

January 2024:

Prismatic-Cell Supercapacitors Enable Thinner Boost Circuits

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

Abstract: Continued advances in ultra-low power (ULP) ICs and the demand for smaller-size portable electronics have combined to create an opportunity for small, thin supercapacitors. Supercapacitors can help achieve extended battery life by supplementing peak power delivery from primary and secondary batteries. Moreover, depending upon the power budget, supercapacitors can even eliminate batteries altogether in some applications. When charged by an energy harvesting source, supercaps by themselves can power some circuits, enabling a near limitless number of charge and discharge cycles. Prismatic-cell supercapacitors offer an additional advantage as they reduce the height of the supercap versus what would normally be required with a conventional device packaged in a radial can. The PrizmaCap series supercapacitors can maximize this benefit as they offer the highest energy density of any prismatic electrochemical double layer capacitor.

Notes: 8 pages, 5 figures, 1 table.

Read the full story...

Laplace Transform Simplifies Analysis Of Realistic SMPS Waveforms

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

Abstract: When making calculations with the rectangular waveforms present in switched-mode power supplies, designers try to avoid the difficulties associated with the real shape of these pulses. They ignore that these pulses are not actually *rectangular* as in the ideal case, but rather *trapezoidal*. Unfortunately, replacement of trapezoidal pulses with the ideal rectangular ones may adversely affect assessment of power loss since overlapping of turn-on and turn-off times of, for example, transistors in the same column of the bridge, is the main source of dynamic power loss. While there are "artificial" methods of including the on and off times in the analysis, these may produce false results or be very cumbersome. A simpler alternative method for performing analysis of realistic SMPS waveforms uses the Laplace transform, taking advantage of a previously published formula that represents a series of trapezoidal pulses.

Notes: 6 pages, 6 figures.

Read the full story ...

Improving Durability Of Wire Bonds In EV Batteries

by Dodgie Calpito, Tanaka Kikinzoku International, San Jose, Calif.; and Shuichi Mitoma, Shizu Matsunaga, Kosuke Ono, and Tsukasa Ichikawa, Tanaka Denshi Kogyo, Tokyo, Japan

Abstract: Wire bonds are delicate with limited flexibility, and in semiconductors, they are usually encapsulated by buffer materials such as resin or mold compounds. These materials give them a measure of durability and strength to resist damage from vibration. But that measure of durability is lost in open-air applications in the majority of EV battery packs where there is no material to protect the wire bonds from the effects of vibration, leaving the wire bonds vulnerable to breakage. In this article, we look at ultrasonic wire bonding as it is used for the interconnection of cylindrical lithium-ion (Li-ion) cells in EV battery packs. Specifically, we present a series of vibration tests that were conducted on wire bonds used in EV battery packs to determine the degree to which different aspects of wire bond design affect their susceptibility to breakage.



Design Article Archive

Abstracts of articles published in the January through December 2024 issues

Notes: 8 pages, 11 figures, 3 tables.

Read the full story ...

Inductor Turns For Maximum Energy Transfer With Core Saturation

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In a previous article, an asymptotic semi-log model of core saturation was presented. It has three regions of core operation: unsaturated ($H < H_0$), saturated ($H_0 \le H < H_T$), and fully-saturated ($H \ge H_T$). Power inductors are operated in the saturated region because it is in this region that maximum energy or flux can be stored. This article applies the asymptotic core saturation model to the main magnetics design goal of maximizing energy density in the core for power transfer. This basic performance goal optimizes inductor turns. To do this, we must determine the value of k_{sat} and H (representing average current) in the core saturation model where core transfer-energy density is maximized to achieve maximum power transfer in a power converter for a given core size. Since circuit design parameters determine average current and can affect the minimum allowable k_{sat} , the finding of the optimum k_{sat} may lead the designer to select a larger or smaller core.

Notes: 7 pages, 2 figures.

Read the full story...

February 2024:

How Active EMI Filter ICs Reduce Common-Mode Emissions in Single- And Three-Phase Applications (Part 2): Modeling Ferrite Chokes

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Part 1 of this article series included an overview of active EMI filter (AEF) techniques to diminish the reliance on bulky passive filter components. An AEF circuit can significantly reduce magnetic component and overall filter size versus an equivalent passive filter, enabling higher-density filter designs for size-constrained applications. However, accurate characterization and modeling of the choke impedance is an essential step and of paramount importance in EMI filter design, as the choke impedance directly impacts filter attenuation performance (as well as loop stability in active designs). Following a review of the impedance behavior of ferrite-cored magnetic components, this article describes a SPICE-compatible behavioral model for a ferrite choke using an intuitive circuit structure. This model facilitates easy and accurate system-level EMI simulations in the time and frequency domains for both passive and active filter designs.

Notes: 16 pages, 15 figures, 3 tables.

Read the full story ...

CMOS Buffers Support Cold Sparing For Space ICs Without The Usual Power Penalty

by Mark Hamlyn, Kyle Schulmeyer, Anton Quiroz and Abhijeet Ghoshal, Apogee Semiconductor, Plano, Texas

Abstract: Satellites are designed with duplicate systems or components for critical functions. Where redundant components are used, the back-up systems are powered-off or "cold spared" when not in use. Cold-spare components are electrically isolated from the primary system in operation via separate power supplies. However, the presence of ESD clamping diodes in standard CMOS input and



output buffers creates difficulties in cold-sparing of logic circuits as the diodes create unwanted paths of current conduction via the cold-sparing power supply, wasting power. To address these issues, system designers may add isolation circuitry but that also increases system complexity. With these challenges in mind, Apogee Semiconductor has developed proprietary I/O structures that enable coldsparing without the power penalty associated with use of COTS-based CMOS ICs, while also avoiding the drawbacks of isolation circuitry.

Notes: 6 pages, 5 figures, 1 table.

Read the full story...

Load-Adaptive PSU Can Benefit Server Systems With Reduced Idle Power

by Viktor Vogman, Olympia, Wash.

Abstract: To promote the energy efficiency of server platforms under light loading conditions, the 80Plus program was established to certify computer and server system power supply units that at high cert levels have more than 80% energy efficiency even at 10% of rated loads. However, for systems with lower idle power consumption and PSUs with lower 80 Plus certification levels, there is still an opportunity for improvements. Such opportunity is associated with the use of a load-adaptive PSU architecture that can boost PSU efficiency at such power levels, bring additional energy savings, and be a better choice for such cases. This article studies an opportunity to use such an approach for server power supplies whose efficiency highly depends on the consumed power level.

Notes: 8 pages, 4 figures.

Read the full story ...

Optimizing Winding Design For Low-Resistance Windings—Selecting Wire Or Bundle Size To Fill The Core Window

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: One of the main goals of winding design is to maximize current density in the core window. Then inductor transfer power—energy storage per cycle—is maximized as is converter power density. For transformers, a full window also transfers maximum power. Thus the goal is to put as much conductive area in wire into the window area as possible. This article analyzes how to optimize winding geometry when wire size is large and turns are few—through the selection of wire size, number of layers, and bundle size—to achieve this goal of maximizing conductor area within a given core window. By manipulating the wire and winding parameters, we are able to maximize the window boundary packing factor, a concept that brings us to maximum conductive area.

Notes: 4 pages, 2 figures.

Read the full story...

March 2024:

Designing An Open-Source Power Inverter (Part 15): Transformer Magnetic Design For the Battery Converter

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: This and the next two parts of the Volksinverter design series present an example procedure—a design template—for optimizing the design of converter transformers for boost push-pull



power-transfer circuits. Optimizations include core selection, maximized primary-to-secondary power transfer, optimal winding area allocation, and minimized winding loss. The template is based heavily on previous derivations in other magnetics and Volksinverter series articles published in How2Power Today. Magnetic design, which is the focus of this part, concerns determination of core material and size. The magnetic design is first because a core is needed to determine the parameters of the windings. Winding area allocation is considered under magnetic design because it affects *winding turns* N_p . N_p is an output parameter of magnetic (core) design and an important input to electrical (winding) design. Core choice is affected by winding currents and voltages from the circuit design.

Notes: 11 pages, 4 figures, 2 tables.

Read the full story ...

The Laplace Transform Applies To Nonlinear, Time-Variant Functions Too

by Gregory Mirsky, Design Engineer, Deer Park, Ill

Abstract: In previous articles, the dependence of inductance on time was analyzed using the Laplace transform for simplicity within MathCAD-15. The results were reasonable and caused no problems with the integrals' convergence. However, some readers objected to my methodology, arguing that the Laplace transform is usable only for linear time-invariant systems. To address this concern, in this article I will give some examples that confirm the validity of the Laplace transform for solving equations having time-variant parameters of power electronics components. It is worth recalling that time-variant functions or parameters are those whose values change within the time of the process. The most evident example is the amplitude-modulated signal, which we will review below. It is necessary to emphasize that this method holds true even if the function in question is nonlinear.

Notes: 7 pages, 4 figures.

Read the full story ...

Read the full story...

How Active EMI Filter ICs Reduce Common-Mode Emissions In Single- And Three-Phase Applications (Part 3): Modeling Nanocrystalline Chokes

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Part 1 of this article series provided an overview of active EMI filter (AEF) techniques to diminish the reliance on bulky passive filter components. Part 2 discussed impedance characterization for a ferrite choke over a required frequency range using a behavioral model, which is an essential step and of paramount importance in EMI filter design, as the choke impedance directly impacts filter attenuation performance (as well as loop stability in active designs). More challenging to model than ferrite, however, is a choke with nanocrystalline core material, given its frequency-dependent and nonlinear magnetic permeability. It is for this reason that this article examines comprehensive simulation models for nanocrystalline-cored chokes, with the objective to design and use these magnetic components in both passive and active filter circuits.

Notes: 11 pages, 10 figures.

Why Is Cooling So Important For Magnetics?

by Jim Marinos, Payton America, Deerfield Beach, Fla.

Abstract: Cooling is crucial for magnetics and electronic components in general because it directly impacts their reliability and lifespan. In this article, we'll discuss the mean time between failure



(MTBF) calculation, which is a key metric in assessing the reliability of electronic components, and explain how it can be applied to a magnetic component. The mil standard MIL-HDBK-217F has been used for decades to calculate MTBF for different environments. For this example, I will use the Ground, Mobile (GM) environment for demonstration purposes.

Notes: 2 pages, 1 figure.

Read the full story ...

April 2024:

A Guide To Designing Your Own Rogowski Sensor (Part 1)

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

Abstract: Current measurement is a common requirement in many power converter and inverter designs. Traction inverters are just one example. Rogowski sensors are an interesting option in this case as they have a very wide current range, very high accuracy (up to 0.1%), and are non-saturating. On the down side, they are very expensive, costing as much as \$3000 for an instrument-grade sensor. However, in cases such as a traction inverter, the full accuracy of an off-the shelf Rogowski coil sensor may not be needed. In this case, it may be possible to design and build a lower-cost sensor that retains most of the benefits of this current-measuring sensor. The formulas defining the operation of the Rogowski coil will be derived here in part 1.

Notes: 8 pages, 5 figures.

Read the full story...

Quantifying The Impact Of Series Inductance On E-Load Edge Rates And Current Monitoring Accuracy

by Viktor Vogman, Olympia, Wash.

Abstract: Testing the transient performance of CPU voltage regulators (VRs) has become a challenge due to the increased current slew rates and load step sizes. Modern AI processor chips, CPUs, and FPGAs can now draw peak currents over 400 A with greater than 100-A transients at slew rates exceeding 1000 A/µs. Given these requirements, there are different obstacles when using conventional test instruments to perform transient testing on the VRs. Depending on your requirements, you may choose to use an off-the-shelf e-load to test your VR, or build your own e-load. In either case, it is advisable to quantify the impact of the parasitic series inductance in the current path on the current edge and determine the acceptable value of this inductance that provides the required e-load performance. This article explains how to do that.

Notes: 8 pages, 5 figures.

Read the full story...

Liquid Immersion Cooling For Higher Power Density In Server Power Supplies

by Sam Abdel-Rahman and Ashish Ekbote, Infineon Technologies, El Segundo, Calif.

Abstract: The scaling of cloud-based Internet services and AI have driven significant growth of processing power in data centers. At the same time, the TCO for data centers is rising, increasing demand for highly efficient, reliable, and compact server systems. Moreover, edge servers are being



deployed closer to population centers, where energy and real estate costs are higher. Fan cooling in server switch mode power supply racks is limited by thermal capacity due to poor heat exchange through air. In contrast, liquid cooling is a much more effective method to exchange the racks' heat outside the data center without wasting a significant share of the energy on cooling. This article presents the findings from a recent study that validates the potential benefits of immersion cooling for a server SMPS.

Notes: 7 pages, 8 figures.

Read the full story...

Designing An Open-Source Power Inverter (Part 16): Transformer Winding Design For the Battery Converter—Efficiency Range And Winding Allotment

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: As this Volksinverter design series moves forward, we continue the presentation of the transformer design procedure for boost push-pull (BPP) power-transfer circuits. While the recent part 15 of this series discussed core selection, this part addresses another aspect of the magnetics design—winding area allocation. This represents the first part of the electrical (winding) design. The criteria for winding design are maximum power transfer across windings (primary to secondary) over a specified current range, optimal winding loss, and spatially uniform loss distribution. The discussion in this part determines the electrical parameters of the windings that will produce maximum power transfer, given the core selection and the circuit's operating conditions. The formulas derived here will allow us to determine wire sizes and winding configurations in the next part.

Notes: 10 pages, 6 figures, 1 table.

Read the full story...

May 2024:

Characterizing Dynamic Coss Losses In 600-V GaN HEMTs

by Stefano de Filippis and Matthias J. Kasper, Infineon Technologies Austria, Villach, Austria

Abstract: Every time a power device is switched, its output parasitic capacitance Coss incurs a loss because it is charged and discharged. Coss losses, then, are proportional to switching frequency. Because GaN enables higher-frequency operation, Coss is more of a consideration for GaN power HEMTs than MOSFETs made from other materials. However, Coss losses are not easy to characterize and the industry still lacks a solid understanding of the underlying physics mechanism. This article will explore different methods for characterizing Coss losses—nonlinear resonance, Sawyer-Tower, and calorimetric. After explaining the advantages of the calorimetric characterization method, it will present a novel addition to this method that simplifies setup calibration and speeds Coss loss characterization by eliminating the need to wait until the thermal system has reached thermal equilibrium.

Notes: 6 pages, 6 figures.

Read the full story...

A Guide To Designing Your Own Rogowski Sensor (Part 2)

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



Abstract: In part 1 we learned that a response to the trapezoidal current of a Rogowski coil is essentially a derivative of the measured current waveform. To restore the current waveform, we have to integrate the coil's output voltage. Analytical expressions for these waveforms were derived in part 1 and as noted in that article, we have to push the exponential pulse through an integrator to obtain the expected rectangular output. In this second part of the article, we'll derive the integrator's transfer function and then show how this is used to select the integrator's key components.

Notes: 6 pages, 6 figures.

Read the full story...

Designing An Open-Source Power Inverter (Part 17): Transformer Winding Design For the Battery Converter—Alternative Configurations

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: This latest installment in the Volksinverter design series takes the winding design procedure and formulas from part 16 and applies them to winding configurations in search of the optimal winding plan. The winding sequence is primary first (onto the center-leg of the core), secondary last (exposed to ambient). In general, all windings of the input current polarity are primary and all windings of opposing output currents are similarly lumped together as the secondary winding(s). The Volksinverter has two identical primary windings and only one secondary winding. In part 16 the winding geometric configuration (sequential) and allotment of winding areas in the window were determined, and given the turns, the maximum bundle sizes were determined. But we also need to consider eddy-current resistance ratios in winding design plans, which we'll do here. With large bundle radius, winding aspect ratio becomes a significant geometric parameter affecting winding design. Consequently, we'll examine the wire size fit for the given winding area dimensions.

Notes: 20 pages, 7 figures, 2 tables.

Read the full story...

June 2024:

How Active EMI Filter ICs Reduce Common-Mode Emissions In Single- And Three-Phase Applications (Part 4): Loop-Gain Analysis

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Part 1 of this article series provided an overview of active EMI filter (AEF) techniques to diminish the reliance on bulky passive filter components. Parts 2 and 3 discussed behavioral models to characterize the impedance of ferrite and nanocrystalline chokes, respectively. Deriving a choke model is an essential step and of significant importance in EMI filter designs, as the choke impedance directly impacts filter attenuation as well as stability performance in active designs. To this end, the fourth installment of this series examines small-signal stability by deriving loop-gain expressions for a feedback-type, voltage-sense current-inject (FB-VSCI) AEF circuit implemented using an IC. To validate the proposed analytical approach, the article concludes with simulations and experimental measurements applied to a three-phase EMI filter suitable for an automotive onboard charger (OBC) application.

Notes: 13 pages, 13 figures.

Read the full story...



A Guide To Designing Your Own Rogowski Sensor (Part 3)

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

Abstract: In parts 1 and 2 we discussed designs of the Rogowski coil and integrator. In part 3 we are going to check how the coil and integrator work together as the complete Rogowski sensor through simulation of the previously derived sensor schematic. To verify the sensor's accuracy, these simulations are carried out for current waveforms over a range of duty cycles and frequencies with different waveshapes and both unipolar and bipolar currents.

Notes: 4 pages, 9 figures.

Read the full story ...

The Laplace Transform Is Not Generally Applicable To Functions That Are Nonlinear Or Time Variant

Abstract: In the November 2023 issue of How2Power Today, Gregory Mirsky discussed the application of the Laplace transform to predict saturation in inductors. As some readers took issue with his methodology, Gregory responded with an article titled, "The Laplace Transform Applies To Nonlinear, Time-Variant Functions Too," in which he provided some non-power electronics examples to demonstrate the message in the title. In response to this latest article, readers Dan Simon and Dennis Feucht submitted the following letter

Notes: 4 pages.

Read the full story ...

July 2024:

Resonant Gate Drive Enhances Robustness Of GaN Power Stages

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

Abstract: Resonance driving of silicon-based power devices has been extensively researched. The use of resonance to save power has been a main focus of this research. In this article, we will show an additional use of resonance—to enhance robustness of circuit operation in GaN power stages. We'll also demonstrate how the uP1964 GaN driver is well suited to such applications. The uP1964 is a single-channel GaN driver with performance aspects that help solve common issues with high-voltage and low-voltage GaN devices. The uP1964 can be used with lossy ferrite beads in a resonant-gate-drive topology to minimize problems with gate oscillations, improve cross-conduction immunity in half-bridge topologies, and make drive circuit PCB layouts less critical.

Notes: 16 pages, 23 figures, z tables

Read the full story ...

Using Single-Phase Online Design Calculator To Analyze Stability Of Interleaved Power Stage Designs

by David Baba, Texas Instruments, Chandler, Ariz.

Abstract: Single-output multiphase converter topologies can achieve higher output currents while



managing thermal performance. However, the stability analysis of stacking multiple converter phases presents a more difficult challenge than that of a single-phase converter. That's because online design calculators such as Texas Instruments' Power Stage Designer and those associated with specific controllers, which generate Bode plots for assessing converter stability, are typically designed to work with single-phase power stages. Consequently, the power supply designer must run simulations to determine loop response, and these simulations take more time. In this article, the author describes how to take a single-output multiphase design and modify it to a single-output, single-phase equivalent circuit, allowing loop stability to be analyzed using a single-phase online design calculator.

Notes: 6 pages, 6 figures.

Read the full story...

Designing An Open-Source Power Inverter (Part 18): Transformer Winding Design For The Battery Converter—Secondary Winding Design

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In the most recent installment in the Volksinverter design series, part 17, the previously derived winding design procedure and formulas were used to evaluate various winding configurations for the primary winding in the battery converter's transformer. In this part, the same basic design procedure is now applied to the design of the secondary winding. Plans W through Y, which are described here, follow the scheme of electrically paralleling multiple layers to maximize window utilization. Plan Z changes the winding configuration to multifilar.

Notes: 8 pages, 2 figures, 2 tables.

Read the full story...

August 2024:

New Capacitors Offer Better Balance Of Performance, Reliability And Cost For LEO Satellites

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

Abstract: The global low-Earth-orbit LEO satellite market has morphed into a reasonably sized market with the promise of solid growth over time, and more LEO satellites than ever are being built worldwide. This in turn has led a growing number of passive component manufacturers to dedicate research and development efforts to producing components specifically optimized for LEO satellite designers. Two such capacitor developments are high-capacitance-per-unit-volume (high-CV) multilayer ceramic capacitors (MLCCs) and enhanced-reliability commercial off-the-shelf (COTS) bulk capacitors. In this article, we'll discuss these developments with a focus on two recently introduced series, which address the needs for low-cost alternatives to MIL-PRF-32535 MLCCs in the hardware development phase and to MIL-PRF-55365 tantalums for in-flight use.

Notes: 5 pages, 2 figures, 2 tables.

Read the full story...

Spurious Turn-On Investigation For SiC MOSFETs In Hard-Switched Half-Bridges

by Nico Fontana, Infineon Technologies Austria, Villach, Austria



Abstract: High-voltage 650-V and 750-V silicon carbide (SiC) MOSFETs are key enablers for hardswitching half-bridge topologies. However, in these designs, the SiC MOSFETs may encounter spurious or random turn-ons. These events are not well documented, but they can cause increased switching losses and, in worst case, device failures if not prevented or minimized. To understand these occurrences better, an in-depth study was conducted. In this article, a series of double-pulse test measurements are presented that compare the reverse-recovery charge of commercially available SiC MOSFETs under unipolar versus bipolar driving. This allows us to evaluate the impact of spurious turnon on circuit performance under unipolar driving, and to quantify the performance differences between these two driving schemes under different circuit conditions. Based on that some guidance is offered on the use of unipolar driving of SiC MOSFETs.

Notes: 7 pages, 7 figures.

Read the full story...

Measuring Accurately To 10 MHz With Fluxgate Balanced-Core Current Transducers

by Roland Bürger, Morten Birkerod Lillholm and Henrik Elbæk, Danisense, Taastrup, Denmark

Abstract: For several decades, zero-flux current transducers have been used to extend the measuring range of power analyzers. Common devices usually have a bandwidth in the three-digit kilohertz range. However, when using wide-bandgap semiconductor modules, switching frequencies between 20 kHz and 100 kHz are widely used to generate sinusoidal current signals without heavy and expensive filter elements. At such switching frequencies, harmonics can be detected up to the megahertz range and provide active and reactive power components. As a result, to measure current accurately in such applications, bandwidths wider than those of conventional current sensors are required. This article presents a zero-flux current transducer developed by Danisense (the DW500UB-2V) that can provide linear transmission behavior up to 10 MHz.

Notes: 12 pages, 18 figures, 1 table.

Read the full story ...

September 2024:

A Practical, Easy-To-Implement Energy Harvester For BLE Modules And Other Applications

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

Abstract: This article builds on prior investigations of supercapacitors and tantalum capacitors as well as an energy harvesting controller IC used to power ULP devices. For this work, we employed the same IC (the e-peas AEM10330) to extract energy from a small solar cell, store it in a supercap, and power a Bluetooth Low Energy (BLE) module. The BLE module, in turn, was configured to measure the voltage of the supercap and the voltage supplied to the module, and then transmit those values to a PC for data logging. This real-world example of an energy-harvesting system demonstrates the ease with which such a system can be created.

Notes: 5 pages, 3 figures, 1 table.

Read the full story ...



Designing An Open-Source Power Inverter (Part 19): Controller Design For The Battery Converter

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: The last four parts in this series on the Volksinverter have provided extensive discussion on the design of the transformer for the battery converter. Keeping the focus on this stage, in this article we now explore the design of the control circuit of the boost push-pull (BPP) power-transfer circuit. We will begin this explanation of control circuit design by observing how low output-voltage and output-current conditions on the battery converter's output port complicate converter control. Then, we'll see how to address these requirements by applying a combination of operating modes, and derive the control logic needed to implement these two modes. Based on those logic requirements, a particular control scheme will be recommended. Finally, the various exceptions to the normal controller operating modes will be described.

Notes: 13 pages, 9 figures.

Read the full story...

Can Foil Folding Improve Winding Performance In Transformers?

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Foil as a conductor shape can have advantages over wire. This article explores methods for winding with it. The concept is somewhat reminiscent of origami or Japanese paper folding, though the constraints on winding performance are an additional consideration. Here I'll explore various ideas about how to wind with foil. Although optimal-thickness foil reduces eddy-current constant-frequency resistance ratio F_r to valley values between the low- ξ and medium- ξ regions on Dowell graphs, it lacks the F_r minimization achieved by twisting wire into bundles. If the eddy-current benefits of twisted conductors could be combined with the advantages of foil, winding design might be advanced. This article is a presentation of ideas or "brainstorm" intended to encourage discovery of new folding methods that enhance the use of foil in winding design.

Notes: 3 pages, 4 figures.

Read the full story

Transitioning Voltage Regulator Design From Unidirectional To Bidirectional

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

Abstract: Energy management systems (EMSs) are an emerging set of applications aimed at optimizing the energy flow and storage between electric vehicles, photovoltaic systems, home storage batteries and the electric grid. Such flexible energy management requires that fundamental blocks like voltage regulators and chargers, connected to the EMSs, operate bidirectionally with respect to the energy flow. However, the vast majority of today's blocks power traditional unidirectional loads. A designer that has thus far designed only unidirectional dc-dc converters will find himself/herself in a quite unchartered territory when asked to design an eminently bidirectional phase-shift dual active bridge (DAB) converter. Hence, designers looking to do their first bidirectional power converters. As we'll see, there are already elements of bidirectional energy flow in the familiar unidirectional converters.



Notes: 5 pages, 6 figures.

Read the full story ...

October 2024:

Deriving The Control-To-Output Transfer Function Of The Weinberg Converter

by Christophe Basso, Future Electronics, Toulouse, France

Abstract: The Weinberg converter was first documented by Alan Weinberg in 1974 when he was with the European Space Agency. The converter is a buck-derived current-fed push-pull topology and has gained popularity in space applications up to several kilowatts, owing to its robustness and almost ripple-free output current. As with any switching converter intended to be operated in closed loop, the stabilization exercise starts with obtaining the control-to-output transfer function of the power supply. While searching the available literature, I have found several papers describing the small-signal response of this converter, but I could not either match their results with simulations in SIMPLIS or derive a useful expression from a long list of matrices. Finally, since this structure was not analyzed in my previous book on transfer functions, I decided to take a look at its small-signal response here.

Notes: 22 pages, 24 figures.

Read the full story...

Overcoming Power Challenges In Optical Transceivers With Two-Stage Buck Regulators

by Laurence McGarry, Jim Pflasterer, and Kubo Tatsuya, pSemi, San Jose, Calif.

Abstract: Several challenges face today's network and datacenter system power designers. The increase in data rates translates to increased power requirements usually in the same or smaller space. Traditional methods of power conversion using buck topologies may be battle-hardened but offer little opportunity to significantly improve the efficiency and size of the converter. They also struggle to provide the performance required to support sub-10-nm loads which require very low output voltages often combined with higher currents. In this article, we introduce the two-stage buck regulator architecture as an innovative method of achieving efficient conversion from high input to low output voltages. This novel architecture consists of a first-stage charge pump to divide the input voltage down to a lower intermediate value, followed by a second-stage buck regulator.

Notes: 10 pages, 11 figures, 1 table.

Read the full story...

Designing An Open-Source Power Inverter (Part 20): Converter Inductor Magnetic Design

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: The final magnetic component in the Volksinverter that remains to be designed is the converter-stage inductor of the boost push-pull (BPP) transfer circuit. From control considerations in part 19, the inductor was modified by adding an additional winding so that inductor energy could be transferred through the winding to the output when the transfer circuit does not operate in boost (CA)



mode. The inductor of the Volksinverter converter stage is a two-winding coupled inductor. In this part, in designing the coupled inductor for the BPP stage, we largely follow the generalized transductor design procedure introduced in part 15 for designing the transformer in the BPP stage. As with the transformer design, we'll begin the coupled inductor design with the *magnetic* design, establishing those parameters relating to selection of the core and the number of turns, N.

Notes: 11 pages, 3 figures, 2 tables.

Read the full story ...

November 2024:

Current Mode-Controlled DC-DC Regulators (Part 1): A Review Of Small-Signal Behavior

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: With simple operation and dynamics, current-mode control requires two loops: a widebandwidth inner current loop and an outer voltage regulation loop. Commonly used forms of currentmode control include peak, valley, average, hysteretic, constant on-time, constant off-time and emulated. Each technique offers certain advantages and trade-offs depending on the design requirements. This article, part one of a multipart series, represents an update to a previous series the author wrote in 2014 with more focus on the inner current loop. This part lays the groundwork for a subsequent article that details a cohesive implementation for a constant-current constant-voltage (CC-CV) circuit with two loops using a shared network for compensation. Part 1 begins with an overview of the small-signal behavior in fixed-frequency, naturally sampled, peak current-mode, pulse-width modulated (PWM) dc-dc regulators.

Notes: 12 pages, 9 figures, 1 table.

Read the full story...

Read the full story...

Using VNA Software To Build Measurement-Based Models

by Charles E. Hymowitz, Paul Ho and Michael LaNovara, AEi Systems, Centennial, Colo.

Abstract: In today's power integrity (PI) simulations picohenries matter. Timely availability, fidelity, and model accuracy matter. However, vendor-supplied component models, including those available for passive and other components, are often inaccurate or not available. For system designers performing PI simulations, the answer to this problem is either to obtain better models from third-party sources or to build their own measurement-based models. This second option has been made easier by the new Curve-Fitting–Simulation Model generation feature in the Bode Analyzer software Suite (BAS). The BAS software drives the popular OMICRON Lab Bode 100 and 500 vector network analyzers (VNAs) and with the new model generation feature, this software can curve fit the data from impedance measurements to create lumped element models (SPICE).

Notes: 11 pages, 12 figures.

Output Filter Capacitor Size Depends On Inductor Value

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

Abstract: Typically, in an SMPS, the value of output filter capacitance is calculated based on the



desired output ripple voltage and the assumed ripple current for a given inductor under the given set of operating conditions. However, this approach ignores the interplay between the capacitor and inductor in filtering the ripple current. What results is a non-optimum capacitor selection, both in terms of capacitance value and capacitor size. In this article we will define both the electrical and physical sizes required of a capacitor used for filtering the current ripple in a converter and decide whether this capacitor can handle the ripple current while working in the output filter. To do this, we'll analyze operation of the output filter components in a simple buck converter power stage.

Notes: 8 pages, 1 figure.

Read the full story...

Designing An Open-Source Power Inverter (Part 21): Converter Inductor Winding Design

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: As this series moves forward, we explore the Volksinverter's battery converter stage further, continuing the design of the inductor of the boost push-pull (BPP) transfer circuit. A two-winding coupled inductor, the boost or common-active (CA) PWM-switch inductor is the only power-transfer component (along with the fuse and connectors) that is in series with the battery and conducts the most current of all the Volksinverter circuitry. The procedure for magnetic component design begins logically with the magnetic design—the design associated with the core—for without it, there is nothing on which to base the winding (electrical) design. The previous part in this series presented the magnetic design, establishing key parameters such as L_{min} , the minimum inductance needed for current protection; L_{max} , the maximum inductance and energy storage (or transfer power) value at I_{gmax} and N_{max} ; and N_w , the maximum turns that fit the core window.

Notes: 11 pages, 2 figures, 2 tables.

Read the full story ...

December 2024:

Dynamic Load Stepping: A New Paradigm For Determining GPU/ASIC Power Rail Stability And Impedance

by Steve Sandler, Picotest, Phoenix, Ariz.

Abstract: As GPUs, ASICs, and CPUs continue to push the boundaries of performance, the power systems that support them face unprecedented challenges. Before these advanced processors can be safely powered and tested, their power rails must undergo rigorous assessment with e-loads emulating massive, arbitrary current draw profiles at nanosecond edge speeds. While such challenging load profiles are being applied to the power system, engineers must evaluate critical factors like stability, large-signal voltage responses, and crosstalk between adjacent power rails. This article explores the limitations of the traditional approaches to power rail assessment, highlights the innovations driving a new generation of electronic loads, and introduces dynamic load stepping as a paradigm-shifting solution for assessing the demanding power requirements of cutting-edge GPUs, CPUs, and ASICs.

Notes: 6 pages, 5 figures.

Read the full story ...



Current Mode-Controlled DC-DC Regulators (Part 2): Loop Compensation And Load Transient Performance

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Moving forward with the discussion of current-mode control, this article, part 2 of a multipart series, examines loop compensation of current-mode dc-dc regulators. The goal in the second installment of this series is to uncover simple expressions derived from the small-signal model to yield an intuitive compensator design procedure applicable to single- and multiphase regulator circuits. The simplicity of the design procedure, even with an error amplifier of finite gain bandwidth, will make it convenient for everyday use. A design example using a commercially available two-phase synchronous buck controller, along with circuit simulation in the time and frequency domains, will substantiate the theoretical analysis and demonstrate how to select values for the compensation network to achieve a target crossover frequency.

Notes: 12 pages, 10 figures, 1 table.

Read the full story ...

Designing An Open-Source Power Inverter (Part 22): Converter Regulator Dynamics

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Having addressed the magnetics and control circuit design in recent parts of this series, we now address other elements of designing the Volksinverter's battery converter stage. These relate to regulator dynamics affecting the response of the converter. The converter voltage regulator loop traverses BCV401 and BCV402 Volksinverter modules. The output storage capacitor C_o is yet to be determined along with the BCV402 current-sense amplifier within the larger voltage control loop that includes some of the BCV401 circuitry. Design aspects of these circuits are expounded here. That extends to a derivation of the transfer functions for the voltage control loop of battery converter based on our choice of the CA (boost) converter topology.

Notes: 11 pages, 9 figures.

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