Design Article Archive

Abstracts of articles published in the January through May 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…

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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…

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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 May 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…