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NORTH AMERICA

Power Systems Design: Empowering Global Innovation

SPECIAL REPORT: POWERING INDUSTRIAL APPLICATIONS (PG29)

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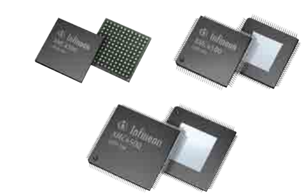
COVER STORY
Industrial Applications Control (pg 17)



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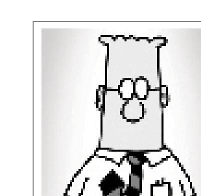

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INDUSTRIAL & CONSUMER DEMANDS

In the U.S. industrial and consumer arena, meeting customer demands means designers need to employ complex, high density ICs to provide differentiated features in many products now hitting the market.

On the consumer side, in a shift that marks a permanent changing of the technological guard, television sets using LED backlighting have taken the lead in the U.S. flat-panel TV market, eclipsing rival sets featuring cold cathode fluorescent lamps (CCFLs). Shipments of LED-backlit liquid crystal display (LCD) televisions amounted to 4.09 million units in the third quarter, compared to shipments of 3.85 million units for sets featuring the formerly dominant CCFL technology, according to from information and analysis provider IHS (NYSE: IHS).

LED and CCFL are the two technologies used for backlighting LCD televisions, but the third quarter marks the first time that LED assumed a larger portion of the market at 44%, compared to 41% for CCFL. The remaining 15% of the market is represented by plasma TV sets, which do not require backlights. Certainly there are interesting times ahead here.

Increasingly, industrial ICs and systems need multiple rails with a corresponding increase in the complexity of system power management. The use of digital power to manage these supplies, for example, is becoming increasingly important. The March issue of Power Systems Design for N. America is themed on this fast growing and broad-based part of the power industry.

PSD features its APEC show report, in our web community section for our readers who could not get there. This year the show was staged in Florida, which is a lot warmer than Munich where I am based, at this time of year!

Chip inventories held by semiconductor suppliers are reported to have declined in the third quarter of 2011, putting a halt to the steady expansion of the previous seven quarters, as the industry cut production in order to reduce oversupply. As calculated by the days of inventory (DOI) measure, semiconductor stockpiles in the third quarter stood at 81 days, down a modest 2.5% from 83 days in the second quarter, according to an IHS iSuppli Inventory Insider report from information and analysis provider HIS. The DOI level had been on the rise since the third quarter of 2009 when it stood at just 65 days—a time when stockpiles were low because production had been reduced during the dark days of the recession.

All the best,
Cliff
Editorial Director &
Editor-in-Chief
Power Systems Design
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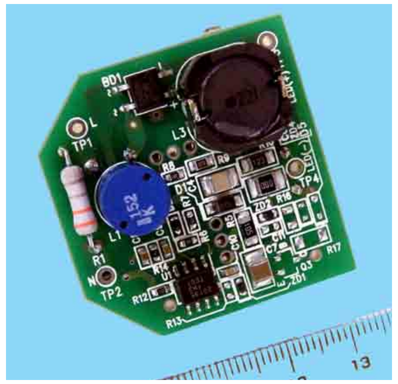
This years winners of Pre-APEC 3rd Annual Golf tournament Bob Carrier, ECI, Brad Atwater, Micrometals, Clark Atwater Micrometals, & Haas Chaudhry, PSD.

A good time for all at beautiful Celebration Golf Course in Orlando, a specials thanks to our Sponsors, Mouser, Coilcraft, Rogers & PSDNA.

RENESAS DRIVER IC FOR INDUSTRIAL AND HOME LED LIGHTING



LEDs are gaining widespread use in industrial and in fixtures for outdoor and household use. The market is expected to continue to grow substantially.

Coloured LEDs are commonly used as indicator lamps in many devices, however white LEDs are now being used for general lighting. LEDs provide more advantages than incandescent light sources including lower energy consumption, longer lifetime, higher brightness, improved robustness, smaller size, faster switching, and greater reliability. However, LED lamp modules are still relatively expensive and require more precise current control and heat management.

LED lighting systems combining low power consumption, high efficiency and long service life have gained considerable attention in recent years amid worldwide efforts to save power and reduce emissions of carbon dioxide.

Renesas Electronics announced the availability of its new driver IC, the R2A20135SP. The newest member of Renesas' driver IC family is designed for high-accuracy, high-efficiency LED lighting systems, and features on-chip dimming and a 40-percent size decrease for the mounting area, making it an ideal solution for LED lighting fixture manufacturers. Renesas will also provide an evaluation board with the new driver IC installed on it to provide development support for system designers. Renesas also offers a lineup of high-performance power MOSFETs for use with driver ICs for LED lighting systems as well as kit solutions featuring both types of devices.

In 2011, Renesas started mass production of the high-efficiency R2A20134 LED driver IC featuring a high-power factor that performs functions such as LED on-off switching and is designed to be mounted inside LED lamps. The company further contributed to the compactness and high-performance of LED lighting systems with TRIAC dimming support with the new R2A20135SP device. Integrating the dimming function eliminates the need for a dedicated external circuit, reducing board space and bill of materials.

Availability

Samples of Renesas Electronics' new LED driver IC are available starting in March 2012. Mass production is scheduled to begin in June 2012 and is expected to reach 5,000,000 units per month in December 2012.

www.renesas.eu

INDUSTRIAL POWER AND THE SMART GRID

By: Richard Ord

The industrial energy sector is often labelled as being, resistant to change and reluctant to adopt new ideas and innovation. But the Smart Grid means there is dramatic change on the way.

Existing grid systems are based on long-established, proven technology with an aging infrastructure that has changed little in decades, serving a user who is largely passive.

The traditional grid has no intelligent link between generation and consumption and especially in the industrial sector; it operates with centralised control, a passive radial architecture, and lacks operational flexibility.

But a shift in supply and demand will introduce new variability. At one end, renewable energy sources are inherently variable and unpredictable. At the other, consumers – industrial and public alike - are being pushed to change their behaviour by governments and suppliers towards a heavily interactive mode, whether with energy monitors, or net zero energy buildings or smart metering.

In between these, transmission and distribution is changing as well, with grids being linked via HVDC across geographic and national boundaries, and the response too all this change is the Smart Grid.

This will combine an active distribution network with local generation and storage, and a communications and control system to deliver a more robust and reliable network. Central to every aspect of the Smart Grid is the ability to sense, monitor, control, and communicate.

At Amantys, we believe the core building block of an efficient and reliable Smart Grid is effective power switching - combining advanced digital control techniques with precision analogue and power engineering to achieve the necessary performance.

The intelligent power switch offers real-time adaptation to varying system, load and environmental needs. It deploys a simple, reusable architecture, with a standard digital communications exporting real-time and non-real-time data from the switch to allow remote monitoring and control.

Perhaps this is why an industry normally so resistant to change is engaging with Amantys to deliver the Intelligent Power Switch to meet some of the challenges of the Smart Grid.

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www.amantys.com

U.S. TO LEAD 2012 FOR INDUSTRIAL AUTOMATION EQUIPMENT

By: Sarah Sultan

The market for industrial automation electronics equipment had a strong year in 2011, growing revenues by 12.1%

The global economy further recovered from the recession, according to figures from IMS Research's Industrial Automation Equipment (IAE) report. While 2010 was a strong recovery year for many industrial automation products, many large projects had still not restarted from the downturn and industry sectors such as oil & gas, shipbuilding & marine, metals and mining remained slow throughout the year. Many restarted in 2011, and automation equipment predominantly used by these industries, grew strongly in the first half of 2011 as a result.

The industrial automation equipment market is predicted to have strong revenue growth of 10.7% in 2012, though with a substantial difference between the motors & motor controls (13.8%) and automation equipment (8.2%) segments.

Sales of motors in particular are predicted to perform very well in 2012, with forecast revenue growth of 16.2%. More than 50% of this figure is attributed to low voltage AC induction motors, which are most affected by the legislative landscape with the Americas region predicted to be strong going forward.

As a result, IMS Research's machinery production forecasts have been lowered slightly for 2012 across all regions except the US. Machinery production makes up only a small percentage of GDP, and is thus only slightly affected; direction of the market is more indicative than the degree of change.

Because the US market was the first region to enter the downturn, the country is also expected to lead the world into sustained growth in the first half of 2012. The rest of the world is expected to continue the recovery later in 2012; therefore, the second half of 2012 is expected to be stronger than the first.

The IMS Research IAEE study is a quarterly report service that publishes revenues for major automation equipment and motors & motor controls markets by the major geographic regions: EMEA, Americas, and Asia Pacific (including Japan). For the first time, the 2012 edition of the report will publish unit shipments and average selling prices of these markets, as well as provide new analysis of the mechanical & fluid power transmission segment.

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HARDWARE TESTI NG AND COMPUTER SIMULATION

By: Dr. Ray Ridley

Introduction:

In over 30 years of designing power supplies, I have written multiple computer programs to help design, simulate, and understand power supply operation. This has culminated in Release 9 of POWER 4-5-6, just announced at the APEC Conference in Orlando.

Despite this strong affinity for simulation, when it is time to build or test a real product, my philosophy on designing is very much rooted in hardware. If you are under a high-pressure schedule, you must get to hardware testing as soon as you possibly can.

In this article, a resonant power supply is described, which was my first introduction to power electronics. Simulation was a tremendous assistance in the comprehension of the circuit and in deriving the conditions under which it would work. However, there was no substitute for hardware testing, and the effects seen during this phase of development. While simulation has its place, the main job in power supply development is building the hardware, testing it thoroughly, and doing everything possible during test to ensure ruggedness.

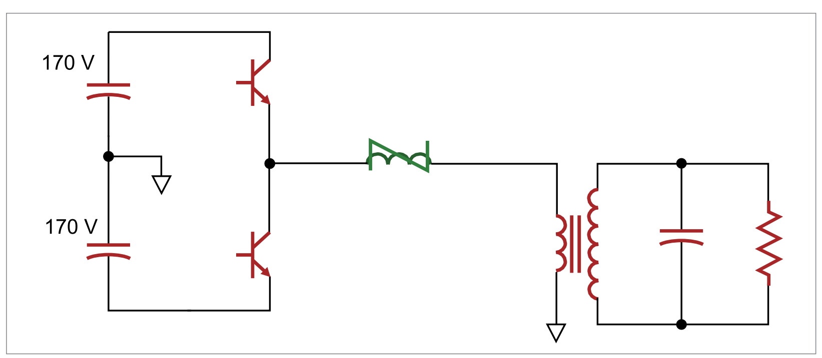

Fig. 1: Half-bridge offline converter driving resonant LC filter with saturable reactor

Ferroresonant Power Supply – My Introduction to Power Electronics

Over thirty years ago, I started my first project in power electronics design. Like many of us in this field, it happened quite by accident, and started a lifelong career.

It was a very simple-looking circuit that I was asked to work with as a senior project at Boston University. The input was the rectified ac line, split into positive and negative rails. Two bipolar transistors (this was before the days of power Mosfets) were then operated in a half-bridge configuration to drive a variable-frequency square wave across an LC filter with a transformer.

The circuit is shown in Fig. 1. This is something of a simplification of the real circuit, but it shows the most important elements.

There were many challenges to this project. First and foremost was the specification.

Input: 95 to 132 VAC, 60 Hz
Output: 5000 VAC at 20 kHz.

Furthermore, the output was to be regulated. The application was for a static-eliminator bar inside a copy machine, and the 5000 VAC would produce a corona discharge on the load through which copy paper would pass to have the static charge removed.

This looks like a very daunting task, but at the time I didn't have enough experience to realize how difficult it should be. Producing a regulated output sinewave is normally something that would be achieved by varying the frequency of the input drive signal, and using the resonant gain characteristics to control the output. This is the more complicated approach.

Surprisingly, however, all of the specifications can be achieved without any control feedback, with the circuit running open loop at a fixed frequency. All that is needed is a nonlinear element, the inductor, which saturated during part of the resonant cycle. This is a form of "ferroresonance" which was the basis of regulated line-frequency ac power supplies for many decades before the advent of modern power electronics. To this day, you can still buy ferroresonant transformers as line conditioners. They are big and very bulky, but they have a reputation for ruggedness and good line isolation for transient events.

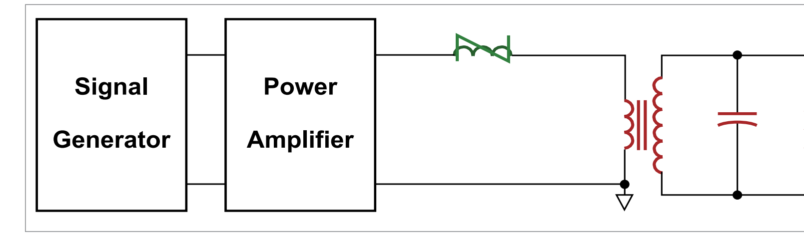

Fig. 2: Resonant LC filter driven by power amplifier and function generator

Ferroresonance is a fascinating field of study. If the circuit is operated above the resonant frequency, there is an intriguing event known as the "ferroresonant jump". As the input voltage is increased, the output voltage increased in proportion to the input while the resonant inductor current remains below the saturation level of the inductor core. Once it exceeds this level, the output voltage of the circuit "jumps" to a higher value, and remains locked at that value with further increases in the line voltage. Very little further change is observed in the output voltage, and the voltage is essentially regulated automatically.

Initial circuit testing was done with the setup of Fig.2, using a signal generator, and high-voltage tube amplifier. This setup showed all of the characteristics of the ferroresonant circuit, and allowed the simulation problem to be set up properly to explore how the circuit worked.

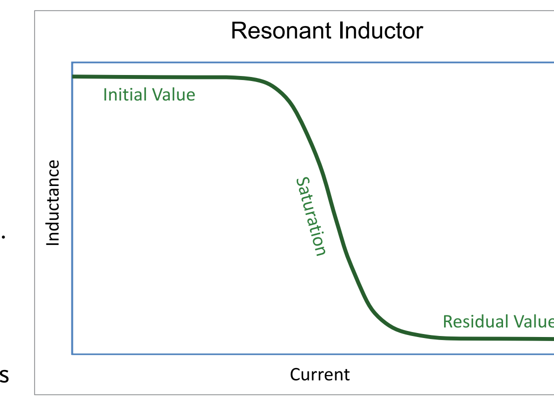

Fig. 3: Saturable inductor characteristics

After many months of writing Fortran code, and running simulations on a mainframe computer (well before the days of the PC) I had achieved an intricate understanding of how the saturable inductor was capable of regulating the output voltage. I could predict where and when the ferroresonant jump would occur, and under what conditions.

The simulator that was written

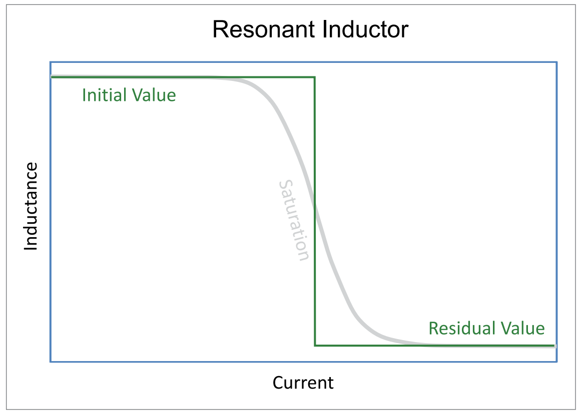

Fig. 4: Simplified saturable inductor characteristics for simulation

for the circuit did not need the exact characteristics of the inductor to show the regulating effects of saturation. All that was required was a piecewise-linear curve, as shown in Figure 4.

I had certainly satisfied the academic requirements for a senior project after all this simulation and made some interesting new discoveries about the circuit that could be the basis for several research papers. However, the company who sponsored the work on this converter needed a working product, not a simulation and publication. So, armed with new understanding, I now had to implement the front end of the converter with transistors rather than a signal generator.

Hardware Testing of Ferroresonant Half-Bridge

Nothing I had seen in any simulations prepared me for what happened next with the real hardware. I built what seemed to be a reasonable circuit according to what I had read from the scant information available on the topic. However, within minutes of turning on the switch, and turning up the input voltage, the input transistors blew up – quite literally. At the end of the day, I had on my hands a box full of blown-up transistors and went home tired, frustrated, and feeling like I knew nothing about the real world of power electronics. I am sure that many of you have been through the same baptism of fire during your first product development.

Nothing in the data books, or application notes even hinted at how hard this was going to be. Modern application notes continue this trend – according to most of them, this kind of work was supposed to be easy, but I certainly didn't find it that way.

The next few months proved to be a trial of perseverance and learning. Once the initial problems of voltage spikes, current runaway, and transistor cross-conduction were solved with modified drives and timing, thermal issues took over as the dominant failure mechanism. Storage time delay in bipolars, rise and fall time, and switching loss became a very familiar topic to me. Simulation and calculation do not come anywhere close to the real losses encountered since many of the hardware effects were simply too complex to be modeled.

With appropriate cooling added, the input voltage was increased further. Then I got my next hard lesson – at a couple of thousand volts, corona started to appear in the transformer, and the circuit failed again. Repeated attempts to wind transformers failed miserably, with every effort resulting in eventual breakdown. I spent many hours in a dark room, watching the circuit and hoping in vain that the familiar blue discharge of corona would not appear – but it always did.

I never did solve the problem then with homemade magnetics, and only a vacuum-impregnated transformer finally worked. This had to be built by a serious magnetics vendor who understood the technology thoroughly.

This project was a tremendously valuable lesson in where simulation is useful, and where it is not. Since then, I have never assumed to understand a circuit, or give an opinion on suitability of a design for production without seeing hardware measurements. I was fortunate to run into so many real-world issues early on, since many of them are commonplace. My design philosophy is this: Get to the hardware stage as quickly as you possibly can. Do not get too deep into simulation without hardware verification, or you will be wasting a lot of time. If customers require simulation as part of a design verification package, the simulation must be refined as you go. In many cases, it is simply not possible to simulate all the effects that are seen in the real circuit. This brings into serious question the point of simulation, and I will continue to try to answer this in future articles. One thing that is certain is that simulation is not a substitute for hardware.

Modern Software

During my first project, no software was available and I had to write my own fast and efficient simulation programs. It was terribly important to understanding how things worked for an unfamiliar circuit. Even if circuit simulation software had been available, the computers of the time would have been far too slow to achieve anything meaningful that would have helped with the real hardware issues.

Thirty years later, computers are incredibly fast with numerous options available for analysis and simulation – POWER 4-5-6, Spice, Simplis, MathCad. They all can have a place during project development, but they must not be allowed to interfere with the real work that must be done – building hardware and testing it. As you choose your tool to aid in the design process, you must be sure that it will accelerate the design process.

Research and Simulation

In the last few years, I have seen a dismaying new trend coming out of research universities around the world. Students will generate a new theory in control, or a new topology that may look promising. However, rather than building hardware to verify what they have done, they depend on a simulation program like SIMPLIS to provide confirmation of analytical results. Perhaps this is a valuable step in the confirmation process, but it does not begin to substitute for hardware testing.

I would encourage all students who are taking this path to heed the following advice:

Do whatever is necessary to confirm your results with hardware. My time at graduate school was most valuable when working in the hardware lab – exploring new circuits, looking at waveforms, and sharing ideas and results with many others doing similar tasks. This is when the best learning is accomplished in a hands-on manner. During the process, you will invariably discover many new effects that complicate the results, but also lead to opportunities for further learning and invention. This rarely happens when running simulators, something that is too easily forgotten with the latest generation of computer experts.

Summary

Simulation has an important role to play in the understanding of circuits, and modeling of the first-order events that will be seen. However, it is no substitute for hardware testing, and you must use simulation to move to the hardware stage as quickly as possible to begin real testing. In over 30 years of power supply design, testing, and reviews, I have never encountered a situation where an anomalous hardware event or failure was solved by using a simulator. Always, the solution has been found with time in the lab.

Ridley Engineering Design Center,

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INDUSTRIAL APPLICATIONS CONTROL

New XMC4000 energy-efficient microcontroller family

By: Gabriela Born

Infineon has taken their wealth of know-how in microcontroller design for real-time critical control applications to combine it with all benefits of an industry standard core.

The unique result, the 32-bit XMC4000 microcontroller family based on ARM® Cortex™-M4, is dedicated to industrial applications. XMC stands for a family of "Cross-market Microcontrollers". Target segments include energy-efficient drives, renewable energy, factory and building automation. This article elaborates on the motivation for Infineon's architecture decision, the portfolio and the key innovations of this family.

Striving for energy-efficient solutions the XMC4000 devices greatly benefit from Infineon's well-known set of configurable peripherals, fast embedded Flash technology, high quality standards, long product life times, and the ability to support high temperature requirements of up to 125 °C, backed by the company's background as a leading supplier to automotive markets. Adding the next-generation of DAVE™ - DAVE™ 3 -, a revolutionary approach to lower software efforts, industrial system developers can count on a powerful microcontroller platform for their numerous industrial applications.

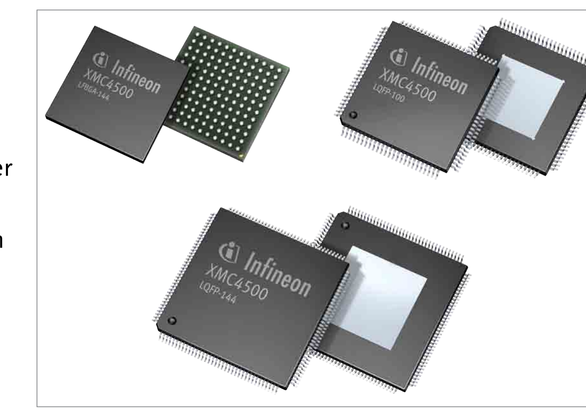

Figure 1: With the new XMC4000 family - starting with the XMC4500 series - Infineon addresses three high-level trends for microcontrollers in industrial applications: higher energy efficiency, enhanced connectivity and reduced software complexity

With the new XMC4000 (Figure 1) family - starting with the XMC4500 series - Infineon addresses three high-level trends for microcontrollers in industrial drives, automation and renewable energy systems: the need to enable higher energy efficiency of the systems, the need to enhance connectivity between systems and the challenge to reduce software complexity which seems to explode in many of today's projects.

Higher energy efficiency

On one hand there is an increasing effort to supply energy from renewable energy systems. One the other hand the best way to cut down CO2 emissions is to reduce overall power consumption, and electric motors play a key role in power consumption. According to a study by VDE electrical drives used in industry and households alone account for 50% of the total electrical energy consumed. According to VDE, more efficient three-phase motors in the power range from 1.1 to 37 kW offer the greatest potential for saving electrical energy.

There are several ways the microcontroller can contribute to this improvement: higher computing performance to allow faster control loops and more advanced algorithms, optimized peripherals to enable faster and more accurate measurement of analog signals and a faster and more adapted PWM generation. The new XMC4000 family of 32-bit microcontrollers provides all the named features and enables very energy efficient designs.

Enhanced connectivity

Enhancing connectivity in industrial systems is another key trend. This trend takes two directions: Connectivity within the real-time critical domain and connectivity to the "outside" world. Within the real-time critical domain simple standards like UART, SPI, IO-Link or proprietary protocols are wide-spread, cost efficient and reliable. For higher band-width requirements real-time Ethernet might be a future trend, but currently suffers due to the fact that there are too many flavors and there is no unique standard established. For connectivity to the outside world there are two main use cases: For manual code update or download a high-speed interface like USB or an SD/MMC interface for data card access are required. For remote process management, monitoring or maintenance Ethernet is evolving as the main standard

Figure 2a and 2b: Infineon's new XMC4000 family provides high scalability

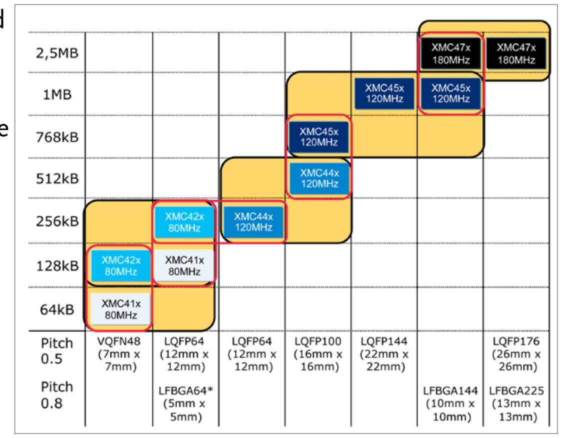

Figure 2a

High-end → Low-end

System Performance	XMC4700*	XMC4500	XMC4400	XMC4200	XMC4100
Core	ARM® Cortex™-M4F				
CPU frequency (at 125 °C)	180 MHz	120 MHz	120 MHz	80 MHz	80 MHz
Co-processor	Floating Point Unit				
Flash size	2.5 MB	1 MB	512 kB	256 kB	128 kB
RAM size	512 kB	160 kB	80 kB	40 kB	20 kB
Cache	6 kB	4 kB	4 kB	4 kB	4 kB

Figure 2b

Reduced software complexity

Both of the previous trends drive up the requirements for software. Several industry studies confirm software complexity is one of the major problems for embedded system development. This is true especially for small and medium sized companies with comparably small development teams of some ten engineers. Especially communications stacks, operating system integration and re-use of optimized algorithms are key challenges.

High-performance core

Infineon selected for its XMC4000 portfolio the ARM Cortex-M4 processor core. The main reason to choose the M4 core instead of the M3 is the availability of DSP instruction support and a floating point unit. Overall this allowed Infineon to roughly double the computing performance compared to its 16-Bit C166 based microcontroller families, which were recognized as leading in real-time performance since their introduction in the early 1990ties. For even higher real-time performance Infineon continuously invests in its TriCore based product families. A significant advantage of the XMC4000 family is the availability of a broad ecosystem and 3rd party software for the ARM Cortex M architecture as a commonly used standard core.

Five series with scalable features

The XMC4000 portfolio consists of five series: XMC4100, XMC4200, XMC4400, XMC4500, and XMC4700 (Figure 2a). These series scale in terms of frequency, memory, number of IOs and type and availability of peripherals (Figure 2b). The basic architecture with a high-performance flash, which is also used in Infineon's automotive qualified TriCore microcontrollers, the high-speed bus-matrix and the 2 peripheral busses, is identical for all family members (Figure 3).

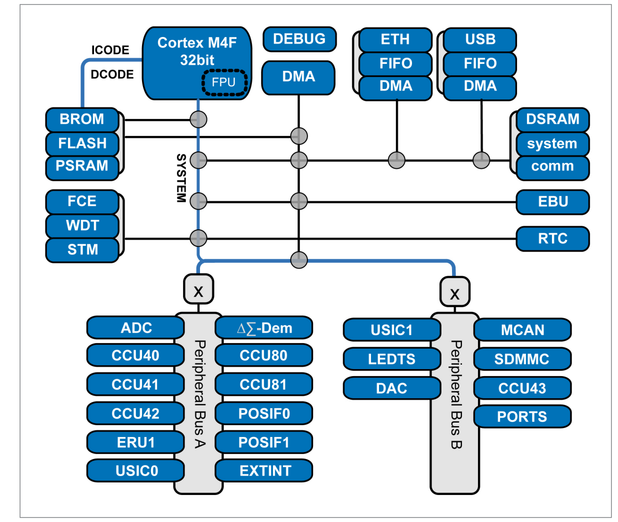

Figure 3: All family members show the same basic architecture with powerful flash memories, a fast bus matrix and two peripherals busses. The main differentiators are the peripherals

All peripherals were optimized for high-level software programming. They are built on flexible hardware blocks which can be configured by software to meet the exact application need. Thus the whole XMC4000 portfolio was defined to be scalable and compatible to allow easy migration from one series to another. The integrated resolver exciter and sigma-delta demodulator are examples of unique features that reduce BOM, system cost and system complexity.

Energy saving peripherals

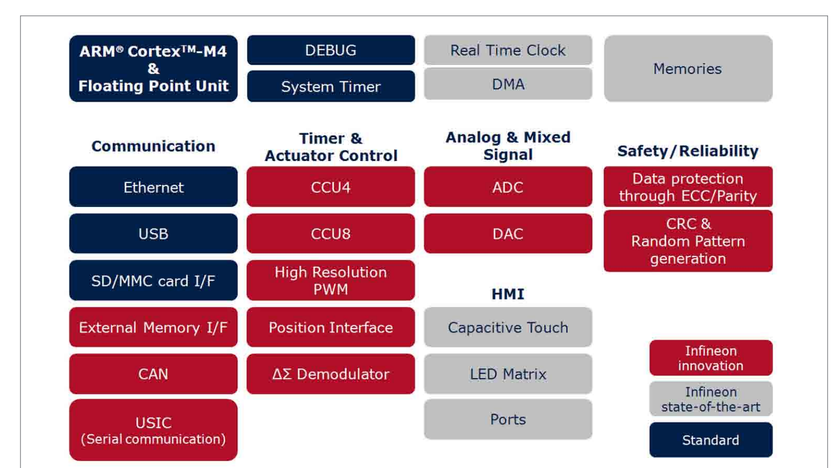

Figure 4: XMC 4000 comes with significant peripheral innovations like four parallel 12-bit ADCs, delta sigma demodulators and new timers (CCU4/CCU8)

XMC4000 comes with several innovative peripherals (Figure 4) like a completely new developed timer unit for PWM generation, allowing efficient control of all motor and inverter types. With this peripheral Infineon levers its vast know-how and experience in timer design: the CCU6 which Infineon introduced roughly 10 years ago for its 16 Bit portfolio is still recognized as leading for electric motor control.

The GPTA unit in the TriCore portfolio is regarded as best in class for engine control. Based on this experience Infineon now developed enhanced timer modules for industrial applications. Key advantages of the new CCU4 and CCU8 timer modules are: They consist of several, identical "capture/compare slices" which can be e.g. easily concatenated. Their register sets and hardware symmetry make it easy to map high-level data structures to the hardware or re-locate code from one unit to another one. Identical, repetitive HW structures allow for SW re-use between the timer slices. Other feature enhancements include a dithering PWM for higher resolution and improved electromagnetic emissions, a floating pre-scaler, asymmetrical PWM generation, asymmetrical dead-time generation for rising and falling edge etc.

The XMC4400, XMC4200 series will contain a high resolution PWM unit with a resolution of 150ps.

This is a dedicated peripheral for highest energy efficiency in power conversion as needed in power supplies or solar inverters.

Up to two positioning interface modules are available to support quadrature encoders, hall sensors or multi-channel positioning information. The unit provides input filtering, edge detection and provides control signals for the PWM unit.

The XMC4000 family comes with up to four parallel 12-Bit ADCs with a sampling time of 70ns and a conversion time of 500ns. Overall those four ADC modules provide 26 high-speed ADC channels. With an oversampling algorithm the resolution can be increased to 14 Bit. The ADCs are optimized to provide a wide range of autonomous operation modes which either allow to save on external components or reduce processor loads. Examples for this include a fast comparator mode, zero crossing detection, conversion of multiple signals in a programmable sequence, signal plausibility checks, arbitration in case of injection conversions, result data processing (IIR/FIR filtering) etc. In case a high-precision or a galvanic isolated ADC measurement is required XMC4000 offers up to four Delta-Sigma interfaces to demodulate and filter up to four data streams. With this optimized ADC functionality the XMC4000 covers a wide range of application use case for inverter control in

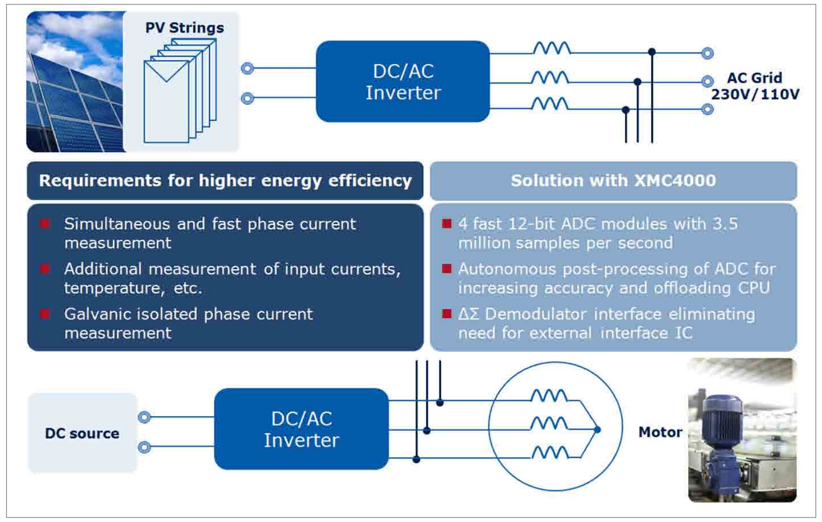

Figure 5: XMC4000 is optimized for inverter control in electric drives and renewable energy systems

electrical motors or renewable energy applications.

Optimized for inverter control
XMC4000 is optimized for inverter control in electric drives and renewable energy systems (Figure 5). Efficiency improvements of inverters require simultaneous measurement of three phase currents and additionally simultaneous measurements of input currents or other environmental parameters. XMC4000 addresses this with up to four parallel 12-bit ADCs. With 3.5 million samples per second the ADCs are not only very fast; they can also post-process the data with digital filters, for example to implement an oversampling algorithm in hardware. On the one hand this offloads the processor, on the other hand it improves real-time performance as the peripherals can act without any software overhead. Galvanic isolated current measurements are supported by an integrated delta-sigma demodulator: This concept reduces system cost when working with an external, isolated delta-sigma ADC, as opposed to current designs it eliminates the need for an additional interface IC.

Besides the fast 12-bit ADCs the new XMC4000 family provides the most advanced PWM units and timers for efficient drives. One of the key strengths of all Infineon microcontroller families is the tight coupling between the PWM generation units and the ADCs. Especially for electric motor control this is a key functionality as it significantly reduces the interrupt load for the processor and enhances the reaction time. In the XMC4000 family those capabilities are even enhanced: Instead of fixed hardware connections it provides a connection matrix which allows FPGA-like connections between different output and input trigger signals of hardware modules.

		XMC4700*	XMC4500	XMC4400	XMC4200	XMC4100
Communication	IEEE 1588 Ethernet MAC	2x	1x	1x		
	USB	HS OTG	FS OTG	FS OTG	FS DEV	FS DEV
	SD/MMC	✓	✓			
	Serial channels (UART, SPI, I^2C, I^2S)	6x	6x	4x	4x	4x
	Ext. Memory I/F	✓	✓			
	CAN	3x	3x	2x	1x	1x
	Touch Button	✓	✓	✓	✓	✓

Figure 6: The XMC4000 family supports a wide range of communication standards

Well connected
As connectivity is a major trend the XMC4000 family supports a wide range of communication standards (Figure 6): Connectivity to the administration and maintenance layer is established via USB OTG, Ethernet and SD/MMC peripherals. USB comes in different flavors depending on the series: high-speed/full-speed, host/device. Ethernet contains the IEEE 1588 time-stamping functionality which allows real-time Ethernet software implementation. Furthermore connectivity within the embedded system can be established with up to 3 MultiCAN nodes and up to 6 universal serial interface channels. Both hardware modules are highly flexible and offload the CPU significantly through pre-filtering of messages or message buffering. The universal serial interface channels can be freely defined by software to implement one of the following standards: UART, SPI, Quad-SPI, IIC, IIS, LIN. This increases the flexibility for the software and hardware designer significantly and allows long-term scalable platform solutions. For external memories and memory-mapped IO devices XMC4000 offers a high-speed parallel external bus interface.

Complete tool chain
In addition to a number of commercial 3rd party development tools Infineon offers DAVE 3, a free, Eclipse-based software framework. This new DAVE includes a free tool-chain and an extendable autocode generator, facilitating the use of pre-defined SW components that can be graphically selected and combined. In contrast to the state of the art approach with libraries and code examples, this new approach allows higher software abstraction, easier integration and maintenance. It is an open platform allowing easy extensions and adaptations, like e.g. the addition of applications through 3rd parties based on a SDK. The DAVE store hooks the user up with an ever growing developer community: Tested low level drivers, RTOS, software stacks and higher-level applications can be downloaded and shared. While the main focus is on free software components DAVE 3 is also ready to integrate commercial 3rd party software components. In addition to the free compiler, linker, debugger and flash loader, there are plug-ins from commercial tool-vendors available. This allows the user to fully benefit from this concept: staying with their preferred IDE while fully utilizing the autocode generation functionality of DAVE 3.

Availability
Samples of the XMC4500 lead series are available since August 2011. After extensive testing customer sampling will start in March 2012. Infineon's DAVE™3, a wide variety of 3rd party tools and evaluation kits will be available at the same time. Volume production starts in Q2 2012. The XMC4400, XMC4200, XMC4100 series will be in production in Q1 2013, samples will be available in Q4 2012.

More details on the XMC4000 with all available variants, application examples and order information are available under www.infineon.com/xmc. DAVE can be downloaded at www.infineon.com/dave

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UNDERSTANDING COMMON-MODE NOISE IN LOW-POWER OFFLINE SUPPLIES

Offline supplies for mobile phones need to be simple, low cost, and highly efficient power converters

By: Vladimir Alexiev

Yet the ruggedness of the underlying technology makes the core designs attractive to a much wider audience, such as industrial users who need low-power supplies for DIN-rail and similar equipment. But while industrial applications stress long-term reliability over cost and have few constraints on form factor, minimal cost and size are essential in the consumer space. EMI suppression then becomes very difficult, with no Earth connection or X/Y capacitors, few input-filter components, and arbitrary power-cable lengths.

Methods exist to mitigate these issues, but rarely in isolation from other contributors. For instance, twisting the power cable's conductors theoretically makes length less critical. But as any EMC test engineer knows, cable length and layout heavily influence results. At another level, a modified topology such as the resonant discontinuous forward converter (e.g. CamSemi C2470 controller family) that softens primary-side switching eases meeting regulatory requirements with minimal EMI-filter hardware. Applicable standards include EN 55022 for conducted and radiated emissions, and ETSI EN 301 489-34 for conditions that apply to mobile phone chargers as defined by IEC 62684.

Yet the touchscreens in today's smartphones are highly susceptible to noise that can be present at a supply's output. Typically, this becomes apparent when using the phone during a charging cycle. Connections to ac-line create a competing noise current path that may swamp the user's connection to Earth, which the touchscreen relies upon for sensing user inputs. Due to consumer requests for a common charger that suits all data-enabled mobile phones, the 'MoU initiative' targets interoperability issues and the environmental impact that results from disposing of countless special-to-type chargers [see http://ec.europa.eu/enterprise/sectors/rtte/chargers/docs/index_en.htm].

Because common-mode noise affects different touchscreens to varying extents, resolving this issue is crucial for interoperability.

Currently in its first edition, IEC 62684 is the MoU initiative's standard for ensuring interoperability between phone-charger power supplies. It specifies criteria such as universal-input ac-line operation, USB Micro-B cabling, compatibility with the USB-IF standard for device-detection and protection, environmental operating conditions, and the charger's dc output characteristics. This last section states that the output voltage shall be 5.00±0.25 VDC from no load to a full output current level that must lie between 500 and 1,500 mA. It also lays the foundation for common-mode noise limits and demands some specific tests.

Mechanisms that create common-mode noise

The flyback topology dominates low-power ac/dc conversion as it is simple, efficient, and inexpensive. We will consider two periods within any switching cycle - the 'charge' period during which energy builds in the transformer's core, and the 'discharge' period while this energy releases into the secondary circuit.

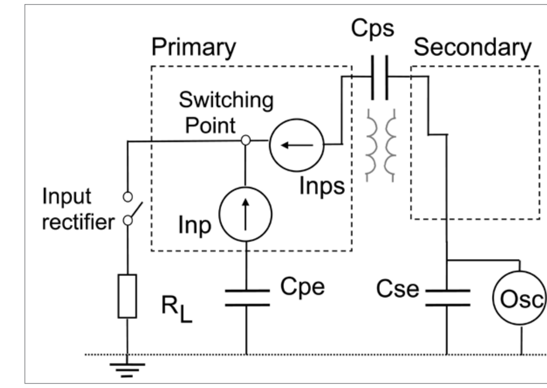

Figure 1. A flyback converter's main common-mode noise sources and transfer paths.

The common-mode noise waveform at the dc output differs substantially during the Bridge Conduction Time (BCT period) when the input rectifier is conducting from the remainder of the ac-line, when it is non-conducting (Bridge Non Conduction Time, BNT). With the switch on the left-hand side of figure 1 representing the input rectifier, we see the two circuits that operate during these periods:

During the BCT period, the switch connects the transformer's primary to ground, causing a common-mode noise current Inps to flow between the secondary and primary to become the dominant noise term. The common-mode signal that results at the charger's output is proportional to the difference between Inps and Inp, which is the noise current that transfers from primary to Earth. There are two possible conditions:

1. Inp > Inps—the resulting waveform is the same shape as the switching signal
2. Inp < Inps—the waveform is proportional to the inverted switching signal—see the top trace in figure 2.

As the bottom trace in figure 2 shows, the waveform during the BNT interval will always be the inverted switching signal, as the main noise source is the primary pushing current to Earth through capacitor Cpe.

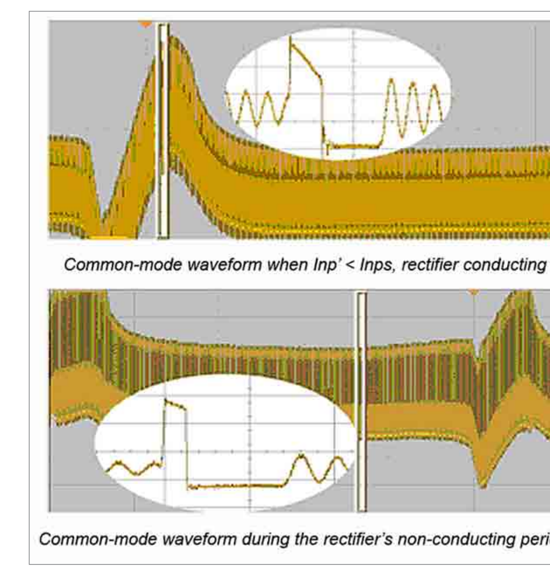

Figure 2. Top trace— common-mode waveform when Inp < Inps
Bottom trace—the waveform during the rectifier's non-conducting period

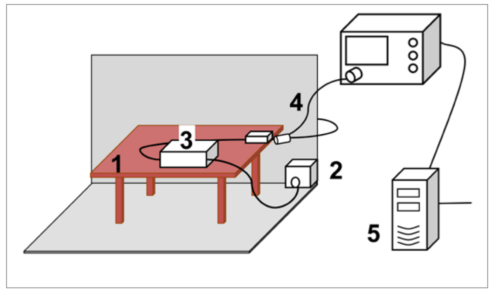

Figure 3. Common-mode noise measurement set-up:
1. *Non-conductive table*
2. *LISN and EPS supply cable*
3. *EPS, output cable, and mobile terminal*
4. *8 pF/10 MΩ probe to the oscilloscope*
5. *Computer*

The main switching components differ between the BCT and BNT periods together with the high-frequency signal content. Because the largest peak-to-peak voltage Vpp can appear anywhere in the ac-line cycle, quantifying Vpp demands identifying the worst-case levels in multiple frequency bands. The key to optimizing conducted emissions lies with precisely balancing the two conditions during the BCT period.

Test configuration set-up
Common-mode noise measurement accuracy depends on test method and setup. To test the external power supply (EPS), we use the set-up that EN 55022 defines together with these modifications from IEC 62684:

- 30 cm distance from the EPS cables, loads, and mobile terminal to Earth
- 10.00 ± 0.01 Ω load
- EPS powered by 253 VAC -1% / +0% at 50 Hz ± 1%
- 1 m cable from EPS to the load.

Figure 3 shows the arrangement:
The LISN (line-impedance stabilization network) decouples the EPS supply from other ac-line connected equipment. It balances line and neutral, provides a suitable point for measuring high-frequency signals, and makes the Earth connection that IEC 62684 stipulates.

Measurement method
An objective within IEC 62684 is to measure the worst-case Vpp signal amplitude over a 20 msec ac-line cycle at 253 VAC, as common-mode noise tends to worsen at high input voltages. CamSemi's approach exploits a digital oscilloscope to acquire the line-frequency signal frame in four million samples. This data passes through digital filters and frame-scan measurements to find the worst Vpp signal in each frequency band.

Recently, the MoU initiative published a "Guide on Implementation of Requirements of the Common EPS" to support IEC 62684: The Guide exempts many of the common-mode noise tests in IEC 62684, recommending instead measurement of all pulses longer than 250 nsec. This effectively results in a single frequency band from below the switching frequency to 4 MHz.

Test results and possible compensation strategies
Examining the common-mode noise shapes and amplitudes after filtering can help identify interference sources and suggest approaches to mitigating the problem. A two-stage approach minimizes noise at source before applying a signal of opposite phase and amplitude to the remaining noise signal. A range of suitable mechanisms for achieving this are discussed in CamSemi US patent 8,023,294 www.google.com.tr/patents/US8023294.

Compensation methods include balancing the transformer's design to "push" noise between BCT and BNT periods. The top traces in figure 4 show the result of pushing the common-mode noise signal during the BNT period.

All compensation methods suffer from signal inaccuracies that worsen as frequency increases. The relationship between the signals in the high-frequency area can be completely different from the main switching frequency band, and the extent of the difference within this relationship is one measure of the quality of the compensation. The bottom traces in figure 4 show the 1 to 100 kHz and 1 to 100 MHz frequency bands for the same signal, revealing the onset of increasing common-mode noise during the BCT period due to signal delays and inequalities in compensation.

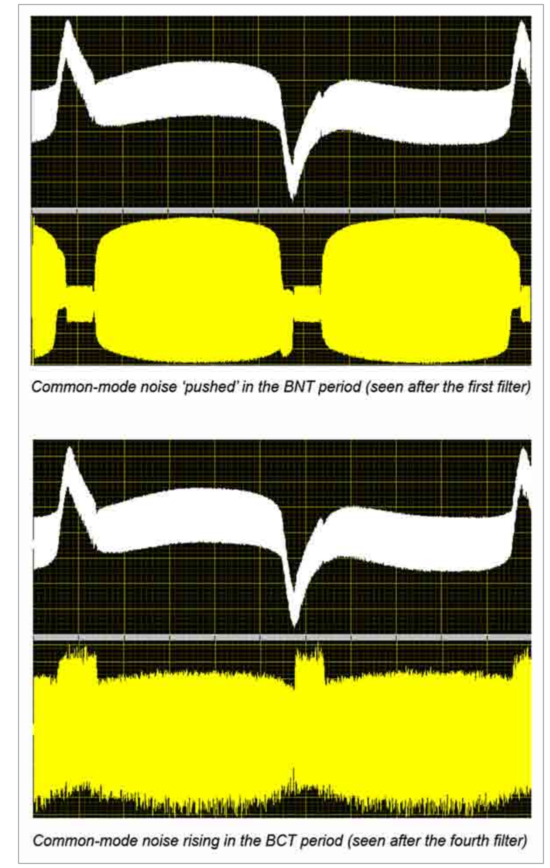

Figure 4. Top traces— common-mode noise pushed in the BNT period (after 1st filter) Bottom—common-mode noise rising in the BCT period (after 4th filter)

Conclusion
While it may not necessarily optimize conducted emissions - adjusting the compensation to drive the signal amplitudes during the BCT and BNT periods to being as close to equality as possible is the best method for minimizing common-mode noise.

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SIMPLIFIED POL DESIGN

SupIRBuck® online design tool makes it easy

By: Peyman Asadi and Parviz Parto

Fast and reliable design and evaluation of Point of Load (POL) circuits is a major factor to reduce the product development cost and time for electronics industry.

Switching power supply circuits such as POLs form a big percentage of the electronic content of products and relatively high power nature of these circuits adds to the complexity of the evaluation and troubleshooting. Furthermore, in response to the expanding need for POL solutions many integrated circuits with variety of features are developed. Selection of the best fit among many options and optimal design of the application circuit is a major challenge for developers, especially digital specialists with limited experience of power circuits. SupIRBuck® online Design Tool is a comprehensive, accurate, interactive, and user-friendly tool for any developer to step by step effectively select the best fit among the SupIRBuck® family and design the application circuit.

IR's SupIRBuck® regulators are highly efficient, easy-to-use, fully integrated synchronous buck converters. These regulators incorporate IR's high performance synchronous buck controllers and benchmark HEXFET® trench technology MOSFETs in a compact Power QFN package. This package is standard, easy to assemble, and scalable. The internal gate-drivers are designed to match the MOSFETs for the best performance and the feature-set for each part number are customized to provide the minimum external components. Thus, the solution is efficient, compact, rugged, and cost effective. Using this technology, the controller can operate over wide input and output voltage range and overcome the limitations of monolithic and discrete solutions to simultaneously improve efficiency and space.

This approach provides enough flexibility for optimizing the converter for different applications with few external components. The current SupIRBuck® family includes more than forty seven members with 4x5mm and 5x6mm size packages, input voltage up to 27V and maximum continuous output current of 25A. The control engines are either voltage mode controlled PWM or constant on-time. SupIRBuck® design tool supports the most recent generation of SupIRBucks® also known as preferred parts.

Design Steps with SupIRBuck® Online Tool

The SupIRBuck® Design Tool is web-based and created on WebSIM® platform. User can create and track designs in an individual account and even share them. As the input, user enters design parameters, selects components, verifies the design by simulation, and specifies the PCB. On the output, user receives Bill of Materials (BOM), simulation results, bode plot, estimated efficiency and power loss, and thermal distribution on the board.

Figure 1 shows the five steps of working with the tool. First, user selects desired features and enters the design inputs such as input voltage, output voltage, load current, and switching frequency. Then, the tool suggests a matrix of part numbers. The 1k budgetary price and efficiency at 10%, 50%, and 100% load for each part are listed, so user can select the price vs. performance among possible options.

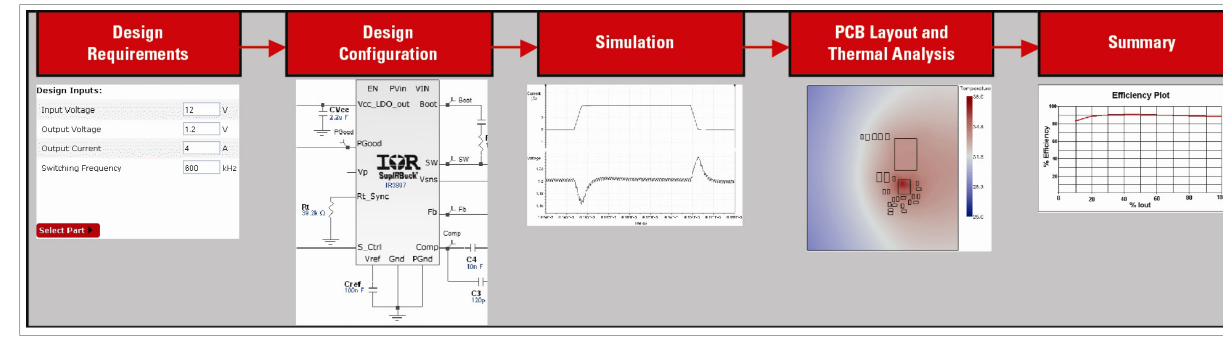

Figure 1: Five steps of working with the SupIRBuck® Online Design Tool

After the selection of part, the tool automatically designs the application circuit with the default design specifications (e.g., output voltage ripple and load transient response) and draws the schematic. The design includes selection of input and output capacitors, output inductor, and compensation values. User can override the default values and re-design the circuit.

Once the schematic is designed, user can perform AC, steady state, and transient analysis. The performance of POL circuits, especially load transient response, cannot be described precisely with design equations. Thus, performing simulations are necessary for verification. SupIRBuck® online tool uses SIMPLIS® for electrical analysis. Although the model created for SupIRBuck® is a detailed switching model, the simulation can finish within few seconds.

One great capability of this tool is defining the electrical specification and mechanical size of PCB and providing the option for the placement of components on the board accordingly. User can even add extra components on the board to create mechanical limitation as the actual PCB. After defining the PCB layout, user can perform analysis to obtain the power loss and the thermal distribution on the PCB.

Finally, the tool generates a complete report of the design including schematic, BOM, electrical simulation results, efficiency versus load current, pie chart of power loss, and results from thermal analysis. In following, features of the tool are explained in more details with an example.

Design Example

An application with single 12V input voltage, 1.2V output voltage, 4A maximum continuous load current, and 600kHz switching frequency is selected as an example. The desired part should have dedicated pin for over-voltage protection, Enable input, PGood output, internal LDO, and input voltage feed-forward control. Thus, the tool suggests IR3897, IR3898, and IR3898. We choose IR3897 for the best price and higher efficiency up to 50% load. The design entries are set to target 120kHz target loop bandwidth and 30% peak to peak inductor current ripple. Figure 2 shows the designed IR3897 schematic. User can edit components and enter custom values or select a part number from the database.

In the next step, electrical simulations are performed to evaluate the performance of the solution under common operating conditions. To demonstrate the accuracy of the tool, simulation results are compared against experimental ones from an IR3897 demo-board with identical schematic. For example, Figure 3 shows load transient response from the experimental and simulation.

User can define the PCB and arrange the placement of components on the board after performing electrical analysis. In the "Board Definition" tab, one can define the size of the board, number of layers, and the thickness of the copper. For this example, the parts are arranged on the board to be identical to the IR3897 demo-board. At this stage, the thermal analysis can be performed. User

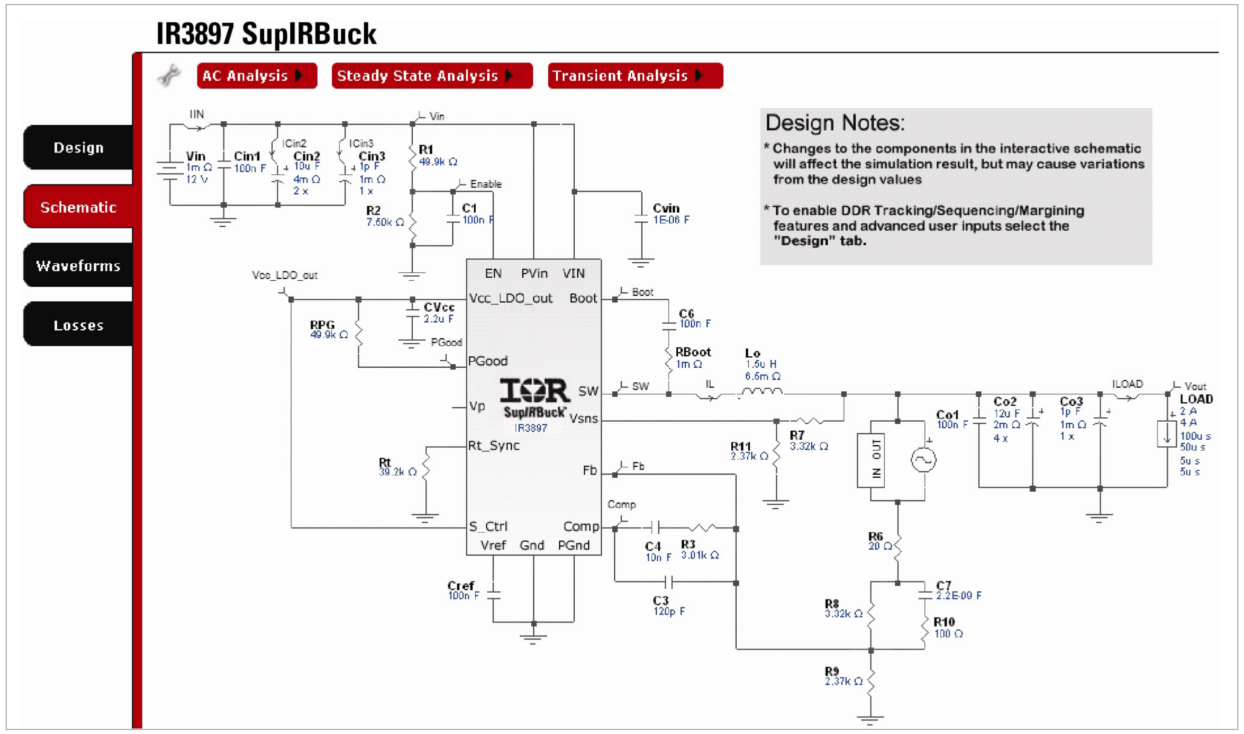

Figure 2: Schematic of the IR3897 design example

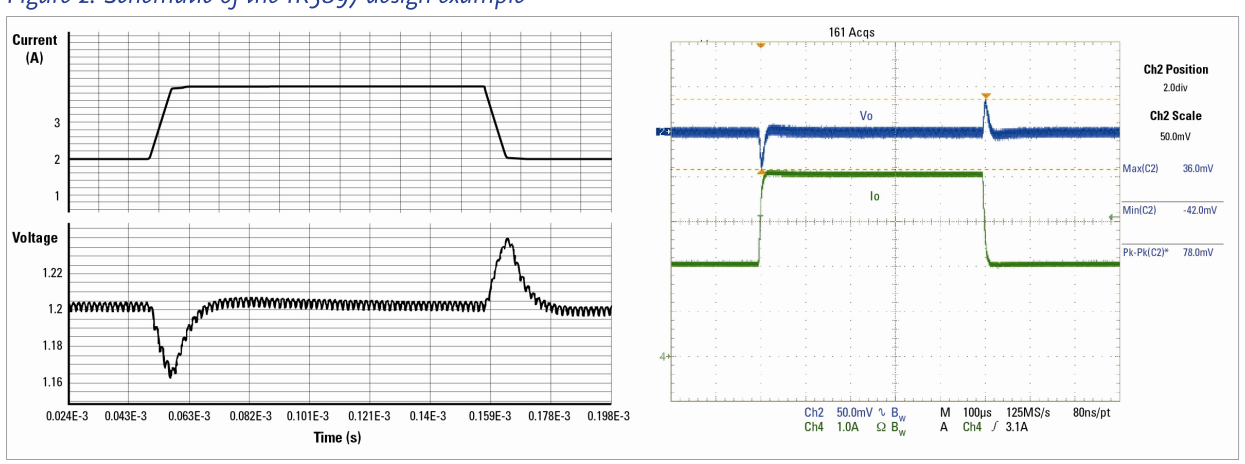

Figure 3: Output voltage response to 2A-4A load transient with 0.3A/us slew rate

has the option to specify the ambient temperature and air flow and its direction. For the given example, the thermal analysis is performed at 25°C and no air flow. Both experimental and simulation results show the maximum board temperature is about 37°C at Sync-FET of IR3897, where the maximum power is dissipating. SupIRBuck® design tool estimates the total power loss of circuit and contribution of each component. The estimated total power loss for this example at 100% load is 633mW, which is very close to the measurement taken on the demo board at similar condition. The match of the simulation results with the experimental ones is another indication of the effectiveness of this tool in rapid and reliable selection, design, and evaluation of SupIBuck® circuits.

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SPECIAL REPORT: POWERING INDUSTRIAL APPLICATIONS

PSD NORTH AMERICA

Power Systems Design: Empowering Global Innovation

INSIDE:

THE POWER OUTPUT STAGE

Designing for performance

By: Alfred Hesener

Power electronics subsystems are often divided in a control and a power circuit, where the power output stage components strongly determine the characteristics of the whole application, like efficiency, robustness or noise.

Good alignment across the entire power stage subcircuit will enable higher performance, but also better robustness and larger design margins. For the gate driver, different choices like halfbridge drivers, optically isolated gate drivers or delay-matched lowside drivers will be compared against discrete solutions, and for the power stage the decision criteria for different power switch technologies are explained with practical examples. Finetuning the driver stage to the power switches plays an important role in the optimization process of the system.

System trends in power electronics applications

In all power electronics applications, two types of power subsystems can be found – power conversion and motion control circuits. The first may also be called AC/DC or power supply, the second can also be called inverter or frequency converter. Both benefit from the same three factors that are driving the development, namely performance of the components, increased integration, and solution or design support.

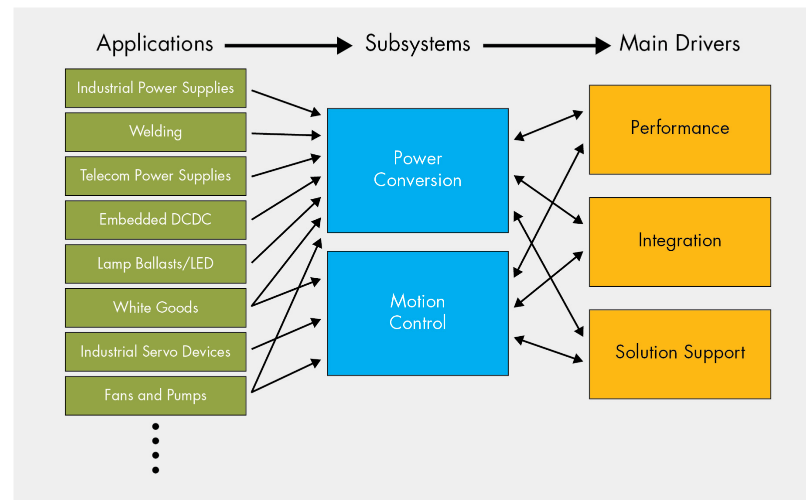

Figure 1

Performance of the controllers, gate drivers and power switches is crucial for increasing performance. Improvements in efficiency in operation and standby power reduction can only be achieved with new technologies for the power switches, and new and improved features for the controllers, enabling not only better performance of existing topologies but also implementation of new topologies. One example is the increased use of quasi-resonant power supplies, enabled today e.g. by Fairchild's PWM controller FAN6300.

Efficient partitioning

Optimizing the power output

stage requires an in-depth analysis of the components and their performance characteristics, not only for pure performance values, like conduction or switching losses, but also regarding the integration with other devices. Without this optimization, larger design margins must be implemented, and no advantage can be taken from the use of more modern components.

Power output stage examples

In both subsystems mentioned above, power is being switched at a considerable frequency – for this article, we will not consider applications where switching is a result of a system status, e.g. line breakers, on/off switches or similar. Switching at a high frequency is desirable to reduce the size of the passive components needed, but at the same time switching losses are increasing. Higher frequency switching can also improve dynamic load transient behaviour, which may be a system advantage.

In most cases, the power switches are not only connected to ground

Technology	Main Characteristics	Typical Component	Applications
Si Bipolar Transistor	Low cost, high breakdown voltages possible; low switching speed, SOA may be limited	Many	LFL ballasts
Emitter-switched bipolar transistor	Medium cost, high breakdown voltages possible; medium switching speed and good robustness	FJAF510	Flyback converters for very wide input voltage range
Planar MOSFET	Low cost, robust; medium power density	FCP7N50NZ	Lighting applications, lower-density power supplies
Superjunction MOSFET – SuperFET® MOSFET	High performance, fast switching enables reduction of passive components	FCA47N60F	High density power supplies, solar inverters, lower power motion control
Superjunction MOSFET – SupreMOS® MOSFET	Highest performance for very high power densities and size reduction	FCA76N60F	High density power supplies, solar inverters, industrial electronics with highest power density
SiC Bipolar Transistor	Very fast switching speed, lowest losses and high temperature stability, promising to have good reliability and robustness	TranSiC®	Solar inverters and other highest-efficiency applications, high temperature applications (future products)
IGBTs with low VCESAT	Low saturation voltage for lowest conduction losses in high current applications, low switching frequency	FGA30N60	Robust higher power motion control, frequency inverters at lower switching frequencies
IGBTs with low switching losses	Low switching losses, but higher saturation voltages ; suitable for medium switching frequencies at higher currents than MOSFETs	FGL40N120	Higher power motion control, boost converters e.g. in solar inverters

Table 1

but also to the input, supply or "bus" voltage. Since these switches must be controlled with a proper gate drive voltage referenced to their source or emitter pin, a so-called "floating" driver is needed. This can be achieved through a junction-isolated driver, as in the case of monolithic gate drivers such as the FAN7080 from Fairchild, or through opto isolation, e.g. as in the FOD3120 from Fairchild.

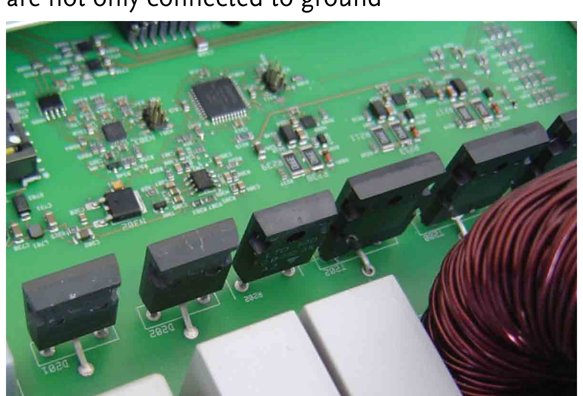

Figure 2

For motion control applications, it may be interesting to consider smart power modules, where the power switches are integrated with the gate drivers. Main advantages include higher reliability, better optimization of the components, smaller form factor, better design flexibility, and better protection features. In fact, the smart power modules demonstrate many of the advantages of a tight integration and alignment of the elements that are contained in the power output stage.

Selection criteria for the components

The two most important factors influencing the choice of IGBTs as well as MOSFETs as main power switches are switching and conduction losses. The application will determine the maximum voltages and currents, and also the switching frequencies required. Table 1 illustrates the differences between the different switch technologies.

For driving the switches, specific gate drivers are being used, that can deliver large peak currents, e.g. up to 11A/12A (sink/source) in the case of Fairchild's FAN3222, and can securely "clamp" the gates when the switch shall remain in off-state. It is important to select the right gate driver peak current – higher currents may give no significant advantage in efficiency, but can cause large voltage overshoots in the system and difficult EMI behaviour, due to the fast edges that contain rich harmonic noise content. Three different gate driver families are available, the monolithic half bridge or high side gate drivers for most applications not requiring electrical isolation, the opto-isolated gate drivers with excellent noise immunities, and the low side driver family with excellent timing performance for higher-power applications, including pulse transformer drive. Table 2 illustrates the different gate driver families and their features.

Technology	Main Characteristics	Typical Component	Applications
Monolithic gate drivers	Low circuit complexity, robust and versatile	FAN7080	High performance power supplies and motion control
Lowside drivers	Strong gate drive currents, excellent timing control, but need pulse transformers for highside drive	FAN3221	Highest performance power supplies, applications with high switching frequencies
Opto-isolated gate drivers	Excellent noise immunity, low circuit complexity, lower speed	FOD3120	Industrial electronics in very noisy environment, and at higher operating voltages
Discrete gate drivers	Very flexible approach, but higher design effort	Various	Optimized cost and switching performance e.g. in high density power supplies

Table 2

System level optimization

The most important factors considered for optimization of the power output stage are of course power efficiency, impacting cost-of-ownership, but also size and cost, all impacted by the three key drivers. Looking beyond, more factors need to be considered in industrial electronics applications, in particular robustness (protection and continued operation in abnormal system states), but also reliability (operation without failure for extended lifetimes), and more severe environmental conditions. These additional requirements will mostly influence the thermal, electrical and layout design, with additional consideration needed regarding EMI behaviour.

Figure 3 shows a power stage layout for a high density power supply, using parallel MOSFETs with both devices on the same heatsink. To improve the switching performance, the gate drive circuits (here with discrete components) are brought very close to the power switch they are controlling, in order to a) improve the gate drive current loop and make it as small as possible, b) reduce the parasitic gate-drain capacitance to prevent parasitic oscillations, c) bring the gate drive impedance as close to the gate as possible, again to prevent parasitic oscillations.

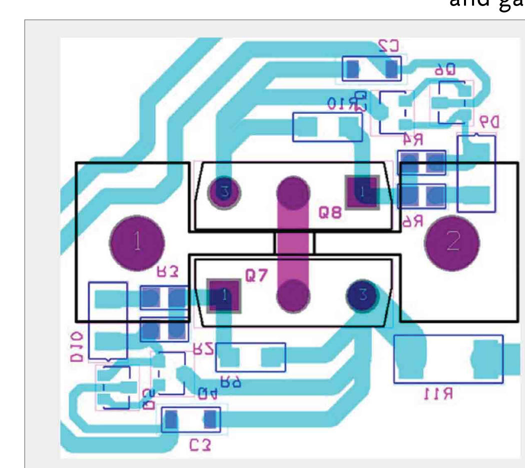

Figure 3

Conclusion

The optimization of the power output stage is complex, with many different choices that can be made at device level, but also many different requirements that may contradict each other. In this article the different technological choices have been illustrated, and optimization possibilities how to maximize the performance have been shown. It all depends on the fine-tuning of the power switches and gate drivers in the system, to achieve optimum "team play".

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MULTIPHASE DC/DC CONVERTERS

Providing high efficiency over the entire load range

By: Bruce Haug

The data centers' incremental overhead power consumption, due to inefficiencies and cooling systems is estimated to be equal to the amount of power that is consumed by servers, storage and networking.

The user of a single PC, workstation, or laptop doesn't see system heat generation as a concern, but for data centers, managing this thermal overhead is as important as the servers themselves. If system power is reduced, then the available overhead can handle a greater IT load and perform more useful work in the same power envelope.

As the data center power demand continues to increase, higher efficiency power conversion is required to reduce the amount of power wasted as heat. Smart multiphase controller technology is an excellent solution for high current POL applications. This architecture allows a high current regulator to achieve well over 90 percent efficiency at full load. However, most designs do not address the need for higher efficiency at light to medium loads. Wasted power at a light to medium load is just as important to save as wasted power at heavy loads.

Most embedded systems are powered via a 48V backplane. This voltage is normally stepped down to a lower intermediate bus voltage of 24V, 12V or 5V to power the racks of boards within the system. However, most of the sub-circuits or ICs on these boards are required to operate at voltages ranging from sub-1V to 3.3V at currents ranging from tens of milliamps to hundreds of amps. As a result, point-of-load DC/DC converters are necessary to step down from either of the 24V, 12V or 5V voltage rails to the desired voltage and current level required by the sub-circuits or ICs.

It is clear that the growing demand for increased current at ever decreasing voltages is driving power-supply development. Much of the progress in this area can be traced to gains made in power conversion technology, particularly improvements in power ICs and power semiconductors. In general, these components contribute to enhancing power supply performance by permitting increased switching frequencies with minimal impact on power-conversion efficiency. This is made possible by reducing switching and on-state losses thereby increasing efficiency while allowing for the efficient removal of heat. However, the migration to lower output voltages places more pressure on these factors, which in turn, creates significant design challenges.

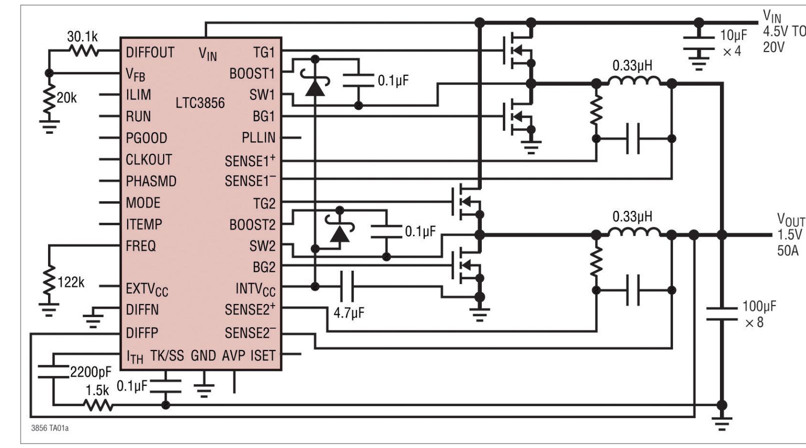

Figure 1: High output current 1.5V/50A application schematic

Multiphase Topology

Multiphase operation is a general term for conversion topologies where a single input is processed by two or more converters, where the converters are run synchronously with each other but in different, locked phases. This approach reduces the input ripple current, the output ripple voltage and the overall RFI (radio frequency interference) signature, while allowing high current single outputs, or multiple lower current outputs with fully regulated output voltages. It also allows smaller external components to be used, producing a higher efficiency converter and also providing the added benefit of improved thermal management with less cooling.

Multiphase topologies can be configured as step-down (buck), step-up (boost) and even as a forward converter, although generally the buck regulator is the more prevalent application. Conversion efficiencies of up to 95% from 12V in to 1.xV out are commonplace today.

At higher power levels, scalable multiphase controllers reduce the size and cost of capacitors and inductors using input and output ripple current cancellation caused by interleaving the clock signals of several paralleled power stages. Multiphase converters help minimize the external component count and simplify the complete power supply design by integrating PWM (pulse width modulation) current mode controllers, true remote sensing, selectable phasing control, inherent current sharing capability, high current MOSFET drivers plus overvoltage and overcurrent protection features. The resulting manufacturing simplicity not only helps improve power supply reliability, but it is also scalable. Such systems can be expanded up to 12 phases for high current outputs as high as 300A.

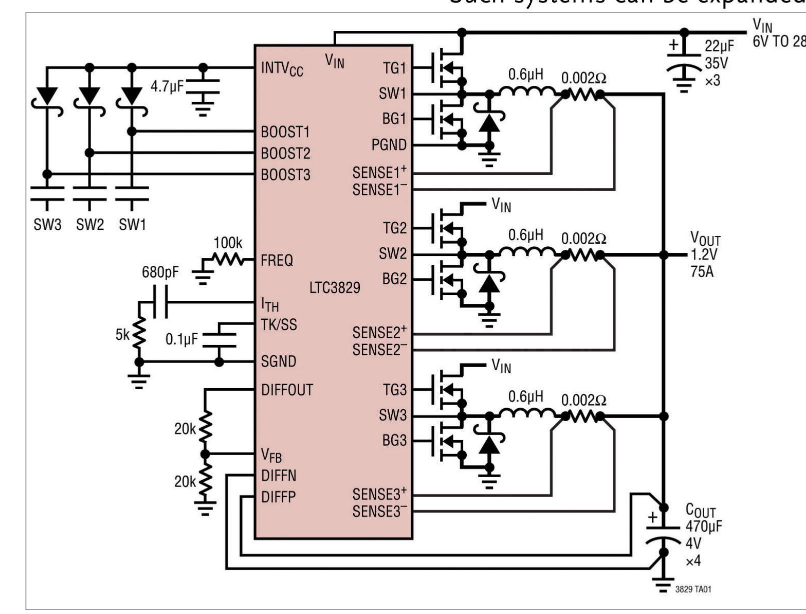

Figure 2: High output current 1.2V/75A application schematic

Linear Technology has several multiphase DC/DC controllers, including the LTC3856 and LTC3829 single output synchronous step-down controllers for high current POL conversion. Not only can these parts increase full load efficiency, but they also have an optional Stage Shedding™ feature that decreases light to medium load power loss as well. The circuit in Figure 1 shows a typical LTC3856 application schematic for developing a 1.5V/50A output from a 4.5V to 14V input voltage using two phases.

The circuit in Figure 2 shows a typical LTC3829 application schematic for developing a 1.2V/75A output from a 6V to 28V input voltage with three phases.

The LTC3856 has two channels and up to 12 phases possible with multiple ICs. The LTC3829 has three channels and can operate at up to 6 phases when used with two ICs. The onboard differential amplifier provides true remote output voltage sensing of both the positive and negative terminals, enabling high accuracy regulation independent of IR losses in trace runs, vias and interconnects.

Additional Benefits

These controllers operate with all N-channel MOSFETs from input voltages ranging from 4.5V to 38V, and can produce ± 0.75% accurate output voltages from 0.6V to 5V. The output current is sensed, monitoring the voltage drop across the output inductor (DCR) for highest efficiency or by using a sense resistor. Programmable DCR temperature compensation

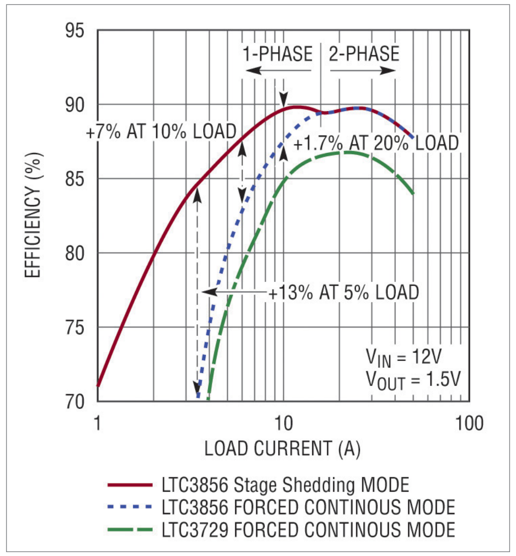

Figure 3: LTC3856 efficiency curve with Stage Shedding phase vs. an older controller

maintains an accurate over current limit set point over a broad temperature range. The powerful onboard gate drivers minimize MOSFET switching losses and allow the use of multiple MOSFETs connected in parallel. A fixed operating frequency can be programmed from 250kHz to 770kHz or synchronized to an external clock with its internal PLL. A minimum on time of just 90ns makes the LTC3729 and LTC3856 ideal for high step-down ratio/high frequency applications.

Stage Shedding Operation

At light loads, switching-related power losses normally dominate the total loss of a switching regulator. Eliminating the gate charge and switching losses of one or more of the output stages during a light load will significantly increase efficiency.

Stage Shedding allows one or more phases to be shut down to reduce switching related losses during a light load condition and is typically used when the load current is reduced to less than 15 amps. The overall efficiency can be increased by up to 13%, as shown in Figure 3. This figure also shows the efficiency of an older comparable LTC3729 2-phase controller. Due to the stronger gate drive and shorter dead time, the LTC3856 can achieve 3-4% greater efficiency than the LTC3729 over the whole load range.

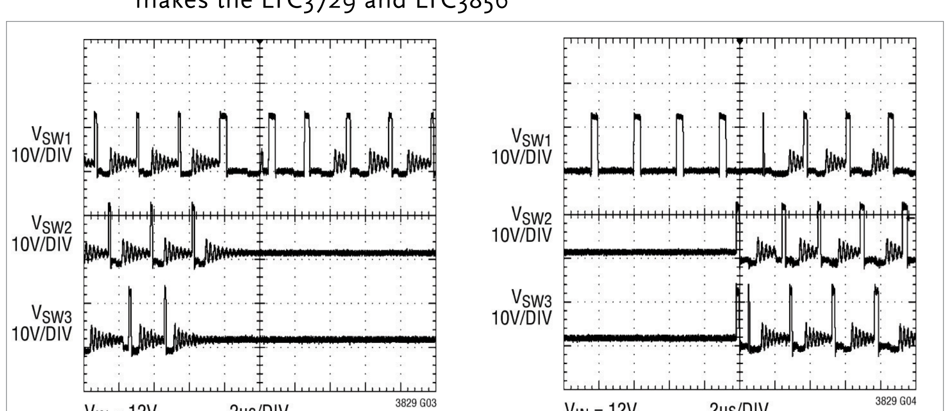

Figure 4: LTC3829 Stage Shedding phase waveforms: (a) Going into Stage Shedding and (b) Coming out of Stage Shedding

Stage shedding operation is triggered when the onboard feedback error amplifier output voltage reaches a user-programmable voltage. At this programmed voltage, the controller shuts down one or more of its phases and stops the power MOSFETs from switching on and off. This ability to program when Stage Shedding takes place provides the flexibility to determine when to enter this mode of operation. The diagrams in Figure 4 show the SW waveform and how the LTC3829 goes into and out of Stage Shedding operation.

The LTC3856 and LTC3829 can operate in any of three modes: Burst Mode® operation, forced continuous or Stage Shedding mode, all of which are user selectable. At heavy loads of greater than 15 amps, these devices operate in constant frequency PWM mode. At very light loads, Burst Mode operation can be selected and produces the highest efficiency at load currents of less than 0.5A. Burst Mode operation switches in pulse trains of one to several cycles, with the output capacitors supplying energy during internal sleep periods.

Active Voltage Positioning

The LTC3856 and LTC3829 also have Active Voltage Positioning (AVP), which reduces the maximum voltage deviation during a step load and reduces the power dissipation at heavier loads further increasing its efficiency. Figure 5 shows the difference in behavior between the circuit in Figure 1 with and without AVP. Without AVP, the maximum voltage deviation for a 25A step load is 108mV. With AVP, the maximum voltage deviation is 54mV for the same 25A step load. In addition, the output voltage drops by 54mV with AVP when the output current goes from 25A to 50A, resulting in a lower 2.7W dissipation by the load.

Conclusion

The need to reduce the power dissipation in data centers will be a major focus for the next several years. Designers of POL DC/DC converters for almost any kind of system face many challenges due to the multiple constraints of limited space and cooling within a given enclosure, as well as the need for high efficiency throughout the entire load range. Despite having to navigate through this myriad of constraints, many of the recently introduced multiphase regulators provide a simple, compact and efficient solution. By moving toward the diverse multiphase topologies, designers can effectively save space, simplify layout, lower capacitor ripple current, improve reliability and reduce the amount of power wasted as heat.

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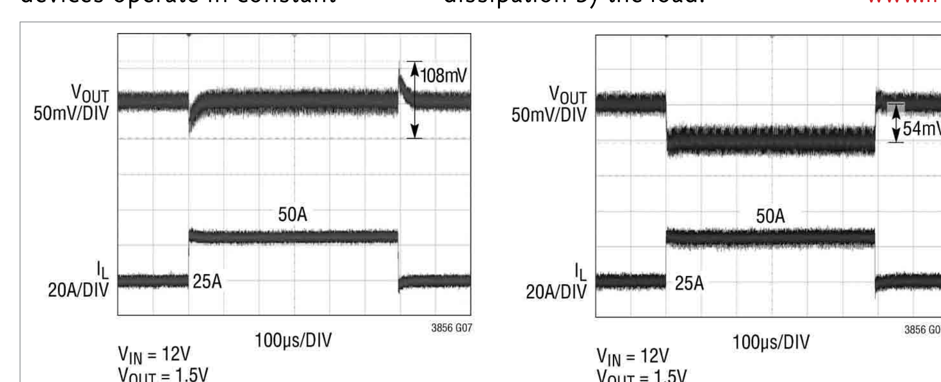


Figure 5: Load step characteristics (a) without Active Voltage Positioning and (b) with Active Voltage Positioning.

INVERTER EFFICIENCY

Advanced ferrite material for photovoltaic systems

Reported by: Cliff Keys, Editorial Director, PSD

Low-loss and high saturation flux density core materials in reactors and transformers are a key determining factor for the efficiency of inverters.

The new TDK PE90 ferrite is a cutting-edge material that minimizes reactor losses in the step-up chopper and smoothing circuits of inverters for photovoltaic systems, thus enabling decisive increases in conversion efficiency.

State-of-the-art inverters and power conditioners for photovoltaic systems have at least two reactors that are vital for the power conversion processes. One reactor is needed for the boost converter (step-up chopper circuit) and one is needed for output EMC filtering or smoothing (Figure 1). The future goal for modern inverters is to achieve an efficiency of 98 percent and higher.

Conventional core materials cause reactor losses of around 0.5 percent of the output power for each reactor. Until recently, this was not considered significant. In the increasingly competitive solar market, however, these values negatively impact on a system's marketability. Thus, the design of the reactors and the transformers is becoming an ever important focus of manufacturers of inverters and power conditioners. If the reactors and transformers are to help make inverters more efficient, they must exhibit a saturation magnetic flux density that is high enough to support the peak current of inverters in the 3.3 to 5.5 kW class, which are widespread for household photovoltaic systems. They must also have much lower core losses than can be achieved with conventional core materials such as silicon steel sheets or sendust. A solution for this application is the advanced TDK PE90 ferrite material with excellent loss and saturation flux density properties.

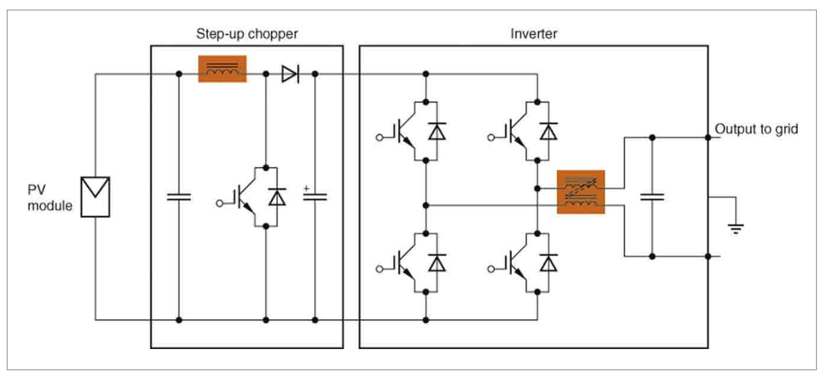


Figure 1: Basic circuit configuration of inverters
Caption: At least two power reactors are needed for solar inverters: one in the boost converter (step-up chopper) and one at the ouput of the inverter for EMC filtering. Besides the IGBTs, the losses in the reactors are a major determining factor of the overall efficiency of the inverter

Advanced TDK PE90 ferrite opens new possibilities

The new TDK PE90 ferrite represents a further development of the existing high saturation flux density material PE22. The two materials were tested in a prototype reactor with dimensions of 109 × 55 × 115 mm³. The adjusted air gap values and inductance values of PE22 and PE90 were at a similar level (1.1 mH), and the DC superposition current peak value, which is determined by magnetic saturation (inductance decreased by 10 percent from IDC of 0 A), was adjusted to around 20 A. DC superposition characteristics, which determine the current capability of reactors and transformers, are a vital factor for their design. While the conventional high saturation magnetic flux density material PE22 reached magnetic saturation at 19 A, the newly developed PE90 could still function as a reactor at up to 21 A, a level about 10 percent higher than that of PE22 (Figure 2).

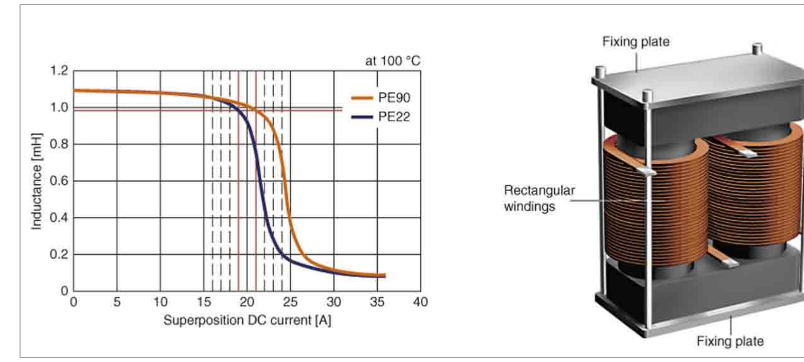
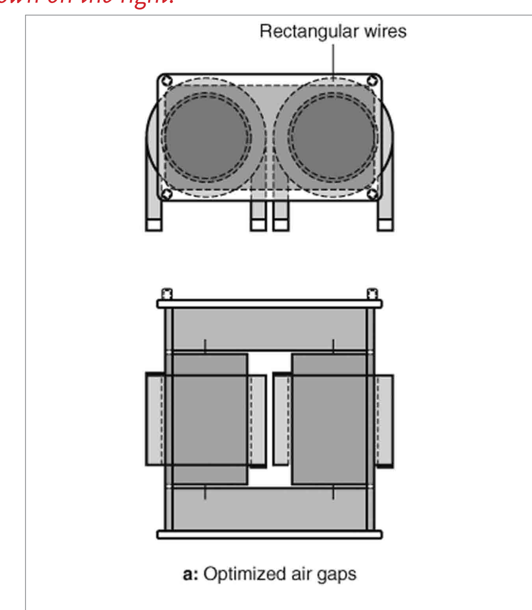


Figure 2: Example of inductance change vs. DC superposition characteristics
Caption: Due to its excellent material characteristics and high saturation magnetic flux density, the TDK PE90 material allows a current level that is approximately 10 percent higher than the conventional PE22 material. The prototype reactor used in the test is shown on the right.

Furthermore, the core loss of TDK PE90 material at 100 °C was 23 percent lower than that of PE22, which makes the rise in magnetic flux density steep, and the minor loop's linearity was maintained right up until it was saturated. In other words, PE90 is an outstanding power ferrite with high saturation magnetic flux density Bs and is the first such material to qualify as a low-loss material. As a result, it is now possible to replace reactors that employ soft magnetic metal with reactors that use TDK PE90, without changing the size.



Basic parameters:

Output power	3 kW	Ripple current	2.8 A_{0-p}
Inductance	1 mH	Peak current	24 A
Effective current	15 A	Ripple frequency	16 kHz

Figure 3: Loss comparison with silicon steel sheet and sendust

Cutting reactor losses by up to a third

The advantages of TDK PE90 ferrite are even clearer when compared to conventional materials such as silicon steel sheet and sendust. A comparison of the actual performance of the reactors integrated in the power conditioner based on their total iron and copper losses demonstrates the superiority of TDK PE90 over conventional materials. In a simulation of the reactors used for the smoothing circuit of the inverters for 3-kW photovoltaic system PE90 material cores exhibit 33 percent lower losses than a similar sized silicon steel sheet reactor and approximately 30 percent less than a similar sized sendust reactor (Figure 3).

Enabling high frequency inverters with smaller reactors

Most inverters that achieve 95 percent efficiency or higher employ trench IGBTs, which provide high-speed operation and low loss properties. But these IGBTs, with a built-in high-speed soft recovery diode, are able to support switching up to approximately 30 kHz, which is beyond the operating frequency range of silicon steel sheets and sendust. Moreover, the latest IGBTs for high power applications feature significantly lower losses and are much faster, enabling 30 to 50 kHz drive elements that are in line with the high-speed switching requirements of power conditioners.

Conclusion

If all of the installed reactors, including those for step-up choppers, are designed with the advanced ferrite material TDK PE90 with its superior core loss frequency characteristics, the operating frequency of inverters can be set at 30 to 35 kHz rather than the currently standard 15 to 20 kHz. Nearly doubling the operating frequency range makes the use of silicon steel sheets and sendust difficult. Even in the higher frequency range, the core loss of TDK PE90 remains much lower than that of the sendust material at 15 to 20 kHz. While the copper loss increases at the higher frequencies, the magnetic flux density required decreases, which means that the core size can be reduced. As a result, the use of TDK PE90 as core material will enable even more efficient inverters with even smaller reactors to be designed.

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ENERGY FROM RENEWABLES

Achieving significant power levels

By: David Andeen

Just imagine a world in which all electricity comes from renewable sources.

Now, consider that the 2011 European Commission Energy Roadmap 2050 proposed a future scenario in which 97% of consumed electricity would actually be generated from renewable sources. Yes, the goal is 97%. What would such a world look like?

Harnessing the main sources of renewable energy

Renewable sources are certainly very attractive options for generating energy. The sun and wind are free, prolific, and permanent. After an initial setup investment, they can be made to produce clean, inexpensive, reliable energy for years. Concurrently, new chemistries such as copper indium gallium selenide (CIGS) and nanoparticles have transformed photovoltaics, allowing for lower production costs and flexible form factors. In addition, high-volume production continues to drive down the cost of conventional silicon and polysilicon panels.

But there is yet another step in the integration of renewable energy sources. After creating electricity from photovoltaic cells, that energy needs to be converted to AC power for use on the grid. To be cost effective, this inversion step must be efficient. In complete photovoltaic systems today, the “balance of the system” (i.e., all components except the panels) now accounts for 44.8% of the system cost. That percentage will increase in 2012. Consequently, there is no argument that these electronics must work efficiently and reliably.

If a utility wants to generate a large majority of energy from renewable sources, then massive installations for solar, wind, and hydroelectric generation must occur. In addition, the distribution grid must be capable of transporting, and likely also storing, these large distributed and intermittent energy sources. Furthermore, conservation and efficiency must also play a significant role. Technologies like LED lighting would require mass adoption.

Scale down to energy harvesting as another option

There is another intriguing alternative energy story worthy of discussion: energy harvesting. Here the task is to think beyond different sources of energy and consider the scale of these sources. A large wind farm or an acre-sized solar farm in the desert provides a tremendous amount of electricity. But what about the breeze that blows leaves across the ground or the ray of sunlight shining through the window? If you consider the scale of these sources, you open up a new range of applications and ideas. You can, in fact, greatly increase the reach of renewable energy.

Small-scale applications for e.g. cell phones, called energy harvesting, are not only possible, but they are closer than you think. These renewable sources require intelligent handling of energy to make the smallest amount of wind, vibration, or sunlight useful.

Achieving the Significant Power

Renewable sources and scale of resources—this is really what we are talking about. Up to this point I have spoken about what some

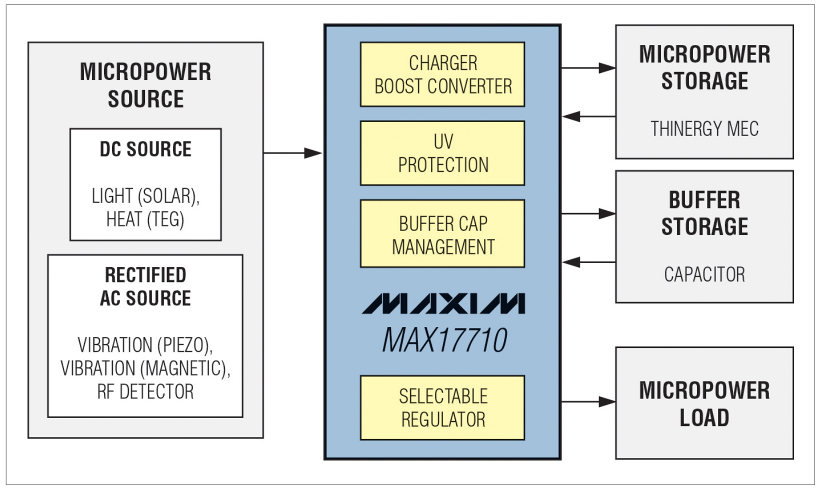

Figure 1: A block diagram of the MAX17710 energy-harvesting charger along with potential energy sources and storage elements or loads

consider "the obvious." Now we can talk about what is already happening. Maxim Integrated Products is offering many products that span the breadth of alternative energy solutions, from small-scale energy harvesting to large-scale solar implementations. For ultra-small energy generation, the MAX17710 (Figure 1) provides intelligent conversion of any source that generates more than 1μW of energy. The IC is considered to be "energy-source agnostic" because it harvests energy from heat, light, vibration, and magnetic sources. The result is a usable voltage that can charge a microcell battery while simultaneously running a sensor.

In a world relying almost entirely on renewable energy, these microsources of power will be a necessary part of the energy portfolio. This is also why energy harvesting tools like the MAX17710 will be so necessary in the future.

Medium- and large-scale energy generation

In medium- and large-scale solar installations, measuring the produced energy provides insight into the status of system operation. The 78M6613 energy-measurement chip accurately measures DC or AC energy to 0.5% across a dynamic range of 2000:1. Actual data is shown in Figure 2. This accuracy and range let power producers monitor and gauge the system performance of their rooftop solar panels that are producing energy in the morning and evening, even in the weakest sunshine.

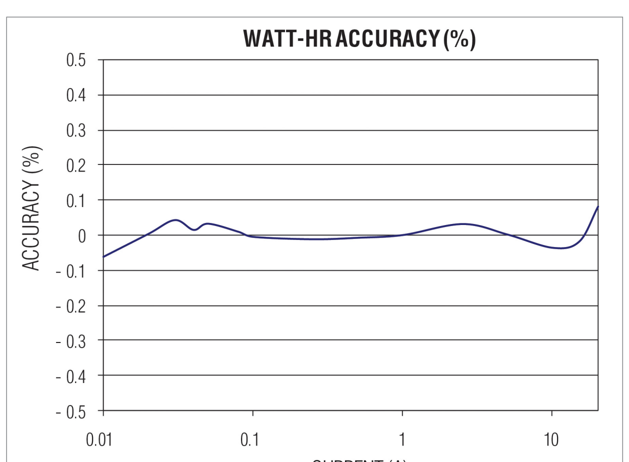

Figure 2: Actual data for energy measurement with a calibrated 78M6613

The 78M6613 also uses four-quadrant measurement to provide an accurate power factor, which determines both the efficiency of transmission and the readiness of the power to go out on the grid. With 8 channels, the 78M6618 energy measurement IC provides similar functionality for applications requiring multiple points of measurement. The 78M6631 thus works in large-scale 3-phase commercial systems. As renewable power becomes a greater percentage of power on grids, utilities will rely on the accuracy and speed of these energy measurements to maintain power delivery while smoothly integrating variable sources.

Measuring, metering, and communicating the power

Renewable energy sources are generally intermittent—the wind is not always blowing nor is the sun always shining brightly. Consequently, to ensure an adequate energy supply when users want it, high quantities of renewable generation will be required. Energy storage on the grid will also be required to buffer the variability of source and demand. Moreover, many of these systems will operate entirely "off grid". When you speak of generating power from renewables, you do not normally think about battery management. But when you consider the issues of energy storage, battery-management techniques become critically important. Battery chemistries evolve based on application and technology, but safety and continuous battery operation remain the primary requirements.

To meet these performance requirements, Maxim offers a variety of 12-cell battery-management products. The MAX11068 manages the energy of up to 12 battery cells, providing integrated cell balancing and over-/undervoltage (OV/UV) detection. For high-voltage applications, the part can also be connected in a daisy-chain configuration of up to 31 modules to manage up to 372 cells. Because it is designed to operate in the -40°C to +105°C temperature range, the harshest winter and summer conditions will not interrupt battery operation.

Power from solar panels must also be converted from DC to AC. This requires a series of frequency switching. Robust and reliable MOSFET drivers, such as the MAX15024 and MAX5048, provide efficient signals to drive the MOSFETs that invert the power. Once the inverter converts the power to grid-compliant AC, that inverter must also communicate over the grid. This communication tells the utility that it can route the energy for the most efficient performance. Maxim's G3-PLC™ chipset, the MAX2991 and MAX2992, communicates across powerlines, even in high-noise situations. Figure 3 schematically shows that G3-PLC also communicates across transformers from low-voltage to medium-voltage powerlines, thereby reducing the number of access points necessary in a powerline network. This communication method is already used in multiple smart meter trials, including the Electricité Réseau Distribution France (ERDF) trial in France. In addition, G3-PLC works effectively for communication within the photovoltaic system. Other forms of communication within a photovoltaic system and from a solar system-to-grid include RS-485, CAN bus, and RF. Maxim provides solutions for all these interfaces.

The situation today

Data indicates that we can achieve significant power with renewables. No one is debating the environmental benefits that will come with renewable integration and conservation. One thing is clear, however. These benefits cannot be achieved without carefully managed renewable resources and a well-engineered grid. The European Commission Energy Roadmap 2050 scenario of 97% renewable energy is clearly ambitious. Achieving something close to that would be a tremendous engineering achievement and likely require the next 50 years. Achieving significant power from renewables must merge engineering creativity, ambitious utility companies, and circuits optimized for the conversion, measurement, and communication of energy sources. When that happens, we will all win.G3-PLC is a trademark of Maxim Integrated Products, Inc.

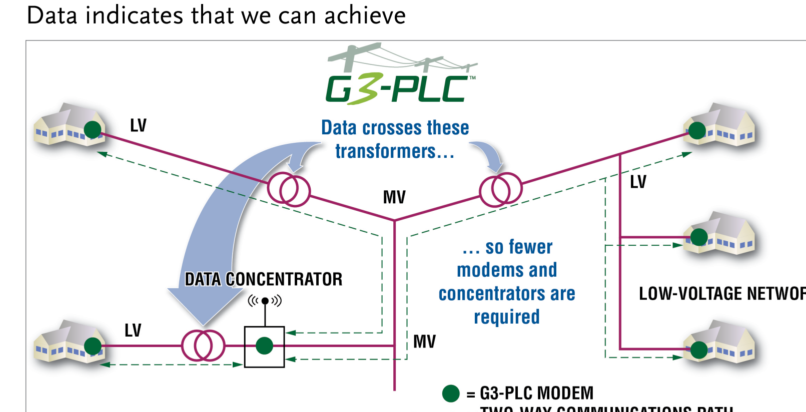

Figure 3: Schematic of G3-PLC communications. Crossing transformers from low-voltage to medium-voltage powerlines reduces the number of access points required in a utility's network

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A DIVERSE DRIVES MARKET DEPENDS ON PE ENGINEERS

By: David G. Morrison

The market for industrial drives encompasses a very wide and varied range of motor and motion control applications. From fractional horsepower to 1000+ hp motors with widely varying voltage levels and wide-ranging control requirements, industrial drives must serve a broad spectrum of needs in powering all types of industrial machinery.

On top of this diversity, there are some common market pressures that add to the challenge of designing and manufacturing industrial drives. Since motors are big energy consumers, it's imperative that the drives (and the machines they're part of) be as efficient as possible. And by virtue of their role in production, drives must be highly reliable with long life expectancy. Meanwhile, as with just about all power supplies, customers want drives to be made as small as possible to help shrink the size of their equipment. All of these goals must be met while balancing other demands such as electromagnetic compliance (EMC) and cost.

When you couple the diversity of application needs with the market pressures for improved performance, you end up with potential opportunities for power electronics (PE) engineers in the industrial automation (IA) field. A recent survey of some of the IA company websites reveals that a number of these organizations are seeking to hire PE engineers. You can see some example job openings in the online version of this article.

In pursuit of the many drive-design goals, PE engineers who develop industrial drives are working to evaluate and deploy the latest generation of silicon-based power semiconductors, while also keeping close tabs on the emerging silicon carbide devices, which promise performance leaps in the near future. These engineers are also working to apply new topology options such as active front ends, which offer multiple application benefits.

A Maturing Drives Market with Diverse Needs

At a high level, the design of power electronics for industrial drives is driven by the same types of technical requirements common to nearly all power electronics applications, explains Bill Drury, a consultant with Emerson's Control Techniques division. Power converters, says Drury are "defined by the tasks they have to perform (and the required performance), the environment they have to operate in, the reliability and lifetime, and finally the cost and price."

In IA, the nature of the tasks being performed can be quite varied, resulting in very different requirements for motor drives.

"Consider, for example, a machine tool axis," says Drury. "In this application, very high levels of acceleration and deceleration are required, often at high repetition rates. The power converter (and motor) have to be able to cope with very high overloads, and indeed are likely to be dimensioned on the basis of those overloads rather than the average loading. By contrast, a fan or pump type of load, where dynamic performance is rarely a requirement, would be dimensioned on the maximum continuous loading."

Meanwhile, the actual power levels and voltages of the motors, as well as their control requirements can also vary widely as described by Tom Lenk, director of Drives Development at Rockwell Automation.

"We are working across the spectrum that goes from fractional horse powers all the way up to a megawatt...and at different voltages, anywhere from 230 V or 480 V all the way up to 15 kV. We're also looking at different control performances," says Lenk.

In addition to the wide range of power levels required, you have a maturing drives market that is demanding more segmentation by power level, according to Lenk. "So the power electronics continues to spread in spectrum as to the number of products that need to be created to fit the more intelligent buyer who is trying to find the specific, right power device for his application."

Drury observes that the drives market is also migrating to higher voltages. "As power ratings for industrial automation products increase, there is a move to products operating at higher supply voltages. This brings with it a range of novel power electronic circuit topologies and power semiconductor devices," says Drury.

Efficiency In Pursuit of Other Goals

High efficiency, high reliability, and small size are high on the list of design goals for industrial drives and pursuing the first tends to support the pursuit of the other two objectives. Achieving these goals depends heavily on the PE engineer's ability to leverage the best available (yet cost effective) power semiconductors including the designer's ability to accurately model these devices.

"Efficiency and reliability are paramount. They have always been paramount, but the numbers that we're looking at for PPMs and uptime have dramatically improved with the improvement of the power semiconductor device and our knowledge of that semiconductor device," says Lenk.

Rather than being an end in itself, achieving higher efficiency is a means to other ends including smaller size and new capabilities. "This is not simply a low carbon issue, but also reflects into product size (less heat means smaller size) and cost of cooling, etc," says Drury. "A lot of work is being undertaken to reduce losses in power electronic equipment, and this will continue."

Lenk observes how the size issue becomes more important for higher-power drives.
"There is a constant market pressure to increase power density. And as you go larger in power, the more dramatic that pressure becomes. On a small 1-hp or 1-kW drive, the control boards and the user interface are quite a bit larger than the power section. But as we go up in power, the power cooling system starts to become a major factor, the capacitors that are supporting the dc bus are a major factor and just the heat removal from the semiconductors is a factor."

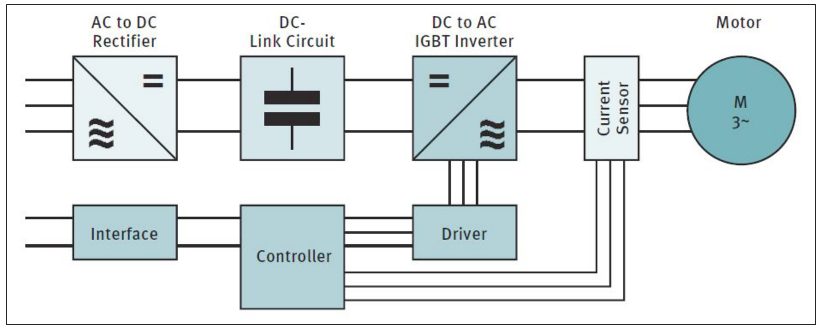
The PE engineer focuses on these thermal management issues.

"The power engineer today is continually playing a thermal tradeoff game with making the devices switch faster to reduce losses, but as we switch faster, we create more noise, so then you need a larger filter. So we're continually working that spectrum of 'where's the sweet spot between losses within the device due to switching versus the cooling system.' And we're working very closely—the top tier companies are all working—with the power semiconductor device makers to get the optimal power device to suite their equation for smallest footprint for the given power level."

Drury ties the size issue to the customer's space requirements in the industrial cubicles or cabinets where drives are housed.

"Machine builders are looking to reduce the size of their machines and control cabinets which contain drives are often the focus of their attention. In the extreme, they are eliminated and a distributed solution is adopted or the available size is reduced," says Drury. "There is also a trend to more and more drives being used on machines and so even if the cabinet is not being shrunk, then more has to be fit into the existing space. Packages exist with more than one drive in a module, and in some situations this can be helpful, but there is continual pressure on size."

Hearing this emphasis on improving efficiency, you might be misled to think industrial drives are relatively inefficient. However, that's not the case. Lenk points out that existing



Motion Control System block diagram. (Courtesy of Infineon Technologies) By replacing the diode- or SCR-based ac-dc rectifier with an active front end, drive manufacturers can provide high power factor and reduced harmonics on the line. Active front ends also enable regeneration—the ability to take the energy produced in braking the motor and put it back on the ac line rather than wasting it as heat.

drives already achieve efficiencies of 97% to 98%.

However, there is a challenge even in maintaining this level of efficiency as drive manufacturers work to add new new capabilities to their products. For example, replacing a conventional diode- or SCR-based front end with an active front end offers big benefits to customers (see the figure.)

With active front ends, which are IGBT-based power converters, the energy produced in slowing down a motor can be put back on the ac line instead of wasting that energy as heat. This process, which is similar to the technique being implemented in hybrid and electric vehicles, is known as regeneration. This capability supports the pursuit of higher (energy) efficiency on a "macro" level for the customer. Meanwhile, active front ends also clean up the line, reducing harmonics drawn by the drive, and raising its power factory to unity, which will also help to reduce the customer's utility bill.

One more windfall from using active front ends—the drive can now accommodate a wider input voltage range. As an example, Lenk points to HVAC applications.

"We have OEMs in the HVAC space who sell a product in the United States. It's a 480-V product and they sell a product in Europe which is a 400-V product. Today, when they don't use drives they have to use two different motors to make up for the 50 Hz and 400 V when they're in Europe. If we put in an active front end, we can actually use that active front end to take the 400 V and boost it up to a dc voltage which is equivalent to the 480 V. Hence, they can use the same motor and same drive for the European skew numbers as they do for the U.S. skew numbers."

Lenk notes that active front ends have tended to be used in the past on higher power drives where energy savings are greatest. But as the associated silicon costs have come down, says Lenk, active front end technology has been applied at lower and lower power levels.

This discussion continues in the online version of this article where you can read about the quest for improved power semiconductor devices and better device models in industrial drive development. This section also looks at other trends in industrial automation and their impact on the drives' power electronics. The article concludes with a listing of recent job openings for power electronics engineers in the industrial automation industry.

About the Author

When he's not writing this career development column, David G. Morrison is busy building an exotic power electronics portal called How2Power.com. Do not visit this website if you're looking for the same old, same old. Do come here if you enjoy discovering free technical resources that may help you develop power systems, components, or tools. Also, do not visit How2Power.com if you fancy annoying pop-up ads or having to register to view all the good material. How2Power.com was designed with the engineer's convenience in mind, so it does not offer such features. For a quick musical tour of the website and its monthly newsletter, watch the videos at www.how2power.com and http://www.how2power.com/newsletters/.

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GLOBAL HYDROPOWER INCREASES

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Industrialized and developing countries continue to rely on their critical water resources as a renewable electricity source.

Global use of hydropower increased more than 5 percent between 2009 and 2010, according to new research published by the Worldwatch Institute for its Vital Signs Online publication. Hydropower use reached a record 3,427 terawatt-hours, or about 16.1 percent of global electricity consumption, by the end of 2010, continuing the rapid rate of increase experienced between 2003 and 2009.

The average cost of electricity from a hydro plant larger than 10 megawatts is 3 to 5 U.S. cents per kilowatt-hour. Hydropower is also a flexible source of electricity since plants can be ramped up and down very quickly to adapt to changing energy demands. Yet there are many negative aspects associated with hydropower: for example, damming interrupts the flow of rivers and can harm local ecosystems, and building large dams and reservoirs often involves displacing people and wildlife and requires significant amounts of carbon-intensive cement.

China was the largest hydropower producer and is expected to continue to lead global hydro use in the coming years. The country produced 721 terawatt-hours in 2010, representing around 17 percent of domestic electricity use. China also had the highest installed hydropower capacity, with 213 gigawatts (GW) at the end of 2010. It added more hydro capacity than any other country, 16 GW in 2010, and plans to add 140 GW by 2015. This is equivalent to building about seven more dams the size of China's Three Gorges Dam, currently the largest in the world.

Hydropower is produced in at least 150 countries but is concentrated in just a few countries and regions. The Asia-Pacific region generated roughly 32 percent of global hydropower in 2010. Africa produces the least hydropower, accounting for 3 percent of the world total, but is considered the region with the greatest potential for increased production.

Micro-hydropower, which is defined as a plant with an installed capacity of 100 kilowatt-hour (kWh) or less, has grown in importance over the last decade and can be an effective means of providing electricity to communities far from industrial centers. As of 2009, roughly 60 GW of small hydro was installed worldwide, accounting for less than 6 percent of the hydropower total. Small hydro is likely to expand, especially as populous countries like India continue to pursue rural electrification.

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