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Special Report - Automotive Electronics Part III

ISSN: 1613-6365

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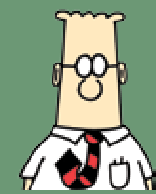

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Registration of copyright: January 2004
ISSN number: 1613-6365

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Volume 4, Issue 8

A Pre-Winter Warmer

Welcome to a frosty October! The weather here in Europe has sure taken a down turn. It looks, though, that things in business take a brighter side in India… according to Frost and Sullivan.

The India Semiconductor Association (ISA), an Indian semiconductor industry organization, has briefed growth, trends and forecasts for the Indian semiconductor market in collaboration with a U.S. consulting company Frost & Sullivan.

According to the report, total semiconductor consumption in India (total value of semiconductors used for devices marketed in India) was $2.69 billion (USD) in 2006. The $2.69 billion represents 1.09% of the global semiconductor market, the report said. Of the total semiconductor consumption in India, consumption by local Indian set manufacturers accounted for $1.26 billion.

The overall Indian semiconductor consumption will grow at an average rate of 26.7% per year in 2006 through 2009, according to the report. Based on the actual consumption in 2006, the overall Indian semiconductor consumption is forecast to be $5.49 billion in 2009. This represents 1.62% of the global semiconductor market in 2009.

Semiconductor consumption by local Indian set manufacturers is predicted to increase at 35.8% per year in 2006 through 2009 and ammount to $3.18 billion in 2009.

Applications expected to consume a large amount of semiconductors in India are mobile phones, desktop PCs, notebook PCs, GSM mobile phone base stations, STBs and power meters, the report said. Most demanded semiconductor products are predicted to be microprocessors, analog devices, memory chips and ASICs.

The falling average unit price of semiconductors has cast a shadow over the large gaps between estimates and actual figures, according to the 2007/2008 edition of the report. The report cited a bill of materials (BoM) for mobile phones as a specific example. Compared with its estimate of $25.7 per unit, the actual BoM was only $11 per unit.

According to iSuppli, the star du jour of the GPS market is the Personal Navigation Device (PND) segment, which continues to develop rapidly as vendors aggressively cut prices to maintain their share of sales amid tough competition. However, with PNDs now in the growth phase of their product life cycle, prices have gone south, with the Average Selling Price (ASP) falling 23 percent year-over-year in 2006. In spite of these dramatic price cuts, the revenue from PNDs is expected to increase by four-fold between 2006 and 2013.

iSuppli estimates 40 companies now are offering GPS navigation capabilities on a range of products, from PNDs and embedded systems, to smart phones.

The navigation market used to be clearly segmented into two separate product families: embedded systems and PNDs.

The more costly embedded systems offer the benefits of integration with improved positional accuracy on a large dash-mounted display. PNDs offer most of the important navigation features on a device priced for the consumer mass market.

Looks like very good news for the semi market.

Enjoy the issue and as always I look forward for your feedback and latest design challenges.

All the best!

Cliff Keys

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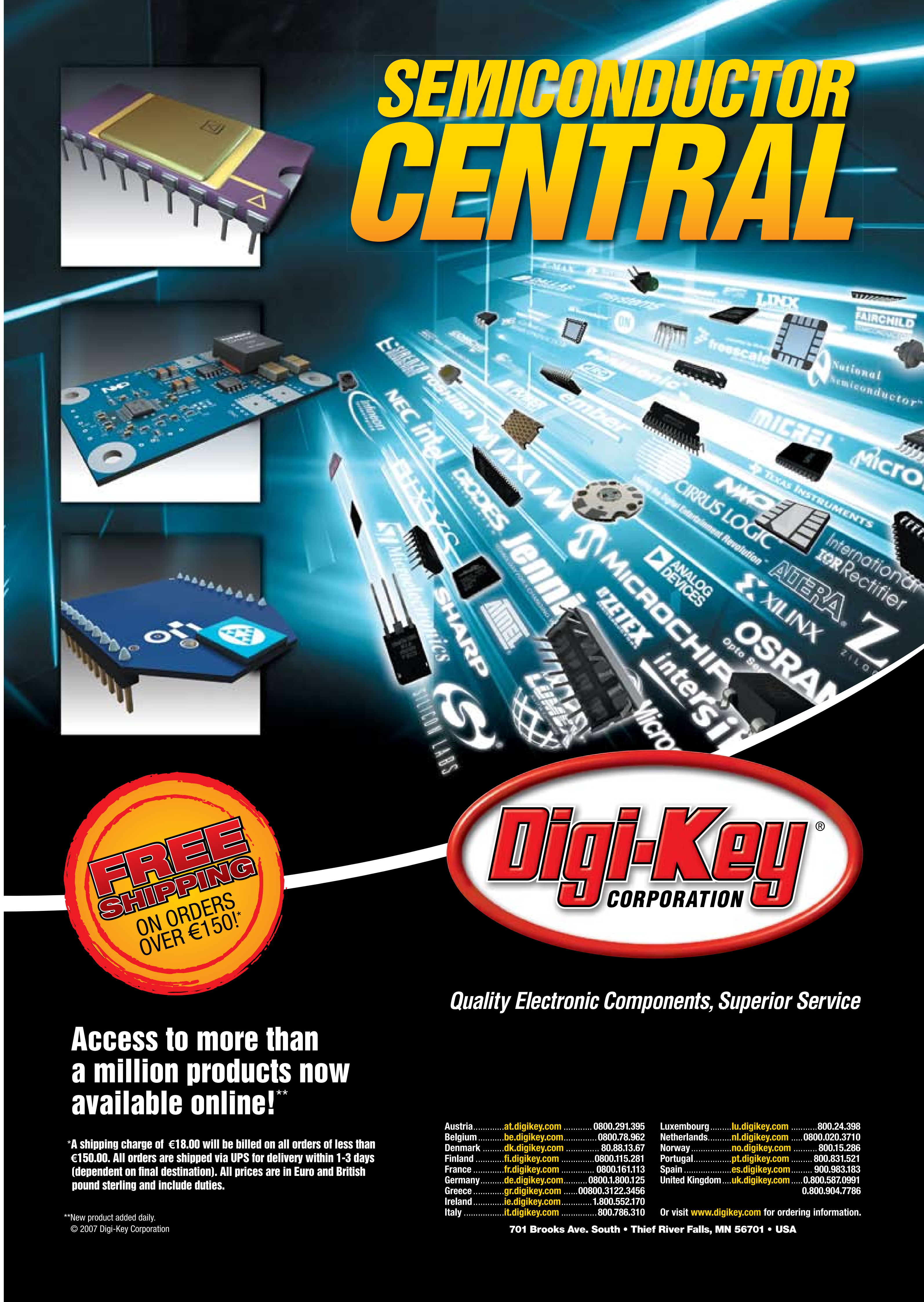


Marriage of UPS and Fuel Cell Technologies Delivers Enhanced Power Protection

UPS and fuel cell technologies have been integrated to produce an advanced backup power system which has been installed for power protection at Investec banking group's London Headquarters. This marriage of a Chloride PowerRACK UPS and a 5kW IdaTech ElectraGen™5XTR fuel cell system delivers high reliability power protection with extended backup power run times to the building's security office.

This state-of-the-art product combines a PEM fuel cell stack, reformer, fuel storage and delivery, controls and power electronics. It provides a clean, compact and quiet alternative to diesel generators for city centre applications. Traditional solutions such as generators, batteries or fuel cell systems using bottled hydrogen are only practical for a limited number of hours. The IdaTech unit internally produces high-grade hydrogen for the fuel cell stack, enabling days of operation from a very compact liquid fuel source. The ElectraGen™5XTR system also provides an economical solution to help avoid the traditional challenges associated with hydrogen delivery and storage by producing hydrogen on-site and as needed. It is perfect for remote locations such as telecommunications towers or in cities where diesel generator operation may be a problem.

IdaTech Sales Director Nicolas Pocard commented: "Key differentiators of the ElectraGen™ solution as compared to alternative models are that it can be used indoors or outdoors while offering predictable, quiet performance from a compact liquid fuel and in temperatures ranging from -40°C to +50°C. By installing the system at Investec, IdaTech's parent company, we are demonstrating the dependability of this advanced power protection system at a site where backup power is critical".

Installed by Cell Care Technologies, the system has gone 'live' and is delivering on its promise of high reliability and extended run times.

www.investec.com/UnitedKingdom/

www.idatech.com

International Rectifier Grants License Agreement for DirectFET® Packaging Technology to Infineon Technologies

International Rectifier, IR® and Infineon Technologies have announced that Infineon will license from International Rectifier its patented advanced power management packaging technology, DirectFET®.

Designed for use in AC-DC and DC-DC power conversion applications in computers, notebooks, telecommunications and consumer electronics devices, the DirectFET power package is an industry-first surface-mount power MOSFET packaging technology for efficient topside cooling in an SO-8 footprint or smaller. Compared to standard plastic discrete packages, DirectFET's metal can construction enables dual-sided cooling to effectively double the current handling capacity of high frequency DC-DC buck converters.

Infineon will deploy the DirectFET power package technology with its OptiMOS® 2 and OptiMOS 3 chip technology and expects to sample the OptiMOS 2 in DirectFET packages starting early 2008.

www.infineon.com

www.irf.com

Students to Benefit from Wokingham Based Semiconductor Giant

A newly-refurbished laboratory was opened today at the University of Reading – thanks to a £40,000 investment from Microchip Technology Inc.

Microchip Technology – whose European Headquarters is based in Wokingham - is a major supplier of microcontrollers, digital signal controller and analogue ICs and has an established track record of supporting education through the donation of funding, equipment and software.

The School of Systems Engineering already uses Microchip Technology's devices in its teaching and project work and when an opportunity arose to refurbish an existing teaching laboratory, an approach was made to see if further support would be forthcoming.

Chris Guy, Head of the School of Systems Engineering, said: "Students on Electronic Engineering and Cybernetics courses will benefit greatly from this exciting new development. It will enhance the learning of all existing students whilst acting as a major recruitment tool for potential undergraduates.

Ganesh Moorthy, Executive Vice-President said "Microchip was delighted to offer a full package to enhance the laboratory, which now boasts a full suite of the latest Microchip Technology hardware, software and development tools. The funding also allowed the laboratory to be fitted out with new benches and chairs, greatly enhancing the look, comfort and student experience. It has been a pleasure to partner with one of the leading technology Universities and to help ensure students learn in a modern, hi tech environment."

www.microchip.com

New Handbook of Standardized Terminology for the Power Sources Industry

The Power Sources Manufacturers Association (PSMA) announces publication of "The Handbook of Standardized Terminology for the Power Sources Industry–3rd Edition" . Revised and expanded, this unique handbook contains hundreds of added terms, especially selected for the power electronics professional. The third edition also contains illustrations and four new appendices, including a listing of EMI specifications, excerpts from international standards of units and symbols, along with guides for authors of technical papers. These added resources provide concise, easy-to-use references for engineers involved in technical writing and presentations.

Many new magnetic terms are described in this new 126-page third edition that are of particular interest to the practicing designer and marketer of power supplies and related products. Valuable information regarding worldwide power sources, standards agencies, and military specifications has been retained, updated and expanded from the previous edition.

The book price is US$25 to PSMA members and US$50 to nonmembers, and may be purchased from:

Power Sources Manufacturers Association
P.O. Box 418 Mendham, NJ 07945-0418
Tel: 973-543-6207
E-mail: power@psma.com

www.psma.com

Sailboat with Hydrogen Fuel Cell Makes History

"I feel like Orville Wright," said Jim Harrington, after unveiling Canada's first-ever hydrogen fuel cell sailboat to the world.

In just six short months, the president of A.G.O. Environmental Electronics Ltd. in Victoria B.C. managed to take his initial idea and make it a reality – to build a completely green sailing machine.

He completed his first successful voyage aboard the six-metre sloop "Jim D." August 23.

"This is history being made," he said. "It is that significant."

Fuel cells generate electrical power quietly and efficiently, without pollution. The by-products of an operating fuel cell are heat and water.

Harrington outfitted the sailboat with a 300-watt Horizon fuel cell system and he managed to do it for about $5,000 in parts, most of which he purchased at Canadian Tire.

"Every so often in history, there's a convergence of where technology and the supply of parts necessary to start a new age occurs," he said.

Harrington says Canadians are on the brink of a hydrogen revolution – as fuel cell technology advances, so will its use in everyday life.

Harrington is working with iGreen Technologies to develop more fuel cell technology products.

Jack Jardine, CEO of iGreen Technologies, says one their plans is to put together fuel cell kits priced at $4,500.

"Before long you'll have guys and gals putting together fuel cell boats in their garages," he predicted.

Harrington's prototype included hydrogen supplied by NRC in Vancouver, which uses photo voltaic panels to transform solar energy into hydrogen to power fuel cells.

Future tests will incorporate larger fuel cells manufactured by Palcan.

Harrington's early calculations suggested the sailboat could reach 2 knots under fuel cell power of this size, but his tests revealed a top speed of 1.5 knots. While he's still working out the kinks, he's enjoying the quiet and clean technology.

"All you can hear is a little poof," he said, referring to the tiny blast of vapour that is released when the fuel cell is in operation.

Harrington comments: "I think that the most significant development from this test was the creation of an almost silent power supply that could feed an inverter to power electrical devices onboard a sailboat."

Compared to the smoke and noise of a big diesel engine, it's a huge improvement, he added.

Jim Harington: info@agoenvironmental.com

www.igreen.ws www.palcan.com

TI Kicks Off 2007 Portable Power Management Design Seminar Series

Seminar Focuses on Latest Design Approaches and Applications

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

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

- New Battery Technology and Portable Power Management Development
- Li-Ion Battery Fundamentals and Battery Pack Electronics Design
- Battery Capacity Monitoring Accuracy and Implementation
- Battery Charging System Design Considerations
- Buck-Boost Converters for Portable Systems
- Driving White LED as Backlight for Small and Medium-Sized LCD Displays
- Portable Power Circuit Collection – Extending Applications of Standard ICs
- PWM and PFM Operation of DC/DC Converters for Portable Applications
- Component Selection, Layout and Thermal Design Consideration for DC/DC Converters

European Dates and Locations:

December 3	Munich, Germany
December 4	Paris, France
December 5	Birmingham, England
December 6	Copenhagen, Denmark
December 7	Eindhoven, Netherlands

Battery Power Management Products

TI meets the power design needs of customers through innovative products and technical support. Through its analog and digital systems expertise and manufacturing capabilities, TI provides high-performance, discrete and integrated power management solutions to fit any portable, line-powered design challenge – from cell phones and PDAs to telecom, industrial and computing applications.

power.ti.com

Power Events

- ***The China International Power Supply (CPS EXPO),*** *November 6-8,Shanghai, China, www.cpsexpo.cn/en/index.html*
- ***APEC 2008,*** *February 28-28, Austin, Texas, USA, www.apec-conf.com*
- ***PCIM China 2008,*** *March 18 – 20, Shanghai, China, www.mesago.de/en/PCChinamain.htm*
- ***Productronica,*** *November 13-16, Munich, Germany, www.productronica.com*
- ***PCIM Europe 2008,*** *May 27-29, Nuremberg, Germany, www.pcim.de*

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

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

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

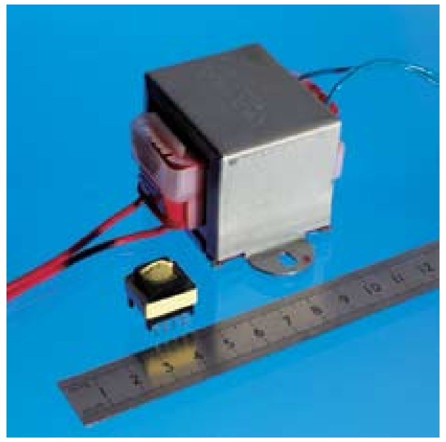


Figure 1. The C2470 family uses a tiny ferrite core in place of bulky and heavy iron-cored transformers.

Figure 2. The C2470 family and RDFC topology are ideal for the replacement of bulky, energy-inefficient linears with small footprint mini adapters.

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

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

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

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

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

The first three members from the C2470 family are for 6 to 40W power range.

www.camsemi.com

PSDE Power Player

PSDE Green Power ENERGY EFFICIENCY

There's More to Energy Saving than Efficiency What about Imagination?

By Davy Lo, Chief Marketing Officer, Zetex Semiconductors

For over fifty years the luminous efficacy of lighting technologies has steadily improved yet today the incandescent light bulb still only achieves between 16 and 20 lumens per Watt (lm/W). For the energy conscious it's the fluorescent lamp and its compact derivative that have become the solutions of choice for energy saving in the home - yet they too only produce between 60 and 80 lm/W. Enter the high brightness LED.

By combining forces, semiconductor and chemical industries have developed high brightness LEDs capable of achieving 80 to100 lm/W, the race is now on to exceed 200lm/W. Such incredible progress constitutes a major technical shift that allows a quantum improvement in lighting efficiency benefiting a broad spectrum of applications in lighting in the home, the street, automotive and LCD backlighting.

But, without the right kind of electronics to drive the latest solid state lighting technology, potential energy saving benefits can not be fully realised. Drive circuits need themselves to be efficient and help deliver a high quality, stable source of light which preserves the technology's long lifetime. An industry focus to improve luminous efficacy and simple drive electronics will not be enough to produce really substantial energy savings and exploit the other benefits of solid state lighting. We need to think differently.

When it comes to lighting systems for example, we're still quite primitive in our energy saving strategy: Turn it on when you need it and off (or at least dim it)

when you don't! As engineers, I'm sure we can be cleverer than this and if we're going to make the most out of the energy saving potential of new generations of solid state lighting then our control system philosophy needs to become a great deal smarter. The only thing that stands in our way is the bound of our collective imaginations.

As a truly 'disruptive technology' high brightness LEDs, in a myriad of different powers and colours, simply invite accelerated usage in lighting applications, in quantities and roles hitherto not even considered before. By introducing smarter control systems that help to substantially reduce energy consumption, the viability of LED based solutions is assured and widespread use in interior and exterior building illumination applications just happens.

What if we start introducing adaptive or interactive lighting systems in the home or in the workplace as standard? How nice it would be for interior lighting to automatically adjust to ambient lighting conditions, avoiding over or under illumination, to suit the needs of different age groups or different types of activity to always be optimised for purpose. Then what about outside? Sensor activated highway lighting that dimmed to a level that suited the average speed and flow of traffic, to achieve the safest and most comfortable driving conditions.

While fluorescents have replaced incandescents on energy saving and environmental grounds, they should nevertheless be regarded as an interim solution. From technical and cost perspectives they simply cannot suit the kind of intelligent energy saving control scheme intimated above. Since high brightness LEDs will, they need to be embraced.

Working together, experts in chemistry, semiconductor and optical technology, chip packaging, thermal and electrical engineering will in time undoubtedly ensure that solid state lighting will become a standard solution for even the most general lighting application.

Solid state lighting presents a vast opportunity for semiconductor and cluster industries as technology lends its full advantages to this sector in driving, controlling, protecting and enriching the functionality of solid state lighting systems. Power management ICs, microcontrollers, DSPs, wired and wireless communication interfaces et al can all be used to build far more intelligent and energy saving lighting systems. We need to use our imagination.

www.zetex.com

Shining the Light on LEDs

Abundant applications adopting the technology and more coming in the next five years

By Marijana Vukicevic, iSuppli Corporation

Light Emitting Diodes (LEDs) have stimulated the interest of numerous applications over the past several years. Many applications have adopted LEDs for use as displays in appliances as well as in consumer, medical and industrial equipment.

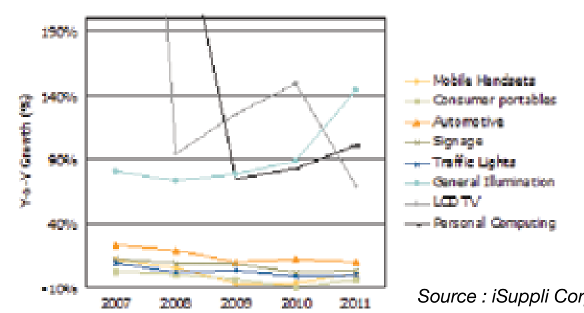
The intriguing thing about LEDs is their small form factor, high efficiency and potentially longer life than that of conventional light sources. While some applications adopted LEDs as a light source many years ago, others have struggled to make LEDs a mainstream light source.

Higher power LEDs (not including display applications) require higher drive capabilities that are usually managed through the combination of power conversion circuitry and driving circuitry. The growth of LED drivers is somewhat connected to the increased number of LEDs used in the applications, but different circuit techniques keep the number of LED drivers used per application at a minimum.

Driving LEDs

Major market applications for LED drivers as of today are in the mobile handset and consumer handheld markets. These markets combined to account for approximately 81 percent of the LED driver sales. The penetration of LED lighting into these markets will peak during the next few years. Saturation of this market is influenced by LED price drops and integration of LED drivers into other power management circuits. This trend will influence LED driver suppliers, shifting it to other potentially higher growth markets.

However, it is the automotive market that is predicted to be a high revenue earner for both LEDs and LED drivers with a forecasted solid 15 percent growth in the next five years. Many LED applications in the automotive market benefit from the usage of compact and efficient sources of light. The LEDs could find themselves in display backlight, interior lights and tail lights. Headlight LEDs have not taken off yet but they are expected to in 2008.



Source : iSuppli Corp. August 2007.

Figure 1: Year Over Year Growth Rates for LED Drivers.

LEDs emerging

Emerging LED markets are notebook monitors, Liquid Crystal Display-Televisions (LCD-TVs) and the general illumination market. The average growth rates for these markets are forecast to be 255 percent, 177 percent and 92 percent, respectively, for the next five years. Of the three, the notebook monitor market has the greatest potential as the application has possibly the highest benefits and solutions.

The LCD-TV market will have moderate penetration of LED backlighting technology until 2010 mostly because LEDs are only used to reduce power consumption and to improve brightness in these big displays—factors that are unlikely to be significant for some time to come.

The general illumination market is one of the most logical markets for LED penetration, but historically the dynamics of this market have shown resistance to change as well as opposition to new technology adoption. Still, the market for LED drivers is predicted to grow to $89 million by 2011, mostly coming from commercial and office lighting.

Figure 1 presents iSuppli's forecast for LED driver market year-over-year growth rates.

Today, the LED driver market is shared among the top LED driver vendors for mobile handsets and consumer electronics. At the top are National Semiconductor, Maxim Integrated Products and Linear Technology. There are other small suppliers that are entering the LED driver business as well, but they hope to compete in other, more niche segments instead of fighting it out in the competitive mobile handset or consumer markets.

www.isuppli.com

Vital Connections for Powering Communications

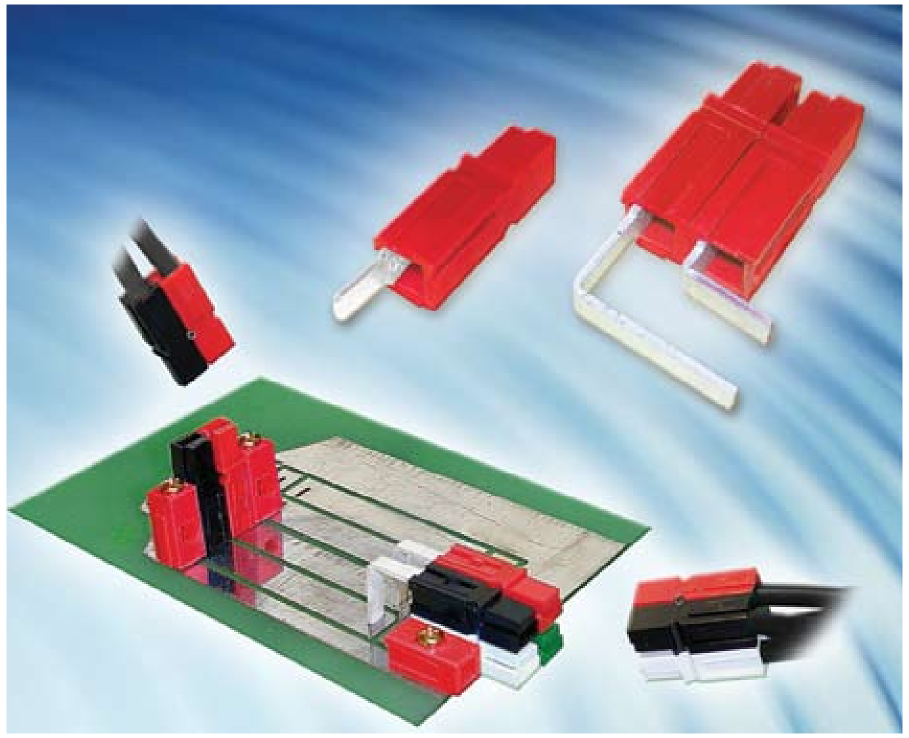
Reported by Cliff Keys, Editor-in-Chief, PSDE

Whenever I thought of connectors for power, especially in critical applications such as cellular base stations, I would always have a sense of unease. Troublesome intermittent faults on some pieces of my own (low quality) radio equipment had given me this misconception. I talked with Jeffrey Burkhardt of Anderson Power Products to investigate the reality.

For any designer with a project on mission critical equipments, the power connectors need to be top quality. Many designs need high current capability as well as the ability to quickly disconnect and reconnect with the highest possible reliability.

Anderson specializes in high reliability connectors, particularly for high current (>30A) applications and has designed in with many of the key players worldwide in applications ranging from blade servers, test equipment installations, network switchers and cellular base stations. They also supply connectors for hot swapping applications where high currents are connected live.

Jeff commented, "Many of our applications are in rugged environments where operation on a continuous 24/7 basis in vital applications such as data centers or base stations, where a loss or interruption of power would prove at the very least, unacceptable and potentially crippling to a service provider with millions of demanding customers subscribing. We have been extremely successful, with these customers, especially those who need extreme reliability and repeatability in the high current arena."



In this highly competitive market place, price is very important, but in these vital applications where a connector failure or intermittency could prove a disaster for a provider, the quality of these devices is paramount.

Anderson Power Products began when the company converted an old brewery in downtown Boston into a foundry. One of the first projects was to cast various parts for the Boston Trolley Transit System. Product development and inventions such as the trolley pole, invented by Johan M. Anderson in 1890, put us on the map. The trolley pole was used in the overhead system of electric railways, providing a simple compact, efficient and durable supporting mechanism. APP received multiple awards for the Anderson brothers' innovative trolley and railway designs. The company has certainly moved forward.

www.andersonpower.com

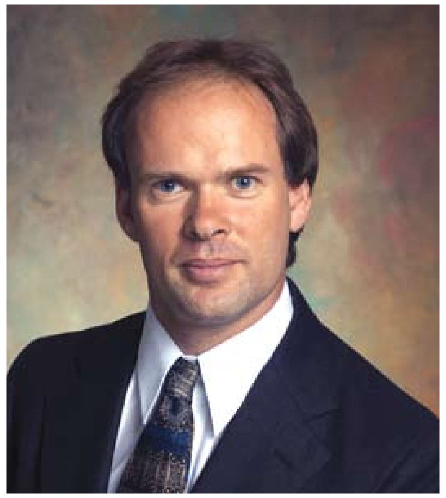
The Nine Most Useful Power Topologies

At the beginning of modern power supply design, about thirty years ago, there were a handful of topologies that served the industry well. In the 1980s, an explosion of research into new and advanced power conversion techniques created hundreds of new topologies that could be used. Today, mainstream industry has reverted back to the early topologies. The same handful of circuits provides the best solutions for most applications.

By Dr. Ray Ridley, Ridley Engineering

In the beginning of power supply design, there were three fundamental converters: the buck, boost, and buck-boost. Early analysis papers cover just these topologies. There were also converters that behaved exactly the same as these fundamental topologies. They were considered to be in the buck, boost, and buck-boost families, with isolation being included in the circuit. Included in the buck converter family are the forward, two-switch forward, half-bridge, full-bridge and push-pull. The boost has an isolated version that can be built with a bridge or push-pull circuit. The isolated buck-boost circuit is the well-known flyback converter.

It is an intriguing research exercise to invent new power topologies and study their operation. This formed a large part of research in the past, especially during the 1980s. Some fascinating circuits were invented that stretch the mind to fully understand their operation. A paper from Caltech came up with over 300 new topologies which used an additional switch and diode. For a while it seemed as if the old standby topologies were in jeopardy of being replaced.



It was a very confusing time for many designers who needed to produce products. After reading conference papers, engineers were tempted to try exotic new topologies that promised superior performance but which proved to be very difficult to implement in production.

As a result, the industry came full circle. Now it relies on the original basic topologies for nearly all designs. Exceptions are made for some very high density applications, or for unusual voltage and power ranges, but the working engineer can almost always get the job done with the basic set of circuits.

That is not to say that industry has not made progress. It has come a long way—just not through the usage of fundamentally different circuit topologies. The main advances have been in judicious use of the correct circuit for the right application, partitioning of power into smaller pieces (such as the motherboard VRMs and point of load converters), advanced packaging, new silicon devices, and careful application of low-loss switching for some of the topologies.

1. Buck Converter

The buck converter is the most fundamental of all power supplies. It supplies a lower voltage output than the input, and is used at all power levels where isolation is not required.

As shown in Figure 1(b), the diode of the buck converter can be replaced with an active switch when the output voltage is low. This provides efficiency advantages. Caution is required when using discrete parts since avoiding overlap of the two switches is essential.

Probably more buck converters are built than any other converter. They form the basis for microprocessor power supplies, providing over 100 A to the load. Modern design techniques break the total load into smaller pieces, using several parallel buck converters. This results in a final power system which can switch faster. It is also smaller and more efficient.

When working with these converters, don't forget that the input is noisy. Good power designers will have input filters on the front end of their buck converters, preventing the large switching currents from creating noise issues elsewhere on the board.

The buck converter becomes less optimal as the input-to-output voltage ratio increases. A 10:1 step down is reasonable as an extreme. Beyond this, the silicon is stressed hard and a transformer topology may be more appropriate.

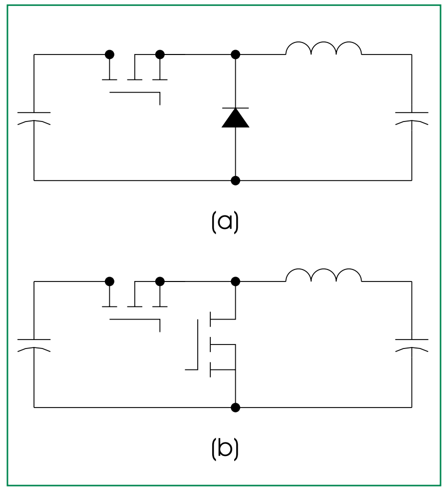


Figure 1: Buck Converter.

• Applications: Step down without isolation for power levels from less than 1 W to over 1 MW.

• Strengths: Low noise output.

• Cautions: Noisy input requires filtering. Don't try to step down too much.

• Advanced application: Synchronous rectifiers, multiphase for current sharing.

2. Forward Converter

If your system requires isolation or a large step down ratio, it can be provided by the forward converter. This inserts a transformer in the circuit and allows appropriate scaling of the input voltage. The transformer also inserts complications – the voltage stress on the switch is increased, and the core must be properly reset when the converter is turned off. In general, forward converters only operate to a 50% duty cycle. The rest of the period is reserved for transformer reset.

More advanced versions of the forward converter can be used in resonant mode, or with synchronous rectifiers for low voltage outputs.

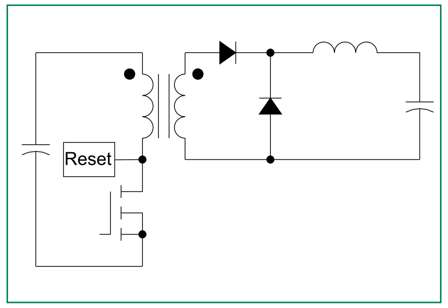


Figure 2: One-Switch Forward Converter.

• Applications: Isolated outputs for power levels from less than 1W to about 100W.

• Strengths: Low noise output, single ground-referenced switch.

• Cautions: High voltage on the switch. Noisy input requires filtering. Transformer reset circuit needed. Maximum of 50% duty cycle.

• Advanced application: Synchronous rectifiers, resonant converters, multiphase for current sharing, resonant reset of the transformer.

3. Two-Switch Forward Converter

The power level of the single-switch forward converter is limited by the voltage stress on the switch. At higher power levels, the converter of choice is the two-switch forward converter, shown in Figure 3. This is the most rugged of all the isolated converters, providing a voltage clamp on the primary power switches. It is used in applications up to 1 kW or higher.

Both switches are turned on simultaneously, and the top switch requires an isolated gate drive. The transformer core is automatically reset through the same diodes that clamp the voltages of the switches to the input voltage source.

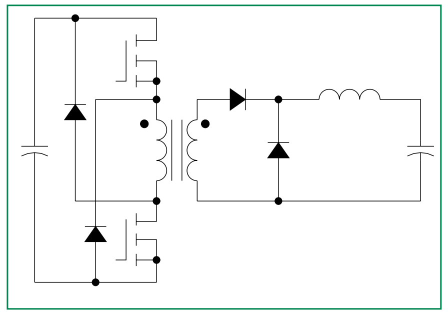


Figure 3: Two-Switch Forward Converter.

• Typical Applications: Isolated outputs for power levels from less than 50W to over 1000W.

• Strengths: Low noise output, clamped primary switch voltages. Very rugged circuit.

• Cautions: Noisy input requires filtering. Maximum of 50% duty cycle.

• Advanced application: Synchronous rectifiers, multiphase for current sharing.

4. Half-Bridge Converter

The half-bridge converter has the apparent advantage over the two-switch forward of driving the core with a symmetrical waveform as each switch is alternately turned on. For years, engineers debated the relative merits of the half-bridge and forward. Once current-mode control became standard, the half-bridge converter fell out of favor as it does not work well with current mode control.

Only recently has it begun to reemerge. Some examples include ballast supplies that need an ac output, and high-density power supplies that switch at very high frequencies, where the reduced core loss of the half-bridge becomes the deciding factor. The topology works well for the non-regulating bus converters of recent years.

For off-line applications, the current-mode issue and other complications of the half-bridge still make the two-switch forward the preferred approach.

• Applications: Isolated outputs for power levels from less than 50W to 500W.

• Strengths: Low noise output, clamped primary switch voltages.

DESIGN TIPS

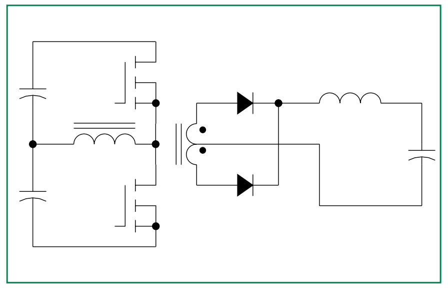


Figure 4: Half-Bridge Converter.

• Cautions: Gate drive noise problems leading to cross-conduction, transformer flux balancing, input capacitor balancing, current-mode control problem. Not recommended for most cases.

• Advanced application: high-frequency bus converters with regulated input, synchronous rectifiers.

5. Full-Bridge Converter

As power levels exceed 500 W or so, some designers will take a pair of two-switch converters in parallel to supply the load. The primaries are switched out of phase with each other to minimize input noise. This is certainly a rugged and reliable approach for high power applications, and it minimizes development time.

Another approach is to replace the diodes in the primary of the two-switch forward with two more switches, and alternate the switching of the diagonal legs to provide the full bridge converter shown in Figure 6. The full bridge provides a lower parts-count solution than a pair of forwards, and is certainly the right choice if you have extra time for development.

Advanced designers use the full bridge in the phase-shifted mode, where the primary switches are always on 50% of the time. This minimizes switching losses in the primary, and eliminates the need for a primary snubber since the leakage inductance energy is circulated in the primary.

However, great care must be taken with this circuit not to ever overlap the drives on the side legs of the bridge. With the high-side drives required, this can be problematic, and solved with gate-drive transformers and careful layout.

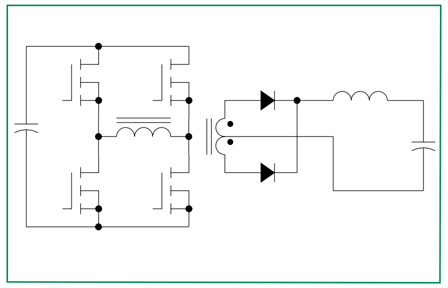


Figure 5: Full-Bridge Converter.

• Applications: Isolated outputs for power levels from 200W to over 5000W.

• Strengths: Low noise output, clamped primary switch voltages.

• Cautions: Gate drive noise problems leading to cross-conduction, transformer flux balancing.

• Advanced application: Phase-shifted operation, current-doubler operation, synchronous rectifiers. High-frequency bus converters with regulated input.

6. Push-Pull Converter

The last of the buck-derived converters is the push-pull. The push-pull converter has two ground-referenced switches, making it easy to drive directly from a PWM control chip. However, its application is limited to low-voltage inputs since each switch sees double the input voltage, plus any leakage energy spikes. It is a common circuit for battery input to higher voltage outputs, but it is not recommended for off-line applications.

It has also been applied successfully in high-frequency bus converters where the input voltage is tightly regulated, such as the half and full-bridges converters.

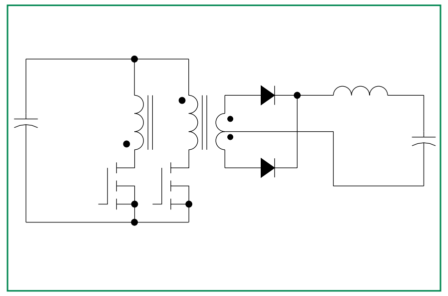


Figure 6: Push-Pull Converter.

• Applications: Low voltage input, isolated outputs for power levels from less than 1W to about 500W.

• Strengths: Low noise output, ground-referenced power switches.

• Cautions: Transformer flux balancing, high voltage on input devices.

• Advanced application: high-frequency bus converters with regulated input, synchronous rectifiers.

7. Boost Converter

The boost converter is the opposite of the buck – it only steps voltage up, its input is quiet, and its output is noisy. It is an ideal choice if you need step up without isolation, and it also finds very wide usage in power factor correction circuits which generate a high-voltage dc bus from the input ac line.

The boost converter is usually seen only in its nonisolated version. Which bridge and push-pull boost circuits can be built, they have issues with start-up that require extra power windings to get the circuit up to full output voltage without overcurrent in the power switch.

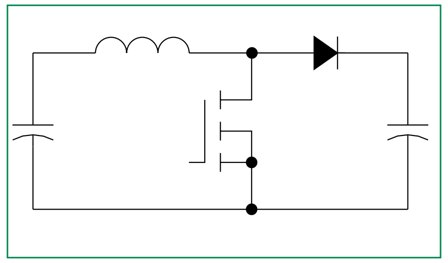


Figure 7: Boost Converter.

• Applications: Non-isolated step up, power from 1W to greater than 1 kW, power factor correction.

• Strengths: Low noise input, clamped output voltage.

• Cautions: Use current mode control to provide good response with this RHP zero converter.

8. Buck-Boost Converter

The buck- boost converter combines the step down of the buck, together with the step up of the boost. Shown in its simplest form in Figure 8, it provides a nonisolated and inverted input. Since this is not a particularly common requirement, and since it has a high-side switch, it is not a particularly common circuit in industry.

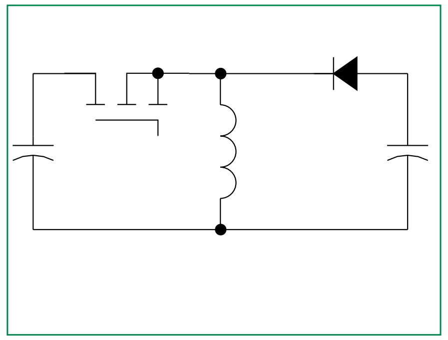


Figure 8: Buck-Boost Converter.

• Applications: Non-isolated step up or step down, inverted output, power from 1W to greater than 100W.

• Strengths: Multiple outputs are easy to add.

• Cautions: Current mode control for RHP zero, noisy input and output.

9. Flyback Converter

The flyback circuit is the isolated version of the buck-boost converter. After the buck converter, it is the most common circuit made. It is popular due to its low parts count, single magnetic element for both energy storage and transformer action, and for the ease it provides in generating multiple outputs.

The flyback converter has many modes of operation – discontinuous mode, continuous mode, quasi-resonant, etc. They are all in common usage. The drawbacks are the high voltage on the power switch, which usually must be clamped, the high noise output which benefits from a second filter, and a power limit corresponding to about 10 A output current.

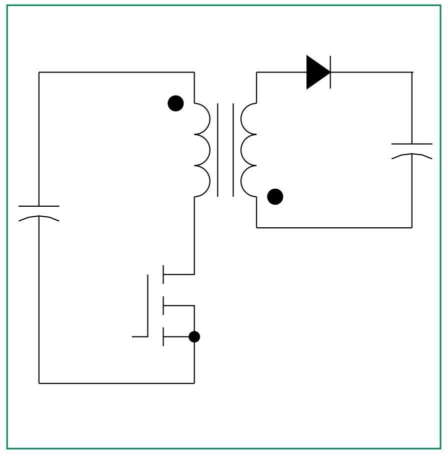


Figure 9: Flyback Converter.

• Applications: Non-isolated step up or step down, inverted output, power from 1W to 100W.

• Strengths: Single ground-referenced switch, automatic core reset, multiple outputs are easy to add.

• Cautions: Current mode control for RHP zero, noisy input and output. Limited to about 10 A output current

• Advanced application: Quasi-resonant operation, synchronous rectifiers.

Cascaded Converters

Most power system designs are done with the above topologies. Sometimes, though, you run into a situation that calls for more functionality than can easily be provided with a single standard power stage. Rather than trying to research other topologies, one of the best approaches is to use a cascade of topologies where each serves its own function.

For example, if you need a very high step up ratio, it can often be best achieved with two boost converters in series, rather than with a single power stage. Some very high performance systems use three or four series converters, each one designed to do a specific job. [1] Some high-density converters also use a cascade of topologies to let each one operate at its optimum point. [2]

This is a relatively new development in the power electronics field, brought on by the availability of low-cost silicon with extremely low on-resistance. It is the basis of most of the high performance power supplies in industry today. This is a big change from the previous decade when the thrust was to accomplish everything in a single power stage.

Other Converters

Sepic, Weinberg, current-driven push-pull, isolated boosts, tapped inductor converters, Cuk converters, and many others can be found in our industry. Rarely do they provide a function that cannot be done simpler with the basic topologies. If you find yourself heading in that direction with a design, make sure you research the implications thoroughly, and examine the alternative architectures you might use for the same job.

Resonant power also has its niche, but some of the most impressive circuits are resonant-transition circuits. They have the same topologies, but simply switch in a soft manner.

Summary

The nine converters that formed the basis of our industry in the beginning are still with us. Do not think of these as "beginner" circuits. They are used in some of the most advanced power systems in the world, and should be your choice as well.

Additional Reading

[1] "IBM's next generation servers look to bus converters" www.switchingpowermagazine.com/downloads/IBM Building Blocks.pdf

[2] "The incredible shrinking power supply" www.switchingpowermagazine.com/downloads/Incredible Shrinking PS.pdf

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Simple Solutions for the Design of High Voltage Battery Packs

Lithium-based battery packs are becoming standard equipment in diverse applications

The past two years or so have seen a dramatic increase in the number of high- voltage battery packs that are using lithium-based cells. These new lithium-based battery packs are replacing previous generations of battery packs that were typically nickel-cadmium or lead acid and the new packs are delivering improved performance, longer usable life between charges, and more charge cycles over their lifetime. These lithium-based battery packs are becoming standard equipment in diverse applications such as power tools, e-bikes and light delivery vehicles, uninterruptible power supplies, mobile medical and diagnostic equipment, and other even higher power consuming products such as hybrid and plug in hybrid electric vehicles. In addition to the performance improvements, lithium based battery systems provide other benefits such as lower weight, longer run times, no memory effects, and they are also better for our environment.

By Mike Coletta, Lead Marketing Engineer,
Battery-Power and Portable Systems Design, Intersil Corporation

The features and benefits of lithium-based packs comes at a price. We have seen numerous recalls of battery packs in the past year, with most of these recalls for lithium ion-based packs. The previous generations of nickel-based battery packs were low cost, simple designs that had minimal electronics within the pack or system for battery monitoring and control. New lithium-based packs can require a significant amount of electronics within the pack to meet the safety requirements as well as to provide a good user experience. The required safety features generally include:

• Pack Overcurrent Monitoring and Short Circuit Monitoring
• Cell Overvoltage and Undervoltage Monitoring
• Pack / Cell Temperature Monitoring

Additionally, cell balancing and pack capacity monitoring may also be included to further enhance the user experience.

Battery-powered products that are used in applications such as notebook computers and video cameras present a fairly constant demand for power from the battery. The more interesting devices such as power tools and various mobility products can demand huge instantaneous loads that must be supplied from the battery. Because of the extreme demands that can come from devices such as power tools, the battery monitoring and protection electronics are more complicated and provide additional levels of protection not found in the notebook type battery monitoring and protection devices. Well-designed multi cell monitoring and protection circuits, such as Intersil's ISL9208 family of products, offer multiple levels of detection for error conditions as well as timing windows

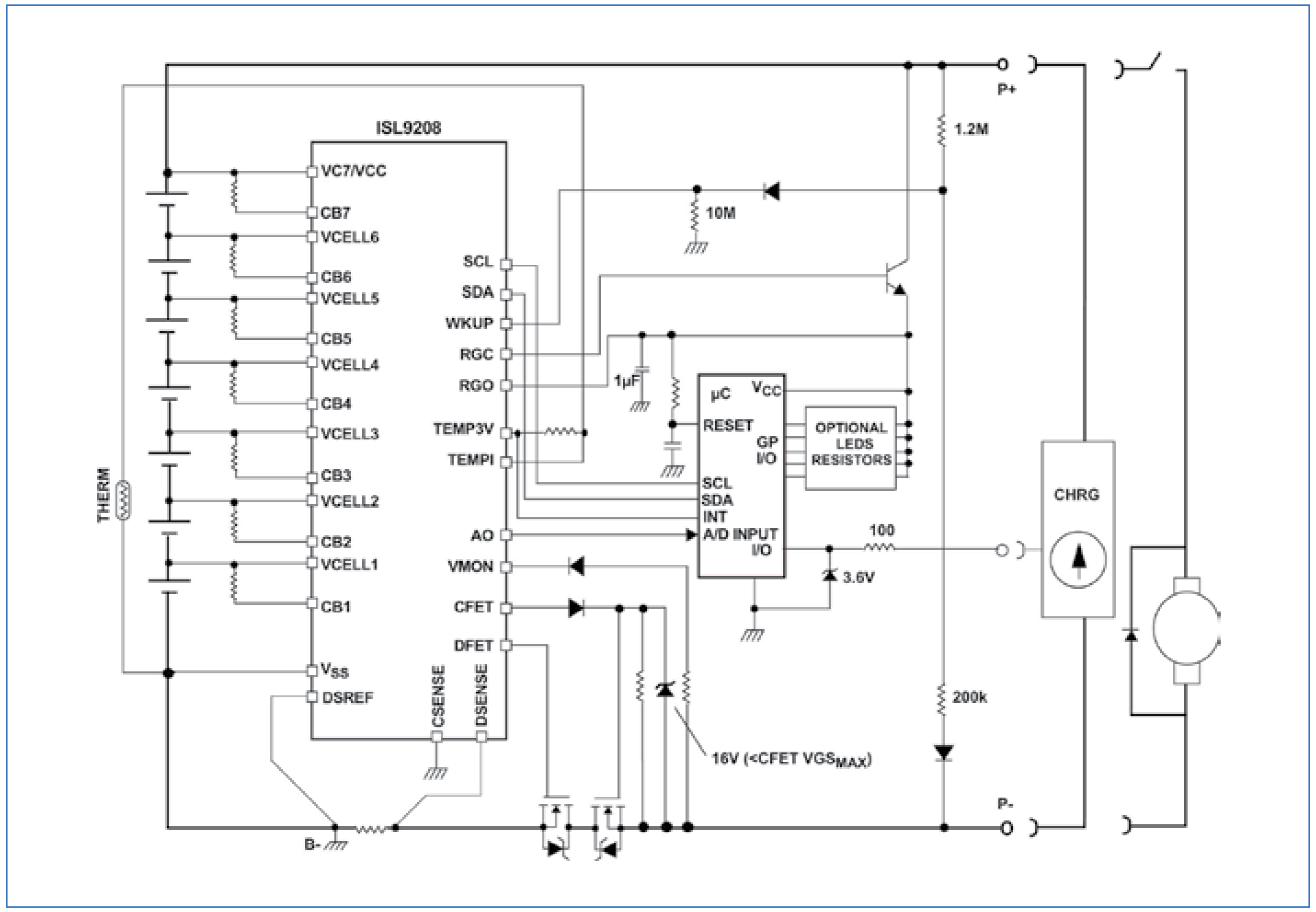

Figure 1

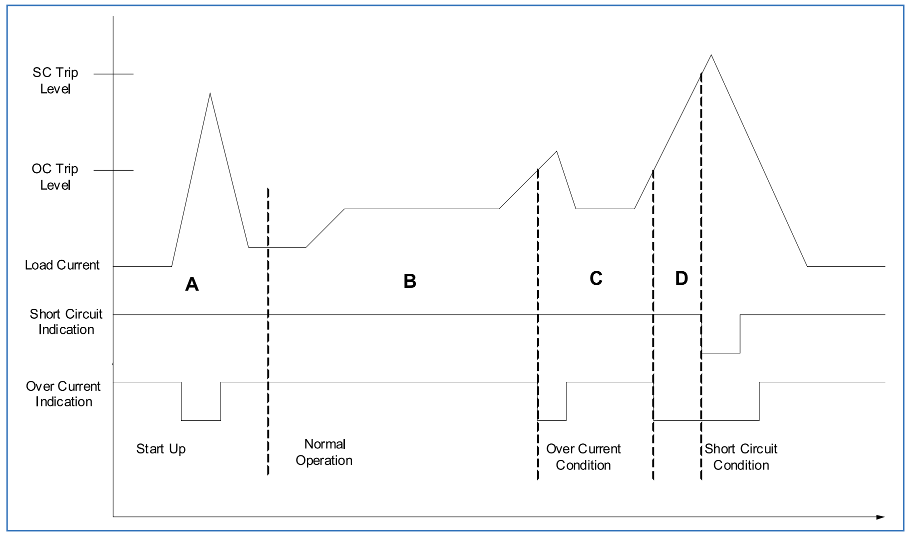

Figure 2

for these error conditions to clear. At the same time, these circuits also provide hard limits beyond which a hard fault condition is deemed to have occurred.

Shown below, we have a simple example of a Li-Ion battery pack that is used in a cordless power tool or e-bike application. This design supports control of both charge and discharge current using a single path with two MOSFETs. It is also possible to support separate charge and discharge paths, if so desired.

This design provides pack current monitoring for overcurrent and short circuit events as well as individual cell voltage monitoring, pack temperature monitoring and fast cell balancing with up to 200mA of balance current. In this example, the ISL9208 functions as an Analog Front End (AFE) and operates in conjunction with a microcontroller. The AFE performs the level shifting of the cell voltages and outputs the voltage on the analog output pin (AO) to the microcontroller. The microcontroller can use this information to monitor the status of each cell during charge or discharge as well as for cell balancing. Along with the analog voltage of each cell, the AFE also reports any error conditions to the microcontroller. The charge and discharge FETs are controlled directly by the ISL9208 and provide an automatic protection mechanism to minimize any possibility of delays in protection being introduced by the microcontroller when critical error states such as overcurrent or short circuit conditions exist. It is possible to disable this feature in the charge and/or discharge modes of operation. In case this automatic protection feature is disabled, the ISL9208 will continue to monitor the current and will report an error condition to the microcontroller which will then direct the ISL9208 to disable the MOSFETs. This allows the system designer the flexibility to implement some unique charge management algorithms. For battery packs that require more than 7 cells in series, as shown in Figure 1, a chipset approach that incorporates a single microcontroller and multiple AFE's is easily implemented.

To illustrate the typical operation of these types of battery packs and systems, we use a simple cordless radial saw example. For this example, the battery pack protection and monitoring electronics are designed for an overcurrent trip point at 50A and a short circuit trip point of 100A. If the overcurrent event is cleared within 125mS, the tool continues normal operation. If the overcurrent event is not cleared within 125mS, or the load current exceeds the short circuit limit, a hard fault condition is considered to have occurred and the tool is shut down. The figure below shows a common scenario.

In phase A, the tool is being started from an initial resting condition. The saw requires in excess of 80A to start the motor, but once the blade is spinning it requires just 4A to 6A to keep the motor running as long as no work is being performed.

In Phase B, the user begins to cut a piece of dry wood and the saw requires between 10A to 20A to maintain the normal cutting operation.

During Phase C, the saw blade happens to hit a knot in the wood, or the blade is somehow bound as it progresses through the cut. The load can increase to as much as 60A for a short period of time and the overcurrent indication is asserted. In this scenario the operator reduces force momentarily on the saw, the load is shown dropping to less than the overcurrent level within the 128mS allowed and the saw continues normal cutting operations.

In Phase D, the operator increases force on the saw stalling the blade while trying to cut the wood and the load current increases accordingly. The first indication from the monitoring and protection circuitry is the assertion of the over current signal followed almost immediately by the assertion of the short circuit indication. Since a short circuit condition is considered to be a hard fault, discharge of the pack is disabled and the saw blade is immediately stopped. Note that the overcurrent and short circuit indication signals are internal to the ISL9208 and are communicated as error conditions to the microcontroller over the I^2C interface.

The digital fault indications shown in Figure 2 are being driven by the analog monitoring and protection circuitry within the AFE. In a well designed circuit, these will be filtered signals to avoid any spurious shutdowns. For example, the Intersil ISL9208 family of products provides multiple voltage, current, and timing thresholds that are programmable by the user for their specific applications. These are:

- 4 discharge overcurrent thresholds
- 4 short circuit thresholds
- 4 charge overcurrent thresholds
- 8 overcurrent delay times (Charge)
- 8 overcurrent delay times (Discharge)
- 2 short circuit delay times (Discharge)

These multiple thresholds provide the designer a great deal of flexibility to deal with the discharge profiles of various types of equipment. In the case of power tools, it may be advantageous to have the tool communicate the limits to the pack when the pack is initially installed in the tool as different tools have different discharge profiles. This technique matches the personality of the pack to the tool/application and can provide the user with maximum functionality of their device.

Overvoltage and undervoltage conditions of individual cells within the battery pack are also important to monitor. If any cell voltage exceeds the manufacturer's specified upper limit, charging must be disabled to prevent a potentially hazardous condition to exist. Similarly, if any cell voltage drops lower

COVER STORY

allow discharge across a wider range of temperatures. Discharge limits of -10ºC to +60ºC are fairly typical and some cell chemistries may be able to discharge within a slightly wider temperature range. Due to the narrow range of temperatures allowed for charging, it may be necessary to actively heat or cool the pack prior to and during charging. Due to cost and space constraints, any heating and cooling devices are typically found in the charging base rather than internal to the pack. Temperatures are thus communicated between the microcontroller in the pack and the controller in the charging base.

Up to this point, we have focused solely on the safety issues of high power battery packs. While safety is the single most important issue in battery pack design, a well thought out product will also take appropriate steps to help ensure a good user experience. New generations of lithium-based packs typically have high cell counts as well as the added cost of protection and monitoring electronics within the pack and system. Costs for spare or replacement packs can be quite high when compared to the previous generations of nickel-cadmium-based battery packs. Users of these new generations of packs want to experience increases in performance, as well as extended run times and shorter charging times. One method to provide the improved user experience is to implement cell balancing within the battery pack.

Cell balancing is a method to maintain all cells within a pack at the same state of charge. The more cells that are connected in series, the more likely it is that cell balancing will be required to maximize the performance and usable life of the battery pack. Most cells from a manufacturer and especially within the same lot are fairly well matched in terms of ability to accept, retain, and deliver charge. However, small variations between cells as well as the differences in temperatures of cells during charge and discharge and can lead to unbalanced conditions. These unbalanced conditions can seriously reduce the usability of a battery pack.

In any battery pack, the charging process must be stopped once the cell voltages have reached the charge termination voltage specified by the manufacturer. Similarly, the discharge process must also be stopped once the cell voltages have reached the discharge termination voltage specified by the manufacturer. In an unbalanced pack, the charge process is terminated as soon as the first cell reaches the charge termination voltage. Discharge is stopped once the first cell reaches the discharge termination voltage. Some cells may have a tendency to charge and discharge faster than the other cells due to their physical location within the pack and/or perhaps small differences between the cells during the

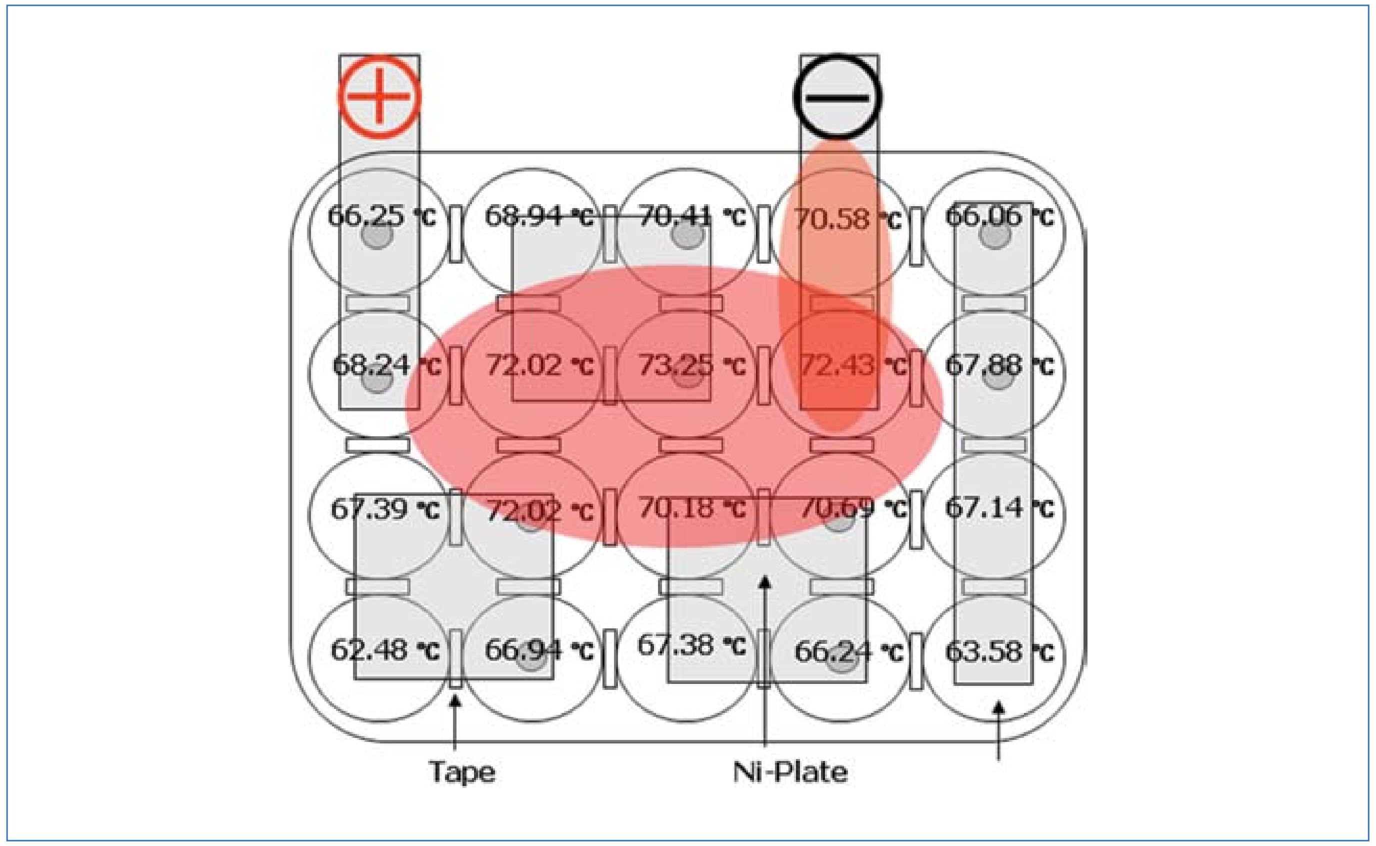

Figure 3

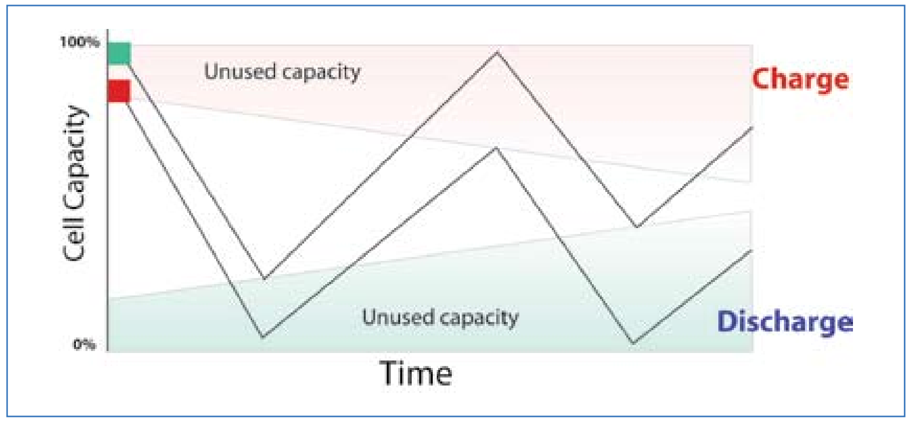

Figure 4

manufacturing process. In a balanced pack, charge is transferred from series cells at higher states of charge to series cells at lower states of charge. Parallel cells self balance. This process can occur during charge as well as discharge of the pack, although it is typically implemented during the charge cycle only for simplicity.

The figure below shows the impact of not balancing cells within a battery pack over multiple charge and discharge cycles. When originally assembled into the battery pack, the cells were all well matched and at the same state of charge, but over multiple charge and discharge cycles they gradually become unbalanced. This results in a significant loss of capacity and significantly reduced usability of the pack. Many notebook users have found this to be the case when after a few months of use their 4-hour typical run time has degraded to less than 4 hours.

Arguments against cell balancing in the past were typically based on the longer charge times that were required for balancing or designs that were too complex to realize at a reasonable cost. That is no longer true. By using internal balance FETs with the ability to handle 200mA of balance current, the ISL9208 family of devices can perform cell balancing quickly and provide the battery pack designer with a design that is relatively simple to implement.

Users of lithium-based battery packs are eager for the performance improvements and other advantages of these new devices. By using the techniques discussed above, it is possible to design high power lithium-based packs that meet all the safety requirements, as well as provide a rich user experience all at a reasonable cost. Using an integrated AFE such as the ISL9208 family of devices provides a very robust design with a minimum of external components and a relatively low total solution cost.

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COMMUNICATIONS POWER

Cleaning Up Communications

Effects of digital power management in mobile communication applications

There is no doubt that ICT (Information Communication and Technology) contributes to making our lives better and more efficient. However, the rapid development of global communications and new technologies do – to an extent - contribute to global warming.

By Patrick Le Fèvre, Ericsson Power Modules

During the Gartner Symposium 'ITxpo 2007 Emerging Trends', Analysts said that the global information and communications technology (ICT) industry accounts for approximately 2 percent of global carbon dioxide (CO_2) emissions - a figure that is equivalent to aviation according to a recent conclusion by Gartner.

This number is an estimation, and ICT is a huge area of applications that includes from power hungry data-centers to Wi-Fi hotspots, and they all performing differently when it comes to energy efficiency and levels of energy savings reached throughout the years.

Among all of the different applications included under the banner of ICT, there is one that merits consideration as example and case study for the next step of implementing digital power management versus existing analog; mobile radio and radio base station applications.

51 years in power

It is only fifty-one years ago (April 25, 1956) that the world's first fully automatic system for mobile telephony was launched in Stockholm.

What was called at the time MTA (Mobile Telephone System A (Figure 1)) began with eight subscribers, and by expending the service to Göteborg, ended the year with 26 subscribers!

In fifty years, the mobile phone industry has grown extremely rapidly and, according to the global trade association GSM association (GSMA), the number of subscribers around the world is set to increase by 40 million per month during 2007.

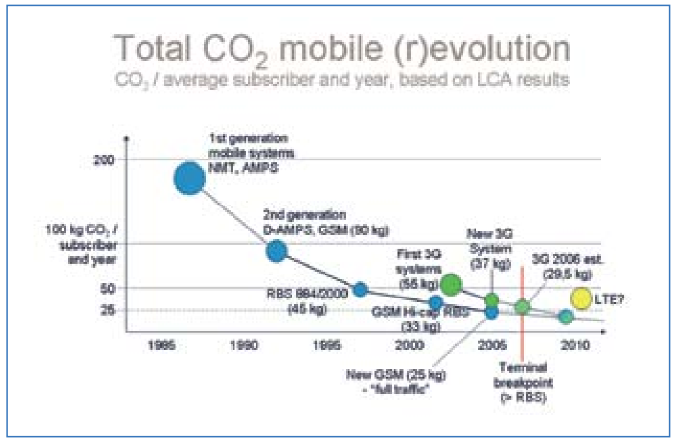
In early May 2007, Ericsson announced that the one millionth radio base station was shipped to a customer, and Powerwave announced that they have deployed more than 1.3 million tower mounted amplifiers for hundreds of cellular, PCS, GSM and 3G networks around the globe.

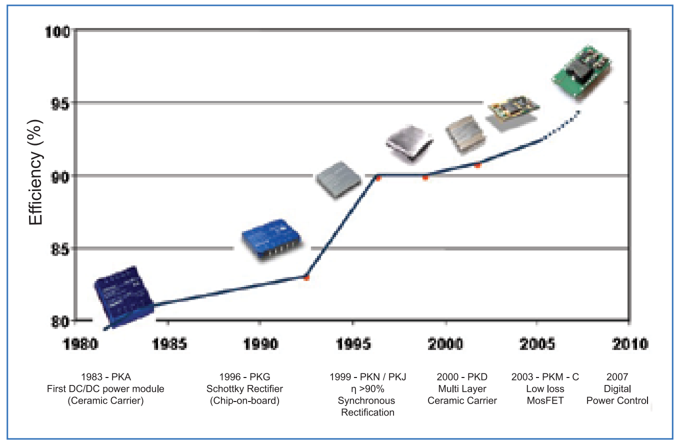
Both announcements reflect the volume of equipments making mobile communication possible, and with the growing demand for long and mid-range mobile-communication systems such as GSM, 3G, and Femto-cells, it is easy to see that the amount of energy consumed by the aggregated number of equipments deployed all over the world will continue to grow, requiring a number of measures to limit their environmental impacts.

Radio base station - good but...

Compared to other industries - and considering the recent estimation presented at Gartner Symposium - the pure telecom industry has relatively low CO_2 emissions, and Ericsson estimates that the industry is responsible for 0.4 percent of global primary energy consumption and 0.3 percent of CO_2 equivalent emissions. Out of this number, assuming 2.6 billion subscribers, it is estimated that the mobile telecom's CO_2 equivalent represents just 0.09 percent.

Looking at the evolution of energy consumed by Mobile Radio and CO_2 evolution (Figure 2), it is clear that since the introduction of the first generation of mobile systems that energy efficiency has improved, while performances and capacity have continuously increased,





though the environmental impact has to be further decreased.

Ericsson's life-cycle-assessment estimates that 52% for GSM and 54% for WCDMA splits wrt CO_2 emission occur when the networks are in operation. These are the parts where digital power and digital power management could contribute to further reduce CO_2 emissions while improving systems' efficiency.

Power efficiency in mobile radio

The result of many different measures and technical innovations, as shown in figure one, the level of CO_2 emission reduced throughout the years follows a general improvement in dc/dc converters efficiency (Figure 3).

Driven by new components and innovative topologies, over two decades the power industry has managed to drastically improve the power efficiency of dc/dc converters and dc/dc regulators, reaching an upper limit that becomes more and more challenging to surpass!

Now components and technologies will continue to improve for sure but recent examples from by the micro-processor industry have proven that energy and data-management can be much better optimized to increase performance while reducing energy consumption (e.g. using multi-core processors instead of single core, PMOS technology, sleep transistors, etc.)

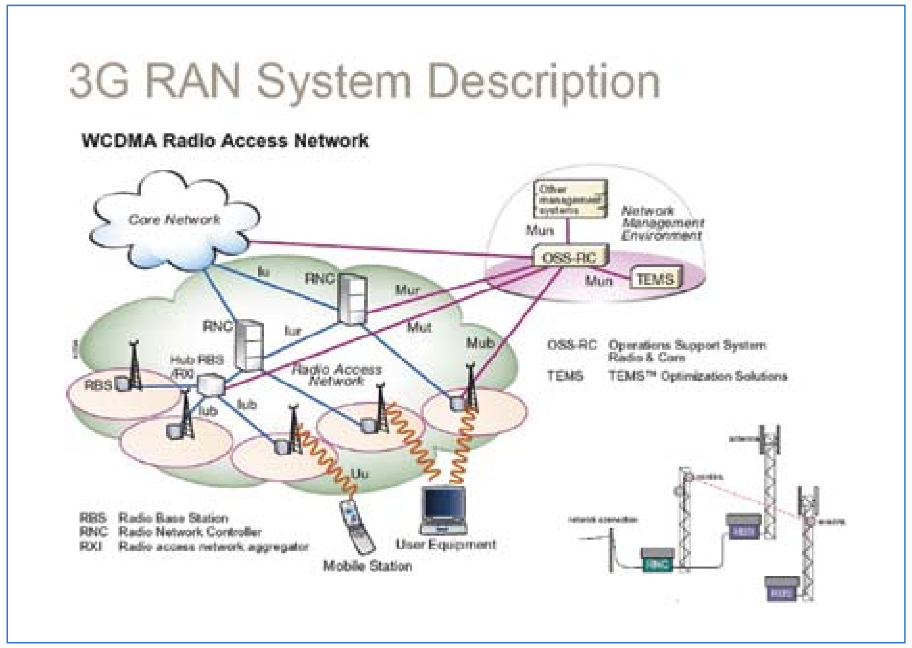
Different parts of a radio system have great room for improvement in energy management terms, and without disclosing advanced research on the radio transmission part, it is evident that performance improvements will not only depend on natural components' evolution but more on a combination of different technologies such as digital power management associated to new components (e.g. Silicon Carbide).

Telecoms systems are very dependant on traffic and inter-operation between the different cells (Figure 4). Besides software managing the split between cells and allocation, the state of the art will be to manage at signal processor level, the energy consumption in real time, and to predict in advance what the energy system might require before requested by traffic (i.e. using pro-active energy management).

As it is for portable and nomadic equipment, reaching the most optimum energy-efficiency-management will require managing energy by function at board level, which based on today's analog solution is very complex, requiring multiple interfaces making things difficult to work together and to communicate with the rest of the system.

Before starting to consider implementing a kind of intelligence in power conversion and power management at system level, it is first important to set a common instruction and language, freely available, that everyone understood.

That was the first task undertaken by the electronics industry, which has been successfully conducted under the PMBus initiative, from which results a standardized protocol already adopted by most of the industry leaders such as



Intel, Dell and many others.

In parallel comes the products dimension and how to convert analog dc/dc converters and dc/dc regulators into units that work with or respond to a digital signal without adding extra interfaces and cost.

This step is now partly completed and different papers presented by Ericsson at DPF, APEC and PCIM demonstrated that the migration from analog to digital power management was technically possible and the implementation of the standardized communication PMBus is a reality.

From that point, how will such technology help telecoms manufacturers and operators to operate their systems in a more efficient way, resulting in less power consumption and lower CO_2 emission?

When digital power becomes a reality

Often one only considers the core processor as being 'the component' requiring tight control. But, if that is a very important part of the system, such components are relatively easy to control because they are already digital.

For some time, the VRM (Voltage Regulator Module) and the VRD (Voltage Regulator Down) have been able to communicate with the processor, so digital control is virtually there. And by adopting PMBus, Intel has given a clear signal that future products will easily be able to communicate with their neighbourhood.

As mentioned, power consumption in mobile radio applications is very much driven by traffic, and by combining traffic management and intelligent power-management it will be possible to only power the required part of the system needed at that time and to standby the rest of the time if not required. Otherwise, when traffic increases the traffic management controller will enable additional functionalities.

For example traffic management could control the number of power amplifiers in operation and decide to power ON or OFF some of them when traffic increases or decreases, or to adjust the polarization voltage to the most efficient profile at time.

At cabinet level, certain boards that include mixed-functionalities that are only required at a certain times during the operation will have the ability to be powered ON/OFF, or adjusted to suit vital parameters, and precisely monitored to make it possible for the traffic management controller to report in real-time to the site manager on different parameters.

Managing power management down to the vital few is also very important to reduce the fixed operational power and especially the power consumed by air-conditioning and ventilation. On average, 30% of the power consumed in a radio base station is for cooling.

Adding digital control to individual boards and PMBus, it becomes simpler to better control cooling and ventilation, optimizing operational conditions to suit specific traffic conditions, and statistically profile the power demand for the requirements of the next flow of traffic.

If considered at start of the project, the same type of topology could easily be deployed to fix access and other ICT applications such as data-centers, reducing power consumption and CO_2 emission.

To conclude

It is always difficult to precisely predict tangible numbers on a new technology and how far such technology will drive the reduction of power consumed by a system though, as reported by Ericsson in the 2006 Corporate Responsibility report, among several activities to reduce CO_2 emission, the implementation of a standby capability during low load, and implementation towards the parking of base stations deployed since 1995 will save between 10 and 20% of energy, resulting in a saving of 1 million tons or more of CO_2 per year.

There is no doubt that the implementation of digital power management will strongly contribute to further reduce energy consumption and what we are seeing today as result of energy management is only the early beginnings of digital power benefits at systems level.

www.ericsson.com/powermodules

Degrees of Freedom for Optimisation of IGBTs for 400V AC line Applications

Chip thickness and MOS-channel width influence performance

This article addresses the question how a variation of the requirements on short circuit robustness and blocking voltage translates into a change of chip performance. Focus is the optimisation of IGBTs for 400V AC power line applications.

By R. Severin, P. Kanschat, A. Ciliox, Infineon Technologies AG, Warstein, Germany
O. Hellmund, Infineon Technologies AG, Am Campeon 1-12, Neubiberg, Germany

The trench field stop technology as used for Infineon's TrenchStop® IGBTs is the state of the art concept in the 600-1200V blocking voltage range. Key performance parameters for hard-switching applications are blocking voltage, on-state voltage, switching losses, softness and short circuit robustness.

Two major parameters influence the IGBT performance:

1. The MOS channel width (*w*):
The larger w the lower the on-state voltage. The short circuit current is increased by a large w.
2. The chip thickness (th_{chip}):
Reducing th_{chip} results in decreased on-state voltage and switching losses.

We compare Infineon's current 1200V IGBT4 (low power) chip generation with a 1200V IGBT^4 fast chip and a third variant of IGBT^3 with reduced chip thickness, increased channel width and a blocking voltage of 900 V and 1000V. In the following they are called the 900V and 1000V IGBT.

Electrical chip performance

Two main aspects have to be considered. One is the static on-state of the IGBT.

The second aspect considers switching losses. In this discussion we focus on the IGBTs turn-off due to the fact that the IGBTs turn-on is mainly dominated by the free wheeling diode used.

Output characteristics

The output characteristics of the IGBT versions can be determined by measuring on-state voltage drops as a function of the collector current. Naturally the different IGBT versions have different current densities where the current density is the collector current per active area of the chip. Figure 1 depicts the measured on-state voltages.

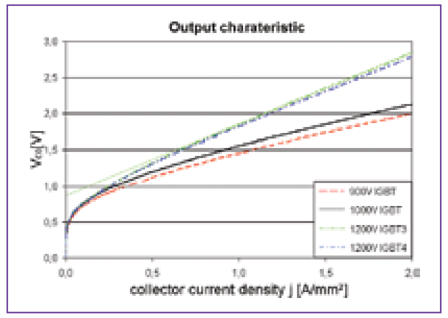


Figure 1: Output characteristic: T_j 150°C, V_{GE} 15V. The green line displays the linear fit to the 1200V IGBT^3.

It turns out that the 1000 V chip shows a 20% lower on-state voltage drop than the 1200V IGBT^3 at a current density of 1.6 A/mm^2.

The achieved threshold voltage (V_t) and resistance times active area (Rc*area) are given in table 1.

Table 1: Linearly approximated parameters of the output characteristic at T_j=150°C.

	V_t [V]	R_c*area [Ω*mm²]
900 V IGBT	0.96	0.028
1000 V IGBT	1.06	0.029
1200 V IGBT^3	0.90	0.062
1200 V IGBT^4	0.88	0.054

The threshold voltages Vt are com

parable. The resistances for a certain area Rc * area of the 900V and 1000V IGBT are in the same range whereas the 1200V IGBT3 shows a value about twice as high due to the increased chip thickness and smaller channel width.

Dynamic properties

The switching losses E_{tot} are the sum of the turn-on and turn-off losses $E_{on}+E_{off}$ as depicted in. fig. 2.

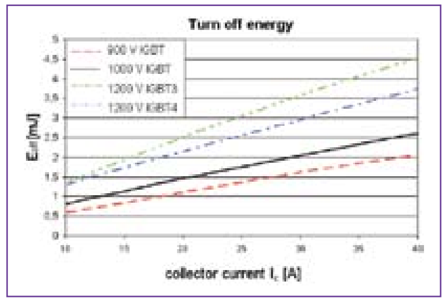


Figure 2 Turn-off losses of the different IGBTs as a function of the collector current (DC link voltage 600V; T_j 150°C; stray inductance of 30nH).

Table 2 summarizes the overall switching energies of the IGBT per unit collector current.

	E_{tot}/Ic [mWs/A]
900 V IGBT	0.146
1000 V IGBT	0.156
1200 V $IGBT^3$	0.216
1200 V $IGBT^4$	0.197

Inverter output current simulated with IPOSIM

All necessary device properties have been analysed and were integrated into IPOSIM. The results of the simulation are given in the figure 3.

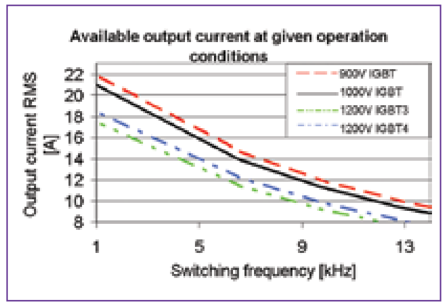


Figure 3: Available inverter output current as a function of the IGBT switching frequency.

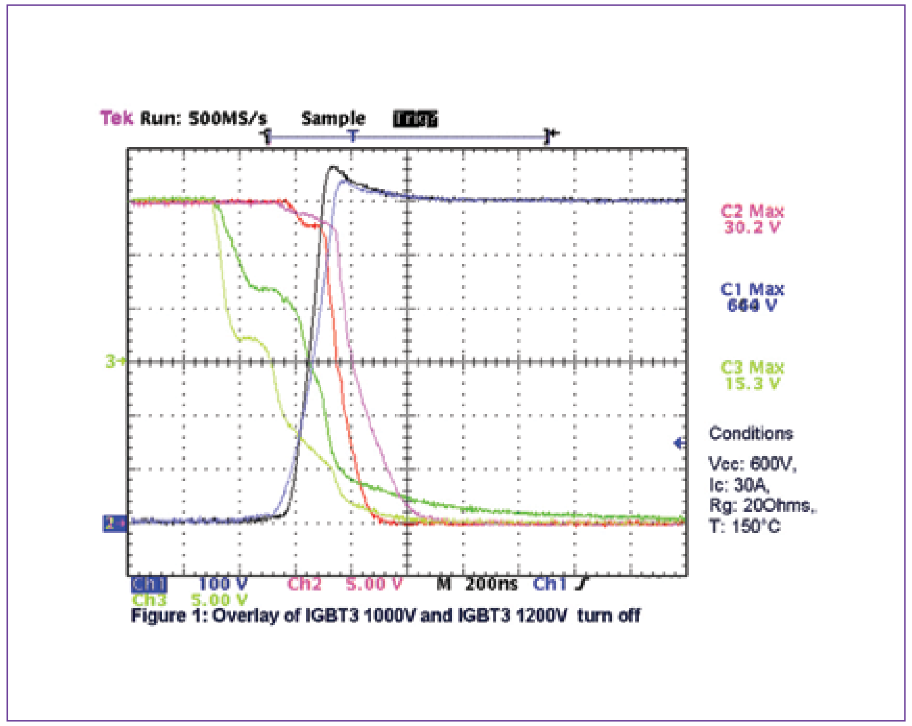


Figure 4: Overlay of 1200V IGBT3 and 1000V IGBT turn-off waveforms. Conditions: DC-link: 600V; T_j 150°C; R_G 20 Ω; I_c 30A. The depicted curves in figure 3 are:
IGBT 1000V VCE: black, I_C: red, V_{GE}: green
$IGBT^3$ 1200V VCE: blue, I_C: violet, V_{GE}: bright green

Conditions: IGBTs scaled to the same size, DC- link voltage 600V; modulation factor 1; power factor 0.9, all simulated with R_{thja} 1.47 K/W and Tamb 40°C.

The simulation shows a benefit of a 20 % higher inverter output current (RMS) by using the 1000V IGBT in comparison with the 1200V IGBT3.

Blocking voltage and switching behavior

In this section of the article we discuss the turn-off waveforms.

In figure 4 the switching behavior of

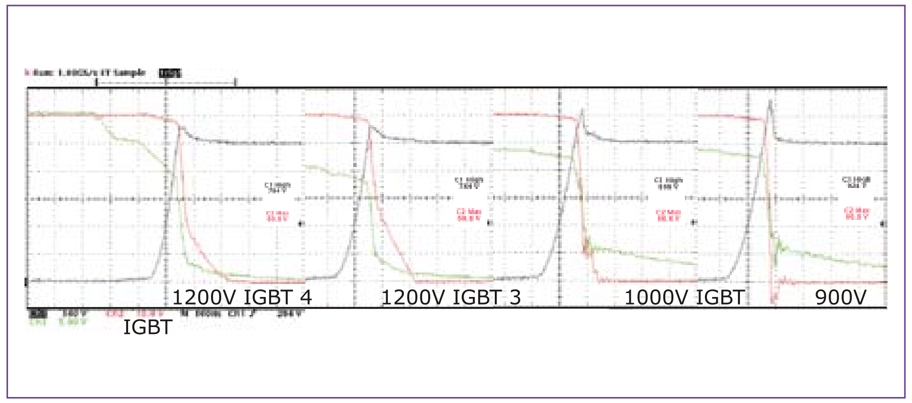


Figure 5: Softness comparison, turn-off waveforms (I_C 60 A, V_{DC} 600V, T_J 25°C, R_G off 30 Ω)
1200 V $IGBT^4$ → Eoff 3.54 mJ
1200 V $IGBT^3$ → Eoff 4.18 mJ
1000 V IGBT → Eoff 3.42 mJ
900 V IGBT → Eoff 2.85 mJ
Red: I_C, black: V_{CE}, green: V_{GE}

the 1000V IGBT is displayed. This chip turns out to be faster than the 1200V $IGBT^3$. Additionally the turn-off losses are significantly smaller. This can be explained by the different chip thicknesses. Not only are the losses important but also the behavior of the IGBT in terms of softness fig.5. The devices were turned off at the same test parameters. The IGBT4 has a reduced current tail with a very soft behavior and lower turn-off losses by 15% at a comparable over voltage peak.

The waveforms of the 900V IGBT show the largest over voltage pulse and a snappy current behavior.

In case of the 1000V IGBT the tail current is smaller but still present. This 1000V IGBT may indicate that this chip might be a reasonable solution for an application which deals with a limited collector current.

Short circuit robustness

The IGBTs today offer the capability for a secure short circuit turn-off under defined conditions. Three different modes of destruction are known. Type one is the destruction mode due to latch up during the current turn-off. This failure mode is well avoided with the TrenchStop® IGBTs of Infineon Technologies. The second failure mode can be called the current destruction mode. This mode is not related to the device's temperature and can be avoided by optimized device design. The third and most common mode is the destruction due to thermal run away after the device is turned off for a view micro seconds as a consequence of tail current phenomena.

Short circuit withstand time t_{sc}

Within t_{sc} the short circuit has to be detected and the driver has to turn off the IGBT.

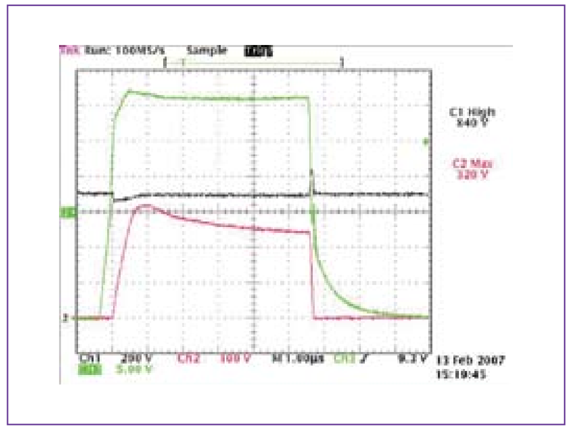


Figure 6: Short circuit withstand of 1000V $IGBT^3$, V_{GE} 16V, V_{DC} 700V, R_G 20ohms, T_J 150° C, t_{sc} 5.6µsec.

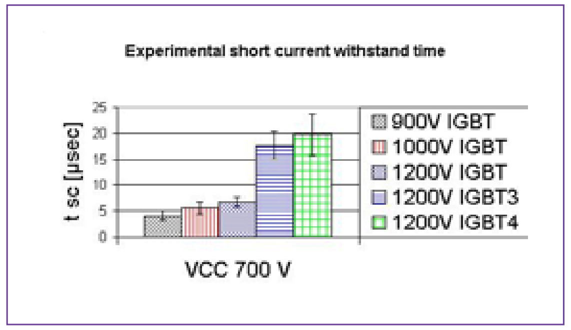


Figure 7: Measured short circuit withstands time of different IGBTs, conditions: V_{GE} 16V, R_G 20Ω, T_J 150°C, V_{DC} 700V.

Figure 6 depicts a successful short circuit withstand of the 1000V IGBT. The t_{sc} can be determined to 5.6 µsec.

Figure 7 shows the experimental results of the short circuit withstand over all investigated IGBT versions.

All the IGBTs have the same cell structure, but differ in their thickness. Within the measurement tolerances the 1200V $IGBT^3$ and the 1200V $IGBT^4$ show the same short circuit current withstand time and distinguish clearly from the three other IGBTs. Hence, the conclusion can be drawn that an increase of the MOS-channel width which reduces the on state losses is also the key parameter determining t_{SC}. The upcoming challenge of a secure short circuit turn-off can be solved by using state of the art drivers like Infineon's 1ED020I12-S driver chip. To avoid high over voltage pulses a two-level turn-off is also integrated. In the measurements the detection and the turn-off was done within 5 µsec at V_{GE} 16V, VDC 700V and T_J 150°C. Figure 8 shows the successful turn-off.

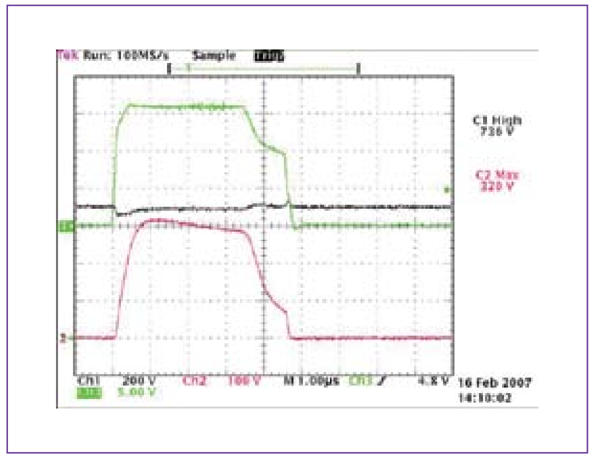


Figure 8: Short circuit test with the 1000V IGBT.

Due to the optimized soft shut down of the 1ED020I12-S limited the over voltage peak to 736V at a DC-link voltage of 700V. So far we have shown that state of the art IGBT driver technology offers the opportunity to deal with a reduced short circuit withstand time.

Conclusion

This article discussed the 1000V IGBT as a possible further step in optimizing the efficiency of 400V applications. Besides the chip performance the reliability of the devices has to be discussed.

In summary, the potential for ongoing performance improvement and cost reduction by intelligent adjustment of IGBT technology and application requirements is shown to be evident and is worth to be subject of further discussions between IGBT (module) suppliers and their customers. Both degrees of freedom investigated, namely chip thickness and MOS-channel width will influence performance parameters like on-state and switching losses. These, however, are traded off versus other parameters, namely over-voltages, cosmic radiation FIT levels, softness and short circuit withstand time.

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Designing for Telecommunications in China

New national mobile phone charging requirements in China drives design requirements

People's Republic of China has recently introduced a new Telecommunications Industry Standard for mobile telecommunication terminal equipment to reduce handset cost for consumers and to minimize electronic waste and help protect the environment. Designs for this market need to be adapted accordingly.

By Takashi Kanamori and George Paparrizos, Summit Microelectronics Inc.

Under the new standard, all compliant wall chargers need to provide a USB connector to ensure universal charging with all mobile phones. Furthermore, specific safety and performance requirements need to be met to make this standard effective. This article analyzes the new standard in detail, discusses its impact on wall charger and mobile phone designs, and introduces a variety of charging implementations that allow system designers to meet these new requirements.

Main Requirements

The new standard introduces a variety of electrical and mechanical requirements that ensure battery charging inter-compatibility and safety. New wall chargers are required to provide a connector that is compliant with the mini USB type A specification. This mechanical implementation allows the mobile phones to be connected to any dedicated wall charger or computing USB port for battery charging purposes. The output current capability of the new wall chargers needs to be at least 300mA and lower than 1.8A. This current range addresses both the low-cost and the high-performance product segment. Last but not least, the output voltage of the new compliant wall chargers needs to be 5V nominal with a ± 5% tolerance.

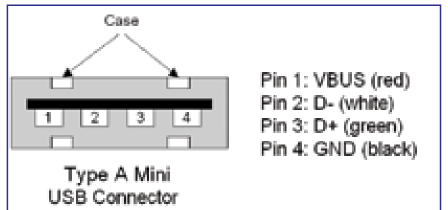

Figure 1: Typical mini USB type A connector and pin description.

Power Source Detection

One of the most critical sections in new mobile phone designs, that need to be compatible with the new directive, is the detection of the connected power source. This is critical because a USB port and a new wall charger will be identical from a mechanical point of view (both utilize USB type A connectors), however their power characteristics are drastically different. For example, when connected to a USB port, the mobile handset needs to fully comply with the USB2.0 specification. In this case, the charger IC needs to initially limit the current to less than 100mA and only allow a 500mA level once "hand-shaking" with the USB host/hub has taken place. On the other hand, when connected to a wall charger, the charging algorithm can be initiated immediately and fast charge current level needs to be adjusted (usually higher) depending on the wall charger rating.

The new standard provides guidelines on detecting the power source type by reading the impedance between D+ and D-. More specifically, a compliant wall charger will have the D+ and D- shorted inside the charger, and the shorted node should be floating. This means that D+ and D- are shorted but not specifically connected to any part of the charger. The new Telecommunications Industry Standard doesn't provide further specifics on D+ and D- short-circuit detection mechanisms.

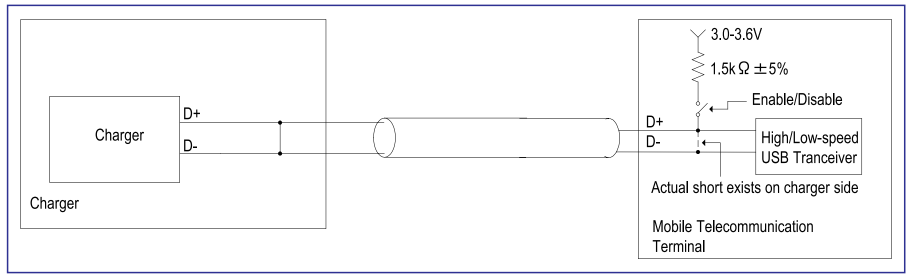

Figure 2: Power source detection implementation for compliant wall charger.

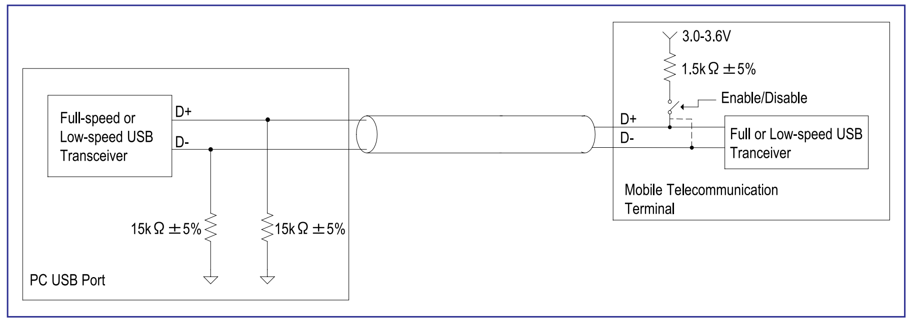

Figure 3: Power source detection implementation for USB port.

D+ and D- are the signal lines used in USB protocol. D+ and D- form a differential pair. D+ and D- line carry binary data from upstream port to downstream devices, or from downstream devices to upstream port. Since D+ and D- is a differential pair, the voltage level on one is greater than the other, except in SE0 state, SE1 state, or when a downstream device is not connected. SE0 is a state that both D+ and D- are low, and frequently asserted to signal an end of packet, and to signal a reset. SE1 is a state that both D+ and D- are high. SE1 is not an intended state, per Universal Serial Bus Specification Revision 2.0. Universal Serial Bus Specification Revision 2.0 specifies that 15kΩ ± 5% resistors connected to ground should terminate both D+ and D- lines at host or hub ports. At the mobile telecommunication terminals, 1.5kΩ ± 5% resistor connected to a voltage source between 3.0V and 3.6V must pull up either D+ for a full speed device or D- for a low speed device. This pull up resistor usually resides inside the USB physical layer (PHY), and gets connected or disconnected by a switch activated by a specific enable signal.

Figure 2 illustrates a simple way to detect whether the upstream port is a charger specified by the new Telecommunication Standard or not. If the upstream port is a wall charger, D+ and D- should be shorted together, and the shorted node should be floating as shown in Figure 2. Then the mobile telecommunication terminal asserts a specific enabling signal for the 1.5kΩ ± 5% pull up resistor inside the USB physical layer (PHY). In this case both D+ and D- should go high. See Figure 4 for the transition diagram. Since D+ and D- are shorted, it does not matter if the 1.5kΩ ± 5% is located on D+ side for full speed device, or on D- side for low speed device. Both D+ and D- will get pulled up simultaneously.

In the case in which the upstream port is not a wall charger specified by the new Telecommunication Standard, D+ and D- are not shorted. Since the connector for the upstream port is a USB standard Type A one, the upstream port is most likely to be a PC USB port. A PC USB port operates under USB protocol specified by Universal Serial Bus Specification Revision 2.0, hence, 15kΩ ± 5% pull down resistors are required on D+ and D- at the upstream port as shown in Figure 3. Then the mobile telecommunication terminal asserts a specific enabling signal for the 1.5kΩ ± 5% pull up resistor inside the USB physical layer. Note that the 1.5kΩ ± 5% pull up resistor is a much stronger pull up than 15kΩ ± 5% pull down resistor. This time, only one of the two signal lines, D+ or D-, should be pulled up high, while the other is pulled down by the 15kΩ ± 5% pull down resistor. Hence, only D+ should be pulled high for full speed device, and only D- should be pulled up high for low speed device. See Figure 4 for transition diagram.

These results are summarized in the truth table (Table 1) below.

If the mobile telecommunication terminal is not equipped with the USB physical layer (PHY) that can enable the 1.5kΩ ± 5% pull up resistor, an alternative detection method can be employed. One example is to apply current source on D+ pin and check its continuity on D- pin. See Universal Serial Bus Specification Revision 2.0, 7-1, for pull up and pull down resistors on D+ and D- lines, and signal timings.

Battery Charger Implementation

A typical charging solution that addresses the new standard is shown in Figure 5. In this example, the wall charger is rated at 500mA. The SMB135 switch-mode battery charger IC can operate from 4.35V to 6.5V and is therefore compatible with the 5V ± 5% adapter output voltage specified by the new Telecommunications Industry Standard. In addition, this charging IC solution incorporates an input over-voltage protection that suspends operation when the wall charger voltage goes above approximately 7V. Additional protection features, including battery over-voltage

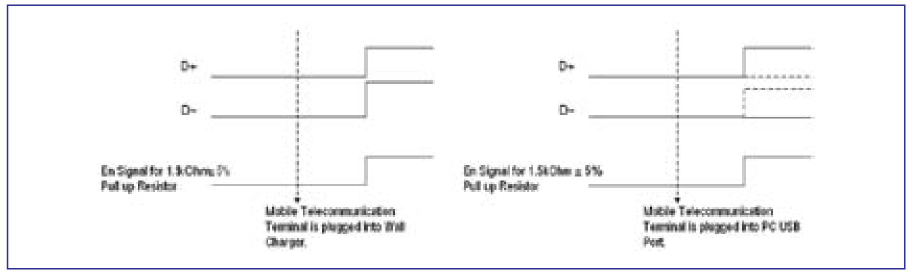

Figure 4: Transition diagrams for power source detection.

Table 1: Truth Table, Signals vs. Upstream Power Source.

Upstream Power Source Signals	Charger	PC USB Port
EN for the 1.5kΩ ± 5% pull up resistor	1	1
D+	1	1/0
D-	1	0/1

and over-current protection, are also available to meet the industry's strict requirement for secondary safety.

When the system detects a wall charger connection (i.e. D+ and D- shorted), the system microcontroller (or a discrete switch implementation) brings the USB500/100 input high, resulting in a fast charge current of 495mA or 525mA (selectable). When the system does not detect a short between the D+ and D- pins, it will assume that the mobile phone is connected to a USB port of a desktop or notebook computer. To be compliant with the USB2.0 Specification, the microcontroller can then enable the charger via the EN input pin and bring the USB500/100 input low. This will result in a fast charge current of 100mA or less (selectable). Once the system microcontroller has successful performed the USB enumeration process, the mobile phone, and therefore the charger IC, can draw as much as 500mA out of the USB port. This can be accomplished by bringing the USB500/100 input pin high. A simplified flowchart describing this operation is demonstrated in Figure 6.

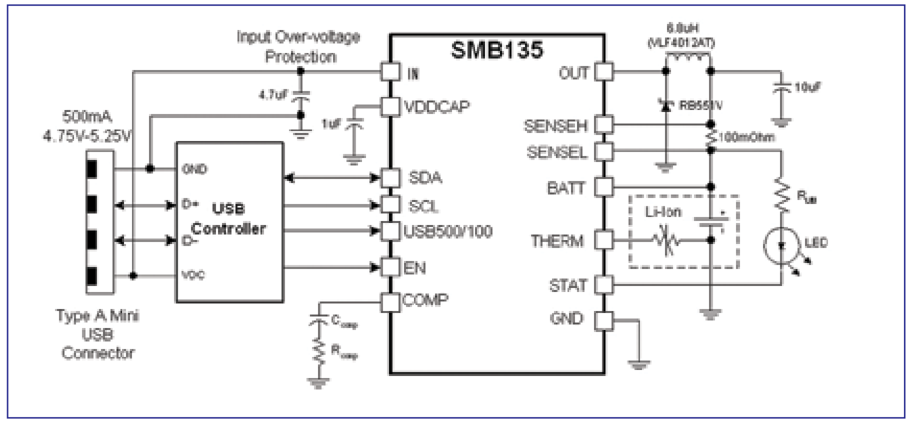

Figure 5: Typical charging application with single AC/USB input that meets the new standard.

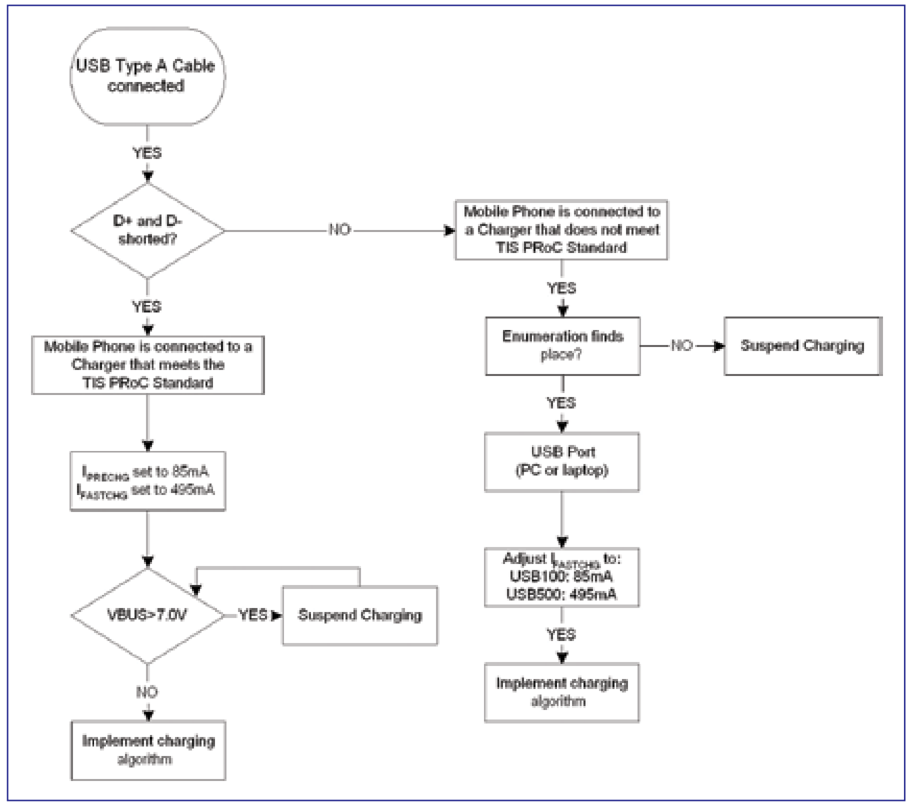

Figure 6: Simplified flow chart that describing a typical, 500mA battery charging implementation that meets the new standard.

In addition to providing full compliance with the new standard, the implementation shown in Figure 5 can provide additional value to the mobile phone design. Unlike traditional linear charging solutions, the basic operation of the SMB135's switch-mode architecture allows for an output (charge) current that can be significantly higher than the input current, resulting in shorter charging times and better consumer experience. This is very beneficial when a USB port is used as a power source (limited at 500mA) as well as with the introduction of the new, compliant wall chargers; many of the new chargers will be limited to low current levels (as low as 300mA) for reduced system cost and lower cost associated with the China Compulsory Certification (CCC). Such cost reduction measures will be necessary, since they will allow the wall charger manufacturers to provide solutions that are priced appropriately for the broad consumer market.

Summary

The new Telecommunications Industry Standard for mobile telecommunication terminal equipment in China is a major step towards universal battery charging. The main goal is to provide consumers a safe and easy way to charge their mobile phones, while reducing the environmental impact and cost associated with non-interoperability. Both wall charger and mobile phone designs need to take into account the new electrical and mechanical requirements and also to develop cost-effective implementations without compromising time-to-market and system safety.

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Frequency Compensation in Switching Regulator Design

Part 2: Feedback path compensation

In part one of this two-part series, the forward path of a switching converter was considered. In this second and final part, the feedback path is considered as the loop is closed and the overall circuit is compensated.

By Nigel Smith, Business Development Manager, Portable Power, Texas Instruments

Once the gain and phase response of the forward path is known, the error amplifier response can be designed. The main aims of frequency compensation are to ensure: (a) an adequate phase margin (typically >45°); and (b) an adequate gain margin (typically >10dB). In addition, the loop gain should pass through unity with a slope of -20dB/decade.

Before the frequency compensation can be designed, a suitable crossover frequency f_c must be chosen. Switching converters with high crossover frequencies respond more quickly to changing operating conditions, and are therefore generally preferred; however, sampling theory limits the maximum crossover frequency that can be used. In practice f_c typically lies between one tenth and one sixth f_{sw}, however, if the error amplifier's open-loop gain is insufficient at this frequency, f_c may have to be further reduced.

Having selected the desired crossover frequency, the gain, phase and slope of the forward path at f_c can be obtained from its Bode plot. The required gain, phase and slope of the compensated error amplifier at f_c can now easily be obtained by comparing the two.

Three types of compensation scheme are commonly-used, known as Type-I, Type-II and Type-III (see Figure 1). Type-I is not commonly used in switching regulator circuits and will not be discussed here.

Type-II compensation exhibits a pole at the origin (to achieve high DC gain) plus an additional zero and pole. The resulting frequency response contains a flat area between the zero and the pole. Type-II compensation is generally used in applications where the output filter exhibits a single-pole roll-off at the cross-over frequency. The desired -20dB/decade roll-off at fc is achieved by ensuring that cross-over occurs somewhere in the flat part of the error amplifier's response.

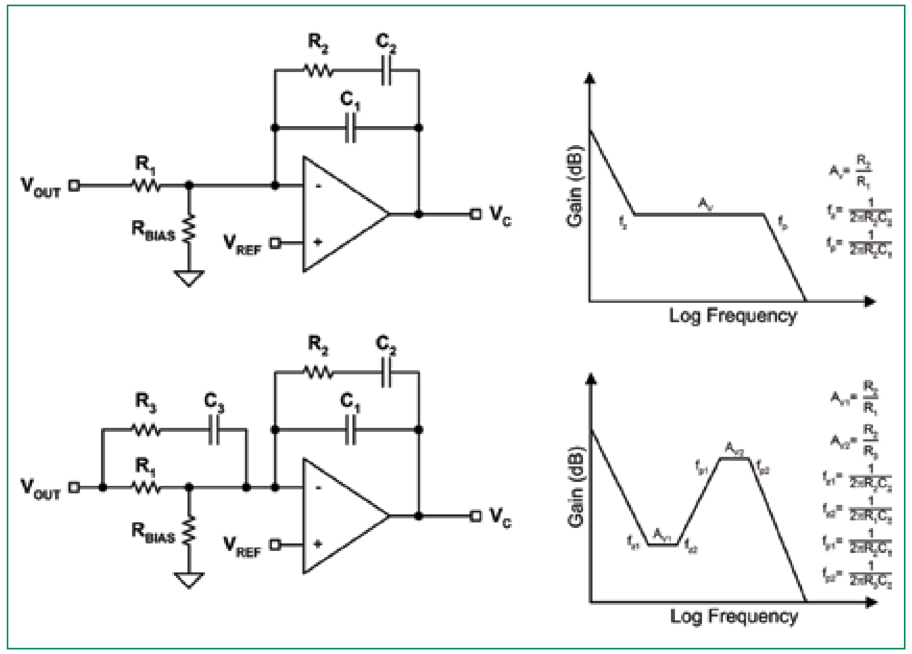

Figure 1. Commonly Used Compensation Circuits and Their Response.

Table 1. Phase Change through a Type-II Compensation Circuit.

		K1									
		10	20	30	40	50	60	70	80	90	100
K2	1.2	-225.5°	-222.7°	-221.7°	-221.2°	-221.0°	-220.8°	-220.6°	-220.5°	-220.4°	-220.4°
	1.4	-221.2°	-218.4°	-217.4°	-217.0°	-216.7°	-216.5°	-216.4°	-216.3°	-216.2°	-216.1°
	1.6	-217.7°	-214.9°	-213.9°	-213.4°	-213.2°	-213.0°	-212.8°	-212.7°	-212.6°	-212.6°
	1.8	-214.8°	-211.9°	-211.0°	-210.5°	-210.2°	-210.0°	-209.9°	-209.8°	-209.7°	-209.6°
	2	-212.3°	-209.4°	-208.5°	-208.0°	-207.7°	-207.5°	-207.4°	-207.3°	-207.2°	-207.1°
	3	-204.1°	-201.3°	-200.3°	-199.9°	-199.6°	-199.4°	-199.3°	-199.2°	-199.1°	-199.0°
	4	-199.7°	-196.9°	-195.9°	-195.5°	-195.2°	-195.0°	-194.9°	-194.8°	-194.7°	-194.6°
	5	-197.0°	-194.2°	-193.2°	-192.7°	-192.5°	-192.3°	-192.1°	-192.0°	-191.9°	-191.9°
	6	-195.2°	-192.3°	-191.4°	-190.9°	-190.6°	-190.4°	-190.3°	-190.2°	-190.1°	-190.0°
	7	-193.8°	-191.0°	-190.0°	-189.6°	-189.3°	-189.1°	-188.9°	-188.8°	-188.8°	-188.7°
	8	-192.8°	-190.0°	-189.0°	-188.6°	-188.3°	-188.1°	-187.9°	-187.8°	-187.8°	-187.7°
	9	-192.1°	-189.2°	-188.2°	-187.8°	-187.5°	-187.3°	-187.2°	-187.1°	-187.0°	-186.9°
	10	-191.4°	-188.6°	-187.6°	-187.1°	-186.9°	-186.7°	-186.5°	-186.4°	-186.3°	-186.3°

Table 2. Phase Change through a Type-III Compensation Circuit.

		K1									
		10	20	30	40	50	60	70	80	90	100
K2	1.2	-181.0°	-175.3°	-173.4°	-172.5°	-171.9°	-171.5°	-171.2°	-171.0°	-170.9°	-170.8°
	1.4	-172.5°	-166.8°	-164.9°	-163.9°	-163.4°	-163.0°	-162.7°	-162.5°	-162.3°	-162.2°
	1.6	-165.4°	-159.7°	-157.8°	-156.9°	-156.3°	-155.9°	-155.6°	-155.4°	-155.3°	-155.2°
	1.8	-159.5°	-153.8°	-151.9°	-151.0°	-150.4°	-150.0°	-149.7°	-149.5°	-149.4°	-149.3°
	2	-154.6°	-148.9°	-146.9°	-146.0°	-145.4°	-145.0°	-144.8°	-144.6°	-144.4°	-144.3°
	3	-138.3°	-132.6°	-130.7°	-129.7°	-129.2°	-128.8°	-128.5°	-128.3°	-128.1°	-128.0°
	4	-129.5°	-123.8°	-121.9°	-120.9°	-120.4°	-120.0°	-119.7°	-119.5°	-119.3°	-119.2°
	5	-124.0°	-118.3°	-116.4°	-115.5°	-114.9°	-114.5°	-114.3°	-114.1°	-113.9°	-113.8°
	6	-120.3°	-114.6°	-112.7°	-111.8°	-111.2°	-110.8°	-110.6°	-110.4°	-110.2°	-110.1°
	7	-117.7°	-112.0°	-110.1°	-109.1°	-108.6°	-108.2°	-107.9°	-107.7°	-107.5°	-107.4°
	8	-115.7°	-110.0°	-108.1°	-107.1°	-106.5°	-106.2°	-105.9°	-105.7°	-105.5°	-105.4°
	9	-114.1°	-108.4°	-106.5°	-105.5°	-105.0°	-104.6°	-104.3°	-104.1°	-104.0°	-103.8°
	10	-112.8°	-107.1°	-105.2°	-104.3°	-103.7°	-103.3°	-103.1°	-102.9°	-102.7°	-102.6°

Type-III compensation contains two zeros and two poles in addition to a pole at the origin. The resulting response contains an area of increased gain at high frequencies and a slope of +20dB/decade in the middle of the frequency range of interest. Type-III compensation is typically used to compensate circuits where the output filter exhibits a double-pole at the cross-over frequency. This is done by ensuring that cross-over occurs midway up the error amplifier's +20dB/decade slope; the combined effect of the error amplifier and output filter slopes is the desired -20dB/decade response.

The relative position of the poles and zeros in the compensation circuit determines the overall phase boost occurring at f_c. Thus, by placing the poles and zeros at suitable frequencies, the desired phase margin can be achieved. There are a number of ways to approach this. One way is to consider the position of the low frequency zero(s) and high frequency pole(s) using two factors K_1 and K_2, as follows:

$$K_1 = \frac{f_c}{f_z}$$

$$K_2 = \frac{f_p}{f_c}$$

By considering the relative values of K_1 and K_2, the phase boost at f_c can easily be determined from Tables 1 and 2.

The gain of a Type-II compensation circuit at f_c is equal to the gain AV at the zero. Type-III compensation has a gain in dB at f_c given by:

$G = A_{V1} + 20log(K_1)$

where A_{V1} is the gain at the second zero in dB.

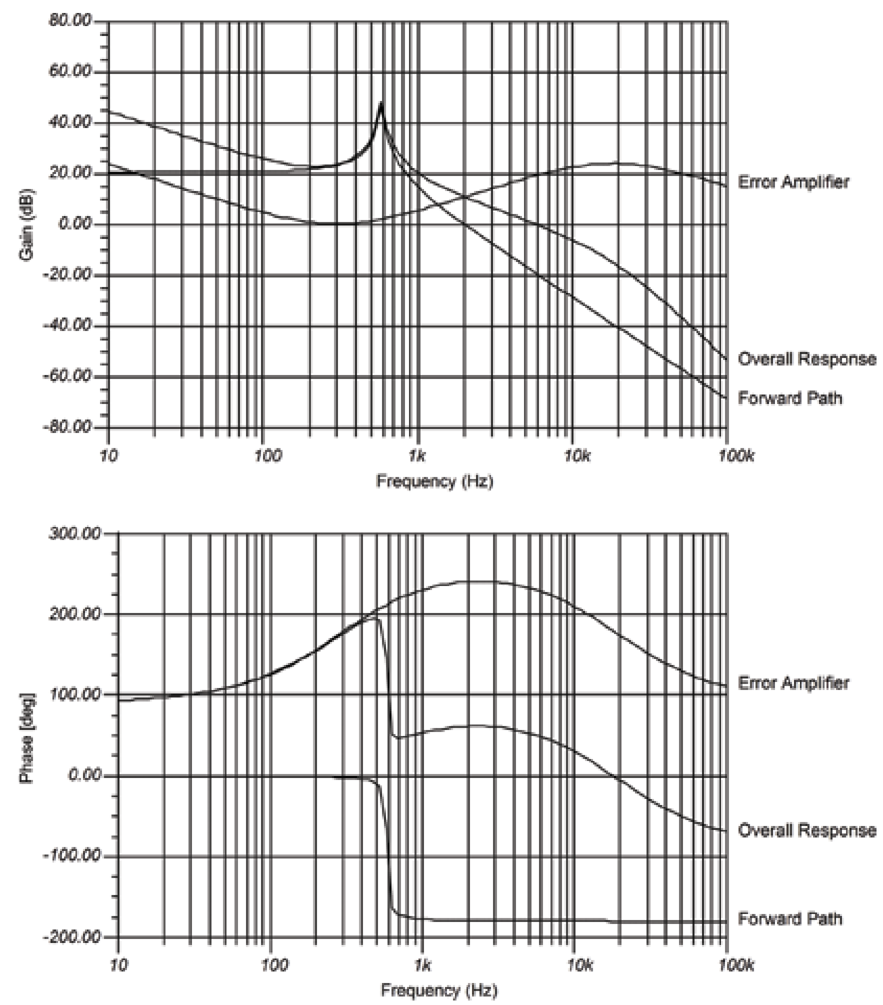

Figure 2. System Bode Plots.

A general procedure for compensating a switching converter can now be simplified to the following:

- Generate the forward-path Bode plots.
- Select a suitable cross-over frequency. Use the rule-of-thumb that f_c should lie somewhere between one tenth and one sixth the switching frequency, but may need to be reduced if the error amplifier's open-loop gain at this frequency is insufficient. Determine the forward-path gain and phase at the crossover frequency.
- From the slope of the forward-path gain at f_c, determine whether Type-II or Type-III compensation is required. If the forward path slope at f_c is -20dB/decade, then Type-II compensation should be used; if the slope is -40dB/decade, then Type-III is necessary.
- Place the compensation circuit's zero(s) approximately one octave below the output filter's break frequency, and calculate the value of K_1. This approach is relatively conservative, but avoids the possibility of conditional stability by ensuring that phase stays well above 0° below f_c.
- Determine the necessary error amplifier gain at f_c and calculate the required error amplifier gain at the zero(s).
- Calculate the maximum phase lag through the compensation circuit and, using Table 2 or 3, and calculate the minimum value of K_2 achieving this phase lag. Calculate the frequency of the compensation circuit's pole(s) using.
- Calculate the individual component values in the compensation circuit required to achieve this response.

Figure 2 shows typical Bode plots for the forward path, error amplifier and overall response of switching converter using Type-III compensation.

Each engineer has his own preferred approach toward frequency compensation, and in practice some iteration will usually be necessary, however, the approach described above provides a good starting point for inexperienced engineers to build a stable circuit with adequate performance.

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On the Road

Reported by Cliff Keys, Editor-in-Chief, PSDE

Micrel

I had the opportunity to speak with John T. Lee, Micrel's Director of Mixed Signal and RF products. John told me much about Micrel's competences that help propel the company ahead of the pack. It was obvious to me that here was a company that has the foresight and the technological capabilities to outstrip many of the 'big boys'. The company philosophy of keeping close to the market and, as important, close to customers, has certainly paid off handsomely. Also, the ability to move fast when a marketing opportunity is identified, gives the company a rocket-propelled route to success.

CableCard 2.0 Integrated Power Switch and Controller in a Single Chip

Micrel has just launched the MIC2569YQS, a CableCard 2.0 Power Controller designed for use in CableCard applications. The new IC is part of Micrel's wide and diverse family of Mixed Signal products and an ideal solution for high volume consumer electronics makers of digital cable receivers, DTV/ HDTVs, digital DVR STBs, and digital satellite receiver applications. The device is currently available in volume quantities and is priced at $3.31 for 1K quantities. A free evaluation board is also available.

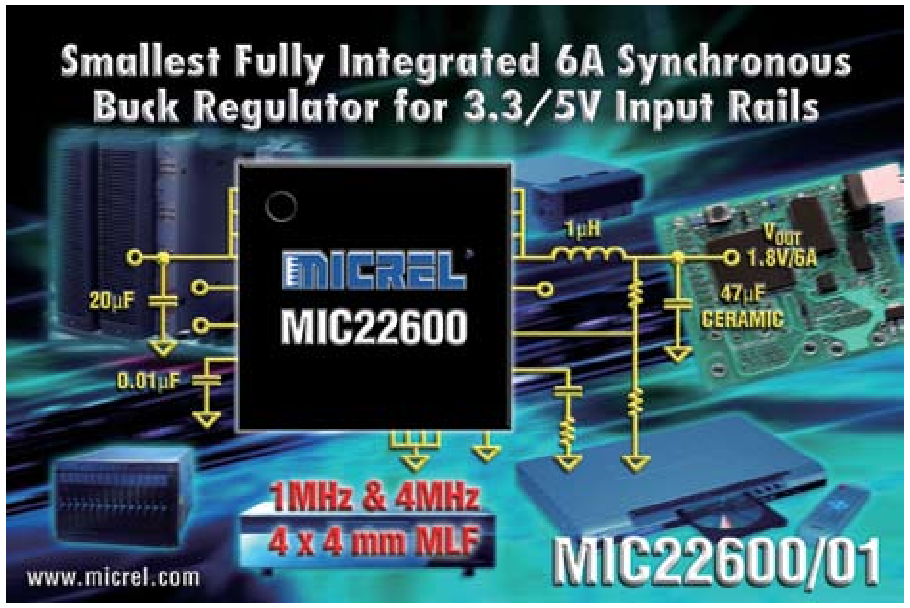
Another great insight from Micrel' s team has put the company in a very strong position. On July 1, 2007, the Federal Communications Commission (FCC) enacted a Congressional mandate that dictates cable providers fully utilize the CableCard™ 2.0 specification in new set-top boxes. The idea behind the mandate is to give consumers a choice between continuing to rent set-top boxes from cable providers or purchasing such units from third-party providers. The Micrel solution is the only integrated circuit on the market that addresses this new mandate and the CableCard 2.0 specification.

John Lee announced, "Micrel's CableCard 2.0 Power Controller has received wide customer acceptance and is the only all-in-one IC CableCard 2.0 Power Controller solution available today. In addition, a major STB manufacturer has received a coveted CableLabs® certification in both dual S-Mode and M-Mode DVR for a STB containing the Micrel device. This is the only STB to-date to receive such a certification."

Micrel's MIC2569YQS is designed to supply power to CableCard 2.0 cards in CableCard host systems. The device supports both S-Mode (Single Stream Video) and M-Mode (Multiple Stream Video) through a simple-to-control parallel interface. All voltage switching is soft-start at turn-on and break-before-make when changing between different voltage supplies. Output capacitors may be discharged during internal shunting of FETs. Built-in current limiting protects both VCC and VPP output lines of the host system from card faults and accidental short circuits. The IC also provides a FAULT/signal to indicate that an over-current or fault condition exists and is equipped with internal thermal monitoring circuitry to protect the device itself in the event of a sustained over-current condition.

Smallest Fully-Integrated 6A Synchronous Buck Regulators for 3V and 5V Rails

Micrel recently introduced a family of the industry's smallest fully-integrated 6A synchronous buck regulators, the MIC2260x series for 3V and 5V supply rails. Operating at 1MHz (MIC22600) or at 4 MHz (MIC22601), the ICs feature built-in sequencing, tracking and ramp control — enabling all power-up sequencing and tracking protocols. Targeted at the communications, computing peripherals, and high-end consumer markets, the solutions are ideal for servers/routers, HD DVD recorders, wireless base stations, FPGAs, DSPs, and low voltage ASICs, as well as other high power density applications.



"Ease-of-use, small size, high efficiency and high integration are key drivers for today's demanding power designs," noted Ralf Muenster, Micrel's marketing director for power products. "The MIC2260x are 6A, high efficiency, current mode buck regulators featuring fully integrated MOSFETs while setting new standards in terms of footprint and functionality."

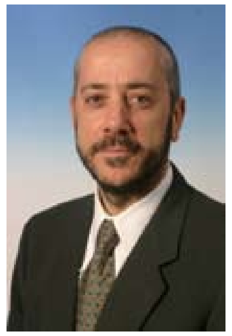
The MIC2260x feature fully integrated 30mOhm P-FET and 25mOhm N-FET switches that deliver a 6A output current with an input voltage range of 2.6-5.5V. The devices have an adjustable output voltage option down to 0.7V and provide efficiencies of up to 93 percent. A proprietary, patent–pending internal compensation scheme makes the devices extremely easy to use. The MIC2260x require very few external components and operate at high fixed switching frequencies, which in turn, reduce the size of passive components. The built-in sequencing/tracking feature enables reliable power up/down in multi-rail ASIC/ FPGA applications. The devices also feature an ultra-fast transient response, thermal shutdown and current limit protection, and a junction operating range from -40°C to +125°C

www.micrel.com

National Semiconductor

In a recent discussion with National Semiconductor executive, Salvatore Napolitano I was briefed on the new line of PowerWise® products being launched.

New Line of PowerWise® Line of Energy-Efficient Products



The three new PowerWise® energy-efficient, high speed differential amplifiers, suited for a wide variety of comms, test and instrumentation, defence and space applications as part of their PowerWise® line of energy-efficient analogue ICs. These parts deliver outstanding performance-to-power ratios. The creation of the PowerWise® line is National's focus on products to enable more energy-efficient designs for engineers.

LMH6552 is reportedly the industry's highest-bandwidth, current feedback differential amplifier at 1.5GHz, with the industry's lowest power consumption at 112 mW, dissipating 44% less power than competitive products. This digital-controlled variable gain amplifier (DVGA) offers an 8 dB noise figure and a 40 dBm output intercept point (OIP3) at 70 MHz for WCDMA, GSM and WiMAX receiver signal paths and enables an 8-bit, 3 Giga-sample data acquisition system with less than half the power consumption of competitive solutions.

LMH6515 DVGA maximises dynamic range of the signal path in IF sampling applications. The amplifier's high linearity, with a third-order intercept point (OIP3) of 40 dBm at 70 MHz, and low noise make it well-suited for both broadband and narrowband receiver paths. It features a noise figure of 8 dB, consumes just 100 mA and operates at a supply voltage of 5V. The LMH6515's small 4 mm by 4 mm, 16-pin LLP package simplifies design and reduces board space by more than 75 percent compared to using a discrete attenuator plus amplifier. In receiver applications, the LMH6515 offers a maximum gain of 26 dB and a wide 31 dB gain adjustment range, with 600 MHz (-3 dB) bandwidth. It delivers gain adjustments in precise 1 dB gain steps -- accurate to within 0.05 dB -- to increase the dynamic range performance of communications systems. This precision enables accurate balancing with other blocks in the signal path.

LMH6555 is the industry's only differential driver optimised for DC-coupled, 8-bit data acquisition applications with input frequencies up to 750 MHz. It converts singled-ended signals into differential signals while providing a fixed gain of 13.7 dB and a wide 1.2 GHz bandwidth. The LMH6555 also provides 0.5 dB gain flatness to 330 MHz, a noise figure of 15 dB at 3.3V, and second and third harmonic distortion of -53 dBc and -54 dBc at 750 MHz – all essential requirements for DC-coupled oscilloscope and data acquisition systems. The amplifier's unique architecture allows it to operate as a fully differential driver or as a single-ended-to-differential converter. Its linearity and 100-Ohm differential load drive capability, as well as assurance against overdriving. ADC inputs, make this amplifier well-suited for driving National's ultra-high-speed ADCs.

www.national.com

Texas Instruments

I had the great pleasure to meet with Francois Malleus, TI's Manager for High performance analog products. He explained to me that the indicators we have on our cell phones were very inaccurate..a fact, I'm sure we can all identify with. He started off by telling me, "With all the features packed into today's phones such as high-definition video and data transmission, the need to conserve and accurately measure the power left in the battery has become an absolutely critical factor in a whole host of applications. Manufacturers like to integrate as many functions as possible, but obviously, they all consume power. We let the consumer know how much time they have left in their equipment, just like the PC manufacturers do. Our portable device customers asked us to help them to incorporate the technology into their mobile designs -- and now they can."

TI Fuel Gauge for Smart Phones and Handhelds Accurately Predicts Battery Life

As part of TIs success in outgrowing competition in power, it has solved this problem by introducing its system-side fuel gauge IC with its Impedance Track™ technology for smart phones and other handhelds. The 2.5mm x 4mm gauge predicts battery life with a staggering 99% accuracy to extend run-time, protect data and provide a better user experience for mobile handheld users.

The bq27500 system-side battery fuel gauge with TI's patented Impedance Track technology accurately measures data from a device's single-cell Li-Ion battery to predict remaining battery capacity under all conditions, even as a battery ages. The tiny IC analyzes precise state-of-charge by correlating between a battery's voltage and cell impedance, and its current integration to adjust remaining state-of-charge up or down the predicted discharge curve.

Most handhelds today do not accurately gauge remaining battery capacity, but simply measure the cell voltage to simply guess the capacity. Traditional gauging techniques used in some handhelds require static and unreliable modeling methods that attempt to compensate for discharge rate, temperature and age of the cell, and must also model self-discharge and other non-measurable currents. Since these models have an inherent error, which is difficult to minimize, an end-user will not accurately know how much run-time remains as the battery ages with the usual disappointment.

I asked Francois, how do you achieve this?

"The bq27500 directly measures the effect of a battery's discharge rate, temperature, age and other factors to accurately predict remaining life within one percent error. By measuring and storing real-time battery impedance values, the IC automatically adjusts to changes in full capacity as a battery ages. State-of-charge and full capacity are calculated from the voltage and impedance measurements, eliminating the need to re-learn from a charge and discharge cycle."

He added, "As handheld systems provide more functions, the need has grown for accurate fuel gauging to intelligently manage available power, alert the user of system operating-time, and extend the run-time of the system as far as possible. Accurate battery data is used by applications processors, such as TI's OMAP3410 processor with SmartReflex ™ power and performance technologies, to optimize the system's complete mobile power operating system. For instance, the system can leverage low-power modes, clock gating, clock throttling and dynamic voltage and frequency scaling capabilities based on battery capacity. The bq27500 provides an accurate reserve energy warning, which allows a system to save data to non-volatile memory at the end of a battery's discharge, so all your valuable work is not lost when battery life runs out.

Also, the bq27500 is implemented on the host system's board, and can support an embedded or removable battery. System-side implementation allows a handheld manufacturer to save cost by designing an end-equipment that does not need extra electronics added to the battery pack. As batteries continue to shrink in size, integration of electronics on the battery becomes more of a challenge. System-side implementation of the bq27500 can control and manage other main battery management functions, such as battery pack authentication."

www.ti.com/battman

Power Systems Design EUROPE

Special Report
Automotive Electronics
Part III

Image Courtesy of DaimlerChrysler

LED Illumination in Automobiles Requires a New Generation of Power IC Designs

Technology requirements are on the rise to meet demands

Each year automobiles continue to incorporate increasingly complex electronic systems. Today, electronic systems account for more than 20% of a typical car's cost, but that figure will jump to more than 30% by 2008. Examples of these electronic systems are infotainment systems, safety systems, engine management, satellite in car radio and TV, hands-free cellular phones and other wireless connectivity. Five years ago, these systems were only found in "high-end" European luxury cars. Now they are now being integrated into midrange automobiles from every manufacturer, accelerating automotive IC growth even faster.

By Tony Armstrong, Product Marketing Manager, Linear Technology Corporation

At the same time, the electronic component count in these systems increases while the available space requirements continue to shrink, greatly increasing the electronic density of each system. All of these systems require power conversion ICs, often with multiple voltage rails for each subsystem. Because of the very high power density and relatively high ambient temperatures, any practical heat sinking is too large to be accommodated. Thus power conversion efficiency becomes critical due to space limitations and operating-temperature-range requirements. At low output voltages and even with moderate current levels above a few hundred milliamps, it is no longer practical to simply use a linear regulator to generate these system voltages because they generate too much heat. As a result of these constraints, switching regulators are replacing linear regulators. The benefits of a switching regulator, including the increased efficiency and smaller footprint, outweigh the additional design complexity and EMI considerations.

LEDs Replacing the Incandescent Bulb

The use of LED illumination in automobiles was merely an idea in concept cars of the past. Today, LEDs are found in the instrument panel backlighting, interior lighting, and brake lights of many cars and trucks. In addition, luxury automobile manufacturers are increasingly taking advantage of the latest technologies in solid-state LED lighting to enhance the aesthetics of their 2007-2008 model cars by relying on these lighter, smaller, and more reliable devices for interior and exterior illumination. LEDs also promise lower cost and longer life; clear advantages over incandescent light bulbs for interior lighting, for example, and HID (high-intensity discharge) and halogen lamps for headlights.

Driving LEDs from a car battery requires a DC/DC converter to accurately regulate the LED current to ensure uniform light intensity and color integrity as well as to protect the LEDs. Moreover, the DC/DC regulator should be optimized for specific power requirements depending on the intended use of the LEDs: headlights, or rear, signal, or interior mood or reading lights. Also, a difficult challenge is to power one or several strings of LEDs from a battery voltage that can be less than, equal to, or more than the load voltage. Another concern is to efficiently dim the LEDs over a large dimming ratio while preserving their chromatic characteristics at both low and high brightness levels. Efficient operation of the DC/DC driver is a crucial requirement, especially in driving HB (high brightness) LEDs, since the power not converted into emitted light is wasted through heat.

Load Dump Condition and Cold Crank Conditions

"Load-Dump" is a condition where the battery cables are disconnected while the alternator is charging the battery. This can occur whether a battery cable is loose while the car is operating, or a battery cable breaks while the car is running. An abrupt disconnection of a battery cable can produce transient voltage spikes up to 80V as the alternator is attempting a full-charge of an absent battery; see Figure 1 for a graphical representation. Transorbs on the alternator usually clamp the bus voltage somewhere between 36V and 60V and absorb the majority of the surge current. However, DC/DC converters down stream of the alternator are subjected to these 36V to 60V transient spikes. As these converters, and the subsystems they power, are expected to survive, and in some instances regulate an output voltage through this transient event, it is critical that these DC/DC converters are capable of dealing with these high voltage transients. There are various protection circuits, usually transorbs, which can be implemented externally, but they add cost and take up valuable space.

"Cold Crank" is a condition that occurs when a car's engine is subjected to cold or freezing temperatures for a period of time. The engine oil becomes very viscous and requires the starter motor to deliver more torque, which in turn needs more current from the battery. This large current load can pull the battery/primary bus voltage below 4.0V upon ignition, after which it typically returns to a nominal 13.8V, see Figure 1. It is imperative for some applications such as engine control, safety and navigation systems to require a well-regulated output voltage (usually 3.3V) through cold crank to operate seamlessly through this scenario.

New IC LED Drivers are Ideal for Automotive Applications

Two new DC/DC LED drivers from Linear Technology Corporation address the many stringent requirements of automotive interior and exterior lighting. They feature high operating efficiency, load protection, wide input and output voltage ratings, and precision current regulation and more. The ICs can easily be configured into several DC/DC topologies, thus offering a designer the option of qualifying one IC to satisfy different applications' conversion requirements.

The LTC3783 is a current-mode multi-topology converter with constant-current PWM dimming for driving high-power

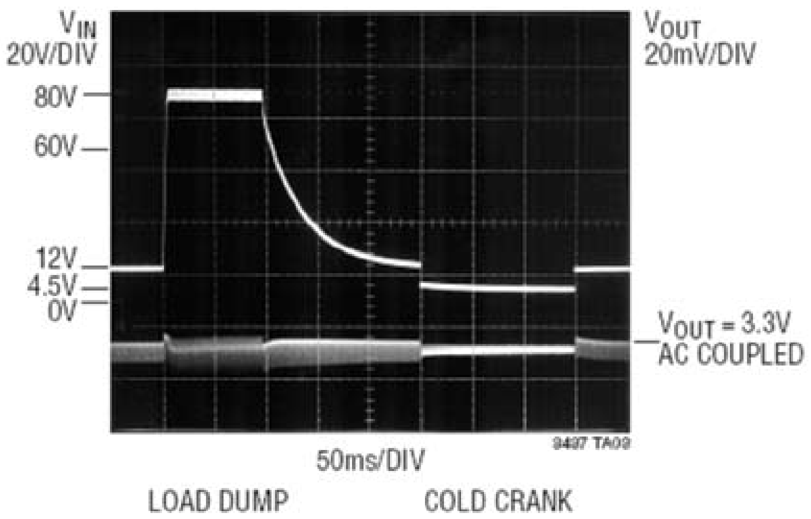


Figure 1. 80V Load Dump Condition and Cold Crank Conditions.

LED strings and clusters. Proprietary techniques provide extremely fast, true PWM load switching with no transient undervoltage or overvoltage issues: dimming ratios of 3000:1 (at 100Hz) can be achieved digitally as True Color PWM ä dimming guarantees color integrity of white and RGB LEDs. The LTC3783 allows an additional 100:1 dimming ratio using analog control. This is an important criterion since the human eye is extremely sensitive to minor changes in ambient light. This versatile controller can be used as a boost, buck, buck-boost, SEPIC, or flyback converter, and as a constant-current/constant-voltage regulator. No RSENSE™ operation uses a MOSFET's on-resistance to eliminate the current-sense resistor and increase efficiency. Applications for the LTC3783 include high-voltage LED arrays and LED backlighting, as well as voltage regulators in telecom, automotive and industrial control systems.

The following features are important to automotive customers for LED drivers, including our LTC3783:

• High Current: To deliver high current (≥1.5A), the LTC3783 drives an external N-channel MOSFET to power high brightness (HB) and Super HB LEDs.

• High Voltage: The LTC3783's 3V to 36V input operation and an output voltage that is scalable depending on the choices of the external power components, easily drives strings (series) or clusters (series + parallel) of LEDs.

• Protection: The IC incorporates accurate current and output voltage regulation necessary to protect HB LEDs. Additional protections include overvoltage, overcurrent, and soft start.

• Dimming: With True Color PWM 3000:1 digital dimming the LED's constant color is preserved over a wide dimming ratio. Also, the LTC3783 is capable of additional analog 100:1 dimming.

Another product is our LT3475, which is a dual channel 36V, 2MHz step-down DC/DC converter designed to operate as a constant current LED driver providing up to 1.5A of LED current per channel. An internal sense resistor and dimming control make it ideal for driving high current LEDs. High output current accuracy is maintained over a wide current range of 50mA to 1.5A while unique True Color PWM circuitry allows a dimming range of 3,000:1.

With its wide input voltage range of 4V to 36V (40VMAX), the LT3475 regulates a broad array of power sources including automotive power systems. Its switching frequency can be set from 200kHz to 2MHz, enabling the use of tiny inductors and ceramic capacitors while staying out of critical frequency bands such as AM radio. Combined with a thermally enhanced TSSOP-16 package, it offers a very compact solution for driving two or four high current LEDs.

The LT3475 utilizes a high side sense, enabling a grounded LED cathode connection, eliminating the requirement for a grounding wire in most applications. Current-mode control and a precise reference voltage optimize loop dynamics for a well-regulated, low ripple constant LED current. Both channels have separate VADJ and PWM signals for independent operation. Each channel switches 180 degrees out-of-phase from the other, reducing output ripple on both channels. It also has an integrated boost diode, further reducing the solution footprint and cost. Additional features include both open LED and short circuit protection.

Conclusion

Although the automotive environment is considered to be extremely harsh, LED lighting system designers do have a number of options available for the selection of rugged LED drivers that can handle their stringent performance requirements. Furthermore, as the adoption rate of LED lighting continues to migrate down-stream into the low-end automobiles, manufactures of LED drivers will deliver new and innovative products to meet their needs.

www.linear.com

Improving Reliability in Automotive Applications with Self Protecting MOSFETs

Potentially destructive environment posed by the extremes of temperature is a huge challenge for the semi industry

These devices are demanded by the auto industry to provide cost effective and fully reliable control functions for the myriad of now-electronically controlled functions commonly found within modern trucks and cars. Power management and control is becoming a vital part of any automotive design. No more is the provision of power from the battery and alternator combination considered an 'unlimited resource', but semiconductors need a little more care on their design than their discrete counterparts. Zetex Semiconductors has invested in developing parts to overcome these issues in MOSFETs, now widely deployed in the automotive sector.

By Simon Ramsdale, Product Marketing Manager, Zetex Semiconductors

Due to these harsh environments unprotected standard MOSFETs have proven not rugged enough for many automotive applications. Inductive spikes and load dumps are transients that either require larger MOSFETs or external clamps to absorb the energy that would otherwise destroy the MOSFET. To overcome many of these limitations, self protected MOSFETs were created. Their internal protecting components commonly reduce the cost and size of solution while increasing overall reliability in many applications.

Lowside self protected MOSFETs are commonly used to drive peripheral loads and for signal interface paths. Typical examples include relay driving, LED driving and communications signalling between modules.

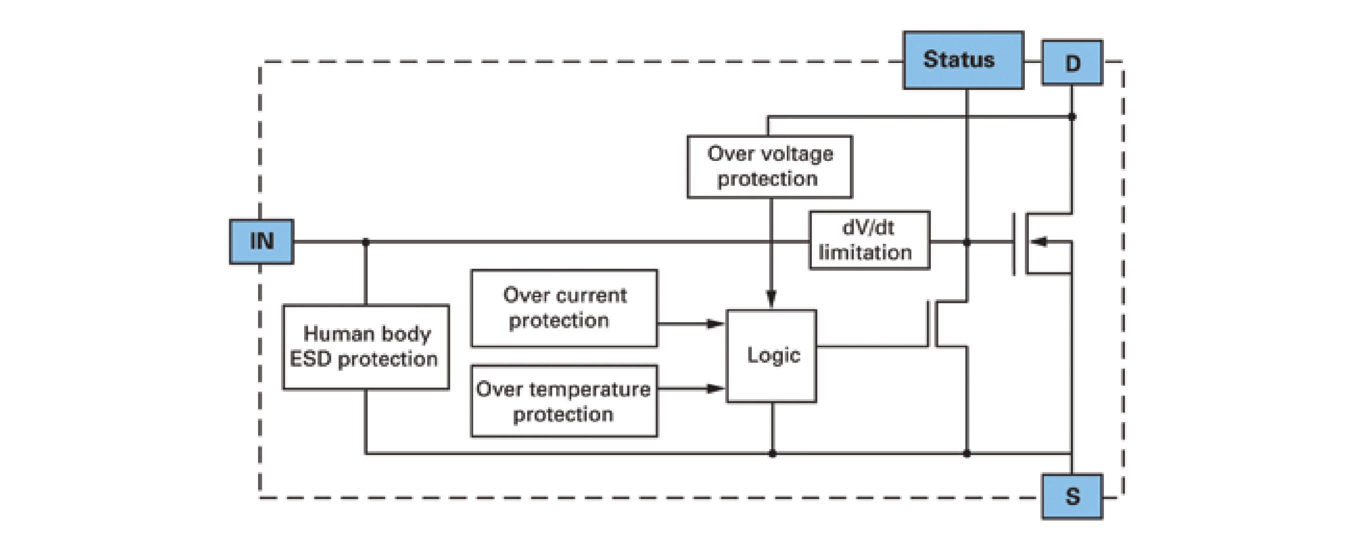


Figure 1. Block diagram of ZXMS6002G self-protected MOSFET.

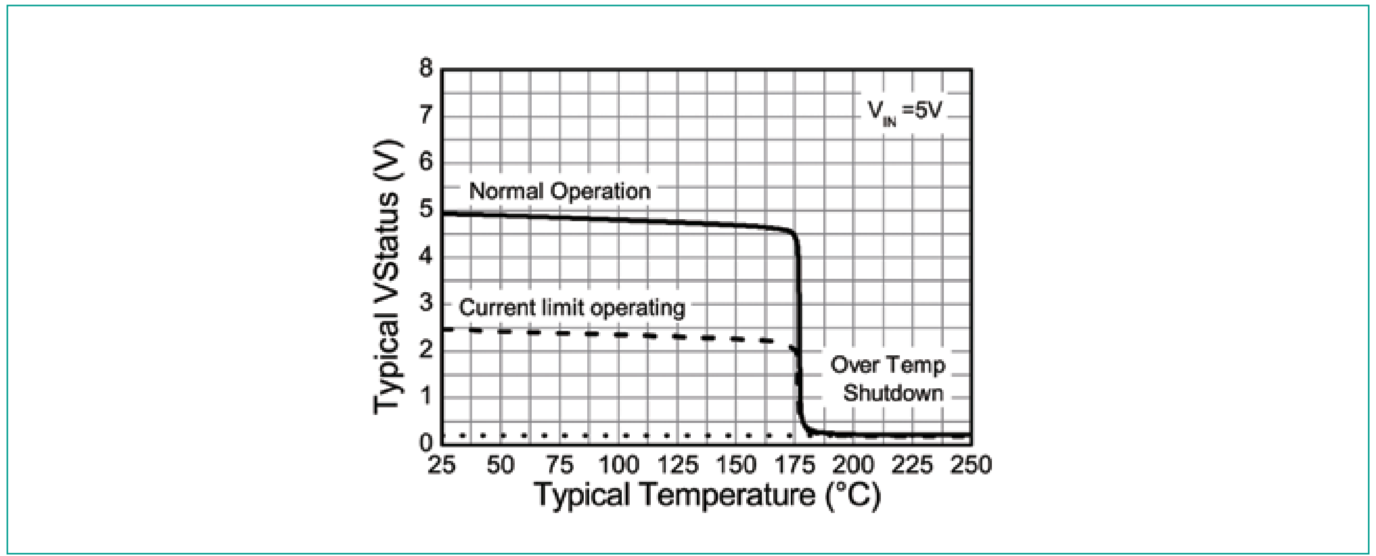


Figure 2. Current limiting and over temperature shutdown status indication of the ZXMS6002.

Relay Driving

Due to the inductive nature of relays large transients can be created when deactivating the relay. These transients have the capability of destroying unprotected drivers. Protected MOSFETs have an integrated voltage clamp, as shown in figure 1, which automatically turns back on the MOSFET when its drain-source voltage exceeds a predetermined level. This also helps protect the device from load dumps; which is important as relays are often used on unprotected rails.

To help cope further with transients most protected FETs also incorporate over-current protection; which helps the FET withstand fault conditions that would otherwise blow standard switch devices. The robustness and reliability is further improved by over-temperature protection. During fault conditions the drain-source voltage increases as the load current increases. This results in device junction temperature increases, which without over-temperature protection would cause the device to be destroyed.

To improve reliability still further some form of diagnostic feedback as to the state of the switch may be provided. In figure 1, the protected MOSFET gives diagnostic feedback on the actual condition of the MOSFET's gate voltage.

During current limit conditions the current limiting circuitry reduces the gate-source voltage. This reduction can be used as the basis for diagnostic feedback.

This change in gate voltage can be detected by the control system; allowing the system to respond to the fault. If the fault should continue then to protect itself the protected FET will normally shut itself off when its junction temperature exceeds 150C. During these conditions the Gate voltage will fall further. Figure 2 shows how the status pin of the ZXMS6002 varies with MOSFET condition providing direct diagnostic feedback which can be used to improve reliability.

This form of feedback can be used to warn the system of a fault enabling the management of the system to make an intelligent decision. This may be to notify the driver of the fault or enable the system to turn off the drive thus increasing the reliability and life of the system.

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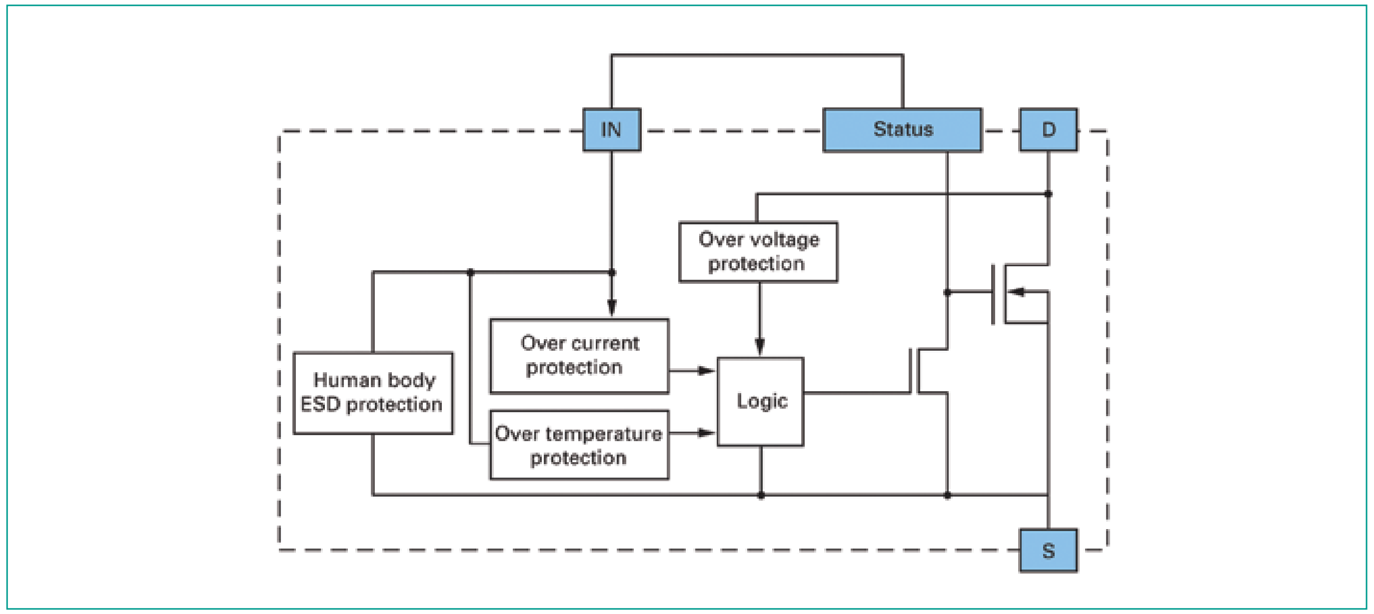

Figure 3. Block diagram of ZXMS6003G self-protected MOSFET.

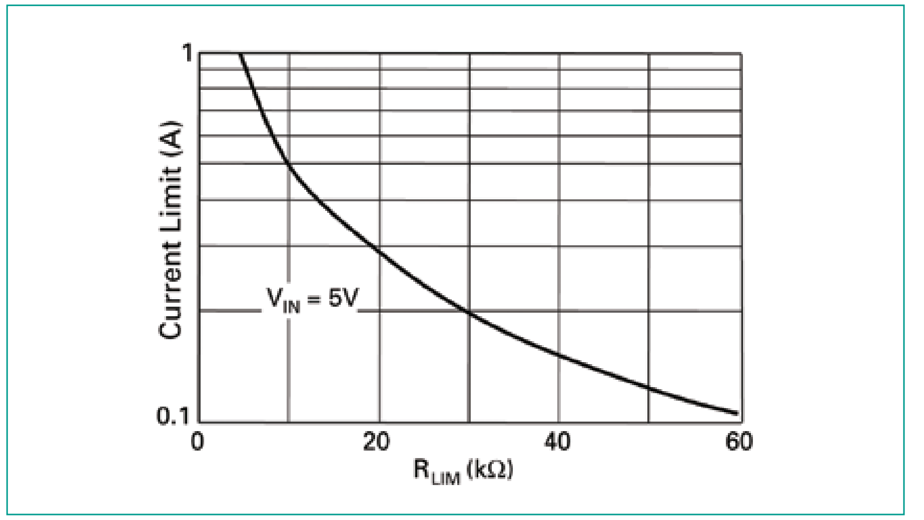

Figure 4. Current limit vs R_{LIM} for ZXMS6003.

Versatility and reliability can be further increased by making the current limit programmable as the protected FETs are rarely used at their rated current limit. By reducing the current limit so that it is closer to the relay switching current fault conditions will be more reliably handled resulting in lower junction temperatures.

Lamp driving

Protected FETs are commonly used to drive lamps; their built-in current limit will limit the in-rush current of incandescent lamps thus protecting the driver and increasing the life of the incandescent lamp. As the lamp heats up, its resistance increases reducing its current.

One way of reducing the cost can be to use a smaller protected FET with a programmable current limit. Figure 3 shows the block diagram of the ZXMS6003, an external resistor R_{LIM} sets the dc current limit. Figure 4 shows how the current limit varies with R_{LIM}. The current flowing into the STATUS pin is mirrored within the ZXMS6003 to set the current limit. This feature allows the ZXMS6003 to provide higher surge currents; by placing a resistor and series capacitor in parallel with R_{LIM} increases the current into the STATUS pin. This raises the short term current limit allowing higher in-rush currents allowing the lamp to heat up in a controlled manner yet providing a lower nominal current limit which helps protect the system from faults.

Inter-module communications

Protected FETs are also used as low cost high reliability communication drivers. Their open drain format allows them to interface to a wide range of voltages and their robustness allows them to withstand a wide range of transients.

With their built-in self-protecting features, self-protected MOSFETs provide a cost effective solution to switching loads in a wide variety of automotive applications. Their intrinsic features increase system reliability which can be further increased by the inclusion of diagnostic feedback and programmable current limit.

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Power Electronic Interface for Ultracapacitor as Power Buffer in a Hybrid Electric Energy Storage System

Active paralleling of Ultracapacitors with lithium - A winning combination

Ultracapacitors store approximately one-tenth the energy of nickel metal hydride batteries but are capable of more than ten times the power. The energy specific cost of the Ultracapacitor is high relative to batteries, but that specific cost of power is just the reverse; for the Ultracapacitor, "cost of power" is low relative to batteries, regardless of type.

By Dr. John M. Miller, PE, Maxwell Technologies, Inc., San Diego, California
Michaela Prummer and Dr. Adrian Schneuwly, Maxwell Technologies SA, Rossens, Switzerland

Ultracapacitor power energy storage cells have been introduced in relatively large volumes since 1996 and continue to experience steady growth. In recent years they have become accepted as high power buffers for industrial and transportation applications in combination with conventional lead-acid batteries, as standalone pulse power packs, or in combination with advanced chemistry batteries. The merits of ultracapacitors in such applications arise from their high power capability based on ultra-low internal resistance, wide operating temperature range of -40°C to +65°C, minimal maintenance, relatively high abuse tolerance to over charging and over temperature, high cycling capability on the order of one million charge-discharge events at 75% state-of-charge swing and reasonable price.

Combining both energy storage technologies together results in an energy storage device with high energy availability combined with high power and high efficiency. This paper examines the recent surge of interest in combining the power dense Ultracapacitor with an energy optimized lithium-ion battery and what the interface requirements are for the ultracapacitor in this active parallel configuration.

Considering Ultracapacitors in combination with lithium-ion batteries, one can see from the cell potential versus cell capacity traces in Figure 1 that lithium-ion has very different potential behavior than the Ultracapacitor. The scales are in proper perspective to illustrate the order of magnitude energy differences between lithium-ion and Ultracapacitor cells. Batteries store and deliver their energy via reduction-oxidation, redox, reactions (i.e., Faradaic or mass transfer processes) and thereby hold near constant potential until the reactant mass(s) are consumed. Ultracapacitors on the other hand are energy accumulators (i.e., non-Faradaic) and require a potential change to absorb or deliver their charge. Because of these very different voltage-current behaviors of the two energy storage components a direct parallel combination will not be as effective as a buffered configuration, what is called an active parallel combination. Active paralleling means having a dc-dc converter interface the ultracapacitor to the lithium-ion battery.

Both direct and active parallel configurations have been explored extensively over the past decade. In fact, the telecommunications industry is

Special Report – Automotive Electronics Part III

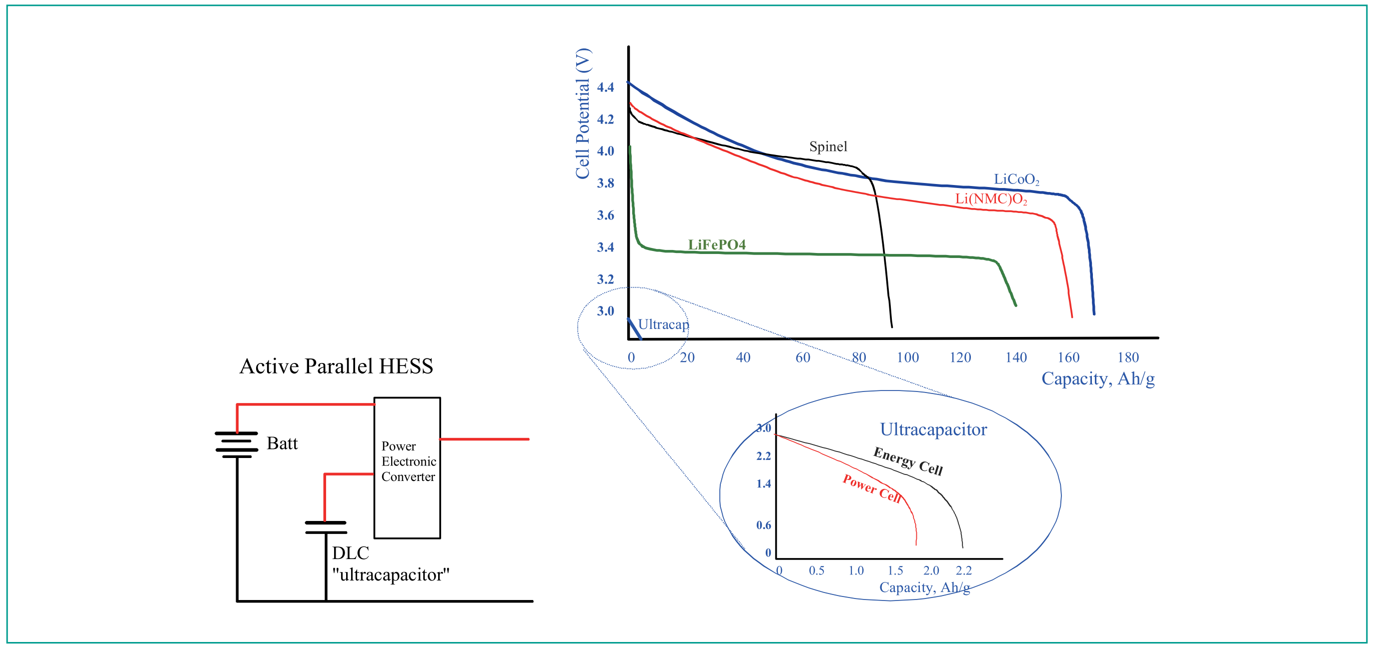

Figure 1: Active Parallel Combination of Ultracapacitor with Battery: Hybrid Energy Storage System, HESS.

well aware of the benefits of the direct parallel combination of ultracapacitors with lithium cells, generally in a parallel circuit of a single lithium cell (OCV~4V) across two series connected carbon-carbon ultracapacitors (OCV=2.3 to 2.5V each). In this direct parallel example the ultracapacitor, because of its very low ESR, supplies a major portion of burst power needed during transmission while the lithium-ion cell provides all reserve power and standby power. The combination results in significant air time improvement. A similar case can be made for heavy transportation, city transit buses for example, or light rail all of which are now exploring the use of ultracapacitor technology or have pilot programs underway.

Figure 1 highlights the need for power electronic conversion to match an ultracapacitor pack to a lithium battery pack in order to simultaneously optimize the pulse power and energy of the combination, [1] The demonstrated benefit of backing up a battery pack with high pulse power Ultracapacitors has been documented by ISE Corp. in their hybrid transit buses for municipal transit authorities.

The Ultracapacitor plus dc-dc converter must deliver a combined efficiency on the order of 90% or better to build a value proposition when combined with a lithium pack of 95% to 90% efficiency over a wide range of loading. Analysis shows that today's Ultracapacitors, possessing ultra-low ESR and hence high efficiency at relatively high power levels, can indeed deliver such efficiency. Figure 2 is the result of such analysis for a typical Ultracapacitor cell undergoing constant power testing. The result is 95% or better efficiency for pulse time intervals ranging from 8s at 10% of matched load power, P_{ml}, to 2s at one fourth P_{ml}, to 1s when the power loading is 40% of P_{ml}. Matched load power is defined in (1) and results when the terminal load equals the cell (or pack) internal resistance, ESR.

$$P_{ML} = \frac{U_{mx}^2}{4ESR_{dc}} \qquad (1)$$

In (1) the maximum cell (pack) potential is Umx and the internal resistance is the dc value of ESR, or the ESR taken at very low (i.e., <100mHz) frequency. At such low frequency, the ESR will consist of ionic (Ri) and electronic (Re) contribution to ESR, or Ri + Re for both Ultracapacitor and lithium-ion cells.

Another observation made from Figure 2 is that the efficiency curve at constant power drops significantly as power level is increased. This is due to the fact that for a fixed power demand, the Ultracapacitor internal potential (i.e.,

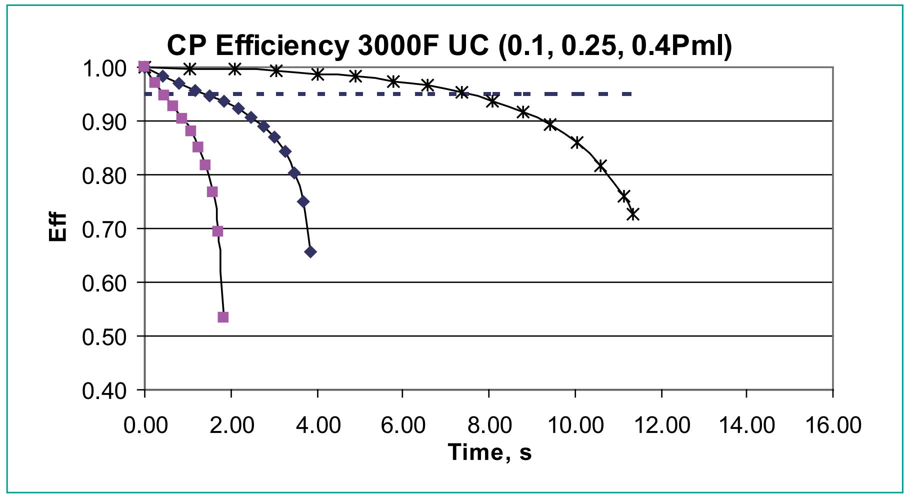

Figure 2: Ultracapacitor Constant Power Discharge Time for >95% Efficiency (8s at 0.1Pml, 2s at 0.25Pml, 1s at 0.4Pml).

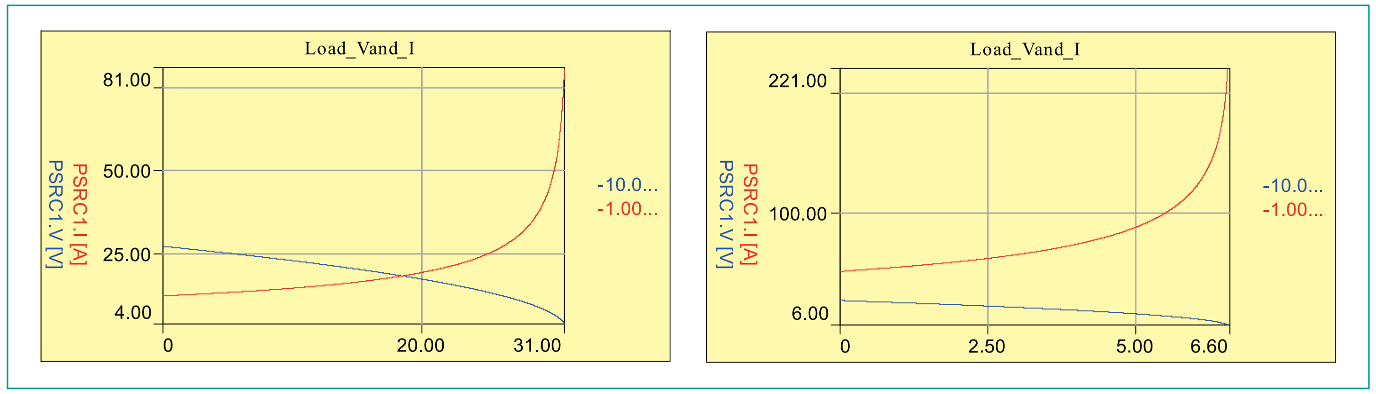

Figure 3: Ultracapacitor Discharge Characteristics Under Constant Power Loading: 0.1Pml (left) and 0.4Pml (right). Voltage scaled by 10x (blue trace), current x1 (red trace).

the potential across the carbon-electrolyte compact layer having non-Faradaic characteristic equal to Q/C) drops non-linearly as charge Q is removed. The removed charge, Q = i(t)*t is itself nonlinear and equal to terminal power, P/Uc. Therefore, Ultracapacitor current must increase as the potential across the double layer decreases. This presents a design criterion for the interface dc-dc converter in sizing of the boost switch.

The terminal potential and current behavior of the Ultracapacitor during constant power loading, which can be viewed as normal operation in a vehicle traction drive, become highly nonlinear as internal potential across the carbon-electrolyte compact layer (i.e., Uco = Q/C(U)) decreases from near maximum potential. Note that in all applications that recuperate energy from the load the energy storage component must have reserve capacity to absorb the anticipated level of return energy. Figure 3 illustrates the ultracapacitor terminal voltage and current under constant power discharge at 0.1Pml and 0.4Pml.

The nonlinear characteristics of Ultracapacitor voltage and current illustrated in Figure 3 for the energy D Cell (350F, 2.5V) are taken at 10% and 40% of matched load respectively. Voltage and current characteristics commence relatively linearly, trending to square law behavior and ending with a strong exponential change as potential approaches cut-off (i.e., the point at which insufficient charge remains to support the current: i(t) = dQ/dt). Table 1 summarizes the characteristics of Ultracapacitor performance under constant power operation.

It is insightful to point out two key time constant aspects of the constant power results shown in Table 2. The power D Cell (310F, 2.5V, 2.87mΩ) characteristics result in a time constant τ = ESR*C = 0.77s. This time constant describes some very fundamental behavior of the cell and can in fact be used to define its efficiency under constant current operation. At matched load conditions the cell energy is depleted in exactly two time constants, T = 2τ = 1.78s for the power cell tested. For rapid discharge (i.e., abuse conditions) and short circuit the stored energy will be dissipated in one time constant.

Energy efficiency under high loading conditions is summarized in Table 1 and shows that at matched load power levels half the stored energy is dissipated internally and half delivered to the load (i.e., efficiency is 50%). For constant power levels well below matched load conditions the Ultracapacitor efficiency trends toward 100% and for cells designed for passenger vehicles the overall efficiency will be as shown in Figure 2, in the range of 95% to 98%.

Table 1: Summary of Power D Cell Ultracapacitor Performance under Constant Power Discharge

Power loading	Load Watts (W)	Voltage cut-off Uco, (V)	Time to Uco (s)	Useable Energy (J)	Delivered Energy (P*t)	Energy Eff.
0.1 P_{ml} =	34	0.45	31	1260.6	1054	0.83
0.4 P_{ml} =	135	0.9	6.56	1230.5	885.6	0.72
1.0 P_{ml} =	336	1.42	1.78	1180	598.1	0.507
1.6 P_{ml} =	538	1.8	0.653	1120.6	351.3	0.313

* Total stored energy at Uc = Umx is 1295 J and for cut-off potential determined as: $U_{c0} = 2\sqrt{ESR * P_0}$

High efficiency means more compact modules and improved product integration, less cooling system burden so that air cooling suffices and reduced overall installation cost. Power cells packaged in modules such as the one illustrated in Figure 4 are state-of-the-art in high specific power (approaching 20kW/kg), low cost (~$12/kW) and high efficiency (>95%). Improved efficiency in energy storage means transportation systems having improved fuel economy, reduced emissions and uncompromised performance.

Armed with this background on ultracapacitors and lithium-ion batteries we shift our attention now to the active parallel combination case shown as Figure 5. In this figure the Maxwell Technologies Ultracapacitor model connects via a half-bridge converter (e.g., buck-boost stage consisting of line reactor L_{bb} and a phase leg module) to the lithium-ion cell model. The most important aspect of this configuration is the key role played by control of the dc-dc converter, in the case presented here, as one of energy management strategy, EMS, resident in a supervisory controller.

Figure 4: Energy D Cell Ultracapacitor Cell (350F, 2.5V, 3.2mW, 60g, Pml=5.6kW/kg) and Module (left), and 48V Module (right) Designed for Heavy Transportation Applications.

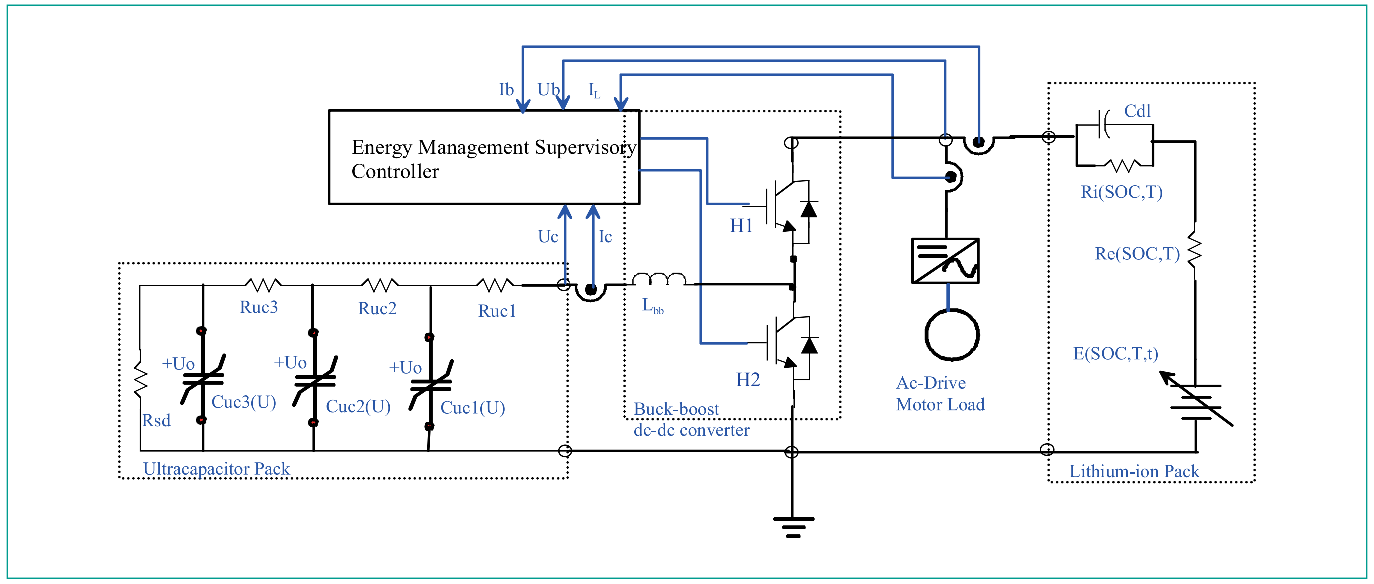

Figure 5: Ultracapacitor with dc-dc Converter plus Lithium-ion Active Parallel HESS.

The EMS supervisory controller for the dc-dc interface converter must continuously monitor load power flows, lithium cell (pack) power flows, and Ultracapacitor cell (pack) power flows. It must also generate buck-boost converter gating signals, necessary to effect bi-directional power flows in proportion to accumulated SOC information on both the lithium cell (pack) and ultracapacitor cell (pack). It must determine, based on SOC information, and connected load power demand the relative contributions of dynamic (Ultracapacitor) and sustained (lithium) power levels. Finally, at a vehicle system level, and in cooperation with a higher level executive controller, the EMS controller must manage the long term trend in relative SOC of the two components so that overall vehicle objectives such as fuel economy and performance can be optimized.

In conclusion:

The system shown in Figure 5 remains at the forefront of power electronics research to address the remaining technology gaps in meeting vehicle level requirements for energy storage over the full operating temperature range and without any sacrifice in performance. Lithium alone cannot meet this challenge because it will lose a significant portion of its power capability for temperatures below -10°C. Nor can Ultracapacitors acting alone meet the energy requirements of passenger vehicles without exceeding allowable package space.

What is recommended is the active paralleling of ultracapacitors with lithium, but with power flows subject to supervisory energy management strategies that seek to maintain both the energy component within its high efficient range – meaning low power stress levels, and the pulse power component within its energy range – meaning without incurring wide SOC swings that shave off efficiency points. The active parallel combination thus requires the most efficient power processor, a bi-directional dc-dc converter, which is comfortable with wide voltage variation on the input and admits instantaneous power reversals without loss of regulation.

Every investigator over the past decade who has pursued Ultracapacitor plus battery combination agree that in combination the benefits far outweigh the performance of either component acting alone. But much remains to build a value proposition and this will only be accomplished with further advances in power electronics for dc-dc conversion.

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Special Report – Automotive Electronics Part III

Automotive System Design for Zero Failures

With smart power solid state devices

A practical example of driving automotive incandescent lamps illustrates the method to predict smart power device lifetime in the real application. Furthermore, enhanced protection architectures are described.

By Romeo Letor, Sebastiano Russo, Roberto Crisafulli; STMicroelectronics, APG Body Division

System design for zero failure requires the definition of a risk assessment to take into account all potential parametric variations. In our specific case, the choice of load driver will be made on the basis of its resulting reliability in terms of number of activations versus all parameters variations (battery voltage, ambient temperature, etc.). This criterion is valid both for nominal operating condition and overload conditions. A minimum life time will be required in nominal operating conditions while a software strategy defining a maximum number of activation will be required to prevent catastrophic failures in overload conditions.

The concept of mission profile is a powerful method to predict the lifetime of a smart power device operating in a given system. The usage of this tool requires the full comprehension and characterization of the stresses applied to the device, which in turn requires a two-sided approach:

1. An electro thermal analysis of the interaction between power device and load in order to identify the stresses applied to the physical structure;
2. A reliability model formulation of the device physical structure versus the stresses.

Both the system designer and the smart power device designers take benefits from this methodology: in fact, from one side, the system designer can safely choose the smart power actuator while, on the other side, the silicon designer can optimize the device protection architecture.

Automotive actuators driving

Nowadays, smart power devices are widely used in the automotive environment to drive various actuators and lighting systems equipping modern cars. The main reasons to use solid state smart power switches are linked to the increased need of reliability, fault tolerance and diagnostic power.

In general, those requirements are in contrast with the market demand for inexpensive and small Body Control Units, the modules in charge of providing power distribution and circuit protection to other units in the vehicle, monitoring sensors and switches and driving output loads. This challenge spurs the silicon designer to embed ever-innovative features into ever-smaller devices.

The harsh automotive environment requires devices able to drive huge inrush currents of automotive loads avoiding unwanted spurious fault detections.

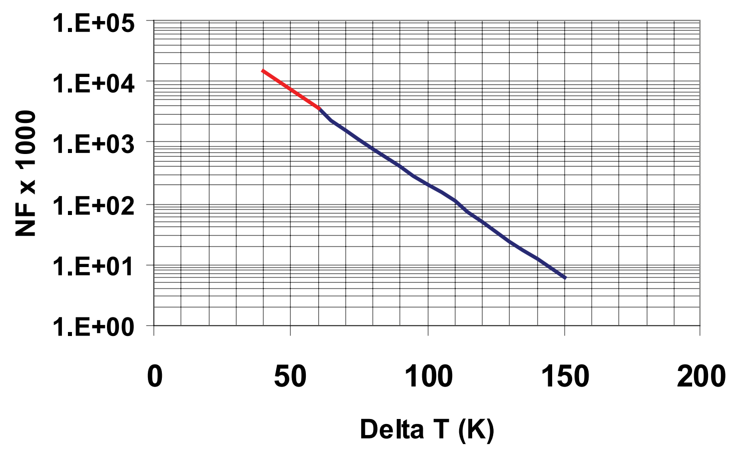

Figure 1: Reliability of smart Power solid state relay physical structure.

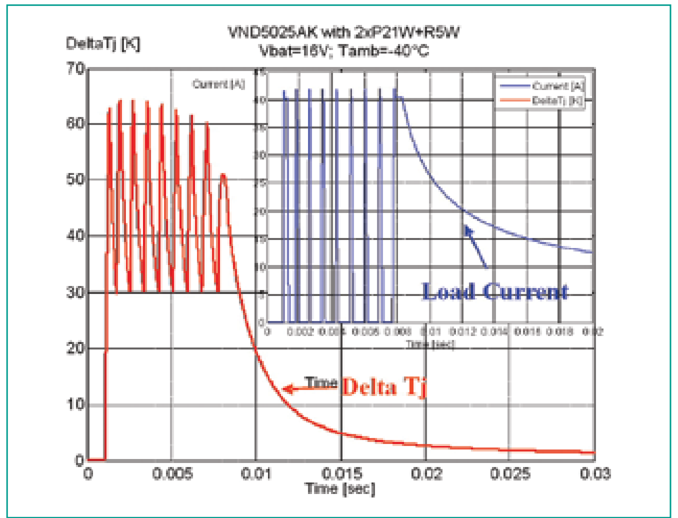

Figure 2: Detailed power requirements for a Portable Media Player system.

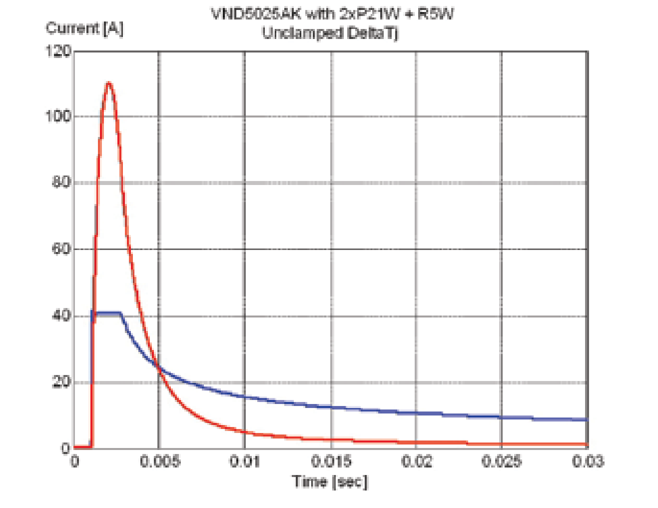

Figure 3: Inrush current and resulting delta T without dynamic delta T control.

A typical example is the dimensioning of a switch to drive incandescent lamps for automotive exterior lighting. Automotive incandescent lamps have peak currents up to about 10 times the nominal value. Consequently, the driver must be sized in order to handle the power dissipated when conducting the nominal current under steady state conditions allowing, at the same time, the few milliseconds inrush transient to safely expire with no consequences on the its reliability. Additionally, the same device must be tolerant to repetitive short circuit conditions of duration ranging between 10ms and 300ms that is typically the time required by the microcontroller to recognize and validate a fault condition. In any case, for evident safety reasons, the device is generally not allowed to switch off the load on its own and suitable protections must prevent the device from destruction, minimizing the resultant stress on its own structure.

For the above mentioned reasons, an overcurrent protection is normally implemented in the form of a current limiter in order to set the device working point inside a safe operating area even during short circuit operation. The choice of a proper value for the current limitation is a matter of trade-off between short circuit reliability and load compatibility. Indeed, extreme environmental conditions, such as very low ambient temperature, and borderline system conditions, such as high battery voltages or low levels of device current limitation, may sometimes cause the inrush of the bulb to be clamped, thus letting the device work in linear mode and dissipate a huge amount of power during the lamp turn on transient. This power dissipation leads to very fast temperature transients responsible of thermo-mechanical stresses and resulting in device permanent damages. The thermo-mechanical stresses caused by fast temperature variations always cause fatigue of the device top layers even though the absolute temperature reached is far below the critical level which is normally masked by the thermal shutdown protection. Therefore, to design a reliable driver, the definition of a proper dynamic thermal protection able to limit steep temperature rises is mandatory as well as the usual overtemperature protection typically set to an absolute temperature value of 175°C.

To correctly define and verify the effectiveness of the dynamic thermal protection, we need data coming from two different sights:

1. The mission of the device in the application. This is described by the load behavior, the number of load activations and the ambient temperature distribution. Nevertheless, these data cannot be used in a direct way to calculate the stress on the device. Behavior of the load is defined in terms of current time curve, while the device is not really stressed by the current amount, but by the temperature variation resulting from the interaction of the driver with the load. Consequently, it is necessary to translate the mission profile in the temperature profile by mean of a precise device and load thermo electrical modeling.

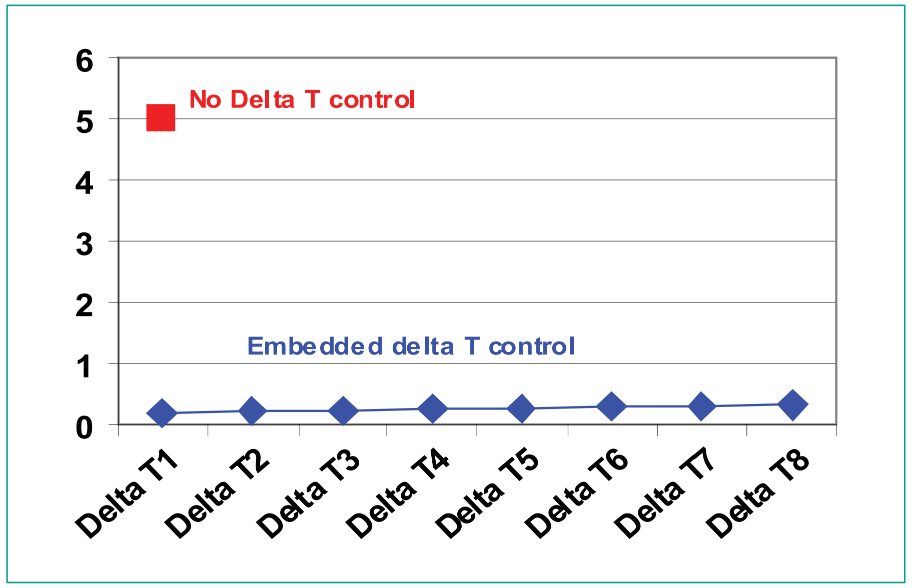

Figure 4: Cumulative damage after 500K activations.

Figure 5: VIPower M0-5 family of automotive high side drivers.

2. A comprehensive description of the physical structure ruggedness versus the applied thermo mechanical stress. This is defined with a curve showing the number of temperature variation cycles to device failure. In this specific case, it is an experimental curve obtained by testing a significant number of devices versus defined temperature variation value ranges. The thermal transient is fast enough so that the stress is bounded to the aluminum top metal layers. The resulting curve "number of cycles versus Delta T" fits with the Coffin Manson law (figure 1). It is an exponential curve modeling of thermo mechanical stress applied to a metal subjected to temperature variation.

Now we have all the data to perform our system definition and validation using the following steps.

1. Define the mission of the device as follows: N1 @ DeltaT1, N2 @ DeltaT2, Ni @ DeltaTi, where N1, N2, Ni are number of activations of a given deltaTi;

2. From the stress characterization, we can derivate the different stresses applied to the device: NF1 @ DeltaT1, NF2 @ DeltaT2, NFi @ DeltaTi, where NFi is the number of cycle to failure at a given DeltaTi;

3. Calculate the cumulative damage applied to the device. The damage is defined as 1/NF, so the cumulative damage is given by S 1/NFi = 1/NF1 + 1/NF2 + ….+1/NFi. This value must be lower then 1 and clearly a low value correspond to a low stress and hence to a high reliability margin.

Let's make an example

The VND5025AK is a VIPower M0-5 25mW dual channel high side driver typically used in turn indicator functions. Like all the other VIPower M0-5 devices, this device is equipped with a dynamic temperature control that limits the maximum temperature variation to 60K with a hysteresis of 30K. The maximum DeltaT = 60K has been chosen because the corresponding thermo mechanical stress is still elastic (i.e. not permanent) so the damage is extremely limited. (NF = 2.5 E 6 @ Delta T = 60K , NF = 30 E 6 @ Delta T = 30K) Let's consider a VND5025AK driving a set of 2x P21W + R5W automotive lamps at T_{AMB}= -40°C and VBATT=16V. This is a widely diffused automotive turn indicator configuration, The interaction of the protection with the lamps induces a DeltaT1=60 K plus 8 times a DeltaT2…T8 = 30K (figure 2). Supposing that the mission is 500K activations, the resulting damage after 500K activations is 0.233 that is far below 1.

To verify the effectiveness of the built-in dynamic temperature control, we can now evaluate the damage on the same device supposing to disable the DeltaT limitation control. In this case, the interaction of the device with the lamps would induce a DeltaT = 110K (figure 3) that, according to the physical structure characterization, corresponds to a maximum number of activations NF = 100E+3.

Thus, after 500k activations, the cumulated damage would be S 1/NFi = 5 that is much higher then the maximum allowed value. This means that our dynamic temperature control has enhanced the reliability of the device by a factor > 20 (figure 4).

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Experimental Detection and Simulation of Temperature Distribution of Smart Power Devices Designed for Automotive Applications

Automotive applications need special treatment

Here follows a special report from the University of Naples covering the specialised area of automotive power electronics, in particular studying electro-thermal phenomena of power devices

By Andrea Irace, Giovanni Breglio and Paolo Spirito
University of Naples Federico II,
Department of Electronic and Telecommunication Engineering, Ital

The incredible demand for reliability of power electronic devices used in automotive application, sometimes with less than one device failure over one million samples, demand for design and characterization tools useful for implementing rugged designs and to investigate unusual failure mechanisms. This is particularly true when effects other than simple electrical behaviour, such as electro-thermal dynamic interactions, appear to limit or eventually jeopardize the long-term reliability of the power device.

In the department of Electronic Engineering of the University of Naples Federico II the research group has been studying electro-thermal phenomena both theoretically, numerically and from an experimental point of view. In what follows we present two of the most interesting outcomes of this research, a dynamic infrared microscope capable of detecting surface temperature on chip with a space resolution of less than 20µm and with a time resolution of less than 2µs and a 3D electro-thermal simulation tool capable of taking into account also particular driving strategies of the electron device, as it may be the case of Smart Power MOSFETs (Fig.1) where a control logic interacts with the power section and controls its dissipated power and temperature. Both these tools have been used to help leading semiconductor manufacturers in understanding their reliability issues and consequently to improve their designs.

The IR microscope

The detection of the temperature

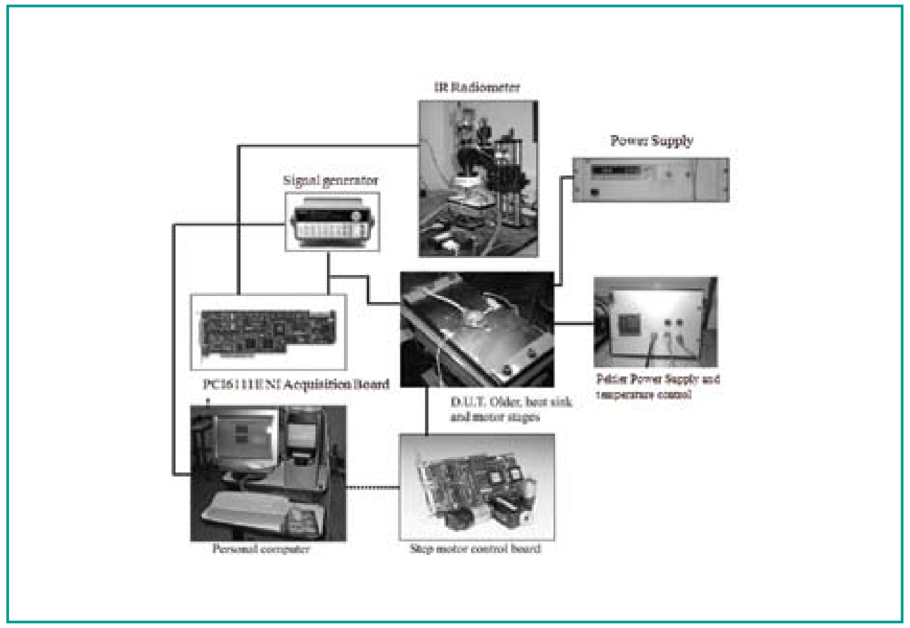

Figure 1: Thermal analyses experimental set-up. The control of the entire system signal is made via GPIB bus.

distribution across the area of the device in transient conditions is made possible by the use of a custom developed radiometric 2D measurement system that allows acquiring the transient temperature maps of the device surface. We use a fast (actual time resolution is less than 2ms) single cooled Cd-Mg sensor mounted in a microscope optical chain that has an equivalent spot size of about 10mm with a working distance of 2.5 mm. In order to perform a 2D scanning of the surface to be mapped, we use an x-y step motor stage controlled via a motor control card installed in a PC which controls device biasing and data acquisition. In such way, the device under test is shifted with respect to the microscope spot, and it is possible to cover the entire surface under observation. The step by step acquisition of the radiometric waveforms coming from the sensor is performed by means of a 5MS/s 12bit A/D converter card that connected via the PCI bus into the PC converts and elaborates the output detected signal. The acquisition software also performs the pre-filtering of the detected signal by using an averaging procedure to increase the signal to noise ratio. The schematic representation of the experimental set-up is sketched in figure 1.

It is important to remember that radiometric systems are able to perform absolute thermal measurement only if the target emissivity coefficient is known. Unfortunately, the surface of power devices is often composed of different materials (i.e. aluminium, passivation, silicon oxide, etc.) that are characterized by different emissivity coefficients. Hence, in our thermal mapping procedure, a preliminary characterization step is also performed in order to determine the emissivity coefficients of the points that define the acquisition grid.

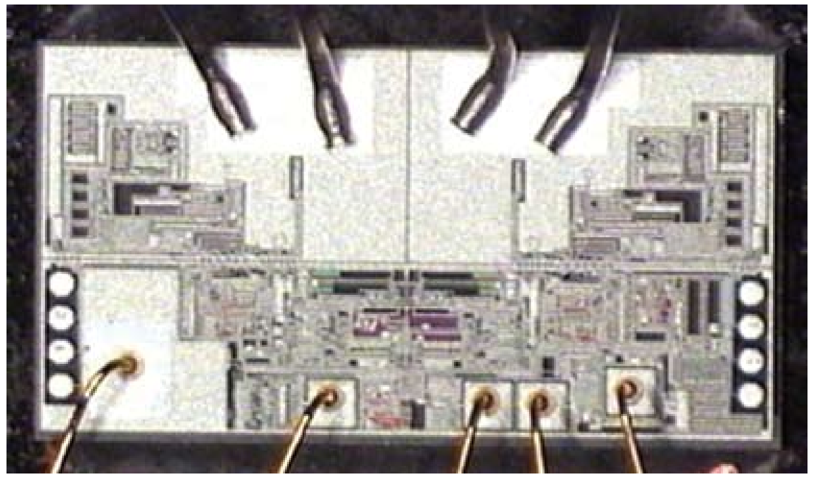

Figure 2: An optical picture of the two channels monolithic smart Power MOSFET (VND830SP).

THERMOS3: a 3D electro-thermal simulator

The THERMOS^3 simulator we propose, entirely written in MATLAB, is based on a forward iterative finite difference time domain scheme where the electrical equivalent of the thermal problem and the electrical quantities (drain current, source voltages) are solved self-consistently at each discrete time step. Non linearity in the thermal conductivity together with voltage depolarization due to finite resistance of the source metallization is explicitly taken into account. The $I_D=f(V_{GS},V_{DS},T)$ behaviour of the unit cell is modelled considering temperature dependence of the threshold voltage, mobility and MOSFET internal resistances. Convection on the surface and sides and isothermal boundary condition at the heatsink has been used.

As an exhaustive example of the capability of this new tool we present the simulation of a smart power device produced by STMicroelectronics (Fig.2). To comply with automotive requirements this class of devices includes several protections. The more restricting rule driving the protection strategy of the Power actuator is to avoid false short circuit detections in the harsh and very noisy automotive environment. Beside a high level of EMI immunity the devices should not turn

PowerPack Power Systems Design

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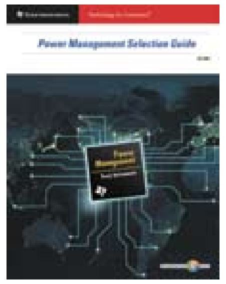

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Anderson Power

Anderson Power Products® (APP), offers its PowerMod® HP (high power) series connector family, featuring touch-safe female housings, cable strain relief and integral positive latches. These safety features, combined with the ease of connector assembly, establish a new standard for cost effective high power connectors.

APP's PowerMod HP Series is RoHS Compliant and rated up to 450 amps for appropriate applications at a 30° C temperature rise. Using APP's patented Sterling contact technology, the PowerMod HP offers low electrical resistance, provides a minimum of 500 mating cycles and is rated for circuit interruption (true hotplug). These connectors are IP 20 rated (touch safe) for user safety. The integral coding key provides further protection by allowing the user to configure unique mating of up to 6 individual connectors. For additional information visit their web site at:

To learn more: www.andersonpower.com

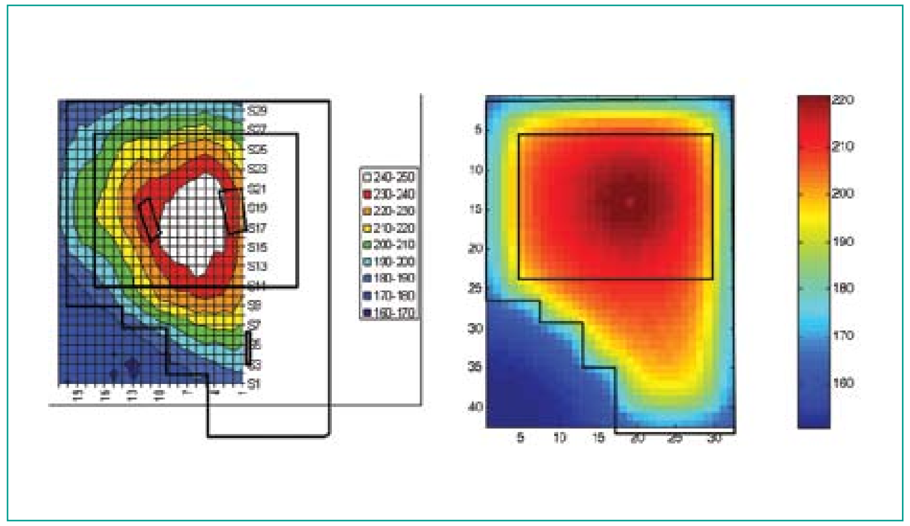


Figure 3: Temperature distribution on chip: experimental (left) and simulated (right).

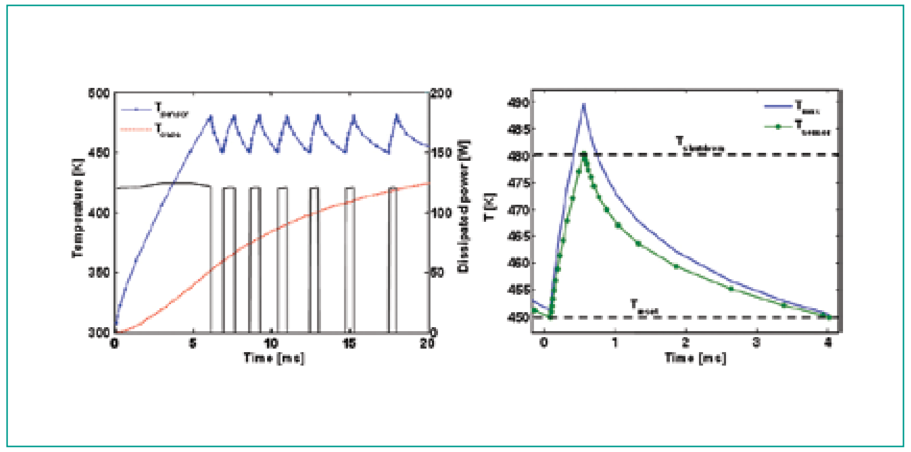


Figure 4: Simulation of the permanent short circuit protection on a VND-800PEP device with a detail of a single heating-cooling transient with comparison between the maximum temperature on chip and temperature detected by the thermal sensor

off either for an inrush condition either for intermittent short circuit. The short circuit protection is implemented using negative feedback to ensure stability and to maintain the device in a predictable status in every condition. A current limitation combined with thermal shut down intervention protects the power device during short circuit operation. The integrated current feedback fixes the working point in the active area of the Power stage. The resulting high power dissipated equal to battery voltage multiplied by Drain current leads to a fast increase of the thermal sensor temperature and to the intervention of thermal shut down block.

Scaled technology permitted a significant die size reduction and the Ron*mm^2 has decreased by a factor 10 in the last 10 years. As a result the size of the silicon can be reduced significantly for the same targeted load. On the other hand the short circuit current of the device cannot be reduced because this value needs to be higher than the inrush current of the targeted loads. The result is that also the power density generated in the device during short circuit increased also by a factor of 10.

To compare and validate the outcome of THERMOS^3 we have experimental temperature map at our disposal. In Fig.3 we report a comparison between experimentally detected temperature distribution and the result of the simulation. As we can note a good quantitative agreement is obtained both in shape and in peak temperature value.

To further investigate the features of the simulator we would like to underline that a well designed thermal shutdown strategy relies on the optimal position of the thermal sensor on the device surface. If this should not be the case, temperature difference between the sensor and the maximum temperature reached on chip can be observed and reliability of the device can be eventually impaired as temperature fatigue of the metals and soldering joint might increase the Ron of the device. In Fig.4 we report a simulation where the temperature sensor has been deliberately placed far from the region where temperature reaches its maximum, we notice how, even if the sensor is correctly switching the device, the maximum temperature on chip reaches values higher than Tshutdown.

From figure 4 the PWM modulation of the dissipated power and the timestepping strategy can also be observed. In particular it is noticeable that as temperature at the sensor location reaches the shutdown threshold timestepping is reduced thanks to the predictive event detection algorithm and the same happens when temperature reaches the reset value with a negative slope.

The value of such a tool in the design stage of a smart power device is straightforward as it can be used to optimize the whole design, influence of layout (i.e. position of temperature sensors, bond pads location etc.) and to investigate the performances of different protection strategies.

www.unina.it

Avago Technologies Introduces New Extra Bright II Oval Red, Green and Blue LEDs for Electronic Signs and Signals Applications

Avago Technologies has announced a new series of Extra Bright II oval Red, Green and Blue light emitting diodes (LEDs) for the electronic signs and signals (ESS) market. Avago's series of 4 and 5mm oval through-hole LED lamps have been specifically designed for use in full color ESS applications such as passenger signs, variable message signs, scoreboards and channel lighting. Avago is a leading supplier of analog interface components for communications, industrial and consumer applications.

Avago's HLMP-Lx63 (4 mm) and HLMP-Hx63 (5 mm) series of LEDs provide an oval shaped radiation pattern, a wide viewing angle and high illumination intensity to make display characters viewable from any angle in bright sunlight. Moreover, these LED lamps have a very smooth, matched radiation pattern to ensure consistent color mixing in full color applications. Each lamp is made with advanced optical grade epoxy to offer superior high temperature and high moisture resistance in outdoor ESS applications.

Designers of electronic signs and signals are seeking higher brightness levels to reduce the number of LEDs in a cluster. With Avago's HLMP-Lx63 and HLMP-Hx63 series of extra-bright 4 and 5 mm oval through-hole LED lamps, electronic signs can be designed using fewer individual LEDs to provide equivalent brightness. Alternatively, signs can be designed with the same number of LEDs, providing substantially higher brightness levels for better readability and contrast. The lead spacing and packages are compatible with conventional high-brightness 4 and 5 mm standard and miniature oval-pattern LED lamps.

The extra-bright HLMP-Lx63 and HLMP-Hx63 through-hole oval LED lamps are supplied in Avago's precision optical performance molded packages to offer high brightness and low power consumption. The packaging design coupled with carefully selected materials allows the lamps to perform with high reliability in a wide temperature range, which is crucial for outdoor applications where the LED is exposed directly to ultraviolet radiation and humid environments.

www.avagotech.com

New Three Channel LED Driver IC Provides High Current Accuracy

Supertex has introduced the HV9982, a new three channel LED driver IC designed to provide high LED current accuracy through closed loop control of the output currents. It is specially designed for applications using RGB LED backlighting or multiple strings of white LEDs.

The HV9982 employs a fixed frequency, closed-loop, current mode control architecture that ensures stable operation over a wide range of input and output voltages. Its high-side current sensing allows it to be used in buck, boost or SEPIC configurations while delivering ±1% current accuracy between strings. The HV9982 features an internal 40V linear regulator providing an 8V power supply to the IC. The IC utilizes an internal control with an external clock source to facilitate synchronization.

Each channel of the HV9982 can drive a LED string of up to 200V, with efficiency greater than 90%. The output current range of each channel is user-programmable with an external sense resistor and can be individually dimmed using either linear or PWM dimming. Three built-in disconnect FET drivers enable high PWM dimming ratios. Programmable slope compensation allows for synchronization and greater than a 50% duty cycle in fixed frequency operation. The IC also includes hiccup mode protection for both open LED and short circuit conditions.

"Because of its closed-loop architecture, the HV9982 delivers exceptionally accurate line and load regulation for multiple LED strings, " states Ahmed Masood, Vice President of Marketing for Supertex. "With the ability to be configured in buck, boost, or SEPIC topologies, and advanced features such as OVP, short circuit protection, and accurate PWM control, this device sets a new benchmark for LED driving applications."

www.supertex.com

Ericsson's Third Generation POLATM Modules Improve Performance and Save Board Space

Ericsson Power Modules' PMN and PMP series point-of-load modules, based on the latest generation of high dynamic-response control IC with embedded TurboTrans™ functionalities, are third-generation POLA™ products. As point-of-load (POL) power modules, they address a wide range of applications – from industry to avionics – including applications in the Information & Communication Technology (ICT) industry.

The modules are the PMN 5118U, rated at 4.5-5.5Vin, 0.7-3.6V @ 30A; the PMN 8118UW, rated at 5.5-14Vin, 0.7-3.6V @ 30A; and the PMP 5818UW, featuring a rating of 4.5-14Vin, 0.7-5.5V @ 16A. The wide input range and fast transient response of these modules makes them particularly suitable for the new generation of DSP and microprocessors that demand such performance levels.

Additionally, and as a result of their TurboTrans™ features, the modules can be operated with far fewer output capacitors than traditional point-of-load devices, reducing the amount of board space required by voltage regulators, and resulting in a much higher power density than conventional units.

Telecom and datacom (router, servers and interfaces) are the prime areas of deployment for the PMN and PMP, but the performance of these products makes them ideal for powering FPGA, DSP and other ASICs requiring a fast transient response and high efficiency at a competitive price.

www.ericsson.com/powermodules

600V/30A IGBT Improves Energy Efficiency in Low-Frequency (50 ~ 400Hz) Industrial Applications

Fairchild Semiconductor's new 600V/30A IGBT, the FGH30N60LSD, addresses the need for low conduction losses in low-frequency (50~400Hz) industrial applications such as solar inverters, welding machines and uninterruptible power supplies (UPS). Featuring extremely low saturation voltage ($V_{CE(sat)}$, Typ. = 1.1 V), the FGH30N60LSD is specially designed to increase system efficiency while meeting low-frequency requirements. For further energy efficiency in industrial applications which are using both low frequency switches and high switching frequency switches such as solar inverters, this IGBT can be combined with Fairchild's FCH47N60F SuperFET™ FRFET®, an advanced MOSFET that offers high operating frequency of up to 250 kHz and extremely low on-resistance ($R_{DS(on)}$, Typ. = 0.062 Ohms).

"Energy efficiency is one of the primary concerns of today's industrial applications such as solar inverters, welding machines and UPSs," says Donghye Cho, director of Fairchild' s High Voltage Functional Power Solutions. "By tailoring our new IGBT to achieve extremely low conduction loss and then combining this product with our SuperFET MOSFET offering high switching frequency and low $R_{DS(on)}$, Fairchild demonstrates its ability to solve complex design challenges."

The FGH30N60LSD is a MOS-gated high-voltage switching device that combines the best features of MOSFETs and bipolar transistors. This device integrates a fast-recovery diode (FRD) to help designers reduce component count while further ensuring system reliability. Uniting SuperFET technology with a lifetime killing process, our SuperFET FRFET offers improved body-diode characteristics, which enable operation at high switching frequency, extremely low on-resistance, excellent turn-off dv/dt immunity and low EMI. All of these features increase system efficiency and reliability.

Fairchild's FGH30N60LSD utilizes lead-free (Pb-free) terminals and has been characterized for moisture sensitivity in accordance with the Pb-free reflow requirements of the joint IPC/JEDEC standard J-STD-020. All of Fairchild's products are designed to meet the requirements of the European Union's Directive on the restriction of the use of certain substances (RoHS)

www.fairchildsemi.com

Companies in this Issue

Please note: **Bold**—companies advertising in this issue

LED to Lead the Way

An excerpt from Vinod K. Sharma/ New Delhi, as recently published in the Business Standard

Reported by Cliff Keys, Editor-in-Chief, PSDE

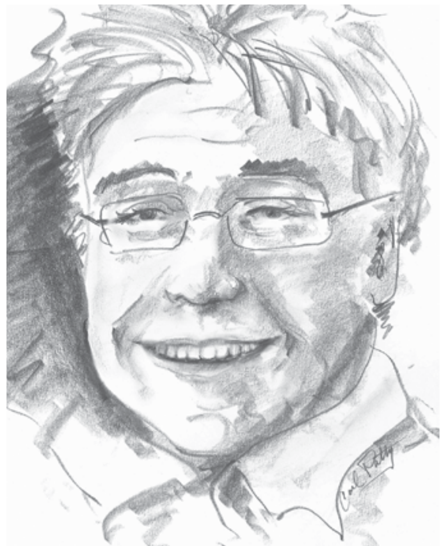
Light, they say, is the darkest chapter of physics. No wonder that 128 years after Thomas Alva Edison invented the light bulb out of fear of darkness, it continues to rule the roost in terms of domestic lighting, not in India alone, but even in the developed countries.

The incandescent bulb, emits only 5per cent of the energy it consumes as light. The rest is emitted as heat, resulting in wastage of energy. That makes the bulb a highly inefficient lighting device. Next in the line are fluorescent lights. Compact fluorescent lamps (CFL) convert between 6-15per cent of the energy into light, emerging as a viable alternative to the bulb.

That these lamps can be fitted in the same holder that holds the incandescent bulb makes them an attractive replacement bet. New investments need not be made in fixtures.

Also, the life of CFL lamp can be as high as 10,000 hours as compared to around 2,000 hours for an incandescent bulb, provided you have already not knocked it down while cleaning the dust.

The tungsten filament in the bulb is yet another weak link in the chain, which makes the bulb vulnerable. The only thing going for the bulb is the low initial price.



As the use of CFL spreads and the volumes improve, the cost of CF lamps could tumble, thereby increasing usage.

While things could become better with more CFL usage, the future clearly lies with LED or light emitting diodes, a technology that has been around for over four decades but is only now being commercialized for everyday use.

An LED lamp consumes far less energy for the same degree of brightness. For instance, it would consume only 6W as against 60W for an incandescent bulb and 14W for CFL for a brightness of 800 lumen. And it could last almost 40,000 hours as compared to 2,000 hrs for an incandescent bulb and 10,000 hours for CFLs.

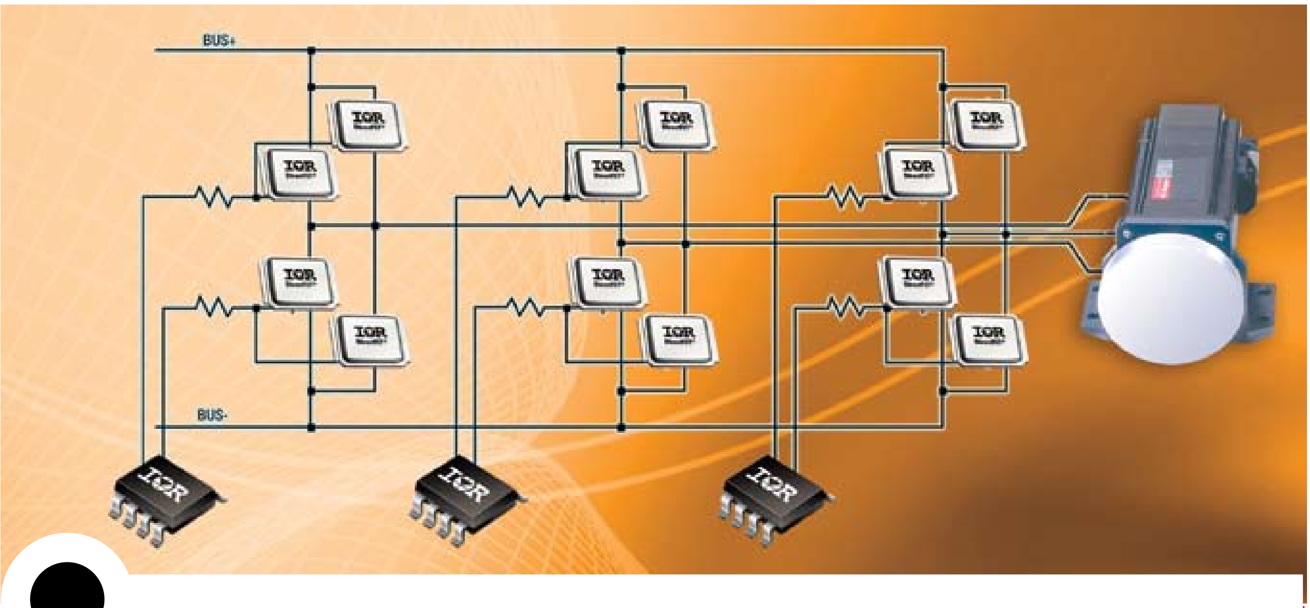
These economic reasons apart, another advantage of LED is it is a solid state lighting system. The term solid state is a reference to light in an LED emitting from a solid object, a block of semiconductor, rather than from a vacuum or gas tube.

This makes them thermal and vibrational shock proof and, therefore, the preferred choice in cabin lighting systems in aeroplanes.

One advantage LED would have over CFLs is that they are environment-friendly and do not use environment degrading halogens and gas vapours. Since 1970, the efficiency of LEDs has improved 10-fold every 10 years.

That would enable LEDs to eventually achieve over 95 per cent efficiency, something that would make LEDs a household name. And companies in the LED lighting systems business would have a future brighter than the lamps they will make.

www.powersystemsdesign.com/greenpage.htm



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IRS2001SPBF	SOIC8 Bulk					
IRS2001STRPBF	SOIC8 Tape & Reel					
IRS2003PBF	DIP8	UVLO, VCC	RoHS & PBF	290 mA / 600 mA	HIN, LIN/N	Deadtime
IRS2003SPBF	SOIC8 Bulk					
IRS2003STRPBF	SOIC8 Tape & Reel					
IRS2004PBF	DIP8	UVLO, VCC	RoHS & PBF	290 mA / 600 mA	IN, SD/N	SD Input & deadtime
IRS2004SPBF	SOIC8 Bulk					
IRS2004STRPBF	SOIC8 Tape & Reel					

DirectFET® MOSFETs

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

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