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Systems Design Motion and Conversion

July 2007

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Never stop thinking

Bodo´s Power Systems

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Bodo´s Power Systems

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Events

Fairchild Power Seminars
http://www.fairchildsemi.com/powerseminar07

EPE, September 2-5, Aalborg DK,
http://www.epe2007.com

Husum Wind, September 18-22, Husum D,
http://www.husumwind.com

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

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

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

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

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

The Challenge of Smarter Design is in Green Power

My PCIM podium discussion on Green Power attracted lots of attention – and it was a theme that appeared everywhere. For those of you who were unable to attend, a summary is included in this issue. Many aspects of the subject were addressed by leading semiconductor and passive component manufacturers. Having had nine speakers, the presentations were brief, but catching up on content is the mission of my publication. The presentations are part of this issue as are URL's for readers interested in contacting the companies directly. The speakers provided proof that everybody is seriously addressing Green Power related improvements in product performance.

Twelve times a year we have the opportunity to provide you, our valued reader, with in-depth content in print and our online edition is updated twice a month. The magazine is always in the mail and on its way to you on the first of the month.

To get a young, potential engineer started on his career path using an Oscilloscope, we would say we need to "trigger the scope." My team and I were thrilled at the show to see so many parents wishing to trigger their child's technical expertise through a Marklin train set. We had a lucky winner each day from all across Europe: Thomas from Baldham near Munich, Robin from Berlin, and Alice from Catania. I will track their progress by keeping in touch with the winners.

What trends and expectations were discussed at the PCIM for practical use in products? Variable speed three-phase motor drives are a standard in the industrial world and it was evident that green benefits have made them attractive for the appliance market as well. Past issues of the magazine have presented a number of products that are breaking new ground in this field. Companies with IGBT expertise have developed solutions tailored to the appliance market. Small module motor drives, in injection-moulded technology are an example of a product addressing this market. Mitsubishi presented a single-chip inverter (see June's Product of the Quarter) while others have driver, single-die switches and rectifiers assembled in the module.

The magazine has provided excellent input on these developments. The April cover story by International Rectifier focussed on motion as did the guest editorial by Alfred Hesener of Fairchild and the Product of the Month from Mitsubishi for the 10A and up level in May. Infineon has clearly addressed home appliances with the CiPoS family – June's product of the month. Other manufacturers undoubtedly plan to also address the low-power motor drive market.

Upcoming events offering a chance to chat are EPE in Aalborg and Husum Wind; both highlighting renewable energy, solar and wind power to help develop a clean future. While the PCIM has a more practical focus towards industry and products, EPE is a major event for universities. Husum Wind is devoted to wind power as its sole topic.

My Green Power recommendation for July is to turn off the engine when you are not driving - an instant reduction of pollution. Your next car might be a hybrid providing automatic pollution reduction with regenerative braking, as well.

Have a nice summer vacation - recharge your batteries and your super capacitors - the second half of 2007 is just ahead!

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Robert Hinke regional VP for Europe

National Semiconductor Corporation announced that Robert Hinke has been appointed to vice president and general manager, Europe. Previously, Hinke served as National's marketing director for Europe. His assignment will become effective May 28, 2007, corresponding with the beginning of National's fiscal year 2008. Hinke will take over from John Phelps, who has been the head of National's European Sales and Marketing organisation since 2002, and is returning to the U.S.

Hinke joined National Semiconductor in 1983 and brings extensive sales and marketing experience to his new position. Since 1998, he has been National's marketing director for Europe, and during the past year, has additionally assumed the role of marketing communications director. He has also served as a member of the company's worldwide Marketing Council, thus being instrumental in shaping National's global marketing strategy.

Before his appointment to European marketing director, Hinke assumed key positions in the company's sales organisation, including worldwide account manager and regional sales manager for National's Central and Southern European Communication Segment. Hinke has studied in Munich/Germany and holds a Master's Degree in Electrical Engineering. In his new role, Hinke will report to Mike Noonen, National's senior vice president, Worldwide Marketing and Sales.

www.national.com

Top 25 Annual Fastest-Growing Tech Company

Ansoft Corporation for the second consecutive year has been named to Business 2.0 magazine's annual list of the 100 Fastest-Growing Technology Companies.

Ansoft is ranked 22nd, improving upon last year's ranking of 29. The ranking is based on growth in revenue, profit and operating cash flow during the past three years, and the 12-month stock return as of Dec. 31, 2006. Additionally, Ansoft ranks 20th in total stock return and 2nd in the state of Pennsylvania.

"It is a great honor to be recognized as one of the top 25 fastest-growing technology companies in the U.S. by Business 2.0," said Nicholas Csendes, president and CEO of Ansoft. "We continue to expand our market share in the high-performance segment of the electronic design software market. This recognition is a validation of our strategic vision, and we anticipate continued innovation and strong growth."

www.ansoft.com

Digital Power Europe Call for Papers

Power Conversion and Power Management Track Call for Papers DPE '07.
The first annual Digital Power Europe forum will be synergistic with the highly successful Digital Power Forum in North America. Join us to hear about the latest components, new design techniques and design tools that are enabling the use of digital power management and digital power conversion technologies in your next design. Delegates will also see demonstrations and application examples for practical digital power designs in the exhibition area.
Digital Power Europe '07 will be the premier "digital power event" in Europe. Don't miss this chance to showcase your latest work in digital power, and to see the most recent development efforts of other leading engineers in this important field.

www.dpfeurope.darnell.com

Share Purchase Agreement

VACUUMSCHMELZE has signed a Share Purchase Agreement with NEOREM MAGNETS OY in Ulvila, Finland a company producing sintered Rare Earth permanent magnets, which are used in applications such as large electric motors and generators (e.g. for wind power generators) and sensor magnets (e.g. for telecommunication).

Neorem Magnets Oy will continue as a part of the VAC Group with its own trademark, NEOREM. The management of Neorem remains on board as minority shareholders of the company. Both VAC and the management of Neorem have strongly committed to further development and expansion of the operations of Neorem Magnets Oy. The technical knowhow of both companies will be combined to give an even better service to the customers. This acquisition will strengthen the position of VACUUMSCHMELZE Permanent Magnet Division in Europe in those applications and regions where NEOREM is focused.

This activity will combine the different focuses of both companies to secure the production of sintered rare earth magnets in Europe. It will support the joint customer base with application know how and expanded capacities.

www.vacuumschmelze.com

The Future of Power Semiconductors at ISPSD'07

Dr. Izak Bencuya, Fairchild Semiconductor's executive vice president and general manager of the Functional Power Group, recently presented the role power semiconductors play in maximizing energy efficiency at the 19th International Symposium on Power Semiconductor Devices and Integrated Circuits (ISPSD'07).

"Wasted energy, or power, can be found everywhere, from lighting to automobiles, and power supplies to electrical conversion. Optimizing the use of power in today's electronic products needs to be a key initiative for power semiconductor manufacturers," stated Bencuya. "It is incumbent on us to provide innovative designs yielding improved performance, reliability and reduced system costs. Providing highly integrated products in thermally advanced packaging offers increased power density and efficiency, and brings value to customers."

Fairchild designs and develops products to efficiently optimize system power. One example of how Fairchild's products offer dramatic reduction of power consumption is in power supplies. Power supplies waste three to four percent of the total United States (U.S.) electricity, and appliances in stand-by mode consume nearly five percent of U. S. residential electricity per year.

An average television uses 32.94kW of standby power annually. Using Fairchild's Green FPS™ products reduces that usage to 7.3kW annually. This is a savings of 25.64 kW for each television per year. If every TV sold worldwide in 2004 realized the 25.64 kW power reduction, it would be a savings of approximately 4.28 TW/year, enough to power millions of households.

www.fairchildsemi.com

SynQor Distribution Agreement with Trium Power

SynQor a leading power solutions company for DC/DC and AC/DC products within the Telecom, Medical and Industrial marketplaces, announced today that it has signed a non-exclusive distribution contract with Trium Power of Dourdan France.
Commenting on the deal, Frederic Martin (Regional Sales Manager for SynQor) explained, "SynQor is pleased and excited to begin our partnership with Trium Power. We are convinced that their background and experience in the power industry will help us in our diversification efforts to further develop business in the Medical, Industrial and Telecom market segments".
He continued, "The addition of Trium Power, working in conjunction with Spectrum Design, our Manufacturer's Rep, and combined with the market specific products we have recently released will enable us to better meet the needs of our customers".

www.synqor.com

Outstanding results at SENSOR+TEST 2007

Attractive three-day programme draws to a close in Nürnberg
Exhibitors, visitors and experts from the AMA Association for Sensor Technology are agreed: SENSOR+TEST 2007 was a complete success. The extremely good general economic development in Germany and Europe also has a positive effect on sensor, measuring and testing technology. The mood at the most important exhibition for this industry in Europe was accordingly good. SENSOR+TEST 2007 produced excellent results over the past three days from 22-24 May. The exhibitors welcomed about 8,600 visitors to their stands, which is 15 % more than the previous year. The supporting programme with conferences, forums and the Action Area was also very well attended. This year's SENSOR+TEST programme offered exhibitors and visitors a wide variety of platforms for exchanging views," says Holger Bödeker, Managing Director of the organiser AMA Service GmbH: "This was especially apparent in the Action Area, which was a big attraction again."
The altogether 610 exhibitors at SENSOR+TEST showed many new products and innovations on a display area of just under 23,000 m². The spectrum ranged from the smallest sensors using microsystem technology to complete test rigs, such as are used in the automotive industry.
The exhibitors were impressed by both the number of visitors and the quality of the talks held.

www.sensor-test.com

Sales Office in Estonia

In the course of its presence throughout Europe, Rutronik Elektronische Bauelemente GmbH is now also represented in Estonia with its own sales office as from 1 April 2007. The office in Tallin focusses exclusively on Estonian customers. Until now, the branch office in Kaunas / Lithuania has been in charge of the customer structure of Estonia, while the branch office in Helsinki has covered the customers with strong ties to Finland. The new location has been assigned to the area of Northeastern Europe under the direction of Dierk Enders, Area Manager Eastern Europe, who is reporting directly to Frank Rotthoff, Sales Director Europe. This ensures the strategic integration into European sales and establishes the interface to Western Europe and Scandinavia. Apart from the Estonian customers, the West-European clientele will also benefit from the new location:
Due to the increasing shift of production facilities to Eastern Europe and Estonia respectively, it is essential that customers across Europe receive the same standards regarding service and quality.

www.RUTRONIK.com

Power Integrations' TinySwitch-PK IC Delivers Up to 280% Peak Power

Enables Simple, Flexible Designs with Fewer Components than Traditional Solution for Consumer Products, Low Power Motors and More

Power Integrations introduced the TinySwitch®-PK integrated power supply control IC with peak power mode. TinySwitch-PK delivers up to 280 percent peak power for short periods of time, enabling designers to specify transformers rated for the continuous power level, significantly reducing size, weight and cost of designs. With its high level of integration and robust feature set, TinySwitch-PK enables simple, flexible designs with far fewer components than competing discrete and integrated solutions.

"The On/Off control method employed by our industry-leading TinySwitch family is very efficient, easy-to-use and has fantastic transient response," explains Doug Bailey, vice president of marketing at Power Integrations. "Such devices with fixed frequency and current limit are, by nature, limited in their peak output power. Our new TinySwitch-PK family delivers all of the design benefits of the TinySwitch and extends the peak power available on-demand."

Many consumer products have seldom-used motors, buzzers or lights that require extra power for short periods. DVD player drawer-opening motors or PVR disk drive motors are good examples. The rest of the time, the hardware performs standard tasks and consumes much less power, yet all the system components ? such as transformers, output diodes and bulk storage capacitors ? must be specified for use at the occasional higher power requirement. The challenge in these systems is to design a power supply that can provide the necessary peaks when needed, but does not burden the application with peak costs. By automatically entering into a special peak mode ? doubling operating frequency and boosting current limit for the duration of the peak power requirement, TinySwitch-PK coaxes up to 280 percent of the design power level out of the same transformer and integrated MOSFET. Moreover, TinySwitch-PK simplifies the transformer construction for multiple-output designs. Due to the chip's higher operating frequency, the number of primary turns may be reduced, making it easier to match common voltage ratios and consequently fit all of the turns onto a short bobbin, reducing total copper usage and cost.

TinySwitch-PK features a 700V MOSFET alongside low-voltage control circuitry on a monolithic IC. Other features include integrated auto-restart, input under-voltage and output over-voltage protection, hysteretic thermal shutdown, and frequency jittering to minimize EMI. TinySwitch-PK also includes selectable current limits, allowing the designer to choose any of three current limit values for each family member without any additional IC pins or external components. This capability enables designers to optimize their power supplies for either maximum efficiency or greatest power output.

TinySwitch-PK is available in lead-free, plastic through-hole DIP-8. Pricing in 1000-piece quantities for the TNY375P, a 6W (12.5W peak) part in a DIP-8 package, is $0.65 each. Small quantities are available now, with production quantities of TNYPK375-377 available in early Q3 and TNYPK378-380 available in late Q3.

www.powerint.com

The Best-Selling 2-Channel IGBT Driver Core

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

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

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

Chipset Features

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

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

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

Isolated DC/DC power supply with 3W per channel

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

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

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

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

As an ideas factory, we set new standards with respect to gate driving powers up to 15W per channel, short transit times of less than 100ns, plug-and play functionality and unmatched field-proven reliability.
In recent years we have developed a series of customized products which are unbeatable in terms of today's technological feasibility.

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

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Let experts drive your power devices

Facts and Myths in LED Lighting

By Frank Marx Chief Sales Officer, Zetex Semiconductors

According to the International Energy Agency (IEA) in Paris, France, lighting is a primary end use dominating global power demand. Worldwide, grid based electric lighting consumes around 19% of total, global electricity production. That's more than is produced by nuclear stations and about the same as produced by natural gas.

The history of LEDs goes back to the 1970's. Originally, the main usage was for indicator LEDs only. Roland Haitz, a scientist at Agilent early on formed a view on LEDs similar to Moore's Law (which asserts that chip performance would double every 18-24 months). In fact, this law held true for the last 30 years. Originally starting at 0.1Lm/Watt in 1970, 10 Lm/W were achieved in 1990, 20Lm/W in 2000, 40 Lm/W in 2004 and 100 Lm/W in 2006. Today's efficacy or the amount of radiated, visible light produced per Watt of electricity, has achieved performance in excess of 120 lm/W but more important to appreciate is the potential positive impact this new white light source may have to the world.

With infrared light-emitting devices, an electrical-to-optical energy conversion efficiency of over 50% has already been achieved. Translating this efficiency for visible light emitting devices, the result is a 150…200 lm/W white light source - two times more efficient than fluorescent lamps and ten times more efficient than incandescent lamps. Doing the maths this would mean that worldwide electricity consumption due to lighting could be decreased by more than 50% - equivalent to a decrease of probably more than 10% of total power consumption. Environmentally we would benefit from the drastic reduction of carbon emissions and usage of mercury as well.

LED powered lighting offers a number of compelling advantages such as reduced maintenance cost, significant energy saving, environmental friendliness (no use of mercury) to name but a few. Hence, one could state it is perfectly positioned as a disruptive

technology to replace traditional lighting. Well, let's challenge that rather bold statement.

Recent announcements from e.g. Australia and the German Minister of Environment suggested banning the traditional filament lamp in the future. Replacing existing sockets though with a screw-in LED light bulb probably would require rewriting a few laws of thermodynamics. The thermal path of the existing sockets is poor considering it was previously designed to protect the base and wires from heat, however something must cool the LED. Lumileds application guide 'Luxeon Thermal Design Guide' states that each watt of LED power needs about 9 square inches of surface area in free air cooling; about the size of post-it-note on your desk.

Another unit of measure for luminance is the light level in lumen per square meter or simply "lux". Efficacy statements are at risk of being misleading considering that an LED achieving 100 lumens per Watt at 25mA will simply have insufficient light output for any professional lighting application and compensating with additional LEDs for the desired illumination level would be cost-prohibitive.

The human eye has a varying range of sensitivity to light, depending on the wavelength characterized in the photopic response curve. Simplified,this means that light of one color may appear brighter than light of another color, even if their intensity is the same i.e. yellow will appear much brighter than a deep blue light. So, any attempt to, for instance, replace a traditional 3000K MR16 with a 4100K LED wouldn't work properly as it will not provide the same spread and distribution compared to the traditional down light.

Much work is still needed on encapsulation materials, power supply, optics, heat sinks and housings. Zetex actively participates in Osram's newly created partnership network 'LED Light For You' contributing to the synergistic alliance of participating organizations that bring together complementary strengths and capabilities in LED lighting. Converting energy into light using LEDs requires electronics expertise traditionally not available (or only to a very limited extent) at the target customer base.

Moving forward, better communication between the LED industry and the lighting designer to define and set standards will be a requirement to enable quick adoption of this new technology. In return potentially reducing worldwide power consumption by 10%, decreasing carbon emissions by more than 10%, enhancing human visual experience through digital and independent control over color, intensity and spatial distribution of lights truly suggests this as an exciting, worthwhile evolution though with disruptive character.

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Electronics Industry Digest

By Aubrey Dunford, Europartners

GENERAL

With part of the inventory that built up in 2006 cleared in the first quarter of 2007, Gartner remains confident that **mobile phones** sales will reach 1.15 billion units for 2007, a 16 percent increase from 2006.

SEMICONDUCTORS

Worldwide sales of semiconductors of $ 19.9 billion in April were 1.6 percent higher than in April of 2006, but 2.1 percent lower than in March 2007, so SIA. Declining ASPs in major industry segments contributed to a sequential decline in worldwide chip sales. Total sales for the first four months of 2007 were up 3.7 percent compared to the same period of 2006.

The **European semiconductor market** declined 2.3% in April, compared to March, in line with the worldwide trend. European sales for computer and industrial applications increased over March, while communication, consumer and automotive applications declined.

Worldwide semiconductor manufacturing equipment billings reached $10.75 billion in the first quarter of 2007, so **SEMI**. The billings figure is four percent higher than the fourth quarter of 2006 and about 12 percent above the same quarter a year ago. SEMI also reported worldwide semiconductor equipment bookings of US$10.50 billion in the first quarter of 2007.

Worldwide **automotive semiconductor market** grew by 6.8% in 2006 to $17.53 billion, after +7.5% in 2005, so Strategy Analytics. With combined revenues of $5.1 billion, Freescale, Infineon and ST were the Top3 vendors.

National Semiconductor announced that Robert Hinke has been appointed to vice president and general manager, Europe. Previously, Hinke served as National's marketing director for Europe.

Microsemi has reversed a decision to phase out operations at its manufacturing facility in Ennis, Ireland (a former Unitrode plant). This decision saves 108 existing jobs and could lead to the creation of an additional 60 to 80 jobs.

Cirrus Logic has named Jason Rhode, 37, as new CEO. Rhode was previously General Manager of the mixedsignal audio line at the company.

OPTOELECTRONICS

Driven by soaring sales of TFT-LCDs, the **global electronic display market is** expected to exceed $100 billion in revenue this year reaching $104.3 billion, so **iSuppli**. Global TFT-LCD revenue surpassed $70 billion in 2006, accounting for 73 percent of display industry revenue for the year. Based on its strength in four major applications—televisions, notebook PCs, desktop monitors and mobile phones—TFT-LCD production will reach nearly 2.5 billion units in 2011, up from 1.2 billion in 2006. LCDs will account for 65 percent of all TV displays in 2011, up from 11 percent in 2005.

LG Group opens a European LCD cluster in Wroclaw, Poland, the company's third LCD cluster worldwide.

The British electronics company **Plastic Logic** laid the cornerstone for its new facility in Dresden. **Quantum Research** Group has set up a design, support and technology licensing business unit in Ireland to develop touch-sensing controls for domestic appliances, mobile phones and personal media players.

PASSIVE COMPONENTS

ITT has signed a definitive agreement with Littlejohn & Co. LLC, a US private equity firm for the sale of its Switches business for an undisclosed amount. The Switches business manufactures switches, dome arrays, interface controls and keypads for a variety of industries including mobile communications, computer and automotive.

PRINTED CIRCUIT BOARDS

Sagem Communications, a subsidiary of French group Safran (aeronautics and communications) will sell its PCB operations (80 persons based in Lannion) to **Elvia PCB**, the former PCB division of Alcatel.

German PCB sales declined sequentially by 7% in February and were down 5% compared to February 2006, so **VdL.** Order input in February declined 2% compared to prior year.

OTHER COMPONENTS

Philips will sell its Power Solutions business to Bobinados de Transformadores, S.L. ("**Bobitrans**") of Spain for an undisclosed amount. Philips Power Solutions develops power supplies for consumer electronics and professional applications and employs approximately 100 people – of whom approximately two-thirds work in Eindhoven, the Netherlands.

ZVEI will be holding the 5th automotive electronics conference on December 3-4, 2007 in Munich, Germany.

EMS PROVIDERS

Flextronics and **Solectron** have entered into a definitive agreement for Flextronics to acquire Solectron, creating the most diversified and premier global provider of advanced design and vertically integrated electronics manufacturing services ("EMS").

DISTRIBUTION

The **German components distribution market** grew 9.3% in the first quarter compared to Q1 2006, to € 710 million, so **FBDi**. Sales were up 9% to € 505 M in semiconductors, up 10.6% to € 107 M in passive components, up 12.9% to € 81 M in Electromechanical components, up 11.4% in power supplies but down 9.3% in displays.

UK distribution market grew by 0.4% in April when compared to March 2007 but declined by 8.5 percent when compared to the same period last year, so Afdec. Semiconductors increased by 2.2 percent, passives increased by 7.1 percent, electromechanicals increased by 0.6 percent, component assemblies declined by 9.6 percent and other products declined by 6 percent.

Elfa, one of the leading electronics distributors in Northern Europe, has acquired the Estonia based Tevalo-group.

Nu Horizons Electronics, a global demand creation distributor, has named Geoff Rose as Director EMS

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

www.europartners.eu.com /services/digest.htm

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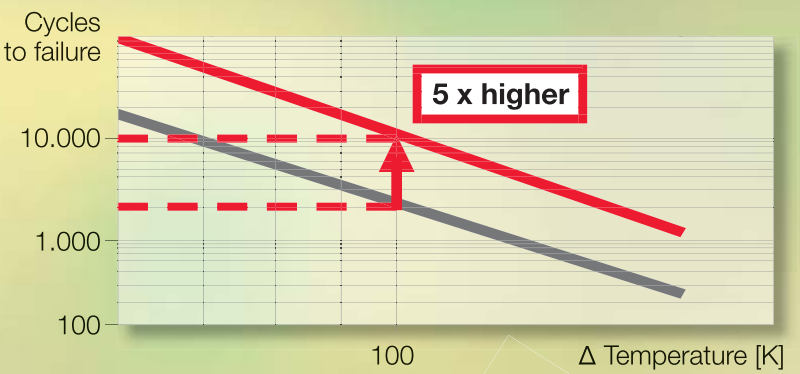

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Power Advances Wireless Networks

Developments in Energy Harvesting, Microbatteries and Power Management ICs for Low-Power Wireless Networks

By Douglas Bess, Editor, PowerPulse.Net

Most of the companies getting a jump on "the next big thing" in power management for wireless networks are not well known in the power electronics industry. Many are start-up companies, and many are based in Europe. With potential unit sales in the billions, however, these companies have targeted the low-power sensor and device market.

This emerging market is made up of many separate applications, with different characteristics defining them and driving them. The energy harvesting companies are, for the most part, small start-up companies. Many are in Europe, like EnOcean, Ubiwave and Perpetuum. Companies like Powercast and Perpetuum have commercial products, while others are still in the prototype stage. The companies offering piezoceramic materials, such as The FACE Companies, are more established, with energy harvesting only one of the industries they supply to.

"Like most emerging technologies, the energy harvesting landscape has many specialized competitors," observed the report's author, Linnea Brush, Senior Analyst with Darnell Group. "The profiles in this report cannot cover them all, but it does provide a detailed review of the more significant products and technologies," Brush concluded.

Many of the energy harvesting companies have found it useful to partner with IC companies. IDS Microchip has a near field communications solution they did for Texas Instruments, for example. Perpetuum is working with Dust Networks. Many of these companies are members of the ZigBee Alliance, as well. The IEEE 802.15.4 standard (ZigBee) is now expected to co-exist with other standards such as Z-Wave, Insteon, EnOcean, Lontalk and others. As a result, products are becoming "ZigBee-qualified."

Still, some companies believe that ZigBee will follow Bluetooth's path in that it will need to find its own "application niche." It is likely that several "standards" will emerge to serve specific application types. For example, EnOcean claims that about 50 companies that have shipped nearly 300,000 EnOcean units for installation in almost 10,000 buildings.

What is agreed upon is that wireless technologies are "hot" - customers want them and find wireless cheaper. Customers also want low power and high reliability. Where demand differences come in is with batteries. Some customers want batteries and some do not. In general, the power requirements of batteries need to be minimized, and both established companies and start-ups are trying to meet this need.
EaglePicher, Tadiran and Varta, for example, are capitalizing on their existing lithium technologies to offer microbatteries for energy harvesting applications. Front Edge, Oak Ridge Micro-Energy and Solicore are newer companies offering ultra-thin film batteries. Although many energy harvesting solutions (such as microgenerators) are aimed at "getting rid of batteries," they are still likely to be used in many wireless sensor networks.

The most established companies offering wireless sensor network and energy harvesting solutions are the power management IC companies. Texas Instruments, Nordic Semiconductor, STMicroelectronics - these manufacturers and more have a variety of products targeted at ultra-low-power applications. Some, like Advanced Linear Devices, have specific modules for energy harvesting. These products are expected to help drive down costs, since high volumes are necessary to achieve market penetration. Radiocrafts, for instance, is "aiming for high-volume manufacturing." Most companies see commercial adoption of ZigBee products and related energy harvesting solutions achieving commercial adoption within 24 months.

Europe Leads the Way

Several European companies are leading the development of power sources for low-power wireless networks. Many of those leaders presented their latest developments at the recent nanoPower Forum (4 to 6 June in San Jose, California).
Dr. Robert Hahn, Head of the Portable Power Supply Group at the Fraunhofer Institute presented a joint paper with Varta Microbattery. Dr. Hahn presented a detailed discussion of the technology involved in a new micro PEM fuel cell in combination with Zn/H2O hydrogen production. He also provided an efficiency evaluation of micro fuel cell systems at low power and pulsed discharge of a typical radio sensor node.
"The power supply is often the major show stopper in efforts to develop miniature systems," stated Dr. Hahn. "We have demonstrated 60 % higher energy of the 4 cubic centimeter fuel cell system compared to alkaline batteries of same size. Three times higher energy (900 Wh/l) compared to alkaline cylindrical cells can be potentially achieved at low power drain," he concluded.
Eddie Shaviv, President of Varta Microbattery followed with a presentation of "Thin-Film Lithium Polymer Batteries." In addition to a general discussion of Varta's thin-film battery technology, Mr. Shaviv provided a brief description of an EU-funded project to develop a combined solar panel/thin-film Lithium-polymer battery system. The resulting 4V power system has been integrated into a portable weather sensing station.
"Varta are developing advanced primary and rechargeable lithium batteries for a variety of applications," Mr. Shaviv stated. "The use a special epoxy resin for the cold lamination of our flat cell LFP25 primary system used in the 'Smart Card Battery' leads to excellent behavior during hard bending. The battery continued to function after more than 1,000 cycles in the ISO Bending Test.

"We are also developing advanced rechargeable lithium batteries with a blend of nano-scale Lithium-Silicon alloys combined with carbon nanotubes, Shaviv continued. "The

resulting batteries have a capacity of more than 1000mAh/g, three times that of graphite systems, and have demonstrated 90% capacity retention after 500 charge/discharge cycles," he concluded.

Energy Harvesting Developments

Dr. Peter Spies from the Fraunhofer Institute lead a discussion of the importance of "power management for energy harvesting applications. According to Dr. Spies, "Besides the improvement of the energy harvesting transducers, high demands are made on power management. Power management can be the 'enabling technology' for the use of energy harvesting power supplies. Improvements in the performance of power management will result in expanding the potential applications for energy harvesting."

There are several duties the power management is responsible for in energy harvesting power supplies. The first task he identified is matching the energy transducers voltage level with those of the electronic circuit or system to supply. The next function is the regulation of the supply voltage, to generate a constant voltage independent of source or load variations. Furthermore the power consumption of the application devices has to be minimized by the power management. So a maximum of functionality, performance and operation time is achieved with the minimum of energy provided by the energy harvesting module. Another task for the power management is the management of the energy and the required storage units like capacitors or rechargeable batteries.

Perpetuum's Roy Freeland warned delegates to "be aware of some wild claims out there" for various energy harvesting technologies and devices. Mr. Freeland provided detailed reviews of energy harvesting technologies and early adopter applications. He observed that while solar is widely used and available, machine vibration/motion energy harvesting is the "ideal source of energy." He went on to provide a comparison of various vibration energy harvesting approaches including piezoelectric, magnetostrictive, electromagnetic and electrostatic.

Freeland concluded that there are still reliability questions remaining about the long-term viability of systems employing magnetostrictive and piezoelectric technologies. His position is that electromagnetic energy harvesting techniques offer the best combination of simplicity, low cost and reliable operation. He reviewed two applications for vibration energy harvesting using electromagnetic devices. Both involved condition monitoring of electric motor systems. One example was an installation at a "major international oil company" the second installation was at the Yorkshire Water utility. Both installations were designed to reduce maintenance costs and system failures.

North American Highlights

While European companies dominate this arena, there are also some notable competitors in North America. For example, The FACE Companies in Norfolk, Virginia, offer a piezoelectric energy harvesting technology called "Lightning" that can generate 300 mJ of energy, or more with larger devices. Producing 300 mJ of energy is one or two orders of magnitude more energy than typically produced by earlier generations of piezoelectric materials.

Lightning elements are a few (typically 6 to 15) thousands of an inch thick. They consist of a PZT ceramic layer bonded to an aluminum substrate using a thermoplastic film. The substrate construction makes Lightning very rugged and contributes to its ability to be cycled millions of times without failure. To bring costs down and compete with battery-powered solutions, the company recently entered volume production of Lightning in a factory in Taiwan.

Front Edge Technology, located near Los Angeles, offers a family of thin-film solid-state rechargeable lithium batteries. The cell construction consists of a Lithium anode, an amorphous ceramic/polymer electrolyte and a nano-crystalline LiCoO2 cathode. Front Edge has produced over 150,000 thin-film cells.

Front Edge has produced a wide variety of cells including a high-temperature battery designed for remote sensor applications. Called the "NX 0201" this unit delivers a capacity of 700 micro-amp-hours at 4.2 V in a 1-inch square by 0.006 inches thick package. It is designed to survive 2,000 temperature cycles from 20 to 150 degrees C and is specified to operate at least 50 hours at 150 degrees C.

The company's largest single cell is the SCX1 that delivers up to 8 mAh at 4.2V. This 1" X 2.2" X 0.006" cell is designed to operate for up to 4 years, or 1, 460 charge/discharge cycles. Delivering only 0.12mAh at 4.2V, and measuring 1.9mm X 8.2mm X 0.12mm, the company's smallest cell is still in development for use in medical implant applications. The company has also developed high-voltage (32V nominal) thin-film batteries, button cells and combined battery/solar cell systems that are only 0.2mm thick, including the solar cell.

Competitive developments in this emerging market are highlighted in the latest report in the Energy Harvesting, Microbattery and Power Management ICs series: "Competitive Environment." This 62-page report discusses the activities of low-profile companies poised to have a big impact in the power supply field. Details are available at

www.Darnell.com

Interview on Technology and Progress

with Eric Lidow, Chairman of the Board and founder of International Rectifier

By Bodo Arlt, Editor BPS

Bodo Arlt: What are your feelings about today's business culture?
Eric Lidow: Today, due to the existence of the Internet most businesses start operating internationally and are able to call themselves international. We are a pioneer and one of the earliest examples of an international business from our very beginning.

Bodo Arlt: I know from many discussions that you had started as an engineer having studied in Berlin.
If you were be able to start again as a young man. Would you start again in engineering?
Eric Lidow: I still believe that electronics engineering is vital but I think if I started today I may focus on bioengineering. I'm fascinated by DNA and stem cell research and feel there is synergy between biotechnology and electronics.

Bodo Arlt: From our first meeting I remember that at lunchtime all the others with us talked about business. I had my Leica Camera with me to take photos. You and I had a chat about old Leica cameras and their value in life. The film material now is nearly obsolete. Most people use digital cameras. What do you think about these drastic changes in photography?
Eric Lidow: This is a fine example of progress and how technology will always lead a market.

Bodo Arlt: Once you said the best time in your life was between 50 and 70. When we first met I was too young to believe it. Now I am 53 and able to agree. Now I need to know what is between 70 and 90 and what will the ongoing future bring to us?
Eric Lidow: There is a longer life span expectation today and if this is combined with a healthy lifestyle men are in their prime in their fifties and can enjoy a high quality of life for a longer period.

Bodo Arlt: To build up a company it needs some passion and vision.
If you had to start again, what would be different from today's perspective?
Answer: Today's entrepreneurs require extensive financial support to engage in a technology start up. It's harder these days to start with $500 and a good idea.

Bodo Arlt: I know you enjoy your work and you are in your office every day. Is this something that keeps you young?
Eric Lidow: I recently saw a discussion on a Chinese television channel about the definition of happiness and according to that discussion by Confucius experts, happiness is when you recognize and are aware of your own abilities and are able to use them to their fullest extent.

Bodo Arlt: I know your son Alex, is the CEO of the company. You handed over responsibility early so that continuity is given. What is your message to other founders that cannot release their dominance in leadership to the next generation?
Eric Lidow: The company founders tend to impart themselves and establish the culture and originate processes in order for the company to continue to grow. Growth and shareholder value determine the best leadership team.

Bodo Arlt: What was your best idea in life?
Eric Lidow: To make a positive contribution to society. Over the years, the company's mission has evolved to one of saving energy. Saving energy is the one true way we can improve the global standard of living and reduce dependence on imported fuels and the effects of global warming. So we are focused on developing power management technologies that contribute in meaningful ways to our improved standard of living, enabling energy efficiency advancements in an array of products from our cars to appliances and computers.

Bodo Arlt: What is your wish if you could influence politics?
Eric Lidow: To harness today's technology in order to save our environment.

Bodo Arlt: What innovation between 1900 and 2000 was the most important one?
Eric Lidow: By far the biggest impact has been the development of the Internet.

Bodo Arlt: As a young man you travelled by boat in the Baltic and had Kiel, my place of birth, as a destination to get away from the upcoming war in Europe. War is still a problem in the world.
From that time in the past we had Vietnam and now Iraq. What would be your recommendation to the world to come to peace?
Eric Lidow: Firstly, we should drive towards a regulated global standard that ensures the highest standards in education and secondly, I feel we need a Global Economical Organisation to represent the global economy.

Bodo Arlt: I am looking forward to my next trip to California to see you and talk and harvest from your wisdom of age. Let me know what I should focus on?
Eric Lidow: Concentrate on the new technological advances and optimise the attention to the key power management challenges for energy-efficiency.

Bodo Arlt: Thank you Mr. Lidow for your time. We look forward to a successful future for power electronics.
Eric Lidow: Thanks Bodo.

Eric Lidow
Chairman of the Board

Eric Lidow, Chairman of the Board and founder of the Company, has been a director since its inception in 1947, and was Chief Executive Officer until March 1995. Mr. Lidow continues as Chairman of the Board and also serves as Chairman of the Company's Executive Committee.
Before the formation of International Rectifier, Mr. Lidow was co-founder and General Manager of Selenium Corporation of America which was established in 1940. In 1944, Selenium Corp. was acquired by Sperry Corporation and Eric Lidow continued as Vice President of Engineering until 1947.
Mr. Lidow was born in Vilnius, Lithuania, and graduated in 1937 from the Technical University of Berlin with a degree in Electrical Engineering. He immigrated to the U.S. from Germany in 1937. He is a Life Associate of Caltech, a Life Member of IEEE, and an Honorary Life Trustee of the Los Angeles County Museum of Art. He also holds an Honorary Doctorate from Technion.

power is our knowledge

DualPack
with Soldering Pins
1200V: 225A - 450A

DualPack
with Spring Contacts
1200V: 225A - 450A

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

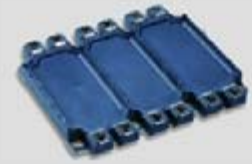
PIM IGBT
600V: 30A - 100A
1200V: 10A - 75A

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

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

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

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



High Power 6-Pack
1200V: 225A - 450A
1700V: 225A - 450A

Special version available for rough environments

Discrete IGBT
600V: 5A - 75A
1200V: 3A - 25A

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

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A New Class in Power Electronics Simulator

The simulator is updated on a regular basis

The demands on power electronics hardware designers are getting higher and higher. In the past, it was common practice that new developments were funded based on design targets only, knowing that new features will justify almost any price. This has changed dramatically over the years.

By Werner Obermaier, Manager Product Marketing, Tyco Electronics

Today the first step, after defining a new product, is to accurately predict the cost of the solution. This has to be realized with the lowest possible time and effort since proper project funding will only be provided when the result of this evaluation shows that cost targets can be achieved and future market success is feasible therefore. Most designers use for this purpose rudimental spreadsheet calculations because the use of accurate simulation tools is normally too difficult to set up. This article describes a new kind of simulator from Tyco Electronics for its power module product range which provides easy to use, easy to set up handling feature and industry-wide unmatched accuracy and simulation speed. This makes *flow*SIM a unique simulator, which can be used during both, the project planning and the design phase.

Simulator Requirements

To make the use of a simulator meaningful the software has to fulfill following prerequisites:

Provide high accuracy and realistic simulation results in order to avoid possible changes later on in the design process with negative impact on cost and/or system performance.

Feature easy and fast usage combined with intuitive handling to reduce familiarization time required to setup and use the tool and to minimize the time and cost for the evaluation.

Show a fast response time (short simulation time) by providing quick results for the defined system and component setup. This enables the designer to check different system conditions and multiple component selections within given time targets, allowing him to select the optimum component and reducing the risk of potentially having to change the components later on in the design process.

Beside the above listed standard features, which should be part of any simulation tool, simulators for power electronics have to offer additional features. These are:

Combined µs to ns simulation capability to accurately determine the transient switching behavior, with ms to sec simulation capability to model the thermal behavior of the system.

An accurate thermal model, taking the thermal capacity of the components into account (use of transient thermal modelsin order to allow the maximum use of each module.

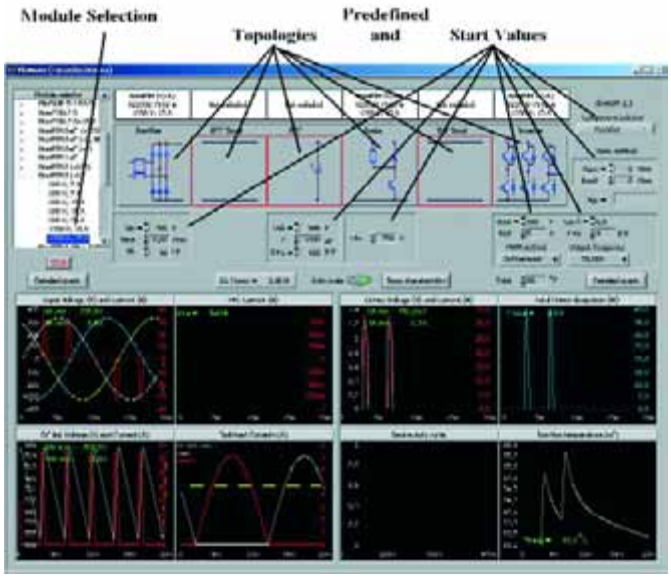
Additional system information. For power circuits this can be in particular information regarding power losses as well as voltage and current exposure of the different components.

Furthermore, a common requirement for simulation tools nowadays is the ability to run on a standard windows PC platform and that they be provided free of charge by the component vendor.

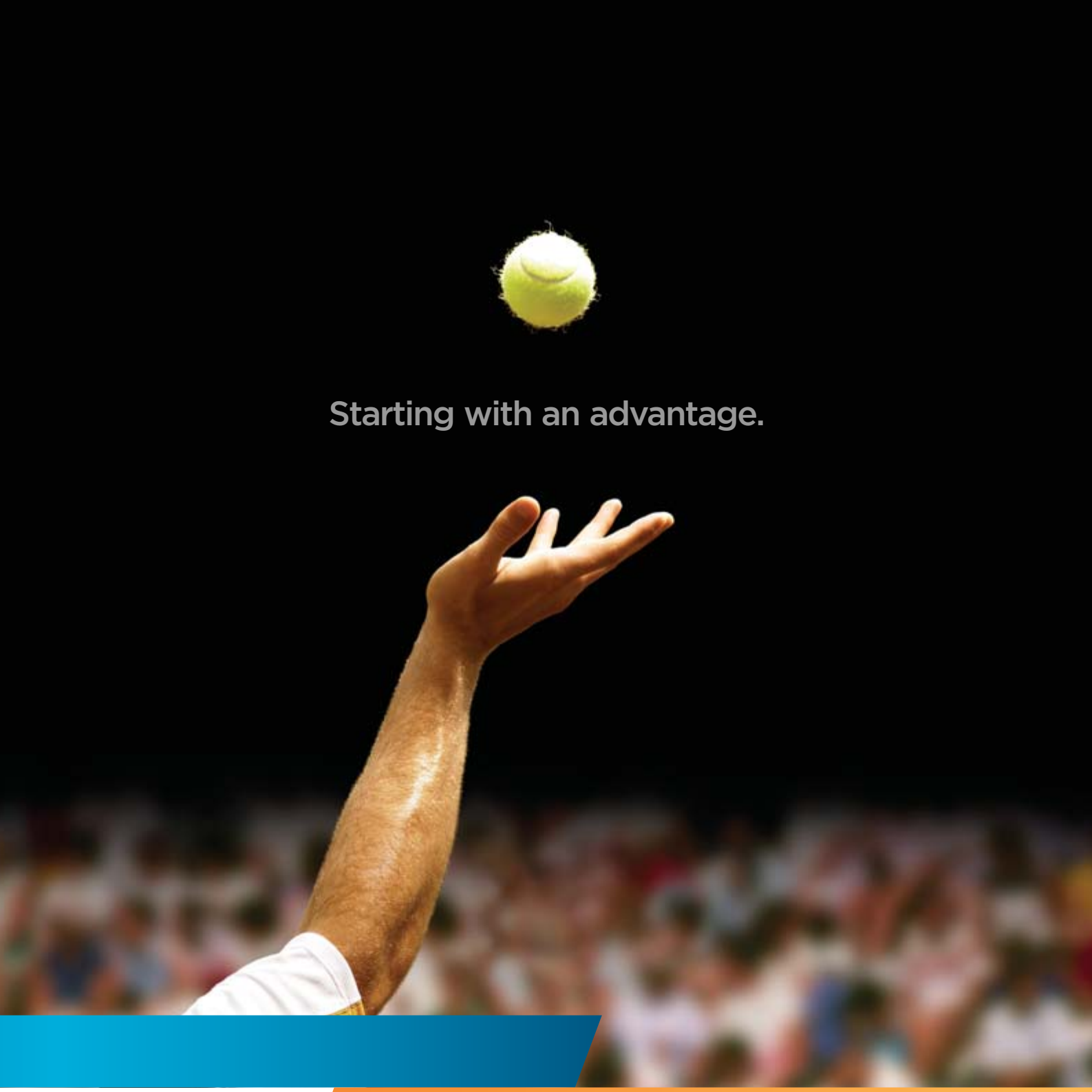
***flow*SIM Features**

The following section describes how these requirements are addressed by the new *flow*SIM simulator. The easy handling of *flow*SIM is achieved by providing predefined circuit topologies and start values accessible via a graphic interface as shown in picture 1. This ensures first simulation results within seconds of use. The simulator currently supports currently the following topologies:

- 3 phase inverter output for motor applications
- Single phase inverter output for power generation and solar inverter applications
- 3 phase input
- Single phase input
- Power factor correction stage for single phase input



Picture 1: flowSIM provides predefined topologies and start values.



From day one, the new Tyco Electronics brings many advantages to our customers, investors, employees and communities. As a $12.8 billion company, with a 60-year head start, we've been at the forefront of the explosive growth in electronics worldwide. With nearly 100,000 employees in more than 45 countries, and a peerless reputation in engineering, our approximately 500,000 products include electronic components, network solutions and wireless systems. Tyco Electronics is committed to the technologies that bring advantages to everyone's life every day.

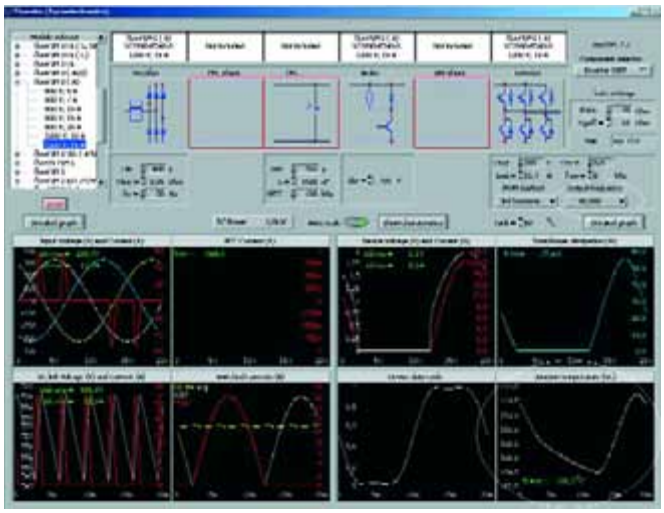
tycoelectronics.com

Tyco Electronics

Our commitment. Your advantage.

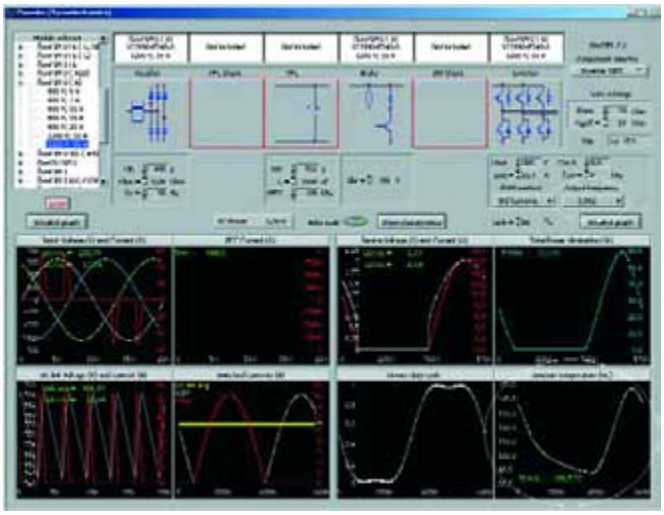
Unlike traditional simulators, which base their results on models of the components under evaluation, *flow*SIM is based on actual measured component data, which is obtained during the characterization of the modules. To support this approach Tyco Electronics collects between 1.5 and 2 Million measurement points during the characterization of their power modules. Up to now, this massive amount of data was captured in data sheets and application notes. With *flow*SIM, this information is available to full extent to all customers. *flow*SIM simulates the output waveforms of the applications and the corresponding wave forms of the components, such as switching current and voltage, duty cycle, device temperature etc. Based on this information, the simulator looks up the actual switching behavior of the components in the components' database. This information, like turn on and off energy, voltage drop etc. is then used to determine the actual power losses and temperature rise of the device. By combining the simulation for the application output wave forms and the calculation of the power component losses based on real measured data, the simulation time is not only reduced to seconds but also the accuracy of the results is improved, as it is not limited to component models.

Furthermore, the simulator uses the transient thermal model of the components to accurately calculate the junction temperature of the devices, taking the thermal capacities of the device and the housing into account. This method ensures more accurate results and avoids the over-sizing of components in the cases when the output frequency is so high that losses need to be averaged across the different components over one output cycle. Picture 2 shows the same output level at 50 Hz motor frequency, where averaging takes place while picture 3 demonstrates the same condition at low output frequency where averaging does not take place.

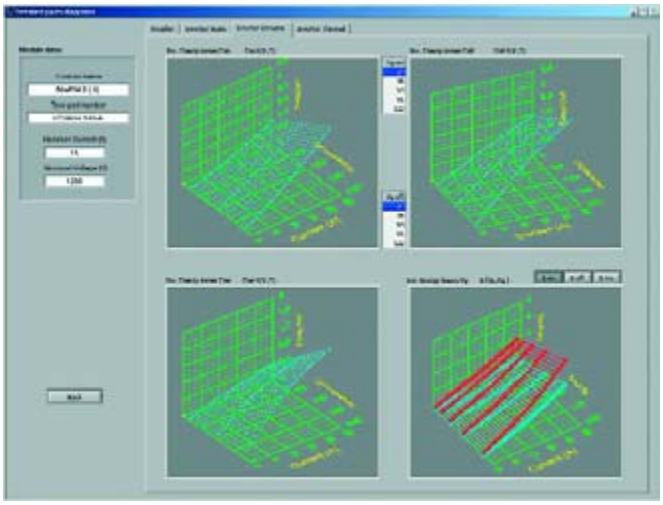


Picture 2: IGBT junction temperature at 50 Hz output frequency

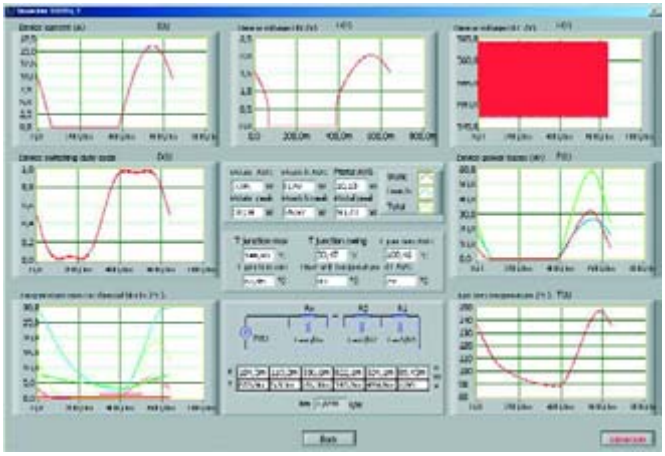
To combine the exact simulation of transients in the ns range with the thermal simulation which takes place in the ms to second range without drastically increasing the simulation time some assumptions had to be made. *flow*SIM assumes that during one switching cycle the system conditions are stable and only the steady state values are used for the thermal calculation. Also, the heat sink temperature is set as a thermal fix point. This simplification enables short simulation times with minimal impact on the precision of the results.



Picture 3: IGBT junction temperature at 1,5 Hz output frequency



Picture 4: Additional inverter output data



Beside the temperature rise of the different components, the simulator also provides additional information, such as input rectifier current, DC link input current, DC link capacitor voltage and the power losses for the different components, as shown in picture 4. This information can be used to select the remaining components of the system, e.g. DC link capacitor, heat sink etc. More detailed information about the power components, such as switching time and loss variation versus gate drive resistor are also given in the simulator; an example of this data is displayed in picture 5.

The software is provided free of charge by Tyco Electronics and supports Tyco Electronis' complete power module standard product portfolio. It is a LabView based program running on standard windows based PC. The software can be downloaded from www.*flow*PIM.com. The program and data files are frequently updated with the new topologies and features as well as latest product developments.

Design Example
In this section an example will be shown. Following are typical requirements for a 3 phase motor inverter application:

Input voltage	400 Vac / 50 Hz
Output voltage:	380 Vac / 50 Hz
PWM frequency:	8 kHz
Gate drive:	Vge = +/- 15 V;
	R_{gon} = 20 Ohm; R_{off} = 54 Ohm;
Modulation type:	3rd harmonic
Heat sink temperature:	80 °C
Motor power cont.:	4 kW
Motor power peak:	6 kW
Motor cos phi:	0,8
0 Hz requirement:	$I_{out\ 0\ Hz} = I_{out\ nom}$
	$f_{PWM\ 0Hz}$ = 4 kHz
Tjmax targeted:	125 °C

Based on this information the maximum phase output current can be calculated:

$$I_{out\ peak} = \frac{6\ kW}{SQRT(3) * 380\ V * 0,8} = 11,4\ A;$$

And the nominal phase ouput current to:

$$I_{out\ nom} = \frac{4\ kW}{SQRT(3) * 380\ V * 0,8} = 7,6\ A$$

The first step is to pick a suitable power module from the list of available modules on the left hand side of the simulator window. For this power level, the P540-A with 1200 V / 15 A should be the right choice. If the simulation shows that the device is either too large or too small, it can be easily changed by selecting a less or more powerful device, without changing the rest of the parameters. Picture 2 shows the simulator with the selected device and the parameters entered. On the bottom right the simulated junction temperature of the IGBT is displayed over one output cycle. At 108,3 °C, calculated average junction temperature is well within the design limit.

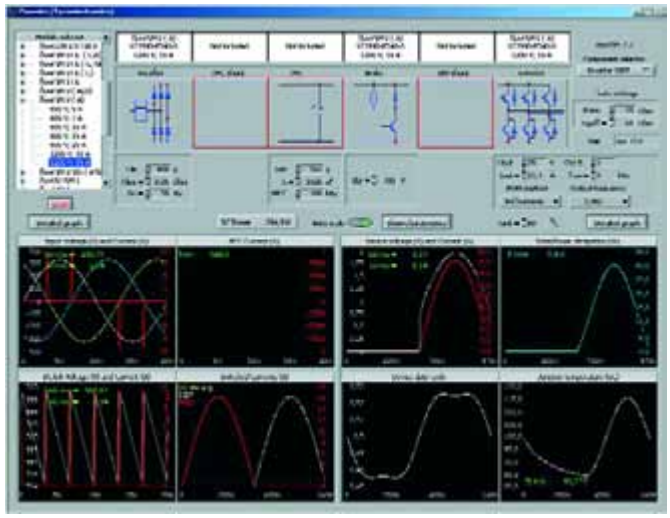
In applications like servo drives or lifting units with low motor frequency or active hold operation, very often the 0 Hz, scenario is the most demanding one and therefore determines the module size. At 0 Hz

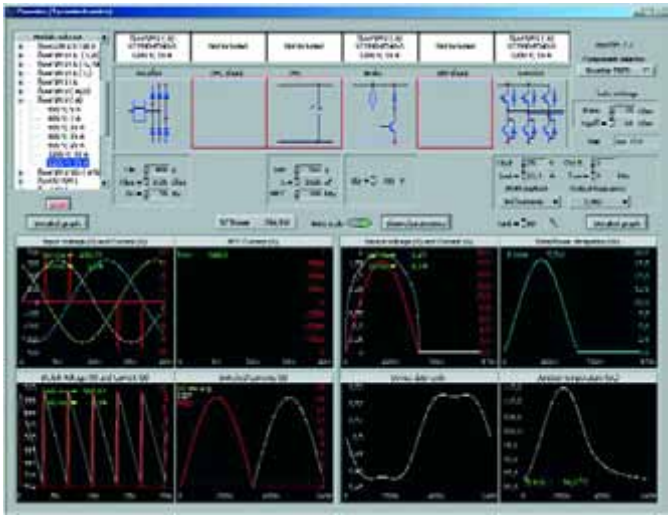
the motor is not turning anymore and does not provide real output power; only the motor losses have to be compensated. Therefore, the actual output voltage drops to around 20 V and the phase current can be continuously at its maximum in 1 of the 6 IGBTs and FREDs of the output inverter. Due to the low output voltage, the duty cycle is around 50 %; thus also the FRED diodes are conducting this current for 50 % of the time. For this reason, the power dissipation and temperature rise should be checked especially at this condition. The simulation could be done by entering the described conditions at 1,5 Hz output frequency but considering the maximum junction temperature instead of the average temperature.

Picture 6a and 6b show the results for the P540-A. There the peak junction temperature for the IGBT has been calculated as 113,71 °C and for the FRED as 114,85 °C, again well inside the design target of 125 °C. A short double check on the next smaller module, the P549-A, reveals that the temperature would be around 130 °C for the FRED and 140 °C for the IGBT in the 0 Hz modus and therefore this device can therefore not be used for this application.

The losses at nominal load have been simulated for the P540 as:
2,9 W per input rectifier diode
9,3 W per IGBT and
2,3 W per FRED,

Resulting in overall losses of
P_{total} = 6 * (2,9 W + 9,3 W + 2,3 W) = 87 W.





Picture 6a and 6b: 0 Hz capability verification IGBT and FRED

This is the total power the heat sink has to dissipate. If the estimated heat sink temperature at this power level differs from the presumed 80 °C, it can be adjusted in the simulator and the losses as well as junction temperatures can be simulated for this condition.

Summary and Outlook

*flow*SIM by Tyco Electronics provides a new state of the art simulation tool for motor drive, welding and power generation applications using power modules. This new approach, using actual measured component data instead of models increases the simulation speed and accuracy. Furthermore, the combination of high frequency transient with accurate low frequency thermal simulation makes the component selection easier, faster and more accurate. With the P540-A40, Tyco Electronics has already added the first power module using IGBT4 technology from Infineon Technologies to the simulator database. This enables the designer to compare the benefits of different IGBT technologies (IGBT2, IGBT2 fast, IGBT2 ultrafast, IGBT3, IGBT3 low loss and IGBT4) at the actual application parameters (current, voltage, gate drive, frequency etc.) without hardware. This makes it possible to select the right IGBT technology prior to the design start. The simulator is updated on a regular basis with the new modules.

www.em.tycoelectronics.com

The HiPak IGBT Modules

Packaging Technology for Reliable Operation

A family of HiPak modules based on ABB's own SPT and SPT+ IGBT and diode chips have been developed for the Traction and Industrial Markets. In this article, we will focus on the development of the packaging technology and show how the modules are designed for long lifetime, safe operation, high isolation and high dc-current capability.

By Daniel Schneider, Dominik Trüssel,
ABB Switzerland Ltd, Semiconductors, Switzerland

The HiPak modules are high-power IGBTs in industry-standard housings with the popular 190 or 130 x 140 mm footprint as shown in Fig. 1. They cover a wide voltage range from 1200 V to 6500 V and a current range from 400 A up to 2400 A. In addition, three different voltage categories for isolation voltages of 4, 6.2 and 10.2 kVRMS are offered. The high reliability requirements specified by the targeted applications have been confirmed by carrying out successfully the standard HTRB (High Temperature Reverse Bias), HTGB (High Temperature Gate Bias), THB (Temperature Humidity Bias 85°C/85% relative humidity), APC (Active Power Cycling), TC (Temperature Cycling), Shock & Vibration and cosmic ray tests.

Figure 1 - HiPak modules

Packaging Technology

The packaging technology has to serve three main functions. First, it must provide a current path from the busbar to the chip and then back. Secondly, it has to cool away the heat generated in the module. Finally, the package has to isolate the contacts (for the different electrical potentials) from each other. In this section, we will highlight the main design principles necessary for fulfilling the above three functions. In Fig. 2, a cross section through a module is shown where the above mentioned functions are attributed to different parts of the module. The red parts illustrate the Current Path Design including the gate-print, bond-wires, and the main/auxiliary terminals. The blue parts show the Thermal Path Design including the base-plate and ceramic substrate. The green parts represent the Potential Isolation Design, which also constitute the overall mechanical design including the housing, silicone gel and epoxy filling. It is clear that this is a very simplified view as different parts of the module are also important for different functions, e.g. the current path design always interacts with the thermal path design and the substrate is important for all three main functions.

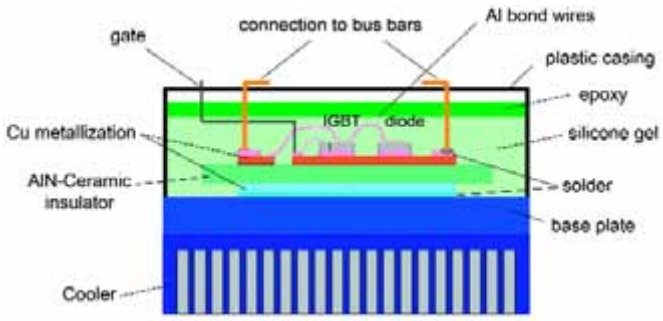


Figure 2 - Cross section of an HiPak IGBT module

a) The Current Path Design

An ideal design for high currents aims primarily towards a low electrical resistance between the user's busbar and the chip. This is important, because a large part of the ohmic heat generated in the terminals themselves flow in direction of the busbar. The laminated busbars, which are generally used, are limited to a maximum temperature of 105°C. Therefore, if not properly designed, the electrical resistance of the terminal connections will limit the maximum dc-current of the module.

There are two issues limiting the use of an ideal contact, which could be represented by a stiff and wide copper bar. First, the modular design makes it necessary to split the terminal contacts into two and secondly, the mismatch in thermal expansion between silicon and the other packaging materials makes it necessary to design flexible current leads to minimize the stress on the solder joints. However, flexibility of the terminals means that small cross sections and long leads are preferred, resulting in a high electrical resistance. Therefore, a compromise must be found for current lead connections with high flexibility while still exhibiting low resistance.
In today's modules, however, rated current can reach as high as 1200 A for a single terminal contact. Because of the high ohmic heat generated in the terminal, these modules cannot be operated at such high currents over longer periods of time without extra cooling of the busbars.

b) The Thermal Path Design

The lower the thermal resistance between the chips and the cooling agent, the higher is the output power of the module. Therefore, a good thermal contact will directly increase the module's rating. The materials used have therefore to be as thin and as thermally conductive as possible. In addition, all ABB modules use Aluminium Silicon Carbide (AlSiC) base-plate material and Aluminium Nitride (AlN) insulating substrates for excellent thermal cycling capability and low thermal resistance as required in Traction applications.

c) The Potential Isolation Design

The Potential Isolation Design is responsible for insolating the different electrical components from each other. In high voltage modules, potential differences of 6.5 kV appear over a distance of only 2 mm. This insulation has to work during the 30 years of operational lifetime of the module under severe mechanical and chemical stress, which makes it necessary to carefully select the materials involved in the module design. Inside the module, the isolation function is normally achieved by the use of ceramic and plastic materials. For a secure insulation, these materials need to be processed free of voids and must also adhere perfectly to each other and on the metal surfaces. On the outside surface, the module has to fulfil the clearance and creepage distances defined by the insulation coordination standards (EN 50124-1). For high voltage applications the material selection for the housing material is therefore strongly limited because a comparative tracking index (CTI) of 600 V is required to fulfil this standard. However, even with materials in the highest CTI class, equal to or above 600 V, very long creepage distances are required. This leads to the design of grooves (see Figure 1), which is typical for high voltage modules.

To prove the capability of the insulation, miscellaneous tests have been carried out. The quality of the insulation between the collector and emitter current leads was tested successfully with HTRB qualification runs at 125°C for 1000 hours. Additional testing was also carried out for the insulation between the baseplate, which is at the same potential as the cooler and the current leads. The insulation test is done at 10.2 kVrms for the high insulation versions including some 3.3 kV and all 6.5 kV modules. The tests done for all modules also include a partial discharge test. This test should prevent long term damage by repetitive discharges, which would, with time, erode the insulating materials. The modules need to maintain their insulating capabilities throughout their lifetime. ABB has measured these insulation characteristics also after severe power cycling tests, which simulate the whole lifetime of a module. No degradation was observed.

Long Term Operation

Fulfilling all of the above basic functions, the package also needs to permit operation of the module for 30 to 40 years. The main degradation factor preventing an infinite lifetime is the occurrence of thermal cycles. Modules in applications undergo a number of power load cycles. A train, for instance, may stop at the station for two minutes during which time the module cools down by several tens of degrees. If the stop is longer, i.e. overnight, the module cools down from its operation temperature at over 100°C to the ambient temperature.

Such thermal cycles stress the module package in different ways. If two materials with different coefficients of thermal expansion (CTE) are joined together, they and the joining layer are stressed whenever the temperature is changed. Most critical are the solder joints, which are stressed most when long cycles with a high temperature difference occur. Another failure location is the contact between the bond-wires and the chip metallization, which represents the main failure mechanism when short cycles with a low temperature difference are applied. Figure 3 shows two typical failure patterns; delamination of the substrate solder joint on the left a lift-off of the bond-wire on the right.

To test the HiPak module capability to withstand thermal cycles, active and passive cycling tests were made. In the active tests, the modules are heated by passing current through them and in the passive test they are heated through air in a furnace. The active power cycling tests are divided further into short cycles in the range of 1 to 5 seconds where, due to the high thermal mass of the module, the chip mainly undergoes thermal cycles and then into longer cycles in the range of 1 to 2 minutes where in addition to the chip, the rest of the package undergoes the thermal cycle. The former stresses the bond-wire connections and the chip metallization, whereas the latter stresses the solder joints.

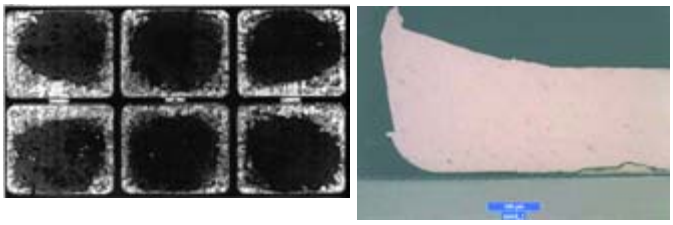


Figure 3 - Left: solder joint delamination – Right: bond-wire lift-off.

To get the most accurate results, it is important to investigate each failure mechanism individually. Figure 4 shows the Weibull distribution for the failures of three different solder joints in the HiPak modules. Delamination refers to the large area solder joint between substrate and baseplate, whereas the auxiliary pins connect the substrates with the gate-print and finally, the main terminals connect the substrates with the busbar.

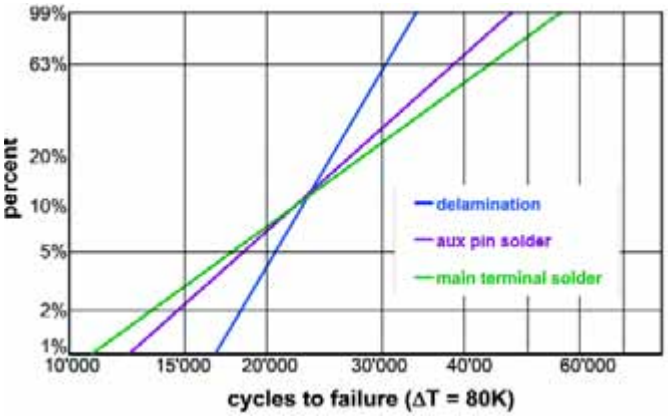


Figure 4 - Distinguishing failure mechanisms in Weibull distribution.

The Weibull distribution used in Figure 4 allows us to predict when a certain percentage of the modules will fail. It is common to use, either 1%, 5% or 10% “confidence” values such that a user, who allows 1% of the modules to fail within the whole lifetime of 30 years would then refer to the 1% value for his calculations.

It is also important to show the capability of the modules in a graph, which indicates the module´s capability at different ΔT values. Figure 5 shows the capability curve for HiPak modules vs. junction temperature swings (blue straight curve). Furthermore, the figure shows how recent trends in increasing the maximum operating temperature will affect the capability. Because of the higher temperatures, the capability will fall (blue arrow) due to accelerated failure mechanisms such as creep. The requirement, on the other hand will increase (red arrow) because the higher operation temperature will lead to higher thermal cycles.

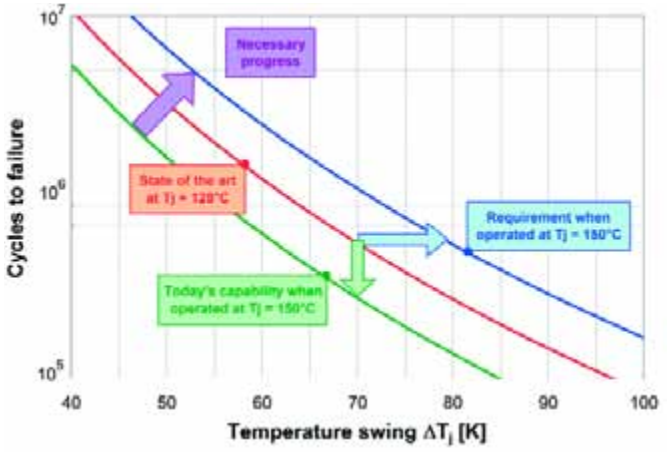


Figure 5 - Capability curve for HiPak modules

HiPak Modules Safe Operation

To make use of the full cycling capability offered, the HiPak module has to operate safely until it reaches the end of its innate life. To prevent early failure of its functions, the module needs to work also in harsh humid and chemical environments or when it is mechanically stressed from the outside. Additionally, if it fails, it has to fail in a controlled manner while not causing damage to neighbouring system components.

The impact of humidity on the functionality has been tested in a temperature humidity bias test (THB). More severe testing has been undertaken in harsher environments such as saltmist or sulphur. The HiPak modules survived all these tests.

Another impact is of a mechanical nature. The terminal connections of the module are contacted with the gate units and the busbars. Therefore, the terminals are able to transmit mechanical stress to the module in a rather undefined manner. To test the modules resistance against such stresses, shock and vibration testing was performed. To make the test more stressful, the HiPak modules were loaded with additional weight on the terminals: 2 kg bars on the main and 250 g bars on the auxiliary terminals. Despite these severe conditions, no defect could be detected afterwards. This outstanding performance of the HiPak modules is made possible by a thick epoxy layer filled with glass fibres and minerals.

Despite careful design and thorough qualification, failures can still occur. Standard failure rates are of the order of several hundred FITs where one FIT equals one module failure in one billion device-operating hours. In this case, it is important that the modules fail safely with the lowest possible impact on neighbouring equipment and with zero impact on human beings. Therefore ABB has chosen a robust design with a thick epoxy layer, which helps absorb, while directing sideways, the energy in case of an explosion. Furthermore, the chosen materials have been certified according to the flammability standards (UL 94 and NF F 16-102). Hence in the case of fire, the materials extinguish and do not develop toxic gases.

Summary of Qualification

The table below gives an overview of the successful qualifications of the HiPak product family.

Test	Conditions	Standard
active power cycling (case)	t_{cycle} = 1-2 mins, ΔT_{case} = 60-80 K	IEC 60747-9, 60749-34
active power cycling (junction)	t_{cycle} = 1-5 s, ΔT_j = 40-80 K	
passive thermal cycling	t_{cycle} = 4 h, ΔT = 165-200 K	IEC 60068-2-14
high temperature reverse bias	Vce= 5200 V, 125°C, 1000 h	IEC 60747–9.8
high temperature gate bias	Vge = +/- 20 V, 125°C, 1000 h	IEC 60749-9.8
temperature humidity bias	Vce = 80 V, 85°C, 85%, 1000 h	IEC 60749–3.4B
saltmist	50 g/l NaCl, 35°C, 16 h	IEC 60068-2-11
sulphur (SO_2, H_2S)	25°C, 75%, 10 days	IEC 60068-2-60
shock and vibration		IEC 61373
fire protection	UL 94-V0, NF F 16-102	

Table. 1 -
Overview on ABB’s qualification program for HiPak modules.

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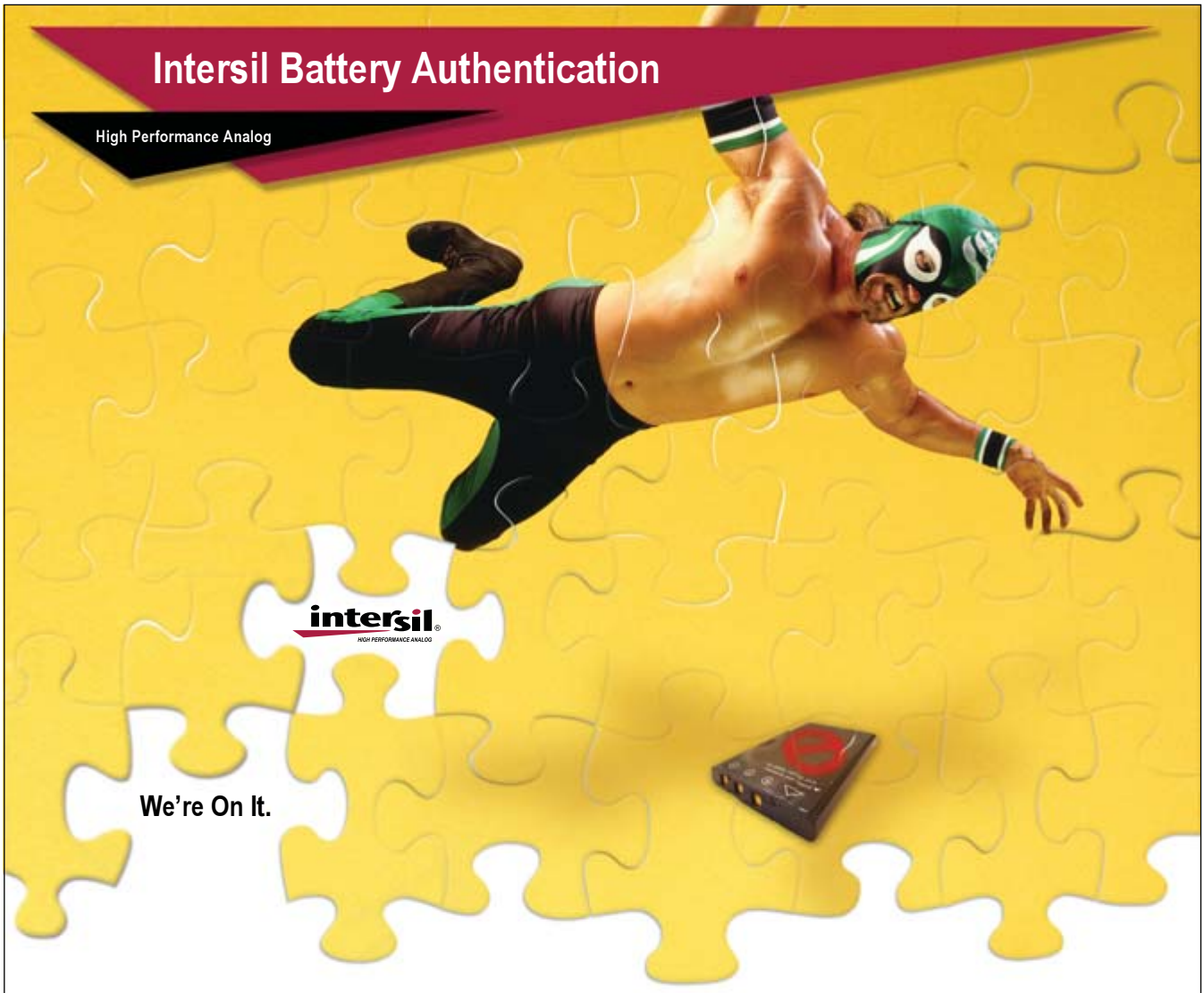
Intersil Battery Authentication

High Performance Analog

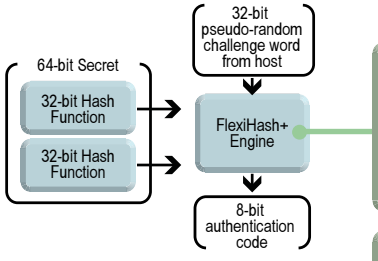


Intersil's **ISL9206 FlexiHash+™ Engine delivers high-security battery authentication** at a low cost.

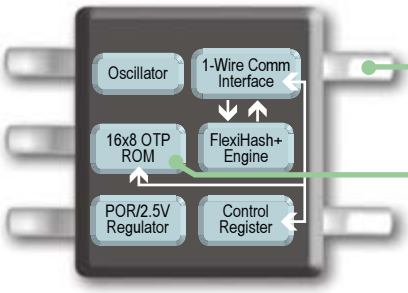
Intersil's ISL9206 is an easy-to-use, robust, and inexpensive battery authentication solution for 1-cell Li-Ion/Li-Polymer or 3-cell NiMH series battery packs.

ISL9206 Key Features:

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



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



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

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

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Among many power semiconductor devices, IGBT has been attracted a considerable attention as a key semiconductor component for power industry due to huge potential to cover large areas of applications. To achieve higher performance and lower cost of IGBTs, extensive research and development activities have been performed.

By Seung-Chul Lee, Kwang-Hoon Oh, Soo-Seong Kim, Kyu-Hyun Lee and Chong-Man Yun
Device Concepts and Technology Development, Fairchild Korea Semiconductor Inc.

Introduction

Continuous demand for efficient control of power conversion and motion control systems drives a rapid evolution of power semiconductor devices through the significant progress in design and process technologies. In order to achieve higher performance and lower cost of power semiconductor devices, research and development efforts for new power device technologies have been continuously performed.

Of the power semiconductor devices, the IGBT has attracted a considerable amount of attention as a key semiconductor component for the power industry due to its huge potential to cover wide range of applications. Before the thin wafer process was available in the early 1990s, the IGBT was based on the punch through (PT) structure. This type of IGBT technology needs additional lifetime control processes to improve the switching performance. Concurrently, the fine patterning was a key design factor for the advancement of the device´s micro fabrication process technology. From the mid 1990s, the trench gate structure appeared in IGBTs, now a familiar active cell designs for high voltage IGBTs rates under 1200-V.

Recently, the combination of trench gate the structure and thin wafer technology has significantly enhanced IGBT performance, utilizing the drift layer while eliminating the redundant parts of the wafer. Owing to the introduction of innovative thin wafer processes, the IGBT has been able to broaden its power ratings and ranges of its applications. With thin wafer and related technologies, NPT (non-punch through) IGBT becomes majority for the high voltage IGBTs, offering a low conduction loss, fast switching capability, enhanced thermal stability and excellent ruggedness.

Furthermore the field stop (FS) concept has has been applied to the NPT IGBT structures in order to maximize benefits of the thin wafer technology as well as the principle of punch-through [1]. In Figure 1, advances of IGBT structures are shown according to thin wafer technology progress.

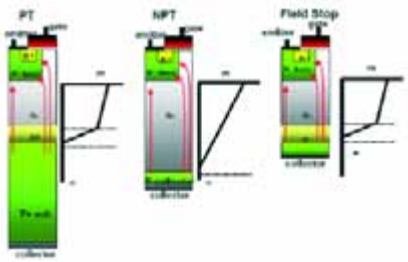

Figure 1. Advance of IGBT structures.

In this article we will discuss recent advanced technologies and design concepts for ultimate performance IGBTs in high power applications, including the wafer thinning process, the pulsed laser annealing, and the super-junction IGBT.

Operational Principle of IGBT

Other than the collector, the IGBT structure shown in Figure 1 is similar to that of a vertical MOSFET. The on and off states of IGBTs are controlled by the gate voltage. When the gate voltage is greater than the threshold voltage, an inversion layer is formed under the gate, supplying electrons from the emitter to the drift region so that holes are injected simultaneously into the n-type drift region from the p-type collector.

This hole injection causes conductivity modulation in the drift region where both the electron and hole densities are several orders of magnitude higher than the original n- doping, which enables low conduction loss of the IGBT during the on-state. Figure 2 shows typical I-V curves according to various gate voltages. Higher collector currents flow with increase in gate bias.

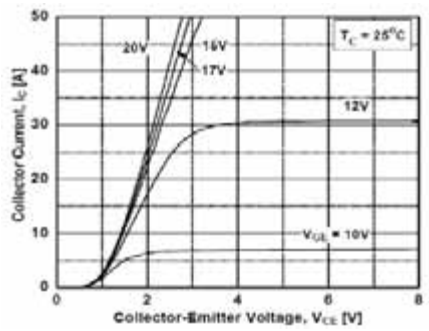

Figure 2. Typical I-V curve of IGBT

In the transient mode operation, when the gate to emitter voltage drops below the threshold voltage, the collector to emitter voltage starts increasing linearly as shown in Figure 3. After the collector voltage reaches Vcc, the IGBT current decreases, showing some tail currents due to the stored minority carriers in the n- drift region. Most switching loss is generated during this period because of the tail current, which limits the switching performance of IGBTs. Since there are trade-off relationships between conduction loss and switching loss in IGBTs, extensive research activities for novel design and

process concepts have been performed for improved trade-off relationships. In this regard, thin wafer technology, pulsed laser anneal, and super-junction IGBT will be discussed as novel technologies for advanced IGBTs.

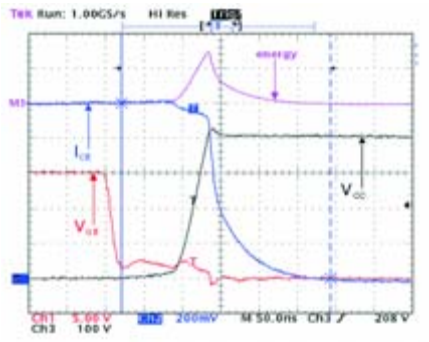

Figure 3. Typical turn-off waveform of IGBT under inductive load.

Thin Wafer Technology

Since the thin wafer based IGBTs, such as NPT or FS IGBTs, employ no lifetime control process high carrier lifetime yields a low on-state voltage drop. Also, by optimizing the injection efficiency of the anode, fast switching capability can be achieved. Furthermore, due to its thin nature, thermal stability as well as durability is better than the typical PT IGBT. In this regard, advanced IGBTs rely on the thin wafer technology, requiring a very thin wafer process, resulting in wafers less 100 μm. In general, 600-V NPT IGBTs need 90 μm ~ 110 μm wafers and 1200-V IGBTs require 160 μm ~ 200 μm wafers and even thinner wafers are required in the case of FS IGBTs.

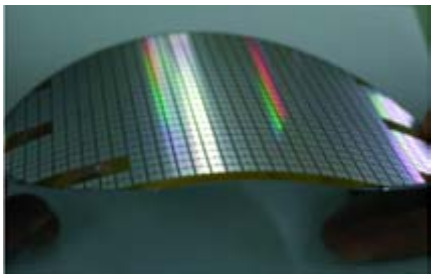

Figure 4. 6-inch 100 μm NPT IGBT wafer.

Therefore, the ultra thin wafer process capability is crucial for advanced IGBT devices and the fabricated 6-inch 100 μm NPT IGBT wafer is shown in Figure 4.

As can be seen, the thinned wafer becomes very flexible and thus, the wafer warpage and bow become more. The fabrication of high performance IGBT with such uneven wafers is very complex since the successive process steps cannot easily proceed and the high risk of wafer breakage is latent. As a result, the wafer thinning process and the relevant unit process steps are main challenges for advanced IGBT fabrication.

Figure 5. Main process steps for thin wafer technology.

The main process steps of thin wafer technology are shown in Figure 5.

After the fabrication of top structures, the wafer thinning is done. Because the ground surface is very rough, wafer polishing or SEZ should follow the thinning process to avoid wafer breakage. The rough surface layers after the backside grinding are shown in Figure 6, and the clean surface can be seen with the successive silicon etch, which smoothes the damaged rough layers.

After the thinning process, the anode implantation, activation and back metallization are sequentially done. At this point, the anode activation process becomes a challenge since the thermal budget available at the annealing step is constrained due to the existing front metal layers. For this reason, the rapid thermal anneal or pulsed laser annealing will be desirable option , rather than the conventional tube annealing.

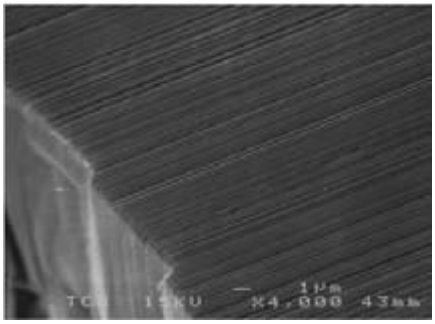

Figure 6a:
Backside surface after backside grinding

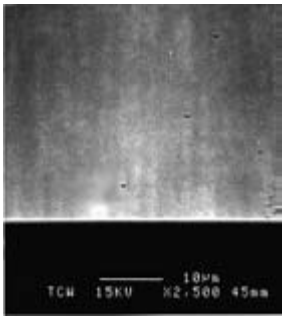

Figure 6b:
Backside after damage layer relief

Pulsed Laser Annealing Process

The anode structure of NPT and FS IGBTs is formed on the backside of the thinned wafer after the top structures are fabricated. Therefore, the backside processes for thin wafers like anode implantation, activation and backside metallization process is considerably difficult. The activation process after anode implantation should be done at a limited temperature where the top surface metal layer can tolerate the heat, not exceeding 500°C.

The conventional activation process in the limited thermal budget leads to low activation rates so control of the forward and reverse characteristics of the IGBT is constrained. In this aspect, the laser annealing technique can be effective because the laser annealing process allows localized rapid heating of semiconductor wafers within the very shallow depth without the impact of temperature to the whole silicon wafer. It has been reported that the laser annealing process can be successfully applied to the anode activation process of IGBTs achieving an activation

rate more than 80% [2]. Therefore, ultra low conduction loss IGBT can be realized with a highly activated anode structure.

In Figure 7, the trade-off performances between V_{cesat} and switching off energy, E_{off} of the laser annealed 600-V NPT IGBTs are shown and compared with the device annealed at the low temperature in the diffusion furnace. The laser annealed NPT IGBTs show a wide span of trade-off performances with the increase of laser energy density.

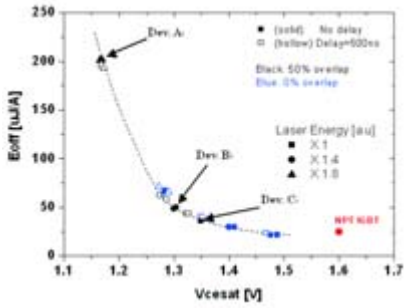

Figure. 7. Trade-off performances of laser annealed NPT IGBTs where V_{cesat} and E_{off} under inductive load conditions are measured at I_c=165A/cm2.

When the device is annealed in the conventional diffusion furnace, the IGBT shows a V_{cesat} of 1.6 V and the switching off energy, E_{off} of 25 μJ/A. The laser annealed NPT IGBT demonstrates the on state voltage drop from 1.17 V to 1.49 V at the collector current density of 165A/cm² while E_{off} ranges from 23 μJ/A to 200 μJ/A , respectively, showing the wide span of trade-off performances.

From the experimental results it can be theorized that a fine-tune of the trade-off performance is achievable with a proper control of laser irradiation condition.

Super-junction FS IGBT [3]

Although field stop (FS) concept can take full advantage of thin wafer technology as well as the principle of punch-through, high resistivity substrate and finite drift layer thickness is inevitably required. This sets a limit to further improvement of device performance.

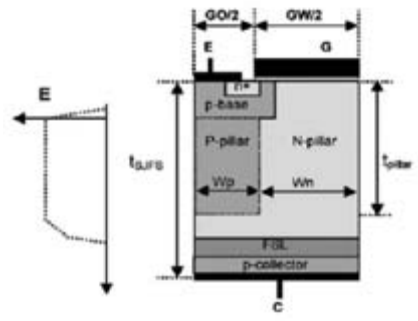

Figure 8. Super-junction FS IGBT [3].

Employing charge balance concept to IGBTs, we can increase the concentration of the drift layer with the reduced thickness of the drift layer while preserving the same blocking voltage. Therefore, a large benefit can be obtained from the super-junction IGBTs, which employ thin and highly doped drift layer with multiple pillars.

In Figure 8, the super-junction field stop (SJFS) IGBT is shown. For the ideal charge balance structure, a perfectly flat electric field profile, that can sustain the significantly high breakdown voltage should be obtained. According to the theoretical calculation, 1200-V in IGBT can be realized with the only ~ 70 μm pillars. By varying of Vceast through control of the collector doping concentration, various trade-off curves are numerically generated as shown in Figure 9. The switching off characteristic of SJFS IGBT can be significantly improved to less than 20 μJ/A for the identical forward characteristics, compared with the typical FS IGBTs. In addition, like the typical NPT IGBTs trade-off performance advances according to decrease of t_{SJFS}.

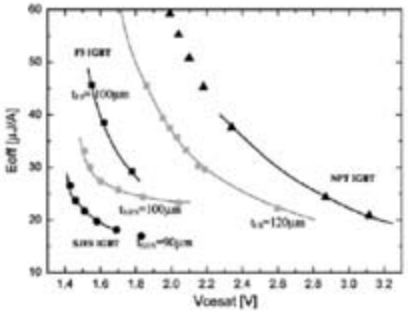

Figure 9. Trade-off curves for the SJFS IGBTs, FS IGBTs and NPT IGBT with different drift-layer thickness [3].

The simulated SJFS IGBT demonstrates V_{cesat} of 1.6 V and E_{off} of 20 μJ/A at the collector current of 100 A/cm², which is considered as the best trade-off performance in its class.

Along with the excellent trade-off performance, very high latch-up immunity in the short circuit condition is expected for the SJFS IGBTs because the p-type pillar functions as a hole current path and enables less hole current to flow underneath the n+ emitter region, increasing the latch-up current level. The peak value of electron current density for the SJFS IGBT is lower, showing more evenly distributed hole current. These characteristics are helpful for reducing temperature rise under high current operation such as short circuit operation.

In Figure 10 (a), the short circuit current flowline for the two IGBTs are shown when the peak short circuit currents flow. A part of the short circuit currents also flow along the p-type pillar for the SJFS IGBT, which eventually exhibit the rather smooth temperature distribution with low peak value as in Figure 10 (b). This intrinsic difference in the operating mechanism of the SJFS IGBT results in high ruggedness, when compared to the typical FS IGBT.

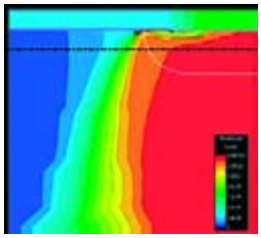

Figure 10a: Current flowlines at the moment of peak short circuit current for the FS IGBT and CBFS IGBT

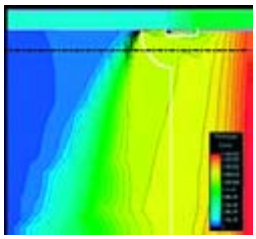

Figure 10b: the corresponding temperature distribution along the line AA' (at y =1 μm)

Conclusions

Recent technology innovations for advanced IGBTs have been presented, including thin wafer technology, pulsed laser-annealing, super-junction IGBT. These advanced technologies can significantly extend performance of advanced IGBTs and expedite research and development activities for novel power semiconductor devices.

Acknowledgement

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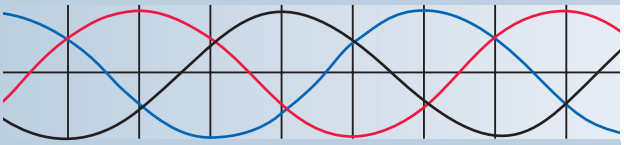
Field Oriented Control



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Never stop thinking

Digital Power-Conversion for the Analogue Engineer

MOSFET replaces the rectifier in the circuit

It is no secret that, in the past, analogue engineers have struggled with the complexity of designing power supplies that require multiple outputs, coordinated load sharing, hot-swap capability, or extensive fault handling.

By Bryan Kris, Staff Architect, Architecture & Applications, Digital Signal Controller Division, Microchip Technology Inc.

Designing power supplies using analogue techniques requires components to be oversized to compensate for component variation and component drift. Even after overcoming these design challenges, the power supplies need manual tuning at the end of the manufacturing line. So, what options do analogue engineers have for designing power supplies? The engineering answer to this problem lies in being able to implement intelligent digital control of the power-conversion feedback loop.

Recently, microcontrollers have enabled analogue designers to implement monitoring, control, communications and even deterministic functions, such as power sequencing, soft-start and topology control in power supplies. However, digital control of the complete power-conversion loop has been impractical, due to the lack of cost-effective, high-performance technology.

DSCs in Switch-Mode Power Supply Design

A new breed of Digital Signal Controllers (DSC) is now making digital conversion possible with features such as intelligent power peripherals that combine counter-based Pulse-Width-Modulation (PWM) modules, analogue comparator-based feedback and coordinated Analogue-to-Digital Converter (ADC) sampling, coupled with fast multiplication in a single clock cycle. The combination of these features allows DSCs to handle the high execution rates needed for control-loop software.

Before starting a power-supply design, the following decisions need to be made:

Choose a topology that fits the application's needs:

a. Step-up or step-down (Boost or Buck)

b. Isolated (Forward, Half or Full-Bridge)

Select a switching technique:

a. Hard

b. Soft-switching: soft-switching techniques such as resonant mode or quasi-resonant mode, offer lower switching losses at the expense of more complex circuitry and control.

Select a control methodology:

a. Voltage mode

b. Current mode

Voltage-mode control and current-mode control are the two methods based on classic analogue Switch-Mode Power Supply (SMPS) control techniques. In voltage-mode, the difference between the desired and actual output voltage (error) controls the time that the supply voltage is applied across the inductor, which indirectly controls current flow in the inductor.

In current-mode control, the difference between the desired and actual output voltage (error) creates a threshold for an analogue comparator to set the peak inductor current, in an attempt to control the average inductor current.

Voltage-mode can provide more stability in a noisy environment or over a wide operating range. Current-mode control offers cycle-by-cycle current limiting and faster transient response. It also prevents ratcheting-up the inductor current, which can result in inductor saturation and lead to catastrophic MOSFET failure.

Select a PWM operating frequency. A higher-frequency PWM enables the use of smaller inductors and capacitors, but at the cost of additional switching losses.

Determine the required control bandwidth. This is largely determined by the expected load transients for the application.

With an estimated control bandwidth requirement, the next step is to allocate processor resources. There are a wide variety of control algorithms, but a common technique is the Proportional, Integral, and Differential (PID) method. Using the common PID algorithm, the control-loop will need to operate at a rate of approximately eight times

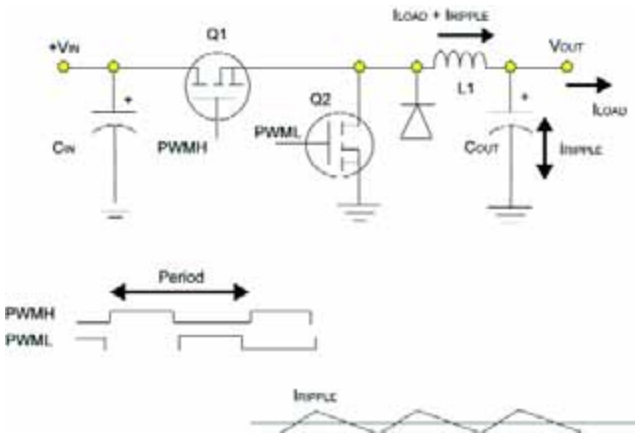

Figure 1: Synchronous Buck Converter

the required control system bandwidth to ensure sufficient phase margin. When estimating the control-loop delays, all delays within the control-loop must be considered (see the section on Computing Control-loop Delay).

The next step is to choose a DSC that meets all or most of the chosen design requirements.

The following example demonstrates a digital SMPS design of a synchronous buck converter based one of Microchip Technology's dsPIC30F2020 DSC for SMPS. This DSC features a hard-switching, voltage-control mode that offers a complementary PWM mode. The buck converter (see Figure 1) uses synchronous switching, and a MOSFET replaces the rectifier in the circuit because it has a much lower forward-voltage drop than the standard rectifier. By lowering the voltage drop, the overall efficiency of the buck converter can be improved by as much as 5 to 10 percent. Synchronous switching with Q2 requires a second PWM signal that complements the primary PWM signal. Q2 is on when Q1 is off, and vice-versa. In addition, dead-band control is required to prevent both Q1 and Q2 from conducting at the same time during the rise and fall edges of the PWM signals.

The input to output voltage relationship in a buck converter is represented by:

$V_{OUT} = V_{IN} * D$, where D = PWM duty cycle = $T_{ON} / (T_{ON} + T_{OFF})$

The ideal output voltage for a buck converter is the product of the input voltage multiplied by the duty cycle of the transistor. By inspection (see Figure 1), the output voltage will equal the input voltage, if transistor Q1 is always turned on. If Q1 is always off, then the output voltage will be zero. In reality, there are voltage drops across the transistor and the inductor that increase when the load current rises.

The design of the digital SMPS control system using DSCs can now begin (see Figure 2).

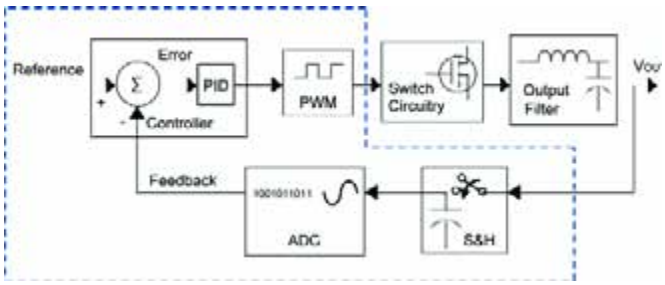

Figure 2: Design of the digital SMPS control system

In this typical SMPS control system for a synchronous buck converter, note carefully that there are delays associated with each block in this diagram

The Sample-and-Hold (S & H) circuit typically samples every 2 to 10 microseconds. The ADC requires about 500 nanoseconds (ns) to convert the analogue feedback signal to a digital value.

The PID controller is a programme running on a DSC with a computation delay of about 1 to 2 microseconds. The controller output is converted to a PWM signal, which drives the switching circuitry. The PWM generator can introduce significant delays if it cannot immediately update its output when given a new duty cycle. The transistor drivers and the associated transistors also introduce delays from approximately 50 ns to about 1 microsecond, depending upon the devices used and the circuit design.

Computing Control-Loop Delay

Total control-loop delay is the sum of the ADC sample and convert time (500 ns), the PID calculation time (1 µsec), the PWM output delay (0), the transistor switching time (50 ns) and the PID execution-rate period (2 µsec). The total loop delay in this example is 3.65 µsec, which implies the maximum effective control-loop sampling rate of 274 kHz.

While the Nyquist Theorem requires a 2x sampling rate to reconstruct a signal, digital control loops must sample at a 6x to 10x rate. The reason for this is that, with only a 2x sampling rate, the phase-lag is 180 degrees. With a 2x sampling rate, the budget of 180 degrees for phase-lag has already been used without considering any other delays in the system. A system with an 8x sampling rate introduces 45 degrees of phase-lag from the sampling process alone, a much better sampling rate. To maximise phase margin, many digital control systems oversample the analogue signals by 10x or more. Assuming a maximum effective sample rate of 274 kHz, the effective control bandwidth is one eighth of this, or approximately 34 kHz.

Importance of PWM in SMPS Design

Different power-supply specifications drive the need for different power-supply topologies. These topologies require different PWM modes, which each support a wide variety of SMPS designs including standard, complementary, push-pull, multi-phase, variable-phase, current-reset and current-limit PWM modes.

The most basic PWM mode is the standard edge-aligned PWM, where the ratio of the on time versus the off time controls the flow of power. Only one of the PWM outputs per output pair is used in these asynchronous buck, boost and flyback converter circuits.

The synchronous buck converter in the example SPMS uses a complementary PWM mode, where the complementary output controls a synchronous switching rectifier that is implemented with a MOSFET, instead of the typical rectifier. The complementary PWM mode can also be used in other circuits that use synchronous rectification to improve system efficiency.

Push-pull converters are commonly used in DC/DC converters and AC/DC power supplies. The term multiphase PWM describes multiple PWM outputs that are not edge-aligned. Multiphase converter circuits are often used in DC/DC converters that must supply high current in applications where the load may change very rapidly.

Phase-shifted PWM mode is becoming more common because of its wide use in personal computer power supplies. Microchip's dsPIC® DSC SMPS family supports all of the known PWM modes currently in wide use by the power-supply industry.

Understanding PWM Resolution

Power-supply designers and customers must correctly understand the term PWM resolution. PWM resolution is not how wide a particular counter is, but how many counts (the minimum possible PWM time slices) that can occur within a PWM cycle period. In the power-supply industry, PWM resolution is specified by the smallest time increment achievable within the PWM duty cycle. This resolution is often specified in ns.

If a PWM module does not have sufficient resolution, the control system hardware or software will dither the PWM outputs to achieve the desired average output. In power-supply applications, PWM dithering can create problems with ripple currents, and cause the control to enter a bad mode of operation called limit cycling.

For example, consider a PWM that can output values of 3 and 4 while the control-loop needs an output value of 3.25. In this case, the PWM dithers between the values 33343334. This is easily put into perspective: many DSCs offer PWM counters that operate in a range from 40 to 150 MHz, yielding PWM resolutions of 6 to 25 ns. The dsPIC® SMPS DSC family features a duty cycle resolution of 1 ns.

In a control-loop, the time from acquisition of voltage and current measurements until the PWM outputs a new duty cycle value is called latency. As latency decreases, the control-loop becomes more stable and responsive. Some DSCs feature PWM modules that accept new duty-cycle data only on a PWM cycle-to-cycle basis. The time lag from the software computation of a new duty cycle value until the PWM module accepts the data increases the control-loop latency, while decreasing its stability. Therefore, it is best to use a DSC with a PWM module that immediately accepts and processes new duty-cycle data.

SMPS ADC Requirements

Analogue design insights can be applied to intelligent power-supply design using DSCs. The on-chip ADC provides the system status feedback to the control loop. Conventional ADCs are designed with an assumption that the ADC values are collected and processed in a group. ADCs in audio processing and industrial control systems typically function in this manner. Group sampling causes the processor workload to peak in groups, and this increases control-loop latency.

Often in SMPS circuits, the analogue signal to be sampled and converted does not exist, or may not be significant at all times. The signal may only be important at specific points in the PWM cycle. Standard ADC modules may, therefore, miss the desired data due to imprecise sample timing.

Figure 3 shows an example circuit where a current-sense resistor is used to monitor current flow. In this circuit, the current can be sensed only when the transistor is turned on. Typical ADC modules cannot accurately command the sample-and-hold circuit to take a sample at the appropriate time. If the application has multiple circuits to sense, then the ADCs are inadequate.

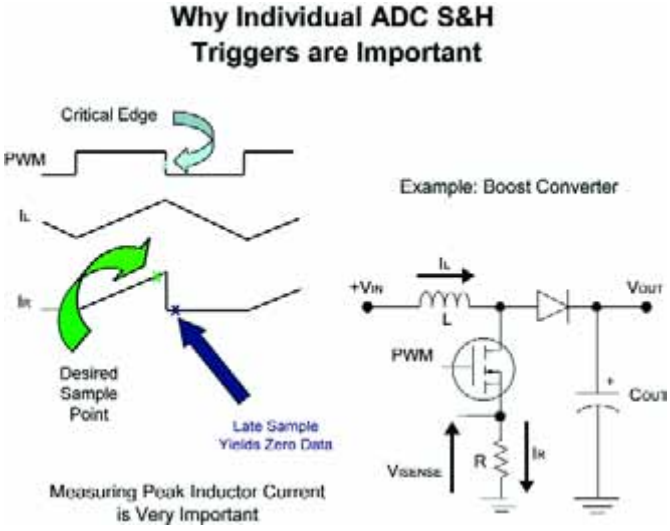

Figure 3: The importance of ADCs with individual sample-and-holds (S & H)

The ADC module on-board the dsPIC® SMPS DSC provides sample-and-hold circuits that can sample independently of each other. It can therefore monitor voltages or currents at precise times, which enables even transitory signals to be sampled. This capability can reduce system costs. In addition, the ADC on-board the dsPIC® SMPS DSC can sample asynchronously, enabling it to support multiple control loops operating at different frequencies, such as PFC (70 kHZ) and DC/DC (250 kHz).

Analogue Comparators Improve Digital SMPS Designs

As ADCs cannot continuously monitor signals, samples can only be processed up to the ADC's Mega Samples Per Second (MSPS) rating. Some DSCs feature analogue comparators that free-up the processor and ADC to perform other valuable tasks. For example, analogue comparators can be used for current control in a manner similar to the way in which traditional linear power-supply controllers directly control the PWM duty cycle. Analogue comparators can also provide independent monitoring of over-voltage or over-current conditions.

This important design issue is illustrated in the following practical example. The reference DACs and analogue comparators on Microchip's dsPIC® SMPS DSCs can achieve latencies from current measurement to a PWM update of approximately 25 ns. Typically, the time when the analogue voltage is sensed until the PWM output is modified by the comparator is about 25 ns. This response time is the quickest, when compared to other DSCs that must use polling techniques with their ADC and processor to modify the PWM outputs in response to changing conditions. This is, in fact, how the DSC implements cycle-by-cycle current limiting, which is required for current mode control. Because the reference DAC tied to the analogue comparator is also 16-bits, the same as the PWM resolution, the same control resolution is available for both voltage and current modes.

PID Algorithm

Using the PID algorithm, the proportional, integral and derivative errors of the actual versus the desired output voltage are combined to control the PWM duty cycle. The PID algorithm can be used in both voltage- and current-mode control loops.

Many analogue engineers think that complex DSP programming skills are required to handle the DSP-like architecture involved with DSCs. However, this is not the case. DSP skills are not needed to handle Microchip's DSCs (see code listing in Figure 5). The central core of the control software, shown in Figure 4, is the PID loop. The PID software is typically small, just one or two pages of code, but its execution rate is very high, often hundreds of thousands of iterations per second. This high iteration rate requires the PID software routine be as efficient as possible to maximise performance. Using an assembler is a good method to insure tight code.

The PID control loop is interrupt-driven by the ADC on a fixed-time basis. Any system function that can be executed in the idle loop should be, in order to reduce the unnecessary workload within the PID control software. Functions such as voltage ramp-up/down, error detection, feed-forward calculations and communication support routines are candidates for the idle loop. Any other interrupt-driven processes, such as communications, must be at a lower priority than the PID loop.

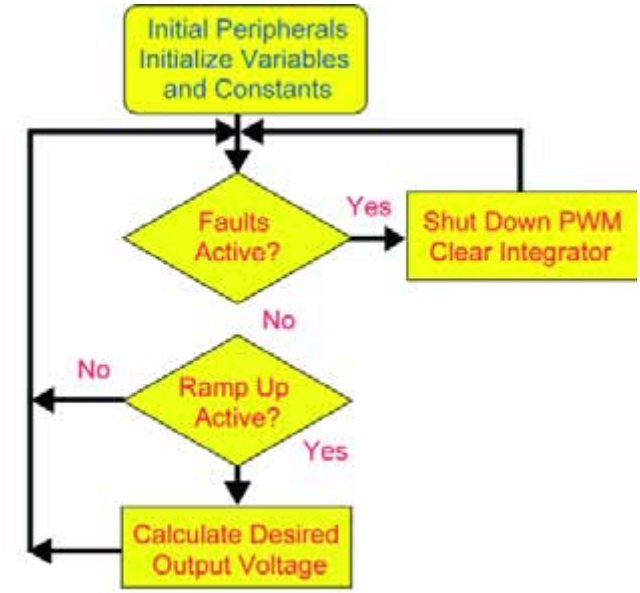

Figure 4: Control Software Structure

The idle loop is entered after completion of the system and peripheral initialisation tasks. Typically, the idle loop monitors temperature, calculates the feed-forward terms, and checks for fault conditions.

The SMPS software implements the control algorithm, with the ADC interrupt-driven PID loop as its most time-critical portion. The PID software should use no more than approximately 66% of the available processor bandwidth, so that the remainder of the computing resources can be allocated to the idle loop software.

Assuming 30 MIPS operation with the PID loop (comprising 30 instructions), the execution time is approximately 1 µsec. If the iteration rate is 500 kHz (2 µsec), then the PID workload consumes one-half of the available processor bandwidth, or 15 MIPS.This code listing shows an example of the PID software for a digital-mode buck converter. Although the PID software would not change for most SMPS topologies, the initialisation code may need to be changed for the peripheral modules.

```
CALCULATE_PID:
  push.s                          ; Save SR and W0-W3
  bclr.b  IFS0+1, #3              ; Clr IRQ flag in interrupt controller
  mov   #PID_REG_BASE, w8         ; Init pointer to PID register block
  mov   #PID_GAIN_REG_BASE, w10   ; Init pointer to PID gain register block

  mov   ADBUF1, w0                ; Read ADC to get voltage measurement
  mov   COMMANDED_VOLTAGE, w1     ; Get commanded output voltage
  sub   w1, w0, w0                ; W0 = proportional voltage error
  mov   PROPORTIONAL_ERROR, w1    ; Get previous voltage error
  sub   w0, w1, w2                ; diff error = new verr - old verr
  mov   w0, PROPORTIONAL_ERROR    ; Store New Proportional Voltage Error
  mov   w0, PREINTEGRAL_TERM      ; Store copy PERR  as pre integral term
  mov   w2, DERIVATIVE_ERROR      ; Store new Derivative Error

;  These registers are reserved for PID calculations
;   w6, w7   = contains data for MAC operations
;   w8, w10 = pointers to error terms, and gain coefficients

SUM_PID_TERMS:
  clr     A, [w8]+=2, w6, [w10]+=2, w7    ; clr A, prefetch w6, w7
  mac     w6*w7, A, [w8]+=2, w6, [w10]+=2, w7   ; MAC proportional term and gain
  mac     w6*w7, A, [w8]+=2, w6, [w10]+=2, w7   ; MAC derivative term and gain
  mac     w6*w7, B, [w8]+=2, w6, [w10]+=2, w7   ; Update Integrator
  add   ACCA                      ; Add ACCB (Integrator)  to ACCA
  sftac   A, -#8                  ; scale accumulator (shift)
  mov   ACCAH,w0                  ; Read MSW of acca (result)
  btst  ACCAU,#7                  ; Check sign bit of ACCA
  bra   z, OUTPUT_PWM             ; Branch if acca PWM value is positive
  clr     w0                      ; Clear negative PWM values
OUTPUT_PWM:
  mov   w0,  DC1                  ; Output new duty cycle value
  pop.s                           ; Restore SR, w0-w3
  retfie                          ; Return from Interrupt
```

Figure 5: 30 MIPS operation with the PID loop

An evaluation board enables designers to test, modify the SMPS control software and understand SMPS design principles. In this case, Microchip's dsPICDEM™ SMPS Buck Development Board shown in Figure 6 provides a rugged, low-power, DC/DC buck converter to evaluate the DSC device and control software. The board derives its input power by the standard AC/DC 9V, 0.75A power-supply. Two independent buck converters are available on the board, and the demonstration software is configured to provide +5V and +3.3V output.

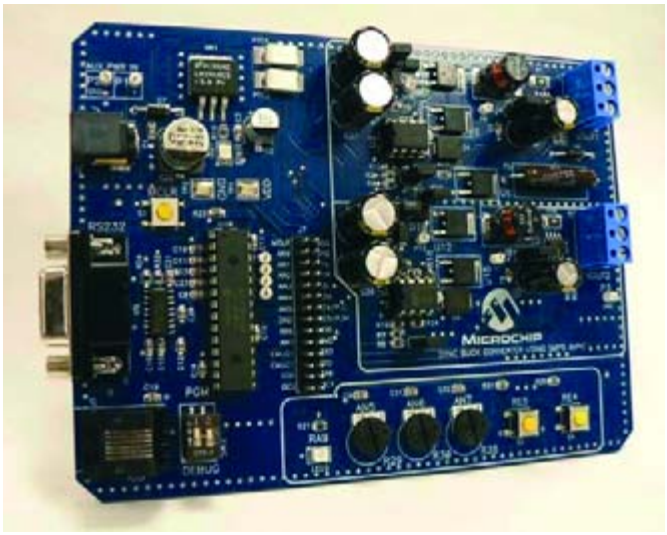

Figure 6: Microchip's dsPICDEM™ SMPS Buck Development Board

The dsPICDEM™ SMPS buck development board accepts an input voltage ranging from 8 – 14V DC. The output loads should be limited to 0.75A each and input power can be supplied through either the coaxial input-power connector J2 or the test clip connections P1 and P2.

This board also provides a dynamic load for the +5V output driven by a 1 kHz square wave signal that is generated by the output compare module. The on-board dynamic load uses a FET to connect a resistor load to the converter output to ground and enables converter stimulation so that the converter's dynamic behaviour can be measured. The use of dynamic loads is user-selectable via jumper blocks and/or software.

Users can choose to operate this board as a standard buck converter or a synchronous buck converter via a jumper setting. The software supplied can operate the board in voltage-control mode, and current monitoring is provided. The board also measures current via a sense-resistor on the output of the converter, with the voltage amplified and presented to the ADC inputs on the dsPIC30F2020 device. Three uncommitted variable resistors that are readable via the ADC inputs are also provided. These pots can be used to simulate signals for prototyping.

Conclusion

Power-supply designers can easily add new features and capabilities to their designs using the latest DSCs optimised for digital loop control. Complex DSP processing skills do not need to be learned in order to do this. Instead, using familiar analogue components and software, designers can quickly and cost-effectively build more intelligence into their power supplies by using DSCs.

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Line Voltage Rated PPTC Devices

Protection for appliance motors and transformers

The popular PPTC (polymeric positive temperature coefficient) resettable circuit protection device is now available in line voltage ratings and offers a simple, cost-effective alternative to fuses and bimetal protectors used in home and professional-grade appliance motors.

Faraz Hasan, Global Industrial & Appliance Marketing Manager
Raychem Circuit Protection, a business unit of Tyco Electronics Corporation

<Although generally reliable, the electric motors used in home and professional grade appliances are subjected to mechanical overloads, overheating, stalls, lost neutral, severe overvoltage conditions, humidity and other damaging factors. Appliance designers employ a variety of circuit protection techniques to help prevent safety and fire hazards, as well as reduce warranty return and replacement costs which may result from motor failure.

The latest generation of PPTC (polymeric positive temperature coefficient) devices includes components that are rated for line voltages of 120 VAC and 240 VAC and can be used in parallel for increased current capacity up to 265. Their low cost, resettable functionality and latching attributes make PPTC devices a reliable, cost-effective circuit protection solution for transformers and for the intermittent and continuous-operation electric motors used in appliances – ideal in industrial and home appliances as a replacement for bimetal breakers.

Protecting an electronic circuit from damage due to excessive current or heat is the primary function of many circuit protection technologies. In the past, this protection took the form of a fuse or fusible link. In today's electric motor applications, resettable devices such PPTC devices, CPTC (ceramic positive temperature coefficient) devices, bimetal circuit breakers and thermostats are the preferred solution. These devices help protect the motor or transformer from overcurrent damage caused by electrical short, overloaded circuit or customer misuse.

PPTC devices help protect against damage caused by both overcurrent surges and overtemperature faults, offer low resistance, and are compatibly sized with fuse solutions. Like traditional fuses, they limit the flow of dangerously high current during fault conditions. The PPTC device, however, resets itself after power to the circuit is removed. This leaves the protected equipment fully functional once the fault condition has been removed, and eliminates the need for fuse replacement.

Technology Comparison – CPTC Devices
Ceramic PTC (CPTC) devices help provide resettable protection; however, their application is limited due to their relatively high operating temperature, high resistance and large size. The composition of the CPTC device tends to be brittle, which makes it vulnerable to damage from shock, vibration, and the thermal stress of heating and cooling found in many appliance applications.

Figures 1 and 2 show the results of comparison testing of CPTC and PPTC devices performed by Raychem Circuit Protection, a business unit of Tyco Electronics Corporation. The PolySwitch™ PPTC devices were compared to CPTC devices as primary protection elements using two identical transformers. The PPTC and the CPTC devices were selected to have the same hold current. In this test, a fault was created with a secondary short while current, coil temperature, and time-to-trip were measured. As shown in Figure 1, the PPTC device reacted more quickly, and at a lower temperature.

Compared to the CPTC device, which had a surface temperature of about 75°C to 185°C, the PPTC device offers a lower surface temperature (about 100ºC to 120ºC) in the tripped state. The PPTC device also has lower resistance in the circuit, is lower in capacitance and less frequency dependent.

Thermal images illustrate the difference in surface temperatures of the CPTC and PPTC devices in Figure 2. In this comparison of a 220VAC trip, the CPTC device reached a maximum temperature of 184.5ºC, whereas the PPTC device reached a maximum temperature of 118.9ºC.

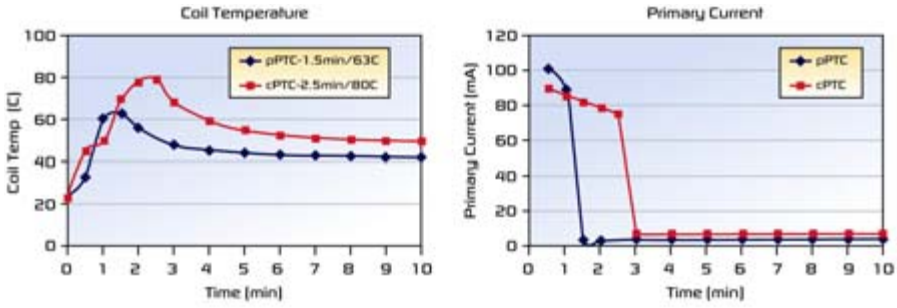

Figure 1. Time-to-trip comparison of CPTC device versus PPTC device in secondary short on 120VAC transformer.

Technology Comparison – Bimetal Circuit Breakers

Bimetal circuit breakers, although widely used to help protect the electric motors found in appliances, do not latch and require additional action to interrupt their on-off cycle. The bimetal strip is constructed of two different metals bonded together. When the bimetal's current rating is exceeded, heat generated by the excessive current causes the bimetal strip to bend and open a set of contacts to stop current flow. With no current flowing the device returns to its normal shape, closing the contacts so current flow may resume. In the case of a stall, the bimetal circuit breaker continues to cycle until power is removed.

The cycling nature of this device has several disadvantages. Among those are material fatigue and a tendency to burn contacts, spark or weld shut. If the device "fails closed" it can cause overcurrent damage to the motor as well as sensitive follow-on electronics. Potential noise or "chatter" and electro-magnetic interference (EMI) can also make bimetal circuit breakers incompatible with advanced electronic control systems.

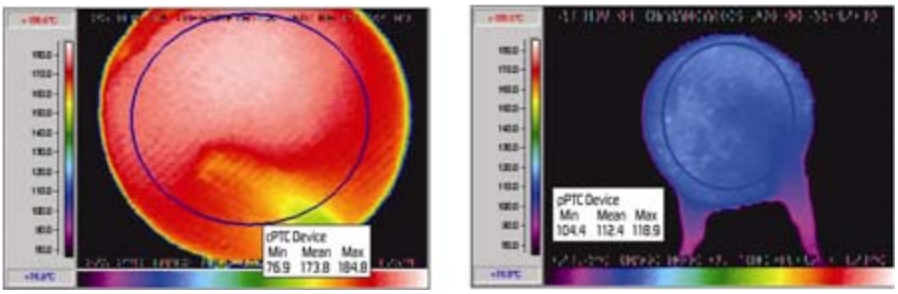

Figure 2. Comparison of maximum surface temperatures of CPTC device and PPTC device in tripped state.

Recent testing by Tyco Electronics compared the thermal and electrical characteristics of a popular bimetal thermal protector and the PolySwitch LVR PPTC device, each installed on an icemaker motor. The protection devices were coupled to the motor winding and the motor shaft was locked during the test period. The voltage, current, temperatures of winding/core and the temperature of the PPTC device and the bimetal protector were recorded during the test.

Figures 3 and 4 illustrate the results of the two tests. In the test using a bimetal circuit breaker, the motor winding reached a temperature of approximately 129°C at 60 minutes. This was significantly higher than the test that used a PPTC protection device, where the motor winding reached a temperature of 44°C within the same time frame.

Intermittent Operation Motor Protection Technique

Intermittent operation motors, such as those used in blenders and food processors, are usually designed to operate for a limited time. In general, operating these products for longer than the designed maximum limit usu-

ally results in stalling, overheating, and ultimately failure. Fault conditions arise when the power is held on, either because of contact failure or customer misuse.

To prevent overheating, the circuit protection device used must "trip" quickly, but not sooner than intended, to avoid creating a nuisance condition for the user. Developing a protection scheme that effectively protects the motor without nuisance tripping is the design challenge.

Nuisance tripping is often caused by inrush currents associated with certain electrical components found on motorized equipment. The major advantage of the PPTC device is that it can be specified with a trip current substantially below the normal operating current of the motor, but with a time-to-trip that is several times longer than a full system operating cycle, to avoid nuisance tripping.

Figure 5 shows how a PPTC device can be installed in a motor circuit to help protect against damage from overcurrent or overtemperature events. When the device is enclosed within the motor housing it reacts to the current flowing in the motor, as well as any temperature rise that may occur during a fault condition.

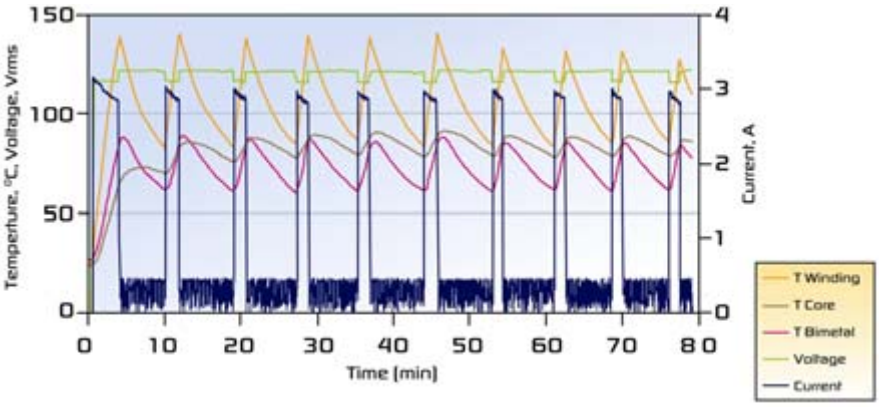

Figure 3. Icemaker motor (rotor locked) test results with bimetal device protection.

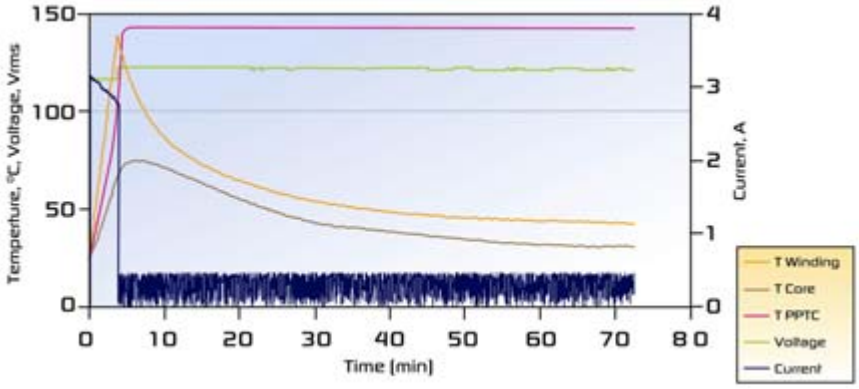

Figure 4. Icemaker motor (rotor locked) test results with PPTC device protection.

Continuous Operation Motor Protection Technique

Continuous-operation motors, such as those used in refrigerators and air conditioning equipment, are designed to optimize size and cost. Since they often drive fans, some airflow can be diverted through the motor to allow operation under more stress than would otherwise be possible. As a result, the stall current of fan motors is usually only two times the run current, compared to a ratio of three to four times run current that is common in other applications. This complicates finding and sizing a fuse that will open reliably if the fan becomes blocked; yet not blow from an inrush when the motor is first switched on.

As noted in the discussion on intermittent-operation motors, PPTC devices offer advantages in motor protection schemes. By altering their characteristics as the motor's vulnerability changes with temperature, they can provide a slower response when appropriate.

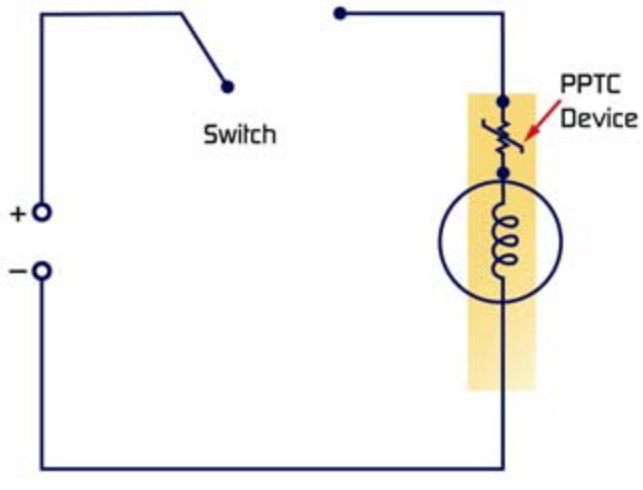

Figure 5. Typical PPTC device application in motor circuit.

In applications where a fan is driven, both the PPTC device and the motor can benefit from being placed in the air stream. With this method, the trip current of the PPTC device will be greatly increased because the airflow tends to prevent it from reaching its trip temperature. However, if the fan stalls for any reason, the cooling effect of the airflow ceases, causing the overrated motor to heat up quickly. This condition causes the PPTC device to trip and limit current flowing to the motor.

Unlike a single-use fuse, the PPTC device helps prevent damage where faults may cause a rise in temperature with only a slight increase in current draw – providing both overcurrent and overtemperature protection with a single installed component.

Summary

New generation PPTC devices [are qualified for and widely used in appliance designs, compliant with the UL 982 standard, and are compatible with lead-free solders and high-volume assembly processes. Their low resistance, fast time-to-trip, low profile, and resettable functionality help circuit designers provide a safe and dependable product, comply with regulatory agency requirements, and reduce warranty repair costs.

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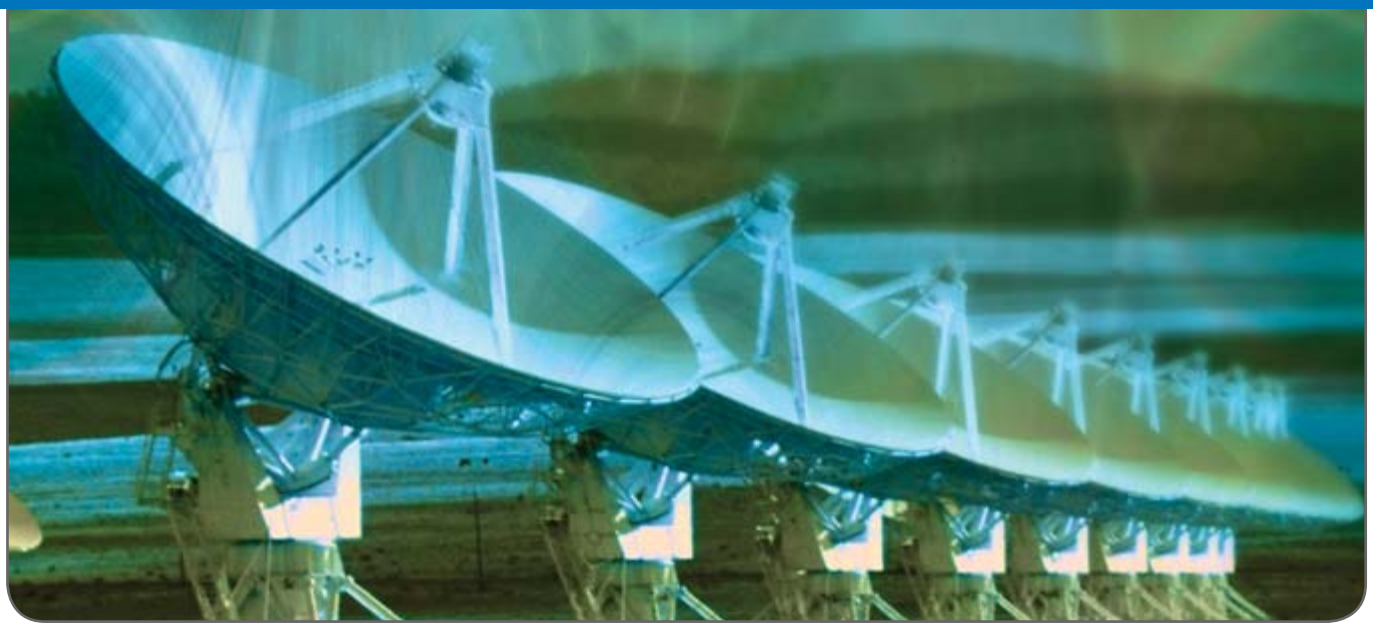

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Green Power -The Challenge of Smarter Design

Moderation of the session

By Bodo Arlt, BPS

Why a High-Tech Industry Turns "Ecological"

By Alfred Hesener, Marketing Director Europe, Fairchild Semiconductor

Improve efficiency in energy conversion applications through better power switches

- Majority of power supplies use switching topologies à Need good power switches
- On-state, switching and drive loss components
- Other important factors: Power density, cost
- Power MOSFETs primarily used due to faster switching and scalability of on-state losses, e.g. SuperFETTM from Fairchild Semiconductor
- Uses charge balance technology•Low COSS
- Fast body diode options with no or little worsening of RDS(ON)
- Excellent body diode di/dt and dv/dt ratings, especially for fast body diode versions
- Designers have more possibilities than ever....
- New functional power devices, state-of-the-art power switches
- Design tools and design support
- .... but they also have more requirements to meet!
- Efficiency and standby power consumption to be improved
- Continuous cost improvement
- Make the power system smaller
- New guidelines and initiatives should be considered an opportunity to differentiate
- Life cycle cost and environmental friendlyness is a feature
- Component suppliers must and will support

www.fairchildsemi.com

Energy Savings in Rectification & AC Switching

By Thierry Castagnet, STMicroelectronics

Rectifier Contributions to Energy Savings in SMPS

Base Station, Server, Industrial, PC Energy savings potential: 6TWh / year

1% efficiency saving by replacing NTC resistor (6W)1.5 % efficiency saving thanks to Silicon Carbide Rectifiers (5W)3 % efficiency saving by using the reliable avalanche Schottky

Energy Management in Refrigeration using AC Electronic Temperature Control

Regulate the cabinet temperature by +/- 1°C
Cut starter stand by losses (- 2.5W)
Reduce the average power consumption (- 7W)

Energy savings potential: 3 TWh / year

www.st.com

Substantial Needs & Highest Level of Awareness

By Dr. Manfred Schlenk, Infineon Technologies, Munich

- Dwindling energy resources combined with growth in electrical energy demand of 2.6% p.a. worldwide forces us to use energy wisely.
- Saving energy is therefore, fast becoming a standard issue for all industrial, commercial and household applications.
- Infineon delivers innovative, high performance solutions with best-in-class technologies that help our customers save energy and reduce pollution.
- Infineon enables the use of available resources as efficiently as possible.

21% of ww power consumption is needed for lighting.
Energy saving of 30% is equivalent to 4% overall saving.

Power Supply: A High Energy Saving Potential
New recommendations will reduce the standby power
SMPS control ICs and CoolMOS from Infineon support these recommendations

www.infineon.com

Minisens for Motor Control

By Bernard Richard, Application Manager, Lem

1. Possibility to measure the motor phase current with isolation
2. Measure all the control state even the current in the free wheel diode
3. Less ripple on current and torque, better control (speed, acceleration, torque)
4. If we keep the same ripple, possibility to reduce the PWM frequency => less losses in the IGBT

Summary – Minisens

- Fully-fledged transducer in a SO8 package
- Ideal for high volume, lower cost applications
- Innovative product featuring cutting-edge technology
- Allows unlimited design flexibility
- Isolated measurement
- Simplifies the control loop
- Meets today's power electronics needs
- We make ourselves small so that our customers can innovate…..

www.lem.com

Improve Chip Designs

By Werner Berns, Application Design Center Manager, National Semiconductor Europe

What´s Possible, to Save Energy?

- Improve chip designs to reduce solutions power consumption
- Changing operating voltages on the fly to the minimum required
- Change SMPS control mode on the fly to reduce losses

•Change behavior/habit of people using electric/electronic devices

Change SMPS Control Mode - On the Fly

- Synchronous buck with auto PFM/PWM selection – LM367x family Improved Efficiency at light load
- Introduce energy efficiency classes to all electric/electronic devices
- Increased transparency for customers

•• **A computer must boot in less than 5 seconds**
Shut down after 5 mins of no use
•• **Banning of certain products**
Linear Regulators (SMPS instead)
Mains transformer (50/60Hz) in consumer products (**SMPS instead**)
Light bulbs (**LEDs instead**)

www.nationalsemi.com

Every Engineer is the Steward of Energy in the System!

By Paul Greenland, VP Marketing Enpirion

- Efficiency vs. Power Density

- 3 to 4% penalty for integrated inductor
- Reduced parasitics
- Trace inductance in switching loops
- Shunt capacitance
- Integrated gate drive

- Conservation of energy is at the heart of all Engineering
- Increased power density forces compromise
- Footprint & profile vs. efficiency
- To design energy efficient power circuits "Think like an R.F Engineer"

www.enpirion.com

Green Power Applications

By Daniel Seng, Application Manager,Semikron International

"Green power" Applications
wind power
solar power
water power

"Green power" Production
SEMIKRON chip fab with closed liquid circuits
Neutralization equipment

"Green power" modules, not only RoHS compatible
Solder free power terminals
Environmental friendly assembly of the final system

Green power modules
Without baseplate for outstanding reliability
No solder fatigue on baseplate soldering
Robustness
Outstanding thermal cycling capacity
Very homogeneous contact module-heatsink
Low Rth(j-h)

Green Modules for Green Applications
Flexible pinout on module level
Flexible layout on DBC level
Flexible use of IGBT's, MOSFET's, SiC diodes, …
No soldered power terminals, just springs

MiniSKiiP is a green module that gives you all the opportunities for a smart and flexible design

www.semikron.com

Bringing Efficient Power Supplies to Market

By Marc.Barboni, Onsemiconductor

Achieving high efficiency and low standby power systematically
1.Component improvements
- Incremental improvements feasible (e.g. change to better diodes or FETs)
- Cost tends to increase exponentially beyond a point

2.Topology improvements
- Seek most appropriate topology for the application
- Consider total system cost (number of components, thermal management, EMI etc.)

3.System architecture considerations
- Does PFC add cost and size? By how much?
- What are other opportunities of energy savings?

ON Semiconductor's holistic approach
- Standby (no load) Power Reduction
- **Improved topologies**: quasi-resonance (valley switching), shutting down the PFC stage in a 2-stage converter
- **New techniques**: frequency foldback, skip cycle, soft skip, high voltage startup circuit

Active Mode Efficiency Increase
- **Improved components**: FETs and diodes
- **Improved topologies**: frequency foldback, synchronous rectification,
  soft-switching: quasi-resonance, full resonance, active clamp (flyback or forward)

Power Factor Correction (or Harmonic Reduction)
- Combining PFC into main power converter
- Optimum PFC control mode for given application and power level: DCM, CRM, CCM

www.onsemi.com

The iMotion Chip Set Provides Sensorless Control

By Aengus Murray, Director of iMotion Marketing, International Rectifier

- Air conditioners consume about 16% of household energy consumption
- Household Air conditioner penetration in Europe now at 13%
- European Air conditioning sales have doubled since 2002

40% of Energy used in buildings for lighting, heating and cooling

The iMotion chip set provides sensorless control of Permanent Magnet Synchronous Motors (PMSM) using one dc link current shunt.

- **Performance advantage:**

Delivers smooth torque
Optimizes torque output from a highly efficient IPM motor

- **Improved reliability:**

Elimination of Hall ICs in fan control avoids field failures
Enables use of simpler single rotary compressor

Integrated Design Platform Summary
Digital Control
- Simultaneous sensorless control of two PM motors and digital PFC
- Motion Control Engine eliminates software coding
- Independent integrated application layer processor

Analog Interface
- Integrates signal conditioning and conversion circuits for single current shunt sensorless control of PMSM• High voltage ICs for analog interface
- Trench IGBTs for efficient inverter switches

Power modules
- Intelligent power modules integrate HVIC and Trench IGBT technologies

www.irf.com

Snapshots of Product Innovation at PCIM Nuremberg

Generation of IGCTs with Increased turn-off Current.

ABB launches a new generation of high power Integrated Gate-Commutated Thyristors with substantially increased turn-off capability. The new generation, designated “High Power Technology”, is capable of switching nearly 50% more current than the current series while still fitting within the same mechanical dimensions of the currently produced devices.
Two new products will enter production in the 4th quarter of 2007: 5.5 kA/4.5 kV and 4.2 kA/6.5 kV
These two devices will be followed in 2008 by a third device rated 5 kA/5.5 kV.
These devices shows the increase of turn-off current capability of the new HPT type 5SHY 55L4500 compared with the current generation 5SHY 35L4510. Whereas the standard type shows a reduced turn-off capability at 0°C, the new generation exhibits increased turn-off at low temperature. Consequently, the datasheets will henceforth show a constant current capability over the usual industrial temperature range of 0 – 125°C (red rectangle).
This increased SOA (Safe Operating Area) has been achieved by both a new silicon design (which exploits some of the patented techniques developed for SPT IGBTs) and a completely new gate-driver design.

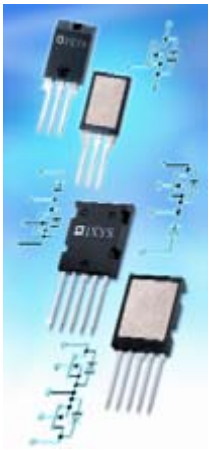
IGCTs are supplied (by definition) complete with their gate-units. This is possible because the gate-unit is not used to control switching characteristics as is the case with IGBTs.
These devices are targeted for Industrial Motor Drives and Wind Power markets in 3-level topologies (3.3 and 4.16 kVRMS lines) and for the 3 kVDC lines as Choppers, Boosters and Solid State Breakers.

www.abb.com/semiconductors

Single-Chip SMD Inverter

Mitsubishi Electric Europe B.V.’s Semiconductor European Business Group announced a new Single-Chip Inverter for drives of typically 90W, addresses BLDC motor drives solutions, for significant energy savings while simultaneously meeting the specific demands of the white good industry.
Dr. Yasuji Nagayama, Senior Executive Officer Group President, Semiconductor & Devices introduced at the press conference at PCIM the Mitsubishi single chip inverter Power IC. Dr. Nagayama explained the Mitsubishi strategy to extend his company’s traditional high power portfolio of products into lower power applications. In the low power area, Mitsubishi will avoid commodity items but will concentrate on products of higher functionality.
The device has been featured in the PCIM Show Special issue and the June07 issue as the product of the quarter.

www.mitsubishichips.com



COOLMOS and ISOPLUS Packaging

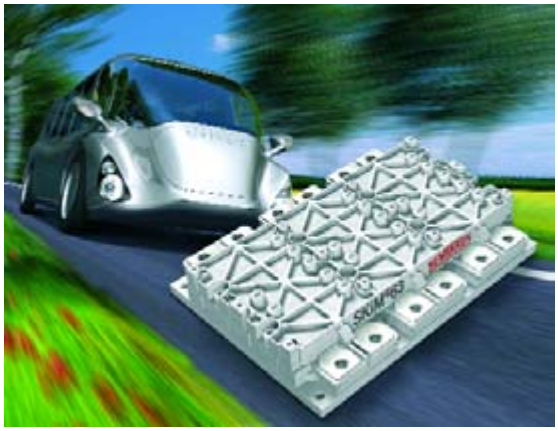
The COOLMOS power MOSFET family enables a significant reduction of conducting and switching losses in Switched Mode Power Supplies (SMPS). The new COOLMOS is available in standard packages. Now IXYS offers also DCB isolated packages like ISOPLUS220. ISOPLUS versions have the same footprint as the unisolated standard packages but offer highest reliability and excellent thermal performance. In ISOPLUS packages the dies are soldered on a DCB. This construction has a thermal expansion coefficient which is very close to that of the silicon and better matched than the Cu based standard packages. Therefore in ISOPLUS packages the die sees reduced mechanical stress under thermal or power cycling resulting in world class reliability.

ISOPLUS packages offer isolation with a very low thermal impedance from die to heat sink.
They provide the most advantageous platform for multi chip packaging. Configurations such as buck or boost converters or half bridge topologies are easy to implement. Features include excellent switching behaviour due to low inductive current paths as dies are located within one package.

www.ixys.com

The first 100% Solder-Free IGBT Module

Semikron introduces a 100% solder-free IGBT module for 22 kW – 150kW train drive converters in electric and hybrid vehicles. SKiM has a five times higher temperature cycling capability compared to modules with base plate and soldered terminals.



While some power semiconductor manufacturers are still improving soldered contacts to meet the high temperature requirements of the automotive industry, solder-free pressure contact technology and sintered chips is the optimal solution to increase the temperature cycling capability to 10.000 cycles at Δ100K. Due to the high temperature capabilities of $T_{junction}$ = 175 °C and $T_{ambient}$ = 135 °C, one separate coolant loop can be omitted.
The solder-free pressure system and an internal laminated bus bar cause a homogeneous current distribution. Every IGBT and diode chip has its own connection to the main terminal. The result is a low module resistance of $R_{CC'+EE'} \leq 0,3\ m\Omega$ compared to soldered modules with approximately 1,1 mΩ.
The connection to the driver board is also solder-free with springs for high temperature cycling and fast solder-free mounting.
The chips are not soldered but sintered to achieve the high power cycling capability. The sinter joint is a thin silver layer that has a superior thermal resistance than a soldered joint and due to the high melting point of silver no joining fatigue leading to an increased service life.
Since there is no base plate, the connection of the DCB to the heat sink has the ability to "move" with no limitation of temperature cycling reliability. SKiM withstands the stringent automotive standards being highly resistant against shock and vibration stress.

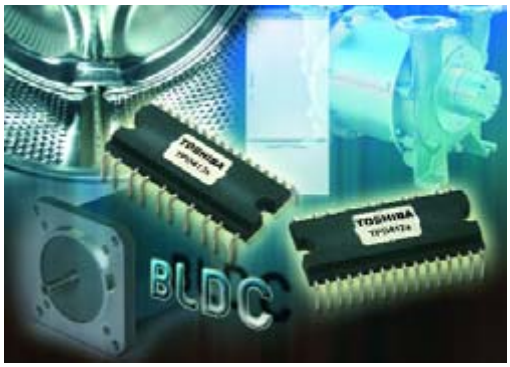
www.semikron.com

PrimePACK Optimized for Industrial Applications and Windmills

The PrimePACK modules of Infineon Technologies in the 1200V and 1700V voltage classes are up to 45 percent lighter when compared to modules with the same power. Infineon is the sole semiconductor company that has achieved production status today for such compact and high-performing IGBT modules. This family of compact IGBT modules enables power converter system solutions optimized for various industrial drives, windmills, elevators, traction or auxiliary drives, power supplies and heating systems in trains and tractors.
The PrimePACK modules are based on an innovative packaging concept that also utilizes the advantages of the Infineon IGBT4 chips, which feature excellent electrical ruggedness. The unique module design offers many advantages, such as the special layout of the IGBT chips inside the module that significantly improves heat distribution. The IGBT chips are closer to the baseplate's screw-fastening points, resulting in a low thermal resistance between the baseplate and heatsink. Internal stray inductance is reduced by approximately 60 percent from that of comparable modules.
The half-bridge configuration and modular design of the PrimePACK modules make it easy to scale the converter power by employing different module sizes or by connecting the modules of a given type in parallel.

www.infineon.com/primepack

Next Generation of Single-Chip Inverters



Toshiba Electronics Europe (TEE) has launched a new generation of single-chip inverters for brushless DC (BLDC) motor applications operating with voltages up to 500V. Available in PWM and non-PWM versions, the new devices integrate into a DIP26 package full three-phase inverter bridge operation and other key features including protection and integrated bootstrap diodes.

The new TPD412x family of DIP26 single-chip inverters is ideal for home appliances. Single-chip inverters are a vital component in reducing the component count, complexity, development time and cost of BLDC motor-based designs.

The new chips combine high- and low-side drivers with six IGBTs to supply current to the motor stator coils. Integrated fast recovery bootstrap diodes reduce component count and cost, while additional on-board functions include protection against overtemperature, overcurrent and undervoltage conditions. Three members of the family also incorporate PWM circuitry and three-phase distribution logic in the same DIP26 package. The 250V inverters offer a 1A output current, while the 500V versions are available with output currents of 1A, 2A or 3A. All of the inverters can interface directly with a host microprocessor.

Toshiba has used silicon on insulator (SOI) technology and a trench isolation structure to bring together low and high voltage circuits in a reliable monolithic device.

www.toshiba-components.com

Miniature LED Driver Tackles Higher Power Tasks

Operating from a 6V to 60V input supply and achieving up to 95% efficiency, the ZXLD1362 from Zetex Semiconductors can drive up to 16 high power LEDs with an adjustable output current of up to 1A.

Provided in the tiny TSOT23-5 package, this LED driver is the smallest of its kind in its current rating, with a maximum footprint of 2.8mm x 2.9mm and off-board height of 1mm.

Simple to use and requiring just four external components, this highly integrated chip supports a range of flexible LED brightness and thermal management schemes. Output current can be adjusted by applying either PWM or DC voltage control signals to the adjust pin. Application of a low voltage signal turns the output off and puts the device into a low current standby mode.

Supporting an operating frequency of up to 1MHz, the ZXLD1362 is able to offer highly sensitive and accurate LED brightness control, with a typical dimming ratio of 1000:1 cited at 300Hz. A soft-start feature can also be achieved by the addition of an external capacitor.

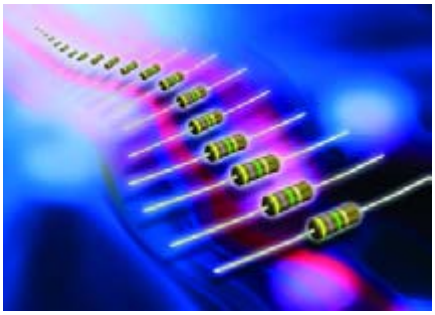
Integrating a 60V MOS switch and a high-side output current sensing circuit, which uses an external resistor to set the nominal output current, the chip enables high power LEDs to benefit from ground referenced return paths, of particular importance in architectural lighting applications.

www.zetex.com

Improved Resistors are Ideal for Circuit Protection

Recently introduced improved CBT series resistors from Tyco Electronics provide excellent pulse withstand capabilities for circuitry associated with surges, high peak power or high energy, whilst remaining very stable. Ideal for protection against lightning strikes, advanced characteristics of the highly reliable 0.25W CBT25 and 0.5W CBT50 resistors have been achieved by selecting materials featuring optimum physical properties and by new developments in the manufacturing process.

Low cost, high performance CBT25 (maximum voltage 250V) and CBT50 (maximum voltage 350V) resistors are constructed utilising a solid carbon composition – perfect for absorbing high energy pulses. A direct replacement for hot moulded carbon composition resistors, solid carbon CBT series resistors offer a much higher pulse handling capability because the entire rod conducts. For example, in case of a fast (<100ms), high-energy pulse, the conductive element is required to withstand all of the energy and

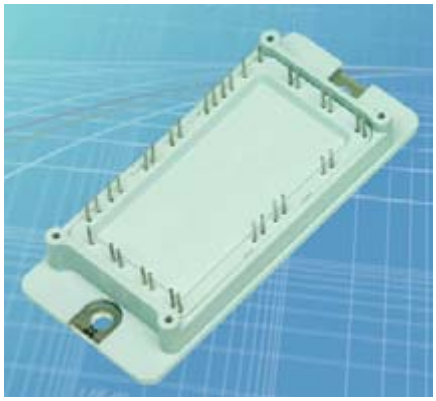


absorb all of the heat generated. This is because it takes a finite time for the heat to be transferred from the conductor to the surrounding materials and the air. Therefore, with a film or wire-wound resistor, the film or wire is required to handle the pulse energy. As the mass of wire or film is low, the energy handling capability is low. However, in the case of a solid carbon resistor, the thermal mass is far higher, which results in a higher energy handling capability.

Benefiting from their small size, a range of resistance tolerances and a wide range of resistance values (1R0 to 5M6 for the CBT25 model and 1R0 to 22M for the CBT50 model), improved CBT series resistors are designed for a very wide operating temperature range of -55 up to 125 degrees Celsius. The insulation resistance for both versions is 1000 M minimum. The devices are supplied ammo pack in boxes of 2000.

www.tycoelectronics.com

flowPIM 2 3rd Gen 100A /1200V in IGBT4 Technology



Tyco Electronics presents the 3rd generation of its biggest PIM Module, the flowPIM 2 3rd gen. It includes rectifier, brake chopper, inverter and mechanically isolated NTC with improved pinout. This Module is equipped with IGBT4 technology in order to improve the EMC behaviour and can support currents up to 100A at 600V/ 1200V. The flowPIM 2 3rd gen is the optimal solution for motor drive manufacturers who require high power density on minimum space for compact devises.
This PIM module provides the following benefits in addition to the former generation:

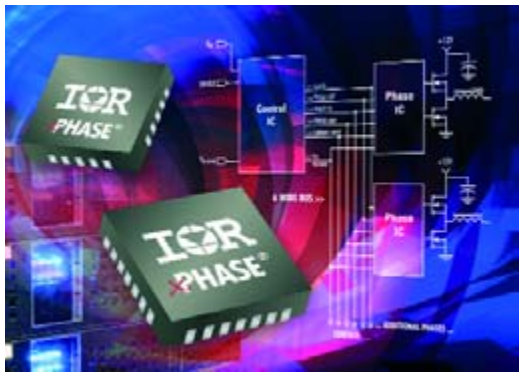
100A at 600V and 1200V in 17 x 108 x 47mm
IGBT4 and EmCon 4 technology for improved EMC behaviour
Mechanically isolated thermistor
Improved pin-layout for easy PCB routing
Tapered pins for easy PCB mounting

The flowPIM 2 3rd gen family (rectifier, BRC, sixpack and NTC) is available in 600V/ from 50A up to 100A and in 1200V/ form 35A up to 100A.

www.tycoelectronics.com

Chipset reduces external part count by 25 percent

International Rectifier has expanded its XPhase family of scalable multiphase converter chipsets with the introduction of the IR3500 Control IC and IR3505 Phase IC.
The new XPhase chipset provides a full-featured and flexible way to implement a complete Intel or AMD CPU power solution, and with simple six-bit voltage programming, the IR3500 is easily configured for use in general purpose, multiphase applications.
The latest XPhase chipset reduces external component count by 25 percent, which combined with a higher switching frequency, reduces the powertrain area by 45 percent in a five-phase design compared to previous generation technology. The solution features the IRF6622 and IRF6628 DirectFET power MOSFETs to achieve a two percent efficiency improvement compared to competing solutions.
The XPhase chipset features programmable dynamic voltage identification (VID) slew rate, programmable VID offset and load line output impedance, hiccup over-current protection with delay to prevent false triggering, and simplified power good output to indicate correct operation and prevent false triggering.



www.irf.com

Isolated SMD Current Transducer Family

LEM has extended its range of current transducer families designed to operate from a single +5V power supply with the introduction of the HMS model. The new unit measures only 16 (L) x 13.5 (W) x 12 (H) mm and integrates a primary conductor. It is directly surface-mounted onto a printed circuit board, reducing manufacturing costs.
Four standard models are available to cover nominal AC, DC, pulsed and mixed isolated current measurement of 5, 10, 15 or 20 ARMS, up to 50 kHz, with a measuring span of up to ± 3 x IPN. The same mechanical design is used for all four models so that they can be used to measure current across a complete range of end products.
The internal reference voltage (2.5V) is provided on a separate pin or can be forced by an external reference (between 2 and 2.8V) for reference thermal drift cancellation. Gain and offset are fixed and set so that, at Ipn, the output voltage is equal to Ref in or Ref out ± 0.625 V.

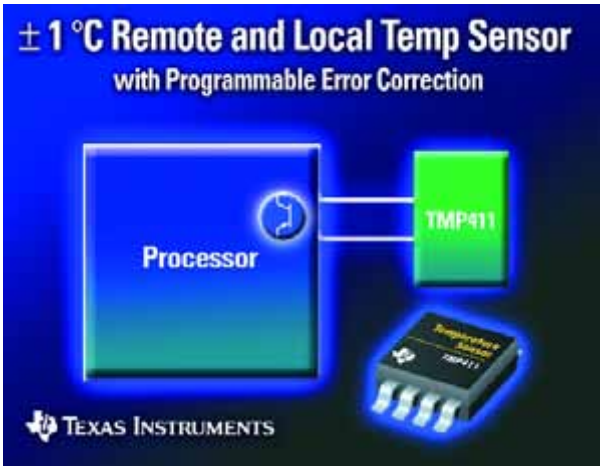
www.lem.com

SMD-resistor series VMx

The new resistor series VMx by Isabellenhütte brings together performance features that are so far unique in this combination. The resistors' pre-tinned, circumferential connecting contacts conforming to standards, the soldering junctions are visible for Automatic Optical Inspection (AOI). Depending on component size (versions 0805, 1206, 2010 und 2512), their values range is between 5 mOhm and 2 Ohm. The resistors are characterised by a comparatively very high power loss, for instance, 3 W for version 2512 (at an ambient temperature of 110 °C) and a low thermal internal resistance.
The VMx precision resistors offer optimal heat dissipation, thus causing only a minor increase in temperature and a very low associated resistance drift even at high loads. Some examples of applications are electronic control units in the automotive industry, power modules, frequency converters, and switching power supplies. In addition, the VMx resistors can be used as sensor resistors for power hybrids.

www.isabellenhuette.de

Temperature Sensor for Thermal System Management



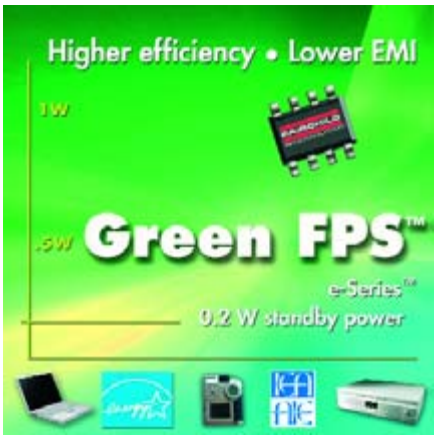
Texas Instruments announced an integrated +/-1C maximum remote junction temperature sensor and local temperature sensor, designed to monitor thermal diodes found in CPUs, microprocessors, graphics processing units and FPGAs. Unlike other devices, the TMP411 features programmable series resistance cancellation and diode non-ideality correction which simplify and remove the time-consuming process of individual processor resistance calibration commonly associated with remote diode monitoring. (See www.ti.com/sc07095.)

The TMP411 provides thermal system management for a wide range of applications such as industrial controllers, servers, desktop and notebook computers, and medical equipment. Additional applications include central office telecom equipment, LCD/DLP/LCOS projectors, storage area networks and processor/FPGA temperature monitoring.

www.ti.com

Green FPSTM e-Series Optimizes Power Efficiency

Fairchild Semiconductor introduces the Green FPS e-Series, a new family of Fairchild Power Switch (FPS) products that provide high energy efficiency and system reliability in DVD player, set top box, LCD monitor and other 25W and lower power supply designs. Based on Fairchild's proprietary valley switching technique, the Green FPS products raise power conversion efficiency by 1% and reduce EMI up to 5dB compared to conventional hard-switch converter topologies. These highly integrated FPS devices combine the functionality of a fully avalanche rated SenseFET, a current mode pulse width modulation (PWM) IC and various protection functions, simplifying design and improving system reliability. Utilizing advanced burst mode operation, the Green FPS e-Series devices meet stand-by power regulations by reducing standby power consumption to below 0.2W at no load conditions (below 1W at 0.5W load).



By employing an advanced control technique, the Green FPS e-Series products allow power converters to operate with narrow frequency variation while maintaining valley switching operation. Valley switching operation enables the MOSFET to turn on with minimum drain voltage and offers inherent frequency modulation resulting in a dramatic reduction in EMI noise up to 5 dB compared to conventional hard-switch converters. This valley switching operation also enables these converters to perform soft switching, therefore increasing power conversion efficiency by 1% while drastically reducing heat generation.

www.fairchildsemi.com

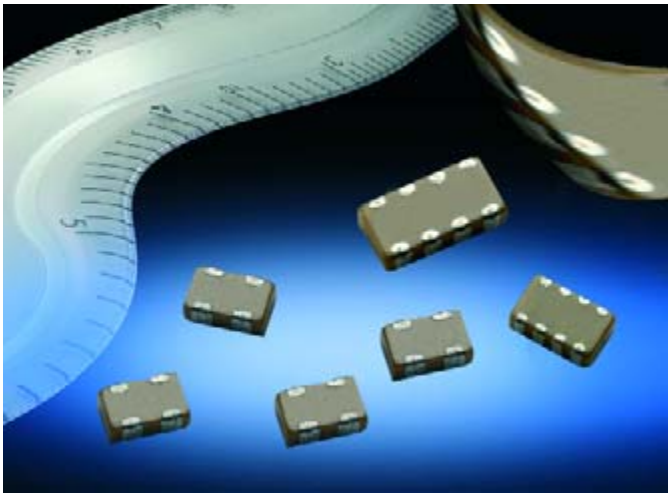
Twice the PCB Flexure of Standard Arrays

Now available from AVX Corporation, the leading manufacturer of advanced passive components, are capacitor arrays featuring FLEXITERM soft termination. Like standard and multi layer ceramic capacitors, arrays will crack under excessive board flexure. However, FLEXITERM arrays can withstand over twice the PCB deflection of standard MLC devices without cracking.

The addition of a layer of epoxy silver in the termination means that the array is able to absorb mechanical stress which helps to protect the internal structure against short circuit failure. FLEXITERM arrays are offered in two or four element packages from 0405 to 0612 case sizes and are all RoHS compliant.

These arrays can be used in a number of high volume commercial decoupling applications, such as mobile communications as well as in higher temperature automotive systems, for example in engine management, control systems and dashboard electronics.

www.avx.com



Magnetics Update –Taking Care of Noise in Power Designs

Right-First-Time Design with RoHS-Compliant Inductors

Magnetic component technology cannot advance in line with Moore's Law, but designers are under pressure to meet tough targets for miniaturisation, time to market and cost. A wide choice of inductors, as well as concise component selection guidance, are both necessary to deliver advanced products on time and on budget. Another factor to consider is the impact of lead-free legislation on the construction and materials of magnetic components to withstand higher reflow temperatures.

By Andrea Polti, Magnetics Product Manager, C&D Technologies (NCL) Ltd

Introduction: Inductors and Power Supply Filtering

The inductor plays a critical role in a wide variety of power-related applications, including filtering and smoothing of input and output power lines when used in conjunction with one or more capacitors. For example, when selecting a storage inductor for use at the output of a switching regulator, the device should be chosen to minimise losses and avoid core saturation, which can occur if the device is under-specified, reducing inductance and thereby impairing filter performance.

In practice, the designer must achieve an optimal balance of component parameters. For example, selecting a lower inductor value results in a lower DC resistance (R_{DC}) leading to reduced losses in the inductor windings. With fewer turns, the lower-value inductor also has a higher DC saturation current and can therefore satisfy higher load conditions with a smaller component. Lower inductor values also display faster transient response and require fewer capacitors for good load transient recovery.

On the other hand, choosing a larger inductance value results in a lower output ripple current, lower inductor losses in the core and windings, along with reduced conduction losses in the switching MOSFETs. In addition, current flow in the inductor is continuous over a wider range of load current values.

The optimum value for the inductor is also related to the switching frequency of the converter. Whatever the inductance value, the R_{DC} should be as low as possible to reduce losses and minimise any self-heating effects of the inductor.

An accepted rule of thumb is to size the inductor for a ripple current (I_{RIP}) between 10% and 30% of the full-load DC (I_L) current. The saturation current should be several times greater than the maximum full-load DC prevent saturation, which otherwise will result in a sharp fall in inductance. Other factors the designer should bear in mind include the applied voltage to the inductor, the maximum physical size of the component, and the operating temperature range.

Calculation and Inductor Selection for Filtering

An understanding of how to identify a suitable inductor for filtering applications can be seen by considering the design of an output filter for a DC/DC converter module (figure 1). In this example the parameters in the table 1are known:

C	R_C	R_L	f
4.7µF	0.23Ω	1.0Ω*	200kHz

**estimated* *Table 1: Parameters for figure 1*

where C is the capacitor value, R_C is the ESR (equivalent series resistance) of the capacitor, R_L is the R_{DC} (DC winding resistance) of the inductor, and f is the operating frequency.

To attenuate noise by a factor of 100 (i.e. from 0.5V to 5mV), the impedance of the inductor (Z_L) must be 100 times that of the capacitor (Z_C) at the given frequency:

i.e.

$$ZL = 100Z_C$$

now, $$Z_C = \frac{1}{2\pi f C} + R_C$$

$$= 0.4\Omega$$

therefore, $$Z_L = 40\Omega$$

now, $$Z_L = 2\pi f L + R_L$$

therefore, $$L = \frac{Z_L - R_L}{2\pi f}$$

$$= 31\mu H$$

So in this situation, a 33µH inductor with a sufficient DC rating would be deemed suitable. In practice, designers should take these guidelines into account to gain an approximate solution, and then identify the optimum inductor after evaluating several closely related components. The inductor must also interoperate optimally with the chosen capacitor values.

Figure 1:
Output filter design for single-output DC-DC converter module.

Rapid Inductor Selection by Look-Up
An easier and faster way to ensure optimum DC/DC converter performance is for the regulator vendor to evaluate a number of inductors and recommend the best device to perform according to a given set of parameters. Examples include the C&D Technologies NME, NMH and NMJ series of DC/DC converters, which have been pre-evaluated to determine an optimal combination of output inductor and capacitors to deliver high all-round performance in relation to efficiency, noise, current-handling and cost. The recommended inductor type and capacitor values are published in the applicable supporting datasheet for fast and easy reference. This represents a similar approach to that of the IC chipset; presenting designers with a turnkey, compatibility-guaranteed solution saving numerous stages of trial and error.

As an example, the C&D Technologies NMJ1205SC 1W, dual output ±5V DC-DC converter module supplies up to 100mA per output and operates at 70kHz switching frequency. An output inductor of 22µH is required to reduce the output ripple voltage to 5mV peak-to-peak at full load current (figure 2). The datasheet recommends the 82223C inductor, which fulfills all of the requirements on the output inductor without involving the designer in lengthy trial and error to identify the optimal component.

Figure 2:
Output filter design for dual-output NMJ-series DC-DC converter.

The 82223C is an I-core surface mount device with a low profile to serve applications including ExpressCard™ technology and handheld devices. Characteristics include very low R_{DC} of 0.92Ù, high saturation current of 320mA relative to the converter output current, and a self resonant frequency (SRF) of 25MHz. At the rated current, the inductor R_{DC} is low enough to ensure that the voltage drop across the inductor is less than 2% of the rated voltage of the DC/DC converter. This is a useful guideline to guard against self-heating of the inductor, leading to loss of inductance.

The datasheet also recommends low ESR ceramic capacitors to complete the output filter design, also shown in figure 2. These are placed between the output ground and the positive and negative rails. Requirements include a voltage rating of at least twice the output voltage of the converter. The recommended capacitors are 10V, 4.7µF, 1206-format surface-mount devices. Similar selection guidelines for input filter design are also available for designers using the NDY-series and NDH-series converters.

In other instances the behaviour of the inductor is critical to operation of the DC/DC converter, for example in converters that employ synchronisation techniques to eliminate dead-time insertion circuitry. These are so sensitive to inductor selection that a recommended, matched inductor must be used to ensure correct operation of the power supply.

Lead-free Device Design
In addition to ensuring optimal electrical operation, designers must increasingly factor in the need to comply with the growing worldwide adoption of legislation on hazardous substances in electronic components. Since the EU RoHS legislation came into force in July 2006, for example, China has also now introduced its own RoHS legislation, making this an even more important consideration for new power supply designs.

While most attention during the transition to lead-free assembly has focused on materials compatibility and optimisation of new reflow profiles, many assemblers are seeing increased instances of thermal damage to components on the board. The peak temperature necessary to solder successfully with lead-free alloys, at around 245°C is very close to the maximum case temperature of 260°C for semiconductor devices, as recommended by the IPC. Results may include cosmetic damage such as scorching of the PCB substrate, or induced functional failures for example by stress-cracking of semiconductor die. These experiences show that source temperatures of soldering equipment should be chosen very carefully, but also highlight a requirement for components to be more robust against exposure to higher lead-free soldering temperatures.

As an example, inductor manufacturers such as C&D Technologies have developed new materials to ensure close matching between the coefficient of thermal expansion (CTE) of the constituent parts of shielded surface mount inductors, throughout the wider lead-free soldering temperature range, to maximise the structural integrity of the device during reflow. A number of leading inductor manufacturers have identified new materials and construction techniques as being critical to completing development of a production-ready RoHS-compliant product range.

Conclusion
Successful product engineering is predicated on achieving right-first-time solutions, quickly, all the way from design to production. Selection of magnetic components can be a skilled discipline requiring specialist knowledge, and increasingly requires manufacturer support to ensure the optimum result and eliminate time-consuming evaluation of multiple candidate components. At the same time engineers need to be sure of high product quality, to maintain consistent production yield and optimal reliability in the field in order to safeguard profitability at a competitive price. Post-RoHS, this also requires component manufacturers to ensure that all devices are able to withstand higher reflow temperatures for lead-free assemblies.

www.cd4power.com

Encapsulated 6A to 12A DC/DC µModule Regulators

Mounting like an IC and include the inductor, MOSFETs and Capacitors

A major obstacle in improving the performance of point-of-load (POL) regulators has been in reduction of their size while increasing output power capability. This is in response to the popularity of densely populated PCBs in high-power applications such as embedded systems with AdvancedTCA or CompactPCI platforms which are imposing new restrictions on the size and performance of these point POL DC/DC power supplies.

By Afshin Odabaee, Product Marketing Engineer, Power Products, Linear Technology Corp.

Designers of these and similar sophisticated digital systems strive to improve the performance without expanding the size of their boards or adding to the cost of manufacturing of their end product. Therefore, an optimum POL DC/DC regulator for these designers should be compact, reliable, surface-mountable, have a thermal impedance packaging, and require minimum power supply knowledge in addition to not requiring any special assembly or tooling.

The existing POL DC/DC solutions offer a compromise in power density and size. These open-frame circuits are available in high power but use tall (high profile) components and large PCBs. They are often too bulky to fit the tight spacing of high-end digital system boards. To offer them in smaller solutions and to meet the space constrictions, the output power delivery of the POL DC/DC regulator had to be decreased. Unfortunately, today's systems require more power to drive multiple FPGAs, microprocessors, megabytes of memory and other ICs with fast I/O signaling. Therefore, these POL regulators with limited output power become inadequate solutions although smaller.

The µModule DC/DC Power Supply Family

A µModule DC/DC power supply occupies approximately 50% less board space than a discrete solution with similar power handling, voltage range and performance. This family of DC/DC solutions allows a compact design with high efficiency synchronous operation, fast switching frequency, and a high performance thermally enhanced packaging.

Figure 1 - A µModule DC/DC converter is a complete power supply solution small and light weight to fit on top and/or bottom of a PCB leaving room for digital ICs.

Because of the µModule converter's short profile (2.8mm height) and light weight (1.73g), it can mount on the bottom of a densely populated system board where more space is available (figure 1 and 6).

Since the introduction of the LTM4600, 10A DC/DC µModule regulator, Linear Technology has expanded this family with five new regulators that feature new functions and power levels to satisfy power requirements of variety of systems. For example, the new µModule regulator, LTM4601, delivers 20% higher current in an identical package size of 15mm x 15mm x 2.8mm LGA. The LTM4601 also provides more functions such as tracking, phase-lock loop (PLL) and remote sensing. In addition, to simplify the task of layout and copying µModule converter's layout, the lower output current version of each µModule regulator (LTM4602 and LTM4603 6A output) is offered in the same foot-print and pin function as its higher current version (LTM4600 and LTM4601, respectively). Also, among the new features, in addition to what was discussed earlier, are remote sensing for precision regulation and current sharing for higher output power by paralleling multiple µModule converters.

Please refer to table 1 for a quick comparison among the members of this family.

Everything Inside and High Performance

The DC/DC controller and MOSFETs (top and bottom) are proprietary and manufactured by Linear Technology Corporation (figure 2). A great deal of attention has been paid to architecture and performance of the controller and MOSFETs so that the µModule not only operates at high efficiency

V_{IN}: 4.5V-28V ; V_{OUT}: 0.6V-5V						LGA Package (θ_{JA}:15°C/W)	
µModule Part Number	I_{OUT}	Current Sharing	PLL	Track, Margin	Remote Sense	Height	Area
LTM4602	6A	Combine two for higher current				2.8mm	15x15mm
LTM4603	6A		√	√	√		
LTM4603-1	6A		√	√			
LTM4600	10A						
LTM4601	12A		√	√	√		
LTM4601-1	12A		√	√			

Table 1: New µModule DC/DC Family: Complete DC/DC Regulator Solutions

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over a wide range of input and output voltages and load currents but also allows the use of small discrete components which, in return, permit the complete solution fit in a 15mm x 15mm footprint with only 2.8mm of thickness.

The DC/DC controller features valley current mode synchronous switching architecture. This architecture allows very low duty cycle operation for high input to low output voltage DC/DC conversion as well as very fast transient response to load current changes. Where other controllers must wait one clock cycle before responding to a load transient, the LTM4600 through LTM4603 react almost instantaneously because of the no clock-latency operation. A benefit of no clock-latency and faster transient response is less dependency on output capacitance and fewer output capacitors. Moreover, the µModule's current mode architecture and internal compensation keeps the operation stable permitting the addition of more capacitance to its output.

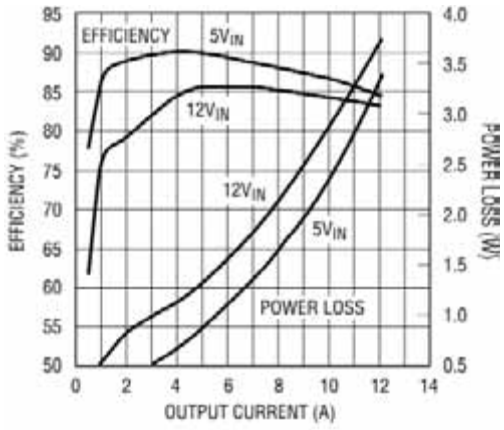

Figure 5 – Efficiency and Power Loss of figure 4

A draw back of switching a MOSFET at high frequency is the increase in the MOSFETs switching losses due to charging and discharging of the gate capacitance. The other factor in MOSFET power dissipation is its resistive dissipation which is a function of the MOSFET's on resistance (RDS(ON)). In a buck converter topology circuit, the switching dissipation is highest at VIN(MAX) and resistive dissipation is at its highest level when the input voltage is at its lowest value (it's assumed that reader is familiar with MOSFET power dissipation equations in a synchronous buck converter). In other words, the MOSFETs must be optimized to operate with minimum power dissipation at high and low duty factor where a duty factor is a function of input and output voltages. The goal in defining the top and low-side (synchronous) MOSFETs for the µModule family was to offer a balanced resistive and switching dissipation across the devices wide operating input voltage range (4.5V to 28V). Linear Technology engineers were able to manufacture such MOSFETs using proprietary DMOS technology to reduce reverse-transfer capacitance and RDS(ON) so that the devices could be used safely to deliver the anticipated power while the entire power supply circuit is enclosed in a tiny molded package.

The combination of die-form and low thermal resistance of the solder create an extremely efficient way for the heat to be removed from the inside to the junction and eventually to the PCB and surrounding air.

The Innovative Packaging

The goal of Linear Technology packaging engineers was to design and manufacture the smallest footprint, shortest profile package that could also have very low thermal resistance. It does not make sense

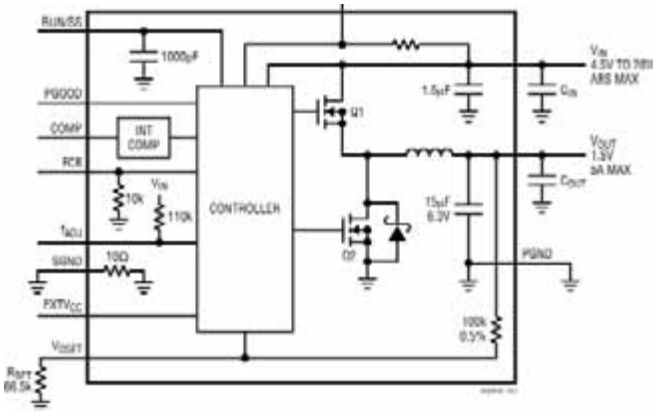

Figure 2- µModule Regulator includes the inductor, power MOSFETs, DC/DC controller, compensation circuitry and input/output bypass capacitors (LTM4602, 6A µModule shown here

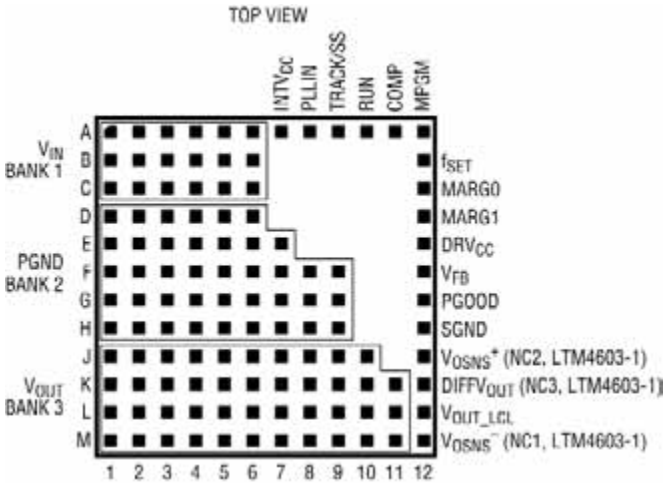

Figure 3- Backside of a µModule converter in 15mm x 15mm x 2.8mm

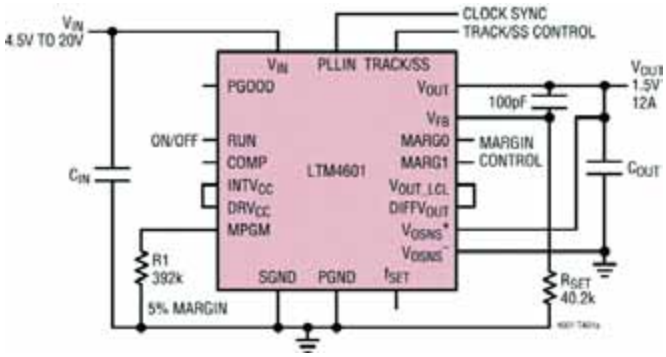

Figure 4 - A µModule requires minimum external components and is stable with additional input and output capacitors when required for lower ripple current (LTM4603 shown here)

to claim high power density for a DC/DC µModule and not be able to deliver the power or run the risk of overheating the device. In addition, the engineers wanted the package to be surface mountable similar to FPGAs or other digital ICs so that the assembly and production houses could use the same pick-&-place machines and soldering reflow methods. A µModule regulator requires no special tooling.

A µModule DC/DC converter's square pads accomplish two tasks. First, is to provide signal functions such as soft-start, ground, and power good. Second, a series of pads are group together to collec-

tively transfer the heat to PCB through the bottom of the package (figures 3 and 6). There are also three banks which include VIN, power ground and VOUT.

Optimized Thermal Performance

A µModule DC/DC regulator's package is designed to dissipate heat from both bottom and top side of it. In addition, the substrate, soldering techniques, thermal planes and layout of contents of a µModule were all calculated to provide extremely low thermal

Figure 6 - Thermally enhanced packaging delivers very high power density switchmode DC/DC conversion in 15mm x 15 mm x 2.8mm surfacemount LGA package

resistance device in a thin and small package. As a result, the junction-to-ambient and junction-to-case thermal resistance values have reached low numbers of 15ºC/W and 6ºC/W, respectively. With these values, these high power µModule solutions can safely and reliably operate at its defined output power capability, although it's housed in a tiny enclosed package. In addition, to lower the thermal resistance of the µModule has been incorporation of generous amount of copper. The ground, input and output paths where high current is directed, all use copper planes which with the solder mask defined PADs on the bottom of the package remove the heat from the inside of the package to the PCB.

For example, a 12V to 3.3V at 10A (33W) LTM4600 design with 91% efficiency has about 3W power loss (figure 7). This loss is attributed to the power dissipation in the DC/DC controller section, and transition losses in the internal top MOSFET. Figure 7 shows a thermal image of this design with several data points. Surprisingly, the maximum temperature is only 66ºC on the

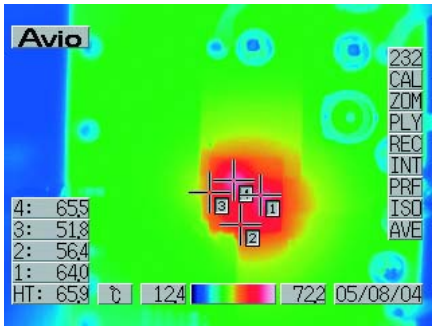

Figure 7- LTM4600 12V to 3.3V at 10A, top view (25ºC, no air flow, no heatsink)

µModule with 3W of dissipation. Note that as impressive these measurements are, they are taken without the use of heatsink on the top of the µModule.

The use of a heatsink will further improve heat dissipation. For more details on more thermal analysis, please refer to application note 103 on www.linear.com/micromodule.

www.linear.com/micromodule

2 MHz Integrated Switch Non-Synchronous PWM Buck

Micrel launched a new family of 2 MHz PWM buck regulators. The new solutions include the MIC4723 (3A); the MIC4720 (2A); and the MIC4721 (1.5A). The MIC4723 and MIC4720 are offered in a 3mm x 3mm MLF-12 and a thermally-enhanced MSOP-10 package, while the MIC4721 is offered in a MSOP-10. The MIC4720/21/23 ICs are the latest additions to Micrel's small footprint, non-synchronous buck regulator family that also includes the MIC4722 introduced late last year. This family of products targets wired and wireless broadband communications, printers, HD set top boxes, computing peripherals and low power FPGAs where total solution cost is critical.

The MIC4720/21/23 feature ultra-fast operation and a proprietary internal compensation which allows for extreme transient response and the use of the smallest and most cost-effective LC components in their class. A low resistance integrated p-channel MOSFET enables the chips to deliver up to 3, 2 and 1.5 Amps, respectively, with more than 94 percent efficiency. The output voltage can be adjusted down to 1V and can operate with a maximum duty cycle of 100 percent for use in low dropout conditions. The P-MOSFET also does away with the need for a sense resistor to provide a current limit, further reducing the need for external components.

www.micrel.com

Sub-1MM Surface Mount Chip Inductor

With a sleek sub-1mm square surface mount chip footprint, the new DR354-0 Chip Inductors from Datatronic Distribution, Inc., feature a miniature design that delivers superior performance and value in high frequency circuit designs for a wide range of electronic equipment.

The DR354-0 Chip Inductors provide reliable protection against challenging EMI problems in high frequency filtering applications. This miniature wire-wound inductor features a low seated height that stands only 0.66 mm above the circuit board. It protects sensitive electronic circuitry and ensures high performance operation in a wide range of compact devices that are shrinking ever smaller in physical size.

The surface mount DR354-0 Series Inductors are available in a wide range of inductance values to meet the needs of just about any circuit. They are ROHS compliant and in accordance with J-STD-020C, with no lead to prevent damage to the environment.

Delivering both high reliability and high performance, the DR354-0 Inductors are ideal in medical devices, military equipment, hand-held scanners, instrumentation, PDAs and much more. They are especially useful in hand-held gear of all types because of their small size and low profile.

Depending on specific model, the DR354-0 Series Inductors feature an inductance range from 1.0 to 68 nH, with a DCR from 0.054 to 0.0912 Ohms maximum over a maximum current rating from 150 to 1360 mA.

www.datatronics.com

2MHz, 500 mA Switching Regulator

Microchip announces the MCP1603 - a 2 MHz, 500 mA switching regulator. This new, low-power switcher provides adjustable and fixed output voltages, operating efficiency of up to 90%, and is available in Thin SOT-23 (TSOT-23) and 2 mm x 3 mm DFN packages. The new device is ideal for extending battery life and reducing heat dissipation in a variety of portable, handheld electronic devices.

The switcher also features a low quiescent current of 45 ìA, a standby current of only 100 nA, under voltage lockout (UVLO), over-temperature and over-current protection and auto transition from PWM to PFM modes for lower energy use and heat dissipation, as well as longer battery life. With an input voltage range of 2.7V to 5.5V and either an adjustable output voltage range of 0.8V to 4.5V, or a fixed output voltage range between 1.2V and 3.3V, the MCP1603 switcher can cover the entire Li-Ion, Li-Polymer, NiCd and NiMH voltage range. The MCP1603 Evaluation Board (Part number MCP1603EV) demonstrates using the MCP1603 as a Buck switcher.

www.microchipdirect.com

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Passive Matrix OLED Boost Regulator

Intersil announces the release of the ISL97701. By combining high current output, an integrated Schottky diode and fault protection, Intersil provides the industry's most complete boost regulation solution for passive matrix OLEDs.

With efficiency up to 87%, the ISL97701 can deliver 50mA of output current at 18V. It can provide up to 28V output, enabling power efficient operations in MP3, portable media players, automotive clustering, and low-end cell phones PMOLED displays. ISL97701 is also suitable for standard boost regulation applications such as WiMax card and LCD bias generator power applications.

The integration of the Schottky diode reduces the BOM cost and saves board space, while an integrated input disconnect switch protects the device against overcurrent, overvoltage and over temperature.

The ISL97701 is highly versatile with a variable output that can be set by external resistors to match the needs of the application. At just 3mm x 3mm x 0.9mm, its 10-lead DFN (Pb free) package is a very compact power management IC for portable applications.

www.intersil.com/power

100 W AC/DC Modules Now With Certification

MTM Power GmbH, the specialist for individual power supplies, has been approved the AC/DC power modules series PMAS/PCMAS100 acc. to CB-Scheme, EN 60 950, UL 60950 and CAN/CSA 22.2 950, 3 edition. The universal compact power supplies with AC and DC wide input ranges and single output voltages of 24, 36 and 48 VDC (others on request) are designed for worldwide application. The small dimensions and the high packing density allow an efficient, cost-saving solution for different tasks where medium-ranged power up to 100 W is needed. The vacuum encapsulated modules have

a high efficiency of ³90 % and are characterised by a compact design due to their mechanical and electrical rugged construction. They are designed for PCB (PMAS: 140,0 x 85,0 x 35,0 mm) as well as for chassis (PCMAS: 166,0 x 85,0 x 35,0 mm) mounting. The basis for the high-quality standard of the whole series is SMD technology, automatic 100 % final test and 100-%-burn-in-test. The AC/DC modules are short circuit protected and need no ground load. They comply with the up-to-date standards as regards CE conformity.

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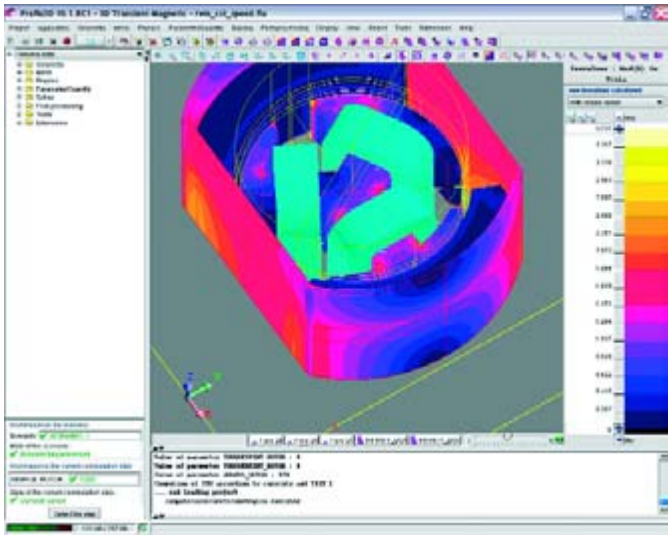
Flux Version 10, 3D Revolution.

CEDRAT is proud to announce the release of Flux Version 10, new generation of simulation solutions for electromagnetics and electromechanics.



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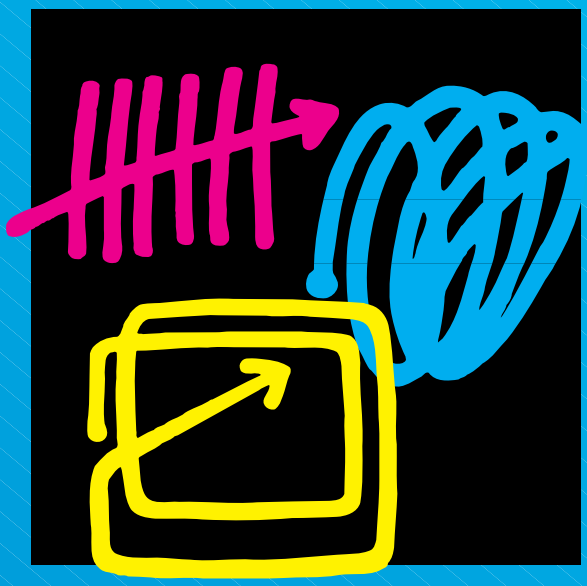
Based on finite elements method, Flux 10 is the ultimate solution to design, analyse and optimise processes and devices such as electrical motors, transformers, high voltage systems, non destructive evaluation processes, ... In a modern interface utilising possibilities given by latest graphic technologies, this new version brings wide automation capabilities of simulation processes. With its command language derived from famous Python object oriented language, Flux 10 allows the user to define its own macros and interfaces to simplify its work, from geometry to results. Motor Overlays, that simplify preprocessing for electrical motors, are significant examples of these capabilities. Perfectly integrated in the CAE chain, Flux 10 communicates easily with numerous tools: to import geometry (CATIA, PRO/E, Inventor, Autocad, ...), to co-simulate with system simulation (Simulink, Portunus) or other domains simulation (FLUENT, EMTP, Ansys, ...), Flux 10 is one of the most open electromagnetic simulation solution of the market.

www.cedrat.com



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TUF Tube Cases

Fischer Elektronik have extended their large range of cases and propose four new aluminium tube cases. The universal tube cases with integral guide slots serve to accommodate non-standard PC boards or components. The special geometry of the aluminium tube section ensures that front foils or key pads are safely kept in place. An EMC version with an electrically conductive surface and additional electrically conductive seals is also available. Using these seals, type IP 54 protection can be achieved.

Machining, surface finishing and printing according to meet customers requirements are possible. The tube sections are delivered as unassembled sets, including the covers and mounting materials. For enquiries and technical advice, please contact the Fischer Elektronik product specialists. They will be pleased to give you any advice you may require.

www.fischerelektronik.de

500 Watts of Compact Power with Multiple Boost

The latest SPH500 model launched by the Munich-based company MGV adds an all-round power supply to the Super Slim Series. This new appliance is extremely compact and meets the most varied demands. Designed for 90-264 Vdc mains, it offers 24V/20A and 48V/10A outputs which can be adjusted between 23-29V and 44-54V. Apart from determining the nominal current, users can also select from four different types of output to suit their own individual applications, namely parallel mode, boost mode, fuse mode or continuous mode. Each mode is µC-controlled and µC-monitored and can be set using a front-panel DIP switch.

With its multiple output modes and an installation width of no more than 62 mm, this power supply is an absolute highlight among the many 500 watt DIN rail power supplies on the market. From the third quarter of 2007, MGV´s Super Slim range will also include the SPH503, a three-phase version of this power supply offering 3x340-550 Vac.

www.mgv.de

ADVERTISING INDEX

29 Palms

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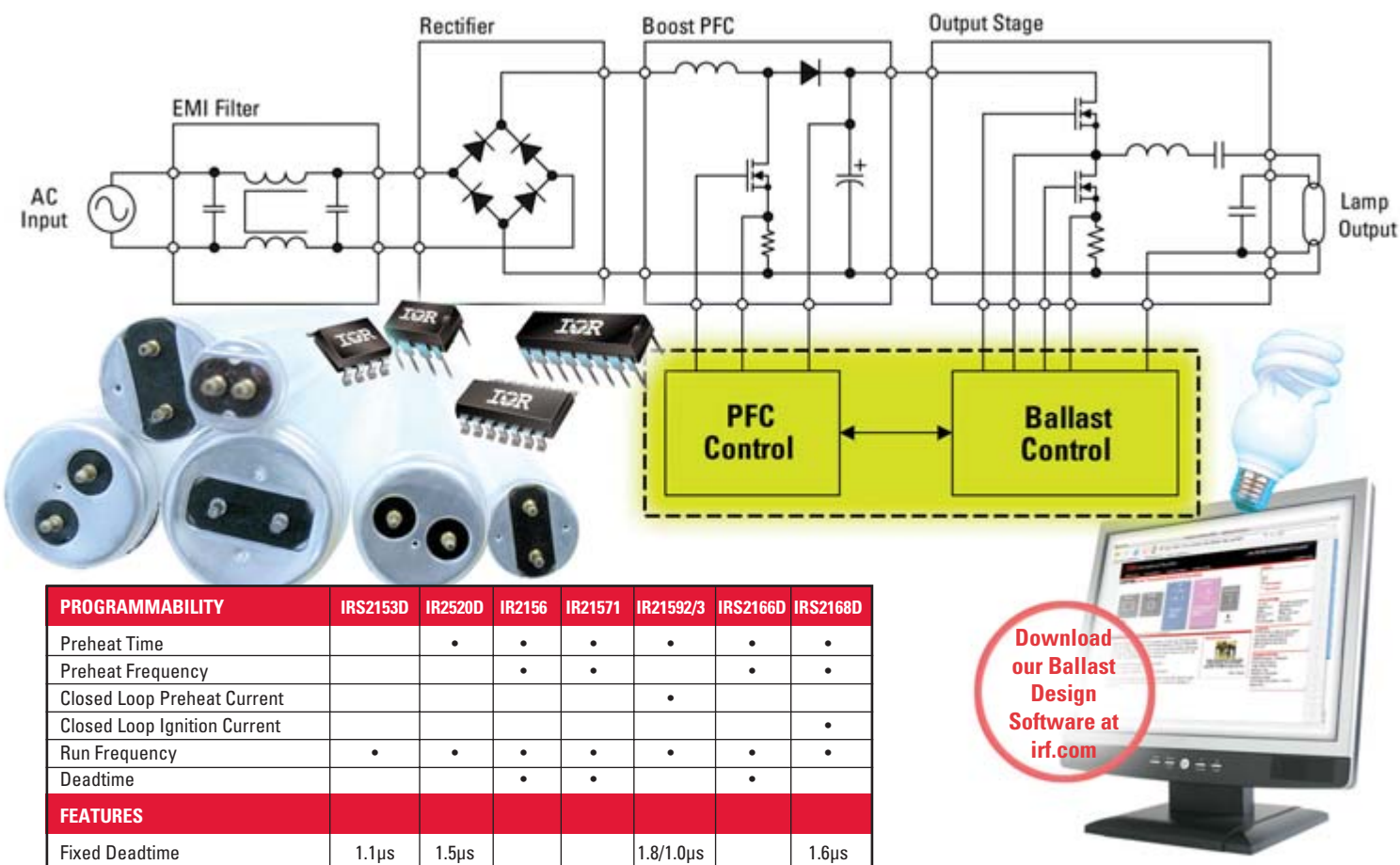

PROGRAMMABILITY	IRS2153D	IR2520D	IR2156	IR21571	IR21592/3	IRS2166D	IRS2168D
Preheat Time		•	•	•	•	•	•
Preheat Frequency			•	•		•	•
Closed Loop Preheat Current					•		
Closed Loop Ignition Current							•
Run Frequency	•	•	•	•	•	•	•
Deadtime			•	•		•	
FEATURES							
Fixed Deadtime	1.1µs	1.5µs			1.8/1.0µs		1.6µs
Over-current Protection		•	•	•	•	•	•
Under-current Protection				•			
Failure to Strike		•	•	•	•	•	•
Open Filament		•	•	•	•	•	•
Brownout Protection		•	•	•	•	•	•
Thermal Overload Protection				•	•		
Shutdown Pin	•		•	•	•	•	•
Dimming					•		
Ignition Detection					•		
Fault Counter							•
End-of-Life Protection						•	•
PFC Over-Current Protection							•
INTEGRATION							
Bootstrap Diode	•	•				•	•
PFC						•	•
Inductor Saturation Detection		•					
Adaptive Non-ZVS Protection		•					
PACKAGE							
DIP & SOIC	8 pin	8 pin	14 pin	16 pin	16 pin	16 pin	16 pin

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