Design Article Archive

Abstracts of articles published in the January through December 2021 issues

January 2021:

Simulation Demonstrates Impact Of Current-Loop Crossover Frequency On Stability

by Christophe Basso, ON Semiconductor, Toulouse, France

Abstract: For switching converters operating in current-mode control, many engineers mistakenly believe that the subharmonic oscillations that occur at half the switching frequency in the voltage loop are caused by a peak in the current loop response at this frequency. In reality, the instability observed as a peak in the voltage loop at $F_{sw}/2$ is simply due to a poor phase margin in the current loop (caused by a pair of right-half plain zeros) not because of a peak there. While this phenomenon was analyzed and explained many years ago through modeling of current-mode control, it can be difficult to find experimental results that demonstrate the underlying relationships between power supply crossover frequency, phase margin and the resulting instability. This article presents circuit models in SPICE and SIMPLIS that engineers can use to simulate these effects.

Notes: 24 pages, 28 figures. Read the full story…

Don't Let Current Sources And Grounds Derail Your Spice Simulations

by Jerry Steele, Red Hill Labs, Tucson, Ariz.

Abstract: Though they've been in use for decades, Spice simulators still have their quirks that cause them to behave in unexpected ways. Usually, these are problems with the models, whether they be the ones inherent to the version of the program you're using, or problems with a model you've been given for a specific device. Either way, the results can frustrating if you're not aware of the problems and the easy fixes that you can apply. This article identifies some common problems with current sources and grounds in Spice, and describes the easy fixes.

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

Using Volt-Second Integral Instead Of Winding Current To Predict Saturation

by Gregory Mirsky, Vitesco Technologies, A Spinoff Of Continental Automotive Systems, Deer Park, Ill.

Abstract: Determining whether a chosen inductor will saturate is not always easy. While many inductor manufacturers will specify a core saturation current—a dc current level—this value is inconvenient for determining whether an inductor will saturate in the intended power supply application where the inductor will be subject to a waveform with both high-frequency ac and dc components. This article explains how saturation can be predicted more conveniently using the volt-second integral also known as the volt-second product.

Notes: 7 pages, 3 figures. Read the full story…

WBG Semiconductors Pose Safety And EMI Challenges In Motor Drive Applications

by Kevin Parmenter, Chair, PSMA Safety and Compliance Committee

Abstract: For years we've been told that silicon (Si) power MOSFETs and IGBTs have largely reached their performance limits and that wide-bandgap (WBG) power semiconductors such as SiC and GaN

MOSFETs will soon take over. One area where this is supposed to happen is in variable-speed motor drives, where SiC MOSFETs are competing with silicon IGBTs to be the power switch of choice for driving permanent magnet synchronous motors (PMSMs). GaN FETs are also being positioned for use in these applications. Despite the hype, there are serious obstacles to overcome in making the WBG power switches viable in motor drive applications.

Notes: 4 pages. Read the full story…

February 2021:

Demystifying Three-Phase PFC Topologies

by Didier Balocco, ON Semiconductor, Vélizy, France and Oriol Filló, ON Semiconductor, Munich, Germany

Abstract: Three-phase power factor correction (PFC) systems are experiencing a sharp increase in demand with two main drivers propelling this trend. First, there is vehicle electrification. Fast dc electric vehicle (EV) chargers, which are ac-dc conversion systems, require three-phase PFC topologies to efficiently and effectively deliver power above 10 kW. The second driver is the advent of silicon carbide (SiC) power semiconductors, which are enabling higher power and higher voltage power electronics applications, including three-phase PFC systems. This article introduces the key advantages of three-phase systems and dives into the essential design considerations for these systems. It presents the most common three-phase PFC boost topologies, discusses their pros and cons and provides guidance on how to approach a three-phase PFC design from scratch.

Notes: 16 pages, 17 figures, 1 table. Read the full story…

A PSU Analytical Power Loss Model For Optimizing The Server Power Delivery Architecture

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

Abstract: Because they reduce data center electricity costs versus less efficient power supplies, 80Plus-certified PSUs have become the market (and industry) standards. But even with the availability of these more-efficient power supplies, there are still opportunities for cost and energy savings. Specifically, the optimization of the sizes and ratings of 80Plus PSUs for the application could further reduce the total cost of ownership for server platforms. Such optimization could be provided very effectively if a PSU power-performance analytical model were available for power architects. This article presents an analytical PSU power loss model that provides a means to assess tradeoffs in continuous vs. peak power ratings of PSUs. This model also can be used for characterizing PSU dynamic efficiency and as a tool for optimization of the system power delivery spec.

Notes: 10 pages, 5 figures, 3 tables. Read the full story…

Determining Design Power Over An Input Voltage Range (Part 2): Inductor Design Power

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In part 1, the maximum power handled by the inductor of a PWM-switch converter was defined in relation to input power for the three PWM-switch configurations. The first power term tells

us the maximum amount of power the inductor will carry over the input voltage range, but this is not the power rating we can use to optimally design the inductor for size. To that end, we need a new parameter, which the author has dubbed *design power*. In this part, he defines inductor design power and shows how it varies in each of the PWM-switch configurations.

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

March 2021:

Rad Hard MOSFETs Enable Easy Upgrade Of Flight-Proven DC-DC Converter

by Andrew Popp and Bjarne Soderberg, International Rectifier HiRel Products (IR HiRel), an Infineon Technologies Company, El Segundo, Calif.

Abstract: Designing power electronics for space applications is often a balance between high reliability and risk. Design engineers look to develop architectures that meet mission requirements for cost and performance, balanced against acceptable risk levels for the mission. In this article, we will look at how a new generation of rad hard silicon MOSFETs enables efficiency and power density improvements in a heritage space-grade dc-dc converter. Specifically, we will examine how the use of IR HiRel's R9 rad hard MOSFETs enables an increase in efficiency and power output capability in a flight proven dc-dc converter simply by replacing the previously used R5 rad hard MOSFETs and with minimal changes to the rest of the circuitry.

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

Comparator Design: User-Defined Threshold With Asymmetrical Hysteresis

by Gregory Mirsky, Design Engineer, Deer Park, Ill.

Abstract: When configuring a comparator circuit, it's common to add hysteresis to the threshold to provide noise immunity. Typically, the designer sets a threshold with a single hysteresis value, so that in effect, there are high and low thresholds that are equidistant from the user-set threshold value. We'll call this symmetrical hysteresis. However there are cases where we'd like to be able to configure a comparator for a threshold with asymmetrical hysteresis. For example, this approach is convenient for providing a reliable safety feature in power supplies incorporating voltage and current protection. This article presents a comparator circuit that can be used to implement asymmetrical hysteresis and derives the formulas required to set the threshold and two hysteresis values.

Notes: 9 pages, 3 figures. Read the full story…

Determining Design Power Over An Input Voltage Range (Part 3): Maximum Transformer Power

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Magnetic components operated as transformers, like inductors, have maximum power ratings. But as was the case with inductors, the maximum power handled by the transformer is not optimal for sizing the transformer. The same analysis which we applied to inductors in parts 1 and 2 can be extended to transformers for the three configurations of PWM-switch converters as we'll show here in this third and final installment in the series.

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

April 2021:

Developing A 25-kW SiC-Based Fast DC Charger (Part 1): The EV Application

by Oriol Filló, Karol Rendek, Stefan Kosterec, Daniel Pruna, Dionisis Voglitsis, Rachit Kumar and Ali Husain, ON Semiconductor, Phoenix, Ariz.

Abstract: Along with the acceleration in the adoption of electrical vehicles (EVs), the demand for fast charging infrastructure is increasing. If you are an application, product or design engineer working in the power electronics field, sooner or later you could be involved in the design of one such charging system. A basic question might arise here, especially if it is the first time you are facing such a challenge. How and where should I begin? What are the key design considerations and how should I address them? ON Semiconductor's EMEA Systems Engineering team is gearing up to help designers address this challenge as we'll demonstrate by designing and developing a 25-kW fast dc charger based on SiC power integrated modules (PIMs).

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

The Engineer's Guide To EMI In DC-DC Converters (Part 17): Active And Hybrid Filter Circuits

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Minimizing the size, weight and cost of the EMI filter stage remains a priority for system designers. To this end, there have been numerous efforts over the past three decades in the application of active EMI filters (AEFs), with results indicating a substantial reduction in filter size and volume relative to a passive-only solution. Along with an AEF, the use of another passive component helps improve the overall attenuation and bandwidth—these circuits are known as hybrid EMI filters (HEFs). This article reviews the theoretical background of AEF circuits in terms of noise sensing, noise injection and control techniques. Experimental results from an automotive synchronous buck regulator circuit—using a controller with integrated AEF functionality for DM noise cancellation—illustrate the benefits available to designers in terms of EMI performance and space savings.

Notes: 9 pages, 8 figures, 1 table. Read the full story…

A Four-Decade, Integrated Current-Sensing Solution With Extended Supply Range

by Bich Pham and Ashwin Badrinarayanan, Maxim Integrated, San Jose, Calif.

Abstract: There is a growing need to measure a wide range of current in a system from miniscule current levels up to several amperes of current. Current-sense amplifiers used in combination with external sense resistors are a traditional choice for measuring current in these types of applications. However, there are performance limitations associated with this option, particularly with respect to dynamic range. This article introduces a resistorless, greater than four-decade dynamic range current-sensing solution and describes a simple method to extend its supply voltage range from 6 V up to 36 V using only a Zener diode and two MOSFETs.

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

Bunched Vs. Cabled: Litz Wire Bundle Twist Geometry Influences Proximity Effects

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Litz wire is a name for strands of individual wire conductors twisted or braided into a bundle that can then be wound on a core bobbin to form a winding. Each turn of the bundle is a winding turn, and within it are strands of wire. A winding bundle can simply be N_s strands twisted together, or can consist of sub-bundles of twisted wire which are twisted together to form the overall bundle. Commercial Litz wire usually consists of sub-bundles and is more elaborate to construct, especially if it is braided. This article describes some of the geometric features of Litz wire consisting of multiple twisted bundles and their magnetic effects, mainly with respect to proximity effects.

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

Safety On The Bench: Hazards And Precautions In The Power Electronics Lab

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

Abstract: It's no mystery that we, as power electronics engineers go through tremendous pains and trials to deliver a product that fulfills the mission requirements demanded by the application and the market. These requirements include reliability, environmental, safety and electromagnetic radiation, conduction and susceptibility constraints, and in some cases heavy ion, gamma ray and neutron events. We take all efforts to assure that the path of least resistance is upheld for the circuitry. This is the path of most resistance for us, but this is the duty. The standards can vary from ambiguous to crystal clear across space, mil, medical, aerospace, defense, consumer, automotive, industrial. But what happens on the bench in the lab during prototype and evaluation stages—*before* the codified standards apply? Shouldn't that be safe too?

Notes: 9 pages, 4 figures, 1 table. Read the full story…

May 2021:

Designing An Open-Source Power Inverter (Part 1): Goals And Specifications

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: This is the first in a series of articles that will disclose the engineering of a kilowatt-level, scalable open-source battery inverter dubbed the "Volksinverter"—a product meant to be suitable for widespread use, and which can be built and/or serviced by technically savvy individuals. Its key characteristic is the open-source nature of this design. In this article series, the design of the Volksinverter will be described in enough detail that a technical owner will be able to maintain, repair, or even modify the design, including the magnetic components. Like Linux, the Volksinverter design will lend itself to discussion by user groups on the Internet who will be able to share ideas, observations, procedures, modifications, corrections and enhancements of it. Anyone will be free to manufacture and sell it, as-is or in modified form.

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

Raising The Plateau Level In Valley-Fill PFC Circuits Improves Efficiency

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

Abstract: The passive capacitive PFC circuit, which employs capacitor-diode networks in the valley-fill (VF) PFC configuration, can improve power factor and reduce harmonic distortion of the input line current with a reduction in volume versus active PFC circuits. However, the operating principle of the existing VF-PFC circuit causes excessive supply voltage variations, resulting in higher current magnitudes and higher power dissipation in the power conversion stages that follow the PFC stage. These losses are influenced by the so-called plateau level in the VF-PFC waveforms. This article discusses the efficiency improvement made possible by a novel implementation of the VF-PFC in which a higher than usual plateau level is employed.

Notes: 9 pages, 5 figures, 3 tables. Read the full story…

Developing A 25-kW SiC-Based Fast DC Charger (Part 2): Solution Overview

by Oriol Filló, Karol Rendek, Stefan Kosterec, Daniel Pruna, Dionisis Voglitsis, Rachit Kumar and Ali Husain, ON Semiconductor, Phoenix, Ariz.

Abstract: In the previous installment of this series, the authors introduced the main system requirements for a fast EV charger, outlined the key stages of the development process for such a charger and identified the team of application engineers which is developing the charger described here. Now, in part 2 they will take a closer look into the guts of the design and unveil more details of it. In particular, they'll review the possible topologies, discuss their advantages and tradeoffs, and discuss the backbone of the system, which includes a half-bridge SiC MOSFET module.

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

Misconceptions In Power Magnetics

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Magnetic components appear to be so simple—just two parts, a core and some wire wrapped around it. How could that be very complicated? If you ask this question of yourself seriously enough, you begin your own descent into the abyss of magnetics design. As a "recovering magnetaholic," I have learned that magnetics really is simple, but the path to simplicity has some misleading ideas and some that are not actually true, though they are widespread. More importantly, some basic concepts that should be widely known are not. This article is a chat about some of them.

Notes: 6 pages, 4 figures, 1 table. Read the full story…

Military- Vs. Commercial-Grade Resistors: Reliability, Performance And Cost Tradeoffs

by Kory Schroeder, Stackpole Electronics, Raleigh, N.C

Abstract: Military-spec resistors provide an essential function in high reliability and critical circuit applications. However, unless you are dealing with such applications regularly, understanding what military-spec (military-grade) resistors offer compared to commercial resistors can be challenging. There are many aspects of military-spec resistors that are unclear or unknown to many customers. For example, a key distinction among military-spec resistors is whether or not they offer established

reliability. This article explains in broad terms how military specifications address reliability in the manufacturing, testing, inspection and processing of resistors, and how these aspects compare with those used to produce commercial- and automotive-grade resistors.

Notes: 4 pages, 1 figure, 2 tables. Read the full story…

June 2021:

Developing A 25-kW SiC-Based Fast DC Charger (Part 3): PFC Stage Simulation

by Oriol Filló, Karol Rendek, Stefan Kosterec, Daniel Pruna, Dionisis Voglitsis, Rachit Kumar and Ali Husain, ON Semiconductor, Phoenix, Ariz.

Abstract: It's time to dive deeper into the design process of the 25-kW EV charger. In parts 1 and 2, we discussed the motivations, specifications and topologies chosen. In this extensive part 3, we will walk through the simulations of the ac-dc conversion stage, a.k.a. the PFC stage, with discussions of the specific goals of our simulations, how the models were chosen, what operating and component parameters were selected, and our takeaways based on the simulation results presented here. In this project, we used Simetrix, a mixed-mode circuit simulator that offers enhanced SPICE for fast convergence.

Notes: 26 pages, 36 figures, 3 tables. Read the full story…

Bidirectional Switches Permit ZVS Operation In Single-Ended Forward Converters

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

Abstract: Hard switching in the single-ended forward converter topology limits the switching frequency and restricts its usage to low-power applications up to a few hundred watts. Meanwhile, implementation of soft switching in the forward converter is problematic because it increases circuit complexity, making other topologies like push-pull-mode bridge and half-bridge topologies with zero voltage switching (ZVS) more popular at higher power levels. However, recent developments in high-voltage-rated SiC MOSFET and bidirectional GaN switch technologies have created new opportunities for forward converter design, simplifying the implementation of ZVS operation and making the forward converter highly competitive in the power range above 1 kW. This article studies opportunities to employ such devices in the forward converter topology and discusses the benefits that such applications can provide.

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

Techniques For Safely Paralleling MOSFETs In Linear Circuits

by Jerry Steele, Red Hill Labs, Tucson, Ariz.

Abstract: In switched-mode power supply applications, the inherent characteristics of the power MOSFET work in the designer's favor when paralleling power MOSFETs used as power switches in the power conversion stages, but not when paralleling the power MOSFETs used in circuit protection and electronic loads. In the former category, efuses and hot-swap circuits are examples where the power MOSFET operates in a linear region. This article discusses the vulnerabilities of power MOSFETs when

paralleled and operated in such linear circuits, and describes techniques for ensuring current sharing in these applications.

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

Advanced MOSFETs Improve Power Conversion In 48-V Mild Hybrid Systems

by Filippo Scrimizzi, Carmelo Mistretta and Giusy Gambino, STMicroelectronics, Catania, Italy

Abstract: With the need to deliver higher electrical power while containing the overall system cost, adoption of 48-V mild hybrid platforms is rapidly growing thanks to the multiple benefits that mild hybrids provide. The 48-V Li-ion battery has the capability to feed the high-power systems in the car and through the 48-V to 12-V dc-dc converter, the 48-V battery can recharge the 12-V lead-acid battery, which powers the low-power systems. This article explains how the dc-dc converter's electrical requirements and its multiphase synchronous buck topology influence the selection of its power MOSFETs. It then demonstrates the levels of performance that are achieved when using ST's 80-V to 100-V STripFET F7 MOSFETs in this converter application and how a new MOSFET technology from ST will take this performance further.

Notes: 7 pages, 9 figures, 2 tables. Read the full story…

July 2021:

The Engineer's Guide To EMI In DC-DC Converters (Part 18): Advanced Spread-Spectrum Techniques

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Power electronic converters normally operate at a fixed switching frequency, which causes concentrated harmonic peaks in the frequency domain. By applying spread spectrum modulation, the switching frequency varies in the time domain such that the power of the distinctive harmonics spreads in the frequency domain, decreasing the respective peak spectral values. Part 9 offered an insight into periodic spread-spectrum techniques to provide a systematic reduction of conducted and radiated emissions, while referring specifically to an implementation using a triangular modulation profile. This article describes an enhanced multirate spread-spectrum technique developed by Texas Instruments that suppresses both acoustic and electromagnetic noise using a combination of periodic and pseudo-randomized modulations. This hybrid technique, known as dual random spread-spectrum, enhances EMI performance across the multiple resolution bandwidth settings specified in automotive EMC tests such as CISPR 25 and EN 55025.

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

Developing A 25-kW SiC-Based Fast DC Charger (Part 4): Design Considerations And Simulation Of The DC-DC Stage

by Oriol Filló, Karol Rendek, Stefan Kosterec, Daniel Pruna, Dionisis Voglitsis, Rachit Kumar and Ali Husain, ON Semiconductor, Phoenix, Ariz.

Abstract: In this new installment of "Developing A 25-kW SiC-Based Fast DC Charger," the spotlight is on the dc-dc dual active bridge phase-shift (DAB-PS) zero voltage switching (ZVS) converter, as introduced and partially described in part 2. Here the authors present some of the design process for the dc-dc stage followed by their engineering team. In particular, they explain key design considerations and tradeoffs in developing such a converter, especially around the definition of the magnetic components, and discuss the power simulations and design decisions made. In this part 4, they also touch on the concept of flux-balancing in a transformer and how it has been addressed for this 25-kW fast dc charger.

Notes: 14 pages, 13 figures, 7 tables. Read the full story…

Predicting Mission Life Performance And Reliability Of Rad-Hard Power Electronics

by Peter Lee, International Rectifier HiRel Products (IR HiRel), an Infineon Technologies company, San Jose, Calif.

Abstract: In space applications, understanding equipment reliability and performance over the mission lifetime remains a critical concern for system designers, especially for long duration, interplanetary and other critical missions. To achieve confidence in space systems requires rigorous design, strict qualification and radiation testing, and controlled manufacturing and screening to eliminate manufacturing defects and infant failures. Providing performance validation over the life of the mission is addressed through extensive design analyses validated by empirical data. Doing the detailed end-of-life performance assessment requires time, resources and expertise in radiation-hardened (rad-hard) electronics. This article will explain IR HiRel's design analysis methodology for its rad-hard hermetic hybrid dc-dc converters that power spacecraft electrical subsystems. This method provides end-of-life verification of the dc-dc converter specifications and performance in accordance with MIL-PRF-38534 Class K.

Notes: 7 pages, 3 figures, 1 table. Read the full story…

August 2021:

Developing A 25-kW SiC-Based Fast DC Charger (Part 5): Control Algorithms, Modulation Schemes And Feedback

by Oriol Filló, Dionisis Voglitsis, Karol Rendek, Stefan Kosterec and Rachit Kumar, onsemi, Phoenix, Ariz.

Abstract: In the previous parts of this series, the authors have extensively described the development of a 25-kW EV charger from a hardware perspective. This part 5 explores the implementation of the control strategy and algorithms for such a system. It provides firsthand details on the approach to control hardware and software development that the engineering team has taken, which helps speed up the firmware development and the validation process. The development process described here ensures that errors are minimized and detected early on, even before prototype hardware becomes available or is being designed. This part describes the steps and tools (MathWorks and Xilinx) to implement such an approach, the state machine and algorithmic blocks for the power factor correction (PFC) stage, and the main algorithmic blocks for the DAB converter.

Notes: 17 pages, 20 figures, 3 tables. Read the full story…

Zener Diode Selection For Faster Inductor Reset in Solenoid Circuits

by Gregory Mirsky, Design Engineer, Deer Park, Ill.

Abstract: A previous article discussed how use of a Zener diode in series with the recuperating diode speeds up operation of a solenoid driver circuit. That article demonstrated the underlying concept that adding a voltage-dropping component in the path of the inductor core's magnetic state recuperating current can shorten the core's magnetic state recuperation process by means of stored energy dissipation, which might also be beneficial for operation of power electronics circuits that use energy storing inductors. This article continues the discussion by offering an analysis of the dissipation of energy stored in the inductor's magnetic core and how the Zener diode shortens the magnetic core recuperation process. The purpose here is to provide formulas and plots that facilitate the Zener diode selection necessary for reducing the energy dissipation time by a user-defined factor.

Notes: 11 pages, 7 figures. Read the full story…

Space-Grade Tantalum Polymer Caps Deliver Lower ESR And Better Current Handling For Bulk Capacitor Applications

by Ron Demcko, AVX, Fountain Inn, S.C. and Slavomir Pala, AVX Lanškroun, Czech Republic

Abstract: Modern space electronics has a need for advances in bulk capacitors. Solid tantalum capacitors using MnO_2 cathodes are used in space applications because of their large capacitance in a small size and their infinite useful life. Significant advances are occurring in traditional tantalum capacitors. Among traditional MnO_2 tantalum capacitor trends are lowered ESR, increased CV, higher voltage rating and smaller case sizes. This article provides an update on advances beyond the traditional MnO_2-based tantalum capacitors. Specifically, it will discuss tantalum polymer capacitors and outline their electrical performance relative to traditional MnO_2 tantalum capacitors. The article will also provide an update on tantalum polymer agency qualifications.

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

Find A Transformer's Turns, Phasing And Coupling Factor With An RLC Bridge

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

Abstract: During his tenure in telecom rectifier and central office power design, the author's engineering lab was a short walk from the factory floor. This was a good environment for learning the benefits of engineering collaboration with production. One time, while releasing a transformer that was to be built in-house, a coil winder taught Paul some valuable lessons in measurement and humility. In this article, Paul shares this story, while explaining the very useful measurements you can make on transformers using a simple RLC bridge. These tricks may save you the trouble of hauling out the bigger instruments, when confronted with undocumented coils in transformers, motors and polyphase systems.

Notes: 5 pages, 3 figures, 2 tables. Read the full story…

September 2021:

Design Article Archive

Abstracts of articles published in the January through December 2021 issues

Integrated GaN Power Stages Enable High-Performance 48-V To 12-V Power Converters

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

Abstract: GaN devices are finding use in an increasing number of applications. To address these applications, uPI is introducing a family of integrated GaN power stages that combine two 100-V GaN FETs in a half-bridge configuration with a dual-channel driver and protection features. These devices simplify the development of GaN-based designs by eliminating the difficulties associated with driving enhancement-mode GaN FETs. In this article, the application of a uPI GaN power stage is demonstrated in a 48-V to 12-V, 180-W synchronous buck converter. This design example showcases the efficiency, thermal and switching performance made possible by the GaN device, while discussing elements of the design, like cooling and inductor choice, that affect converter performance. A low-cost technique for measuring the GaN device's fast switching transitions is also described.

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

Smart Gate Driver IC Simplifies Motor Drive Design In Battery-Powered Applications

by Peter Green, Infineon Technologies, El Segundo, Calif.

Abstract: The design of power-dense motor drive inverters is highly challenging, requiring many components to be placed on an often awkwardly shaped board within a confined space. At the same time, many different functions and protection schemes are necessary to produce a robust system. This article discusses how the high level of integration provided by the 6EDL7141, a smart gate driver IC for three-phase, battery-powered BLDC motor drive inverters, addresses the space limitations encountered in cordless power tools, which operate from battery packs in the 12-V to 48-V range, and similar battery-powered applications. It also explains key details of the design process when implementing motor drive inverters using this IC.

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

Designing An Open-Source Power Inverter (Part 2): Waveshape Selection

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Part 1 of this series discussed the need for an open-source kilowatt-level inverter design and outlined a power architecture for such a design. Besides enabling a more serviceable, maintainable product, the proposed Volksinverter enables many improvements in the performance and functionality of what's typically provided by low-cost power inverters marketed to consumers. Here in part 2, we delve further into system design issues, explaining how battery choices influence the selection of electrical specifications for the inverter, including its power protection features. Then we step back and review some mathematics relating to inverter-produced waveshapes, which will help us later in optimizing inverter design to meet various design goals. But first, we'll note the similarity between inverters and another power supply function, which will help us to understand the origins of certain inverter design equations.

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

Design Article Archive

Abstracts of articles published in the January through December 2021 issues

Transformer Winding Design: Bundle Layer Approximation As Rings

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Wire bundles consist of strands of individual wire conductors bound together and wound as turns in a winding of a magnetic component such as a transformer. Having less than five strands minimizes the proximity effect within a bundle when twisted. Some bundles have many more than five strands, and within the bundle, those strands form the same kind of pattern as wire wound in layers in a winding, with the same packing properties. With multiple layers of strands within a bundle, the proximity effect becomes significant. To estimate what it might be from Dowell's equation (or algebraic approximations of it) some estimate of the number of layers of strands, M_s, within the bundle is needed. This article derives various formulas for estimating M_s and gives rationales for them.

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

A Standalone Controller Eases Compliance With USB PD Standards

by Samantha Morehead and Sagar Khare, Maxim Integrated, San Jose, Calif.

Abstract: USB Power Delivery (PD) poses new power requirement challenges because of the variety of voltage and current combinations available—5 V, 9 V, 15 V, 20 V, 28 V, 36 V, 48 V and 1.5 A, 3 A, and 5 A, etc.—to supply the wide range of power levels the USB PD standard can provide. The power source and the inline devices communicate their power capabilities and power needs, respectively, in proper voltage and current levels before the source provides power over the USB cable. Some solutions require multiple ICs, including port detectors, microcontrollers and chargers for power delivery. While these solutions work, they take up space on a board, increase the solution cost, and require custom firmware, which can be time-consuming to create. A standalone PD controller can help address these challenges by managing the power negotiations without firmware development.

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

October 2021:

Linear Voltage Ramp Generator Supports Motherboard Power Cycling Tests

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

Abstract: A motherboard (MB) validation process is made up of several steps starting with PCB impedance measurements and signal integrity verification and then proceeding to finished product. One of the most significant milestones in this process is MB power cycling validation. Today's computer and server motherboards incorporate high-performance processing devices and other components that require multiple voltage rails to power their circuitry. These types of applications demand very specific voltage rail power-up ramps and sequencing to guarantee reliable MB transition into normal operating mode, reliable steady-state operation, overall system health and issue-free mass production. This article describes a simple low-cost voltage ramp generator power stage that is easily configurable for supplying different output voltages to motherboards and server platforms, and which enables users to set up a comprehensive MB automated power cycling test process.

Notes: 11 pages, 7 figures. Read the full story…

Design Article Archive

Abstracts of articles published in the January through December 2021 issues

Understanding Supercapacitor Discharge Into A Constant Power Load

by Gregory Mirsky, Design Engineer, Deer Park, Ill.

Abstract: Supercapacitors are gaining popularity as backup devices in diverse power supplies. Many of these supplies are intended for delivering constant power to the load for some period of time i.e. microprocessors should be supplied for some time during the device turn-off, same as memory ICs should be reliably powered before the system de-energizes. In order to design the supercapacitor-based backup module correctly, engineers should clearly understand that when activated, the backup supercapacitors will discharge to the constant power load in a way that's absolutely different from the discharge into a regular resistor. Moreover, the discharge will occur at a rate that is much faster than discharge into a regular resistor. This article is intended to fill the void in the existing online literature by providing a thorough description of what happens when a supercapacitor supplies a constant-power load.

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

Developing A 25-kW SiC-Based Fast DC Charger (Part 6): Gate Drive System For Power Modules

by Karol Rendek, Stefan Kosterec, Rachit Kumar, Didier Balocco, Aniruddha Kolarkar, Parthiv Pandya and Will Abdeh, onsemi, Phoenix, Ariz.

Abstract: Parts 1 through 5 of this series extensively described the development of a 25-kW EV charger from a hardware perspective and a control strategy. Here in part 6, we turn our attention to the gate-drive circuitry needed to drive SiC MOSFETs. As more of these devices become available in the market, it is important for designers to understand both the commonalities and the differences between SiC MOSFETs and silicon IGBTs and superjunction MOSFETs so that the user can get the most out of each device. This article is based on the lessons learned while building a 25-kW fast EV charger using new SiC modules from onsemi. Here, we will see how to design and tune the coupled gate driver-and-SiC MOSFET combination in a high-power application.

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

Determining Optimal Wire Size For Toroidal Windings

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In a previous series of articles, the design equations were derived and explained for optimizing winding design. For planar or *linear* (constant turns per layer) windings of EE, ETD, ETF, PQ, RM or other cores, the design formulas were easier to derive than for toroid or ring cores, where the winding layers curve to form a loop and the turns per layer decrease as layers are added. A subsequent article went further in defining the optimum operating point for toroid cores, and included formulas for determining optimal wire size for a given winding window area. This article derives the design formulas for the optimal wire size based on the Dowell equation valley point between the low and medium wire-size regions. In the previous series, this corresponded to magnetic operating-points on the curve for f_{rv}. The optimization in this article does not constrain winding area or number of bundle strands.

Notes: 8 pages, 2 figures. Read the full story…

November 2021:

Why EM Is Replacing SPICE For Simulation Of Board-Level Power Delivery

by Heidi Barnes, Keysight Technologies, Santa Rosa, Calif. And Steve Sandler, Picotest, Phoenix, Ariz.

Abstract: In the power electronics world of voltage regulators there is such an entrenched history of SPICE models that few engineers look further than running a freeware LTspice simulation with vendor-supplied models to predict behavior. This "lumped-SPICE" type simulation assumes perfect conductors between the bill-of-material components in the schematic. However, signal integrity engineers designing power delivery to high-speed digital loads are finding out the hard way that lumped-SPICE simulations are leaving out critical time delays and parasitic behaviors that only an EM simulated model of the PCB interconnect can get right. Getting it wrong can result in incorrect prediction of power rail resonances and lead to voltage regulator designs that are on the edge of instability. Ultimately, it can lead to a complete failure of the high-speed circuitry.

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

Consider The Tradeoffs When Choosing Probes For 48-V Applications

by Ken Johnson and Yash Gupte, Teledyne LeCroy, Chestnut Ridge, NY

Abstract: With growing power requirements necessitating voltage levels higher than 12 or 24 Vdc, markets for products powered by 48 Vdc are growing quickly. Simultaneously, GaN is displacing silicon in many applications because its faster rise times translate to better efficiency, smaller size and lighter weight. However, the faster rise times require about 1 GHz of oscilloscope and probe measurement bandwidth. A thorough understanding of the different types of probes available for use, and their tradeoffs, will allow you to make the best possible measurements of signals in your 48-V power-conversion systems. This article looks at active and passive probe types that are candidates for measuring switching waveforms in 48-V power converters, particularly those using GaN power transistors.

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

MOSFET Packaging Innovations For SWaP-Optimized Space Power Systems

by Oscar Mansilla, Rushi Patel and Michelle Lozada, International Rectifier HiRel (IR HiRel), an Infineon Technologies Company, San Jose, Calif.

Abstract: In space-rated power electronics, reliable attachment of surface-mount hermetically-packaged MOSFETs to printed circuit boards (PCBs) has been an elusive task for space system designers for many years. Material differences between the circuit board and surface mount device (SMD) package result in a mismatch between their coefficients of thermal expansion (CTEs). This CTE mismatch makes it difficult to maintain reliable solder joints between the PCB and the SMD package. This article will look at how IR HiRel's advanced rad hard FET package design, the SupIR-SMD, solves these difficult challenges while enabling significant size, weight and power (SWaP) and cost advantages to the space power system design community.

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

Stored Energy In A Saturating Inductor Is Not Constant

by Gregory Mirsky, Design Engineer, Deer Park, Ill.

Abstract: The behavior of magnetic components in saturation is a topic that is not always well understood. One misconception that I encountered recently was that the energy stored in a saturating inductor remains constant regardless of the magnetic core's status. However, in a previous work, I derived formulas that allow us to quantify the dependencies of both inductance and stored energy on magnetizing current. From those equations, we can demonstrate that the energy stored in the inductor does not remain constant in saturation as we'll show in this article. This behavior is worth analyzing because inductors in various applications (such as solenoids and chokes) are frequently driven into saturation. The energy stored in the inductor is ultimately released and affects other components.

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

December 2021:

Design, Development And Performance Of A Power Generating Suspension System For Energy Harvesting In Commercial Vehicles

by John M. Miller, Jon Hurry, and Elsbeth Hurry, Propitious Technologies, Phoenix, Ariz.

Abstract: There is a big opportunity to reduce harmful CO_2 emissions through the advancement of innovations related to the use of motor vehicles. An efficient and commercially viable power generating suspension system (PGSS) enabled with a power generating strut (PGS) and other system components can harvest energy created while using a vehicle to increase vehicle efficiency or offset the need for diesel-powered cooling systems. Using a new fractional slot concentric winding (FSCW) linear generator design with a mechanical arm for use in a PGSS allows for energy harvesting at levels that provide substantial value in the commercial sector including many different motor vehicle segments. Leveraging this PGSS with intuitive modifications can eliminate the need for diesel fuel currently used to power refrigerated trailers and/or can eliminate or significantly reduce the size of the required battery in battery-powered refrigerated trailers.

Notes: 28 pages, 25 figures, 2 tables. Read the full story…

Modern Control Methods For LLC Converters Simplify Compensator Design

by Christophe Basso, Future Electronics, Toulouse, France

Abstract: Resonant converters are found in many power structures with output power levels from a few hundred watts up to several kilowatts. Among the possible architectures, the LLC converter has gained popularity owing to the many integrated circuits now available on the market. With its nice sinusoidal waveforms, this converter supports soft-switching and EMI-friendly applications. This article reviews the techniques available to control LLC converters and provides an overview of recommended controllers available from a range of suppliers. In particular, this article focuses on the more up-to-date LLC operating methods such as bang-bang charge control, charge-current-mode, current-mode and time-shift control. By changing the ac response of the LLC converter, these control techniques

simplify the required compensator design, while providing other benefits such as faster transient response.

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

Modular Power Supplies Save Cost, Speed Product Development For Medical Applications

by Dermot Flynn, Advanced Energy Industries, Cork, Ireland

Abstract: When specifying power for new designs, "make versus buy" is a constant dilemma—especially for medical power. While optimized for the application, fully customized solutions take time to design, prototype and manufacture, and are subject to extensive and time-consuming certification tests before they can be deployed. Custom approaches also carry an inherent level of risk versus standard solutions. However, choosing standard, off-the-shelf supplies can require compromises in performance, size and thermal management. This is why medical manufacturers are increasingly looking at a "third way"—high-efficiency modular power supplies that can be configured to exactly match application requirements while being fully safety certified and ready for immediate use.

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