Design Article Archive

Abstracts of articles published in the January through December 2022 issues

January 2022:

Ruggedizing Buck Converters For Space And Other High Radiation Environments

by Nazzareno (Reno) Rossetti, Alphacore, Tempe, Ariz.

Abstract: Any off-the-shelf component utilized in a space application will likely degrade and fail prematurely once exposed to the severity of the space environment. But not all is lost, as a wealth of ruggedization techniques are able to meet the challenges of this unforgiving environment. In this article, we review the effect of radiation on passive and active electronic components and the technologies, processes and device techniques that make them radiation-tolerant or radiation-hard. Subsequently we discuss Alphacore's design of a radiation-hardened dc-dc converter at the heart of a space power management and distribution system. Able to properly function at up to 200 Mrad of TID, the converter can operate within the large hadron collider at CERN, and in space satellite and probe missions.

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

Improving Solar Inverter Reliability: Techniques For Protecting Output Power Switches

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

Abstract: Ac power inverter reliability is a concern in a variety of fields ranging from utility to industrial power systems. However, this article focuses on another inverter application area—inverters used in off-grid and grid-tied, photovoltaic systems for residential rather than commercial use. The power range for such inverters ranges from several hundred watts to about 20 kW. Very little has been written regarding the most stressed devices in the inverter—that is, the output power switches and associated circuitry. Inverter output switch design is a key area that needs attention to achieve improvements in inverter failure rates. This article discusses the benefits of foldback current limiting and other techniques in protecting the MOSFETs.

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

Resonant Current Source Powers Arbitrary Load

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

Abstract: There is a little-known class of ac current sources whose operation is based on the effect of limiting ac load current in a series resonant circuit if the load is connected in parallel to the resonant capacitor. Since this circuit can be used as a good ac current source, it is safe at the load short circuit and can be used as a step-up converter for supplying loads at voltages which are not physically practical using conventional converter circuits. Step-up coefficients in the resonant circuits can attain values of 15 to 20 and higher at efficiency above 95%. Moreover, the circuit property of pushing constant ac current to the load does not depend on the load type: it works equally well into a reactive or a resistive load and even into a rectifier. This ability to supply unchangeable ac current into any type of load is a very valuable—and rarely considered—property of the resonant current source (RCS).

Notes: 10 pages, 4 figures. Read the full story…

Design Article Archive

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Developing A 25-kW SiC-Based Fast DC Charger (Part 7): Auxiliary Power Supply Units For 800-V EV Chargers

by Karol Rendek, Stefan Kosterec, Didier Balocco, Aniruddha Kolarkar, Parthiv Pandya and Will Abdeh, onsemi, Phoenix, Arizona

Abstract: In the 25-kW EV charger design presented in this series, an auxiliary PSU is used to power the controllers, drivers, communications components, and sensors of the submodules, while taking its input power directly from the dc link voltage. That's generally 400 V or 800 V based on the car maker's choice of battery. While 400-V batteries are currently dominant in the EV market, the trend is toward use of the higher-voltage, 800-V batteries. This article describes the design of an auxiliary PSU using a reference design that was developed for EV applications.

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

A Simplified Winding Design Procedure For Transformers

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: An alternative transformer winding design procedure to that given in the references is presented here that is somewhat simpler and more like procedures typically found in textbook literature. In many cases this procedure should result in a sufficiently optimized design. It is iterative, minimizes eddy-current effects, and provides turns limits from static conditions. The rationale is to achieve a desired winding resistance R_w by using the eddy-current Dowell plots in reverse. Unlike more comprehensive procedures, no distinction is made between strands in turns bundles and windings without bundled strands. The total number of strands, whether bundled or not, is calculated from Dowell plot variables, wire size, and layers without regard to bundling or its effects on eddy-current behavior.

Notes: 8 pages, 4 figures, 3 tables. Read the full story…

February 2022:

Polymer And Hybrid Styles Improve Performance And Reliability of Aluminum Electrolytic Capacitors

by Ron Demcko and Daniel West, AVX, Fountain Inn, S.C.

Abstract: Aluminum electrolytic capacitors (Al-Els) are popular in many applications because they offer high capacitance values with high RMS values at low cost, and a wide range of voltage ratings and package styles. But conventional aluminum electrolytics employing a liquid electrolyte have drawbacks such as electrolyte leakage and dryout, which hurt component reliability and limit lifetime. Wet aluminum electrolytics also exhibit higher ESR and greater variation in ESR over temperature versus other capacitor styles. However, the development of conductive polymer and hybrid aluminum electrolytics has increased reliability and alleviated performance limitations versus wet electrolytics, improving the usefulness of Al-Els. This article discusses the benefits offered by recent developments in conductive polymer and hybrid aluminum electrolytic capacitors, and illustrates their use in an example power supply application.

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

Design Article Archive

Abstracts of articles published in the January through December 2022 issues

Developing A 25-kW SiC-Based Fast DC Charger (Part 8): Thermal Management

by Karol Rendek, Stefan Kosterec, Didier Balocco, Aniruddha Kolarkar, Parthiv Pandya and Will Abdeh, onsemi, Phoenix, Arizona

Abstract: This 8th part in the series addresses the last aspect of the fast EV charger design. It focuses on thermal management of the overall design to improve efficiency, reliability and prevent premature failures in the system. First, the authors go over the various advantages of SiC MOSFET modules versus discrete SiC MOSFETs from the perspective of switching losses and thermal assembly. Second, they describe thermal management techniques and calculations used to design the cooling fan assembly and control system, and how they leveraged the internal NTC feature of the SiC power module to automatically control fan cooling in the PFC and dc-dc stages. The design of the PWM-to-voltage converter that is used to regulate fan RPM is discussed at length.

Notes: 14 pages, 19 figures, 4 tables. Read the full story…

Back To Basics: Stabilizing Your Power Factor Correction Stage

by Christophe Basso, Future Electronics, Toulouse, France

Abstract: A PFC stage becomes mandatory in Europe if the average input power of your converter exceeds 75 W. Despite a very low crossover frequency, a PFC boost converter remains a closed-loop system delivering a high-voltage output. Therefore, properly stabilizing the converter is key to achieving reliable and long-term operation. This article sheds light on how to do that with the aid of modern simulation tools. This discussion begins with a review of the popular design choices for architecture, topology, control mode and other operating techniques used in the PFC stage. It then explains the concepts used to simply model the control-to-output transfer function of this stage, which leads us to a suitable compensation scheme. Simulation of the PFC stage using SIMPLIS enables us to quickly check the performance of the compensated circuit.

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

A Simple Magnetic Design Procedure Determines Core Size

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Applying concepts from previous magnetics design articles about maximizing magnetic power density in a magnetic component, this article explains another aspect of design: how to choose the core material and core size for a magnetic component that maximizes core transfer-power density. After explaining the origins of this design procedure in a previously derived transfer power equation and its steps, the author discusses an example of its use in the design of a magnetic component—the coupled inductor for a Ćuk power-transfer circuit. For those who read last month's "A Simplified Winding Design Procedure For Transformers," this article represents a sort of "pre-quel" in that the article on winding design assumed the core had already been selected. So designers looking for a simplified approach to the overall design of a complete magnetic component may begin here.

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

March 2022:

Design Article Archive

Abstracts of articles published in the January through December 2022 issues

Correcting AC Source Distortion Enables Accurate Power Factor Measurements

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

Abstract: Ac power sources provide isolated ac voltage output, simulate a wide variety of ac line conditions, and perform accurate power measurements and analysis. These capabilities make them crucial tools for power supply validation and certification such as 80Plus, which establish requirements for both power supply efficiency and power factor (PF). However, distortion in the sinewave output produced by the ac power source can introduce errors in the PF and efficiency measurements required for such certifications. This article analyzes how this distortion interacts with the input EMI filter of the power supply under test to affect both the PF and efficiency readings, and presents two techniques for eliminating the effects of the ac power source distortion.

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

High-Temperature Capacitors Push Performance To 200°C And Beyond

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

Abstract: Capacitors are among the most widely used passive components in electronics, so naturally they find their way into many applications in harsh environments. In certain applications such as those in oil logging, jet aircraft and other industrial applications, these components are subject to extremely high temperatures, often in the range of 180°C to 300°C. For MLCCs and tantalum capacitors, the traditional 125°C limit on operating temperature for military components is problematic. In this article, we review the history of the early efforts to address the need for more-robust capacitors. We then discuss the high-temperature options available today for MLCCs and tantalum capacitors; the material systems, manufacturing processes and terminations which enable these parts; and how the different material systems affect key performance parameters.

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

Power Supply Design Considerations For Patient Monitoring Patches

by Fahad Masood, Analog Devices, Austin, Texas

Abstract: Remote patient monitors are continuously evolving to include more features that enable doctors to gain greater insights into their patients' health. These features create greater demands on the single-cell batteries that power the monitors. This article provides a power supply solution based on the MAX38640A buck regulator for an ECG remote patient monitoring patch that preserves battery life to take advantage of these features. The article also presents strategies to accurately estimate battery life for a remote patient monitor as well as ways to extend the battery life of the remote patient monitor before it is even powered on. These include use of mechanical or electronic battery seals to combat battery drain while the product is sitting on the shelf prior to first use.

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

Analysis Of Energy Storage Inductor Eases Converter Design

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

Abstract: This article is an extension of a previous work in which the author discussed misconceptions about gapped-core inductors and described a new approach to designing them. As in the earlier article, the focus here is on inductors used in converters where energy is first stored in the inductor core and then released into the load, as occurs in flybacks, boost converters and their derivatives. But here some additional theory is covered relating to effective core permeability, which is a versatile tool in selection of magnetic core size. Although this article is an extension of the existing one, it can be used on its own for a complete analysis of magnetic cores and magnetizing winding, including sizing of the core gap (if a gapped core is necessary) and determining the number of winding turns.

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

April 2022:

SEE Testing On GaN FETs—Interpreting Results For Space Power Applications

by Kiran Bernard, Renesas Electronics America, Palm Bay, Fla.

Abstract: The space and high-reliability industry have been looking at new wide-bandgap devices such as GaN and SiC in power applications. These devices provide many advantages over traditional silicon, allowing power management solutions to achieve higher efficiencies in a smaller PCB footprint. However, there is an added benefit, especially from GaN devices, that make them attractive to the space market—studies have shown that these devices are inherently radiation hard to total ionizing dose (TID). Still, their performance with respect to single event effects (SEE) requires further investigation. After going over the advantages of GaN, this article will discuss the SEE testing performed on three power GaN FET devices and the implications of these test results for use of GaN devices under practical operating conditions in low earth and geostationary orbits.

Notes: 5 pages, 2 figures, 4 tables. Read the full story…

Designing An Open-Source Power Inverter (Part 3): Power-Transfer Circuit Options

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Previous parts of this series discussed system-level goals and specifications for this design and system-level design considerations such as the impact of battery selection, output waveshape, and circuit performance parameters of interest—mainly current form factor. In this part, various candidates for the inverter's converter-stage power-transfer circuit are reviewed, the optimal circuit is chosen, and design equations are developed for it. In addition to addressing the requirements of the Volksinverter design, this discussion is also intended as a general tutorial on how to evaluate power transfer circuits for power inverter applications.

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

Wide-SOA Trench MOSFET Enables Rugged Linear-Mode Operation

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

Abstract: An advanced trench MOSFET from STMicroelectronics offers significantly improved linear-mode ruggedness, thus providing excellent performance in 48-V telecom, server, industrial and motor drive applications. This article describes some of the applications requiring a combination of linear-mode and ohmic-region performance, explaining how their requirements influence the optimization of MOSFET characteristics in the design of ST's new wide-SOA device. The characteristics of this wide-SOA trench MOSFET are compared with a standard trench MOSFET from the same family and the best competing device on the market. Finally, the linear-mode operation of the wide-SOA trench MOSFET is assessed in a telecom-type hot-swap application.

Notes: 8 pages, 13 figures. Read the full story…

A Guide To Automating Layout Of Planar Magnetic Designs

by Alfonso Martínez, Frenetic and AutoPlanar, Madrid, Spain

Abstract: Though planar magnetics have been around for years, the task of routing the windings for a planar magnetic component has largely remained a manual and tedious task. In addition to being time consuming, manual routing also entails a barrier to minor adjustments and improvements, as even minor changes imply a large or complete redesign of the PCB, which slows down product development and decreases final quality. To overcome these problems, the author developed a free online tool called AutoPlanar, which automates the process of laying out windings for a planar transformer or inductor. In this article, he explains the design rules governing AutoPlanar's operation, and walks the reader through the process of laying out a planar magnetic component using the tool's PCB Wizard and how to create a new design or edit an existing one using the feature for advanced users, the PCB Advanced Creator.

Notes: 17 pages, 31 figures. Read the full story…

May 2022:

A Guide To Power Electronics Design For Off-Battery Automotive (Part 1): EMC And Line Transient Requirements

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Given the increasing number of power electronic systems integrated within vehicle designs, it is essential to consider the complicated electrical and electromagnetic environment in which these systems operate. All vehicle OEMs and most component suppliers to the OEMs perform tests to verify the electromagnetic compatibility (EMC) of their devices. In a previous 18-part series, the author discussed requirements related to conducted emissions and radiated emissions. However, there is another area of EMC that is equally important and it encompasses three types of immunity—conducted, radiated and electrostatic discharge—which you should understand before tackling an automotive power design. In part 1 of this series, the author discusses the immunity, ESD and supply-line transient requirements associated with conventional vehicle electrical systems, both 12 V and 24 V.

Notes: 11 pages, 9 figures, 6 tables. Read the full story…

Designing An Open-Source Power Inverter (Part 4): The Optimal Power-Line Waveshape

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: What is the optimal waveshape for a power-line inverter to generate? In part 2 of this series, we began to address this question, noting the effects of inverter output waveshape on power component ratings, efficiency and its influence on the choice of the two-stage power architecture selected for this Volksinverter design. We concluded by noting that ultimately these considerations led to our selection of a third-harmonic sine wave (3HSW) for the inverter waveshape. In this part 4, we'll delve further into why that waveshape is optimal. After comparing waveshape characteristics of sine waves, square waves and third-harmonic sine waves, we'll look at some PWM switching techniques that can be applied to the H-bridge to generate these waveforms.

Notes: 6 pages, 3 figures, 1 table. Read the full story…

Adjust The Output Of An Inverting Buck-Boost Regulator Without Level Shifting

by Hrag Kasparian, Texas Instruments, Santa Clara, Calif. and David Baba, Texas Instruments, Phoenix, Ariz.

Abstract: Switching power applications sometimes require external adjustment of the output voltage setpoint. A common way to adjust the setpoint is to use a microcontroller to generate a variable voltage through either a D-A converter or an averaged PWM signal. This is straightforward when the dc control voltage, input voltage, output voltage and regulator share the same reference—typically the system ground reference (GND). But things get interesting when trying to adjust the output of an inverting buck-boost regulator, where the output voltage is negative and the regulator GND reference is not the same as the system GND. Typically, a level-shifting circuit is required, which adds several extra components. However, under certain operating conditions, the level shifter can be eliminated and a very simple voltage-adjustment scheme can be applied.

Notes: 7 pages, 5 figures, 1 table. Read the full story…

Calculating Minimum Magnetic Core Size For A Transformer

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

Abstract: In inductors the load current is the core magnetizing current, while in transformers the core magnetizing current is separate from the load current. This is why in inductors (chokes) the size-defining parameter is operating power, while in transformers the magnetizing current ripple, which may constitute 0.5% to 1% of the input ac current, determines core saturation and thus the minimum size of the core. Therefore, a transformer design needs answers to more questions on what assumptions should be made to design a transformer properly. This article is going to clarify what these assumptions are, while deriving the equations needed to determine minimum core size in a power converter application.

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

June 2022:

Slammers And Software Verify Performance Of Advanced Voltage Regulators

by David Baretich, ProGrAnalog, Portland, Oreg.

Abstract: Voltage regulators must meet increasingly stringent supply requirements. Peak load currents of several hundred amperes are common, and transient load steps can be a high percentage of full load current. Test equipment designed to exercise and verify these regulators has previously existed only in the realm of custom testers for vendor-specific ICs. This article looks at the utilization of load slammers, a class of off-the-shelf voltage regulator test devices from ProGrAnalog—and sometimes constructed by engineers for in-house use—as a test utility for high-performance transient load testing. Mainly the focus here will be on how to configure the LoadSlammer's GUI to perform a variety of transient, pulse train and impedance tests. Example test results are presented and analyzed with attention given to the various features of the GUI that aid our analysis.

Notes: 10 pages, 11 figures. Read the full story…

A Guide To Power Electronics Design For Off-Battery Automotive (Part 2): DC-DC Conversion From 12 V

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: In this second installment, the author presents a voltage regulator design that demonstrates how the immunity requirements explained in part 1 can be met in practice and verified. He walks through several steps within the context of a power circuit development flow for an automotive application. The steps include creating a list of circuit specifications to meet the application requirements; compiling a schematic and bill of materials; using a calculation or simulation tool to optimize and fine-tune the design; selecting components to achieve low power loss; optimizing board layout to meet electromagnetic interference (EMI) and thermal management constraints; and finally, conducting functional validation and performance testing of the final design. By way of example, the author delves into an implementation that powers an electronic control module (ECU) with a maximum load current requirement of 15 A.

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

Advanced PMICs Can Flatten The Processor Power Curve For Data Centers

by Trey Roessig, Empower Semiconductor, San Jose, Calif.

Abstract: With data center operators under pressure to keep energy consumption and costs to a minimum, they are looking for the most efficient ways to address increased power demands and to break the linear relationship between increased processor power and increased rack power. This article looks at the factors driving increased rack powers and the importance of voltage regulator transient response and dynamic voltage scaling (DVS) in maximizing server energy efficiency. It then introduces a PMIC technology that can significantly reduce the overall power consumption needed to drive next-generation processors. This technology, which is implemented in Empower Semiconductor's IVR family of devices, reduces the usual tradeoff of efficiency for higher switching frequency, enabling development of highly compact and very fast voltage regulators.

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

July 2022:

IC Simplifies Analog Control Of The Totem-Pole PFC Stage

by Christophe Basso, Future Electronics, Toulouse, France

Abstract: Although conceived over 25 years ago to regain the precious percent of efficiency lost in the front-end bridge of high-power pre-converters, the totem-pole power factor correction (TPFFC) circuit did not become practical until the introduction of wide-bandgap semiconductors—the SiC and GaN power switches. Since these devices became widely available, TPPFC solutions have become popular and are currently implemented using digital control carried out by a microcontroller. However, analog solutions are now emerging, such as the NCP1680 from onsemi which brings a fully integrated product for operating a borderline conduction mode (BCM) TPPFC. This circuit lends itself well to powering converters up to a level of 300 W for a universal mains application, while incorporating the benefits of higher efficiency and increased power density which the TPPFC supports.

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

Designing An Open-Source Power Inverter (Part 5): Kilowatt Inverter Circuit Design

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: This series has introduced the design objectives, considerations and a proposed circuit architecture for an open-source power inverter dubbed the Volksinverter. It has also analyzed key design choices such as output waveshape selection, and explored variations on the proposed two-stage inverter architecture. Here in the latest installment, the article delves further into the design of the inverter output stage by presenting a detailed circuit implementation capable of delivering 1.2 kW of output power. This part 5 specifically explains the design and operation of the gate-drivers, ground fault protection and current sensing and overprotection.

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

Electrothermal Models Predict Power MOSFET Performance More Accurately

by Andy Berry, Nexperia, Manchester, U.K.

Abstract: One of the biggest challenges facing engineers when designing with discrete power MOSFETs is the fact standard simulation models provided by many manufacturers are limited in how well they emulate real-world performance. For example, most standard models can only be used to simulate how a discrete device will behave at a nominal temperature (typically 25°C). In addition, they neglect important device parameters that could provide insight into the electromagnetic compatibility (EMC) performance of a circuit. In this article we explore the limitations of standard models for power MOSFETs by simulating a simple half-bridge circuit typically used in a range of motor control applications. We then demonstrate the improved accuracy that can be obtained by performing the same simulation using an advanced electrothermal model developed by Nexperia.

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

Transformer Design Pitfalls: Stepup Is Not As Easy As Stepdown

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

Abstract: When designing transformers, engineers often forget that they not only transform one voltage into another but also transform impedance. The apparent input impedance has a component that is the secondary impedance divided by the squared transformation coefficient. This causes certain problems with power transfer at high frequency by means of a stepup transformer. In particular, these problems relate to the impact of the turns ratio and other factors on the input circuit time constant. In

this article, we will analyze the relationship between these parameters and demonstrate this relationship with a design example.

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

August 2022:

Stepdown Voltage Regulator With Reduced Input Current Ripple

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

Abstract: In the early days when switched-mode techniques were first being adopted, a noteworthy buck converter topology was introduced by Alfred Leifer in the form of a class D modulator of a high-frequency transmitter. The topology used in this application has several advantages over the conventional buck regulator that is so common nowadays. One of the most valuable benefits of the mentioned technique is that it provides continuous current at the converter input. This feature enables minimization of the filtering cap value and elimination of the filtering inductor without affecting the converter's transient performance. This article examines the operation of this converter in more detail and studies an opportunity for adopting such a regulator technique if a suitable controller IC were to be made available.

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

Designing An Open-Source Power Inverter (Part 6): Kilowatt Inverter Control Circuits

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In the most recent installment of this series, the design of the inverter output stage for a 1.2-kW output was explained. That part 5 focused on the gate drivers and protection circuitry. Here in part 6, discussion of the inverter stage design continues as the control circuits driving the power-transfer circuit are described. The control circuit diagram for the inverter stage is shown in the figure. Its three functions are generation of the third-harmonic sine-wave (3HSW), fault protection (in conjunction with the circuitry described in part 5), and synchronization with an existing output waveform.

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

Automotive MOSFETs Enhance Performance Of Power Distribution Systems

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

Abstract: The growing demand for higher-power electronic control units (ECUs) is driving system designers to develop dedicated power distribution solutions. Replacing traditional fuses with solid-state switches can protect the final load from overcurrent in fault conditions and avoid fire events. For traditional automotive architectures powered by a 12-V lead-acid battery, the solid-state protection has to withstand both high energy discharge and high continuous current flow. STMicroelectronics' new STPOWER STripFET F8 40-V series is well suited to the stringent requirements of solid-state high-current electronic fuse (eFuse) solutions with its sub-milliohm on-resistance AEC-Q101-qualified MOSFET. This article discusses the performance of the first member of this series, the STL325N4LF8AG MOSFET, when used as an Efuse in a smart automotive power distribution system.

Notes: 13 pages, 18 figures, 4 tables. Read the full story…

Transformer Design Pitfalls (Part 2): Demonstrating Stepup Difficulties

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

Abstract: In part 1 of this article an analysis of the transformer turns ratio on input impedance and the associated input time constant revealed that the turns ratio in stepup transformers has a significant impact on these two transformer input parameters. In this follow-up article, we'll show another effect of the turns ratio in loading a transformer's driver circuitry. In this case, we'll examine the impact in a popular emerging application—battery chargers in electric vehicles. An LTspice simulation of a stepup transformer similar to one that might be used in this application demonstrates the difficulty.

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

September 2022:

Inverter With Modified PLL Control Transitions Seamlessly Between On-And Off-Grid Operation

by Basil Issac, Eram Power Electronics, Bangalore, India

Abstract: The phase, amplitude and frequency of the utility grid are critical information for the operation of grid-connected inverters. In such applications, an accurate and fast detection of the phase angle of the utility voltage is essential to assure correct generation of the reference signals for synchronizing operation of the inverters with the grid. Another key element in these applications is the phase-locked loop (PLL) structure. In a grid-connected system, the purpose of the PLL is to synchronize the inverter voltage phase angle with the angle of the grid voltage, in order to obtain zero phase shift and frequency difference between the grid voltage and the inverter. In this article, an enhanced PLL-based control technique for a grid-connected inverter is introduced and simulated using MATLAB software.

Notes: 13 pages, 21 figures. Read the full story…

Designing An Open-Source Power Inverter (Part 7): Kilowatt Inverter Magnetics

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: The last two parts of this series described the design of circuitry for the inverter stage (INV401) of the 1.2-kW Volksinverter design. This part shows how to design the output inductor for this stage. Specifically, it is a coupled inductor having two identical windings, and forms an LC filter with an output capacitor. This coupled inductor rejects noise and prevents overcurrent of the output waveform. This design begins with a set of min and max constraints on the range of inductance values for this component. From there a saturation model derived by the author enables us to identify the most suitable core material based on cost and size. Core material selection then leads to details of core size selection and winding design including number of turns, wire size and wire bundling, number of layers and wire length.

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

Roshen's Models Offer An Advanced Approach To Modeling Core Losses

by Alfonso Martínez, AutoPlanar, Madrid, Spain

Abstract: Because of the vicissitudes of my professional life, I have ended up in a curious position where my duties include finding, understanding, implementing, and comparing models for magnetic components. And along this path I came across the work of Waseem Roshen. What did he model, you may wonder? Core losses like Steinmetz? Winding losses like Dowell? Well, both, which made it really easy for me to admire him. Since this article was intended to be about core losses, we will save his work on winding losses for another occasion and focus here on explaining how Roshen models the three sources of core losses—hysteresis, classical eddy current and excess eddy current losses. We'll also discuss how these models compare with Steinmetz-derived models.

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

October 2022:

Assessing Cooling System Efficiency

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

Abstract: A correctly designed cooling system plays a very important role in high-power equipment like electric vehicles (EVs) where the cooling system removes heat from the power components. The cooling system usually consists of a locked pipeline built into the metallic body of the device being cooled, and liquid coolant that circulates in the pipeline, delivering hot coolant to the external heat exchanger (heat sink). It is very important to keep the cooling system efficiency high to ensure the heat transfer at any stage occurs at the maximum possible rate. This efficiency depends on achieving both the required coolant speed and coolant flow turbulence in the pipe. The level of turbulence can be evaluated using the Reynolds number. In this article, the author derives an expression for coolant velocity, which can then be applied to calculate the Reynolds number and assess the efficiency of a cooling system design.

Notes: 3 pages. Read the full story…

A Guide To Power Electronics Design For Off-Battery Automotive (Part 3): DC-DC Conversion From 48 V

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: With the growing power requirements of advanced automotive systems and the conversion of mechanical components to electrical functions in order to reduce weight, the traditional 12-V lead-acid battery architecture has reached its usable power limit of approximately 3 kW. To address these challenges, automakers have commercialized a dual-voltage electrical system that combines a smaller-sized 12-V battery with a 48-V Li-ion battery pack that runs high-power loads while also enabling implementation of an integrated starter-generator (ISG), which is the key element of a mild hybrid electric vehicle (MHEV). This article charts several steps in the design of a dc-dc energy-management system for an MHEV, examining a bidirectional current regulator that enables energy exchange between the low- and medium-voltage domains.

Notes: 12 pages, 12 figures, 3 tables. Read the full story…

Radiation-Tolerant Power Electronic Systems Are Hard To Design

by Ken Coffman and Salah Ben Doua, Vicor, Andover, Mass.

Abstract: Electronic systems in space are exposed to many hazards. Among other things, without the Earth's protective magnetic field deflecting particles and our atmospheric blanket absorbing solar and cosmic rays, systems are exposed to greater levels of wave and particle radiation. This article explores these issues as they relate specifically to the design of space power systems. The focus here is narrowed even further to those "new space" applications where "radiation tolerant" components and circuitry are required rather than the more robust "radiation hardened" devices and circuits. While semiconductor device selection is at the heart of developing rad-tolerant power systems, it is just one of many design strategies that can be deployed at the component and circuit levels. This article discusses the basic strategies as well as the benefits of soft switching in rad-tolerant power systems.

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

Using Current Transformer In Core Saturating Mode Enables DC Current Measurements

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

Abstract: Current transformers (CTs) in which the primary and secondary windings are not electrically connected are among the most effective isolated current sensors and can measure up to thousands of amperes. Besides providing immunity to common-mode noise and low power dissipation, a CT does not require the usage of separate converters supplying isolated dc voltage to power up the sensor input circuitry. Normally, CT-based current sensors are only intended for monitoring of ac or pulsing currents with zero minimum levels. However, utilizing the transformer's saturation mode and a special technique for detection of the dc component can expand CT-based sensor usage to enable dc current monitoring, for example, in dc output power supplies or dc PDN applications. This article studies an opportunity for adopting such a technique and presents design considerations for CT-based dc current monitoring.

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

November 2022:

A Guide To Power Electronics Design For Off-Battery Automotive (Part 4): DC-DC Conversion From 400 V

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: At the heart of every battery electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV) are several power electronics subsystems: a traction inverter, onboard charger, dc-dc converter and battery management system. Two voltage domains exist, based on a high-voltage battery pack for traction and a low-voltage auxiliary battery to supply legacy vehicle loads such as body electronics, lighting and infotainment. Whereas an ICE vehicle uses a belt-driven alternator to charge the low-voltage battery, a BEV or PHEV uses an auxiliary power module (APM) for dc-dc conversion between the high-voltage battery pack and the low-voltage battery. This traction-to-auxiliary (T2A) dc-dc converter operates continuously during vehicle use and behaves effectively as an "electric alternator," with power levels up to 5 kW. This article charts several steps within the context of designing a dc-dc power stage with a high conversion ratio for an APM subsystem.

Notes: 14 pages, 9 figures, 5 tables. Read the full story…

Designing An Open-Source Power Inverter (Part 8): Converter Control Power Supply

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Having delved into the design of the inverter stage circuitry and its magnetics in recent installments in this series, this article now turns its attention to another stage of the Volksinverter—the converter control power supply. As a converter controller, the BCV401 has its own 24-V-input switching supply that outputs +12 V to control circuits. The control power supply is a minimal-parts switching converter using generic components. The operation of this switching power supply will be described in the first section of this article and a prototype will be presented. This converter uses hysteretic control, primarily in continuous conduction mode except at very light loading. In the second half of this article, hysteretic control will be explained and design equations will be given as well as measured waveforms confirming the expected operation of the converter.

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

Why Phase-Shift Converters Are More Accurate Than PWM Converters

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

Abstract: PWM and phase-shift power converters are being widely used for medium- and high-power applications. The dc output of these converters is obtained from a filtered rectangular pulse train. Ideally, the converter feedback control system that regulates the output voltage derives the average value of the pulse train and keeps it proportional to the internal or external reference voltage. Typically the converter output should follow the reference voltage very accurately over a wide range of the duty cycle to achieve high stability over a wide voltage range, requiring strict proportionality of the output voltage to the duty cycle. However, this tight relationship between duty cycle and output voltage is not maintained if —in addition to the pulse train—there is some extra voltage filling the gap between pulses. Such is the case with PWM converters.

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

Popular Magnetic Cores And Wires: Their Properties, Accessories And Tables

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Magnetic components such as inductors and transformers are usually designed for a specific application. However, certain applications of these components are sufficiently popular that they are offered as standard products. More commonly, though, magnetic components are custom-designed, resulting in thousands of magnetic parts variations designed from more basic components: cores and conductors (wire). Although core and wire components also have multiple variations, the number of them is manageable for stocking the inventory of a power-electronics laboratory or prototyping facility. This article describes how the Innovatia laboratory is stocked as an example of how relatively few cores and wire sizes can suffice for a wide range of typical magnetics designs. What not to stock (much of) is also recommended.

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

December 2022:

Design Article Archive

Abstracts of articles published in the January through December 2022 issues

Designing An Open-Source Power Inverter (Part 9): Magnetics For The Converter Control Power Supply

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: As we continue exploration of the Volksinverter design, we pick up the discussion of the converter control power supply started in part 8. Located on the converter controller board, BCV401, this switching power supply uses hysteretic control to step down the 24-V source to 12-V for powering the control circuits. This part 9 reviews the design of the inductor for this power supply. The inductor design is not performance-driven, and this greatly simplifies the design, given here in a step-by-step template form so that both switching converter and inductor design can be applied more generally in other projects.

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

Getting The Most From The Improved Howland Current Pump: Output Impedance

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

Abstract: The improved Howland current pump has been the subject of many papers and articles, with the majority of them discussing stability and the circuit techniques for providing stability. However, few articles discuss how to get the best accuracy and performance and usually recommend careful matching of the gain setting resistors with little further elaboration. Most often these recommendations are intended to provide the best gain accuracy, but in high-performance applications the improved Howland has another important performance parameter: output impedance. Little has been published regarding achieving maximum possible output impedance for performance improvement as a pure current source. That objective will be the focus of this article.

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