Design Article Archive

Abstracts of articles published in the January through December 2019 issues

January 2019:

High-Power Wireless Charging For EVs (Part 1): Understanding The Basics

by Patrice Lethellier, WAVE, Salt Lake City, Utah

Abstract: Charging an electric vehicle (EV) battery through wireless power transfer, also known as wireless charging: why is there interest? It is mainly because the line cord is a liability. Plugging in a line cord 365 times a year becomes tiresome and sometimes you may forget. For a company with a fleet, plugging in a line cord may require a qualified electrician. The cost and reliability of high-voltage, high-current connectors are also issues. This article explains the principles of operation for high-power wireless chargers in the range of 250 kW that are being developed for charging commercial EVs (including buses and trucks) and industrial equipment. The characteristics of power transfer in a wireless charger are compared and contrasted with those of a conductive or wired charger.

Notes: 3 pages, 2 figures. Read the full story…

Two-Switch Flybacks Outperform LLC Resonant Converters On Most Parameters

by Jiri Jirutka, STMicroelectronics, Prague, Czech Republic

Abstract: While price usually comes first, the other main criteria when designing a power supply are high efficiency, low standby power and high power factor. In terms of efficiency and switching losses, the LLC resonant converter is now preferred over the flyback because it offers the advantage of zero-voltage switching (ZVS). But because of its high circulating current in the resonant circuit, the LLC shows worse efficiency at low load. However, an alternative is emerging thanks to some new design options discussed here. Specifically, the two-switch flyback implemented with a quasi-resonant (QR) PWM controller brings significant improvement in all of the key power supply parameters. In this article, the author demonstrates how new QR resonant PWM controllers and SiC MOSFET-compatible gate drivers are making the two-switch flyback converter a lower cost, higher performance alternative to the LLC resonant converter, especially in cases with high-voltage input.

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

MLCC Shortages—Polymer Electrolytics Can Help

by Wilmer Companioni, KEMET, Fort Lauderdale, Fla.

Abstract: The multi-layer ceramic capacitor (MLCC) industry is currently experiencing a significant capacity and supply issue. Manufacturers are putting in capacity, but this takes time to feed through and presents little comfort for manufacturers and engineers dealing with looming line stop situations, and supply chain managers who are having to seek parts from non-preferred sources. At times like this, engineers should explore new options and alternative techniques that don't necessitate having to go through circuit or product redesigns. Polymer electrolytic capacitors such as Kemet's KO-CAP series capacitors are one alternative that, given certain conditions, can help. This article discusses the operating conditions under which polymer electrolytics are viable replacements for MLCCs in power supply applications.

Notes: 3 pages, 2 figures. Read the full story…

Designing Energy Storing Inductors Properly

by Gregory Mirsky, Continental Automotive Systems, Deer Park, Ill.

Abstract: This article attempts to show that when designing an energy-storing inductor, one should consider not just the current ripple in the coil and filter capacitors but also the dc biasing current and power that the inductor must store and release. Engineers usually overlook the dc bias and do not link the inductor's physical size with the required power. Instead, they focus on the desired current ripple, obtaining a value for the core's physical size from the winding size. After deriving inductor design equations that account for dc bias and the amount of power to be stored, use of the equations is demonstrated with a boost inductor design example. This article may be useful for those who design diverse types of power converters, filters subject to dc biasing, solenoids and other electromagnetic components such as electromagnetic accelerators and weapons.

Notes: 9 pages, 1 figure. Read the full story…

February 2019:

Using Power Delivery Path Resistance For Precision CPU Current Monitoring

by Viktor Vogman, Power Conversion Consulting, Olympia, Wash.

Abstract: To monitor CPU current (and power), typical CPU voltage regulator (VR) designs use the VR inductor's winding equivalent series resistance (ESR) and/or VR switching transistor's $R_{DS(ON)}$ as current sensors. When processor current is constant or varies slowly, i.e. for load current frequencies much lower than the LC-filter bandwidth, the inductor current (or MOSFET current magnitude) signal practically replicates the CPU current waveform and such sensing techniques provide reasonable accuracy. However, in very dynamic modes with high current slew rates, sensing "internal" VR currents instead of the actual load current has one major drawback: the effect of LC-filtering results in latencies and level errors attributed to these latencies. This article describes the implementation of a current monitoring technique developed to address this issue. The technique performs nonintrusive, real-time current monitoring of the actual CPU current consumption.

Notes: 10 pages, 7 figures. Read the full story…

The Engineer's Guide To EMI In DC-DC Converters (Part 8): Common-Mode Noise Mitigation In Isolated Designs

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Part 8 of this series reviews common-mode (CM) noise mitigation for isolated dc-dc converter circuits. Converters operating at a high input voltage—such as the phase-shifted full-bridge and LLC series resonant converter in applications such as electric vehicle onboard charging, data center power systems and RF power amplifier supplies—can generate large CM currents. The effect is more pronounced when applying gallium-nitride (GaN) switching devices, as they switch at higher dv/dt than their silicon counterparts. A wide variety of techniques exist for mitigating CM noise in isolated designs, including symmetrical circuit arrangements, connecting a capacitor between primary and secondary grounds, shielding, adding balance capacitors, optimizing transformer winding design and using an adjustable CM cancellation auxiliary winding. This article reviews these techniques, focusing mostly on flyback circuits.

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

HOW2POWER TODAY

Design Article Archive

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Evaluating Tantalum Electrolytics As Replacements For MLCCs In High-Capacitance Applications

by Chris Reynolds, AVX, Fountain Inn, SC

Abstract: Because of MLCC shortages, designers are reconsidering electrolytic capacitors for applications that had switched to class II ceramics in recent years. However, migrating circuit designs from MLCCs to tantalum electrolytics requires an understanding of multiple issues that impact how these different styles of capacitors will perform in the intended application. This article discusses the key parameters that differentiate these two capacitor categories in the various roles they play in power supply applications (bypassing, filtering, decoupling, bulk hold up and pulse power). It not only describes the range of parametric values, characteristics and options associated with MLCCs and tantalum electrolytics, but also the underlying differences in device construction and material properties. The discussion on electrolytics covers both tantalum and niobium oxide types.

Notes: 10 pages, 9 figures, 1 table. Read the full story…

How Wire Bundle Configurations Influence Eddy-Current Proximity Effects

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Eddy-current proximity effects can be estimated and simplified for calculator-based transformer design for different wire-bundle configurations. This article describes bundling and how it influences the proximity effect, both between bundles (interbundle) and within bundles (intrabundle). The author begins by explaining bundle packing factors and twist factor as these will be important in the determination of proximity effects and the calculation of eddy-current losses and winding resistance. He also explains conceptually how the number of strands in a bundle (and whether they are twisted or braided) impact the interbundle and intrabundle proximity effects. This discussion leads to some simple rules for minimizing the proximity effects.

Notes: 5 pages, 2 figures, 1 table. Read the full story…

March 2019:

Active Clamp Flyback Converters—How They Work And Tips For Design Success

by Michael O'Loughlin, Texas Instruments, Manchester, N.H.

Abstract: In low-power applications (typically 150 W or less), the active-clamp flyback (ACF) converter is becoming a popular choice over the quasi-resonant flyback (QRF) converter. When designed correctly, an ACF topology will have a nearly lossless leakage energy clamp and will be able to achieve zero voltage switching (ZVS) on the primary MOSFET over a wide input voltage and output load range. In low-power applications, it's possible to design an ACF for power densities as high as 39 W/in^3 and with peak efficiencies that exceed 94%.The only problem with ACF is that the topology is fairly new; some designers may not have heard about it, and/or may be reluctant to use it. This article reviews the benefits and operation of an ACF and gives some design guidance and tips on applying it.

Notes: 8 pages, 5 figures, 1 table. Read the full story…

Base Metal Electrodes Reduce Size And Weight Of MLCCs In Satellites

by John Marshall, AVX, Coleraine, United Kingdom and Ron Demcko, AVX, Fountain Inn, S.C.

Abstract: The rate of change in the satellite world is accelerating and along with that comes the changes needed for power supplies onboard. This article provides a high-level view of the emergence of base metal electrode (BME) multilayer ceramic capacitors (MLCCs) for satellite applications. After providing some background on MLCCs and the development of their electrode materials, this article describes the advances in component materials, construction and fabrication techniques, and the track record in automotive and other sectors that have proven the reliability of BME MLCCs. Then the size advantages which motivate the use of these capacitors in space are discussed. The rest of this article reviews the reliability studies that AVX has performed to qualify BME MLCCs for space, and the status of space approvals for these capacitors, particularly Mil Prf 32535. Finally, it discusses details of BME capacitor design for space.

Notes: 6 pages, 2 figures, 3 tables. Read the full story…

Configurable IC Simplifies Conversion Of Temperature To Frequency

by Oleksiy Kravchenko, Dialog Semiconductor, Lviv, Ukraine

Abstract: Temperature sensors are one of the most important types of physical sensors because many different processes are regulated by temperature. For example, the temperature measurement in a power semiconductor device is necessary to rapidly identify damage to power components—just one of many uses in power electronics. Typically, sensors convert a measured physical value into an analog signal. Then, for processing by a CPU or computer, the analog temperature signal must be converted into a digital form, typically using expensive analog-to-digital converters. This article presents a simplified technique for direct conversion of the analog signal from a temperature sensor into a digital signal with proportional frequency using a GreenPAK configurable mixed-signal IC. Subsequently, the frequency of a digital signal that varies with temperature can then be more easily measured with a fairly high accuracy and then converted to the required units of measurement.

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

How To Thermally Model Magnetic Components

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: The most difficult aspect of magnetic component design is the quantification of thermal behavior. Core and winding temperatures are the ultimate limitation on how much power can be transferred through a magnetic device, yet to calculate allowable power transfer at maximum design temperatures is challenging. This article surveys some of what is involved in thermal modeling and how to conceptualize it.

Notes: 6 pages, 4 figures, 2 tables. Read the full story…

April 2019:

Using A Four-Switch Buck-Boost Bidirectional DC-DC Converter For Battery Backup Applications

by Bosheng Sun, Texas Instruments, Dallas, Texas

Abstract: In this article, the author discusses a dc battery backup system employing a bidirectional dc-dc converter based on the four-switch buck-boost topology. This article begins by reviewing the requirements for a battery-based backup power supply system and explains why the four-switch buck boost converter is well suited to this application. After a quick summary of how the converter's switches operate under a basic control scheme, a more elaborate six-mode control scheme to achieve high efficiency is described. New challenges caused by the six-mode control scheme such as how to drive the high-side MOSFET with 100% duty, how to transition smoothly between modes and how to optimize loop compensation are also discussed. This is followed by a brief discussion of how this control scheme can be implemented using the UCD3138 digital controller.

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

Zero-Drift Precision Op Amps: Measuring And Eliminating Aliasing For More Accurate Current Sensing

by Farhana Sarder, ON Semiconductor, Phoenix, Ariz.

Abstract: Zero-drift precision op amps are specialized op amps designed for applications that require high output accuracy due to small differential voltages. Not only do they feature low input offset voltage, but they also have high CMRR, high PSRR, high open-loop gain, and low drift over temperature and time. These features make them ideal for applications such as low-side current sensing and sensor interface. While manufacturers of zero-drift op amps sometimes claim that these devices are free from aliasing effects, in reality, they may in fact be vulnerable to aliasing since these devices use sampling to minimize the input offset voltage. Therefore designers should test their op amp circuits for aliasing. This article presents an effective method for doing so and applies this method to observe differences in aliasing produced by different implementations of zero-drift op amps.

Notes: 15 pages, 14 figures, 2 tables. Read the full story…

How Ulta-Low I_Q Boost Converters Extend IoT Device Runtime

by Reno Rossetti and Tom Bui, Maxim Integrated, San Jose, Calif.

Abstract: Common characteristics in internet of things (IoT) devices include small form factor and the need to operate for long periods of time without consuming too much power. In consumer electronics, boost converters are commonly used to raise and stabilize the sagging voltage of their lithium-ion batteries under load. In this article, the authors discuss a typical IoT power management solution for small, portable gadgets, as well as its shortcomings. They then introduce a boost converter, the MAX17222, which addresses these shortcomings while also providing the ability to operate down to minimal amounts of residual battery energy.

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

Configurable IC Simplifies Control Of Animated LED Turn Signals

by Muhammad Saqib and Aamir Hussain Chughtai, Dialog Semiconductor, Lahore, Pakistan

Abstract: Many automotive manufacturers now provide indicator lights (turn signals) with animated LED patterns to enhance the aesthetics of these lights and to create a "trademark" look that distinguishes their vehicles. The animations can be implemented without an MCU but typically require several discrete ICs. These control components are used in combination with an LDO regulator and one or more automotive LED drivers. An alternative approach to generating the LED control signals based on the SLG46620 configurable mixed signal IC (CMIC) is presented here. The configurability of the CMIC provides a high level of flexibility, which allows a supplier to cater to the varying requirements of several manufacturers without any change in hardware design. Moreover, this approach achieves significant reductions in the PCB footprint and the bill-of-materials cost.

Notes: 14 pages, 15 figures, 2 tables. Read the full story…

How To Optimize Turns For Maximum Inductance With Core Saturation

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Some inductor applications require a minimum inductance over the full current range of inductor operation. As current increases, saturation increases and the *saturation factor*, k_{sat}, decreases from 1 at zero current. The typical inductor operating range of k_{sat} in power applications is 0.8 to 0.5. As turns, N, are increased, inductance, L, increases by N^2, but so does saturation, causing k_{sat} to decrease. N has an optimal value, N_{opt}, at maximum L because increasing saturation progressively decreases L with increasing turns (as Ni increases) while the turns themselves increase L. If the saturation curves decrease faster than N^2, then adding more turns decreases inductance. So in essence, finding the optimum number of turns (and achieving max inductance) means finding the maximum number of turns that can be wound on a core before inductance starts to decrease due to saturation. Therefore to solve for the optimal operating-point, we need an equation that models core saturation.

Notes: 7 pages, 4 figures, 2 tables. Read the full story…

May 2019:

Optimizing Transfer Switch N+1 Redundant Power Architectures

by Viktor Vogman, Power Conversion Consulting, Olympia, Wash.

Abstract: Automatic transfer switches (ATSs) have gained popularity in data center power distribution networks due to several advantages. They provide fail-safe ac power redundancy, achieve highly efficient power distribution in server racks, enable redundant power feeds for single ac power cord arrangements, and reduce UPS power conversion losses. In terms of ac redundancy, if the primary power feed becomes unavailable, the rack ATS will supply power from the secondary feed without interrupting server operation. At the same time transfer switch arrangements can advance traditional dc redundant architectures supporting seamless dc power flow to the server when one of the power modules fails. This article examines opportunities for adoption and optimizing of ATS techniques, specifically in N+1 dc redundant configurations where N>1.

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

Another Look At The Refined Model Of Current-Mode Control

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: The analysis of current-model control in power conversion has a long history, going back over four decades, encompassing different approaches that capture different aspects of converter behavior. These different forms of current-loop models have evolved over time as their developers have attempted to improve their accuracy or completeness. First-generation models by Middlebrook, Macsimović and Erickson were followed by Ridley's sampled-loop model and then Middlebrook and

Tan's unified model. In a previous article series on peak-current control, the author described the development and evolution of these different current-loop models and how they led to his development of a new model called the *refined model* of current-loop control. For those not yet familiar with the refined model and those generally curious about modeling of current-mode control, this article offers a summary of the earlier seven-part series.

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

Measuring The Negative Input Resistance Of DC-DC Converters

by Steve Sandler, Picotest, Phoenix, Ariz

Abstract: It seems that most power integrity engineers spend time focused on the output impedance of their board-level dc-dc converters. Many power integrity engineers argue that we don't even need to include the dc-dc converter in our simulations, we can simply use a passive network to represent the output impedance. However, the power supply has many noise sources and sensitivities at both its input and the output and a passive network isn't sufficient to model them. Such is the case with the negative input resistance of a dc-dc converter. In this article, the author explains why this negative resistance exists, why it matters and how to measure it more easily using a new device.

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

June 2019:

Closing The Loop Of An Active-Clamp Forward Converter

by Christophe Basso, ON Semiconductor, Toulouse, France

Abstract: This article describes in detail how to compensate an active-clamp forward converter (ACF). It introduces the ACF transfer function—something not seen previously in the literature—shows Bode plots for a design example based on the NCP1566 active-clamp PWM controller and discusses selection of the crossover frequency. The design of a type-3 compensator, as well as a strategy for applying this compensator to the ACF, is described and demonstrated using a Simplis simulation. All of this leads to the presentation of a complete circuit for the design example, and its key features, circuit elements and additional design considerations are discussed. Finally, a common technique for making the Bode plot measurements of the loop's gain and phase margins is reviewed and the benefits of using a low-cost oscilloscope and frequency response analyzer (Cleverscope) to make these measurements are highlighted.

Notes: 16 pages, 13 figures. Read the full story…

A Methodical Approach To Snubber Design

by Gregory Mirsky, Continental Automotive Systems, Deer Park, Ill.

Abstract: Even in a correctly designed switching power supply, stray capacitance and inductance in the traces and leads can cause oscillation in switching currents at turn-off due to the energy stored in these parasitic components. Since the oscillation may occur at many megahertz, satisfying requirements for the electromagnetic compatibility (EMC) of the switching power supply may be challenging. Properly designed snubbers may absorb the energy stored in the stray components and make the switching process smooth and oscillation-free. Unfortunately, many designers overlook the physical processes in switching circuits and just pick values for snubber components using trial and

error, leading to poor results. This article explains the underlying process that leads to oscillation in switching power supplies and describes an analytical approach to designing an RC snubber that will effectively dampen the oscillation.

Notes: 8 pages, 3 figures. Read the full story…

Verifying Error Budget Analysis For A Buck Converter—On The Bench

by Benjamin Lampe, Maxim Integrated, San Jose, Calif.

Abstract: A previous article looked at hand calculations for buck converter error budgeting and saw how they stacked up against simulations from EE-Sim, Maxim Integrated's online SIMPLIS power supply design and simulation tool. This naturally leads to a deeper question: how closely do the hand calculations and models match bench measurements? Because at the end of the day, it's the physical silicon that matters, and all the calculations and simulations in the world won't help if they don't adequately model your real power supply. In this article, we go one step further in verifying the output voltage error budget analysis performed on the MAX17242 buck converter design by comparing simulation results with bench measurements on working hardware.

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

New Packages Offer Smaller Size, Greater Reliability For Rectifiers—With Some Tradeoffs

by Jos van Loo, Taiwan Semiconductor Europe, Zorneding, Germany and Kevin Parmenter, Tawian Semiconductor America, Chandler, Ariz.

Abstract: Since the introduction of the SMA, SMB and SMC rectifiers in 1990 and 1991 (earlier for transient voltage suppressors), customers have complained about their height. In addition, the SMA/B/C packages were initially TVS packages and nobody ever claimed that their thermal design was very good. The rectifier industry just started using them because they were available at the time and customers wanted to replace MELFs. But the SMA/B/C packages reflected the technology available 30 years ago and there is room for improvement. As a result, a number of new packages have been introduced recently by Taiwan Semiconductor (TSC) and other vendors to address the shortcomings of these older packages. Sometimes downsizing to the newer packages will be easy and straightforward, but not always. This article will discuss how the smaller packages will influence designs and applications.

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

Designing Low-Power Flyback Inductors Using Tiny Toroids (Part 1): A Boost Converter Application

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Power-converter design requiring 0.2 W to 2 W of power can most easily be solved with a linear supply. But in power-critical applications, if the input and output port voltages are significantly different, the result can be excessive or unnecessary power loss. The three configurations of PWM-switch converters can deliver the required power at high efficiency, though they involve the design of a small inductor. This article offers some insight into how core sizes relate to circuit requirements and presents a design example. Can toroid cores, such as iron-powder (Fe-pwd) cores that are as small as magnetic beads, be used for power conversion? The answer is affirmative. Though some agility is

required in building the prototypes, it is less than required for working with TSSOP-size components on boards.

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

Measuring Common-Mode And Differential-Mode EMI Currents

by Kevin Parmenter, Chair, and James Spangler, Co-chair, PSMA Safety and Compliance Committee

Abstract: Line-conducted EMI current is composed of two elements: common mode (CM) current and differential mode (DM) current. Either one of these contributors to line-conducted EMI may be responsible for a unit failing EMC testing. And without knowing why a unit is failing, coming up with a solution can become a time-confusing exercise in trial and error. On the other hand, by measuring CM and DM EMI currents separately, engineers can identify why their products are exceeding the specified EMI limits and quickly tailor an EMI filter solution to pass EMC testing. Although the techniques for measuring CM and DM currents are well documented in the literature, many power supply engineers are still unfamiliar with them and therefore do not make these measurements. In this article, the authors review the literature regarding measurement of CM and DM EMI currents, offer an overview of the different measurement techniques and point to the references where readers can delve more into the details of making the measurements.

Notes: 6 pages, 5 figures, 1 table. Read the full story…

July 2019:

Surpisingly Simple Control Method Slashes Vampire Power

by Tom Lawson, CogniPower, Malvern, Pa.

Abstract: There are billions of wall-mounted ac-dc converters in daily use, which collectively consume many gigawatts of power annually. Most of these chargers are doing nothing useful most of the time. They stay plugged in because it is hard to reach them where they tend to be found, down along the baseboard. Further, if they are left plugged in to the device they charge, the chargers are running at a very low percentage of their rated output just to keep the batteries topped up. So they run most of the time at very low efficiency. What is the best way to solve this problem of wasted energy, also known as vampire power? CogniPower's answer is make a more efficient charger with much lower standby power that is smaller and cheaper than the best of the current crop. A new control method known as Demand Pulse Regulation (DPR) makes these objectives possible.

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

Verifying Safe Levels Of Hydrogen Diffusion In Wet Aluminum Electrolytic Capacitors

by Wilmer Companioni, KEMET, Fort Lauderdale, Fla. and Samuel Accardo, KEMET, Dallas, Texas

Abstract: Aluminum electrolytic capacitors are widely used in the industry due to their relative high ratio of energy density to cost. In fact, they are used in such a wide variety of applications that many design engineers might overlook some aspects of the capacitor’s behavior based on its underlying technology. For example, it is important for design engineers planning to use wet aluminum electrolytic capacitors to consider and mitigate the diffusion of hydrogen. This article looks at

hydrogen diffusion, how to determine the resulting levels of hydrogen that a wet electrolytic capacitor will produce in an application and whether these levels are safe. Safety in this case, means below the thresholds that would lead to ignition or even detonation of the hydrogen. This discussion is mainly relevant to applications in which the capacitor is housed in a sealed enclosure and subject to a possible source of ignition.

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

Sense Current Over A Wider Range For Better Battery Management

by Bonnie Baker, Maxim Integrated, San Jose, Calif.

Abstract: In battery-powered portable and mobile devices, the proper way to determine the battery's discharge status is to track the current outflow to the device over time. Some say that the appropriate solution to this current-sensing challenge is to use an ultra-small resistor value in the power-supply path followed by a difference amplifier. This appears to be an effective and appropriate solution. However, the hidden sensing resistor and following amplifier provide a somewhat restricted measurement range and require a relatively large PCB footprint. This article examines ways to overcome this challenge with an innovative solution to the current-sensing issues—one that uses an active sensing transistor alternative in the power supply's current path.

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

The Op Amp-Based Differential Amplifier: Not As Easy As It Looks

by Gregory Mirsky, Continental Automotive Systems, Deer Park, Ill.

Abstract: When an inexpensive differential amplifier is needed, designers often use the familiar circuit and just choose resistor values to achieve equality of gains in both inverting and non-inverting branches, forgetting that the sources of the signals may have different output impedances. This impedance difference may completely destroy the differential amplifier operation, causing an output offset and compromising the common-mode rejection ratio (CMRR). Given a value of R1 and a required gain, we can select the values of the remaining resistors, R3-R4, with the goal of setting the input impedances equal. This article explains how to calculate those required resistor values, while also accounting for the variability of these values to initial tolerance, thermal coefficient of resistance, and aging.

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

Designing Low-Power Flyback Inductors Using Tiny Toroids (Part 2): Calculating Losses

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Part 1 of this article described the design of a low-power flyback converter inductor using three stacked T20-26 cores—the smallest core in the Micrometals catalog. Here in part 2 we present further details of the inductor design, specifically the additional design formula required for determining the winding turn length of the unibundle-constructed 6-strand winding previously specified. This part also explains how to determine winding resistance and both core and winding power loss. Using this loss information, the effect of the inductor on converter efficiency, based on ideal output power, can be found. Does this design approximately balance core and winding losses to achieve optimum efficiency? If not, which loss dominates and why? The factors at play are explained and some conclusions are drawn about the usefulness of small cores in low-power converter designs.

Notes: 4 pages. Read the full story…

August 2019:

The Engineer's Guide To EMI In DC-DC Converters (Part 9): Spread-Spectrum Modulation

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: For high-frequency switching dc-dc converters, the presence of high slew-rate voltages and currents during switching commutations may generate severe conducted and radiated interference within the regulator itself as well as nearby susceptible circuits. In general, complying with electromagnetic standards is an increasingly important task for switching power supplies, not because of excessive total spectral energy, but more so due to concentrated energy in specific narrow bands at the fundamental switching frequency and its harmonics. Spread-spectrum frequency modulation (SSFM) is a way to distribute spectral energy in the frequency domain and thus flatten the fundamental and harmonic noise peak amplitudes. The spread-spectrum effect is available as an additional and complementary method of noise reduction with respect to the EMI mitigation techniques described in previous installments of this series. Here the author explains the math behind SSFM and details of its practical implementation.

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

Versatile SiC JFETs Benefit Power Switching And Circuit Protection Applications

by Peter Losee and Anup Bhalla, UnitedSiC, Monmouth Junction, N.J.

Abstract: After more than two decades of promise, SiC switch technology has finally emerged as a contender for various power electronics applications, driven largely by adoption in automotive and industrial charging sectors, energy storage, PV inverters and even EV drivetrain inverters. Continued advancement in cost-performance metrics of SiC switches have even yielded inroads in growing volume applications such as telecom rectifier and server power supply applications, where silicon superjunction FETs have reigned supreme. Although most of the major players in the power semiconductor world have focused their attention on SiC MOSFETs, the case can be made that the SiC JFET is the highest performance and most versatile switch technology available. In this article, we examine some of the unique attributes of SiC JFETs that are so attractive across a variety of potential applications.

Notes: 10 pages, 15 figures. Read the full story…

Advanced Scopes And Probes Help Optimize SMPS Gate Drives For EMC

by Michael Fuchs, Bernhard Auinger and Lukas Pichler, Institute of Electronics (IFE) at the Graz University of Technology, Styria, Austria; Markus Herdin, Rohde & Schwarz, Munich, Germany; and Bernd Deutschmann, Institute of Electronics (IFE) at the Graz University of Technology, Styria, Austria

Abstract: The introduction of wide-bandgap semiconductor materials such as SiC and GaN has enabled higher switching frequencies as well as much steeper edges on switching waveforms. This increases the efficiency of switched-mode power supply units, but results in unwanted, high-frequency interference that propagates along connecting cables or is emitted as electromagnetic waves. The Institute of Electronics (IFE) at the Graz University of Technology in Austria is conducting electromagnetic compatibility (EMC) research on gate drive methods with a view to minimizing spurious emissions. High-performance oscilloscopes such as the R&S RTO2000 enable these optimization measures to be implemented on the developer's lab bench. This article describes the measurements necessary for gate drive optimization and offers some measurement examples to illustrate the setups and measurement results that can be obtained.

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

Square Vs. Round Core Legs—Balancing Core And Winding Losses

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: When designing transformers and inductors for power electronics, engineers have a choice of magnetic core shapes. Newer core shapes such as EC, ER, and ETD have round center legs whereas older shapes such as EE and EI have square center legs. For toroids, both round and square or rectangular rings prevail. This article analyzes the performance differences between round and square shapes. Round center-posts are compared to square ones according to two criteria, winding length—hence resistance—and thermal performance. Understanding the impact of core center-post shapes on these two factors can help designers optimize magnetics' performance in the application in terms of balancing core and winding losses. This article quantifies the differences in winding length and thermal shape factor (a measure of a core's ability to dissipate heat versus a sphere) for round versus square center posts.

Notes: 3 pages. Read the full story…

September 2019:

Novel Switched-Capacitor Converter Supports 48-V Power Architecture In Data Centers

by Rehan Tahir, Infineon Technologies Americas, Milpitas, Calif.

Abstract: Adoption of 48-V main bus architectures is driving down operating costs for leading data center operators by reducing distribution losses by a factor of 16 compared to 12-V power delivery. The move to 48 V has triggered innovation in the design of board-level power supplies such as the zero-voltage-switching switched-capacitor converter, or ZSC, developed by Infineon. The ZSC topology is based on the Dickson charge pump; the voltage step down is achieved via capacitive energy transfer. This article describes the principles of operation of the ZSC and offers tips for successfully implementing this topology.

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

Using Mini E-Loads To Emulate Fast Slew Rates And High Peak Power Levels

by Viktor Vogman, Power Conversion Consulting, Olympia, Wash.

Abstract: There are obstacles when using the existing test instruments to perform transient testing on VRs and server power supplies. The limiting factor in most low-voltage VR dynamic loading situations is the series inductance between the unit under test and the bulky electronic load (e-load). On the other hand, applying high current spikes to an ac-dc power supply output typically demands paralleling and synchronizing multiple e-load modules, which is not trivial. What's needed is a

miniature e-load capable of generating high-current slew rates and magnitudes. Such devices are known as slammers, or some variation on this name, and are available for purchase from vendors. You can also build these test tools to address your specific test needs and this article describes the design and operation of one I call a *microslammer*. This particular design addresses the need to test CPU power virus protection.

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

Secrets Of The Datasheet: What Rectifier Specs Really Mean

by Jos van Loo, Taiwan Semiconductor Europe, Zorneding, Germany and Kevin Parmenter, Taiwan Semiconductor America, Chandler, Ariz.

Abstract: Rectifiers are considered some of the easiest semiconductor components to design with. Their datasheets are not very complex. Nevertheless, in a lot of high-volume designs they can be highly stressed: they operate at very high junction temperatures and voltages. To minimize field returns and achieve zero defects, designers need a good understanding of rectifier manufacturing processes, test programs and statistics. Despite their simplicity, rectifier datasheets may puzzle modern designers. In this article, we will discuss the key specifications that designers, especially power supply designers, must consider when selecting rectifiers, and explain how semiconductor manufacturers test and then specify these parameters on their datasheets. This in turn leads to advice on how designers should interpret or apply this data.

Notes: 5 pages, 2 figures, 1 table. Read the full story…

Waveform-Based Design: Key Parameters And Figures Of Merit For Power Circuit And Magnetics Optimization

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Magnetics and power-converter design are related by common design variables that are electrical functions of time, or *waveforms*. This article offers a brief tutorial on waveforms commonly encountered in both magnetics and circuit design, their performance parameters, and why they are important in design optimization. While the author has used these waveform parameters and figures of merit throughout his writings on power circuits and magnetics, in this article, he takes a step back and defines these terms more methodically, while also noting where these terms come into use.

Notes: 6 pages, 2 figures, 1 table. Read the full story…

October 2019:

Dynamic Motor Power Measurement Enables In-Vehicle Testing Of EVs

by Mitch Marks and Mike Hoyer, HBM Test and Measurement, Madison, Wisc.

Abstract: In the emerging electric vehicle market, electrical power measurements on motors and related power conversion circuitry are becoming necessary to perform an evaluation of a vehicle. Mobile power measurement was previously difficult due to the dynamic nature of the vehicle speed. However, unique features provided in HBM's eDrive, a system for testing electric machines and drives, make mobile electrical power measurements possible in real-world operating environments. After some initial discussion of why in-vehicle testing is needed, power measurement challenges, and the limitations of traditional power analyzers, this article will explain how eDrive performs dynamic power

measurements and publishes cycle-based calculations to a CAN bus for correlation to an existing DAQ system, and the implications for testing EVs under real world conditions.

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

Field Solvers: A Different Perspective On EMI In Power Electronics

by Paul L. Schimel, Microchip Technology, Chicago, Ill.

Abstract: As computers and modeling improved, tools known as field solvers began to run Maxwell's equations for complete circuits and board layouts for RF systems. Running Maxwell's equations accounted for the parasitics, dielectrics, trace routing, plane layers, trace widths, thicknesses, etc. The ability to model and predict RF circuit behavior in this way cut down on design iterations, helping engineers to be more productive. In this article, the author argues that field solvers could soon have a similar impact on power electronics. Although there are differences between RF and power supply signals and circuits, power electronics engineers also care about fields, particularly when it comes to designing power circuits for low EMI and ultimately to meet EMC requirements. As field solvers continue to evolve, we could soon be using these tools to simulate the E and H fields our power circuits are generating, to the point of achieving first pass design success in EMC, as the author explains.

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

How To Select Bridge Rectifiers

by Jos van Loo, Taiwan Semiconductor Europe, Zorneding, Germany and Kevin Parmenter, Taiwan Semiconductor America, Chandler, Ariz.

Abstract: Choosing to use a bridge rectifier in a design vs. discrete rectifiers is often a tradeoff in terms of space, size, cost or whatever the case may be. Sometimes pc board space and the insertion of a single component into the board (versus four) are the most important issues, other times not. Sometimes power levels dictate the use of a packaged bridge rectifier. This article assumes that the choice to use a bridge rectifier rather than discretes has already been made. Given that decision, what are the electrical and mechanical specifications that need to be considered and what are the designer's options when selecting a bridge rectifier? In this article the authors identify the relevant specifications, outline the options, and offer advice on how to navigate the specs, quality and cost considerations.

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

Magnetics Utilization Vs. Converter Topology: A Little Extra Silicon Goes A Long Way

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: One of the goals of magnetics design is to achieve the greatest *utilization* possible from a magnetic component, to get the most use out of it as possible. Utilization, U, is defined quantitatively based on waveforms, usually current waveforms, as the average value of current (or voltage) divided by the peak value of current (or voltage). U expresses the extent to which a component is able to deliver the desired quantity, the average, relative to the maximum of that quantity that it must handle, or the peak rating. The ideal value is $U = 1$; the component need not be rated at any greater amount than what is used. Although the ideal of one is desired, the extent that it can be achieved varies based on the circuit of the magnetic component. In this article, we'll examine four popular

isolated power supply topologies—the flyback, forward, full bridge and half bridge converters—to see the impact that each has on utilization of the transformer.

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

Selecting An AC Line Filter For Switching Power Supply Applications

by Kevin Parmenter, Chair, and James Spangler, Co-chair, PSMA Safety and Compliance Committee

Abstract: While guidelines have been written on how to select EMI line filters, many system engineers still aren't aware that they need EMI filters. When they do realize they need one, they often select a filter without regard to their actual filtering needs. They may also ignore the impact of the filter on other requirements (such as leakage current), and issues such as customer support. In this article, the authors identify some of the popular bad practices being used to choose EMI line filters, explain why they're wrong and provide a quick guide to proper filter selection that will help designers avoid the common pitfalls. They identify the key criteria you'll need for filter selection including rules of thumb and key specs that will guide designers in making good choices. Armed with this information, designers will be better equipped to apply the EMI selection guides and tools already available.

Notes: 4 pages, 1 figure. Read the full story…

November 2019:

How To Drive Rad Hard E-Mode GaN Transistors Efficiently And Safely

by Tony Marini and Jim Larrauri, Freebird Semiconductor, Haverhill, Mass.

Abstract: A portfolio of high reliability, radiation hardened (rad hard) eGAN HEMT devices represents an exciting development for the space circuit design community. These transistors offer the designer a vastly improved C_{iss} * $R_{DS(ON)}$ figure-of-merit (FOM) as well as much faster switching times when compared to conventional rad hard silicon MOSFETs. Naturally being a newer technology, there are potential interface-related questions about the technology. In particular, designers new to the application of rad hard eGaN HEMT transistors typically want to understand how to deal with the narrower gate-source voltage operating range of the eGaN HEMTs as compared to that of the familiar silicon MOSFETs. For a space-level application design, there are additional complications and this article explains the various factors that influence the choice of the correct gate-source voltage in a space application and how to account for them in designing rad hard gate-drive circuits.

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

Accelerating UPS Wake-Up Can Improve Power Supply Efficiency

by Viktor Vogman, Power Conversion Consulting, Olympia, Wash.

Abstract: For corporate data centers, where downtime is unacceptable and expensive equipment must be protected from power quality problems, standby UPSs are usually insufficient and usage of double conversion (online) UPSs is required. However, recently the standby UPS has expended its reach in the industry in the form of the dc UPS, which integrates battery backup modules into the server power subsystems. Applying fast fault detection and accelerated redundant power supply wake-up methods developed for servers, the dc UPS wake time can be drastically shortened versus that of the standard offline UPS, even when the battery is not directly interfaced to the dc PDN. This articles

explains how speeding up the standby UPS wake-up process creates an opportunity for significant efficiency improvements.

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

The Engineer's Guide To EMI In DC-DC Converters (Part 10): Input Filter Impact on Stability

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Complying with regulations designed to limit conducted electromagnetic interference (EMI) usually requires the insertion of a low-pass EMI filter between a switching power converter and its source. Part 2 of this EMI article series provided a detailed perspective of noise propagation and the requirement for both differential-mode and common-mode input filtering as an essential part of switching power-supply design. However, dynamic interactions may occur due to a poorly damped EMI filter subsystem when connected to a regulated dc-dc converter. Here in part 10, the interaction between EMI filter and dc-dc converter is addressed including its impact on overall system stability and transient performance. Following an analysis of cascaded systems and the impact of impedance interaction dynamics on stability, this article presents simulation results using a synchronous buck controller with voltage-mode control to illustrate the important characteristics of the stability criteria.

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

Flyback Magnetics: Winding-Current Transition Is Key To Efficiency

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Flyback converters are isolated PWM-switch common-inductor (CL) configured converters, and a common power supply design choice at low power (<100 W). This article presents, with derivations, the design formulas that apply to flyback converter coupled inductors as part of the magnetics design of the converter. After a brief review of flyback circuit operation and the role of the coupled inductors, the design of the coupled inductors or *transductor*, is discussed at length.

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

Maintaining Battery Safety And Life Of Battery Are Top Priorities In Battery Charger Design

by Kevin Parmenter, Chair, and James Spangler, Co-chair, PSMA Safety and Compliance Committee

Abstract: Over the years, various rechargeable battery chemistries have been developed including sealed lead acid (SLA), NiCd, NiMH, Li-ion, Li-ion polymer and lithium iron phosphate (LFP or $LiFePO_4$). All of the rechargeable chemistries have advantages and disadvantages, but they've all had safety issues related to charging. In this article, we'll discuss the risks to battery safety and long operating life posed by charging errors, and describe the techniques used in charger design to prevent these errors. We'll also identify some of the governing standards. This information may be of value both to those designing battery chargers as well as those who are specifying battery charger products.

Notes: 7 pages, 6 figures, 1 table. Read the full story…

Design Article Archive

Abstracts of articles published in the January through December 2019 issues

December 2019:

Matching Driver IC And FETs Bring GaN Benefits To Low-Voltage POL Converters

by Ron Vinsant, uPI Semi, Mountain View, Calif.

Abstract: There are two well known advantages of using higher switching frequencies (>1 MHz) in lower voltage (12 V to 1 V) point-of-load (POL) dc-dc converters. First, the inductors are smaller. Secondly, less capacitance is needed in the output filter. A less discussed advantage is the potential for increased control loop bandwidth, which results in lower output capacitance to meet voltage excursion requirements during fast load transients. These benefits can't be obtained using silicon MOSFETs without sacrificing efficiency. However, due to the recent advent of low-voltage GaN FETs and matching drivers, giving up efficiency is no longer necessary. This article will demonstrate the performance improvements that can be obtained when using GaN FETs in combination with suitable GaN FET drivers in 12-V input to 1-V output point-of-load converters.

Notes: 7 pages, 9 figures. Read the full story…

Integrated Current Limiter Eases Power Protection In High-Voltage Space Applications

by Salvo Pappalardo, STMicroelectronics, Milan, Italy and Ignazio Mirabella, STMicroelectronics, Catania, Italy

Abstract: Latched current limiters (LCLs) have been extensively used in the aerospace environment, especially in the European institutional missions and for many years have been the fundamental power protection devices in earth observation satellites. However, nowadays, even if the functionality and the main performance requirements of these LCLs do not change from one project to another, they are routinely redesigned and implemented using discrete components. Obviously, an integration of certain key LCL functions could reduce or eliminate such redesigns. This opportunity was recognized by the ESA, which proposed development of an integrated current limiter of universal use, which in turn gave rise to the RHRPMICL1A IC, a rad-hard integrated current limiter (ICL). A high-voltage application solution described in this article allows its use in a power bus of 100 V or higher.

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

Design Platform Combines Ready-To-Use Motor Control Algorithm With Application-Oriented Enhancements

by Ingo Skuras, Infineon Technologies, Munich, Germany

Abstract: The widening of the application scope for variable speed drives (VSDs) has driven Infineon to adopt a new approach in iMOTION, the company's family of integrated solutions for the control of VSDs. These products integrate a production-grade control algorithm for the motor, and an optional power-factor correction (PFC) control algorithm along with all required hardware functions. This article describes why and how the hardware and software were changed to address the new application requirements, and how the new features and architectural changes in iMOTION 2.0 enable higher performance, reduce bills of materials and enhance design flexibility in the applications. A hair dryer design example illustrates how these new features are put to use in one of the newer applications for VSDs.

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

X-Capacitor Discharge Must Satisfy Both Safety And Energy Efficiency Rules

by Kevin Parmenter, Chair, and James Spangler, Co-chair, PSMA Safety and Compliance Committee

Abstract: Many products including power supplies and household products are connected to the ac line. Within these products we find the X capacitors used to provide line filtering. If no measures are taken to discharge these capacitors, they can retain a high-voltage charge even after ac power is removed from the product. There are regulations to prevent the consumer from being shocked if their fingers should touch the metal prongs of the ac power plug while they are removing it from the outlet. Satisfying these safety requirements for the discharge of X capacitors would be straightforward were it not for the energy efficiency standards, which are pervasive and over time are becoming more demanding. This article discusses both the safety and energy efficiency requirements, looks at the different circuit approaches to discharging X capacitors and how well they do in terms of satisfying the energy efficiency regulations.

Notes: 4 pages, 3 figures, 2 tables. Read the full story…