Design Article Archive

Abstracts of articles published in the January through December 2015 issues

January 2015:

Model-Based Design Streamlines Embedded Motor Control System Development

by Dara O'Sullivan, Analog Devices, Cork, Ireland; Jens Sorensen, Analog Devices, Wilmington, Mass. and Aengus Murray, Analog Devices, Costa Mesa, Calif.

Abstract: System and circuit modeling has long been an important aspect of motor control system design. The latest simulation tools from MathWorks can model complete embedded control systems including the electrical circuit and mechanical system domains. Embedded coding tools generate C code from control system models to enable direct deployment of control algorithms on embedded control platforms. These tools enable a model-based design process where control algorithms can be designed and fully tested on a simulation platform before the final hardware test. This article describes the detailed steps in building a model-based design (MBD) platform around an ARM-based embedded motor control processor. It follows with examples of basic permanent magnet synchronous motor control algorithms initially deployed and the ease of extending the functionality to include multi-axis position control for automation systems.

Notes: 14 pages, 12 figures, 2 tables. Read the full story…

Pre-Regulator Design Protects High-Voltage Power Supplies From Phase Faults (Part One)

by Jean-Paul Louvel, ON Semiconductor, Toulouse, France

Abstract: Power supplies for applications such as e-meters and high-power appliances designed to run from a three-phase supply must be able to withstand incorrect connection between phases that can cause very high voltages to appear at the input. To survive these faults, the main ac-dc power supply must be able to withstand an applied voltage of approximately double the mains RMS supply voltage. For a system operating in the U.S., a switched-mode power supply (SMPS) with universal input can meet this requirement. But in Europe or Asia, the SMPS must be capable of withstanding an applied voltage of 460 V (over 600 V dc when rectified.) This article discusses several approaches for designing a fault-tolerant power supply, including a new pre-regulator topology that helps simplify circuit design and component selection while ensuring high efficiency and reliability.

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

Common-Mode Transformer Aids Noise Reduction In High-Power Supplies

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In a typical switched-mode power supply transformer, the capacitance between primary and secondary windings is distributed along the windings. This interwinding capacitance can be represented by an equivalent capacitor, C_{seq}, across the middle of the primary and secondary windings. This interwinding capacitance offers a path for parasitic currents, which result from voltage differences across the primary and secondary windings. Those parasitic currents, in turn, can become a source of noise, which is particularly troublesome in power supplies with higher power output.

However, these parasitic currents can be avoided with the addition of a common-mode transformer as explained in this article.

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

February 2014:

Partial BCM Mode Of Operation Improves Efficiency For Primary-Side Regulated Flyback LED Driver

by Roy (Ningliang) Mi, Fairchild Semiconductor, Chicago, Ill.; John (Xiukuan) Jing, Fairchild Semiconductor, Los Angeles, Calif.; and Jason Guo Sr., Fairchild Semiconductor, San Jose, Calif.

Abstract: This article explains the operating principles of the primary-side regulated (PSR) flyback topology in the LED lighting application with high power factor (PF) and high operating efficiency. The basics of the PSR flyback LED driver are presented and its merits are addressed. A design procedure is proposed and described in detail for engineers to achieve the optimum design balance between the ac-dc LED driver's efficiency, power factor (PF), THD and flyback transformer design. The unique approach to PSR flyback design described here allows the driver to operate partially in boundary conduction mode (BCM) at low input voltage. This enables the driver to achieve high efficiency, while maintaining high power factor and low THD. A quick design example is also given at the end of the article for verification.

Notes: 17 pages, 11 figures, 1 table. Read the full story…

Choose The Right Regulator For The Right Job

by Don Corey, Maxim Integrated, Chelmsford, Mass.

Abstract: It can be a daunting task for an engineer, who is responsible for all aspects of a complex board, to choose the optimum regulator for a particular point of load. Several IC suppliers offer very good solutions, but that does not assure you of obtaining the right regulator for a particular application. In this three-part article series, the author provides the background on the various regulator control schemes and design considerations that the non-power expert will need to select a switching regulator for his/her application. After reviewing the importance of application duty cycle and load usage, part 1 introduces regulator control schemes, explaining PWM operation under voltage-mode and current-mode control, discussing the differences, critical parameters, and compensation schemes. There's also discussion of internal vs. external FETs.

Notes: 8 pages, 6 figures, 1 table. Read part 1 of the article…

Abstract: Part 2 describes more control schemes such as constant on-time, hysteretic, and pulse frequency modulation (PFM) , explaining how they work and where they are effective.

Notes: 6 pages, 6 figures. Read part 2 of the article…

Abstract: Part 3 works through an example of how to select a switching regulator IC and simulate a design based on it using a vendor supplied tool. But first, this part reviews the equations required for inductor and capacitor selection, and notes some vendor tools and references that will be helpful in calculating these component values.

Notes: 10 pages, 9 figures, 1 table. Read part 3 of the article…

March 2015:

Practical Power Flow Controller Brings Benefits Of Power Electronics To The Grid

by Kalyan K. Sen, Sen Engineering Solutions, Pittsburgh, Penn.

Abstract: The capacity of the power grid's transmission system can be expanded by building new high-voltage transmission lines. But that can take years. A more immediate solution is to increase the power flows in underutilized lines. This can be achieved using a full power electronics-based solution, an electromechanical solution or a hybrid of the two. This article discusses the evolution of the power electronics inverter-based solution, explaining its interesting capabilities and also why its adoption to date has been limited. Then a new solution known as the SMART Power Flow Controller (SPFC) is introduced. The SPFC offers the choice of either a low-cost electromechanical design using impedance-regulating transformers and mechanical load tap changers (LTCs) or a power electronics-based design that replaces the mechanical LTCs with thyristor-based LTCs.

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

PMBus Gives Designers New Options For Meeting Adaptive Voltage Scaling Requirements

by Peter James Miller, Texas Instruments, Manchester, N.H.

Abstract: While adaptive voltage scaling (AVS) has been around for more than two decades, it has severely limited a designer's choice of power solutions. Today, an emerging, open-source serial communications protocol known as PMBus is opening new possibilities for flexibility in power design. This article looks at how PMBus can enable digital system and power designers to realize their AVS power needs. After providing some background information on AVS and PMBus, it explains the basics of how to implement an AVS solution using the PMBus communications protocol, both with the standard VOUT_MODE and VOUT_COMMAND commands and using manufacturer-specific commands.

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

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Interface Panel Addresses Special Connection Challenges In On-Wafer Testing Of Power Semiconductor Devices

by Jennifer Cheney, Keithley Instruments, Cleveland, Ohio

Abstract: Measuring dc and capacitance parameters for high-power semiconductor devices requires substantial expertise to optimize the accuracy of various measurements. Even for those with this level of expertise, managing set-up changes between on-state current-versus-voltage (I-V), off-state I-V and capacitance-versus-voltage (C-V) measurements can be time consuming and prone to errors; this is especially true in the on-wafer environment. This article begins by examining the various measurement requirements that make wafer-level testing of power devices challenging with respect to making the test set-ups. It then describes the unique features of the Model 8020 interface panel that can be used to simplify the test setups, while making them more accurate and repeatable.

Notes: 5 pages, 5 figures, 1 table. Read the full story…

Streamlining Synchronous Buck-Boost Converter Design

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Buck-boost conversion is essential across numerous applications including battery charging, solid-state lighting, industrial computing, and automotive. This article offers a brief review of many factors associated with four-switch buck-boost converter designs. It specifically addresses component selection and power loss calculations, and pulls from a quick-start calculator tool to coordinate and accelerate converter design flow. The particular design example presented here is based on the LM5175 buck-boost controller, which employs a unique scheme in buck-boost mode whereby both buck and boost legs switch at reduced frequency in quasi-interleaved manner, providing substantive advantages for efficiency and power loss.

Notes: 8 pages, 5 figures. Read the full story…

The Shape Of Optimal Magnetics: Why Flatter Is Better

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: What are the best designs for magnetic cores and windings that minimize their design constraints? The ultimate constraint on the design of transformers and coupled inductors (or *transductors*) is that the structure of the device not change after it is manufactured. Power loss in either the core or windings causes a rise in temperature that results in either a breakdown in winding insulation or a change in the core's magnetic structure. A design scheme that minimizes temperature rise prevents such damage to the windings or core, keeping the device within its safe operating limits. This article examines design optimality from the standpoint of shape or geometry. By analyzing the impact of device geometries on core and winding temperatures, some insights are gained into the optimal shapes for cores, conductors and winding configurations.

Notes: 7 pages, 1 figure, 2 tables. Read the full story…

April 2015:

Application-Specific FOM: Key To Choosing The Right MOSFET

by Sanjay Havanur and Philip Zuk, Vishay Siliconix, Santa Clara, Calif.

Abstract: As key contributors of loss in power supply designs, power MOSFETs should be chosen carefully to yield the lowest loss for the given operating environment. But given the wide range of MOSFETs available today, it is not practical to experimentally evaluate all the devices in what would be considered a representative sample. Some designers choose the lowest R_{DSON} device from a given set, which leads to a costly, suboptimal solution. Others rely on the popular figures of merit (FOMs), which are rooted in device design but are "blind" to the application. Instead of applying these generic formulas, designers need to do a simplified loss analysis at the system level and use it as the basis for device selection. This article illustrates the process for the common power factor correction (PFC) stage. However, the principle of loss-derived FOM is applicable to any topology.

Notes: 9 pages, 5 figures. Read the full story…

Don't Throw That Switch Yet! First Steps In A Large Inverter Design

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

Abstract: In our last segment, we discussed selecting the right IGBT module for the application. This included understanding the machine and its operating conditions, the IGBT module construction and the various IGBT ratings. With that as the foundation, the next logical step is to begin the inverter design. This work will take a look at the first three topics along that path. The first of these topics is the dc link, which requires that the capacitors, bussbars and interactions be carefully addressed. From this point the conduction and switching losses for the IGBT and FRED die are calculated with datasheet parametric values. Finally, this discussion segues into thermal design.

Notes: 5 pages, 1 figure. Read the full story…

Automated Tools Improve Frequency Response In Switching Regulators

by Wanda Garrett, Texas Instruments, Santa Clara, Calif.

Abstract: Many power supply design tools such as TI's WEBENCH Power Designer include selection of compensation components. A few also include information to help assess a regulator's stability, like estimated phase margin and/or electrical simulations showing Bode plot and/or transient response. What happens, though, if key schematic components have to be changed? How does the compensation change to match? Again, this varies by design tool. WEBENCH Power Designer includes a new Compensation Designer that makes it easy to update the compensation, and even improve it to gain faster response or better phase margin. This article will present a design example that demonstrates how to use Compensation Designer and the different options it offers for obtaining the desired transient response and stability.

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

Determining Maximum Usable Switching Frequency For Magnetics In CCM-Operated Converters

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Power converter size limitations require that magnetic components be made as small as possible while delivering the specified output power. The goal of this article is to develop design constraints for the optimum switching frequency that produces maximum core power transfer within acceptable power loss for converters operating deep in continuous conduction mode (CCM.) These include buck-boost (common inductor), flyback and Cuk-derived circuits.

Notes: 5 pages, 1 figure. Read the full story…

May 2015:

Output Tracking And Sequencing Improve FPGA Reliability

by Tu Bui, Intersil, Dallas, Texas

Abstract: This article describes the underlying mechanism that is responsible for latch-up in FPGAs, so that designers understand why tracking and sequencing are needed. Specifically, this article explains the impact of power supply start-up on the FPGA's internal ESD protection diodes and how improper sequencing stresses these components. It then discusses how to configure various voltage output tracking and sequencing options for an FPGA or microprocessor that will enable the proper startup and shutdown of sensitive multi-rail systems. The article also examines a ratiometric and coincidental setting on the ISL8002B stepdown regulator that prevents an FPGA's internal electrostatic discharge (ESD) diodes from biasing or being overstressed during rising or falling outputs.

Notes: 6 pages, 7 figures. Read the full story…

Pre-Regulator Design Protects High-Voltage Power Supplies From Phase Faults (Part Two)

by Jean-Paul Louvel, ON Semiconductor, Toulouse, France

Abstract: Power supplies for applications such as e-meters and high-power appliances designed to run from a three-phase supply must be able to withstand incorrect connection between phases that can cause very high voltages to appear at the input. Part one in this series introduced the different SMPS concepts that can satisfy the high-voltage requirement including a novel pre-regulator. Here in part two, the operation of this pre-regulator and its advantages are described in greater detail. The pre-regulator circuit operation is explained as well as its circuit protection features, bulk capacitance requirements, and the efficiency of the overall power supply design. In addition, a detailed analysis of the pre-regulator's cost benefits is presented. Finally, the limitations of this pre-regulator approach are noted.

Notes: 14 pages, 8 figures, 7 tables. Read the full story…

Take The Edge Off High dV/dt Supplies

by Rob McCarthy, Maxim Integrated, San Jose, Calif.

Abstract: High dV/dt rise times on the power supply can cause problems with downstream components. This is especially true in 24-V powered industrial and automotive systems with high-current output drivers. This design idea describes how to control the rise time while limiting the power loss through the control FET. Rather than using a p-channel MOSFET as the current-limiting element, this circuit employs an n-channel MOSFET, which offers lower on-resistance and therefore limits power dissipation better. This capability makes the circuit well suited for applications where supply current is 8 A or higher. The circuit is built around the MAX16127 controller, which was developed to provide overvoltage protection but serves well in this role in controlling power supply rise time.

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

*Nano-Magnetics For High Efficiency Power Supplies**

by Santosh Kulkarni, Microsystems Center, Tyndall National Institute, University College Cork, Cork, Ireland

Abstract: Magnetic passive technology based on ferrite core material is a key roadblock in the reduction of passive component volume, mainly due to the material's lower saturation density. This presentation highlights the challenge of developing high flux density material with superior performance to ferrites. It evaluates the potential of available thin film materials as replacements for ferrites. Then, the author shows how a post-processing technique for thinning nanocrystalline material overcomes its major limitation—high eddy current losses. An inductor developed using this material is evaluated in a buck converter design, where the material is shown to reduce inductor volume and component losses versus a ferrite-based inductor.

*This material was originally presented at APEC 2015

Notes: 63 slides. Read the full story…

June 2015:

Infrared Light-Based Battery Charging And Communications May Improve Convenience And Robustness Of Implantable Medical Devices

by Albert Wong, Sunnyvale, Calif.

Abstract: This article describes the design and construction of a prototype apparatus using infrared (IR) technology to recharge a battery in an implanted medical device, thus replacing electromagnetic methods. Furthermore, it also demonstrates how communication between the device and host can be accomplished using an IR link instead of a radio frequency (RF) based system for telemetry data collection and device adjustment. The test results and observations presented here suggest that IR technology is practical for extending battery life in vivo (in living organisms) and a viable replacement for conventional wireless transceivers. The ability to recharge the implanted battery can, in some cases, eliminate the need for costly procedures and the associated inconveniences of periodically

replacing primary (non-rechargeable) cells and the potential hazard of charging secondary (rechargeable) cells via RF and wired means. Moreover, the use of an optical communication methodology removes or reduces the interference associated with magnetic objects and other EMI radiation sources.

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

July 2015:

Advantages Of GaN FETs Versus "Best Of Breed" Silicon MOSFETs

by Anthony Esposito, Avatar Engineering, Fountain Hills, Ariz.

Abstract: It's just good engineering to scrutinize the hype that follows the introduction of any new technology. GaN power FETs are an excellent example where the caveats are less exposed than their benefits. When should we abandon the established recent generation of silicon MOSFETs with proven reliability, high performance, and low cost for the claims made about GaN devices? In this article, the author examines some of the claims made about GaN power transistors from his perspective as a power system designer and development consultant for a large semiconductor corporation.

Notes: 8 pages, 4 figures, 1 table. Read the full story…

Designing Offline LED Drivers With GaN

by Eric Faraci, Texas Instruments, Santa Clara, Calif.

Abstract: Converters for LED lighting must have a small form factor and operate in high-ambient temperatures due to the proximity of the LED light source. GaN overcomes these obstacles by decreasing the size of the switched-mode power supply with significantly higher switching frequencies and by improving power supply efficiency due to the improved figure of merit of GaN over silicon. Despite these improvements, using GaN imposes new challenges at the system-level design of the converter. By switching at high frequencies, key current loops and parasitics in the switching converter that could previously be neglected now become prominent. Unless measures are taken to minimize them, they can cause serious degradation in performance or even prevent circuit operation. This article discusses the design tradeoffs and shows how to properly apply GaN devices in a 20-W offline LED driver design example. Important details are explained such as the methodology behind the topology selection, the control technique, component selection, and layout design. By reading this article, the designer will learn how to take advantage of the benefits that GaN provides while avoiding the pitfalls.

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

Two PSE Controllers Deliver 80 W For Class 5 PoE Power Injector

by Brian Rosario and Phill Leyva, Maxim Integrated, San Jose, Calif.

Abstract: Many power over Ethernet (PoE) applications require 25.5 W or greater and Class 5 operation over a single port. This article explains how to use two power-sourcing-equipment (PSE) controllers with integrated power switches to obtain between 25.5 W and 80 W for a single-port PoE power application. This approach offers a cost-saving alternative to designs employing PSE controller ICs in combination with discrete power MOSFETs. It also provides higher power over a single port rather than resorting to a quad-port design. The article begins by discussing the wiring configuration that will be required to transmit up to 80 W using Cat 5e cabling and the associated transformer/connector needs. Basics of the PSE, which will use either the MAX5971A or MAX5971B controller, and PD configurations are then given before describing in further detail the configuration of two MAX5971A PSE evaluation kits for full-power, single-port Class 5 operation. Test results for this PoE single-port power injector are provided in a separate spreadsheet.

Notes: 3 pages, 1 figure, 2 tables. Read the full story…

August 2015:

Understanding Evolution Of SiC Schottkys Is Key To Device Selection

by Thomas Barbieri, Cree, Durham, N.C.

Abstract: Silicon carbide (SiC) power devices are being specified more frequently in a growing number of power electronics applications, especially in solar inverter designs. In particular, SiC Schottky diodes have been favored by design engineers seeking to develop new inverter designs that are more compact, more efficient, and more reliable than those based on silicon power devices. During the 10+ years since SiC diodes were introduced, both their device design and reliability parameters have undergone significant evolutionary changes. These changes have resulted in a broadening portfolio of SiC Schottky diodes available on the commercial market. As such, discerning design engineers should be aware of the differences between these diodes and take them into consideration during the design cycle. This article will characterize the evolution of modern SiC Schottky diodes, from Schottky barrier to junction barrier to merged p-i-n structure, and illustrate the differences in their performance, reliability, and robustness.

Notes: 7 pages, 6 figures, 2 tables. Read the full story…

Demystifying Power MOSFET Voltage Ratings

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

Abstract: Two kinds of voltage ratings are provided for MOSFETs in their datasheets—V_{DS} and V_{GS}. For each, both absolute maximum and rated voltages are specified. Usually the numbers are the same but manufacturers use them in different contexts and for different purposes. This article aims to demystify some of the issues surrounding MOSFET voltage ratings. The underlying mechanisms and

failure modes by which excessive values of V_{DS} or V_{GS} lead to device destruction will be explained along with the operating conditions that may produce such overvoltages. Then, the issues surrounding derating of power MOSFETs for switching applications are discussed. This includes a look at industry standards such as IPC9592, which recommend their own derating guidelines, and the design considerations and tradeoffs that designers must address when derating power MOSFETs for their applications.

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

External Power Supplies And The New Level VI Specifications: Evolution Or A Different Species?

by Jeff Schnabel, CUI, Tualatin, Ore.

Abstract: A new generation of external power adapters is entering the market and they are significantly different from their immediate predecessors. The driver behind these changes is the new Level VI specification of the International Energy Efficiency Marking Protocol for External Power Supplies, which was published in 2014 by the U.S. Department of Energy and is scheduled to come into force in the U.S. in February 2016. At the time of adoption, it will be the toughest efficiency specification in force anywhere in the world. This article describes the changes to the energy efficiency protocol and explains how one adapter manufacturer has updated the power supply control strategy, secondary rectification circuitry and other aspects of the design to meet the new and tougher standby power and average efficiency targets.

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

Area-Product Method Can Simplify Core Selection—But Beware Of The "Constants"

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: A popular method for simplifying core selection for a given transductor power level is the area-product method. This article reveals the assumptions of the method and why, if it is used, it should be used with these assumptions in mind. The area-product method of core sizing is based on the winding-window turns maximum constraint, $N_W = A_W/(A_C/k_p) = A_W/A_{cwp}$, where A_w is the winding window area; $k_p < 1$, and is the wire packing factor and A_c is the conductive area of the wire. Then A_{cwp} is the larger area occupied by a single turn, taking the packing factor into account. The area-product method chooses core size from the equation, area product = $A \cdot A_{w,}$ where A is the magnetic-path cross-sectional area of the core. In applying the above equation, it is typically assumed that certain terms such as k_p are constant. However, these terms are actually dependent on variables such as wire size and other parameters. These relationships will be explained here.

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

September 2015:

Novel GIT Structure Solves Current Collapse In GaN Power HEMTs

by Howard Sin, Panasonic Semiconductor Solutions, Singapore and Saichiro Kaneko, Panasonic Semiconductor Solutions, Kyoto, Japan

Abstract: The advantage of GaN power devices in terms of performance is no longer hype but a reality that has empowered many power supply designers to build new applications that are more efficient, compact and able to operate in harsher environments. Many new players are in the field and introducing new devices at an exceptional rate. Naturally, the question arises as to whether the devices are reliable enough with sufficient understanding of the failure modes such as the current collapse phenomenon, which causes an increase in dynamic $R_{DS(ON)}$ that can lead to catastrophic failure of GaN devices. Panasonic is so far the only GaN device vendor that has openly declared the complete elimination of current collapse. The company has also understood that the standard qualifying methodologies i.e. JEDEC and AEC are insufficient and could not test for current collapse. Therefore, for the first time ever, this article will describe a novel hybrid-drain gate injection transistor structure and the dynamic testing procedure employed to ensure that Panasonic X-GaN is highly reliable.

Notes: 5 pages, 5 figures, 1 table. Read the full story…

Optimizing The Efficiency Of The Four-Switch Buck-Boost Converter

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: With higher ambient operating temperatures now prevalent in automotive and industrial applications, efficient and reliable dc-dc power solutions are a necessity. A converter with excessive component temperature rise can mandate a circuit redesign or a board layout revision, possibly compromising committed schedule dates. A keen understanding of a converter's operating modes and power losses is both essential and invaluable. A primary objective of this article is to look closely at the four-switch buck-boost converter's efficiency. This converter is a convenient platform to study dc-dc converter efficiency as the analysis is primarily based on buck and boost switching modes. By deriving the relevant duty cycle in each mode, we can calculate efficiency and power losses over input voltage and output current ranges.

Notes: 9 pages, 6 figures, 2 tables. Read the full story…

Overview Of Voltage Regulation Schemes For Utility And Industrial Applications

by Kalyan K. Sen, Sen Engineering Solutions, Pittsburgh, Penn.

Abstract: Voltage regulation techniques have been practiced in power grid applications with the use of inductors, capacitors, transformers and load tap changers since the early days of electrical engineering. However, the latest trend is to use power electronics-based solutions. Even though the costs of the solutions vary widely, the basic underlying theory of voltage regulation remains unchanged. The voltage control techniques described in this article are applicable in electric

transmission lines as well as applications such as motor drives, flicker control, harmonic mitigation, and others. In examining the various solutions for voltage regulation, this article looks at how these solutions address both functional and cost demands. This article also discusses the evolution of the power electronics inverter-based solution, explaining its interesting capabilities and the challenges to its expanded use.

Notes: 18 pages, 22 figures, 1 table. Read the full story…

Magnetics Optimization (Part 1): Equal Core And Winding Losses Do Not Maximize Power Transfer

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: This two-part article reexamines loss optimization in the design of transformers and coupled inductors (collectively known as transductors.) It shows that equalizing electrical (winding) and magnetic (core) losses does not maximize power transfer through the transductor. Refined criteria for power-transfer optimization are derived from the secondary-referred circuit model.

Notes: 12 pages, 8 figures. Read the full story…

October 2015:

Controller IC Eases Design Of Quasi-Resonant AC-DC Converter Using SiC Power Switch

by Raimund Wagner and Walter Balzarotti, Rohm Semiconductor, Willich-Münchheide, Germany

Abstract: SiC power semiconductors are expected to gain ground over silicon devices due to their superior characteristics. However, until now, there has not been a control IC that can sufficiently draw out the performance of SiC MOSFETs, especially in ac-dc converters. Lacking a suitable controller chip, some designers have resorted to discrete controller and gate-driver designs. However, ac-dc converter design has proved difficult when using discrete configurations due to the large number of components required. As a result, designers implementing ac-dc converter designs using SiC power MOSFETs are faced with numerous challenges relating to power consumption and stability in a variety of high-power applications. To address these concerns, ROHM has developed an ac-dc converter controller (the BD768xFJ-LB) specifically for driving SiC MOSFETs. The performance of this new controller is demonstrated in a design presented here. In this example, the controller IC drives a SiC MOSFET in a quasi-resonant switching ac-dc converter.

Notes: 9 pages, 5 figures. Read the full story…

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Leakage Inductance (Part 1): Friend Or Foe?

by Ernie Wittenbreder, Technical Witts, Flagstaff, Ariz.

Abstract: There are situations in which leakage inductance in a transformer or coupled inductor creates power losses and generates unwanted noise. In these situations, the designer seeks to minimize leakage inductance as much as possible. There are other situations in which leakage inductance provides a benefit. Moreover, in certain situations leakage inductance plays a critically important role in the operation of the circuit to great benefit. This three-part article series will attempt to foster a better understanding of leakage inductance, how to design around problems that leakage inductance creates, and how to use leakage inductance to advantage, to reduce power losses, size, and cost. Part one describes leakage inductance and the science and math behind it.

Notes: 9 pages, 8 figures. Read the full story…

*Film Capacitors For High Temperature Switches And Power Electronics Applications Above 125°C**

by Joe Bond, Electronic Concepts, Eatontown, NJ

Abstract: The availability of wide-bandgap semiconductors capable of high-temperature operation is creating requirements for high-temperature capacitors, particularly in emerging applications such as traction inverters for electric vehicles. After discussing the application drivers for high-temperature capacitors, this presentation provides information on the currently available capacitor dielectric options and the high-temperature dielectric materials under development by Electronic Concepts (ECI). The capabilities and limitations of the existing dielectic materials and barriers to their development are discussed. Performance of ECI's proprietary dielectric materials is compared to that of the existing dielectrics, especially bi-axially oriented polypropylene (BOPP) which is the dominant dielectric for power capacitors. New capacitors built with ECI's high-temp dielectrics are described and ongoing R&D efforts are outlined.

Notes: 88 slides View the presentation…

**This material was originally presented at APEC 2015.*

Magnetics Optimization (Part 2): Maximum Power Transfer Of The Primary-Referred Circuit

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: This two-part article reexamines loss optimization in the design of transductors (i.e. transformers and coupled inductors) demonstrating that equalizing winding and core losses does not result in maximum power transfer through a transductor. While part 1 derived refined criteria for power-transfer optimization from a secondary-referred circuit model, here in part 2, max-η conditions will be derived for a circuit model referred to the primary side of the transductor. While the primary-referred circuit model continues down the path of optimizing efficiency, η, an alternative possibility is the use of maximum output power as the optimization criterion. But as will be seen, this has undesirable consequences. This part 2 discussion also considers the possible effect of a current source load on the maximum power transfer, leading to the conclusion that both primary and secondary

winding resistance must be retained in transductor models used to optimize power transfer. Finally, a heuristic formula for the power-loss ratio for overall maximum power transfer is derived.

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

November 2015:

Modeling The Effects of Leakage Inductance On Flyback Converters (Part 1): Converter Switching

by Christophe Basso, ON Semiconductor, Toulouse, France

Abstract: The frequency response of a flyback converter operating under voltage mode (VM) control and driven in continuous conduction mode (CCM) is that of a second-order system. If the vast majority of analyses predict a transfer function whose quality factor is solely affected by the various losses (ohmic paths, magnetic losses, recovery time-related losses and so on), very few tackle the damping effect brought by the leakage inductance. However, transient simulations predict the damping of output oscillations as the leakage inductance increases. Because formulas available in the literature do not reflect this effect, a new flyback converter model is necessary and will be described in this article. Part 1 of this series begins by explaining the leakage inductance-induced damping effect on flyback waveforms and then derives a new dc transfer function that accounts for this effect. Finally in this part, the leakage inductance effects are observed in measurements taken on a prototype circuit.

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

Leakage Inductance (Part 2): Overcoming Power Losses And EMI

by Ernie Wittenbreder, Technical Witts, Flagstaff, Ariz.

Abstract: Leakage inductance is our foe when it creates problems such as power losses, EMI, or degraded regulation. In most isolated converters, leakage inductance contributes to both power losses and EMI, but there are ways in which power losses and EMI can be avoided by design. The first course of action is to design the transformer for low leakage inductance, but sometimes that approach is too costly or requires more space than is available, so other methods are needed. In this part 2, the various clamp and snubber options are discussed including RCD clamp, RC snubber, LCD clamp and active clamps. The pros and cons and varying requirements of the different approaches are discussed mainly within the context of the flyback topology, but also touching on the LCD clamp in the single-ended forward converter, and active clamps in the coupled-boost converter. Finally, this part looks at techniques for improving load regulation degraded by leakage inductance.

Notes: 17 pages, 9 figures. Read the full story…

Free Tool Takes The Drudgery Out Of Designing EMI Filters

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

Abstract: A free online power supply design tool available at the PowerEsim website provides a very simply way to predict the EMI caused by the line ripple. This tool contains a complex model that considers all the parasitic elements of the input filter and an equivalent arbitrary current source. Engineers can change those parameters to predict the EMI that will be observed on the input of the power supply. If this level of simulation of EMI is not enough, engineers can go a step further and use PowerEsim's converter build. This will allow engineers to immediately see the EMI result under any operating conditions. This article will explain how engineers can use PowerEsim's EMI simulation tool to predict the EMI that will be generated by their power supply designs and to optimize their input EMI filters for maximum attenuation of this EMI.

Notes: 9 pages, 12 figures. Read the full story…

December 2015:

Leakage Inductance (Part 3): Improving Power Supply Filtering, Efficiency And Density

by Ernie Wittenbreder, Technical Witts, Flagstaff, Ariz.

Abstract: Part 1 of this article series focused on the science and math of leakage inductance and described methods for calculating leakage inductance and related quantities. Part 2 showed how leakage inductance creates EMI, power losses, and load regulation problems, and also described some remedies for these problems. This final installment of the series describes some of the ways that leakage inductance is a friend, offering benefits in filter and power converter circuits. In EMI filters, leakage inductance can enhance the filter's attenuation of both differential- and common-mode noise. And in multi-output forward converters and other topologies, leakage inductance in coupled inductors can provide filtering of output ripple. Leakage inductance also aids zero voltage switching (ZVS) in the active-clamp flyback converter, enabling lower switching losses and/or use of higher switching frequencies. Similar benefits are obtained in the active-clamp coupled-boost converter.

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

Modeling The Effects of Leakage Inductance On Flyback Converters (Part 2): The Average Model

by Christophe Basso, ON Semiconductor, Toulouse, France

Abstract: The first part of this article described the switching effects produced by leakage inductance: a reduced effective duty ratio, which extends the secondary-diode conduction time and delays the appearance of the secondary-side current after the main switch has turned off. As a result, the output voltage is lower than what the original formula predicted and power dissipation increases in the *RCD* clamping network. Given the impact of the leakage term on operating waveforms, it would be interesting to investigate its influence on the small-signal response of the flyback converter. However, in order to perform small-signal analysis, a good average (or large-signal) model is needed. Here in part 2, the author develops this average model by applying Vorpérian's PWM switch model to the CCM flyback converter with adjustments that account for the effects of leakage inductance.

Notes: 12 pages, 14 figures. Read the full story…

Reducing Noise Generated By Switching Regulators

by Frederik Dostal, Analog Devices, Munich, Germany

Abstract: Switched-mode power supplies generate noise. In many applications this noise needs to be limited so that analog data integrity is not compromised and also to pass certain EMI requirements. This article will introduce different types of noise we find in switched-mode power supplies (SMPSs), discuss different noise-coupling mechanisms and ultimately present solutions to reduce the generation of noise and to filter remaining disturbances with the best strategies. While the concepts discussed here are generally applicable to all SMPS designs, the focus here is mainly on the type of nonisolated, dc-dc converters or point-of-load converters (POLs) that are used to generate the various low-voltage supply rails in electronic systems.

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

Understanding Power Flow In Ćuk Converters

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Ćuk-type converters are now commonplace but not always well understood. Of the various design considerations, little is said in the literature about the flow of power within the converter itself. This article intends to make power flow in the Ćuk converter explicit and discuss some of its consequences. With two reactive elements, the power flows not only from input to output but also between inductive and capacitive elements. In this discussion, the different power flows are identified and from them the amount of power handled in both reactive elements derived.

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