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Volume 1, Issue 8

It is Fall and we are ready for Show Time

All electronic companies are very active with prepress conferences announcing activities at Electronica trade show in Munich. All of the trade journal editors like myself are running back and forth to get important information about the news in electronics.

The good thing for me being focused into power makes it a little bit easier. Power is a big family and we know each other quite well. Power has its own conferences and dedicated shows also upcoming for the next year. Spring into summer will have PCIM2005 in Nuremberg and APEC (very similar show but in the US) and summer into fall will have EPE2005 in Dresden, Germany. Their deadline for abstracts is 30th of October or 1st of November of this year. Just a reminder for the ones working on new projects.

Now we are focusing on Electronica. Autumn Rain during the weekends will be good to get all our final work done, Electronica takes place November 9-12. Electronica has the spirit to be the big party for all electronics and the atmosphere during the show will be the indicator of the global economic trends. I remember the time working in marketing and application and having spent quite a bit of time using the old airport in Munich-Riem to departure and arrive back home. Now this place has become the Messe München fairground.

My memory takes me back when I was a young engineer visiting the show downtown where you could easily walk over into town for a relaxing evening in the Hofbräuhaus. Now you use the shuttle busses to move you to downtown.

Our American friends have to decide whether they will celebrate Thanksgiving at home or in Munich. It is always an important decisions around an important American holiday. Last year around Christmas our magazine needed full attention so we missed some of the celebrations. PSDE magazine will soon celebrate the first anniversary in January 2005.

This time my grand nephews and I are planning ahead of Christmas time to set up the size 1 Märklin trains in my house. To lead them into an engineering future I have to allocate time for them and have to help to learn what planning means. Last year we did not open the train boxes as our magazine needed the full attention. We have published 8 issues including 72 in-depth technical features and about 432 pages of technical information to our readers. Our industry has provided strong support to us and we are focused on covering the topics most important to our readers. You will notice PSDE is at any significant event that has impact on power. Our worldwide activity gives us the fuel to serve our readers with crucial up-to-date information on articles news and products.

Fall shows us the change of colors on the leaves and we are ready for the upcoming events listed in our "Power Events" on page 6, chose your event to go to. All of these are focused events with strong subjects to power and electronics. For engineers it is a never ending process in our profession to learn all our life.

The next upcoming key event for us is Electronica in Munich. Mark up your calendar for Electronica on Thursday 11th of November in Hall C1 to attend the podiums discussion from 10:00 to 12:00 having the topic "Chose the Right Electronic Power Switch".

A good time to meet with me will be after the podium discussions. Look forward to seeing you at Electronica!

Best regards

Bodo Arlt

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Fairchild VP Sales and Marketing for Europe

Fairchild Semiconductor announced the promotion of Ole-Petter Brusdal to vice president of Sales and Marketing for Europe. Based at Fairchild's Global Power Resource design centre and sales office in Fuerstenfeldbruck, Germany, Ole-Petter will direct all sales and marketing activities in Europe. He will report to Tom Beaver, Fairchild's executive vice president, Worldwide Sales and Marketing.

"Europe is an integral part of Fairchild's plan to expand our leadership role as The Power Franchise(r). With a focus on automotive, industrial, consumer and communications segments, our European organization provides strong design expertise and customer support, from design to delivery," said Beaver. "Ole-Petter has contributed significantly in the on-going development of our presence in Europe and the successful implementation of our power design centre in Germany. One of six Global Power Resource design centres worldwide, the Fürstenfeldbruck site can turn complete power solution designs in as little as two weeks, enhancing customers' critical time to market requirements. Ole-Petter has the leadership ability and people to grow Fairchild's presence while driving superior customer support in the OEM, distributor and EMS segments in Europe."

Ole-Petter joined Fairchild when the company was established in 1997 and has held various sales and marketing positions supporting segments and geographic territories in Europe and the Americas. His 18-year career includes previously working for companies such as National Semiconductor and Tahonic (Arrow).

www.fairchildsemi.de

Sauer-Danfoss and Texas Instruments for OEM Mobile Machinery

Allowing original equipment manufacturers (OEMs) to reduce design time while increasing system features and functionality, Sauer-Danfoss and Texas Instruments announce the availability of eight Plus 1 hardware modules based on TMS320F2810 and F2812 digital signal controllers. The F28x based modules let OEM de-signers tap into 150MIPS of TI's leading digital signal processing (DSP) technology to develop high per-formance control systems for machinery functions such as transmissions, hydraulics and operator inter-faces with lower running costs and longer service lives, while enjoying the peripheral integration and ease-of-use typically found in a microcontroller (MCU) based system. For more information about the F2810 and F2812 digital signal controllers, please visit www.ti.com/sauerpr.

In the competitive heavy equipment market, OEMs often turn to Controller Area Network (CAN) serial communications networks to meet their customers' ever-increasing standards in areas ranging from through-put based performance and operator safety to environmental regulations. As part of the extensive system of easy-to-use software tools, powerful programming environment, input/output (I/O) modules, graphical terminals and joysticks software and hardware modules, the PLUS 1 systems allows manufacturers of mobile equipment to design CAN based electronic control systems that provide fast closed-loop, real-time performance with increased reliability. Using the PLUS 1 system, design engineers can select from a library of software control object and modular control hardware to build a system scaled to their specific needs. TI's DSP-based F2810 and 2812 controllers provide eight of these PLUS 1 modules with an integrated processing core to control the system's transmissions, drive-trains and valve controls. Functionality also extends to controlling equipment such as blades, grippers and buckets as well as hydraulic and electronic control steering.

www.sauer-danfoss.com

www.ti.com

PSMA and PICMG Form Alliance to Advance Power Supply Developments

The Power Sources Manufacturers Association (PSMA) announces that it has entered into a Memorandum of Understanding (MOU) with the PCI Industrial Computer Manufacturers Group (PICMG) intended to foster collaboration and information exchange between the two organizations. The collaboration outlined in the MOU will provide suppliers of power source products (PSMA members) with market insights from users while at the same time providing users (PICMG members) with improved information about current and evolving power source technology. As part of the alliance, reciprocal Affiliate Membership will be afforded to each organization.

According to Gino Nanninga, VP Sales for Positronic Industries, "PCMIG will maintain a liaison group known as the PICMG/PSMA Advisory Group to act as a hub for exchange of information between PSMA and PICMG. The group will be made up of Executive Members of PICMG and Regular or Associate Members of PSMA."

"As part of our collaboration, PICMG will create a separate Power Supply category in its online Power Directory," said Kevin Parmenter, ON Semiconductor's Director of Central operations, speaking for PSMA. "All PSMA members companies will be urged to list their power supply and power conversion products on this site."

As part of the agreement, each organization will authorize use of each other's trade-marks and logos, share documents and cross-link their websites.

www.psma.com

www.advancedtca.org

DOSA adds Lambda as a Member

The Distributed-power Open Standards Alliance (DOSA) is pleased to announce that Lambda, a leading provider of standard and custom power supply solutions, has joined the industry alliance. DOSA was established in February 2004 to ensure future dc-dc product compatibility and standardization within the increasingly fragmented power converter market, and its membership includes Tyco Electronics Power Systems, Inc., SynQor, Inc., and Celestica Power Systems.

"We are proud to be part of the DOSA team," said Bill Steckel, president of Lambda. "DC-DC converter technology is evolving rapidly. By following the open DOSA standards, Lambda's customers will benefit from a clear product roadmap that incorporates Lambda technology to deliver leading-edge industry standard solutions."

Founded by Tyco Electronics and SynQor, DOSA's mandate is to establish standards over a broad range of power converter form factors, footprints, feature sets and functionality for both non-isolated point-of-load (POL) and isolated applications, including intermediate bus converters.

"Lambda supplements the DOSA membership very well by adding further credibility, additional technical expertise and a strong Asian presence to the alliance," said Joseph Coupal, executive vice president, marketing and sales for SynQor.

"With the addition of Lambda, DOSA continues to march forward," said Sabi Varma, vice president, marketing and business operations for Tyco Electronics Power Systems. "As the primary beneficiaries, our customers are excited by these efforts and recognize the commitment DOSA has made to ensuring their needs are met."

www.dosapower.com

National Sets Single-Year Patent Record

National Corporation announced that it has been granted 221 United States patents in fiscal year 2004 for a wide variety of product inventions and process innovations, the most it has received in a single year since its founding in 1959.

Approximately one-third of all National patents are in analogue technologies, giving the company one of the largest portfolios of analogue patents in the semiconductor industry. The balance of National's patent portfolio includes processing, device design, packaging, architecture, and other key integrated circuit (IC) technologies.

With a portfolio of more than 2400 active and 700 pending patents, National maintains a strategic programme of protecting its research and development investment with patents. Approximately 250 of National's current employees are holders of US patents. National Semiconductor is number 87 on the Intellectual Property Owners (IPO) list of top patentees in the United States for calendar year 2003. For more information, see www.ipo.org.

National also has approximately 1,300 active foreign patents, although a single National U.S. patent may have several foreign counterparts. The company generally pursues patents in countries consistent with its markets, and has significant patent holdings in Germany, Taiwan, Korea and other countries.

www.national.com

Artesyn and Summit Enter Strategic Agreement

Artesyn Technologies and Summit Microelectronics have entered into a Strategic Cooperation Agreement to develop comprehensive power system control and conversion solutions. The agreement combines the strengths of both companies to define and provide the next generation of semiconductors and modules for DPA (Distributed Power Architecture) designs targeted at telecommunications and data-communications systems.

Under the agreement, Artesyn Technologies and Summit Microelectronics will share applications knowledge, circuit design solutions, market trends and other proprietary information to define architectures and products that enhance power control capability to support the communications infrastructure marketplace. First products from the agreement will be released to market before the end of 2004.

Summit's semiconductor solutions integrate control logic with precision analog circuits and embedded nonvolatile EEPROM. The control IC's are programmable through an on-chip I2C interface via a supplied Windows-compatible GUI development software system. This enables Summit to provide platform based solutions that address the growing complexity of power needs of IC's moving toward finer process geometries, higher densities, and lower and multiple voltages. Summit addresses these requirements by providing configurable devices that guarantee critical circuits will turn on and off in the proper sequence, receive precise specified voltages, monitor/record faults, and reset the system if necessary, resulting in improved control, flexibility, reliability and cost. For example, Summit's proprietary Active DC Output Control (ADOC) technology enables the control of any voltage to within +/-0.2% accuracy.

www.artesyn.com

www.summitmicro.com

Power Events

- ***Power Conversion Design***, *October 12-15, Portsmouth UK, www.ejbloom.com*
- ***Ansoft Seminar***, *October 21, Stuttgart/Sindelfingen www.ansoft.com/gsem04/*
- ***Electronica 2004***, *November 9-12, Munich, www.global-electronics.net*
- ***Synqor Power Supply Workshops at Electronica***, *Nov. 9-12, sales-europe@synqor.com*
- ***Surface Mount 2004***, *November 16-18, Brighton UK, www.smartgroup.org*
- ***SPS/IPC/DRIVES 2004***, *November 23-25, Nuremberg, www.mesago.de*
- ***embedded world 2005***, *February 22-24, Nuremberg, www.embedded-world.de*

MOSFETs Switches Low Voltage Power

Trench structure and increased cell density per unit area is the innovative application in design. The avalanche capability in inductive switching is one of the most important parameter for keeping the device within the safe operating area.

By Bodo Arlt, Power Systems Design Europe, Editor-in-Chief

MOSFETs have become more and more the switch of choice. MOSFETs and specially the enhancement type is the one which had made the most impact in industry. However, the depletion type is still something that can be useful in a special design.

Concentrating on the enhancement type with optimization of the thermal resistance in the package is the focus. Continued improvement in silicon with minimized switching losses and conduction losses in today's MOSFETs has been achieved. The current technology with its trench-gate components brings significant advantages thanks to the improved conduction characteristic in low-voltage applications with MOSFETs. The traditional V MOSFET structure has been present for a long time. Trench structure and increased cell density per unit area has been the innovative step forward. Beside there are many other parameters to consider in a MOSFET for your design. For example, the avalanche capability in inductive switching is one of the most important parameter keeping the device within the safe operating area. Matching all zener diodes of the individual cells with a very identical breakdown voltage to turn them simultaneously on is the trick that makes it works. No hot spots are allowed therefore the simultaneously behavior is a must. Even active clamping is demonstrated for quite a while, first shown with automotive devices.

As a component for fewer than 200 volts the MOSFET continues as the dominant switching element especially in automobiles. The 42 volt supply and the sophisticated elements of future automobiles, like starter alternator and drive by wire applications, will inspire more tailored devices for this volume market. All MOSFET manufactures have a 75volt product and future development continues to support the automotive industry. Modules and advance packaging is important for this market segment.

The main contribution for MOSFETs is recognized in DC/DC converters, which in combination with optimized passive components demonstrates over 90 percent efficiency. Here, synchronous rectification with suitable MOSFETs and necessary control is of crucial importance. In distributed power architecture DC/DC convert ion is the way to achieve point of load supply.

The traditional V MOSFETS designs are being replaced with trench design. Trench offers more active space for the current flow regarding the given die space. Trench devices reach a higher current density.The supply voltages of modern ICs demanded an increasing range with the tendency for controller ICs at ever lower voltages. These systems can be optimally configured only by distributed power technology.

Electronics have the trend for smaller packaged designs with increasing performance features and all at decreasing costs. The convergence of datacom and telecom into a unified network is requiring increasing system performance to process and route data on these networks. As a result, integrated circuits are being designed to operate at higher frequencies with increasing transistor densities. An optimized supply with perfect MOSFETs in converter design is the consequence for the designer. As the integrated circuit increases in transistor density, power dissipation within the IC package will naturally increase. Dynamic power dissipation can be reduced by circuit design, semiconductor processing technology, and reducing the supply voltage.

There are a growing number of parts in industry that have been optimized for the DC/DC conversion process to minimize losses during high-speed switching. Summarizing we can say loss reduction and space minimization is a key goal achieved by MOSFETs offering extreme low on resistance replacing Schottky diodes and also being the main switch working at the high switching frequency to keep magnetics small in the converter design. Optimization of topologies and their driver systems together with the passive components like the magnetic designs which have to fit into the overall basket, lead to the high performance of today.

Design by Application or Application by Design?

By Mr. T. Kurosu, Hitachi Ltd, Power Semiconductor Device Development Center

Power semiconductors used as the main switch for power control to process the signal of a microcomputer or memory device, continue to find themselves in the spotlight to help meet global energy saving and environmental targets. In both the medium and large capacity inverter markets, those exceeding dozens of kilowatts especially, the Insulated Gate Bipolar Transistor (IGBT) continues to see widespread use.

Within the power supply field there are two key applications: distributed and the electric conversion of natural energy. Within the motor control field, the largest expectations for rapid and high volume demand are seen to be within the Automotive sector, namely electric vehicles (EV), where the inverter topology is critical for energy saving.

The present IGBT market demand is approximately 1100M$, consisting of die, discrete and modules, of which approximately 830M$ is apportioned to the module package type. Predictions made by independent research companies continue to report a strong upward demand trend. However, in reality the power device market tends to fluctuate greatly. Despite this many manufacturers within Europe, United States, and Japan have entered into this market, making it a market of severe competition.

Enormous research and development investments are being made across the world in order that detailed process technologies can be implemented to support improvement in performance and therefore increased output power (W) per mm2 of a module's footprint. This investment is indispensable and

requires a large amount of plant and equipment. It is thought that in order to deploy such new process technologies into the market then we will begin to see stronger alliances between both semiconductor manufacturers and their customers.

The performance requirements of the IGBT demanded by the EV application are in simple terms a reduction in the device losses, package miniaturisation and high reliability

.

Whilst EV has a mandatory adoption of fine pattern structures, lower losses have been attained by optimization of the p-n junction structure year on year. Within the 600V class, this performance is now close to the limit of p-n junction technology, as realised by present conditions. The disadvantage of greater switching speeds is also apparent. The subject of surge capability due to instant large power demands at the time of voltage step up during switching; reservations to safe operation area, and short circuit capabilities are all indicated as critical future development areas.

In the case of a power semiconductor, the chip shrink by fine pattern technology may well result in a reduction in its heat handling capacity, consequential from an increase in thermal resistance. As a direct effect such process changes add to the need for additional investigation into package technology. It is therefore not only device design at the silicon level that is important, but also an overall understanding of the optimal processing of one's knowledge of the application. A thoughtful mechanical and thermal approach is an indispensable element of the power device designers brief.

Now, when a future market trend is seen, many highly efficient power devices are required. Recent examples include practical use of IGBTs for natural energies, such as wind power, and the electric vehicle. There are already many complex areas where IGBT technology has been adopted and nurtured, for example in railway propulsion and the medium class power supply markets. Even though the actual results of existing market experiences and the requests for improved product specifications are implemented, the hurdles for the EV market may well be higher. It is a fact that the technical subject matter, which many are still required to improve, will also strengthen the cooperation between an application and device development—even more so in the future. The continuous market support of the power semiconductor optimised for every application will play a larger role in what form a power device product will have to take.

www.hitachi-eu.com/pdd

Integrated High Voltage IC and Reference Designs

Key elements to light the way for rapid ballast design

High-voltage ICs and accompanying tools and reference designs can help engineers simplify electronic lamp ballast designs while reducing cost and time-to-market.

By Cecilia Contenti, International Rectifier

In recent years electronic ballasts based on a controller IC and MOSFETs have become commonplace, thanks to their enhanced starting control, protection and superior reliability when compared with conventional self-oscillating bipolar transistor ballasts. Until now, however, self-oscillating transistor ballasts have had the edge in terms of size and component count. Recently this changed with the launch of International Rectifier's IR2520D high-voltage IC. Here we look at this product and introduce new reference designs that will dramatically simplify the development of lighting ballasts for the European market.

Designed to overcome the disadvantage of discrete self-oscillating solutions while maintaining low cost, International Rectifier's IR2520D is intended for driving lamps in CFL or small size ballast applications. The IR2520D integrates all of the necessary functions for preheat, ignition and on-state operation of the lamp, plus lamp fault protection and low AC-line protection, together with a complete high- and low-side 600V half-bridge driver. Despite this high level of integrated functionality, the IR2520D has only eight pins, fits into a standard SO8 or DIP8 package, and allows the component count for a complete ballast to be reduced to maximum of just 20 components.

Figure 1 shows a block diagram of the IR2520D. At the heart of this device is a voltage-controlled oscillator (V_{CO}) with externally programmable minimum frequency (F_{min}) and a 0V-5V analogue voltage input. The IC includes adaptive zero-voltage switching (ZVS) and non-ZVS protection. One of the biggest advantages of the IR2520D is that it incorporates an internal current crest factor driven shutdown function and it eliminates the need for a high-precision current sensing resistor that is typically used to detect over current. The IC uses the VS pin and the RDSon of

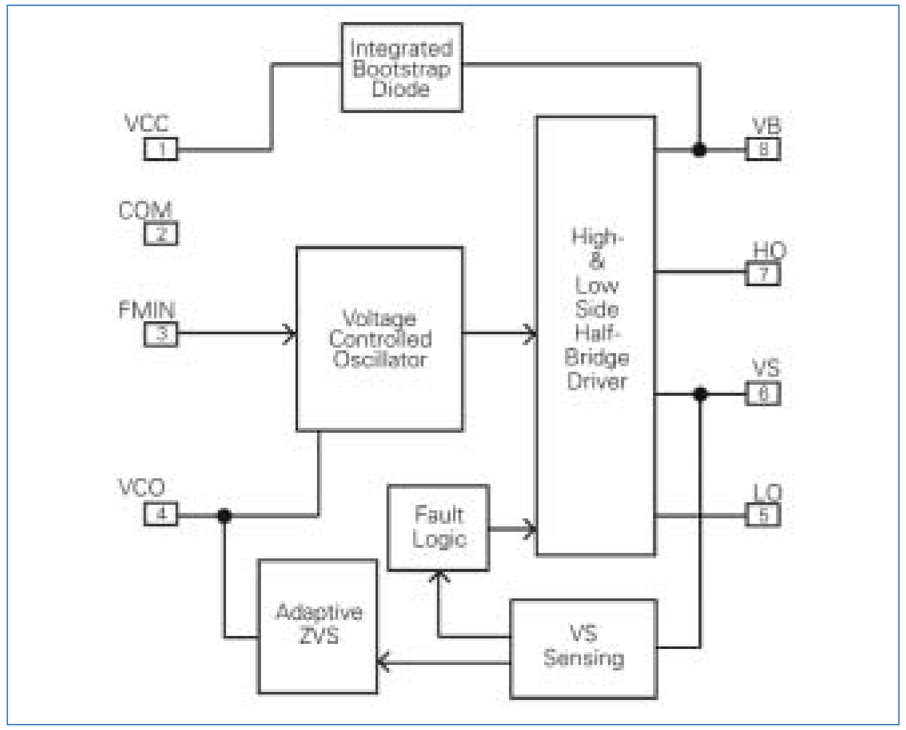

Figure 1 Block diagram of the IR2520D.

the low-side half-bridge MOSFET for over-current protection and to detect non-ZVS conditions. An internal 600V FET connects the VS pin to the VS sensing circuitry and allows for the VS pin to be accurately measured during the time when pin LO is high, while withstanding the high DC bus voltage during the other portion of the switching cycle when the high-side FET is turned on and VS is at the DC bus potential.

Designing with the IR2520D is very simple because it has only two control pins: VCO (0-5V_{DC} oscillator voltage input) and F_{MIN}. To modify the design for a different lamp power, it is necessary to modify only few external components.

The F_{MIN} pin is connected to ground through a resistor (RF_{MIN}). The value of this resistor programs the minimum frequency of the IC and the starting frequency of the IC (about 2.5xF_{MIN}). The IR2520D will work in run mode at the minimum frequency unless non-ZVS is detected. Generally, to work with constant frequency, the minimum frequency needs to be chosen above the resonant frequency of the low-Q R-C-L circuit. In this case, one can increase the value of RFMIN to decrease the frequency and increase the lamp power, or, decrease the value of RFMIN to increase the run frequency and decrease the lamp power.

The V_{CO} pin is connected to ground through a capacitor (C_{VCO}). The value of this capacitor programs the time the frequency needs to ramp down from 2.5 times F_{MIN} (F_{MAX}) to F_{MIN}. One can increase the capacitor value to increase the preheat time, or, decrease the capacitor value to decrease the preheat time.

The quickest and easiest method to select the values of the external components used with the IR2520D is to use the International Rectifier Ballast Design Assistant (BDA) software. The new version of the software, including the IR2520D, will be available in December 2004 to be downloaded from *www.irf.com*. The BDA can calculate approximate values of all external resistors and capacitors, and these values may then be used to make an initial breadboard type ballast setup. The final refining and obtaining of the exact component values will need to be carried out in the lab by experimentation.

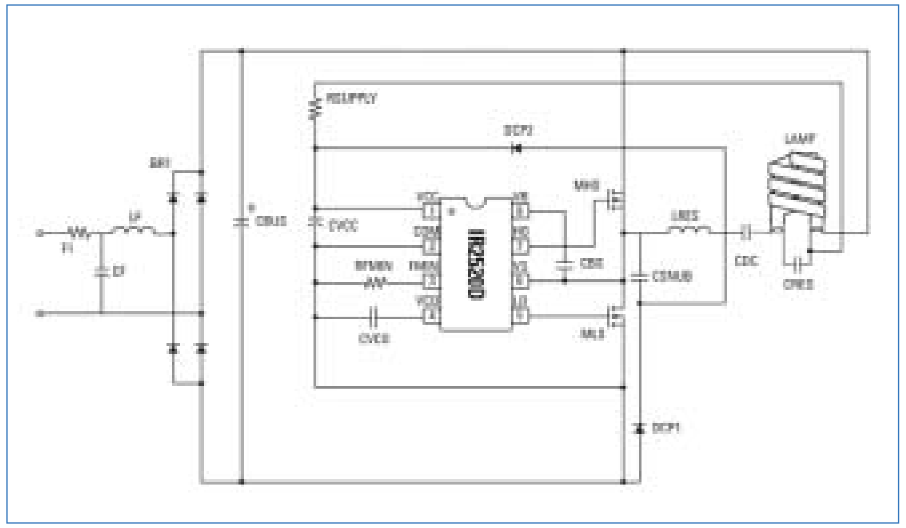

Figure 2. Schematic of the IRPLCFL5E reference design circuit.

To further simplify and speed the implementation of ballasts using the new IC, International Rectifier has created reference designs based on the part. These reference designs represent complete electronic ballast solutions for three target applications; a CFL ballast for a 220VAC 26W/spiral lamp; a CFL ballast for a 120VAC CFL 26W/spiral lamp; and a mini-ballast for a 230VAC 25W lamp. The reference designs are intended for evaluation only. The design has not been tested for EMI or other certification tests. The design needs to be reviewed and finalized to obtain a production-ready product.

The reference designs are similar in layout and components—in each case the circuits provide all of the necessary functions for preheat, ignition and on-state operation of the lamp, as well as including the EMI filter and the rectification stage. We will now look at one of these designs—the IRPLCFL5E CFL ballast for 26W/spiral lamps with 220VAC input—in more detail.

Figure 2 shows a schematic of the IRPLCFL5E reference design circuit. Key features that the reference design provides are: Programmable run frequency; Programmable preheat time; Open filaments and no-lamp protection; Failure to strike and deactivated-lamp protection; Low AC line protection.

As the diagram shows, the ballast incorporates a fuse, EMI filter, input rectifier, bus capacitor, half-bridge, control and output stage. The output stage is the classical resonant circuit consisting of an inductor, LRES, and a capacitor, CRES. The circuit is built around the IR2520D Ballast Control IC, whereby the IR2520D provides adjustable preheat time, adjustable run frequency to set the lamp power, high starting frequency (2.5 times FMIN) to avoid lamp flash, capacitive mode protection for open filament condition, and current crest factor protection for failure to strike or no lamp conditions.

The AC line input voltage is rectified to provide a bus voltage of approximately 300V. The startup resistors, Rsupply1 and Rsupply2, are sized such that they can supply the micro-power current during under-voltage lockout (UVLO). When VCC exceeds the UVLO+ threshold, the IR2520D begins to oscillate and the charge pump circuit (CSNUB, DCP1 and DCP2) supplies the current to VCC that causes the internal 15.6V Zener clamp to regulate. The IR2520D Ballast Control IC controls the frequency of the half-bridge as well as the ballast states and protection modes such as lamp preheat, lamp ignition, running mode, low AC line protection and lamp/ballast fault protection.

Figure 3 shows the voltage across the lamp and the current in the resonant inductor LRES during startup, preheat, ignition and run mode. When power is turned on, the IR2520D goes into Under Voltage Lockout (UVLO) mode.

The U_{VLO} mode is designed to maintain a very low (<200uA) supply current and to guarantee that the IC is fully functional before the high- and low-side output drivers are activated. During UVLO, the high- and low-side driver outputs (LO and HO) are both low and pin VCO is pulled down to COM for resetting the starting frequency to the maximum. Once VCC reaches the start-up threshold (U_{VLO+}), the IR2520D turns on and the half-bridge FETs start to oscillate. The IC goes into Frequency Sweep Mode. At start-up, VCO is 0V and the frequency is very high (about 2.5 times FMIN). This minimizes voltage spikes and lamp flash at start-up. The frequency ramps down towards the resonant frequency of the high-Q ballast output stage, causing the lamp voltage and lamp current to increase. During this time, the filaments of the lamp are preheated to the emission temperature to guarantee a long lamp life. The frequency keeps decreasing until the lamp ignites. If the lamp ignites successfully, the IR2520D enters RUN Mode. If the minimum frequency has been chosen below or very close to the resonant frequency, the IC will work near resonance and will adjust the frequency continuously to maintain ZVS at the half-bridge and to minimize the losses in the FETs. If the minimum frequency has been chosen higher than the resonant frequency the IR2520D will work at the minimum frequency.

Figure 4 shows the current across the resonant inductor and the voltage across the lamp filaments at start-up, and Figure 5 shows the VS (HB) voltage, the lamp voltage and the lamp current during Run mode.

In case of fault conditions such as open filaments, failure to strike, deactivated lamp or no lamp, the IR2520D will go into fault mode. In this mode the oscillator is latched off. To reset the IC back to preheat mode, VCC must be recycled below and above the U_{VLO} thresholds. This is done by resetting the mains. In case of low AC line, the IR2520D will automatically increase the frequency to maintain ZVS. In this way, the ballast will work at a lower power during a low AC line condition and will operate at the proper power again when the line increases again.

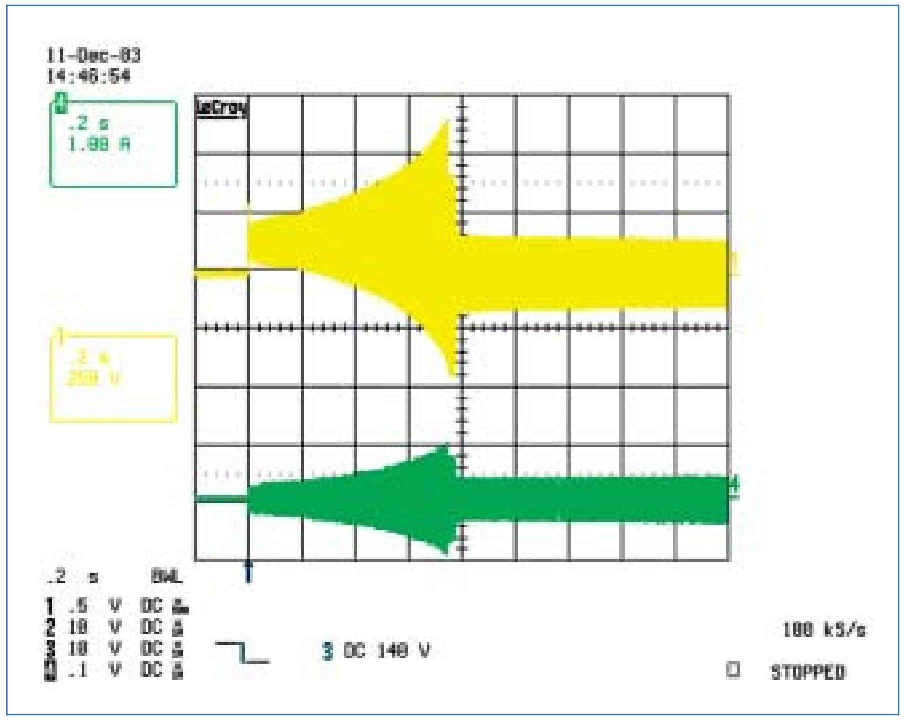

Figure 3. Voltage across the lamp and the current in the resonant inductor.

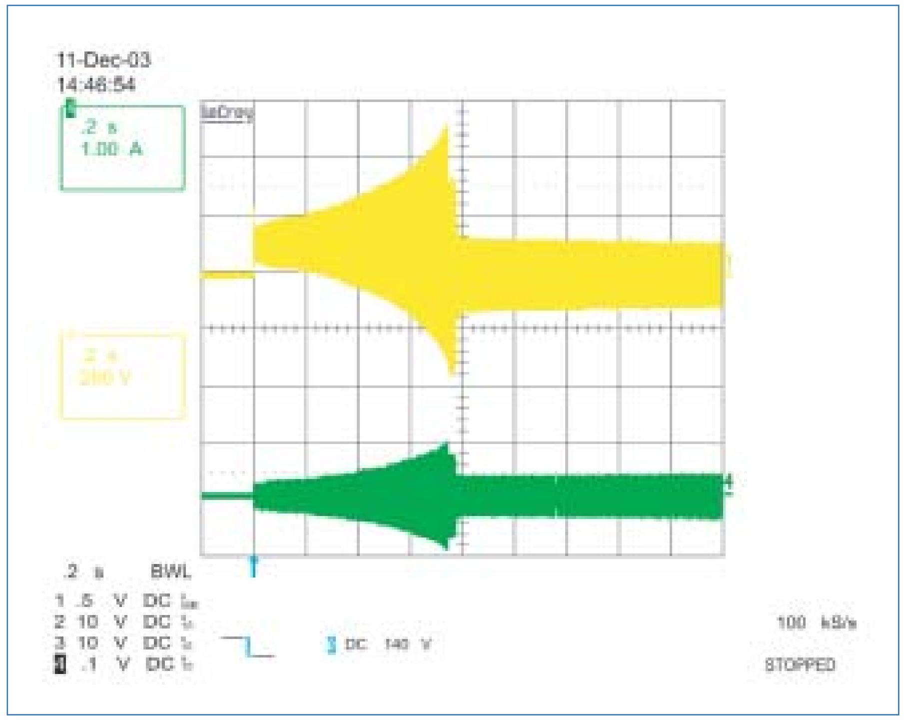

Figure 4. Current across the resonant inductor and the voltage across the lamp.

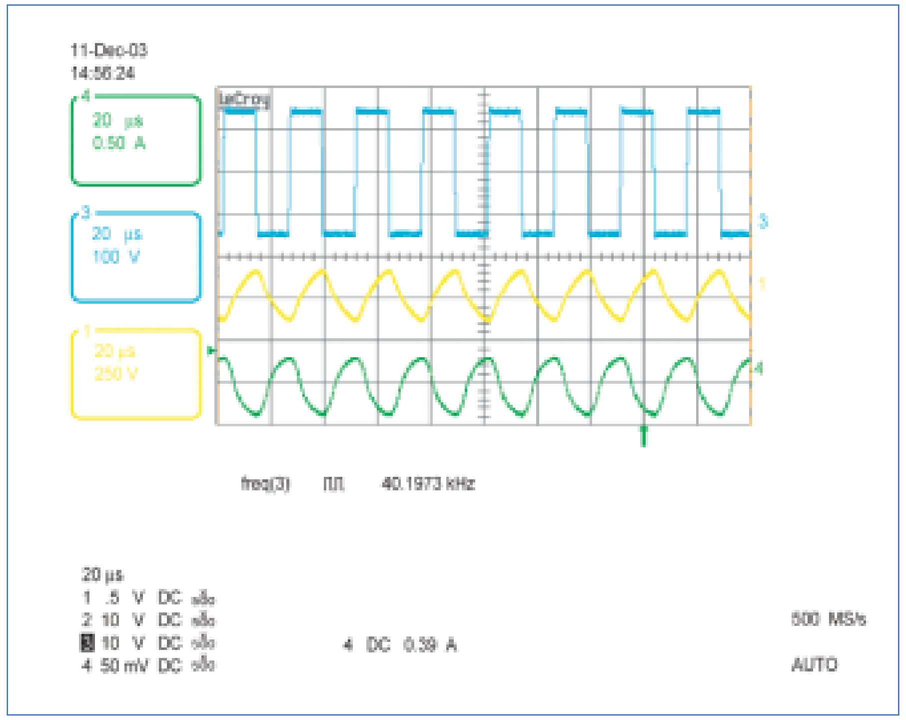

Figure 5. Lamp voltage and the lamp current during Run mode.

The IR2520 HVIC is set to help engineers deliver advanced ballast solutions with significant advantages over previous controller/MOSFET and self-oscillating bipolar transistor designs. To further support application development, engineers can use IR's Ballast Design Assistant (BDA) Software for the rapid identification and selection of the requisite external components. Using the ballast reference designs in conjunction with the BDA further simplifies and speeds the development, prototyping and implementation of ballast applications.

About International Rectifier

International Rectifier (NYSE:IRF) is a world leader in power management technology. IR's analogue and mixed signal ICs, advanced circuit devices, integrated power systems and components enable high performance computing and reduce energy waste from motors, the world's single largest consumer of electricity. Leading manufacturers of computers, energy efficient appliances, lighting, automobiles, satellites, aircraft and defence systems rely on IR's power management benchmarks to power their next generation products. For more information, go to www.irf.com.

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The Evolution of Power Distribution Architectures Continues

Factorized power architecture reorganizes conversion functions

Factorized Power Architecture (FPA) reorganizes the basic power conversion functions _ voltage transformation, isolation, and regulation _ and implements them in IC-style packages. A buck/boost Pre-Regulator Module (PRM) provides a stable voltage from an unregulated DC bus, and a Voltage Transformation Module (VTM) steps the voltage up or down and provides isolation at the point of load.

By Andrew Hilbert, Vicor

With each generation of processor, memory chip, digital signal processor (DSP), and application-specific integrated circuit (ASIC), the trend to lower voltages at higher currents continues to challenge the infrastructure needed to support these contemporary loads. This trend has exposed, in turn, the limitations of known distribution architectures, including Centralized Power Architecture (CPA), Distributed Power Architecture (DPA), and Intermediate Bus Architecture (IBA). The newest of the power architectures _ Factorized Power Architecture _ promises to provide the performance needed to meet these challenges today.

Centralized Power Architecture. The classic CPA, which is simple and cost effective, continues to be applied wherever appropriate. Starting with communications systems applications, however, Centralized Power ran into a brick wall because of its inability to effectively deliver lower voltages at higher currents.

A centralized power supply contains the entire power supply in one housing æ from the front end through the DC-DC conversion stages (Figure 1). It converts the line voltage to the number of DC voltages needed in the system and buses each voltage to the appropriate load. It's cost effective and doesn't consume valuable board real estate at the point of load with the power conversion function. It is fairly efficient because it avoids serial power transformations, and it concentrates the thermal and EMI issues into one box. In the past, the centralized system, usually a custom design, was often chosen because it was the least expensive approach. These systems, in general, work well when the power requirements, once defined, are not likely to change and space is not an issue.

In order to minimize I2R distribution losses, the central supply should be located near the load. For safety and EMI reasons, it should be located as close as possible to the AC entry point. This is often a difficult trade-off.

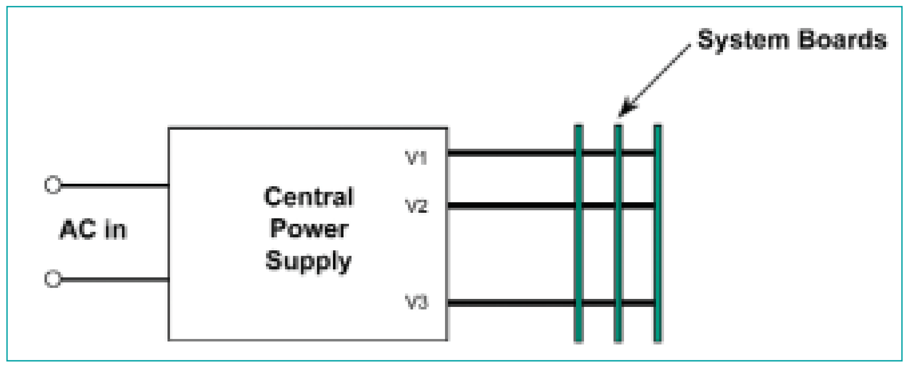

Figure1. A centralized power supply contains the entire power supply in one housing and buses each voltage to the appropriate load.

Although centralized power works well for many applications, it becomes most unsuitable when it is necessary to distribute the hundreds of amps common with low voltage loads today. Centralized power is also not scalable. Many systems can be configured with varying numbers of function cards representing widely varying loads (e.g., line cards in a PBX). With centralized power, the power supply must be sized to handle the maximum configured system, which could put the small configurations at a cost disadvantage.

What's more, the remoteness of the supply from the load negatively impacts its transient response – the ability of the supply to react to rapidly changing loads. Also, thermal management can be a special challenge in a centralized architecture, where excess heat could amount to hundreds of watts all in one concentrated area. Large heat sinks and fans are often needed to keep the power supply from becoming overheated. System hotspots are a source of reduced reliability.

Distributed Power Architecture. As low voltage loads proliferated, bricks and distributed power came of age. Distributed power put DC-DC converter "bricks" on system boards near the loads they were powering. Since the 1980's, the bricks of DPA have delivered the classic functions of the DC-DC converter (isolation, voltage transformation and regulation) to the point of load. But as the number of voltages required at the board level continued to increase, DPA began to take up too much valuable real estate and the cost of duplicating the full converter functionality many times over became too much.

Distributed power is a decentralized power architecture characterized by bussing a "raw" DC voltage, usually 48 or 300 Vdc depending on the power source, which is then converted by on-board DC-DC converters located near the loads they serve. On-board isolated DC-to-DC converters are matched to the load requirement. This helps with dynamic response and eliminates the problems associated with distributing low voltages around the system.

A distributed approach spreads the heat throughout the system, greatly reducing or eliminating the need for heat sinks or high velocity airflow. With temperatures more evenly maintained throughout the system, reliability specifications are easier to meet. Also, since the power is located on the board, configuring system variations and options is much more cost effective than in a centralized architecture, which requires the power supply to be sized for worst-case

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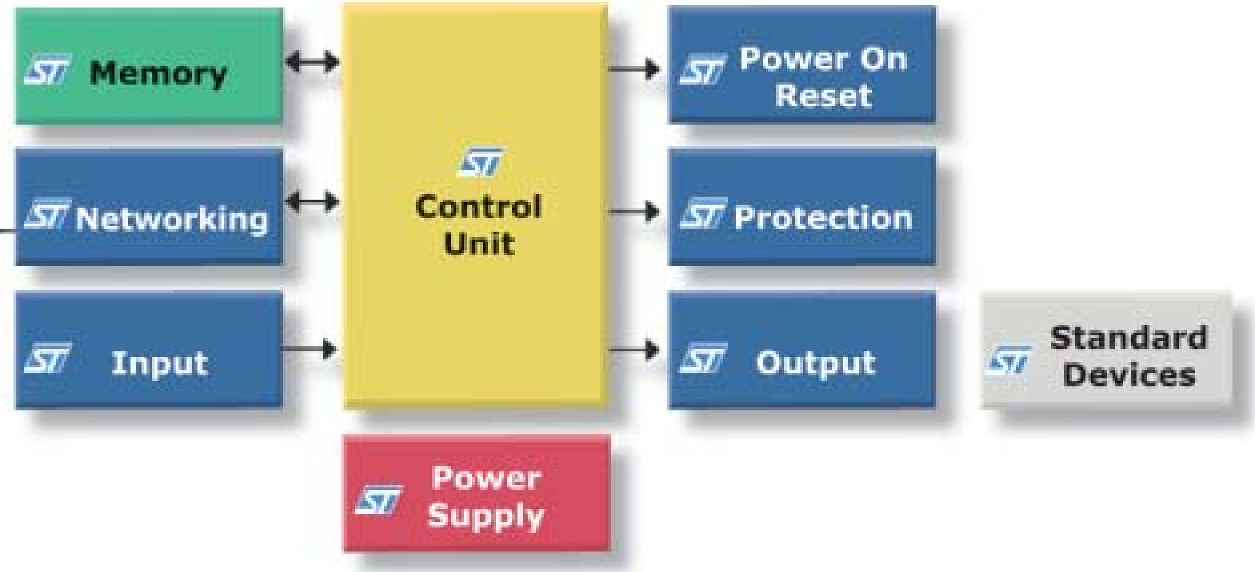

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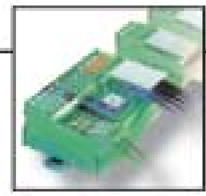

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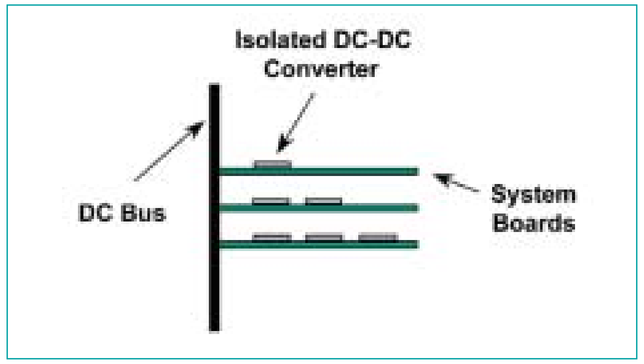

Figure 2. Distributed power is a decentralized power architecture consisting of DC-DC converters located near the load they serve.

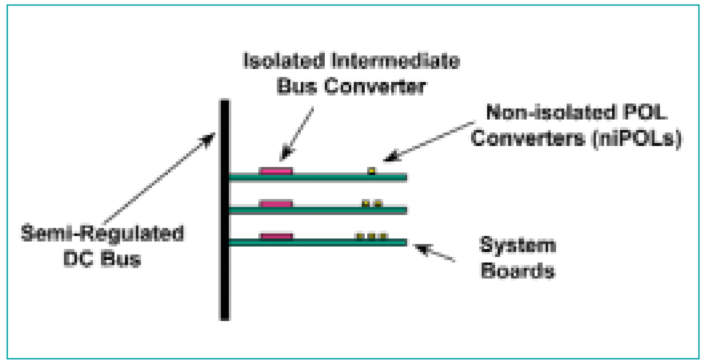

Figure 3.The intermediate bus architecture uses an isolated intermediate bus converter to provide an unregulated voltage to power non-isolated and relatively inexpensive POL converters.

loading. Redundancy is easy to implement for any critical load by simply paralleling additional DC-DC converters where required.

DPA, however, can also be more costly. Since isolation, regulation, transformation, EMI filtering, and input protection are repeated at every load, as the loads proliferate, both the costs and board area for power conversion increase.

Intermediate Bus Architecture. To deal with the multiplicity of low voltages more cost effectively, IBA relies on non-isolated point of load regulators (niPOLs), reducing the POL function to regulation and transformation. The niPOLs operate from an intermediate bus voltage provided by upstream isolated converters. IBA can be a more cost-effective solution because niPOLs, being non-isolated, are less expensive than complete DC-DC converters. But typical niPOL buck converters are in constant conflict between efficient power distribution and efficient power conversion duty cycle.

The intermediate bus architecture differs from the distributed power architecture in that it converts the raw DC voltage (e.g. 48 or 300 Vdc) to an intermediate voltage, typically 9.6 or 12 Vdc, to feed non-isolated and relatively inexpensive POL converters (Figure 3). The niPOLs are also likely to be smaller and lighter than DC-DC converters, providing the benefits of a small footprint and consuming correspondingly less board real estate. Non-isolated POL converters within the Intermediate Bus Architecture forego isolation and high voltage transformation ratios to improve cost-effectiveness.

The niPOLs of IBA depend upon a bus converter to provide isolation and voltage step-down from the raw DC bus. This is accomplished by the intermediate bus converter, which is usually either a complete DC-DC converter operating from a wide range DC source, or an unregulated IBC operating from a narrow range input. The conversion to the intermediate bus voltage intrinsically reduces efficiency of the system. Also, the intermediate bus converter really does need to be located close to the load, because, even with a 12 Volt intermediate bus, four times the current needs to be moved around the board as compared to a 48V distributed power system, so larger traces or shorter runs are needed.

The 12-Volt intermediate bus is also too high for efficient conversion to low voltage outputs (<2 Vdc) as the transformation ratio becomes too high, and the switch duty cycle becomes too low. Lowering the bus voltage to overcome this limitation simply increases the problems associated with the previous issue.

Since the niPOL includes regulation, it needs an inductor in series with its output. These same low voltage loads generally need fast transient response, but now inertia has been imposed right where agility is most needed. These are the fundamental limitations of IBA when it comes to powering today's sophisticated low-voltage, high-speed loads.

Another disadvantage with niPOLs is their lack of isolation: loads are vulnerable to deadly faults and the entire system is susceptible to ground-loop and noise coupling problems.

Factorized Power Architecture. FPA reorganizes the basic power conversion functions _ voltage transformation, isolation, and regulation _ and implements them in IC-style packages. A buck/boost Pre-Regulator Module (PRM) provides a stable voltage from an unregulated DC bus, and a Voltage Transformation Module (VTM) steps the voltage up or down and provides isolation at the point of load. High-frequency FPA V x I Chips using zero-current/zero-voltage soft switching topologies, offer designers a number of advantages such as small size, high efficiency, low noise and fast transient response combined with extremely high power density (>1,000 W/in3 at the point of load).

Figure 4 shows the FPA modules in a basic arrangement, but the PRM and VTM can be operated alone, together, open loop, local loop, adaptive loop, remote loop, co-located, separated, paralleled, or combined with conventional power conversion devices (e.g., DC-DC converters, point-of-load converters, charge pumps) to achieve the desired power solution.

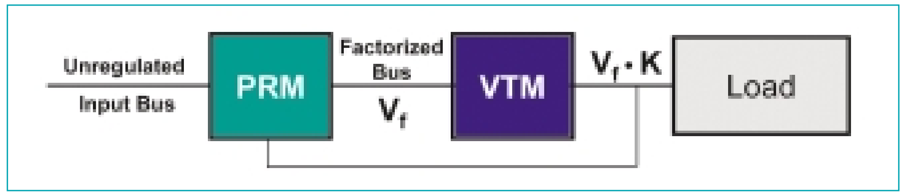

Figure 4. Basic FPA block diagram.

The VTM is enabled by a new class of power conversion topologies called Sine Amplitude Converter (SAC), which offers designers a number of benefits that include, for example, high power density, high efficiency, fast transient response, and low noise.

Characteristics of the SAC that contribute to these benefits and that overcome the limitations of IBA include:

- 3.5 MHz fixed switching frequency. The high switching frequency significantly reduces the size of all reactive components, is very easy to filter, and decreases the response time.
- Zero-voltage and zero-current soft switching. Lossless switching increases efficiency, reducing power losses and heat dissipation. It also reduces _ by as much as an order of magnitude _ dV/dt and dI/dt, resulting in low noise.
- Minimal serial energy storage (no output inductor). There is no power loss associated with an output inductor, a loss element in a typical converter. There is no current inertia to overcome, contributing to very fast dynamic response.
- 100% switch duty cycle at any transformation ratio. The high duty cycle results in efficient power train utilization.
- Bi-directional power processing. Load dump energy is recycled to the input, improving transient response.
- Capacitance reflection and multiplication. This SAC characteristic results in high effective point-of-load capacitance without the physical presence of bulk capacitance.
- Power train symmetry. Symmetry produces cancellation of common mode noise.

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POWER Micro-Electro-Mechanical Systems (MEMS)

Innovative design for ambient vibration scavengers

Key elements of the future intelligent environment are wireless autonomous sensors, embedded in numerous objects and constituting an entire network. Both low-power electronics and energy-scavenging devices are necessary to realize this vision of autonomous sensor nodes.

By Els Parton, Tom Sterken and Paolo Fiorini, IMEC Leuven

Vibration energy can be harvested from the ambient using MEMS technology. These MEMS vibration scavengers are expected to generate power density levels in the range of 100 µW/cm_ to 1 mW/cm_. Recently, prototypes were developed based on an innovative design using electret layers. This concept ensures high-voltage operation and eliminates the need of any voltage source in the scavenger.

Small, smart, autonomous

The ever continuing scaling of transistor dimensions has led consumer electronics into a world of portable devices. Whereas these devices rely on batteries, this will not be an option for the next generation of applications: small wireless computing and communication devices embedded in our surroundings and even in our body. It is not feasible to replace depleted batteries in medical implants, embedded sensors (for example in buildings) or elaborate networks of miniaturized sensor nodes.

The solution lies in energy scavenging from the ambient. The evolution towards low-power electronics compensates for the small power density of this type of energy source. The best-known and most mature energy scavenging devices are solar cells, transforming light energy into electrical energy. On a sunny day this system can realize a power density of 15,000 µW/cm_. However, less than 10 µW/cm_ is available when used indoors. Another option is the use of thermal energy. Experiments showed that thermo-electrical power generators are able to output 15 µW/cm_ from a 10°C temperature difference. Again, this type of energy source is not available for many applications envisaged. Mechanical energy on the other hand is amply available in the environment, be it as strain or vibrations. Vibration-rich environments include spaces with industrial equipment, small household appliances, heating and cooling ducts in buildings, automobiles and aircrafts. Researchers expect power densities in the order of 100 µW/cm_ from this type of ambient energy source.

Scavenging vibration energy

Most vibration-scavenging devices are based on Newton's law of inertia and use the relative movement of a mass, suspended by a spring, as compared to the frame to which the spring is attached. There are different methods to convert this relative movement into useable electrical energy, illustrated in electromagnetic, piezoelectric and electrostatic vibration scavengers. Electromagnetic vibration-to-electricity converters connect the mass with a magnetic material and combine this with an inductive coil. Movement of the mass is translated to a flux change in the coil. A second option is the use of piezo-electric vibration converters based on a beam of piezo-electric material to connect the mass with the reference. Movement of the mass results in beam stretching, creating a dielectric displacement across the beam. Finally, electrostatic vibration scavengers make use of variable capacitors between the mass and the reference mass. When the mass moves, the overlapping area between the parallel plates of the capacitor changes and thus the capacitance changes, a factor capable of generating an electrical current in an external circuit.

Choosing between these three conversion mechanisms is easily done

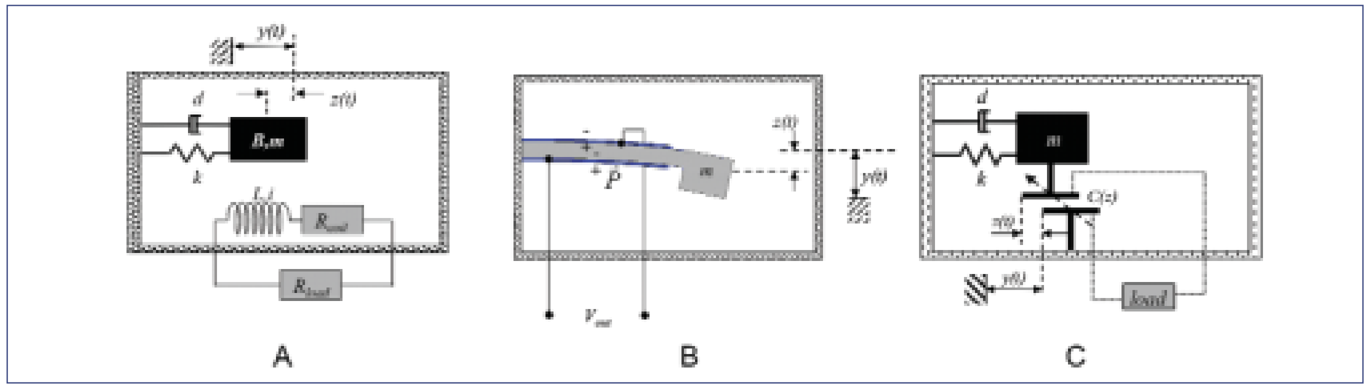

Figure 1. Working principle of electromagnetic (A), piezoelectric (B) and electrostatic (C) vibration scavengers.

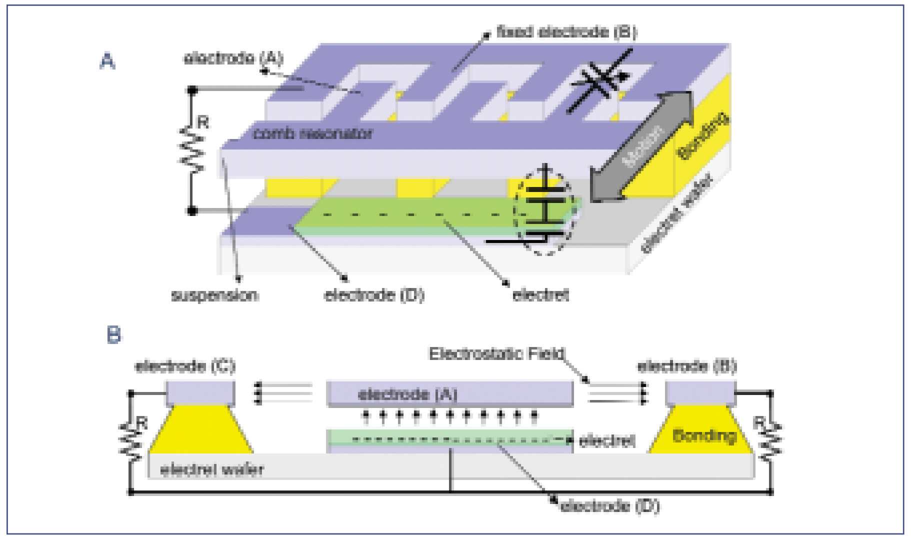

Figure 2. Cross-section (A) and side view (B) of the proposed electret-based vibration scavenger architecture.

when you take fabrication issues into consideration: the use of 3D coils in electromagnetic converters is not feasible in a 2D wafer technology, also the use of magnetic or piezo-electric materials is not standard in IC-fabrication, leaving the electrostatic vibration scavenger. This type of converter has the advantage that the variable capacitor structure can be realized with MEMS technology, a plus for integration with silicon-based electronics and miniaturization.

Electret-based electrostatic vibration scavenger

Researchers at IMEC recently developed a new concept for a MEMS-based electrostatic vibration scavenger. It is a two-wafer design. The top wafer contains a movable electrode with mass m, suspended by clamped beams that act as springs. Two fixed electrodes are positioned on both sides of this movable electrode, making up two interdigitated variable capacitors with opposite capacitance variations. This double architecture implies that the charge transport to the common electrode of the capacitors is zero, which reduces energy losses due to internal resistivity. The most innovative aspect of this vibration scavenger is situated in the bottom wafer. This contains a charged dielectric or electret, contacted by an electrode. The use of this electret shows many advantages: (1) the capacitor can be polarized without the need for a charge pump circuit or voltage source (as in the research of MIT and Berkeley research groups), (2) the electrical field that is generated between the plates of the variable capacitors due to the presence of the electret is equivalent to the field generated by a voltage source of 100 V to 300V, (3) the lifetime of the electret exceeds decades.

To verify the feasibility of this electret-based vibration scavenger architecture, a multi-domain model was worked out including an electret model, a variable capacitor model and a mechanical model. When assuming state-of-the-art micro-machining dimensions, the device is expected to generate up to 1 mW/cm_ at resonance.

As a quick feedback to this model, a prototype was designed using an SOI-based surface-micro-machining MPW service. A drawback to this approach is the technology-specific restrictions such as a limited beam length and a limited mass thickness (20 µm). This results for example in a poor stiffness in the direction of the electret. The electret voltage has to be limited to 50 V to prevent pull-in in this direction. The designed prototype has a total length of 2.4 mm and a width of 1.1 mm, occupying a surface of about 2.65 mm_. In this area two times 255 comb-pairs are realized to obtain two capacitance of 0.6 pF. The maximum displacement is fixed to 25 µm by stoppers, to obtain an 83% capacitance swing. The gap between the 2 µm wide fingers is 2.2 µm, whereas the overlap between the fingers is 30 mm. The beams that act as springs have a meandering structure to reduce and linearize

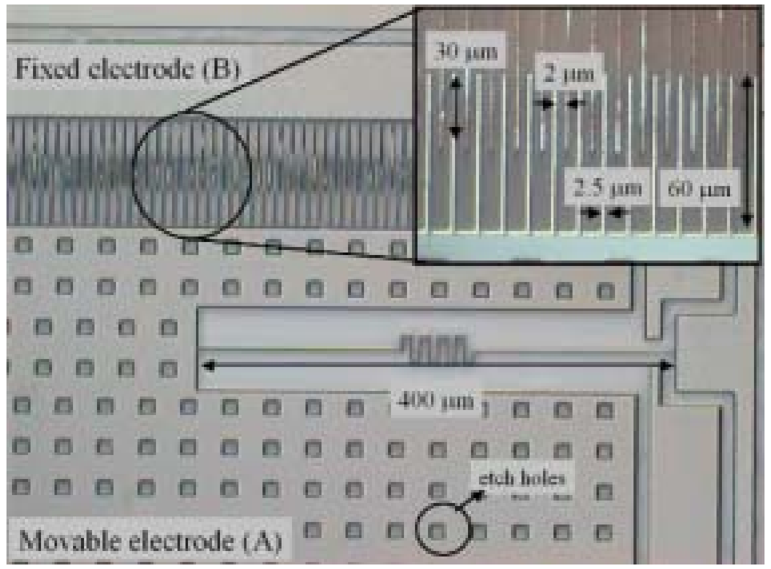

Figure 3.The prototype device.

the spring constant. The prototype device has a resonance frequency of 980 Hz and is expected to generate 1 µW when an external vibration of 0.1 µm is applied.

Several innovative concepts were proposed in the design of electrostatic vibration scavenger devices: a two-wafer device with two complementary variable capacitors and an electret layer to polarize the capacitor, equivalent to a voltage source of 100 to 300 V. A closed-form equation was obtained for the output power, indicating power generation capabilities up to 20 µW for a 0.1 cm_ surface. A first prototype was build.

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Monolithic Step-Down Converters with On-Chip Sequencing

Power supply with simple and compact footprints

Many microprocessors and digital signal processors (DSPs) need a core power supply and an input/output (I/O) power supply which must be sequenced during start-up. Designers have to consider the relative voltage and timing of core and I/O voltage supplies during power-up and –down operations to comply with manufacturers' specifications.

By Tony Armstrong, Linear Technology Corporation

Without proper power supply sequencing, latch-up or excessive current draw may occur that could lead to damage to the microprocessor's I/O ports or the I/O ports of a supporting device such as memory, programmable logic devices (PLDs), field programmable gate arrays (FPGAs), or data converters. To ensure that the I/O loads are not driven until the core voltage is properly biased, tracking of the core supply voltage and the I/O supply voltage is necessary.

Although start-up and shutdown tracking can be implemented externally for any given DC/DC converter, the power supply sequencing requirements will vary from system-to-system. These solutions include application specific standard products (ASSPs) that can be configured via a programmable interface or by external components; programmable microcontroller-based solutions and FPGA solutions.

In its simplest form, a basic power supply sequencer will initially turn on the first supply, then wait for a specified amount of programmed delay time before it turns on the second supply, and so on. However, this type of method is not robust and could have catastrophic consequences in most systems. A basic power sequencer could improve on this approach by implementing a soft start using a fixed pattern without any feedback. The majority of applications require such a sequencer to ensure that all supplies are ramped together with the ramp rate of each tightly controlled, while simultaneously tracking each other. This method would minimize the instantaneous voltage difference between supplies, thereby reducing the likelihood of latch-up and damage to the devices.

Or, put another way, voltage tracking requirements usually specify that the voltage difference between two power supplies must never exceed a certain limit. This constraint applies at all times; during power-up, power-down and steady state operation. In contrast, supply sequencing requirements specify the order in which supplies power-up and power-down. Figure 1 shows various tracking and sequencing scenarios.

The penalty for poor tracking or sequencing is often irreparable damage to devices in the system. FPGAs, PLDs, DSPs and microprocessors typically have diodes placed between the core and I/O supplies as a component of ESD protection. If supplies violate the tracking requirements and forward bias the protection diodes, the device may be damaged.

Forward biasing internal diodes, whether protection diodes or other diodes inherent to the CMOS process, may trigger latchup destroying the device. In other cases, when the I/O supply rises before the core supply, undefined logic states in the core can cause excessive current in the I/O circuitry. Even when the individual

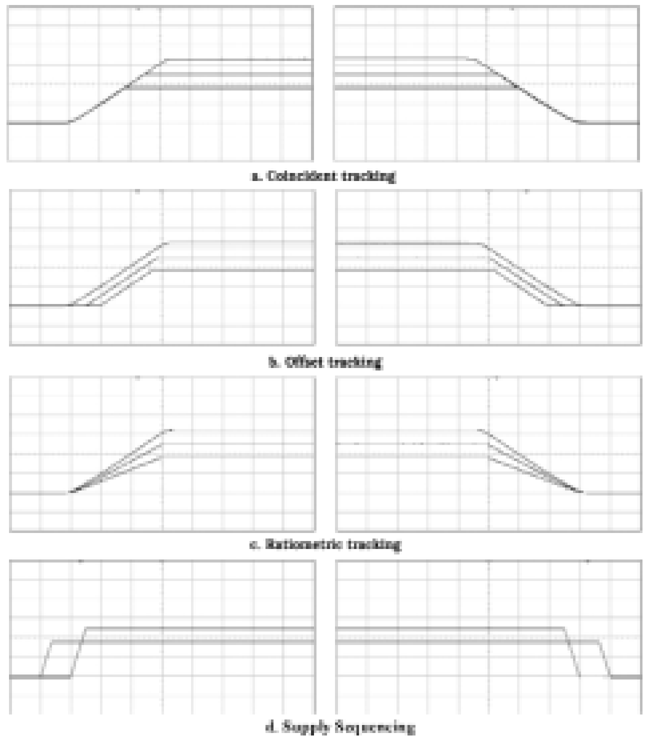

Figure 1. Types of Power Supply Voltage Tracking.

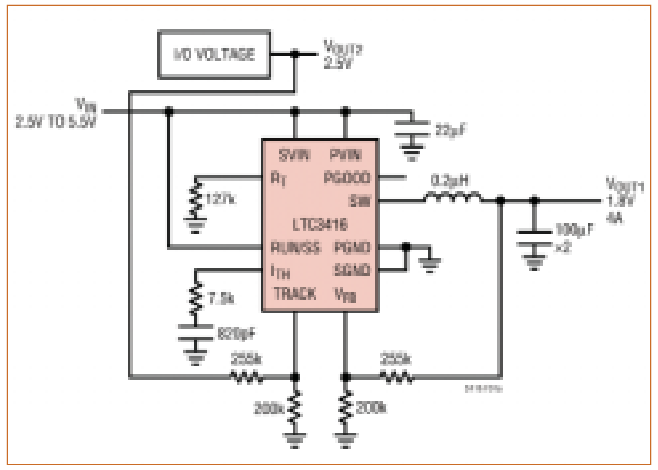

Figure 2. A 2.5V to 1.8V at 4A Step-Down Regulator with Tracking.

components of a system do not require supply tracking or sequencing, the complete system may require it for proper operation. For example, a system clock may need to start before a block of logic is powered.

One of the more important factors to consider when selecting a particular solution for any given application is the method to control ramping. In terms of the ramp rate, there is a trade off. That is, the power supply must be in regulation within the minimum time required by the device and overall system; but the faster the ramp, the greater the strain on the decoupling capacitors. By selecting a sequencer that allows programming of the ramp rate, the designer can optimize this trade-off, minimize component costs and increase reliability. Finally, the precision with which the power sequencer can control the ramp rate is also a key consideration.

Linear Technology has implemented on-chip tracking capability to allow for a simple and effective means to provide power supply sequencing. One such example is the LTC3416. The LTC3416 is a monolithic, constant frequency, current mode step-down converter with a frequency range of 300kHz to 4MHz that allows easy power supply sequencing. The forced continuous operation allows the LC3416 to maintain a constant frequency throughout the entire load range, making it easier to filter the switching noise and reduce the radio frequency (RF) interference, which is very important in electromagnetic interference (EMI) sensitive applications. Furthermore, the LTC3416 operates from an input voltage range of 2.25V to 5.5V and can generate an output voltage between 0.8V and 5V, as shown in Figure 2.

Applying a ramp voltage to the TRACK pin of the LTC3416 enables voltage tracking. When the voltage on the TRACK pin is below 0.8V, the feedback voltage regulates to this tracking voltage. When the tracking voltage exceeds 0.8V, tracking is disabled and the feedback voltage regulates to the internal reference voltage.

Tracking is implemented by connecting an extra sense resistor divider to the I/O supply voltage. The ratio of this divider should be selected to be the same as that of the LTC3416's feedback resistor divider. The circuit shown in figure 1 shows a 1.8V step-down DC/DC converter tracking an I/O supply voltage of 2.5V. This circuit operates from an input voltage range of 2.25V to 5.5V and provides a regulated 1.8V output at up to 4A of load current.

The LTC3416 with its tracking ability is well suited to applications involving microcontroller-based circuits with dual supply architectures. Its high switching frequency and internal low RDS(ON) power switches enable the LTC3416 to provide a small solution size with high efficiency for systems with power supply sequencing requirements.

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Modular Technology Concepts for Converters

Optimised to serve 42/14V DC/DC Automotive

The increasing demand for electric power has resulted in a shift from 14V to 42V system voltage in automobiles. Due to the complexity of automotive systems this transition goes through an intermediate step of having a dual 14V/42V powernet. This provides an opportunity for a high volume application of power electronic converters [1]. However, the requirements on power electronics in automotive applications are rather harsh.

By Jelena Popovic and Braham Ferreira, Delft University of Technology; Rob Cornelissen, Betronic Hybrid Circuits and Eberhard Waffenschmidt, Philips Research Laboratories

The automotive market is highly cost driven which sets boundaries on technologies that can be used to build power electronic converters. On the other hand, power electronic converters are intended to operate in the engine compartment which sets rigorous temperature and size restrictions. The present practice of constructing power electronic converters meets none of these requirements.

Power electronic converters are still primarily discrete components assemblies. Each discrete component beside the part that does the main electrical function has in itself a number of parts for electrical interconnection with the outside world, mechanical support, protection and insulation. Furthermore, each component has to take care of its own thermal management. These components are assembled to make a power electronic converter, again using a number of parts to ensure the integrity of the converter assembly. If all the constructional parts in the converter are added up, one can end up with a number that is 5 times higher than the number of components in the circuit assembly. All these parts have to be manufactured and assembled which makes the total cost of manufacturing a converter high. These parts also take up volume, which makes the overall converter unacceptably big for the restricted space in the engine compartment. The thermal management parts of all the components in the converter have to be packaged together on the assembly level. This results in a bulky and inefficient thermal management structure. All these reasons make it clear that the current practice of constructing converters is not satisfying and new concepts must be sought after.

In order to improve construction of power electronic converters, it is necessary to look deeper than discrete components we assemble with [2]. Hence, a typical converter is taken apart down to its basic constructional parts: functional elements—parts that perform fundamental functions (electrical and thermal) and packaging elements—parts that perform packaging functions (electrical interconnection, insulation, mechanical support, heat removal and protection). Typical functional elements are: power and IC dies as semiconductor functional elements, metallized film roll as capacitive functional element, wire or planar copper conductors and magnetic core as magnetic functional elements. Typical packaging elements are: semiconductors lead frames, components leads, cases, bobbin, PCB dielectric etc. Now the question is: once the converter is stripped down, how can it be put back together in a better way, with fewer constructional parts and manufacturing processes? This can be achieved by integration.

Three levels of integration: Modular integration

In order to achieve a cost-effective construction it is desirable to use commercially available technologies that lend themselves to mass production. The main drawback of the majority of these technologies is their limits in power level. Hence, in order to achieve the desired power rating, a number of converters implemented in these technologies are to be connected in parallel.

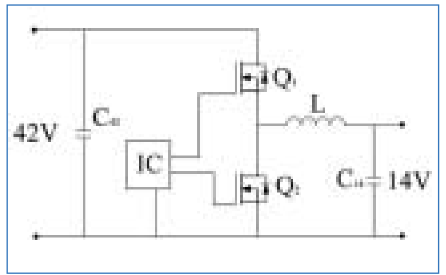

Figure 1a.

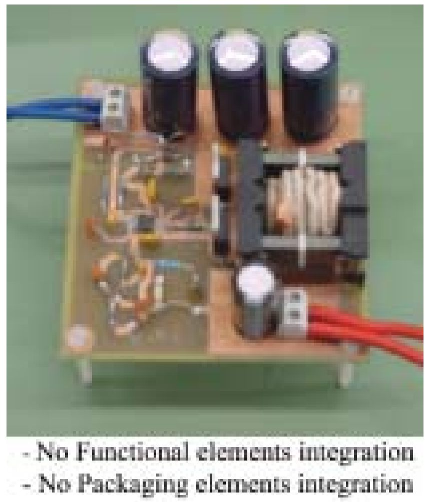

Figure 1b.

Figure 1a and 1b: DC/DC 42/14V converter in conventional discrete technology.

Each module is designed to have a good thermal management and effective spatial design.

Functional elements integration

Looking at the converter breakdown, the logical start would be to start with functional elements. Fewer functional elements means fewer packaging elements needed to "serve" them. One way is to integrate a number of functional elements into one as it is done with monolithic semiconductor integration or electromagnetic integration of passives. This brings benefits in size reduction. Another way is to construct a number of functional elements in one integration technology (thick film, LTCC etc.). This brings cost reduction due to fewer manufacturing processes.

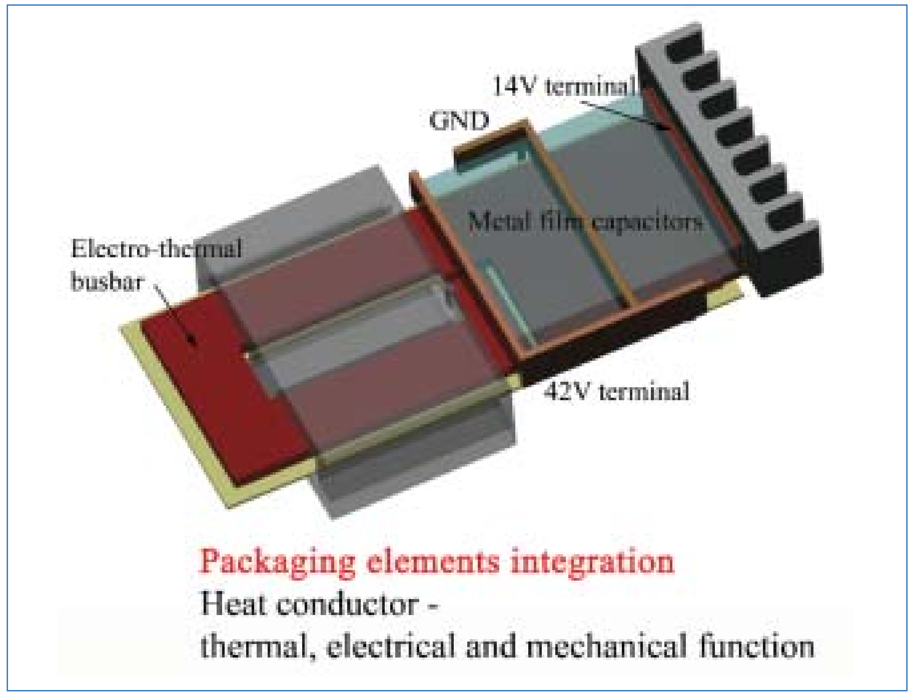

Figure 2a.

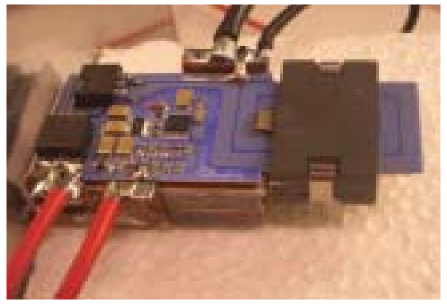

Figure 2b.

Packaging elements integration

Functional elements integration has its limits such as electromagnetic, manufacturing, economic etc. These limits determine how far this type of integration can be pushed. Once it reaches these limits we are left with a number of functional elements that have to be electrically interconnected, mechanically supported and protected in order to make the functional assembly. Instead of packaging each functional element separately as it is done in discrete components they can be packaged together for e.g. using common housing, shared heat path and the same electrical interconnecting process. A typical example of packaging elements integration is a power module.

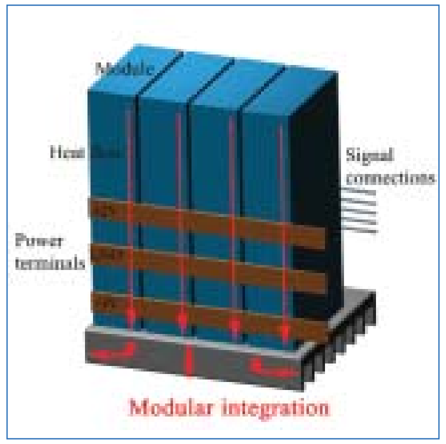

Figure 2c.

Figure 2a, 2b and 2c: Heat conductor converter.

Novel concepts with higher integration level

A DC/DC, 42/14V@15A converter in synchronous buck topology (Figure 1a) is implemented in a number of concepts using functional, packaging and modular integration. Two of them will be presented here. Figure 1b shows this converter built in conventional technology, on a standard double-sided PCB, with discrete components, a wire-wound inductor and discrete thermal management.

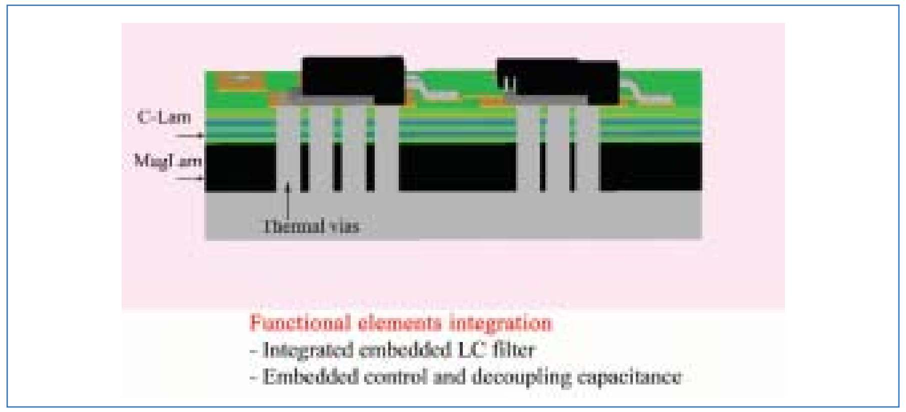

Figure 3a.

Figure 3b.

Figure 3a and 3b: PCB embedded converter.

This results in large numbers of functional and packaging elements.

Heat conductor converter

Figure 2a shows the converter conceptual design. The converter is assembled on a ceramic carrier. A thermal busbar is glued onto the bottom side of the ceramic with an electrically conductive silver-based adhesive with high thermal conductivity. This busbar collects the heat from the inductor windings, magnetic core and power MOSFETs and delivers it to the heat sink. Since the thermal busbar is made of highly thermally conductive material such as copper it can also be used as electrical interconnection. It also provides mechanical support for the circuitry. The inductor winding consists of two parts. The first part is integrated in the ceramic metallization while the electro-thermal busbar forms the second, one-turn part. It also acts as the 14V terminal. A planar E-I core is used to provide the magnetic path. The space underneath the ceramic is used to place the input and output low profile metallized film capacitors (PCC capacitors by EPCOS [3]) offering a potential for a high power density. Figure 2b shows the converter assembly built on a ceramic carrier (Alumina (Al_2O_3), thickness 0.635mm), metallized in thick film technology (silver palladium, conductor thickness – 55_m power conductors, 10-12_m the rest of the conductor pattern). The power MOSFETs and control circuitry are in SMD form. The prospective modular arrangement is shown in Figure 2c.

PCB embedded converter

In power electronic converters, Printed Circuit board (PCB) is mainly used for electrical interconnections and mechanical support. In the past few years in both micro- and power electronics some efforts have been put into increasing PCB functionality mainly by incorporating passive components into PCB [4]. The authors believe the integration benefits from this technology combined with the proper thermal management design will result in a converter with higher integration level and less number of construction parts and processes. Figure 3a shows the virtual design of the DC/DC converter case study implemented in this technology. The output LC filter is integrated and embedded in the PCB using embedded capacitive (C-Lam material by Isola) and magnetic layers (Ferrite powder in polymer matrix –MagLam material by Isola [5]). These materials are compatible with the standard PCB manufacturing process. The decoupling and control capacitors are also embedded. The power MOSFETs and control circuitry are implemented in SMD technology. The MOSFET drain copper pads are used for heat spreading. Thermal vias take the heat produced by MOSFETs through the PCB resulting in a heat sink embedded in the PCB. Figure 3b shows an example of a 60W off-line converter built in this technology.

In this article two novel concepts are presented that have been engineered to lend themselves to mass production using existing technology platforms achieving a high level of integration, low number of construction parts and manufacturing processes and good thermal management. The disadvantage of being limited in power level is overcome by employing a modular approach. The benefit that comes from this approach lies in standardization and potential for the cost reduction.

The authors propose that with this approach the cost-performance criteria of future power electronic converters in automotive applications can be met.

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[5] Isola, www.isola.de handling and control, into a single functional and mechanical unit. The objective of mechatronics is to increase quality and combine it with improved functionality and reduced costs. It requires a simultaneous and unprejudiced design process, evaluation of all technologies,materials and processes and a willingness to build new production structures from the separated production lines of today.

http://ee.its.tudelft.nl/epp

Elements to Achieve Automotive Power

Current switching and voltage regulation

Power Semiconductors, like low Rds(on) MOSFET, smart power switches, supply ICs and highly integrated ASSPs, are key enablers for innovation in Automotive Electronics.

By Frank Heinrichs, Infineon Technologies

Electronics have become essential to modern vehicles. From lowering emissions to saving people's lifes, or just making driving more pleasant, electronic control units (ECU) increasingly define the look and feel of individual transportation. In principle, ECUs comprise of three fundamental functions: sense – control – actuate. The optimum distribution of those functions and integration into several ICs – called partitioning – is based on a thorough cost-performance analysis and key to the commercial success of a particular ECU design.

Infineon Technologies provides the most comprehensive offering of integrated circuits that have been optimized for application specific chip sets. Dedicated technologies in silicon wafer processing as well as packaging have been developed to design optimized chip set solutions. The functionalities range from discrete power switches with and without protection and diagnosis features to highly integrated complex system ICs including sensor interface, supervision, supply, communication, and switching capabilities. As technology no longer is a barrier to integration level or complexity of ICs, the "gap" in complexity between power ICs and µ-Controllers will soon be closed by embedded Power (ePower) products.

Following the general automotive trend of replacing mechanical and hydraulic systems by electrical systems, power steering for example, the amount of MOSFETs used in automotive applications will increase. This fact is even boosted by the introduction of emergent high current applications such as starter alternator (14V and/or 42V) or electronic turbocharger - two applications helping to reduce the fuel consumption and thus the CO_ emissions.

For these applications the reduction of the on state resistance Rds(on) of a MOSFET is a key factor to minimize the power losses and thus increase the efficiency of the load control (mainly high current motors). The design of Infineon's latest automotive trench MOSFET technology OptiMOS-T is optimized for this Rds(on) reduction. A 55V OptiMOS-T can achieve a maximum Rds(on) as low as 2.7mOhm. OptiMOS-T will be available in a "green package" for compatibility with the lead free solder process.

Parameter	Symbol	BTS 5240 L BTS 5240 G BTS 5440 G	BTS 5241 L BTS 5241 G BTS 5441 G	BTS 5234 L BTS 5234 G BTS 5434 G	BTS 5230 GS
Package		P-DSO-12 P-DSO-20 P-DSO-28	P-DSO-12 P-DSO-20 P-DSO-28	P-DSO-12 P-DSO-20 P-DSO-28	P-DSO-14
Operating voltage	$V_{bb(on)}$	4.5 ... 28 V	4.5 ... 28 V	4.5 ... 28 V	4.5 ... 28 V
Over voltage protection	$V_{bb(AZ,min)}$	41 V	41 V	41 V	41 V
On-state resistance	$R_{DS(ON,max)@25°C}$	25 mΩ	25 mΩ	60 mΩ	140 mΩ
Nominal load current	$I_{L(nom)}$	5.7 A 5.4 A 5.6 A	5.7 A 5.5 A 5.6 A	3.5 A 3.3 A 3.4 A	2.1 A

Figure 1. Infineons ProFET product family featuring the latest Smart SIPMOS technology generation.

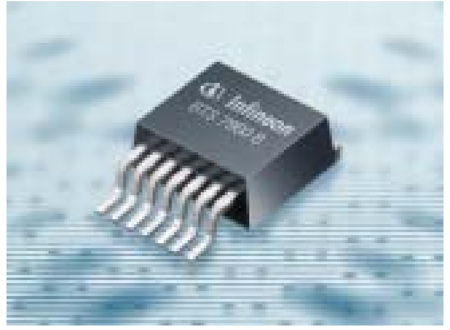

Figure 2. The BTS 7960B is a 40A, 20kHz half-bridge for motor-applications.

Especially in automotive, power switches require additional features like protection against load- and supply failures and the diagnosis of the failure. This requires extra circuitry to drive and protect the MOS-FET. For this kind of application, Infineon Technologies offers the product families TempFET, HitFET and ProFET. In these products, the MOSFET itself and the external circuitry is integrated into one device with the help of the dedicated Smart SIPMOS technology. The latest generation of this technology was launched recently with the release of a new ProFET family.

These new ProFETs are multi channel high-side power switches for automotive applications, using n-channel vertical power MOS-FET with a charge pump. They provide embedded protective functions and an enhanced IntelliSense output which provides a sophisticated diagnostic feedback signal including current sense with high accuracy over a wide load current range and open load diagnosis.

An increasing number of applications in automotive require the actuation of electric motors. The motor currents range from below 1A up to 100A and more. The applications range from comfort functions like window-lift or mirror positioning to powertrain applications like throttle control and automatic gear shift.

For motors with currents below 10A, Infineon Technologies offers a range of integrated H-bridges from generic, easy-to use H-bridges such as the TLE 4207G up to more sophisticated products like the SPI-controlled 6-fold half-bridge TLE 6208-6G, or the 7A power H-bridge TLE 7209-2R.

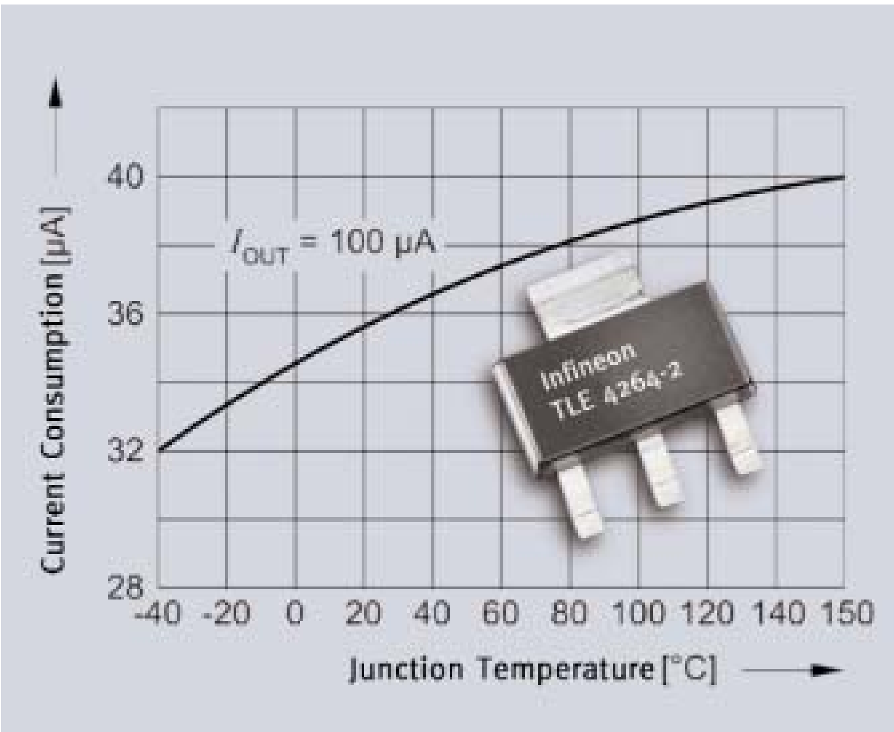

Figure 3. The TLE 4264-2 Voltage Regulator with only 40µA current consumption is Infineons solution for lowestquiescent current applications.

For the current range of up to 25A, Infineon Technologies offers the TrilithIC family. These products use a multi-chip approach with a split lead frame which allows the use of vertical power MOS technologies like Smart SIPMOS and OptiMOS, resulting in low ohmic and cost effective solutions down to 50mOhm path resistance. Given the protection and diagnostic functions as well as the small package outlines, this product family is successful especially in applications like door lock, mirror flap and power seat.

IFX is currently setting up a new product family of multi chip motor-drive devices for the current range of 15 to 40A, called NovalithIC. This new concept, combining a n-channel low side MOS and p-channel high side MOS together with a MOS-FET gate driver in one D_-Pak, enables IFX to offer low ohmic, fast-switching half bridges in combination with short-circuit protection and current sense features. These devices are ideal for applications that require PWM up to 20 kHz, current sense and load failure protection. The first device of this product family, BTS 7960B, offers about 10mOhm per switch. Typical applications are power window, transfer cases, wiper drives or even 3-phase motors with peak currents up to 40A.

For even higher motor currents, discrete power MOSFETs in combination with separate gate driver ICs are the solution of choice. Infineon H-Bridge and 3-Phase Driver ICs (TLE628x) were designed for those high current motors operated in PWM mode and can form an entire power stage with the addition of a few external components and OptiMOS N-Channel power MOS-FETs, thus completing the product portfolio for high end applications. Several safety functions are implemented in these driver ICs to meet the requirements of safety-critical automotive applications.

All electric applications in industrial or automotive reqiure regulated Voltages or currents, supplied by dedicated power supply ICs. The requirements for such a supply ICs differ across a wide range, driven by some key parameters like input voltage, output voltage and –current, operating temperature range and current consumption, and by additional micro controller supervisory features, such as under Voltage reset, early warning or watchdog. Infineons linear- and switched Voltage regulator portfolio offers a wide range of devices, covering all typical requirements.

Lately, current consumption has become a critical key-parameter in some specific applications, such as handheld devices and body electronic applications in cars. Why? – Let's have a look at a typical automotive application which operates while the car is parked, such as remote keyless entry. This application must always be able to unlock the car whenever activated by the remote control, even when the car is parked for weeks. Under such conditions, the current consumption of the relevant unit must be as low as possible, to avoid an dead battery at the end of the parking period. Some car manufacturers specify a quiescent current limit as low 100µA for the entire module. Infineon's state-of-the-art designs of voltage regulators have a quiescent current of typically 65µA. An example of these Low Drop Output (LDO) Voltage regulators is the TLE4299 with adjustable reset, inhibit and early warning included. Even lower quiescent currents can be achieved with TLE4264-2 and TLE4266-2 V-Regs with a typical current consumption of 40µA in ON-mode. The development of future automotive supply products is clearly driven by this trend, and Infineon will continue moving ahead with new innovative approaches.

Most of the products shown so far are more or less generic, addressing a number of different applications, even if a specific application was the motivation when originally designing the part. However, in many areas of automotive electronics, application specific solutions with a high level of integration have been established. Specific ICs cover all power functionalities like communication, supply, current- and Voltage regulation and switching. Infineon Technologies offers a wide range of custom specific ICs as well as open-market Application Specific Standard Products (ASSPs) and standard chipsets for various automotive applications like door-modules, body controllers, engine management, ABS and airbag ECUs.

To conclude, a large variety of products is necessary to match the requirements of automotive electronics in terms of features, cost and quality. Infineon Technologies is a leading supplier of automotive power semiconductors, meeting those demands with its broad portfolio, innovative technologies and high quality standards.

www.infineon.com/power

Tiny Silicon Sensors Tackle Industrial-Strength Current Measurements

Consider magnetoresistive current sensors

Portable electronics is one of today's prime drivers in semiconductor development. And just about every portable demands some form of power management, for functions that range from battery charging to power metering.

By Alan Buxton, Zetex

As a result, you can choose from a number of integrated-circuit current monitors to perform what's rapidly becoming—after temperature—the second commonest electronic measurement. But what you may not realise is that some of these devices are sufficiently robust to tackle automotive and industrial applications, while retaining tiny surface mount outlines and their consumer-market cost advantage. Simply adding a resistor and a Zener to a commodity IC can protect against high-voltage transients, reverse-polarity operation and automotive load dump conditions.

A classic method for monitoring current inserts a sense resistor in the power-supply return line. In applications such as AC-line current sensing, this arrangement often works well. Sensing in the neutral line avoids high common-mode voltages, and for either AC or DC circuits, refers the measurement to "ground" potential, which—notionally at least—simplifies the measurement circuit. However, locating the sense resistor to reflect the load current of interest can be difficult if there are multiple circuits on a spur. Worse, if you have to interconnect signals between circuit blocks, an offset voltage is present that varies with each circuit's dynamic load current. This offset may be acceptable with some digital circuitry, but will create measurement errors between analogue signals.

Because the sense resistor is low-value to minimise power dissipation, it's almost always necessary to amplify the sense voltage. In equipment that has only positive supply rails, you'll need an op-amp with a common-mode range that encompasses ground. The performance of such "rail-to-rail" devices typically declines as the input signal approaches either supply rail. If you're forced to choose a rail-to-rail op-amp, there are two types—rail-to-rail input, and rail-to-rail input/output. The first has an input stage that accommodates common-mode voltages that sometimes exceed either power-supply rail; the second adds a driver stage that comes within millivolts of either supply rail. The penalty for a wide-ranging input stage is often an impedance change towards the rail voltages, as the transistors that provide most of the working range cut off, and a second set optimised for close-to-rail operation takes over. This can create non-linearity in the crossover region. Rail-to-rail output capability comes from the relatively high-impedance collectors of the output-driver transistors, limiting bandwidth, gain, and possibly introducing stability issues.

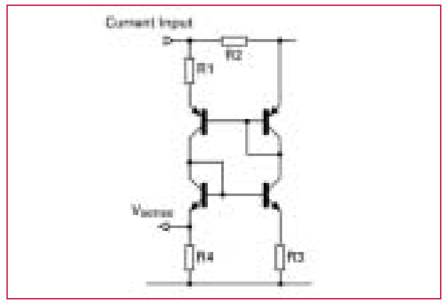

Figure 1. A current mirror eases high-side current measurements and provides a ground-referenced output.

A better way that more naturally suits most applications replaces the sense resistor in series with the load's positive supply rail. This eases monitoring individual loads, and removes the ground-offset problem. However, the amplification issue remains, and it's now almost invariably essential to refer the high-side sense voltage to ground. One solution that's similar to many low-side-sense circuits employs an instrumentation amplifier to measure the differential voltage across the sense resistor. This amplifier is subject to the same common-mode performance constraints as its low-side equivalent. If built from discrete op-amps, the circuit requires a number of matched gain-setting resistors to preserve accuracy. You may also need to consider biasing and offsetting the input signal to scale the output to the desired level.

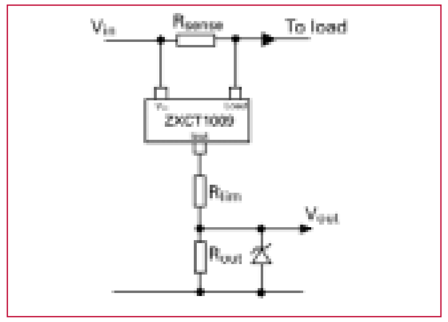

Figure 2. A current-limiting resistor and an optional Zener clamp protect sensitive inputs from line-borne transients.

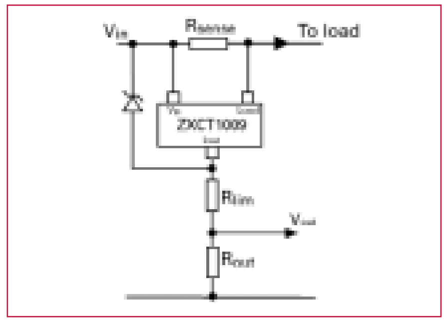

Figure 3. Another Zener provides the current-mirror IC with overvoltage and reverse-voltage protection.

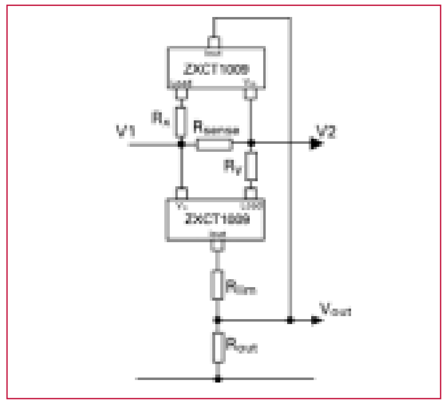

Figure 4. Two back-to-back current mirror ICs enable bidirectional measurement ability.

Another method employs matched transistor pairs to create a current mirror that drives a ground-referred resistor (see Figure 1). Here, the voltage that develops across sense resistor R2 causes a balancing current to flow in R1. Assuming ideal components and that R3 equals R4, the transfer characteristic becomes V_{sense} times R4/R1. Thus, you can easily scale the ground-referenced output.

Because transistors on the same silicon slice match well, figure 1's circuit suits integration. It appears in the first-generation ZDS1009 from Zetex Semiconductors. Later products, such as the ZXCT1009, extend the concept and dispense with the need for accurately matched resistors. This device has a typical accuracy of 1%, an input voltage range from 2.5V to 20VDC and an operating range from –40°C to +85°C. Bandwidth is as much as 2MHz for a 100mV sense voltage. Theoretically, a translation circuit with a fixed offset voltage of 1mV and a 100mV sense voltage has a best accuracy of 1%. Because accuracy is generally dependent on the ratio between sense voltage and the IC's input offset voltage, alternative devices are available to suit different sense voltages.

The ZXCT1009's SOT-23 package and 4uA quiescent current suit portable operation, but the application simplicity, versatility, and ruggedness of such devices promote operation in tougher environments. Adding a current-limiting resistor and a Zener protects sensitive A-D converter inputs from powerline transients (see Figure 2).

As a guide, a limit resistor value of around 3kW protects against millisecond-duration transients of as much as ±130V. Alternatively, a Zener across the device's voltage input and current output terminals guards the IC against both overvoltages and reverse polarity events (see Figure 3).During an overvoltage, the Zener conducts to maintain a safe voltage across the device. The current-mirror nature of the circuit means that the IC's transistors will be forward-biased if subjected to reverse polarity operation, but the Zener again conducts to preserve the device.

The ZXCT1009 is a three-terminal circuit that lacks a separate ground connection, so it's possible to "float" the device and accommodate input voltages over its normal 20V limit—simply insert a Zener in series with the ground-reference resistor. Other devices are available in a five-pin SOT-23 package with ground connections, which maximises accuracy by removing quiescent current flow from the measurement circuit. More surprisingly perhaps, it's also easy to create a bidirectional current-sensing circuit by connecting two devices back-to-back (see Figure 4).

If V1 is greater than V2, the lower device is active and the upper device is cut off—and vice-versa. This works fine for sense voltages below about ±500mV, above which level resistors Rx and Ry are necessary to limit device forward-bias current to about 1mA. Because only one device is active at any time, you can use a single ground-reference resistor, or choose two resistors to separate positive and negative cycles.

To choose the output scaling resistor divide the required output voltage signal by the output current from the ZXCT1009 for the given sense voltage. Commodity 0603 size parts are fine as there will be no power dissipation concerns. The sense resistor can be more challenging, especially at higher currents. A sensible value of R_{sense} should be chosen to give an adequate V_{sense} value, while ensuring the dissipation of the current sensing resistor is kept to a minimum. Sometimes, the power dissipation of a series resistor is unacceptable, or it's impossible to insert components in series with a power feed. But if you can get alongside a conductor, consider magnetoresistive current sensors that alleviate insertion loss issues. Typically, magnetic current sensors are insensitive, but the Zetex ZMC devices cover the 5-to-20A range without requiring current-amplification cores. They are more expensive than resistive sensors, have a bandwidth that's limited to about 100kHz, and are linear to within only some 12%. However, these devices are sensitive to both AC and DC currents, and their galvanic isolation enables measurements that may otherwise prove impossible.

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Energy Measurement ICs Make Feature-Rich Meters

ICs allow all-electronic energy meters easy to design

Today's electricity companies are demanding more information from meters in the residential sector where metering has typically been limited to kilowatt-hours. New features such as multi-tariff billing, reactive energy measurement, and power quality monitoring are desirable to improve generation, distribution, customer service and billing.

By Rachel Kaplan, Analog Devices

Electro-mechanical meters have been the standard for metering electricity since billing began. In order to accommodate the advanced requirements not available in electro-mechanical meters, manufacturers have begun adopting all-electronic solutions. New energy measurements ICs (integrated circuits) are enabling accurate, dependable, and robust meters with all the bells and whistles.

Analog Devices has extended its expertise in high performance analog to digital converter (ADC) design to revolutionize electronic energy meters. The new ADE (Analog Devices Energy) measurement IC's combine high accuracy ADCs with fixed function digital signal processing (DSP). The products interface directly with current and voltage sensors and perform the calculations necessary for metering. A Serial Port Interface (SPI) on the ADE products enables communication with a small microprocessor to control the functionality, perform digital calibration, and read the results of the measurements. Meter designers can now spend far less time developing algorithms in their micro-processors, and solutions with higher-level functionality can be deployed in shorter time.

The newest energy measurement IC are the ADE7753 and ADE7758 which combine proprietary energy measurement technology with high performance ADCs to offer the most extensive feature set available today in a metering IC.

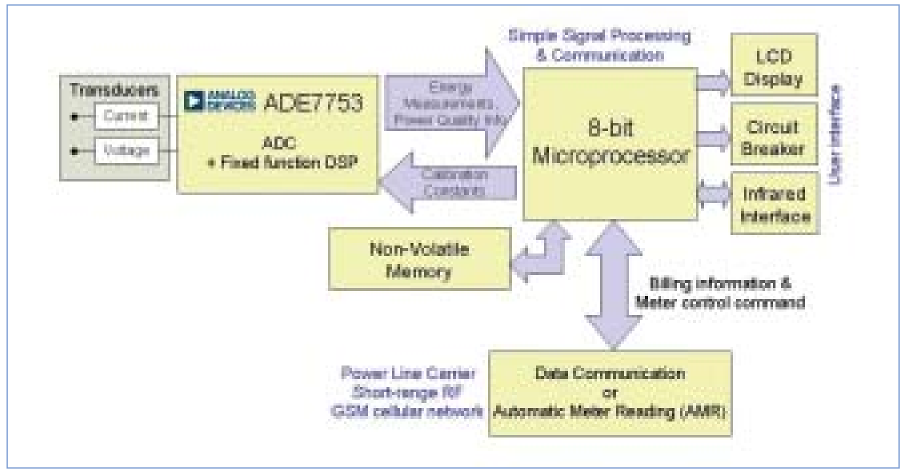

Figure 1. Block Diagram of All-Electronic Energy Meter using ADE7753.

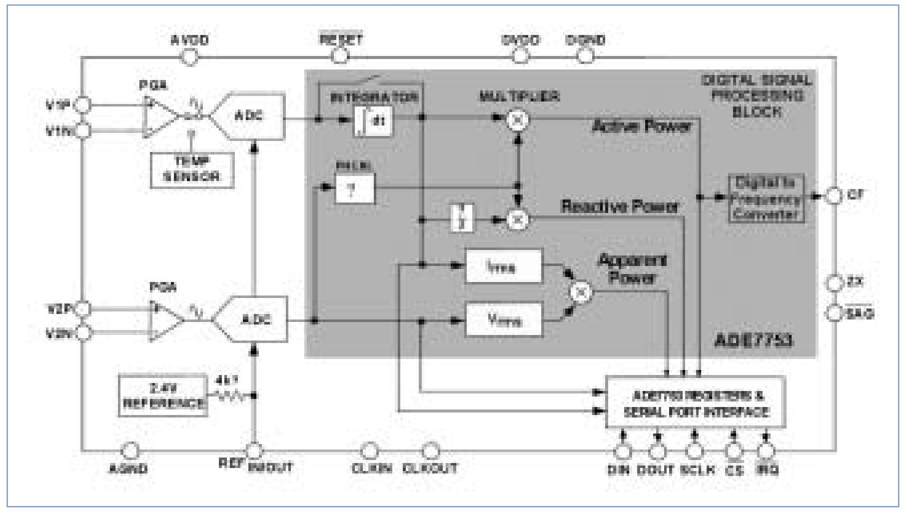

Figure 2. Block Diagram of ADE7753

The ADE7753 and ADE7758 give designers freedom to choose from a variety of current sensors: shunts (ADE7753 only), current transformers (CT) or Rogowski coils. For low current single phase meters, the programmable gain amplifier (PGA) allows a small, low-cost shunt to be connected to the ADE7753. In higher current meters, poly-phase meters and where line isolation is required, CTs with burden resistors are most common. The phase calibration register can be set up to correct for phase shift introduced by the CT. Rogowski coils output a voltage signal proportional to the time derivative of the current (di/dt). The ADE7753 and ADE7758 have a selectable digital integrator for use with this sensor type to convert the signal back to I(t) for further processing.

Household loads are not exclusively resistive and utilities want to recover revenue lost due to the inductive and capacitive loads unaccounted for in KWh-only billing. Utilities are increasing metering requirements to include VA and VAR-hour outputs, four-quadrant billing, and power factor information. The ADE7753 and ADE7758 address these advanced needs, by providing signed registers for active, apparent, and reactive energies for all phases individually.

Accurate reactive energy measurement is achieved through a low pass filtering method. Traditional time-delay and power triangle methods for calculating reactive energy rely on assumptions that the current and voltage signals are perfect sinusoids at the fundamental line frequency. The low-pass filtering method reduces the error in reactive energy calculation when harmonics are present on the line. Additionally, frequency compensation using the ADE7753 and ADE7758's period measurement feature lessens error due to variations in line-frequency. Apparent energy is calculated inside the ADE7753 and ADE7758 by multiplying the Vrms and Irms measurements. The RMS values of the current and voltage signals are available in the registers.

The ADE7753 has an optional accumulation mode, which will accumulate energy only when the sign of the power is positive. This "positive only accumulation mode" is required in the UK and results in billing only for imported energy and not for energy exported by the customer. Additionally, a selectable indication shows when the direction of power flow changes.

In noisy environments, meters can register additional kilowatt-hours by accumulating the small noise resulting in "creep" and over-billing. The ADE7753 and ADE7758 internal "No-Load threshold" prevent the accumulation of this noise.

The ADE7753 and ADE7758 have sag detection, which monitors the line voltage. When the power supply begins to drop, the IC provides a warning to the microprocessor so that the last value of the energy registers can be stored in the non-volatile memory. In this way, energy accumulation is not lost when power outages occur.

The ADE7753 and ADE7758 exceeds the IEC62053-21 Class 1 and ANSI Class 0.2 meter specifications with 0.1 % linearity error for active energy accumulation over current dynamic range of 1000:1 (typical). The design also accommodates the IEC62053-23 for Class 2 VAR-hr meters.

The ADE7753 and ADE7758 take advantage of automated digital calibration for excellent long-term stability. This calibration does not rely on mechanical gears that wear out over time. The one-time digital calibration can be automated by programming the microprocessor to calculate the calibration constants. Once the gain, offset and divider constants are determined, they are stored in the non-volatile memory. When power outages or voltage sag events occur and are resolved, the meter can reload the calibration constants to the ADE7753 or ADE7758 from the memory.

A calibration pulse output (CF) displays a frequency proportional to active energy. During production, CF may be monitored under a test load and compared to the expected impulses/kWh to verify calibration. A similar test may be performed in the field to prove a meter's accuracy. Meters that must operate in harsh environments can take advantage of the ADE7753 and ADE7758's temperature sensor for additional compensation.

Power quality monitoring has traditionally been reserved for industrial customers. Today even residential customers are sensitive to the changes in

Meter Type	Part Number	Key Features/Output Parameters
ADE Products with Pulsed Outputs only		
Single Phase	ADE7751	Hardware Calibration + Anti-tamper (watt only)
	ADE7755	Hardware Calibration (watt only)
	ADE7757	Hardware Calibration (watt only) with integrated oscillator
	ADE7760	Hardware Calibration + Anti-tamper (watt only) with integrated oscillator
	ADE7761	Hardware Calibration + Anti-tamper (watt only) with integrated oscillator + missing neutral billing
Polyphase	ADE7752	Hardware Calibration (watt only)
ADE Products with Serial Interface		
Single Phase	ADE7753	Software Calibration (watt + VA + VAR + V_{rms} + I_{rms}) with di/dt integrator
	ADE7756	Software Calibration (watt only)
	ADE7759	Software Calibration (watt only) with di/dt integrator
	ADE7763	Software Calibration (watt + VA + V_{rms} + I_{rms}) with di/dt integrator
Polyphase	ADE7754	Software Calibration (watt + VA + V_{rms} + I_{rms})
	ADE7758	Software Calibration (per phase watt +

Figure 3. ADE Product Selection Guide.

power quality. With the ADE7753, a low-cost residential meter can also monitor power quality events. With additional information utilities can make more informed decisions about generation, distribution and customer services.

The ADE7753 and ADE7758 records peak current and peak voltage levels, voltage sag events, line period, and missing (voltage) zero crossings. Additionally, the waveform register contains the digitized waveform that can be captured and reconstructed for analysis.

Many meters do not require the extensive features that the ADE7753 and ADE7758 offers. Analog Devices has an extensive portfolio of high performance metering ICs to accommodate a variety of single and polyphase meter architectures. Simple kilowatt-hour, stepper-motor counter designs can be achieved using ADE7751, ADE7755, ADE7757, ADE7760, or ADE7761 for single phase and ADE7752 for poly-phase meters. For advanced feature, LCD display meters, designers may choose the ADE7756, ADE7759, ADE7763 or ADE7753 for single phase and ADE7754 or ADE7758 for poly-phase systems.

www.analog.com

Power over Ethernet Opens New Applications

Transfer power through cat 5e ethernet cable

It is now possible to power a vast range of devices down a conventional twisted pair Cat 5e Ethernet cable and to activate – i.e. power up and down – these devices remotely. The only hardware required is some new products based on the new IEEE 802.3af Power-over-Ethernet (PoE) standard.

By Martin Schiel, Future Electronics Europe

Power over Ethernet (PoE) will enable Ethernet to expand from high speed network comms into also being a remote control and monitoring technology. It will also help eliminate cable clutter and the physical restriction of having to locate products near to power sockets, simplifying installation.

PoE will pave the way to cost effective applications such as plug&play Voice-over-IP (VoIP) phones, smart IP signs, vending and gaming machine monitoring, audio and video juke boxes, retail point of information systems, building access control and security, battery chargers for mobile phones and PDAs, and electronic instruments.

PoE products are classified into three categories: Power Sourcing Equipment (PSE) including switches, routers and hubs; 'Midspan' products used to add PoE to existing Ethernet products, and the end Powered Device – or PD – that draws its power from the Ethernet cable.

Most PoE 'technical overhead' is intentionally placed onto PSE and Midspan equipment. In operation this looks for and requires a PD signature (a 25 KOhm resistance) on a port before applying power to it. There is an optional classification that allows the PD power level to be determined as well.

PoE also does not stipulate any Ethernet PHY or MAC requirements for PDs, so there are low technical (and cost) requirements, and PDs don't even need to be Ethernet devices.

Power is transferred through a standard Cat 5e Ethernet cable via two or its four twisted copper pairs. This does not affect data transfer rates because for 10BaseT (10 Mbit/s) and 100BaseT (100 Mbit/s) Ethernet only two of the four pairs are used for data. (Note: only 1000BaseT, 1Gbit/s uses all four pairs).

PoE allows two power options for Cat 5e cables. First, as illustrated in Fig. 1, the pair on pins 4 and 5 can be connected together to form a positive supply, and the pair on pins 7 and 8 connected to form the negative supply. A late change to the PoE spec also means this pin polarity can be reversed if desired.

Alternatively, the conventional data pairs can be used (Fig. 2), as there is no physical difference in their construction.

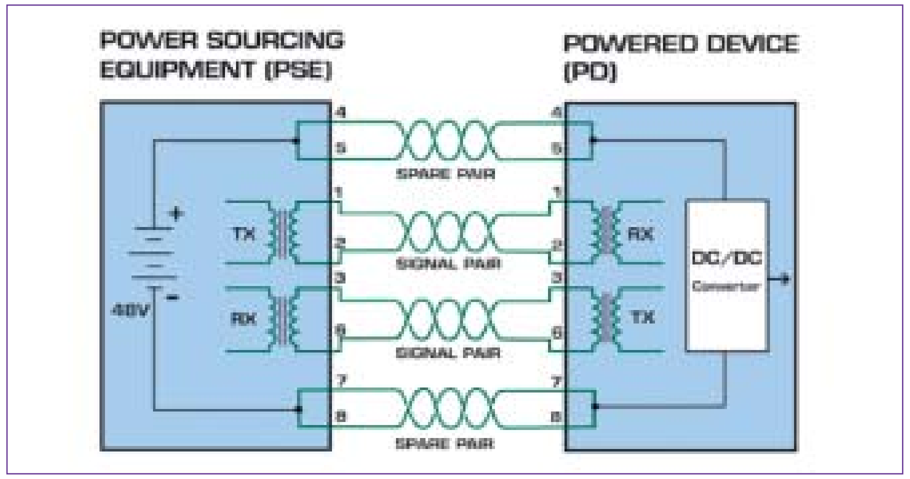

Figure 1. PoE Separated power.

POWER MANAGEMENT

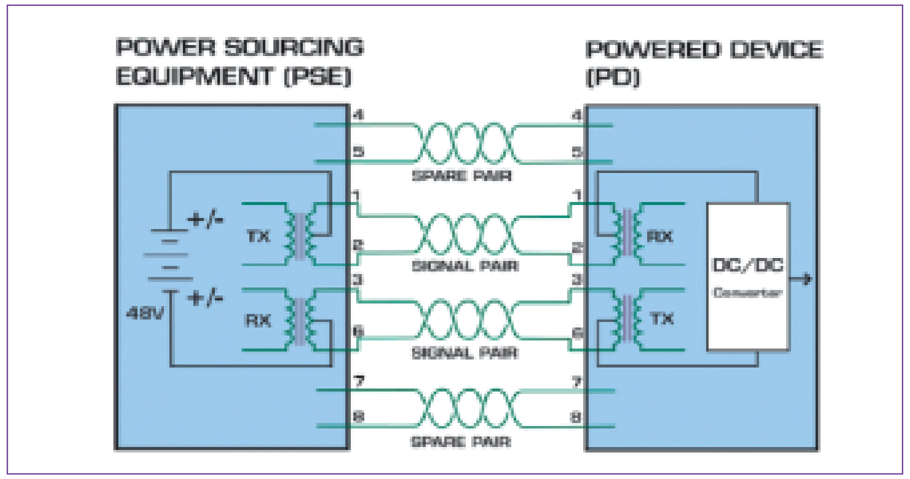

Figure 2. PoE Integrated Power.

Figure 3. The core building blocks of a PD.

Since Ethernet pairs are transformer coupled at each end, it is possible to apply DC power to the centre tap of the isolation transformer without affecting the data transfer. In this mode of operation the twisted pair on pins 3 and 6 and the pair on pins 1 and 2 can be of either polarity.

The voltage is nominally 48 V, and about 13 W of power is available at the PD. An (isolated) DC-DC converter transforms the 48 V to a lower voltage suitable for the electronics in the PD, while maintaining 1500 V of isolation for safety reasons. This isolation is necessary in case there is more than one PD connected, or the PD has a housing connected to an electrical system accessible to the end user.

Another PoE standard safety aspect prevents damage to existing Ethernet equipment. A small current-limited voltage runs from the PSE to examine the Ethernet cables and look for the signature resistance characteristic of PoE devices.

This resistance must be close to 25 KOhm and the capacitance across the power interface (PI) less than 100 nF for the full 48 V PoE voltage to be applied. It is current-limited to prevent damage to cables and equipment under fault conditions. An under voltage lockout (UVLO) for voltages over 20.5 and below 36 V is used to prevent a bad signature resistance measurement allied with a minimum 100 mA classification for the current flow.

Optionally, a classification current can be taken from the PI to indicate to the PSE the equipment's power class. The PD must also continue to draw a minimum current. If it does not (e.g. when the device is unplugged) the PSE removes the power and the discovery process begins again.

Analogue handshake circuit with classification. The requirement of this circuit is that it draws zero current below 10.1 V and a defined fixed 'classification current' between 14.5 and 20.5 V. The circuit shown in Fig. 4 (courtesy Micrel*) performs this function. The constant current is set by D1 and Q1 and a second transistor – Q3. This prevents classification current flow until VPI rises above 10.1 V (top of signature voltage) and also cancels VBE base emitter voltage variations in the current limit circuit.

The slope of the current VZENER (9.1 V) to the constant current region is proportional to Q1HFE (forward current gain) and 1/R1. The slope on top of the constant current is the additional resistance R1 in series with D1 and Q3 VBE. The equation for PI current above the Q3 turn on voltage is therefore:

$$I_{PI} = (V_{D1} – V_{CE}\,sat_{Q3})/R2 + (V_{PI} – V_{D1} – V_{BE\,Q3})/R1 + V_{PI}/25k$$

This circuit (fig. 5) uses a very low cost 100 V, 600 mA MOSFET (in a SC70 package) to isolate the load from the PI during the 'discovery' routine of the PSE (< 20.5 V). A 21 to 30 V Zener diode can be used, although to provide maximum gate drive at the lowest operating voltage of the DC-DC converter (36 V), a lower value is usually preferential.

The current limit circuit is also an additional but simple and low cost, general purpose NPN transistor and a 0805 resistor. Maximum power dissipation is $(0.4 A)^2$ x 1.5 _ = 240 mW. When the voltage across the 0805 resistor reaches the V_{BE} of the transistor, the isolation MOSFET gate is pulled low and then enters a constant current region. After 75 ms, the PSE will remove power from the port due the over current condition, therefore the transistor will not overheat.

It is important to limit the voltage at the gate to 20 V maximum. This is achieved using the resistor R4 and another resistor (not shown) from gate to source such that at 60 V the Vgs_{MAX} is 20 V. In the graph showing the switch on at 30 V and current limit at 400 mA, the Zener diode used was 24 V. Rgs is 63 KOhm, which means the implementation of the above can be done using small, cheap discrete components.

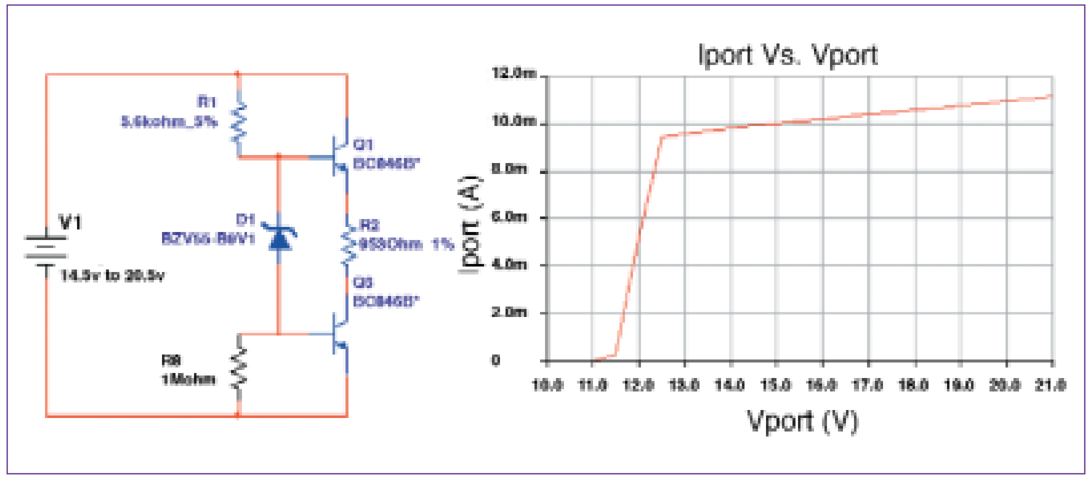

Figure 4. This circuit draws zero current below 10.1 V.

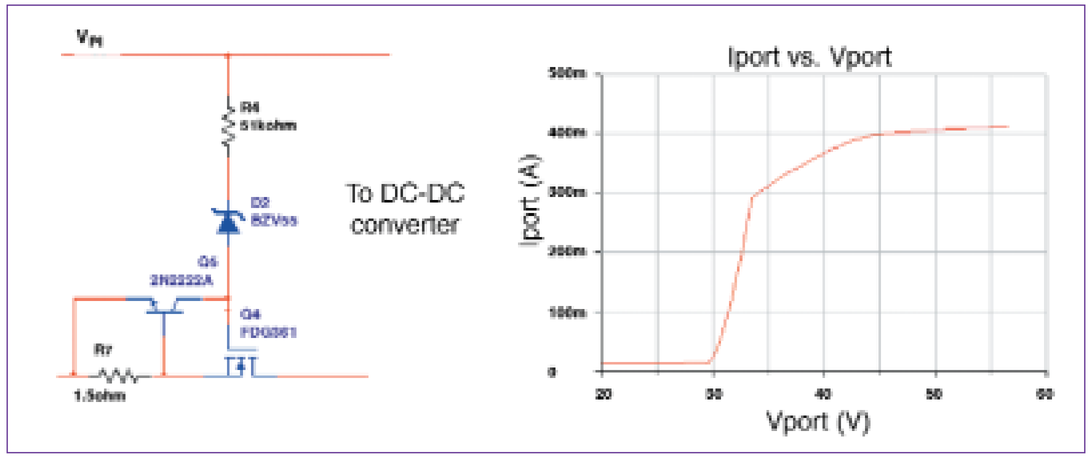

Figure 5. Current limit by general purpose NPN.

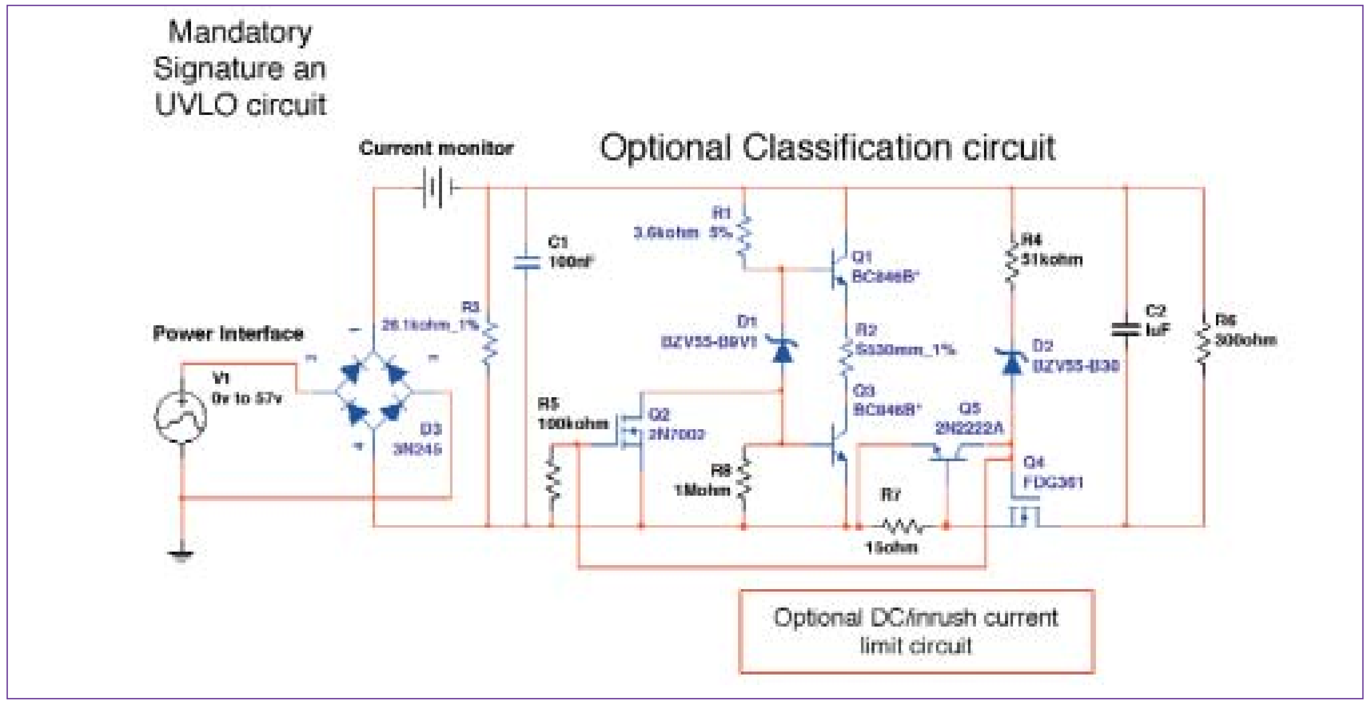

Figure 6. Complete PoE Analogue Handshake.

Figure 6 illustrates a complete PoE analogue handshake circuit (courtesy Fairchild) where classification is not required. This is a low cost design based on discrete components that is not dissimilar to that described above. A diode is used to protect against reverse currents while a voltage suppressor is used to clamp voltage spikes. The 25 kOhm signature resistor remains across the input leads consuming minimal power. The primary Zener enables load switch gate circuitry at 30 V, but an adjustable MOSFET is used as an in-line load switch with only 80 mOhm RDS_{ON}.

The previous Micrel circuit can also be modified if no classification is required. Simply remove components R1 and 2, R8, Q1, 2 and 3, and D1.

Following the classification circuit, you will typically require or find a DC/DC converter in flyback topology. This provides the required isolation and enables multiple output voltages to be generated, if required.

A National Semiconductor non-isolated solution exploits an LM5020 single ended Pulse Width Modulation (PWM). The main supporting building blocks are a switching MOSFET (Si7888), transformer and feedback circuit consisting of only a resistor divider. This can easily be transformed into an isolated version, adding an LM431, an optocoupler and a few passive components. Fairchild and Micrel both offer alternative solutions.

The enhanced technical design requirements of PoE aren't trivial but are certainly not overly onerous once understood. Yet the end application benefits are literally enormous and PoE looks set to become a huge technological success with end users.

This article gave the core technical information needed to design PoE into an Ethernet application. Sample designs and circuits from leading PoE suppliers such as Fairchild Semiconductor, National Semiconductor and Micrel Semiconductor are included. All mentioned products and full technical support are available from Future Electronics Europe.

The author would like to thank Sean Montgomery at Micrel for assistance in producing part of this article.

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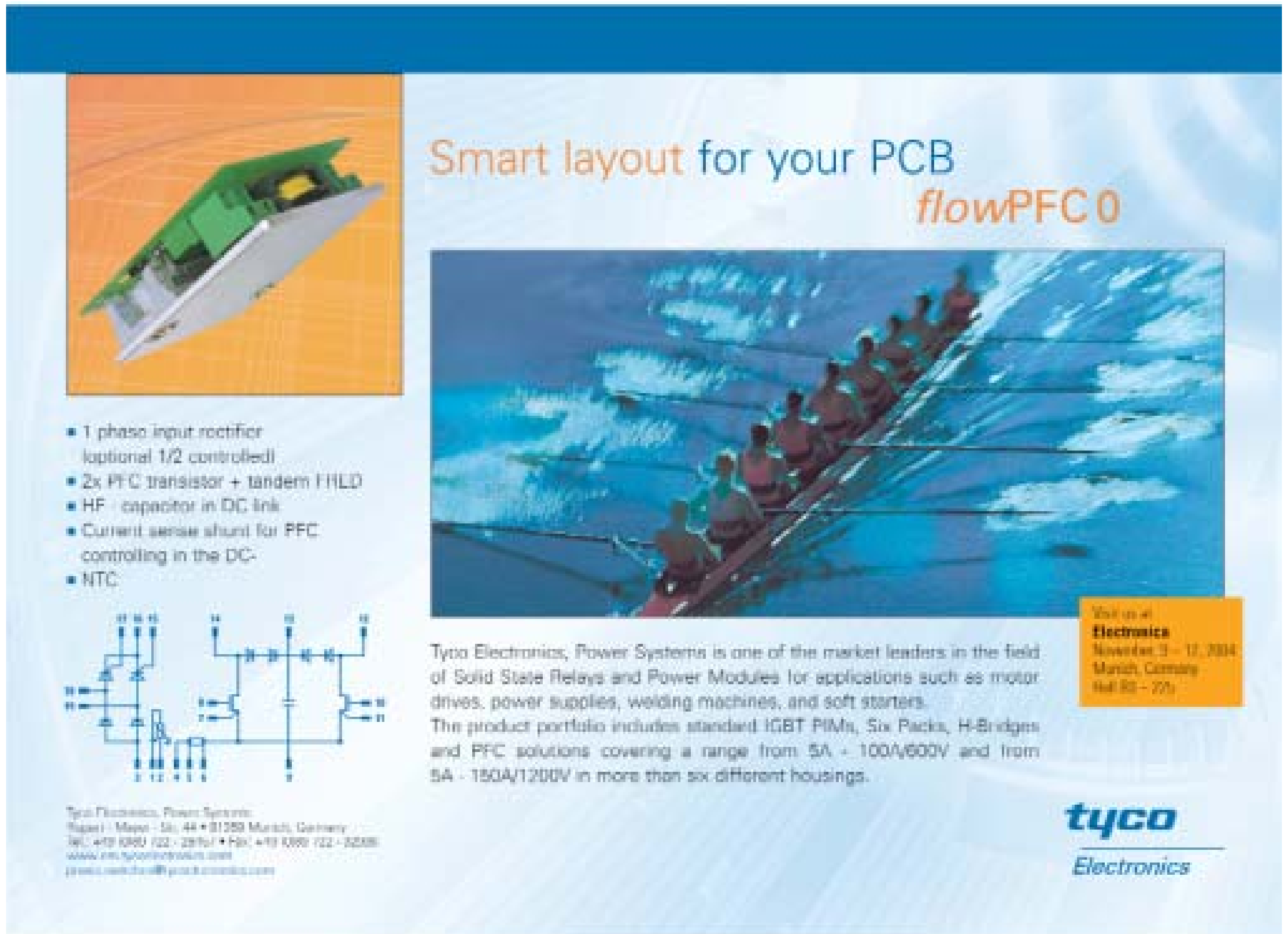


DirectFETKY DC-DC chip set boosts efficiency

International Rectifier has introduced a control and synchronous switching chip set for high-frequency DC-DC converters powering next-generation Intel and AMD processors in high-end advanced servers and desktop computers. Other applications include point-of-load (POL) DC-DC conversion in telecom and datacom systems.

The chip set pair delivers 84.5% efficiency at 90A in a four-phase 1U (1.75-in height) VRM outline system switching at 750kHz per phase and 87% efficiency at 150A in an eight-phase embedded VRD10.2 design switching at 400kHz per phase.

The first device is the monolithic IRF6691 DirectFETKY, which integrates a Schottky diode and synchronous MOSFET into a single package to enable an efficiency improvement of 1.1% at 1MHz per phase at full load compared to other existing highest-performing 20V synchronous FETs on the market when using the same control FET. The IRF6691 also features a typical RDS(on) of

1.2 mOhm at 10VGS (1.8 mOhm at 4.5VGS) and a typical Qrr of 26nC, providing the best thermal performance with lower reverse recovery losses and reduced overall part count.

The second device is the IRF6617 DirectFET HEXFET Control MOSFET. Specifically tailored for control FET switching, the IRF6617 features a very low total gate charge (Qg of 11nC), delivering a 33% reduction in on-resistance times gate charge product of 87mOhm-nC at 4.5VGS compared to previous 30V devices.

Both devices feature International Rectifier's patented DirectFET packaging technology that presents a whole new set of design advantages not previously delivered by standard plastic discrete packages. By deploying a new dual-side cooling design, the DirectFET power MOSFET family effectively doubles the current handling capacity of high frequency DC-DC buck converters powering advanced processors.

Data sheets and devices are available immediately.

www.irf.com

Smallest, Most Efficient Power Conversion IC

Smart Phones, Portable Wireless Electronics get powered by 3-MHz, 500-mA Step-Down DC/DC converter in Ultra-Small 2 mm x 1 mm Package to extend battery life.

Giving portable designers the ability to extend battery life in smaller designs, Texas Instruments announced the industry's smallest, most efficient, high-accuracy, step-down DC/DC converter for space-constrained applications. The tiny power management integrated circuit (IC) is ideal for smart phones, WLAN and Bluetooth equipment, digital still cameras and other battery powered devices. See: www.ti.com/sc04161.

Leveraging advanced analog process technology, TI's new TPS62300 step-down, 500-mA converter with integrated FETs delivers unprecedented levels of power conversion efficiency and voltage regulation accuracy from a lead-free, 2 mm x 1 mm chip scale package. The synchronous, switch-mode device achieves up to 93 percent power conversion efficiency while operating at a fixed frequency of 3-MHz.

The TPS62300 can deliver DC voltage regulation accuracy from -0.5 percent to 1.3 percent over the entire industrial temperature range. In addition, the device's excellent load transient response and flexible output voltage range of 5.4 V down to an ultra-low 0.6 V, allows it to effectively support demanding core power requirements of low-voltage digital signal processors (DSPs), multimedia application processors and communication chip sets.

www.ti.com

DC/DC-Converter for white LEDs

A driver IC for white LEDs is offered by ASIC manufacturer PREMA Semiconductor. Its core consists of a step-up converter with current output, which provides an output voltage of typically 3.6 V for white LEDs. The input voltage can be as low as 0.9V, thus allowing a. single cell battery operation.

Depending on the application the LEDs can be driven with pulsed or constant currents. The first alternative has the advantage of an optimized battery lifetime, and only a coil is required as an external component. If optimized for maximum brightness, an external Schottky diode and a capacitor have to be added.

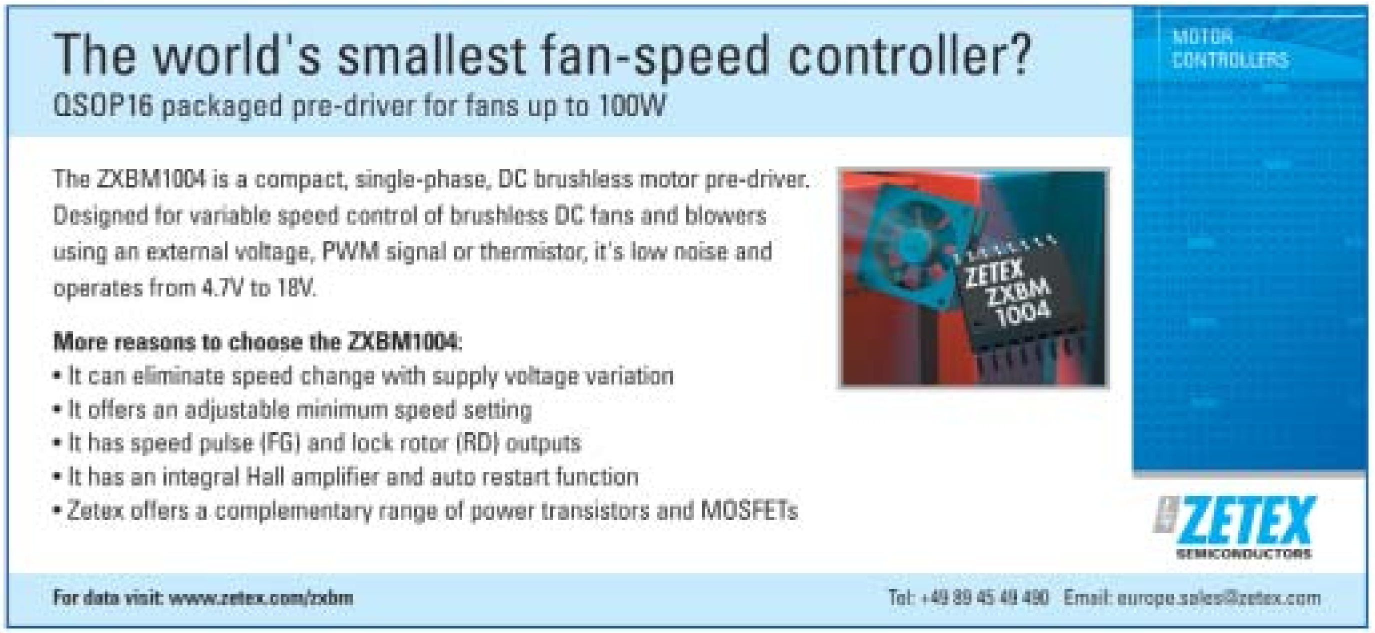
Additional features can be integrated into the ASIC on customer's request. A charge control circuit or an undervoltage detection might be desirable to avoid a total discharge of a rechargeable battery. A sensor amplifier or a digital control are other examples for additional features.

All functions necessary for a compact LED pocket torch with various extra functions, or other battery driven devices with LED illumination can be integrated into one IC.

These and other useful circuit blocks are part of the PREMA cell library. The cells are used as a basis for the chip design and are customized for the specific application.

PREMA Semiconductor exhibits at the electronica 2004 trade fair in Munich, 9 -12 November. In hall A4, booth 406 our application engineers are available for consultation on analog and mixed-signal ASICs.

www.prema.com



Piezo Inverter for improved Reliability

Global Display Solutions (GDS), the industrial displays specialist, launches its new Piezo Inverter for multi-lamp backlight systems such as LCD TVs, high brightness LCD solutions and headrest displays. GDS's Piezo Inverter's balanced output is the 'first of its kind', giving exceptional uniformity and dimming performance.

The Inverter has improved reliability, safety and EMI performance compared with existing wire wound component systems. This is due to a reduced overall size and lower component count. In addition, with the use of the Piezo Inverter each lamp in multiple lamp systems will operate independently in the event of a single or multiple lamp failure, enabling continued operation of the display.

By using GDS's patented balanced output configuration, dimming ratios of > 500:1 are easily achievable, which is at least five times the dimming range of conventional inverter systems (50-100:1 or less).

Following advantages are included: 12-24 vdc; Control circuitry and the low voltage power supply can be remotely mounted allowing better thermal management of the display (e.g. head rest displays); Optical feedback provides uniform lamp output and can compensate for brightness variations caused by temperature changes in the display; Very compact; and Improved safety and easier integration due to the elimination of high voltage connections.

GDS's Piezo Inverter, which is the ideal low-cost, efficient and reliable solution for LCD manufacturers to use in multi-lamp back-light systems, is just now entering the market following a lengthy R & D program.

Info at +44 (0) 1274 230150, visit www.gds.com or email sales@gds.com

www.gds.com

Low-Power Voltage Regulator System IC

The XC6207 from Torex Semiconductor Europe is a low noise, high speed, low dropout (LDO) voltage regulator with a difference—it is equipped with a green operation (GO) function that makes it super energy efficient. This provides an extremely attractive solution for a wide range of hand-held and portable equipment applications.

Depending on the load current level, the XC6207 automatically switches between high speed mode and power save mode, efficiently reducing power consumption at appropriate times. In high speed mode power consumption is typically 50µA and in power save mode this falls to 6.0µA. The switch point is fixed internally within the IC. When only high speed operation is required high speed mode can be fixed by inputting a high level signal to the XC6207's GO pin, thus creating operating conditions with the most suitable level of supply current for the application. Standby current is less than 0.1µA (typ).

The green LDO incorporates a voltage reference, error amplifier, current limiter and a phase compensation circuit plus a driver transistor in a single IC. It gives designers a low dropout voltage of 45mV @30mA and fast ripple rejection of 70dB @ 1kHz. The XC6207 is available in a wide range of output voltage ratings, from 0.8V to 5.0V and selectable in 50mV increments. Operating voltage range is 2.0 to 6.0V, maximum output current is 300mA.

The XC6207 is available in SOT-25, SOT-89-5 and ultra compact USP-6B packages. Operational temperature range is –40 to +85°C.

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SATISFY CONTROL REQUIREMENTS WITH MAXIMUM DESIGN FLEXIBILITY

International Rectifier's New 600V Half-Bridge Control ICs

Part Number	Drive Current (mA)	V_{OUT} (V)	Input Logic	VIH/ VIL (V)	Typical. Dead time (ns)	Delay Matching (ns)	Turn On (ns)	Turn Off (ns)
IR2304	60/130	10-20	HIN/LIN	2.3/0.8	100	50	220	200
IR2308	120/250	10-20	HIN/LIN	2.9/0.8	540	46	220	200

IR's IR2304 and IR2308 600V half-bridge control ICs give circuit designers the ability to select the best control IC for their lighting ballast, appliance and SMPS applications.

The IR2304, with a high pulse current for minimum driver cross conduction, is an optimized solution for low drive current MOSFETs or IGBTs. The IR2308 is a rugged IC with two non-inverting inputs for larger MOSFETs or IGBTs in high frequency applications.

Features

IR2308

- Cross conduction prevention logic
- Rugged negative transient voltage tolerance
- Under-voltage lockout for both channels

IR2304

- Cost-effective, 600V half-bridge control IC
- Optimized gate drive for smaller MOSFETs
- Logic compatible

Benefits

- Improved time to market
- Reduced board space
- Reduced design risk
- High noise immunity
- Maximum design flexibility
- High- and low-side driver ouputs

So leave those discrete, pulse transformer and opto-coupler solutions behind and take advantage of reduced component count, space savings and increased reliability with optimized control ICs from International Rectifier.

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