ISSN: 1863-5598

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Bodo's Power Systems®

Systems Design Motion and Conversion

December 2007

Make Linear Mode Work

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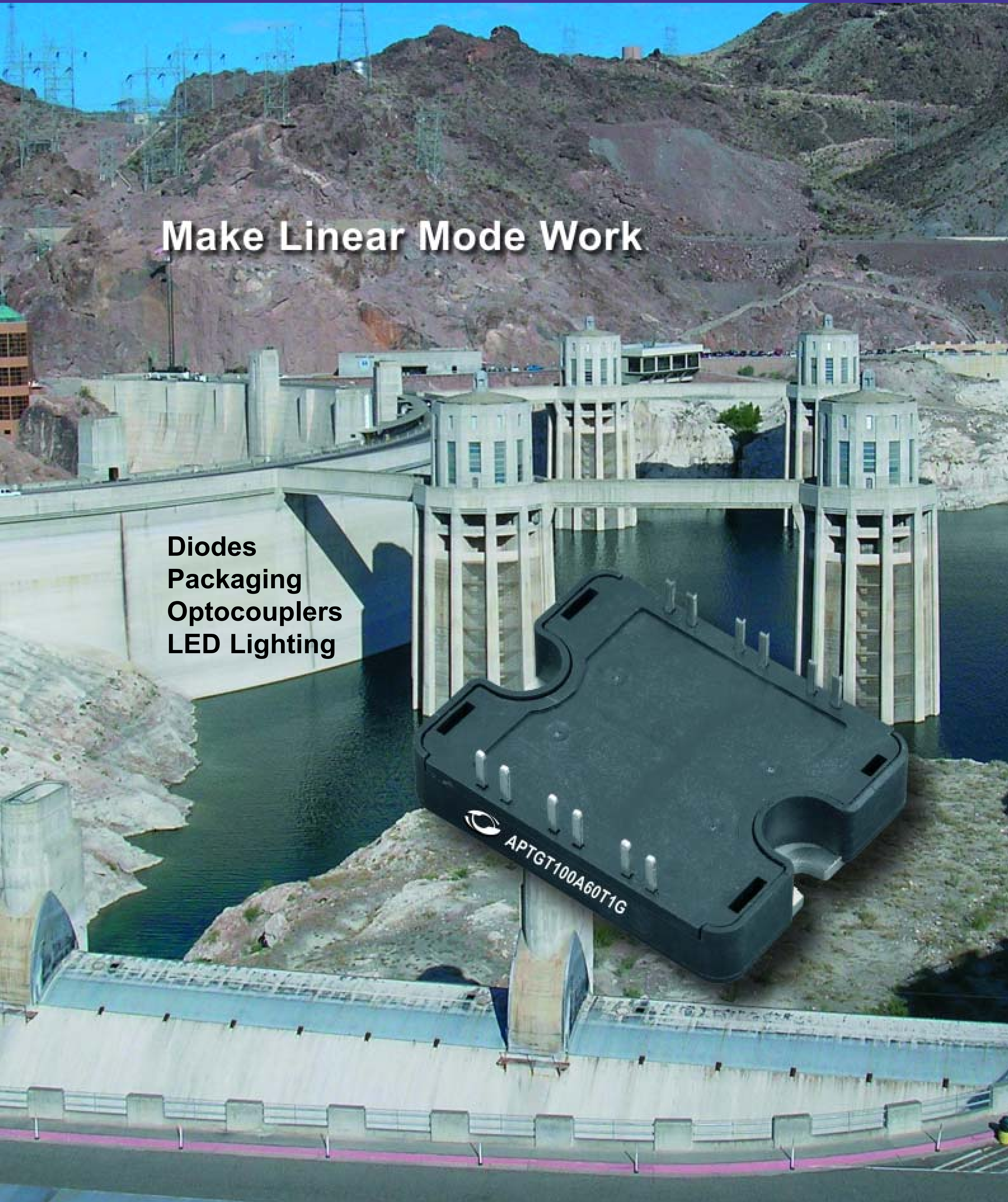
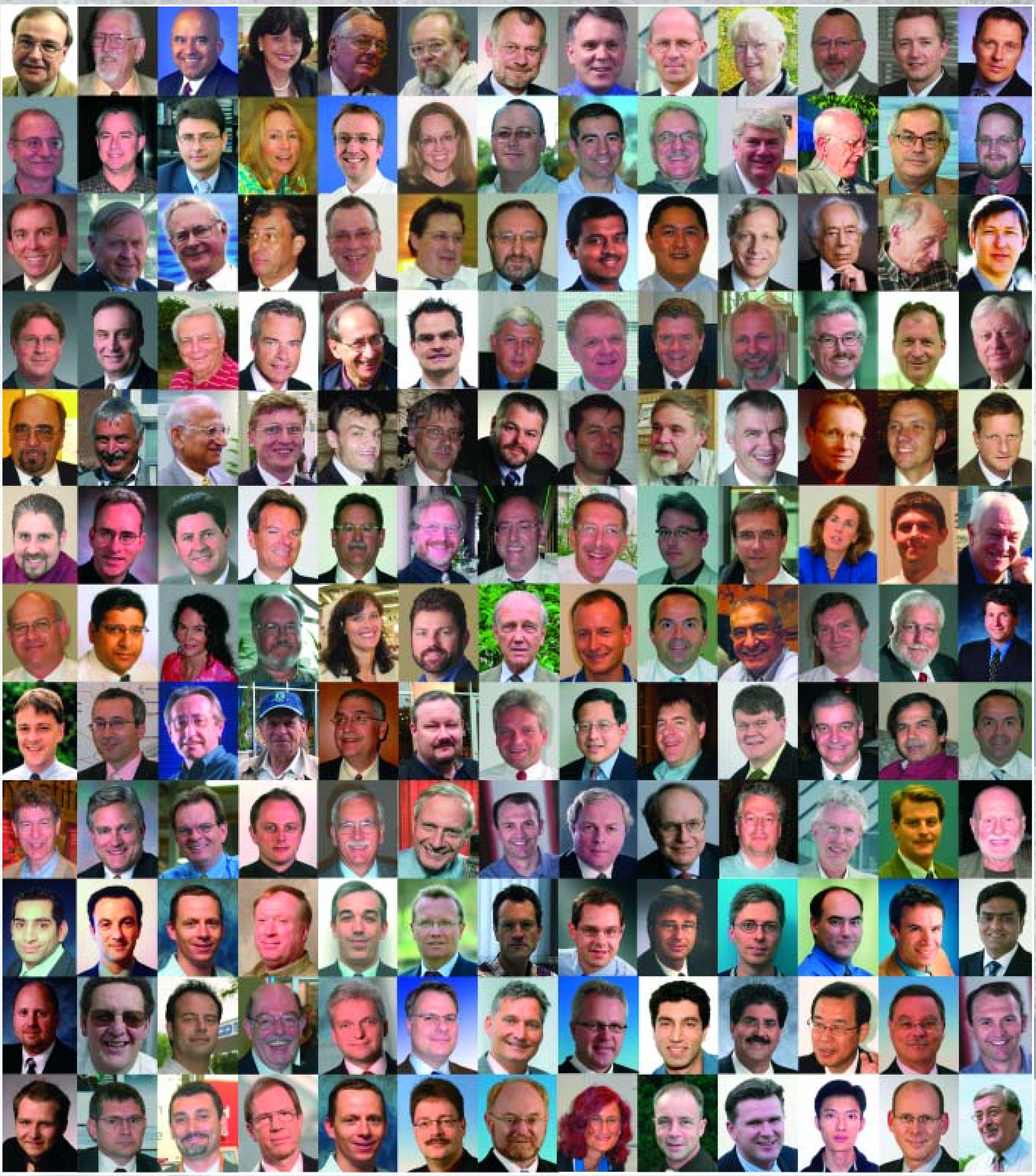


The Gallery



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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.

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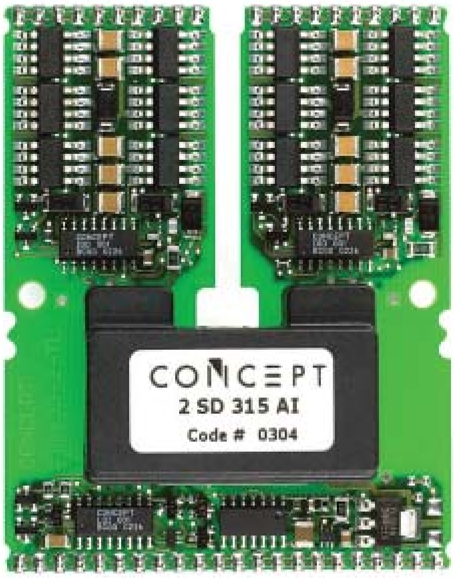
- Duty cycle 0...100%
- Delay time typ. 325ns



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

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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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Repro Studio Peschke
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Free Subscription to qualified readers

Bodo´s Power Systems magazine is available for the following subscription charges:
Annual charge (12 issues) is 150 € world wide
Single issue is 18 €
subscription@bodospower.com

circulation ASC audit since 09/2006 printrun 20000

Printing by:
Central-Druck Trost GmbH & Co
Heusenstamm, Germany

Events

EMC 2008
Düsseldorf/Germany Feb. 19-21.
http://www.mesago.de

APEC 2008
Austin Texas Feb. 24-28
http://www.apec-conf.org

CIPS 2008
Nuremberg/Germany March 11-13
http://www.cips-conference.de

PCIM China 2008
Shanghhai March 18-20
http://www.mesago.de

PCIM Europe 2008
Nuremberg May 27-29
http://www.mesago.de

Locomotives and Men

A good year is ending well. 2007 brought us exciting Conferences and Exhibitions such as the APEC, PCIM, EPE, Productronica and SPS/IPC/DRIVES just to mention the most important. The Power Electronics Industry is doing quite well and a “new” semiconductor material, Silicon Carbide (SiC), is on its way to commercialization. More and more companies are publicizing their R&D efforts with switches remaining mostly in the structures invented in silicon and then transferred to SiC. Silicon Carbide will move a number of applications towards higher efficiency.

But IGBT’s are the established tools for line voltage and motion and those associated with Power Electronics have developed vast potential for the IGBT switch. Today, it can be found in traction, automotive and other ignition applications, motor control and, yes, even in switch mode power supplies. I dare say that the IGBT is the switch of choice for applications requiring voltages in excess of 600 volts.

Traction is a word which brings me to locomotives. Steam is now history and electric locomotives are the standard today for efficiency and speed. Nonetheless, however, if locomotive drivers go on strike our modern lifestyles will be affected. Train strikes are new to us in Germany and a learning experience but not so in neighboring countries.

Looking ahead - it will soon be Christmas and, as always, toy train time. Are you ready to open the boxes again and get them going? Let us never forget our cherished childhood memories.

Wintertime is here, Christmas is coming, and I have a special centerfold prepared - we are all grown up kids with lively imaginations. My Advent Calendar centerfold has windows for each day running up to Christmas with friends portrayed in each window who will be familiar to you from my gallery. The windows are numbered for the days in December from 1 to 24. Send me a note or email listing those you can identify by window and name. Five or more correct will get you into the Christmas tombola and there will be nice gifts from Saint Nick for six winners. The drawings will take place every weekend prior to Christmas Eve.

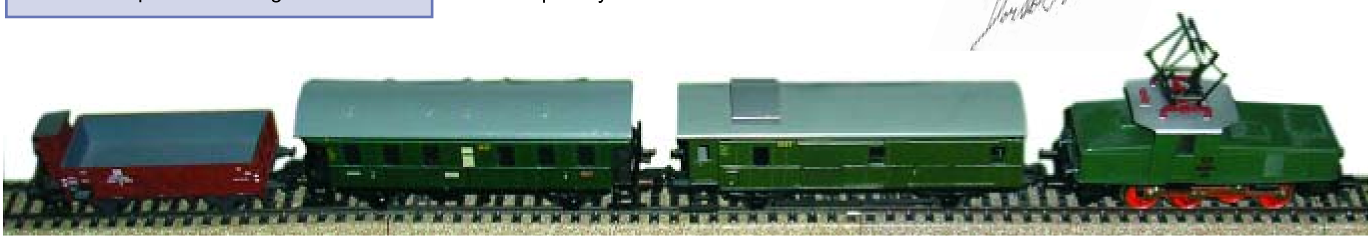
It is also time to say, “Thank You”, to all my contributors and to the highly motivated backstage team that makes this magazine a valuable tool for industry.

The New Year will start strongly with a number of events, so we will plan our resources carefully to best serve you and continue to provide comprehensive and important information that counts.

Let us all enjoy peaceful holidays, get ready for Santa and take a well-earned rest before kicking-off the New Year full of power.

My green power tip for this month: reduce the heat in the oven slightly just before the Christmas Turkey is done and let thermal inertia finish the job.

Merry Christmas and a Happy New Year



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Ultravolt Purchases High Voltage System Integration Company

UltraVolt announced it completed intensive growth financing, which included the purchase of a high-voltage system integration company, and is now poised to ensure significant future growth.

To further its goal of “Making High Voltage Easier”, UltraVolt, Inc. has acquired Galluppi Associates, Inc., one of the world’s leaders in high-voltage system integration. Over its 20-year history, Galluppi Associates has introduced systems and solutions for various military COTS programs, semiconductor equipment tools, industrial equipment, medical devices, and biotechnology systems. Galluppi Associates’ experience in high-precision, ultra-low-noise high-voltage systems extends into various applications and industries including devices using e-beam, i-beam, and X-ray technologies.

Synergies in the combined operations will accelerate the development of standardized system products and product lines based on UltraVolt high-voltage standard product modules. UltraVolt will continue to use its time-proven business model to meet more customers’ needs by providing an even greater range of advanced products and high voltage solutions.

“Acquiring Galluppi Associates was the right move at the right time for UltraVolt and its customers,” said James Morrison, UltraVolt’s co-founder and Chief Executive Officer. “With this added expertise, we will be able to offer both high-voltage modules and systems, introduce new products, and expand current product lines to reach many more customers.”

www.ultravolt.com

Cherokee Wins Contract from Major European Telecom Provider

Cherokee International announced the company has signed a frame contract with Deutsche Telekom AG. Under this agreement, Cherokee International will supply its Magell@n power solution to power Deutsche Telekom´s expanding German broadband network.

The Magell@n solution will provide reliable DC power to Deutsche Telekom’s Digital Subscriber Line Access Multiplexers (DSLAM), the devices that link many customer DSL connections to a single high-speed line. This DSLAM equipment is located outdoors in cabinets, poles and underground locations to bring voice, video and data services to the “last mile” of telecom subscribers. Magell@n offers a highly-reliable, highly-efficient energy source for Deutsche Telekom’s remote access nodes and transforms the mains power supply into 48-60VDC and also provides backup power in case of a power outage.

With DSLAM access nodes located away from the central station and closer to the end user, the Magell@n power solution provides enterprises a critical service feature — remote monitoring. Magell@n allows remote control and supervision of various parameters in the outdoor cabinet to speed up management response and increase Deutsche Telekom’s operational efficiencies. With the technology from Cherokee International, Deutsche Telekom will be the first in Germany to install active broadband equipment close to the customer, allowing Deutsche Telekom to offer a variety of innovative and advanced services — such as “Entertainment” for IP/TV inclusively HDTV, video or games on demand and music.

www.cherokeepwr.com

Andreas Mangler becomes Director of Strategic Marketing Europe

With effect from 1 September, Rutronik Elektronische Bauelemente GmbH has appointed Andreas Mangler as Director of Strategic Marketing Europe.

The company created a new European key position to expand its activities on the continent, harmonise the European linecard and control all corporate product marketing measures centrally. The reason for the restructuring is the above-average speed of growth of the broadliner over the past five years, in response to which the European high-level management has been appropriately modified. Mangler has been promoted internally to head the international electronics sector. He can in fact look back over a 13-year career with Rutronik during which time he has occupied various management positions. His most recent was as Director European Line Management.

Following his studies in electrical engineering, he worked in analogue development and the semiconductor industry. The vacant position of Director European Line Management is to be filled by Thomas Ulinski, also an established industry expert and long- standing Rutronik employee. Mangler’s long-term strategic objective is to increase the share of turnover for complex consultancy-intensive design-in products to 50 percent.

www.RUTRONIK.com

VACUUMSCHMELZE celebrates the 10th anniversary of its Slovakian site

Around this time, VACUUMSCHMELZE GmbH & Co. KG is celebrating the tenth anniversary of its Slovakian site. Which was originally a small company in Piestany, founded by a former VAC employee of Slovakian nationality, was acquired on 17th September 1997 by VACUUMSCHMELZE GmbH & Co. KG and relocated to Horná Streda. Six months later, the first production lines began to roll at VAC’s new plant. The plant has undergone continuous expansion over the years and now numbers almost 1,000 employees, supplying an extensive range of products and improving its production processes on an ongoing basis.

Initially the Slovakian works produced only inductive components and laminated core packages, until VACUUMSCHMELZE acquired the company and relocated it to a new site at Horná Streda. The first product to be manufactured at the new plant was a current sensor. As time progressed, the range of products was extended; in 2000, for example, a production line for VITROPERM® cores was added in response to customer demand, and a production facility for magnetic systems was established when VACUUMSCHMELZE’s Hanau plant was no longer able to meet the keen demand of the automotive industry.

www.vacuumschmelze.com

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HIGH PERFORMANCE ANALOG

Industry Veteran, Dr. Michael A. Briere, Appointed as CTO

International Rectifier announced a new organizational appointment to the company's leadership team. Dr. Michael A. Briere, 45, previously Executive Vice President, Research & Development for the company, has been appointed to the role of Executive Vice President, Research & Development and Chief Technology Officer. In his new role, Dr. Briere will be responsible for the company's technology and product development strategies.

Dr. Briere joined International Rectifier in 2003 and most recently served as the company's Executive Vice President, Research & Development. In that role, Dr. Briere led a team of 250 engineers and scientists on all aspects of International Rectifier's research and development programs. Prior to that role, Dr. Briere served as the company's Vice President of Integrated Circuit Development where he was responsible for the company's global research and development of its wafer fabrication processes, device design, and characterization. He also led the electronic design automation and test technologies for integrated circuits used in power management applications.

www.irf.com

Excellence in Supplier Account Team Service Award from Cisco

Fairchild Semiconductor was presented with the "2007 Excellence in Supplier Account Team Service Award" from Cisco. The award was presented recently at the Cisco 16th annual supplier appreciation event to the supplier who best demonstrated proactive, consistent support across Cisco's organization and regional locations.

"Our supplier excellence awards are designed to recognize companies that consistently meet and exceed our expectations, and in turn, provide a benefit for our customers," said Todd Myers, director, Global Supplier Management, Cisco. "Fairchild has set the standard for proactive account management, regularly providing us with creative solutions to enhance our supply chain performance."

"We're honored to receive the 2007 Excellence in Supplier Account Team Service Award from Cisco. Achieving this was a result of Fairchild employees across the company including sales, field applications, marketing, product lines, supply chain management, quality, operations and executive management working together to go the extra mile for the customer," said Greg Chapin, Cisco Global

www.fairchildsemi.com

R&D Contract to Develop Silicon Carbide RF Power Products

Microsemi Corporation has announced that the Air Force Research Laboratory (AFRL) has awarded $1.6 million on August 3, 2007 to allow Microsemi's Power Products Group (formerly Bend, Oregon-based Advanced Power Technology) to develop technology related to the use of silicon carbide RF Power semiconductor components in military avionics applications.

The development of the new silicon carbide technology supports future designs of lighter and more efficient jet fighter avionics, communications and radar systems, and will enable substantial growth of Microsemi's operations in Bend. The AFRL program complements the initial license agreement with Northrop Grumman Corporation, released in February 2006, wherein Microsemi will provide leading edge silicon carbide products to this leading defense contractor.

www.microsemi.com

Power Integrations Establishes Foundry Partnership With Epson

Power Integrations announced that it has established a foundry partnership with Seiko Epson Corporation. Qualification was completed during the third quarter of 2007, and production of Power Integrations' high-voltage power-conversion ICs is now ramping at Epson's wafer-fabrication facilities in Japan.

"Epson's high-quality, cost-effective foundry makes them an ideal partner with which to implement our proprietary high-voltage manufacturing process," said John Tomlin, Power Integrations' vice president of operations. "This partnership gives us production capacity to support the long-term growth of our business while helping us meet our cost-reduction goals."

According to Toshio Akahane, President and CEO of Epson Electronics America, "We are delighted that Power Integrations has selected Epson to produce its innovative power-conversion ICs. PI is a leading enabler in the effort to make electronic products more efficient, a priority that Epson shares. Both companies have worked diligently to move to the production stage, and we now look forward to a long-term wafer foundry relationship."

www.powerint.com

www.epson.co.jp/e/

ROAL Electronics. Launches New "Living Energy" Website

ROAL Electronics announced the launch of it's new official website www.roallivingenergy.com. Visitors to the old site will be automatically redirected to the new website where they will enjoy a simpler, more personal experience. In an effort to better meet the interests and needs of ROAL Electronics customers and visitors, our new website brings a fresh new look and the promise of exciting new product offerings in the fields of digital power and digital light for LED Lighting applications.

The new website provides enhanced access to ROAL Electronics information and resources. A cleaner structure, simplified navigation and improved functionality make finding information easier than ever.

www.roallivingenergy.com

SMIC Announces HFSS-Based Library for High-Performance Design

Leading Chinese Semiconductor Company Adopts Ansoft to Extend its RF CMOS Design Capabilities

Semiconductor Manufacturing International Corporation (SMIC) announced its commitment to Ansoft Corporation's simulation technology for S-parameter extraction, frequency-dependent SPICE model extraction and EMI prediction. SMIC's adoption of HFSS extends its RF CMOS design capabilities and provides a proven platform on which to build accurate and traceable on-chip model libraries.

SMIC will use HFSS to provide a unique library of complex, high-speed and high-frequency passive structures for accurate, next-generation designs traceable to the foundry. "Our customers are requesting high-Q spiral inductors with small form factors for their high-frequency, portable communication platforms," said Dr. Lee Yang, head of RF Application and Design Support at SMIC. "Our research and testing shows that Ansoft offers the best solution to help our customers meet these objectives."

www.smics.com

www.ansoft.com

WEBENCH tool helps select LEDs

National Semiconductor introduced its light-emitting diode (LED) WEBENCH® online design environment that helps engineers select from, and design, with more than 200 high-brightness LEDs in minutes. Products from Avago Technologies, Cree, Lite-On, Nichia, OSRAM and Philips Lumileds are compared across multiple parameters, including light output, colour, footprint, viewing angle, current and power rating. A unique 'Build It!' feature ships a custom prototype kit to the engineer within 24 hours.
With National's LED WEBENCH suite of tools, engineers can configure a system with up to 60 LEDs in serial or parallel strings. With a single keystroke, the LED WEBENCH tool matches an LED with one of National's PowerWise® energy-efficient LED drivers and creates an optimised power supply circuit. The engineer can easily "dial-in" their size and efficiency requirements, and then simulate the circuit behavior under dynamic conditions, including start-up, steady state, pulse-width modulation dimming and line transient. After fine-tuning the system in just minutes, the 'Build It!' feature provides a complete bill of materials for the LED circuit and the ability to quickly ship a custom prototype kit containing the selected LED, PC board, driver IC and passive components. The LED WEBENCH toolset works seamlessly with National's other WEBENCH tools for power, signal path design, audio, amplifiers and active filters, including National's Analogue University® online learning facility.

http://power.national.com

PIC® Microcontroller Line extended to 32 Bits With PIC32 Family

Microchip announces the PIC32 family of 32-bit microcontrollers (MCUs), adding more performance and memory while maintaining pin, peripheral and development compatibility with Microchip's 16-bit MCU/DSC families.

Key Facts:

- PIC32 Family Launched with 72MHz, 1.5 DMIPS/MHz MIPS32 M4K Core
- 64 and 100-pin Devices offer up to 512 Kbytes of Flash and 32 Kbytes of RAM
- Pin, Peripheral and Development Tool Compatible with 16-Bit PIC Microcontrollers

The new PIC32 family is fully supported by Microchip's free MPLAB® Integrated Development Environment (IDE) which now offers unprecedented compatibility by supporting Microchip's complete portfolio of 8-, 16- and 32-bit devices.

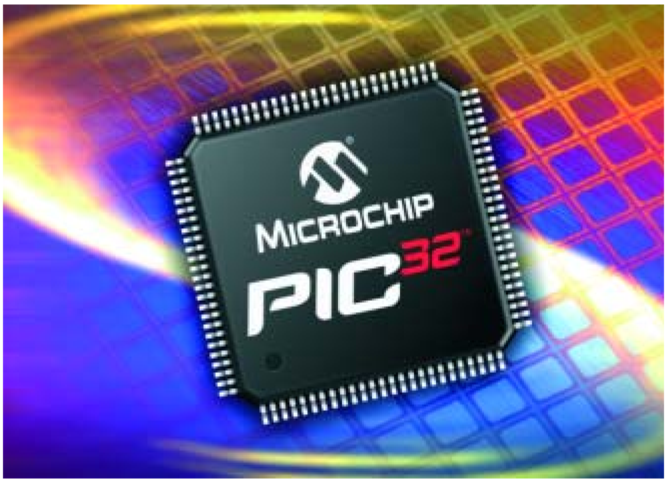

Figure 1: MC838 - PIC32 Chip Photo

Launching with seven general-purpose devices, the PIC32 family operates at up to 72 MHz and offers ample code- and data-space with up to 512 KB Flash and 32 KB RAM. The PIC32 family also includes a rich set of integrated peripherals including a variety of communication peripherals and a 16-bit Parallel Master Port supporting additional memory and displays.

The PIC32 family is based on the industry-standard MIPS32® architecture, with its leading combination of high performance, low power consumption, fast interrupt response and extensive industry tool support. The PIC32's high-performance MIPS32 M4K® core can achieve best-in-class 1.5 DMIPS/MHz operation, due to its efficient instruction-set architecture, 5-stage pipeline, hardware multiply/accumulate unit and up to 8 sets of 32 core registers. In addition, to reduce memory requirements, the PIC32 supports the MIPS16e™ 16 bit ISA – enabling code-size reductions of up to 40%.

All PIC32 products are supported by Microchip's world-class development tools, including the MPLAB IDE, the new MPLAB C32 C compiler, the MPLAB REAL ICE™ emulation system, the MPLAB ICD 2 in-circuit debugger and the Explorer 16 development board.

The PIC32 is also launching with broad MIPS-based tool support throughout the industry. Complete tool chains are available from Ashling, Green Hills and Hi-Tech—including C and C++ compilers, IDEs and debuggers. RTOS support is available from various vendors including CMX, Express Logic, FreeRTOS, Micrium, Segger and Pumpkin. In addition, graphics display tools providers include EasyGUI, Segger,

RamTeX and Micrium. A full list of third-party support for the PIC32 family can be found at www.microchip.com/PIC32.

Figure 2: MC838 - PIC32 Block Diagram

The PIC32 Starter Kit comes complete with everything that developers need to get started, including the USB-powered MCU board, MPLAB IDE and the MPLAB C32 C compiler, documentation, sample projects with tutorials, schematics, and 16-bit compatible peripheral libraries. Application expansion boards are also being made available, which plug into the expansion slot on the bottom of the MCU board. The PIC32 Starter Kit (part number DM320001) is available now at www.microchipdirect.com, for only $49.

Figure 3: MC838 - PIC32 Starter Kit

The first devices in the PIC32 family come in 64- or 100-pin TQFP packages. The new family has been sampling into early adopter designs, and is now available for general sampling. Volume production for all seven initial devices is expected in Q2 2008.

www.microchip.com/PIC32

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1200V : 10A - 75A

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1700V : 1200A - 3600A

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

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

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Industrial and Medical Markets Demand High Efficiency, too!

By Todd Hendrix – Head of Marketing & Sales, SynQor, Inc.

Ten years ago a revolution took place. Using synchronous rectification instead of traditional Schottky diodes, SynQor – then a start up – delivered a new generation of open frame dc/dc power converters that moved efficiency ratings from the mid 70% range up to 90% and beyond.

Increased efficiency means more power can be delivered from smaller units, so in many cases, designers were able to use quarter or eighth brick units instead of half or quarter brick products. Also by using more efficient power converters, bulky items such as heatsinks could be thrown away. The need for forced air cooling was reduced, so the requirement for unreliable items like fans was reduced. Power system design became simpler because the converters needed less derating.

Moreover, efficient dc/dc converters are also much more reliable since they do not waste energy as heat - which is a component killer. (And of course they require less cooling from unreliable fans). Reliability translates directly into cost savings.

The telecoms industry was the first to benefit from the move to high efficiency power converters. Telecoms systems are almost always tight for space, must run reliably for many years and are optimised for cost. So the fit between SynQor's new high efficiency converters and the needs of the telecoms market was obvious. Very quickly, other major dc/dc converter companies responded with their own synchronous rectification-based converters and the overall bar was raised.

However, for the rest of the market there was little change. Industrial, medical and military users who could not base their systems on converters designed for telecoms applications had to make do with only minor improvements in efficiency. Now, ten years on from the birth of the company, SynQor is introducing an entirely new range of products targeted at the industrial and medical markets, ensuring for the first time that designers in those sectors will be able to benefit from high efficiency power products.

It is useful here to stop and consider what efficiency levels really mean. A converter's rated efficiency measures how much of its input power is converted into useable output power. An ideal converter that is 100% efficient would transfer all of its input power into useable output power delivered to its load. Unfortunately, all converters waste some of their input power due to switching and conduction losses. This power is dissipated as heat throughout the converter and is directly proportional to its measured efficiency.

Consider a standard old-style encapsulated, baseplated 24Vin/3.3Vout quarter brick device from a well-known producer. This device operates at 79% efficiency levels and 75W. The equivalent new industrial quarter brick open frame device from SynQor produces 100W – delivering 33.33% more available power, and dissipating only 11.1W rather than the 19.9W of the competitor's part. If we normalise around the 75W power levels, then SynQor's converter dissipates just 7.9W, an impressive 60.5% savings over the competitor's product.

The use of high efficiency power converters also results in power savings in other parts of the power system. As the new converters require less input power, upstream power supply equipment similarly does not have to work so hard, so it too will dissipate less power.

Aside from very obvious space and power savings, the real advantage of running at high efficiency must be increased reliability. There is a simple rule of thumb that says: 'for every 10degC rise in temperature, MTBF is halved'. It is hard to translate this into a similar expression for power dissipation, and companies still selling encapsulated, baseplated products will say: 'as long as you keep the baseplate below 100degC, you will be fine'. However, the customer does not know the operating point of temperature sensitive components inside their, and it is quite likely that the junction temperature of some of the diodes is approaching danger levels. SynQor's open frame construction plus the high efficiency design means that the junction temperatures of the MOSFETS used will always be below 125degC – well within operating tolerance.

SynQor has built a reputation for reliability in the telecoms market through its design and production methods which ensure that there is complete traceability, not only of the converters but also of the components used. Moreover, each unit is tested thoroughly and the test results for each converter are available for inspection. It is this approach – proven in the telecoms field – which will ensure that SynQor's industrial and AC/DC supplies will also achieve the highest reliability standards.

For example, the new industrial quarter brick units have an MTBF calculated according to MIL-STD-217F of around two million hours. Field reliability figures – calculated as total device hours (number of units in the field multiplied by hours spent in the field) divided by the total number of field failures – are not yet available for the new InQor converters, but similar telecoms quarter brick families show demonstrated MTBF figures in the hundreds of millions of hours.

SynQor's use of highly automated production lines and a high commonality of parts also enables the company to be very flexible, resulting in very high levels of service and support. This also means that, unlike other power supply companies, SynQor has been able to introduce a very wide range of products for the industrial, medical and other sectors in a very short time period.

Today it is not just telecoms companies that care about power efficiency, reliability and small size. By delivering a comprehensive portfolio of high-efficiency converters based on new technology, innovative topology and the use of intellectual property in both design and production, SynQor now ensures that the industrial and medical markets sectors are benefiting, too.

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March 18-20, 2008
2008年3月18日-20日
Shanghai, China
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ELECTRONICS INDUSTRY DIGEST

By Aubrey Dunford, Europartners

GENERAL

The European Commission started legal action against eight member states for not properly transposing EU legislation to tackle waste of electrical and electronic equipment (WEEE) and the hazardous substances contained in such products. The Commission considers that Estonia, Latvia and Lithuania have not correctly transposed certain provisions of the WEEE Directive and that six member states (Belgium, Denmark, Lithuania, Malta, Finland and Sweden) have not properly done so for the directive restricting the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive).

SEMICONDUCTORS

MEDEA+, the EUREKA pan-European program for advanced co-operative R&D in microelectronics, announced details of the new EUREKA program called CATRENE (Cluster for Application and Technology Research in Europe on NanoElectronics) that will take up the challenge of increasing Europe's strength in nanoelectronics after MEDEA+ in 2008. While the JESSI, MEDEA and MEDEA+ programs were divided into technology and applications sub-programs, CATRENE recognizes the increasing convergence of technology and applications.

Worldwide sales of semiconductors in September were USD22.6 billion, an increase of 5.9% from September 2006, so SIA. Sales were up 5.0% from August 2007. Third-quarter sales of USD67.8 billion increased 5.9% from the like period of 2006 and were 13.2% higher than the second quarter of 2007. For the first nine months of 2007 sales were USD188.8 billion, 3.5% ahead of the first nine months of 2006.

Semiconductor sales

in September 2007 amounted to USD 3.532 billion, so WSTS, up 4.6% versus the previous month. This corresponds to a 3.5% growth compared to the same month last year. Measured in Euro, semiconductor sales in September 2007 were Euro 2.570 billion, up 3.3% on previous month and down 3.9% versus the same month a year ago.

Sanyo has come to the decision that it will not sell its semiconductor business or transfer shares to a third party.

ELECTRONICS INDUSTRY DIGEST – FORMERLY THE LENNOX REPORT

STMicroelectronics net revenues for the third quarter increased 6.1% sequentially to USD2,565 million from the USD2,418 million reported in the prior quarter, with growth led by application-specific wireless and computer products.

NEC Electronics plans to invest USD 87.8 M to increase its power chip production capacity by roughly 40%. Construction at the Otsu, Shiga Prefecture, plant is scheduled to begin this month and be completed by June 2008, with mass production beginning the following October.

Cambridge-based CamSemi has announced the completion of one of the largest VC funding rounds for a European fabless semiconductor company this year by raising USD26M. CamSemi develops power management ICs for offline power conversion.

Tyco Electronics will sell its Power Systems business to The Gores Group for USD100 million in cash. Tyco Electronics Power Systems, with approximately 2,500 employees, is a manufacturer of power solutions, including board-level conversion components and complete power conversion and backup power systems for telecom applications. Tyco Electronics' strategy is to streamline its portfolio and reallocate resources to its core operations.

Applied Materials opens its SunFab Technology Center in Alzenau, Germany. The facility will serve as Applied Materials' principal solar research and development center with a focus on boosting module conversion efficiency and lowering production costs. Applied Materials has also named Dr. Hans Stork as chief technology officer (CTO) and group vice president of its Silicon Systems Group (SSG). Dr. Stork was recently CTO and senior vice president of Silicon Technology Development at Texas Instruments.

PASSIVE COMPONENTS

Germany's PCB revenues for July were down compared to the previous month, and likewise compared to the same month last year, according to VdL and ZVEI. Less than 60 percent of the expected annual turnover was achieved in the first half of the year. Incoming orders in July were 10% lower than July 2006 and the first half of 2007 was down 7% in terms of incoming orders compared with the same period last year.

Epcos sales in fiscal 2006/2007 have grown by 10 percent to approximately EUR 1438 million and earnings before interest and taxes (EBIT) have risen by 75 percent to approximately EUR 82 million.

DISTRIBUTION

Abacus Group has entered into a franchise agreement with Power Integrations, a supplier of high-voltage power conversion ICs. This agreement empowers Abacus to distribute PI power supply ICs in the UK..

Anglia announces the launch of Anglia Lighting, a new division dedicated to providing a broad range of products to manufacturers, contractors and installers of LED lighting systems. Anglia has built up a strong presence in optoelectronics, with a portfolio that includes LEDs from Cree and Avago Technologies; drive circuitry from Zetex and Power Integrations; microcontrollers from ST and Microchip; thermal management products in the form of heatsinks from Aavid Thermalloy and Calinar; and fans from NMB Minebea.

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

or by fax 44/1494 563503.

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European Firms Increase Participation in American Renewable Energy Markets

By Douglas Bess, Editor, PowerPulse.Net

From Germany to Spain, a growing number of European firms are targeting growth opportunities in renewable energy markets in North America including both photovoltaics and wind power. Not only are those firms making more and more sales in North America, many are also expanding production in the U.S. European firms are engaged in mergers as well as setting up their own manufacturing operation to strengthen their standings in North America.

North America is a Shining Opportunity for Photovoltaics

Q-Cells AG, its subsidiary Calyxo GmbH and US-based Solar Fields LLC have decided to merge their activities in the production of CadmiumTelluride photovoltaic modules. The three companies have been working closely together since Solar Fields exclusively licensed its deposition technology to Q-Cells' subsidiary Calyxo.

To accelerate the development and commercialization of the technology and to make optimal use of its economic potential, Q-Cells and Solar Fields have now entered into an arrangement that they claim aligns their businesses and provides for a successful expansion strategy. Calyxo GmbH takes over all of Solar Fields IP and thus strengthens its technological basis by gaining perpetual exclusive access to the technology and its exploration.

Solar Fields' assets have been transferred into a 100% US subsidiary of Calyxo GmbH, the newly formed Calyxo USA Inc., that shall focus on R&D activities and rapid further improvements of the technology. To this, all of Solar Fields' employees will also be transferred to Calyxo USA.

Solar Fields itself has in return received 7% of the shares in Calyxo and thus become a minority shareholder in Calyxo GmbH. It can hence participate in the significant upside potential of the technology. The company also receives a one-time payment of US $5 million. Q-Cells AG retains the other 93% of the shares.

Calyxo is currently building its first prototype facility with a nominal capacity of 25 MWp at its company site in Bitterfeld-Wolfen (Germany), which is expected to start production in the first quarter of 2008. Q-Cells has committed itself to secure the financing of future expansion plans and to support the further growth ambitions of Calyxo GmbH.

OC Oerlikon Corp. AG, a global manufacturer of production systems, components and services for high-tech industrial applications, announced that Oerlikon Solar will become a new segment within the Oerlikon Group as the company continues to expand its commitment to its solar business. This new business segment is under the leadership of Oerlikon Solar CEO Jeannine Sargent.

"The creation of a stand-alone segment within Oerlikon further strengthens our solar presence and will enable us to extend our leadership in the marketplace," Sargent said. "We are in a strong position to grow our market share while continuing to supply the industry with highly efficient solar manufacturing fabs."

To escalate production capacities, increase research and development activities and enter new business areas quicker, Oerlikon Solar will bring together all solar core competencies and new technologies under one umbrella. Providing complete, fully automated solar production solutions to customers requires seamless integration of key technologies such as thin-film coating, laser advancements, specialized mechanical engineering fields and global customer support. As part of this push, Oerlikon Solar plans to double production capacity at its plant in Truebbach, Switzerland and has established a 1 MWp pilot line.

Additional manufacturing locations in Asia-Pacific and the United States are also currently under evaluation. Moreover, beginning in 2008 Oerlikon will report the solar segment financial figures separately as part of an ongoing effort to increase transparency. Additionally, Oerlikon Solar will carry full profit and loss responsibility for its global business.

North American Wind Blowing Opportunities to Europe

Recent announcements reveal the continued extent to which European companies are investing in the North American wind energy market, which the Global Wind Energy Council has declared will be the most important regional market in the world between 2007 and 2010.

The Power Generation Group of Siemens AG announced that it will supply 86 of its SWT-2.3-93 wind turbines with a capacity of 2.3MW each for the Wolf Island Wind project, located near Kingston in Eastern Ontario, Canada. The purchasing company is a subsidiary of Canadian Hydro Developers Inc.. The wind farm is expected to be operational by 2008. Canada is expected to be one of the five largest wind power markets in the next ten years.

With the most recent order, Siemens states that it has secured wind turbine orders in 2007 totaling more than 750MW in North America (with a monetary total of USD $1.1 billion, €770 million).

Vestas announced that it had received an order of 201MW for 67 units of its V90-3.0 MW wind turbines from American company Horizon Wind Energy, to be installed at Horizon's Meridian Way Wind Farm located in the state of Kansas. The order comprises of the supply and commissioning of the turbines, and a five-year service and maintenance agreement. Delivery of the 67 wind turbines is expected to begin in the middle of

2008. Horizon is a fully-owned subsidiary of Energias de Portugal S.A., one of the world's largest generators of electricity from renewable sources.

Siemens Power Generation announced the grand opening of its new wind turbine blade factory in Fort Madison, Iowa. The factory is expected to produce approximately 600 wind turbine blades per year, which will be shipped to wind farms in the U.S. It's the company's first manufacturing plant for wind turbine components in the U.S., for which the total investment is more than €20 million (approximately $28 million USD).

Siemens established the 311,000-square-foot turbine blade manufacturing facility in Fort Madison to better meet the strong demand for clean wind energy in the U.S. Blades for the company's 2.3-MW wind turbines are manufactured at the new site. The first 148-foot-long, 12-ton blades were delivered to a customer site in Texas in August 2007. So far, the company has hired 220 employees in Fort Madison – a number that is expected to grow to 260 people by the end of the year.

The total employee headcount of the Siemens Wind Division has quadrupled since the acquisition of the Danish company Bonus Energy in December 2004. Siemens Wind Power now employs more than 3,200 employees worldwide, including 400 people in the U.S. The number of its wind turbine installations also has tripled since 2004. The company expects to install 1,500 MW of new capacity worldwide in 2007.

Since entering the wind industry, Siemens has greatly expanded the capacities of its worldwide manufacturing network. In addition to opening the wind turbine blade manufacturing facility in Iowa, the Danish facilities in Brande and Aalberg have been expanded, and a new blade factory was opened in Engesvang, Denmark, in 2006.

"By opening a new factory in Iowa we will be able to increase our ability to competitively serve the important North American market," stated Andreas Nauen, Head of Siemens Wind Power. "We are especially pleased that we were able to build our first U.S. facility in Fort Madison. Iowa is one of the most supportive states of wind energy and other renewables."

European Power news is published daily at:

www.PowerPulse.Net

How to Make Linear Mode Work

Linear mode is in the "saturation" region of the transfer characteristic

Linear mode is when a power transistor is operated partially on rather than fully on or fully off. The control or limiting of current through a transistor in linear mode combined with the ability to turn the transistor fully on are very useful for applications like electronic loads, circuit breakers, solid state relays, inrush current limiters, and even transient voltage suppression.
The versatility of a power transistor enables combining these functions into a single unit, like a "smart" solid state relay that protects itself and the load.

By Jonathan Dodge, P.E., Applications Engineering Manager, Microsemi Power Products Group

Theoretically, linear mode operation is very easy. Simply bias the gate to deliver some desired amount of current or power, and stay within the manufacturer's Forward Safe Operating Area (FSOA) according to the datasheet. The reality however is that linear mode operation is one of the trickiest power applications of all, turning many "simple" designs into a reliability nightmare. This article points out the pitfalls of linear mode operation and provides guidance and examples for highly reliable linear mode designs. The discussion focuses on power MOSFETs but applies equally to IGBTs.

The Linear Mode Challenge

There are three fundamental challenges with linear mode design:

1. The information in manufacturers' datasheets is often inadequate or even incorrect concerning linear mode operation.
2. Thermal instability makes linear mode operation much more delicate than indicated by maximum power dissipation or die junction temperature ratings.
3. Insulated gate devices (MOSFETs and IGBTs) vary significantly in threshold voltage and transconductance from part to part.

Thermal Instability and Gain

The drain current is easily controlled by adjusting the gate-source voltage. However, there is inevitably some variation in temperature across the die, causing thermally-induced variation in current across the die. If the temperature-dependent change in current density is thermally unstable (which is normally the case in linear mode), the result can be hot spotting and current hogging within the die. This hot spotting phenomenon leads to a failure mode similar to second breakdown in bipolar transistors. This failure mode limits the true FSOA to a much smaller area than an FSOA based only on thermal resistance, which is often published in datasheets. Avoiding this failure mode is the biggest challenge with linear mode design. Therefore, it is worthwhile to understand the cause of this failure mode.

Linear mode operation is in the "saturation" region of the transfer characteristic (as opposed to the Ohmic region), as shown in Figure 1.

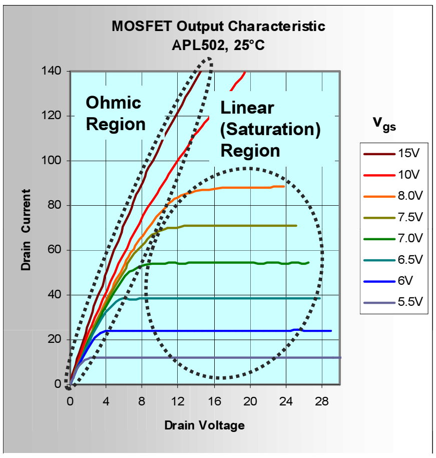

Figure 1: MOSFET Output Characteristic

In this area of operation, the drain current is related to the gate-source voltage v_{gs} and the threshold voltage V_{th} by the equation:

$$i_D = \kappa(v_{GS} - V_{th})^2 \quad (1)$$

where:

$$\kappa = \frac{\mu_e \cdot C_{OZ} \cdot W}{2L}$$

and μ_e is the electron mobility, C_{OZ} is the gate oxide capacitance, W is the channel width, and L is the channel length. Gain and κ are related in that the wider the channel width W is and the shorter the channel length L is, the higher the gain is.

Since μ_e decreases with temperature, κ also decreases with temperature. (The capacitance does not change value with temperature but does with drain-source voltage). Likewise, V_{th} decreases as the temperature increases. As a device operating in linear mode heats up, the reduction in electron mobility tends to reduce the drain current, thus leading to thermal stability. This is countered by the reduction in threshold voltage, which tends to increase the drain current. The negative temperature coefficient of the threshold voltage leads to thermal instability.

These relationships can be expressed mathematically by differentiating (1) with respect to temperature, and substituting in the relationship for power dissipation and temperature $\partial T = \partial i_D \cdot R_\theta \cdot V_{DS}$, such that we have a stability factor S:

$$S = R_\theta \cdot V_{DS} \cdot \left[-2\sqrt{\kappa \cdot i_D}\frac{\partial V_{th}}{\partial T} + \frac{\partial \kappa}{\partial T} \cdot \frac{i_D}{\kappa} \right] \quad (2)$$

The larger the value of *S* is, the more thermally *unstable* the device is, meaning that a localized temperature increase is regenerative. If *S* is negative, the device is thermally stable in linear mode. Note that the values of

$\frac{\partial \kappa}{\partial T}$ and $\frac{\partial V_{th}}{\partial T}$ are always negative.

From (2) we can see that a device becomes more thermally stable (*S* becomes smaller) as:

1. The thermal resistance is reduced
2. The drain-source voltage is reduced
3. The drain current increases
4. The gain (and hence κ) is reduced
5. The magnitude of the threshold voltage temperature coefficient $\frac{\partial V_{th}}{\partial T}$ is reduced

The fourth and fifth items depend entirely on the device design. Thus a device can be designed to be more thermally stable, resulting in a wider safe operating area in linear mode. This is what has been done for the Linear MOSFET series and most ARF series RF MOSFETs from Microsemi Power Products Group (formerly Advanced Power Technology).

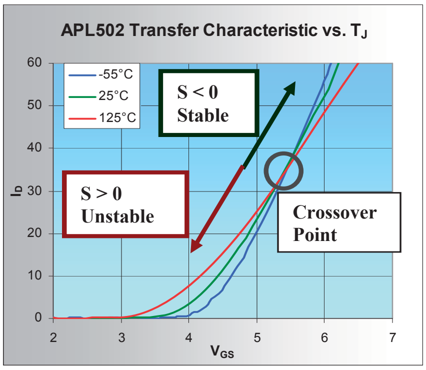

Figure 2: MOSFET Transfer Characteristic

Figure 2 shows the transfer characteristic of a MOSFET at three temperatures. This graphically illustrates the thermal stability factor expressed in equation (2). There is a crossover point through which each temperature curve passes. Below this point, the threshold voltage effect dominates, and localized changes in current are thermally unstable. Above the crossover point, the change in gain dominates, and the device is thermally stable.

The Failure Mechanism

Since the transfer characteristic crossover point is at a relatively high current, linear mode operation is almost always in the thermally unstable area below the crossover point. The problem is that the hotter areas on the die have higher current density, thus reinforcing hot spotting.

Every MOSFET and IGBT has an intrinsic bipolar transistor. The gain of this transistor increases as the device heats up, and as the drain-source voltage increases. The bipolar transistor base resistance also increases with temperature, and the base-emitter voltage drops. All these factors combine to increase the likelihood of generating enough voltage across the base resistance to turn on the bipolar transistor as the die heats up. Thus if a hot spot on the die gets hot enough, it can turn on the bipolar transistor in the area of the hot spot. This is what causes linear mode failure: the device latches up in a hot spot, and the resulting thermal runaway and extreme heating cause a burnout spot, shorting the drain to the source and possibly the gate to the source as well. Some damaged devices can actually be turned on, but when turned off they can only support voltage with a huge leakage current through the damaged area.

Linear Mode Design Guidelines

The first step to create a reliable linear mode application is to contact a device manufacturer's applications engineer. You may find a treasure trove of information and tips that are not published in datasheets. The second step is to determine the true FSOA for devices you are seriously considering to use. Unfortunately this cannot be done by simulation because simulation models do not tell you when a device would actually fail. A number of devices must be tested to failure to determine the operating FSOA. This is a benefit of step one: this work is probably already done. Once you have a graph of failures at various voltages and the corresponding currents, you can create a curve fit or mathematical model for the data. By adding some safety margin, you get a true FSOA.

V_{CE} (V)	I_C (A)	Power (W)
500	0.227	114
450	0.25	113
400	0.338	135
350	0.413	145
300	0.473	142
250	0.565	141
200	0.68	136
150	1	150
100	1.84	184

Table 1: Linear Mode Failure Data: APT200GN60J

Table 1 shows linear mode power dissipation data for an APT200GN60J IGBT, where the collector-emitter voltage was fixed and the linear mode current was increased until the device failed. Results at several collector-emitter voltages were recorded.

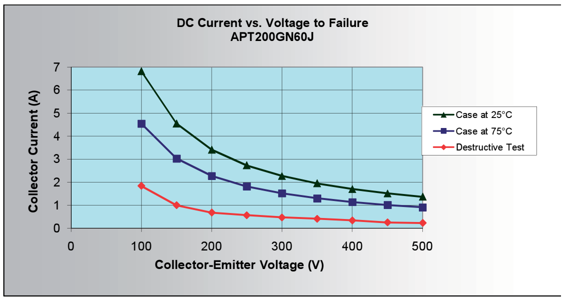

Figure 3: Measured & Theoretical FSOA

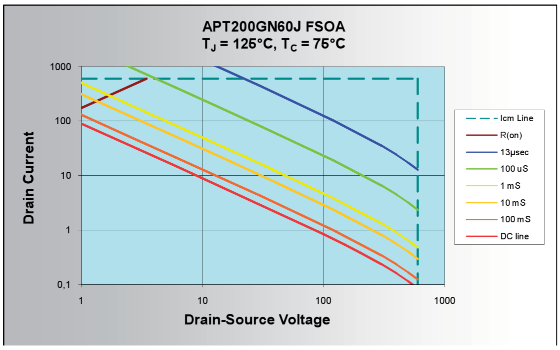

Figure 4: Usable FSOA: APT200GN60J

The parts were mounted on a liquid-cooled heat sink. The measured case temperature T_C was about 75°C at failure. Based on curve fitting, the average junction temperature at failure is estimated to be about 175°C, which happens to be the same as the rated maximum junction temperature. It is important to note that some devices fail in linear mode with an average junction temperature well below the rated maximum.

Figure 3 shows the data in Table I as well as the theoretical FSOA curves based on constant power dissipation with T_J = 175°C and T_C = 75°C and 25°C. Notice how much less the true FSOA is than what would be predicted based on constant power dissipation, limited only by thermal resistance (represented by the curves with T_C = 25°C and 75°C). Most datasheets publish an FSOA curve with the case at 25°C. Designing to that curve would result in six times more current at high voltage than the device can actually handle!

Even derating to the measured case temperature of 75°C would result in too much current unless the hot spotting failure mode is taken into account. The only way to do that is to test several devices to destruction.

A curve fit was applied to the DC current destructive test data in Figure 3. Then pulse FSOA curves were generated based on transient thermal impedance data. The results are shown in Figure 4. This is a usable FSOA for the APT200GN60J part. By setting the junction temperature to 125°C (below where the part fails), some safety margin is created. Notice the DC curve is shifted down in current compared to the destructive test curve in Figure 3. It is always recommended to stay well away from the maximum rated junction temperature in linear mode, and there should be at least 20°C margin from the average junction temperature at the point of failure. For Figure 4, 125°C is the maximum recommended junction temperature, providing a healthy 50°C margin from the failure temperature.

Now let us consider the FSOA of a MOSFET that was designed specifically for linear mode operation: the APL502J.

Figure 5 shows the usable FSOA for the APL502J. Compared with the FSOA of APT200GN60J in Figure 4, the APL502J has a wider FSOA. The tradeoff is conduction loss versus FSOA ruggedness. Turned fully on and with a 200A load, the typical collector-emitter voltage of the APT200GN60J is only 1.7V when hot (1.5V at room temperature). By comparison, at 26A, 125°C, the APT200GN60J has about 6 times less conduction loss than the more rugged APL502J.

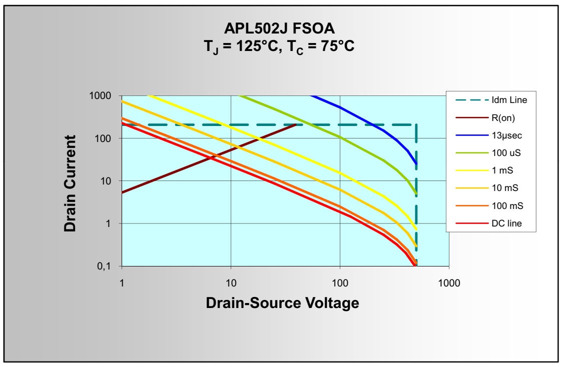

Figure 5: Usable FSOA: APL502J

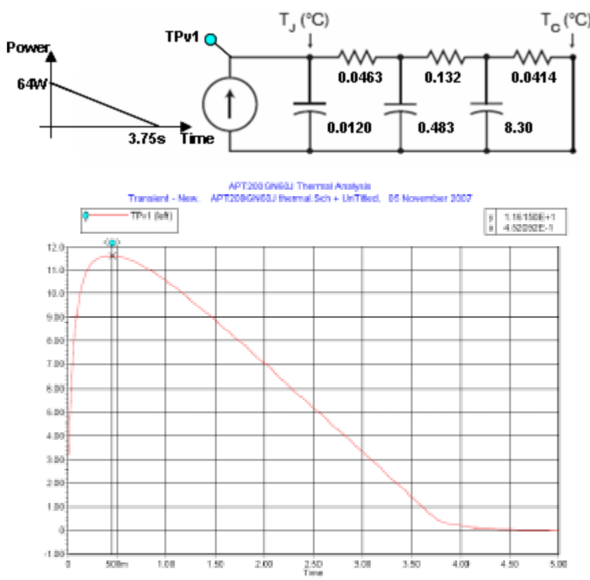

Figure 6: Transient Thermal Simulation

Notice in both Figures 4 and 5 that the FSOA curves drop at higher voltage (plotted on log-log scales). The FSOA curves based on constant power dissipation are straight lines. If you see a straight-line DC FSOA curve in a datasheet, beware! The graph is probably not usable for linear mode.

Design Examples

DC Solid State Relay

The APT200GN60J works well in a DC SSR application where it can operate in linear mode to limit current while charging a large capacitor bank, then operate fully on with minimal conduction loss. The capacitor charging current would need to be very limited to stay within the FSOA of the IGBT. This may not be an issue if there is no stringent charge time requirement.

Requirements

Suppose that we need to charge a 1500µF capacitor bank from 0 to 400V. We do not care how long it takes. The heatsink can keep the case temperature of the SSR at 75°C or less.

Solution

According to the FSOA graph in Figure 4, the current is most constrained at the maximum applied voltage, which is 400V in this case. From data used to create Figure 4, at 400V we can safely charge the capacitors with 0.16A (which according to Table 1 happens to be about half the current at the point of failure, so there is good safety margin). At 0.16A charge current, the capacitor bank will be charged from 0V to 400V in 3.75 seconds. Certainly it would be faster to charge the capacitors by following the DC SOA curve, thus increasing the charge current as the capacitor voltage rises (collector-emitter voltage falls). However, we don't care about charge time, and a constant charge current simplifies the control circuitry.

Staying within the DC FSOA is only half of the problem. The other thing to consider is the peak power dissipation and the resulting peak junction temperature. Since charge current is kept at a fixed (DC) value, the collector-emitter voltage will decrease linearly from 400V to almost 0V as the capacitor bank charges. So the power dissipation will peak at 64W (0.16A · 400V) as soon as voltage is applied and will decrease in a linear fashion, resembling a triangular waveform if plotted versus time.

Figure 6 shows the result of a simulation using the APT200GN60J transient thermal impedance RC circuit model, applying a linearly decaying 64W peak power pulse. The peak junction-case temperature is about 12°C. If the case temperature reaches 75°C, the average junction temperature would reach 75°C + 12°C = 85°C, well below our maximum allowed 125°C.

Electronic Load

The Linear MOSFET APL502J works well where a wider FSOA is required, such as an electronic load. In this application, many parts would be connected in parallel to meet the power dissipation requirement as well as the maximum on-state voltage requirement.

Requirements

For this example, our homemade load has a working range up to 400W, 400V, 20A, and a fully-on voltage drop of 1V or less at 20A. The heatsink can keep the case temperature of the devices at 75°C or less.

Solution

We will use the FSOA curves in Figure 5, so we want to keep the junction temperature below 125°C. First check the on-state

Figure 8 Transistor, Current Sense Resistor, and Temperature Sensor in SP1 Package

requirement. The APL502J has an $R_{DS(on)}$ of 0.090Ω maximum at room temperature (and 26A). At 125°C the $R_{DS(on)}$ is double, so 0.180Ω per part. The maximum total resistance allowed is 1V / 20A = 0.050Ω. The minimum number of parts required to meet the on-state voltage requirement is found as: 0.180Ω / 0.050Ω = 3.6, so 4 parts minimum. Note that we need some voltage drop headroom for current sense resistors, which will be discussed.

Considering the FSOA limitation, the least amount of power can be dissipated at the highest applied voltage; in this case 400V. For the APL502J with the case and junction temperatures at 75°C and 125°C respectively, the maximum current per part at 400V is 0.2A at a power dissipation of 80W. We find the minimum number of parts to handle the 400W total load as: 400W / 80W = 5 parts minimum. All our worst-case conditions are met with a minimum of 5 APL502J parts in parallel.

It would be tempting to simply parallel the parts directly, installing a separate gate resistor to each part to prevent oscillation; and monitor the current from a single point. If we simply did that however, the result would certainly be failed devices.

Now we address the last remaining challenge of linear mode design: part-to-part variation of the threshold voltage. In linear mode, parts cannot be directly connected in parallel; each part must be forced to carry its share of current. This can be done in a number of ways.

If the maximum on-state voltage requirement allows it, a fairly high resistance can be installed in series with each MOSFET, thus carrying a significant portion of the thermal load (the resistors get hot). The resistors can also be used to somewhat balance the current between the MOSFETs by connecting a resistor between the source of each MOSFET and the gate drive return, providing negative feedback to each gate. Perfect balancing would not be possible. Also, sorting parts based on threshold voltage is not feasible since a tiny difference in threshold voltage between MOSFETs results in a substantial current mismatch.

With the low on-state voltage requirement of this design example, a cost-effective technique is to use a current sensor and an amplifier circuit to individually control the current by adjusting the gate-source voltage of each MOSFET. Figure 7 shows a conceptual schematic with three parallel MOSFETs. Low-value resistors or Hall Effect sensors must be used to keep the total voltage drop within specification.

To simplify assembly and minimize system size and cost, Microsemi Power Products Group is introducing a series of parts intended mainly for linear mode operation, although suitable for switch-mode applications as well. These parts, in a compact SP1 package, include a suitable power transistor (Linear MOSFET or Field Stop IGBT), a low-inductance current sense resistor in series with the source, and a temperature sensor.

The integrated current sense resistor is mounted on the same ceramic insulator as the power transistor, minimizing inductance and providing cooling for the resistor, which dissipates only a few Watts at maximum load. This makes it simple to monitor the drain-source voltage, the drain current, and the case temperature simultaneously. This information can be processed digitally such that the FSOA curve can be followed, allowing full utilization of the device and minimal system cost.

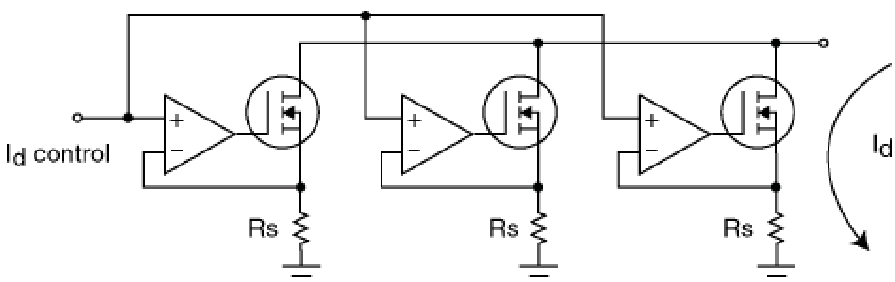

Figure 7 Linear Mode Paralleling Concept

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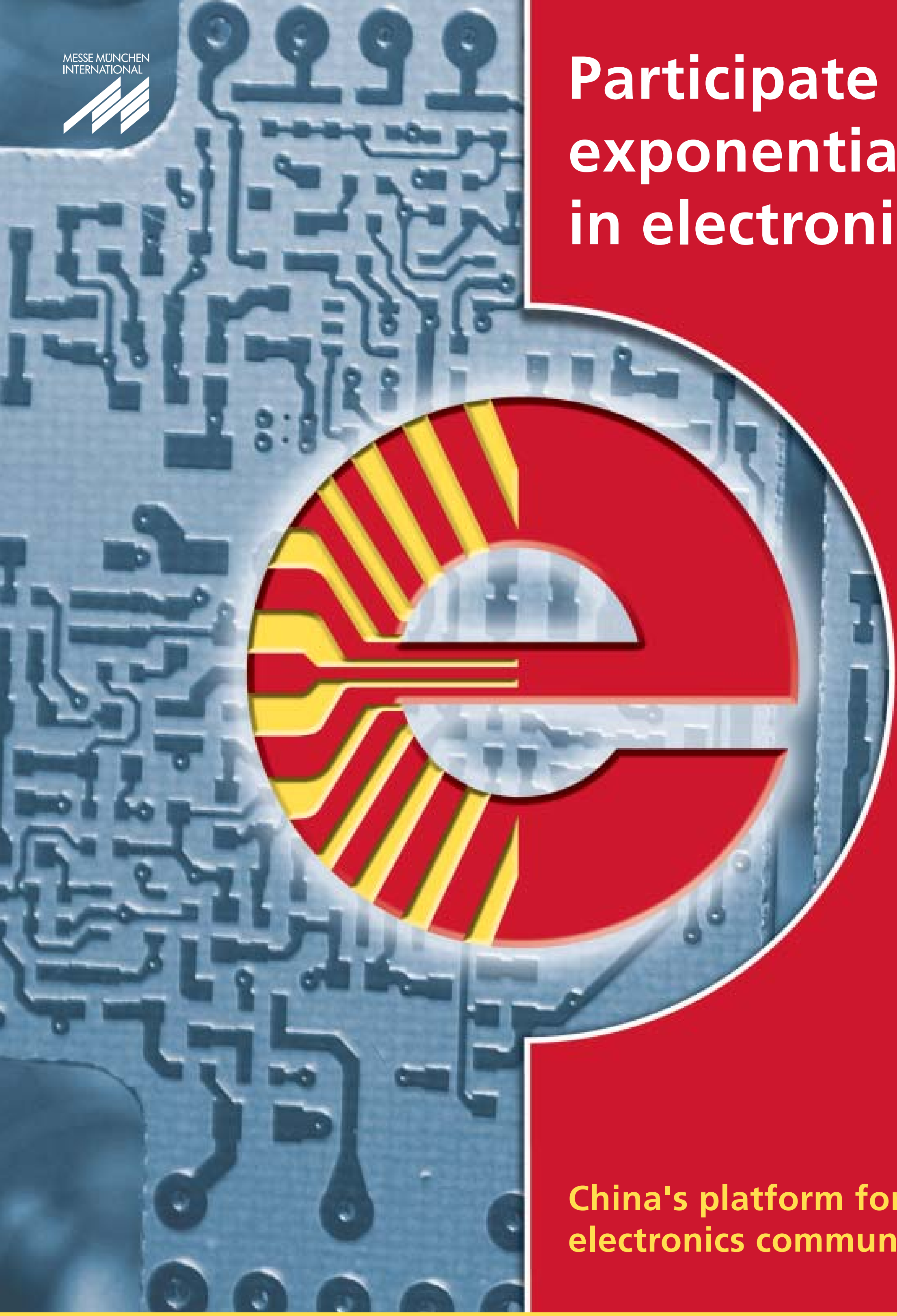

My Advent Calendar centerfold has windows for each day running up to Christmas with friends portrayed in each window who will be familiar to you from my gallery. The windows are numbered for the days in December from 1 to 24. Send me a note or email listing those you can identify by window and name. Five or more correct will get you into the Christmas tombola and there will be nice gifts from Saint Nick for six winners every week. The drawings will take place every weekend prior to Christmas Eve.


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The Application-Specific Power Semiconductors Diodes

One diode technology is not suited for all applications

Development trends in high voltage power devices continue to move towards high performance, application-specific devices, and higher levels of integration and advanced packaging. The demand for electricity is increasing and at the same time, the cost of power generation is also going up.

By Sampat Shekhawat, Fairchild Semiconductor

There is increasing pressure to reduce the harmful emission of gases. This is forcing equipment designers to increase efficiency and performance. It looks like even government agencies will set the new minimum efficiency limits. Different applications use different power topologies. In all these topologies, device parameters play vital role in circuit performance. This is generating the need to tune the device parameters and stray capacitances for each application. Almost all the power equipment used in the industry such as automotive & transportation, household & home entertainment, communication, power generation, military & aerospace and alternate source of renewable energy that one can think of, use these power devices. The performance, size and cost of these equipments also depend on these devices. This is driving the need for application-specific devices. This paper describes what kind of power devices are needed for different applications.

Introduction

Switch-mode power supplies (SMPS) and white goods are increasingly being designed with an active power factor control (PFC) input stage to meet international regulatory standards for harmonic content. Historically, power factor correction circuits have used a boost converter topology that combines a power switch and boost diode. The active boost PFC circuits use different topologies and need application-specific devices in-order to get the best performance. DC/DC power supplies encounter the power levels, some where from a few watts for battery-operated portable equipment, several hundred to several kilo-watts for home entertainment, computer and office equipment. Synchronous rectification is also becoming popular method to improve SMPS efficiency. Motor drives can use from a tenth of a Watt to few mega Watts. Rectifiers and inverters are designed for several hundred mega Watts of power levels used for transmission of electric power. All these systems need application-specific devices to optimize performance and reduce cost. The most popular power devices used are diodes, IGBTs, and MOSFETs will be discussed in these three different sections.

Diode

Rectifiers are one of the most common devices used in power electronics. Some of these common uses are input side rectification, secondary side rectification, AC switch, free wheeling diode (FRD) for inverters and DC/DC converters, boost diode for both discontinuous & continuous current mode PFC, etc. In all of these applications, diode selection is very important. Like any other semiconductors a diode is not an ideal device. If the diode is not selected or designed properly for the application, the diode parameters can increase the turn-on losses for the IGBT or MOSFET and even for the diode itself. Snappy diodes as shown in figure 1 will increase the EMI in the circuit and also can destroy themselves as well as their co-pack IGBT switch in inverters (motor drive, UPS and solar inverter) during reverse recovery. The performance of P-i-N diodes has been continually improving as a result of new simulation tools to optimize structure. Maximizing operating frequency requires faster and faster diodes. In silicon technology, diodes have been optimized for different applications and these minority carrier silicon diodes are categorized as follows.

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

Figure 1 shows the comparison of reverse recovery and V_F of some of these 600V different technology silicon diodes and also silicon carbide (SiC) Schottky diode too.

Diode Switching Performance

Figure 2 shows a hard-switched (continuous conduction mode) boost PFC power supply circuit. The load is connected across V_O. The control pulses are applied to the negative bus and gate of the MOSFET (Q_b) through a gate driver circuit. In the inductor charging mode when Q_b is switched on, the input current rises through the boost

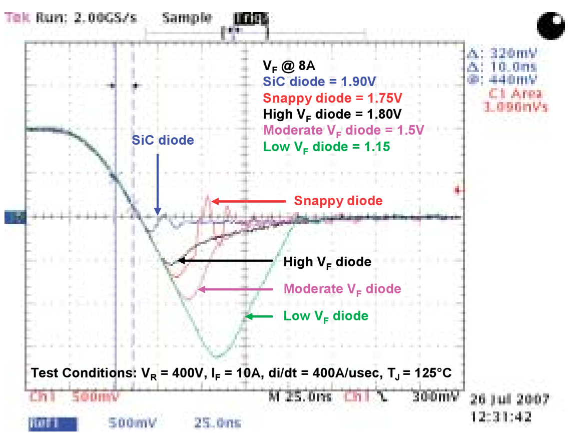

Figure 1:
Reverse recovery mechanism of different diode technologies

inductor (L_b) and the boost MOSFET. During this mode, the energy is stored in the boost inductor. In inductor discharging mode when the Q_b is turned off, the stored energy in L_b is transferred to the load and output filter capacitor through D_b. The D_b conducts the current when Q_b is off. The power dissipation during this time is due to the forward drop of D_b. Just before diode is forced from a forward to reverse bias condition the intrinsic region of the P-i-N diode is flooded with minority carriers during forward conduction. These carriers must be removed from the P-i-N junction in order to support the reverse voltage. As Q_b turns on again, the boost diode current I_F, as shown in Figures 3, is transferred from the D_b to Q_b. The transfer of current begins when the gate voltage of the Q_b equals the threshold voltage at ($t = t_o$). At time $t = t_1$, all of the boost diode forward current has been diverted to Q_b. The D_b current decays at the rate di_F/dt from time to to t_1. The time duration from t_0 to t_1 (t_r) is dependent upon the di_F/dt. The turn-on energy loss $E_{(ON1)}$ in the boost switch during t_r is given by following equation:

$$E_{(ON1)} = \left[\frac{V0}{2}\right] I_L \times t_r \qquad (1)$$

Higher t_r means lower di_F/dt, which will allow more minority carriers to recombine, hence less I_{RRM} but that still increases $E_{(ON1)}$. At time $t = t_1$, diode reverse recovery mode starts. An extra current starts to flow through the C_f capacitors, stray inductance, and boost diode during this mode. During t_a, the diode is not yet able to support bulk capacitor (C_f) voltage. Therefore, Q_b supports the bulk capacitor voltage. Hence, Q_b is stressed due to the presence of both high voltage and high current. The results in significant power dissipation during ta for the boost switch. This Q_b turn-on loss $E_{(ON2)}$ during ta is given by the following equation 2.

$$E_{(ON2)} = V_0\left(I_L + \frac{I_{RRM}}{2}\right)t_a \qquad (2)$$

If the I_{RRM} is excessive, electrical stresses may exceed the SOA limit, and cause failure of Q_b or D_b. The higher I_{RRM} also increases ripple current in the output filter capacitors C_O. The I_{RRM} and correspondingly ta of the diode should be lowered in order to reduce $E_{(ON2)}$. The I_{RRM} can be reduced through the use of increased gate resistance (R_G), which lowers di_F/dt and increases t_r and t_a. This results in higher $E_{(ON1)}$ and $E_{(ON2)}$. This phenomenon is shown in figure 4. The reduction in I_{RRM} gets overcompensated by increase in t_r and t_a. Conversely, as gate resistance is lowered, the resulting voltage overshoot and oscillations during the tb phase of diode recovery dictate the lower limit of R_G. Reducing the gate resistance below this practical limit, which largely depends on the boost switch and boost diode combination, may increase reliability problem. Both I_{RRM} and t_a of the Fairchild Stealth™ & Stealth™ II diode have been reduced compared to competitors diodes for the same di_F/dt. This lowers the turn-on loss of the Q_b. Additionally, the soft recovery characteristics of the Stealth™ design result in reduced oscillations during the t_b phase. This property provides a measure of dynamic ruggedness, which is not present in snappy recovery diode designs. This is due to the fact that voltage overshoot present during the recovery of snappy diodes may be in excess of the rated blocking voltage of the boost diode or diode-IGBT co-pack for inverter applications. High voltage and current are present across the diode during t_b, resulting in a higher dissipation. Large voltage spikes and ringing also may appear during this phase. This is caused by snappy recovery (high di_{RM}/dt) of the diode and stray inductance in the current path. Snubber circuits are commonly employed to overcome voltage overshoot due to snappy recovery. Unfortunately, these components add cost to designs, take up valuable space and often contribute additional losses. Use of a soft recovery diode eliminates the need for a snubber because of reduced ringing and overshoot due to the lower di_{RM}/dt during the t_b phase. The Fairchild Stealth™ diode has a softness ratio greater than one. For critical current mode or boundary current mode PFC, moderately low V_F and moderately low I_{RRM} diodes are ideal since there may be still some minority carriers may be left when boost switch is turned on.

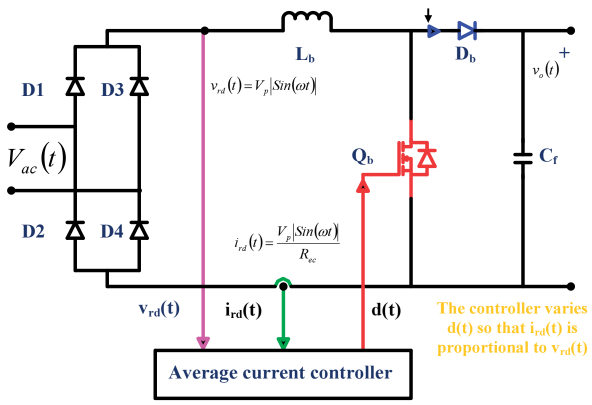

Figure 2: Boost PFC

As the operating frequencies (f_s) of power supply designs continue to increase, diode performance must be optimized. Accordingly, fast and soft recovery diodes generally reduce overall losses by lowering the turn-on loss of boost switch and or co-pack IGBT. Additionally if the softness is increased too much then also IGBT turn-on loss ($E_{(on3)}$) will increase as shown in equation 3.

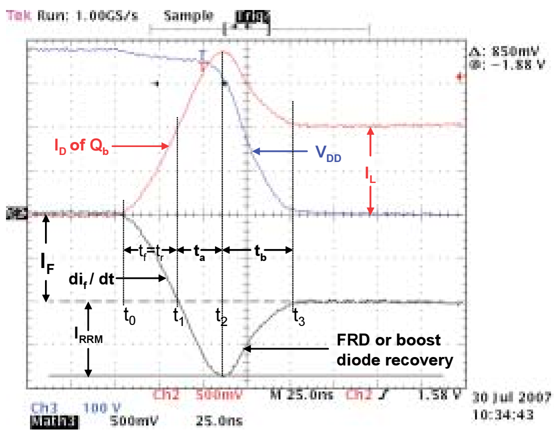

Figure 3: Transfer of current from boost diode to boost switch

$$E_{(ON3)} = V_0\left[\frac{I_L}{2} + \frac{I_{RRM}}{3}\right]t_b \qquad (3)$$

Figure 4 shows that the increase in R_g increases $E_{(ON3)}$ even though I_{RRM} is reduced but reduction of I_{RRM} is overcompensated by increase in t_b. Equation 4 shows total turn-on loss of the boost switch Q_b

$$E_{on} = \frac{V_0}{2}\left[I_L\left(t_r + 2t_a + t_b\right)\right] + \frac{V_0}{6}\left[I_{RRM}\left(3t_a + 2t_b\right)\right] \qquad (4)$$

The loss in the diode during to tb is shown in following equations 5

$$E_{OFF(D)} = V_{DC} I_{RRM} \frac{t_b}{6} \qquad (5)$$

This loss further increases as the ambient or diode junction temperature is increased. This causes further increase in stored charge and greater reverse recovery losses due to higher junction temperature.

Finally, diode leakage current is another important parameter to consider, especially at high temperature operation. The anode to cathode leakage current should be kept as low as possible in order for the

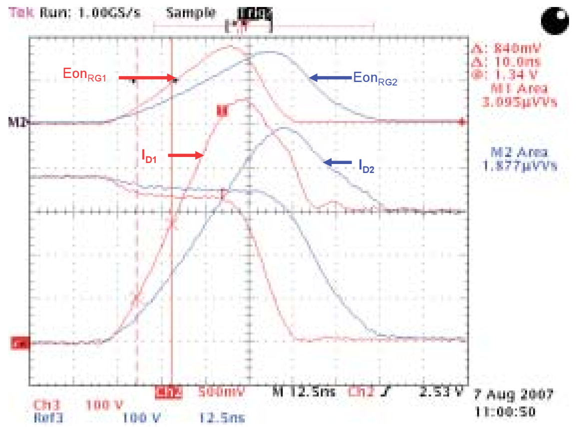

Figure 4:
Effect of gate resistance (Rg) on turn-on loss and diode recovery

power dissipation in the off state to be kept at a minimum. Forward recovery is also important. For hard switching application forward switching should be considered and diode should be designed or chosen with less forward recovery voltage and time.

Diode Selection

Another PFC known as discontinuous current mode (DCM) is used at very low power level where the diode recovery problem is not there and control is also simple. However the increased input pulse current increases EMI and the system can become unstable at light loads. This needs an oversized boost switch since R.M.S current is high due to higher peak current. Ripple current stresses the filter capacitor. There is no diode recovery problem so a low forward voltage (V_F) drop diode can be used. Fairchild's low V_F Ultrafast™ and moderate V_F Hyperfast™ diode will be good choice for this application. However low V_F Ultrafast™ diode has high Q_{RR} and T_{RR} and can not be recommended for hard switched applications. The disadvantages of DCM PFC can be over come by CCM boost converter where boost diode and boost switch generally operate in the hard-switching mode. The drawback of hard switching is that the diode reverse recovery characteristics increase the switching device's turn-on loss and the generated EMI. The diode's reverse recovery characteristics describe how the device transitions from the forward conducting state to the reverse voltage blocking state. If the return of the reverse recovery current from I_{RRM} to zero is too snappy as shown in figure 1, high voltage spikes and severe EMI are generated. Slowing down the switch turn-on rate increases the switch turn-on loss. Adding soft switching circuitry adds to circuit cost and complexity. However, with the use of Fairchild's soft and low Qrr and Trr Stealth™ diode, the diode snubber circuitry can be eliminated or reduced, the boost switch turn-on loss is reduced and CCM PFC can be implemented in the hard-switched mode up to 130 KHz .

For input side rectification Ultrafast™ (low V_F diode) diode provides the best performance because of low forward voltage dropHowever for inverter (DC/AC) and DC/DC application Hyperfast™ (moderately low V_F diode) didoe technology is further optimized for the free wheeling diode (FRD) because the frequency of operation is not high. These two diode technologies can be used as FRD for high frequency soft switched applications too where co-pack diode turns on before its IGBT turns on. In such applications, the diode recovery problem is not there. The Hyperfast™ diode has lower V_F and higher Q_{RR} and T_{RR} compared to Stealth™ diode however it has higher V_F and lower T_{RR} & Q_{RR} compared to Ultrafast™ diode, so it is good for hard switched medium frequency to high frequency applications. In some HV DC/DC applications where frequency (50 KHz to 130 KHz) of operation is high, Stealth™ diode is recommended. As the rail voltage is increased >600V switching loss starts to dominate compared to conduction loss soft and faster recovery diode can be a better choice even at medium frequencies above 15 KHz operation.

For output side high frequency rectification, the diode can increase the turn-on loss of the primary side switches then Hyperfast™ diodes or Stealth™ diodes are recommended depending on operating frequency. One can chose one of these diodes depending on frequency of operation. The Stealth™ diode can be used for high frequency and Hyperfast™ diode can be used at low frequency for these applications since there is a trade of between forward voltage drop and diode recovery. This way that one can optimize the losses by selecting proper device. The following table shows the trade-off of high V_F (Stealth), moderate V_F (Hyperfast™) and low V_F (Ultrafast™). These measurements have been taken at I_F = 10A, T_J = 125°C, V_R = 400V and di/dt = 400A/µSec.
By using equation 4 and table 1 one can do trade-off and select these diodes depending on application.

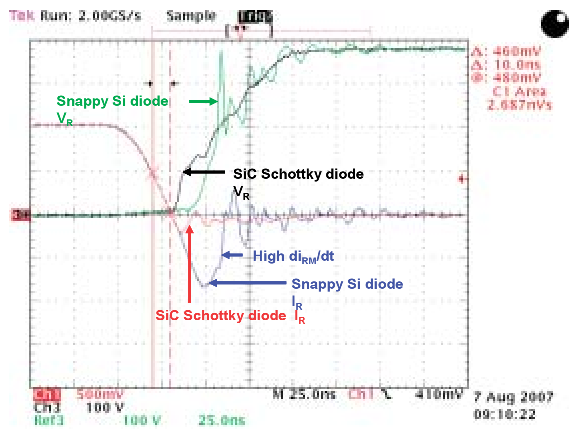

Figure 5: Reverse recovery comparison of Silicon and SiC Schottky diode

	V_F (volts)	I_{RRM} (amps)	t_a (nsec)	t_b (nsec)	Q_{rr} (nC)
Stealth	1.8	5.5	21	52	198
Hyperfast	1.5	9.1	28	44	292
Ultrafast	1.15	16.3	45	45	720

Table 1: Rectifier Selection Criteria

SiC Schottky diode

Recently, high voltage (>300V) SiC Schottky diodes also known as near zero recovery (superior dynamic performance) diodes have been introduced by few companies and are gaining popularity. These diodes can be used for high end telecom and computer power supplies. The reverse recovery characteristic is shown in figure 1 as is compared with P-i-N silicon diode. The only reverse current (IR) it carries is due to junction capacitance which is independent of temperature, forward current, etc. This current is very small as shown in figure 4.

These diodes have following advantages

1. Majority Carrier Device so zero reverse recovery current.
2. Only small junction capacitance: The charging displacement current flows which acts like reverse recovery current but it is independent of temperature and diode forward current. This acts as QRR
3. QRR is about 1/5th of the Silicon P-i-N diode
4. SiC thermal conductivity is about two - three times than that of silicon
5. Leakage current is low
6. RSPON for SiC is about 1.7mOhm-cm2 compared to 73mOhm-cm2 for Silicon @ 600V so Smaller foot-print
7. Band gap of SiC is three times higher and break down field is ten times higher than silicon
8. Much less EMI and reduced snubber size for boost & FRD
9. Boost, Buck DC/DC and DC/AC inverter (FWD): Switch turn-on loss reduced
10. SiC diode turn-off loss is less compared to Silicon P-i-N diode
11. Higher operating temperature
12. Reduces component count by converting soft switched topology to hard switched topology without effecting circuit performance
13. Higher PFC efficiency & reduced heat sink size
14. High frequency of operation so reduced boost inductor value for the PFC application hence simplified power circuit, high power density/compactness and high reliability.

But there is a trade-off between overall system cost and these advantages.

Figure 5 shows that the snappy diode has much higher diRM/dt during tb phase of the diode recovery and generates oscillation when it is going into blocking state. This oscillation can kill co-pack IGBT or even diode itself. SiC Schottky diode is ideal diode as a free wheeling diode for inverters used for motor drive, UPS, PV solar inverters, automotive grade inverters etc. Efficiency is very important for PV Solar Inverters and SiC Schottky diode can help to improve that. It also increases reliability because reverse recovery dv/dt is low compared to a snappy diode as shown in figure 4.

Conclusion

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

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The Ecconowatt Line of Power Semiconductor Packaging

Ceramic packages exclusively for Power Semiconductors

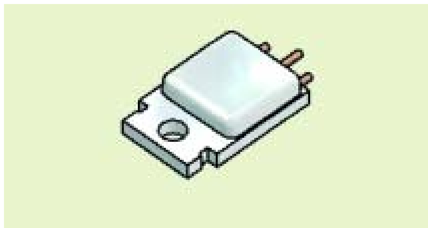
The driving forces in the semi-conductor market make it the correct time to market a low cost ceramic package to the power semi-conductor industry. CNS has patented a low cost ceramic package and has designed the equipment and process to enable customers to assemble and seal this package at a significantly lower cost than current plastic packaging processes while achieving the reliability of ceramic.

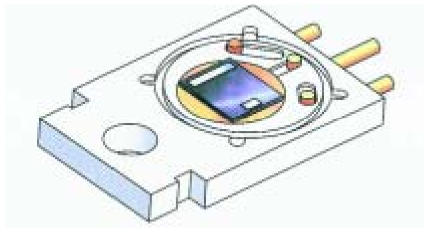
By: R.J Satriano, R. Culbertson and D. Nicoletta, CNS Ceramix, Inc.

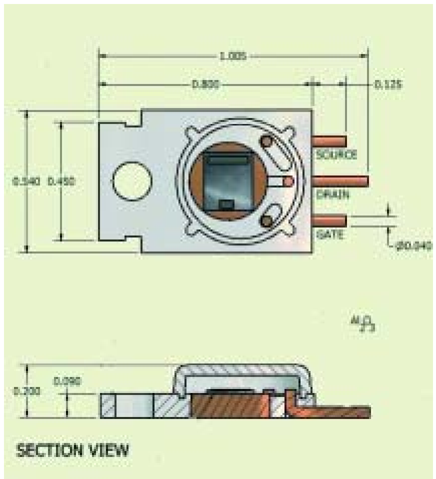
Ceramic Packaging was the enabling technology for the commercialization and growth of semi-conductor devices in the late 1960's and throughout the 1970's. As the demand for semi-conductor products soared the semi-conductor industry searched for lower cost packaging concepts to migrate their higher volume products. Early in the development of semi-conductor technology and the packages required to protect them the industry typically cycled from 40 pin packages to 14 and 16 pin packages as they progressed from development to larger scale production achieved through higher yields and smaller die. Later the development of low cost ceramic Cer-Dip Packages provided a low cost alternative and later, the development and implementation of plastic molded packaging. Today literally tens of billions of chips are packaged in plastic each year.

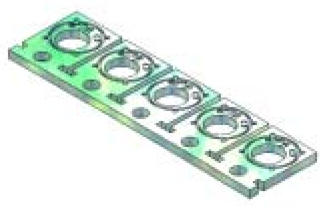
CNS has devised and patented a CERAMIC PACKAGING CONCEPT that provides the high reliability required for packaging space and military semi-conductor circuits and is cost competitive with plastic packaging systems. The Ecconowatt concept was born of a desire to provide a hermetic cost competitive header package designed to fit the footprint of the To 254 package. Recent discussions with potential customers have validated CNS's opportunity to provide packages for space and military applications and for multi-chip-module spark systems for automotive cylinder control and spark systems. The opportunity for the Ecconowatt in automotive is cost and reliability. The Ecconowatt package provides excellent mechanical and hermetic protection to circuits that are increasingly sensitive to environmental factors under the hood as plastic packaging is called upon to encapsulate larger and more complex circuits. As always the future of packaging technology is dictated by future semiconductor chip technologies and as usual there are several trends divided by the needs of various major users of electronic devices. However, as new technologies are deployed or adopted, some trends cut across all market segments, these include gate sizes, wiring density, interconnect pitch in smaller areas, heat dissipation and mechanical attributes. The new generation of circuits is relying on multi-chip-module substrate technology utilizing larger semi-conductor devices with more circuit density. All of this is expected to require increased power for high clock rates at low voltages, which equates to very high currents. All of these driving forces is pushing plastic to and in some cases beyond the capability of plastic in the areas of thermal dissipation, hermeticity, mechanical reliability, and sensitivity to mechanical and environmental forces impacting electrical performance of the circuits.

These and other market driving forces are opening the door again for a larger market share to be serviced by ceramic technology. CNS's patented ceramic packaging technology is positioned to exploit these market trends particularly in the traditional transistor header markets for space and automotive. It is expected that within 5 years the Ecconowatt family of packages can achieve manufacturing volumes of tens of millions of packages per month or more. As the Ecconowatt family develops the expected reputation for cost, performance and reliability the major plastic users will begin to switch new products to the simple and elegant Ecconowatt packaging concept and the higher end packaging market will adopt the









Ecconowatt packaging system as a cost effective alternative to higher cost ceramic and metal packaging technologies.

The Ecconowatt package provides unparalleled cost competitiveness to the existing plastic packaging process while providing the mechanical and environmental advantage of traditional ceramic packaging. CNS has designed all the required equipment for implementing the production of large volumes of Ecconowatt or related packages with an efficiency that improves upon the cost and performance of plastic packaging. The market timing is right for implementation of the Ecconowatt line of packages and its elegant, cost effective assembly system.

The Technical Aspects

The Ecconowatt family of packages achieves cost parity with plastic packages through the use of common materials and processes in a patented design. The combination of materials and manufacturing technique provides significant manufacturing cost reduction through the use of alumina and solution metal technologies. 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

The core forming technology is a proprietary re-forming technology developed and offered to CNS on an exclusive basis by a partnership of American Ceramic Technology, Inc./Ragan Labs, LLC. This technology enables the manufacture of simple and complex shapes at room temperature using low pressure re-flow technology. An added feature of this reforming technology is that it can be reformed in one or multiple steps without inducing density variations. Further the technology is offered in multiple ceramic compositions that can be tailored to a specific customer's requirement, as needed.

CNS's patented Ecconowatt package is not only a family of ceramic packages but an entire manufacturing system designed to provide the customer the ability to produce high reliability devices at plastic cost and as such it is unique. Additionally, the Ecconowatt can be designed as a single chip or multiple chip module depending on the customer's intended application.

The Ecconowatt technology provides CNS the ability to capture new applications where plastic is not reliable and metal and ceramic packages expensive. The manufacturing and assembly technology will permit CNS to migrate from development to very high volume eliminating migration to alternative low cost technology such as plastic to satisfy the high volume cost requirements.

Strategy

The Ecconowatt is initially being targeted for space, automotive and other markets where the cost and reliability advantage of the Ecconowatt can be brought to bear. Current space applications are generally less cost sensitive than automotive. This market currently is serviced by metal and multilayer ceramic designs. These packages cost several dollars each and typically require individual bonding and assembly. Due to the low cost to manufacture the Ecconowatt, it can be positioned to benefit from the high price of the competitive packaging products.

A ECCONOWATT PRODUCT ATTRIBUTES

1. Designed to be handled in multiples of 5 position strips.
2. Device assembly automatable.
3. Hermetic.
4. Surface Mountable.
5. Light in Weight.
6. Vacuum braze sealed.
7. Low Cost.
8. Patented.
9. Can be manufactured in multiple ceramic compositions.

B. ECONONWATT CONFIGURATIONS

1. Miniwatt – To-251-D-Pak Footprint
2. Mediwatt – To-220/To-257 Footprint
3. Ecconowatt – To 247-218-254 Footprint
4. Decawatt – A new outline 10 leaded Package

C. ECCONOWATT VS PLASTIC COMPARISON OF PRODUCT & PROCESS

ECCONOWATT	PLASTIC
Hermetic	NON-Hermetic
Ready to assamble as received	requires extensive assembly
can be tested prior to sealing	tested only after encapsulating
automatable assembly	automatable assembly
high volume sealing	high volume encapsulating
no expensive seal tool	very expensive molds, frequent repair
no secondary seal process	sprue and runner removal
separation process required	separation process required
surface mountable as received	lead bending required prior
may be used in space and military	limited use in space and military
protects large mcm circuits	plastic deformation impacts circuits upon molding & potting
lower cost alternative	higher overall costs than ecconowatt

Conclusion

CNS plans to continue to develop the Ecconowatt package technology in a partnership relationship with selected customers. CNS expects to limit exposure of the robustness and cost competitiveness of the Ecconowatt until it has been demonstrated successfully at strategic partners. CNS believes this patented package can become a standard in the power semi-conductor industry.

The Ecconowatt line of packages achieves cost advantage over plastic packaging through innovative processes and equipment developed by CNS for die bonding, wire bonding, testing, and sealing. This equipment is designed and ready to be built by Bob Satriano, the inventor of the Ecconowatt. Bob has developed and built plastic and other automated circuit assembly equipment and processes. Bob's understanding of these processes for the packaging of header products enabled him to develop CNS's simple but elegant process for the assembly of the Ecconowatt family of packages.

www.cnsceramix.com

Sensorless and Sensibility - Field Oriented Control Models for AC Motors

Reducing processing costs and integrated control ICs mean that sensorless motor control techniques are now viable for low end industrial and appliance applications. FOC (field oriented control) theory facilitates good dynamic control of machine flux and torque in such applications.

By Aengus Murray; International Rectifier

All electric motors operate on common principles where the electromagnetic forces on the armature coils due to the magnetic field produce a torque proportional to coil current, and that moving the coil in the field generates a back EMF proportional to angular velocity. When the coil rotates the conductors continuously move between magnetic poles of opposite polarity. Switching coil current polarity as it changes pole alignment maintains unidirectional torque. The generated Back EMF also switches polarity as it rotates. In a dc motor, a mechanical commutator switches the polarity of the coil connection to the brushes so that there are time-varying DC currents and voltages at the brushes. The ideal DC electrical machine model is a dc voltage source whose magnitude is proportional to the armature speed and magnet pole flux. This ideal machine is a fundamental component in the models of real DC and AC machines.

The real DC machine model includes winding inductance and resistance. If voltage drop across the armature winding resistance is relatively small then motor back EMF will closely track input DC voltage.

A controller that increases motor armature voltage as a function of target speed can control the speed of the DC machine.

An alternative speed control approach adjusts the field winding current to regulate the pole flux while maintaining constant armature voltage. Here speed is inversely proportional to pole flux and field winding current. Armature voltage control has the advantage that speed is a linear function of input voltage. However, field voltage control allows the motor to further increase speed after reaching the armature-supply voltage limit.

DC and AC Machines

A DC machine has a stationary field coil that controls the air gap flux and rotating armature windings that carry the torque-producing currents. An AC machine has rotating field coils and stationary stator windings that generate torque. In either case, alignment of current with air gap flux is necessary to produce constant torque. In the AC machine, synchronisation of stator frequency current with that of the rotor achieves this alignment.

Considering the AC machine from a reference frame synchronised with the rotor, the field system appears stationary. The stator windings will appear as rotating armature type coils and we can imagine a commutator system that switches coil current polarity as they rotate. This is the principle behind field oriented control (FOC), which combines DC machine models with co-ordinate transformations to model AC machines.

AC machine modelling

Figure 1shows a two-phase AC machine where there is a fixed-field system on the rotor but the magnetic flux coupled by the stator windings varies with the spinning rotor so that the windings generate AC voltages.

Spatial separation of the windings imposes a time delay between the flux waveforms coupled by each winding. Conversely, driving time phase separated AC currents into spatially separated AC windings generates a field system that appears to rotate at AC current frequency. The currents in the phase-A and phase-B windings act along the x-axis and the y-axis respectively

AC currents in the winding are out of phase in time by 90° so that the peak of phase-A current occurs when phase-B current is zero and vice-versa. At the 0° electrical point (phase-A peak) net field acts along the positive x-axis. A quarter time cycle later (phase-B peak) net field acts along the y-axis and so on - in one electrical cycle, the field rotates through 360°. Thus, the stationary two-phase windings with AC currents produce the same effect as a rotating winding with dc currents.

Several mathematical transforms simplify AC machine modelling by transforming circuit descriptions between fixed and rotating references. The forward-Park vector rotation transform, for example, calculates stator winding flux as a function of rotor flux and rotor angle. The reverse-Park transform cal-

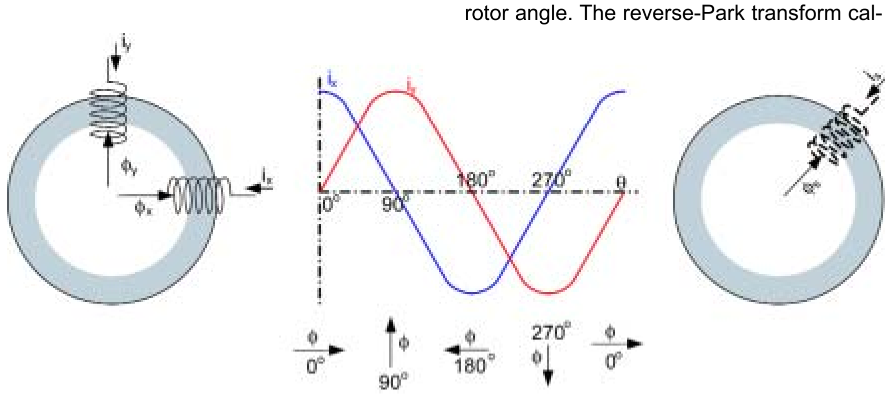


Figure1: two-phase AC machine where there is a fixed-field system on the rotor

culates equivalent rotating rotor flux vectors corresponding to stator winding flux – it transforms the two-phase AC machine currents and voltages in the machine's stator windings into an equivalent set of currents and voltages in rotating windings. The current values that the transform provides have two components: one directly aligned with rotor flux (Id) and another in quadrature with flux (Iq). The direct component is equivalent to field winding current while the quadrature component is equivalent to DC armature current. The transform simplifies analysis of two-phase AC machines by providing a link to equivalent DC models. The principle extends to the Clarke transform for three-phase machines by resolving the flux for each winding into components along the x- and y-axis to calculate two-phase-machine equivalent values. The use of these transforms can improve AC machine controller designs.

Field Oriented Control

A basic principle of AC machine control is that stator voltage magnitude must increase with frequency and rotor speed tracks this frequency. An open loop control system uses a three-phase power inverter to vary motor winding voltages using a constant volt-per-hertz control law, but does not deliver good dynamic control or maximum efficiency. Good dynamic control of DC motors is possible by controlling armature current. Field oriented control principles allows a similar performance in ac motors.

The application of Clarke and reverse-Park transforms to stator current values calculates the equivalent torque- and flux-current components in the rotating reference frame. The transformed AC model now behaves like a wound field DC machine. The AC machine controller independently controls torque and flux current by adjusting the rotating reference frame voltages Vd and Vq (Figure 2).

The space vector PWM accepts the two-phase AC reference inputs and calculates the three-phase inverter timing signals. An advantage of this structure is that current loop compensation is independent of stator frequency. The velocity control loop performs the same function as it does in the DC servo system and provides the input reference to the Iq current loop controlling torque. The flux control loop maintains a constant flux at low speeds to maximise efficiency but reduces flux at higher speeds in a field control mode when stator voltage reaches its limit.

In a permanent magnet AC machine, the controller sets the Id current reference to zero at low speeds because the rotor magnet produces all the flux. An induction motor requires magnetisation current and so the controller sets Id to maintain rated flux in the low speed range. Permanent magnet AC machines do not require magnetisation current so operate with greater efficiency than induction machines at low speeds. The converse is true at high speeds because permanent magnet AC machines require Id current injection to weaken the field to operate above base speed.

Rotor flux angle is a key variable in FOC and an accurate machine model combined with rotor speed measurement enables flux estimation. However, in appliance and low end industrial applications, direct measurement of rotor position is cost prohibitive. Fortunately, reductions in computation cost in recent years have made possible sensorless measurement of rotor position based on machine models and the measured winding currents. This is because the two-phase circuit model of a permanent magnet AC machine includes sine and cosine functions for rotor flux. Using the motor currents and voltages in the circuit model yields the winding Back EMF which on integration yields rotor flux. A phase locked loop tracks the rotor sine and cosine flux function to generate the rotor angle and velocity estimates.

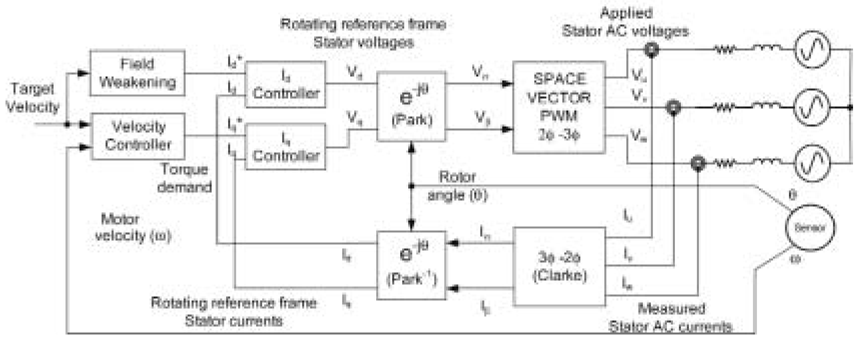


Figure 2: AC machine controller independently controls torque and flux

Get More Power from Power-over-Ethernet

Higher power POE standards are presently being defined

This article is a collection of power supply circuits that explain how to draw power from two or more Ethernet ports. An overview of each circuit is provided as well as some of the design issues faced with each implementation.

By Brian King and Robert Kollman, Texas Instruments

Power over Ethernet (PoE) has become a popular concept and is being used in products such as Internet telephones, security cameras and point-of-sale terminals. Power over Ethernet distributes power through an Ethernet connection. In a network providing POE, power is supplied by the power source equipment (PSE), which generates a 44-57V output on the Ethernet connection. At the other end of the Ethernet connection, power is consumed by the powered device (PD). Although higher power POE standards are presently being defined, the power available to the PD currently is limited to about 13W on a single Ethernet connection. Unfortunately, this often is not enough power for complex applications. Consequently, some high power PD designs need to convert power from multiple ports into usable voltages with galvanic isolation from the 48V input. Several techniques exist for providing isolated power conversion from multiple input sources.

Droop

One technique for paralleling DC/DC power supplies commonly is referred to as the droop method. Paralleled power supplies will share current if their output voltage decreases with increasing load currents. This requires no communication between the supplies and eliminates potential single fault failures. Minimal additional parts are needed to implement this technique. If current mode control is used, you can simply limit the DC gain of the control loop to introduce output voltage droop that is proportional to load current. If more accuracy is desired, the circuit can be implemented as shown in Figure 1. This circuit measures the output current with differential amplifier, U1B, and injects an error into the regulation loop at the compensation amplifier, U1A. Only a few resistors and a single amplifier need to be added to get autonomous current sharing.

Unfortunately, droop sharing is not very accurate. Figure 2 shows worst case variations with one percent resistor tolerances, 1.5 percent reference tolerance and 10 percent total droop. The design has a nominal set point of 5V and a variation of ±5 percent droop. The minimum and maximum curves show component tolerances at their extremes. If you put these three power supplies in parallel, at no load, the supply with the highest output tends to regulate the output voltage. If the supplies used diode regulation as in Figure 1, the supply with the lowest output voltage will not output any current. As the

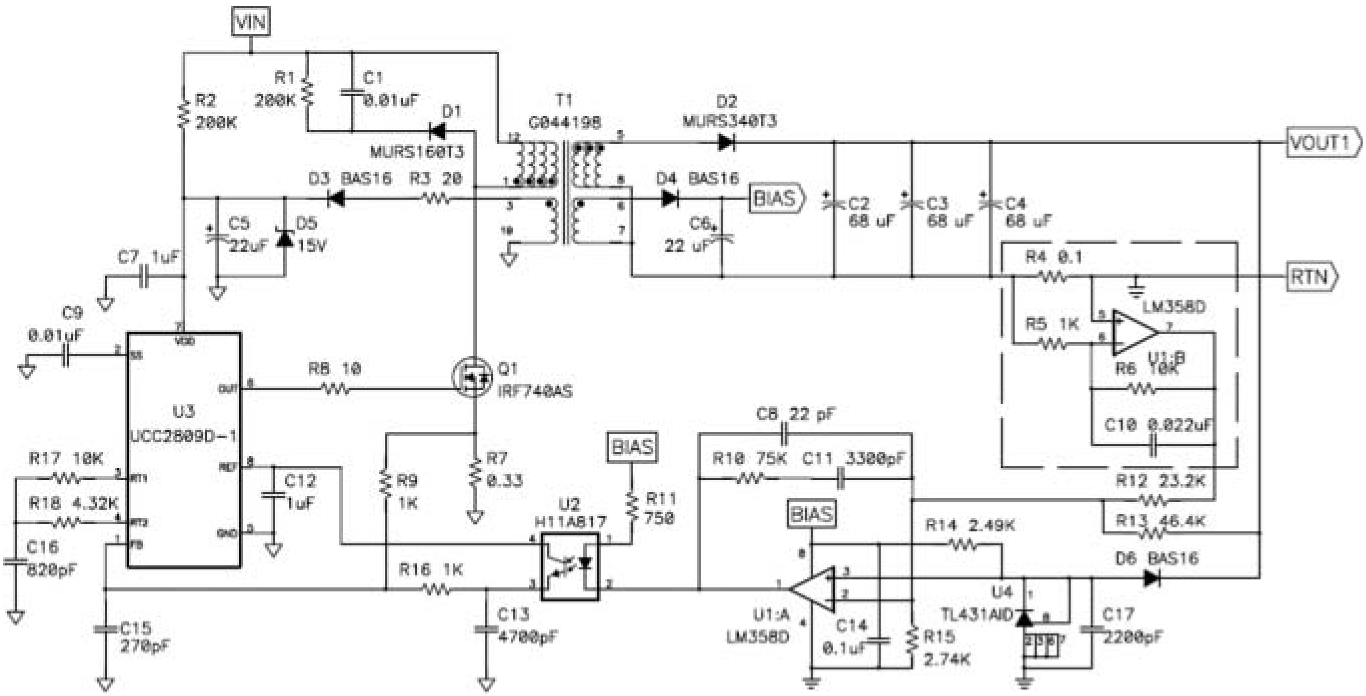


Figure 1: Droop adds few parts.

load current increases, the output voltage starts to fall. The supply with the highest output voltage sources all the current until its output falls to 5.25V. Then the supply with the second highest output starts to source current. With this set of assumed worst case tolerances, the first supply provides almost 70 percent of its output power before the supply with the lowest output voltage starts to contribute. This is undesirable because it is unreliable; however, in some instances it could be acceptable. As the load current is further increased, the first supply may go into current limit. Further current increases are handled by the two remaining supplies, thus allowing full-rated power operation.

Power supply topologies with synchronous rectification allow the power supply to either source or sink output current, which is extremely problematic for this control scheme. In the extreme case, one supply may try to regulate to the high end and the other at the

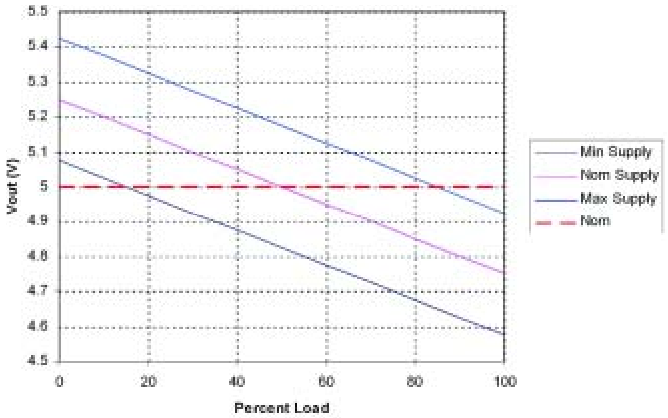


Figure 2: Droop Method Current Sharing is Relatively Poor

low end. When this happens at no load, some supplies will source current to the output while others will sink current from the output. This pulls power from one source and feeds it back to the second with no power delivered to the load. For this reason, disabling the synchronous rectifiers at zero amps is recommended.

Interleaved Flyback

Interleaving provides another technique for balancing the power drawn from multiple inputs. Just like the droop method, interleaving uses a separate power stage for each input and supplies power to a common output. Unlike the droop method, the interleaved power stages, also referred to as phases, share a common single primary side controller. This provides a reduction in cost, and allows each power stage to be synchronized out of phase. Synchronizing reduces the ripple current in the output capacitors, and results in a smaller output filter. Interleaving requires all power inputs to share a common return, which may prohibit this approach from being used in some applications.

Many PWM controllers are designed specifically for interleaving. If only two phases are required, significant cost savings can be realized by using a push-pull controller to perform the interleaving. Figure 3 shows a schematic for a two-phase interleaved flyback supply using a push-pull controller like the UCC2808. This chip limits the duty cycle of each phase to fifty percent and switches the two power stages 180 degrees out of phase. This push-pull controller uses peak-current mode control, which keeps the peak current of both phases close to the same value. In a discontinuous flyback, the output power (per phase) is proportional to the square of the peak primary current. As a result, the power drawn is naturally balanced from the two inputs. This technique equalizes the power drawn from the two input sources to less than five percent. Switching delays on the

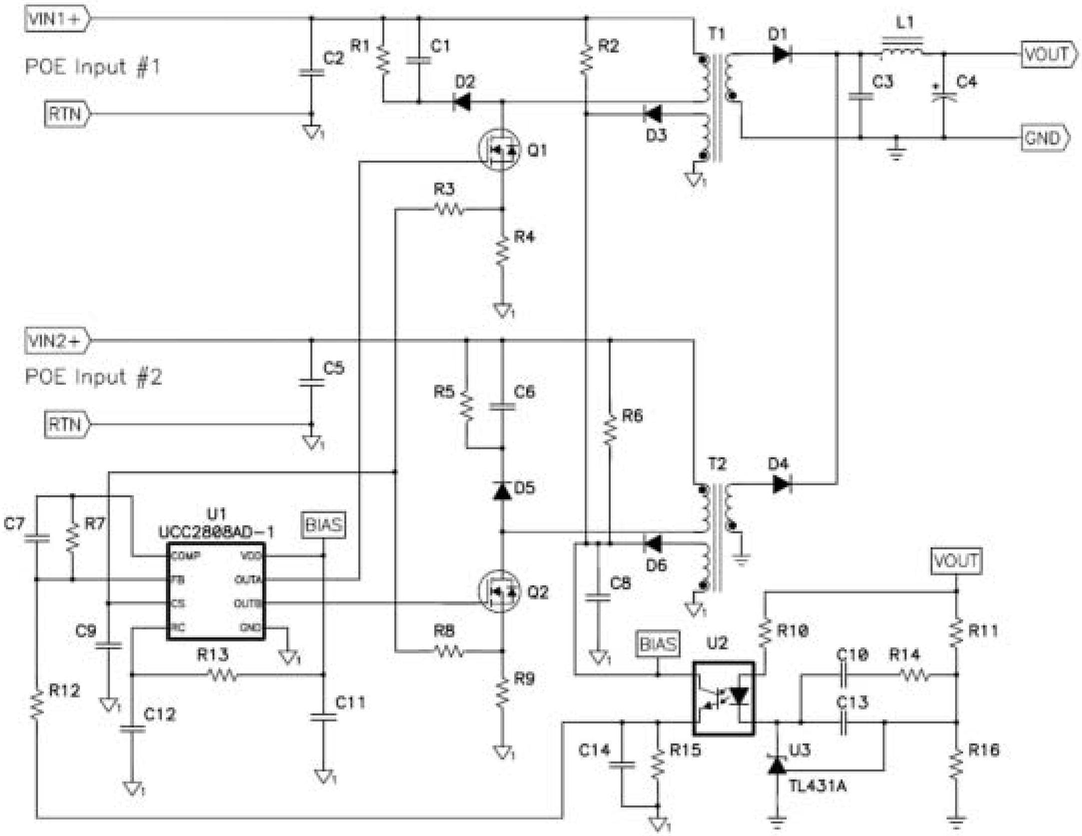


Figure 3: A push-pull controller drives an interleaved flyback.

	Complexity	Cost	Common Power Return	Single Point Failure	Load Regulation	Load Share Accuracy
Droop	Simple	$$	N	N	Poor	Poor
Interleaved	Moderate	$	Y	Y	Excellent	Good
Load Share IC	Moderate	$$$	N	Y	Excellent	Excellent
Opto-CT Current Share	Complex	$$	N	Y	Excellent	Good

Table 1: Load Share Controller Provides Best Performance, but at a Price.

primary MOSFETs are the main source of imbalance, which is worst when the two input voltages are unequal. The peak current limit provided by the controller limits the maximum power drawn from either input, and the duty cycle clamp limits the input current during undervoltage and fault conditions.

Power Share Using a Secondary Side Load Share Controller

A third method for sharing power among multiple inputs is provided by a secondary side load-sharing ICs. Using this method, any number of independent power supplies with power supplies with remote sensing capability can share a common output. Load share ICs are commonly used with power supply modules. An example is shown in Figure 4. A shunt resistor is used to measure the current supplied by each converter. Due to tolerances and parasitic impedances, one of

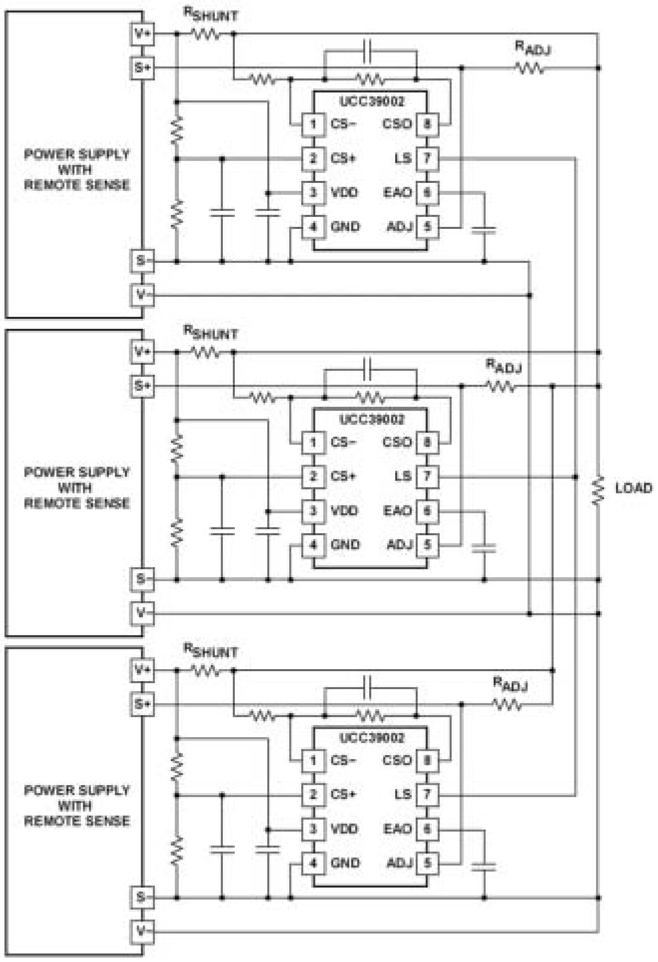


Figure 4: The UCC39002 Load Share Controller Allow Parallelling Independent Supplies.

the power supplies will deliver more current than the others. This supply acts as the master and will set the voltage on the load share (LS) bus. Slave units use this load share bus voltage as an input reference to control their output currents. Slave units are adjusted by injecting a voltage on the remote sense leads of the slave converters. This allows the master to control the output voltage to the load, which ensures good load regulation. This master/slave approach results in very good current sharing accuracy, which typically is better than three percent at full load.

Since one load share controller plus external discrete components are required for each paralleled supply, component count and cost with this method are slightly higher versus the droop or interleaved approach. Additionally, load share controllers are not recommended for use with synchronous rectifiers, which may cause problems during startup or when adding or removing individual supplies.

Master/Slave Isolated Primary-Side Current Share

Another technique that can be used to parallel power supplies is to sense the primary current of one (master) and compare it to another (slave). Using either optocouplers or current transformers provides a means of communicating current information between supplies while maintaining isolation. Current transformers represent the best choice because good performance can be achieved at the lowest price. In addition, current transformers have good accuracy when compared to optocouplers. Their accuracy is set by the turns ratio tolerance, which is better than two percent, and resistor tolerance, which is typically one percent. Optocouplers rely on the tolerance of their current transfer ratio, which is 30 percent at the very best.

Conclusion

Table 1 shows a comparison of the four load share methods. The droop method is the simplest and one of the cheapest methods, but results in the worst performance. It is also tolerant to single failures. Usually, the best performing technique, the load share controller, results in the most expensive solution. Using either the interleaved primary controllers or the optocoupler/current transformer technique provides a compromise between cost and performance. Additional factors, such as the use of synchronous rectifiers, the number of PoE inputs, and whether the PoE inputs must be isolated from each other need to be considered before selecting an approach. Using the appropriate technique for your application will ensure that you get the maximum power from your PoE.

LTCC Technology for Sensor- and RF-Applications

LTCC-ceramics has small temperature expansion

LTCC substrates manufactured to customers' specifications are utilised in many applications. This paper highlights the specific benefits of „Low Temperature Co-fired Ceramics" (LTCC) and provides an outlook to future developments.

By Dr. Arne Albertsen; Manager Field Application Engineering and Marketing, KOA Europe GmbH

The trends of miniaturization, increased reliability and high ambient operating temperatures for electronic circuits have driven the deployment of ceramic substrates and packages.

Among other technological approaches, LTCC have proven their superior performance in a variety of applications. These comprise high temperature automotive, highly reliable medical applications and RF modules for wireless communication. A strong growing segment is the manufacture of packages for Micro Electrical Mechanical Systems (MEMS).

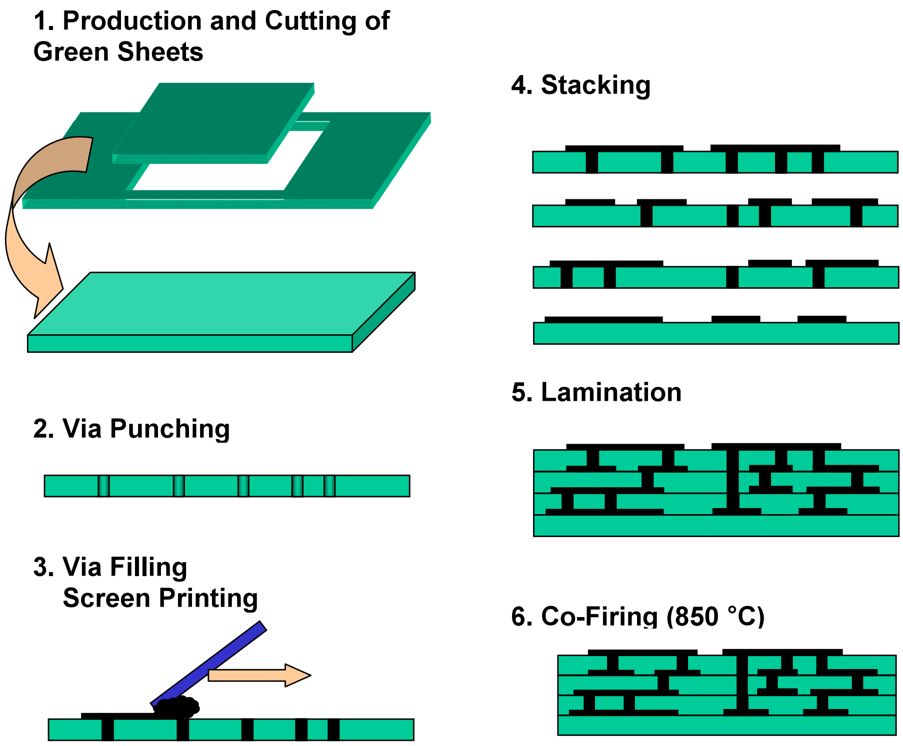


Figure 1: Process Steps of LTCC- Substrate Production

What exactly are LTCCs and which properties make this substrate so popular? A quick glance at Wikipedia, the free encyclopedia, helps to find answers:

"Low temperature co-fired ceramic (LTCC) is a well-established process that has been in use for many years in the microelectronics packaging industry. It is similar to the thick film hybrid process employed for mutlilayer ceramic capacitors and chip inductors. LTCC technology is especially used for wireless and high-frequency applications. In RF and wireless applications, LTCC technology is also used to make multilayer hybrid integrated circuits, which can include resistors, inductors, capacitors, and active components in the same package. LTCC hybrids have a smaller initial ("non recurring") cost as compared with ICs, making them an attractive alternative for small scale integration devices.

This technology presents advantages compared to other technologies: the ceramic could be fired below 900°C due to a special composition of the material. This permits the co-firing with high conductive materials (silver, copper and gold). LTCC also permit the ability to embed passive elements, such as resistors, capacitors and inductors into the ceramic package; hence the size of the components decreases."

On the contrary, High Temperature Cofired Ceramics (HTCC) are made of alumina and fired at temperatures around 1600 °C, such that only metals with high melting points like molybdenum or tungsten can be used as conductors. Since their electric conductivity is poor compared to silver or gold, bigger losses occur.

The in-house manufacture of the ceramic base material for the LTCC production, the „green sheets", KOA ensures a maximum flexibility especially with regard to the mechanical properties of the substrates.

Figure 1 shows the main manufacture steps of the LTCC substrate production, starting with the unfired „green sheets".

After cutting the sheets to the desired size, via holes and cavity openings are mechanically punched.

The next step is the via filling with conducting silver paste. The paste is applied through a mask with openings at the positions of the vias. Standard via diameters are 100, 150, and 200 µm. Then, the conducting traces are screenprinted. The minimum line width and the minimum line space is 60 µm, each.

The printed sheets are stacked and aligned and afterwards isostatically laminated in a water-filled pressurized tank.

The final process step is the firing at temperatures of up to 850 °C. The fired material shrinks – approx. 15 % in x- and y-directions and approx. 20 % in z-direction. The highly homogeneous structure of the green sheets and a precise temperature control ensure

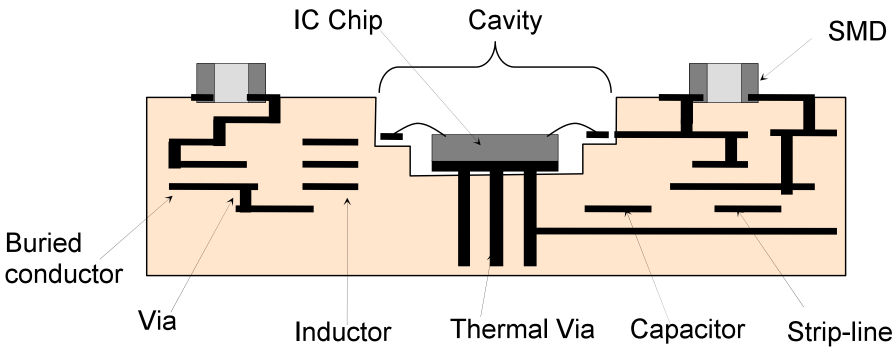


Figure 2: Cross-Section of LTCC-Substrate with „buried“ passive Components

high reproducibility of the dimensional accuracy. This high accuracy allows for the realization of dimensionally accurate cavities for the mounting of semiconductor chips.

Figure 2 depicts a cross-section through a LTCC-substrate that holds a cavity for chip mounting. The cavity offers the benefit of short bond wire lengths to connect the chip to the substrate. The short wire length minimizes the influence of parasitic inductances on signal integrity, which is of use especially at high frequencies. To facilitate the heat conduction from the chip to the ambient, thermal vias can be utilized.

A plot of the dielectric losses (Figure 3) of organic FR4 vs. LTCC substrate shows that LTCC have significantly lower loss at high frequencies than FR4. Another advantage of LTCC-ceramics is their small temperature coefficient of expansion: the numerical value of LTCC's T.C.E. is in between those of Si and GaAs and thus closer than the T.C.E.s of FR4 or HTCC.

Applications are for example wireless telecom equipment and „intelligent“ sensor systems. Figure 4 illustrates an example LTCC substrate with cavities.

Advantages of LTCC-technology

- Multi-layer structures up to 20 layers possible
- Supports fine line / space structures down to 60 / 60 µm
- Buried components (R, L, C) can be implemented
- Low loss up to 60 GHz
- Narrow mechanical tolerance and high reproducibility
- Cavities available
- T.C.E. similar to Si, GaAs
- Robust under temperature cycling conditions
- Custom specific solutions starting from 5000 to 10000 pieces/year

Outlook

KOAs manufacture process allows for line / space of 60 / 60 µm. The main targets for the development of the technology affect the further miniaturization and the increase of the production efficiency, the latter especially for small quantities. Hence, KOA's research

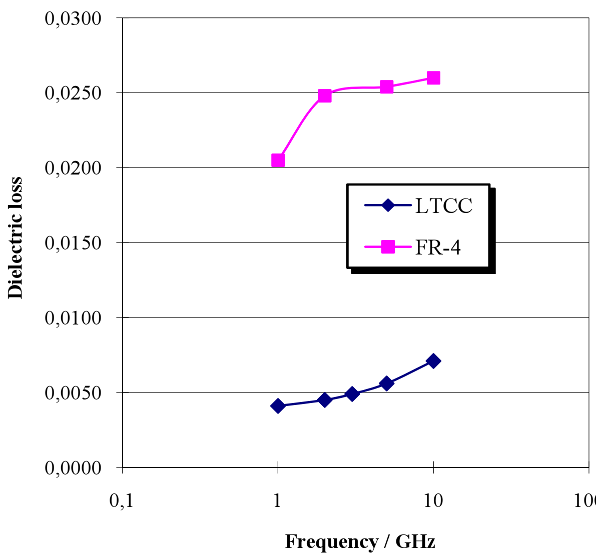


Figure 3: Dielectric losses of LTCC- vs. FR4-Material

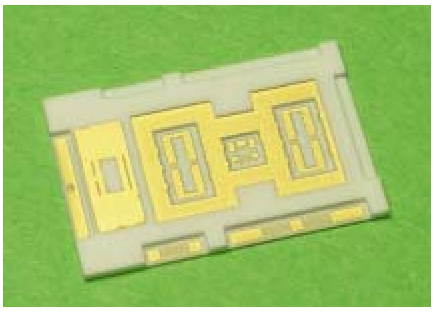


Figure 4: LTCC-Substrate with Cavities

activities focus on the enhancement of the methods and processes for creating conducting tracks on the multi layer substrate.

A major achievement towards highly efficient production is the application of ink-jet technology to print directly from a file onto the green sheets. In addition to the time savings, finer line /space patterns can be produced compared with traditional screen printing. In a joint-research project together with Seiko-Epson, KOA managed to demonstrate the feasibility of line / space structures with 30 / 30 µm.

The researchers prepared a special nano-dispersed silver-ink that was printed onto standard green sheets by a dedicated ink-jet printer.

Enhancements for the structuring of the metallization layers (e.g., conducting traces in thin film technology) and via (e.g., laser punched fine vias) will allow for further miniaturization of the substrates. The number of applications that will become accessible to LTCC substrate solutions will grow significantly during the next years.

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High-Linearity Analog Optocouplers

Extend Working Insulation Voltage to 1.4 kV

High linearity analog optocouplers provide the versatility required to meet a wide range of analog isolation needs. For designers of high voltage applications, high linearity analog optocouplers can reliably send analog signals across very high voltage area and low voltage area without distortion.

By Chen Hong Lei, Avago Technologies

This article examines the internal operation and servo control mechanism of high linearity analog optocouplers in detail. Application examples are also presented, ranging from motor control current sensing to traditional current loop communication in process control.

Selecting the Ideal Optocoupler for High Voltage Applications

Standard digital optocouplers have long been used to address the optoisolation needs in high voltage applications. Combining a digital optocoupler with signal processing circuitry meets the need of high voltage isolation, but this complicates the design and is not suitable for applications that require analog in and analog out. Some linear optocouplers available in the market do provide analog isolation, however they fail to deliver necessary performance such as linearity, gain accuracy, along with high enough working insulation voltage. Isolation amplifier optocouplers can also be considered, but designers must consider the trade off between cost and performance [1].

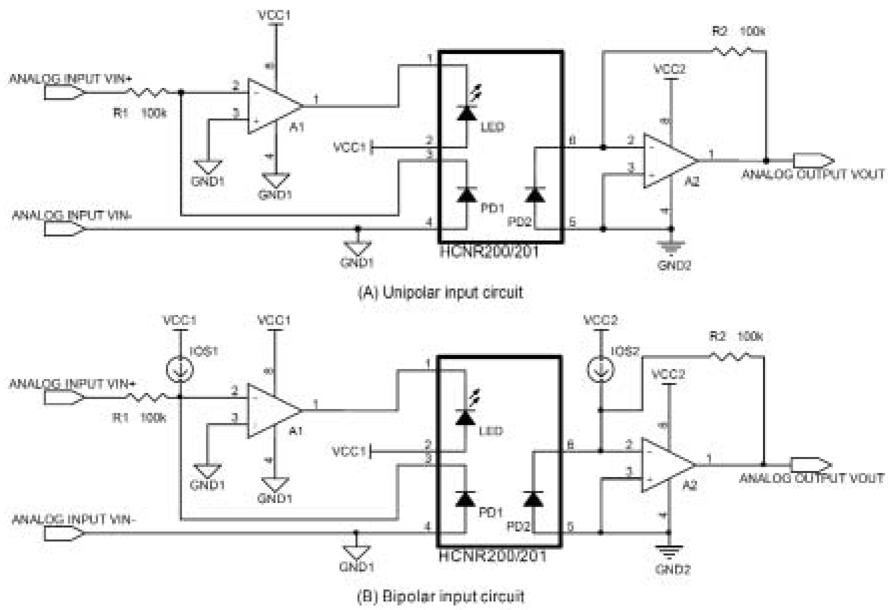


Figure 2. Simplified schematic of the Analog Isolation Block for (A) unipolar input, and (B) bipolar input.

An analog optocoupler with high linearity is ideal to isolate analog signals in a wide variety of applications that require excellent stability, linearity and bandwidth. An optimally designed circuit is capable of handling different type of signals including unipolar/bipolar, AC/DC and inverting/noninverting. Certain applications require very high isolation voltage. For example, in motor drive high side current sensing and phase current sensing applications, the working voltage could be as high as 1 kV. An optocoupler needs to be specially constructed to work under such harsh conditions. The following examples use Avago Technologies' HCNR200/201 optocouplers to illustrate the wide range of isolation applications that can benefit from high linearity and up to 1.4 kV working insulation voltage.

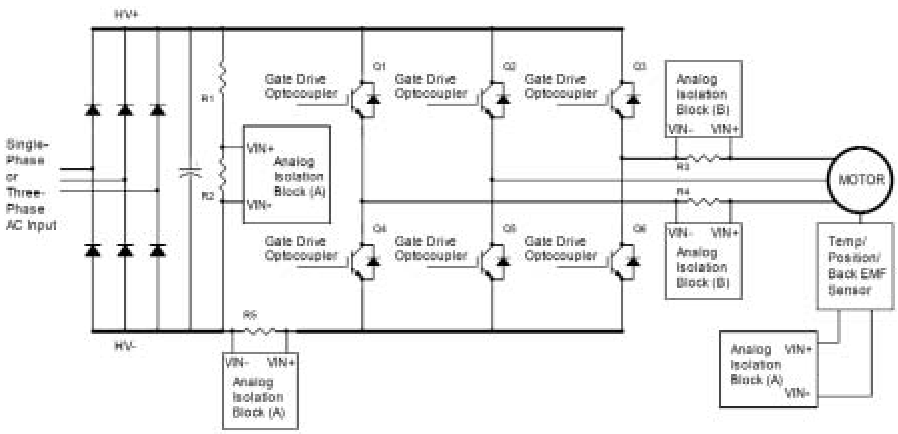


Figure 1. A typical motor drive block diagram.

Current Sensing and Voltage Monitoring Applications

High linearity is critical for current sensing and voltage monitoring in various application areas, such as motor control drives, switching power supply feedback loop, and inverter systems. As part of the motor control drives, variable-speed motor drives are finding increasing applications not only in industrial applications but also home appliances. Among the key components such as IGBT/ MOSFET, gate drivers, and of course the microcontroller unit (MCU), analog current and voltage sensors are critical to feed back to the MCU for stable and protected system control. Because of the presence of high voltages, it is necessary, and often mandated by safety and regulatory agencies, that people operating the motors and low voltage digital electronics are protected through galvanic isolation. An optocoupler with very high insulation voltage (5 kVrms/1 min rating) is required to handle DC bus voltage monitoring, DC bus current sensing, and AC phase current sensing, as well temperature and positioning sensing.

Figure 1 shows these applications (framed in the box named Analog Isolation Block) in a typical motor drive block diagram [2]. From this figure, one can figure out resistors R2 and R5 are used to measure the HV DC bus voltage and DC bus current respectively, while resistors R3 and R4 are used to measure motor phase current. Parameters such as temperature and position can be sensed by appropriate sensors attached to the motor, whose output is fed to another Analog Isolation Block. All the parameters are then transferred across the isolation barrier and collected by MCU. Figure 2 A and B [3] show a simplified schematic of the Analog Isolation Block for unipolar input and bipolar input circuit respectively, which are discussed in next section.

Theory of Operation

The operation [3, p. 15] of the circuit may not be immediately obvious just from inspecting Figure 2A, particularly the input part of the circuit. The op-amp always tries to maintain the same inputs voltages at its two inputs in a linear feedback close loop connection. Thus, the input side op-amp A1 always tries to place zero volts across the photodiode PD1. Now, if some positive voltage V_{IN+} is applied at the input, the op-amp output would tend to swing to the negative rail causing the LED current to flow. This V_{IN+} will cause a current flowing through R1, and the LED light output will be detected by PD1 and generates and a current I_{PD1} flowing from the "+" terminal to GND1. Assuming that A1 is a perfect op-amp, no current flows into the inputs of A1; therefore, all of the current flowing through R1 will flow through PD1. Since the "+" input of A1 is at 0 V, the current through R1, and therefore I_{PD1} as well, is equal to V_{IN+}/R1, or

$$I_{PD1} = V_{IN+}/R1.$$

Notice that I_{PD1} depends ONLY on the input voltage and the value of R1 and is independent of the light output characteristics of the LED. As the light output of the LED changes with temperature, amplifier A1 adjusts I_F to compensate and maintain a constant current in PD1. Also notice that I_{PD1} is exactly proportional to V_{IN+}, giving a very linear relationship between the input voltage and the photodiode current. The relationship between the input optical power and the output current of a photodiode is very linear. Therefore, by stabilizing and linearizing I_{PD1}, the light output of the LED is also stabilized and linearized. And since light from the LED falls on both of the photodiodes, I_{PD2} will be stabilized as well.

Since PD1 and PD2 are identical to each other, I_{PD2} shall be equal to I_{PD1} ideally, while being varied by a coefficient K_3 in reality. So we have

$$I_{PD2} = K_3 \times I_{PD1},$$

where K_3 is the transfer gain defined in the data sheet ($K_3 = I_{PD2}/I_{PD1} = 1$). Amplifier A2 and resistor R2 form a trans-resistance amplifier that converts I_{PD2} back into a voltage, V_{OUT}, where

$$V_{OUT} = I_{PD2} \times R2.$$

Combining the above three equations yields an overall expression relating the output voltage to the input voltage,

$$V_{OUT}/V_{IN+} = K_3 \times (R2/R1).$$

Therefore the relationship between V_{IN+} and V_{OUT} is constant, linear, and independent of the light output characteristics of the LED. The gain of the Analog Isolation Block circuit can be adjusted simply by adjusting the ratio of R2 to R1.

Figure 2A is in a unipolar configuration that accommodates only positive voltage input. Figure 2B is configured to accommodate bipolar input (a signal that swings both positive and negative). Two current sources, I_{OS1} and I_{OS2}, are added to offset the signal so that it appears to be unipolar to the optocoupler. Current source I_{OS1} provides enough offset to ensure that I_{PD1} is always positive. The second current source, I_{OS2}, provides and an offset to obtain a net circuit offset voltage of a desired value (e.g., a 0 V may be desired if both positive and negative power supplies are used, whereas a midway voltage could be more appropriate for the case of single positive power supply circuit). Current sources I_{OS1} and I_{OS2} can be implemented as simply as resistors connected to suitable voltage sources. A note is that the offset performance is dependent on the matching of I_{OS1} and I_{OS2} and is also dependent on the gain of the optocoupler.

Current Loop Communication Application

In the process control industry, current loops have become the standard method for sensor signal transmission [4]. This method is especially useful for long distance transmission (up to 10 km). Current loop is a very flexible communication interface. There are a couple of types of current loops: analog (linear current represents analog signal), logic (high and low logic levels represent MARK and SPACE states), and combined analog and digital current loop that uses HART® (Highway Addressable Remote Transducer) communication protocol. Comparing to voltage signals, current loops have the following benefits:

* Insensitive to noise and are immune to errors from line impedance
* Long-distance transmission without amplitude loss
* Inexpensive 2-wire cables
* Lower EMI sensitivity
* Detection of offline sensors, broken transmission lines, and other failures

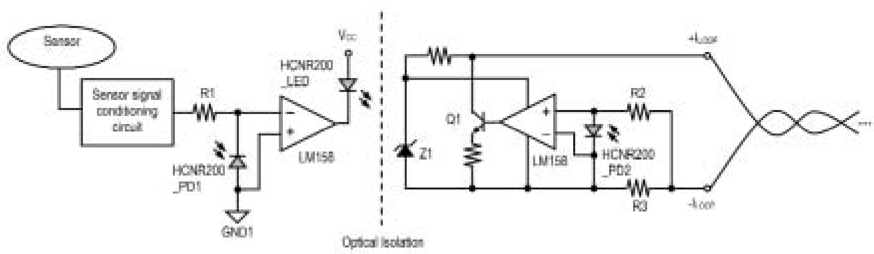


Figure 3. Block diagram of a 4-20 mA analog current loop transmitter

Adding insulation to the 4-20mA current loop is important to protect system electronics from electrical noise and transients, which commonly present in the industrial process-monitoring applications. The insulation barrier allows transducers to be galvanically separated by hundreds or even thousands of volts. Avago's HCNR200 and HCNR201 offer the highest level of safety and regulatory performance available today, which make them suitable for these applications. An example block diagram of a 4-20 mA analog current loop transmitter and receiver is shown in Figure 3 and 4 [3, Figure 21, 22], respectively. Avago also offers optically coupled 20 mA current loop transmitter and receiver (HCPL-4100 and HCPL-4200) for systems using the 20 mA logic current loop [5, 6].

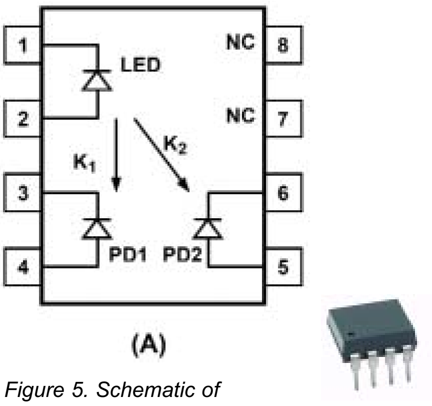


Figure 5. Schematic of HCNR200/201 (A) and the Widebody package (B).

Elements and package construction

The superior performance and the design flexibility of high linearity analog optocouplers make it increasingly adopted for a wide variety of applications. Many new high linearity optocouplers are on the market today that tout similar benefits, but can make it a daunting selection task for designers. Some optocouplers consist of LED and PIN photodiodes, while other products are built with LED and photo-transistors. All of them offer similar element arrangements to utilize the servo-feedback advantages for better linearity performance.

Avago Technologies' high-linearity analog optocoupler consists of a high-performance AlGaAs LED that illuminates two closely matched photodiodes PD1 and PD2, as shown in Figure 5A. The input photodiode PD1 can be used to monitor, and therefore stabilize, the light output of the LED. As a result, the nonlinearity and drift characteristics of the LED can be virtually eliminated. The output photodiode PD2 produces a photocurrent that is linearly related to the light output of the LED. The close matching of the photodiodes and advanced design of the package ensure the high linearity and stable gain characteristics of the optocoupler [3].

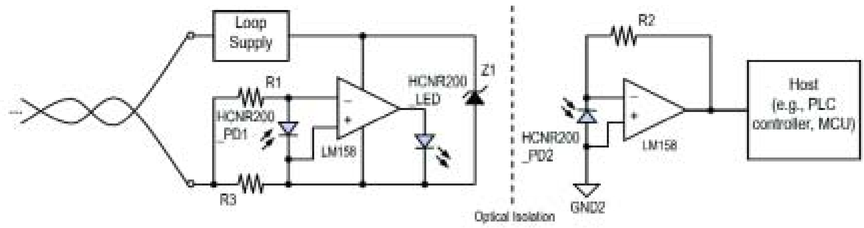


Figure 4. Block diagram of a 4-20 mA analog current loop receiver.

All these advanced elements are housed in a unique widebody package (see Figure 5B). Avago has designed the HCNR200/201 with 400 mil lead spacing, 1 mm internal clearance (through insulation distance), 10 mm external creepage, and 9.6 mm external clearance. It is able to satisfy demanding external creepage and clearance requirements. These parts come with worldwide safety approvals including CSA, UL 1577 recognition of 5 kVrms/1 min rating, and the IEC/EN/DIN EN 60747-5-2 working insulation voltage of 1414 Vpeak. These devices are suitable for not only applications that require reinforced insulation but also failsafe designs.

Linear Input Range

In addition to linearity performance, a final point of consideration during component selection is the circuit's linear input range (LIR). A circuit's LIR determines the input signal dynamic range that can enjoy the linearity claimed on the sheet, which is in turn determined by a particular optocoupler's linear response range specified in its data sheet. For example, on the HCNR200 and HCNR201 data sheet, it is specified that the HCNR200's "DC NonLinearity (Best Fit)" has a typical value of 0.01% and a maximum value of 0.25% under "Test Conditions" of "5 nA < I_{PD} < 50 mA, 0 V < V_{PD} < 15 V" [3, p. 7]. Test conditions of photodetector current or worked-out photodetector current (when LED current is specified) in respective data sheet are used to calculate LIR of the circuit.

Assumption of application circuit topology is made to reach a comparison of LIR for various linear analog optocouplers from different vendors. In this case, the application circuit shown in Figure 2A has been used to calculate the LIR of input voltage. From the comparison chart shown in Figure 6, it can be seen that the HCNR200/201 has a much wider linear response range, which means a circuit applying HCNR200/201 enjoys a much wider linear input voltage range than its counterparts (60dB wider than that of Comp A, and 66dB wider than that of Comp B).

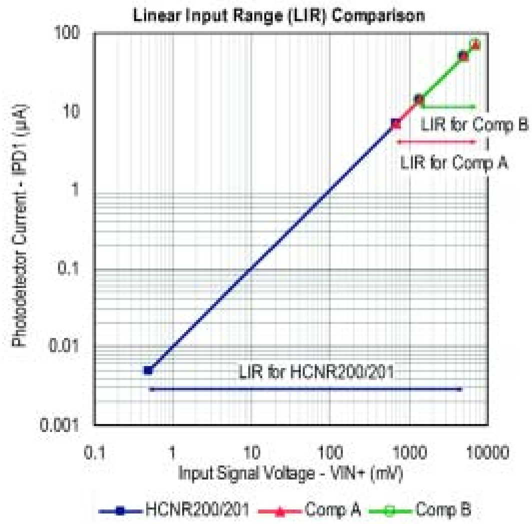


Figure 6. Comparison of different optocoupler's linear input range.

Summary

In a typical high-linearity analog optocoupler application, an external feedback amplifier can be used with PD1 to monitor the light output of the LED and automatically adjust the LED current to compensate for any nonlinearities or changes in light output of the LED. The feedback amplifier acts to stabilize and linearize the light output of the LED. The output photodiode then converts the stable, linear light output of the LED into a current, which can then be converted back into a voltage by another amplifier. By appropriate design of the application circuit, these well-established and versatile analog optocouplers are capable of operating in many different modes to meet various analog isolation needs.

www.avagotech.com

CamSemi Controller Answers Need for Low-Cost Energy-Efficient Power Supplies

CamSemi has launched its first products - a family of breakthrough performance controller ICs – that will enable power supply designers and volume manufacturers for the first time to develop more energy-efficient products at lower cost than existing inefficient solutions.

The C2470 family is based on recent advances in intelligent digital/analogue control, coupled with a neat and simple resonant single-switch topology that has never before been exploited in an integrated form for off-line AC to DC power conversion. This patented, proprietary approach allows manufacturers to secure operating efficiencies in excess of 80% and 100 mW standby but at a new low-cost price point. While offering higher performance and superior safety features, products based on the C2470 family are cost competitive with iron-cored linear transformers and significantly cheaper than currently popular Switched Mode Power Supply (SMPS) approaches.

Picture 1: CamSemi's new products will allow the rapid development of low cost embedded power supplies for applications such as audio systems and DVD players. They offer power conversion efficiencies in excess of 80% with standby consumptions of 100 mW.

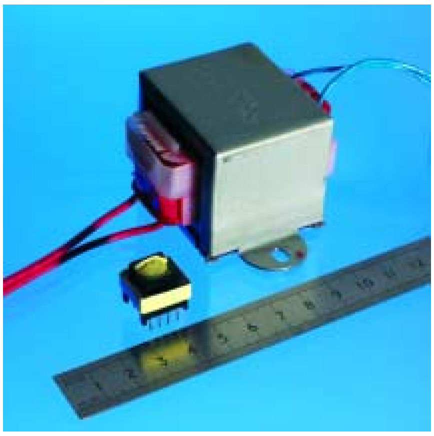
Given initiatives such as ENERGY STAR and the California Energy Commission, manufacturers are under increasing market and legislative pressures to stop producing bulky and energy-inefficient linear transformers that place an unnecessary burden on the environment. However, until today, a manufacturer's only option was to migrate to much more costly and complex SMPS flyback or Ringing Choke Converter (RCC) designs.

"When we first introduced our mixed signal controller concept and RDFC [Resonant Discontinuous Forward Converter] topology to early-adopter customers, the feedback was so positive that we took the strategic decision to bring them to market in advance of our other product developments. Our goal is to enable energy-efficient off-line power conversion without a cost penalty and the C2470 family of controllers does just that. The devices have been specifically optimised for high volume, low cost, single rail input markets while offering double the efficiency over traditional linear supplies," said David Baillie, CEO of CamSemi.

"The C2470 family is a major advance for power supply designers in using a forward resonant topology with naturally high efficiency and low EMI. Now manufacturers can produce small, lightweight and more energy-efficient supplies without having to design-in complex EMI filtering circuitry typically needed with SMPS," said John Miller, VP of Business Development at CamSemi.

CamSemi's new controllers simplify circuit design by cutting a manufacturer's bill of materials, improving margins and speeding up product development cycles while also providing built-in protection and other features as standard within the controller. They employ sophisticated mixed signal control allowing the use of lower cost bipolar junction transistors, as opposed to more expensive MOSFETs and lead to lower overall system costs than the currently popular SMPS flyback designs. At output power ratings of around 6 W and above they become cheaper than linear power supplies, currently the industry's lowest-cost standard solution for off-line power conversion but which suffer from poor conversion efficiency and are bulky.

CamSemi's new devices can easily be incorporated into energy-efficient power supplies, for a wide range of applications, with only minimal changes to layouts and components allowing multiple new product developments to be carried out in parallel. By operating in resonant mode, EMI is greatly reduced enabling the replacement of linear power supplies in demanding applications such as audio products and cordless phone chargers. As secondary feedback circuitry is no longer required, component counts are lower, circuits are simpler and with no opto-couplers or 'Y' capacitors safety approval is easier.



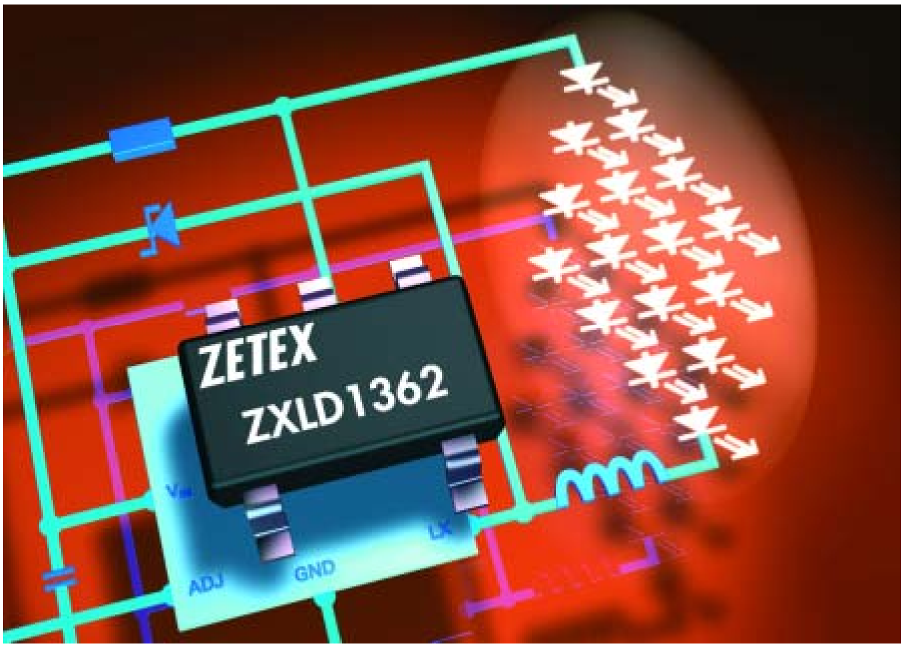
Picture 2: The C2470 family uses a tiny ferrite core (shown on the left above) in place of bulky and heavy iron-cored transformers. This offers manufacturers multiple environmental and commercial benefits including: less demand on raw materials such as steel, copper and plastic; products are easier and cheaper to manufacture and recycle; and transportation costs are significantly lower.

The first three members from the C2470 family being announced today are for the 6 to 40 W power range and are available in volume for applications such as battery chargers, mini adapters, routers, cordless phones and audio systems. Indicative pricing for C2472PX2, the SO23-6 part, is $0.45 each for 1000 piece quantities. Samples and more detailed ordering information are available from CamSemi.

www.camsemi.com/sales

Why Constant Current Drives Beat Voltage-Resistor Drives in LED Lighting

Constant current boost converter improves the energy utilization



The design considerations for LED lighting systems powered by 1, 2 or 3-cell battery sources are to say the least numerous: battery energy utilisation, battery life, constant luminous flux output, the light signature (colour temperature), solution size, weight and of course total solution cost.

By Khagendra Thapa, Principal Systems Engineer, Zetex Semiconductors

In spite of such criteria, voltage-resistor drives (and even direct voltage drives) are often still employed for driving LEDs. When it comes to high power LED driving, such simple approaches don't yield the best results. It's worth recalling why.

As a function of both the manufacturing process and the operating conditions, LED forward voltage has a tendency to vary, and the use of a simple voltage-resistor drive with high power LEDs is not an ideal solution. Consider a high power white LED, its forward voltage can typically be anywhere between 2.95 to 4.25V. Not only does this change in response to LED current, it also changes with respect to temperature, at a rate of typically -2mV/K, so self-heating will also change the current.

To reduce the current variation the series connected limiting resistor will of course help but it will not solve the drive issues. To have as little LED current variation as is possible in the face of such a wide tolerance in forward voltage, the current setting resistor by necessity needs to be trimmed for each different LED forward voltage. Furthermore, in battery powered voltage resistor drives, a change in battery voltage adds to the LED current variation.

In practice, a single cell or dual cell NiCd/NiMH/Alkaline battery is not practical to use with a voltage-resistor drive for a high power LED; therefore limiting the drive's use to batteries using 3-cells and above. Bear in mind too that at and below the LED forward voltage the battery just can't drive the LED, requiring a change of battery or a whole unit replacement. This means the energy in the battery may not be fully utilized and the drive is therefore not an efficient and economical solution in the long term.

And a quick note on direct voltage drives: don't use them! With a direct voltage drive, the LED current variation just can't be determined and makes the drive simply impractical for use.

To maintain LED luminous flux and the light temperature signature throughout the lifetime of the LED, a constant current drive is

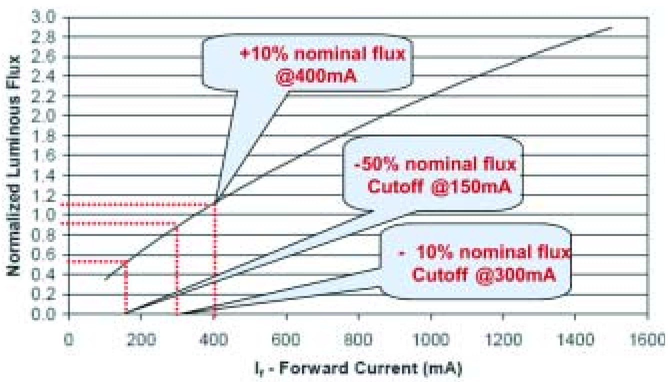


Figure 1: Normalized luminous flux vs. LED current

required. With a constant current drive, the effects of the great variations in LED forward voltage and supply voltage become less of an issue. By comparing typical voltage-resistor drives and constant current boost converter drives against exactly the same LED driving requirements, the advantages of dedicated constant current solutions are apparent.

Consider the Luxeon LXK2-PW12 LED and a nominal drive requirement of 350mA. If we set 10% and 50% reductions in light flux as points for comparison, then from Figure 1, it will be seen that these cut-off points occur at 300mA and 150mA respectively. Operating from a 4.5V supply (3-cell AAA alkaline batteries), a voltage-resistor drive for this type of LED with a typical forward voltage of 3.4V would then require a 3.14Ω current setting resistor.

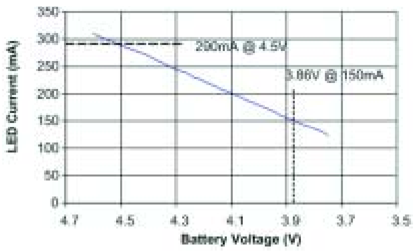


Figure 2: LED current vs. battery voltage in 3-cell voltage-resistor drive; 3Ω resistor

Consider now Figure 2 showing the current in the same type of LED but with a forward voltage of 3.65V (rather than the typical value of 3.4V). The current obtained at 4.5V is 290mA, which doesn't meet the 10% nominal flux cut-off criteria, highlighting the fact that resistor tuning is required for each different LED forward voltage. The discharge time to 150mA (50% reduction in light flux cut-off point), shown in Figure 3, is approximately 53 minutes. The battery voltage, Vbat, at this current is 3.86V. At this voltage, the battery will still have some energy remaining but the light output no longer meets the 50% light reduction cut-off point criteria.

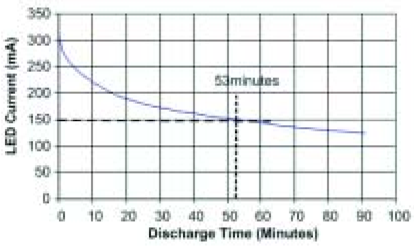


Figure 3: LED current vs. battery discharge time for 3-cell voltage-resistor drive; 3Ω resistor

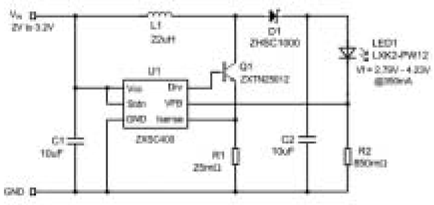


Figure 4: 2-cell ZXSC400 circuit for 1W LED

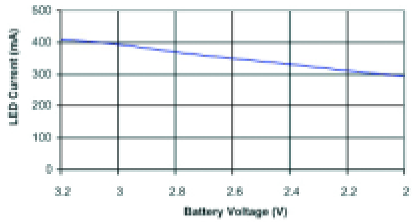


Figure 5: LED current vs. battery voltage; 2-cell battery with ZXSC400.

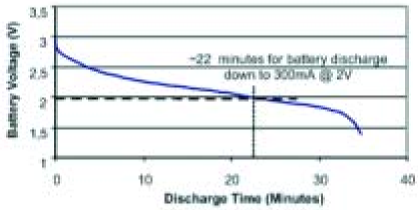


Figure 6: Battery voltage vs. discharge time; 2-cell battery with ZXSC400

As alternatives to the previous 3-cell drive solution, Figures 4 and 7 show typical constant current boost converter circuits for a 2-cell battery system. The ZXSC400 operates from voltages down to 1.8V while the ZXSC310 operates down to 0.8V.

Figures 5 and 6 show the 'LED Current vs. Battery Voltage' and 'Battery Voltage vs. Discharge Time' curves for a 2-cell alkaline source used with the ZXSC400 driving an LED at 350mA nominal. At 300mA (10% reduction of luminous flux) the battery voltage is 2V and it can be seen that the time for the battery voltage to drop to this level is approximately 22 minutes.

Figures 8 and 9 show the same curves for the ZXSC310. At 150mA (50% reduction of luminous flux) the battery voltage is 2Vand the time for the battery voltage to drop to 2V is approximately 56 minutes.

These results demonstrate that a 2-cell AAA battery used in conjunction with a ZXSC400 constant current boost converter provides a longer operational time than a 3-cell AAA battery used with a voltage-resistor drive and

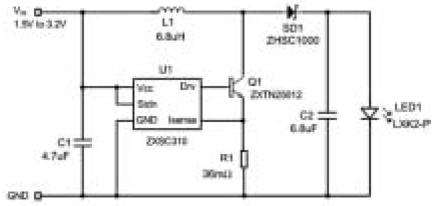


Figure 7: 2-cell ZXSC310 circuit for 1W LED

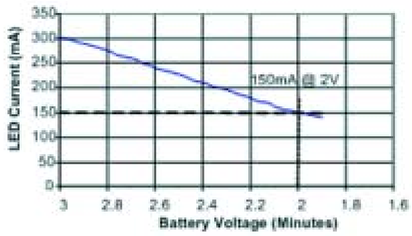


Figure 8: LED current vs. battery voltage; 2-cell battery with ZXSC310

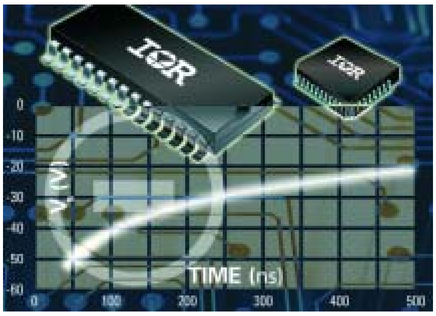
Figure 9: Battery voltage vs. time; 2-cell battery with ZXSC310

also provides a near constant luminous flux. For a 50% luminous flux cut off point, a 2-cell AAA battery based ZXSC310 system gives a similar run time to a 3-cell AAA battery used with a voltage-resistor drive. Therefore, use of a constant current boost converter improves the energy utilization, the battery life and/or product life, the total run cost of the solution and contributes to a 'greener' environment.

A constant current drive has the added advantage then of being able to remove the issue of variation in LED forward voltage, which voltage-resistor and direct voltage drives fail to achieve. With no need for forward voltage binning or resistor matching, the cost is further reduced. Use of a 2-cell rather than a 3-cell system also produces a significant reduction in the overall space and weight of the solution.

Three-Phase 600V ICs Offers Integrated Bootstrap Functionality

International Rectifier has introduced the IRS2336xD protected 600V three-phase gate driver ICs with integrated bootstrap functionality for appliance motor control,



servo drives, micro-inverter drives, and a wide range of general purpose applications. IR's latest high-voltage gate drivers are ideal for three-phase applications that require industrial level ruggedness. These new ICs feature IR's proprietary negative Vs immunity circuitry, allowing the devices to withstand the very large negative Vs transients that are seen during high-current switching and short-circuit conditions. Additionally, an advanced input filter improves system performance while the integrated bootstrap functionality reduces the circuit footprint.

IC Details

Integrating power MOSFET/IGBT gate drivers with three high-side and three low-side referenced output channels, the IRS2336xD ICs provide 180mA/330mA drive current at up to 20V MOS gate drive capability operating up to 600V.

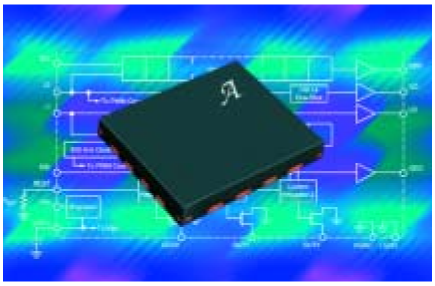
Part of International Rectifier's G5 HVIC platform, these devices incorporate advanced functionality including negative Vs immunity circuitry to protect the system from catastrophic events that can be seen during high-current switching and short-circuit conditions, critical for industrial systems that require high levels of robustness and reliability.

www.irf.com

LED Driver with PWM Brightness Control

The A6281 from Allegro MicroSystems Europe is a three-channel constant-current LED driver IC with an on-chip oscillator for simple programmable brightness control. The device is ideally suited to driving clusters of red/green/blue (RGB) LEDs in applications where the cluster forms one pixel in a large display or a lighting fixture. It precisely controls LED brightness via 10-bit pulse-width modulation (PWM) on each channel, complemented by 7-bit analogue current control on each channel to adjust colour balance.

The A6281 drives up to 150 mA per channel and operates from a supply voltage of up to 17 V, which allows series strings of four or more LEDs to be used on each output. An on-chip voltage regulator supplies the internal logic and reduces the number of external components and connections.



Control data is loaded serially, which minimises the number of pins on the device and the package size. Only four control signals are needed: clock, serial data, latch and output enable. These signals are buffered on the chip to drive the next pixel in a daisy-chained cascade. An innovative clock regeneration scheme allows large numbers (hundreds, depending on clock frequency and pixel spacing) of devices to be daisy-chained. Pixel spacing can range up to 3 metres.

www.allegromicro.com

Transformers Approved for use with High Speed Transceivers

Murata Power Solutions (formerly C&D Technologies' Power Electronics Division) has announced a new series of transformers that simplify implementation of isolated RS-485 and RS-422 interfaces based on Analog Devices chipsets by eliminating the need to select, compare and test alternative solutions.

Each device in the new 782485 converter transformer series has been specifically

designed for use with the Analog Devices ADM2485 high speed, isolated differential bus RS-485 transceiver. Fully approved by Analog Devices, the transformers are also recommended in the company's ADM2485 datasheets and reference design documentation.

www.murata.com

Fuseac, a Revolutionary Capacitor Technology

On the heels of its two-year R&D project to deliver a heightened level of safety and security for power management systems, Electronic Concepts, Inc. today announced a new and revolutionary capacitor technology designed to provide certainty against overheating of metallized dry film capacitors.

The technology, dubbed Fuseac, provides a new level of control to potential overheating, especially in AC application, in situations that may cause catastrophic failure, by having its patent pending fuse technology intuitively disconnect upon detecting the hazardous condition.

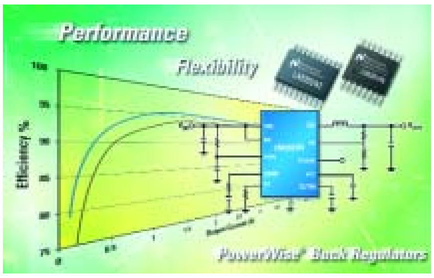
From inception, the Fuseac technology was created to provide designers of power management systems, utilizing metallized dry film capacitors, with a superior protection mechanism that detects capacitor hot spots and electrically disconnects upon reaching a defined critical value. Metallized film capacitors, mainly due to self healing of inherent defects, are reliable and long lasting over the life of the product. However excessive self healings can create an overheating runaway condition, especially in uncontrolled, unmonitored circuits, and fail catastrophically. Fuseac provides added insurance against this type of disastrous failure. For more information visit fuseac.com on the web.

Fuseac is a patent pending technology and on request can be incorporated in a host of Electronic Concepts products, especially into designs needing added overheating protection.

www.electronicconcepts.com

High-Power-Density, Self-Synchronizing Buck Regulators

National Semiconductor introduced a new line of buck switching regulators that are the first in the industry to feature high power density and self-synchronization. These 10 full-featured, synchronous buck regulators provide high-efficiency DC-DC power conversion for point-of-load power supply designs in applications such as communication, data storage, industrial and automotive.



Part of National's PowerWise® energy-efficient product family, the highly integrated regulators feature a variety of input voltages and output currents, and offer a combination of power sequencing, adjustable switching frequency and clock synchronization options. The line of LM201xx and LM202xx synchronous buck regulators includes 2A, 3A, 4A and 5A output current devices. Each regulator integrates two switching MOSFETs and utilizes an externally compensated peak current-mode control loop, providing superior load transient response in low duty cycle applications. The external compensation allows the performance to be optimized for the output capacitor and inductor. With current-mode control, just two external components are needed for compensation. The ability of the 3A and 4A clock synchronization devices to self-synchronize when in out-of-phase operation reduces input capacitance and voltage ripple in power supply designs.

National offers a downloadable power supply design tool for the new low voltage synchronous buck regulators that eliminates the need for tedious hand calculations. The tool, in a Microsoft Excel spreadsheet format, calculates component values based on user-specified design parameters to quickly create a complete power supply design. The design tool allows the design engineer to quickly analyze the control loop response, thermal performance and efficiency of the design.

www.national.com

Dual-Voltage Level 200-mA LDO for Handheld Devices

Texas Instruments introduced the first dual-level 200-mA low-dropout (LDO) linear regulator with simple dynamic voltage scaling in a tiny, five-ball chip-scale package. The flexibility of this device benefits applications that require two levels of output voltage regulation for programming of eFUSE or SIM cards with additional memory, such as wireless handsets, PDAs, smart phones, MP3 players and other handheld devices.

TI's TPS728185315 LDO features a very low dropout of 230 mV with an input voltage range of 2.7 V to 6.5 V and fixed output voltages between 0.9 V and 3.6 V. The LDO also comes with EEPROM preset voltage options of 1.85 V and 3.15 V. The LDO enables the designer to set switchable voltages for eFUSE and SIM cards, such as a higher voltage for fuse programming or with detection of the SIM card, and a lower voltage at the end of programming. The designer can switch between two voltages in a finite amount of time without over and undershoots. Dynamic voltage scaling also helps reduce leakage currents in sub-micron multi-million transistor processors used extensively in portable applications, such as TI's ultra-low power MSP430 microcontrollers.

An integrated precision bandgap and error amplifier provides an overall 2.5 percent accuracy over load, line and temperature extremes. The TPS728185315 provides a high power-supply rejection ratio (PSRR) over a wide frequency range of up to 1 MHz, fast 160 µs start-up time and excellent line and load transient response. The device is fully specified over a temperature range of -40º C to 125º C.

http://power.ti.com

Smallest Combination Buck Regulator/LDO

Micrel launched the MIC2225, an ultra-small dual channel power management IC that provides two high-performance outputs.

The integration of a 2MHz synchronous buck regulator with an independent 300mA LDO offers portable electronics designers maximum flexibility for space constrained applications such as smart phones, GPS and digital still cameras. The MIC2225 is an ideal solution for applications where an additional set of voltages is needed to support an applications processor or co-processor. The MIC2225 is currently available in volume, with pricing at $1.30, for 1K quantities.

"The MIC2225 addresses three major concerns in today's portable electronic market: performance, size, and cost," said Ralf Muenster Micrel's marketing director for power products. "With high efficiency and small board area, circuit designers will find the MIC2225 an optimally balanced solution for converged portable devices that require more than one processor."

The combination of the 600mA DC-to-DC plus 300mA linear regulator permits the use of small value inductors and capacitors that reduce board space, support continuous load currents up to 600mA, and achieve more than 90 percent efficiency. The MIC2225 employs a ìCap design which allows stable operation with very small ceramic output capacitors and a small inductor. This reduces required board space and external component cost. Fixed output voltages options are available down to 1V on the DC-to-DC converter and 0.8V on the LDO. The unique PWM architecture also offers fast transient response, high efficiency and low output ripple. The package is a very small leadless 10-pin 2mm x 2mm thin MLF? with a junction range temperature from -40-degC to +125-degC.

www.micrel.com

Boostcap Ultracapacitors for Dantherm Power's Fuel Cell-Based UPS

Maxwell Technologies announced that Dantherm Power A/S, a leading developer of hydrogen and fuel cell-based power supply solutions, has selected Maxwell's Boostcap ultracapacitors as the short-duration "bridge power" element of its integrated uninterruptible power supply (UPS) systems for telecommunications and fiber broadband applications.

David Schramm, Maxwell's President and Chief Executive Officer, said that Dantherm Power, based in

Skive, Denmark, has signed a strategic supply agreement through which it will source ultracapacitors exclusively from Maxwell, and has placed an initial purchase order through Alphatron Electronic Parts B.V., Maxwell's business partner for Denmark, Belgium, Luxembourg and the Netherlands.

Per Albaek, Dantherm Power's President and Chief Executive Officer said that the systems use

ultracapacitors to instantaneously (0 msec) buffer protected loads from short-duration power disturbances and, in the event of a longer power outage, to supply bridging power for fuel cell backup power to reach its nominal capacity.

"In tandem with fuel cells, ultracapacitors enable our systems to meet our customers' toughest requirements and offer a number of advantages over batteries," Albaek said. "Ultracapacitors have much longer operational life, require little or no maintenance and are far more reliable, especially in harsh environments where backup power often is needed most. The use of ultracapacitors also reduces the overall system weight and volume due to the stable capacity in farads that enables us to scale the bridge power to the exact system requirements."

"The Dantherm Power UPS solution is an excellent example of how ultracapacitors can be used to enhance the reliability and efficiency of systems that generate or consume energy," Schramm said. "We are pleased to be aligned with one of the industry's leading power systems innovators."

www.dantherm-power.com

www.maxwell.com

Non-volatile Digital Potentiometers With SPI Interface

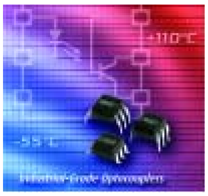
Microchip announces the MCP4141/2 and MCP4241/2 non-volatile digital potentiometers. The new 7- and 8-bit devices have an SPI interface and are specified over an extended temperature range of -40 to +125 degrees Celsius.

Unlike mechanical potentiometers, the MCP41XX/42XX devices can be controlled digitally, via an SPI interface. This can increase system accuracy, flexibility and manufacturing throughput, while decreasing manufacturing costs. Non-volatile memory enables the devices to retain their settings at power down, and their low static current consumption of just 5 µA maximum helps to extend battery life. The MCP41XX/42XX digital potentiometers are ideal for a wide range of trimming, calibration, set-point, offset-adjust, signal conditioning and control applications.

The MCP4141/2 digital potentiometers are available in 8-pin SOIC, MSOP, PDIP and 3 mm x 3 mm DFN packages. The MCP4241 is available in 14-pin SOIC, PDIP and TSSOP packages, and a 10-pin 4 mm x 4 mm QFN package. The MCP4242 is available in a 10-pin MSOP and an 8-pin 3 mm x 3 mm DFN package

www.microchip.com

6-Pin DIP Optocouplers Offer High Temperature Ratings



Everlight Electronics announces a new family of 6-pin DIP phototransistor optocouplers featuring wide operating temperature range (-55 C to +110 C), low-profile surface mount availability (S1 option at 3.9mm max), high collector-emitter breakdown voltage (min BVCEO = 80V), high-isolation voltage (5kVrms), more than 7mm creepage distance, as well as a wide selection of Current Transfer Ratio (CTR) ranges. These key device features combine to offer exceptional flexibility when designing power supplies, programmable logic controllers and general-purpose switching circuits.

The 6-pin DIP optocoupler family of 21 devices is grouped into the 4N2X, 4N3X, H11AX and CNY17-X, CNY17F-X series.

Each optocoupler consists of an infrared-emitting diode optically coupled to a phototransistor. All products are lead (Pb)-free and RoHS-compliant.

Competitive device families on the market meet some, but not all, critical device specifications that make Everlight's line of 6-pin DIP optocouplers ideal for industrial and control designs. For instance, compared to conventional optocouplers, Everlight's 6-pin DIP devices offer a higher maximum operating temperature (110 C vs. 100 C), allowing designers to derate their boards to a higher temperature and improve thermal stability.

These 6-pin DIP devices, like all Everlight DIP optocouplers, are available in two surface leadform options (S and S1). In addition to saving space in height-constrained applications, the lower profile S1 option retains the >7mm creepage and 5kVrms isolation voltage safety benefits of a DIP package.

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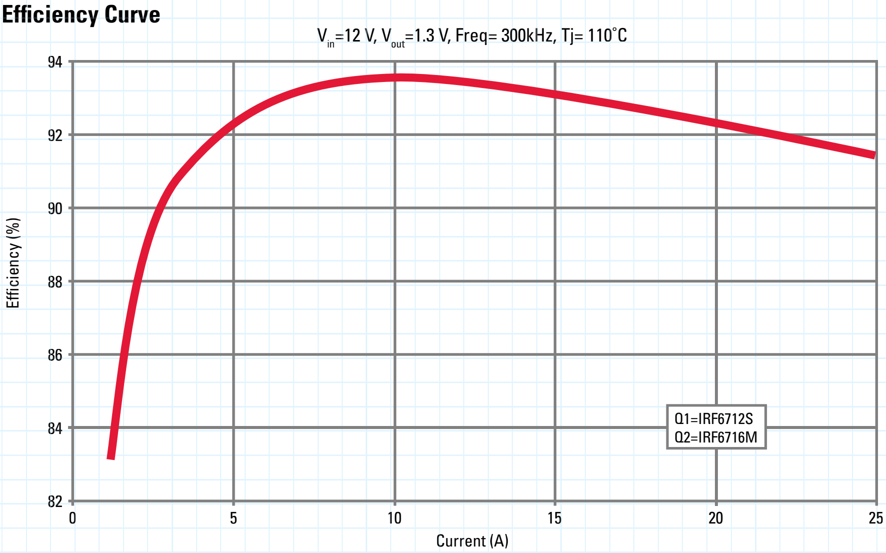
ADVERTISING INDEX

Lowest $R_{DS(on)}$ Drives The Coolest Data Centers

Efficiency Curve



Specifications

Part Number	Package	BV_{DSS} (V)	$R_{DS(on)}$ max @ 10 V (m Ω)	$R_{DS(on)}$ max @ 4.5 V (m Ω)	V_{GS} (V)	I_D@ Tc = 25°C (A)	Qg typ (nC)	Qgd typ (nC)
IRF6716MTRPbF	DirectFET	25	1.6	2.6	20	180	39	12
IRF6712STRPbF	DirectFET	25	4.9	8.7	20	68	13	4.4

The IRF6716 with low typical $R_{DS(on)}$ of only 1.2 mΩ at 10 V_{GS} and 2.0 mΩ at 4.5 V_{GS} , and IRF6712 DirectFET chipset feature extremely low device on-state resistance ($R_{DS(on)}$), to achieve high efficiency and superior thermal performance for the most energy-efficient data centers.

Features & Benefits

- 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 same footprint as SO-8
- Over 90% lower die-free package resistance (DFPR) than SO-8
- 0.7mm profile
- Direct chip attach with no wire bonding or lead-frame
- Lower package inductance for higher frequencies

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