HOW2POWER TODAY

Design Article Archive

Abstracts of articles published in the January through December 2014 issues

January 2014:

Video: RoHS and Power MOSFETs: An Evolving Standard Influences Package Selections Now And In The Future

by Brian LaValle, International Rectifier, El Segundo, Calif.

Abstract: Most engineers know that the Restriction of Hazardous Substances, commonly known as RoHS, prohibits the use of lead (Pb) in electronic components and this has driven a changeover to Pb-free solder throughout the industry. But many engineers may not be aware that the current version of this directive includes an exemption for the use of Pb-based solder within semiconductor packages. Some of the existing power MOSFET packages like DPak, D2Pak and PQFNs take advantage of this exemption because suppliers have not yet come up with a Pb-free alternative for die attach in these packages. However, with the exemption allowing Pb inside the package due to expire in two years, some are wondering how to address this issue. In this 9-minute video, Brian LaValle discusses the technical and compliance issues surrounding the use of Pb in power semiconductor packages. He assesses the status of existing power MOSFET packages with respect to the current and pending versions of RoHS, describes an existing proprietary package that does comply with both versions of the standard, and offers general guidance on how designers and those in design support roles can address requirements for fully lead-free power MOSFET packaging in the long term.

Notes: 9-min. 27-sec. runtime. Watch the video…

Troubleshooting Distributed Power Systems (Part 8): Making Time Domain Measurements

by Steve Sandler, AEi Systems and Picotest, Phoenix, Ariz.

Abstract: There are inherent challenges in measuring power supply waveforms in the time domain. Limitations in oscilloscopes and probes, difficulties imposed by linear time and amplitude scales, and even seemingly helpful scope features can either degrade measurement fidelity or hide "glitches" and waveform anomalies that can wreak havoc with system performance. In previous videos, Steve Sandler discussed measurement of power supply signals such a switch-node waveforms and output ripple. Here in this last installment of the video series, he delves further into the subject of how to make time-domain measurements of power supply signals, providing further discussion on the sources of measurement error and many examples of noise and stability problems that engineers may be missing. Sandler dispenses techniques and tips on how to observe hard-to-spot problems and how to make higher-fidelity measurements in general. Even experienced power supply designers may be disappointed to hear that their oscilloscopes are underpowered with respect to bandwidth and sampling speeds, but then this video may help them to justify requests for better instruments. As with the earlier videos, this one is not just for power supply designers, but for any circuit designers concerned with power integrity in their system designs.

Notes: 9-min. 14-sec. runtime. Watch the video…

Design Article Archive

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Modular Solution Simplifies Design Of PFC Front-End For Inverters In Energy-Efficient Air Conditioning Systems

by Alberto Guerra, International Rectifier, El Segundo, Calif.

Abstract: Developing a power management circuit solution for energy-efficient air conditioning applications is not easy. Achieving a solution that meets the criteria for full-scale efficiency, cost, reliability and ease of design poses a great challenge to designers. Adding to the challenge is the demand for power factor control as required by new regulations in Europe and China. IR's new IRAM630-1562F Intelligent Power Module for energy efficient compressor applications has been developed to specifically address these design needs by offering a complete front-end and inverter solution in a small compact and efficient integrated module. In addition, the packaging technology applied in the design of this module is capable of accommodating GaN switches and rectifiers as they become available in the future. This capability opens the door to further reductions in module and overall inverter design size. This article will present actual examples of high-performance input converters for compressor drives and motor control drives using the new topology and the proprietary iMotion packaging technology.

Notes: 6 pages, 6 figures, 2 tables. Read the full story…

Testing What You Know About Copper Wire - The Answers

Abstract: For those who enjoyed Martin Kanner's article, "Everything You Wanted To Know About Copper Wire But Didn't Know To Ask" in the November 2013 issue, and took the exam on this material presented in the December 2013 issue, we now provide the **answers** to that test.

February 2014:

The Small-Signal Model of An Active-Clamp Forward Converter (Part 1): Basics of The Forward Converter And Its Transfer Function

by Christophe Basso, ON Semiconductor, Toulouse, France

Abstract: Introduced more than 20 years ago, the active-clamp architecture elegantly overcomes multiple limitations of the standard forward converter topology. Among other benefits, it increases the allowable range of duty ratio, provides self-driven synchronous rectification, and makes possible zero-voltage switching (ZVS), which in turn enables an increase in switching frequency and the associated shrinking of magnetic components. But as with any dc-dc converter, you need to obtain the power stage's small-signal response before attempting to stabilize the loop. The purpose of this article series is to show how to build a small-signal model of the active-clamp forward converter operating in voltage mode and derive its ac transfer function. This series begins with the study of the classical single-switch forward converter and explains how to obtain its transfer function.

Notes: 17 pages, 17 figures. Read the full story…

Design Article Archive

Abstracts of articles published in the January through December 2014 issues

Video: Inside the 21st Century Power Test Lab

*with Steve Sandler of AEi Systems and Picotest, Phoenix, Ariz. Video courtesy of SpinQ Studios (**SpinQ.com**).*

Abstract: Making high-fidelity measurements on high-performance power converters—when measured alone or in distributed power systems—can require a number of different test instruments encompassing multiple measurement domains. And with the performance of these converters and systems on the rise, the performance required of the test instruments is growing too. In this 5-minute video, Steve Sandler takes you on a tour of an advanced power test lab that contains a wide assortment of instruments for measuring various power supply waveforms and troubleshooting various power-related problems, particularly those encountered in power distribution networks or PDNs. Sandler introduces a number of different test instruments that he has used to make various measurements, and discusses their measurement capabilities. In the process, he provides some guidance on the instrument specs required to measure power converters and PDNs, today and in the future.

Notes: 5-min. 31-sec. runtime. Watch the video…

Control Circuit Simplifies PFC Boost Converter Design

by Tom Ribarich, International Rectifier, El Segundo, Calif.

Abstract: A new control circuit enables simple and cost-effective solutions for power factor correction (PFC) boost converter designs. The applications for PFC boost converters include ac-dc power supplies, electronic ballasts, and LED drivers. Each of these applications typically has a boost-type front end to perform the necessary power factor correction of the ac mains input current. This article reviews the basics of PFC boost circuit operation, describes the new control circuit design, provides design equations for selecting circuit components, and presents final circuit performance data.

Notes: 6 pages, 6 figures, 2 tables. Read the full story…

USB Charger Provides Battery Backup And Load Switching With Easy, Low-Cost Design

by Budge Ing, Maxim Integrated, San Jose, Calif.

Abstract: The circuit described here takes power from a USB port and uses it to both power a low-current consumption device and to charge a 1-cell Li-ion battery. When the USB power drops out, the circuit switches the load over to the battery backup. The circuit also disconnects the battery when the terminal voltage drops to a user-determined voltage. Consisting of just a few ICs and some external parts, this design represents a low-cost, easy-to-implement solution that requires no coding and has an ultra-small footprint. Although it's designed to operate from a 4- to 7-V supply, it can withstand inputs up to 28 V.

Notes: 1 page, 1 figure. Read the full story…

Understanding Tradeoffs In Core Geometry Aids Transductor Design

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Although the design of magnetic cores is usually left to magnetics manufacturers, having some insight into why cores have particular geometric parameters can aid power supply engineers in transductor design. This article explains why core geometries dictate tradeoffs in various core parameters and in figures of merit such as maximum power-transfer utilization and windability, which will give designers a better handle on how to optimize core selection. Furthermore, it will give designers some insights into the impact of shrinking core sizes on these tradeoffs.

Notes: 4 pages, 2 tables. Read the full story…

March 2014:

Do You Know The ABCs Of Inverter Testing?

by Fred Zhu, Inverters and Product Safety, TÜV Rheinland, Pleasanton, Calif.

Abstract: After the recent economic slowdown during which some medium-sized inverter manufacturers went out of business, new companies have begun to enter this market. In part, the growth has been due to the introduction of new technology and designs to meet the changed market needs. These include higher dc input voltage, dc-side arc fault protection and interruption, and transformer-less inverters for better power conversion efficiency. As tech innovations are taking over the market, the need for testing services for these products—often to differing standards of import markets—has increased as well. Yet, many manufacturers are unsure what exactly the requirements are and what happens during testing. This knowledge gap may be especially detrimental if an inverter design needs to be changed in the late stages of the development process because of the need to comply with a certain standard requirement. This article offers answers to some of the most often asked questions about inverter testing.

Notes: 3 pages, 1 figure. Read the full story…

The Small-Signal Model Of An Active-Clamp Forward Converter (Part 2): Active-Clamp Forward Converter Operation

by Christophe Basso, ON Semiconductor, Toulouse, France

Abstract: In the forward topology, energy is absorbed from the source and transmitted to the load during the power switch on-time. During this period, the magnetizing current energizes the core but plays no role in the power transfer. To keep the core away from saturation, you must ensure a proper demagnetization of the transformer before the next cycle takes place. In the classical forward converter, this is the goal of the tertiary winding with its voltage stress and hard switching drawbacks. The active-clamp technique not only limits the voltage excursion on the power transistor drain at turn-off, it also helps achieve near-zero voltage switching operation under certain conditions. When switching losses are minimized, it becomes easier to increase switching frequency and shrink magnetics. Here in part 2, the structure of the active-clamp forward converter is introduced, its

operation is explained, and a large-signal model is derived, enabling SPICE simulation of the converter and generation of its Bode plot.

Notes: 11 pages, 14 figures. Read the full story…

Design Considerations For DCR Current Sensing In Boost Converters

by Haifeng Fan, Texas Instruments, Phoenix, Ariz.

Abstract: Higher efficiency and smaller solution size typically are the top priorities for designers of dc-dc converters. Using a current-sense resistor to detect overload conditions generates additional conduction loss and requires a large footprint for heat dissipation. Additionally, a current-sense resistor has a relatively high cost. Inductor direct-current resistance (DCR) current sensing can be used to eliminate the current-sense resistor. This potentially can reduce the solution size while improving efficiency. Size and efficiency improvements could be significant in high-current, low-voltage applications. This article explains how to design a DCR current-sensing circuit and discusses practical design considerations to improve current-sensing accuracy and achieve higher efficiency in boost converter designs.

Notes: 6 pages, 8 figures, 1 table. Read the full story…

Controller IC Implements Compact, Power-Saving Solution For Hot-Swapping And Active ORing In Telecom Systems

by Dongming Liu, Maxim Integrated, San Jose, Calif.

Abstract: A telecom system is a multicard application with embedded microprocessor-based cards plugged into the backplane. Once up and running, these cards are not supposed to be powered down for service or repair. All updates can only be done by hot-swapping the cards in and out without powering down the entire system. A telecom system also uses redundant power supplies to ensure reliability and therefore requires ORing of power supply outputs. This article introduces a high-integration hot-swap and ORing controller (the MAX5944) that protects a telecom system against a power supply fault. The operation of this controller IC is explained and measurements demonstrating its performance are presented.

Notes: 4 pages, 4 figures. Read the full story…

Single-Bundle Windings Make It Easier To Build Custom Magnetics In-House

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Two decades or more ago, America had numerous magnetics parts suppliers who were willing to provide free samples for prototype builds. Nowadays, the situation is quite different; the parts are built overseas and the only suppliers left in N. America are those with price-insensitive markets or those making standardized parts. One solution to the custom magnetics supply problem is to build your own transformers and coupled inductors (transductors). If that notion sends a red flag up in your mind, this article might offer some relief. There is a way of simplifying transductor construction

so that even members of a company without any assembly experience could build these parts. At the same time, this method of construction also has electrical advantages.

Notes: 5 pages, 6 figures. Read the full story…

April 2014:

Power Supply Control With FPGAs: Model-Based Design With Matlab, Simulink And DSP Builder

by Peter Markowski, Envelope Power, Chebeague Island, Maine

Abstract: Digital control has taken the power supply industry by storm and today almost no one needs to be convinced of its merits. But in the low to medium ranges of power and cost, this digital revolution is largely focused on implementations using microcontrollers, DSPs or ASICs, entirely neglecting programmable logic devices like FPGAs and CPLDs. However, a methodology know as Model-Based Design (MBD) has lowered the barrier to applying FPGA-based digital controllers in power conversion. Correctly applied, MBD reduces design time and the number of errors, while also enabling higher performance. After briefly explaining the benefits of FPGA-based design in power conversion, this article presents a step-by-step example of how to design a basic FPGA-based power supply controller using the MBD methodology.

Notes: 13 pages, 15 figures. Read the full story…

The Small-Signal Model Of An Active-Clamp Forward Converter (Part 3): Active-Clamp Forward Converter Transfer Function

by Christophe Basso, ON Semiconductor, Toulouse, France

Abstract: Parts 1 and 2 of this article series explained the differences between a classical forward converter and its active-clamp version. This third and last part of the series will show how to derive the control-to-output transfer function of the active-clamp converter operated in voltage mode. While our large-signal approach helped to deliver the control-to-output Bode plot, and eventually, stabilize the converter, we still do not know where the poles and zeros hide and how to counteract their variability. This is the goal of deriving a complete transfer function which, once organized in a low-entropy form, must reveal dc gain, poles/zeros contributions and quality factor, if any.

Notes: 13 pages, 15 figures. Read the full story…

Technology Recycles Noise Currents To Reduce Power Drain Of Digital Circuits

by Michael Hopkins, CurrentRF, Discovery Bay, Calif.

Abstract: In systems with digital signal processing circuits, the process of bypassing the noise currents away from the supply rail ultimately creates a "throw away" dc power drain on system power sources, batteries, and capacitors. A new methodology developed by CurrentRF reduces this digital power drain without the need for costly digital design rework and as a secondary benefit, enhances the stability of the system's power rail. This methodology has been implemented in a production-ready integrated circuit, which is then the basis for "add on" solutions to existing digital and system designs. In this article, the principles of operation behind the CC-100 Power Optimizer technology are explained at a high level and results obtained with two implementations of the technology are presented to illustrate the possible power savings. Then, the CC-100 Power Optimizer reference design and its various packaging options are discussed, illustrating various options for applying the technology.

Notes: 13 pages, 15 figures. Read the full story…

May 2014:

Synchronous Zeta Converter Outperforms The SEPIC

by John Betten, Texas Instruments, Dallas, Texas

Abstract: The SEPIC converter has become increasingly popular because of its ability to regulate an output voltage by bucking or boosting equally well. The functionally similar Zeta converter has not seen quite as much usage. A traditional Zeta power stage requires a high-side power switch, lending itself nicely to basic buck controllers that directly drive p-channel FETs. Yet, using an output rectifier diode limits the output current to a maximum of 3 A to 4 A. Toss in limited documentation, and it's easy to see why it's rarely used. However, as explained in this article, the ZETA's usefulness can be extended by converting it to fully synchronous operation and broadening the range of controllers capable of driving it. As a result, its efficiency and flexibility can be significantly improved beyond that of a traditional SEPIC converter.

Notes: 6 pages, 5 figures, 2 tables. Read the full story…

Using Ruggedized EMI Filters To Pass The CS101 Requirement Of MIL-STD-461D-F

by Kevin Seaton and Leonard Leslie, VPT, Blacksburg, Va.

Abstract: Power systems designed for military applications that require compliance to MIL-STD-461D-F must use an input EMI filter that contains adequate damping to meet the conducted susceptibility requirements of CS101. The risk of failing the CS101 test is often highest in the mid-frequency range, which includes the EMI filter cutoff frequency (typically 1 kHz to 10 kHz) where some filters exhibit peaking in their responses. In this article, the CS101 requirements are examined and its implications for the design of the power system—the combination of input EMI filter plus power converter—

specifically a dc-dc converter in this case—are discussed at length. Finally, a discussion of the CS101 test methods is presented, including a number of testing precautions that designers should observe.

Notes: 6 pages, 4 figures. Read the full story…

New Topology Eliminates Extra Stage Normally Required For PFC

by Tom Lawson, CogniPower, Malvern, Penn.

Abstract: In ac-dc power converters, the usual way to obtain a high power factor is to add a boost stage and bulk storage capacitor between the power converter and its ac input. But instead of adding on a separate power factor correction (PFC) stage, it is possible to blend PFC as part of the regulation process. CogniPower is patenting a topology for this purpose called the Compound Converter. In this converter, the majority of power moves through only a single stage of power conversion, providing an immediate reduction in losses of 25% to 50%, depending on load. Efficiency improvements increase with decreasing load, making it easier to hit the established targets for low-load efficiency. This article offers an introduction to the Compound Converter, explaining its principles of operation, benefits, and guidelines for designing converters using this new topology.

Notes: 4 pages, 3 figures. Read the full story…

On-Chip Drivers Enable High-Current, Normally Off GaN Transistors (Part 1)

by John Roberts and Iain Scott, GaN Systems, Ottawa, Ontario, Canada

Abstract: Gallium nitride (GaN) offers significant speed and density benefits for switching power systems. But driving GaN transistors, especially above 100 A, has proved difficult to achieve reliably as the low-voltage threshold of enhancement-mode GaN power switches leads to unwanted turn-on. This problem has been solved with a new approach to implementing the gate-drive circuitry via on-chip drivers. This technique is being used by GaN Systems to deliver a wide range of higher-current normally off GaN transistors that are reliable and simple to drive. In this article, the advantages of GaN transistors and their gate-drive requirements are reviewed leading to a discussion of the on-chip gate driver concept. The structure and operation of an enhancement-mode GaN HEMT power device with on-chip drivers is then explained including simulated data on the transfer characteristics and switching losses of this 200-A, 650-V device.

Notes: 4 pages, 5 figures. Read the full story…

What Is To Be Optimized In Magnetic Component Design?

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: It is generally believed that the best strategy for optimizing the design of magnetic components is to design the magnetic and electrical aspects for equal, or near-equal power loss. This principle has a sound basis in the maximum power-transfer theorem from passive circuits theory.

However, a different and not necessarily contradictory strategy is to maximize the *utilization* of the core. The difference in these strategies is explored in this article.

Notes: 4 pages, 2 figures, 1 table. Read the full story…

June 2014:

Current-Mode Control Stability Analysis For DC-DC Converters (Part 1)

by Timothy Hegarty, Silicon Valley Analog, Texas Instruments, Tucson, Ariz.

Abstract: Current-mode control (CMC) is an extremely popular dc-dc converter loop architecture—and with good reason. Simple operation and dynamics are achieved even though two loops, a wide-bandwidth current loop lurking inside an outer voltage loop, are required. Peak, valley, average, hysteretic, constant on-time, constant off-time, and emulated current-mode are commonly used. Each technique offers plusses and minuses pertaining to the overall design. This article, part one in a two-part series, highlights the fundamentals of loop stability in fixed-frequency, naturally sampled, peak current-mode, buck-derived converters, specifically for industrial and automotive applications. Following a brief review of the operating principles of peak and valley current-mode architectures, the small-signal model for peak current-mode control, including control-to-output transfer function, is set out in detail. Design of the current loop follows, including conditions for slope compensation.

Notes: 7 pages, 4 figures. Read the full story…

FPGA-Based Power Controllers Offer Greater Speed And Computational Power Than Microcontrollers And DSPs

by Peter Markowski, Envelope Power, Ansonia, Conn.

Abstract: In this article, the discussion of digital power control continues by exploring the specific advantages of using an FPGA rather than a microcontroller or DSP as the power supply controller. After a brief explanation of the differences in structure that distinguish FPGAs from microcontrollers and DSPs, this article will describe how those differences lead to specific benefits for FPGAs when applied in power supply designs. The long list of benefits relates mostly to the higher bandwidth and faster dynamic response enabled by the speed and computational power of FPGAs. The article concludes by discussing a number of applications that could potentially benefit from the superior speed and computational power offered by an FPGA.

Notes: 7 pages, 8 figures. Read the full story…

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Cutting Power Transformer Size In Half While Doubling Transistor Efficiency: It's All In The Topology

by Martin Kanner, KEMCO, Power Controls Div., Plainview, N.Y.

Abstract: Once upon a time, I was designing switching power supplies for a highly secure military communication system. Initially the requirements for the supplies were not unusual. They called for multiple regulated dc outputs generated from a 28-V dc supply specified by Mil-Std-704. Naturally the supplies had to satisfy the EMI requirements of Mil-Std-461 for conduction and radiation and be reasonably efficient. The various modules ranged from 10 W to 200 W with size and weight appropriately specified. But sometime after the project was underway, the program manager said he needed an another power supply—one with a regulated 40-V dc, 1500-W output, and at least 90% efficiency, plus tight size and weight specs. This is the story of how I met these requirements using a nonisolated push-pull topology that performed voltage doubling while maximizing efficiency and minimizing transformer size.

Notes: 4 pages, 4 figures. Read the full story…

July 2014:

Enhanced OTA Models Improve Design Of Feedback Compensation Networks

by Alain Laprade, ON Semiconductor, East Greenwich, R.I.

Abstract: An operational transconductance amplifier (OTA) generates a current-source output that is proportional to a differential input voltage. To achieve ESD robustness in OTAs, a current-limiting series protection resistor and voltage clamp are installed between the die's OTA output and the package pinout. Device manufacturers consider the influence of this ESD protection resistor as negligible and the parameter is not described in datasheets. However, when designing power supply circuits, neglecting to consider the influence of the ESD protection resistor on OTA output impedance may introduce gain and phase errors in the feedback loop compensation. This article presents derivations of the transfer functions for power supply OTA compensation that include the effects of this resistor.

Notes: 13 pages, 15 figures. Read the full story…

Current-Mode Control Stability Analysis For DC-DC Converters (Part 2)

by Timothy Hegarty, Silicon Valley Analog, Texas Instruments, Tucson, Ariz.

Abstract: This article discusses current-mode control loop compensation for industrial and automotive applications. Starting from the small-signal model, simple expressions are derived that yield an intuitive procedure for designing the compensator for a current-mode-controlled buck converter. Even with an error amplifier of finite gain-bandwidth, the simplicity and convenience of this design procedure makes it viable for everyday use by the practicing power electronics engineer. To bolster the theoretical analysis, an actual design example based on a commercially available PWM regulator is

presented here with simulation used to verify the results obtained from the aforementioned design procedure.

Notes: 9 pages, 6 figures. Read the full story…

Simple Method Of Implementing Digital Loop Compensation In An FPGA

by Peter Markowski, Envelope Power, Ansonia, Conn.

Abstract: Previous articles in How2Power Today presented the Model-Based Design methodology for implementing a digital power supply controller in an FPGA and discussed examples of engineering challenges that might be addressed effectively with FPGA controllers. Here the author explains how a standard linear compensator can be implemented digitally in an FPGA. While there are already many references available on this subject, most of them are unnecessarily complex and rely too much on the theory of discrete circuits. However, by applying the Model-Based Design methodology and using Matlab, Simulink and DSPBuilder, the whole task of implementing digital loop compensation in an FPGA can be shown to be relatively straightforward and reliable. This particular design example will apply type III compensation.

Notes: 10 pages, 13 figures. Read the full story…

Ripple Steering Can Enhance Magnetics Circuit Function Through Ripple Reduction

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Elimination of current ripple in transductor (transformer or coupled inductor) windings is an ideal in converter design, and current-ripple "steering" essentially accomplishes it. The behavior of the transductor is central to an understanding of current steering and this article explains this behavior using a simple model. Then, it is shown that ripple steering is not only applicable to Ćuk-derived converters, but also to any of the basic PWM-switch converter configurations—buck, boost, or buck-boost. Finally, this article discusses tradeoffs in implementing ripple steering and how a slight variation—one which does not eliminate ripple but instead reduces it—represents a more-practical application of this decades-old concept.

Notes: 5 pages, 5 figures. Read the full story…

August 2014:

Cascode Configuration Eases Challenges Of Applying SiC JFETs In Switching Inductive Loads

by John Bendel, United Silicon Carbide (USCi), Monmouth Junction, N.J.

Abstract: The high switching speeds and low $R_{DS(ON)}$ of high-voltage SiC JFETs can significantly improve the efficiency and power density of many power conversion applications. However, the conventional view of these devices is that, despite the parametric advantages, JFETs are difficult to

implement due to non-standard drive voltages and a lack of an intrinsic diode when switching inductive loads. This article describes the use of a JFET in cascode to solve both of these issues by utilizing the intrinsic diode and the drive voltages of a standard low-voltage MOSFET. It will also highlight the general robustness of SiC JFETs in cascode with respect to short circuit and avalanche conditions. A comparison of the cascode's reverse recovery with that of a SiC MOSFET reveals that the JFET cascode actually performs better than the SiC MOSFET over temperature.

Notes: 9 pages, 11 figures, 2 tables. Read the full story…

Inductance-Measuring Algorithm Speeds Start Up Of Sensorless BLDC Motors

by Jiri Ryba, STMicroelectronics, Prague, Czech Republic

Abstract: In a sensorless brushless dc (BLDC) motor control application, the rotor position must be known or the rotor must be aligned to a known position to ensure successful motor start up. Aligning the rotor to a defined position is the most widely used method to start a motor. But this method is slow and the motor is vulnerable to undefined movement during rotor alignment. This article examines a method to detect rotor position in mere milliseconds. This method, which is based on an inductance-measuring algorithm that ensures the rotor starts in the right direction, detects saturation in synchronous permanent magnet (SPM) motors by applying high current to the motor for a very short time. And the simplicity of the algorithm provides a low-cost way to safeguard the start-up of sensorless BLDC motor control applications.

Notes: 5 pages, 5 figures. Read the full story…

FPGA-Based Controller Plus Integrated Power Stage Builds Envelope Tracking Modulator With No Compromises

by Peter Markowski, Envelope Power, Ansonia, Conn.

Abstract: This article presents an example of a high-performance FPGA-based digital power supply controller used in an envelope tracking (ET) voltage modulator. The ET modulator design discussed here takes advantage of a new integrated power stage component with very high switching frequency capability, practically no dead time, very low delay and excellent timing accuracy—all critical in high-bandwidth voltage modulation applications. The combination of a low-cost FPGA controller with the integrated power stage enables design of a new topology multilevel converter that overcomes the limitations of other circuit solutions for ET, which sacrifice efficiency gains in order to limit switching frequency to a manageable level. Those alternative approaches are briefly discussed before the author describes implementation of a 16-level envelope tracking power converter.

Notes: 10 pages, 14 figures. Read the full story…

PQFN With Ribbon Bond Boosts Power MOSFET Performance While Reducing System Cost For Automotive Applications

by Jifeng Qin, International Rectifier, El Segundo, Calif.

Abstract: The trend of vehicle electrification continues to increase the burden on the 12-V battery system. Today, the total load can easily reach 3 kW or more. Developers of automotive electrical systems are driven to improve their designs in terms of both efficiency/power density and cost to ensure that they keep pace with current and future industry needs. One of the tools designers rely on to meet these increasingly stringent requirements are power semiconductor components, particularly power MOSFETs, which can have a significant impact on both the performance and cost of automotive electrical systems. This article looks into the key challenges that automotive designers face when selecting power MOSFET packages, and in turn discusses the next-generation power package requirement. Then, a new automotive qualified package, a 5-mm x 6-mm PQFN, is introduced with a detailed discussion of how its unique features are well suited to the trends in automotive electronic system design.

Notes: 5 pages, 5 figures. Read the full story…

September 2014:

Topology Twists And Circuit Tricks Improve Performance Of Multi-Output Converters

by Bob Zwicker, Analog Devices, Olympia, Wash.

Abstract: SEPIC, Ćuk, Zeta, flyback and inverting buck-boost converters are some of the most common “go-to” topologies when the buck and boost cannot quite do what is needed. After allowing for turns ratios and voltage inversion, they are all governed by the same relationship between voltage and duty cycle. While there are many useful variations for producing one output, the group is particularly well-suited for generating two or more outputs. The author has been working with these converters for many years, and in the process has developed some topology variations and techniques that can improve performance. This article describes some common and some less-well-known multiple-output buck-boost topologies, along with three favorite “tricks” that improve their performance. It also explains why these tricks work.

Notes: 25 pages, 27 figures, 4 tables. Read the full story…

The Most Important Concept In EMI Diagnosis

by Franki N.K. Poon, PowerELab, Shatin, N.T., Hong Kong

Abstract: After all the work that has been done to analyze and treat EMI in power supplies, it is about time we stop describing the analysis and treatment of EMI as a “black art.” Clearly, EMI topics have been studied to the point where the underlying issues are understood, techniques for dealing with EMI are well established, and this knowledge is readily available to the engineering community. Nevertheless, EMI engineers still feel frustrated at times with theories and real world measurements.

One of the sources of this frustration is the conflict between the log scaling required to measure and assess EMI and the engineer's "linear" mindset. It is important for engineers to adapt to log scales in order to apply EMI theories on diagnostic techniques effectively, gain valuable experience in these areas, and to obtain more consistent results. This article discusses some common mistakes that engineers make in interpreting log-scale EMI measurements, explains why different engineers performing similar tests draw different conclusions about the causes of EMI, why the search for a "dominant" noise source is counterproductive, and describes a more effective approach to addressing EMI issues in power supply designs.

Notes: 8 pages, 10 figures. Read the full story…

Video: PDN Basics For Power Designers

by Steve Sandler, Picotest, Phoeniz, Ariz.

Abstract: In modern electronic systems, the performance of FPGAs, CPUs, and other high-speed logic devices depends on the power distribution networks or PDNs that power these devices. Within these PDNs, power converters in the form of point-of-load regulators (POLs), voltage regulator modules (VRMs), dc-dc converters, and linear regulators play a crucial role. Yet, many engineers who develop these power converters may be unfamiliar with PDN concepts and how power converters affect PDN and system performance. In this three-part video series, Steve Sandler introduces three basic PDN concepts that developers of board-level power solutions need to understand.

Part 1: What's A PDN? In this 4-min. video, Steve explains what PDNs are and why they matter, particularly to developers of POLs and VRMs. Watch the part 1 video…

Part 2: Keep Impedance Flat. In this 6-min. segment, Steve discusses power converter output impedance and why designers of board-level power converters need to keep their output impedance curves flat. Watch the part 2 video…

Part 2: Impedance Matching Is Critical. In the last video, which runs 3 min., Steve explains why the output impedance of a power converter needs to be matched to the impedance of the PDN in which it is used. Watch the part 3 video…

Latest Generation Of 3D Electromagnetic Finite Element Analysis Software With Breakthrough Simplicity Facilitates Magnetic Component Design

by Peter Markowski, Envelope Power, Ansonia, Conn.

Abstract: Finite element analysis (FEA) software is a great tool for simulating electromagnetic fields in chokes and transformers, allowing accurate computation of the spatial distribution of the current, flux density, associated losses and resulting temperature rise as well as the impact of the magnetic component on the efficiency of the converter. By manipulating dimensions and geometrical arrangements we can arrive at the most compact, efficient and lowest-cost structure. Unfortunately, 3D FEA software gained the reputation of being expensive, tedious and requiring a highly skilled operator to obtain sufficiently accurate results. Consequently, practicing power supply designers were forced to resort to simpler methods. However, FEA vendors have been busy trying to improve the ease of use, accuracy, stability and versatility of their tools. And as the author explains in this article, some

of them have become truly practical design tools for hands-on power supply designers with general knowledge of magnetic components.

Notes: 5 pages, 7 figures. Read the full story…

October 2014:

How2 Turn On A MOSFET

by Sanjay Havanur, Vishay Siliconix, Santa Clara, Calif.

Abstract: On a portal dedicated to power electronics professionals the topic of turning on a MOSFET might sound trivial, like asking how to boil water on a cooking show. After all, it shouldn't be a major issue. MOSFETs are voltage driven, they turn on when a voltage, equal to or greater than the threshold, is applied to the gate, right? Just how wrong depends on when the mistake is discovered. The most common time frame is a few days before the mass production deadline. In this article, the author debunks popular misconceptions concerning MOSFET turn on (including ones relating to R_{DSON} and switching speed), explains which datasheet specs are really relevant and how to interpret them, and describes the mechanisms responsible for MOSFET turn-on and turn-off.

Notes: 7 pages, 8 figures, 1 table. Read the full story…

Raising The Bar For Flyback Primary-Side Regulation: Enabling Accurate CV-CC Solutions From 5 W To 150 W

by Adnaan Lokhandwala, Texas Instrument, Dallas, Texas

Abstract: Primary-side regulation (PSR) in flyback converters has been widely adopted in many low-power (<5-W) ac-dc applications. PSR is advantageous because it eliminates secondary-side feedback components—reducing component count, PCB space, and bill-of-materials cost. This regulation method, however, has been limited to very low-power designs because the existing controllers lack the intelligence needed to accurately control higher-power designs. In this article, the author addresses this gap. He discusses some key system-level benefits of PSR that are less apparent, challenges in implementing this architecture at higher power levels, and how smart high-voltage IC technology can simplify and make PSR viable for ac-dc flyback converter designs from 5 W to 150 W.

Notes: 5 pages, 4 figures. Read the full story…

3D FEA Software Solves Tough Inductive Noise Problems

by Peter Markowski, Envelope Power, Ansonia, Conn.

Abstract: Switched-mode power supplies are notorious for hard-to-eliminate noise problems simply because we cannot completely avoid proximity of high-power switching circuits and sensitive controls. Good engineering practices such as minimizing high-frequency current loops and voltage surfaces, perpendicular arrangement of potential source-target sets and using large copper planes for shielding are naturally a must. But without any way of quantifying problematic phenomena it is impossible to know if we are pushing our luck and if we did the best we could within the given constraints. However, as the author explains here, dangerous noise can be reduced and many layout re-spins avoided if we model potential trouble spots with the latest-generation 3D FEA software, which has the necessary modeling power and user friendliness to be applied in power supply design.

Notes: 10 pages, 11 figures. Read the full story…

November 2014:

Actively Managed Storage Capacitor Offers Host Of Benefits In AC-DC And DC-DC Applications

by Tom Lawson, CogniPower, Malvern, Penn.

Abstract: Modern digital loads can slew at rates in excess of 100 A/µs. Often these extremes are handled by enabling and disabling multiple parallel power stages. Techniques using new, faster power switches and sophisticated controllers allow simpler structures to respond as quickly, but regardless of how the output regulation is accomplished, the peak currents and edge rates required continue to rise, and the ratio of peak to average current will rise as well. To keep a point-of-load converter (POL) operating properly, a large amount of input filter capacitance is required to absorb the severe edges. The intermediate power supply feeding the POL must then drive a highly capacitive load, which is an invitation to instability when using most control methods. The high edge rates also complicate the design of the PDN. This article explores an alternative approach to POL design that reduces the input filter capacitance required in the face of fast slewing loads, while also improving other aspects of converter performance. This approach is based on a proprietary technology known as the Compound Converter.

Notes: 5 pages, 3 figures. Read the full story…

Sense Power Switch Current Without Increasing Losses Or Parasitics

by Tom Ribarich, International Rectifier, El Segundo, Calif.

Abstract: Conventional approaches to current sensing such as the use of current-sense resistors or transformers add power losses and cost to power supply applications. Those drawbacks can be eliminated with the application of a new current-sensing IC, the IR25750. This chip provides a simple and innovative solution for measuring the $V_{DS(ON)}$ of a power MOSFET or the $V_{CE(ON)}$ of an IGBT. Unlike existing current-sensing ICs employing series-connected methods, the IR25750 implements a parallel-connected solution so it does not add to the circuit's power loss or its parasitic inductance. This article describes the functionality of this new IC, presents simulation and experimental results, and provides helpful guidelines for PCB layout.

Notes: 7 pages, 7 figures. Read the full story…

An Analytical Approach To Modeling RC Snubbers And Clamps In Inductive Power Circuits

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Power circuit modeling is unrealistic unless it includes parasitic elements of actual components. A circuit element is *parasitic* if it is unintended yet nevertheless present and thus must be included for realistic analysis. Parasitic capacitances across switch terminals can resonate with the converter power transformer or other inductive components. These undesired resonances result in unwanted oscillations that add noise and reduce efficiency. The design solutions for them are often in the form of RC *snubbers* and RCD *clamps*. These resonance-compensating circuits are presented here. They are easily modeled on a circuit simulator but are more difficult to analyze using non-numeric network analysis. The transformer, in particular, requires some skill to model correctly as the circuit changes modes of behavior.

Notes: 6 pages, 5 figures. Read the full story…

November 2014:

Mission IGBT: Understanding And Specifying IGBT Modules

by Paul Schimel, International Rectifier, El Segundo, Calif.

Abstract: Choosing an IGBT module for your traction inverter, motion control, renewable energy inverter or related high-power designs does not have to be a "mission impossible," if you understand which criteria are most important in module selection. In this article, the author offers a brief look at the internal structure of an IGBT module and the considerations used to select the proper device for an application. This article builds on an earlier work in which the author reviewed IGBT concepts and described specific device technologies.

Notes: 5 pages, 2 figures. Read the full story…

Amplifier IC Generates A Negative Voltage Reference With The Fewest Parts And A Single Supply Rail

by Chapin Wong, Maxim Integrated, San Jose, Calif.

Abstract: Certain applications require the use of a negative voltage reference, which is usually not readily available. A common way to generate a negative voltage has been to use an op amp to invert the output of a positive precision voltage reference. This approach typically requires a positive reference, the op amp, and two supply rails to generate the negative output. Another approach to generate the negative supply rail uses a charge-pump inverter. This method requires a voltage reference, a charge pump, an op amp, and a positive supply rail. This article presents a simpler way to generate the negative voltage reference from a single supply using an op amp with an integrated charge pump.

Notes: 3 pages, 4 figures. Read the full story…

Design Article Archive

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Bandgap Voltage Reference Achieves High Performance At Low Supply Voltages

by Sándor Petényi, STMicroelectronics, Prague, Czech Republic; Calogero Ribellino and Giuseppina Bille, STMicroelectronics, Catania, Italy

Abstract: This article presents a practical chip-level design for a precise bandgap voltage reference circuit built in 0.35-µm BCD technology. This circuit's excellent electrical performance is achieved by application of an optimized bandgap core, base-current compensation and a feedback-mode bias current generator. The bandgap core works in shunt-mode operation so all sensitive circuits are supplied by the regulated bandgap voltage level. This circuit is distinguished by its ability to generate a regulated bandgap voltage from a supply just 10 mV above the natural bandgap level while still providing high levels of precision, regulation, and supply voltage rejection. As a result, this voltage reference offers high performance at low supply voltages such as those encountered in battery-powered applications.

Notes: 13 pages, 12 figures, 1 table. Read the full story…

Voltage References Behaving Badly: Output Caps Are Key Source Of Poor Stability

by Steve Sandler, Picotest, Phoenix, Ariz.

Abstract: The purpose of a voltage reference is to provide a very precise dc voltage level, which in turn will be used by other circuitry. By its very nature, a voltage reference is quite susceptible to control loop issues. This is due in part to the low dc output resistance of the reference and its low power circuitry, which generally results in a relatively high effective output inductance. Furthermore, the low dc output resistance results in this output inductor being a high Q inductor that is very sensitive to external capacitance. Yet many voltage reference manufacturers recommend the use of an output capacitor. In this article, a series of measurements are presented to highlight issues resulting from the addition of the output capacitor to the voltage reference circuit or, in some cases, the selection of an inappropriate output capacitor value.

Notes: 6 pages, 6 figures. Read the full story…