HOW2POWER TODAY

Design Article Archive

Abstracts of articles published in the January through July 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…

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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…