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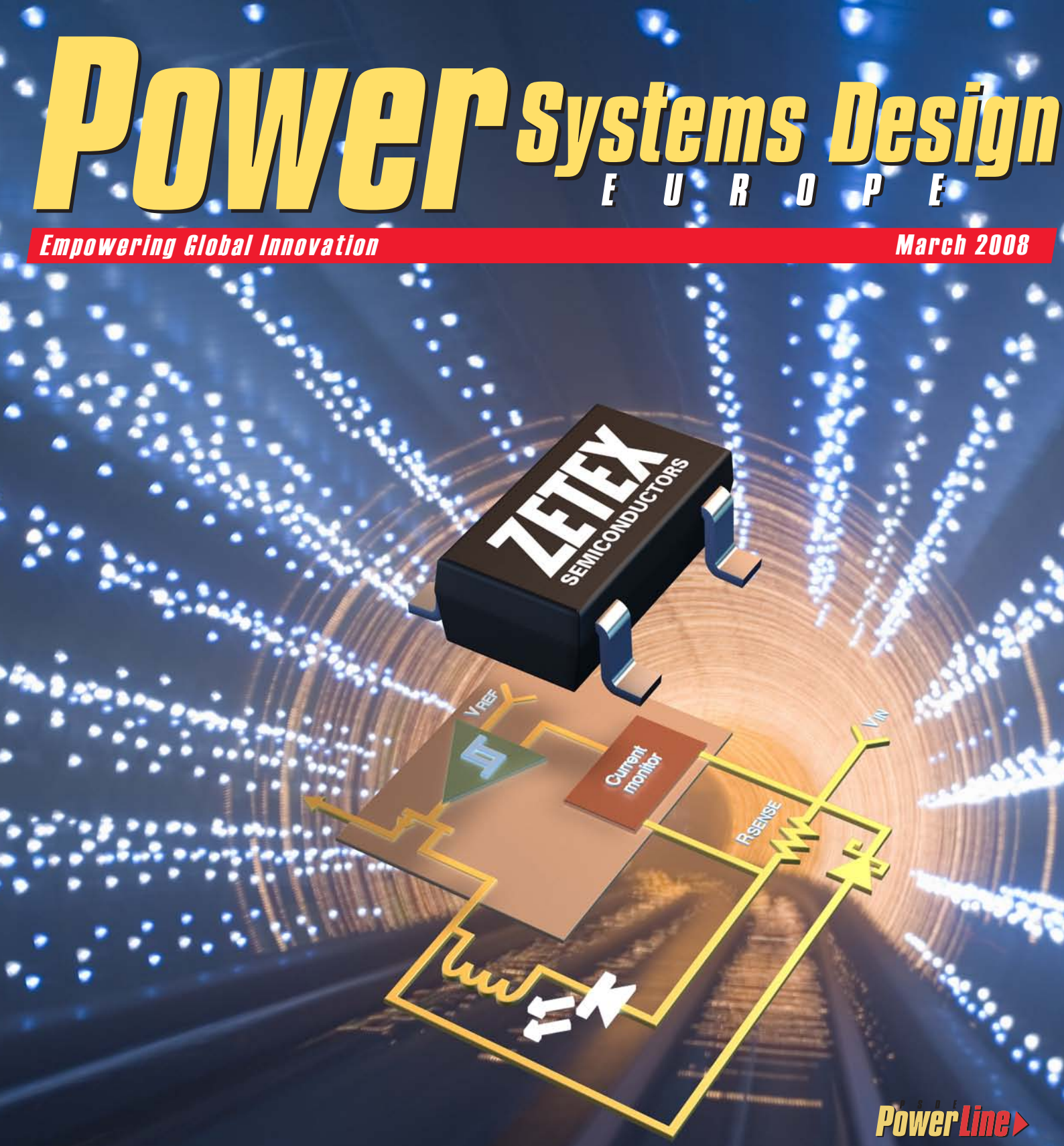
March 2008



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Special Report - Lighting Systems Part I

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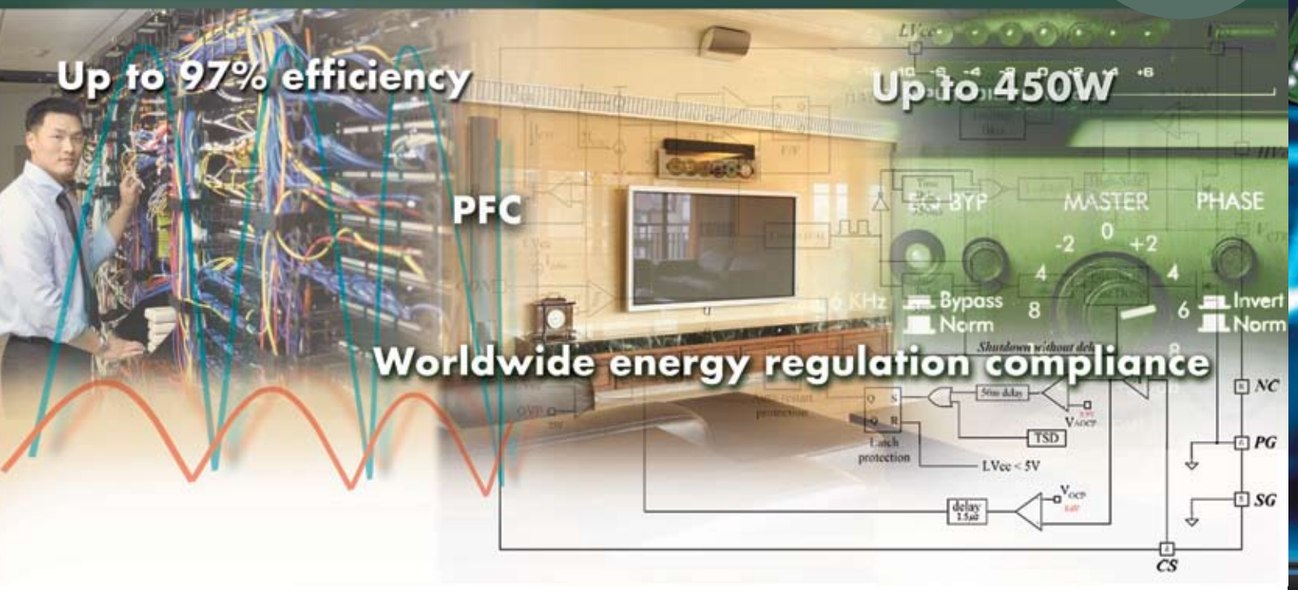

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Power Systems Design EUROPE


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Power Systems Design Europe

AGS Media Group
146 Charles Street
Annapolis, Maryland 21401 USA
Tel: +410-295-0177
Fax: +510-217-3608
www.powersystemsdesign.com

Editor-in-Chief
Cliff Keys
cliff.keys@powersystemsdesign.com

Contributing Editors
Liu Hong
Editor-in-Chief, Power Systems Design China
powersdc@126.com

Marijana Vukicevic, isuppli Corporation
mvukicevic@isuppli.com

Dr. Ray Ridley, Ridley Engineering
RRidley@ridleyengineering.com

Publishing Director
Jim Graham
jim.graham@powersystemsdesign.com

Publisher
Julia Stocks
julia.stocks@powersystemsdesign.com

Circulation Management
Kathryn Ferris
kathryn.ferris@powersystemsdesign.com

Research Director
Meghan Corneal
meghan.corneal@powersystemsdesign.com

Magazine Design
Beata Rasmus, Eyemotive
beata@eyemotive.com

Production Manager
Abby Wang
abbyw@action-new.net

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circulation@powersystemsdesign.com

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Volume 5, Issue 2

Illuminating Times Ahead

Energy efficiency and renewable sources are at the very top of the priority list for industry leaders, politicians and a compelling ongoing story for the broad media. These issues are now therefore becoming 'front of mind' issues in the general public domain. This all makes great press and interesting reading, but more importantly for us, raises the profile -and rightly so- of the vital future role of the power designer and our industry as a whole.

If we toss aside those who merely slipstream real industry progression for their own political agendas, we find that the dynamic force driving forward the progress of real solutions in this critical area clearly comes from engineering and engineering management in its many diverse disciplines.

After returning from APEC, held this year in Austin, Texas, I am refreshed in the knowledge that in engineers' hands and minds we are safe. The products and technologies displayed at the conference captivated my attention for the five days I was there and I share this information with you in my APEC Roundup..

At the end of 2007 President George Bush signed the Energy Independence and Security Act into law. He announced that this would make a major step toward reducing dependence on oil, confront global climate change, expand the production of renewable fuels and give future generations (in the US) a nation that is stronger, cleaner and more secure adding that the bill included revisions to improve energy efficiency in lighting and appliances.

In fact, the bill will certainly give a clear path for alternative lighting with a mandated phase-out of inefficient incandescent bulbs in favour of more efficient lighting solutions such a compact fluorescent lamps (CFLs) and LEDs.

The Act gives a great financial boost to the industry for developers and manufacturers, through the 'Bright Tomorrow Lighting Prizes', totaling USD $20 million. There are three prizes to be awarded.

Ten million dollars is for the 60-Watt Incandescent Replacement Lamp Prize and will be awarded for a standard A19 form factor in a single contact medium screw base. It will have to produce minimum 900 lumens using less than 10 watts or an efficacy of >90 lm/watt. The color rendering index (CRI) must be 90+ with a correlated color temperature (CCT) between 2750K and 3000K. Lumen longevity must be 70% at 25000 hours. The lamp must also be available commercially by conventional channels.

A further Five million dollars will go for the PAR Type 38 Halogen Replacement Lamp Prize. This lamp must produce 1350 lumens with less than 11 watts, or an efficacy of 123 lm/watt or greater. All other criteria are the same as for the 60 W incandescent lamp replacement.

The final five million dollars is for the 'wildcard award' - the 21st Century Lamp Prize for producing 1200 lumens at an efficacy exceeding 150 lm/watt, with a CRI of 90 or greater and a CCT between 2800K and 3000K.

The US Department of Energy will administrate the competition which is essentially for US-based companies. It will be interesting to see what lies ahead for our community here in Europe.

In this issue of PSDE, we run with the theme of "Lighting Systems Part I", one that has proven highly popular, particularly and not surprisingly in the LED arena. I hope you enjoy it and, as always, keep the feedback coming.

All the best!

Cliff Keys

Editor-in-Chief, PSDE
Cliff.Keys@powersystemsdesign.com

Cree to Acquire LED Lighting Fixtures, Inc.

Cree has announced the signing of a definitive agreement to acquire privately-held LED Lighting Fixtures, Inc. (LLF).

LLF is pioneering the development of LED lighting retrofit products and is recognized in the lighting industry as the first company to develop a viable, energy-efficient, “no-compromise” LED down-light for general illumination. This award-winning product is being used in commercial and residential applications and is based on the combination of Cree’s lighting-class XLamp® LEDs and LLF’s patented color-mixing technology that produces both very high efficiency and superior color quality.

The acquisition will expand Cree’s market opportunity by providing direct access to the lighting market. It will enable Cree to drive retrofit solutions to convert existing lighting infrastructure to energy-efficient lighting and to accelerate the adoption of LED lighting. With this acquisition, Cree's business will encompass LED chips, components and lighting solutions.

“The combination of Cree’s lighting-class LEDs and LLF’s lighting-systems technologies should set the stage for Cree to obsolete the light bulb, a 19th century invention that wastes energy and pollutes our environment," said Chuck Swoboda, chief executive officer of Cree. “We believe the market is at a tipping point, with billions of sockets in existing fixtures now addressable with energy-efficient LED lighting. Accelerating this market transformation benefits Cree, our LED customers and lighting consumers.”

LLF will be renamed Cree LED Lighting Solutions. Neal Hunter, chairman and chief executive officer of LLF and Cree co-founder, will rejoin Cree as president of Cree LED Lighting Solutions. The remainder of the LLF management team will continue in their roles within the organization.

"Cree is as passionate as we are about moving the lighting market forward and making an impact on energy consumption into the next decade and beyond," said Hunter, LLF chairman and chief executive officer. “This acquisition should make Cree a powerful force for innovation around cutting-edge LED lighting solutions that are unmatched in the industry."

www.cree.com

Digi-Key Corporation and SSI Technologies, Inc. Announce Global Distribution Agreement

Electronic component distributor Digi-Key Corporation and SSI Technologies, Inc. have announced that the companies have entered into a worldwide distribution agreement. SSI Technologies, Inc. is a leading designer and manufacturer of sensors, sensors based monitoring and powdered metal products for the transportation, heavy equipment, manufacturing, process and many other industries and applications.

The SSI Technologies MediaSensor™ P51 pressure transducers and MediaGauge™ digital pressure gauges stocked by Digi-Key are featured in its print and online catalogs and are available for purchase directly from Digi-Key. This new distribution agreement with SSI Technologies will enable Digi-Key to fulfill both the design and production quantity needs of its diverse customer base.

"We are very pleased to add SSI Technologies to our repertoire of supplier partners," said Mark Larson, Digi-Key president. "Designed for industrial and commercial applications where cost, size and performance are critical, SSI’s products are certain to be of consequential interest and appeal to our customers."

"We are excited that Digi-Key, with its strong leadership position in this industry, will carry and promote SSI products as part of their comprehensive offering," said Matt Weber, vice president and general manager of SSI’s Controls Division. "We look forward to a mutually beneficial relationship."

www.digikey.com

Growth Potential for Automotive LEDs

Twelve white OSRAM Advanced Power TOPLEDs per headlight now provide daytime running light on the Audi A4.

According to a recently published report, 'LEDs in Automotive Applications', from IMS Research, the car is becoming an increasingly important source of applications for light-emitting diodes (LEDs) as an alternative to incandescent light bulbs and halogen and xenon lamps.

Their importance is set to rise substantially, doubling from a EUR0.45billion ($0.65billion) business in 2006 to EUR0.90billion ($1.3billion) within 10 years.

Today most of the value comes from applications inside the car, such as backlighting dashboards and displays, and supplying a wide range of indicator lamps. However, the LED value from external lamps will rise from one-third of the LED total to over one-half by 2013. Most external LED lamps are used at the rear, as brake, tail and turning lights. However, analyst Jamie Fox states: “Daytime running lights (DRLs) will become much more widely used in the future. The DRL business will grow from under $5million [EUR3.48million] last year to over $100million [EUR69million] by 2013.”

Not all cars use DRLs. In some countries, such as Canada, Finland and Sweden, they are obligatory. In other countries, such as the USA, they are not required but are used on many vehicles. In some countries, such as the UK, they are little used. However DRL use is growing overall. In particular, EU studies have concluded that DRLs save lives, so a law requiring DRL use throughout the EU is widely anticipated.

DRLs will offer a good opportunity for LEDs, according to Fox: “LED DRLs have long lifetime and low power consumption, as well as an attractive appearance.” LED DRLs, which were first introduced on the Audi A8 in 2004, are currently used on less than one per cent of vehicles. However, IMS Research forecasts that, with very strong growth after 2009, the market revenues for LED DRLs in the next decade will be similar to revenues for LEDs for functions used in rear lighting applications today.

www.imsresearch.com

SL Power Electronics to Market and Support Teal Products Across Europe

SL Power Electronics Corp. announces that it has formed a partnership with fellow SL Industries subsidiary company TEAL Electronics, the leading developer of OEM power conditioning equipment and power subsystems, with a focus on the Medical Imaging, Medical Treatment, Defence-Aerospace, and Semiconductor Test markets.

With immediate effect, SL Power Electronics will market and support the TEAL product offering throughout Europe from its HQ in the UK and from its German facility in Moerfelden-Walldorf.

Commenting on the partnership with TEAL Electronics, European Managing Director for SL Power Electronics Nigel Davies says, “All of us in Europe are excited about the potential offered by the TEAL product range. The products are used worldwide in CT, X-Ray, and MRI applications, and include the innovative internet-based remote power monitor, TEALwatch®.”

TEALwatch is an embedded power monitor that can be integrated into 3-phase OEM power subsystems to provide 24/7 monitoring from anywhere using standard web-browser software. It is easy to use and has fully adjustable and programmable triggering set points for maximum flexibility.

www.slpower.com

Day4 Energy Completes 1 MW Solar Project with German Energy Supplier EnBW

Day4 Energy Inc., a leading manufacturer of high performance, cost-effective solar electric modules, has completed the first months of operation of the 1 megawatt (MW) solar energy project with EnBW, one of Germany's largest energy suppliers. Delivering reliable renewable energy to the area of Sigmaringen, the photovoltaic (PV) installation is the largest to-date for both companies. Based on the system's successful completion and favorable initial performance, EnBW has now extended its contract with Day4 and scheduled two additional large-scale projects set for construction in 2009 and 2010.

Located in Riggenbach, Germany the solar energy project was formally brought into operation in October 2007 at a dedication ceremony attended by the State of Baden-Württemberg's Minister for Environment Tanja Gönner. Day4 Energy's German project management subsidiary Day4 Systems supplied the solar energy array's more than 6,200 highly efficient Day4 48 MC solar modules on 2.3 hectares of former landfill. The system will generate enough clean power to meet the energy needs of 300 German homes per year and avoid approximately 750 tons of carbon dioxide emissions annually, the equivalent of removing 469 German cars from the road per year.

www.day4energy.com

XP Power Expands Production Facilities in Shanghai

XP Power announced today that it has bought out its partners 50% shareholding of their manufacturing joint venture, Forton XP Power. The $2.5m deal gives XP Power complete control and ownership of the power supply manufacturing operation that was established with Forton in 2006.

Expansion plans, already commenced, will provide an additional 6000 sq m of manufacturing and administration space. As part of the increased manufacturing facilities, a short-run production line will be set up. This will allow pre-production units to be delivered to customers within 4 – 6 weeks of order. With an increasing number of customers requiring modified standard power supplies, the short-run facility will also give customers early access to product so that they can complete their own prototype and system testing early.

James Peters, Deputy Chairman XP Power comments, “Driving down product cost and having total control of product quality are extremely important to us. This acquisition enables us to achieve both these goals. A strict quality regime is vital to our business; our customers, large and small, highly value it too.” He continues, “Having our own purchasing team in the region means we can review the build cost as part of our design cycle with a bill of materials based on locally available parts. Unit design can be quickly adapted should some components prove to be difficult or expensive to source. We believe that being totally responsible for product quality, designing-in at point of component source and the introduction of a short-run facility gives us a strong competitive edge.”

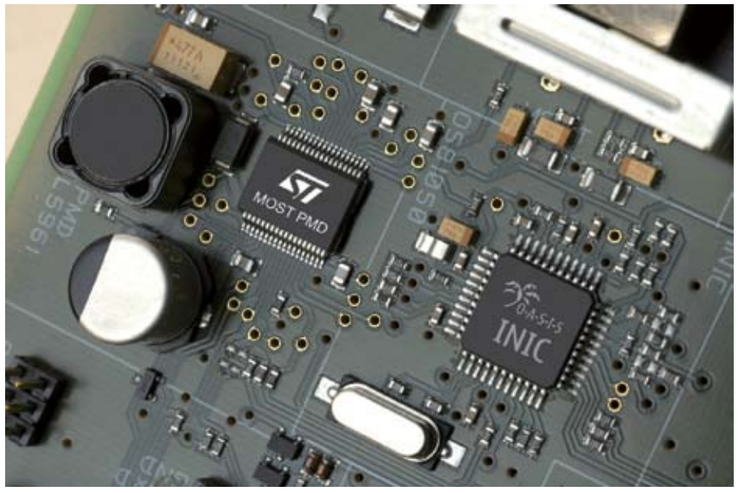
www.xppower.com

Power Events

- ***China Hydrogen Energy & Fuel Cell Exhibition,***
  March 31-April 2, Shanghai, China, www.fuelcelltoday.com/events/event/2008-03/2008-China-Hydrogen-Energy--amp-
- ***SENSOR+TEST 2008,***
  May 6-8, Nürnberg, Germany, www.sensor.test.de
- ***PCIM Europe 2008,***
  May 27-29, Nuremberg, Germany, www.mesago.de/en/PCIM/main.htm
- ***euroLED 2008,***
  June 3-5, Birmingham, United Kingdom, www.euroled.org/2008/index.php
- ***European Fuel Cell Forum 2008,***
  June 30-July 4, Lucerne, Switzerland, www.efcf.com/exhibition/
- ***EPE-PEMC 2008,***
  September 1-3, Poznań, Poland, www.epe-pemc2008.put.poznan.pl
- ***23rd European Photovoltaic Solar Energy Conference,***
  September 1-5, Valencia,Spain, www.photovoltaic-conference.com
- ***electronicIndia 2008,***
  September 2-5, Bangalore, India, www.global-electronics.net/link/en/16545148
- ***Husum WindEnergy,***
  September 9-13, Husum, Germany, www.husumwind.com
- ***electronicAsia 2008,***
  October 13-16, Hong Kong, China, www.global-electronics.net/link/en/16545145
- ***SPS/IPC/Drives 2008,***
  November 25-27, Nürnberg, Germany, www.mesago.de/en/SPS/main.htm

STMicro Integrated Power Management Chip for Multimedia Networking in Cars

STMicroelectronics, a world leader in automotive semiconductors has announced the launch of the industry's first integrated power-management solution for MOST (Media Oriented Systems Transport) networks. MOST is a networking standard intended for interconnecting multimedia components in automobiles and other vehicles. Unlike many other existing vehicle bus technologies and utilizes optical fiber, so that it can operate at higher bit-rates than wired buses.



Optimized for in car multimedia and infotainment applications, the MOST network also has a wide range of applications in many other industries. MOST technology primarily allows for a range of multimedia devices, such as CD or DVD players, car radios, and personal navigation devices, to be added into the car environment with minimal effort.

The new L5961 power management IC, which has been designed in co-operation with fabless semiconductor manufacturer SMSC to work with that company's MOST network processors, includes both the power supply and MOST-compliant power-management control logic, together with enhanced diagnostic and full system monitoring (power supply, network status, wake-up events, temperature).

A chipset combining the L5961 power-management IC and SMSC network processor can serve as a building block in any MOST network node, and provides significantly more independence from the individual applications that are connected to the network, in terms of turn-on/off timing and device failure, for example. Additionally, the combined chipset, once validated, can be placed in any MOST application without having to be redesigned and revalidated each time.

The current solution in the industry uses discrete components to implement the power management for MOST network nodes. ST's integration of both the power-management control logic and power supply within the L5961 therefore provides several key advantages for automotive OEMs, including significant PCB space savings, lower cost, lower cost of ownership and lower stand-by-mode power consumption, helping to meet specifications recently issued by many leading car manufacturers. In particular, the device features multiple power modes, including an Ultra-Zero Power Mode that offers a typical quiescent current of only 5 microamps, a considerably lower value than that achieved with discrete components. The overall offering is a cost- and space-optimized solution that provides considerable advantages in terms of reproducibility and fail-safe behavior of the application.

Other features of the L5961 include: an integrated 5 or 3.3V, 650mA DC-DC converter, which supplies the network processor and can also supply power to an external low-voltage application; two voltage regulators to supply power to the fiber-optic transmitter and fiber-optic receiver; a diagnostic transceiver for the network physical layer; and the integration of three battery detectors for voltage monitoring, which are currently stand-alone functions in discrete component solutions.

Available in PowerSSO36 packages, or in the PowerSO36 option for applications requiring a higher thermal dissipation, engineering samples of the L5961 are now available to lead customers. Full qualification of the L5961, ready for volume production, is planned for Q3 2008.

www.st.com

LED Lighting – The Next Great Prize?

By Balu Balakrishnan, CEO, Power Integrations

Perhaps the greatest challenge that faces the world at the moment is global warming. Understanding the importance of capturing the public mood and incentivizing change, the US Congress has mandated a $10M prize for the first company to create a commercially viable LED-based screw-in replacement for the standard Edison-type 60-watt incandescent light bulb, while using only 10W of AC power. The prize is one element of the 'Bright Tomorrow Lighting' Prize, which is part of the Energy Independence and Security Act which was recently accepted into US law.

Unlike incandescent or fluorescent light sources that can be powered directly from the mains supply, each LED light bulb requires a power supply to be incorporated within the Edison (E27) or Bayonet (GU10) socket. The winner of the prize will have to earn their victory by combining the best in high-efficacy LED technology with a high efficiency power supply and a heat sinking solution that dissipates waste heat safely. The precise balance of LED efficacy and power supply efficiency may vary, but it' s likely to be somewhere in the order of 120 lumens/watt and 90% respectively. At Power Integrations, we have been concentrating our development efforts on the power supply.

Producing a power supply circuit that fits within such a small space is not a trivial task, especially if you effectively attenuate EMI to the current standards. To address the size constraints posed by this application, we recently started offering our LinkSwitch-TN family of non-isolated offline switcher ICs in tiny SO-8 packaging. We also introduced a design idea (DI-172), describing the circuit details. We hope that this 91% efficient solution will provide those LED bulb and fixture makers aiming for the prize with a good starting point.

We have also been actively working with LED, ballast and fixture manufacturers to develop efficient power solutions for the broader lighting market – from low-power incandescent bulb replacements to street and architectural illumination running up to 200W and beyond. We have discovered that it is up to power specialists to match the tremendous reliability and lifetime offered by LED technology; after all, what is the point of installing LEDs that have MTBF ratings of 50,000 hours or more, if the power supply fails after six months? This is especially true for street lighting and illuminated signage applications. Here companies and city councils may not be so concerned with energy savings, they are more interested in reducing the number of times a light must be replaced.

We have been diligent in developing and maintaining Power Integrations' reputation for reliability. We design our products conservatively so that they always function well within their SOA (safe operating area), then test them all extremely thoroughly. Moreover, because our technology allows us to combine the switching power MOSFET, control functions and protection features on the same piece of silicon, the MOSFET is operated very efficiently and monitored very closely. Also, we include many protection features in our product families – LinkSwitch, TinySwitch, TOPSwitch etc. - including thermal shutdown; output overvoltage shutdown (OVP); line under-voltage (UV) detection to prevent turn-off glitches; line over-voltage (OV) shutdown which extends the line surge limit; accurate, programmable current limits; optimized feed-forward for line ripple rejection; and auto-restart functionality that delivers less than three percent of rated power in short-circuit conditions.

Prizes such as 'Bright Tomorrow Lighting' are often awarded for endurance, speed and exploration. In the past, these kinds of awards have been keenly contested by individuals racing against each other to win and claim their place in history. Today's challenges will not be solved by individuals working alone, nor by any single industry. Power specialists must work with LED companies to find answers that consumer companies can productize, enabling customers – be they governmental, corporate or individual – to choose the efficient, low-energy way forward.

www.powerint.com

Digitally-Controlled Power Semi Market to Approach $1 Billion by 2011

DPMs dominates sales, but DCP revenue rises more quickly

By Marijana Vukicevic, iSuppli Corporation

The market for digitally-controlled power semiconductors is set to emerge from the nascent stage over the next three years, as increased adoption in applications including notebook PCs, servers and Digital Televisions (DTVs) drives revenue to nearly $1 billion by 2011.

Global revenue from shipments of Digital Power Managers (DPMs) and Digital Controllers of Power (DCPs) is set to rise to $904 million by 2011, almost six times the revenue of $153 million in 2007, iSuppli Corp. predicts. DPMs will remain the biggest revenue producer within the digital power semiconductor market, with sales of $613 million in 2011, rising at a Compound Annual Growth Rate (CAGR) of 52.2 percent from a projected $174 million in 2008. However, DCP revenue will grow at a faster rate, rising to $291 million in 2011, for a CAGR of 69.3 percent from $60 million in 2008.

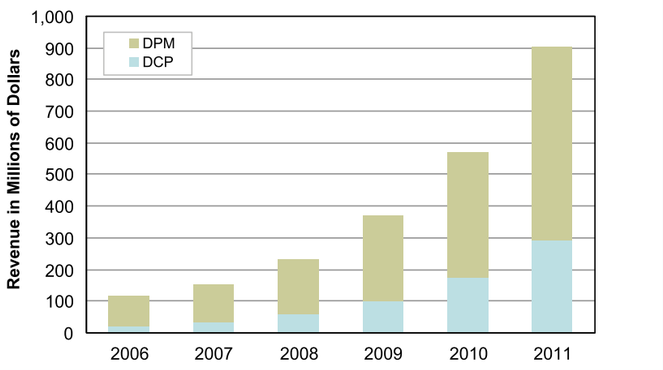


Figure 1 Presents iSuppli's forecast of worldwide DPM and DCP revenue.

Digital Power 101

iSuppli defines DPMs as devices that use digital information to manage the overall functioning of a power system and the power supplies within it. With DPMs, digital signals are used for communication to and from the power supplies to monitor and manage power-up, sequencing, load sharing and balancing, fault conditions, hot swapping, maintenance issues and other functions.

DCPs use digital techniques to control the power switching functions within a power supply unit. In its most theoretical form, this means performing the analog-to-digital conversion as early as possible so that all feedback and control functions in the supply are processed in the digital domain.

DPMs now dominate the market, accounting for 77.8 percent of global revenue in 2007. This is because DPM semiconductors today are effective, intermediate solutions for most DC/DC applications. DPM suppliers are striving to define the buses and to develop more user-friendly design interfaces for their products, which enable DPMs to dominate the digital power market.

iSuppli believes that DPMs over the next three years will achieve better success in low-end equipment like notebook computers. Meanwhile, DCPs will capture more of the high-end equipment market, including servers.

Notebooks Deliver Powerful Growth

The fastest-growing application for

digitally-controlled power semiconductors from 2008 to 2011 will be DC/DC conversion in notebook PCs. Global DPM/DCP revenue for this application will rise to $149.8 million in 2011, growing at a CAGR of 131.3 percent from $12.1 million in 2008. DPMs will account for the majority of revenue, with 73.7 percent of sales in 2008 and 66.3 percent of sales in 2011.

Even in 2011, this market will have plenty of room for further growth, with only 10.4 percent of notebooks using digitally controlled power semiconductors for DC/DC conversion.

Digitally-controlled power solutions are gaining fast acceptance in notebooks because of the requirement for improved efficiency. As a new, more powerful generation of microprocessors is being adopted, and battery-life issues gain in importance, efficiency is more essential than ever. Another reason for the fast growth of DPMs in this segment is the boom in notebook sales relative to desktop PCs.

High-end gaming PCs also are expected to generate a strong DCP/DPM CAGR of 110.1 percent, with revenue rising to $11.3 million in 2011, up from $1.2 million in 2008.

Serving Up the Revenue

The next-fastest growing area after notebooks will be high-end servers, which will consume $28.4 million worth of DCP/DPM silicon in 2011, rising at a CAGR of 114.3 percent from $2.9 million in 2008.

Mid-range servers will generate only a 43.6 percent CAGR during the same period, but will grow to $125 million by 2011, making them the second-largest application for digitally-controlled power during that year. DCPs will dominate this area.

The usage of DCPs in servers is being driven by major challenges in managing data centers and server farms. Such facilities are major energy consumers and heat produced at these centers sometimes results in equipment failure. A portion of the losses comes from energy conversion. The efficiency of energy conversion can be enhanced by using DPMs and DCPs. The difference in power consumption between analog and digital solutions is particularly significant in idle mode.

Digital Power for Digital TVs

Another fast-growing application will be DTV. Consumption of DCP/DPM solutions by the DTV market will rise to $39.6 million in 2011, growing at a CAGR of 104.4 percent from $11.4 million in 2008.

As TV screens get larger, the amount of energy needed to run them is becoming significantly higher and so is the importance of their power efficiency. DPMs will penetrate the DTV market more quickly than DCPs as the prices for DPMs are expected to have a sharper decline than for DCPs. iSuppli expects penetration of digital power in the DTV market to amount to 3.4 percent in 2011.

After years of talk, DCPs and DPMs now are ready to emerge as high-volume, revenue-generating products, bringing significant power savings to products, and significant sales to suppliers of such devices.

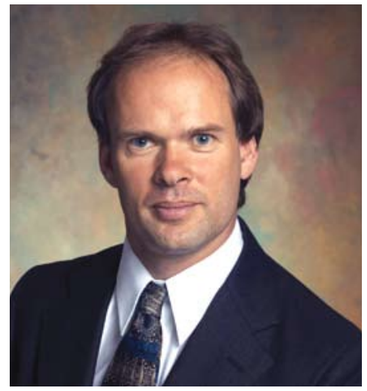
www.isuppli.com

30 Years of Current-Mode Control

2008 marks the 30th anniversary of the publication of a landmark paper on current-mode control. Since then, current-mode has become the industry standard for controlling switching power supplies. In honor of the occasion, we are making available, for the first time ever, a free downloadable copy of Dr. Ray Ridley's definitive 200-page book on current-mode control.

By Dr. Ray Ridley, Ridley Engineering

In 1978, Cecil Deisch published a paper that introduced current-mode control in a practical and easy-to-understand circuit. While this was not the first publication on current-mode control, it was the one that popularized it in industry. Up until that time, power supply designers had used voltage-mode control for switching power supplies. Voltage-mode control compares a sawtooth ramp to an error voltage to set the duty cycle of the power switch of the converter. In this way, the output voltage and inductor current are indirectly controlled.



Current-mode control directly controls the peak of the switch (or inductor) current. As soon as it was introduced, it became widely accepted as a preferred method of control, offering the following advantages:

1. Peak current limiting on a cycle-by-cycle basis;

2. Damping of the LC-filter characteristic;

3. Ability to parallel multiple converters together to provide higher power, (critical for the multiphase power supplies used for microprocessors);

4. Increase of phase of the control-to-output transfer function;

5. Optimal compensation for both continuous-conduction mode (CCM) and discontinuous-conduction mode (DCM) operation;

6. At least a ten times reduction of input-to-output noise transmission; and Simplified design of the feedback compensation.

It took several years before Unitrode came out with the first current-mode control chip, and once this happened, there was no turning back for the industry. However, along with all of the advantages of current-mode control came some drawbacks:

1. The signal-to-noise ratio of the control modulator is not as good as voltage-mode control. Great care must be taken with the current sensing implementation.

2. The feedback current loop, although an intuitive control scheme, has an inherent instability as a 50% duty cycle is approached. This became known as subharmonic oscillation since it occurs at one-half the switching frequency.

3. Existing analysis methods were unable to properly explain the operation of the current-mode system.

First, let's address the signal-to-noise issue. It is your job as a designer to make sure the current is sensed cleanly and accurately. For almost all power supplies, the best way to do this is with a current transformer for lowest dissipation, or with a sense resistor at lower power levels. Trying to use the on-resistance of a FET as the sensing element is not a well-controlled approach. While clean current sensing requires some work, the advantages of current-mode greatly outweigh the downsides, and it should always be the first choice for your power supply.

Secondly, the subharmonic instability in the current loop was quickly discovered. It was found it could be stabilized by adding a sawtooth ramp back into the system – or a little bit of voltage mode control. How to add the compensating ramp is another question. Most methods suggested by control chip application notes do not work well, and it is recommended that you read the paper at the end of for the best way to implement this.

That leaves us with the modeling issue. For many years, from 1978 until 1989, there was no clear-cut method of modeling the current loop that explained all of the behaviors observed. Simple models that treated the inductor as a current source could not explain the instability. More complex models that recognized that the current loop gain was finite also failed to properly explain the instability. They also varied greatly from one to another in terms of system parameters. Researchers could not even agree on a methodology for measuring

and designing the system properly.

The most complex models of all, using discrete-time analysis instead of averaging techniques, gave accurate predictions for the current-mode instability, but failed to result in a usable model for the design engineer.

I first became aware of the problems of current-mode models while working on my first production power supply in 1981. I saw that one of the popular published models predicted a loop gain crossover in excess of half the switching frequency, and this conflicted with what I knew about the Nyquist criteria. It took me 8 more years of studying literature, measuring circuits, and working with some of the top researchers in the field of power electronics before arriving at the proper model for current-mode control.

My PhD dissertation, finished in 1990, compared all of the different modeling approaches, and resolved their differences. This resulted in a model that accurately predicted the current loop instability, used average models for the part of the circuit where it applied, and sampled-data analysis for the current loop phenomena. A simple approximation produced results that were very easy to use.

Since this work was done, there has been nothing published to improve on the model, and the results are used widely in the industry and in research. The new current-mode model offered several insights that helped understand the system properly:

1. The best representation of a second-order converters is given by a third-order transfer function. A dominant pole represents the current-source effect, and a double pole at half the switching frequency shows the subharmonic oscillation. The double pole is damped by compensating ramp addition.

2. Current-mode control can go unstable even at duty cycles below 50%, and a compensating ramp must be added even for some converters that are limited to 50% duty cycle.

3. The current feedback loop has two right-half-plane zeros in the transfer function that lead to instability.

4. The PWM switch model, developed by Vorpérian, works perfectly well in the current-mode model. This allows a single model to be used for current-mode, voltage-mode, and the important case where significant compensating ramp is used and the resulting system is somewhere in between the two.

Full details of the model are now available for free in the current-mode book which can be downloaded from www.ridleyengineering.com. This 200-page book covers the history of current-mode control and modeling, detailed analysis, practical application examples, and PSpice model listings. Complete unabridged details from the PhD dissertation are included. An abbreviated summary at the end gives quick results for helping you with design when you don't have the time to read the full story.

We hope that you find this book useful. Please feel free to email any comments to ridley@ridleyengineering.com

www.ridleyengineering.com

Wolfson Launches Mobile Handset AudioPlus™ Audio and Power Management Solutions at Mobile World Congress

I had a discussion with Nat Edington, VP Marketing and Paul Wilson, Product Line Manager from Wolfson Microelectronics who announced the latest additions to their AudioPlus™ Smart Power product line -enabling exciting new levels of user experience connecting the digital world with the human senses.

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

The WM8400 combines a multimedia CODEC with integrated power management features to deliver the high performance audio and mixing capability, longer battery life and reduced system cost required in the leading multimedia mobile handsets.

Functions include a high performance multimedia CODEC, on-chip FLL, two DC-DC converters and four LDO regulators, all inside a compact 6x6mm BGA package.

Flexible hardware control enables the WM8400 to support the generic power management needs of leading multimedia companion processors. With this level of integration, the WM8400 can help mobile handset designers to save up to 25 percent on the device bill of materials (BOM) and up to 40 percent on board footprint.

The WM8400 incorporates a low power audio CODEC, delivering 98dB SNR and supports the signal switching, audio conversion and voice mixing requirements of next-generation mobile phones allowing designers to quickly add new features and enable flexible end-user modes such as mobile TV while receiving a voice call. The digital core consumes less power than similar devices and can be as low as 5mW during a voice call.

In addition, the WM8400's CODEC is able to select, in software, Class AB or Class D speaker driver operation meaning handset designers can deploy filter-less Class D technology into a wider range of increasingly diverse, handheld form factors, where restrictions such as noise and interference previously demanded a Class AB driver topology. System designers may select the most appropriate mode of operation for the anticipated usage scenario, allowing battery life for the end user to be maximised.

The device also includes a powerful 1W mono speaker driver and low leakage, high PSRR and pop/click suppression enable direct battery connection for the speaker supply. Four headphone driver outputs support conventional, fully differential or cap-less drive. Multiple microphone or analogue line inputs (mono or stereo, single-ended or differential) can be supported and a programmable high-pass filter is provided to remove low frequency noise from the input signal.

The digital audio interface supports most commonly-used data formats and clocking schemes while time-division multiplexing and an additional DAC interface provide additional flexibility.

From a power management perspective, the WM8400 includes two programmable 2MHz DC-DC step-down (Buck) converters, four low-dropout (LDO) regulators. The startup sequence and default voltages for the core regulators; DC-DC1, DC-DC2, LDO1 and LDO2 are selectable in hardware via external pins, and all regulators are also software programmable. The core regulators are intended to power the multimedia application processor sub-system while LDO3 and 4 are specifically designed to power the on-chip audio CODEC.

The WM8400 is available for sampling now in a 105-pin 6x6mm BGA package.

New leading Class AB/D Speaker Driver

The WM9001 mono 1W switchable

Class AB/D speaker driver is designed to deliver exceptional audio performance and enhanced flexibility to portable applications system designers.

User selectable features such as class D or AB output modes, single ended or differential input modes, device clocking and speaker boost gain can all be configured by the system designer for application optimization.

The small footprint allows placement close to the speaker housing, enabling simplified PCB layout and maintaining signal integrity by minimizing high frequency signal track lengths. Audio performance is enhanced through differential input and output modes to remove undesired noise. Additionally, RF noise suppression is improved and external component count reduced by an integrated oscillator for clocking the class D outputs. Low leakage, high PSRR and pop/click suppression enable the speaker supply to be connected directly to the battery without compromising battery life or audio quality.

WM9001 also connects seamlessly with both the WM8990 audio hub codec and the new WM8400 audio and power management IC, enabling a full stereo 1W class AB/D speaker drive solution for multimedia rich mobile handsets. The WM9001 can easily connect to Wolfson's portfolio of high performance, low power audio CODECs and DACs, bringing quality speaker drive performance to portable applications.

The WM9001 is available in small, low profile 3 x 3mm QFN-16 and 1.64 x 1.64mm CSP package options, making it ideal for space constrained applications such as mobile phones, navigation devices, media players, laptops and electronic dictionaries. Samples are available now and priced at $0.45 in quantities of 10,000.

Ultra Low Power Multimedia CODEC with Class G Headphone Amp

The new WM8900 AudioPlus™ Smart Power solution is a high performance, ultra low power audio CODEC with Class G, ground referenced headphone driver. The WM8900 offers longer battery life in portable media players and multimedia handsets with reduced external component requirements.

The WM8900's quiescent headphone playback power consumption is under 6 mW in voice mode and under 11mW in Hi-Fi mode, ideal for extending battery life in portable audio applications and betters the quiescent power consumption of many feature rich multimedia CODECs with ground referenced headphone outputs by up to 25%. When using a typical 300 mAH battery, the WM8900 solution can extend battery life by up to 11 hours during headphone music playback at a typical 2 mW/ch listening level.

Wolfson has addressed cost and board space by implementing ground referenced headphone outputs that remove the need for bulky DC blocking capacitors. The device is offered in a low profile 0.55mm high 40-pin QFN package, which makes the WM8900 ideal for slim, portable electronic applications.

www.wolfsonmicro.com

Microsemi Drives Inroads in PoE with Industry's First Family of IEEE802.3at IC Solutions for High Power Applications

I talked with Daniel Feldman, PoE Product Line Manager at Microsemi Corporation, leading manufacturer of high performance analog mixed signal integrated circuits and high reliability semiconductors. He walked me through the company's announcement of the industry's first IEEE802.3at-ready power over Ethernet (PoE) integrated solution family, delivering up to 60 watts power for devices ranging from video screen phones and WiMAX transmitters to pan-tilt-zoom cameras, thin-clients and laptop computers.

Reported by Cliff Keys, Editor in Chief, PSDE

Power over Ethernet is a cost-saving technology for wired Ethernet, the most widely installed local area network technology in use today. PoE allows the electrical power necessary for the operation of each end-device to be carried by data cables, rather than by separate power cables. It minimizes the number of wires used to install the network, resulting in lower cost, less downtime, easier maintenance and greater installation flexibility.

The technology was pioneered by PowerDsine, a founding member of the IEEE 802.3af Task Force and a member of the current IEEE802.3at Task Force. The company was acquired by Microsemi Corporation in January 2007 and is part of Microsemi's Analog Mixed Signal Group.

Microsemi's newest product family includes the PD69012 12-port PSE High PoE Manager and the PD69008 8-port PSE High PoE Manager. Both feature external power FETs, enabling switch manufacturers to build switches that can drive 36W for every two-pairs and interface to devices consuming up to 30 watts, with ongoing currents of 720mA, as required by IEEE802.3at-draft 1.0.

Applications requiring up to 60 watts can use the same Microsemi integrated circuits in a 4-pair configuration. The new ICs support Layer-2 Classification and 2-event classification, which reduces the software resources required to implement PoE switches and is essential for building IEEE802.3at midspans.

"The PD69012 and PD69008 were built to support the higher currents required by PoE Plus, allowing not only peace-of-mind but full optimization for IEEE802.3at," said Daniel Feldman, PoE Product Line Manager at Microsemi.

"The PD690XX family builds upon our experience of having shipped more than 35 million PoE ports, millions of them midspan ports, to enable customers to have the smallest real-estate and lowest power dissipation, while keeping Microsemi's power management algorithms," Feldman said.

Both the PD69012 and PD69008 include all of the features found in lower power PD64012G and PD64004A circuits and in the pre-standard PD64012GH and PD64004AH, including detection of pre-standard devices, dynamic power management and emergency power management. In addition, the new devices also add support for power management based on Layer-2 classification.

With increases in the maximum theoretical power per port, advanced power management features become critical for the design of PoE switches, saving integrators an average of 50 percent of the cost of adding PoE to a switch, by allowing sharing of power supplies and the employment of smaller power supplies.

"The PD69012 allows the industry to build next generation IEEE802.3at or PoE Plus switches and midspans, enabling support for products that require more power, such as PTZ security cameras and 802.11n APs," said Val Oliva, Director of Product Strategy at Foundry Networks. "Microsemi's solution helps deliver PoE Plus to prepare for higher power PoE installations today, while maintaining support for the existing IEEE802.3af standard."

The PD69012 and PD69008 can be configured on a port-by-port basis to work in IEEE802.3at mode or 100% IEEE802.3af compliant mode. Both PoE Managers can be used standalone or with the PD69000, which enhances the power management support and provides a backwards compatible interface with the PD63000 and PDIC66000, guaranteeing customers which have been shipping PowerDsine PoE solutions in switches since 2002 can make minimal software changes to adopt the latest PoE technology.

"The IEEE802.3at standard brings a breakthrough in usability of PoE for applications in the enterprise, SME, SOHO and residential markets," said Steve Litchfield, Executive Vice President and President of Microsemi's Analog Mixed Signal Group. "The PD69012 and PD69008 are designed with the flexibility to allow for both 36W and 72W solutions, enabling our customers to have compliant and efficient products ready when the IEEE802.3at standard is ratified in early 2009," he said.

PoE technology and its widespread adoption are moving fast and Microsemi looks to be in great shape and poised to take full advantage of this. Microsemi, with the huge benefit of their acquisition of PowerDsine's pioneering designers, have the capacity and flexibility to capitalize on the new IEEE802.3at standard.

PoE will certainly become far-reaching. Not just IP telephones and wireless access points. Most network-connected devices need local power for their operation. Power over Ethernet represents an opportunity not only to provide the connectivity that these devices need, but also to deliver power in a simplified, easy-to-manage environment. Microsemi is convinced that in the future we will be able to charge laptops, integrate security systems and automate buildings all over a universal connection - Ethernet. A whole new range of new, easy-to-install devices can be installed wherever an Ethernet cable can be deployed.

From a global perspective, PoE represents the only universal power standard in existence today. Currently, there are different power currents and plugs. PoE can deliver a universal voltage, current and plug, simplifying the manufacture and deployment of devices around the world. This would certainly be a blessing to business travelers.

The PD69012 and PD69008 are sampling now and will be in volume production in Q2 2008.

www.microsemi.com

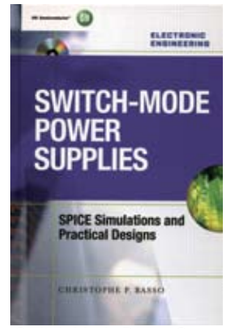
On the Road

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

Christophe Basso – On Semiconductor

New Power Design Reference Book

After a discussion on technical reference with Christophe Basso, application manager at ON Semiconductor in Toulouse I received a copy of his latest book, "Switch Mode Power Supplies: SPICE Simulations and Practical Designs" which bridges the worlds of academia and practical application by offering a theoretical study of power conversion in the dc-dc and ac-dc fields via a systematic equation-based approach. Then, capitalizing on the experience accumulated by Christophe at ON Semiconductor, the book shows how SPICE can help designing power factor correctors, flyback and forward converters with real case situations: small-signal analysis first, using new auto-toggling average models specifically developed for this publication, and practical implementation with more than 10 design examples. The 800 pages can be seen as a design companion for the practicing engineer and as an in-depth tutorial introduction to power conversion design for students and newcomers to this field.



Switch Mode Power Supplies: SPICE Simulations and Practical Designs was released by McGraw-Hill on January 15th 2008.

I found the book enlightening and a great balance between theory and real-world application.

www.onsemi.com

National Semiconductor

With low power ADCs very much at the forefront of low power portable equipment design, particularly in the medical field, I was intrigued to hear about this new device; the industry's first high-speed, continuous-time sigma-delta analog-to-digital converter, from Nationals portfolio at their recent European launch. Subsequently I talked with Salvatore Napolitano, National's Marketing Manager, European Signal Path Group.

PowerWise CTSD ADC Consumes 30% Less Power than Competition

Continuous-time sigma-delta (CTSD) analog-to-digital (A/D) conversion technology shatters the conventional wisdom that pipeline analog-to-digital converters (ADCs) are the only conversion technique available for high dynamic performance, sub-100 MSPS (mega-samples per second) applications. Besides providing the power conscious designer much higher power-efficiency, CTSD technology also offers unique features that greatly reduce the challenges of deploying such ADCs in high-speed, high-performance systems.

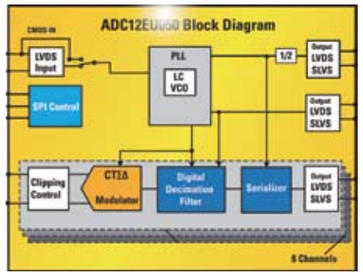
The ADC12EU050, a member of National's industry-renowned PowerWise® energy-efficient family, is an 8-channel, 12-bit, 50 MSPS ADC that offers an alias-free sample bandwidth up to 25 MHz, while consuming 30 percent less power (350mW) than competing pipeline devices. This low-power breakthrough enables manufacturers to

extend battery life and reduce heat in portable medical ultrasound and industrial imaging equipment.

CTSD technology has been the subject of university and industry research for more than 15 years. With the introduction of the ADC12EU050, National is the first manufacturer to successfully transition CTSD technology from the research lab to the production line. National plans to expand its CTSD ADC product offering for imaging, communications, and test and measurement applications that require high dynamic performance at extremely low power. The continuous-time architecture greatly simplifies system design as it allows the integration of other signal-path functions, such as signal conditioning, while incorporating anti-aliasing filtering into the ADC.

The ADC12EU050's innovative CTSD architecture offers many advantages compared to traditional pipeline architectures:

- Lower power dissipation
- Integrated low-pass, brickwall anti-aliasing filter that blocks out-of-band signals from aliasing down in-band
- Easy-to-drive, purely resistive input stage that does not require a sample-and-hold amplifier
- Integrated phase-locked loop (PLL)



and voltage-controlled oscillator (VCO) that performs clock conditioning, enabling system designers to use inexpensive clock sources

- On-chip instant-overload recovery (IOR) circuitry that recovers from saturation within one clock cycle, if the input exceeds pre-determined limits

Key Technical Features

The ADC12EU050 12-bit, ultra-low-power, octal CTSD ADC offers an alias-free sample bandwidth up to 25 MHz and a conversion rate of 40 MSPS to 50 MSPS. The device features 68 dB of signal-to-noise and distortion (SINAD) and a signal-to-noise ratio (SNR) of 70 decibels full scale (dBFS). Operating from a 1.2V supply, it consumes 44 mW per channel at 50 MSPS for a total power consumption of only 350mW. The ADC12EU050 reduces interconnection complexity by using programmable serialized outputs, which offer industry-standard low-voltage differential signaling (LVDS) and scalable low-voltage signaling (SLVS) modes. The ADC12EU050 operates over the -40°C to 85°C temperature range and is supplied in a 10mm by 10mm, 68-pin LLP® package.

National's portfolio is rich in differentiated products that offer a unique set of value-added features, including the fastest 8-bit analog-to-digital converters (ADCs) with speeds up to 3 GSPS, 12- and 14-bit ADCs featuring high input bandwidth of 1.1 GHz at speeds up to 170 MSPS, and the easiest-to-use family of pin- and function-compatible 8-, 10-, 12- and 14-bit low-power ADCs and digital-to-analog converters (DACs) with speeds up to 1 MSPS. National's PowerWise data converter products offer the optimal performance at the lowest power consumption for communications infrastructure, medical imaging, test and measurement, and other applications. For more information about National's data conversion products.

www.national.com/adc

Texas Instruments

I attended the TI launch of their new low power ADCs, presented by Christoph Gromann, EMEA Business Development Manager, High Performance Analog (HPA) and felt that the significance of these devices in the power aspects of the design budget would be important to our readers. Developments in data converter technologies center on increasing speed and resolution, reducing power consumption, shrinking package size and improving overall performance in a broad range of applications.

Eight-Channel ADCs Cut Power Consumption by 30%

The new family of 10- and 12-bit, eight-channel (octal) analog-to-digital converters (ADCs) introduced by Texas Instruments claimed as the industry's lowest power consumption and smallest size. The new data converters enable smaller and more energy-efficient medical imaging, wireless communications, military guidance, automatic test equipment and video equipment. The ADS5281 family offers high resolution and sampling speeds of up to 65 million samples per second (MSPS), low noise performance and advanced digital features, which are critical in sensitive imaging applications like portable ultrasound and MRI equipment.

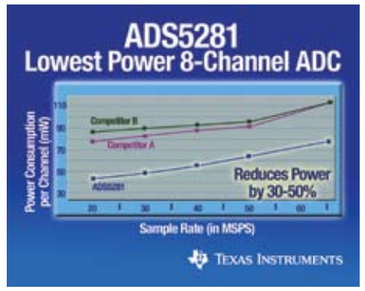
"As medical imaging systems become more portable and compact, TI is committed to solving challenges manufacturers face when designing these increasingly complex systems," said Art George, senior vice president of TI's high-performance analog business unit. "The ADS5281 ADC family and TI's octal amplifier provide the ultra-low power and high density these systems require, without sacrificing performance and image quality."

Lowest Power Consumption Critical to High-Density Systems

The ADS5281, ADS5282 and ADS5287 ADCs feature market-leading power consumption, 30 percent less than competing solutions. At the highest sample rate of 65 MSPS, the ADS5281 family consumes as little as 77 milliwatts (mW) per channel. With dynamic scaling, at a 30 MSPS sample rate, the per-channel power consumption is as low as 48mW per channel.

The ADS5281 family is designed to interface with TI's new octal variable gain amplifier, the VCA8500, which features 0.8 nV/square root Hz input noise at only 63 mW per channel power consumption. When combined, the ADC and octal amplifier offer a complete medical signal chain solution with better noise performance and a combined power of less than 130mW per channel at 50 MSPS, less than any competing solution on the market today.

Space-Saving Packages Enable Compact Medical Imaging Systems



The ADS5281 devices and VCA8500 come in the industry's smallest 64-pin 9 x 9 mm QFN package, a space savings that is essential for high-density systems. Connecting the amplifier to the ADC does not require additional components, and implementing the combined solution requires the same footprint as any comparable integrated device.

Advanced Features Enhance Performance

The ADS5281 family also includes an array of features to enhance performance. A low-frequency noise suppression mode eliminates the 1/f (Flicker) noise, improving SNR by up to 4.2 dB over a 1-MHz band in baseband and time-domain applications. Overload recovery circuitry allows each ADC to provide valid data within one clock cycle after an input overload as high as 6dB, allowing for immediate signal recovery and processing. And with programmable gain from 0 to 12dB, full-scale outputs can be provided for input signals as low as 0.5Volts peak to peak (Vpp).

Tools, Support, Signal Chain Solutions Speed Time to Market

Easy-to-use evaluation modules (EVMs), deserializer and capture cards available from TI allow fast and cost-effective evaluation to help customers speed the design process and penetrate the market quickly. To further simplify design, TI offers a wide variety of parts to complete the signal chain. Aside from the VCA8500 for medical imaging, TI offers signal chain solutions for wireless communications systems including the DAC5672A, TRF3710, TRF3703, GC5016 and THS45xx family of amplifiers, as well as TI's family of single- and multi-core wireless infrastructure-optimized digital signal processors (DSPs).

www.ti.com

Synopsys

I had the pleasure to meet with Larry Vivolo, Director of Low Power Solutions at Synopsys recently in Munich and he walked me through Eclypse, the new offering from Synopsys, a world leader in electronic design automation (EDA) software for semiconductor design.

The company is already well known for its semiconductor design and verification platforms, IC manufacturing and yield optimization solutions, semiconductor IP and design services. These solutions enable designers to develop complex ICs and electronic systems and the company now addresses the key challenges designers and manufacturers face today; power management, accelerated time to yield and system-to-silicon verification.

Synopsys Optimizes Power in IC Design with Eclypse™

More than ever before, manufacturers need to put power at the top of their priorities. The complex blocks making up a system, whether it be a cellular phone or a server farm, need to conserve energy from a customer and environmental standpoint.

The challenges facing chip designers now have never been greater and much effort has been invested by Synopsys to help designers to optimize complex chip

designs for power conservation.

Synopsys has launched the Eclypse low power solution as part of its commitment to serve the power design community in the great task that lies before it.

Low Power Design Challenges
System-Level Concerns
- Battery life
- System cooling
- Reliability
- Packaging cost
- Operating cost
- Air conditioning cost
- Carbon footprint
- Green initiatives

Silicon-Level Concerns
- More functionality
- More computing power
- Limited power budget
- Design complexity
- Verification complexity
- Testing
- Reliability
- Schedule

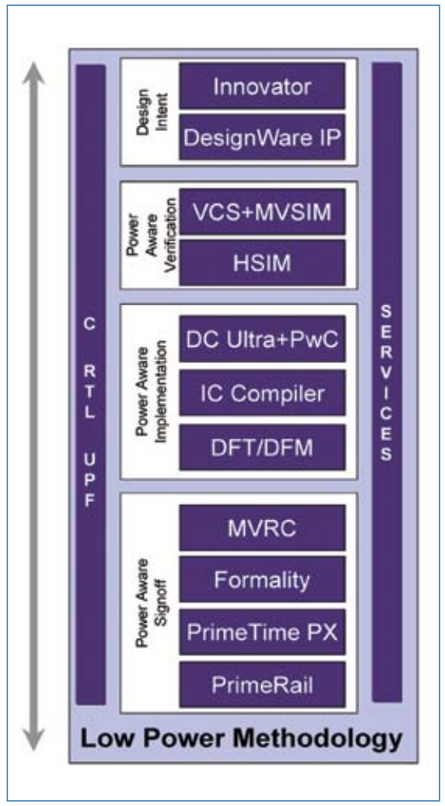
Designers were asked by Synopsys as part of their preparation to serve the design community just what their major concerns were in their new designs.

An astounding 49% of surveyed customers identified power management as their major concern with typical feedback comments as below:
- "How do I describe my power requirements?"
- "How do I know if I have a power problem?"
- "Which advanced techniques are worth the effort?"
- "I know the concepts, but I don't know how to implement them"
- "Can you make low power design easier?"

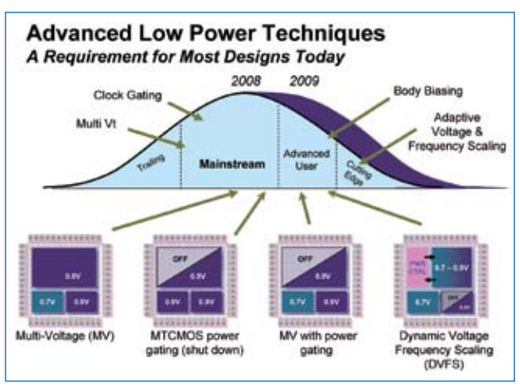
Most design teams seemed overwhelmed by the huge task before them and felt under prepared. Synopsys' Goal was developed accordingly to deliver the most comprehensive solution to enable all designers to be able and equipped to build the most advanced, low power chips and systems in the world.

Working with customers, Synopsys developed Eclypse, a toolkit focused on engineering needs to give a 'right from the start, end to end' system to enable the goal of power optimization in chip design.

The Eclypse solution aligns Synopsys' proven offerings into a streamlined, easy-to-use low power workflow that encompasses each phase of the design process. As a result, the Eclypse solution enables design teams to adopt advanced low power techniques while boosting productivity, reducing risk and ultimately delivering high quality silicon in an effort to meet or beat power, area, speed and yield objectives.



Advanced low power design techniques, such as MTCMOS power gating, multi- voltage, and dynamic voltage and frequency scaling (DVFS), force a major shift in how engineers create and verify chips. These techniques can dramatically reduce power consumption in deep submicron chips but have traditionally required ad-hoc, time-consuming, risk-prone, and manual verification and implementation approaches. The Eclypse Low Power Solution combines a wide array of advanced techniques, methodologies, standards, and automation to simplify advanced low power design and verification.

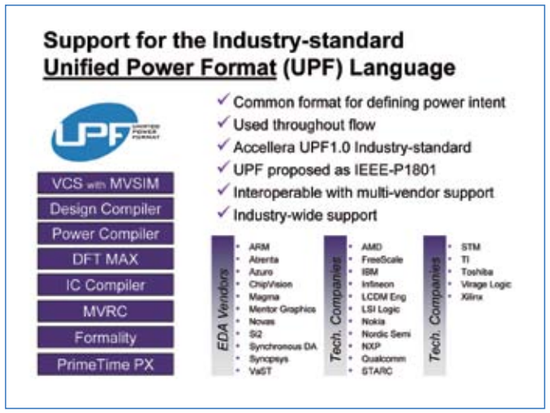


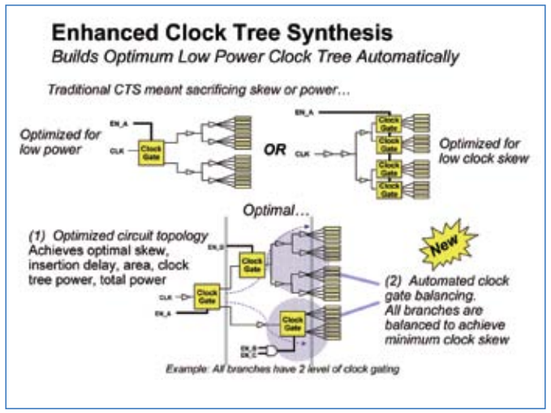
Building on more than 10 years of low power design leadership, the Eclypse Low Power Solution delivers several new, advanced low power technologies. Enhanced clock gating and low power clock-tree synthesis allow designers to optimize their clock structures for low power while also achieving required skew and timing goals.

The Eclypse solution supports the industry-standard Unified Power Format (UPF) language, which is used to capture low power design requirements. The following UPF-enabled tools are included: MVRC™ and VCS® with MVSIM™, key components of the Discovery™ Verification Platform, and Design Compiler®, Power Compiler™, IC Compiler™, DFT MAX™, Formality®, and PrimeTime®, key components of the Galaxy™ Design Platform.

UPF Specification

UPF is the electronics industry standard for capturing and using low power design intent for design automation. UPF was ratified by the Accellera standards





organization in February 2007 and now forms the basis of the IEEE standards project 1801, the standard for low power IC design and verification. The UPF standard enables end users to create a consistent, succinct, unified description of the low power design intent for use by EDA tools offering advanced features for design and verification of today's low power integrated circuits (ICs).

This benefits designers in two key ways. First, UPF supports integrated low power design flows from RTL to silicon, enabling consistent low power design intent to be applied and used throughout the flow. Second, the UPF standard enables interoperability, so tools from over two- thirds of the EDA marketplace can be used together utilizing the same low power methodology and design specifications.

Analysis/ Automation

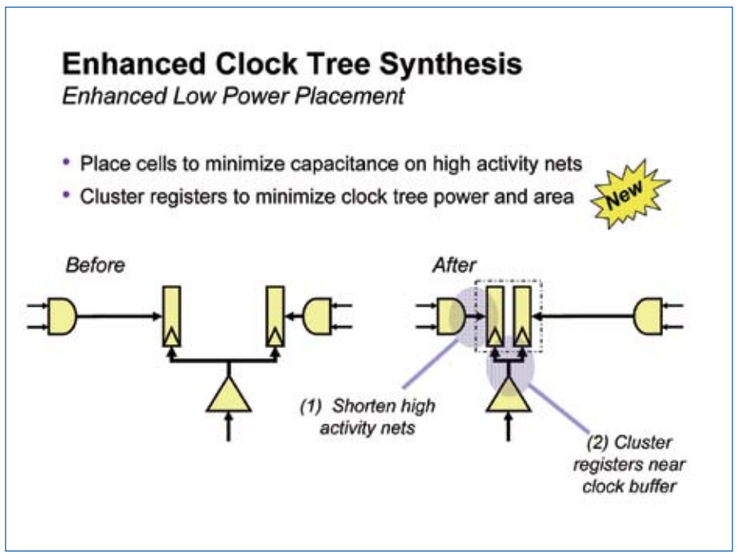
New technologies
- Low power clock tree synthesis
- Automated power switch handling
- Automated power state assertions

and coverage reporting

Education

Enabling broad adoption
- Low power design seminars
- Online low power design community
- Low power consulting services
- Low Power Methodology

Completing the solution are additional tools for low power design, including Innovator™, HSPICE®, HSIM®, NanoSim®, TetraMAX®, and PrimeRail™, as well as DesignWare® IP and Synopsys Professional Services. The Eclypse solution supports open methodologies, including those described in the "Low Power Methodology Manual" (LPMM), co-authored by Synopsys and ARM.



The Eclypse Low Power Solution is the result of an intensive, effort over many years to create the industry's most comprehensive and silicon-proven solution for low power chip development. With Eclypse, Synopsys has aligned its proven low power tools, IP, methodologies and services into an easy-to-use solution so that design teams can quickly and confidently adopt the most advanced low power techniques.

Eclypse Low Power Seminar Series

Synopsys are conducting a series of Eclypse Low Power Seminars in which ARM will participate. These seminars are designed to help chip development teams understand how they can employ the latest advanced low power design techniques with the Eclypse solution. The seminars will include an overview of the Eclypse solution and detail key elements of an automated low power design workflow. Synopsys is a member of the ARM Connected Community.

www.synopsys.com/eclypse

Hysteretic Converters in High Brightness LED Control

Inherent problems and their impact on particular applications

Hysteretic converters are widely used to drive LEDs in many lamp replacement and emerging lighting applications. The ease of use and inherent stability of the topology makes it a good first choice for efficient inductive switching regulator solutions. This simple topology can be used in many different configurations, sometimes outside their intended use. However, there are difficulties to overcome, and understanding their limitations can help maximize the system performance.

By Colin Davies, Global Applications Manager, Dr Alan Dodd, Senior IC Designer, Silvestro Russo, Systems Application Engineer, Dr Kit Latham, Senior Applications Engineer, Zetex Semiconductors

The hysteretic converter is essentially an on-off topology. It can be used in buck, boost or buck-boost configurations, but its inherent stability makes it most suitable for step-down LED driving applications, since hysteretic converters stabilise within one oscillation, while PWM controllers for example usually take many tens of cycles to regulate. The hysteretic converter can be described in terms of control mechanism, accuracy, frequency, duty cycle and propagation delay.

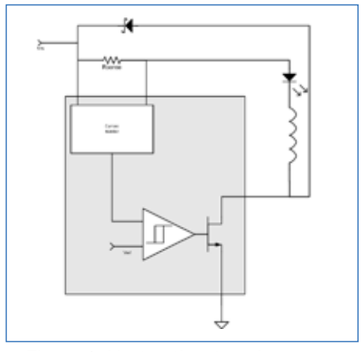


Figure 1: Hysteretic, step-down converter.

With reference to Figure 1, control is based around a comparator with a predetermined hysteresis. The current in the LED is usually measured with a resistor and ramps up and down to the limits set by the comparator. Setting the level is a trade-off between measurement accuracy/noise immunity and efficiency. Typically a hysteresis voltage between 50mV and 250mV is chosen.

Frequency of oscillation is dependent on many factors, inductor choice being the most important. One of the key points about hysteretic converters is they are self oscillating. This means the frequency will vary due to input voltage, LED current and the number of LEDs being driven. They are however always running in continuous mode, which means the inductor never saturates or is completely drained of current. This

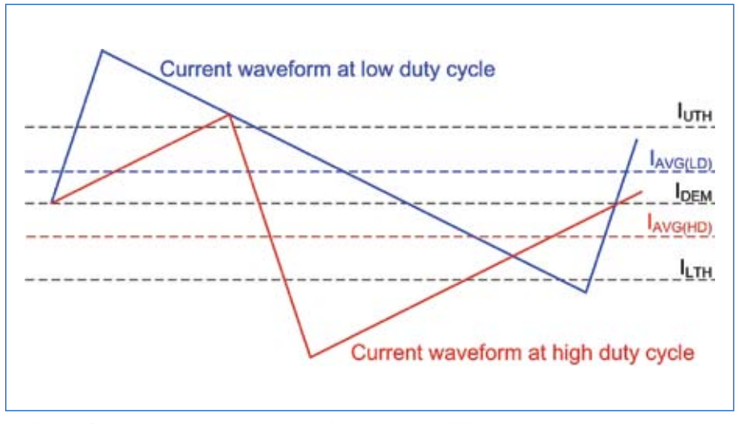


Figure 2: Accuracy considerations for dimming LEDs when using hysteretic, step-down, DC-DC converters.

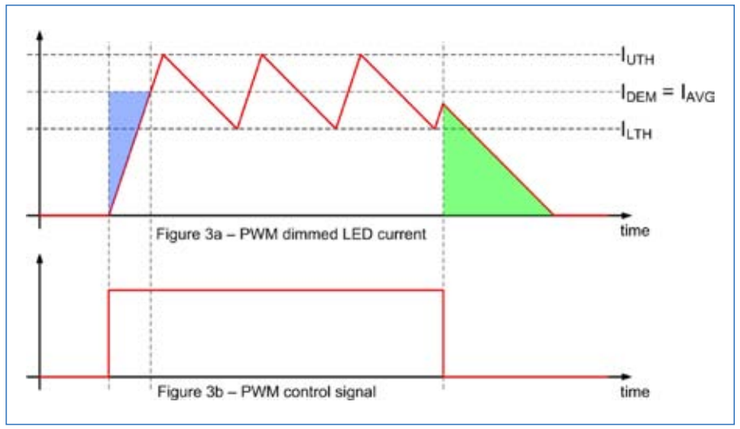


Figure 3a & 3b: PMM dimming.

inherent stability means hysteretic converters operate over a wide voltage range and do not require compensation with external components. They are also not limited to duty cycle ranges as with many PWM topologies.

Duty cycle however does affect accuracy. The duty cycle is essentially governed by the ratio of the input voltage to the output voltage, which in turn is usually determined by the number of LEDs being driven compared to the input voltage. For example, a high input voltage e.g. 30V driving a single 3V LED will produce a duty cycle of 10% whereas nine, 3V LEDs (at 27V forward voltage) on a 30V supply produces a 90% duty cycle. The second situation produces a more efficient solution. The problem with both of these extremes is the current in the LED is averaged from the hysteretic (ripple) sense voltage which at 50% duty cycle is approximately an equal triangle. At the extremes of the duty cycle, effects such as propagation delay and overshoot result in the current deviating from the demand, see Figure 2. Tight current control is not usually possible at duty cycles <20% and >80%.

Propagation delay and rise time also affect the maximum frequency of operation as well as self-heating and accuracy. As the frequency increases, transition losses begin to dominate power loss in the switching element above DC losses, although this is true of any switching topology.

Accuracy Considerations When PWM Dimming LEDs

PWM is the preferred method for dimming LEDs, in order to avoid changing the colour of the LEDs and to provide dimming over a wide brightness range. However, to maintain accuracy across the full resolution when using inductive, hysteretic converters there are a number of factors to be considered.

A simplified circuit for driving white LEDs is shown in Figure 1. In this type of converter, no output smoothing capacitor is required and the LEDs are in series with the inductor. This gives an advantage in terms of speed of start-up, solution size and cost. However, the lack of an output capacitor means that energy can only be stored in the inductor. When dimming, all the energy is discharged during off-cycles and must be restored during the on-cycles.

Figure 3a shows the current in the LEDs. When the supply voltage is applied, the internal MOSFET switch conducts and the current through the sense resistor, LEDs, inductor and switch ramps up from zero to an upper threshold. On reaching this threshold the current then begins to ramp down to the lower threshold I_{LO} and then starts to ramp up again towards I_{UP}. The thresholds are determined by the sense resistor and an internal reference voltage.

PWM Dimming

The PWM waveform shown in Figure 3b could be the least significant bit of an 8-bit signal used to control the brightness of the LEDs. For ideal dimming, driving of the PWM signal high should result in an immediate oscillation with an average value equal to I_{AVG} and the current should drop to zero as soon as the PWM signal is taken low.

The trace in Figure 3a shows there are two major contributions to error in the output current, as indicated by the shaded areas. During the initial ramp-up (shaded blue) the current should be

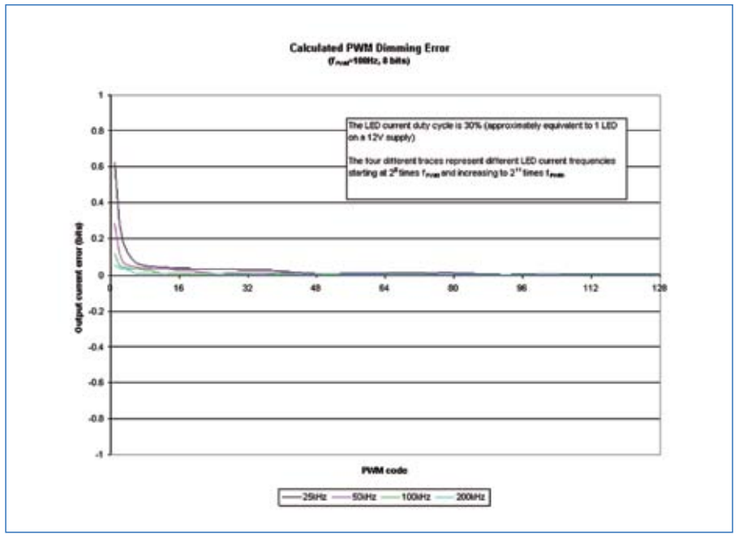


Figure 4: Output current error: 8-bit resolution, 100Hz PWM.

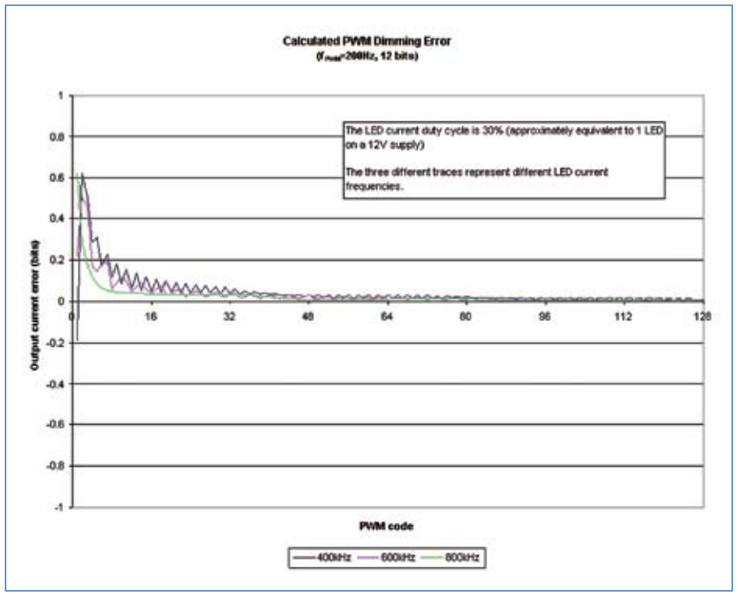


Figure 5: Output current error: 12-bit resolution, 200Hz PWM.

equal to I_{AVG}, for this period of time the average current is too low. Similarly, during the final ramp-down the current should be zero but the area shaded green shows that this is not the case. If the duty cycle of the LED current is 50% the rising / falling slew rates are the same and these two errors will cancel, but the duty cycle will often vary from 50%. If the converter performs many cycles of oscillation during the on-period of the PWM then the effect of these errors will become negligible.

At high PWM duty cycles, small errors may not be perceptible due to the response of the LED and the human eye, but at very low PWM duty cycles the errors may become significant. Figure 4 and Figure 5 show how the output current accuracy changes with the ratio of the PWM to converter oscillation frequencies at low PWM duty cycles. Each trace represents a different converter oscillation frequency; the PWM frequency is 100Hz and the PWM duty cycle is represented by the x-axis. The y-axis shows the error in the average output current in terms of the bit-resolution. So for example, with a full-scale output current of 1A and 8-bit dimming, each bit would represent (1/28)*1A = 3.91mA. Looking at the 25 kHz trace, the error is +0.63 bits, so the error in the output current would be 0.63*3.91mA = 2.46mA. This means the output current is 6.37mA rather than 3.91mA.

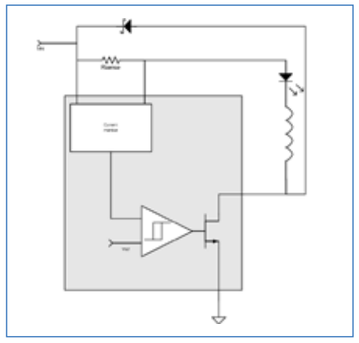


Figure 6: PWM dimming using shunt PMOS.

Consider as an example, the ZXLD1362 LED driver driving 3.5W white LEDs from a 48V supply using a 100µH inductor. If it is PWM dimmed at 200Hz to 10-bit resolution, then the output current accuracy will be as shown in table 1.

When PWM dimming hysteretic converters the ratio of the PWM frequency to converter frequency determines the accuracy at low output currents. For best accuracy, it is recommended that this ratio is much greater than the number of dimming steps, i.e. the period of one PWM bit should be much greater than the period of one converter cycle. A rule of thumb is that for n-bit dimming, the LED hysteretic switching frequency should be greater than 2^n times the PWM frequency, ideally greater than $2^{(n+2)}$. One of the key compromises is avoiding stroboscopic effects with low frequency PWM dimming and the amount of accuracy that is needed, particularly at low brightness levels or as the PWM frequency is increased relative to the converter switching frequency.

One method to improve the accuracy of PWM dimming is to use a bypass element across the LED(s), for example a PMOS, as shown in Figure 6. In this way, the inductor current always flows and hence the ramp-up and ramp-down errors are removed which will improve the accuracy, however efficiency is compromised.

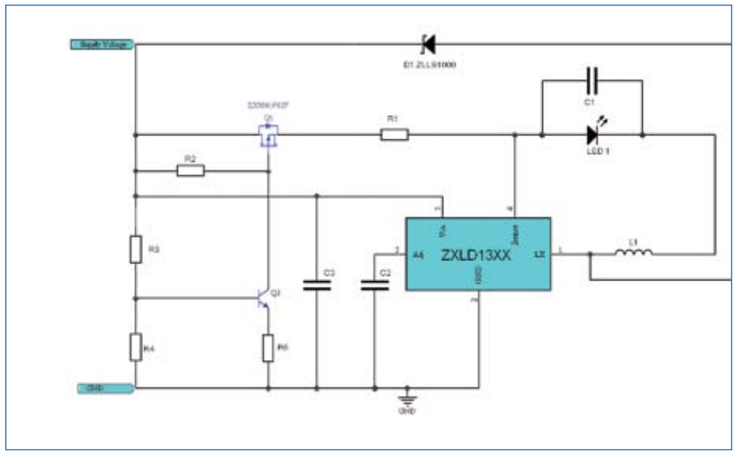


Figure 7: Circuit for efficient DC input voltage dimming control.

PWM code	Output current error		
	2 LEDs f=185kHz, Dled=20%	6 LEDs f=300kHz, Dled=48%	10 LEDs f=225kHz, Dled=78%
1	144% of 1 bit	5% of 1 bit	73% of 1 bit
2	77% of 1 bit	10% of 1 bit	46% of 1 bit
3	44% of 1 bit	3% of 1 bit	30% of 1 bit
4	22% of 1 bit	6% of 1 bit	23% of 1 bit
5	15% of 1 bit	2% of 1 bit	18% of 1 bit
6	15% of 1 bit	4% of 1 bit	15% of 1 bit
7	14% of 1 bit	1% of 1 bit	12% of 1 bit
>=8	<13% of 1 bit	<2% of 1 bit	<10% of 1 bit
>=32	<5% of 1 bit	<1% of 1 bit	<3% of 1 bit
>=64	<3% of 1 bit	<0.5% of 1 bit	<2% of 1 bit

Table 1: The impact of PWM frequency and resolution on output current accuracy.

DC Dimming by Adjusting the Input Voltage

DC dimming is not usually used in controlling high brightness LEDs. This is due to changes in the colour temperature of the LED. White LEDs however generate their colour from a phosphor excited by a blue LED and in this case the colour is less affected by the LED current. For architectural and mood lighting colour rendering may not be too important, even if the colour changes a little as the intensity is reduced. In any event for white LEDs the colour change during dimming will be much less than that occurring with the equivalent incandescent lamp when similarly dimmed.

Many switching controllers do not offer good dimming ranges - typically 10:1 reduction from a maximum value. Because the eye responds in logarithmic fashion a 10:1 dimming in current would not produce a pleasing reduction in brightness and would still appear to be only half the full brightness. The circuit in Figure 7 shows a method which takes advantage of the simplicity, inherent stability and flexibility of the hysteretic topology to produce a DC dimming range of around 50:1.

In some architectural applications, dimming the light by reducing the input voltage would be an advantage. A simple circuit with a resistor in series with an LED would have the desired effect, but if a 12V supply is used to drive a 5W led there would be about 10W dissipated in the resistor at full brightness. The circuit in Figure 7 produces the desired effect of efficiently reducing the current whilst maintaining current control as the voltage across the two input terminals is reduced.

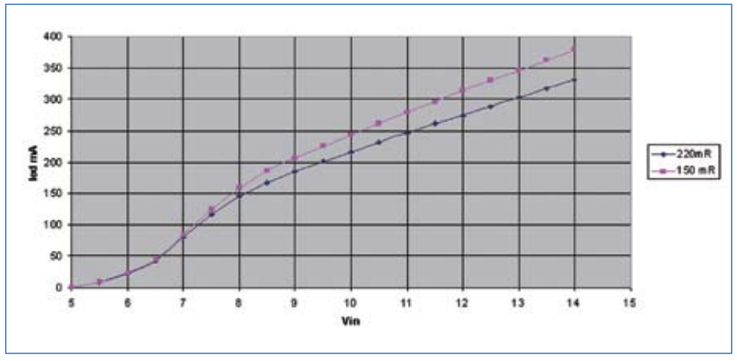


Figure 8: LED current versus input voltage for circuit in Figure 7.

The converter controls the current by maintaining an average of 100mV between the terminals V_{in} and Isense. There is normally a single resistor in this position. A degree of current adjustment is available by over or under driving the ADJ pin. The circuit works by combining this with a P-channel MOSFET whose small signal resistance adds to the normally fixed resistance between the terminals Vin and Isense. At low voltages the $RDS_{(ON)}$ of the MOSFET dominates the effective resistance. At higher voltages the total current is boosted by raising the ADJ pin voltage, which maximises the dynamic range.

The MOSFET $RDS_{(ON)}$ could have a variation between devices of about 20%. In practice this is likely to be around 10% for the overall sense resistance.

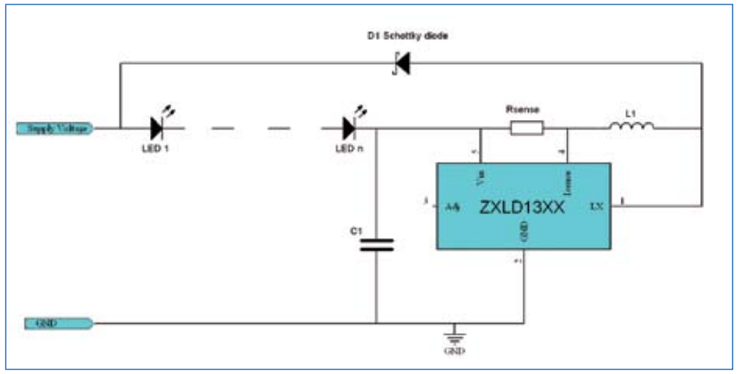


Figure 9: Common Anode Topology.

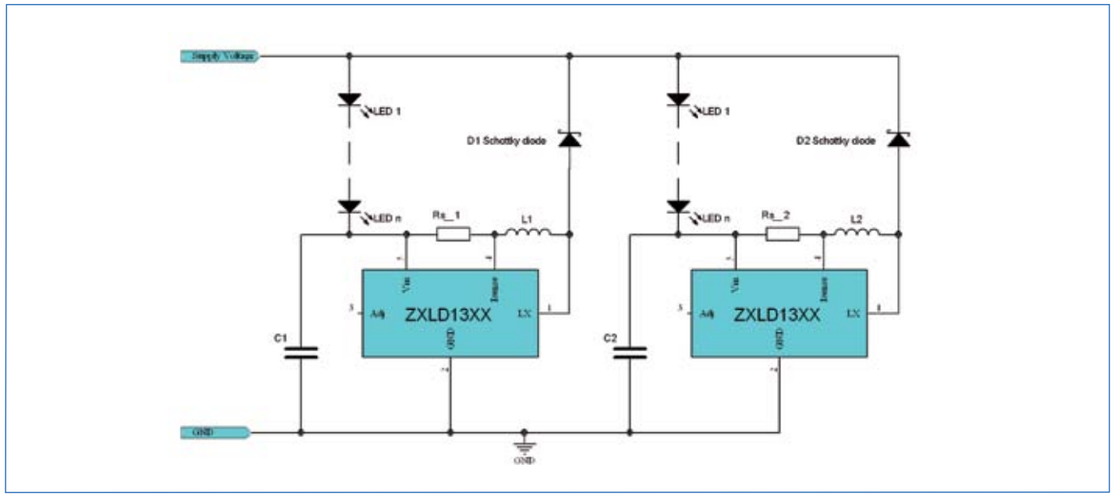


Figure 10: Multiple channel LED control using common anode topology.

This means there will be a variation between different lamps driven from the same reduced voltage. The LEDs will also vary in their intensity versus current characteristics. The effect of $RDS_{(ON)}$ variation depends on its proportion of the total sense resistance.

The operating frequency will rise at the lower currents causing a loss of efficiency but this is not serious as the LED power is low. In this way a much smoother dimming control is possible and it does not require any more than the standard 2 pins normally fitted to the LED lamp.

The measured characteristic for 2 values of sense resistor is shown in Figure 8 and the circuit diagram in Figure 7.

Common Anode Connection

For Buck LED controllers high sided current sensing is preferred which naturally positions the LED after the current sense resistor and inductor. The simplicity of the hysteretic converters provides the means to drive LEDs with a common anode scheme.

The common anode circuit is shown in Figure 9, and consists of connecting the anode of the LED directly to the supply voltage. The LED string is still in series with the sense resistor and the inductance, allowing the normal operation of the hysteric converter. The Common Anode name usually refers to a configuration with a single LED (or a set of LEDs in parallel), but the concept could be extended to a series of LEDs, or several chains of LED that share the same V+ rail.

This configuration has several advantages related mainly to the circuit performance, but also to installation convenience and component count in the system. From the performance point of view, the circuit shows an improved load regulation compared to the standard buck topology. Moreover, the circuit has a lower switching frequency which reduces the switching power losses and improves efficiency. Thermal management also becomes simpler for multiple LED chain systems as all the anodes can all sit on one heat sink at the same potential (see Figure 10). Since the voltage variation on the input is reduced, the common anode configuration allows for a smaller input capacitor.

The common anode topology simplifies the installation in signage and light wall applications, where drivers are usually remotely separately from the LED chains. In such cases, the first anode of each chain is directly connected to the power supply, so a single wire is needed to connect all the chains. Nonetheless a separate wire is still needed to connect the cathodes of each chain.

Finally, the common anode enables savings not only on the wiring side, but also on the component side. There is usually a capacitor in parallel with the string of LEDs to reduce the ripple voltage across the LEDs. This is not necessary in the common anode connection as the input capacitor already fulfils that requirement. It should be noted that the supply current to the hysteretic converter passes through the LEDs but has negligible effect on efficiency.

The main disadvantage with the common anode connection in hysteretic converters is that the available LED output voltage has to be lower than the minimum operating input voltage of the hysteretic converter. This reduces the maximum number of LEDs that can be driven compared to the standard buck configuration.

Conclusion

Hysteretic converters can be used over extensive voltage ranges and with a wide number of LED loads. The topology is suitable for PWM or DC dimming, however to maximise circuit performance limitations must be understood. The inherent simplicity and stability can be of benefit to an increasing number of LED lighting applications.

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Lighting Systems Part I

LEDs Shine a Light on a Bright Future

Optimized LED drivers now available to meet design needs

Year 2007 was a pivotal time for the adoption of LEDs into what will become a mainstream business for many analog IC suppliers. During the course of the last twelve months, some key metrics were met by the LEDs themselves, which will translate into a significant increase in the demand for the LED driver ICs necessary to power them in all end applications.

By Tony Armstrong, Product Marketing Manager, Power Products Group, Linear Technology Corporation

By examining a few of the catalysts which will precipitate the escalation of demand for LED driver ICs from their current embryonic stage and into an accelerated growth stage, it is evident that LEDs will quickly be a mainstream lighting source. Four of these main drivers are automotive lighting, LED light output, LED cost factors and their potential use as a replacement for incandescent light bulbs. Each of these factors will be examined in more detail below.

Automotive Headlights

Audi was the first automotive manufacturer to use LED headlights in its models. Their assembly contains two low-beam headlamps, as the main function, consisting of two LED arrays with four active elements each. Three additional LED arrays with two LED chips each are located behind the optical lens; their task is controlling the bright/dark boundary and the range of the headlights. For the high-beam headlight, a four-LED array is located adjacent to the low-beam arrays. Near the lower edge of the assembly, a row of 24 LEDs forms the daytime running light. At a current of 1A, each LED array achieves a luminous flux of six hundred 600 lumens. This assembly is offered as an option in the R8 luxury sports car for the 2008 model year. Although the first, there will be many more such headlights appearing very quickly as this type of headlight becomes mainstream in the automotive sector.

LED Light Output

A high-power LEDs' light output has achieved a critical milestone of 100 lumens/W, with some manufacturers claiming 120 lumens/W. This means that the LED has now surpassed the CFL (80 lumens/W) in terms of energy efficiency. It is further projected that by 2012, the LED will attain150 lumens/W output. Furthermore, with all the current focus on being "green," the LED does not contain any hazardous materials like the CFL, which has toxic mercury vapor inside the tube.

This is significant since the U.S. Department of Energy has stated that lighting consumes 22% of the electricity produced in America. Widespread use of LED lighting could cut this consumption in half. To put this into perspective, by 2027, LED lighting could cut the annual energy use by the equivalent of 500 million barrels of oil, with the attendant reduction in emissions of carbon dioxide

LED Cost Factors

The cost of LED lighting has come down very quickly. Polybrite (a leading manufacturer of lighting products which incorporate LED technology) has stated that the cost of individual white-light diodes, several of which go into an LED bulb and make up much of the cost, have come down in price from about $8 to $1.50 in the last twelve months. They further project that by the end of 2008 LED bulb replacements for the incandescent light bulb will be priced at a level that will be acceptable for the consumer.

LEDs Can Replace the Incandescent Light Bulb

Cree (a North American manufacturer of the die used inside many different medium- to high-power LEDs) has claimed that it has designed a light-emitting chip that could power a LED bulb producing light comparable to the 75-Watt incandescent bulbs so commonly used in American homes. This type of LED chip requires 4 amps of current in order to be able to output this amount of light.

Special Report – Lighting Systems Part I

LED Trends and Their IC Drivers

The LED drivers which are used to drive white LEDs commonly found in the backlighting of small displays in many handheld battery-powered portable products represents approximately 50% of the total LED driver market. However, this application has matured and does not have significant compounded annual grow rates (CAGRs) over the next five years. The three largest market segments with growth rates far greater than that of the handheld backlighting market segment for LED lighting applications are automotive headlamp illumination (CAGR of over 200%), followed by large LCD TV (CAGR of over 120%), and finally general purpose lighting (CAGR of over 30%).

Clearly, there is a great deal of design activity going on as a result of these LED lighting trends. And so, an obvious question is: 'what does this all mean to a system designer?' Well, system designers are clearly faced with a dilemma when selecting an appropriate LED for their end product, for example, what size and type of LED should be used, and more specifically, should a white LED be used over an RGB LED. Furthermore, the outcome of this selection process will determine the type of LED driver IC need to drive the LED, since white LED drivers differ from RGB drivers.

An inductorless low noise LED driver IC designed to drive low-profile RGB LEDs in a portable electronic device display or in a general backlighting application has different performance criteria versus a standard white LED driver IC. This is due to the fact that RGB LEDs have different forward voltages than white LEDs, thus requiring a different IC architecture. Typically, the RGB LED driver will have a single-wire ON/OFF interface and three individual resistor-programmable LED current sources to control dimming and brightness. A "White" mode would be used to optimize the red, green and blue LED current ratios for optimal white color when all three RGB LEDs are programmed "On".

Nevertheless, a RGB LED actually expands the range of visible light when compared to a cold cathode fluorescent light (CCFL), which have a limited color spectrum and lack color vividness. CCFLs exhibit about 80% of the National Television System Committee (NTSC) defined colors while RGB can reveal up to 110% of the NTSC color spectrum – enabling a more accurate representation of images on the screen. Furthermore, the largest possible color spectrum is achieved by using three monochromatic light sources such as red, blue and green lasers.

Meanwhile, white LED backlighting is well suited for handheld and mobile display panels since they have small form factors, are simpler to drive, are less sensitive to mechanical stress and have twice the life expectancy when compared to CCFL. However, white LEDs share the same disadvantage in color spectrum as CCFL because a white LED is equivalent to a broadband light source. A white LED is a blue diode covered with phosphor to convert a portion of the blue light to yellow light. This combined spectrum is perceived as white light. Although recent, so-called, warm white LED more closely match the NTSC color spectrum.

Still, RGB LEDs come closer to delivering a narrow-band spectrum at a fraction of the cost of monochromatic light sources. Not only do RGB LEDs improve the color spectrum, but they also improve efficiency as well because RGB LEDs only emit optical energy as needed – red, green and blue. Broadband light sources such as white LEDs and CCFL have a relatively high presence of unwanted colors that deteriorate the color spectrum and therefore cause a loss in efficiency. Since individual colors can be driven independently, the white point, or the color temperature of an RGB LED, can be corrected – whereas both CCFLs and white LEDs have a fixed white point.

In some instances, even though more RGB LEDs and therefore RGB LED drivers might be needed to backlight a display when compared to white LEDs, the color spectrum and more accurate color image can be worth the additional design complexity to a system designer. It is justifiable to use RGB LEDs instead of white LEDs due to the expanded color spectrum that significantly improves picture quality because consumers will pay a premium for color vividness when deciding between LCD TV models. Nevertheless, using RGB LEDs involves a larger, more complex and more costly solution. Thus, in applications where the expanded color spectrum is not going to allow the end product to have a price premium, the white LED solution as the backlighting source is an acceptable one.

Traditionally, the dimming of LEDs was done by adjusting the forward current flowing in the LEDs via a DC signal or a filtered PWM. Reducing the LED current adjusts the intensity of the LED light output; however, a change in forward current also changes the color of the LED as the chromaticity of the LED changes with the current. Many applications, such as automotive and LCD TV backlighting, cannot tolerate any shift in the color of the LED. Wide dimming ranges are needed in these applications because of the different light variations in the ambient environment and the fact that the human eye is sensitive to minor changes in light intensity. Controlling the intensity of the LED via applying a PWM signal allows dimming of the LED without changing the color.

"True Color PWM dimming" dims a LED via a PWM signal. It essentially involves turning the LED on and off at full current at the PWM frequency (as seen in figure 1). The human eye has a limit of 60 frames per second. By increasing the PWM frequency, say from 80Hz to 100Hz for example, the eye can be de-

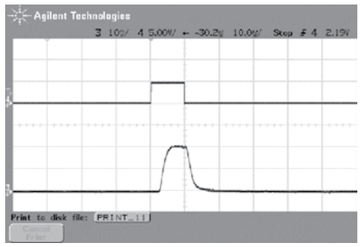

Figure 1. The LT3476 PWM/LED Current Waveforms. The top trace is the PWM pulse at 5V/div. The second trace is ILED at 500mA/div. The time scale (x-axis) is 10ms/div. [PWM Frequency = 100Hz]

ceived into believing that the pulsed light source is continuously on. Additionally, by modulating the duty cycle (amount of "on-time"), the intensity of the LED can be controlled. The color of the LED remains unchanged in this scheme since the LED current value is either zero or a constant value. Many LCD TV designers are requiring dimming ratios of upward of 3,000:1 to adjust to a wide array of ambient lighting conditions.

One example of an RGB LED driver would be Linear Technology's LT3476 quad LED driver. Each channel of the LT3476 can drive up to eight 1A LEDs in series (red, green, blue or white), enabling the LT3476 to drive up to 32 x 1A LEDs while delivering efficiencies up to 96%. Each of the four channels is independently operated by a True Color PWM signal, enabling them to be dimmed independently to ratios as high as 1000:1. A fixed frequency, current mode architecture offers stable operation over a wide range of supply and output voltages. A frequency adjust pin enables the user to program the frequency between 200kHz and 2MHz to optimize efficiency while minimizing external component size. Its thermally enhanced 5mm x 7mm QFN package offers a very compact solution footprint for 100W LED applications commonly found in large LCD TVs.

Another example would be the LT3496 - a triple LED driver. Its three-channel design makes it ideal for driving RGB lighting arrays. In step-down mode, each channel of the LT3496 can drive up to seven 500mA LEDs in series, enabling it to drive up to twenty-one 500mA LEDs while delivering efficiencies of up to 96%. Each of the three channels is operated by an independent True Color PWM signal, enabling each channel to be dimmed independently to ratios as high as 3,000:1. A fixed frequency current, mode architecture ensures stable operation over a wide range of supply and output voltages. Its input voltage range of 3V to 30V (with transient protection to 40V) makes it ideal for automotive and industrial applications. A frequency adjust pin enables the user to program the frequency between 300kHz and 2MHz to optimize efficiency while minimizing external component size. Its thermally enhanced 4mm x 5mm QFN package provides a highly compact solution footprint for 50W LED applications.

The LT3496 senses output current at the high side of the LED, enabling buck buck-boost or boost configurations. With an external sense resistor, the user can program the output current range of each channel. Each of the 3 independent driver channels utilizes an internal 750mA, 45V PNP switch and has a built-in gate driver for PMOS disconnect. Other features include LED protection and thermal limiting.

Conclusion

Clearly, a system designer has to make a cost performance trade off on the type of LED to be used in the end system. This will usually entail the selection of the panel size and the type of LED required to backlight it. However, whether it is a white LED or a RGB LED, there are plenty of optimized LED drivers available to meet their needs.

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Special Report – Lighting Systems Part I

The Design Challenges of Driving LEDs

Power supply topologies for LED Lighting

This article presents an overview of LED characteristics and the trade-offs in driving them. It provides a detailed discussion on various switching power supply topologies suitable for driving and dimming LEDs, as well as detailing their relative merits.

By John Betten, Application Engineer and Senior Member of Group Technical Staff and Robert Kollman, Senior Applications Manager and Distinguished Member of Technical Staff, Texas Instruments.

As production costs of LEDs fall, they are being used more often in applications ranging from handheld devices to automotive to architectural lighting. Their high reliability (operational life of greater than 50,000 hours), high efficiency (>120 Lumens/Watt), and nearly instantaneous response make them very attractive light sources. LEDs produce light in as little as 5nS compared to the 200mS response time of an incandescent bulb. As a consequence, they have been embraced by the automotive industry in brake lights.

Driving LEDs

Driving LEDs is not without its challenges. A controlled brightness requires driving the LED with a constant current, which must be maintained regardless of input voltage. This is far more challenging than powering an incandescent bulb by simply connecting it to a battery.

An LED has a forward V-I characteristic similar to a diode. Below the LED turn-on threshold, which is approximately 3.5V for a white LED, very little current flows through it. Above that threshold, current flow increases exponentially for an incremental increase in forward voltage. This allows the LED to be modeled as a voltage source with a series resistance with one caveat: the model is valid only at a single operating DC current. If the DC current in the LED is changed, then the resistance of the model should be changed to reflect the new operating current. At large forward currents, the power dissipated in the LED heats the device, which changes the forward voltage drop and the dynamic impedance. It is critical to consider the thermal environment when the LED impedance is determined.

When an LED is driven by a buck regulator, the LED often conducts the inductor's AC ripple current in addition to the DC current, depending on the output filter arrangement chosen. This increases the RMS magnitude of the current in the LED and can increase its power dissipation. This can increase the junction temperature and have a major impact on the life of the LED. If we establish a 70 percent limit on light output as the useful life of the LED, an LED's lifetime can be extended from about 15,000 hours at 74 degrees Centigrade to 40,000 hours at 63 degrees Centigrade. Power loss in the LED is determined by the LED resistance times the square of the RMS current, plus the average current times the for-

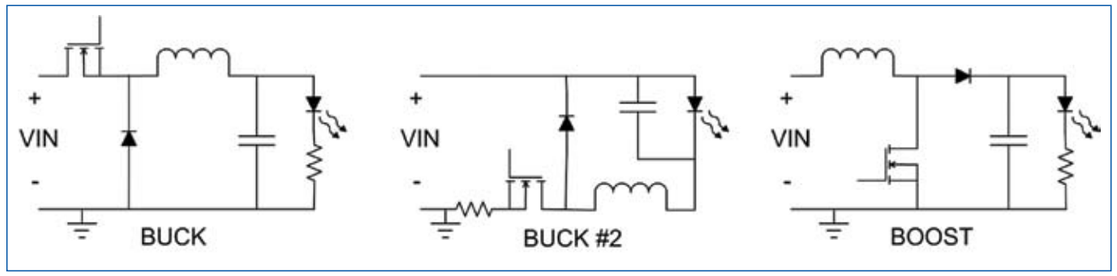


Figure 1: Simple buck and boost topologies for power LED's.

Topology	Vin > Vout Always	Vin < Vout Always	Vin < Vout And Vin > Vout	Isolated
Buck	✓			
Boost		✓		
Buck-Boost			✓	
Buck or Boost			✓	
Sepic		✓	✓	
Flyback	✓	✓	✓	✓

Table 1: Candidate LED Power Supply Topologies.

ward voltage drop. Since the junction temperature is determined by the averaged power, even large ripple currents have little impact on power dissipation. For instance, in a buck converter, a peak-peak ripple current equal to the DC output current (Ipk-pk = I_{out}) adds less than 10 percent to the total power loss. Much above this level, AC ripple current from the supply needs to be reduced to maintain junction temperatures and operating life. A useful rule of thumb is that the semiconductor life increases twofold for every 10 degrees Centigrade reduction in junction temperature. In practice, most designs tend toward much lower ripple currents because of inductor constraints. Additionally, peak current in the LED should not exceed the manufacturer's specified maximum safe operational rating.

Topologies Choices

Information presented in Table 1 can assist with selecting the best switching topology for an LED driver. In addition to these topologies, you can also use a simple current limiting resistor or linear regulator to drive the LEDs, but these approaches usually waste too much power. The input voltage range, number of LEDs driven, LED current, isolation, EMI constraints, and efficiency are all pertinent design parameters. Most LED drive circuits fall into the following topology categories; buck, boost, buck-boost, sepic and flyback.

Figure 1 shows three examples of the basic power supply topologies. The first schematic shows a buck regulator that can be used if the output voltage is always less than the input voltage. In Figure 1, a buck regulator controls the current into the LED by varying the on time of the MOSFET. Current sensing is achieved by measuring the voltage across a resistor, which is in series with the LED(s). A significant design challenge to this approach is driving the MOSFET. From a cost and performance perspective, using an N-channel FET, which requires a floating gate drive, is recommended. This requires either a drive transformer or a floating drive circuit, which can sustain a voltage higher than the input.

Figure 1 also shows an alternative buck regulator (buck #2). In this circuit, the MOSFET is driven with respect to ground, significantly easing drive circuit requirements. This circuit can sense LED current by monitoring the FET current or, optionally, a current sense resistor in series with the LED. The latter requires a level shift circuit to get this information to the power supply ground and complicates a simple design. A boost converter, also shown in Figure 1, is used when the output is always larger than the input. This topology is easy to design in that the MOSFET is driven with respect to ground, and the current sense resistor is also ground referenced. One shortcoming of this circuit is during a short circuit, there is nothing to limit the current through the inductor. Fault protection can be added in the form of a fuse or electronic circuit breaker. Alternatively, some of the more complex topologies can provide this protection.

Figure 2 shows two buck-boost circuits that can be used if the input voltage can be both higher and lower than the output voltage. They feature the

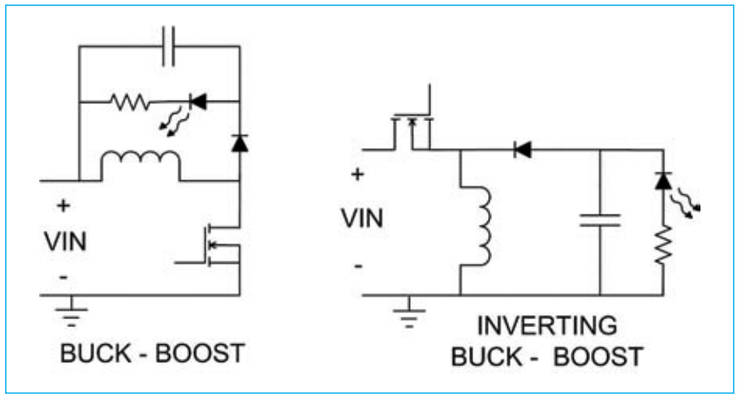


Figure 2: Buck-Boost topologies accommodate input voltages greater or less than Vout.

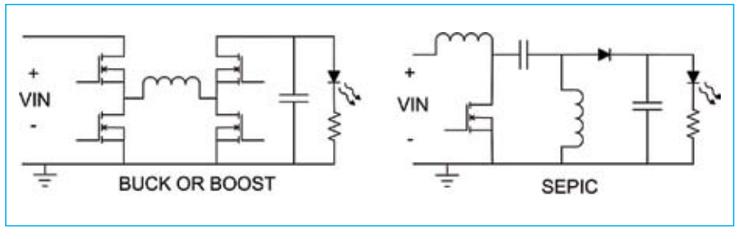


Figure 3: Buck or Boost and SEPIC topologies provide higher efficiency.

Special Report – Lighting Systems Part I

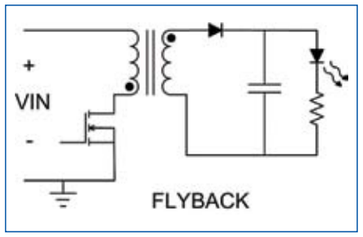


Figure 4: Flyback can offer isolation and power factor correction.

same tradeoffs found in the two buck topologies concerning the location of the current sense resistor and the gate drive. The buck-boost topology in Figure 2 shows a ground referenced gate drive. It requires a level-shifted current sense signal whereas the inverting buck-boost has a ground referenced current sense and a level-shifted gate drive. The inverting buck-boost can be configured in a very useful way, if the control IC is referenced to the negative output and the current sense resistor and LED are swapped. With the proper control IC, the output current can be measured directly, and the MOSFET can be directly driven.

One drawback to the buck-boost approach is the relatively high currents. For example, when the input and output voltage are the same, the inductor and power switch currents are over twice the output current. This has a negative impact on both efficiency and power dissipation. In many cases, the "buck or boost" topology in Figure 3 will mitigate these issues. In this circuit, there is a buck power stage followed by a boost. If the input voltage is higher than the output voltage, the buck stage provides voltage regulation while the boost stage just passes the power. If the input voltage is less than the output voltage, the boost provides regulation and the buck passes the power. There usually is a provision for some overlap of the boost and buck operation so there is no deadband going from one mode to another.

When the input and output voltages are nearly equal, this circuit has the advantage of the switch and inductor currents being nearly equal to the output current. The inductor ripple current also tends to be less. Even, though there are four power switches in this circuit, there are usually significant efficiency improvements which are critical in battery applications. The sepic topology, which requires less FETs but more passive components, is also shown in Figure 3. It has the advantages of a simple ground-referenced FET driver and control circuit. Furthermore, the dual inductors can be combined into a single coupled inductor, saving area and cost. But like the buck-boost, it has higher switching currents than the "buck or boost" and pulsating output currents, which require capacitors capable of large RMS currents.

Safety concerns may dictate using isolation between an off-line voltage and the output voltage. In this application, the most cost-effective solution is the flyback converter (Figure 4). It requires the fewest number of components of all isolated topologies. The transformer turns ratio can be designed to buck, boost, or buck-boost the output voltage, providing great design flexibility. A disadvantage is that the power transformer is typically a custom component. Additionally, there are high component stresses in the FET as well as the input and output capacitors. In constant lighting applications, power factor correction (PFC) can be implemented by the use of a "slow" feedback control loop that regulates the LED current in-phase with the input voltage. This regulates the desired average LED current along with an input current in-phase with the input voltage, providing a high power factor.

Topology	Typical Applications
Buck	Automotive, Signage, Projector, Architectural
Boost	Automotive, LCD Backlight, Torch (flashlight)
Buck-Boost, Buck or	Medical, Automotive Headlamp; Torch (flashlight),
Boost, Sepic	Emergency Lights, Signage
Flyback	Architectural Lighting

Table 2: Numerous LED applications dictate a variety of power supply topologies.

Dimming Techniques

Quite often, LEDs require dimming. For instance, it may be desirable to dim a display or dim architectural lights. There are two ways to accomplish this: either reduce the LED current, or quickly turn the LED on and off and let the eye average it out. The least effective method is to reduce the current because the light output is not completely linear with current. Moreover, the LED color spectrum tends to shift at currents below full rating. Remember: human perception of brightness is exponential, so dimming can require large percentage changes in current. This has a profound impact on the circuit design as a three percent regulation error at full current can become a 30 percent or more error at 10 percent load due to circuit tolerances. Dimming the current through pulse width modulation (PWM) is more accurate, although there is a speed of response issue. In lighting and displays, PWM above 100 Hz is desired so the human eye does not perceive flicker. A 10 percent pulse width is in the millisecond range and requires the power supply to have a bandwidth greater than 10 kHz.

Conclusion

As Table 2 indicates, LED's are becoming widely used across numerous applications. It will take a wide range of power supply topologies to support these applications. Generally, the input voltage, the output voltage, and the need for isolation will dictate the proper choice. Where the input voltage is always more or less than the output, the choice may be obvious with the buck or boost. However, when this relation is not so constrained, the choice becomes more difficult with numerous tradeoffs including efficiency, cost and reliability.

For further information on LED and lighting solutions from Texas Instruments, visit:

www.ti.com/lighting

Light-Up with LED Design Solutions

Driving large numbers of LEDs for backlighting applications

Cold Cathode Fluorescent Lamps have dominated LCD display backlighting in large screens such as computer and television displays. The great steps made in LED technology have enhanced the overall performance of TFT displays, offering more compact solutions with higher efficiency and longer life. Driving LED backlight panels in space-critical applications, such as infotainment and small medium format displays, presents a real challenge for designers. This article highlights how these challenges can be addressed, using a dedicated LED driver.

Michele Sclocchi, Principal Applications Engineer, Power Management Europe, National Semiconductor

The CCFL backlight solution is commonly used in large colour displays, PC monitors and flat panel TV sets, since it offers relatively uniform and bright white light at low cost. However it presents several disadvantages that limit use on other portable devices, high reliability systems, automotive displays, and high efficiency systems.

CCFL backlighting requires high voltage DC-AC inverters, operating at 30-40kHz, and offers a limited lifetime of around 20.000-25.000 hours.

Applications subject to high mechanical vibration such as automotive, aviation and portable equipment gain the full advantages of LED technology since an LED backlight solution is less sensitive to mechanical stress and offers higher efficiency with twice the lifetime offered by today's CCFL technology.

CCFL technology also suffers from limited colour spectrum light emission which translates to reduced brilliance and contrast ratio of the display.

For all these reasons, LED technology has been established as a standard solution for the backlight in displays.

LED Backlight Panel Configuration

Two different approaches can be adopted to achieve a homogeneous light on the back of the display:

LCD display (inches)	Number of LEDs	One string Maximum forward voltage (Volt)	Two strings Maximum forward voltage (Volt)	Three strings Maximum forward voltage (Volt)
7"	15-21	52-73	25-35	18-25
8"	20-25	70-88	35-45	18-28
10"	30-40	105-140	52-70	35-46
14"	60-80	210-280	105-140	70-95

Table 1: Number of LEDs and the maximum forward current depends on the application and size of display

- Direct backlight: LEDs are mounted on a PCB with a draughtboard configuration with the same spacing between each LED to achieve a homogeneous illumination of the display. A diffuser foil is mounted between the back of the display and the LED PCB. This configuration results in higher brightness and more homogeneous light.

- Reflected backlight: the LEDs are mounted on the back frame of the display and a reflector foil, placed between the LED mounting and the display, ensure the uniform distribution of light.

Regardless of the technique adopted to achieve homogeneous light, a relatively large number of LEDs are required for backlight illumination.

The total number of LEDs and the maximum forward current depends on the application and the size of the display, typically a 7 inch display requires 15-20 LEDs, 10-12 inches 40-60 LEDs, with maximum forward current from 10mA to 100mA.

As all LEDs must have the same brightness and colour temperature, they need to be driven with constant current and a pulse width modulation (PWM) dimming technique should be used.

LEDs can be driven in parallel or in series; serial connection is the preferred method for backlight driving because of simple PCB mounting, perfect current matching between LEDs, and easy control. However, a single serial connection string of LEDs would require a boost converter with very high voltage limiting its application to 10-20 LEDs, depending on the minimum input voltage of the source.

A combination of parallel strings of LEDs connected in series is preferred for large arrays of LEDs. Table 1 shows the different distribution of large arrays of LEDs.

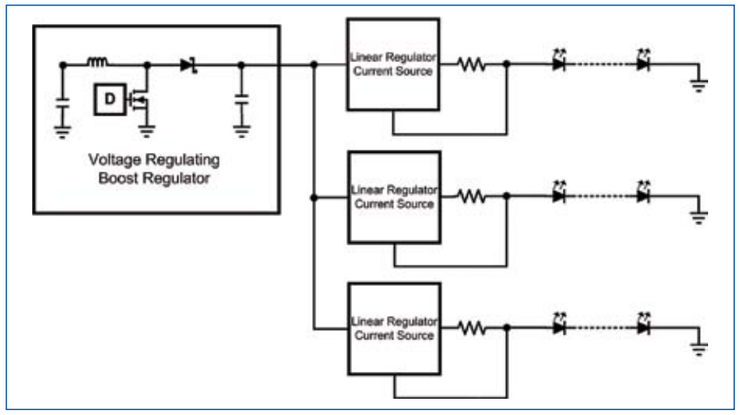


Figure 1: Voltage regulating boost converter plus three linear regulator current sources.

LED Configuration

Large arrays of LEDs can be configured with a voltage regulating boost power supply. It boosts the input voltage just above the maximum total forward voltage of the LED strings, and a linear current source regulator on each string to accurately regulate the current.

The challenge of this configuration is to reduce losses in the linear regulators by adjusting the output boost voltage to just above the dropout threshold.

This configuration is well-suited for LED backlighting applications for TFT displays where a large number of LEDs has to be powered by the same output current. However, this solution presents some limitations on the overall efficiency and precision:

- Forward voltage drop varies from LED to LED, and from different lots of the same type of LED.

- Power dissipation across current regulators: The output voltage of the boost stage should have enough margin to cover LED voltage variations, plus linear current regulator; each LED string has different forward voltage drop, hence a high LED rail voltage is used to ensure all channels are in regulation. In some cases, a serious voltage dip occurs during turn-on when PWM dimming is used and extra margin needs to be added. Also, the extra rail voltage leads to higher power dissipation on the linear stages.

Brightness change with forward current variation:

- LED luminous intensity varies with forward current. Tight control of forward current in individual channels is required to maintain even brightness; typically a variation within ±3% is required.

Backlighting Design Challenges

Besides LED current accuracy there are other significant challenges in the design of a backlight display with large arrays of LEDs:

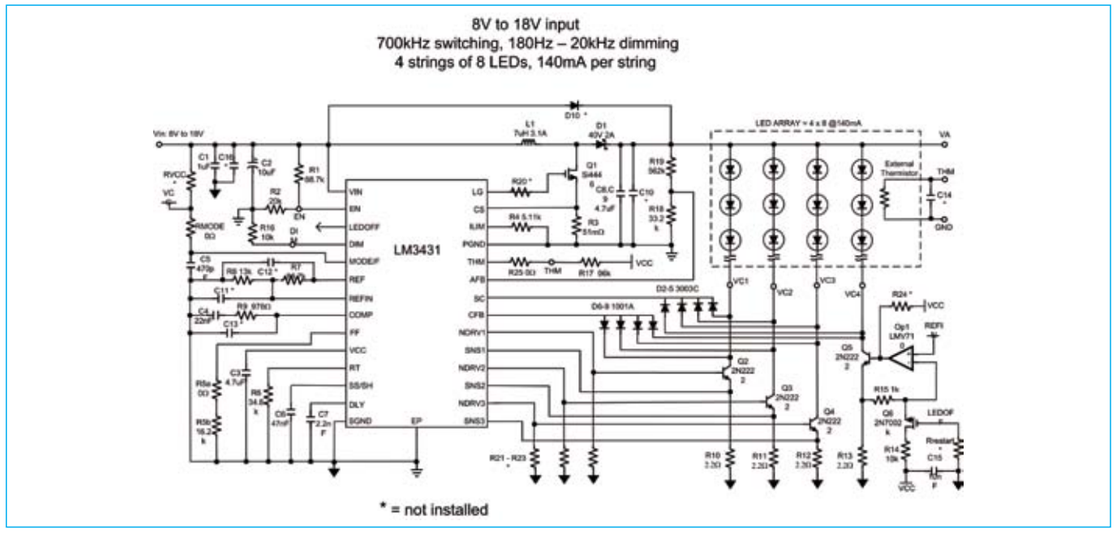


Figure 2: Backlighting design example with National Semiconductor's LM3431 LED driver.

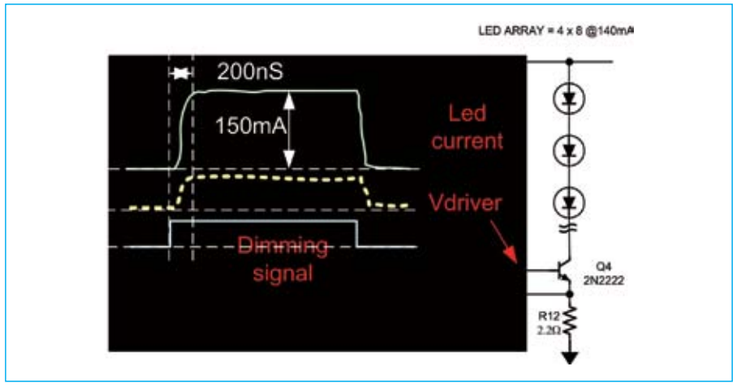


Figure 3: Dimming linearity is achieved with dedicated LED current regulator.

• Accuracy between strings: each string of LEDs should have the same brightness in order to give a homogeneous light on the back of the display.

• High contrast ratio is essential in display system. Fast light dimming control with constant ratio above 1000:1 is achieved with high slew rate current control.

• Dimming linearity: PWM duty cycle versus light output

• Audible noise from output capacitors: audible noise could be generated by the output ceramic capacitors of the boost converter during LED dimming. Audible noise increases with the amplitude of output voltage transient.

• LED fault protection: external circuitry should be added to detect and protect the LED array fault conditions – i.e. when one or more LEDs fail open or short, during under-voltage lockout or temperature shutdown.

• LED forward voltage tempco: the forward voltage drop varies with temperature with a coefficient of about -4 mV/°C.

• Overall high efficiency with small solution size.

The schematic in figure 2 shows a typical application of LED lighting for a TFT display, where four strings of LEDs are controlled through four external PNP transistors.

The LM3431 combines a boost controller and three constant current regulator controllers in one device. To simplify the description, these two blocks will be described separately as Boost Controller and LED current regulator.

Boost controller stage:

• The overall system efficiency is optimized by the "headroom controller" of the boost output stage.

• The boost stage controls the LED cathode voltage (VC1-4 of the schematic in figure 3) in order to drive the LED strings with sufficient headroom.

• There are two feedback paths for LED-on and LED-off states: it regulates the lowest cathode voltage during LED-on, and it regulates the output voltage during LED-off, which is during startup and dimming-off cycles.

• Ideally, during the LED-off stage, there is no load and no constant switching on the boost stage; however the output voltage is maintained constant with a "sample and hold technique" to avoid audible noise on the output capacitors and to achieve highest possible dimming ratios.

The boost stage should be operated in continuous conduction mode; in order to achieve better dimming response a small output inductor should be selected. The PWM current mode control with external compensation allows fast response time with fast regulation. An internal feed-forward technique has been added to achieve faster load transient response.

LED Current Regulator

The LED current control allows low LED ripple current (<5mA peak-peak at 150mA) with high string-to-string accuracy (within 2mA over temperature and 1.5mA typical).

The LED current regulator also provides fault detection and protection for three types of LED fault conditions:

• One LED is open or short: the controller continues to regulate and fault flag is set.

• All LEDs are open or multiple LEDs are short: the controller latches off or restarts.

• During Under Voltage Lockout (UVLO) or temperature shut-down, the device goes into stand-by mode.

High dimming linearity is achieved with fast LED current slew rates, typically in the order of 1.2A/µsec, and short propagation delay from the dimming input and NPN linear output (figure 3).

Conclusion

This article provides a design solution for driving large numbers of LEDs in TFT displays. National's LM3431 LED driver addresses all the challenges of these applications, offering a compact and reliable solution. In summary the main advantages this LED driver offers to the designer are:

• Perfect current matching between strings of LEDs

• Improved efficiency with headroom voltage control

• Avoidance of audible noise in the output capacitors

• Achievement of a high contrast ratio up to 5000:1, resulting in much higher brightness and contrast ratio on the TFT screen.

Additional design resources can be found at National Semiconductor's website under: http://www.national.com/pf/LM/LM3431.html, including dedicated demo-board, application notes and design tools.

www.national.com

Lighting World Reinvented with Ever Improving HBLED Technology

Design optimization of High Brightness LED drivers

Within the range of different light sources, high brightness LEDs (HBLEDs) are currently the fastest growing and beginning to replace other types of lighting, such as incandescent, halogen, fluorescent and even HID. In the past, LEDs have been suitable only for instrumentation lighting, constrained by their limited light output.

By Peter B. Green, Senior Systems Engineer, International Rectifier

In recent years, the development of high brightness LEDs (HBLEDs) has enabled their use for architectural and decorative lighting as well as signage. HBLEDs have also become an attractive alternative to CCFL (cold cathode fluorescent lamp) light sources as backlighting for LCD TVs and monitors. As HBLED technology continues to improve, the luminous efficacies possible have reached 35 to 50 lm/W (lumens per Watt), which surpasses incandescent and halogen lamps and matches fluorescent lamps. Improvements will produce devices with luminous efficacy >100 lm/W, exceeding fluorescent lamps and eventually matching HID lamps.

It should be noted that dimming, while difficult and expensive to accomplish with fluorescent lighting - and impossible below 50percent light output for HID lamps - is very easy to achieve over the entire range with HBLEDs.

HBLEDs are produced in a range of different colors, sizes and power ratings. Their electrical characteristics, particularly the forward voltage drop will vary substantially between the different types. In addition, there are significant variations between different production lots resulting in wide tolerances. The forward voltage drop also possesses a negative temperature coefficient, which further adds to the problem of defining a suitable power supply for the application. At the present time many power supplies are being sold on the market for the purpose of driving clusters of HBLEDs, which simply provide a constant voltage. This method, although simple to understand for the non-technical user, is counter-intuitive and introduces limitations to the system as well as reduced efficiency.

HBLEDs are rated by their current and not their voltage. For example, a family of HBLEDs will contain several members, all of which have different colors

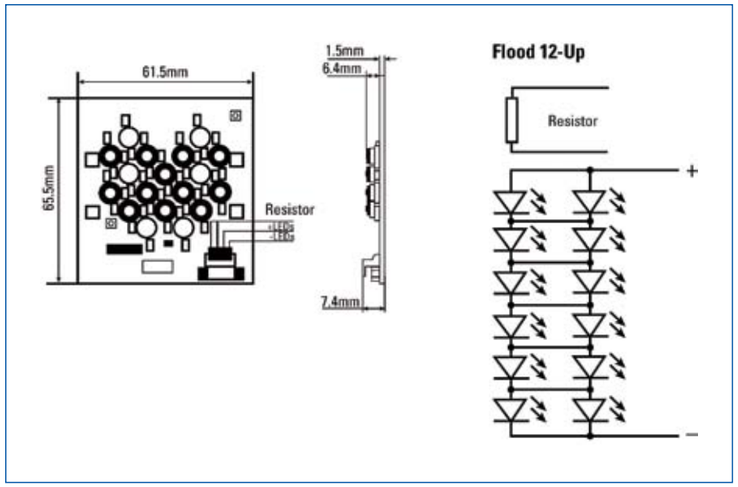


Figure 1. A typical 12 HBLED panel.

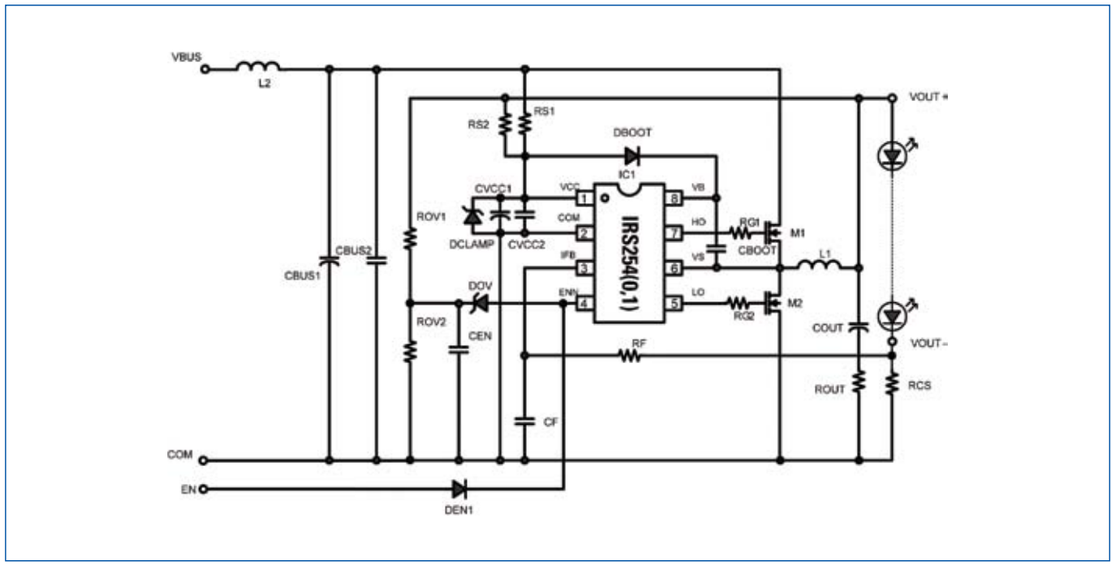


Figure 2. The IRS2540 LED converter.

and forward voltage drops but all have the same current rating, for example, 350mA or 700mA.

As well as being sold individually, HBLEDs are also widely sold in panels, which contain several connected together.

HBLEDs connected in series will inherently supply the same current in each individual LED. However, since the forward voltage drop of each one is something in the region of 4V it can be seen that the cumulative voltage of a series of HBLEDs will rapidly add up. To prevent the panel supply voltage from being higher than is desirable the panels are generally comprised of series and parallel LED networks. For example, a Lumileds Flood panel consists of 12 LEDs which are connected as 6 series pairs of parallel LEDs as shown in Figure 1.

In this example the manufacturer has connected the HBLEDs in parallel pairs. Since they possess a negative temperature coefficient of forward voltage drop, in order to prevent one LED in the pair from drawing more current than the other they must be carefully matched in production. Unfortunately, even a small mismatch will tend to be amplified in operation because if one LED draws slightly more current than the other due to the fact that it has a lower forward voltage drop, it will heat up more rapidly and, therefore, its forward voltage drop will be further reduced and at a greater rate than the other, further amplifying the imbalance. Assuming that the manufacturer is successful in selecting matched pairs, it can be seen that six pairs are connected in series so that the individual pairs can have different forward voltage drops. The total voltage for the whole panel in this case is six times the forward voltage drop of one single HBLED. This panel is available in six different colors and the forward voltage drop varies from 17 to 21V between these. To add to this the tolerance is also large, for example, for a white panel it is from 16 to 24V. The temperature coefficient of this voltage is rated at -12mV / °C meaning that if a panel at room temperature of 25 °C has a voltage of 17V then at 50 °C it will be 16.7V. The important point here is that in all cases the panel current rating remains at 700mA.

Although HBLED power supplies are currently being sold on the market, it is clear that these are not able to supply an LED array as described above, without the addition of a series current limiting resistor. The addition of such a resistor may allow, for example, a 17V rated panel to be supplied from a fixed 24V power supply at 700mA but would introduce an unnecessary power loss of (24 – 17) x 0.7 = 0.49W of energy dissipated as heat. This goes against the entire ethos of energy saving in lighting. In addition, it is not very accurate. A resistor can be calculated to provide 700mA from a 24V supply to a 17V panel, (24-17) / 0.7 = 10 Ohms. However if the panel voltage is only 16V the current supplied will be (24-16) / 10 = 800mA which is substantially higher than the rated current and would overdrive the LEDs in the panel, reducing their working life. On the other hand if the panel voltage were 18V then the current would be (24-18) / 10 = 600mA which would produce a significantly reduced light output. It is unnecessary to add in the effects of forward voltage variations over temperature to illustrate the obvious drawbacks of the constant voltage approach and it becomes increasingly clear that a constant current supply is needed to drive HBLEDs.

The IRS2540 control IC recently launched by International Rectifier is utilized in a Buck converter topology designed to provide a stable, regulated current source over a wide variation in input voltage and output load conditions, making it ideal for many applications where isolation is not required, i.e. where the supply source is already iso-

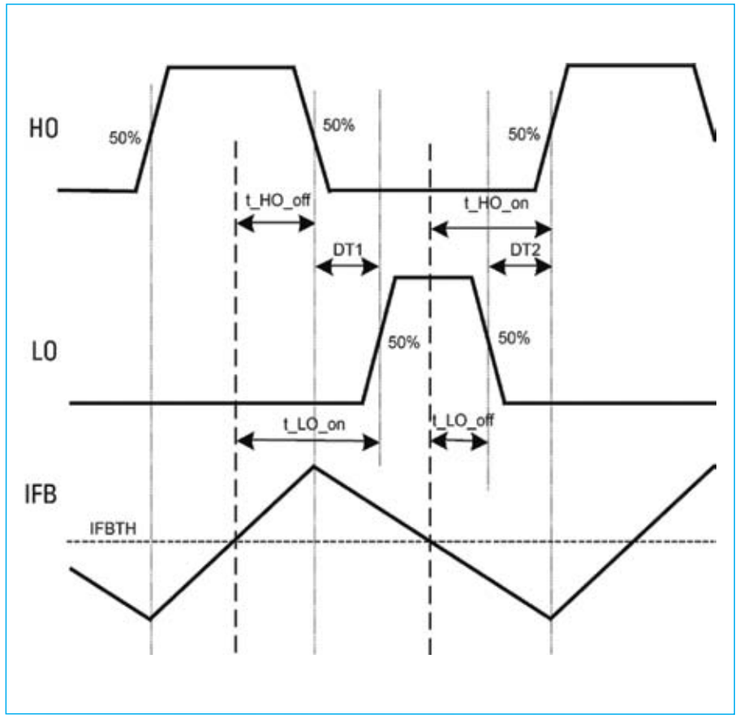


Figure 3. IRS2540 Average current control.

lated or where the HBLEDs are enclosed within a class 2 fixture and are not accessible, such as traffic lights. It should be noted in architectural lighting that electronic ballasts for fluorescent or HID lamps are also generally not galvanically isolated from the AC line.

The Buck circuit topology is suitable only in applications where the input voltage is higher than the output voltage, which covers most signage, decorative and architectural situations. Since the most common HBLED failure mode is by short circuit, it is worth noting that in a series run when one LED fails the others will all continue to operate normally. However, in a parallel arrangement, a short circuit would prevent all of the other LEDs in the array from operating. In the example of Figure 1, if one HBLED in the array fails short circuit, it's partner in the pair will no longer operate but the others will continue to function normally.

The IRS2540 based Buck converter with its unique high side driver allows the continuous monitoring of the load current, which is accurately regulated by means of its patented time delayed hysteretic control method.

The overall system is also very simple and flexible, enabling LEDs to be powered from a DC bus or directly from the rectified AC line. The floating high side driver enables the IRS2540 to sense the LED load current both while the Buck regulator switch is in its on and off phases, providing a significant advantage enabling average current control to be realized as opposed to alternative systems where the current is only detectable during the on phase that must utilize peak current control. Average current control provides inherently stable regulation that is able to operate over a wider line and load range without running into design limitations, since it is able to regulate the on and off times rather than just the on time.

The advantage is that a very accurate current control can be achieved using a very straightforward design concept, which is inherently stable and requires no complex circuit analysis.

Since the LED load requires a DC current with minimal ripple, constant current drivers operate in continuous conduction mode regardless of whether peak or average current mode control is used.

In the case of the IRS2540, care has to be taken to limit stress during hard-switching by the inclusion of defined delays between the time the load current exceeds or falls below the reference level and the time the Buck switch changes state. These delays in conjunction with the dI / dT of the load current (IFB) also determine the frequency and duty cycle of operation, which are further determined by the value of the Buck inductor and output capacitor as well as the input and output voltages of the converter.

Overload and short-circuit protection are inherently provided in this configuration since the output current is constant and open load protection can easily be implemented.

It is well known and documented that switching power supply designs that operate in continuous mode using peak current control run the risk of unstable operation due to sub-harmonic oscillation.

Although this can be eliminated by slope compensation, certain LED con-

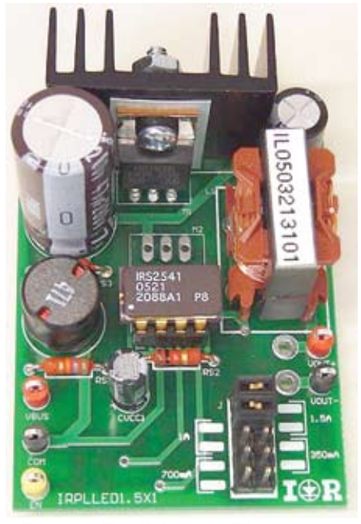


Figure 4. The IRS2540 LED converter demo board.

Special Report – Lighting Systems Part I

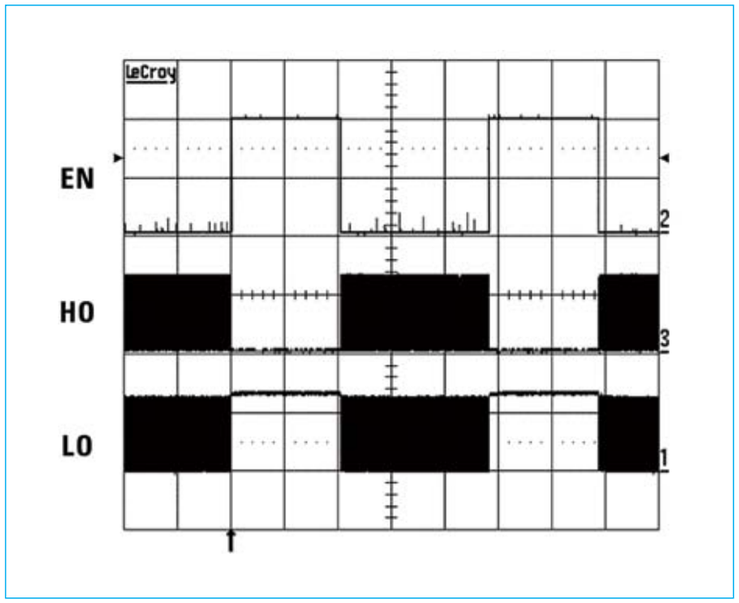


Figure 5. Dimming operation.

trollers currently on the market do not provide access to the oscillator capacitor, which makes such a scheme more difficult to implement. In addition, the slope compensation would also introduce an error between the sensed current and the actual LED load current.

Instead they attempt to get around the problem by operating with a fixed off time rather than a fixed frequency. This does alleviate the sub-harmonic oscillation and allows operation at duty cycles above 50%, however in order for the duty cycle to increase the frequency must drop resulting in a wide frequency variation over the duty cycle range.

In a fixed off time system where the frequency is 100kHz at 50% duty cycle the frequency must be 20kHz at 90% duty cycle and 180kHz at 10% duty cycle.

The IRS2540 does not have this limitation as the on and off times can both vary independently so that the duty cycle can change with little effect on the frequency.

Large frequency variation has the disadvantage of requiring that the inductor value must also be comparatively large.

Changing from a fixed to a variable frequency approach now makes redundant any argument that fixed frequency operation may possess some EMC advantage over the variable frequency operation of the IRS2540 based system in terms of filter simplicity.

This point, however, may well be a misconception based on the assumption that the filter design for a fixed frequency circuit is simpler than that for a variable frequency system, which is not necessarily the case. However, it is clear that in a system where the frequency can vary by an order of magnitude the filtering requirements must be greater.

The IRS2540 method has been demonstrated using the demo board shown in Figure 4, which is capable of driving a string of LEDs with a 17V forward voltage at 1.2A, directly off a rectified 110VAC supply with efficiency above 85% at a frequency of 175kHz.

In many applications dimming is also required. In addition, where there is a combination of LEDs of separate primary colors it is possible by adjusting the intensities of each color, to create any color of the spectrum allowing many possibilities for display lighting, signage and mood lighting. The Buck regulator system based around the IRS2540 is capable of dimming over the full range from logic level a PWM control signal. The PWM signal being at a relatively low frequency is used to switch the drive current to the LEDs on and off and by altering the duty cycle change the light output intensity, without changing the color.

The PWM dimming control signal is shown in Figure 5. The high frequency Buck converter oscillator is being operated in "Burst mode" to adjust the average current in the LEDs. The frequency of the signal is not low enough for flickering to be visible. This allows simple interfacing with microcontroller based dimming control circuitry.

High brightness LEDs are enabling architects, designers, specifiers and manufacturers to create lighting effects and design luminaries not previously possible for theaters, studios, nightclubs, restaurants and other high visibility venues. Using digital control, for example, through the DMX512 protocol, vibrant and changing light can appear to come from a variety of places. Whether embedded in a countertop, ceiling, or wall, lamp size no longer dictates where light can originate from. The lighting world is being reinvented with the introduction of ever improving HBLED technology.

Landscape lighting and outdoor lighting also naturally lends itself to HBLED light sources, which offer advantages over incandescent and fluorescent lamps such as longer life and consequently reduced maintenance costs, as well as less vulnerability to moisture ingression. Unlike conventional light bulbs, LEDs have no fragile internal components such as filaments to break, even when handled roughly. The IRS2540 based converter is ideally suited for many of these applications.

www.irf.com

APEC - The Green Powerhouse of Conferences

The Applied Power Electronics Conference, APEC, this year held in Austin, Texas, exceeded expectations on all fronts. Records were set in all categories of attendance. The whole area including conferences, technical break-outs, rap sessions and the adjacent exhibition were bustling with activity. As it has always been, it was a real feast for me to see so many power companies together. It underscores the fact that our industry continues gaining momentum, enthusiasm, talent and stature. Especially in light of the huge ground swell movement on energy efficiency, renewable energy and alternative energy, led in part by industry leaders, government officials and conservation organizations. We at PSDE have labeled and branded this as 'GreenPower'.

I met and talked with as many companies as I could and would really recommend a visit to APEC next year if you can make it. For many it is not feasible so I have tried to pull together a space-limited selection to give you a sense for what APEC is about. I hope you enjoy it and can make it next year in Washington, DC.

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

Alpha & Omega Power Management Solutions

I talked with Francois Hebert PhD, Chief Technology Officer and Tony Grizelj VP, Marketing of Alpha & Omega Semiconductor.

Established September, 2000 with corporate headquarters in Sunnyvale, California the company has its R&D center in USA and Operations center in Shanghai with sales offices worldwide.

The company specializes in power semiconductor solutions such as power MOSFETs, power ICs and transient voltage suppressors and has been profitable since Q4 2002 with $200M/year revenue and over 2 billion units shipped per year.

With over 300 employees the company has enjoyed explosive growth due to their commitment to value, technology and service in the three broad areas covered.

Power MOSFETs: Products optimized for low RDS(ON), DC/DC conversion, load switching, motor control, power management, battery protection.

Power ICs: "EZ" family of DC/DC regulators, smart load switches, battery protection.

Transient Voltage Suppressor (TVS) & EMI Filters: Family of ultra-low capacitance products with high ESD ratings and tight clamping voltage designed to protect high speed data interfaces.

The company is a pioneer in 8" fab-lite model for Trench MOSFETs and develops proprietary processes using advanced 8" fabs deploying state-of-the-art equipment to deliver the highest performance and cost-effective and well supported solutions for its customers.

www.aosmd.com

Fairchild's Power-SPM™ Module

Enables Power Supplies to Meet Stringent ENERGY STAR® Requirements

Fairchild Semiconductor now offers power supply designers a Power-SPM module that increases efficiency in power supplies to meet stringent ENERGY STAR requirements. The Power-SPM FPP06R001 is a highly integrated synchronous rectification module that increases power efficiency, system ruggedness and space efficiency in power supply designs. Incorporating two PowerTrench® MOSFETs and a high current gate driver in a compact transfer-molded package, the Power-SPM simplifies board design, eliminates up to 10 discrete components and reduces board space by 20 percent.

It provides 10 percent lower on-resistance and 16 percent lower stray inductance compared to discrete solutions, which results in lower thermal dissipation and reduced voltage stress. Its high efficiency is instrumental in helping power supply designs meet next generation ENERGY STAR requirements. These requirements specify that power supplies must achieve 85 percent or greater efficiency at normal output load conditions.

"Fairchild is at the forefront of solving energy-efficiency challenges. The ENERGY STAR requirement for power supply units will soon increase to 88 percent minimum efficiency at the medium output load condition. This Power-SPM module will be instrumental in helping power supplies meet this requirement," says Donghye Cho, Director of Fairchild's Power Supply System team.

The Power-SPM module is part of a comprehensive portfolio of Fairchild's energy-efficient products. From 1W to 1200W, Fairchild's solutions meet regulations that are of paramount concern to today's designers such as ENERGY STAR, PFC requirements, the <1 Watt Initiative and other green regulations.

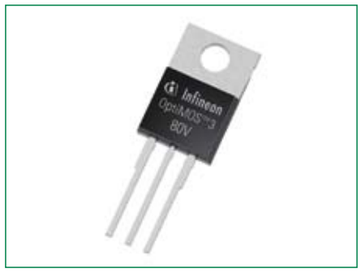
Fairchild recognizes that today's applications require increased efficiency even as their product features multiply and the product itself shrinks in size. Fairchild continues to develop cutting-edge solutions that integrate functionality and advance packaging technologies to improve efficiency and thermal characteristics while saving board space and reducing component count.

www.fairchildsemi.com

New Infineon MOSFET Families

Reduce Power Losses by up to 30%

Infineon Technologies has announced three new families of power semiconductors to its extensive OptiMOS™ 3 N-channel MOSFET portfolio. The OptiMOS 3 40V, 60V and 80V families offer industry-leading performance in such key power conversion metrics as on-state resistance, which allows them to reduce power losses by as much as 30 percent in a given standard TO (Transistor Outline) package. The low switching losses and on-state resistance of the OptiMOS 3 40V, 60V and 80V families enable an increase in power densities by up to 30 %, and a reduction in part



count for a given application of more than 25 percent, compared to competitive solutions.

The new MOSFETs are intended for a variety of power conversion and management applications, including SMPSs (switched-mode power supplies), DC/DC converters and DC motor drives in computers, home appliances, small electric vehicles, industrial automation systems, telecommunications equipment and such consumer devices as power tools, electric lawnmowers and fans.

OptiMOS 3 families include MOSFETs offer best-in-class $R_{DS(on)}$, achieving an $R_{DS(on)}$ as low as 1.6mΩ for 40V products in SuperSO8™ packages, 3.5mΩ for 60V products in D-PAK packages and 2.5 mΩ for 80V products in D-PAK packages. The FOM (figure of merit, calculated as on-state resistance times gate charge) of these devices is as much as 25 percent better than that of their closest competitors, enabling fast switching while minimizing conduction losses and on-state power dissipation, allowing higher power densities. It also results in less heat generation in the driver and, therefore, improved system reliability. In addition, the low $R_{DS(on)}$ allows the use of smaller packages, such as the 3mm x 3mm S3O8 (Shrink SuperSO8), so less space is required in a design thereby increasing power density.

www.infineon.com/powermosfets

www.infineon.com/optimos

First 900 V Superjunction MOSFETs

Increases Efficiency in Power Supply, Industrial and Renewable Energy Applications

Infineon has introduced the industry's first 900 V superjunction MOSFETs specifically intended for high-efficiency SMPS (switched-mode power supply), industrial and renewable energy applications. Continuing Infineon's history of innovation in the power semiconductor industry, the new energy-saving CoolMOS™ 900 V power MOSFET family overcomes the "silicon limit" in power transistor manufacturing, and provides an alternative for high-voltage designs using standard TO (Transistor Outline) packages. With extremely low static and dynamic losses, the CoolMOS 900V family enables design of more efficient and cost-effective topologies for such applications as LCD TVs, solar power generation systems, PC "silverbox" power supplies and lighting systems.

The Infineon CoolMOS family of power transistors uses an innovative technology approach to overcome the silicon limit, a characteristic of MOSFET semiconductors in which doubling of voltage blocking capability leads to a five-fold increase in R DS(on) (on-state resistance). In overcoming the silicon limit, the CoolMOS 900 V devices achieve the industry's lowest R DS(on) per package type. On-state resistances of 0.12 ohm in a TO-247 package, 0.34 ohm in a TO-220 package and 1.2 ohms in D-PAK packages are at least 75 percent lower than can be achieved in such packages using conventional 900 V MOSFETs. Because of the low R DS(on), the new CoolMOS 900 V devices can offer an FOM (figure-of-merit, calculated as on-state resistance times gate charge) as low as 34 ohms*nanocoulomb, which results in extremely low conduction, driving and switching losses, and leads to increased efficiency.

www.infineon.com/power

www.infineon.com/coolmos

New 600V Trench IGBTs from International Rectifier

Reduce Power Dissipation up to 30 % in UPS and Solar Inverter Applications

International Rectifier has introduced a family of 600V insulated gate bipolar transistors (IGBTs) that reduces power dissipation by up to 30 percent in uninterruptible power supply (UPS) and solar inverter applications up to 3kW.

Traditionally, IGBT devices have excessive switching losses at the frequencies used in UPS and solar inverters. IR's new Trench IGBT devices have lower switching energy coupled with low conduction losses. These lower losses provide higher efficiency, reducing the size of the unit and the cost of power generation to the end user.

Special Report – APEC 2008 Roundup

Co-packaged with ultrafast soft recovery diodes, the new family of IGBTs has lower collector-to-emitter saturation voltage ($V_{CE(on)}$) and total switching energy (ETS) than punch-through (PT) and non-punch-through (NPT) type IGBTs. In addition, the internal ultrafast soft recovery diode improves efficiency and reduces EMI.

Real-time Power Monitoring IC

Accurately Captures Highly Dynamic Power Information and Maximizes System Performance

The versatile IR3721 output power monitor IC for low-voltage DC-DC converters is used in notebook, desktop computers, and energy-efficient server applications and utilizes IR's patent-pending TruePowerTM technology to accurately capture highly dynamic power information with 2.5 percent accuracy at 65°C.

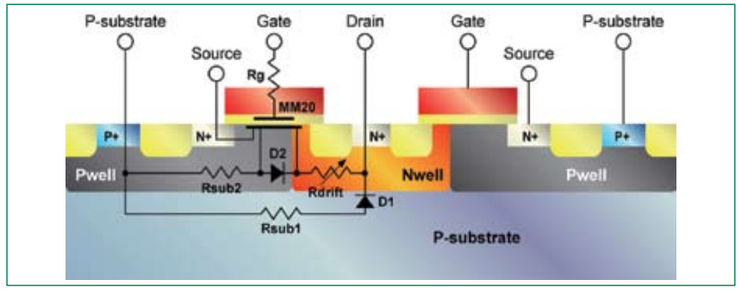
The device measures dynamic power at the output/load side of voltage regulators to deliver a significant improvement in dynamic power measurement accuracy compared to competing power monitor ICs. TruePowerTM technology addresses dynamic errors which can account for more than a 30% error in competing solutions which monitor voltage and current separately in dynamic conditions with independent A/D conversion.

"By monitoring instantaneous power, the power system can accurately predict thermals in the system at any given point in time, said Jeff Sherman, IR's senior product marketing manager for Enterprise Power Products. "With this intelligence, the power system can manage the load's electrical characteristics to limit its power and establish the correct cooling conditions in advance so that the load does not leave its required thermal envelope, optimizing its throughput, and hence its performance," added Sherman.

The IR3721 IC monitors the output filter inductor current in buck or multi-phase converters from 0.5V to 1.8V and provides the options of using resistive sensing or inductor DCR current sensing with an internal thermal compensation feature to achieve one percent higher efficiency compared to existing solutions while reducing bill of materials and board size requirements.

www.irf.com

JAZZ Semi's Advanced HV BCD Power Platform



Jazz Semiconductor, analog-intensive mixed-signal (AIMS) foundry and wholly owned subsidiary of Jazz Technologies™ Inc., has announced enhancements to its advanced Bipolar CMOS DMOS (BCD) process platform to include an ultra low Rdson scalable NLDMOS device. This Rdson reduction enables up to a 50% shrink in die size in most power devices. Customers benefit from a smaller form factor, ever critical in today's portable applications. In addition, Jazz has leveraged its RF modeling expertise to offer leading-edge power modeling which allows IC designers to confidently design large drivers required in high speed switching applications.

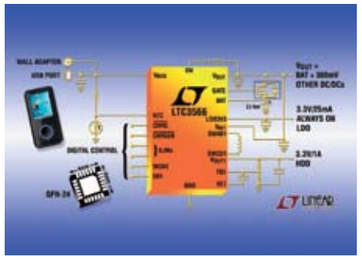
Jazz offers a full line of high voltage BCD process technologies, ranging from 0.5-micron to 0.18-micron, providing a complete array of solutions from linear regulators to the most advanced digital control Point of Load (POL) regulators. The BCD process platform offers a total solution for power management IC designers and is well-suited for low leakage power requirements.

The feature set of these process technologies includes: 5V CMOS, a 1K ohm poly resistor, MIM capacitors, and a broad voltage range of LDMOS transistors designed to operate at 12V or 20 to 40V with ultra low Rdson at all voltage levels. Additional features include: VIA stacking, thick top power metal (3µm) for improved current-carrying capacity, ESD protection circuits, and triple well isolation. The 0.18-micron BCD process adds the combination of high density 1.8V digital CMOS with higher voltage drivers required for highly integrated Power SOC designs.

The company offers a full design kit and modeling support for the BCD process platform including support for digital standard cells and analog models for all devices. The design kit also includes a novel scalable model for the LDMOS devices that allows designers to vary the voltage rating (and Rdson) of the high voltage LDMOS devices continuously from 20 to 40V rather than making use of fixed cells as typically done in the past. This provides IC designers an added tool in optimizing the tradeoff between die area and voltage handling performance to result in the lowest die cost for a wider variety of applications.

www.jazzsemi.com

Linear's Switch Mode USB Power Manager with Integrated 1A Buck-Boost Maximizes Battery Run Time & Minimizes Heat



Linear Technology Corporation has announced the LTC3566, the latest in a family of compact next-generation, multi-function power management solutions for Li-Ion/Polymer battery applications. The LTC3566 integrates a switching PowerPath™ manager, a standalone battery charger, a 1A high efficiency synchronous buck-boost regulator, an ideal diode and controller, plus an always-on LDO, all in a compact, low-profile 4mm x 4mm QFN package. The PowerPath control feature seamlessly manages power flow between multiple input sources such as a wall adapter or USB port and the Lithium battery while preferentially providing power to the system load. In addition, its "instant-ON" operation ensures power to the system load even with a dead battery. For fast charging, the LTC3566's switching input stage converts nearly all of the 2.5W available from the USB port to charging current, enabling up to 700mA from a 500mA limited USB supply and up to 1.5A when wall powered. An internal 180milliohm ideal diode plus optional external ideal diode controller provide a low loss power path from the battery to the system load, further minimizing heat generation and maximizing efficiency.

The onboard synchronous buck-boost regulator can deliver up to 1A continuously and is ideal for efficiently regulating a 3.3V output voltage over the full Lithium battery voltage range, down to 2.75V input. The regulator's internal low $R_{DS(ON)}$ switches enable efficiency as high as 94%, maximizing battery run time. In addition, Burst Mode® operation optimizes efficiency at light loads with a quiescent current of only 20uA (<1uA in shutdown).

The high 2.25MHz switching frequency allows the use of tiny low cost capacitors and inductors less than 1mm in height. Furthermore, the regulators are stable with ceramic output capacitors, achieving very low output voltage ripple.

The LTC3566 features USB-compatible programmable current limiting to 100mA/500mA/1A, while its BatTrack™ adaptive output control enables high efficiency battery charging and reduces power dissipation. Stand-alone autonomous operation simplifies design, eliminating the need for an external microprocessor for battery charge termination. To preserve battery energy, the device draws only 38uA in suspend mode. The charger is compatible with inputs up to 5.5V (7V absolute maximum transient for added robustness).

The LTC3566 is available from stock in a compact, low-profile (0.75mm) 4mm x 4mm QFN-24 package.

www.linear.com

Micrel Set for Stardom

I met with John Lee, Micrel's Director, RF/ Mixed-Signal Products, who took me through Micrel's plans and very solid achievements in terms of business success with their market-beating products and truly innovative packaging. With their 30% penetration into Digital TV market sockets, Micrel look set to take this industry by a storm with their low form factor, high density products designed to power all top brands in this field. This is great news from this ' powerhouse' company. It comes as no surprise to me that analysts are actually marking-up Micrel's own forcasts as too conservative!

Micrel underscored its pedigree with a fully-integrated 4A synchronous buck regulator, the MIC22400 for 3V and 5V supply rails. With operating frequency programmable from 800 KHz to 4 MHz, the IC features 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 solution is ideal for servers/routers, HD DVD recorders, wireless base stations, FPGAs, DSPs, and low voltage ASICs, as well as other high power density applications.

Also featured was MICRF218, the world's first programmable receiver featuring jam avoidance, part of Micrel's QwikRadio® family, is targeted at garage door openers and tire pressure monitoring systems. It is the world' s first integrated ASK/OOK receiver with selectable IF bandwidth for 300 to 450 MHz operation.

Finally, Micrel showcased the MIC94064/5, a series of high-side load switches that extend the company' s industry-leading MIC9406x family of high-side load switch products. The MIC9406x family now covers a wide range of battery-powered consumer and industrial applications that require a variety of turn-on characteristics, including portable computers, cell phones, and personal media devices.

Great things lie ahead. This company is ahead of the curve in their field.

www.micrel.com

Microsemi's Ultra Compact Power Modules

For High Performance, Cost Competitive Applications

Microsemi Corporation has announced a new line of 38 standard power modules in the very low profile and compact SP1 package. Main applications are in power factor correction, motor control, UPS, power supplies, solar inverters and welding converters.

The new line's 12mm profile provides minimum parasitic inductance, while solderable pins provide easy mounting to top-printed circuit boards. The modules integrate a base plate which allows the use of thinner DBC substrates. The result is excellent heat spreading and low thermal resistance, with full electrical isolation to the heatsink.

The new compact power modules fill the size gap between SOT227 and SP3 products by offering the equivalent of two SOT227 packages in a single SP1 device. SP3 modules integrate the equivalent of four SOT227's.

"The low mechanical profile and internal layout of the SP1 package results in very low parasitics, allowing the end user to get outstanding performance from ultrafast semiconductor devices," said Serge Bontemps, Power Modules Products Development Director in Merignac, France. "With a choice of 38 modules in our new SP1 line, there are excellent options wherever space, electrical and thermal performance, weight and cost are a concern," he said.

The new Microsemi modules line includes phase leg, full bridge, buck and boost configurations. Emitter/Source switches on the bottom of the full bridge modules provide separate connections for possible use of current sensors. All the new modules integrate a thermal sensor to monitor case temperature and provide over-temperature protection.

The four module configurations provide a variety of transistor options: FREDFET switches for the phase legs and full bridge modules; standard MOSFETs for buck and boost devices, plus CoolMos™, NPT, and TRENCH IGBTs.

All the SP1 MOSFET and FREDFET standard modules use the latest MOS8TM Power MOSFET from Microsemi's Power Products Group. Current ratings range from 11A to 70A @ Tc= 80 Deg. C for voltages in the range of 500V to 1200V for MOSFET, FREDFET and CoolMos™ modules. Current ratings range from 20A to 150A @ Tc= 80 Deg. C for voltages in the range of 600V to 1700V for NPT and TRENCH IGBT modules.

While the SP1 line is designed as standard modules for industrial applications, they are easily upgraded to withstand more demanding environmental conditions:

- Aluminum Nitride substrate can replace standard alumina for improved thermal performance
- SiC diodes can replace FREDs for improved switching losses or increased operating frequency
- Aluminum Silicon Carbide (AlSiC) base plate can replace the standard copper base plate for reduced weight and extended lifetime against temperature cycles of wide amplitude

www.microsemi.com

Molex Showcases EXTreme Power Series For High-Current Applications

"Molex EXTreme Power products are a direct response to our customers' electrical and mechanical design challenges," said Mike Bean, product manager, Molex Incorporated. "Since no two applications are the same, the EXTreme Power family includes several products that cover a wide range of current levels, mechanical envelopes, mating terminations, and configuration choices; giving system designers the ability to maximize their power interconnect needs."

Available now with a standard six to eight week lead time, the Molex EXTreme Power family includes the:

- **EXTreme PowerMass™ Connector** – an innovative, high-current power interconnect that delivers up to 350.0A per inch. As one of the highest capacity board-to-board connectors on the market, its multiple capacity power modules and wide signal count capability allows more power to be placed where needed, without wasting board space. Ideal for systems operating in challenging thermal-constrained spaces, the EXTreme PowerMass connector can be found in telecommunications, high and mid-range computers, power supplies and cellular communications applications. Since the EXTreme PowerMass connector can be assembled on a metal stiffener backbone, modules can be placed in any position with almost any centerline spacing. This gives custom-

ers complete freedom to pack a design as tightly as possible, or open the spacing between any or all of the modules to enhance system airflow. Additionally, if an application calls for only one or two modules, the EXTreme PowerMass product can be mounted individually without the use of the stiffener.

• **EXTreme LPHPower™ Connector** - a mixed, high-current power and signal connector system that picks up where traditional connectors leave off. Designed with power blades parallel to the PC board, its extremely low-profile height of only 7.50mm (.295") allows greater system airflow while taking up 53 percent less space than traditional connectors with the same current rating. Molex's EXTreme LPHPower system provides up to 127.0A per linear inch of space.

• **EXTreme PowerEdge™ Connector** - incorporating Molex's proven design elements of high performance terminal contacts with redundant interface points for optimum mating of double-sided card edge gold fingers. For high-current requirements, the EXTreme PowerEdge connector offers 40.0A rating per contact and 160.0A per inch of PCB real estate. It is a low-profile power card edge interface for applications in telecommunications, high and mid-range computing, uninterruptible power supplies, cellular communication and DC-DC conversion.

• **EXTreme ZPower™ Connector** – which uses a unique interface for mezzanine-style power connections. Anchored to the baseboard with press-fit power pins, the top board is screwed securely down from the top. The EXTreme ZPower connector not only transfers power between boards, but can double as an effective stand-off. Offering 50.0A and 30.0A versions, the EXTreme ZPower connector can be used in a variety of applications and industries where power connection between parallel boards is necessary in a very small space.

• **EXTreme MicroPower™ High-Current Header** – used in VRM / DC-DC converters or any board-to-board application where power transfer is needed through a non-separable interface in a compact design. The EXTreme MicroPower header offers a higher current density, rated at 16.0A per blade at 30°C T-rise, while its low profile design of 4.17mm (.164") off the PCB enhances system airflow. This connector is available in right angle and vertical mounting configurations.

• **EXTreme PowerPlus™ (SSI) Connector** - an expandable power and signal connector that conforms to the Server System Infrastructure (SSI) open specification, as well as many power and signal combinations beyond those covered in the SSI standard. The EXTreme PowerPlus connector system is rated at 30.0A per power blade and can be made in specified power and signal combinations to suit the application.

• **EXTreme PowerBBC™ Connector** - a compact, high-current connector for direct mating of power bus bars typically found in power supply or power distribution applications. Rated up to 320.0A, the EXTreme PowerBBC connector offers over 20 percent more current than competing products. Its high-performance contact design is rated for current interruption to match true hot-plugging requirements.

www.molex.com/link/ext-power.html

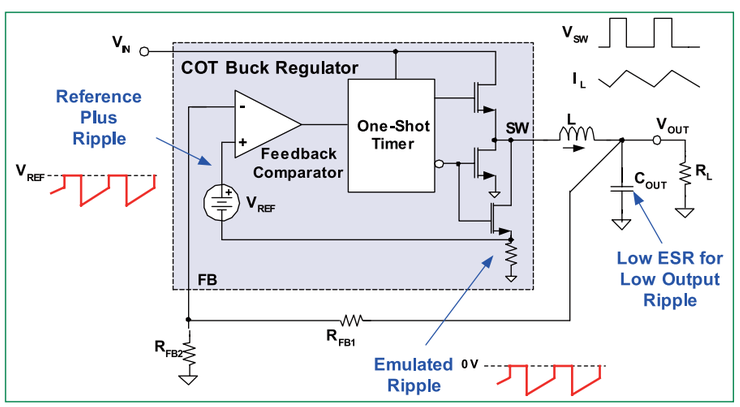
National's ERM Technology

Overcomes drawbacks of conventional circuits

I met with David Pace, Director of National's Phoenix Design Center where he has led the development of National Semiconductor's LM5000 series of high voltage power management products. He led me through National's Emulated Ripple Mode Technology.

Using PWM Control, the ramp signal is the weak link. Deriving the ramp from the inductor current or other analog signals introduces noise from the high speed switching transients. National's Emulated Ramps are noise-free imitations of current or voltage signals.

Current Mode Control is a preferred PWM control scheme for its ease of loop compensation and inherent line regulation. However, current mode control suffers from noise sensitivity and minimum duty cycle limitations.



Emulated Current Mode Control (ECM Control) was developed and patented by National Semiconductor to overcome current sensing issues of current mode control without sacrificing any advantages.

Constant on-time control (COT) is preferred for its simplicity (low cost) and ultra-fast transient response. However, this requires relatively high ripple from the output to trigger the feedback comparator at regular time intervals.

Emulated Ripple Mode Control (ERM Control) was developed by National to eliminate requirement for output ripple in COT regulators and allowing use of ceramic output capacitors.

To ensure stable switching frequency two constraints must be met: The feedback comparator (FB pin) must receive sufficient voltage ripple from the output to trigger another on-time and the feedback ripple must be in phase with the inductor current.

ERM technology satisfies ripple requirements of COT control: Emulated ripple is coupled internally to feedback comparator from low side switch of buck power stage and no ripple required at regulator output.

New ERM technology allows Constant On-Time Regulators to deliver a cleanly regulated output virtually free of output ripple and to operate with smaller, less expensive ceramic output capacitors.

Benefits of Ceramic Output Capacitors

• Lower output voltage ripple
• Lower profile and smaller size
• Insensitive to Transient Voltage Stress
• Higher reliability
• Non-polarized – easier to assemble

This is yet another leap forward in National's PowerWise® portfolio of solutions for energy efficient designs.

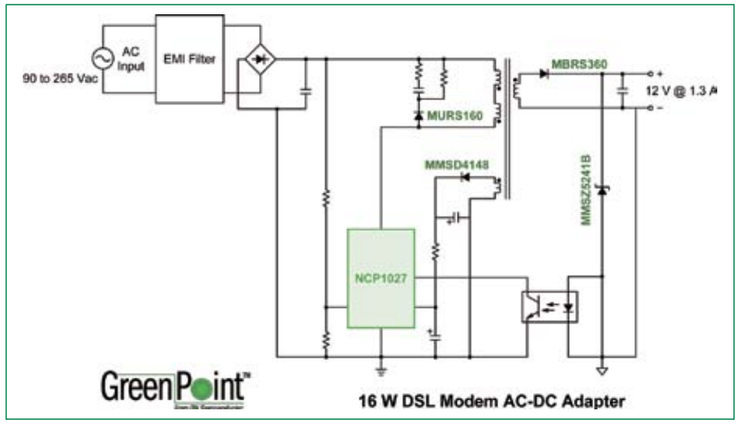
www.national.com

ON Semiconductor Goes Green

Exceeds ENERGY STAR® requirements

ON Semiconductor introduced a GreenPoint™ open reference design for a 16 watt (W) ac-dc adapter for xDSL modems. This design exceeds ENERGY STAR® requirements for single voltage ac-dc and ac-ac external power supplies revision 1.1, for high active-mode power efficiency and low standby-mode power consumption. The reference design can also be easily modified for use with 10-20W, single output-voltage adapters for printers, routers, and hubs.

This fully-implemented and tested solution achieves active-mode efficiency of 78 percent at 120Vac and 79 percent at 230 Vac, exceeding ENERGY STAR® guidelines of 74 percent for both input voltages. In standby-mode, the solution consumes only 240 milliwatts (mW) at 120Vac and 200mW at 240Vac, exceeding ENERGY STAR® guidelines of 0.5W for both input voltages. In addition, the design complies with FCC Part 15 Level B EMI requirements.



"ON Semiconductor's new 16 W GreenPoint™ reference design expands the power range of ON Semiconductor's portfolio of efficient reference designs for ac-dc adapters," said Andy Williams, senior vice president and general manager of ON Semiconductor's Automotive and Power Regulation Group. "By utilizing this proven solution, customers can quickly deploy consumer products that comply with evolving efficiency standards in a wide variety of geographic markets."

The reference design addresses all functional blocks of the adapter, utilizing several of ON Semiconductor's power management devices and drawing from its leading discrete component portfolio to achieve superior efficiency performance.

Key Products in the Reference Design Include:

• NCP1027: This high voltage switcher includes a power MOSFET together with a startup current source, all directly connected to the bulk capacitor. To prevent lethal runaway in low input voltage conditions, an adjustable brown-out circuit blocks the activity until a sufficient input level is reached.
• MURS160: This 1 ampere (A), 600 volt (V) Ultrafast Rectifier.
• MBRS360: This 3A, 60V Schottky Rectifier.
• MMSD4148: This 100V Switching Diode.
• MMSZ5241B: This 500mW Zener Diode.

www.onsemi.com

Primarion Unveils Power on Demand Solution

Meets today's green energy standards

Primarion has introduced its PX3664, a digital multi-phase power controller with dynamic phasing for synchronous DC/DC buck converters in computing and communications applications. The highly configurable and easy-to-use controller improves overall system efficiency across the entire operating load range with its autonomous phase dropping/adding capability.

"Today's power systems are optimized to provide high efficiency at full load, however, most of the time computing, communications and datacom equipment run at very light loads," said Deepak Savadatti, vice president of marketing at Primarion. "Power supplies are designed and optimized to deliver high efficiency at full load, which results in very low efficiency at light loads. The PX3664 addresses this important issue by delivering over 90 percent efficiency across the entire operating range. The controller automatically drops phases as the load decreases to maintain very high efficiency over the entire operating range. Additionally, being a digital

controller, it also optimizes loop compensation while operating with a lower number of phases to maintain system stability. With the PX3664 designers can meet the challenge of delivering power on demand and achieving dynamic energy savings without adding to the cost of the overall power solution."

Digital Multi-Phase Controller for Power Conversion

With up to four phases, each capable of up to 2 MHz operation, the PX3664 can be used to build DC-DC converters that provide up to 120A, low ripple, low component count and excellent efficiency across the entire operating range. Interleaved timing of the phases result in a higher ripple frequency, reducing input and output capacitors.

Phase Dropping Capability Helps Increase Efficiency at Light Loads

The PX3664's dynamic phasing capability allows the system to shed one or more phases based on the user defined average current. The autonomous phase feature drops phases when the average current falls below a specified threshold, and adds phases when the average current is above the threshold. The dropping of phases at lighter loads increases the efficiency by several percentage points and significantly reduces the cost of power over the life of the product. The PX3664's autonomous loop optimization makes it possible to meet the transient and ripple requirements, while operating at the lower phases.

The PX3664 uses two bits via PD1 and PD2 or a I2C-bus serial interface to control and monitor phase dropping. The interface also allows the power supply designer to monitor real time system performance and quickly optimize designs.

Primarion's Graphical User Interface Simplifies Design Process

The PX3664 is supported with an intuitive and user-friendly graphical user interface (GUI). The GUI takes the designer step-by-step through the process of debugging and modifying the power system design. The ease with which the GUI can be used to intelligently manage the design process contributes to reducing the final product's time to market.

www.primarion.com

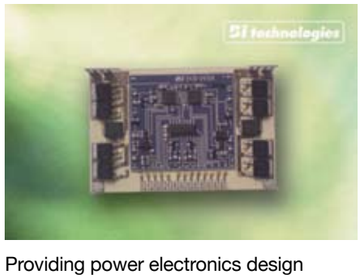
BI Technologies High Stability, Constant DCR Power Inductor

Providing design engineers with a stable power device capable of sensing current, TT electronics BI Technologies has developed a constant DCR surface mount power inductor. Designated the HM69S Series, the inductor maintains a constant DC resistance value, with a shift of only ±2% at room temperature and 7% over a 100°C temperature range.

Power engineers often use the resistance of the inductor to detect current in a PWM circuit because the inductor's DCR is lossless and quite accurate. Although a good means of detecting current, stability over the temperature range must be compensated due to the use of a copper conductor, which is typically unstable with TCR at 3900ppm/°C. By developing an inductor with a TCR of 700ppm/°C, BI is able to provide customers with a stable and accurate device.

www.bitechnologies.com

Integrated Control and Power Handling Hybrid Solutions



Providing power electronics design engineers with a high power, thermally efficient hybrid solution, TT electronics BI Technologies has combined its small signal and power hybrid technologies to develop an integrated control and power handling hybrid solution. While conventional assemblies require larger packaging to provide adequate thermal management, BI technologies' hybrid module combines thermally conductive ceramic substrates with discrete components or bare die through the use of vacuum low flow die attach, providing a smaller, more efficient solution than comparable products.

Typical applications for the custom hybrid modules include motor drives, power amplifiers and power conversion. The hybrid module is capable of handling power to 100A, with a voltage rate of 1000V.

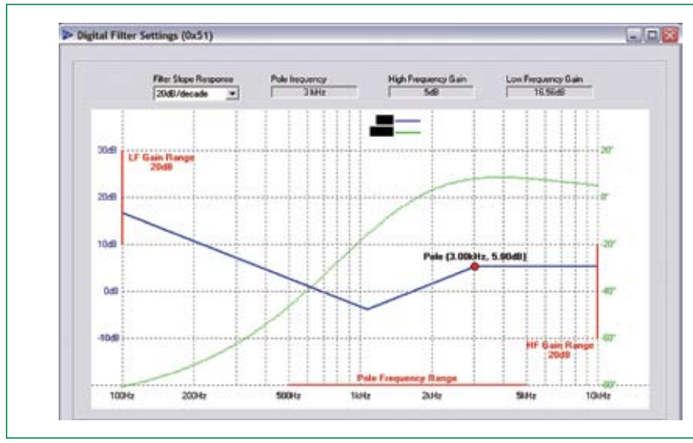
www.bitechnologies.com

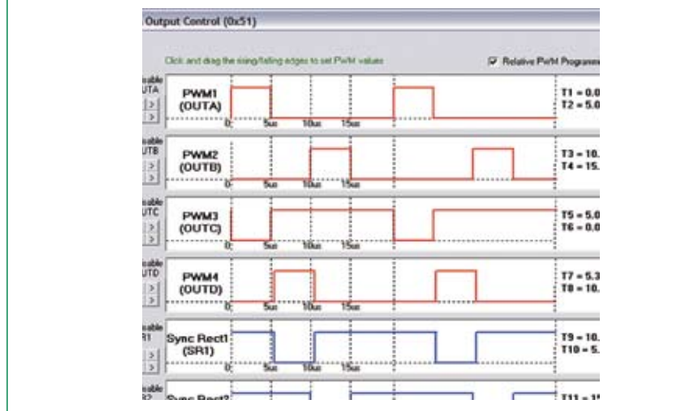
Analog Devices Forges Ahead on Power Management

ADI showed me a digital power controller developed specifically for engineers designing ac-to-dc and isolated dc-to-dc power supplies in high-reliability server, storage, and communications infrastructure equipment.

The ADP1043 digital PWM power control and management device provides a highly integrated circuit architecture and the flexibility to configure system power-supply parameters in a matter of minutes using an intuitive GUI (graphical user interface). Design engineers with no prior programming experience can use the GUI to monitor and quickly adjust power functions such as frequency, timing, voltage settings and protection limits. In end-system implementations, the ADP1043 helps system integrators optimize power supply energy efficiency, while reducing design cycle time and enabling intelligent power management systems.

Peter Henry, ADI's Vice President and General Manager for Power Management Products, said "We defined the GUI and the architecture of the ADP1043 to help power design engineers develop intelligent, adaptable power management solutions that accurately report parametric information in real time, without requiring the designer to program in C++ or other languages. With the ADP1043, ADI addresses the requirements of high-reliability power supply systems, where digital power introduces significant control and monitoring benefits to provide a competitive advantage in server, storage, and communications infrastructure applications."





The GUI demo was clear, very intuitive and hearing about the resources ADI are investing in staff and R&D, feel this will convert many designers to the advantages of digital power, where the application warrants it.

www.analog.com

IRC Current Sense Metal Element Resistors Rated for 3W at 80°C

Providing design engineers with an economical surface mount current sense device designed to maximize thermal performance and minimize power consumption, TT electronics IRC offers their metal element chip resistors for high volume, high current power electronics applications. Designated the ULR Series, the RoHS-compliant surface mount metal element resistors feature tight TCRs and low inductance values ideal for applications involving current detection and monitoring in densely-packed applications such as voltage regulation modules, power supplies, DC-DC converters, and electric motor control devices.

www.irctt.com

Power Resistors Achieve 600W Rating

An extended range of high-power resistive devices in industry standard TO-126, TO-220, TO-227, and TO-247 transistor outline packages, IRC's family of power resistors is designed to suit applications requiring high stability and low inductance. Designated the MHP Series, the resistors feature power ratings from 10 watts to 600 watts. The small size, high power dissipation, high stability and low inductance values make the resistors ideal for compact power supplies and motor drives.

www.irctt.com

New Rapid Lock Connector

250 Amp Torque-Less Power Applications

These new connectors offer quick connect/disconnect capabilities for torque-less power applications. The connector can be used as a replacement for threaded studs, thus eliminating any loose nuts with no fretting or heat rise.

Using proven ELCON CROWN BAND technology, Tyco Electronics' RAPID LOCK connector handles currents from 60 to 250 Amps and is available for wire sizes from 2.5 to 95mm^2.

The RAPID LOCK connector is available with color coding for easy identification, includes protective cable and crimp covers, and works with industry standard crimp tooling.

www.tycoelectronics.com/powerconnectors

Vishay Products Saving Energy For a Greener Environment

I met with Vishay's Spiro Zefferys and Michael Choi who took me through their new TrenchFET Gen III MOSFET.

Energy savings in computers and telecom equipment can help to keep greener environment and the demand today for better MOSFETs to improve the efficiency at light load is increasing as well as under heavy load conditions.

In modern designs, the high Side MOSFET, low Qgd is required to reduce switching loss. While in the low side MOSFET, lower Rds is required to reduce conduction loss. It is also important to note that the body diode & gate drive loss become more critical to improve efficiency at light load.

Vishay Introduced TrenchFET Gen III using 30V MOSFET Technology which delivers

- 41% reduction in RDS*Area
- 30% reduction in device RDS(on)
- 38% Reduction in device Figure of Merit RDS(on) MAX * QG TYP

Spec comparison between Gen II and Gen III

	Rds(10V)	Rds(4.5V)	Qg[nC]	Qgs[nC]	Qgd[nC]
Si7658DP	0.002	0.0026	48.5	21	12
Si7192DP	0.0016	0.00185	43.5	14	12.5
Reduction	20%	29%	10%	33%	-4%

So, what is Trench MOSFET Gen III?

A new MOSFET from Vishay to achieve best performance in high frequency DC-DC applications which achieves industry best Rds(4.5)max*Qg (typ): 98 [mohm nC]

Gen III is high density/ Low Qg process delivering low conduction loss under heavy load conditions and low gate driving loss under light load conditions.

- Rds(4.5V) : 29% lower than Gen II Improved Heavy load efficiency
- Qg:10% & Qgs:33% Lower than Gen II Improved Light load efficiency

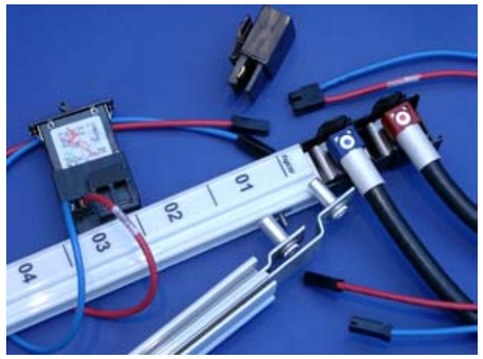
The trench FET Gen III 30V MOSFET technology improves efficiency and reduces power loss in buck converter circuits at light load and peak load condition and has achieved rank performance in the industry with an aggressive development plan going forward.

www.vishay.com

Special Report – APEC 2008 Roundup

Pluggable Power Distribution Bus Bar System (PDBS)

Repeatable Low Impedance Performance



Tyco's PDBS is ideal for power distribution in equipment cabinets, telecom base stations, computer servers, storage systems and military applications up to 250Amps.

The unique finger proof feature is designed to reduce assembly time, give repeatable low impedance electrical performance, and reduce wiring errors with predetermined input / output connections. System thermal characteristics are improved with the use of flat copper layers allowing better airflow and reducing current skin effects compared to conventional large AWG cables.

The PDBS consists of an extruded profile holding two solid copper conductors. Power is supplied to the bus bar conductors using 95mm^2 cables and color coded RAPID LOCK right angle sockets. The option to vary conductor thickness provides a flexible and adaptable design up to two meters in length with the ability to pre-form conductors to fit into awkward envelopes.

A Circuit Breaker Connector (CBC) can be mated onto the bus bar at any location along its length. The CBC accepts industry standard circuit breakers with tab terminals. A POSTIVE LOCK cable assembly connects from the CBC to deliver power where it is required. Power input and output connectors use proven ELCON CROWN BAND and CROWN CLIP contact systems for a reliable, low loss connection.

A PDBS sample kit is available to demonstrate this product.

www.tycoelectronics.com/powerconnectors

Companies in this Issue

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

Power Systems Design Europe **Green Page**

Go Green…Go PV!

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

With the continuing mega-trend towards renewable energy and energy conservation, I am seeing more and more reports and announcements from a wide range of companies on this just and righteous pilgrimage. The problem for me and I suspect others is, where the PR spin stops and where the facts begin.

Within the true engineering community, particularly in power, there is a great and I believe true spirit of challenge. The pressure is on and competition is fierce. This is where the real achievements are being made - tangible, measurable and quantifiable. Photovoltaics (PV) are now coming to the fore in this and I'll report more in future issues of PSDE.

Frost and Sullivan reported that the renewable energy boom across Europe has opened up an unprecedented market for solar energy-based inverters. An indispensable component of PV power systems, inverters typically convert direct current generated via PV modules from sunlight to alternating current for grid-connected systems.

The inverters for solar energy systems hold 99.4% of the renewable energy markets and the revenues are expected to increase at a compound annual growth rate (CAGR) of 24.9% from 2004 to 2011.

Germany takes the lion's share of sales in Europe. It is a major producer and consumer of PV inverters and maintains a clear lead.

"The German trump card is not an excess of sunshine over other regions" says Frost & Sullivan Research Analyst Chandni Raj. "It is the far-sighted vision and support of the German government, precisely the Renewable Energy Sources Act of 2000 according to which Germany has to generate an extra 9,500 GW from renewable sources by 2010.

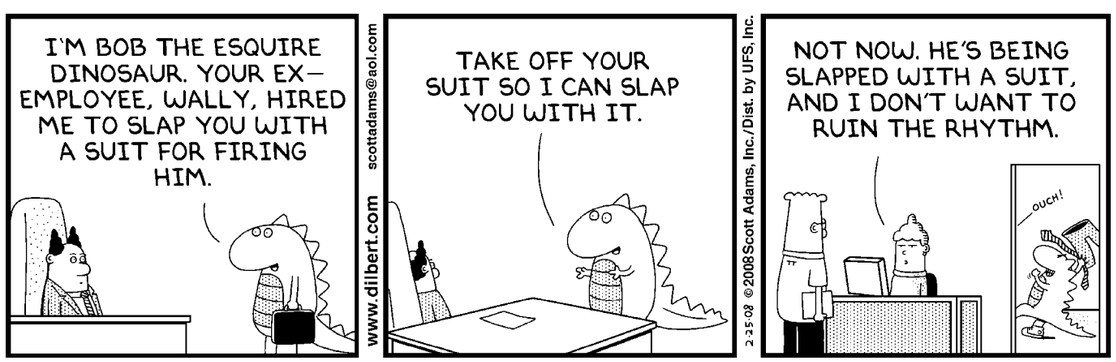
To encourage people, the government offered four times the market price for power generated from renewable energy for 20 years, thereby making it easier and faster to pay back investments. The Act that prioritized renewable energy relates to its purchase and compensation. Its amendment in 2004 boosted the industry. The feed-in tariffs (FITs) and incentives worked like magic, accelerating renewable energy growth".

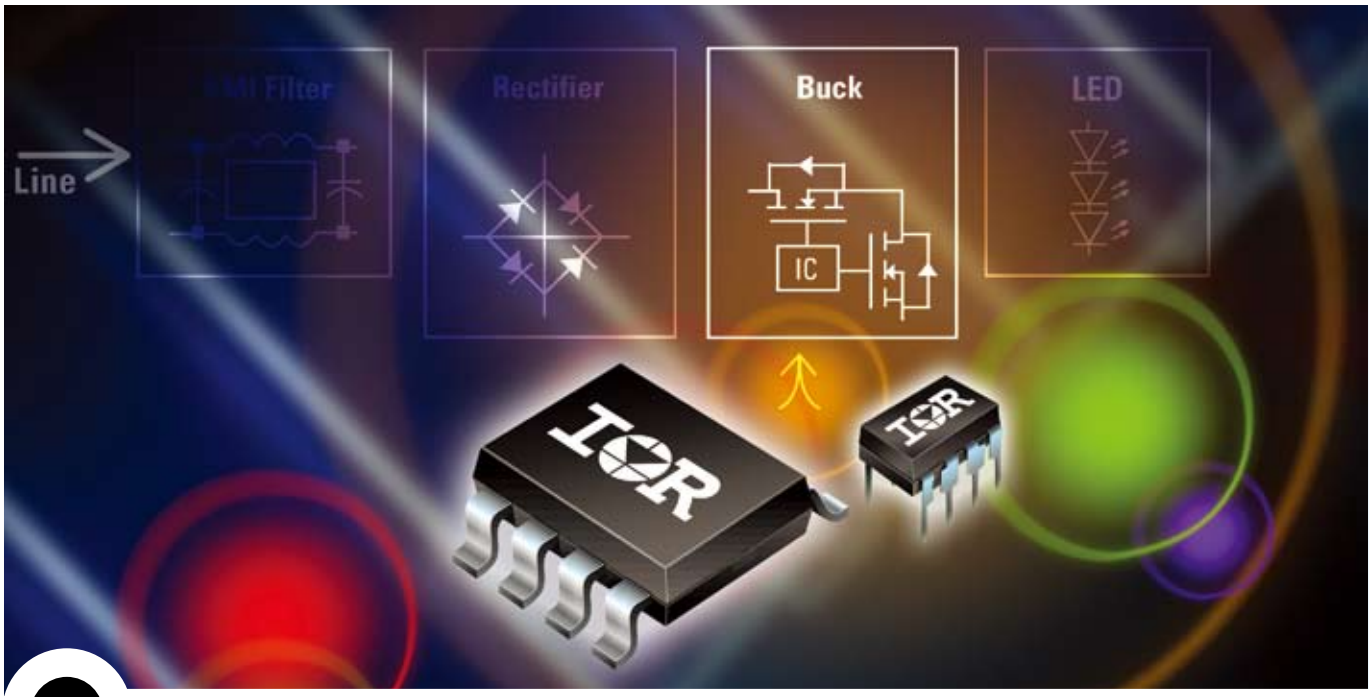
Germany is followed by Spain that is another PV inverter hotspot. "Spain has made amazing strides in the renewable energy-based inverters industry in a short span of time owing to the generous government subsidies" confirms Raj.

Germany and Spain drive ahead the European market for PV inverters and boast of some of the top-rung players in the industry. Italy, UK, Austria, Switzerland, Denmark and Netherlands have small but growing markets with Greece and Portugal looking extremely promising.

With the large number of players, innovations and new entrants, the market for PV inverters in Europe is exceedingly competitive. As a result, it is expected that inverter prices will come down and products with innovative features and greater efficiency will flood the marketplace.

www.powersystemsdesign.com/greenpage.htm

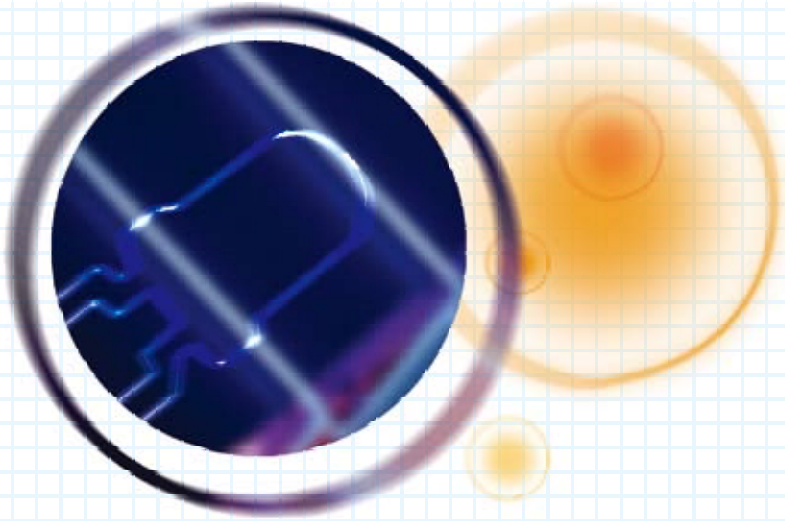




Precise, Reliable, High Brightness LED Driver ICs

For Constant LED Current Regulation

Part No.	Package	Voltage	Load Current Regulation	Micro-power Start-up	Deadtime	Frequency
IRS2540PbF	DIP8, S08	200V	+/-5%	<500µA	140ns	<500kHz
IRS2541PbF	DIP8, S08	600V	+/-5%	<500µA	140ns	<500kHz



IR's high-brightness LED driver IC's, adapt and compensate to LED parameter variations to enable a highly accurate and inherently stable design.

Features

- 200V or 600V control IC in compact 8-pin DIP or SO package
- Incorporates continuous mode, time-delayed hysteretic buck regulator
- External high-side bootstrap circuit delivers frequencies up to 500kHz
- Micro-power startup of less than 500µA
- 140ns deadtime for continuous current regulation
- Auto restart, non-latched shutdown and PWM dimmable capability

For more information call +33 (0) 1 64 86 49 53 or +49 (0) 6102 884 311

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