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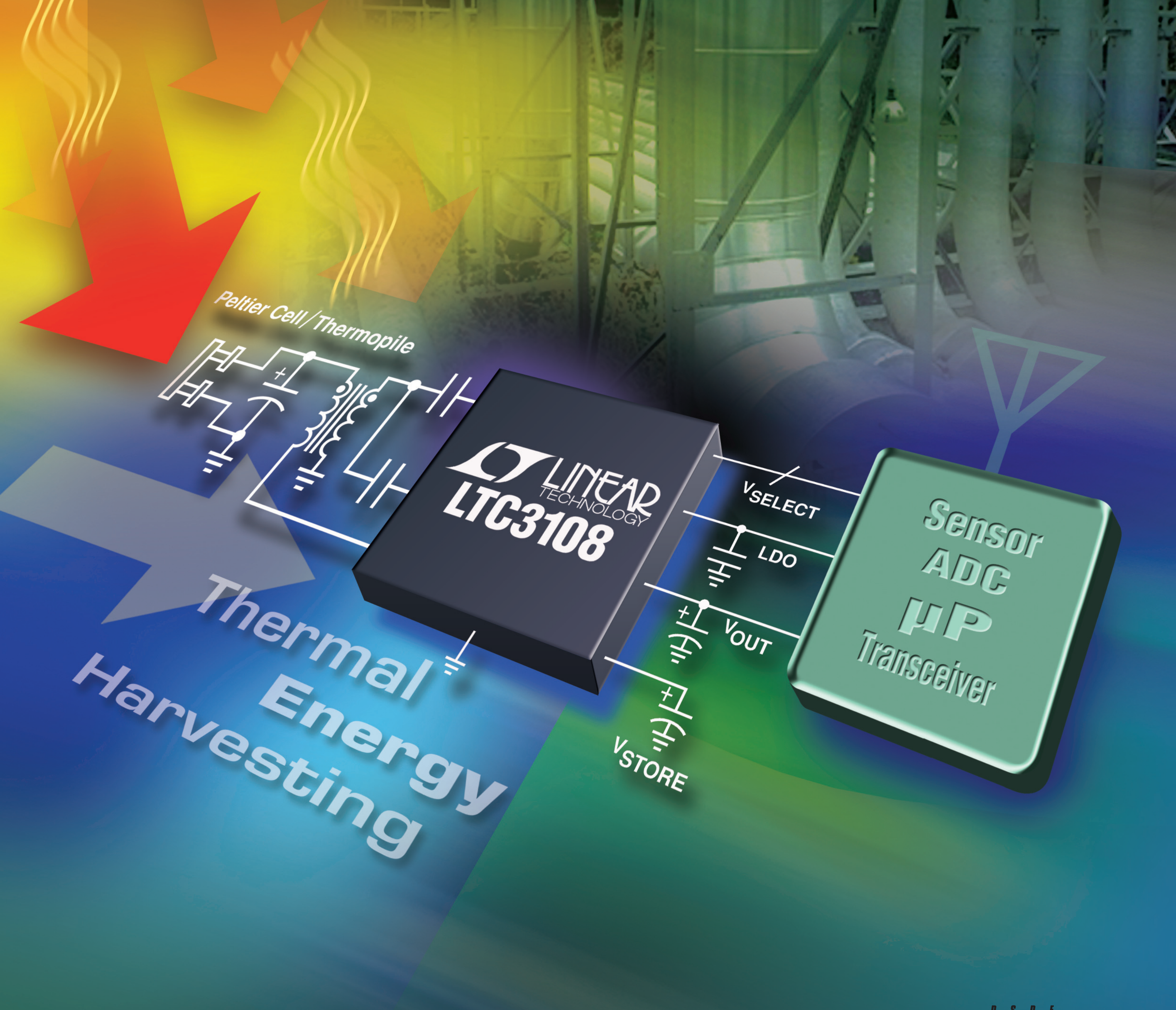

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ENERGY EFFICIENCY

Special Report – Energy Efficiency / Energy Harvesting

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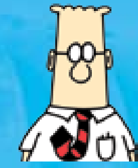

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PSDE Green Power ENERGY EFFICIENCY

E³: Engineering Energy Efficiency

We hear constantly about the economic woes of the various civilized nations of the world. We hear a lot about the various factors that are determining the erosion of our environment. We also hear much about the depleting energy sources and the dire need to conserve this valuable commodity. We now are told that nuclear energy sources are green. I guess it depends on how one views green.

The comments I am now often hearing are those concerning education. The UK Government is considering cutting university places available to aspiring higher education students, presumably to save costs. I would hope that this is to 'focus' the courses rather than to cut them across the board. Only time will tell.

When will elected servants in government realize that we need good, creative engineers? Those who can see a big-picture problem as an opportunity and who can develop designs to reduce the energy we consume and cleaner, greener ways to generate that which we need.

But where will these folks come from? They normally will not come from an education-starved system or from companies fuelled only by the single desire to please shareholders or management.

Hopefully our industry will soon recover and attract the quality engineers we need. Some segments such as automotive are already reporting resurgence; iSuppli commented that the year 2009 will be remembered as one of the most dismal years in the history of the global semiconductor business, with a plunge of more than $32 billion in revenue compared to 2008.

The difficult year for Uninterruptible Power Supply (UPS) hardware revenues also continued in 2009 with global revenues down more than 20% according to IMS Research. By contrast, UPS service and support revenues are forecast to have actually increased in 2009 by over 5%. For four straight quarters UPS hardware revenues have declined year-on-year. Geographically, the UPS market recovery is predicted to begin first in the Americas to be followed by EMEA and Asia, though it will be several years before demand returns to 2008 levels.

As many before me have predicted, it looks from the snapshot view that I get from our industry that while our natural start-of-the-year optimism will drive us positively forward. I think we are all aware that business will be tough for the foreseeable future. Probably a median somewhere between the analysts' reports and the over-upbeat talk-ups from beleaguered firms is a good place to start.

Finally, at this time of year, we are looking forward to the highlight in the Power conference calendar, APEC. This year it is to be held in Palm Springs and PSD will as always, be participating. I hope to see you there.

Enjoy the issue, keep the feedback coming and check out our fun site, Dilbert, at the back of the magazine.

All the best!

Cliff Keys.

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

Fairchild's New Energy-Efficient LED Driver

Lights the way at OSRAM

Fairchild Semiconductor has been selected by one of the world's largest lighting manufacturers, OSRAM®, to supply LED driver solutions. The FSEZ1016A was developed by Fairchild to meet and exceed the stringent performance benchmarks set by OSRAM.

Fairchild's FSEZ1016A fits OSRAM's 1W-4W LED products. OSRAM is also considering deploying Fairchild's FAN6300 LED driver for its 12W to 60W products. The new FSEZ1016A and FAN6300 are designed for lighting manufacturers seeking energy-efficient LED driver solutions.

Lighting applications consume nearly 22% of electrical energy generated worldwide. Reducing wasted energy in these applications can have a significant impact on energy conservation. As the industry moves from standard incandescent light bulbs to CFL, LFL and LED lighting, a 75% energy saving can be realized. Fairchild provides solutions for all lighting applications including linear fluorescent ballast, compact fluorescent ballast, LED and HID. The company's extensive product portfolio ranges from discrete to integrated solutions that contain PFC controllers, ballast control ICs, high voltage gate drivers and MOSFETs.

The FSEZ1016A is a primary side regulation (PSR) pulse-width modulation (PWM) controller, addressing a critical need in the high brightness (HB) light emitting diodes (LED) market by simplifying design, reducing board space and providing important performance advantages. The FSEZ1016A is an EZSWITCH™ device that integrates a PSR PWM controller with a power MOSFET. Through this integration, this controller achieves the most accurate constant current (CC) through built-in proprietary TRUECURRENT™ technology and tight constant voltage (CV) without using secondary-side feedback circuitry. By tightening the constant current over a wide voltage range, the same circuit can accommodate different numbers of LED units in a string, increasing design flexibility, accelerating time-to-market and stretching the lifetime of HB LEDs. With this high level of integration, this PSR PWM controller conserves board space, accommodating the form factor of lamp cases that continue to diminish in size. To minimize the standby power consumption, the proprietary green-mode function provides off-time modulation to linearly decrease PWM frequency under light-load conditions. This green mode function assists the power supply in meeting power conservation requirements.

The highly integrated FAN6300 PWM controller provides several features to enhance the performance of flyback converters. A built-in HV startup circuit can provide more startup current to reduce the startup time of the controller. Once the VDD voltage exceeds the turn-on threshold voltage, the HV startup function is disabled immediately to improve power consumption. An internal valley voltage detector ensures the power system operates at quasi-resonant operation in wide-range line voltage and any load conditions, and reduces switching loss to minimize switching voltage on drain of power MOSFET.

To minimize standby power consumption and light-load efficiency, a proprietary green-mode function provides off-time modulation to decrease switching frequency and perform extended valley voltage switching to keep to a minimum switching voltage.

The FAN6300 controller also provides many protection functions. Pulse-by-pulse current limiting ensures the fixed peak current limit level, even when a short circuit occurs. Once an open-circuit failure occurs in the feedback loop, the internal protection circuit disables PWM output immediately.

www.fairchildsemi.com

Energy Efficiency

Opportunities for action

By Oleg Khaykin, President and CEO, International Rectifier

As rising oil prices, soaring petroleum costs and global warming dominate the news, energy-efficiency has become a familiar catch-phrase. Hardly surprising when you consider world energy consumption is expected to double between 2005 and 2030, forcing world organizations and governments to take action. However, transforming the global energy system is a major technology challenge and one in which power management plays a critical role, particularly in the key areas of automotive, appliances, lighting, renewable energy and network computing, where huge potential energy savings can be realized using existing and emerging technologies.

Automotive

Analysts project that the US government's mandate to increase fuel economy standards by 40% for new cars and light trucks fleet-wide by 2020 will increase the cost of a vehicle by $1,500, although $5,000 of fuel cost savings would be recovered over the life of the vehicle. Diesel vehicles play their part in the drive for a sustainable energy future, delivering fuel economy gains of 25 to 30% over similar sized petroleum engines. Hybrid automobiles today achieve an extended range, but by adding a plug-in feature to full hybrids, fuel economy and range of up to 3 times could be realized. Consequently, IR has established a dedicated automotive business unit that manages five product lines to address all power management requirements in a standard car today or tomorrow's electric or hybrid electric vehicle.

Appliances

Electric motors in household and commercial appliances consume 40% of total electricity worldwide. Designers must achieve high performance at relatively low cost for the high-volume appliance market, desiring components with small form factors and a high level of integration to simplify manufacturing. Integrated design platforms like iMOTION™ offer a compelling argument to manufacturers to adopt variable-speed motion as a higher performing and viable cost-effective alternative to electromechanical techniques. The integrated design platform blends the best silicon, packaging, processes and software to optimize performance while simplifying the design task to meet critical cost targets and bring products to market faster.

Lighting

Innovative semiconductor and packaging technologies help reduce the price of a fluorescent bulb in comparison to its incandescent counterpart, which coupled with a lower operating cost make for a more attractive value proposition. Bright opportunities are on the horizon for dimmable fluorescent lighting systems, where a further 30% of energy savings can be achieved in the vast number of industrial, commercial and institutional buildings that currently use non-dimmable linear fluorescent lighting. Next-generation control ICs now offer a high level of integration and small form factor enabling designers to create new dimming product lines using several different control methods.

Renewable energy

As the EU targets a 20% share of renewable energy in final energy consumption by 2020 the boom in renewable energy sources is evident. As inverters continue to push efficiency limits there are challenges to overcome. AC solar converters, for example, face weight and cost issues in addition to high switching and conduction losses due to the use of non-optimized power devices. Advances are being made by adopting lightweight, high frequency transformers, and using integrated AC modules to reduce overall system cost together with optimized power management chipsets that can cut power losses by 30% and increase current by 60%.

Network computing

Energy consumption of servers and server infrastructure is projected to double by 2011 but 45% of energy savings could be achieved across the total server market, if energy-efficient hardware and intense use of power management are implemented. Advanced power control and conversion technology like IR's XPhase™ scalable multi-phase architecture and DirectFET® MOSFETs, make it possible to increase system efficiency to over 91%. About 900kW-hr per year per server can be saved by reducing the power supply's power loss by 40%.

At International Rectifier, energy efficiency is not just a buzzword. It's our mission - through power management innovation.

www.irf.com

Energy Efficiency - A Decade of Achievements, but More Needed!

By Ash Sharma, Research Director, Power & Energy Group, IMS Research

As we start the new decade, energy efficiency remains a hot topic and high on the political agenda. The recent draft Copenhagen Accord was met largely with disappointment and scepticism; however, it did demonstrate political commitment to tackle climate change from some of the world's biggest polluters.

Today, the question facing electronics companies remains the same as it was at the start of the last decade: What energy efficiency gains can the industry achieve to help tackle climate change? To answer this question, we need to look back over what was achieved in the last decade.

In 2008, consumers flocked even faster towards hybrid electric vehicles (HEVs) and in 2009, close to one million HEVs were produced. IMS Research predicts demand for HEVs will accelerate further, reaching almost 10% of car production by the end of this decade. Such rapid growth will only be possible with further advances in battery and power electronics technologies, with potentially huge rewards for suppliers. Battery revenues are forecast to exceed $40 billion by the end of this decade (up from 'just' $2 billion in 2009), whilst semiconductor revenues are projected to exceed $6 billion, with most of this accounted for by power products.

Legislation banning incandescent light bulbs within the European Union in 2009, led to a surge in demand for energy efficient CFL bulbs. Similar legislation in the US and China will lead to even

greater demand, whilst advancements in LED lighting technology will encourage even greater changes in the way we light our homes, offices, factories and roads over the next decade.

Another was the 'One Watt Initiative' proposed by the International Energy Agency to reduce standby power in household equipment to just 1W. Standby power is estimated to account for around 10% of all household energy consumption.

Consumers have also benefited from having an increasing range of energy efficient home appliances to choose from. Driven again by legislation and industry initiatives, 'high efficiency' major home appliances accounted for 47% of shipments in 2009.

In 2009, the American Recovery and Reinvestment Act set aside $11 billion for the development of a US 'smart grid'. Smart meter deployment is forecast to grow rapidly as governments strive for an intelligent electricity grid and aim to provide more information to consumers about their energy use.

Finally, in the last decade great strides were made in the use of renewable energy sources, particularly wind and solar (PV) technologies. By the end of 2009, IMS Research estimates 148GW of wind power was in operation, with global PV installations totalling 20GW. This relatively fast adoption of renewable energy sources was driven largely by legislation and by promoting wind and PV as investable technologies. Despite this progress, fossil fuels still dominated more than 90% of global energy production at the end of the last decade. Over the next 10 years, wind and PV power deployment will accelerate, driven by falling equipment costs, greater innovation and continued governmental support.

This outlines just a few of the achievements of the last ten years. However, it also highlights just how much more there is to accomplish, and this will bring huge new opportunities for existing and new suppliers alike.

www.imsresearch.com

Testing Off-Line Power Supplies

Isolate and ground your circuits for best results

In this article, Dr. Ridley shows how to safely test off-line power supplies, without the use of expensive (and sometimes hazardous) high-voltage dc power sources.

By Dr. Ray Ridley, Ridley Engineering

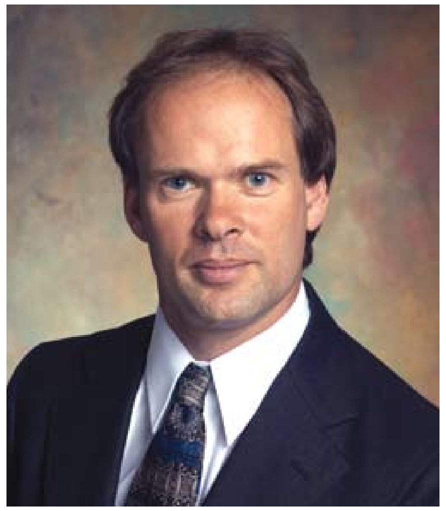
Off-Line Power Supply Design and Testing

Off-line power supplies can be dangerous circuits to test and debug, especially at high power levels. Standard off-line designs generate dc input voltages up to 424 VDC after the rectifier – a voltage level that can be hazardous. Proper testing of these power supplies is essential to ensure a reliable product, and this testing must be thorough and safe.

Figure 1 shows the typical configuration of an offline power supply, omitting the input filter for simplicity. The ac line is rectified through a full bridge, producing a dc input voltage equal to the peak of the ac input. For a 240 VAC nominal input specification, experienced designers will test their power supplies at up to 300 VAC to ensure proper design margins to cope with real-world variations.

With the circuit configured as shown, there is a problem with testing the power supply. Much of the control circuitry is referenced to the return of the input rail. However, this circuit node is connected to the neutral of the input ac supply for half of the input line cycle, and to the live of the input ac supply for the other half of the line cycle. There is no ground reference for the circuit, making waveforms difficult to measure.

Floating the Oscilloscope



One solution to the problem is to put a "cheater" plug on the oscilloscope, and allow it to "float" at whatever voltage the connection requires. You can certainly do this, albeit very carefully. The oscilloscope will become a part of your system, and will place a complex (high-impedance) load at the connected node of the circuit. Don't ever connect it to a high-frequency node, such as the drain of the FET of the flyback circuit shown. This will have a drastic effect on circuit waveforms, leading to unreliable measurements or possible failures.

It is acceptable to connect the ground reference of the scope to the negative rail. First, however, you must be aware that the entire body of the scope, and the probe grounds of the other input channels, are then referenced to hazardous voltages. I have done this in the past, but it is always an uncomfortable experience touching the scope carefully and avoiding any metal parts of the instrument.

Differential probes can also be used, but these can be inaccurate when the common-mode voltage is moving by hundreds of volts over a cycle. Failures of semiconductors can be due to events which last for 100 ns or less, and these can be inaccurately observed with ungrounded systems.

Using a High-Voltage DC Lab Supply

Another solution for power supply testing is to use a dc input source. You can purchase lab supplies which have an output voltage range of 500 to 600 VDC. My past experiences have made me wary of this type of supply. There are not many vendors that like to produce such products since the outputs are very dangerous. Also, if you buy a 1 kW

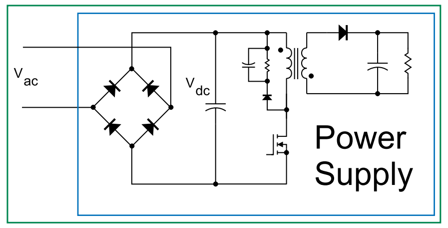


Figure 1: Offline power supply with full-bridge rectifier on input.

supply at 600 V, it can only produce 1.7 A. For low-line testing, this will be inadequate, giving you only 250 W capability at 150 VDC input, the range where many power supply designs will try to get started. Inrush requirements may require that you have a 5 kW dc lab source, just to test a 1 kW power supply design. Such bench supplies are expensive if you can find them.

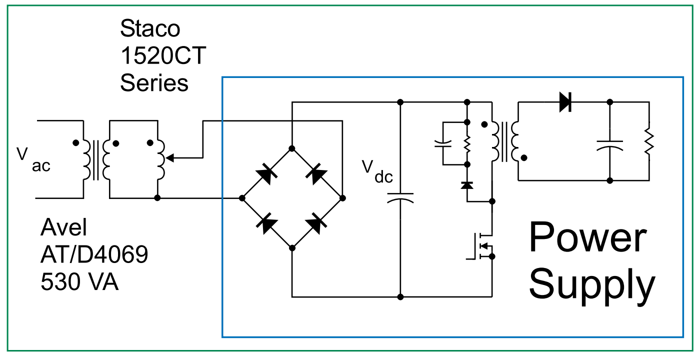


Figure 2: Transformer and Variac used to isolate and control input voltage supply.

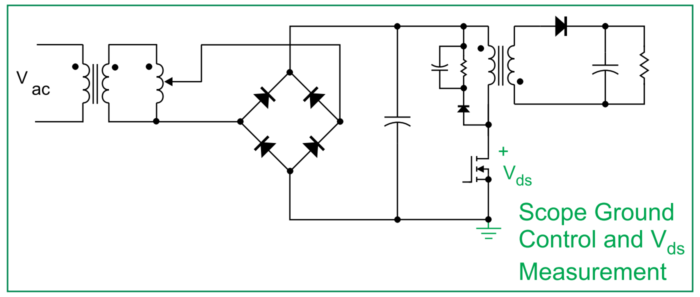


Figure 3: Input negative rail grounded with scope probe for control and Vds measurements.

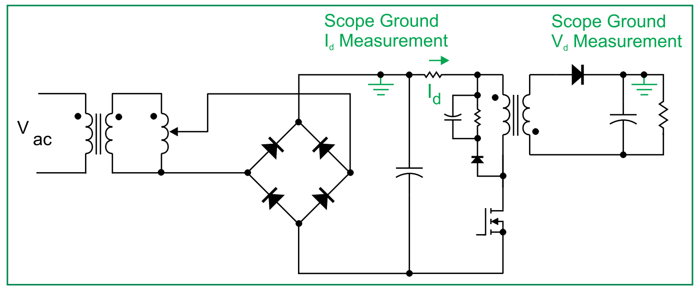


Figure 4: Input positive rail grounded with scope probe for Id current measurement. The secondary can also be grounded for accurate diode voltage measurements..

Past generations of high-voltage dc power supplies have also had some interesting characteristics that can lead to unintentional overvoltage on the input of your test circuit. For example, one particular brand I worked with in the past would surge the input voltage to over 400 V upon activation of the input breaker, regardless of the setting of the output voltage. We learned early in testing to always leave the power supply on, and to connect an additional switch to connect the circuit under test to the output terminals of the supply. The system never felt particularly safe.

There is another drawback to doing DC-only testing. It delays the inevitable fact that you must eventually power the system from an ac supply, and this will produce new events and stresses that can lead to failures. Isolated ac testing will uncover these problems earlier in the design cycle.

Isolating and Re-Grounding The Circuit

My preferred approach to testing is to supply my power circuit with an isolated, variable AC supply. This can be done with a line-frequency transformer and a variac, as shown in Figure 2.

The AVEL transformer specified in Figure 1 has dual primaries and secondaries, allowing you to reconfigure connections to provide the desired voltage for testing. The toroidal design provides a low leakage that allows for fast voltage rise time when the input is applied.

This test setup allows you to establish a ground on the power supply being tested. The position of the ground is chosen to suit the measurements that you want to make. It is still inadvisable to ground the circuit at a high-frequency node since this will adversely affect waveforms. However, you do have the choice of grounding either the positive or negative input rail, depending on which quantities you want to measure.

For control and FET voltages for the flyback circuit shown, the ground is connected to the negative rail, as shown in Figure 3. Most testing will be done with the connection, since there are many aspects of the control operation that will need to be verified.

As discussed in [1], sometimes the best way to sense the FET current is with a sense resistor connected to the positive rail of the power supply. In that case, the scope ground is connected to the positive rail, and the voltage measured across the sense resistor, as shown in Figure 4.

Depending on how the outputs are referenced to the primary and to the ground, you can also connect a scope probe as shown in Figure 4 to accurately measure the diode voltage stress. Overvoltage on the output diode is a common cause of power supply failures, and it should always be properly measured and documented for all test conditions.

Summary

The safest and most dependable way to design and measure power supplies is to isolate them and establish a proper ground for instrumention. This can be less expensive and safer than using a dc bench supply. Using a floating-ground ac source from the beginning of your experiments minimizes the impact of the eventual connection to the raw ac supply, and speeds up the development process.

Using a grounded scope connected to the appropriate node of the supply under test provides the optimum lab procedure for avoiding shock hazard to users. It also provides the most accurate waveform measurements.

References

1. "Power Supply Reliability - Always Measure the Switch Current", Power Systems Design Magazine, Design Tips Archive. http://www.powersystemsdesign.com

www.ridleyengineering.com

On the Road

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

Analog Devices

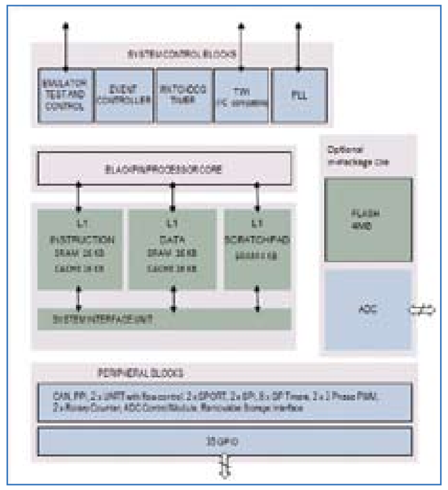
I was invited to the press launch of Analog's Blackfin BF50x processors with integrated ADI ADCs which deliver best-in-class energy efficiency and precision for industrial control and advanced power applications, with low cost evaluation kits providing unmatched value.

Analog's Efficiency & Performance Breakthrough

New Blackfin processors break price/performance barriers for industrial applications

Analog Devices unveiled the latest entries in its Blackfin family of processors for converged digital signal and control processing applications – the Blackfin BF50x series, delivering up to 100% greater performance than competing, comparably priced processors with integrated analog-to-digital converters (ADC) and flash memory.

BF50x series processors enable designers to achieve significant gains in signal conversion and computational precision, and apply advanced power control techniques to yield greater energy efficiency for industrial applications. Analog Devices also introduced a new low-cost ($199) EZ-KIT Lite evaluation platform for the Blackfin BF50x series, providing a cost-effective entry point for processor evaluation. Blackfin BF50x processors are sampling to customers today.



BF50x block diagram.

Blackfin BF50x processors deliver up to 400MHz of performance at a price point where 150-200MHz clock speeds have been the norm, extending high-performance digital signal processing capabilities to a wider range of applications, including applications previously serviced by high-end microcontrollers. This performance headroom enables designers to achieve greater system functionality and precision through the use of more sophisticated algorithms, and allows greater flexibility to optimize system interface and control capabilities. Designers are also enabled to utilize more advanced software tools and libraries for code generation, which helps shorten product development cycles and speed time to market – without compromising on processor cost.

BF50x processors combine industry-standard interfaces with a high-performance signal processing core to ensure that applications can be developed quickly and cost effectively, without the need for costly external components. With optional integrated dual SAR 12-bit ADI ADCs for more accurate data conversion and 4MB of on-board executable flash memory, Blackfin BF50x processors minimize off-chip components to lower overall system costs.

The highest performing DSP with integrated ADC

No other DSP with integrated ADC matches the 400 MHz performance of Blackfin BF50x processors. The optional dual SAR ADI ADC integrated within the Blackfin BF506F leverages ADI's world-class ADC technology expertise to deliver true 12-bit resolution, making it an ideal fit for applications including power inverters, UPS, servo controls and motor controls. The Blackfin BF50x also introduces a new peripheral to the Blackfin portfolio - the ADC Control Module (ACM) - which provides a low overhead, precise means to synchronize ADC sampling with external events.

A new standard for industrial applications

Blackfin BF50x processors equip designers with the performance they need to develop more accurate, energy efficient systems for industrial control and automation applications spanning power inverters, UPS, power and motion control, as well as smart metering and advanced sensing applications including power metering and flow/level metering.

Greater processing performance

The performance headroom provided by Blackfin BF50x series processors enables modern control theory and mathematics to be used in advanced system modeling, resulting in optimal power and control efficiency for any real-time system. Designers will use Blackfin BF50x processors to yield more precise control (e.g. motion), efficiency (e.g. power consumption), reliability (e.g. power quality), and capabilities (e.g. power line communications).

Independent validation of price/performance leadership

Berkeley Design Technology, Inc.'s (BDTI) benchmark analysis of the Blackfin BF504 confirmed its placement ahead of all other competing, BTDI-benchmarked digital signal processors in terms of speed-per-dollar ratio for fixed-point processors, with a BDTIsimMark2000/$ score of 498. BDTI benchmarks provide performance expectations for real-world applications and are among the most widely used digital signal processing benchmarks in the world.

New low-cost development platform

EZ-KIT Lite evaluation kits for Blackfin BF50x processors are available for only $199, and include an evaluation suite of ADI's VisualDSP++ development environment.

ADI also offers a $150 Blackfin emulator (ADZS-ICE-100B), providing designers with a comprehensive development platform that lowers the cost of entry to the Blackfin BF50x series.

Partners providing value added design services and technology for Blackfin BF50x include Boston Engineering, Advanced Energy Conversion, and Schmid Engineering.

"Designers who have previously been constrained by the performance profiles of low-cost processors and microcontrollers can now overcome these limitations to realize new levels of performance and cost efficiency via an elegant, unified processing platform," said Jerry McGuire, vice president, general purpose DSP division, Analog Devices, Inc. "Blackfin BF50x processors provide the performance headroom and integrated peripherals to drive greater innovation in embedded applications, with low-cost evaluation kits and a rich ecosystem of software tools to ensure unmatched value."

Pricing and Availability

The BF50x family includes the BF504 starting at $4.50, the BF504F with integrated flash memory starting at $6.50, and the BF506F with integrated flash memory and ADC starting at $10.60 - all prices are based on 10,000 unit quantities. Processors are sampling today. EZ-KIT Lite evaluation kits for Blackfin BF50x processors are available from ADI's authorized distributors and are priced at $199.

Supporting Resources

Analog Devices Blackfin Processor Evaluation-Kits: http://www.analog.com/en/embedded-processing-dsp/blackfin/content/blackfin_evaluation_kits/fca.html

BDTI BF50x benchmark results: http://www.bdti.com/bdtimark/chip_fixed_cost_scores.pdf

www.analog.com

TI's Cool Power

New power MOSFETs with reduced top-side thermal impedance for high-current DC/DC applications

I talked with Jeff Sherman, TI's Product Marketing Engineer for Texas Instruments' Power Stage business, based in North Carolina, about the company's new DualCool™ NexFET™ power MOSFETs which offers up to 80% higher power dissipation and up to 50% more current in a standard footprint.

Reported by Cliff Keys, PSDE

In February 2009, TI acquired Bethlehem, Pennsylvania-based CICLON Semiconductor Device Corporation for its innovative, high-efficiency power management solutions. Adding the NexFET power MOSFETs to TI's existing power management portfolio has enabled TI to provide its customers with complete solutions for high efficiency power supply designs. DualCool™ NexFET power MOSFETs mark the first new power MOSFET offering from TI since this vital industry acquisition.

Texas Instruments has now launched the industry's first family of standard-footprint power MOSFETs that dissipate heat through the top of the package for high-current DC/DC applications. DualCool™ NexFET™ power MOSFETs reduce end equipment size, while providing up to 50% more current through the MOSFET and improving thermal management over other standard-footprint packages. See: www.ti.com/dualcool-preu.

This new family of five NexFET devices allows computing and telecom system designers to use higher current processors with expanded memory while saving board space. These MOSFETs in an advanced package can be used in a wide range of end applications including desktop personal computers, servers, telecommunications or networking equipment, basestations, and high current industrial systems.

Jeff explained that many customers now demand higher current DC/DC power supplies in a smaller footprint to meet the urgent need for increased processing power in the broad infrastructure market. The new DualCool NexFET power MOSFETs meet this need with the unique ability to conduct more current within the same form factor.

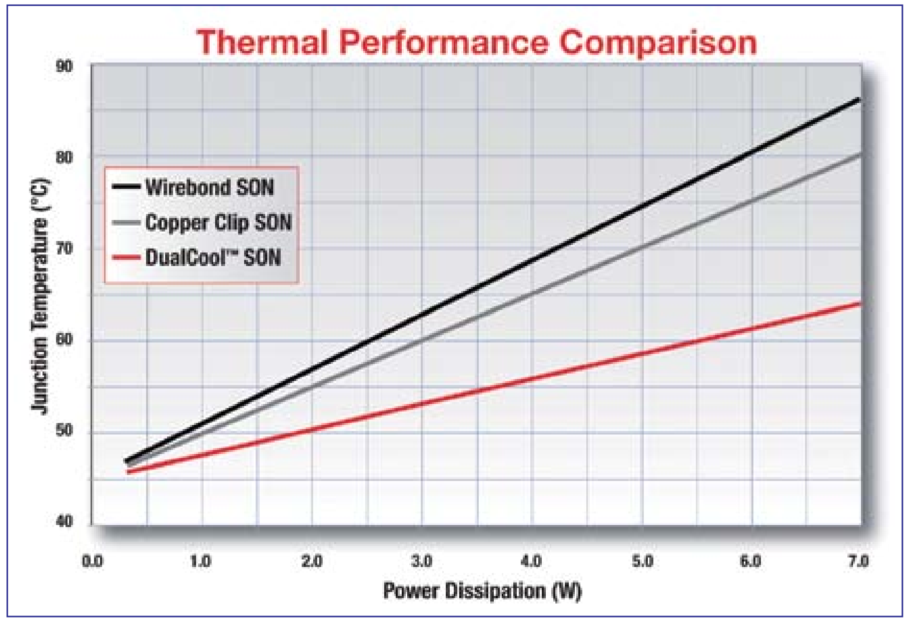
Key features and benefits of DualCool NexFET power MOSFETs:

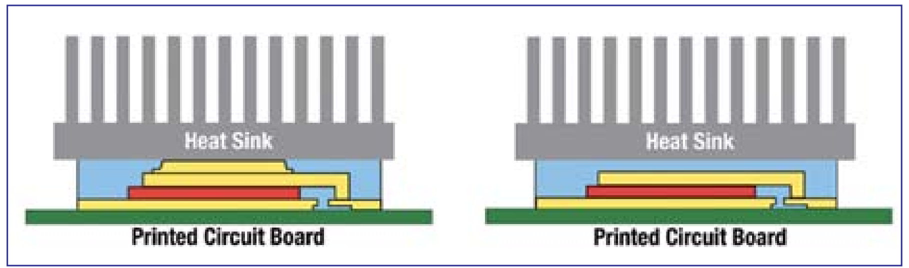
• Single phase 35A synchronous buck converter MOSFETs, using single MOSFETs for both the high and low side switches in high-current DC/DC applications.

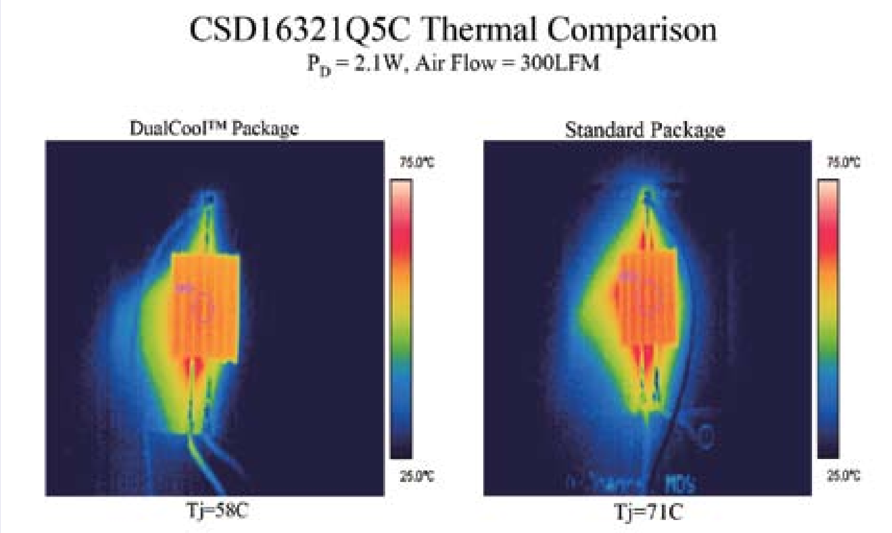
• Enhanced packaging technology reduces thermal impedance to top of package from 10º to 15°C per watt to 1.2°C per watt, increasing power dissipation capability by up to 80%.

• Efficient dual-side heat sinking enables up to 50% more current through the FET, giving designers the flexibility to use higher current processors without increasing end equipment size.

• Industry-standard SON package with a 5mm x 6mm footprint eases design and keeps cost down, saving 30mm^2 compared to using two standard packages.







Thermal comparison between DualCool (Left) and Standard (Right) packages.

Availability and pricing

DualCool NexFET devices are available in volume now from TI and its authorized distributors. Suggested resale pricing for the CSD16325Q5C is $1.47 in 1,000-unit quantities. Samples and application notes are available.

Find out more about TI NexFET MOSFETs and other power offerings by visiting the links below:

• Order NexFET evaluation modules and samples: www.ti.com/mosfet-dcpr

• DualCool NexFET power MOSFETs video demonstration: www.ti.com/mosfet-vpr

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www.ti.com

Infineon's 3rd Generation SiC Schottky Diodes

Value-added performance and reduced cost of power conversion systems for motor drive and renewable energy applications

I had a discussion recently with Jan-Willem Reynaerts, Business Segment Manager High-Voltage for Infineon Power Discretes. He described the success of the company's pioneering of silicon carbide (SiC) Schottky diodes, and specifically about the progress of Infineon's third generation thinQ!™ SiC Schottky diodes which were introduced a year ago.

Reported by Cliff Keys, PSDE

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These devices feature the industry's lowest device capacitance for any given current rating, enhancing overall system efficiency at higher switching frequencies and under light load conditions, the new thinQ! diodes help reduce overall power converter system costs.

Additionally, with its third-generation, Infineon provides the industry's broadest SiC Schottky diode portfolio which not only includes the TO-220 package (2-pin version) but also the DPAK package for high power density surface mount designs.

Main application areas for SiC Schottky diodes are active Power Factor Correction (CCM PFC) in Switched-Mode Power Supplies (SMPS) and other AC/DC and DC/DC power conversion applications such as solar inverters and motor drives.

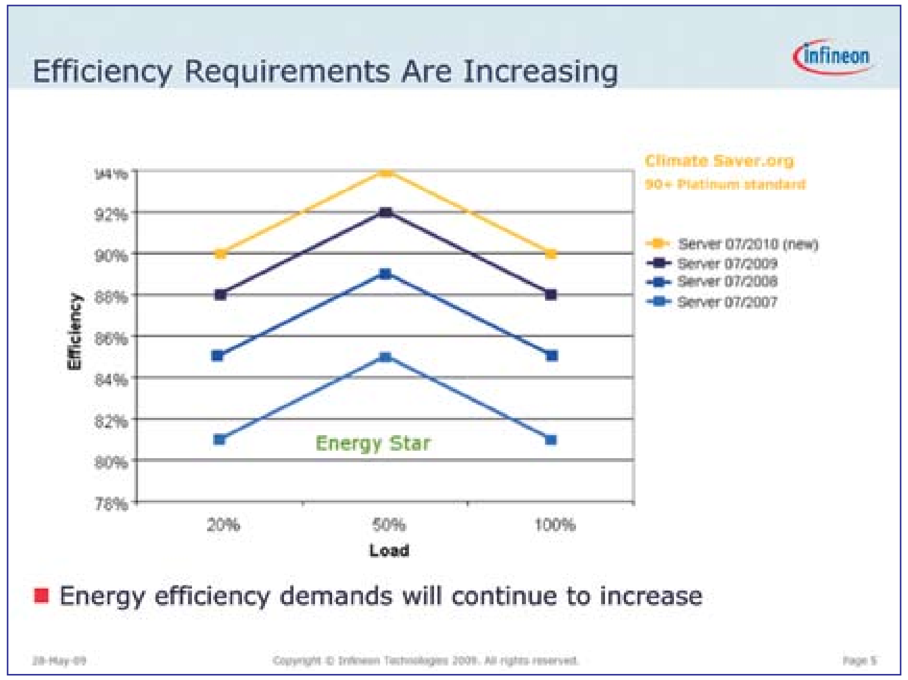
Compared to the second generation, the device capacitances of the Infineon third generation SiC Schottky diodes are about 40% lower, which reduces switching losses. For example in a 1kW PFC stage operating at 250kHz there will be an improvement of 0.4 percent in the overall efficiency under 20% load conditions.

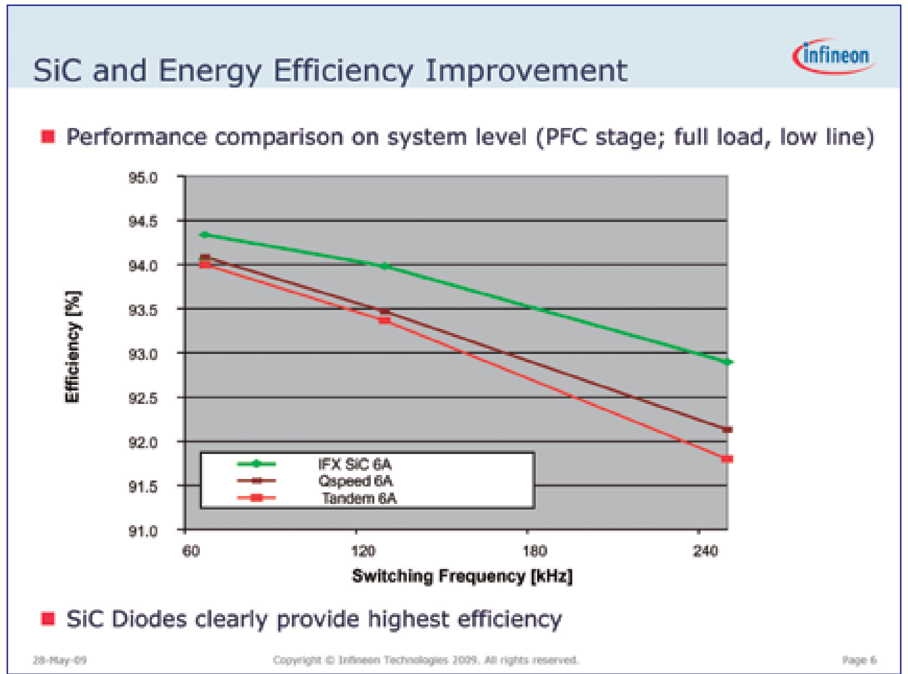
Higher switching frequencies al-

low the use of smaller and lower cost passive components, such as inductors and capacitors, resulting in higher power density designs. Reduced power losses result in several benefits, including reduced cooling requirements in terms of size and number of heatsinks and fans, which enables system cost reduction and increased reliability levels. This also contributes to reduced system level energy requirements to provide an appropriate cooling environment. Infineon expects system cost reductions in some SMPS applications of up to 20%.

In addition to the ability to use smaller MOSFETs in an energy-efficient design, these products are extremely robust with extremely low failure rates monitored over the past five years.

Although at a system level, SiC delivers an impressively lower cost of ownership, we are still some years away from a diode-for-diode cost parity between silicon and SiC, commented Jan-Willem. However with all the other advantages considered, SiC enables a more dense and efficient design.





Jan-Willem explained further that Infineon was the world's first provider of SiC Schottky diodes, introducing its first products in 2001. During the last nine years, Infineon has made a number of significant improvements to its SiC Schottky diode technology in areas such as surge current stability, switching performance and in product cost, extending the benefits of SiC technology. SiC is a truly innovative and value-adding technology which helps to support the global climate saving trend and to drive new markets such as solar energy and high-efficiency lighting systems. It clearly underlines Infineon's leadership in and commitment to the power management market.

And there is still more to come from Infineon. The recession has been a good time for companies to re-evaluate their designs and there has been much design activity below the surface. The huge uptake of Infineon's third generation of its thinQ!™ SiC Schottky diodes also builds on the success of its CoolMOS technology. Customers have shown a high level of interest in the adoption of the company's SiC offering with double-digit growth in orders achieved.

Availability, packaging and price

Infineon's third generation thinQ! SiC Schottky diodes are available in 600 Volts (3, 4, 5, 6, 8, 9, 10, and 12A), in both TO-220 and DPAK packages, and in 1200 V products (2, 5, 8, 10, and 15 A) in TO-220 package. In quantities of 10,000 pieces, third generation SiC Schottky diodes with a blocking voltage of 600 Volts (3A) are priced at Euro 0.45 per unit. The 4A version is priced at Euro 0.60 per unit, the 8A version at Euro 1.20 per unit.

Further information on Infineon's SiC Schottky diodes is available at www.infineon.com/sic

Further details on Infineon's power semiconductor product portfolio is available at www.infineon.com/powermanagementdiscretes

www.infineon.com

Modern Motor Drive Circuits

Optimizing efficiency and reducing operating temperatures

In motor drive circuits, optimizing the efficiency and the deliverable power to the motor and controlling the maximum junction temperature depend heavily on how the power amplifier IC is mounted. The choices include mounting the IC directly on a printed circuit board, with or without a heatsink, or incorporating air flow with convection or forced air. In addition, the size and orientation of the heatsink, if used, must be selected to manage the average power dissipation of the power IC.

By Dan Leih, Product Marketing Engineer, Cirrus Logic Inc

General Guidelines - Mounting Options

Each motor drive application is unique and there are a number of mounting options to consider. The challenge is to choose the best one for the constraints of the particular application. The following three design examples provide an evaluation of different mounting and cooling options and define the basic capabilities of each. The derivation of the maximum power and thermal system dynamics is discussed in Reference 1.

This first example evaluates surface mount options using a Cirrus Logic SA306-IHZ motor drive IC married to a Microchip Technology PICtail Plus Adapter Board. This configuration was designed specifically for use with a Microchip 16-Bit dsPIC33 Digital Signal Controller (DSC). This DSC includes a motion control interface that offers the ability to control the SA306-IHZ with both block and sinusoidal excitation waveforms.

Mounting without Heatsink - For Low-Power Applications

The most cost effective way of mounting a surface mount power IC is to solder it in the traditional SMT (surface mount technology) fashion. This involves mounting the IC directly onto a printed circuit board (PCB) without any additional heat sinking components, as

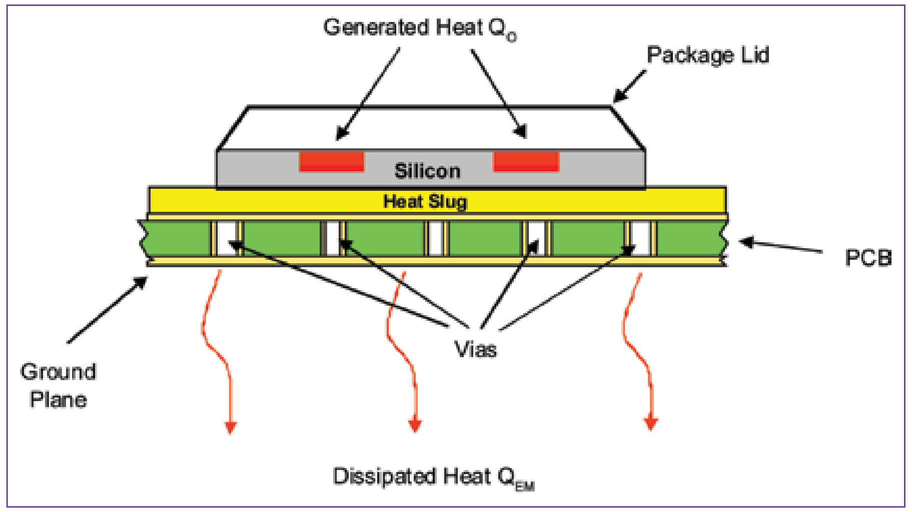


Figure 1: Mounting without a Heatsink - For low-power applications.

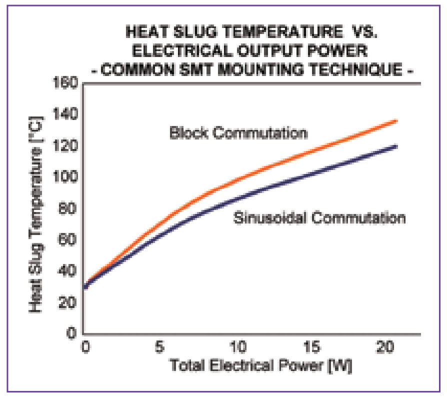


Figure 2: Heat Slug Temperature versus Total Electrical Power - Shown for the surface mounted SA306-IHZ when used in low-power motor drive applications.

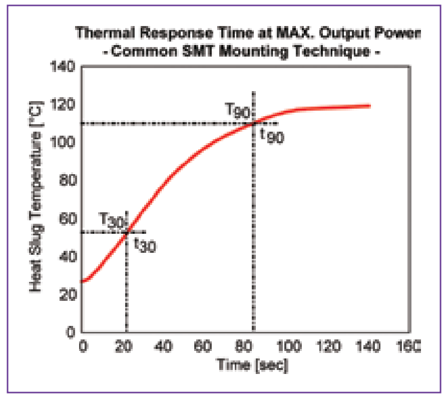


Figure 3: Thermal Response Time - At a maximum output power of 9 watts.

depicted in Figure 1.

By mounting the motor driver IC in this fashion, the heat slug on the bottom of the IC's conventional power package becomes an effective thermal path for conducting heat away from the device and directing it to a one-ounce or two-ounce copper ground plane on the top of the printed circuit board. Beneath the heat slug, several vias pass through the board for the purpose of carrying heat to the back of the board. It is important with this mounting technique that sufficient solder paste be applied beneath the power IC for a good thermal connection to the ground plane.

As depicted in Figure 2, at an output power of 20 watts, a temperature gradient of +99.6°C was obtained. This means the junction temperature will be approximately +130°C at an ambient temperature of +30°C. The plots in Figure 2 denote a value of +136°C case temperature at an ambient temperature of +30°C, with a thermal resistance junction-to-air of approx. 5.343°C /W.

After derating the device to allow for increased ambient temperatures, the maximum continuous deliverable output power is approximately nine watts for an application covering the entire industrial ambient temperature range up to +85°C using this mounting technique.

Thermal Response Time

The values depicted in Figure 2 were generated with motors running at constant speed. However, in applications in which the motor is frequently accelerating and decelerating, it is important to know the thermal response time. Plotted in Figure 3 is the time interval for a case temperature rise of 60°C from +30°C to +90°C. This is the time required to transfer a specific amount of heat from the die to the back of the PCB. It is the temperature characteristic of the ground plane from the ambient T30 to the maximum temperature T90, when the motor is driven continuously at a maximum power of 9 watts.

Although a maximum power rating of nine watts may seem low, many power devices are nonetheless capable of delivering high peak currents for several seconds. This mounting technique is appropriate for small, low-power or high-speed drives in cost-sensitive applications such as fans, pumps, scanners, surveillance cameras, labeling machines and paper feeders where size and production costs are crucial.

See the full and comprehensive article by Dan Leih of Cirrus Logic online by following the link: www.powersystems-design.com/index.php?option=com_content&view=article&id=544&Itemid=113

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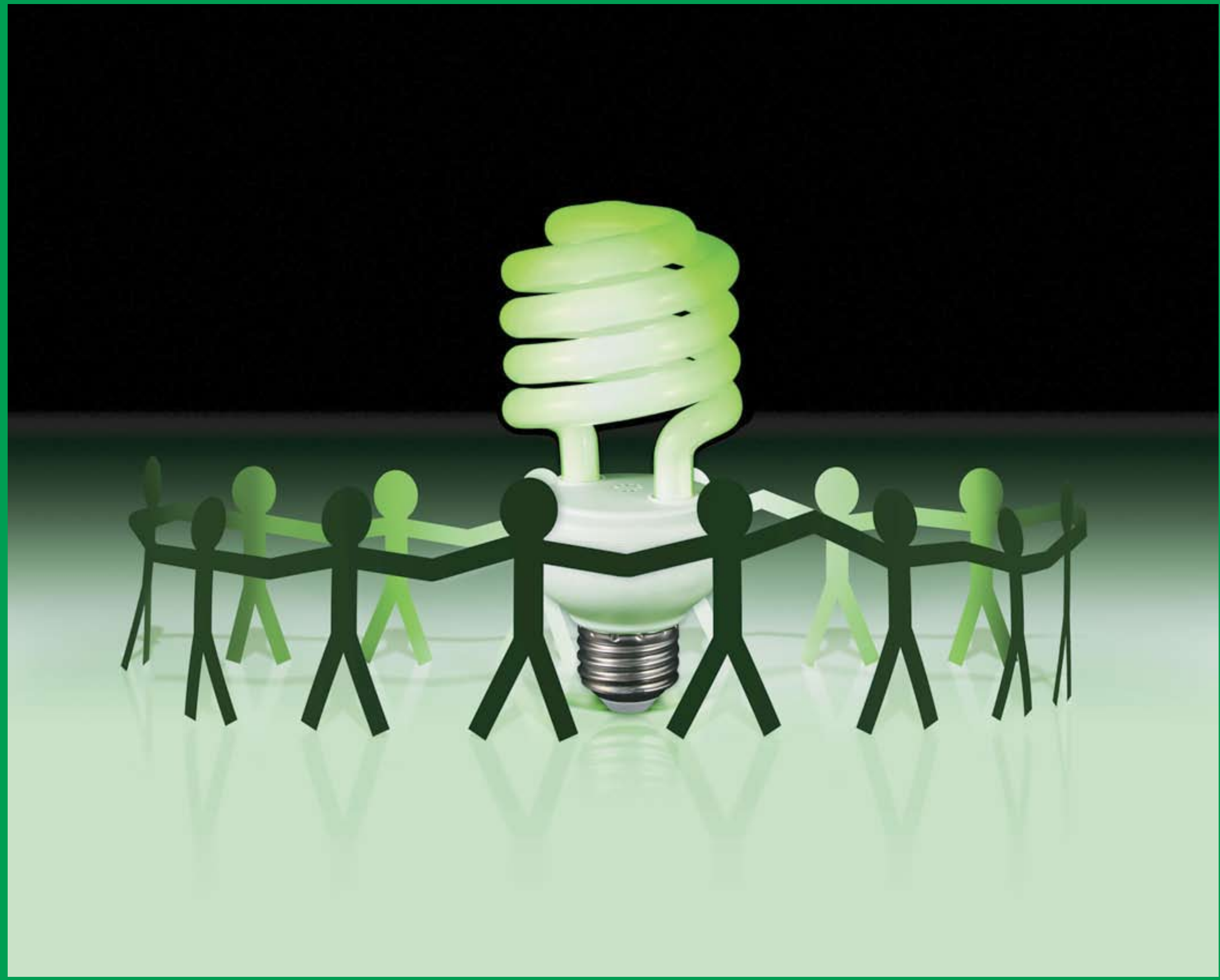
PSDE Green Power
ENERGY EFFICIENCY

Special Report: Energy Efficiency / Energy Harvesting



Finally: The Missing Link for Energy Harvesting

Optimized power acquisition and utilization now a reality

Everywhere you look, engineers are coming up with new and innovative ways to harness non-traditional energy sources to solve real world problems. Increased safety and accessibility, lower maintenance costs, improved energy efficiency and system flexibility are just a few of the benefits attainable with "harvested" energy, wireless sensing and monitoring/control systems. The high cost of energy, new government regulations and environmental concerns have greatly increased demand for more efficient use of power everywhere. Emerging technologies in alternative energy and improvements in power utilization have the potential to enable performance breakthroughs in many diverse markets. Furthermore, new products that can take advantage of these new technologies represent excellent growth opportunities both in short and long term.

By Tony Armstrong, Director of Product Marketing, Power Products, Linear Technology Corporation

A wide range of low-power industrial sensors and controllers are turning to alternative sources of energy as the primary or supplemental means of supplying power. Ideally, such harvested energy will eliminate the need for wired power or batteries altogether. Transducers that create electricity from readily available physical sources such as temperature differentials (thermoelectric generators or thermopiles), mechanical vibration (piezoelectric or electromechanical devices) and light (photovoltaic devices) are becoming viable sources of power for many applications. Numerous wireless sensors, remote monitors, and other low-power applications are on track to become near "zero" power devices using harvested energy only (commonly referred to as "nanoPower" by some).

Although energy harvesting has been emerging since early 2000 (its embryonic phase), recent technology developments have pushed it to the point of commercial viability. In short, in 2010 we are poised for its "growth" phase. Building automation sensor applications utilizing energy harvesting techniques have already been deployed in Europe, illustrating that the growth stage may have already begun.

Existing Applications Demonstrate Commercial Viability

Even though the concept of energy harvesting has been around for a number of years, the implementation of a system in a real world environment has been cumbersome, complex and costly. Nevertheless, examples of markets where an energy harvesting approach has been used include transportation infrastructure, wireless medical devices, tire pressure sensing, and of course, building automation. In the case of building automation, systems such as occupancy sensors, thermostats and light switches can eliminate the power or control wiring normally required and use a mechanical or energy harvesting system instead. This alternative approach can also mitigate the costs of routine maintenance normally associated with wired systems in addition to eliminating the need for wiring to be installed in the first place, or for regular battery replacement in wireless applications.

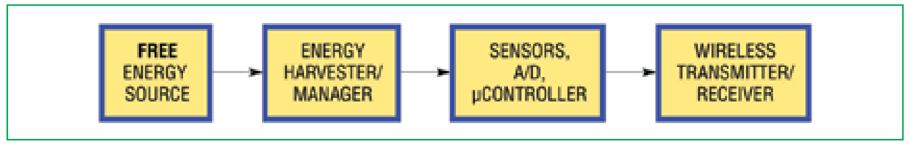


Figure 1: The four main blocks of a typical energy-scavenging system.

Similarly, a wireless network utilizing an energy harvesting technique can link any number of sensors together in a building to reduce heating, ventilation & air conditioning (HVAC) and lighting costs by turning off power to non-essential areas when the building has no occupants. Furthermore, the cost of energy harvesting electronics is often less than running sense wires, so there is clearly economic gain to be had by adopting a harvested power technique.

A typical energy scavenging configuration or system, (represented by the four main circuit system blocks shown in Figure 1 below), usually consists of a free energy source such as a thermoelectric generator (TEG) or thermopile attached to a heat generating source, such as an HVAC duct for instance. These small thermoelectric devices can convert small temperature differences into electrical energy. This electrical energy can then be converted by an energy harvesting circuit (the second block in Figure 1) and modified into a usable form to power downstream circuits. These downstream electronics will usually consist of some kind of sensor, analog-to-digital converter and an ultralow power microcontroller (the third block in Figure 1). These components can take this harvested energy, now in the form of an electric current, and wake up a sensor to take a reading or a measurement then make this data available for transmission via an ultralow power wireless transceiver – represented by the fourth block in the circuit chain shown in Figure 1.

Each circuit system block in this chain, with the possible exception of the energy source itself has had its own unique set of constraints that have impaired its commercial viability until now. Low cost and low power sensors and microcontrollers have been available for quite sometime; however, it is only within the last couple of years that ultralow power transceivers have become commercially available. Nevertheless, the laggard in this chain has been the energy harvester and power manager.

Existing implementations of the power manager block are a low performance discrete configuration, usually consisting of 35 components or more. Such designs have low conversion efficiency and high quiescent currents. Both of these deficiencies result in performance compromised in an end system. The low conversion efficiency will increase the amount of time required to power up a system, which in turn increases the time interval between taking a sensor reading and transmitting this data. A high quiescent-current limits how low the energy-harvesting source can be since it must first overcome the current level needed for operation before it can use any excess to supply power to the outputs. Finally, it also requires a very high degree of analog switchmode power supply expertise – something that is in short supply around the world!

The "missing link," if you will, has been a highly integrated DC/DC converter that can harvest and manage surplus energy from extremely low input voltage sources. However, that's all about to change.

The Missing Link

Linear Technology has recently introduced its LTC3108 – an ultralow voltage step-up converter and power manager specifically designed to greatly simplify the task of harvesting and managing surplus energy from extremely low input voltage sources such as thermopiles, thermoelectric generators (TEGs) and even small solar panels. Its step-up topology operates from input voltages as low as 20mV. This is significant since it allows the LTC3108 to harvest energy from a TEG with as little as 1°C temperature change – something a discrete implementation struggles to meet due to its high quiescent current.

The circuit shown in Figure 2 uses a small step-up transformer to boost the input voltage source to a LTC3108 which then provides a complete power management solution for wireless sensing and data acquisition. It can harvest small temperature differences and generate system power instead of using traditional battery power.

The LTC3108 utilizes a depletion mode N-channel MOSFET switch to form a resonant step-up oscillator using an external step-up transformer and a small coupling capacitor. This allows it to boost input voltages as low as 20mV high enough to provide multiple regulated output voltages for powering other circuits. The frequency of oscillation is determined by the inductance of the transformer's secondary winding and is typically in the range of 20kHz to 200kHz.

For input voltages as low as 20mV, a

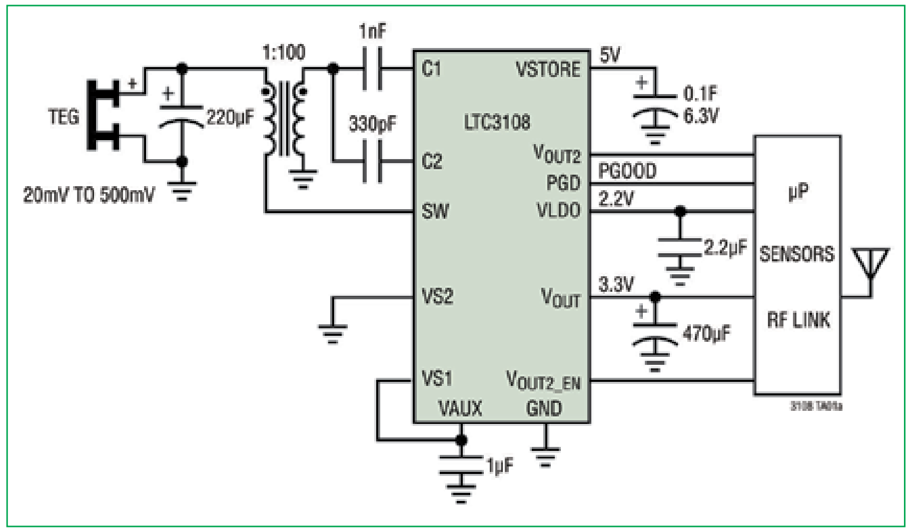


Figure 2: LTC3108 used in a wireless remote sensor application powered from a TEG (Peltier Cell).

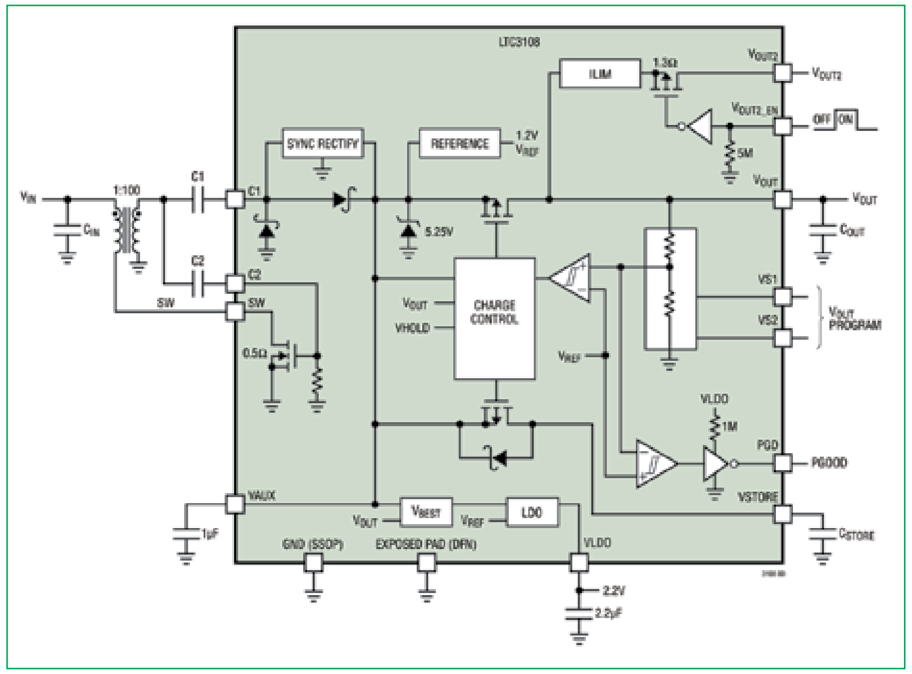


Figure 3: LTC3108 block diagram.

primary-secondary turns ratio of about 1:100 is recommended. For higher input voltages, a lower turns ratio can be used. These transformers are standard, off-the-shelf components, and are readily available from magnetic suppliers. Our compound depletion mode N-channel MOSFET is what makes 20mV operation possible.

As can be seen in Figure 3, the LTC3108 takes a "systems level" approach to solving a complex problem. It can convert the low voltage source and manage the energy between multiple outputs.

The AC voltage produced on the secondary winding of the transformer is boosted and rectified using an external charge pump capacitor (from the secondary winding to pin C1) and the rectifiers internal to the LTC3108. This rectifier circuit feeds current into the V_{AUX} pin, providing charge to the external V_{AUX} capacitor and then the other outputs.

The internal 2.2V LDO can support a low-power processor or other low power ICs. The LDO is powered by the higher value of either V_{AUX} or V_{OUT}. This enables it to become active as soon as V_{AUX} has charged to 2.3V, while the V_{OUT} storage capacitor is still charging. In the event of a step load on the LDO output, current can come from the main V_{OUT} capacitor if V_{AUX} drops below V_{OUT}. The LDO output can supply up to 3mA.

The main output voltage on V_{OUT} is charged from the V_{AUX} supply and is user programmable to one of four regulated voltages using the voltage select pins VS1 and VS2. The four fixed output voltage are: 2.35V for supercapacitors, 3.3V for standard capacitors, 4.1V for Lithium-Ion battery termination or 5V for higher energy storage and a main system rail to power a wireless transmitter or sensors – thereby eliminating the need for multi-meg-Ohm external resistors. As a result, the LTC3108 does not require special board coatings to minimize leakage, such as discrete designs where very large value resistors are required.

A second output, V_{OUT2}, can be turned on and off by the host microprocessor using the V_{OUT2_EN} pin. When enabled, V_{OUT2} is connected to Vout through a P-channel MOSFET switch. This output can be used to power external circuits such as sensors or amplifiers that do not have low power sleep or shutdown capability. An example of this would be to power on and off a MOSFET as part of a sensing circuit within a building thermostat.

The V_{STORE} capacitor may be a very large value (thousands of microfarads or even Farads), to provide holdup at times when the input power may be lost. Once Power-up has been completed, the Main, Backup and switched outputs are all available. If the input power fails, operation can still continue, operating off the V_{STORE} capacitor. The V_{STORE} output can be used to charge a large storage capacitor or rechargeable battery after V_{OUT} has reached regulation. Once V_{OUT} has reached regulation, the V_{STORE} output will be allowed to charge up to the V_{AUX} voltage, which is clamped at 5.3V. Not only can the storage element on V_{STORE} be used to power the system if the input source is lost but it can also be used to supplement the current demanded by V_{OUT}, V_{OUT2} and the LDO outputs if the input source has insufficient energy.

A power good comparator monitors the V_{OUT} voltage. Once V_{OUT} has charged to within 7% of its regulated voltage, the PGOOD output will go high. If V_{OUT} drops more than 9% from its regulated voltage, PGOOD will go low. The PGOOD output is designed to drive a microprocessor or other chip I/O and is not intended to drive a higher current load such as a LED.

Conclusion

In summary, the LTC3108 thermal energy harvesting, DC-to-DC step-up converter and system manager is a revolutionary device that extracts energy from solar cells, thermo-electric generators or other similar thermal sources. Its unique resonant power converter topology allows it to start up at an extremely low 20mV input voltage. Its high integration, including power management control and off-the-shelf external components, make it the smallest, simplest and easy-to-use solution available to complete the energy harvesting chain.

www.linear.com

PSDE Green Power ENERGY EFFICIENCY

Manage the Power

Blackfin powers Siemens' meter energy management solution

Increasing the use of smart meters across local and country-wide power systems is key to achieving accurate, reliable energy management. With energy deployment 'under-the-microscope' it is vital we manage our use of resources in these cost and energy-sensitive times. Analog Devices provides the solution here for Siemens.

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

Consider a local energy bill that not only details the price of kilowatt hours used per month, but specifically highlights the cost and energy use by time of day and potentially by the appliance that consumes it. Even better, consider the energy company, through its ability to gather this real time information, offering significant discounts to consumers who modify their energy usage from peak to off-peak, for example, giving energy credits for running a washing machine at 9:00pm instead of 6:30pm.

By leveraging the cost-effective computational performance of Analog Devices' Blackfin processor at the heart of its "smart meter" technology, the Siemens Automated Metering and Information System (AMIS) has made this kind of scenario a reality. The result gives both energy companies and consumers the ability to manage their costs and ultimately conserve the use of precious energy resources.

"Our smart metering solution AMIS is the result of many years of research," says, Alexander Schenk, Business Segment Manager for AMIS systems at Siemens Energy, Power Distribution Division, "It is Analog Devices' Blackfin that enabled us to offer sophisticated measurement and communication at the meter level, enabling a true system-wide energy management tool."

Early in the AMIS design stage, Siemens recognized that to accomplish this goal, these smart meters would require exceptional in-meter processing power, dynamic and grid-integrated communications and true scalability, all at a low per-unit cost. Siemens chose the Blackfin convergent processor because of its ability to seamlessly operate both as a DSP and an MCU, making it uniquely suited to Siemens AMIS' high processing and dynamic communication application requirements.

Analog Devices' Blackfin enabled Siemens to offer sophisticated measurement and communication at the meter level.

Blackfin's exceptional performance, low cost and scalability gives power companies the edge in seamless smart meter implementation. Blackfin calculates the consumer energy usage at the smart meter and performs the powerline modem functions, creating an efficient bi-directional communication flow with the power line concentrator. With AMIS, power companies are now able to implement energy saving initiatives and respond quickly and effectively to government mandates for increased smart metering. Blackfin's configurability eases a multi-regional power company's expansion into differing community or regional standards. With AMIS, new features and standard adoption simply requires a straightforward software upgrade over the grid. In addition, AMIS facilitates the incorporation of a full range of meters for new alternative energy technologies, creating a consistent, scalable energy management system.

"ADI processors are a natural choice for the dynamic and powerful processing needs of today's smart meter," says Colin Duggan, Industrial and Instrumentation Segment manager for ADI's General Purpose-Digital Signal Processing Division. "We are especially happy to be a part of the larger solution of true demand and energy management which benefits consumers as well as significantly contributing to en-

PowerPack Power Systems Design

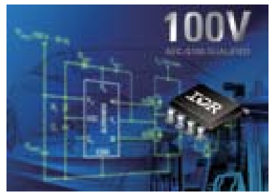
Fairchild Semiconductor

Improve Efficiency at Light Load

This PWM controller improves energy savings during light load by 25 percent, enabling notebook power supply designers to meet stringent energy-saving regulations.

www.fairchildsemi.com/pf/FA/FAN6754.html

International Rectifier



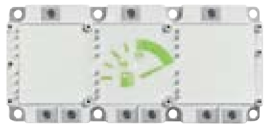
Half-bridge Driver IC Reduces Footprint for Space Constrained Automotive Applications

International Rectifier has introduced the AUIR2085S automotive-qualified control IC for low- mid- and high-voltage automotive drive applications including DC-DC converters, HEV auxiliary converters and battery management converters.

A self-oscillating half-bridge 100V driver IC with 50 percent duty cycle, the AUIR2085S features an integrated soft-start capacitor that gradually increases duty cycle from zero to 50 percent for 5msec. This limits in-rush current during start up, and maintains equal pulse widths for the high- and low-side MOSFETs throughout the start-up sequence.

www.irf.com/whats-new/nr091001.html

Infineon



HybridPACK™ 2 - Compact Power for Your Electric Drive Train.

Based on the long time experience in the development of IGBT power modules and intense research efforts of new material combinations and assembly technologies, Infineon has developed – dedicated for automotive applications – this HybridPACK™ 2 power module belonging to the HybridPACK™ family. With its pin fin base plate for direct water cooling Infineon HybridPACK™ 2 is designed to fulfill the requirements of your electric drive train application with power ratings of up to 80kW.

www.infineon.com/cms/en/product/channel.html?channel=db3a3043136fc1dd011370e812b7043a

LEM

Visit LEM at PCIM 2009 in Hall 12-402. This year, LEM will be highlighting a range of products, including the CAS, CASR and CKSR family of current transducers. They are suitable for industrial applications such as variable speed drives, UPS, SMPS, air conditioning, home appliances, solar inverters and also precision systems such as servo drives for wafer production and high-accuracy robots.

LEM is a leading manufacturer of current and voltage transducers used in a broad range of industrial applications, including variable speed drives for motors and power supplies, AC/DC converters, UPS systems for computers as well as in new innovative energy applications, such as micro-turbines, wind and solar power generation.

For further information please go to

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ITW Paktron

Non-Polarized Polymer Film Capacitors (CS Series) Designed for Mission Critical Applications

ITW Paktron's Multilayer Polymer (MLP) Film Capacitors (Type CS Series) feature ultra-low ESR and high ripple current capability and are designed for high frequency filtering and EMI/RFI suppression in power conversion applications. Provides mechanical and electrical stability, compared to multilayer ceramic capacitors. Features "non-shorting" operation and does not crack like large ceramic chip capacitors under temperature extremes or high vibration. There are no DC or AC voltage coefficient issues with polymer film capacitors.

Capacitance values range from 0.33µF to 20µF and voltage ratings are 50 to 500 VDC. Lead time is stock or four to six weeks.

www.paktron.com

vironmental conservation."

With Blackfin's real time energy collection and communication capabilities, power companies can now limit negative environmental impact, reduce skyrocketing energy costs, and solicit customer participation in tailored energy conservation programs.

The low-cost Blackfin's ability to process raw, real-time energy usage data at the meter level as well as power communications between the meter and the grid offered a one stop, low cost, and easily configurable solution. As energy companies implement AMIS smart meters beyond local grids, the Blackfin-based meter elements are also easily adapted via software to match disparate local or country-specific communication standards.

Fully Integrated Whole-Grid Communications

Grid-wide data capture and communication between power companies, power grids and consumers is what distinguishes Siemens AMIS' smart meter capability. By designing smart-meter components around the Blackfin processor, AMIS leads this power-grid transformation by not only measuring consumption in homes, but also extending across the entire energy chain ecosystem, from power plant to consumer. In fact, a Blackfin-powered data concentrator at a local transformer substation collects energy use data on a second-by-second basis, monitors the power grid and transmits the data to a control station. Uniquely self-sufficient, Siemens AMIS uses power line technology to transmit data, eliminating separate, costly radio, internet or local exchange carriers, although AMIS makes it possible to adopt these mediums, if desired.

Blackfin-based smart meters satisfy today's design requirements, but also anticipate next-generation energy-management technology, incorporation of new, disparate grid appliances, and the facilitation of alternative energy-use credits for consumers. As future standards are developed, they can be simply downloaded over the power line grid into the Blackfin-based meter components, creating a seamless transition.

Incorporating other utility usage such as gas and water can be accomplished via wireless communication into the remote metering system. To support the increasing adoption of alternative energy systems, the AMIS system meter, for example, can control the feed-in of electricity from solar cells to or from a power plant.

The true beneficiary of smart meter technology is the environment. Until the right technology existed at the right cost point to implement real-time smart-metering, there was insufficient information to detect or correct wasteful energy use. With Blackfin's real time energy collection and communications capabilities, power companies now have the information they need to conserve energy consumption, directly reducing carbon emissions in the environment.

www.analog.com

APS Maintains Power Continuity

Rebuilding generating station feedwater heaters, on-line, with minimal downtime

Rebuilding makes better economical sense versus buying new, while allowing utilities to keep up and running. At one Texas generating station, rebuilding saved one-third the cost of new while improving heat efficiency index. American Power Services (APS) of Erlanger, KY served up the solution.

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

It used to be an old myth that rebuilding a feedwater heater takes longer than installing a new replacement, or that it couldn't be done with the unit in operation or on-line. Not any more. Today's rebuilding companies can rebuild aging units in a matter of weeks, keeping plant downtime to a minimum. In many cases, rebuilding can proceed with the plant on-line, so that even plants with only one string of heaters can continue to generate electricity. Plants can now rejuvenate old heaters without having to resort to a planned outage.

For generating stations that need a new feedwater heater urgently, the option of going with a rebuilt unit on-site makes even more sense, as new replacement units can take a year or two to manufacture, all the while the plant is operating in a derated capacity and is forced to burn more coal. Whereas a quick rebuild can return a plant to designed capacity in a matter of weeks.

Ultimately, though, the fact that rebuilt units save anywhere from 25-50% of the cost of a replacement unit makes the argument for rebuilding hard to ignore, especially in the face of today's economy.

"It required four weeks to completely rebuild two heaters, and by rebuilding over buying new feedwater heaters we saved about one-third the cost," says Nick Samford, the Engineering Supervisor at NRG's Limestone, Generating Station, in central Texas.

Debunking old myths to solve today's problems

Failure to take advantage of the tremendous saving afforded by rebuilding often stems from the perpetuation of untrue myths that rebuilding takes too long, or that it can only be done during a scheduled downtime. This simply is no longer the case. For example, many utilities are forced to operate with "dead" heating units on the belief that they must go off-line to repair the problem. The situation is particularly acute for smaller plants relying on only one string of feedwater heaters. Without built-in redundancy, engineering staff traditionally felt their only option was to order a brand new heater, which can take over a year to build from scratch. In the meantime, the plant would limp along in a derated status, burning more coal, thus driving down efficiency. However, this old way of operating wanes in the face of today's reality that rebuilding companies can now overcome any lack of redundancy within the facility.

APS undertook the rebuilding project, utilizing its ASME Code shop and 50 certified and trained heat exchanger technicians, code welders, as well as their NDE staff. The work was completed per code, per insurance regluations within a scheduled four week outage.

"For about half of the heaters we rebuild, we isolate the heater and re-tube it on-site while the unit is on-line, by isolating the defective heater," says David Grimes, an Engineer at American Power Services "APS" of Erlanger, KY, a provider of heat transfer equipment services that include troubleshooting and repairing, to complete rebuilding projects. "Bypass lines can be installed so that the rebuilding can proceed without the plant having to wait for an outage. This, by itself, saves money." Contrary to the opinion perpetuated by some heater manufacturers that on-site rebuilding can't take place at all, sometimes it is a complete replacement that often proves impossible.

"When you buy a new heater from a manufacturer, it will typically come already assembled and ready to be installed," continues Grimes. "But we've seen cases where there was not sufficient room to physically get a new heater into position. As a plant expands over the years around the original installation, extra equipment gets installed and before you know it, the heater that was once in the wide open is now behind three walls. In contrast to installing a replacement heater, a rebuilding project can still take place within those same space constraints."

Any doubts that rebuilt units can't match the thermal efficiency of new replacement units were quickly dispelled since the original tube material can be changed during a rebuild to actually improve the thermal performance of the original design.

Additionally, a rebuild or retubing can extend the life of an existing heater by 20 to 30 years-just as long as a total replacement but at far less capital expense. Additionally, many components that once were considered obsolete and/or not reusable such as the tubesheet, channel and shell can be returned to 'as new' condition.

Advanced rebuilding techniques and tools make quick rebuilds possible

With a mindset of time and cost-effective repair and service—versus throwing everything out and starting from scratch—the rebuilding process begins with testing and troubleshooting analysis. Sophisticated equipment determines the exact location, nature and severity of a problem via eddy current, ultrasonic, dye penetrate, magnetic particle, hydrostatic, and boroscopic testing procedures.

With testing data in hand, a rebuilding company can make recommendations on cost-effective options for remedial correction, retubing to original specification, or rebuilding to improve performance. Specialized tools have done much to speed the process. Hydraulic tube pullers, power tube strippers, tube joint milling tools and plasma arc ID tube cutting facilitate the rebuilding process. Additionally, new technology allows for defective or leaking tubes to be explosively plugged with the unit on line by utilizing a robotic arm to install the required tube plugs. Doing so provides a safer method of installing tube plugs by not having to place personnel in harms way.

Rebuilding cost-savings in practice

Founded in 1989, NRG Energy, Inc. is a wholesale power generation company, primarily engaged in the ownership and operation of power generation facilities and the sale of energy, capacity and related products in the US and internationally. The company's global portfolio of projects totals over 24,000 net MW. Located between Houston and Dallas, NRG's Limestone station is a coal-fueled plant with two units: 836-MW and 864-MW. Both of the OEM heaters had been in service for over 20 years. However, the desuperheater was a little too large, resulting in saturated water exiting at excessive velocities that caused tube erosion.

"We initially considered buying completely new heaters, but ultimately decided not to because of the additional cost," continued Samford.

Damage to the desuperheater tubes due to steam impingement.

This additional space allowed with the hemi head removed, directly led to a more efficient rebuilding project by providing full access to the tubesheet.

APS undertook the rebuilding job, utilizing its ASME Code shop and 50 certified and trained heat exchanger technicians, code welders, as well as their NDE staff. The process started with a failure analysis that identified vibration in the desuperheating zone as a cause. APS then redesigned the desuperheater to eliminate the wet wall condition of the tubes and to reduce the velocity of the steam entering the desuperheater while maintaining the original design thermal and operational parameters.

Work began in late February 2009. The internal structure was rebuilt while changing the steam inlet location. Additionally, the desuperheater flow path was rerouted during the rebuilding process. In order to speed up the process, a specialized motor driven plasma arc cutter was used to remove the hemi head in order to facilitate better access to the tubesheet during the rebuilding process. This additional space directly led to a more efficient rebuilding project by providing full access to the tubesheet, rather than working inside the hemi head. This allowed the use of efficient tools to quickly pull the tube stubs, weld the new tubes to the tubesheet and mechanically expand the tube ends into the tubesheet. The job finished within 25 days.

The work was completed per code and per insurance regulations within the time frame of a scheduled four week inspection outage.

This rebuilt feedwater heaters allowed the Limestone plant to facilitate superheat at exit of the desuperheater thereby eliminating the wet wall condition. As a result, either of the two units can be taken off-line and the plant can still generate 100% power output. Since the condensing zone steam velocity was increased, thermal efficiency improved slightly.

"By rebuilding instead of simply buying a new unit, we saved our company money," concluded Samford.

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Beyond the Power Supply

System architecture and integration trends for 2010

Modern portable electronics rely on extracting every last Coulomb of charge from the batteries they contain. The trend in the past has been to improve both the size and efficiency of power supplies through technology such as trans-mode conversion. Looking forward to 2010 and beyond, attempting to extract a few additional percent of conversion efficiency from power supplies will take a back seat to new, more efficient methods of using energy to accomplish the same function. Here we examine trends in system architecture and integration of power systems that go well beyond what would be possible for power supplies alone.

By Richard F Zarr, PowerWise® Technologist, National Semiconductor

Since the beginning of the 21st century, there has been a convergence of function and a drive to make things mobile. The Apple iPhone is a classic example of fusion – the combination of cellular communications, entertainment and Internet access. This trend has driven both mobile processing power as well as energy management to provide the best, long lasting user experience possible with today's limited battery technology. However, the power supply is only part of the equation. Providing 94% conversion efficiency is good, but redesigning the system to use 30% less energy is far better.

Where to begin

Most designers begin their new designs based on what was done previously. This is often the case due to time constraints or lack of personnel. What's interesting about this tactic is that inefficient subsystems can continue to propagate into newer designs. It is not always easy, but gains can be found by re-evaluating these subsystems and how they perform their function. Since power subsystems have been the focus for many years, their efficiencies have greatly improved. Most off-the-shelf integrated switching regulator designs can easily top 90% power conversion efficiency.

Going forward, these gains will not be so easy. Now only single-digit efficiency gains in the power supply can be found, so designers must look elsewhere for improvements. It is not always obvious, but rethinking how a system solves a problem can yield results. For instance, finding a better algorithm to encode or decode a data stream can result in a lower frequency clock thus saving power. Sometimes, digital is not always better than analog. Sometimes using analog processing to supplement or replace digital processing can also greatly reduce power.

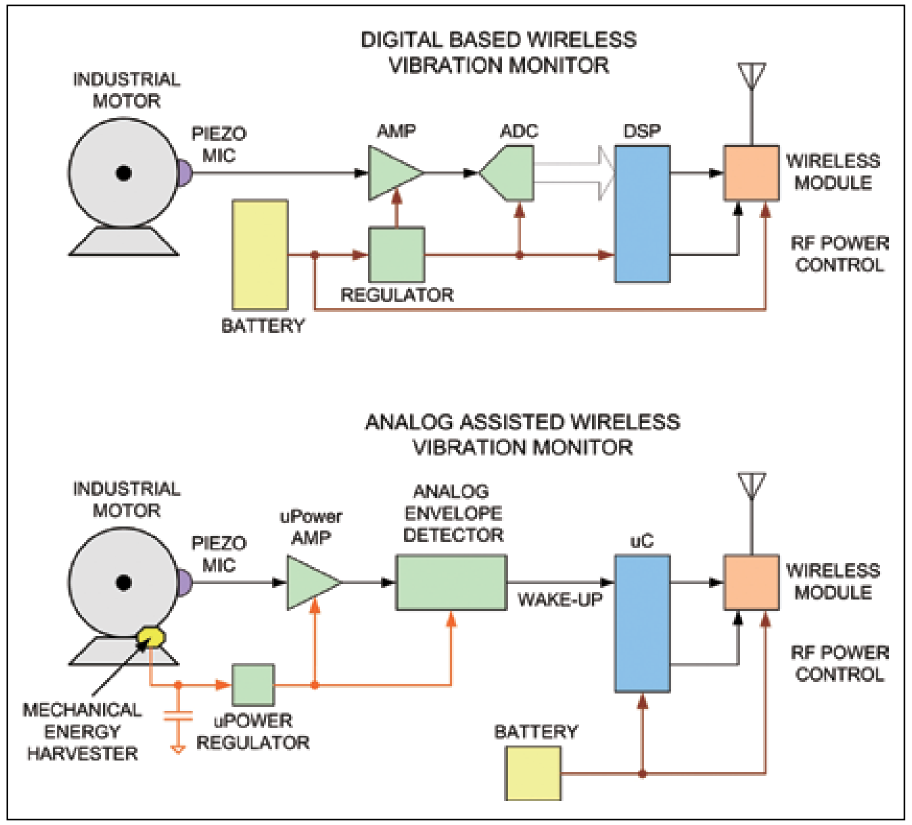

Figure 1: Two designs for wireless vibration monitors.

Figure 1 shows two block diagrams of a wireless industrial vibration monitor – one using conventional DSP processing and the other using energy harvesting to power an all-analog envelope (excessive vibration at various frequencies) detector. The traditional way is to convert everything immediately to the digital domain and process the information with DSP functions. This consumes a great deal of power since the ADC and DSP must be active during the sampling and calculations. The analog assisted version uses a continuous-time micro-power filter to monitor for various frequencies along with their amplitudes. Once a limit is reached, a wake-up call is sent to the microcontroller to signal the monitoring station. Only during that time is the battery in use. The mechanical energy harvested from normal vibrations power's the analog front end. The microcontroller can even wake up periodically to report normal status to ensure normal operation and still use a much smaller battery.

The trend will be to provide more monitoring capabilities along with wireless communication for ease of deployment as well as placing sensor where no convenient power exists. This is especially important in applications such as home land security where monitoring must be placed in remote areas. The cost of the equipment will be secondary to the cost of replacing batteries or the liability of system failure due to dead cells.

Going deeper

Beyond the overall equipment design are the system-on-a-chip implementations. Many are now designed in 65nm or smaller geometry CMOS processes. The trend has continued for quite some time to place more transistors on a single device to provide more functionality in a smaller space. The problem is that more transistors switching faster increases energy consumption. Equation 1 shows the fundamental relationship between the energy consumed in CMOS and the supply voltage, clock frequency, internal capacitive loading and leakage terms as well as how long a task is running. Looking at the equation there are two major terms – the dynamic component and the static component. The dynamic term suffers the most from supply voltage due to the squaring of the voltage term however leakage is becoming a more serious problem at smaller geometries. This is primarily due to the scaling of the transistors.

As the transistors shrink, the oxide

$$E=(\underbrace{\alpha C F_{CLK} V^2}_{\text{DYNAMIC TERM}} + \underbrace{V I_{LEAK}}_{\text{STATIC TERM}}) \cdot T_{TASK}$$

Equation 1: Fundamental CMOS energy consumption.

thickness needs to also shrink in thickness. This causes electrons to leak through the oxide by tunneling or finding paths via the drain and source extensions. The transistors also suffer from the sub-threshold leakage where the transistors are conducting even though the gates are below the turn-on threshold. Some of this is due to short channel effects such as Drain Induced Barrier Lowering which moves the threshold and increases leakage.

Many process techniques are being used to control static losses such as the introduction of Hafnium based oxides which electrically have the correct dielectric constant for the scale, but are mechanically thicker to prevent tunneling. However, architectural changes can help solve both the dynamic and static loss issues. The obvious first step would be to allow a system to dynamically alter the supply voltage when the frequency is reduced – this is known as Dynamic Voltage Scaling and has been used for years especially in microprocessors for mobile applications. When the loading on the processor is reduced, a command is sent to the power management unit (PMU) which can reduce the voltage saving significant energy. This technique can only compensate for the frequency of operation, but does nothing to adapt for the variations in process or the operating conditions such as ambient temperature.

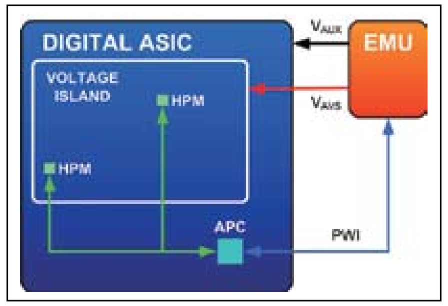

Figure 2: Adaptive Voltage Scaling (AVS).

An improved technology pioneered by National Semiconductor in early 2000 is called PowerWise® Adaptive Voltage Scaling (AVS). This technique compensates for the frequency of operation and additionally compensates for process or temperature variations including aging. Figure 2 shows the basic block diagram of how a system using AVS works. The HPM or Hardware Performance Monitors are synthesized along with the application and continuously monitor the performance of the process. The status is reported to the Advanced Power Controller (APC) which determines if the process is running fast enough for the application. If the process needs to go faster, the APC sends a command to the external Energy Management Unit to increase the supply voltage in very fine steps until the performance level is met. Conversely, if the process is running faster the same function reduces the supply voltage. This can dramatically reduce the energy consumption of the device since the majority of the time the process is faster than it needs to be and the ambient temperature is not at the extremes. ASICs using this technology have seen savings up to 40% and more in specific applications. These gains are far greater than trying to improve the power supply efficiency a few percent.

Conclusion

Power supplies have matured and now routinely provide conversion efficiencies of over 90%. Engineers need to look beyond the power supply for savings and rethinking old methods of building functional blocks. Additionally, re-architecting existing designs can yield significant energy savings as well. With trends moving to more remote wireless applications and more processing with less power, new techniques must be employed to reduce energy consumption and meet the demand of the next decade.

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From Passive to Active Efficiency

The history and future of power management

At a time when energy conservation is on everyone's mind, designing for efficiency seems to be a basic fundamental, but for power engineers it has been a permanent quest driving an amazing level of innovation that started many years ago when transistors were made of Germanium and J.F. Kennedy declared in his speech delivered in 1962 at Rice University in Houston, Texas, "We choose to go to the Moon…"

By Patrick Le Fèvre, Marketing Director, Ericsson Power Modules

From that day, DC/DC power designers targeted energy efficiency as prime driver for new technologies, though despite very innovative new topologies, energy efficiency has been very much driven by components' performances nowadays reaching a level of evolution that requires additional magic in order to walk the last mile.

The following article honors those that brought men to the Moon and the thousands of power engineers that, in the secretion of their laboratories contributed to make DC/DC converters highly efficient, and recently, introduced new technologies such as digital power control and power management providing the missing link from passive efficiency to active efficiency.

Passive beginnings

From the early origins of DC/DC power conversion, energy efficiency has been an issue that power and components designers have addressed to improve products and systems' performances. This became critical when systems' reduced availability of space for power conversion, simultaneously requiring lower power dissipation and longer lifetime, when combined together require higher efficiency DC/DC power converters.

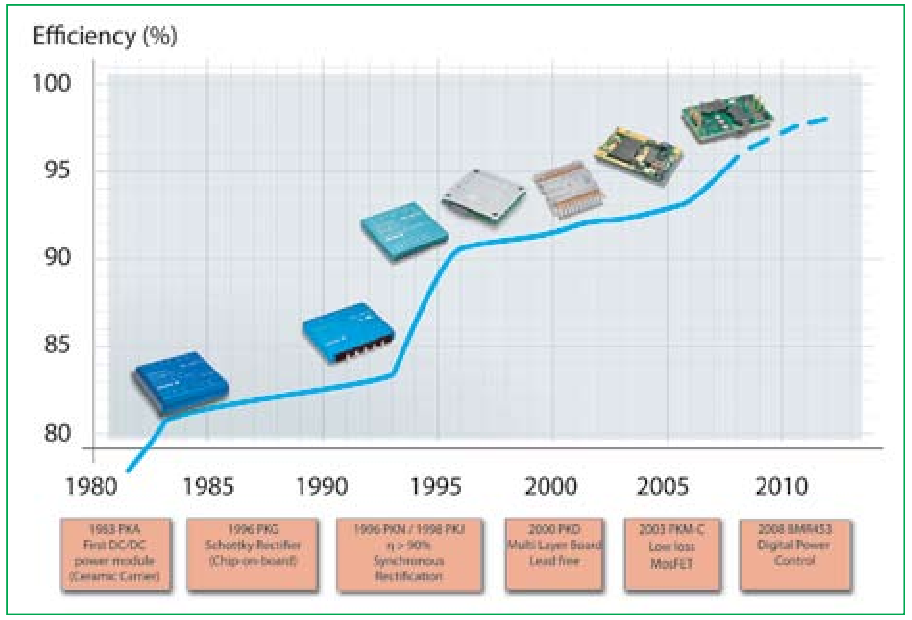

Figure 1: DC/DC efficiency curve.

Considering where we are today, it is wise to take a minute to look back into the power history to really understand the long road we've traveled, moving from <50% to over 96% efficiency and to realize today's concerns are very similar to what the power electronics pioneers faced in their time.

There are many good examples that illustrate the evolution of energy efficiency, but to start I would like to mention what I consider as being the first challenging project power supplies designers faced when designing DC/DC power solutions to power the Apollo Spacecraft.

In those days, most of the DC/DC converters where designed for military applications and the average efficiency topped, at best, 40% resulting in very-high power dissipation. The Apollo program triggered the demand for 'higher efficiency DC/DC converters' and a young engineer named Nicholas G. Tagaris, who later formed DATEL, was one of the engineers to consider new ways of working and thinking out of the

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box to step-down the 28V internal bus while reducing power losses.

The Apollo Spacecraft and especially the Lunar Excursion Module (LEM) required a new way to distribute energy throughout the space vehicle while preserving the precious energy delivered by the fragile batteries. Part of this project investigated in a new concept to create 'integrated DC/DC converters', ten years later to be known as 'bricks'. However the real challenge for those guys, despite an almost unlimited budget, was to improve the efficiency of something already limited by the components and topologies available at the time, often just a push-pull switcher inherited from audio systems, post-regulated by a series of transistors ballast-connected in parallel - and to use a brand new emerging technology called integrated circuits.

During that project, designers had to consider a number of constraints today's engineers are also facing; "How to reduce energy consumption to the lowest level" and the answer was simple, switch OFF everything you don't have a need for and turn it ON when it's time.

In 1969 energy management was already considered as a way to reduce power consumption but it has taken 40 years for this concept to find its way to become easily manageable at board level.

When in July 20, 1969 the LEM landed on the Moon, DC/DC converters were in their early development phase but from that date, the electronics industry gradually implemented DC/DC board-mounted power sources in various equipments and push-pull post regulated by using linear regulators, step-by-step to be replaced by new topologies.

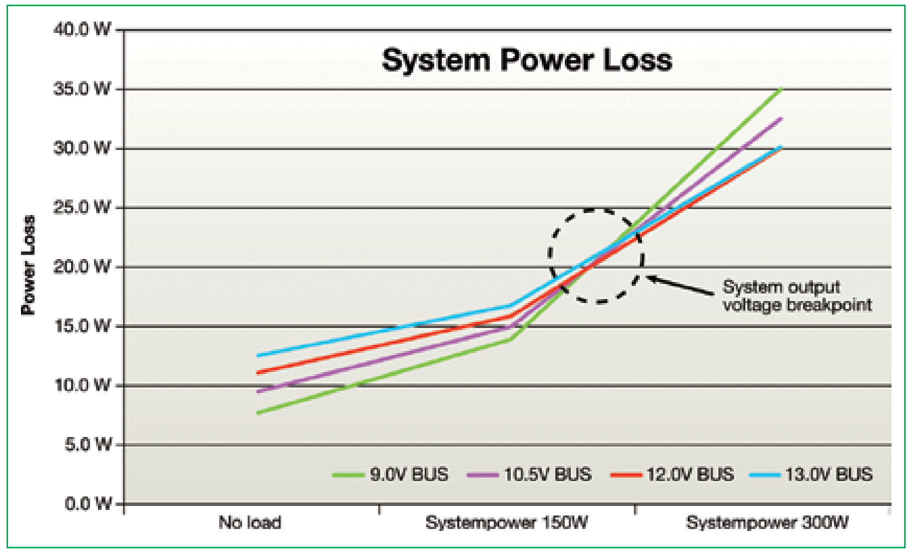

Figure 3: Optimized bus voltage.

Figure 1 illustrates the evolution of the efficiency curve throughout the years, but hidden behind the major steps, reflecting improvements brought about by new components, a very large number of technical improvements remain invisible.

Starting in the late seventies, the telecoms industry adopted the bricks-concept and Ericsson's PKA was the first BMP power module to break the standardized 60% efficiency that BMP modules performed in those days. To break this limit, engineers had to introduce several major innovations embracing designing a new set of power controllers, using a ceramic substrate, new ferrites, faster diodes, and new switching topologies resulting in a product performing at 80% efficiency.

As for many power supply companies, the adoption by the telecom industry of a new power distribution, the so-called 'distributed power architecture' has been the ignition point for intensive research to improve energy efficiency as illustrated in Figure 1.

From below 50% when Neil Armstrong said famously: "one small step for man, but one giant leap for mankind" to over 93% in 2000, the improvement is significant but despite expectations we may have in new materials such as Oxide Carbide or Gallium Nitride and others, we could consider the way to reach >98% efficiency as complex and as difficult as bringing men to march; not impossible but very costly.

Components and topologies will continue to progress but as illustrated in Figure 1, after having improved powertrains to the highest extent, by around 2006 the efficiency curve started to flatten, requiring engineers to consider other methods to improve efficiency and to move from passive efficiency to active efficiency.

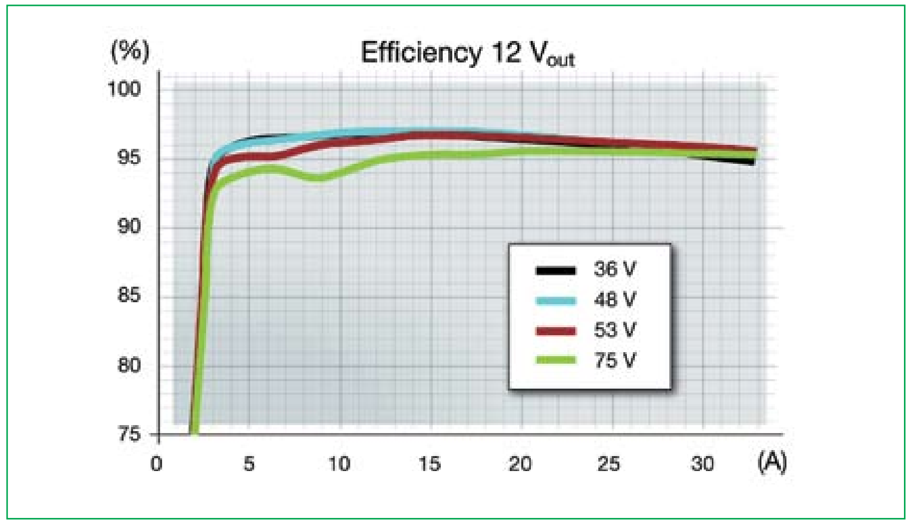

Figure 2: Optimized DC/DC efficiency.

Active efficiency arrived

Considering that powertrains have reached a state of the art level, that some limits inherent to components are difficult to exceed and that the market is not ready to pay for a little extra efficiency resulting from an experimental new generation of components or materials, DC/DC power modules' efficiency curve started to flatten. As it was for Nicholas G. Tagaris when considering powering spacecraft Apollo, power engineers had to think out of the box, considering combining the best of what analogue has already achieved with the benefits of an emerging new technology, digital power control and management.

DC/DC power converters are commonly designed to deliver the best performances at a certain point of operation that when in operation is not always the case. For example, recent studies from a datacenter have demonstrated under-utilization of power supplies, often being used at 25 to 35% of their capacity, which is outside the 'optimized performance point', resulting in poor efficiency and higher power losses.

Introducing a technology that permanently monitors load and input voltage conditions in order to dynamically adjust switching parameters to reconfigure power supply parameters to real conditions, will result in optimized performances at any load condition, limiting power losses to the lowest extent (Figure 2).

Also, the recent evolution of the distributed power architecture in migrating to a 12V intermediate bus voltage simplified the board designers' task but as it has been debated in many forums, 12V might not be the most optimized voltage at any point of systems' operation. Adding the possibility to adjust the bus voltage to suit load conditions, for example 9V when low utilization and 12V when full performance is required will result in an extra energy saving without adding cost (Figure 3).

Combining digitally controlled DC/DC converters and systems energy management lifted board-mounted power solutions from passive efficiency to active efficiency, closing the gap between product and systems optimization.

Conclusions

Maybe not as ambitious as walking on the Moon but when designing systems with power efficiency in mind, new technologies such as digital power management and control will contribute to reduce energy consumption, and active efficiency is still only in its infancy. I'm convinced that technology will take men to Mars and further, but until then it will change the way systems' architects consider DC/DC board-mounted power solutions that have now moved from passive to active status.

To close, I refer to a sentence often used by Antoine de Saint-Exupery (1900 – 1944), who said: "We haven't inherited the earth from our ancestors; we borrow it from our children."

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Performance PFC

Improve PFC efficiency with variable output voltage

The need to minimize power loss drives engineers to incrementally improve efficiency in multi-stage power supply designs for the 100-120V line power used in North America, Japan and Taiwan, and the 220-230V AC mains used in Europe and in the rest of the world, with variable PFC output. Careful consideration of the PFC stage design helps maximize efficiency for the overall power supply

By Aung Thet Tu, Product Line Director, Power Conversion America, Fairchild Semiconductor

A typical offline or ac-dc power supply includes a number of stages. Generally a bridge diode rectifier creates an unregulated dc voltage from the ac input. The downstream dc-dc converter stages deliver the regulated stable dc output voltages required for the application at hand. The PFC stage sits between the rectifier and the dc-dc converter stage (Figure 1 depicts a typical rectifier and PFC stage). The PFC stage leverages switch-mode technology so that the PFC converter draws nearly sinusoidal AC current that is in phase with the line voltage and therefore yields a PF (real power / apparent power) close to the ideal value of 1.

Theoretically, you could use most any switching converter topology in the PFC stage. The boost topology is a popular choice for several reasons. The boost converter has a relatively small BOM (bill of materials) when line filter requirements are considered. Moreover, typical boost converter designs minimize EMI noise.

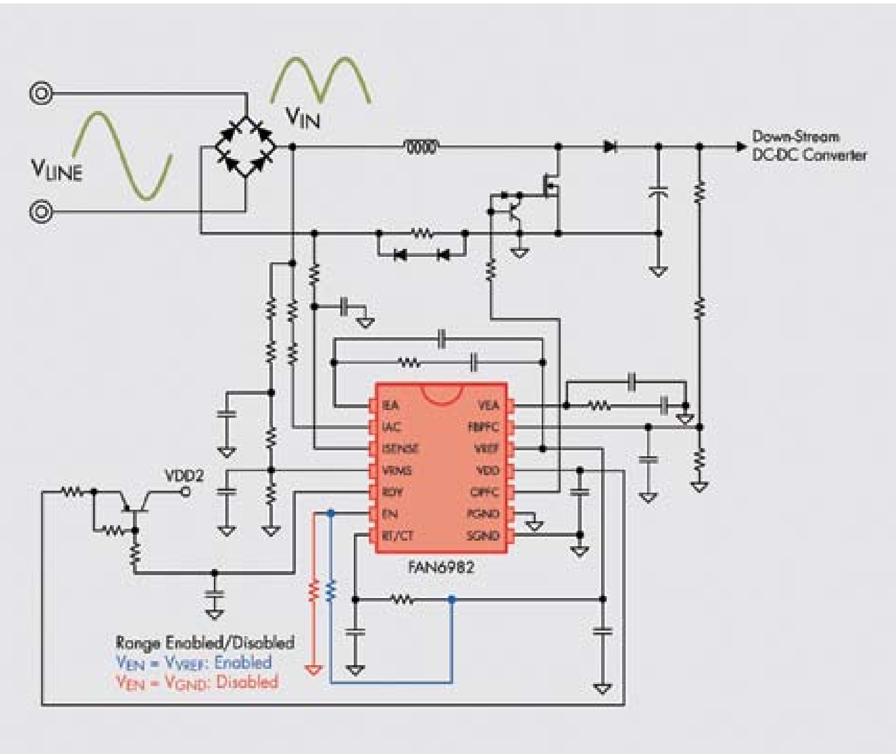

Figure 1: A typical PFC power stage.

Let's consider a typical universal PFC boost converter. With a 220V input, the output of a full bridge rectifier is in the range of 350V to 360V. The boost converter design must output a higher voltage than the input to both ensure proper boost operation and to shape the input current waveform. Subsequently, typical PFC boost converters have an output voltage in the range of 400V.

Why PFC output voltage matters

Generally, a higher voltage delivers more efficiency in terms of the energy stored in the PFC stage. Conversely, a higher output voltage equates with greater switching losses here – especially in light-load conditions. A lower output voltage from the PFC stage can incrementally increase total system efficiency. It can improve the PFC stage efficiency at light load condition by reducing capacitive switching loss. It can also improve the efficiency at low line voltage by reducing the voltage conversion ratio because a large voltage conversion ratio (Vo/Vin) results in severe conduction loss in the boost switch. The flip side for the downstream dc-dc converter is that it has to be designed for a wide input voltage range which is not good for efficiency.

DC-DC converter ramifications

While the ability to adjust PFC output voltage might be valuable in absolutely maximizing efficiency, we need to consider how a variable PFC output might affect the dc-dc stage. And then we need to discuss practical ways to handle the adjustment realizing that the adjustment scheme and the dc-dc-stage design are very much intertwined.

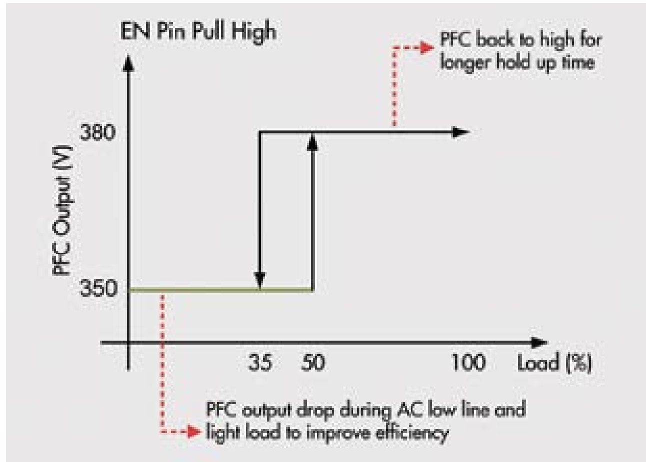

Figure 2: Simple PFC output adjustment scheme.

Hold-up time is one power-supply spec that comes into play. Hold-up time specifies how long the supply will continue to output a voltage above a specified minimum after the AC input goes away. The input voltage range of the dc-dc converter affects hold-up time as does the output capacitor that stores energy at the output of the PFC stage. Power-supply designers must ensure that a lowered PFC output voltage does not cause the dc-dc stage to fail the hold-up time requirement. At the same time, the dc-dc stage must be designed based on the range of the variable PFC output.

Designers must consider two dependent variables when contemplating an adjustable PFC output voltage. In an input-voltage-dependent design, sometimes referred to as the boost follower technique, the PFC output voltage is set proportionally to the rms value of the ac input. Typically, a predetermined constant offset value added to the AC input determines the PFC output.

Alternatively, the output power of the PFC stage can serve as a reference for PFC voltage adjustments. While the algorithm is slightly more complex than a linear function, essentially PFC output voltage can be controlled as a linear function of output power. You do have to ensure that PFC output voltage never drops below the input voltage in such a scheme. Under high-line voltage, low-load conditions, the linear control could result in such an undesirable circumstance. So a typical implementation must also monitor the input voltage and use that information to gate the floor of the PFC output range.

Moreover, a PFC stage operating at reduced output during light load conditions would not respond as quickly to a rapid load increase as would the dc-dc stage. So the designer must carefully select a floor for PFC output voltage to correspond with the minimum input of the dc-dc stage.

One of the ramifications of universal the input voltage dependent design is a typically broader range of PFC voltage output. Therefore, the designer must develop a dc-dc stage that can handle that input range. The wide output voltage range also hampers compliance with hold-up time specifications and typically would require a large output capacitor value.

A PFC converter that uses output power as a reference is called a load-dependent design. The PFC output voltage range is relatively narrower, resulting in a simpler dc-dc converter design and a relatively smaller output capacitor.

A simple load-dependent implementation

It turns out that the load-dependent scheme is also relatively simple to implement. Instead of a continuously variable PFC output capability, designers can turn to an implementation where the PFC voltage output is adjustable between fixed levels. For instance at full load and full line power, the PFC will be nominally 380V. At some trigger point of lighter load and/or lower input voltage, the output might drop to 350V. The graph in Figure 2 depicts such an operational scenario based on load. When the load drops to approximately 35%, the PFC output drops. When it climbs beyond 50%, the output returns to the nominal level.

Design teams can implement this simple adjustable output PFC converter suitable for most consumer electronic applications. The Fairchild FAN6982 Continuous Current Mode (CCM) PFC Controller, for instance, integrates a "range" function that can modulate the PFC output. This feature on the FAN6982 can be enabled by simply pulling the EN (Enable) pin high. To disable

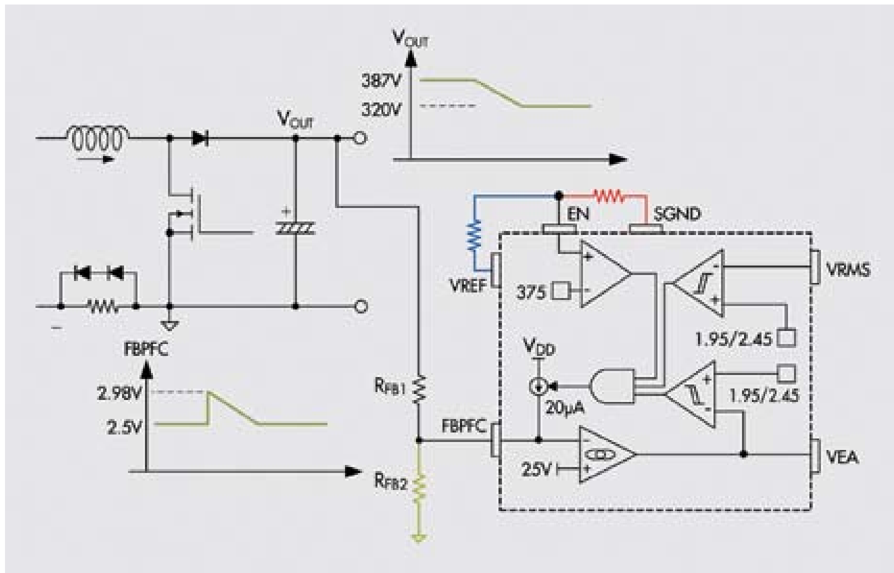

Figure 3: PFC output voltage adjust configuration on FAN6982.

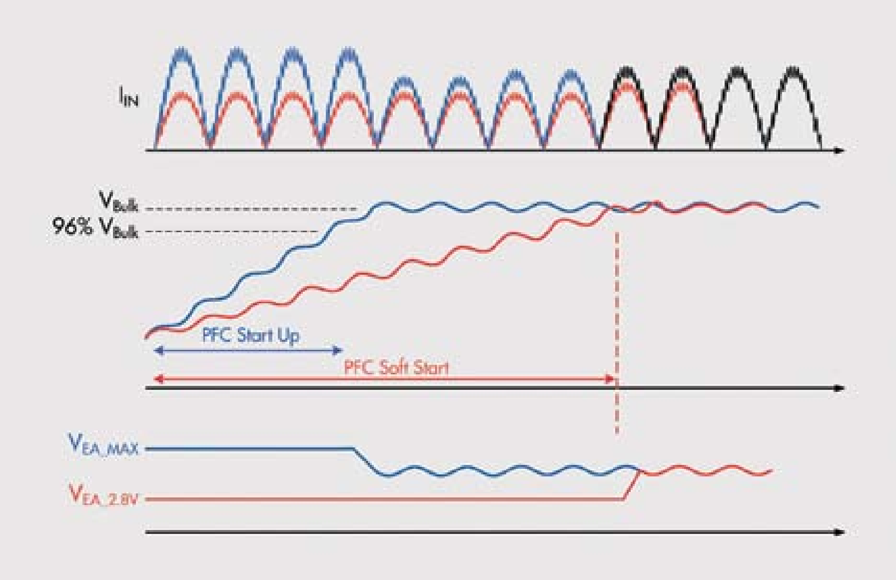

Figure 4: PFC soft-start implementation.

the range feature it can be pulled low to signal ground (Figure 3).

The designer still has some flexibility in setting of the lower PFC output voltage. When low-load and low-line conditions trigger a transition to the lower PFC output level, the converter instigates the action by enabling a 20μA internal current source that is internally connected to the inverting input of the error amplifier which is the voltage feedback input (FBPFC pin). By changing the apparent feedback divider ratio, the error amplifier adjusts to provide a lower PFC output voltage. You can set the voltage of the lower PFC output level by adjusting the bottom resistor (RFB2) of the two-resistor voltage divider between the output voltage and ground (Figure 3).

Other keys to maximum features and minimum external component counts

Having addressed light-load efficiency with a minimum of external components, and therefore cost, let's discuss a few other capabilities that designers should consider in PFC implementations. Certainly you should include a robust set of circuit protection features, and also consider converter IC functions that can simplify the design task to meet application requirements.

Let's focus for the moment on the protection area. A failure in a PFC feedback circuit could prove catastrophic to a power supply with the PFC output exceeding operating limits. In the case of the FAN6982, an internal protection circuit monitors the FBPFC pin. The circuit can detect open-, short-, and floating-circuit faults in the voltage feedback path. Fairchild calls the capability TriFault Detect™. The capability requires no external components and complies with the UL 1950 safety standard.

Brownout is another significant concern. Your design should ensure that the PFC stage does not enter an over-current state with sagging input voltage. The FAN6982 internally monitors the VRMS pin. When the voltage drops below the 1.05V threshold, the IC shuts down the PFC stage. The boost stage is enabled once VRMS reaches 1.9V.

One feature that many applications require these days is soft start. The design must limit the input current during startup to prevent saturation of the boost inductor and over-current stress of the switching device. You can avoid that situation with a soft-start design that sequences power to the stages.

In a PFC-based implementation, the designer needs to address soft start in both the PFC and dc-dc stages. The FAN6982 includes an integrated PFC soft-start function. The controller monitors the PFC output voltage and clamps the output of the voltage error amplifier when the voltage drops below 96% of a nominal value. In that mode, the output of the error amplifier (VEA) is clamped, the current loop limits the line current, and the PFC exhibits a lengthened rise time until the PFC output voltage passes through the threshold and the voltage error amplifier assumes normal operation (Figure 4).

To make sure that the dc-dc stage does not demand full power while the PFC stage is in soft-start operation, the PFC stage needs to manage the dc-dc soft-start sequence. In the case of the FAN6982, for instance, the PFC controller includes a Ready (RDY) pin or "synchronizing pin" that can charge the soft-start capacitor of the dc-dc stage only when the PFC output voltage is established within 96% of the nominal designed voltage.

One final area of interest is input current shaping because that function contributes heavily to optimizing the power factor. The FAN6982 integrates current shaping capability using a gain modulator. The AC input current, voltage error amplifier and VRMS signals drive the modulator. The output automatically adjusts the reference input to the current-control error amplifier.

Summary

Careful consideration of the PFC stage design can result in maximum efficiency for the overall power supply in popular applications such as PCs, servers, industrial power supplies and consumer electronics such as display power. A simple adjustment of PFC output voltage design incrementally improves the efficiency. A highly integrated PFC controller can realize such energy savings and provide circuit protection and features such as soft-start capability with a minimal external component count.

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High Efficiency at Heavy and Light Loads

Constant on-time control and charge pump combination for portable devices

As demand for longer battery life and the push for "greener" systems increases, the pressure to build power supplies that can respond efficiently from light to heavy loads is constantly mounting. However, improving the efficiency performance of a single phase synchronous buck DC-DC converter from light load to heavy load with wide input voltage has many challenges.

By Kit Nguyen, Sr. Application Engineer and John Lambert, Product Marketing Manager, International Rectifier Corp

Generally wide input voltage variation impacts the stability of controllers and power loss at high loads increase exponentially. These losses translate into higher power dissipation, which may require complex thermal management to keep the portable device cool resulting in more components and larger board space.

However, employing a single-phase synchronous buck PWM controller with constant on-time control and a gate drive charge pump can minimize losses at both ends of the load. Constant on-time control timing diagram is shown in Figure 1. This type of control scheme, combined with diode emulation, helps to cut power losses when the output current is low.

Along with constant on-time control, IR's IR3710M single-phase synchronous buck PWM controller also incorporates a gate drive charge pump capability to enable designers to maximize efficiency at higher output current levels. In other words, the PWM controller has features to deliver high efficiency over the entire output current range. A schematic for wide input voltage 24A synchronous buck DC-DC converter built with this controller is shown in Figure 2.

Unlike traditional voltage mode regulators, the constant on-time control method has a faster transient response time. Consequently, when the load current increases, the system requires less output capacitance and reduces the cost and size. Additionally if higher efficiency is desired at the higher current range, the IC features at gate charge pump option which increases the gate voltage of the low side and or the high side MOSFETs. This in-turn decreases the on-resistance of the MOSFET which lowers the conduction losses in the MOSFETs and consequently lowers the total power loss of the converter.

Understanding constant on-time

In the constant on-time control scheme, the circuit uses a portion of the output voltage ripple to compare with the reference voltage, VREF. The output voltage ripple, in fact, has a similar waveform as inductor current, and is equal to peak-to-peak inductor current multiplied by equivalent series resistor of the output capacitor bank. The IR3710M PWM controller turns on the upper gate (UGATE) when the voltage at the feedback input pin FB is lower than reference voltage. The feedback voltage is tapped from the output resistor divider and then compared to 0.5V internal reference voltage VREF As shown in Figures 1 and 2.

The on-time duration for the upper gate is programmed by an external resistor RFF from input voltage V_{IN} to feed

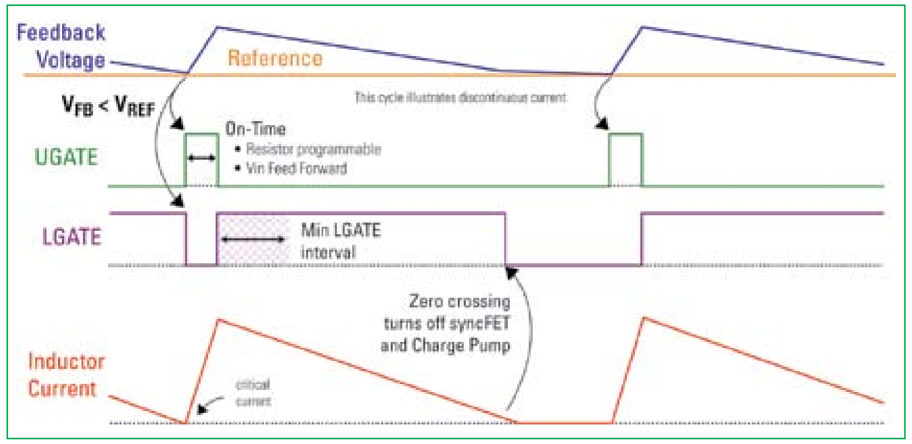

Figure 1: Constant on-time timing diagram.

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forward pin FF. This on-time duration T_{ON} is calculated as depicted in the equations below:

$$T_{ON} = R_{FF} * 1V * 20pF / V_{IN} \text{....(1)}$$

$$R_{FF} = V_{out} / \{1V * 20pF * Fsw\} \text{....(2)}$$

Where Fsw is the switching frequency

From the above equations, we can see that this on-time is inversely proportional to the input voltage. When input voltage is higher, the on-time is smaller and is larger when input voltage is smaller. This method automates the control of the output voltage ripple as the input voltage changes. In our design, with R_{FF} = 180kΩ, V_{OUT} = 1.1V and V_{IN} = 12V, typical on-time duration TON is 300ns with a 300kHz switching frequency

As a result, the voltage at the FB pin rises above the reference voltage in the slope which depends on the input and output voltages, inductance and programmed switching frequency. The IR3710M controller turns on the lower gate drive (LGATE) after the end of upper gate period with some dead-time between the gates to avoid the shoot through which causes a short from input voltage to ground. As the result, the voltage at the FB pin decreases until it's lower than the reference voltage, when the upper gate (UGATE) signal turns on again.

The rate of decline for the FB voltage depends on output voltage, inductance and the switching frequency. In the steady state, this process repeats for the next cycle. Unlike traditional architectures using voltage feedback, the IR3710M uses a comparator for this function instead of an error amplifier. Consequently, it eliminates the need for a compensation network, which can be time consuming and complex and calls for additional components.

Key Attributes

By comparison to traditional voltage mode, another advantage of this architecture is that it provides faster response time during the load transient as shown in Figure 3. When the load increases with demand, the output capacitor bank supplies the initial charge to the load. Initially, the output voltage drops as load increases. The amount of voltage drop depends on the rate of load increase, equivalent series resistor and equivalent series inductor of output capacitor bank. The voltage at FB pin follows the output voltage drop below the reference voltage. As a result, IR3710M forces the upper gate on to supply the additional charge to the load. Subsequently, the switching frequency increases from 300kHz to 1.5MHz. This scheme decreases the number of switching cycles to increase the inductor current in the shortest possible time, thereby allowing the output voltage to recover faster. This reduces the amount of output capacitance required and therefore saves space and saves system cost.

In order to reduce power loss and MOSFETs temperature at heavy load conditions, the controller circuit (see Figure 2), uses external diodes (BAT54S) in combination with a ceramic capacitor to convert 5V and 3.3V power supplies into a 7V supply for the gate drive (PVCC). The concept here is to boost

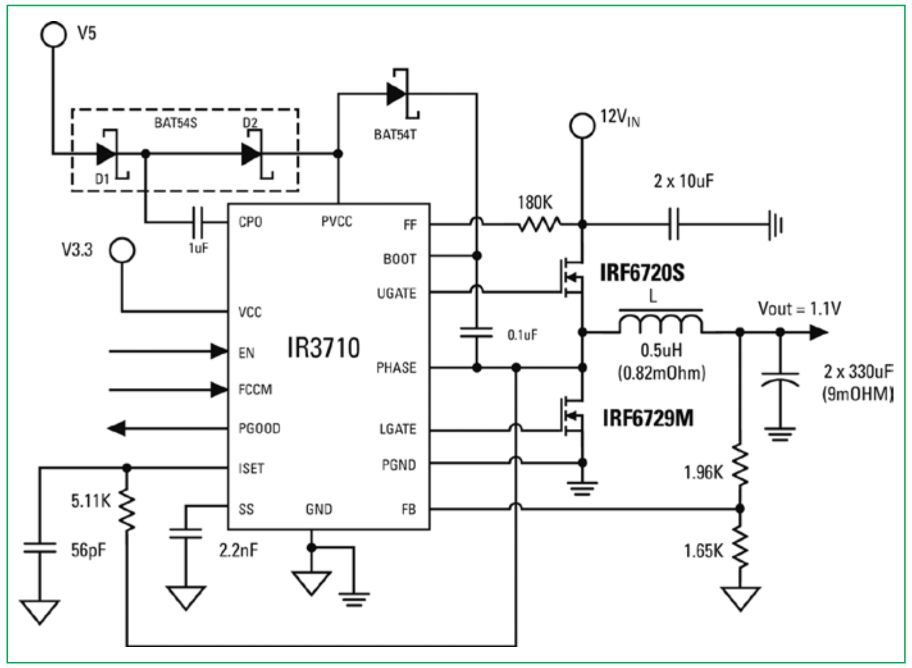
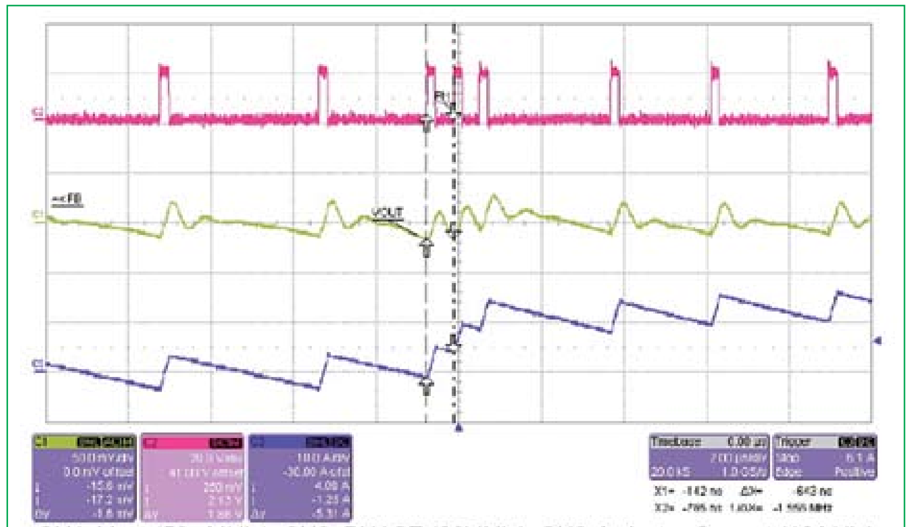


Figure 2: Circuit schematic for a wide input 24A synchronous buck DC-DC converter using IR3710M.



CH1: Vout (50mV/div), CH2: PHASE (20V/div), CH3: Inductor Current (10A/div)

Figure 3: Waveform showing frequency boost from 300kHz to 1.5MHz with a 14A load step.

the gate drive voltage of the upper and lower MOSFET gates. Using higher gate drive voltage lowers the on-resistance of the MOSFETs, thus, reducing their conduction losses. In fact, the majority of the power loss for the lower MOSFET comes from the conduction loss. The switching loss is negligible because the voltage across the MOSFET during the dead time is approximately 0.7V from the body diode before the lower MOSFET turns on. Accordingly, less expensive smaller MOSFETs can be selected here, which in-turn reduces the system cost.

Now, the inductor current determines the two basic modes of operation—continuous and discontinuous. In the discontinuous mode (DCM) operation, defined as the lower peak of inductor current at 0A, the controller turns off the charge pump feature, allowing the voltage at PVCC pin to drop below 5V

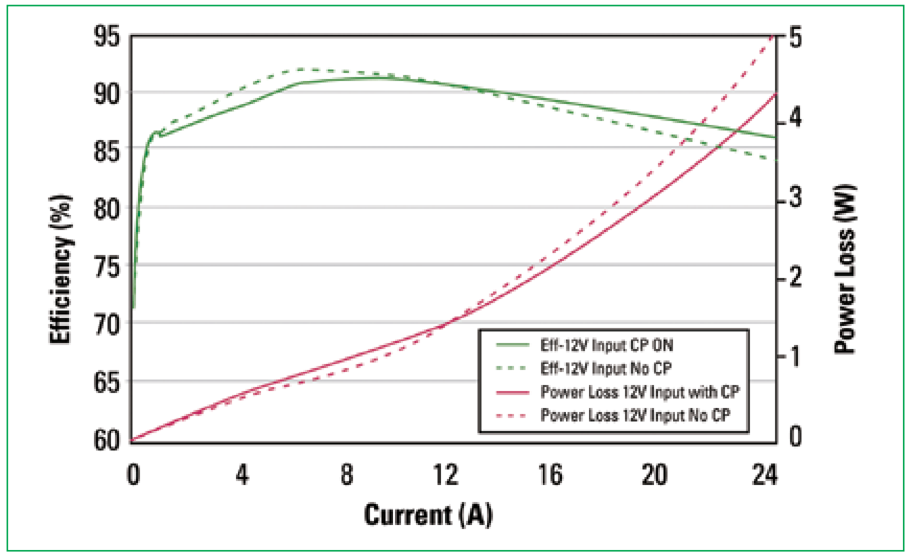


Figure 4: System power loss and efficiency comparison with and without the enhanced driver (charge pump) feature.

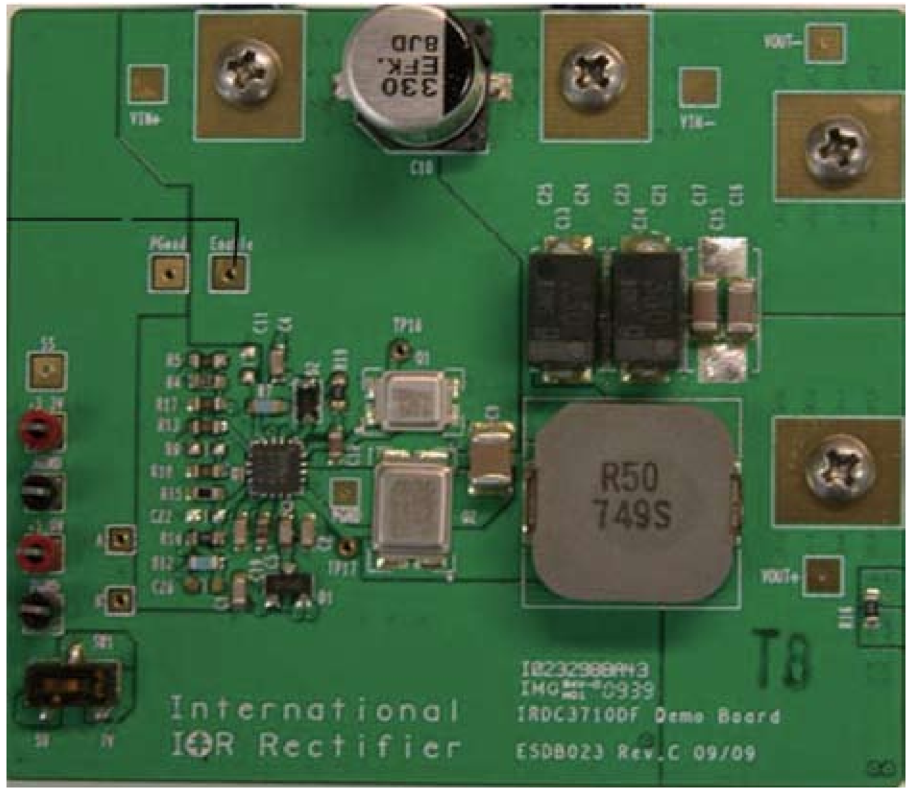


Figure 5: PCB design with IRF6720S and IRF6729M DirectFET MOSFETs.

supply. Consequently, it reduces the power loss of the driver. And, thereby, improves the efficiency during light load. Also, in this DCM mode configuration, IR3710M turns off the lower gate signal when the IC detects the inductor current at zero level. Subsequently, it prevents the discharge current flowing from the output capacitor through the inductor, and the switching frequency reduces proportionally to the load. In essence, this feature also cuts conduction loss to improve system efficiency.

The impact of this enhanced driver feature on conduction loss and associated improvement in system efficiency is illustrated in Figure 4. It compares the power loss and system efficiency with and without the enhanced gate drive feature and demonstrates that the efficiency increases by 2% at full-load with enhanced driver.

In summary, besides cutting power consumption and enhancing overall system efficiency, the constant on-time control method also offers fast load transient response with no loop compensation required, hence, needing fewer external components to simplify the design and offers a solution that ultimately cuts project design time. The controller also provides a gate drive charge pump to improve efficiency at higher output current levels, thus, ensuring high conversion efficiency over the entire output current range. By improving efficiencies at both light and heavy loads, the IR3710M based synchronous buck converter solution maximizes the overall efficiency of the portable system, consequently, enabling the battery to perform for a longer durations. Higher efficiency keeps the MOSFETs cool and reduces or eliminates the need for a cooling system, which in-turn saves space and cost.

With built-in over current protection and under/over voltage shut down, the controller also enables key safety features. The same feature-rich controller IC is also utilized in the IR3870M SupIRBuck™ integrated point-of-load (POL) DC-DC voltage regulator that integrates IR's high performance control ICs optimized with benchmark HEXFET® MOSFETs in a power QFN package.

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A New Class of Power Connector

New technology for high current, low insertion force, low resistance and long cycle life power connectors

In league with today's "green" movement, power converter designs have become increasingly efficient. Contemporary converter efficiency can be 5 or more percentage points higher compared to just a decade ago. While converters have improved, not much is said about the system interconnects, the means by which high currents are distributed throughout a system – until now.

By Russ Larsen and Forrest Sass, Methode Power Systems Group, San Jose, California

Low loss, high current (>50A) connector design is challenging. The most commonly desired spec is low contact resistance, and for good reason. Lower resistance has the beneficial effect of minimizing IR voltage drop, making voltage regulation easier. Lower resistance also reduces I^2R power losses, reducing contact temperature, improving connector reliability, wasting less energy and allowing for a smaller connector.

In addition, low insertion / extraction force is also highly important. Insertion / extraction force is simply the mechanical force necessary to mate or unmate the connector. Reducing this force has the beneficial effect of minimizing contact surface wear, a major factor in connector failure. Recent connector improvement efforts concentrated almost entirely on developing improved contact surface coatings and materials. Other design efforts modified the pin shape to minimize the insertion force.

Can the common power connector be further improved?

The answer is yes, initiated by a MIT by a professor and graduate students investigating tribology, the science and technology of interacting surfaces in relative motion including the principles of friction, lubrication and wear. The researchers developed a prototype power connector with significantly superior qualities. The Tribotek connector, as it was later called, had very low contact resistance as well as very low insertion force, without a commensurate connector volume increase.

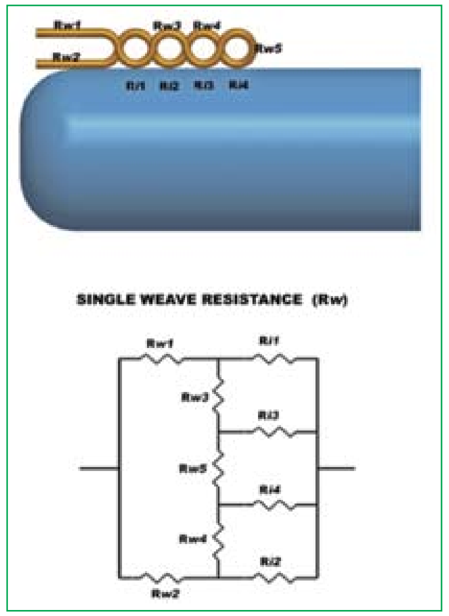
Tribotek connector basic elements showing pure copper wire wrapped around Kevlar tensioning fiber and held in contact to a copper mating pin.

The Tribotek connector performance was based on maximizing the number of discrete points of contact rather than attempting to increase the contact surface area or polish the mating surfaces to a finer degree. Furthermore, the conductors were pure copper to minimize resistance.

The group fabricated a socket-style connector by weaving pure copper wire around a Kevlar non-elastic cord held under tension to produce a connector with many points of contact around the circumference of the mating pin.

Seen at a microscopic level, a single conductor weave has at least four points of contact resulting from the four wraps around the Kevlar spring. Each electrical path can be modeled as a resistor in a matrix, which results in four parallel paths. In addition, the resistance contributed by the copper wire itself is 4 times lower than the more frequently used beryllium copper.

The Kevlar spring need only provide enough force to assure surface intimacy. The resulting lower insertion force



Equivalent resistance model of a single weave.

means less sliding resistance to mate the contact and therefore less wear over time.

By arranging all individual weaves in a circular assembly results in massively parallel contact points, significantly lowering overall connector resistance. Low contact resistance means less heat generated and lower power loss.

The connector technology handled almost 500A with very low voltage drop and very low insertion force. However, because the fabrication of this connector is labor-intensive, it tends to be used for high value applications.

Conventional connector design challenges

In order to increase contact surface area and lower resistance, manufacturers finely polish and plate mating contact surfaces. This leads to a general misconception that current flows through the entire mated surface area. However, the actual percentage of that area which actually makes contact with the mating surface is very small. A connector's polished mating surface, viewed on a microscopic level, consists of peaks and valleys called asperities. Electrical current is concentrated and passes through the asperities which are in actual contact. The percentage of the surface area which actually passes current is very small.

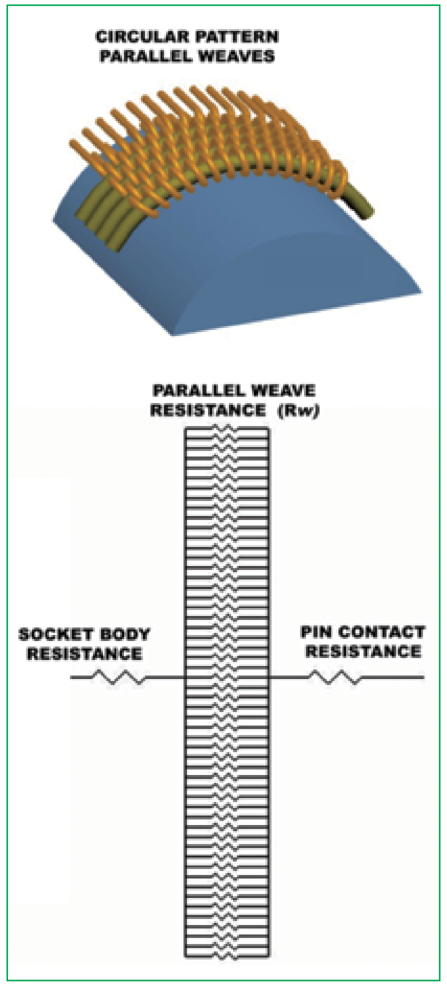
Manufacturers have adapted to this limited amount of contact area using different methods to maintain low contact resistance, including

1. Increasing the contact mating area, resulting in many more microscopic points of contact. The result is a larger, more costly connector.

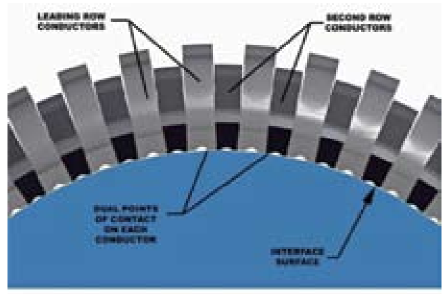
2. Increasing the "normal force" pressing the two mating surfaces together, which slightly deforms the asperities thereby increasing contact surface area. The result is a connector with high friction force that is more difficult to mate, or an expensive connector mechanism to provide the additional force after mating.

3. Using a manufacturing process to reduce the surface asperities

The need to mechanically force the mating surfaces together has led to many design compromises. Since copper is one of the very best reasonably-priced electrical conductors (excluding gold, silver and other exotic materials), it would be a good choice for the mating parts of the connector. However, copper has poor mechanical spring properties. If either mating surface were pure copper, the connector would also require an additional spring to maintain copper-to-copper contact. In the connector world, that yields an expensive product.



Equivalent resistance of multiple weaves.



Microphotograph of a PowerBud connector showing two rows of contact fingers. Each finger is formed to allow two points of contact. The illustration shows the details of the first and second conductor rows and the dual contact points on each finger.

A more practical solution is to choose a material with both spring and conductive qualities such as beryllium copper or tin copper. While less conductive than pure copper, these alloys are easily fabricated into a part that serves as both spring and conductor. This solution is widely used today in low cost connectors.

Evolution of the PowerBud connector

Methode acquired Tribotek, the company founded by the MIT researchers, in March 2008 and began to evolve the connector with the goal of making it more manufacturable. The result was a new class of patented power connector named "PowerBud"™ that successfully overcomes key limitations of conventional power connectors.

	PowerBud	Typical conventional connector
Voltage drop @ 240A	12mV	28mV
Temp rise @ 240A	30ºC	43ºC
Mating force	4N (0.9 lb)	21N (4.7 lb)
Unmating force	4N (0.9 lb)	13N (3 lb)
Cycle life	10,000 cycles	1,000 cycles est

The PowerBud uses two rows of conductors arranged one over the other to create massively parallel points of contact. Instead of using pure copper for contacts, the PowerBud uses a proprietary performance-engineered copper alloy material that is substantially better than the more commonly used beryllium copper. The conductors have a larger cross-section than those on the Tribotek connector to partially compensate for the alloy's higher resistivity.

The high performance copper alloy is easily fabricated using automated processes. In addition, each copper alloy beam includes a slight indentation in the finger tip to create dual contact points, adding to the massively parallel contact points.

Like Tribotek, the PowerBud technology lowers both contact resistance and contact normal force without increasing connector volume, a feat that counters conventional wisdom. The resulting connectors exhibit lower insertion force, lower temperature rise, lower power loss and higher cycle life than conventional high current connectors.

Conclusion

The PowerBud represents a new class of power connector offering lower voltage drop and lower insertion force resulting in lower temperature rise and greater longevity than typically power connectors. The mechanical construction evolved from pioneering research at MIT which resulted in the Tribotek connector, which delivered a major improvement in power connector performance.

PowerBud allows more current to pass through a connector that occupies a small volume, potentially reducing package footprint. The lower voltage drop can eliminate the need for a local voltage regulator module. The lower temperature rise reduces system thermal load. PowerBud technology is suitable for tens or hundreds of amps, and is particularly suitable for systems that require the connector to be mated and unmated frequently.

Finally, this new connector technology shows that significant technological improvements are possible even in the technologically slow-moving world of power connector design.

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Test for Success

Testing energy efficient designs in portable electronic devices

Energy efficient design techniques in portable devices have created new and complex test challenges, requiring design engineers to make numerous difficult measurements and to troubleshoot fast-changing signals, complicated protocols, and small changes in voltage and current. To validate, debug and characterise these designs, a powerful and complete measurement tool set is needed; one that has the performance and time-saving features to address the latest energy saving design techniques.

By Dave Ireland, Technical Marketing Manager, Tektronix

As portable electronics reach higher levels of performance and functionality, the embedded systems that drive them are also significantly more sophisticated. This means that today's energy management techniques must look at the entire embedded system to drive down overall power consumption.

An example of energy efficient design: The mobile handset

A mobile handset offers a good example of the different techniques used today in energy efficient designs. Throughout the years, mobile handsets have undergone a transformation from pure voice-only devices to multimedia powerhouses featuring internet browsing, gaming, photo and music sharing, navigation and much more.

Every new feature added to a mobile handset requires a portion of the often limited energy budget, yet most handsets today rely on battery capacity similar to that of a voice-only design. Achieving such rich functionality has required design engineers to forge new ground in low power design.

The different circuits in the handset often require different supply voltages, necessitating that each circuit has a separate DC/DC converter. Traditional converters used linear regulators and lossy components, resulting in a power conversion efficiency of 50% or less. Today, switch-mode power supplies (SMPS) are the most common architecture, providing efficiencies of up to 90%.

Power conversion measurements

A SMPS minimises the use of lossy components (such as resistors and linear-mode transistors), and emphasises components that are ideally lossless (switch-mode transistors, capacitors, and magnetics), thereby enabling high power conversion efficiencies. Figure 1 shows a simplified SMPS schematic.

Validating and characterising a SMPS often requires measuring switching loss and magnetic power loss to determine the efficiency of the SMPS. Other considerations may include power line measurements (such as power quality and current harmonics).

Switching loss

The switch-mode transistors used in a SMPS often have fast switching times to minimise energy loss and therefore dissipate very little power in either the On or Off states. The largest source of energy loss for a SMPS occurs during switching (due to the discharge of diode-stored charge and the discharge of energy stored in parasitic inductance

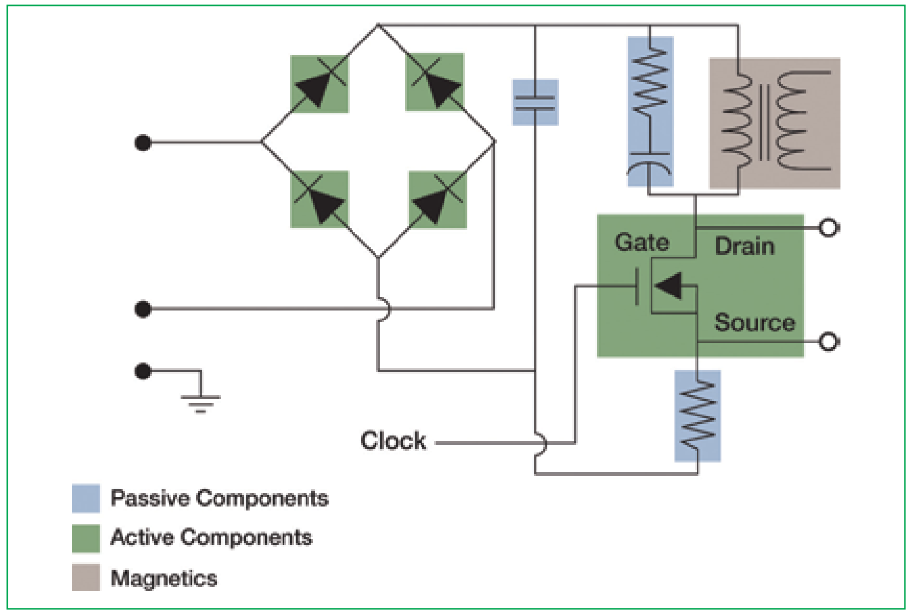

Figure 1: Switch-mode power supply simplified schematic.

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and capacitance).

The total energy loss for an entire switching cycle includes the switching losses (turn-on and turn-off losses) and conduction losses. The total loss is given by the formula:

$$E_{Loss} = E_{turn\text{-}on} + E_{on} + E_{turn\text{-}off}$$

Where:

- E_{Loss} is the energy loss in the switch for a switching cycle
- $E_{turn\text{-}on}$ and $E_{turn\text{-}off}$ are the switching losses
- E_{on} is the conduction loss

A proper analysis of these losses is essential to characterise the supply and gauge its efficiency. Figure 2 shows switching loss measurements made with an oscilloscope. By using an oscilloscope with specialised power analysis software, switching losses and conduction losses can be measured across multiple switching cycles to determine device behaviour over time. Measurement statistics easily show how the measurement results are changing.

Accurately measuring turn-on and turn-off losses can be a challenge since the losses occur over very short time periods, while the losses during the remainder of the switching cycle are minimal. This requires that the timing between the voltage and current waveforms be very precise and that measurement system offsets are minimised. Making accurate power measurements therefore requires careful consideration of probing.

Magnetic power loss

Magnetic power loss affects the efficiency, reliability, and thermal performance of the power supply. Two types of power losses are associated with magnetic elements: core loss in the ferrous core and copper loss in the copper windings.

Magnetic Loss = Core Loss + Copper Loss

The total power loss and the core loss can be quickly derived using information from the core vendor's data sheet and results from an oscilloscope running power measurement software. Copper

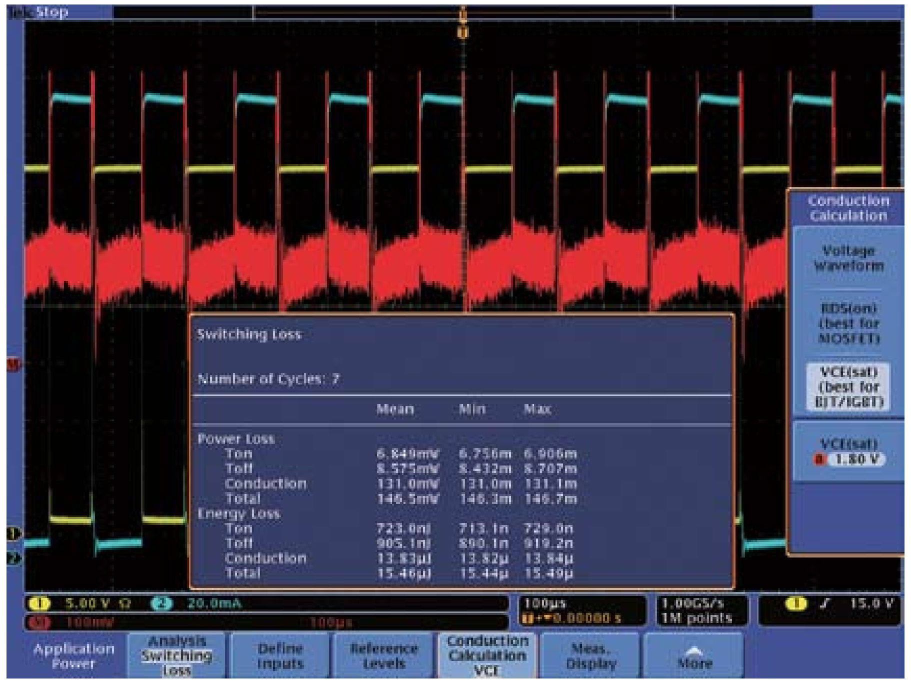

Figure 2: Switching loss measurements including statistics on the Tektronix MSO/DPO4000 Series oscilloscope and DPO4PWR power analysis software.

loss can then be calculated from these two values. Knowing the different power loss components makes it possible to identify the cause for power loss at the magnetic component.

The method for calculating the magnetic component's total power loss depends in part on the type of component being measured. The device under test may be a single-winding inductor, a multiple-winding inductor, or a transformer.

Throughout the design, components are optimised to provide the lowest power consumption. Displays that use specialised backlight LEDs provide power savings of up to 80%, when compared to the Cold Cathode Fluorescent Lamps (CCFLs) which, until recently, were commonly used in LCD displays. The use of Low Voltage Differential Signalling (LVDS) for data transmission saves power while maintaining data integrity. The most accurate and reliable method for measuring differential signals is to use an active differential probe, which places a difference amplifier near the probe tips and transmits the voltage difference to the oscilloscope. Since there is only a single oscilloscope connection per channel, differential probes can double the number of signals measured by the oscilloscope.

As designs have become more complex, techniques to manage energy at the system level have emerged. Processors and communication buses (where frequency is scaled based on actual need) combined with power management that scales down voltage with frequency, offer significant reductions in energy consumption.

System-level energy management

Energy management techniques, such as Dynamic Power Management (DPM), Dynamic Voltage Scaling (DVS) and Dynamic Frequency Scaling (DFS), look at the system-level operation of a design for opportunities to reduce power consumption. These energy management techniques can be applied to both individual processing elements (CPUs, FPGAs, ASICs), as well as the communication buses that transfer data between them.

Dynamic Power Management

With DPM, processing elements and communication buses are put in to standby or sleeping modes whenever they are idle. Since it takes time and energy to reactivate these elements, DPM is carefully applied to ensure there are no violations in system operation or actually an increase in power consumption because of reactivation. Even when components are in standby mode, they

dissipate energy as determined by the static power of the component.

Dynamic Voltage and Frequency Scaling

With DVS and DFS, the switching power dissipation is reduced by scaling down the supply voltage and operational frequency of a processing element. Since reducing the operational frequency increases the computation time, DFS can only be applied when there is slack time in the system-level operation of the design.

Even if dynamic voltage and frequency scaling is applied to all components adapting their performance to the actual requirements of the system schedule and minimising energy consumption, there will still be idle times. DPM can then be used to shut down components that are idle at a specific time for even further energy savings.

Energy dissipation of communications buses

In embedded systems with multiple processing elements, communication between elements is essential. With every data transfer over a communications bus, the line capacitance is charged and discharged, drawing current from the I/O pins of the elements and thereby dissipating power.

In the case of communications buses, the transmission voltage can only be reduced by so much because of noise issues (low voltage communications could be corrupted by noise, causing reliability problems). Similar to DFS, the operational frequency or data transfer rate of the bus can be scaled down if the system schedule has slack time for bus communication. The bus can also be put into a standby state during idle times, similar to DPM.

Low Power DDR DRAM devices as well as several of today's communication buses offer low power modes, including PCI Express®, MIPI® D-PHY and M-PHY, USB 3.0, Mobile PCI Express® Module (MXM) and others, however debugging these buses can be challenging without the right measurement tools.

Finally, standby power has been minimised. It has been estimated that standby power (the power consumed by a product when it is switched off but continues to consume a reduced level of power) represents 10% or more of all residential electricity demand. For battery-powered products like mobile handsets, standby power is a result of bright displays, backlit buttons and instant-on power switches. Even with low-voltage, low-power logic and microprocessor "sleep mode" power management, standby power consumption can significantly limit battery life and the usability of the handset.

Throughout the mobile handset, energy efficient design techniques have been implemented to provide a wide-range of features while maintaining long battery life. This same trend has been applied to other portable and line-power electronics. With these changes, test and measurement techniques have evolved to help engineers to effectively debug and validate their low power designs.

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Wide Load Efficiency

New controller addresses energy saving in server power system

New government and industry standards and regulations require increased efficiency across the whole load range for data and telecommunications server power systems. One example is the "ENERGY STAR® Program Requirements for Computer Servers," effective May 15, 2009. As a result, different aspects of designing a power supply including system architecture, topology, components and control must be considered together. This article focuses on efficiency improving control and a concept controller for the DC/DC converter.

By Rais Miftakhutdinov, Power Supply Control Technologist, and Zhenyu Yu, Marketing Manager, Texas Instruments

Striving for efficiency

High efficiency at full load has always been critical for data and telecommunications server power supplies. Recently, however, the focus has shifted to efficiency over the entire load range. This is because these systems spend significant time operating at mid- and light-load. New standards and regulations have been introduced to address this shift. One example is the ENERGY STAR Program Requirements for Computer Servers, Version 1, effective May 15, 2009. This regulation sets efficiency and power consumption requirements for server power supplies as in Table 1.

Typically, a server power supply includes a power factor correction (PFC) stage followed by an isolated DC/DC and low-power standby power supply. The efficiency goal for each part of the power supply must satisfy the ENERGY STAR requirements. This is illustrated in Table 2 for a server power supply that includes PFC, 660-W DC/DC and 5V/2A standby.

Power saving control strategies

The next step for designing a DC/DC converter is to select the optimal topology and control including:

• Interleave phases for better current and temperature distribution at maximum load with phase-shedding at light load;

• Synchronous rectification using MOSFETs with diode emulation at light load to avoid current circulation. It is best to shut off rectifier MOSFET drive circuits at light load. Performance of the synchronous rectifier depends significantly on accurate timing between primary and secondary side switches;

• Proper implementation of zero-voltage-switching (ZVS) and zero-current-switching (ZCS) reduces switching losses. This requires optimal adaptive or predictable delays between switching events;

• Optimally adjusting the intermediate bus voltage, drive voltage and other system parameters;

• Smooth transition from one mode to another, depending on operating conditions. For example, from continuous current mode to discontinuous, from fixed frequency to frequency foldback, etc.;

• Proper use of pulse skipping or burst mode at light and no load.

Rated Output Power	10% Load	20% Load	50% Load	100% Load
≤ 500 W	70%	82%	89%	85%
501 – 1000 W	75%	85%	89%	85%
> 1000 W	80%	88%	92%	88%

Table 1: Efficiency requirements for single output AC/DC or DC/DC server power supplies.

Rated Output Power	10% Load	20% Load	50% Load	100% Load
Efficiency from Table 1	75%	85%	89%	85%
AC/DC Efficiency	80.8%	88.8%	90.5%	85.1%
PFC Efficiency	95.3%	96.4%	97.6%	97.7%
Standby Power Efficiency	80%	82%	85%	85%
DC/DC Efficiency Goal	85.2%	92.7%	93%	87.1%

Table 2: Efficiency goals for pfc, standby power supply, and 660-w DC/DC converter.

It is preferable to use ZVS topologies for post-PFC converter, like phase-shifted full-bridge, asymmetrical half-bridge and LLC resonant. Phase-shifted full-bridge has a long history of usage due to the combination of useful properties. But, to maintain high efficiency over a wide-load range, additional optimization in control is needed.

Phase-shifted DC/DC with advanced controller

Major advantages of a phase-shifted converter are ZVS of the primary side MOSFETs, fixed frequency PWM, reliable handling of shorts with cycle-by-cycle current limiting, and wide input voltage range. A major drawback is current circulating through primary switches during off interval and the need for snubber or clamping circuits for the synchronous rectifier. Efficiency improvement is achieved by using synchronous rectification, control that provides ZVS over the entire load range, accurate adaptive timing between primary and secondary MOSFETs, and special operating modes at light load. There are a number of digital and analog controllers from Texas Instruments to address this application. A simplified diagram of such a converter with a conceptual controller is shown in Figure 1.

The controller is on the secondary side, allowing easier communication and better handling of certain transient conditions that require fast direct control of the rectifier MOSFETs. For 12-V output, using a center-tapped rectifier is a popular choice.

To maintain high efficiency across the load, the converter operates in normal synchronous rectification mode at mid- and high-load, transitions to diode rectifier mode at light load, and to burst mode as load drops further (Figure 2). All these transitions are based on primary side current sensing using current transformer (CT).

Proper timing between primary and rectifier MOSFETs is critical for highest efficiency and reliable operation. The controller adjusts the turn OFF timing of rectifier MOSFETs as a function-of-load to ensure minimum body diode conduction time and recovery losses.

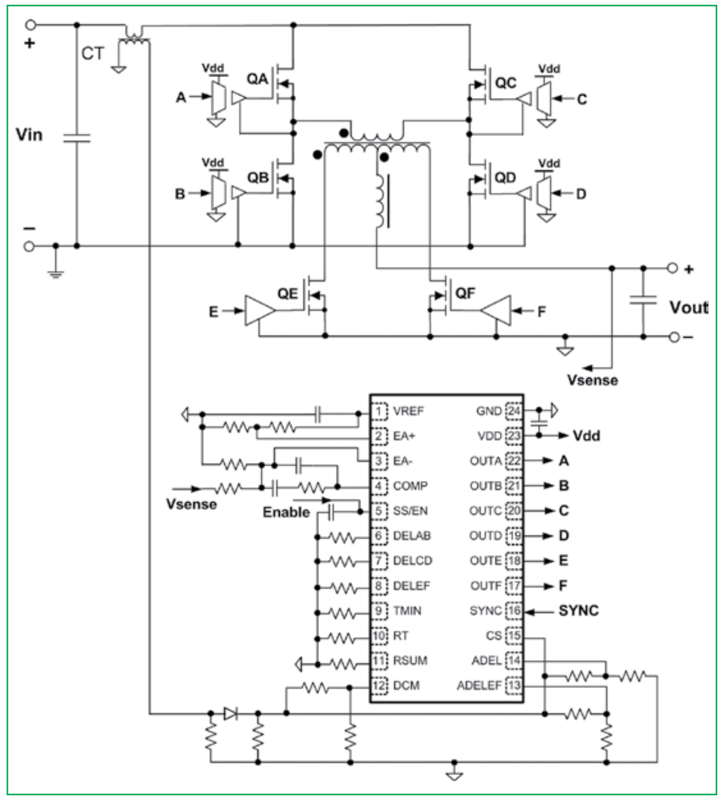

Figure 1: Phase-shifted, full-bridge converter with advanced controller.

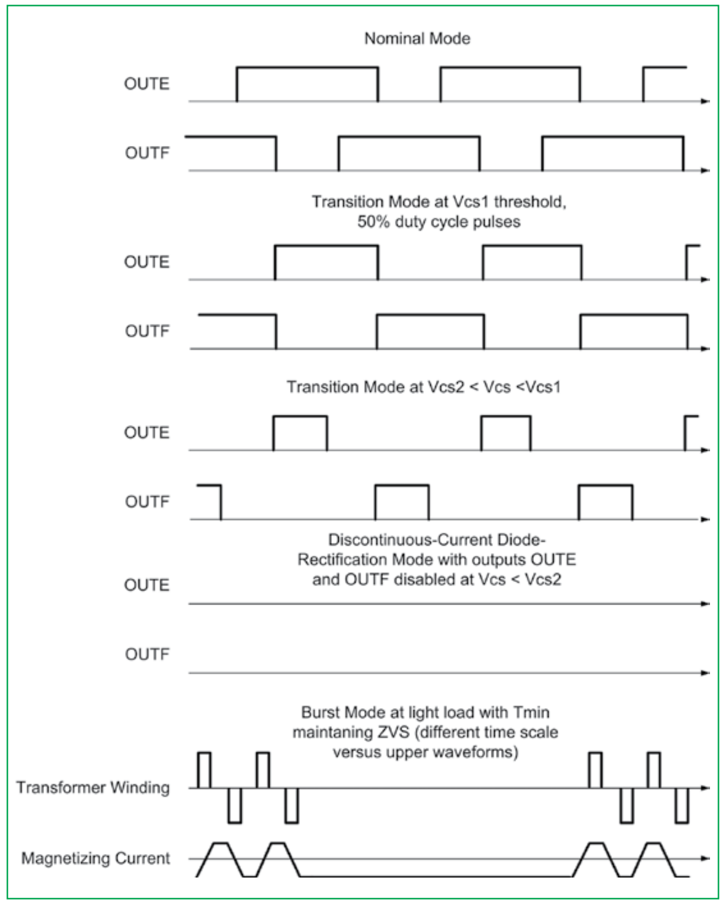

Figure 2: Timing diagrams and transitions between power saving modes.

To ensure ZVS conditions over the entire load range, the controller adjusts delay time between primary MOSFETs in the same leg in accordance to load. The controller also limits the minimum ON-time of pulse at light load, allowing the storage of sufficient energy for ZVS.

It is necessary to prevent reverse current flow through rectifier MOSFETs and output inductor at light load during parallel operation and under certain transient conditions. Such reverse current results in the circulation of extra energy between source input and load and, therefore, causes increased losses. Another negative effect is the loss of ZVS. The suggested control scheme prevents reverse current flow while keeping most of the benefits of synchronous rectification. At a pre-determined load current, the controller reduces synchronous rectifier drive signals from overlapping to 50 percent, and then gradually reduces their pulse duration until shutting off at the second predetermined threshold. This is called transition mode.

Below a certain current threshold, the rectifier-MOSFET-drive related losses exceed the savings provided by synchronous rectification. This is when it is beneficial to disable the drive circuit and use body diodes or external diodes in parallel with the MOSFETs for output rectification. This mode of operation is called discontinuous-current diode-rectification mode.

At very light and no load, the duty cycle, demanded by closed-feedback-loop

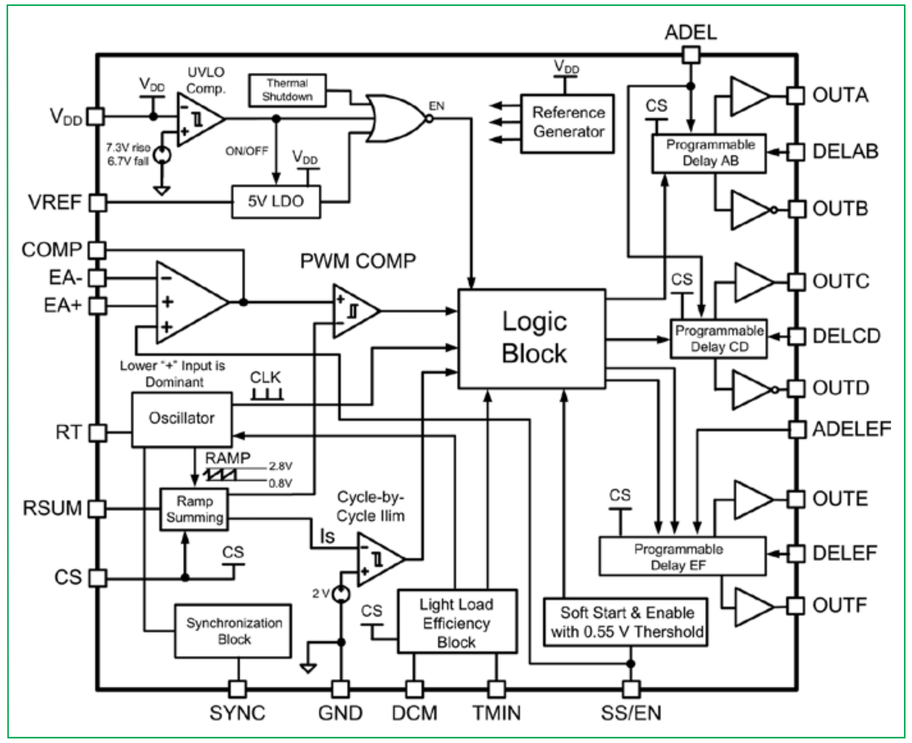

Figure 3: Block diagram of the advanced phase-shifted contoller IC.

control, can be very low and could lead to loss of ZVS and increased switching losses. To avoid this, the control circuit limits the minimum ON-time pulse applied to the power transformer. Therefore, the only way to maintain regulation under this condition is to skip pulses. The controller skips pulses in a controllable manner to avoid saturation of the power transformer. This is called burst mode.

The block diagram of this controller is shown in Figure 3. This controller provides adaptive timing between primary and secondary MOSFETs, and adaptive delay for primary switches in the same leg based on the current sense signal (CS). At light-load the efficiency management block provides optimal transition between different modes in Figure 2 as a function of the CS. Additionally, the controller provides all major functions and features usually found in such ICs.

Conclusion

The new industry requirements and regulations for increased efficiency over a wide-load range for server power supplies have been outlined and control strategies providing high efficiency over entire load range listed and discussed. The phase-shifted full-bridge is selected for further consideration. Advanced control of such a converter has been discussed along with a conceptual controller.

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Special Report – Energy Efficiency / Energy Harvesting

Optimised Efficiency

High performance power supply units

It is sometimes not appreciated that although efficiency in power supply systems has been improving for close to 40 years, until relatively recently, efficiency was not directly a driver of design. The majority of improvements were effectively side-effects of other trends, or sometimes, despite other trends.

By Dermot Flynn, Director of Sales, Excelsys Technologies Ltd, Cork, Ireland

The biggest design change in power supplies was the move to switch mode operation in the 1970's. As a result of using switching techniques, efficiency of around 70% was achievable for 5 Volt outputs, which was over double that which could be obtained from linear devices.

The 1980's saw the shift to FET devices. By the mid 90s there was a significant move towards the use of synchronous rectification to produce the DC output voltage of power supplies. Better magnetic materials, improved and cheaper FETs, cheaper multilayer boards, and more sophisticated integrated controllers have led to steady improvements since that time.

Regulatory requirements: Safety

In the USA, lower mains voltages (and consequently higher currents) have meant that the main focus of safety regulation is fire hazard. This has primarily resulted in the need for care in choice of materials, but has little direct influence on design otherwise. In Europe, by contrast, the prime focus, because of the higher mains voltages used, has been on preventing electric shock. This has been done by mandating the quality of insulation, but also, critically, by mandating creepage (across a surface) and clearance (through air) distances which must be used when providing safety isolation from mains voltages. This has the effect of setting minimum dimensions for isolating transformers.

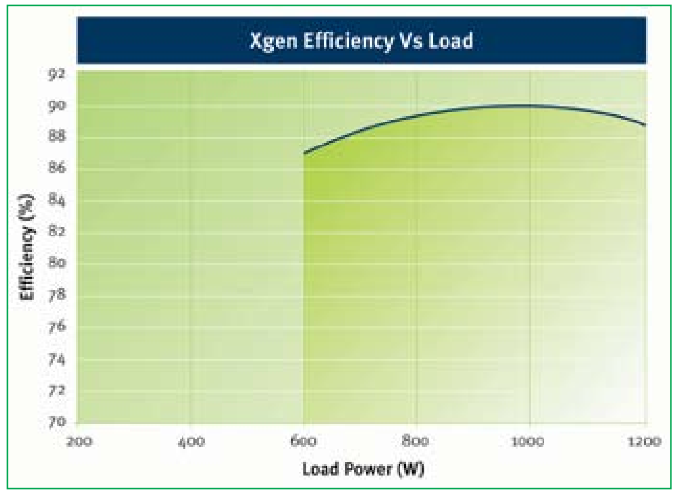
The Xgen series from Excelsys offers class-leading efficiency offering very high power densities with low noise and high temperature operation.

Environmental concerns

It is hardly necessary to repeat the current worries about global warming. Unfortunately as long as a significant proportion of our energy needs are met by burning fossil fuels, more power used will lead to more CO_2 in the atmosphere. Also unfortunately, a significant amount of the power used in most current systems ends up as heat in the power supply itself. An efficient supply produces less heat per unit output. Many benefits flow from reducing this heat which we will address a little later, but it is clear that all responsible organisations and individuals would wish to minimise this wasted energy, and it would seem likely that in the foreseeable future regulatory authorities will take a serious interest. Initiatives like Energy Star are now becoming the de facto standards. It is clear that the effort is currently concentrated on the PC and server market, simply because that is where the biggest savings in power can be made, due to the quantity of product sold, and the relatively short life of such products, but the benefits are available to users of configurable, modular PSUs too, with the Xgen series from Excelsys. Note also, that the longer useful life of such applications, compared to PCs and servers, make it important to introduce efficiency improvements now.

Major Benefits of high efficiency power converters

Less CO_2



Less power wasted equals less fossil fuel burned.

Lower temperatures
Less heat produced implies lower temperatures and less cooling required (fans and air conditioning)

Higher reliability
Lower temperatures mean higher reliability. All currently used reliability models predict this. As an order of magnitude 10°C cooler means double the MTBF (MeanTime Between Failure).

Longer operating life
In addition to MTBF considerations electronic assemblies have parts that wear out. In particular the evaporation of the electrolyte in electrolytic capacitors and loss of lubricant in fans are inevitable. (Insert Loss Vs Efficiency Graph here). The rate of such loss goes up with temperature, and thus the working life of such components is reduced when they run.

Smaller size
With surface mount components and smaller magnetic parts the size of electronic assemblies is now primarily governed by the ability to remove heat from available surfaces. Less heat means smaller possible size.

Lower noise
Less heat needs smaller fans to remove it (or none). For machine shop environments this may not be critical; for domestic and office environments it is. Note also that although lower noise (for similar airflow) fans are available they are usually more expensive.

Less infrastructure cost
With high efficiency, and PFC, upwards of 1200 watts of regulated DC power can be made available even when the mains connection is a simple wall socket. Dedicated wiring is avoidable, at these powers, which is not possible with earlier designs.

Longer battery life
Even with mains powered equipment many applications will have an emergency battery powered Uninterruptible Power Supply (UPS) providing some temporary back-up in the event of mains failure. The less power is wasted, the longer this will last.

The design
As a standard product the Xgen series is used in an extremely wide variety of applications. Thus control and protection are critical. A range of current/power limits, overvoltage protection, overtemperature protection, and current share control mechanisms ensure that it is extremely difficult to overstress the devices.

The efficiency of a supply will always vary somewhat with load. At low loads the basic overhead of control functions will dominate, and at the highest loads I^2R loss will become increasingly significant. Particularly for a standard product the designer must attempt to ensure good performance over a reasonable range of loads.

The Efficiency Vs Load graph shows that tuning of the quasi-resonant switching loss characteristics has created a product with efficiency within 3% of maximum from half to full load (600W to 1000W). For the user who wishes to optimise his application efficiency, using 70% to 92% of capability will achieve that goal.

The Xgen utilises leading edge switching techniques, synchronous rectification and the use of best in class components such as silicon carbide diodes, planar magnetics. The result is a design has higher efficiency and close to double the power density of competing products, and which can be specified with high temperature, low noise or medical variants.

Summary
The Xgen series of standard product from Excelsys offers class leading efficiency which results in the ability to offer very high power densities with the options of low noise and high temperature operation. This performance is achieved with carefully optimised choices both in component selection and circuitry choice, while still permitting the use of power factor correction. Overall efficiency in energy utilisation still requires the system designer to optimise his application circuitry, and to apply common sense principals when connecting the power supply, but the use of the Xgen solution gives him a head start in producing the energy efficient systems necessary in today's world.

www.excelsys.com

PV and TV Panels Move Ahead

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

All things 'green' seem to be now attracting private and government investors as well as intensive media coverage in the popular press. This has naturally heightened consumer awareness and desire for energy efficiency products. We can, as a result, expect to see a flow of innovations from the electronics industry. But green products work commercially only when there is a compelling business argument too. This is where the creativity between engineering and marketing professionals works at its best. Regulation for energy efficiency by authorities alone will not suffice.

Enel Green Power, Sharp and STMicroelectronics have signed an agreement for the manufacture of triple-junction thin-film photovoltaic panels in Italy. At the same time, Enel Green Power and Sharp signed a further agreement to jointly develop solar farms.

The agreement regarding the photovoltaic panel factory follows the Memorandum of Understanding between Enel Green Power and Sharp. STMicroelectronics has joined this strategic partnership.

This agreement brings together Enel Green Power, with its international market development and project management know-how; Sharp, and its exclusive triple-junction thin-film technology, which will be operational in the mother plant in Sakai, Japan as of spring 2010; and STMicroelectronics, with its manufacturing capacity, skills and resources in highly advanced, hi-tech sectors such as microelectronics.

The factory, located in Catania, Italy in a facility to be contributed by STMicroelectronics, is expected to have an initial production capacity of 160MW per year and targeted to be increased to 480MW per year over the next years. Photovoltaic panel manufacturing at the Catania plant is expected to start at the beginning of 2011.

Huge LED growth forecast

LEDs have received an unprecedented boost in many regions with the increasingly stringent government policies forcing television manufacturers to shift their backlighting to 'greener' technologies that consume less electricity, especially at the larger TV sizes where power is a major concern.

LED backlit LCD Televisions will gain huge momentum this year and beyond because of the increasing commitments from various parts of the TV supply chain, consumer demand and a higher focus on green technologies, according to iSuppli Corp.

Shipments of LED-backlit LCD-TV 40-inches and larger in size will this year alone rise by a factor of nearly eight, reaching 18.8 million units, up from 2.5 million in 2009 and by 2013, 83.2% will use LED backlights, up from just 0.1% in 2008 and 6% in 2009.

Panel makers have been investing heavily in LED chipset makers or have been developing their own internal technologies in order to take advantage of what they believe LED-backlit LCD-TVs bring to the table: differentiation, innovation, low power consumption and, of course, the potential to reap the benefits of higher revenue. A barrier to mass adoption is the higher cost at present.

www.powersystemsdesign.com/greenpage.htm

Benchmark Power MOSFETs for High Performance Applications

Benchmark Point of Load: VRM, Buck Regulation

Part Number	V_{DS} (V)	I_D (A)	$R_{DS(on)}$ Max V_{GS}=10V (mΩ)	Qg (nC)	Package
IRFH7921PBF	30	14	8.5	8.3	PQFN (5x6)
IRFH7932PBF	30	25	3.3	34	PQFN
IRFH3702TRPBF	30	16	7.1	9.6	PQFN (3x3)
IRFH3707TRPBF	30	12	12.4	5.4	PQFN (3x3)
IRF8721PBF	30	14	8.5	8.3	SO-8
IRF8788PBF	30	24	2.8	44	SO-8

Benchmark Power Supply: Synchronous Rectification

Part Number	V_{DS} (V)	I_D (A)	$R_{DS(on)}$ Max V_{GS}=10V (mΩ)	Qg (nC)	Package
IRFB(S)3004PBF	40	330	1.75	160	TO-220(D^2-PAK)
IRFB(S)3006PBF	60	270	2.5	200	TO-220(D^2-PAK)
IRFB3077PBF	75	210	3.3	160	TO-220
IRFB4110PBF	100	180	4.5	150	TO-220
IRF7853PBF	100	8.3	18	28	SO-8

Benchmark Industrial: Industrial Battery, UPS

Part Number	V_{DS} (V)	I_D (A)	$R_{DS(on)}$ Max V_{GS}=10V (mΩ)	Qg (nC)	Package
IRF3205Z(S)PBF	55	110	6.5	76	TO-220(D^2-PAK)
IRFB(S)3806PBF	60	43	15.8	22	TO-220(D^2-PAK)
IRF1018E(S)PBF	60	79	8.4	46	TO-220(D^2-PAK)
IRFB(S)3607PBF	75	80	9.0	56	TO-220(D^2-PAK)
IRFB(S)3307ZPBF	75	120	5.8	79	TO-220(D^2-PAK)

IR's latest MOSFETs offer benchmark performance and are tailored for DC/DC conversion, AC/DC synchronous rectification, and Industrial Battery applications such as E-Bike and UPS systems.

IR's latest Trench technology in a wide range of packages up to 250V enables low $R_{DS(on)}$, low gate charge, and high switching capability for today's demanding designs.

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