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Bodo´s Power Systems

Systems Design Motion and Conversion

October 2007

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Digital Power ICs to Speed Adoption

DCDC Conversion
Current Monitors
MOSFETs

Architecting Digital Power ICs to Speed the Adoption of Digital Power

Analog Power with Digital Communication and Control

The adoption of digital power solutions has been slower than expected in spite of the now large number of digital power ICs on the market. The adoption of digital power solutions can be accelerated by architecting digital power conversion chips which can be readily integrated into existing power supply design flows. A hybrid power IC comprised of an analog control topology and a digital management and communication system allows end users to quickly and efficiently produce robust and reliable power supply systems that reap the benefits of digital power.

By Gus Mehas, Staff Applications Engineer, Intersil Corporation

The State of the Digital Power Market
Power conversion chips have been in use for many years now in specialized applications, but in the last five years, since the inception of the PMBus (Power Management Bus), there has been a major focus on the use of digital control and processing for mainstream power supplies. Digital power chips offer many benefits over analog power ICs and promise to solve many of the problems in power supply design and implementation, enabling the development of smaller, cheaper, more reliable and more efficient power conversion systems.

Even the most basic digital power chips feature extensive configuration, control and monitoring of the power supply system, allowing power supply designers to obtain information about all the operating parameters of their designs. This reduces development time and enables the design of more robust and reliable power supplies. More advanced digital power chips feature exotic functions such as nonlinear control loops, adaptive loop compensation, and predictive dead-time control that provide reduced component count and increased efficiency.

Today there are a number of power conversion ICs from at least seven different IC vendors that can be classified as “digital power”. Digital power ICs are available to serve AC/DC, isolated DC/DC and nonisolated DC/DC power systems. Additionally, there have been many papers and technical articles published from industry and academia on designing and employing digital power systems.

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SPT+ Diodes to Match IGBTs

Diodes / Rectifier
IGBT Modules
Silicon Carbide

High Voltage SPT+ Diodes

The Perfect Match

The newly developed SPT+ diode technology platform for 3.3kV, 4.5kV and 6.5kV diodes for next generation high power IGBT modules is described in this article. The new diode range offers low losses and soft recovery characteristics combined with a high reverse recovery safe operating area and superior surge current capability.

By A. Kopta, M. Rahimo and U. Schlapbach, ABB Switzerland Ltd, Semiconductors

The main challenge in the design of high voltage diodes for IGBT application is to ensure low losses combined with soft reverse recovery behaviour. The high stray inductances encountered in these applications, together with design restraints mainly given by the need for a high immunity against cosmic ray induced failures, have a strong impact on the diode performance. With the recent introduction of the next generation of high voltage SPT+ IGBTs comprising significantly reduced losses, the development of a new diode generation matching the performance of these IGBTs has become inevitable. Today, state of the art high voltage diode designs utilize technologies comprising either local lifetime control, or the usage of low concentration diffusion profiles to control the emitter efficiency of the anode and cathode emitters.

In this article, we present a newly developed technology utilizing a double local lifetime-control technique to optimize the on-state charge distribution in the diode. Thanks to the improved plasma distribution, the overall losses were reduced, while maintaining the soft recovery characteristics of the standard technology. This new diode technology is referred to as SPT+, where the abbreviation SPT stands for Soft Punch-Through, referring to the soft reverse recovery characteristics of the diode.

Figure (1) shows the maximum output current as a function of the switching frequency of the new 3.3kV/1500A HiPak module comprising 24 SPT+ IGBTs and 12 anti-parallel diodes using both SPT and SPT+ diodes. The figure shows the module output current in inverter mode (black curve) as well as in rectifier mode for the standard SPT diode (blue curve) and the new SPT+ diode (red curve). The standard SPT diode has too high total losses and would clearly limit the output current of the module in rectifier mode. At a switching frequency of 400Hz, the output current would only be 1250A as compared to the SPT+ IGBT capability in inverter mode of nearly 1500A. By using the new SPT+ diode with lower total losses, the output current in rectifier mode can be increased to match the inverter mode performance over the entire frequency range. Therefore, the main objective was to develop the new SPT+ diode technology with the required loss reduction to match the capability of the SPT+ IGBT. At the same time, the diode softness and ruggedness had to be at least as good as in the original technology to ensure that the new diode could be switched as fast as for the standard one.

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Integrated ballast control ICs simplify designs

Now you can eliminate components and complexity in ballast designs. For example, our new FAN7711 features all the optimum power functions as well as circuitry protection required for CFL and LFL applications. Fairchild gives you more functionality, in less space, with improved reliability—combined.

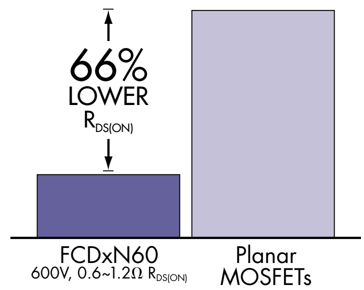
FAN7711 Electronic Ballast Control IC

Gate drivers improve system reliability

Combining exceptional noise immunity with high-side driver operation that features negative V_S swings of –9.8V (V_{BS} = 15V) to protect against negative noise, Fairchild's HVICs enhance system reliability and minimize power consumption.

High-performance SuperFET™ MOSFETs

SuperFET MOSFETs minimize conduction and switching losses to help improve overall system efficiency. Their combined low on-resistance, DPAK packaging and ability to withstand high speed switching transients make them the ideal MOSFETs for ultra-slim ballast designs.



To learn more about our complete lighting solutions—including PFC ICs, IGBTs and transistors—please visit www.fairchildsemi.com/lighting.

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The Gallery

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Events

Ansoft Design Seminars
www.ansoft.com/firstpass

Microchip MASTERs Conference,
Munich Nov. 6- 8,http://microchip.com

National Power Seminars
www.national.com/see/powercourses

Fairchild Power Seminars
www.fairchildsemi.com/powerseminar07

TI Portable Power Design Seminars
www.ti.com/portable-power-e-pr

Semicon Europa, Oct. 9-11, Stuttgart D,
www.semi.org/semiconeuropa

Electrical Power Quality and Utilisation,
Oct. 9-11, Barcelona, www.epqu2007.com

Digital Power Europe, Nov. 13-15, Munich,
http://www.dpfeurope.darnell.com

Productronica, Nov. 13-16, Munich,
http://www.productronica.com

SPS/IPC/DRIVES, Nov. 27-29, Nuremberg,
http://www.mesago.com

Silicon Carbide Switches become Reality

The world can expect more efficient power electronic switches and systems with a reduction in key losses such as conduction and switching.

A number of Silicon Carbide (SiC) power rectifiers are already available on the market as standard products and are in use in power supplies. Silicon Carbide switches in different products - jFETs, MOSFETs and IGBTs - have been successfully produced and demonstrated in applications but we are still about two to three years away from the volume introduction of switches in silicon carbide. Defect density in the raw material is still a subject for improvement.
As you'll see in this issue, manufacturing has taken a step ahead; the Cree article explains a move from 3 inch to 4 inch wafers in manufacturing.

The ECPE workshop in Copenhagen gave a good overview - where we are and what will happen next with international experts presenting on the subject.

Application areas awaiting SiC include high-speed trains with higher voltages than the 6.5 kV limit silicon switches dictate or in the automotive industry, more efficient inverters in hybrid vehicles. Another focus is to reduce weight in airplanes where silicon carbide at lower voltages can lead to less weight and more power. The new super airplanes such as the Airbus 380 will require up to a MW more power !

New technology goes into volume production only if it makes sense economically. While silicon carbide has many advantages it also presents challenges in mounting and packaging with 300°C temperatures requiring new approaches. The associated passive devices must be reliable at higher temperatures. Primarily we'll see ceramic solutions for resistors and capacitors and possibly new driver ICs at higher temperatures. So silicon carbide is on its way to a breakthrough in this decade.

The month of September was dominated by two events in Denmark. The first was the EPE conference held in Aalborg in Jütland followed directly by the above mentioned ECPE SiC workshop. Professor Frede Blaberg and his team made Aalborg the center of the world's discussion of power electronics - progress in research and development. A thousand attendees, a full technical program and Danish hospitality made Aalborg a great success. I will select topics covered there for articles in upcoming issues. Also Aalborg is famous for its Aalborg Aquavit: a special Scandinavian liquor that helps with the digestion of the delicious Danish food served at the meeting.

We are in northern Germany close to Denmark and the wind power conference in Husum. I will cover more on the HusumWind and wind power in the November issue.

The falls' show season soon kick-off and I look forward to seeing you in Munich at the Productronica or in Nuremberg at SPS/IPC/DRIVES.

My Green Power tip for the month
– this winter use a thermos bottle to keep your coffee warm.

Best regards

Pennsylvania at the HUSUMwind

US State on the East Coast sets priorities with the "Energy Independence Strategy"
The question of the future of the American energy supply is still at the top of the political agenda of the USA. At the US state level, the energy shift was begun long ago: Pennsylvania as the first US state has committed all state institutions to draw 10 percent of their power from alternative energy sources in order to stimulate demand. By 2020, 18 percent of power consumption is supposed to come from renewable energy sources.

Now with the announcement of his "Energy Independence Strategy," Governor Edward G. Rendell again decisively set priorities for the energy shift in Pennsylvania. The aim of the strategy is lowering of energy costs by 10 billion US dollars in the next ten years. In addition, by increasing domestic production of alternative and renewable energy, dependence on imported fuels is supposed to be reduced.

With over 12 million residents, the Commonwealth of Pennsylvania in the eastern US is among the largest states in the United States. With the city of Philadelphia, this is the political cradle of the American nation. The Pittsburgh region is considered "the American Ruhr region." Not only did 60 percent of US steel production come from Pennsylvania a hundred years ago, but also
America's energy past based on oil and coal was located here. Today, very promising beginnings of America's energy future are located here.

You can find information on the Pennsylvania Energy Development Agency (PEDA) at:

www.dep.state.pa.us

www.awea.org/pennsylvania

PIV Technology launches with RECOM as first franchise

A new specialist power conversion distribution company, PIV Technology, has been launched promising to deliver the best quality products at the right price with full technical and logistical support, from design through to production. Founded by Marc Hogg, who brings more than 15 years' experience of working in the power supply market, PIV Technology's first franchise is RECOM, the Austria/German based manufacturer of DC/DC products.

www.pivtechnology.com

Solar Cells with "Metal Wrap Through" Technology

The goal of every manufacturer of solar cells is to reducesolar power costs. In this sense, applied research can greatly contribute to innovative cell concepts. In their prototype production line, the scientists at the Fraunhofer ISE – working in close cooperation with industry – have successfully completed a multi-crystalline solar cell with rear side contacts. The solar cell does not only have greater efficiency; it also comes in a new design.
In comparison to the production of standard solar cells, there are three process stages of MWT solar cells, which also give it its name. MWT stands for "Metal Wrap Through" and is a concept which partially shifts the front side contacts over to the rear side, thus reducing the front side metallization almost in half. First, a laser is used to drill holes into the cells. The through-connection of the cells is simultaneously achieved through the subsequent silkscreen printing process for the production of the rear side contacts. To this effect,
the silk-screen printing paste is used to fill the recently created holes, thus establishing the electrical connection to the front side. Contrary to typical processes, the isolation of the contacts reduces additional costs. The rear side contact of the MWT solar cells demands a small modification of the standard process.

www.ise.fraunhofer.de

Collaboration Agreement for 3D Wafer-Level Packaging

Amkor Technology and IMEC announced that they have entered into a 2-year collaboration agreement to develop cost-effective, 3D integration technology based on wafer-level processing techniques.

"This collaboration with IMEC will enhance our continuing efforts to develop low cost, state of the art packaging solutions for our customers", said Dan Mis, Amkor's Senior Vice President for Wafer Level Advanced Product Development.

Luc Van den Hove, IMEC's Executive Vice President and Chief Operating Officer, commented: "We are pleased that one of the leading semiconductor packaging service providers has joined our 3D system integration program that targets the development of post-passivation technology for 3D interconnects at the IC bond pad level."

www.amkor.com

www.imec.be

The Best-Selling 2-Channel IGBT Driver Core

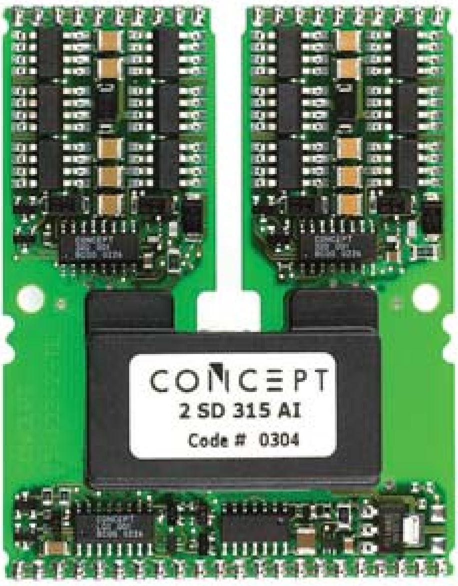
The 2SD315AI is a 2-channel driver for IGBTs up to 1700V (optionally up to 3300V). Its gate current capability of ±15A is optimized for IGBTs from 200A to 1200A.

The 2SD315AI has been established on the market as an industrial standard for the last four years. The driver has been tried and tested within hundreds of thousands of industrial and traction applications. The calculated MTBF to MIL Hdbk 217F is 10 million hours at 40ºC. According to field data, the actual reliability is even higher. The operating temperature is -40ºC...+85ºC.

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.

Chipset Features

- Short-circuit protection
- Supply undervoltage lockout
- Direct or half-bridge mode
- Dead-time generation
- High dv/dt immunity up to 100kV/us
- Transformer interface
- Isolated status feedback
- 5V...15V logic signals
- Schmitt-trigger inputs
- Switching frequency DC to >100kHz
- Duty cycle 0...100%
- Delay time typ. 325ns



Driver stage for a gate current up to ±15A per channel, stabilized by large ceramic capacitors

Specially designed transformers for creepage distances of 21mm between inputs and outputs or between the two channels. Insulating materials to UL V-0. Partial discharge test according IEC270.

Isolated DC/DC power supply with 3W per channel

More information: www.IGBT-Driver.com/go/2SD315AI

CT-Concept Technology Ltd. is the technology leader in the domain of intelligent driver components for MOS-gated power semiconductor devices and can look back on more than 15 years of experience.

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.
In recent years we have developed a series of customized products which are unbeatable in terms of today's technological feasibility.

Our success is based on years of experience, our outstanding know-how as well as the will and motivation of our employees to attain optimum levels of performance and quality. For genuine innovations, CONCEPT has won numerous technology competitions and awards, e.g. the "Swiss Technology Award" for exceptional achievements in the sector of research and technology, and the special prize from ABB Switzerland for the best project in power electronics. This underscores the company's leadership in the sector of power electronics.

CONCEPT

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Let experts drive your power devices

Ultracapacitor Products for Wind Turbines

Maxwell Technologies has obtained a non-exclusive worldwide license from Enercon GmbH of Aurich, Germany, for a patent covering the use of ultracapacitors in wind energy systems, including their use as backup power source for wind turbine blade pitch systems.

Dr. Richard Balanson, Maxwell's president and chief executive officer, said that the license clears the way for Maxwell to market its BOOSTCAP ultracapacitor products to any wind turbine or blade pitch system manufacturer that wants to incorporate the technology into its products.

"We have been in contact with a number of manufacturers that are interested in using ultracapacitors in their backup power systems, but have been waiting for this patent situation to be resolved," Balanson said. "This agreement opens up a significant portion of the rapidly growing wind energy market that otherwise would not have been available to us."

Blade pitch systems enhance the consistency of wind turbines' energy output by "trimming" turbine blades to compensate for changes in wind velocity. Backup power allows for an orderly shut down in the event of interruption of the primary power source. Ultracapacitors' long operational life and reliable performance in low temperature environments reduce maintenance and replacement costs associated with battery-based backup power systems.

www.maxwell.com

Tunisia Factory

Roal Electronics officially announces the beginning of operations of its new factory in Tunisia. The Tunisia investment is part of the company's long term commitment to enhance its ability to respond to the constantly changing requirements of its customer base, which requires flexibility, efficient logistics and integration, and constant attention to cost containment.

Roal's decision to create a manufacturing plant in Tunisia was fostered by the successful experience ROAL has had with one of its key subassembly suppliers, who has been operating a facility in Tunisia for the past several years nearby the new ROAL plant. In addition to a very central Mediterranean location (the plant is a short one hour flight from the company's headquarters) Tunisia offers an improving business environment, a favorable taxation system, a highly qualified and motivated workforce, as well as a flexible labor market.

ROAL Tunisia will enable our company to efficiently serve our customers as well as support their future growth.

www.roallivingenergy.com

European Conference by Microchip

Microchip announces it is accepting registrations for its first ever European Microchip's Annual Strategic Technical Exchange and Review (MASTERs) Conference, to be held in Munich from November 6th-8th 2007.

MASTERs is an in-depth, bi-directional exchange of technical information between Microchip subject-matter experts and the Company's technical partners, including consultants, customers, third parties, distributor FAEs and design houses. Topics presented cover a broad range of subjects, from board layout topologies to real-life reference designs and embedded applications.

Microchip technical experts will join delegates for evening events and discussions. Centred around activities designed to interest engineers, these informal events allow time to share design experiences, and challenges, with like-minded engineers from across Europe.

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E-mail: suzy@napier.co.uk

http://microchip.com

Portable Power Seminar Series

Building on the success of its popular power design seminars, Texas Instruments announced the schedule for its 2007 Portable Power Design Seminar series. Leading TI power management experts will conduct the one-day seminar in 5 cities in Europe, starting in December. For more information, see: http://www.ti.com/portable-power-e-pr

The 2007 Portable Power Design Seminar series provides practical sessions focused on advanced battery management and power conversion concepts, basic design principles and "real-world" application examples, such as notebook computing and portable navigation systems. Seminar presenters will cover design issues and considerations, design techniques, topologies, tools and examples.

www.ti.com

Lowest Power Zero-Crossover Op Amp For Battery-Powered, Portable Applications

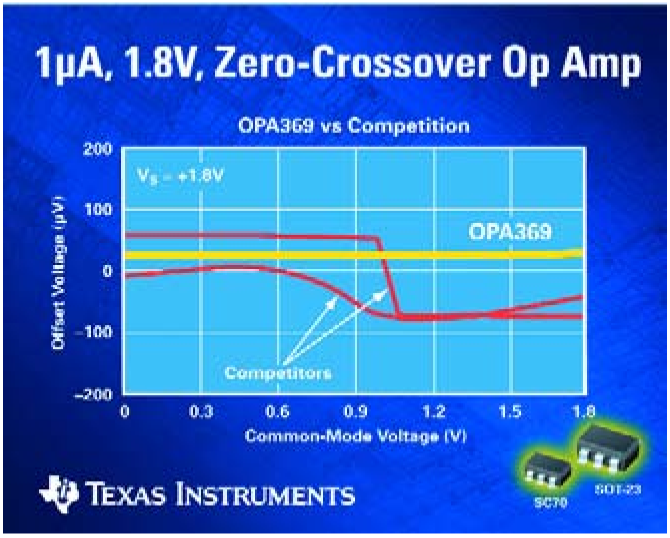
Precision, 1μA Amplifier Simplifies High-Performance Designs

Texas Instruments introduced the industry's lowest power zero-crossover operational amplifier (op amp). Featuring a unique single-input-stage architecture, the OPA369 achieves rail-to-rail performance without input crossover to solve the common design problem of input offset distortion due to the change in common mode voltage that is very prominent in low-voltage, rail-to-rail applications. Combined with 1μA quiescent current, SC70 package and operation down to 1.8V, the OPA369 simplifies high-performance designs in battery-powered, portable products.
(See http://www.ti.com/opa369-pr.)

"The OPA369 utilizes TI's innovative zero-crossover topology and next-generation CMOS process technology to offer precision performance previously unavailable in 1μA single-supply amplifiers," said Art George, senior vice president of TI's high-performance analog business. "Typically, designers are forced to choose between power consumption and the AC or DC performance of their signal conditioning amplifiers. The OPA369 will enable customers to increase the precision in their portable applications without complicating the design or increasing their power budget."

The single-input stage architecture delivers outstanding offset voltage of 750μV over the entire rail-to-rail input range and a common-mode rejection ratio (CMRR) of 100dB minimum, thereby maximizing the useable input dynamic range for low supply voltage applications. Other features include low noise of 120nV/rtHz, gain bandwidth of 12kHz on 1μA, low input bias current of 50pA maximum, low voltage offset drift of 1.75μV/°C (max), PSRR of 94dB and low 1/f noise of 3.6μVp-p (0.1 to 10Hz)

The OPA369 offers the precision, low power and small packaging required in a wide variety of applications such as portable medical



devices (glucose meters, oxygen metering), portable instrumentation (gas detection/monitoring, handheld test equipment), sensor signal conditioning and portable consumer devices.

TI provides customers with a state-of-the-art signal chain solution for portable applications: analog-to-digital converters such as the ADS1100; digital-to-analog converters such as the DAC8811; and precision voltage references such as the REF33xx. The OPA369 is also optimized to work with TI's MSP430 ultra-low-power microcontroller family.

Availability and Packaging
The dual OPA2369 is available now from TI and its authorized distributors in SOT23-8 and MSOP-8 packages. Suggested resale pricing for the OPA2369 starts at USD1.20 in 1,000-piece quantities.

The single OPA369 is sampling now, with volume production scheduled for 4Q 2007. The device is available in an SC70-5 package and suggested resale pricing starts at USD0.80 in 1,000-piece quantities. In addition, TINA-TI SPICE-based analog simulation software is available for easy-to-use circuit simulation.

TI offers analog engineers a wide-ranging support infrastructure that includes training and seminars, design tools and utilities, technical documentation, evaluation modules, an online KnowledgeBase, a product information hotline and a comprehensive offering of samples that ship within 24 hours of request. For more information on TI's complete analog design support, and to download the latest Amplifier and Data Converter Selection Guide, visit:

www.ti.com/analogelab

Analog or Digital?

By Dipl.-Ing. (FH) Alexander Gerfer,
Director International Product Management,
Würth Elektronik eiSos, Germany

Analog or digital – on which technology is your heart set? This is one of our standard questions in interviewing engineers applying for a job in our product design team.

And very often, no - mostly, the answer is: Digital, or Software.

Well I hope I can motivate young technicians or engineers to look on the field of analogue electronics with more interest.   Why?

Well, first of all – job opportunities are excellent. Finding well educated or trained analogue designers gets more and more difficult. And for even the inexperienced, most companies will train on the job. You can be sure of all these things.

Secondly, in today's high-speed digital world, information must be treated as high frequency analogue signals. The time for low frequency digital electronics is over. PCB board signals must be treated in the right way (e.g. transmission line design, termination, grounding) – otherwise your electronics may not work at all, or not reach the desired performance, or will have lots of EMI problems!

Thirdly, Power Electronics Design is sophisticated – it is artwork! Beyond the simple

application of Integrated Circuits, the functioning and efficiency of a power supply will be satisfactory only if one understands the component selection criteria, for semiconductors as well as passive components. An additional and interesting study of component non-ideal behavior and parasitics is often necessary. Many suppliers provide support in this area through simulation models – free software tools to let you easily design your power supply (and in using simulation you are in a sense back in the digital world…).

And when you have first built your own transformer- then you quickly learn how many options you have in arranging the windings, and how different are the results in efficiency and parasitics. Then to optimize the transformer is – as I said – artwork!

Würth, as a manufacturer of passives – Magnetics – knows your headaches in choosing and making the best application of components. We can help where education in high school and university has been inadequate, or too theoretical to handle the real world.

We hope that more and more experienced designers (are invited to) share their knowledge with students in practical design lessons. By doing so, we are able to keep ahead in technology and solutions.

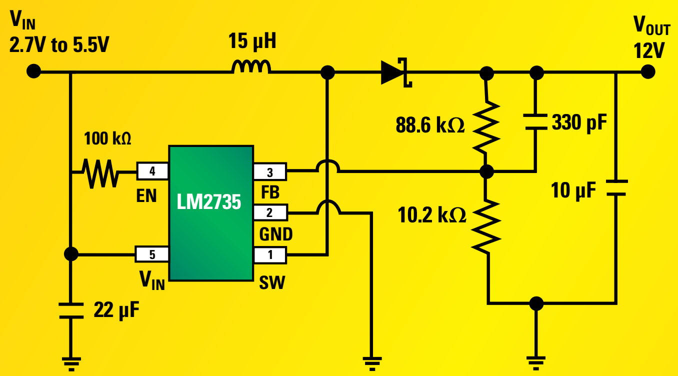
Looking forward to seeing you or your friends at one of our analogue design seminars about EMI or Magnetics.

www.we-online.com

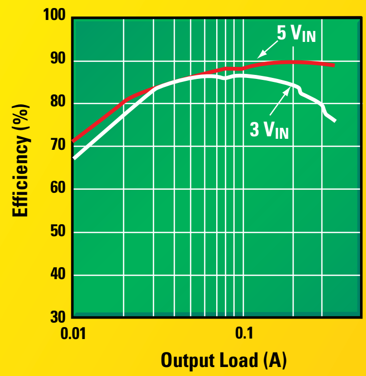
Tiny Boost Regulator Provides Ease-of-Use and High Output Current

LM2735 Delivers 2.1A Switch, Internal Compensation in Tiny Packages

Typical Application Circuit



Efficiency vs Load Current V_{OUT} = 12V



Features

- 2.1A switch current over full temperature range
- Two switching frequencies
  LM2731/33: 600 kHz/1.6 MHz
  LM2735: 520 kHz/1.6 MHz
- Boost from 5V to 12V at 700mA
- LM2735: internal soft-start limits in-rush current at start-up
- Ceramic capacitor stability enables small size and eliminates high frequency noise
- Internal compensation allows for ease-of-use and minimal external components
- 1.6 MHz operating frequency uses tiny passive components
- SOT23-5, LLP-6, and eMSOP-8 packages ideal for space-constrained applications

SOT-23 Boost Regulators

AVAILABLE LEAD-FREE

Product ID	V_{IN} Range	Switch Current	V_{OUT} Max	Frequency	Ideal for	Package
LM2731	2.7V to 14V	1.4A	22V	600 kHz 1.60 MHz	XDSL modem, portable devices, white LED current sources	SOT23-5
LM2733	2.7V to 14V	1A	40V	600 kHz 1.60 MHz	TV tuners, set top boxes, white LED current sources	SOT23-5
NEW LM2735	2.7V to 5.5V	2.1A	24V	520 kHz 1.60 MHz	LCD and OLED-Displays for portable applications, USB powered devices, white LED current source	SOT23-5 LLP-6 eMSOP-8

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National Semiconductor
The Sight & Sound of Information

Electronics Industry Digest

By Aubrey Dunford, Europartners

SEMICONDUCTORS

European semiconductor sales in July 2007 amounted to $ 3.285 billion, up 2.4% versus the previous month, so WSTS. Measured in euro, semiconductor sales in July 2007 were € 2.426 billion, up 2.0% on previous month and down 2.9% versus the same month a year ago. On a YTD basis semiconductor sales showed a decline of 3.6% versus the same period in the year 2006. The German semiconductor market further dropped in July, registering a 5% decline, after a minus 3% growth in June and May, according to the ZVEI.

STMicroelectronics and IBM have signed an agreement to collaborate in the development of next-generation process technology. For bulk CMOS development, ST will establish a research and development team in IBM's Semiconductor Research and Development Center in East Fishkill and Albany, New York. At the same time, IBM will establish a research and development team at ST's 300mm wafer semiconductor R&D and fabrication facility in Crolles, France.

IBM and Infineon announced an agreement in principle to divest their shares in Altis Semiconductor, their manufacturing site in Corbeil-Essonnes, France, via a sale to Advanced Electronic Systems, a Swiss affiliate of GIS (Global Information Services), a Russian-based holding company.
Infineon also plans a joint venture with Siemens Power Transmission and Distribution (PTD) aiming at providing high-power thyristors for high-voltage DC (HVDC) power transmission lines, so EETimes.

Vishay intents to sell the Automotive Modules and Subsystems Business Unit (ASBU) recently acquired from International Rectifier as part of the Power Control Systems (PCS) business.
Philippe Lambinet has joined ST as Corporate Vice President and General Manager of the Company's Home Entertainment and Displays (HED) Group, reporting directly to President and CEO Carlo Bozotti. He will also hold responsibility for ST's Grenoble, France, site.

Texas Instruments has opened a new Customer Support Center and representative office in Prague (Czech Republic), adding to existing recently established offices in Warsaw, Moscow and Istanbul and providing new levels of support to Eastern European markets by extending its local customer service.

Maxim Integrated Products has entered into a definitive agreement to purchase the Storage Products Business of Vitesse Semiconductor for $63 million in cash.

Analog Devices will consolidate its Limerick (Ireland) Wafer Fab operations in an expansion of its existing 8" wafer facilities. Analog Devices plans to transition ist current 6" Wafer processing Fab to its newer 8" Fab and plans to phase out and close its Limerick 6" Fab by the end of 2008. The transition will result in approximately 150 position redundancies.

OPTOELECTRONICS

Sharp has made the decision to build a new LCD panel plant, the first in the world to use 10th-generation glass substrates, the world's largest size (2,850 mm x 3,050 mm). Construction is slated to start in November of this year, with production operations scheduled to start by March 2010. Sharp also inaugurated its new LCD module and LCD TV production base in Poland. Sharp will gradually increase production capacity in Poland to 10 million LCD modules a year in 2011.

Osram Opto Semiconductors will be exiting the production of passive matrix displays based on organic
LEDs (OLEDs) at the end of the year. The company will be concentrating its OLED activities on developing market-ready OLED lighting solutions.

PASSIVE COMPONENTS

Xindeco will transfer its entire aluminum electrolytic capacitor production facility in Xiamen to its Chinese JV with Epcos. For its part, Epcos is increasing its capital investment and will therefore continue to hold 60% of the shares in the JV.

Tyco Electronics has been named Michael Robinson as senior vice president of operations in charge of the company's strategic purchasing, manufacturing, logistics and quality assurance.

EMS PROVIDERS

The worldwide EMS market grew 17.6% in 2006, as the worldwide electronics assembly market grew 13.9%, so Electronic Trend Publications. ETP estimates that total electronics assembly value was $923 billion in 2006 and will grow to nearly $1.3 trillion in 2011. Fueled by this huge market, ETP believes that the EMS industry will grow from $223 billion in 2006 to $442 billion in 2011.

DISTRIBUTION

The 2d quarter European semiconductor distribution market was 1.37 Billion Euro, so DMASS. The first half of 2007 still showed 0.9% growth compared to all-time high levels of 2006, but the second quarter already recorded a decrease of 3.15% compared to Q2/2006. Eastern Europe is on the verge of becoming the third largest market region with a growth of 19.6% (€ 149 M).
Rutronik expanded its presence in Eastern Europe with a sales office in Serbia.

This is the comprehensive power related extract from the « Electronics IndustryDigest », the successor of The Lennox Report. For a full subscription of the report contact:
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European Firms Targeting Hybrid Vehicle Technologies

Hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) are receiving growing attention from European firms. Compared with an HEV, which is not designed to travel more than a few hundred meters on battery power, a Prius-size PHEV could run for about 100 to 125 km on a charge, without using the on-board internal combustion engine. The increased range of PHEVs makes them much more dependent on battery charging stations compared with HEVs which are self-contained.

By Douglas Bess, Editor, PowerPulse.Net

Toyota Motor Corp. and **Electricite de France SA** (EDF) announced plans to jointly develop recharging points for PHEVs. The companies intend to develop an electricity infrastructure to service the PHEVs that Toyota is slated to unveil in the next few years.

Only a few large cities (such as London) currently provide recharging points. It is believed by many observers that the future commercial viability of plug-ins will largely depend on the expansion and wider availability of recharging points. The Toyota-EDF project will probably cover only France at first, but could expand to other countries due to EDF's ownership of utility companies in Germany, Italy, and the United Kingdom.

Also in France, **Saft** announced that it is manufacturing what is claimed to be the highest power lithium-ion (Li-ion) cells in the world. The VLV range of cells are said to exhibit a specific power double that of typical high power cells that are available for defense applications and hybrid electric military vehicles.

Saft's high power VLV line consists of three sizes of cells (VL4V, VL8V, and VL12V), which comprise what is claimed to be the highest power cells commercially available in the world today. New for 2007 will be the VL6A, a high power cell designed for civil applications that require peak power, such as windmill blade pitch control.

"Our VLV cells are already being manufactured and are currently in use on military fighter aircraft providing emergency back-up power to operate flight controls and to start the APU," said Dr. Kamen Nechev, Manager of Advanced Development, Saft Space and Defense Division. "The VL6A is an exciting addition to our portfolio of very high power cells and will satisfy the power demands of many emerging technologies. We are in a unique position because Saft is the only supplier offering cells of this high level of power."

Saft's portfolio includes 6, 8 and 12A hour cells with a max charge voltage of 4.1V and an average voltage of 3.6V. Specific power exceeds 9kW/kg for two-second-long pulses and 12kW/kg for 100ms-long pulses. The cells are capable of continuous discharge of 6kW/kg. The cells are used in battery products ranging from 28V to as high as 600V.

Saft developed the cells complete with electrical hardware and software monitoring capabilities to provide a completely safe power solution for its customers. The cells can be used for a variety of applications, including emergency power for military fighter aircraft, supplemental acceleration and breaking in military hybrid electric vehicles, as well as intermediate energy storage in directed energy systems. The full line is available now.

A fleet of Dodge Sprinter plug-in hybrid delivery vans will be operating within the United States, powered by Li-ion batteries developed by **Johnson Controls-Saft Advanced Power Solutions** (JCS). The test fleet is claimed to be helping to usher in a new age of extremely fuel-efficient and environmentally friendly, urban transportation.

"Advances in lithium-ion battery technology are bringing the reality of plug-in hybrids closer to commercialization," said Mary Ann Wright, who leads the JCS joint venture and is Vice President and General Manager of Johnson Controls' hybrid battery business.

According to Wright, the Dodge Sprinter is an ideal vehicle to carry a large battery pack and still have ample room readily accessible for use as a delivery vehicle.

Fleets of Sprinter plug-in hybrids were put into service in Los Angeles, New York and Kansas City in 2006 during the first phase of Chrysler and Daimler's plug-in hybrid development program.
Powered by Johnson Controls-Saft nickel-metal hydride (NiMH) and Li-ion battery packs, the Sprinter vans have provided valuable data to accelerate the development of future battery technology.

It is claimed that the Li-ion battery packs in Sprinter plug-in hybrids will be 47% lighter compared to previous NiMH systems and deliver more power than today's conventional hybrid batteries.

"Advanced battery technology is the single most important enabler in making all types of electric vehicles practical," stated Wright. "Plug-in hybrids, conventional hybrids, electric vehicles (EVs) and hydrogen fuel cell vehicles will benefit from lithium-ion technology. Johnson Controls-Saft is determined to deliver state-of-the-art batteries to power advanced, environmentally friendly vehicles."

According to the companies, plug-in hybrids can travel much farther on emission-free electric power than conventional hybrids, and are particularly well-suited for urban delivery vehicles operating in heavy traffic and making frequent stops. Plug-ins can be charged overnight using less-expensive off-peak electricity. Very large battery packs, however, are needed to store the electric energy for daily use.

Johnson Controls-Saft is a joint venture that has brought together **Johnson Controls** – a leading supplier of automotive batteries and a company experienced in integrated automotive systems solutions – with **Saft**, a French advanced energy storage solutions provider with Li-ion battery expertise.

In the United Kingdon, **FiFe Batteries Ltd.**, a developer of second-generation Li-ion battery technology, recently announced a partnership with **Enerize Corp.** to develop what is described as safe, low-cost, high-energy Li-ion rechargeable batteries for various applications including HEVs.

These batteries will feature advanced electrode materials based on new types of TiO2 used by FiFe, as well as high conductivity/high tap density MnO2 and low cost modified natural graphite developed by Enerize. In combination, these new materials have the potential to deliver what is claimed to be significantly improved durability, reduced self-discharge and lower cost than conventional Li-ion batteries.

The new materials will be complemented by other proprietary Li-ion technologies developed by Enerize and FiFe, including electrolyte additives for increased cycling stability and new electrode coating process that will allow the batteries to deliver more power on demand. During manufacture, new nondestructive test systems from Enerize will be used for quality control. Enerize nondestructive methods and systems can also be applied for real-time in-line quality control at the facilities of other battery manufacturers.

Dr. Elena Shembel, CEO and co-founder of Enerize Corp., commented, "Development of safe low-cost, high efficiency Li-ion batteries is critical for new electronic devices and next-generation hybrid electric vehicles. We believe that our partnership will address these requirements, and we are excited to work with FiFe Batteries in this endeavor. Rob Neat has an impressive track record of successful exploitation of IP and technology-based products, including successful management of Li-ion cell manufacturing businesses. We are also looking forward to working with auto manufacturers on the in-vehicle integration and testing of the new Li-ion batteries."

Dr. Rob Neat, CEO of FiFe Batteries, commented, "We believe that our partnership represents a strong combination of R&D and manufacturing capabilities. We are impressed with the IP portfolio and R&D capabilities of Enerize Corp. and are looking forward to complementing it with our R&D and manufacturing capabilities. Our joint goal is to produce multi-ton quantities of these new materials for electrodes, as well as development and testing of battery cells, modules, and packs."

www.powerpulse.net

Energy Savings and Performance Ensure Digital Power Dominance

Emerging digital power technologies are poised to save millions of Euros in electricity consumption and will result in a corresponding reduction in green house gas emissions.

By Linnea Brush, Senior Analyst, Darnell Group

Enterprise-critical installations such as data centers can use up to 100 times the electricity of a typical office building on a square foot basis, with electric bills often exceeding 500,000 Euros per month. This presents a significant opportunity for digital power conversion and energy management technologies to have an immediate impact increasing energy efficiency and dramatically reducing energy costs.

While price parity is an important factor in the growing interest in digital power, superior performance will ensure digital power's domination. Superior performance of digital control compared with analog will be a key focus of the upcoming Digital Power Europe conference. For example, papers to be presented by Ericsson Power Modules, Texas Instruments and Zilker Labs will be among those highlighting the performance benefits enabled by digital power techniques.

The paper from Ericsson presents a case study of energy management and digital control in a MicroTCA power system. This technical case study will demonstrate that digital solutions are expected to not only ensure that the right tolerance and performance levels are met, but also to improve design integration and meet power density expectations. The authors will also show how synergies can be found, and performance improved even further, by allowing IPMI-based management components in the system to interact directly with power conversion elements using a serial bus. Such a serial bus can be used by system-level components to undertake 'active' energy management to improve efficiency and also collect data on temperature, voltage and current.

Authors from Texas Instruments will introduce a strategy used in a digital controller to optimize power converter efficiency. Power efficiency in a dc-dc buck converter with multiple-phase operation can be optimized using a different number of phases, based on real-time load conditions. Efficiency can be significantly increased at light load if a single phase is enabled instead of turning on all phases. Using that optimization strategy, the plant is changed under single-phase operation compared to full-load operation when all phases are enabled. Therefore, the compensation loop needs to be changed so the converter can keep the same dynamic performance with varying phase configurations. In addition to changing the loop compensation, phase shift among the phases needs to be adjusted in order to decrease output voltage ripple. All these changes can be implemented in real time in a digital controller.

Zilker Labs' paper "aims to clarify some of the issues" related to the commercialization and wider adoption of digital control for point-of-load converters. Implementation of digital power controllers can result in a higher level of flexibility and performance in terms of ability to better match load characteristics. Several independent tests also demonstrated that higher efficiency was achieved by utilizing digital dc-dc controllers. Efficiency improvements were achieved through implementation of advanced operating algorithms and improved thermal management.

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Architecting Digital Power ICs to Speed the Adoption of Digital Power

Analog Power with Digital Communication and Control

The adoption of digital power solutions has been slower than expected in spite of the now large number of digital power ICs on the market. The adoption of digital power solutions can be accelerated by architecting digital power conversion chips which can be readily integrated into existing power supply design flows. A hybrid power IC comprised of an analog control topology and a digital management and communication system allows end users to quickly and efficiently produce robust and reliable power supply systems that reap the benefits of digital power.

By Gus Mehas, Staff Applications Engineer, Intersil Corporation

The State of the Digital Power Market

Power conversion chips have been in use for many years now in specialized applications, but in the last five years, since the inception of the PMBus (Power Management Bus), there has been a major focus on the use of digital control and processing for mainstream power supplies. Digital power chips offer many benefits over analog power ICs and promise to solve many of the problems in power supply design and implementation, enabling the development of smaller, cheaper, more reliable and more efficient power conversion systems.

Even the most basic digital power chips feature extensive configuration, control and monitoring of the power supply system, allowing power supply designers to obtain information about all the operating parameters of their designs. This reduces development time and enables the design of more robust and reliable power supplies. More advanced digital power chips feature exotic functions such as nonlinear control loops, adaptive loop compensation, and predictive deadtime control that provide reduced component count and increased efficiency.

Today there are a number of power conversion ICs from at least seven different IC vendors that can be classified as “digital power”. Digital power ICs are available to serve AC/DC, isolated DC/DC and nonisolated DC/DC power systems. Additionally, there have been many papers and technical articles published from industry and academia on designing and employing digital power systems.

However, in spite of the benefits and advantages that digital power IC’s provide and in spite of the large amount of knowledge in the industry and a number of products available on the market, the adoption and growth of digital power has been slower than predicted. In March 2006, one IC vendor predicted that sales of digital power supplies would total $3 billion by the end of 2008 and $8 billion by the end of the 2010 and that digital power would pervade every branch of power conversion: AC/DC, isolated DC/DC and non-isolated DC/DC power systems. But today traditional analog power systems still dominate the market and digital power has not achieved the mainstream success that was predicted.

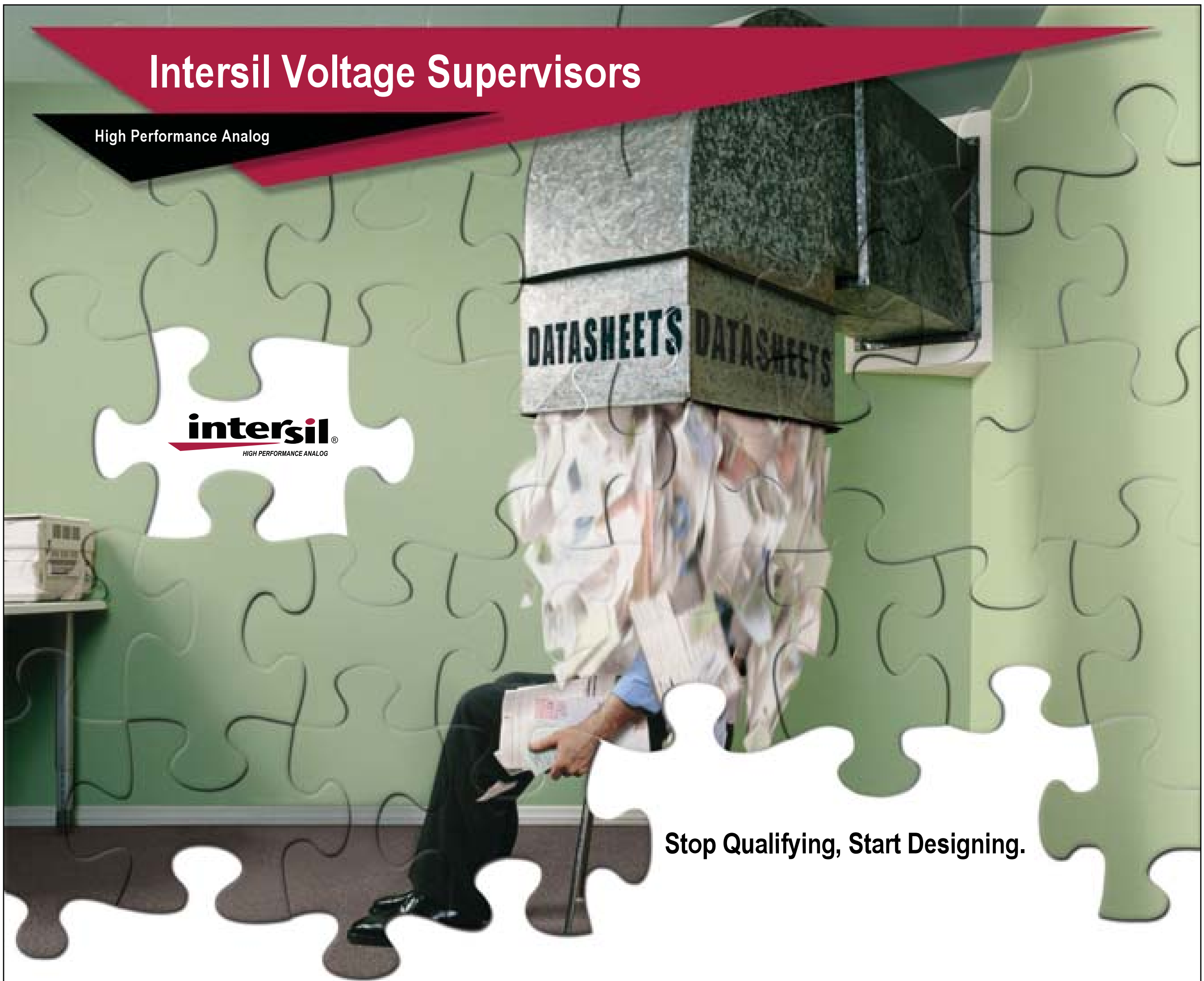
The problem is not one of product availability or knowledge, but rather of infrastructure, support, and education. Digital power chips promise many benefits, but they require new workflows, are seen as being more complex than analog power chips, and require new learning and training to be incorporated effectively into power designs. These issues provide significant barriers to the adoption of digital power by the power supply designers who would use them. The solution is to develop digital power chips for power supply designers that offer the advantages that digital brings to the power world while still being familiar and intuitive.

New Workflows Required for Digital Power

Using digital power chips with digitally-implemented control loops requires new workflows and design methodologies as compared to traditional analog power ICs. For the rest of this article, products with analog control loops will be referred to as ACL products and products with digitally-implemented control loops will be referred to as DCL products.

With traditional analog power ICs (i.e.; the ACL products), the control loop dynamics are determined by passive components. With DCL products, the loop dynamics are programmed into the chip via software. This software is usually a graphical user interface (GUI), but even with software that is simple to use, the process of configuring the digital control loop to achieve the desired transient response may not be a straightforward one, and will be entirely unfamiliar to power supply designers who have spent their entire careers working in the hardware realm with soldering irons and passive components.

Not only is the method of interacting with and configuring a digital control loop product very different from an analog control loop product, employing DCL power ICs requires analysis and calculation in the discrete time domain, as opposed to the continuous time domain



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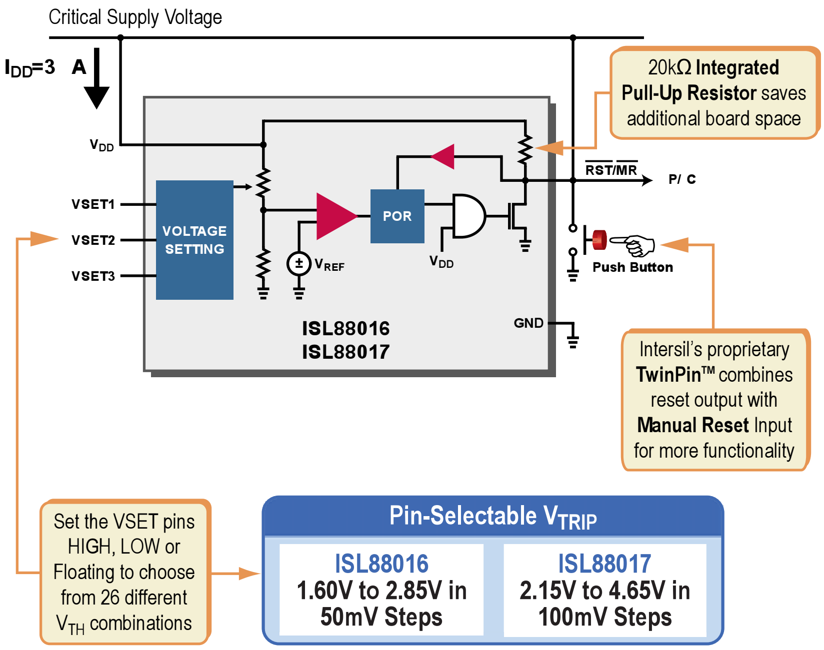

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with ACL chips. By definition, the digital control loop is implemented via discrete time sampling systems with finite resolution and this may have significant effects on the system depending on the design and the application. The power supply designer needs to consider these effects in order to develop a power supply that works as expected.

As a result of this, the existing infrastructure of design tools and software, as well as most of a designer's intuition, experience and knowledge in analog power cannot be directly reused to employ DCL products. Power supply design engineers need to utilize new workflows and design methodologies as well as acquire new skill sets and intuition in order to develop power supplies that use ICs with digitally-implemented control loops.

Increased Complexity of Digital Chips

DCL power chips are more complex than analog power chips, and this has a major impact on the power supply design process.

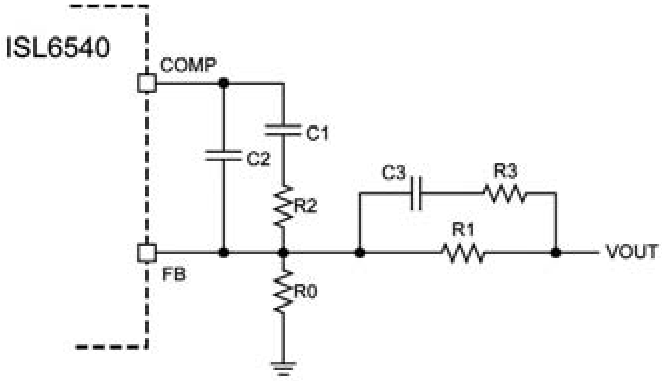

Figure 1: Type III Compensation Network for ACL Chip

The primary task in the process of designing a power supply is constructing a stable control loop without which the power supply would be useless. In an ACL product, the loop dynamics are controlled by passive elements around the error amplifier, as shown in Figure 1, which depicts the Type-III compensation network used for the ISL6540, a standard analog power IC.

The voltage-mode and current-mode control loops present in ACL chips have a long history, are proven and well-understood, and feature loop dynamics that are well-predicted. Choosing the appropriate

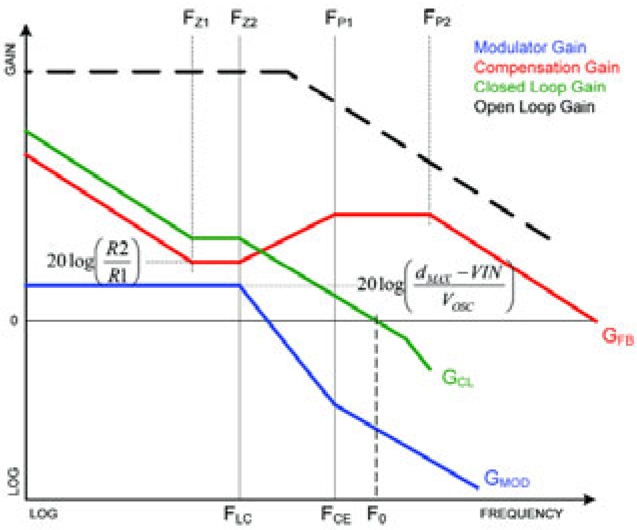

Figure 2:
Bode Plot for ISL6540 Control Loop and Compensation Network

compensation values is a straightforward process that can be done analytically via equations or graphically via Bode plot, as shown in Figure 2.

In addition, the loop dynamics are a strong function of the actual compensation network and only weakly dependent on actual IC performance parameters such as error amplifier gain-bandwidth product, PWM comparator offset voltages, and so on. This means that knowledge gained from one ACL power chip can be applied to another with minimal re-learning, and different ACL power chips can be expected to have similar transient characteristics if they are compensated with the same network.

By comparison, in a DCL power chip, the loop dynamics are controlled by software-programmed coefficients and are strongly dependent on the actual IC implementation and performance. The transfer function of the control loop is distilled down to one equation, such as shown in Figure 3, which depicts the transfer function of the ISL6595, a standard DCL power IC.

$$H(z)=\left(\frac{K_i}{1-z^{-1}}+K_p+K_d(1-z^{-1})+K_{d2}(1-z^{-1})\right)\left(\frac{1+K_{fz1}+K_{fz2}}{1+K_{fp1}z^{-1}+K_{fp2}z^{-2}}\right)\left(\frac{K_{mod}}{N_{ph}\bullet div\_sel}\right)\left(\frac{V_{in}}{Q}\right)$$

Figure 3: ISL6595 Transfer Function Equation

In order to establish the appropriate loop dynamics, the power supply designer must derive the correct coefficients for the equation, which may or may not be a simple process depending upon the software that the DCL chip vendor has provided to accomplish this task.

Parameters such as duty cycle quantization, PID loop sampling rate, propagation delays in the system, and the implemented poles and zeroes will all substantially affect the characteristics of a particular digital control loop. Different DCL chips may behave differently from each other, and the performance of the chip may not be as documented in the IC datasheet.

New Learning Required for Digital Chips

Power supply chips with digital control loops are avoided by many older generation power supply designers as well as a large number of younger designers just entering the industry.

The older generation power supply designers that are entrenched in traditional analog power design resist digital power because of its heavy dependence on software. They consider themselves to be hardware experts, not software gurus. The software is seen as a barrier to execution of the power supply design itself and is perceived to require extensive retraining.

The younger power supply designers who are just entering the industry are hesitant to adopt DCL chips because those chips do not look like what they learned in school. Despite the large number of digital power chips on the market, colleges and universities featuring strong power supply design programs still focus heavily on analog power. In addition, when newly-graduated power supply designers enter the industry, their companies focus on mainstream solutions, not emerging technologies, so these new graduates have little mentoring in the area of digital power. Finally, their mentors are themselves the older generation power supply designers that are resisting digital.

The Solution: Hybrid Digital Power IC

To alleviate the issues involved with DCL chips, and speed the adoption of digital power solutions, Intersil has developed the ISL8601, which is a Hybrid Digital Power IC that implements the PMBus standard. The objective is to provide power supply designers with a digital power IC that looks like the analog power chips that they are used to using, but that gives them the benefits of control and monitoring provided by digital power.

A hybrid digital power IC features an analog heart with a digital brain: an analog control loop with a digital command and control interface. The architecture of a hybrid IC consists of four main components: a voltage-mode or current-mode control loop implemented in the traditional analog way, a data acquisition system comprised of ADCs and DACs, a digital communication interface, and digital control logic to provide command and control functionality.

The diagram shown in Figure 4 depicts the architecture of the ISL8601. The four main architectural components are illustrated. The error amplifier and the PWM comparator are the heart of the system, forming the analog voltage-mode control loop. This structure is identical to that of traditional analog power conversion IC's.

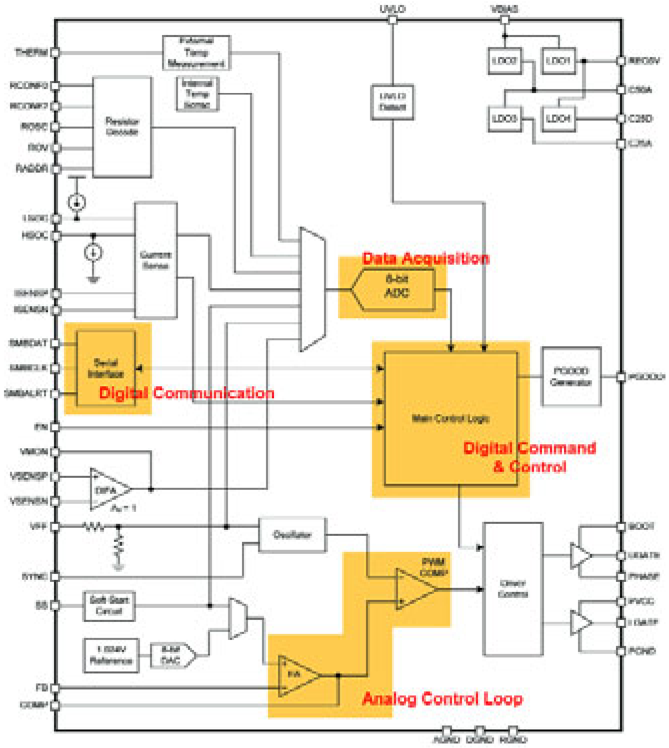

Figure 4: Architecture of ISL8601, Hybrid Digital Power IC

The 8-bit ADC in conjunction with DACs on the internal reference as well as on other parameters not show in the diagram form the data acquisition system that allows all the relevant parameters of the power system to be controlled and captured. Digitally-acquired data parameters include input voltage, output voltage, output current, and temperature. At any given cycle in the operation of the power converter, the ADC onboard the ISL8601 is capturing multiple parameters and delivering that information back to the internal control logic.

The brain of the ISL8601 is the main control logic section, and this forms the third component of the hybrid digital power IC architecture. This block is a state machine that implements that PMBus command functionality as well as tying together and controlling the various analog components on the chip. This block also enables advanced functionality to be built into the ISL8601 that would not be possible in a traditional analog power IC without any control logic. For example, the ISL8601 features multiple programmable soft-start modes, multiple prebiased startup handling modes, and multiple fault handling modes. Other advanced features such as a digital phase-locked loop and extensive calibration of the measurement system are made possible by the state machine on the chip.
Finally, the ISL8601 features a serial interface that implements the physical layer of the PMBus specification, which allows complete configuration, control and monitoring of the power supply system from a remote system host.

Hybrid IC Versus Standard Analog IC

The ISL8601 is intended to resemble as closely as possible the standard analog power IC's that are currently on the market, not only on the inside with its architecture, but on the outside with its pinout. One popular analog power IC is the ISL6540. This product is a full-featured, single-phase PWM controller IC with integrated MOSFET drivers. As shown in Figure 5, the major functions of the ISL8601 are the same as those in the ISL6540.

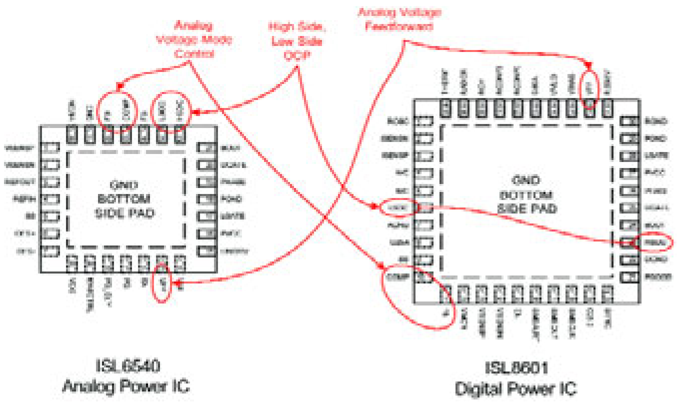

Figure 5: ISL8601 vs. ISL6540 Pinout

The ISL8601 features an analog voltage mode control loop with pins FB and COMP, it features analog voltage feedforward compensation on pin VFF, and it features analog overcurrent protection on pins LSOC and HSOC. Because these features on the ISL8601 are the same as those on the ISL6540, power supply designers using the ISL8601 can implement digital power supply designs using the same techniques as they do for their existing analog power supply designs. Additionally, the ISL8601 can be fully configured without the use of software, via external resistor components.

Speeding the Adoption of Digital Power with The Benefits of Hybrid ICs

Hybrid digital power ICs like the ISL8601 provide power supply designers a path to intuitively implementing digital power supplies with all their associated advantages without having to relearn power supply design or adjust their work flows. The primary objective of any power conversion IC is power regulation. All the system management and communication features are secondary: if the architecture of an IC does not lend itself to easy power regulation, then all its advanced features are useless. The Hybrid ISL8601 allows designers to use their customary step-by-step approach to developing their power supplies. Because of its analog heart, i.e. analog control loop, the ISL8601 allows power supply designers to implement power regulators without having to consider any of the ICs digital functionality. Later in the design process when the digital control and monitoring features are required, they can be accessed easily. The availability of hybrid digital power chips such as the ISL8601 mitigates the major barriers to the acceptance of digital power and help speed its widespread adoption.

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High Voltage SPT$^+$ Diodes

The Perfect Match

The newly developed SPT+ diode technology platform for 3.3kV, 4.5kV and 6.5kV diodes for next generation high power IGBT modules is described in this article. The new diode range offers low losses and soft recovery characteristics combined with a high reverse recovery safe operating area and superior surge current capability.

By A. Kopta, M. Rahimo and U. Schlapbach, ABB Switzerland Ltd, Semiconductors

The main challenge in the design of high voltage diodes for IGBT application is to ensure low losses combined with soft reverse recovery behaviour. The high stray inductances encountered in these applications, together with design restraints mainly given by the need for a high immunity against cosmic ray induced failures, have a strong impact on the diode performance. With the recent introduction of the next generation of high voltage SPT$^+$ IGBTs comprising significantly reduced losses, the development of a new diode generation matching the performance of these IGBTs has become inevitable. Today, state of the art high voltage diode designs utilize technologies comprising either local lifetime control, or the usage of low concentration diffusion profiles to control the emitter efficiency of the anode and cathode emitters.

In this article, we present a newly developed technology utilizing a double local lifetime-control technique to optimize the on-state charge distribution in the diode. Thanks to the improved plasma distribution, the overall losses were reduced, while maintaining the soft recovery characteristics of the standard technology. This new diode technology is referred to as SPT$^+$, where the abbreviation SPT stands for Soft Punch-Through, referring to the soft reverse recovery characteristics of the diode.

Figure (1) shows the maximum output current as a function of the switching frequency of the new 3.3kV/1500A HiPak module comprising 24 SPT$^+$ IGBTs and 12 anti-parallel diodes using both SPT and SPT$^+$ diodes. The figure shows the module output current in inverter mode (black curve) as well as in rectifier mode for the standard SPT diode (blue curve) and the new SPT$^+$ diode (red curve). The standard SPT diode has too high total losses and would clearly limit the output current of the module in rectifier mode. At a switching frequency of 400Hz, the output current would only be 1250A as compared to the SPT$^+$ IGBT capability in inverter mode of nearly 1500A. By using the new SPT$^+$ diode with lower total losses, the output current in rectifier mode can be increased to match the inverter mode performance over the entire frequency range. Therefore, the main objective was to develop the new SPT$^+$ diode technology with the required loss reduction to match the capability of the SPT$^+$ IGBT. At the same time, the diode softness and ruggedness had to be at least as good as in the original technology to ensure that the new diode could be switched as fast as for the standard one. A lower di/dt capability would otherwise increase the IGBT turn-on losses, which would adversely decrease the output current in inverter mode and in this way limit the module performance.

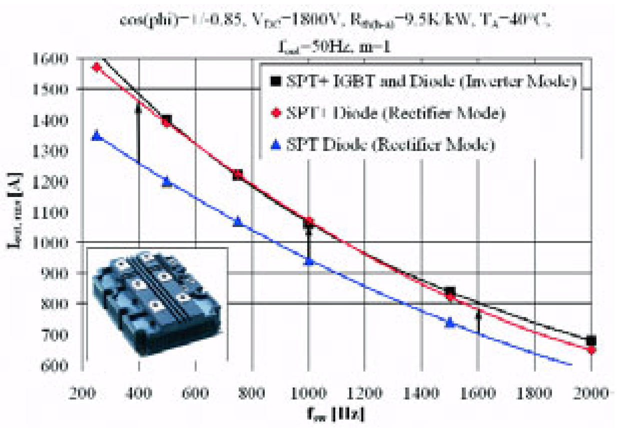

Figure (1) Simulated output current as function of the switching frequency of the 3.3kV/1500A SPT$^+$ HiPak module (24 IGBTs and 12 diodes).

SPT$^+$ Diode Technology

In Figure (2), a cross-section of the SPT$^+$ diode and the corresponding carrier lifetime profile can be seen. The SPT$^+$ diodes utilize the same silicon resistivity and thickness as well as anode and cathode diffusion profiles as the original SPT diodes. On the anode side, a high-doped P$^+$ emitter is used. The emitter efficiency is adjusted with a first local lifetime peak placed inside the P$^+$ diffusion profile as for the standard SPT diode. In order to control the plasma concentration in the N-base region and on the cathode side of the diode, the SPT$^+$ technology utilizes a second local lifetime peak, placed deeply inside the N-base from the cathode side. In this way, a double local lifetime profile as shown in the right part of Figure (2) was achieved. With this approach, no additional homogenous lifetime control in the N-base as used in the SPT technology, is necessary. The new technology has been applied successfully for the full high voltage range including 3.3kV, 4.5kV and 6.5V.

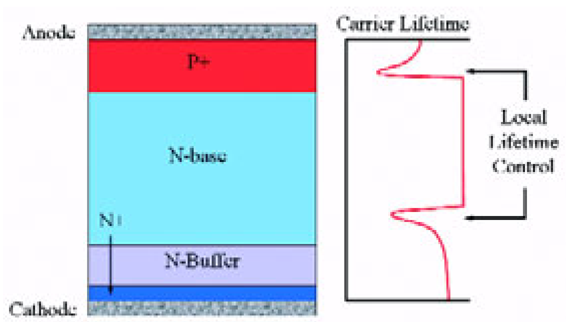

Figure (2) SPT$^+$ diode cross-section and carrier lifetime profile.

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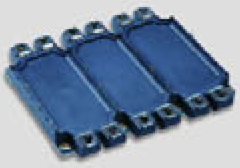
2-Pack IGBT
600V : 50A - 600A
1200V : 50A - 450A
1700V : 150A - 400A

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



High Power 6-Pack
1200V : 225A - 450A
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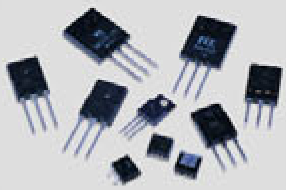

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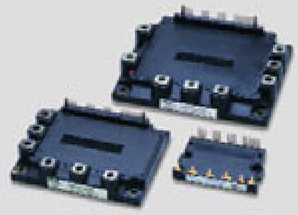

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In Figure (3), a comparison of the simulated on-state plasma distribution between the SPT⁺ and the standard SPT diode can be seen. Homogenous lifetime reduction in the N-base, as employed in the SPT diode, leads to a hammock shaped plasma distribution (red curve). The low plasma concentration in the middle part of the diode results in high conducting losses, whereas the high plasma concentration on the cathode side results in a long reverse recovery current tail and high recovery losses, without offering clear immunity against current snap-off under all conditions. In the SPT⁺ diode, the more advanced double local lifetime control scheme using Helium irradiation leads to an improved plasma distribution resulting in a shorter current tail and lower recovery losses. By controlling the depth and the concentration of the second local Helium lifetime peak, an optimum trade-off between losses and recovery softness can be achieved.

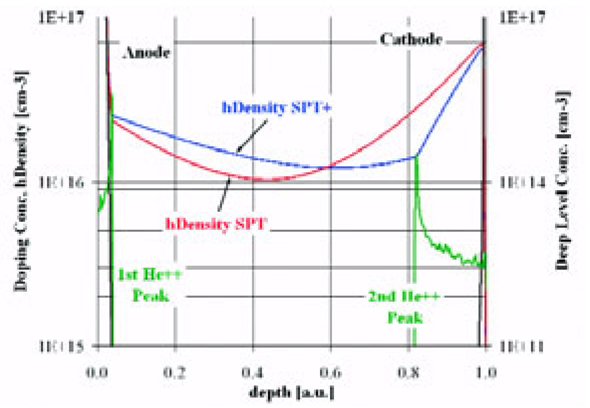

Figure (3) Simulated on-state hole density in high voltage SPT and SPT⁺ diodes.

In Figure (4), the total reduction of the on-state losses as compared to the SPT technology for the entire voltage range can be seen.

In Figure (5), the technology curve of the 4.5kV SPT and SPT⁺ diodes can be seen. Both diodes have an active area of 0.8cm² and were characterized using the SPT⁺ nominal current of 83A, which corresponds to a current density of 105A/cm2. Under these conditions, the original SPT diode has an on-state voltage drop of 3.2V and 255mJ recovery losses. The final SPT⁺ diode design has about 150mV higher on-state voltage drop but only 155mJ or 40% less recovery losses compared to the standard diode, which represents a significantly improved technology curve.

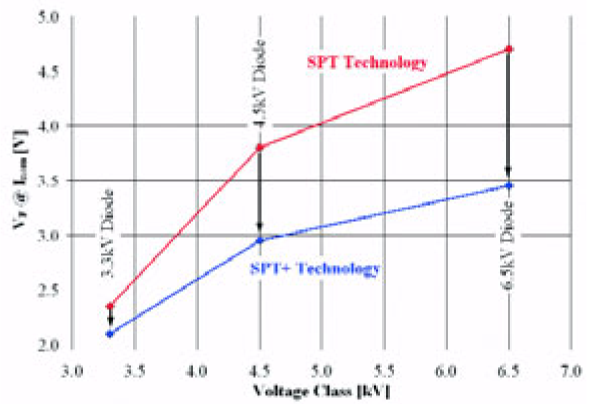

Figure (4) Reduction of the on-state voltage drop achieved by the SPT⁺ diode technology for 3.3kV to 6.5kV diodes.

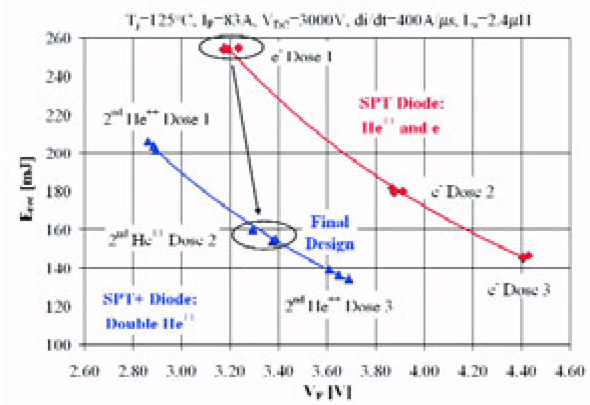

Figure (5): Technology curve of the 4.5kV SPT and SPT+ diodes under nominal conditions. The different points on the two technology curves were in the case of the SPT diodes achieved by different electron irradiation doses, and in the SPT⁺ diodes with different 2nd Helium peak doses.

In Figure (6), the on-state characteristics of the 4.5kV SPT⁺ diode are shown. The diode has a positive temperature coefficient of the on-state voltage drop (VF) already well below the nominal current level, which is necessary to ensure good parallel operation within the IGBT module. At rated current and 125°C, the diode has a typical on-state voltage drop of 3.4V, or 400mV higher than at room temperature. Under the same conditions, the standard SPT diode only has a difference of 200mV between the 125°C and room temperature voltage drops.

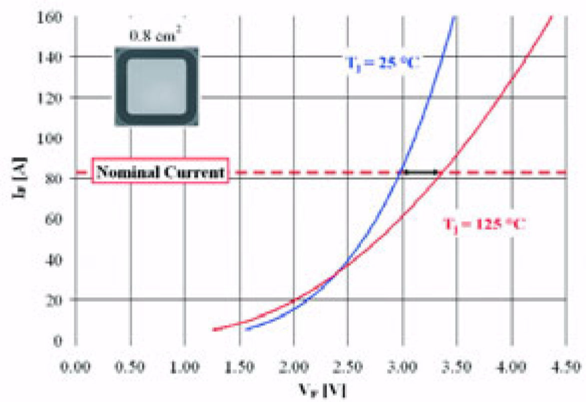

Figure (6) 4.5kV SPT+ diode on-state characteristics at room temperature and 125°C.

In Figure (7), the recovery waveforms measured under nominal conditions for both SPT and SPT⁺ diodes can be seen. The second local lifetime control peak used in the SPT⁺ diodes significantly reduces the plasma concentration on the cathode side, which reduces the recovery current tail and thereby the recovery losses. In spite of the fact that both diodes use the same Helium irradiation in the anode, due to the missing homogenous lifetime reduction, the SPT⁺ diodes have a higher plasma concentration on the anode-side of the N-base. This causes the SPT⁺ diode to have an increased peak current (IRR), which can have negative effects on diode softness and SOA. On the other hand, this also slows down the initial voltage rise during recovery (dV/dt), which reduces the stress on the electrical insulation in the driven motor. The plasma concentration in the middle of the N-base can be controlled by the depth and irradiation dose of the second local lifetime Helium peak. Since the reduction of the cathode-sided plasma concentration can be critical for the diode softness, the irradiation scheme in the SPT+ diodes had therefore to be thoroughly optimized in order to reach the desired characteristics. By choosing the parameters of the second Helium peak properly, the SPT+ diode can be made as soft as when utilizing the traditional irradiation scheme of the standard SPT technology. It was also concluded that a long current tail is not always necessary to achieve soft recovery behaviour. The shape of the current tail given by the shape of the remaining plasma is much more decisive for the softness then the actual tail length. In this way, the SPT+ diodes are designed to achieve the best trade-off between losses and softness.

Reverse Recovery Ruggedness

The reverse recovery safe operating area (SOA) of the new SPT+ technology was extensively investigated and compared to the standard SPT technology. For the 6.5kV diodes, the SOA limit was measured using a high DC-link voltage and a high stray inductance (VDC = 4500V, Ls = 3uH). In Figure (8), the SOA reverse recovery waveforms of the SPT+ diode can be seen. The diode shows an extremely rugged performance with a peak-power of 600kW/cm² under these extreme conditions. The high recovery robustness was achieved thanks to the combination of a highly doped anode emitter, which prevents any reach-through effects and a carefully designed charge shape.

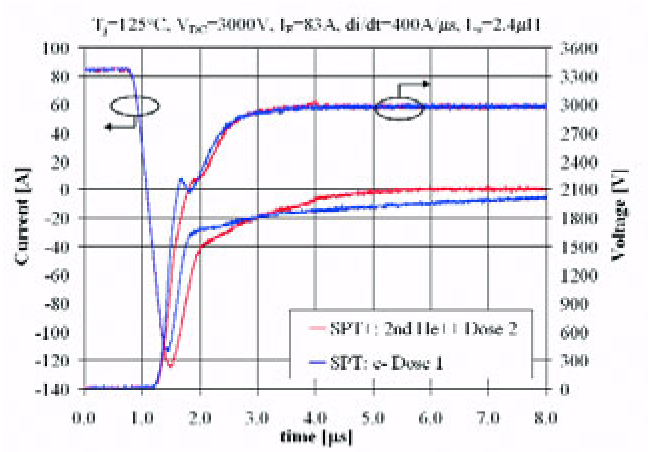

Figure (7) 4.5kV diode reverse recovery waveforms under nominal conditions.

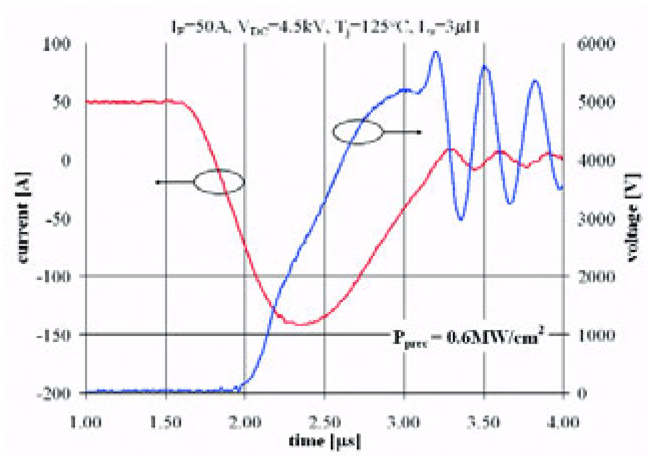

Figure (8) 6.5kV remove SPT+ diode SOA-waveforms at VDC = 4500V.

In Figure (9), the surge current waveforms of the 4.5kV SPT+ diode are shown. The measurements were made on module level, which means that 12 diodes with a total active area of 9.5cm² were tested in parallel. The pulse duration was 10ms in this test. The diodes reached a peak current of 12.4kA, corresponding to an I2t value of 830kA²s before failing. The achieved surge current capability is thereby very similar to the one of the standard SPT diodes. The different irradiation schemes do not have an influence on the capability. The high surge current capability is achieved thanks to the strongly doped and deeply diffused anode and cathode emitter profiles.

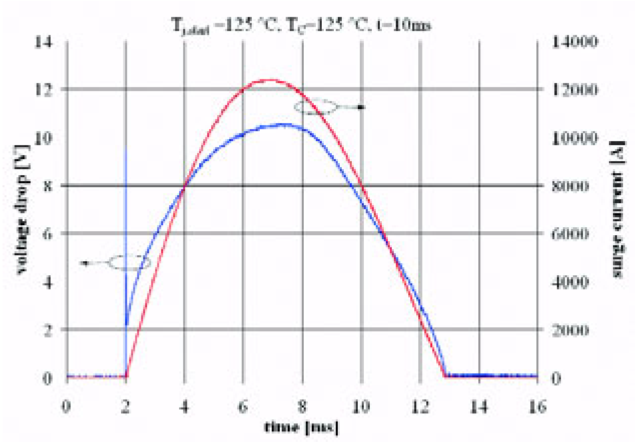

Figure (9) Surge current waveforms of the 4.5kV SPT+ diode on module level. The I2t value is 830kA2s.

Conclusions

In this article, a newly developed high voltage diode technology for IGBT-modules was presented. The new diode technology uses a double-sided local lifetime control to adjust the on-state charge distribution. The new diodes offer significantly reduced total losses combined with soft reverse recovery behaviour and high ruggedness.

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The 4th Generation of the 1200V Emitter-Controlled Freewheeling Diode

- A Soft Alternative

Freewheeling diodes are one of the important components for IGBT modules and have to satisfy a number of demands. Especially in hard switching applications, such as inverters for industrial drives or UPS, a soft switching behaviour of the diode as well as low losses and high ruggedness – is of major interest. A high softness reduces EMI problems and enables a faster turn-on of the IGBT.

by Wilhelm Rusche, Frank Hille, Infineon Technologies AG, Germany

In inverter design the softness of freewheeling diodes in modules with IGBT switches has often been considered. Especially for high power applications with currents in the range of several kA the soft switching behavior is very important since stray inductances lead to very high dynamic voltage overshoots when the reverse recovery current of the diode snaps off. Therefore, the turn on speed of the IGBT must be reduced in order to achieve a soft switching of the diode. This causes an increase of the turn on losses of the IGBT.
This article focuses on high power applications, namely modules with more than 1200A current rating. The measured results presented in this article were done using a 2400A Infineon IHM single switch module.

Diode Characteristic
For such high power applications the IGBT[4] - P4 [3, 4, 5] has been developed and this new power semiconductor with its improved softness needs an equivalent freewheeling diode. At typical stray inductances of such high power applications in the range of L_s=60nH to >100nH the softness of the diode becomes even more critical. The new diode technology given with the 4[th] generation Emitter-Controlled High Power version is dedicated for applications where extremely high currents have to be controlled. The new 4[th] generation diode is based on the well-established Emitter-Controlled technology [1,2].

The softness achieved with the new High Power 4[th] generation diode is superb, compared to the 2nd generation (Emitter-Controlled-FAST) version, especially for low currents as shown in Figure 1, which is the critical case with respect to diode softness. The new High Power diode is much softer, even when the switching speed of the IGBT is increased by reducing the external gate resistor R_{gon} as shown in figure 1.
The new 4[th] generation diode shows no oscillations, even at more severe switching conditions.

In order to achieve an even more dramatic softness improvement, the deep field stop concept is supported by the classical Emitter-Controlled plasma engineering [6] for the 4[th] generation High Power version. This yields in a diode which has approximately 200mV lower forward voltage drop but higher recovery losses at T_{vjop}=125°C compared to the present technology of the 2[nd] generation with the FAST version. In Table 1 the static and dynamic parameters under nominal conditions are compared.

The new 1200V IGBT[4] power semiconductor generation allows a maximum operation temperature of T_{vjop}=150°C - compared to the operation temperature of 125°C of the previous generation.
A maximum operation temperature of 150°C was introduced for the first time by Infineon at 600V power semiconductors of the third generation [8, 9].

This higher operation temperature results in the potential of higher output power by use of the full temperature swing under the same cooling conditions.

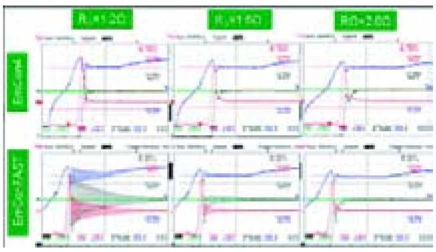

*Figure 1: Turn-off measurement of the 4[th] generation vs. the FAST version (FZ2400R12: I = 1/10*I_{nom}=240A, T_{vj} = 25°C, V_{DC}=600V, L_s=60nH)*

I_{nom}=2400A	EmConFAST	EmCon4 HighPower
V_F @25°C	2,20V	1,90V
V_F @125°C	2,00V	1,85V
V_F @150°C	n.a.	1,80V
Erec @125°C	70mWs	150mWs
Erec @150°C	n.a.	170mWs

Table 1: Static and dynamic parameters of the new 4th generation High Power version compared with the FAST diode of the 2nd generation.

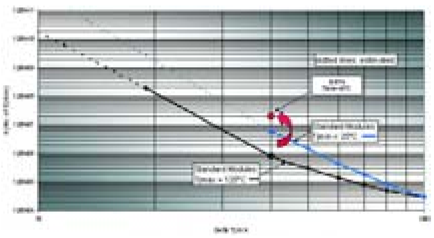

Figure 2: Power cycling (PC) reliability diagram for 1200V Standard modules and typical lifetime for a EconoPACK® module with IGBT4 at ton ≈ 1s, I≈Inom.

Additionally the optimization of the assembly technology shows a noteworthy power cycling (PC) improvement shown in figure 2. This ensures at least the same PC lifetime expectation and higher output current as a consequence of the increased operation temperature – or enhanced lifetime at comparable output power as can be chosen by the user [4].

Calculation by IPOSIM

Since the softness has been increased one can ask how to use this benefit for performance improvement.
The trade off point is chosen in such a way that the increase in recovery losses is basically compensated by the reduction of conduction losses for a switching frequency of f_{sw}=2kHz of the inverter. The advanced softness is once again used to increase the switching speed of the IGBT. This improves the overall system performance. Thermal calculations with IPOSIM [7] allow displaying the output current as a function of the switching-frequency under motoring and under braking conditions.

In braking conditions the energy is transferred from the machine to the DC link via the freewheeling diode; the corresponding graph is given in figure 3. The calculation shows that the diode does not limit the module output power under braking conditions.
Compared to the IGBT[3] / FAST diode technology, the high power IGBT[4] -P4 / 4th generation High Power variant achieves an increase of output current that amounts to 10% at T_{vjop}=150°C. Still, the diode remains extremely soft.

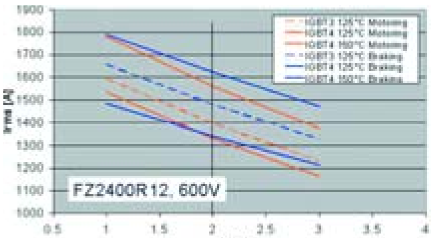

Figure 3: Maximum RMS output current vs. switching frequency of a 2400A single switch IHM module at 600V DC link voltage, calculated by IPOSIM.

Conclusion

The new high power chips IGBT[4] -P4 / Emitter-Controlled diode 4th generation has been optimized to improve its characteristic and to increase the output power of the inverter as a consequence of the increased operation temperature of T_{vjop}=150°C.

The softness improvement can on the one hand be exploited to design diodes with better trade-off relationship. On the other hand an increased turn-on speed of the IGBT is possible, which reduces the overall dynamic losses. Both measures enable the customer to achieve higher power ratings with his design while EMI problems stay negligible.

Though the higher output current is a consequence of the increased operation temperature, additional optimization of the assembly technology ensures the same lifetime expectation or enhanced lifetime at comparable output power as can be chosen by the user [4].

With all these improvements the high power modules with the IGBT[4] + Emitter-Controlled diode of the 4th generation are an excellent choice for high current applications.

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A New VRM Architecture for N+1 Redundancy at the Point of Load

Support output currents above 300A by adding the required number of phases

The preferred power distribution topology for servers and switches confines redundancy provision to card- or rack-level. A new POL topology supporting hot-swapping moves N+1 redundant design closer to individual ICs.

By George Schuellein, Director, DC/DC Applications Engineering, International Rectifier

A distributed power architecture incorporating non-isolated point-of-load (POL) regulators is the solution of choice for systems containing modern ICs with multiple power domains, low operating voltages and high current requirements. But conventional regulators are not able to support N+1 redundant power design at the point of load.

For telecom, internet and server equipment, where 99.999% (or five-9s) availability is required, this has prevented designers from implementing redundancy on a per-rail basis and has restricted redundant design to the board or rack level. This results in at least two disadvantages. Firstly, the entire board or rack must be replaced if an individual component fails. The second disadvantage is the loss of customer data being processed at the time of the failure.

The key deficiencies in a conventional POL converter, from the redundancy point of view, concern the absence of hot-swap capability, including the need to isolate the input and output.

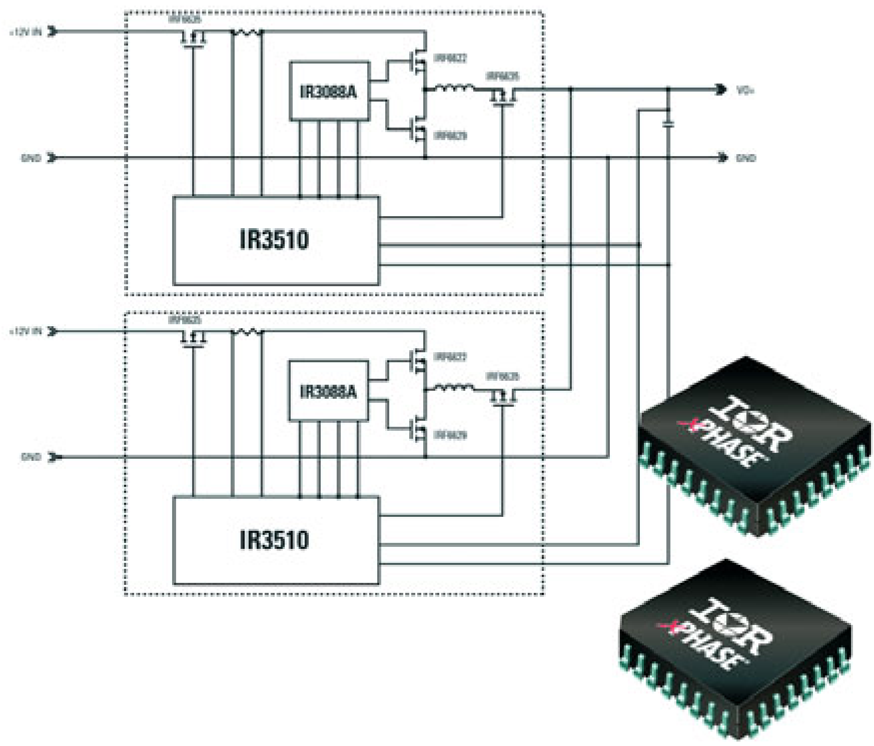

Figure 1. N+1 redundant power at point of load.

N+1 Redundancy at Point of Load

To address these limitations of conventional POLs, International Rectifier has developed an N+1 redundant POL Voltage Regulator Module (VRM) by combining a new, dedicated control IC and companion phase IC with input MOSFETs allowing hot-swapping and output MOSFETs for ORing.

Figure 1 shows how the IR3510 control IC and IR3088 phase IC create an efficient synchronous buck converter providing system protection against failures such as short circuits. The chipset provides input isolation, which allows hot-swapping of power modules while enabling 100% availability of power to the system.

The topology is scalable to support output currents above 300A by adding the required number of phases. The IR3510 provides overall system control and interfaces with multiple IR3088A phase ICs through a five-wire analogue bus. For its part, the IR3088 implements the functions required by the converter of each phase. These include the gate drivers, PWM comparator and latch, over-voltage protection, and current sensing and sharing.

From the system perspective, this architecture reduces redundant silicon in multiphase systems compared to other solutions such as a four-phase controller that can be configured for two-, three- or four-phase operation. PCB layout is also easier, since short gate-drive and current-sense connections can be implemented locally to the phase ICs.

Chipset Operation

The IR3510 controls the input and output FETs, using an on-chip charge pump supplying 13V of gate drive to ensure full MOSFET enhancement. The output transistors can be paralleled as required to support the desired input and output current rating.

The input MOSFET provides both hot-swap capability and input overcurrent protection. Converter input current is accurately sensed across a high-side current-sensing resistor. A programmable linear current limit controls the input current during inrush but will latch off the input MOSFET if the overcurrent persists for longer than a programmable delay period.

Protection for a short-circuit across the input MOSFET is implemented by detecting whether the input voltage supplied to the Synchronous Buck power stage rises prior to turn-on of the charge pump. If this occurs operation of the Synchronous Buck is inhibited and the error condition communicated to the host system.

At the output of the system, the body diode of the ORing MOSFET allows current to flow to the load. The IR3510's active ORing control function senses the voltage drop across the Source-Drain terminals and will apply gate drive to turn the device on if a programmable threshold is exceeded. Reverse current, which may be caused by a synchronous MOSFET short-circuit failure or other converter malfunction, will cause the controller to quickly turn off the ORing MOSFET. The output voltage will then be supplied by one or more other redundant POLs.

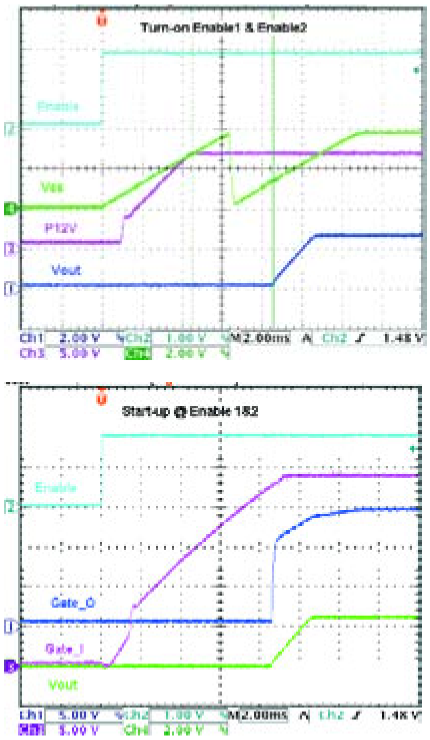

Figure 2a and 2b: Protection and Failover Capabilities

To maximise MTBF, the IR3510 uses average current mode control to implement active droop sharing between converters. This eliminates the need for any control wires connecting between two or more current sharing POLs and prevents a potential single-point-failure mode from disabling the system. An analogue current monitor signal is provided and allows the system microcontroller to monitor the current being delivered by each POL. A digital interface is also included to transmit data back to the host system indicating status of the POL's output voltage, input MOSFETs, and ORing MOSFETs.

Soft-Start Sequence

The IR3510 implements a programmable two-stage soft-start with timing programmed by an external capacitor. Typical start-up waveforms are shown in Figures 2a and 2b. Following receipt of an Enable signal from the host, the soft start capacitor begins linearly charging from ground. The voltage on the soft start capacitor (Vss) is used to control the gate of the input MOSFET (Gate_I). This provides closed-loop control, ensuring a controlled ramp of the Synchronous Buck input voltage (P12V).

After the input voltage has fully ramped the soft-start capacitor is discharged and a 2nd soft start is initiated to ramp the POL output voltage. The charge pump continues to boost the voltage on the input MOSFETs gate up to Vin+13V to ensure it is fully enhanced. The rising output voltage causes current to flow out of the POL and turns on the gate of the ORing MOSFET Gate (Gate_O). The charge pump continues to boost this gate voltage up to Vout + 13V.

A number of faults can give rise to an output over voltage condition, including a shorted control MOSFET or open-circuit control loop. The IR3510 provides an independent input for an over-voltage comparator whose threshold is programmable. Since the remote sense lines cannot be relied upon to provide valid sense data in the event of a fault, over-voltage is typically sensed locally within the POL.

When operating in N+1 mode the goal is to identify and disable the failed POL while keeping "good" POL(s) operating and maintaining a stable output voltage.

The "good" POLs will act to maintain regulation of the output voltage. To this end, they will sink current from the output as they try to clamp the over voltage. This causes the ORing MOSFETs to turn-off, which effectively disconnects them from the load and prevents damage to the "good" POLs. The Input MOSFET(s) of the "good" POL remain on.

"Bad" POLs will source current such that the associated their ORing MOSFETs will be turned on when the over-voltage threshold is exceeded. This provides the indication they are "bad". In this case the input MOSFETs are quickly turned-off, removing the source of the overvoltage event. Once the output voltage has dropped down to normal levels the remaining "good" POLs will begin switching and providing positive current to the load. The "bad" POL will remain latched off. The host system can then be notified and a service call scheduled to replace the "bad" POL.

N + 1 Transition

POLs are enabled and disabled from an operating N+1 redundant system. To replace a POL it is first disabled and then physically removed from the equipment, typically with a connector designed to facilitate this. The replacement POL is then inserted into the connector and enabled. The ORing MOSFETs will block negative current in an enabled POL until its output voltage exceeds the already regulated output voltage.

During the transition from N to N+1, the output voltage will overshoot during the period when POLs that are already operating reduce their output current to match the newly enabled POL. Conversely, a small undershoot occurs during N+1 to N transitions while the remaining POL(s) increase their output current to the level required by the load.

Conclusion

While infrastructure owners count the total cost of system downtime in thousands or millions of dollars, wholesale replacement of cards or racks is also expensive. Support for N+1 redundancy at the POL level now combines the advantages of high system reliability with economic replacement of individual components.

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Potential of SiC in Power Electronic Applications

2nd SiC User Forum — Report of Conclusions

After the first Silicon Carbide (SiC) User Forum organised by ECPE in 2006, technology has developed further — in particular new power electronic systems with SiC components and new SiC devices have been reported. Time had thus come to continue the exchange between experts involved in converter and device development.

By Andreas Lindemann; Otto-von-Guericke-Universität Magdeburg; Chair for Power Electronics

General

The second SiC User Forum has focused on typical power electronic systems, the use of SiC is highly promising for i. e., electric drives, converters in transportation and power supplies; additionally an insight in recent material and device technology — which is the base for future system development — has been given. Renowned experts from all over the world have been invited to give an overview in keynotes, to in depth explain their research and development work in technical presentations and to share their knowledge in discussion forums as an indispensable part of the event.

The SiC User Forum this way became a platform to share experience and ideas, to discuss and find out which power electronic systems are predestinated for usage of SiC and how to appropriately design-in those novel, almost ideal but also challenging components. It aimed at finding and pointing out approaches to exploit the high potential of SiC and to support its beneficial introduction in power electronic systems.

SiC User Forum 2007 —attended by some 120 international participants —took place right after EPE conference 2007 in the Danish capital Copenhagen. Prof. Andreas Lindemann (Ottovon-Guericke-Universität Magdeburg, Germany) took the chair together with Dr. Hiromichi Ohashi (National Institute of Advanced Industrial Science and Technology, Japan) and Mr. Thomas Harder (ECPE). The major findings of the event are summarised in the following:

State of the Art

Series production of different converters using SiC Schottky diodes has been reported: A family of 690V AC drives makes use of their superior switching behaviour, which helps to reduce dynamic losses also in the Silicon IGBTs and thus permits to increase switching frequency to 16kHz. This way, the size of output sine wave filter can be reduced in such a significant way that it can be integrated in the converter unit. The motor thus can be operated through relatively long unshielded cables, keeping electromagnetic emissions of the drive system and bearing currents low. Here, SiC devices have shown to be an enabling technology to achieve a highly effective and integrated system design. Basically the same applies for switched mode power supplies — often including an input stage for power factor correction — where power density can be increased reducing the size of inductive components and switching losses, which on the one hand permits to shrink heat sinks and on the other hand is very useful to achieve an optimum effciency.

This progress became possible due to the availability of SiC devices: Namely Schottky diodes up to 1200V breakdown voltage have reached a high level of maturity, with technologies to achieve surge current and avalanche ruggedness being known, and proven reliability. In addition, various types of transistors have been demonstrated and sampled; their usage however still is mainly subject to research as outlined in the following section. Anyway, device technology depends on material, where major progress towards the elimination of micropipes and the increase of wafer size to 100mm — which is relevant for cost reduction — has been reported. It should be further noted that SiC devices in today's volume production are using standard packaging technologies, which is a reason why they need to be operated in the usual temperature range of some $-55°C \leq T_J \leq 175°C$.

Outlook — Research

It seems to become possible to exploit the aforementioned benefits of SiC technology in systems for further applications, which is subject to current research: E. g. a photovoltaic inverter has been demonstrated with extraordinary effciency which is a major technical feature and sales argument. It has been achieved replacing Silicon IGBTs and diodes with 1200V SiC MOSFET devices, showing resistive RDSon conduction characteristics in forward and — when turned on — also in reverse direction; this is beneficial especially at currents lower than nominal current as they appear within each sine wave and as is also typical for frequent partial load operation. Further, switching losses are low due to the fast reverse recovery of body diode. There seems to be no particular need to operate the devices in this kind of converter beyond the aforementioned standard temperature range. Depending on the particular concept, this will partially also apply to high power converters for different kinds of applications: In the distribution network, converters would be useful to couple energy storage to the grid or as active filters; in railway traction, the bulky and heavy low frequency transformer might be replaced, or the drive motors might be supplied through inverters operated at frequencies higher than 300Hz as typical today, permitting to optimise the machines. In both cases, a switching frequency of about 2kHz together with blocking voltages in the range of several Kilovolts seems appropriate, which cannot be realised with today's high voltage Silicon IGBTs and diodes. Impressive results of long-term research have been presented during the event, e. g. a 180kVA pulse width modulated inverter with SiC devices for the distribution network, or also switching behaviour of cascaded SiC JFETs in a 5kV converter operated at 50kHz. Of course, an elevated range of operating temperature helps to increase converter power ratings; in some cases it seems even more advantageous, such as in automotive converters where a keynote highlighted the achievements in hybrid cars made with Silicon technology —

e. g. the increase of power density — and the potential for further optimisation with SiC, the voltage range up to some 1000V seems to be suficient for. This in general also applies for the more electric aircraft, where a tremendous change of electrical system is in progress, leading to a variable frequency or DC supply with nominal power in the order of magnitude of 100kW, requiring power electronic conversion on the generation and load side. Here however, an operating temperature of at least 200° C together with a withstand capability against harsh environmental conditions such as shock and vibration are considered to be indispensable in addition. This demanding application might become a technology driver, because technology can be considered to be crucial here despite the related cost.

On behalf of the components, several types of SiC devices have been reported: Above some 5kV rated voltage, bipolar pn diodes will be preferable compared to unipolar Schottky- or also merged Schottky-pn devices. Extraordinary ratings have been demonstrated with a 19,7kV low current pn diode or a 3kV 600A pn diode module. The group of unipolar active switches has been represented by JFET and MOSFET. In spite of circuit designers' preference for familiar normally-off devices, the JFET can claim a high level of maturity also in terms of ruggedness, being not affected by oxide stability which is still subject to research.

Among the bipolar devices, an NPN transistor with rated 1200V and 6A or a 4,5kV 120A SiC commutated gate turn-off thyristor have been reported. Generally, forward drift of bipolar SiC devices will need to be addressed by future work. Further, high temperature packaging technology is an important issue, where results of research on a basically disc-shaped package, being rated for 400° C and using an appropriate high-temperature resin, have been reported. Still, reliability of novel devices and components needs to be proven. On material level, research is focused on minimisation of dislocations and on further increase of wafer diameter to 150mm. It has been noted that Gallium Nitride(GaN) devices might increasingly compete to SiC. Regarding high temperature systems, an adaptation of other components such as passives — e.g. capacitors and magnetics with cores — seems necessary in addition. Increasing operating voltage above the level reached with Silicon devices may also pose questions regarding isolation materials.

Conclusion

SiC Schottky diodes are nowadays available in production volumes and they are applied in power electronic converters o?ered in the market. The potential to increase switching frequency — leading to superior system performance, a higher degree of integration or a decrease of system cost respectively — clearly turns out to be the main motivation for their introduction. Results of current research show a significant potential to make use of this also in other applications such as transportation in automobiles, trains or aeroplanes, and energy supply such as through photovoltaic inverters or the distribution network. Its exploitation is expected to be enabled by the ongoing development of active switches, of high voltage devices and of high temperature packaging technology, together with the required proof of reliability and cost reduction, the fields of application being already established contribute to. The recent SiC User Forum shall support this desirable advancement; the next steps might be reported on the occasion of a similar event planned for the future.

European Center for Power Electronics e. V. (ECPE)

www.ECPE.org

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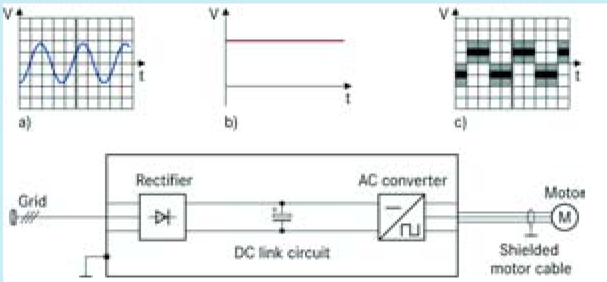
EMC Filters Cut Costs and Protect Motors

Never again shielded cables

The SineFormer™ from EPCOS is an output filter that is easy on the motor and makes shielded motor cables superfluous. It allows costs to be reduced while improving performance.

By Carsten Juergens, Product Marketing Manager, EMC Filters and Christian Paulwitz, Manager EMC Laboratory

Asynchronous motors must often be operated at continuously variable speeds. Pulse-width modulated frequency converters with an unregulated input rectifier shape the DC voltage from the DC link circuit to an output voltage by using suitable driving of the semiconductors (usually IGBTs). The principle is shown in Figure 1.



The AC converter forms a pulse-width modulated output voltage with steep edges from the DC link voltage
a: Sinusoidal input voltage
b: DC voltage in the DC link circuit
c: Pulse-width modulated output voltage (phase-to-phase voltage)

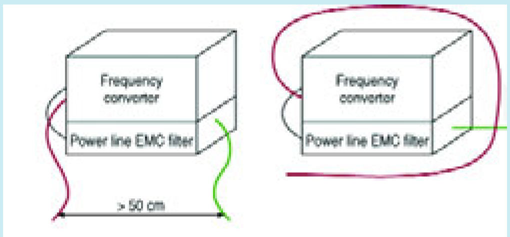
Figure 1: Block Diagram of a Frequency Converter

As Fig. 1 shows, the voltage at the converter output is very far from having an ideal sinusoidal shape. The square-wave pulses of typical converter output voltages have an edge steepness of between 5 and 10 kV/µs that causes high-frequency currents in the motor cable. The phase-to-ground voltage shows a similarly high edge steepness due to parasitic capacitances of the converter topology. Parasitic motor capacitances also lead to very high bearing currents that shorten the operating life of the motor.

Common mode interference necessitates shielded cables

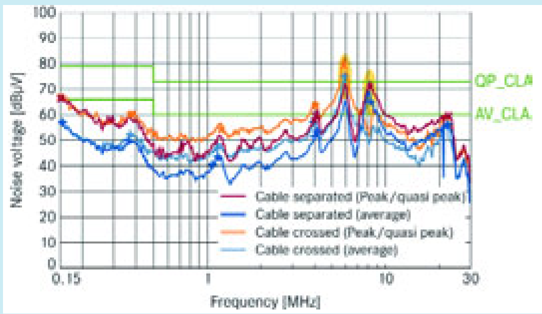
Longer motor cables also have high parasitic capacitances to ground that are approximately proportional to the cable length and significantly influence the design of the power filter. In order to reduce the further electromagnetic propagation of the interferences on the motor cable by coupling or radiation, the cable must be shielded unless effective filter measures are taken on the motor side of the converter.

Shielding becomes more important the higher the frequency range is. It is already indispensable for the frequency range < 30 MHz. As illustrated in Figures 2 and 3, even with an almost ideal positioning



Structure of a converter with a power line filter and an unshielded motor cable without an output filter.
Left: Power and motor cables are separated from each other by a significant distance
Right: Power line and motor cables are crossed at right-angles

Figure 2: Cable Configurations at Converters.

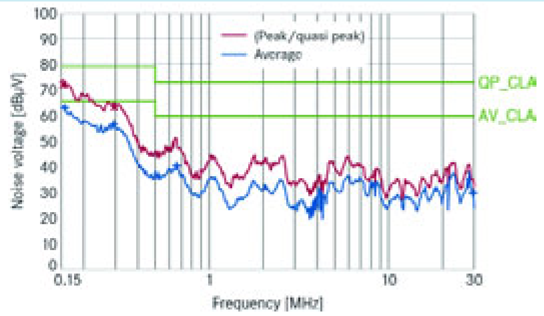


Power supply side measurement of the interference voltage at a frequency converter with an EMC power line filter and a 100 m unshielded motor cable without an output filter: dependence of the measured results on the position of the motor cable, with reference to the limits specified in EN 55011 class A (group 1) and EN 61800-3 category C2

Figure 3: Interference Voltage with unshielded cables

with a spacing of more than 50 cm between power and motor cables, the specified limits can rarely be met if the motor cables are unshielded. In practice, the installation specifications usually allow the motor and power cables at least to cross at right angles. Due to the stronger capacitive coupling, however, the interference spreads more extensively than if the cables are separated from each other, also reaching the power line and causing the limits to be exceeded to a much greater extent (Fig. 3). However, it is not only important to observe the EMC limits on the power line. If the high-frequency interference parts couple over to data and sensor lines, they produce signal errors and thus jeopardize the functionality of the system.

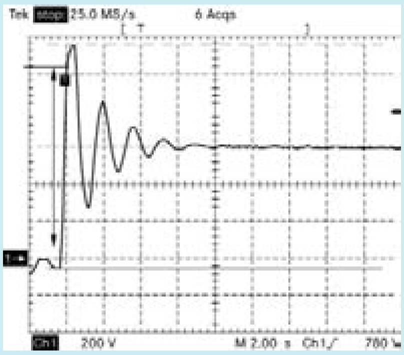
However, if the same test set-up consisting of power line filter, converter and motor is operated with a suitable shielded motor cable of equal length, then the specified industry limits are observed as expected (Figure 4). Coupling of the interference from the motor cable to data and sensor lines can also be prevented or at least significantly reduced, so that operational failures can be avoided.



Measuring the interference voltage (power supply side) at a frequency converter with a power line filter and a 100 m shielded motor cable without an output filter. The specified limits are met.

Figure 4: Interference Voltage with shielded Cables

Apart from these EMC problems, the user must also deal with the bearing currents in the motor. This is because the high edge steepness of the converter output voltage stimulates parasitic resonant circuits consisting of motor and cable capacitances as well as parasitic inductances. As a result, transient resnses are superposed onto the converter output voltage, which produces voltage surges on the motor side, often with amplitude peaks that the motor is not designed to handle over the long term (Figure 5). High bearing currents lead to premature wear of the bearings, but also stress the insulation of the motor winding, thus shortening the operating life of the motor.



Voltage surges lead to breakdowns of the motor insulation.

Figure 5: Voltage Surge due to parasitic effects on the cable

Essentially three different filter concepts may be used to alleviate this problem:

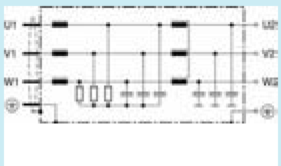
- dv/dt filters
- Sine wave filters
- EMC sine wave filters (SineFormer)

At first sight, the least expensive solution would seem to be a dv/dt filter. Designed as an LC low-pass filter between the motor phases (differential mode), it reduces the steepness of the voltage pulses and the voltage peaks at the motor winding. However, as especially the higher-frequency parts of the common mode interference current to ground are not suppressed, shielding of the motor cable is necessary. Cable lengths of up to about 100 m are typically possible. However, greater lengths can lead to resonances and impermissible heating of the dv/dt filter, ultimately leading to destruction of the choke.

The structure of the sine wave filter is similar to that of the dv/dt filter. The sole but significant difference: the limit frequency of the LC low-pass filter lies between the maximum permissible rotating-field frequency and the lower permissible switching frequency of the converter. The advantage: the sine wave filter has a greater efficiency than the dv/dt filter, the switching-frequency parts of the (differential mode) phase-to-phase voltage disappear almost completely and the output voltage is sinusoidal. However, the LC circuit of the sine wave filter operates only symmetrically, so the (common mode) voltage of each phase with respect to ground still contains significant higher-frequency parts. Although this allows motor cable of much more than 100 m and greatly improves the motor protection, the insufficient common mode filter effect nevertheless means that shielding of the motor cable is still necessary.

SineFormer optimizes suppression and cuts system costs

To solve this problem, EPCOS has developed the SineFormer. It offers optimized motor protection and simultaneously reduces the system costs. The SineFormer technology not only produces a sinusoidal voltage between the phases, but also significantly reduces the common mode interferences between the phases and ground. The SineFormer consists of a symmetrical inductor and capacitors that form a sinusoidal voltage between the phases. These are supplemented by a current-compensated choke as well as capacitors to ground designed to significantly reduce the common mode interference parts on the motor cable. Figure 6 shows the basic circuit diagram of a SineFormer.



The SineFormer attenuates both differential and common mode interference. This makes expensive shielded cables unnecessary and protects the motor.

Figure 6: Circuit of the SineFormer

The EMC concept with SineFormer is distinguished by numerous technical and cost benefits.

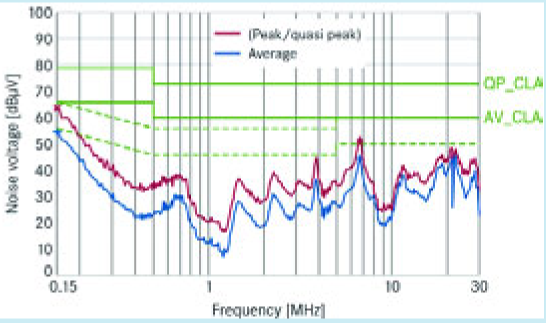
The special advantage of dispensing with shielded cables is that the SineFormer is simply less expensive, depending on the cross-section and length of the cables. Frequently, the costs of the filter are already compensated by the use of unshielded cables of around 100 m. If only the cost of the SineFormer and that of unshielded cables is compared with the cost of a sine wave filter and shielded cables, the break-even point can be achieved at cable lengths of less than 50 m – and this comparison does not even include the higher assembly expenses for shielded cables.

Technical benefits of the EMC concept with SineFormer:
- Reduction of the dv/dt to <500 V/µs
- Reduction of the acoustic noise produced by the motor
- Significantly lower eddy current losses
- Significant reduction of bearing currents
- Avoidance of interference coupling from the motor cable to other power and signal lines
- Improved EMC performance compared with shielded cables
- Radiated interference within normative limits
- Optimum reduction of interference (conducted and radiated) compared to other output filter solutions
- No feedback loop to DC link of the frequency converter is necessary

Cost benefits of the EMC concept with SineFormer:
- Unshielded motor cables can be used, thus reducing assembly expenditures, increasing the operating life and reducing cable costs
- Motor size can be reduced
- Motor operating life can be significantly increased
- Longer motor cables possible (measured with up to 1000 m unshielded motor cable)
- No maintenance costs, as the SineFormer is built without forced ventilation
- Compact filter solution (not modular system) with lower volume and weight
- Reduced demands on the power filter
- Increased system availability
- Also suitable as a retrofitting set

Infobox: SineFormer in Overview

Figure 7 shows the efficiency of operation of the SineFormer technology in an impressive way compared to Figure 3. Even if the power line is crossed with an unshielded motor cable, the specified limits are met (here to EN 55011, class A – group 1 or EN 61800-3 category C2). The optimum performance of the new filter technology is clearly shown by the almost complete absence of coupling. Thanks to the use of SineFormer filters, the use of shielded cables can finally belong to the past. The system costs can be reduced and the system availability increased.



Despite an unshielded cable, the permissible limits are observed.

Figure 7: Measuring the Interference Voltage at the SineFormer

SineFormer filters are also ideally suited for retrofitting, namely whenever EMC problems caused by the motor cable only occur during operation. It is naturally always important to select a suitable EMC filter on the power side, for example by using EPCOS' new B84143D*R127 power line filter series for up to 300 m for class A and 200 m in class B (EN 55011).

The new SineFormer filters are distinguished from the sine wave filters currently available on the market by additional innovative features. They are available as a compact filter solution, thus obviating the extensive assembly costs typical of modular systems. There is also no need for a feedback to the DC link circuit. In the latter case, the relevant cable must be shielded on both sides. However, in many cases no such provision to contact a shield is made for the DC link circuit terminal at the converter, thus incurring a risk of high interference radiation.

Because the SineFormer needs no internal forced cooling, it is maintenance-free. In contrast, filters with fans have a major drawback, namely that the operating life of a commercially available fan depends on the ambient temperature: its operating life drops as the temperature rises. Worse still: because the temperature in the filter fluctuates as a function of the load current, the exact failure or maintenance time cannot be determined. As a rule, the fan can only be replaced by the filter manufacturer, and thus incurs further costs.

With the SineFormer, EPCOS has developed a pioneering filter technology that offers a convincingly superior EMC performance as well as impressive cost benefits.

Ordering code:	B841V*R127
Rated voltage:	520 V up to 180 A or 600 V from 320 A
Rated current:	11 A up to 320 A
	(600 A and 1000 A in preparation)
Converter pulse frequency:	
	4 to 8 kHz up to 180 A
	and 2.5 to 3 kHz at 320 A
Approvals:	UL/CSA up to 180 A

Product profile: SineFormer

www.sineformer.com

Changing the Paradigm for Power Systems

Higher Accuracy, Lowest Loss AC Current Sensor

Historically, traditional magnetics in the form of a current transformer and its associated bill of materials or possibly a series resistor, Hall-effect and magneto-resistive device play the role of generating an output signal proportionally to measured current in a power system.

By Brett Etter, Silicon Laboratories

Little innovation has occurred in this area for some time. But that has changed. Silicon Laboratories' Si85xx family of products is the world's best AC Current Sensor with higher accuracy, smaller size and more integration than competing technologies. These new current sensors enable an on-board processor that eliminates the need for external circuitry reducing board area by 75% reduction in board area. They also reduce volume by 80% when compared to competing transformer solutions.

Silicon Labs leverages a history of mixed-signal innovation to create unique circuits in CMOS that offer integration and price advantages over traditional solutions. The AC Current Sensors are no different, offering a highly compact solution without performance compromises. The Si85xx current sensor replaces traditional current transformers in a much more integrated and small space. By placing a coil on the silicon die, induced voltages are integrated and conditioned to give an output signal that is proportional to the input current. The method of operation is magnetic coupling which is very similar to a current transformer, but much more efficient and with much fewer losses.

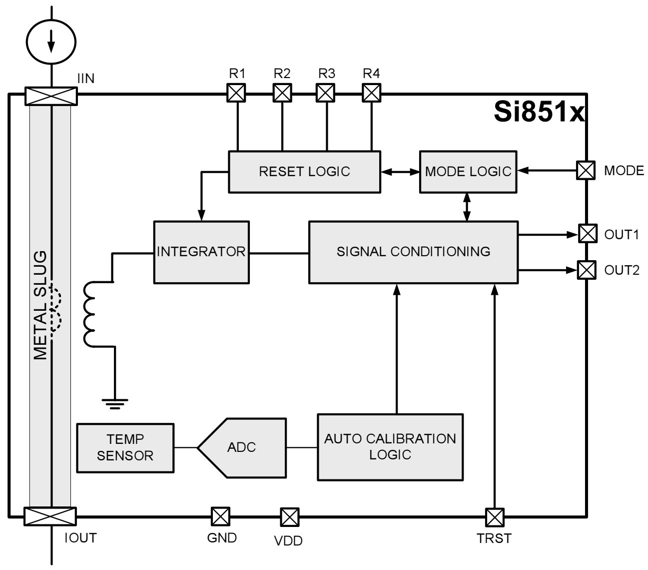


Figure 1. Si85xx Block Diagram

Unique features make the transition from a traditional solution to Silicon Labs' AC current sensor very easy. With extremely low series inductance, the sensing method does not significantly alter the current path. The Si85xx family of current sensors has less than 1.3 mΩ of primary series resistance and less than 2 nH of primary inductance at 25 ºC. Extremely low series resistance results in minimized conduction losses through the part, thus resulting in lower power losses. Lower losses in the supply directly contribute to an increase in efficiency. Also, it does not significantly affect the control and compensation for the supply. This results in a component that is easier and faster to design into a power supply. Also, with the accuracy of +/- 5%, no additional calibration steps are required during the supply assembly process.

Mixed-signal design in CMOS also creates integration opportunities that translate to benefits for the customer. The Si85xx AC current sensor is 4x4x1 mm compared to a current transformer that is 8.4x7.2x5.1 mm. This is a strong enabler for power supply makers to enhance their value to the end customer through better power density. Increasing the power density is a critical point of differentiation for power supply manufacturers.

And finally, it is a low risk, easy to evaluate part. Silicon Labs provides a solder-in evaluation board designed to enable a customer to solder the board to an existing application and evaluate the performance of the device immediately. The customer is not required to layout a new board—but can use an existing design he already has working to test the performance of the Si85xx family!

The Si85xx current sensors are ideal for a range of applications. They are typically used in ac-dc and isolated dc-dc power supplies, and brushless dc motor controls. Since the Si85xx requires much less board area (only 16mm^2) and are only 1mm tall; this results in dramatic savings of board area and volume density. With the inevitable march towards higher power densities, the Si85xx family enables design engineers to rapidly move up the power density curve and pack more power into the same existing space.

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fastPACK 0 H 2nd gen & fastPHASE 0

fast switching for welders of ever decreasing size and price

In recent years, size and weight have been playing an increasing role in the design of welding equipment. This is particularly true in the case of handheld equipment, which needs to be light and small enough for the operator to carry. For welders of higher power, size is becoming increasingly important as a cost factor, e.g. in determining the total surface of a production line. In both cases, the price pressure is high.

By Simon Sidiropoulos, Product Marketing Manager, Tyco Electronics

The fastPACK 0 H 2nd gen and fastPHASE 0 families of power modules are Tyco Electronics' answer to these requirements. The portfolio of CoolMOS and fast IGBT full-bridges and half-bridges, along with optional AlN substrate and/or integrated capacitors, enable the fast switching required to reduce the size of the transformer. Containing chips of various sizes, these modules cater for almost every need in welding for up to approximately 30 kW. The compact flow0 housing and efficient layout design lead to a high power per area rating, thus satisfying the demands for both small size and low price.

Part	Configuration	Voltage	Current	Technology	Substrate
P622-F04*	H	600 V	30 A	CoolMOS	Al_2O_3
P622-F14*	H	600 V	30 A	CoolMOS	AlN
P623-F04*	H	600 V	60 A	High Speed IGBT2	Al_2O_3
P623-F14*	H	600 V	60 A	High Speed IGBT2	AlN
P569-F40	Half bridge	1200 V	100 A	Fast IGBT2	Al_2O_3
P569-F50	Half bridge	1200 V	100 A	Fast IGBT2	AlN

*optionally available with internal DC link capacitors (P72x family)

Table 1: overview of fastPACK 0 H 2nd gen & fastPHASE 0 modules for welding

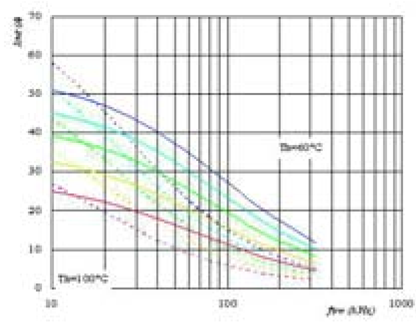


Figure 1: 600V High Speed IGBT2 vs std IGBT3
Typical available current at Tj = 125 °C as function of frequency
(parameter: heatsink temperature)
• continuous lines: P623-F04 (60 A rating, High Speed IGBT2)
• dashed lines: P624-F24 (75A rating, std IGBT3)

Overview of fastPACK 0 H 2nd gen and fastPHASE 0 modules for welding

An overview of the modules in question can be seen in Table 1.

The technologies used are
- 600 V: CoolMOS and High Speed IGBT2
- 1200 V: Fast IGBT2

Optionally available is an AlN substrate instead of the standard Al2O3 substrate for better thermal performance. The P72x modules feature the same layout and components as the P62x family and additionally feature internal DC link capacitors for reduction of Eoff losses.

The simulation results shown throughout this document were generated using a linear interpolation model based on actual measurements. This tool allows the comparison of two modules under the same conditions. A more detailed simulation for specific cases can be done using flowSIM, the power module simulation tool by Tyco Electronics.

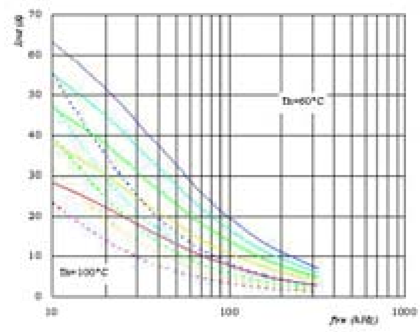


Figure 2: 1200V fast IGBT2 vs std IGBT3
Typical available current at Tj = 125 °C as function of frequency
(parameter: heatsink temperature)
• continuous lines: P569-F50 (100A rating, Fast IGBT2)
• dashed lines: P569-F30 (100 rating, std IGBT3)

For more information see Bodo's Power Systems, July 2007, pp. 16 – 20.

Component Technology

At 600V, CoolMOS is used for the P622 and P722 modules. It is ideal for applications requiring extremely fast switching without short circuit capability. High Speed IGBT2 at 600V and Fast IGBT2 at 1200V are IGBT platforms designed for extremely fast switching, with less focus on conduction. A comparison between the different technologies based on an application example can be seen in Figure 1 (600 V) and Figure 2 (1200 V). The conditions chosen are typical for welding applications and can be found in Table 2.

600V	1200V
U_{dc} = 320 V U_{ce} = U_{dc} = 320V R_{gon} = 4 Ohm R_{goff} = 2 Ohm	U_{dc} = 600 V U_{ce} = U_{dc} = 600V R_{gon} = 6 Ohm R_{goff} = 6 Ohm
T_j = 125 °C Ioutpeak/Iout = 1.3 T_{sink} = 60 °C to 100 °C in steps of 10 °C ZVS DC output	

Table 2:
Parameters for application examples

As can be seen in Figure 1, for any frequency above 13 kHz to 18 kHz (depending on the heatsink temperature), the High Speed IGBT2 module P623- F04 provides a clear advantage over the even higher rated IGBT3 module P624- F24. At 1200 V, the Fast IGBT2 module P569-F50 performs better than the equally rated standard IGBT3 module P569-F10 for any switching frequency above 10 kHz (Figure 2).

DC link capacitors

The internal DC link capacitors of the P72x family aim at reducing the parasitic inductance and the Eoff losses during switching. The great advantage of capacitors inside the package is the extremely short current path, which would be impossible to achieve with an external capacitor. As can bee seen in the example in Figure 3, the switch-off over-voltage peak in a module with capacitors reaches 120% of the nominal DC voltage, as opposed to 138% in a module without capacitors. This 15% reduction in the turn-off voltage peak extends the lifetime of the module and increases its reliability. In some cases, it makes the use of lower rated components possible (eg when the peak would exceed 600V in a 600V rated module without capacitors).

The conditions used for the example in Figure 4 were:
Uce (100%) = 400 V
Uge (100%) = 15 V
Ic (100%) = 60 A
Rgon = 4 Ohm
Rgoff = 2 Ohm

AIN substrate
The AIN substrate reduces the thermal resistance of the module by approximately 30% compared to a module with an Al2O3 substrate. The lower temperature rise means that either smaller chips and potentially smaller modules can replace bigger ones, or

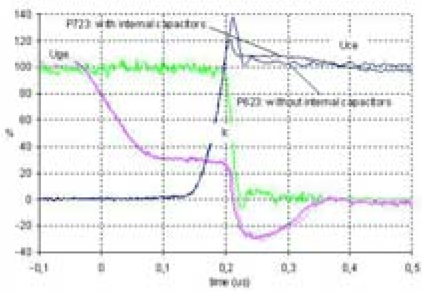


Figure 3: Turn-off characteristcs w/o internal capacitors
- *light coloured lines: P623-F10 (no capacitors)*
- *dark coloured lines: P723-F10 (with internal capacitors)*

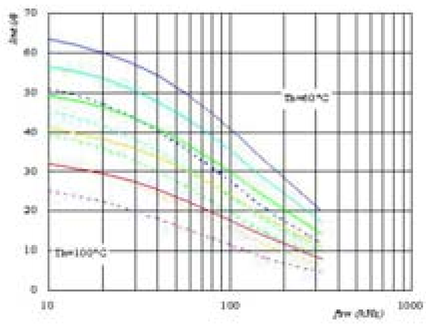


Figure 4: AIN vs Al2O3 substrate
Typical available current at Tj = 125 °C as function of frequency
(parameter: heatsink temperature)
- *continuous lines: P623-F10 (AIN substrate)*
- *dashed lines: P623-F04 (Al2O3 substrate)*

that the modules can be driven at a higher switching frequency, thus leading to an advantage in size and price. The 600 V example in Figure 4 illustrates the advantage of a module with AIN, using the conditions in Table 2. The two modules used were P623-F14 and P623-F04, which feature the exact same layout and components, apart from the substrate.

The losses for the two modules are almost identical, which is why the P623-F14 with the AIN substrate is superior to the P623-F04 (Al2O3 substrate) for all frequencies.

flow0 housing
The flow0 housing by Tyco Electronics features a number of advantages for circuit design and handling in production. At 66 mm x 13 mm x 17 mm, this is one of the most compact housings in the market. The flexibility in selecting the pin positions means that the DCB layout and the pinout itself are always optimized for the application in question. In this case, the DC+ and DC- are side by side for low inductive supply and hard switching, common to welding. Furthermore, mounting on the PCB is easy via the simple clip-in mechanism; screws are only needed for mounting onto the heatsink. For details see Figure 5.

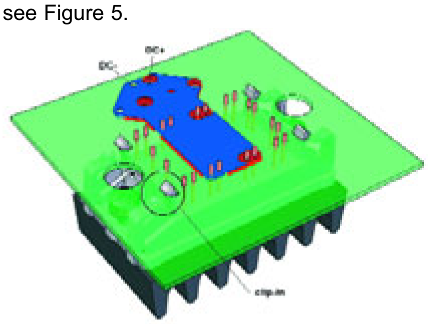


Figure 5: P62x family with DC+ & DC- side by side in flow0 housing with easy clip-in mechanism

Conclusion
The fastPACK 0 H 2nd gen and fastPHASE 0 families are designed to meet the requirements of today's welding manufacturers: fast switching in a compact design. The combination of H-bridge and half-bridge configurations, along with the optional AIN substrate and internal DC capacitors, cover the spectrum of up

to approximately 30 kW output power as single modules. Due to the positive thermal coefficient of the IGBTs used, complete modules or even the individual phases of the H-bridges inside the modules and the modules themselves can be used in parallel, thus supporting even higher power applications. Tyco

Electronics also offers the corresponding input rectifier stages in the flowCON 0 family (P590 and P600 modules), as well as PFC stages (P80x family), also designed for the area of welding.

www.flowpim.com

The Power of Symmetry in Power Design

All MOSFETs must share the load equally

Late last year, I began the conversion of my 1998 Chevy S10 pickup truck from gas to all electric. As an electronics engineer, the challenge of designing my own electronic systems was more than interesting to me. A low-voltage charger was needed for the 12-V system battery, a high-voltage three-stage charger was needed for the lead-acid battery bank for motive power (16 series-connected 6-V golf-cart batteries) and, the greatest challenge of all, the heavy-duty power controller for the motive system.

By Mark E. Hazen, engineer and technical writer, evhelp.com

These electronic systems are available off the shelf, but there is nothing more gratifying than designing and building your own. Both battery chargers were fairly straightforward, even the three-stage design for the main motive battery bank was not that difficult. However, the motive power controller became a quest for me. Not wanting to wait until I had time to complete my own power controller, I went ahead and purchased an industrial power controller to get me on the road. This strategy bought me time to design and build something unique – a non-breadbox circular symmetrical power controller.

Figure 1: Hazen's Power Wheel Provides Thermal and Electrical Symmetry and Efficiency

The breadbox industrial controller, which I purchased and had been using, is rated for a voltage range of 96 to 144 VDC and 500 A (maximum). Those design parameters are just fine for the on-road EV market. I have no complaint with this controller. It's seems to be well designed and has plenty of thermal and electrical margin for my EV application. However, I wanted to create something even more robust and efficient – I wanted to climb the mountain myself. It wasn't long until my thoughts turned to a circular and symmetrical design, which I have fondly named 'Hazen's Power Wheel'. Figure 1 shows the power wheel installed. It has all the characteristics of an early prototype or proof of concept.

The idea behind the circular and symmetrical concept is to distribute electrical and thermal currents evenly to help ensure that all MOSFETs are treated equally. This design does not 'force' all of the MOSFETs to operate equally – it requires highly controlled semiconductor manufacturing conditions and/or somewhat sophisticated electronic controls to do that. Instead, the physical design sets the stage for operational fairness for all of the MOSFETs, which means equal and symmetrical gate drive, power current flow paths and heat distribution and dissipation. These are some of the key problems that power designers face in applications that require high-power paralleled switches. Reasonable care must be taken to ensure that all MOSFETs share the load equally.

The key to the design, and the focus of this article, is the physical circular symmetry. This was accomplished with two juxtaposed aluminum discs, both visible in Figure 1.

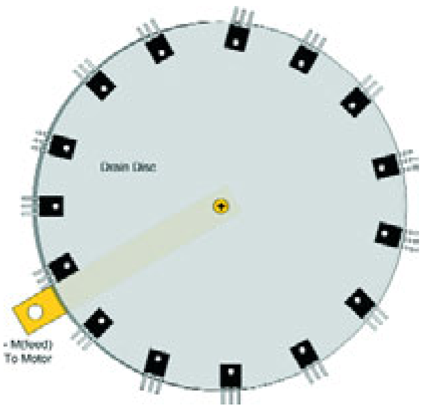


Figure 2: MOSFETs Evenly Spaced Around the Circumference of the Drain Disc

Sandwiched between the two discs are 15 MOSFETs, mounted around the rim of the Drain Disc as illustrated in Figure 2. The MOSFETs chosen for this design are the IRFP90N20s from International Rectifier, each rated 200 V and 94 A (90 A package limit). These MOSFETs together deliver overall ratings of 200 V and 1350 A.

Each MOSFET of Figure 2 is mounted directly to the Drain Disc with 4-40 hardware and thermal compound for good heat conductivity. A copper bus bar (-M(feed)) collects the total motor drive current at the center of the disc. The only physical contact between the bus bar and disc is at the center. I made the disc in Figure 2 semitransparent so you can see the bus bar connection behind.

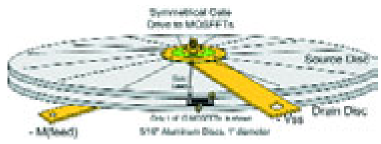


Figure 3: Aluminum Discs Bridge Provide Thermal and Electrical Symmetry

In Figure 3, you can see the Source Disc in place with a representative MOSFET sandwiched between the two discs. The discs are separated with nylon spacers and nylon bolts. There is a small gap between the top surfaces of the MOSFETs and the Source Disc. The power cable that comes from the negative supply terminal of the motive battery bank connects to the –Vss bus bar, which delivers the current to the center of the Source Disc for unbiased distribution through the disc to the source leads of all MOSFETs. Again, the bus bar only contacts the disc at its center.

Note also the Gate Distribution Disc in the top center of Figure 3. This small disc evenly distributes gate drive to all MOSFETs via an interconnecting lead and small gate resistor for each.

As a side note, the source and drain leads of each MOSFET are pinned to the edges of the discs using brass washers and screws. Also, the electrical portion of this design does not use any electrical means of load balancing among MOSFETs. The physical symmetry of the design and the quality of the MOSFETs has eliminated the need for that.

Finally, Figure 4 provides another perspective that shows the disc sandwich and the means by which gate drive is symmetrically distributed. A single gate 'super driver', using a MOSFET half bridge, provides ample and equal drive to all MOSFETs. The switching frequency is a fixed 4 kHz. I designed and included a trimmer-adjustable current limit circuit that prevents the motor current from exceeding a maximum level in the range of 325 to 1350 A. I also included a watchdog circuit that shuts the controller down if the control resistor, which is connected mechanically to the 'gas' peddle, becomes open or disconnected.

Under the hood, the performance of this controller is very strong. From the beginning, I included in the physical design a 4" center-mounted fan to force air over the Drain Disc (see Figure 1 again). As it turns out, the Drain Disc becomes barely warm in normal operation. Nevertheless, the fan will remain to provide for additional thermal margin. Tests with the fan and fan platter removed show that the temperature is constant around the Drain Disc because of the symmetrical MOSFET placement and thermal mass of the aluminum Drain Disc.

Going forward, I will complete the controller by adding a weather/dust encasement and take the circuit boards to, shall we say, a higher level of sophistication – you know how disheveled proof of concepts can get.

For those of you who are interested, many more details regarding the conversion of my Chevy S10 are presented on my Web site, evhelp.com. I created evhelp to assist others in making the conversion from gas to electric. You will find many helpful tips and articles to explain most every detail of the process, including a generous FAQ section.

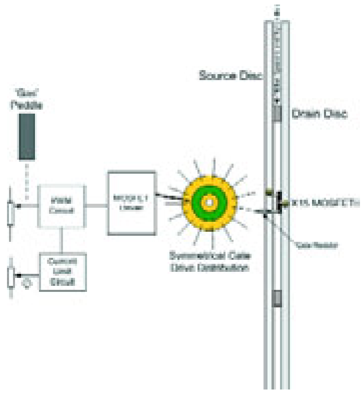


Figure 4: One MOSFET Super Driver Feeds Center-Mounted Gate Drive Distribution Disc

About the Author

Mark E. Hazen is an electronics engineer and professional writer. He has written several college-level engineering textbooks, a paperback on alternative energy and innumerable articles covering analog circuits and communications. He holds a patent on PWM motor control and obviously enjoys power design.

www.evhelp.com

Advances in SiC Rectifiers

SiC can eliminate the need for many other components

One of the biggest advances in silicon carbide rectifier technology is the creation of better material in larger sizes. By moving from 3-inch wafers to 4-inch, suppliers have achieved greater manufacturing efficiency and are driving down the costs of SiC devices.

By John Palmour, Executive VP of Advanced Devices, Cree Inc.

In the past, cost issues were driven by the fact that SiC is a very difficult material to create, infinitely more difficult to make than Si because of the high processing temperatures and pressures that need to be used. Unlike silicon, silicon carbide has no molten state, so manufacturers must work with gases and controlled temperature gradients that make the process difficult and costly.

The new 4-inch wafers make the creation of SiC power devices more cost-effective. If you're processing devices that are about 4mm x 8mm on small-diameter wafers, the device yield of each wafer is limited. As the diameter of that wafer increases, manufacturers can produce more devices at one time. By using the 4-inch wafer, 40-percent less manufacturing capability is needed to manufacture the same number of die, making SiC devices more cost-effective than ever before.

The material quality also continues to greatly improve, allowing device manufacturers to design and create very large devices. Cree has introduced a very large 1200-volt, 50-amp device—the largest commercially available device in SiC. This development will enable many higher power conversion systems to use SiC now, especially in large inverters that would be used to drive power trains on hybrid electric vehicles, large solar inverter systems, and wind generation systems. Those applications were closed to SiC devices before because manufacturers could not yield a large enough device in appropriate quantities.

The improvements in material quality and increase in size are especially important in what has become the main consideration for most in the power industry—energy efficiency.

SiC may initially cost more when compared to alternative materials, but it can eliminate the need for many other components in power supplies, which can save in overall costs. For example, power supply makers can use a smaller EMI filter and reduce the number and size of the MOSFETs used with a SiC Schottky diode, so the net cost today is usually lower for a SiC-based solution than a silicon-based solution.

Cree uses SiC to manufacture high-voltage Schottky diodes. There is no minority carrier recombination, which leads to zero reverse recovery currents. There is, however, a very small junction capacitance charge. The magnitude of this charge is negligible in comparison to the equivalent reverse recovery charge in a Si PiN device, and it is also independent of temperature, forward current and switching di/dt. These Schottky diodes also have zero forward recovery voltage and turn on immediately. These switching characteristics also have the often-overlooked benefit of greatly reducing EMI. These devices eliminate diode-switching losses in a power conversion system, which in turn greatly reduces the turn-on losses in the associated switch that has to commutate the reverse recovery currents associated with Si PiN devices. Because of this increased efficiency and performance, SiC Schottky diodes are the ideal solution for applications where energy efficiency is the major concern.

According to Report #: DOE/EIA-0484 (2007), energy demand in the United States is expected to increase by 19 percent within the next ten years, and in developing countries demand is expected grow even faster. Because of this, energy users are demanding improved efficiency from the products they purchase. Even just a 1-percent improvement in efficiency of a power supply can save energy and money. For example, a 1000W power supply that is operational 18 hours per day, 365 days per year, in an area with an electricity cost of $0.10/kWH will generate energy costs of $657. A 1-percent efficiency improvement will save $6.57 annually. Consider the savings that $6.57 for every single power supply provides to an application such as a server farm. Considering that electricity costs are now the single largest cost of running a large data center, the savings from incorporating a slightly more expensive SiC Schottky diode into the power supply can recoup the incremental costs several times over in one year.

SiC devices are expected to become increasingly important in the global effort to become more efficient. Today, Schottky diodes up to 1200V packaged to 20A are available, and large area Schottky diode die up to 1200V/75A are producible. SiC MOSFETs, BJTs and PiN diodes for high voltage are all in development. For high-voltage, high-temperature power devices, SiC is the more efficient material of choice due to a higher breakdown field, lower specific on-resistance, faster switching, better thermal conductivity and higher temperature operation.

In a power supply, SiC diodes offer lower switching losses to improve system efficiency, and because of this, they reduce the system size by requiring fewer and smaller additional components, which can lower overall system costs.

How do these features make power supplies more efficient? Lower switching losses can be used to raise the operating frequency and reduce the overall size of the converter. It will also lead to lower operating temperatures for the semiconductor devices, resulting in higher MTBF. A lower switching loss will lead to component reductions that can translate to a higher power density for the power supply.

Increased efficiency will be the driver in future advancements in SiC rectifiers. The technology is a perfect fit for optimizing the performance of energy-saving products such as hybrid electric vehicles and solar energy systems.

Currently, in hybrid electric vehicles, a separate liquid cooling system, comprised of a electric water pump, pump control electronics, pump motor drive electronics, hoses, wiring and a separate radiator, is needed for the power electronics. But with SiC devices' lower loss, coupled with higher temperature capability, there could be a reduction or elimination of the need for liquid cooling, allowing for weight reduction (and energy savings). SiC devices can operate at high voltage with better performance than lower-voltage silicon devices, which would optimize the electric power train for better acceleration. Further, switching to SiC Schottky diodes would result in these vehicles' reduction in electric motor drive losses. Overall, coupled with as much as a 50-percent reduction in inverter losses, there is a projected fuel efficiency improvement of 5 to 15 percent.

Another example of what is driving advancements in SiC technology to the next level is SiC Schottky diodes' use in solar energy systems. In such a system, solar panels collect the sun's energy and convert it to a positive DC voltage, which is boosted to a fixed DC voltage by means of a boost converter switching at high frequency. Cree's SiC Schottky diodes eliminate the boost diode switching losses and greatly reduce the MOSFET or IGBT turn-on loss. This significantly improves the boost section efficiency. An inverter then converts the fixed DC voltage to a usable AC voltage of fixed frequency. The SiC Schottky diodes eliminate diode-switching losses in the free-wheeling diodes of this section along with reducing IGBT turn-on losses. Inverter efficiency is significantly improved. Silicon-based inverters typically operate at close to 96-percent average efficiency. With a more efficient system, more of the energy delivered by the solar panels gets converted to usable electricity. With SiC devices, the inverter's average efficiency can be boosted up to 97.5 percent. This represents up to a 25-percent reduction in inverter losses.

The consensus estimate from available sources shows that electricity accounts for more than 39 percent of the world's energy use. In the next few years, advances in SiC technology, especially rectifiers, are expected to have a dramatic impact in optimizing usage in all segments, including motion applications, IT equipment, lighting, and heating and cooling.

www.cree.com

Beyond LDOs and Switching Regulators

New Technology Solutions

Different solutions may vary depending upon specific needs, whether it is size, efficiency, price, performance or simply ease-of-use. Although solutions may be plentiful, there are two popular solutions that are commonly used and they distinctively differ from one another — linear regulators and switching regulators.

By Brian Huang, Product Marketing, Micrel, Inc.

This article discusses current solutions on the market and then presents new technology alternatives to typical LDO and switching devices.

Linear Regulators

A linear regulator is a dissipative step-down power regulator. This initial description sounds wasteful because a linear regulator will literally convert a higher input voltage to a lower output voltage by dissipating power through an active component. This component is usually a bipolar junction transistor (BJT), as seen in Figure 1. The output voltage is set by the feedback resistor network (R1 and R2), which tells the error amplifier (EA) how much power to dissipate in order to get the desired output voltage.

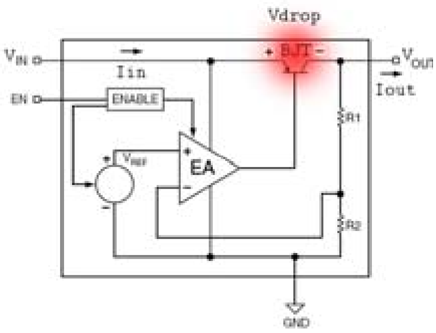


Figure 1. Typical Linear Regulator Circuit.

Linear regulators are simple, offer good transient performance, have very low output noise and ripple, and can be inexpensive. However, one huge drawback inherent to linear regulators is efficiency. The efficiency of a linear regulator depends largely upon the input to output voltage ratio. If the input voltage is much higher than the output voltage, then more voltage needs to be dropped across the BJT. The BJT acts as a variable resistor to actively manage the voltage drop (Vdrop). Since current from input to output goes through the BJT continuously, the input current is about equal to the output current, neglecting some losses in the control circuitry. For simplicity's sake, assume the input current is equal to the output current. To calculate the efficiency of a linear regulator, divide the output power by the input power:

Linear Regulator Efficiency
= Output Power / Input Power
= Vout * Iout / Vin * Iin (Assume Iin = Iout)
= Vout / Vin

As shown in the calculation above, the efficiency of a linear regulator can be estimated to be the output voltage divided by the input voltage and does not depend upon the output current. For example, if Vin equals 3.6V and Vout equals 1.8V, then the efficiency is 50 percent, assuming other small losses in the system are negligible. If one converts a 5V input voltage to a 1V output voltage using a linear regulator, then one would only get 20 percent efficiency. This means that's 80 percent of the total input power is dissipated. At higher currents the dissipated power could generate a considerable amount of heat which can then lead to thermal issues (shown in red in Figure 1).

Although linear regulators have many advantages, their efficiency can be extremely poor, depending upon their input to output voltage ratio. Efficiency in portable applications is extremely important due to battery life and is the reason more efficient voltage converters are in high demand.

Switching Regulators

A switching regulator converts power much more efficiently than a linear regulator because it utilizes the electrical properties of inductance and capacitance to store and transfer energy. There are three main types of switching regulator configurations — the buck (step-down), the boost (step-up) and the fly-back (buck and boost) regulator. In this article we will mainly focus on the buck switching regulator, Figure 2.

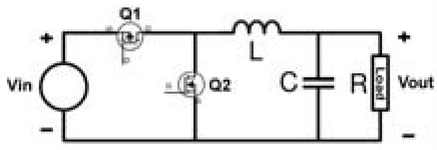


Figure 2. Typical Synchronous Buck Regulator Circuit.

The buck regulator converts a higher input voltage to a lower output voltage just like a linear regulator. The difference is that it uses a pair of transistors (BJTs or MOSFETs) and an inductor to alternately deliver energy to the output. Figure 3 depicts a diagram of the buck regulator's switching cycle.

During Phase One, the Q1 transistor is on while the Q2 transistor is off and energy is delivered from input to output while the inductor is charged (energy is stored in the inductor's magnetic field).

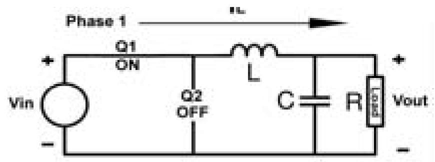


Figure 3a. Buck Regulator ON-TIME Circuit.

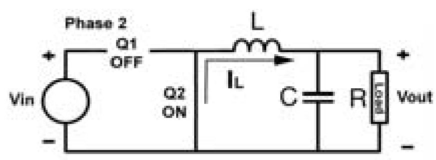


Figure 3b. Buck Regulator OFF-TIME Circuit.

During Phase Two, the Q1 transistor turns off and the Q2 transistor turns on. The input is now disconnected from the output, but current still flows to the output because the energy stored in the inductor's magnetic field is converted back to current. This allows energy to continually be delivered to the output without interruptions even when the input is disconnected. Due to the inductor's ability to store energy, one can still manage the power delivery from the input to the output by adjusting the amount of time Q1 and Q2 stays on. The ratio of Q1's on-time to the overall period is called the duty cycle (D). Neglecting some losses across the transistor and the inductor during switching cycles, one can calculate the D to be equal to Vo/Vin. If one wanted to convert an input voltage of 5V to an output voltage of 1V, it can be done with a duty cycle of 1V/5V, which is 20 percent. This means for each switching period, turn Q1 on 20 percent of the time (Q2 is OFF) and then turn Q2 on for 80 percent of the time (Q1 is OFF). By managing the amount of power delivered from the input to the output, the buck regulator does not need to dissipate as much power, and is thus more efficient.A typical constant frequency, pulse-width-modulated (PWM), buck regulator can convert a 3.6V input voltage to a 1.8V output voltage at over 90 percent efficiency under "optimum output current conditions." Unfortunately, typical PWM buck regulators are not 90 percent efficient throughout the entire output current range. At light loads, the PWM buck regulator will continue to switch no matter what the output current is. Due to losses in non-ideal switches (BJT and MOSFET), the efficiency of a typical PWM buck regulator suffers at light loads. Figure 4 shows an efficiency comparison plot.

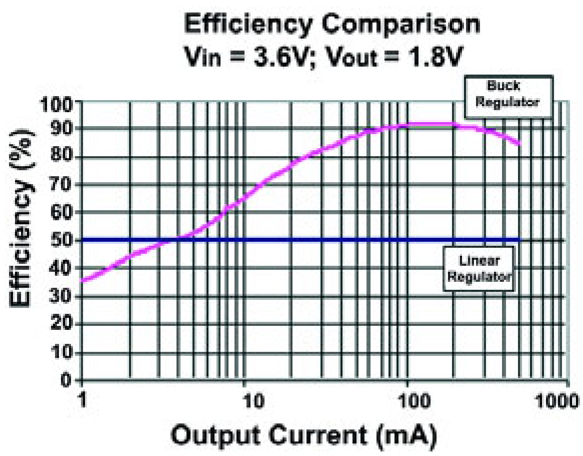


Figure 4. Efficiency Comparison.

As shown in the graph, when the output current is 1mA, the efficiency of the PWM buck regulator is at about 35 percent. At 1mA, the efficiency of the PWM buck regulator is even lower than the linear regulator. In fact, until about 3mA, the linear regulator has higher efficiency. Due to power loss in non-ideal switches, the efficiency of a constant frequency PWM buck regulator can be quite poor. This is why a switching regulator that is efficient throughout the entire load range was developed.

Hyper Light Load Mode™

The Micrel MIC23050/MIC23051 Buck Regulator is one of the most advanced switching regulators for portable applications using the trademark switching scheme known as Hyper Light Load™. The "Hyper" refers to the ultra-fast load transient response. The "Light Load" refers to high efficiency at light loads. Hyper Light Load™ was developed to fill a need in the portable electronics market where efficiency and fast transient performance is a must.

“Hyper”

Figure 6 shows the Hyper Light Load™ using a constant-on-time control scheme where the on-time of the Q1 transistor is set by the output voltage divided by the input voltage. Unlike PWM buck regulators, where the duty cycle (on-time) is controlled, in Hyper Light Load™, the off-time is controlled. The MIC23050/51 uses an error comparator that compares the feedback voltage ripple with an internal band gap voltage. By only regulating the off-time, a single error comparator can control the output. See Figure 5.

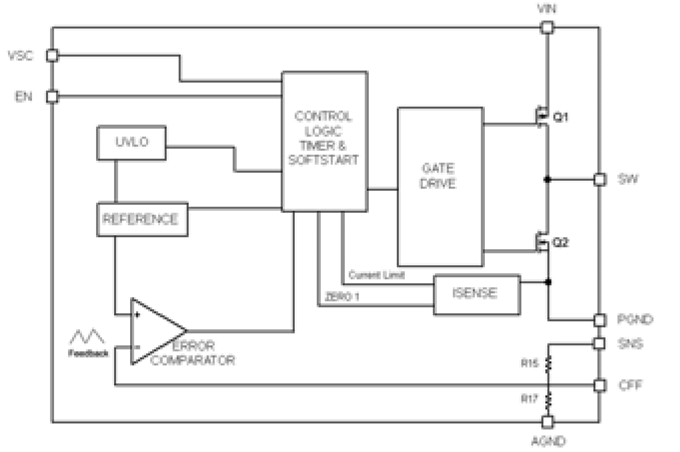


Figure 5. MIC23051 Hyper Light Load Block Diagram.

As shown in Figure 5, the feedback voltage ripple is compared to the band gap reference voltage by the Error Comparator. The on-time (positive slope of the ripple) is set by Vout/Vin and is constant. The off-time (negative slope of the ripple) will fall until it is below the band gap reference voltage. The output of the error comparator is fed directly into the MOSFET control circuit. When the ripple voltage is higher than the band gap voltage, the output of the error comparator will be negative. This tells the control circuit that the output voltage is too high. As a result, the amount of time Q2 stays on increases so that the input delivers less energy to the output. When the feedback voltage is lower than the band gap voltage, the output of the error comparator will be positive. This tells the control circuit that the output voltage is too low. As a result, the amount of time Q2 stays on is decreased and more energy is delivered from the input to the output. The regulation of the device depends upon how long Q2 stays on or off.

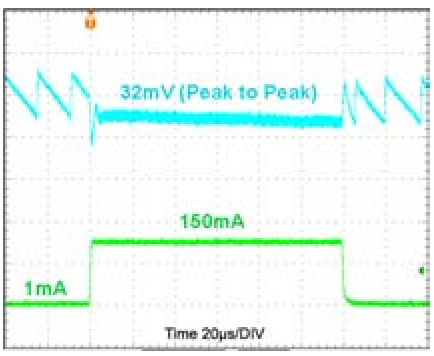


Figure 6. MIC23050 Load Transient.

The MIC23050/51 load transient response is ultra-fast because any change in the feedback is immediately compared and outputted to the control circuitry. The main difference between MIC23050/51 and other switching regulators is that it does not have an Error Amplifier before the comparator and saves time needed to charge the compensation capacitor often at the output of the Error Amplifier. Not using the Error Amplifier removes an extra block in the control loop and reduces the amount of time it takes to respond to change. As a result, the load transient response of MIC23050/51 is unmatched, as shown by Figure 6.

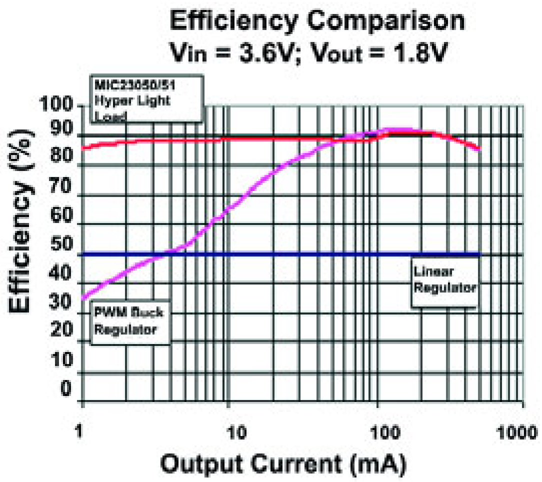


Figure 7. Efficiency Comparison with Hyper Light Load.

“Light Load”

The Hyper Light Load™ has two modes of operation. At low output currents (discontinuous mode) it is governed by pulse frequency modulation (PFM). At higher output currents (continuous mode) it is governed by a constant-on-time, controlled off-time, control scheme. The combined control method is what allows the MIC23050/51 to be efficient under all load conditions.

Typical constant frequency PWM buck regulators have been shown to be less efficient at light loads due to switching losses. In order to improve light load efficiency, at low output currents the Hyper Light Load™ becomes pulse frequency modulated (PFM). Since the output current is low, the output capacitor can maintain the voltage longer during the off cycle. During the on-time, the output voltage increases, but is slowly being pulled down by the load. After the on-time, everything is turned off in the control loop except the band gap and the comparator. This saves power during off-time. As the output voltage slowly decreases, it is being compared to the band gap voltage. Once it is below the band gap voltage, the comparator immediately tells the control loop to turn the Q1 transistor on again. This control method uses PFM mode to vary the switching frequency depending on the output current. If the output current decreases, the frequency decreases and if the output current increases, the frequency increases. This reduces excessive switching and reduces power loss. The reduced switching and the power saved from turning off most of the device saves power. This makes the MIC23050/51 efficient, even at light loads. The formula to calculate when PFM mode takes place is:

$$I_{LOAD} < (Vin\text{-}Vout) * D / 2Lf$$

At higher output currents the MIC23050/51 switches at around 4MHz and maintains high efficiency like most switching regulators (except it controls the off-time instead of the duty cycle). Refer to Figure 7 for the updated performance comparison.

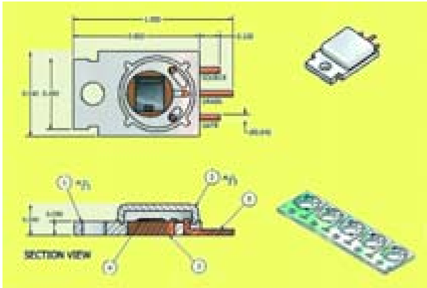
Conclusion

There will always be innovation to create the best power converter in power electronics. As the demand for smaller, faster, more efficient, less noisy, easier to use and cheaper regulators grow, there will be innovators to fill the need. The MIC23050/51 is a modern buck regulator designed specifically to fit into today’s demand. Micrel’s Hyper Light Load™ switching scheme created a new standard for other switching regulators to follow.

www.micrel.com

Ceramic Power Semiconductor Packages

CNS Power Ceramix announces The Ecconowatt Line of ceramic Power Semiconductor Hermetic Packages that meet the JEDEC TO-251,220,218,247,254 outline. The patented attractive Ecconowatt is designed to be handled in strip form, five positions per strip, similar to plastic encapsulated package manufacturing systems. This feature and the reduced amount of process operations renders the Ecconowatt cost competitive with the plastic encapsulated devices. The Ecconowatts are device assembly automatable with short cycle time processing and vacuum sealed. Additional favorable features include surface mount capability, light weight, withstands high temperature and made up of few parts.
The internal geometrical design features ample space for multiple bond wires where necessary. Low thermal resistance is achieved by including a brazed insert of Silicon Cemented Diamond (SCD) material on which the chip is mounted. SCD Material has a Thermal Conductivity of 580w/mk and a coefficient of thermal expansion of 1.30 ppm/k. The Ecconowatt accommodates single chip devices as well as circuit devices requiring five leads. Currently the



Ecconowatt is being considered for the Ignition Spark Driver Circuit for Automotive Ignitions. Packages will be available in 2nd Quarter 2008.

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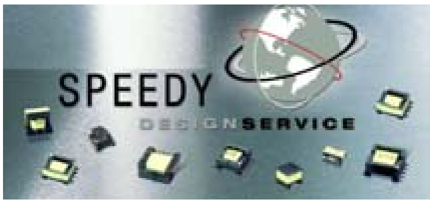


nical parameters e.g. primary inductance, current, turns ratio and switching regulator IC as well as agency requirements. Within the selected service time you receive 10 customized pieces with specification sheet, test data and deviation report.

www.we-online.com/speedy

NPT Technology For High Switching Frequency Applications

Microsemi Corporation has announced a new series of high speed IGBT transistors developed for welding, low to mid-power solar inverters, uninterruptible power supplies and industrial switch mode power supply applications.
Designated the Thunderbolt HS™ IGBT Series, the new IGBTs are Microsemi’s next generation of NPT technology targeting high switching frequency applications. These devices exhibit higher saturation voltage and significantly lower turn-off energy losses than previous generations. Low switching losses enable operation at switching frequencies over 100kHz, approaching power MOSFET performance but at lower cost. Thunderbolt

HS IGBTs are available as single devices or packaged with a DQ Series fast, soft recovery diode.
An extremely tight parameter distribution combined with a positive temperature coefficient make it easy to parallel Thunderbolt HS IGBTs. Controlled slew rates result in high noise and oscillation immunity and low EMI. The short circuit duration rating of 10 microseconds makes these IGBTs suitable for inverter and motor drive applications. Reliability is further enhanced by avalanche energy ruggedness.

www.microsemi.com

First 4.7µF MLCC in 0402 Case Size

Taiyo Yuden announces the mass production availability of its new AMK105BJ475MV multi-layer ceramic capacitor (MLCC) for decoupling power-line circuits in high-performance ICs used in cell phones, digital still cameras and other battery-powered portable electronics. The AMK105BJ is the first MLCC to achieve a capacitance rating of 4.7iF in the 1.0 × 0.5 × 0.5mm (EIA 0402) case size. The AMK105BJ allows designers to obtain the desired capacitance value from a single 0402-size device, where two 2.2µF-rated 0402 capacitors were previously

required. This saves cost and simplifies manufacturability by reducing parts count by 50 percent for this application. Moreover, the AMK105BJ allows designers to downsize from 0603 size components (1.6 × 0.8 × 0.8mm) to the more compact 0402 size, resulting in space savings of 76 percent (volume) and 61 percent (area) without sacrificing device performance.

www.yuden.us

Hot-Swap Protection IC uses Hall-Effect Current Sensing

The ACS760 from Allegro MicroSystems Europe is a hot-swap protection IC designed for 12 V high-side applications.
The device combines Allegro's Hall-effect current sensing technology with hot-swap control circuitry, resulting in a highly efficient integrated controller. No external sense resistor is required, resulting in greatly reduced I2R losses in the power path.
The ACS760 incorporates an external high-side FET gate drive, and produces an analogue output voltage (factory trimmed for gain and offset) which is proportional to the current sensed in the device lead-frame. The soft-start/hot-swap function is accessed via the logic 'enable' input pin and an optional user-defined soft-start capacitor.
When the ACS760 is externally enabled and the voltage rail is above the internal under-voltage lockout threshold, the internal charge pump drives the gate of the external FET. When a fault is detected, the gate is disabled while simultaneously alerting the application that a fault has occurred.

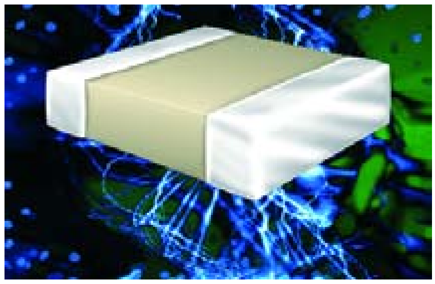
www.allegromicro.com

Industrial Power Supplies

Harting has introduced two new families of industrial power supplies to complement its range of Ethernet switches. The pCon 7000 product family, with a high IP 65/67 degree of protection, is designed for distributed applications in harsh environments, while the pCon 2000 is for use in control cabinets.
The pCon 7000 product family is designed for use with control units, Ethernet devices and other automation components in industrial areas and harsh environments.
The devices can be installed without problems in any factory in the world, in production cells or machines or on walls, columns and mounting rails.
For ease of installation, mounting sets for panels or standard DIN rails are available, while pluggable connections guarantee an easy and secure assembly. pCon 7000 is available with either M12 or HanÒ 4 A output terminations.

www.harting.co.uk

Capacitors with Flexible Termination



Kemet has expanded its range of surface mount X7R multi-layer ceramic capacitors with the introduction of flexible termination or FT-CAPs. The new devices offer an increased measure of protection against capacitor failure due to short-circuit caused by PCB flexing.
FT-CAPs complement Kemet's existing Open Mode and Floating Electrode technologies that provide flex crack mitigation.
Designed for high capacitance applications, FT-CAPs use unique end-termination technology to add pliability, shifting any flex stress into the termination area and away from the ceramic body and the component's active layers. FT-CAPs provide protection for up to 5mm of PCB flex-bend.
With regard to KEMET's existing technologies, Floating Electrode capacitors (FE-CAPs) provide flex crack mitigation in low capacitance value applications, while Open Mode technology is relevant to mid-values capacitance devices.

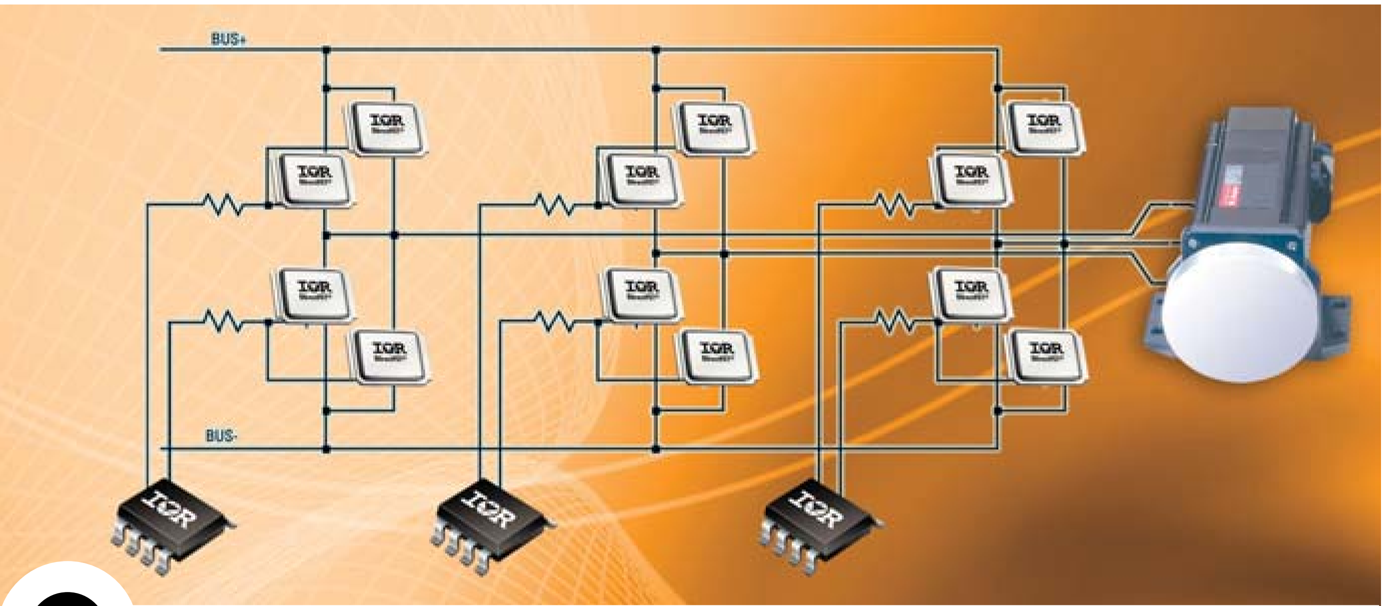
www.kemet.com

Complete Product Offering for Railway Applications

SynQor announces the release of the IQ36xxxQTA family of Isolated Quarter Brick DC/DC Converters. While targeting predominantly the Railway & Transportation industry, the devices will also suit a variety of other applications due to the ultra wide 4:1 input voltage range of 18-75V.
By adding this 36V nominal input device to the InQor™ family of Industrial DC/DC converters, SynQor now offers a complete suite of quarter brick products for Railway applications required to operate from a nominal 24V, 36V, 72V or 110V input. Each individual voltage range is designed to meet the respective input requirement of EN50155 including associated transients.
The devices are available in one of three mechanical configurations - open frame for convection-cooled applications; with an attached baseplate for conduction-cooled applications; and fully encapsulated for harsh environment applications. The encapsulated option brings the additional benefit of having reinforced-grade isolation from input to output.

www.synqor.com

ADVERTISING INDEX



Greater Protection; 50% More Power Density in a Compact Footprint

Complete Solution for Low- and Mid-Voltage Applications

200 V Driver ICs

Part	Package	UVLO	Compliance	Typical Current	Input Logic	Additional Features
IRS2001PBF	DIP8	UVLO, VCC	RoHS & PBF	290 mA / 600 mA	HIN, LIN	Independent high & low side drive
IRS2001SPBF	SOIC8 Bulk					
IRS2001STRPBF	SOIC8 Tape & Reel					
IRS2003PBF	DIP8	UVLO, VCC	RoHS & PBF	290 mA / 600 mA	HIN, LIN/N	Deadtime
IRS2003SPBF	SOIC8 Bulk					
IRS2003STRPBF	SOIC8 Tape & Reel					
IRS2004PBF	DIP8	UVLO, VCC	RoHS & PBF	290 mA / 600 mA	IN, SD/N	SD Input & deadtime
IRS2004SPBF	SOIC8 Bulk					
IRS2004STRPBF	SOIC8 Tape & Reel					

DirectFET® MOSFETs

Part	Package	Polarity	VBRDSS (V)	$R_{DS(on)}$ 4.5 V Max. (mΩ)	$R_{DS(on)}$ 10 V Max. (mΩ)	I_D @ TC = 25° C (A)	Qg Typ	Qgd Typ	$R_{th(JC)}$	Power Dissipation @ T_C = 25° C (W)
IRF6635	DirectFET	N	30	2.4	1.8	180	47.0	17.0	1.4	89
IRF6613	DirectFET	N	40	4.1	3.4	150	42.0	12.6	1.4	89
IRF6648	DirectFET	N	60	—	7.0	86	36.0	14.0	1.4	89
IRF6646	DirectFET	N	80	—	9.5	68	36.0	12.0	1.4	89

DirectFET® is a registered trademark of International Rectifier Corporation

IR's rugged 200V driver ICs and benchmark DirectFET® MOSFETs deliver more protection and higher power density in a compact footprint.

IRS200x Features

- High-side circuitry powered by bootstrap power supply
- Undervoltage lockout protection
- 3.3 V, 5 V, and 15 V input logic compatible
- Cross conduction prevention logic (for half-bridge drivers)
- Shutdown input available on IRS2004(S)PBF
- 50 V/ns dV/dt immunity on floating Vs pin

DirectFET Features

- 1.4° C/W junction to case thermal resistance ($R_{th(J-C)}$) enables highly effective top-side cooling
- Less than 1° C/W $R_{th(junction-pcb)}$ in half the footprint of a D-Pak
- Over 80% lower die-free package resistance (DFPR) than D-Pak
- 0.7 mm profile compared to 2.39 mm for D-Pak

for more information call +49 (0) 6102 884 311 or +44 (0) 1737 227 215

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