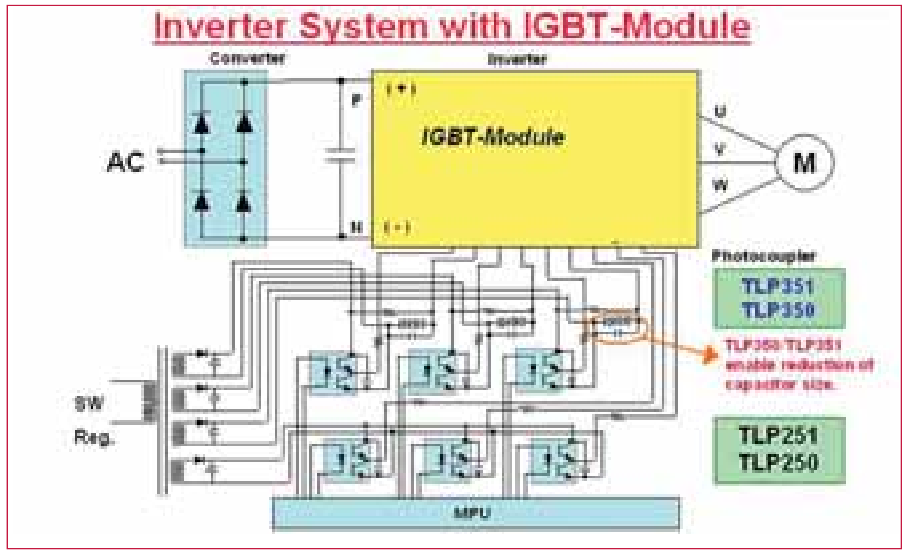


Figure 3. IC couplers in a typical IGBT-based inverter system..

drive to data communications that combine high-speed switching with industry-standard (VDE, UL, SEMKO and TUV) isolation.

The TLP705 device, for instance, is designed for high-speed driving of IGBTs and MOSFETs. With a switching time of less than 200ns and 3mA current drive capability, the device can be used as a high-speed inverter in factory automation applications, and to drive plasma display panels (PDPs).

For inverter drive and UPS applications, the company's TLP350/351 devices rely on another innovation in manufacturing techniques: they are fabricated in a BiCMOS process, reducing their current consumption requirements by around 80% when compared with Toshiba's previous generation of devices. The TLP350 includes a UVLO function, and delay time is guaranteed at 0.5μs over an extended temperature range of -40°C to 100°C. The devices are housed in space-saving 8-pin DIP packages, but perhaps the most important contribution to miniaturisation in applications such as motor drives is rooted in the TLP350's lower power consumption. Such applications typically require the inclusion of relatively large bypass capacitors between power supply and ground pins: by reducing power consumption so substantially, the device allows the designer to choose smaller ceramic capacitors over the bulky electrolytics that would otherwise have been required. Figure 3 shows how such IC couplers can be employed in a typical IGBT-based inverter system.

The increased market acceptance of IPMs has also led to the development of IC coupler products specifically for use in this area. Devices such as Toshiba's TLP102/106 provide totem pole outputs at voltages of up to 20V. Whilst reducing external component count by eliminating the need for a pull-up resistor, these devices also exemplify the overall market trend towards smaller packages, higher speed and better isolation: supplied in 5-pin MFC, their switching time is 0.4μs, and isolation voltage is 3750V rms.

Photorelays

The final area where photocoupler products are making inroads is in replacing the once ubiquitous electromagnetic relay. Photorelays consist of an LED coupled with a photoMOSFET and offer many intrinsic advantages over their older competitors, not least the ability to be directly driven by logic or a microcontroller. They switch approximately five times faster; their power consumption when switching is as much as two orders of magnitude lower; they are small (and can be further miniaturised); and they offer inherently low-noise operation as they suffer from none of the contact bounce and back-EMF generation problems of their electromagnetic counterparts.

The key figure of merit for components in this area is the product of on-resistance and output capacitance: current state-of-the-art developments focus on reducing this figure to below 1pF$\mu\Omega$, and on cutting package size. Components in SSOP4 packages with dimensions of 2.04mm x 3.8mm are already available, whilst isolation voltages are up to 2.5kV and a wide range of current-handling capacities are available.

Summary

Overall, the move to optical isolation is part of a wider trend towards semiconductor-based operation in all aspects of product manufacture. By eliminating wound and electromagnetic components, designers can reap considerable benefits: by deploying one of the increasing range of photocoupler components intended to directly serve their applications, they can simplify their designs even more. Manufacturers such as Toshiba will continue to increase the usefulness of their devices by integrating more circuitry, by offering a greater variety of options in terms of drive outputs, by continuing to miniaturise and by further reducing power consumption.

www.toshiba-components.com

IPOSIM, a Flexible Selection and Calculation Tool

Find the right IGBT module for your inverter

There is no simple criterion or rule of thumb available to select a properly suited IGBT module. This is due to the multiplicity of inverter applications in traction and industry, the individual conditions regarding DC input and AC output voltage, switching and output frequency, inverter power rating, overcurrent and overload capability as well as the influence of different cooling conditions.

By Dr. Thomas Schütze, Infineon

A detailed consideration, accounting for the worst case operating conditions, is compellingly necessary. By using Infineon´s dimensioning program, IPOSIM, for loss and thermal calculation, this procedure can be conveniently accomplished.

Module Selection

At present eupec's product spectrum covers over 300 module types in diverse housing designs and current ratings.

As a first step the characteristic parameters of a yet to be determined operation point has to be defined. Values which are affected by these parameters are indicated in parentheses:

- DC link voltage and switching frequency f_{sw} (switching losses)
- Modulation factor m and cos φ (conduction losses)
- RMS current (switching and conduction losses)
- Output frequency f (temperature ripple)
- Case and max. Junction temperature (thermal utilization)

After entering the parameters into the main input mask, IPOSIM will make a pre-selection of all suited modules from the available product spectrum. A restriction to a specific module housing is possible. The applied criteria to select a module are:

- Suited module voltage class as per a given DC link voltage
- Adherence of the module's peak current capability which is limited by its RBSOA to $I_{rms} \leq 2\ I_{nom} / \sqrt{2}$
- Compliance with the thermal limits; due to the presetting of case and maximum junction temperatures, the total losses of IGBT or diode must fulfil $P_{tot} {}^{*} Rth_{jc} \leq T_j - T_{case}$

Loss calculation

The Infineon application note [1] covers how to calculate the major IGBT operating parameters by using the datasheet as a source for device characteristics. These calculations deliver power dissipation, total power losses as well as junction and heatsink temperature.

The presented methods are applicable for continuous and pulsed collector currents but will not be adaptive for voltage source inverters with naturally sampled PWM and sinusoidal output currents. For these common applications [2] gives an approach to calculate average and total power dissipation of IGBT and diode. It uses a closed solution for the conduction and switching losses without summing up several switching energies of the single switching instants.

The conduction losses of an IGBT with sinusoidal current ı sin(ωt) are given by

$$P_{cond,IGBT} = \tfrac{1}{2}\left(V_{CE0} \cdot \frac{\hat{i}}{\pi} + r \cdot \frac{\hat{i}^2}{4}\right) + m \cdot \cos\varphi \cdot \left(V_{CE0} \cdot \frac{\hat{i}}{8} + \frac{1}{3\pi} \cdot r\hat{i}^2\right)$$

Where V_{CE0} and r are threshold voltage and slope of the output characteristic.

The conduction losses can be described by

$$P_{sw,IGBT} = \frac{1}{\pi} f_{sw} \cdot \left(E_{on}(I_{nom}, V_{nom}) + E_{off}(I_{nom}, V_{nom})\right) \frac{\hat{i}}{I_{nom}} \cdot \frac{V_{dc}}{V_{nom}}$$

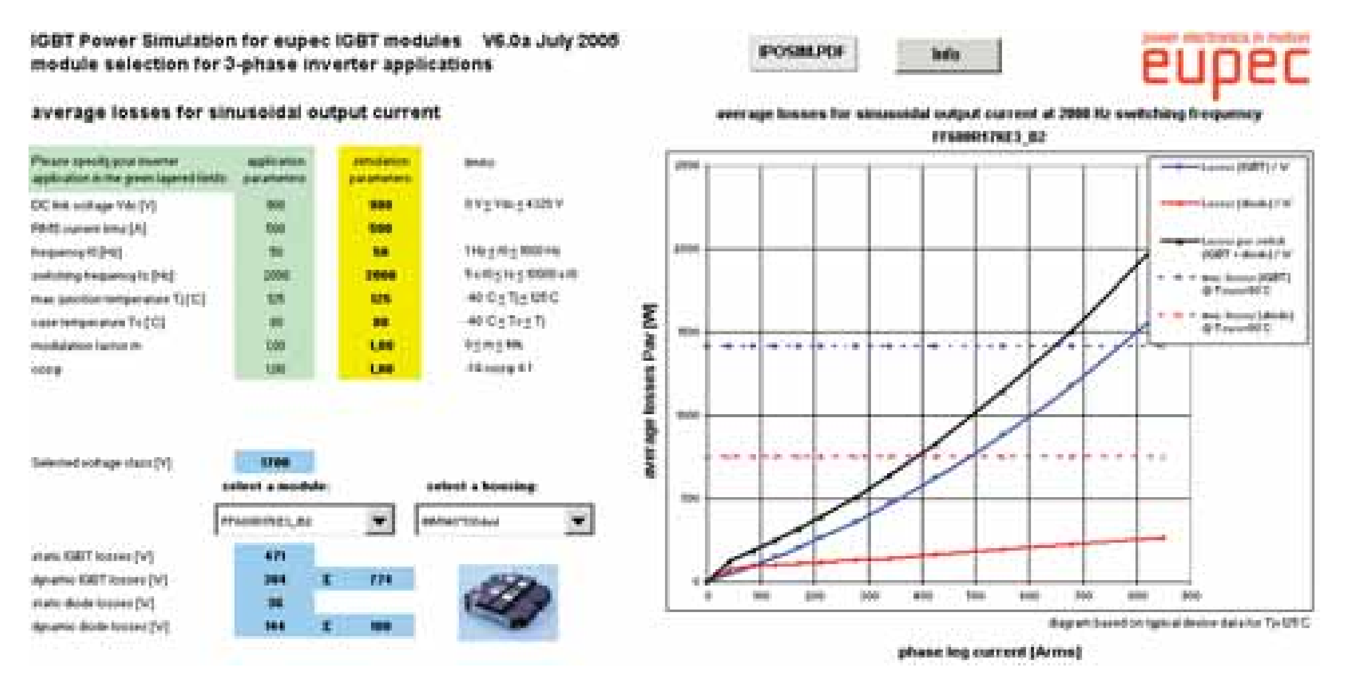


Figure 1. IPOSIM entry mask and 'average power losses vs. RMS phase leg current' diagram.

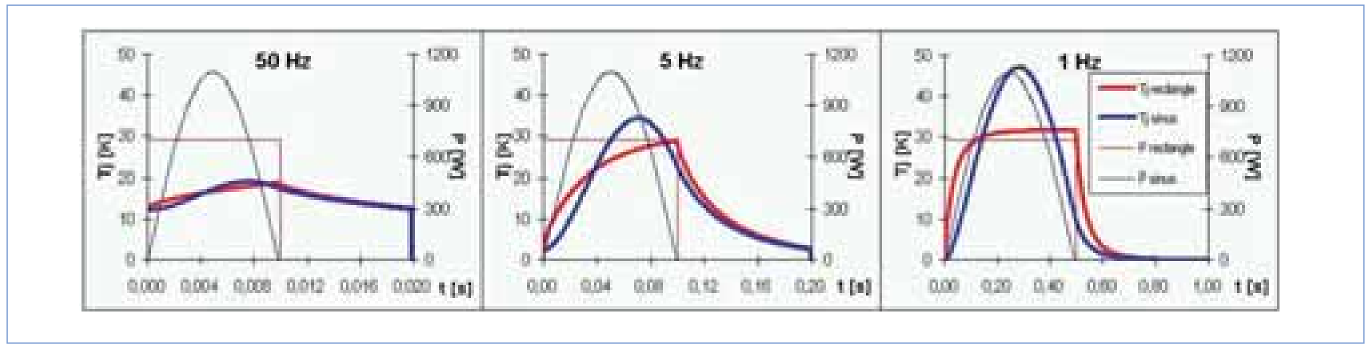


Figure 2. junction temperature for sinusoidal and rectangular shaped power loses at 50, 5 and 1 Hz.

The nominal switching losses (at data sheet conditions) are scaled by the current and DC voltage at the respective operation point. For a more detailed derivation of these formulas see [2] or [3]. The calculation results in a diagram showing the average power losses P_{av} for IGBT and diode at sinusoidal currents versus the RMS phase leg current (Figure 1).

Thermal calculation

IGBT as well as diode are conducting for 50% of the cycle-time of the sinusoidal output. Losses in these devices appear for one half-period at a time, while the IGBT or diode in the opposite inverter position is not active. The junction temperature therefore oscillates with the output frequency. There are three approaches for its thermal calculation:

- By using the average losses P_{av}, we achieve an average junction temperature $T_{jav} = P_{av} * R_{thjc}$. Due to the ripple on the output, the peak junction temperature will exceed the calculated T_{jav}.

A simple approach is to assume that the average losses P_{av} are dissipated in a rectangular shaped block of two times Pav during one half period of the phase current. The simulation (Figure 2) shows a comparison of the junction temperature rise for sinusoidal (blue) and rectangular (red) shaped power losses p(t) at 50, 5 and 1 Hz respectively with the same value for the average power P_{av}.

At 50 Hz the junction temperatures (bold curves) behave quite similar. At 1 Hz it becomes obvious, that due to the low output frequency and its relation to the time constants of the transient thermal resistance junction-to-case, the temperature closely follows the shape of the predetermined loss curve. Therefore a rectangular approximation is not generally applicable for sinusoidal losses!

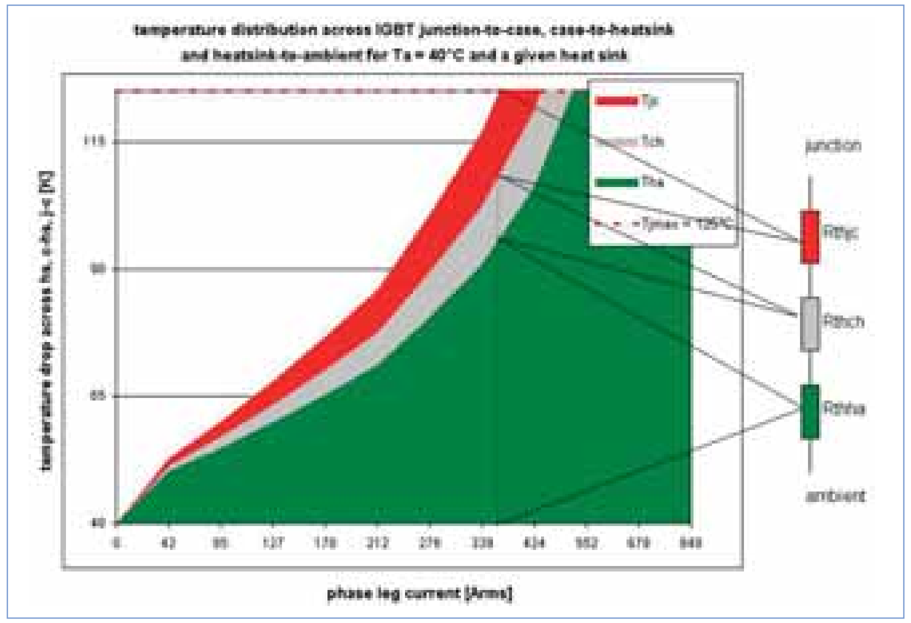


Figure 3. temperature distribution across junction-case-heatsink-ambient vs. load current.

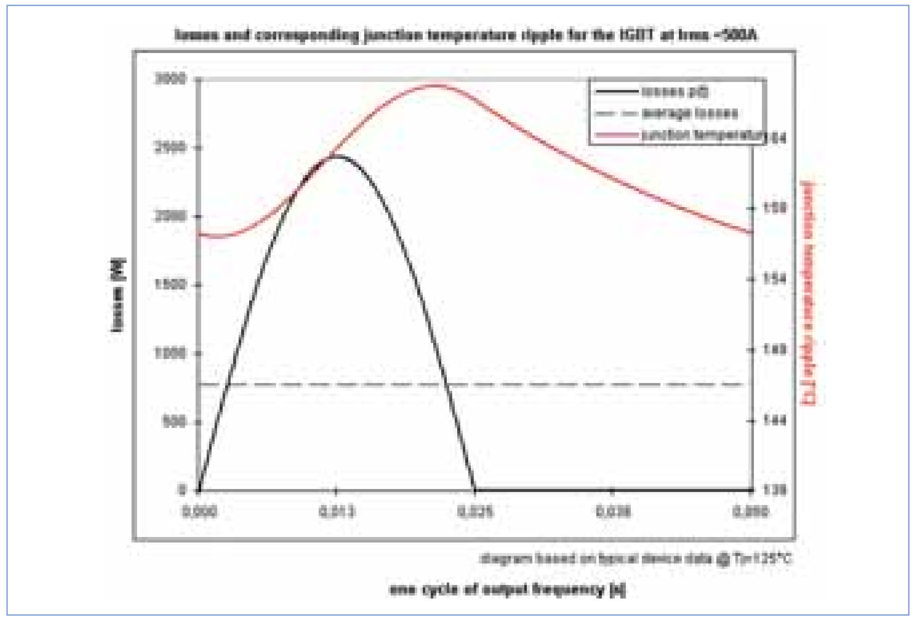


Figure 4. losses and junction temperature ripple for one period.

IPOSIM assumes a half-wave sinusoidal shape for the average power losses Pav. Only with this assumption the distinct fluctuation of the junction temperature is considered properly. The ripple and therefore the peak junction temperature increases at lower frequency and decreases with higher frequency.

The mentioned setting of a case temperature can only be estimated. This is sufficient for a module comparison and as a first guess. By defining a heat sink and with the easier to appraise maximum ambient temperature (e.g. 60°C for water and 40°C for air cooled systems) an accurate junction temperature calculation can be achieved.

Figure 3 visualizes the temperature distribution across the different layers junction-to-case, case-to-heatsink and heatsink-to-ambient for different load currents.

A detailed evaluation of the ripple (Figure 4) gives minimum and maximum junction temperature in the considered operation point as well as the maximum achievable current while keeping the limit of T_{jmax} e.g. below 125°C. By choosing between IGBT and diode the calculation can be performed for the IGBT as well as for the diode part of the module. In most cases, the highest temperatures for IGBTs will be reached in motor operation while diodes will reach highest temperatures in regenerative operation.

Load cycle calculation

So far IPOSIM assumed steady state operation with the primarily entered parameters. Further worksheets offer the option to not only calculate losses and temperatures for single operation points, but also for complete load cycles. With sampling points of changing parameters it is possible to freely define application specific operational cycles with up to fifty sets of data. You have the option to enter, save and later on restore and if necessary modify these cycles.

During the previous steady state approach, there was no need to define the transient characteristic for the heat sink. Considering now fluctuating cycles in the time frame of seconds, the transient response of the heat sink must be considered by a time constant.

The calculation finally ends up in load cycle diagrams which give a graphic presentation of the input data, the calculated losses and resulting temperatures for IGBT, diode and heat sink. Figure 5 shows a typical example for a traction cycle comprising acceleration, coasting and braking phase.

The most current version of IPOSIM, as well as an additional technical docu-

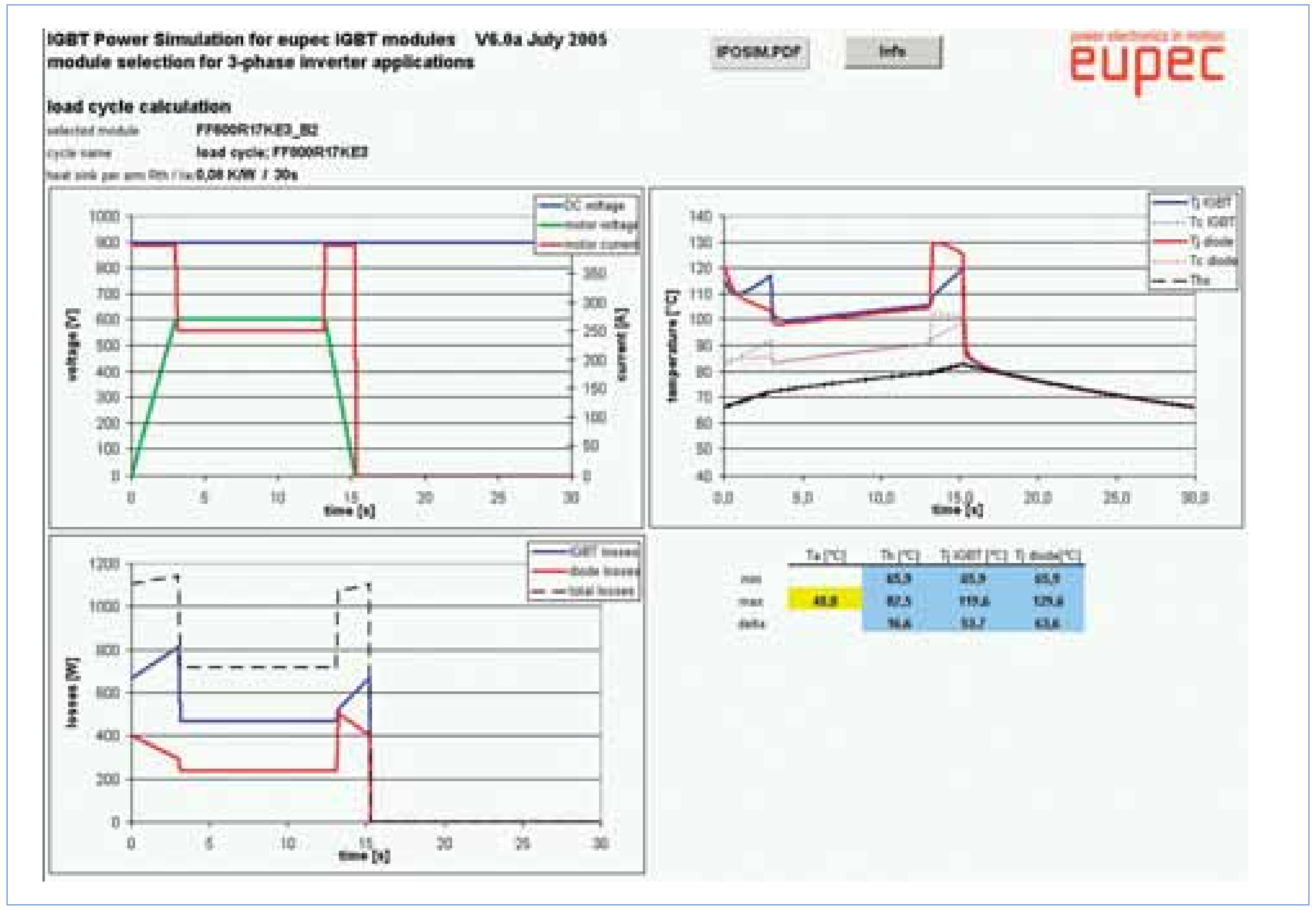


Figure 5. load cycle diagrams.

mentation, are available for download on eupec's homepage („Products & Solutions" and then „Simulation Tools").

References

1 nfineon Technologies Application note ANIP9931E: Calculation of major IGBT operating parameters

2 D. Srajber, W. Lukasch: The calculation of the power dissipation for the IGBT and the inverse diode in circuits with the sinusoidal output voltage; electronica ´92 Proceedings, pp. 51-58

3 eupec Technical documentation: Dimensioning program IPOSIM for loss and thermal calculation of eupec IGBT modules

www.infineon.com

www.eupec.com

ABB Voltage Detector

ABB is producing the first Voltage Detector VD1500, adapted completely to meet the major specifications of the traction market. The new ABB Voltage Detector VD1500 has been designed incorporating a new ABB innovation, a 100% electronic solution. This safety product will be used in applications such as on-board railway equipment (main converters, auxiliary converters) and in power electronics systems (battery chargers, choppers, sub-stations, etc.). It allows the maintenance operator to verify the presence of a dangerous voltage (AC or DC) up to 1500V on any equipment. Dangerous voltage indication is provided via 2 independent LEDs that flash when the voltage detected is higher than a specified limit (maximum 50V according to standards such as CF60-100). The mechanical and electronic concept ensures an excellent reliability of the product through two independent electronic boards (redundancy of the same function in only one product). The Voltage Detector (VD) operates from –40°C up to +70°C. The VD range has been designed to comply with traction standards: EN50155 for high-tech electronic design and tests, EN50124-1 for electrical insulation and EN50163 for voltage. The VD range has also been designed in compliance with safety standard EN50129 for communication, signalling and processing systems.

The ABB Voltage Detector provides a cost-effective solution that is easy to install and use.

ABB has been concerned for long with the protection of the environment and has been ISO 14001 certified in 1998. This environmental approach is particularly noticeable in the production of the VD range with the reduction of the number of components, use of a low-energy manufacturing procedure and recyclable packing.

www.abb.com/lowvoltage

Tantalum Chip Capacitors

EPCOS has added the SpeedPower II and III series to its SpeedPower range of tantalum chip capacitors because more and more applications call for diversification of equivalent series resistance (ESR) as well as of capacitance and rated voltage in capacitors. ESR is often the critical factor for the entire design.

The SpeedPower II series extends the range of capacitors in case sizes B to E with several gradations in the ESR limits. This series also introduces tantalum capacitors in case size A.

The SpeedPower III series features an optimized anode design with a larger surface area for even lower ESR.

Both series cover the ESR range from 40 m_ to 15 _ at rated voltages of 2.5 to 50 V in case sizes A to E. If the low-ESR types are used, connection of capacitors in parallel can be avoided. This leads to more compact designs, enhanced reliability and reduced placement costs.

The capacitors selected are used through-out electronics. Typical applications will be found in telecommunications, automotive, consumer and industrial electronics, data systems, and all applications where space is at a premium.

www.epcos.com/tantal_capacitors

100V MOSFET Modules

Advanced Power Technology Europe is pleased to announce the addition of 100V MOSFET modules to the existing product range in SP3, SP4, and SP6 packages.

These modules are offered in single switch, buck, boost, dual common source, phase leg, full bridge, asymmetrical bridge, dual boost, and dual buck configurations. Current ratings range from 50A to 600A @ TC = 80°C.

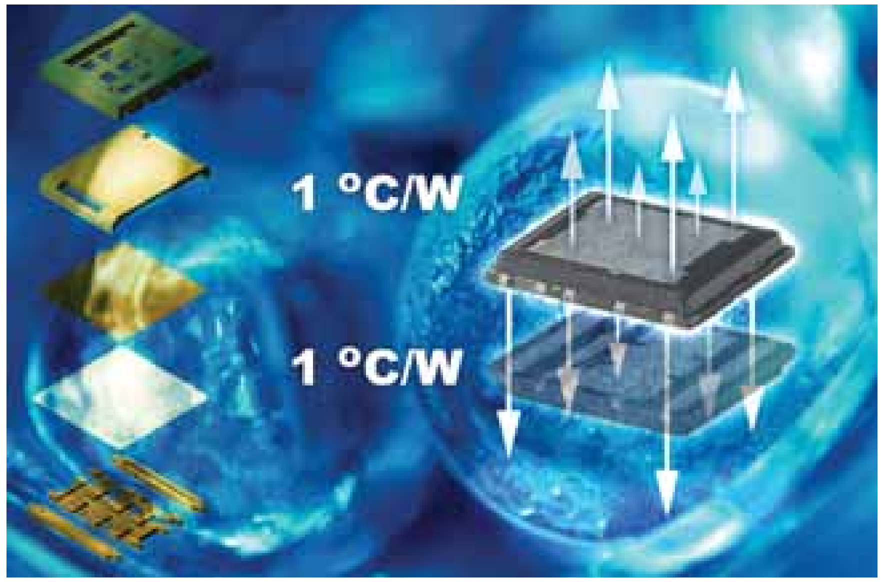
Single switch, phase leg, and full bridge configurations integrate FREDFET devices for improved body diode recovery characteristics and better dv/dt capability. High current single switch modules are offered in standard with AIN substrates for best thermal characteristics.

With 12mm height for the SP3 and 17mm height for the SP4 and SP6 packages, these modules exhibit minimum internal parasitic resistance and inductance, offering high frequency operation capability. The use of PowerMOS V FREDFETs allows operating in hard switching mode in the range of several tens of kHz without the need for series and parallel diode combination. All modules offer very low thermal resistance which leads to high current capability for a given RDS(on) switch resistance.

Main applications for this extended family are motor control, UPS, power supplies, and all other equipment operating from battery voltages in the range of 24V to 48V.

www.advancedpower.com

MOSFETs With Double-Sided Cooling



Vishay announced that it is shipping the first two power MOSFETs to be offered in its innovative PolarPAK package, which uses double-sided cooling to reducing thermal resistance, package resistance, and package inductance for a more efficient, faster switching power MOSFET.

PolarPAK was specifically designed for easy handling and mounting onto the PCB with high-speed assembly equipment and thus to enable high assembly yields in mass-volume production. This is one reason why PolarPAK has already earned the distinction of being the first MOSFET package with double-sided cooling to be sourced by multiple manufacturers, beginning with a license agreement concluded between Vishay and STMicroelectronics in March 2005.

The first PolarPAK power MOSFETs are the 30-V n-channel SiE802DF and SiE800DF. Optimized for the low-side control switch in synchronous rectification dc-to-dc converters, the SiE802DF offers exceptionally low on-resistance of 1.9 milliohms maximum at a 10-V gate drive (2.6 milliohms maximum at 4.5 V) and can handle current levels up to 60 A. The SiE800DF, optimized to work as the low-duty-cycle high-side MOSFET in synchronous dc-to-dc converter designs, features a very low typical gate charge Qg of 12 nC, with on-resistance of 7.2 milliohms maximum at 10 V and 11.5 milliohms at 4.5 V.

The new PolarPAK power MOSFETs, which have the same footprint dimensions of the standard SO-8, dissipate 1 °C/W from their top surface and 1 °C/W from their bottom surface. This provides a dual heat dissipation path that gives the devices twice the current density of the standard SO-8. With its improved junction-to-ambient thermal impedance, a PolarPAK power MOSFET can either handle more power or operate with a lower junction temperature. Typical applications for the new PolarPAK devices will include voltage regulator modules in notebook and desktop PCs, and other systems requiring high-efficiency dc-to-dc conversion.

www.vishay.com

Automotive Intelligent Power Device

To further strengthen its automotive semiconductor business, NEC Electronics Corp. and its subsidiaries in the United States and Europe, NEC Electronics America, Inc. and NEC Electronics (Europe) GmbH, announced the μPD166007, an intelligent power device (IPD) for use in on-board electronic control units (ECUs) supporting applications such as headlights, anti-lock braking systems and air conditioners. With this new device, the mechanical switches or relays conventionally used to control these units have been replaced by semiconductors to enable smaller and lighter ECUs with improved on/off control and high reliability. This innovation frees cabin space and contributes to a lower environmental impact by reducing engine load. Further environmental benefit is achieved through the μPD166007 IPD's lead-free design.

The device features a specific switching control to limit rapid fluctuations in output current. This reduces the electromagnetic noise and improves ECU performance. The μPD166007 IPD supports a current sensing function to monitor current flow during normal operation, and a diagnosis function to detect over-current and overheating. Support for these features allows an accurate grasp of the output status and the detection of abnormalities.

The μPD166007 uses a stacked construction in a multi-chip package (MCP). The device also features vertical type field-effect transistors (FET) using a UMOS trench cell structure. This structure has a solid track record for low resistance and low heat generation, and with an on-resistance of 10 mW (see note), the μPD166007 is ideal for use in on-board control units. The device comes in a compact TO-252 package with 5 external pins in line with JEDEC standards.

Samples of the μPD166007 IPD are available now. Mass production of approximately 1 million units per month is scheduled to start in the second quarter of FY2006.

www.necel.com

NEW PRODUCTS

Application-Specific Switches

STMicroelectronics has introduced a portfolio of application-specific analog, digital, and power switches, named NEATSwitch, designed to address the growing demand for application-specific switches that deliver higher performance while meeting increasingly demanding cost, space, and power constraints.

This demand is driven by the continuing rapid convergence of functions in mobile and digital consumer equipment and the multiplicity of new, emerging standards in high-speed data communication such as HDMI/DVI, 10/100/1000 Gigabit Ethernet LAN, and PCI-Express. These functions require application-specific signal switches built with state-of-the-art technology solutions such as very low-capacitance transistors or copper metallization, combined with innovations in circuit design and packaging technology.

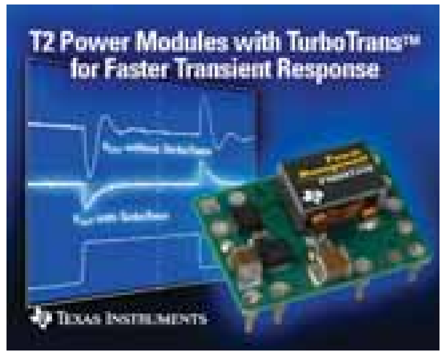
The NEATSwitch products leverage ST's unsurpassed ability to combine deep submicron geometries with relatively high-voltage (5V) operation, its long-term leadership in mixed-signal circuit design, and its expertise in innovative packaging. This unique combination enables ST to design and fabricate switches that offer very low on-resistance, low capacitance, high bandwidth and low power consumption and which are housed in the smallest packages.

For example, analog switches in the NEATSwitch range include the world's smallest 16-pin SMD quad-SPDT (single-pole, double throw) switch in a 2.6 x 1.8 x 0.55mm QFN16 package and the smallest dual-SPDT switch, housed in a 2.5 x 1.3 x 0.7mm DFN10 package.

The NEATSwitch power-switch family exploits ST's long-standing leadership in smart power technologies, mixing analog and logic circuitry with integrated power MOSFETs. These devices integrate two 80m-ohm N-Channel MOSFET high-side power switches, each controlled by an individual logic-enable signal, and capable of continuous current intake of up to 500mA. Future offerings will integrate both start-up blanking features and reverse current protection, providing even higher levels of performances and accuracy than are currently available.

www.st.com/neatswitch

Point-of-Load Power Modules



Texas Instruments announced today a family of non-isolated, plug-in power modules with a new technology that provides ultra-fast transient response rates and dramatically reduces customers' need for output capacitors. Featuring a tight 1.5 percent output voltage regulation, the point-of-load modules offer increased performance in a smaller footprint for designers of 3G wireless infrastructure, networking and communication systems that use advanced DSPs, FPGAs, ASICs and microprocessors.

Extending TI's popular line of PTH devices, the new T2 series of point-of-load modules will support step-down DC/DC conversion from a wide 4.5 V to 14 V input with adjustable output voltages down to 0.7 V at output currents up to 50 A making them ideal for intermediate bus architecture

(IBA) applications. The power modules offer several advanced features to reduce the overall power solution footprint by as much as 50 percent compared to TI's previous generation devices.

Faster Transient Response and Less Output Capacitance, Advanced processing platforms, such as TI's new 1-GHz TMS320TCI6482 DSP for 3G wireless base stations, requires extremely fast transient responses for a system to perform at a high-level. To achieve certain transient targets,

thousands of microfarads of capacitors must be added to most power supply systems. Even with higher volumetric efficiency, the added level of capacitance may expand the size of the overall power solution to more than that of the power supply alone—space that may have not been budgeted for or available.

The T2 power modules feature an innovative new TurboTrans technology, which allows a power supply designer to dynamically "tune" the modules using a single external resistor to meet a specific transient load requirement. The end-result is faster transient response with 40 percent less output voltage deviation and a five to eight times reduction in output capacitance. In addition, system stability is enhanced when using ultra-low equivalent series resistance (ESR) polymer tantalum or ceramic capacitors.

In addition to TurboTrans technology, the T2 modules incorporate an innovative SmartSync function that allows the designer to synchronize the switching frequencies of multiple T2 devices to maximize power efficiency and minimize electromagnetic interference (EMI).

www.ti.com

High-Current Power Distribution Switch Family

Micrel rolled out six new additions to its family of high-current power switches, the MIC2007/08/09 and the MIC2017/18/19. The MIC2007/08/09 feature adjustable current limiting and the MIC2017/18/19 offer both adjustable current capability and Kickstart, a unique new feature that handles high current surge devices without the stalling or stuttering caused by standard current limiting devices. The chips are part of the expanding family of MIC20xx power distribution switches introduced just last quarter. The ICs are aimed at PCs, set-top boxes, docking stations, game controllers and USB host devices where current limiting as protection against excessive loads and short circuits is required. The MIC2007/08/09 and the MIC2017/18/19 are available in volume quantities and in two package options; SOT-23 and 2mm x 2mm ML. Pricing starts at $0.69 in 1K quantity for SOT-23 and $0.80 in 1K quantity for MLF packaging.

The MIC2007/08/09 and MIC2017/18/19 feature the industry's highest power-to-footprint ratio: 0.5A/mm2. In addition, these ICs are among the first to offer adjustable current limiting, up to 2 Amps, in such small packages.

Adjustable current limiting allows the customer to set a limit of his or her own choosing rather than choosing from a list of pre-set factory limits. Adjustability also helps inventory control as, with adjustable current capability, one IC can easily address the power needs of many designs.

The ICs all offer 100mohm maximum on-resistance and an adjustable current limit in the smallest form factors available on the market today. These chips are capable of serving multiple (USB) ports which provides both cost and space savings. Standard features include a 2.5V to 5.5V operating range, output Enable control input, thermal protection, under voltage lock-out, low quiescent current and fault masking, which prevents nuisance alarms on current surges or hot plug events.

www.micrel.com

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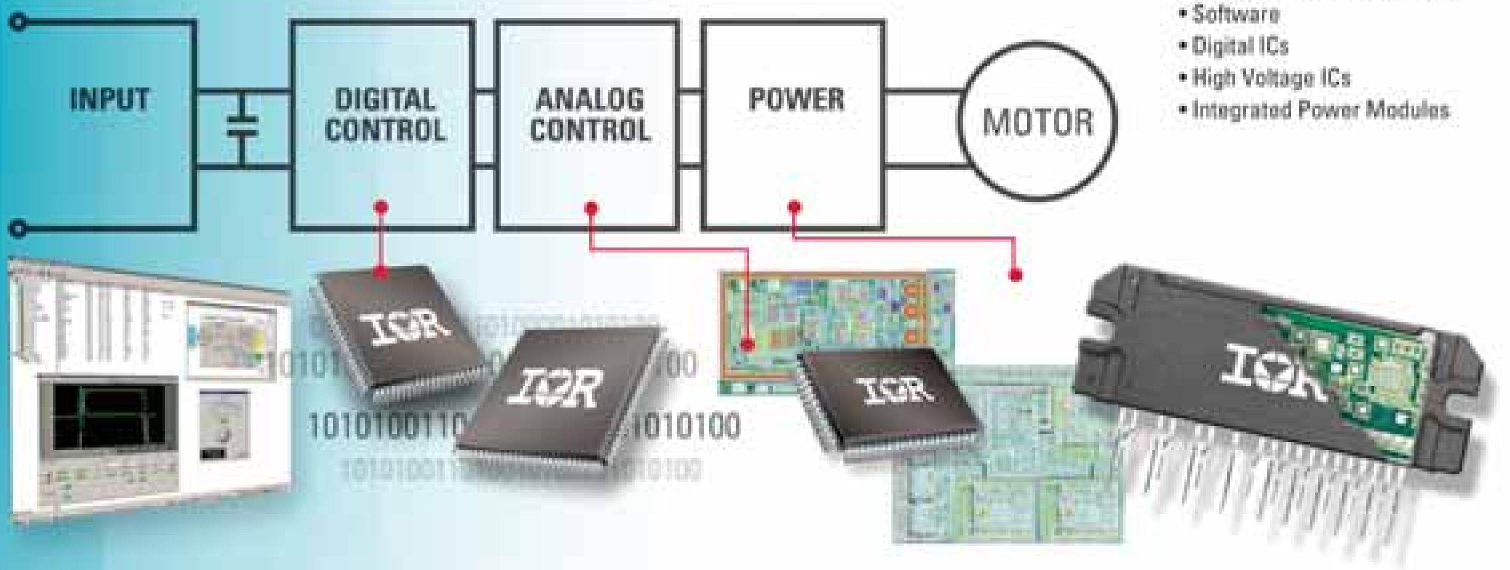

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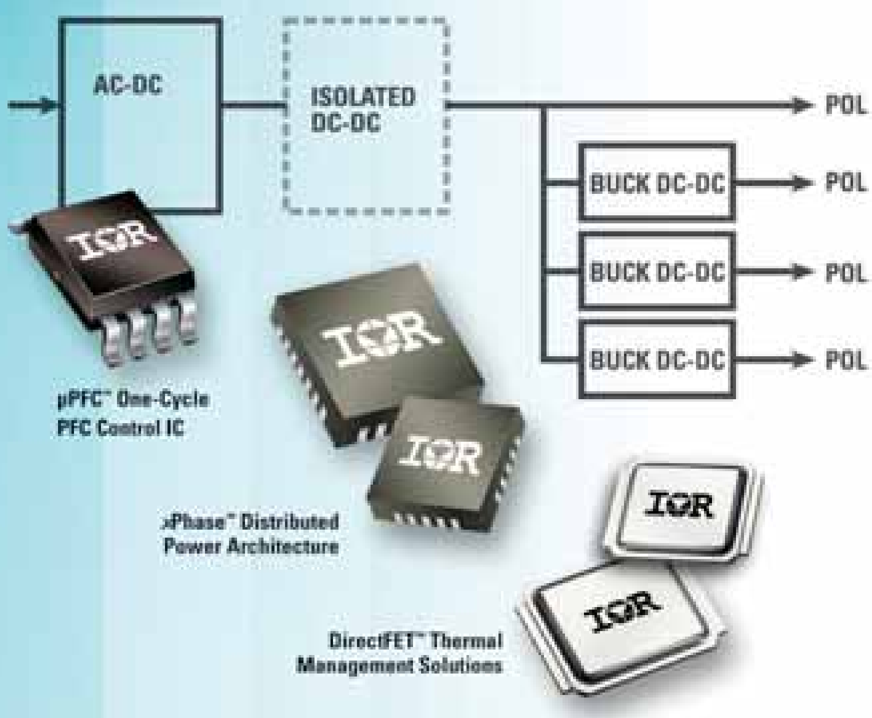

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