HOW2POWER TODAY

# Design Article Archive

Abstracts of articles published in the January through December 2023 issues

## January 2023:

### *Quasi-Resonant Vs. Resonant Operation—Which Has Better Power Utilization?*

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

**Abstract:** One of the widespread solutions for reducing power supply losses is to implement resonant or multi-resonant operation, as embodied in the LLC converter. However, an LLC converter has a pretty complicated control scheme and requires use of a gapped transformer. In contrast, the ZVT phase-shift converter offers simpler control and a simpler (ungapped) transformer design. This type of converter is non-resonant but uses a resonant condition that occurs only during the switching process, and therefore operates in a quasi-resonant mode. In this article, we will compare the efficacy of half- or full-bridge configurations when operating in resonant and quasi-resonant modes. Specifically, we will assess the power utilization of a resonant LLC converter versus an equivalent phase-shifted ZVT converter to see which one delivers more power under the same operating conditions.

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

### *Rad-Hard P-Channel FETs: A Simpler And More-Reliable Solution For Power Distribution In Space*

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

**Abstract:** Overall system reliability remains critical in space applications. This is especially true for the power management and distribution (PMAD) needed to keep the spacecraft operational. With space systems only as strong as their weakest parts, reliability starts at the discrete component level. That includes power MOSFETs, both those used in power converter power stages and those used in power distribution. For a typical satellite, the mix of power FETs needed is approximately 60% n-channel and 40% p-channel. In this article, we'll discuss the importance of robust safe operating area (SOA) particularly vis-à-vis power applications requiring p-channel FETs, including load switching, load sequencing, redundancy for power sources and loads and inrush current limiting.

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

### *Do Eddy Current Effects And Self Heating Cause Distortion In Audio Cables?*

*by Dennis Feucht, Innovatia Laboratories, Cayo, Belize*

**Abstract:** Eddy current effects are a fundamental concern in power magnetics design for switched-mode power supply applications. Conceptually, they are a potential concern in another area of electronics—audio applications, specifically in audio cables connecting amplifiers and speakers. Since eddy current effects lead to variations in resistance, they are a potential source of distortion in audio cables. While the issue of audio cable distortion falls outside of the realm of what's typically addressed in power electronics forums, it's notable (and hopefully interesting to designers) that the analytical tools used to design power supply magnetics can also be applied to analyzing audio cable distortion.

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

### *Deploying Current Transformers In Current And Voltage Monitoring*

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

**Abstract:** Many power subsystems have requirements for galvanic isolation of their loads and control circuits from the primary power source. To meet this requirement, high-frequency power transformers are used to electrically separate the primary side of the power conversion stages from the load. At the same time, output voltage and input current monitoring used in these systems for control purposes must also include an isolating component in the control signal processing path. Two of the most efficient methods of providing these features are use of isolated differential amplifiers for voltage sensing and use of specialized current transformers (CTs) for current sensing. However, besides monitoring current accurately, CTs can also be used as analog signal/voltage sensors, enabling the transfer of an analog voltage signal among two circuits that are not electrically coupled.

Notes: 10 pages, 6 figures. Read the full story…

## February 2023:

### *Enhanced Switched Tank Converter Offers Flexible Fixed-Ratio Power Conversion For Data Centers*

*by Paolo Sandri, STMicroelectronics, Santa Clara, Calif.*

**Abstract:** Data centers have been moving from 12-V to 48-V buses for in-rack power delivery for several years in order to reduce distribution losses. This move, in turn, is driving innovations in the design of power converters that step down the 48-V bus for local, on-board power delivery to the high-power chipsets. This article discusses ST's recently developed hybrid switched tank converter (HSTC), an unregulated topology that takes advantage of recent changes in data-center power specifications from the Open Compute project to provide greater efficiency and higher stepdown ratios. Topics covered include the motivation for developing the HSTC topology, its principles of operation—which revolve around use of a transformer—and an analysis of its circuit operation. The article also presents efficiency results for a 700-W HSTC reference design.

Notes: 11 pages, 7 figures, 4 tables. Read the full story…

### *Designing An Open-Source Power Inverter (Part 10): Converter Protection Circuits*

*by Dennis Feucht, Innovatia Laboratories, Cayo, Belize*

**Abstract:** Recent installments in this Volksinverter article series have discussed the design of the control power supply which resides in the BCV401 module. This module also incorporates the battery-converter protection circuits. These include undervoltage and overvoltage protection, overtemperature protection, fan control of temperature, and overcurrent protection. This article presents and explains the operation of these protection circuits, which are essential yet do not require high performance in precision or speed. They are designed with low-cost, commodity-grade op-amps and comparators. All protection and fan control circuits have some hysteresis built in to keep them from dithering around the threshold. In addition, all of them drive the system fault bus that shuts down both converter and inverter stage drivers.

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

# Design Article Archive

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### *Addressing Design Challenges In 48-V MHEVs: Buck Converter Choices Can Help*

*by Harrison Overturf, Texas Instruments, Santa Clara, Calif.*

**Abstract:** In 48-V mild hybrid electric vehicles (MHEVs), a relatively new automotive powertrain topology is used that provides many of the benefits of a full hybrid solution at only a fraction of the cost. In addition to the traditional 12-V battery, this topology includes a 48-V battery for hybrid features such as start-stop, regenerative braking and torque assist, and which can also be used to offload high-power systems from the 12-V battery. The 48-V battery MHEV system is a compelling intermediate step between the low cost of an internal combustion engine and the high efficiency and high cost of a full hybrid, but has its own challenges. In this article, I will discuss those challenges, where they come from, and how to address them.

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

### *Analysis Of Core Hysteresis Loss Underscores Transformer Efficiency Challenges*

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

**Abstract:** Rapid development of very fast and efficient SiC and GaN semiconductors allows for creating highly efficient power converters operating in the megahertz range. Some designers and manufacturers boast product efficiencies above 99%. To achieve this high total converter efficiency requires not only that the semiconductor portion of the converter be extremely efficient, but also that the power transformer must have record-high efficiency. Although modern magnetic materials have many outstanding parameters, the laws of physics cannot be violated, and therefore, the transformer's efficiency is limited by a few factors, which describe power loss in the magnetic core. In this article we will analyze how the hysteresis loss affects the magnetic core loss, and what core material properties affect the hysteresis loss most of all. Analyzing this loss underscores the difficulty of achieving extremely high efficiency in transformers because if hysteresis loss is significant, the other losses will be even more so.

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

## March 2023:

### *Design Considerations For Use Of A Forward DC-DC Converter In Arc Welding*

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

**Abstract:** This article studies an adaptation of the forward converter that delivers the output regulation characteristics necessary for arc initiation and stability while maintaining the high energy efficiency inherent to operation at a fixed output voltage. This method overcomes the efficiency penalty associated with existing switched-mode designs. In this new approach, the forward converter's output voltage is raised at light loads through the application of a voltage-boost channel operating in parallel with the main output and connected to that output using an inductor that facilitates a load line that falls with rising current. The booster channel function and key equations describing the operation of this converter are provided in this article and converter losses are analyzed. Details of a practical implementation are discussed.

Notes: 11 pages, 8 figures, 1 table. Read the full story…

### *Designing An Open-Source Power Inverter (Part 11): Minimizing Switch Loss In Low-Input-Resistance Converters*

*by Dennis Feucht, Innovatia Laboratories, Cayo, Belize*

**Abstract:** Low-voltage, high-current input, or low-$R_g$, power converters are becoming more common as supply voltages are reduced and currents increased. Examples are the point-of-load converters for computer microprocessors and battery chargers for cell phones. However, off-grid inverters also have low-$R_g$ battery-input power ports exemplified by the design of the off-grid 24-V battery converter of the Volksinverter. In this part in the article series, we address a key aspect of optimizing the battery converter stage. As with other low-$R_g$ converter designs, the design of this battery converter begins with a decision about which power-transfer circuit is optimum for this stage. Here in part 11, we consider this issue in terms of which topology minimizes switching loss.

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

### *Calculating System Efficiency With Multiple Independent Power Modules*

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

**Abstract:** Very often complex power electronics systems incorporate multiple converters and inverters that differ by operating power and efficiency. In many cases, different modules in such a system are scattered across the system and are connected as needed, either in series or parallel. When it is necessary to assess the total expected efficiency of such a system, designers often calculate erroneous results. While the efficiency of serially connected power modules is simply the product of their efficiencies, the calculation is not quite so simple for the modules in parallel or not connected at all. In this article, we'll see what can be done to properly assess total system efficiency of such a system containing multiple independent power modules.

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

### *Step-By-Step Process Of Designing Flyback-Converter Coupled Inductors (Part 1): Theory Of Magnetics*

*by Louis R. Diana, Texas Instruments, Iselin, N.J.*

**Abstract:** Flyback converters are popular in offline battery chargers and system housekeeping supplies—or any applications that have system isolation and low cost as design priorities. In order to truly understand the inner workings of a flyback converter, it is beneficial to understand the design of a flyback's coupled inductor and how it works. A flyback magnetic is referred to as a coupled inductor because it stores energy in one half-cycle and then delivers that energy to the secondary on the next half-cycle; in contrast, transformers receive and deliver energy to the secondary within the same cycle. In this two-part article, the author will provide an in-depth approach to designing a flyback converter's coupled inductor. Part 1 is a review of magnetic theory and foundational design calculations.

Notes: 9 pages, 7 figures, 1 table. Read the full story…

## April 2023:

# Design Article Archive

Abstracts of articles published in the January through December 2023 issues

## *Stiff Voltage Clamping Reduces Input Current Ripple In Single-Ended Converters*

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

**Abstract:** In the "single-ended" topologies, such as forward, flyback, and push-pull, in which the switching transistors are connected to electrical ground, the energy stored in the leakage inductance can be recycled with the help of nondissipative networks, providing stiff voltage clamping. These networks contain an additional winding coupled to the ground and a "flying" capacitor connecting identical terminals of the transformer's primary windings and absorbing the energy stored in the leakage inductance. Besides improving converter efficiency and alleviating problems arising from leakage-inductance spikes, using such an energy recovery technique also opens an opportunity to significantly reduce the current ripple produced by the converter in its primary power delivery path, helping to minimize the size of the input EMI filter. This article examines processes in the most widely used forward and flyback single-ended topologies with stiff voltage clamping.

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

## *Evaluating Waveform Form Factors Of FW And HW Rectifiers In SMPSs*

*by Dennis Feucht, Innovatia Laboratories, Cayo, Belize*

**Abstract:** Full-wave (FW) and half-wave (HW) rectifiers typically are found in the secondary circuits of transformers in switched-mode power supplies. FW rectifiers have four diodes for an untapped secondary winding, consisting of two branches of two diodes in series in each. Sometimes the diodes are discrete and suspended in air or separated on a circuit-board. Or they are part of a module of four diodes, one per side of a square, filled with epoxy resin. Sometimes dual diodes in a rectifier are monolithic, which makes them the most tightly coupled thermally. Because the currents fed to these rectifiers are generally square waves of varying duty cycle, with different RMS and average values, one way to gauge the effects of rectifier packaging on power dissipation is to evaluate the waveform form factors of different rectifier styles.

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

## *Step-By-Step Process Of Designing Flyback-Converter Coupled Inductors (Part 2): A Practical Example*

*by Louis R. Diana, Texas Instruments, Iselin, N.J.*

**Abstract:** In part 1 of this two-part article, the author provided a review of magnetic theory and foundational design calculations for designing a coupled inductor magnetic for a flyback converter. In this second installment, he will show how to apply these calculations in an example design. Specifically, he will calculate inductance, wire gauge and ac-dc losses, flux density, core and bobbin fill factor, and inductance rolloff; select a core material; and show how to achieve good coupling by properly layering the primary and secondary windings on a bobbin.

Notes: 10 pages, 6 figures, 5 tables. Read the full story…

## *New JEDEC Guidelines Help Designers To Realistically Predict Stability Of SiC MOSFETs In Applications*

*by Thomas Aichinger, Infineon Technologies, Villach, Austria*

**Abstract:** With the recent publication of JEDEC guidelines for SiC MOSFETs, the promised benefits of silicon carbide (SiC) MOSFETs can now be fully realized and consistently demonstrated through recognized industry guidelines. Concurrently, newly introduced high-voltage (1200-V) SiC MOSFETs have improved threshold voltage stability that can be validated by the new testing procedure. Systems engineers that have previously evaluated SiC MOSFETs and observed somewhat different threshold voltage ($V_{TH}$) variations compared to silicon MOSFETs now have an answer on how to measure $V_{TH}$ reproducibly in pristine devices and what is the worst-case drift of critical electrical parameters that can be expected in different SiC MOSFET applications. This article will provide background on the SiC market, discuss the JEDEC guidelines and testing performed by Infineon and conclude with details on newly implemented test procedures.

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

## May 2023:

### *EV Traction Inverters And EMC: Keeping Car Radios Working*

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

**Abstract:** "EVs have no AM radio option due to interference from the inverter" and "state, local and/or national safety agencies are furious that EVs will not be able to receive emergency broadcasts via AM radio." These headlines aren't new concepts in the world of electromagnetic compliance and electromagnetic compatibility. However, I believe our duty is to improve traction inverter emissions in EVs. To me, eliminating the AM radio is no more of a solution to the EMC problem than the ostrich sticking its head in the sand. In this article we'll look at the problem from both radio frequency (RF) and power design perspectives and I'll propose possible paths to solving the electromagnetic incompatibility between the radio and the traction inverter.

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

### *Designing An Open-Source Power Inverter (Part 12): Sizing The Converter Magnetics*

*by Dennis Feucht, Innovatia Laboratories, Cayo, Belize*

**Abstract:** As this series on designing the Volksinverter continues, we address another aspect of the battery converter stage. Specifically, we delve into the design of the magnetics in the BCV402 power-transfer circuit. The power-transfer circuit has two magnetic components: a coupled inductor and a transformer. It operates normally in CA or boost push-pull (BPP) mode whenever $V_s' > V_g$ but otherwise reverts to CP (buck) mode when output current or voltage is low. Transformer design is based on the CA mode whereby the transformer transfers the full-scale output power and is the normal mode of operation. In this application, magnetics sizing—determining the power rating of the magnetic components—is a basic design consideration complicated by battery input voltage $V_g$ range.

Notes: 8 pages, 3 figures, 2 tables. Read the full story…

### *The Magnetic Agnostic Structure (Part 1): A Proposed Language For Describing And Documenting Magnetic Components*

*by Alfonso Martínez, OpenMagnetics, Madrid, Spain*

**Abstract:** Do you remember, dear reader, any structure that you followed to store the information about any magnetic you have designed? Did you put any thought into its maintainability or scalability? In this article I'll discuss the shortcomings I see in the way engineers document their magnetic component designs, and propose a new language for doing so which I am calling the Magnetic Agnostic Structure or MAS for short. In introducing MAS, I'll explain how I arrived at my proposed format for defining magnetic components, and its various uses. Delving further, I'll provide a high-level description of how the magnetic component (the "magnetic") is defined as a whole, and then go into much more detail on how the core can be defined in this format.

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

## June 2023:

### *Characterizing Di/dt Of A CPU Operating With A Mixed Array Of Decoupling Caps*

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

**Abstract:** Decoupling capacitors improve the load-transient performance of a CPU voltage regulator, keeping the supplied voltage within the required tolerances and playing a crucial role in maintaining reliable processor operation. Typically, different capacitor chemistries or types are required to achieve the required transient performance or flat output impedance of the decoupling caps. However, there are many possible combinations of capacitors that provide flat output impedance or the same decoupling capacitance but have different load transient performance. Consequently, for proper selection of the decoupling caps, it is important to know what load transient performance is required. This article examines the implementation of a parallel non-intrusive current monitoring technique that allows a user to determine di/dt of fast varying loads, such as a high-performance CPU, when supply voltage stability is provided with different types of decoupling caps.

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

### *Designing An Open-Source Power Inverter (Part 13): The Differential Boost Push-Pull Power-Transfer Circuit*

*by Dennis Feucht, Innovatia Laboratories, Cayo, Belize*

**Abstract:** In part 3 we discussed three different options for the power transfer circuit used in the battery converter (dc-dc) stage. We considered push-pull (PP), boost push-pull (BPP) and SEPIC topologies, ultimately concluding that boost push-pull was the optimum of the three. We did further analysis in part 11 to compare the BPP circuit with both PP and single-ended PWM-switch circuits to determine which scheme yielded lower switching losses, with the BPP coming out ahead again. However, there is another variation on the BPP that deserves consideration. This part introduces a circuit modification of the common-active (CA) PWM-switch or boost push-pull (BPP) power-transfer circuit that changes it to an interleaved or *differential BPP* (DBPP)—differential in circuit symmetry.

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

### *Inductor And Transformer Core Volumes Should Be Different—Even When Handling The Same Power*

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

**Abstract:** Being able to determine minimum core size for inductors and transformers aids designers in achieving the smallest possible size for their magnetics and minimizing their cost. However, in practice, many designers don't perform such calculations, which can lead to poor design choices with magnetics that are either oversized or undersized. In this article, we consider the case where the same converter (a half-bridge or full bridge with a single output) may have a power transformer and an output filter inductor operating at the same power. When this occurs, designers sometimes choose the same core for both devices. By applying the equations derived previously for inductor and transformer core volumes, we can show that these volumes should not be the same for an inductor and transformer handling the same power levels.

Notes: 3 pages. Read the full story…

### *Meeting The Challenges Of USB-PD Extended Power Range With An Asymmetrical Half-Bridge Flyback Topology*

*by Alfredo Medina-Garcia, Martin Krueger, Markus Schmid and Josef Daimer, Infineon Technologies, Munich, Germany; and Manfred Schlenk, Dr. Schlenk Consulting, Augsburg, Germany*

**Abstract:** The new USB-PD Extended Power Range (EPR) standard is designed to enable a universal power supply capable of charging a wide range of devices. However, supporting a variable output voltage from 5 V to 48 V at up to 5 A while maintaining high conversion efficiency raises new challenges for engineers. Further complications arise from the need to also maintain a small footprint, accept a wide input voltage range, provide power factor correction, support standby power modes, and dissipate heat only through passive cooling. This article describes how a hybrid flyback topology meets the requirements of the USB-PD EPR standard while achieving a full load efficiency of up to 96.84% across an input voltage range of 90 to 265 Vac and a power density of 44 W/inch$^3$.

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

## July 2023:

### *Battery Energy Storage Systems: Topology Selection Depends On Application Needs*

*by Kane Jia, onsemi, Shanghai, China*

**Abstract:** Batteries can be used to store the energy produced from renewable sources like solar and wind at peak times, allowing them to be drawn upon when environmental conditions are less favorable for energy production. This article reviews power conversion topologies for residential and commercial battery energy storage systems (BESSs) with details on the different topology options for different systems and the design tradeoffs among those topologies. This article begins with an overview of the benefits provided by BESSs, and describes their key building blocks. The role of power conversion in these systems is then discussed, first with regard to residential systems and then for commercial systems.

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

### *Designing An Open-Source Power Inverter (Part 14): Boost Push-Pull Or Buck Bridge?*

*by Dennis Feucht, Innovatia Laboratories, Cayo, Belize*

**Abstract:** In the ongoing search for the optimal power-transfer circuit for the Volksinverter, this article compares the differential boost push-pull (DBPP) power-transfer circuit of part 13 to a bridge-switched common-passive or buck (CP-BRG) transfer circuit to determine whether the DBPP and BPP (i.e. the CA-PP) or the CP-BRG has lower loss as a low-$R_g$ power-transfer circuit. This comparison of the CA-PP with the CP-BRG is motivated in part by the popularity of the full-bridge buck circuit, which will be familiar to designers because of its common use in inverters. The DBPP is used as the initial point of reference here because it was most recently discussed in the last part and is similar enough to the BPP that the comparisons here with the CP-BRG apply to both circuits.

Notes: 11 pages, 5 figures, 1 table. Read the full story…

### *The Magnetic Agnostic Structure (Part 2): Describing Wires And Coils*

*by Alfonso Martínez, OpenMagnetics, Madrid, Spain*

**Abstract:** The Magnetics Agnostic Structure (MAS) has been proposed as an unambiguous language for describing magnetic components. In the previous part in this series, I explained the motivations for developing such a language, the requirements that it should fulfill in order to be useful, scalable, and universal; and explained how a magnetic core, any magnetic core, can be described without ambiguities using the MAS. In this second part, I will continue the process of defining the MAS, explaining a structure for describing wires and full coils. As noted in part 1, the structure (also referred to as a format or language) which is being presented here is not meant to be final. Rather it is intended as a starting point for collaborative efforts to develop a standardized methodology of defining and documenting magnetic components designs.

Notes: 11 pages, 3 figures. Read the full story…

## August 2023:

### *Predicting GaN Device Lifetimes In Solar Microinverters And Power Optimizers*

*by Shengke Zhang, Siddhesh Gajare and Ricardo Garcia, Efficient Power Conversion, El Segundo, Calif.*

**Abstract:** Microinverters and power optimizers are widely utilized in modern solar panels to maximize energy efficiency and conversion. Such topologies and implementations usually require a minimum of 25 years of lifetime, which is becoming a critical challenge for market adoption. Low-voltage gallium nitride (GaN) power devices ($V_{DS}$ rating < 200 V) are a promising solution and are being used extensively by an increasing number of solar manufacturers. In this article, a test-to-fail approach is adopted and applied to investigate the intrinsic underlying wear-out mechanisms of GaN transistors. The study enables the development of physics-based lifetime models that can accurately project the lifetimes under the unique demands of various mission profiles in solar applications.

Notes: 11 pages, 6 figures, 1 table. Read the full story…

### *Active Clamp Flyback And GaN Switches Shrink Auxiliary Power Supply Size*

*by Brian King, Texas Instruments, Dallas, Texas*

**Abstract:** In high-power systems, the design of the main power converters receives much attention, while the design of the auxiliary supply is sometimes an afterthought. In this article, the author focuses on a server power-supply unit (PSU) auxiliary supply as defined by the modular common redundant power supply (M-CRPS) specification created by the Open Compute Project (OCP). However, you can easily apply the design procedure and decisions described here to other applications. After reviewing the relevant details of the M-CRPS specification and the chosen board dimensions, power supply design choices are discussed, beginning with the selection of the active clamp flyback in combination with a GaN-based power stage. The design of a planar transformer and its performance is then explored in greater detail.

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

### *Piezoelectric Machine Model Aids Design Of Motion Control Systems*

*by Dennis Feucht, Innovatia Laboratories, Cayo, Belize*

**Abstract:** Piezoelectric devices are emerging in importance, in molecular mechanics (as positioners), in medical diagnostic and surgical instruments (phacomachines for cataract surgery), and for vibration or noise suppression. As a particular kind of energy converter or transducer—translational, electric (or electrostatic) machines—they can be modeled using basic electromechanics theory, as presented for instance in *Electromechanical Motion Devices*, by Paul C. Krause and others. While the familiar magnetic motor, with energy stored in a magnetic field, dominates electric-machines textbooks, the authors of the aforementioned text also present the dual theory, of machines with their energy stored in electric fields. Leveraging that theory, this article introduces first the more familiar magnetic machine model and works toward a circuit model of the fully electric machine.

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

### *The Magnetic Agnostic Structure (Part 3): Defining Design Requirements And Excitations*

*by Alfonso Martínez, OpenMagnetics, Madrid, Spain*

**Abstract:** We now come to the final part in this series dedicated to unambiguously describing magnetics with a common language that we have called the Magnetics Agnostic Structure (MAS). Previously, we discussed how to describe the magnetic core, wires and coil. But a magnetic is not complete without the requirements that produced it and the excitations that will make it work. In this last part, we will be describing how MAS can be used to define both of those elements of a magnetic component design.

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

## September 2023:

### *GaN HEMT Package Improves Paralleling Of Devices In Space Power Applications*

*by Tony Marini, EPC Space, Andover, Mass.*

**Abstract:** As more processing power and more complex loads are placed on-orbit or into deep space missions, it is sometime necessary to parallel two or more power switches. However, conventional power device packages, such as the FSMD-A/B/C/D and their I/O pad provisioning make it difficult to accomplish paralleling these devices in a performance-conscious manner. When paralleled, the gate and source-sense pads on these packages either serve to block the most efficient/shortest interconnect from

package-to-package for the drain and source connections or for the gate and source-sense pads. So in parallel configurations, there is always a compromise between optimized drain-source load-circuit performance and gate-source-sense drive-loop performance. This article introduces the FSMD-G discrete HEMT package and explains how the reconfiguration of its I/O pads overcomes these limitations when paralleling GaN HEMTs.

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

### *Tradeoffs In Raising The Maximum Duty Ratio In Forward And Flyback Converters*

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

**Abstract:** In single-cycle isolated power converters, such as forward and flyback, the allowable duty ratio does not usually exceed 50%. Expanding the operational duty ratio beyond the 50% mark and providing a balance of the volt-second areas of the positive and negative portions of the transformer windings' voltage waveforms would require the primary switches to operate at higher voltage levels. Recent developments in high-voltage-rated MOSFET technologies have created new opportunities for single-cycle converter designs in such modes. If usage of the stiff voltage clamping feature can be extended to higher voltage levels, it might be of interest to examine the benefits of extending the operational duty ratio beyond the 50% point. This article studies the impact of such an operating mode on power loss in the converter's active components in the most widely used forward and flyback single-ended topologies.

Notes: 9 pages, 4 figures, 2 tables. Read the full story…

### *How Twisted Bundles Reduce Eddy-Current Effects In Winding Bundle Design*

*by Dennis Feucht, Innovatia Laboratories, Cayo, Belize*

**Abstract:** The criteria for optimal winding design in SMPS transformers are maximum power transfer across windings (primary to secondary) and optimized (usually minimized) winding loss with the goal of making winding resistance optimal: $R_{wp} = R_{wpopt}$. The geometry of windings—that is, the number and size of the wires and how they are arranged within the winding window—greatly affects their eddy-current resistance. Previous articles have discussed the benefits of using twisted wire bundles for transformer windings as a means of reducing proximity effects and minimizing eddy current resistance. This article gives a more causal explanation of how twisting reduces eddy-current effects, then draws concepts from the previous articles that are applied into a working procedure that prepares us to design windings with twisted bundles.

Notes: 14 pages, 7 figures, 1 table. Read the full story…

## October 2023:

### *How To Remove Heat From A MOSFET Bridge Quickly*

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

**Abstract:** In modern electric vehicles multi-phase motors and inverters are used. At startup when the motor is still stalled, the inverter transistors' current may reach 900 A to 1000 A, which causes

instantaneous power release of up to 2.5 kW in the inverter transistors. This power (heat) should be immediately removed from the transistors and diverted either to some power absorption component or some power conducting component for further dissipation to the atmosphere or cooling system. Typically, we are talking about time intervals of up to just 5 seconds. The heat absorbing method discussed here is based on heating a massive thermally conductive pad, whose temperature rises within a safe range for a short time keeping the inverter transistors within their safe temperature range. The heat absorbing pad may then be cooled more slowly using various methods.

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

## *Essential Considerations For Soft-Start Parameter Selection In DC-DC Converters*

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

**Abstract:** Transients associated with charging of output filter components at power supply startup can overstress the PSU's power switches. That is why PSUs use a so-called soft start, which produces a gradual increase of pumped energy over time. In practice, the soft start time gets selected either arbitrarily or based on the output voltage rise specifications. Typically, soft-start time is chosen without assessing the stress on the converter's power switches caused by the inrush current in the output caps. This article attempts to quantify the rise (soft start) time needed to reduce this stress to the desired level. It also provides recommendations for the selection of the soft-start process parameters that minimize the converter components' stress at startup as well as recommendations for an "instant" converter activation in cold-redundant power delivery arrangements.

Notes: 10 pages, 6 figures. Read the full story…

## *Magnetizing Current And Transformer Design Optimization*

*by Dennis Feucht, Innovatia Laboratories, Cayo, Belize*

**Abstract:** Transformer design is often optimized by filling the winding window with windings to minimize winding loss. Magnetizing current is negligible with maximum winding inductance from maximum turns, resulting in negligible core loss from magnetizing-current ripple. These conditions usually prevail for transformer applications having high primary voltage and low current, which is high input-resistance $R_g$ design to which textbook transformer models largely apply. However, there is a trend toward low-converter-port resistance $R_g$ in digital logic, point of load (POL) and battery-sourced converters. This article is about a different category of low-$R_g$ power-transfer circuits, those with transformers, and addresses transformer design optimization for such circuits. Since magnetizing current cannot be eliminated, we can use it to optimize transformer designs through its impact on three design criteria—core utilization, power transfer, and operating frequency.

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

## *Extending The Benefits Of Remote Centralized LED Drivers From Indoor Horticulture To Commercial And Industrial Lighting*

*by Frank Cirolia, Advanced Energy, Winter Springs, Fla.*

**Abstract:** Removing the power supply or driver from the LED light fixture in indoor farming offers reductions in both capital and operating expenditures through simplified installation of the lighting systems, energy savings and improved system reliability and uptime. Locating the driver at a remote

location away from the growing area also reduces unwanted heat to the plants. The remote centralized driver approach can offer similar benefits in other commercial and industrial applications. This article begins by discussing the use of remote centralized drivers in indoor horticulture. Then it examines how the advantages of these drivers are also relevant in commercial and industrial lighting systems such as those used in box stores and factories, and other indoor and outdoor lighting applications.

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

## November 2023:

### *How Active EMI Filter ICs Reduce Common-Mode Emissions In Single- And Three-Phase Applications (Part 1): An Overview*

*by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.*

**Abstract:** In space- and weight-constrained systems such as automotive on-board chargers and aerospace power supplies, a compact and efficient design of the EMI input filter is one of the main challenges. Common-mode (CM) filters for equipment with conductive parts accessible to humans typically have limited Y-capacitance because of touch-current safety requirements, thus requiring large-sized CM chokes to achieve the requisite attenuation. This results in EMI filter designs with bulky, heavy and expensive passives. Using active EMI filter (AEF) circuits enables more-compact filter solutions. This article introduces the topic of active EMI filtering and provides practical circuit realizations using a new family of standalone AEF ICs for CM noise mitigation in single- and three-phase systems. Measured results from a 3.3-kW totem-pole power factor correction (PFC) stage will illustrate the benefits of EMI reduction and board space savings.

Notes: 11 pages, 13 figures, 1 table. Read the full story…

### *Design Considerations For High-Speed Three-Phase PMSM Motor Drives For Consumer Home Appliances*

*by Lei Han, Infineon Technologies Americas, El Segundo, Calif.*

**Abstract:** Today motor drives for applications like high-performance cordless vacuum cleaners, hair dryers and leaf blowers demand ultra-high-speed performance, often exceeding 100,000 RPM. In each case, designers are faced with a common challenge, producing a compact and lightweight product that balances the needs of battery-operation and efficiency with a low total cost for the solution. While the technical requirements seem to call for the use of wide-bandgap components, use of highly-integrated digital motor control ICs, precise gate drivers and silicon-based switches can produce a very cost-effective solution, while still meeting the performance requirements. This article will focus on three challenging areas faced by designers of high-speed motor control drives: deadtime effect and optimal deadtime selection, control-loop design optimization and accommodations for power-dip-ride-through situations that occur in high-speed operation.

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

### *Inductor Saturation Model Supports Analysis Of Inductor And Transformer Designs*

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

**Abstract:** This article offers an analytical expression for an inductor in a saturation mode. The method described and supporting plots should significantly facilitate inductor design and can also be helpful for assessment and calculation of magnetizing effects in switching transformers. The analysis is based on an analytical hysteresis loop equation and the derived dependence of magnetizing inductance on magnetizing current, which may be familiar to the readers from the reference. The novelty here is the author's description of how to use this dependence to plot the magnetizing current versus time using readily available core datasheet parameters, number of turns, and the applied voltage. This plot clearly shows when the inductor saturation begins. Knowing that, designers can change circuit parameters to avoid the saturation of the core.

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

## December 2023:

### *A Novel Lead Network Improves Performance Of Buck Controllers With Fixed Compensation*

*by Alain Laprade, onsemi, East Greenwich, R.I.*

**Abstract:** Microprocessor input voltage rails have tight regulation requirements that are subject to high-slew-rate, large-amplitude current transients. Often, the buck regulator used to generate the required supply rails is implemented using a PWM controller with internally fixed compensation. This imposes limitations on the response that can be achieved given the available capacitor options, which in turn leads to requirements for more output capacitance and the associated increase in space requirements. Or a multiphase design may be needed. This article introduces a novel voltage feedback lead-network that can be added to a discrete current-sense resistor's filter network to improve the dc-dc converter's dynamic response. Further, this improvement presents an opportunity to reduce the total output bulk filter capacitance as well as the possibility of reducing the number of output phases.

Notes: 11 pages, 19 figures, 1 table. Read the full story…

### *Supercapacitors Enable Miniature Energy Harvester ICs In Powering ULP Devices*

*by Ron Demcko, Ashley Stanziola and Daniel West, KYOCERA AVX Components, Fountain Inn, S.C.*

**Abstract:** Several individual electronic trends have come together to create low-cost, easy-to implement energy management circuits capable of total power supply control of scavenged and harvested energy supplied to small loads. These circuits can significantly extend the life of a battery powering the load or entirely replace the battery. Among the trends propelling practical, low-cost scavenged energy modules are the development of ultra-low power (ULP) ICs; the ability to create efficient ultra-low-power dc-dc converters with control logic, allowing intelligent energy measurement and management functions; and the introduction of high-capacitance storage devices in miniature sizes. This article will discuss the performance and characteristics of a scavenging/harvesting circuit in powering the equivalent of a ULP IC and document its performance using prismatic-cell supercapacitors, radial-can supercapacitors, and extended-value tantalum capacitors.

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

### *Maximizing Power-Transfer Efficiency Over A Current Range*

*by Dennis Feucht, Innovatia Laboratories, Cayo, Belize*

**Abstract:** Power-transfer circuits in converters have ranges of transformer winding current over which they are specified to operate, and within these ranges, power-transfer efficiency varies. The goal of this article is to build on power-transfer theory developed in previous How2Power Today magnetics articles to determine the optimal winding resistance that matches an efficiency curve $\eta$ to a specified current range to obtain the same minimum efficiency at the low and high extremes of current. The minimum efficiency therefore is specified for the entire current range. This optimization prevents typical low-current fall-off of efficiency by matching its minimum value to that for maximum current, thereby determining the optimal efficiency curve. This is done by selecting the optimal efficiency curve for the current range from a family $\eta$ curves.

Notes: 12 pages, 7 figures, 1 table. Read the full story…