Design Article Archive

Abstracts of articles published in the January through December 2018 issues

January 2018:

Estimating Output Current Tolerance Of A Primary–Side-Regulated Constant-Current Flyback Converter (Part 1): The Analytical Model

by Stéphanie Cannenterre, ON Semiconductor, Toulouse, France

Abstract: The primary-side-regulated (PSR) flyback converter is a popular converter widely used in the LED drive market and in the portable electronic market for travel adapters. In such converters, the output current can be estimated by sensing the current in the primary-side MOSFET. However, what precision on the controlled parameter can be expected with this technique? LED driver manufacturers are usually targeting ±5% at a given input voltage. Using worst-case circuit analysis techniques, this article will detail how to estimate the accuracy of the flyback output current and compare the obtained results against the ±5% target. The first part of this article will introduce an analytical model of the primary-side constant-current flyback control scheme. Subsequent parts of this article will present a Monte Carlo Analysis of the converter output current followed by an extreme value analysis and a sensitivity analysis.

Notes: 10 pages, 9 figures, 1 table. Read the full story…

Online Simulation Validates Output Error Budget Analysis For Buck Converter

by Brooks Leman, Mark Fortunato and Nazzareno (Reno) Rossetti, Maxim Integrated, San Jose, Calif.

Abstract: A buck converter design for a particular Maxim customer specified a tight output voltage tolerance across all operating conditions. To ensure the ensuing design met this goal, it was necessary to perform an output voltage error budget analysis. In general, the biggest contributor to the error is the output droop consequent to the load step. However, using different methods to estimate the droop led to different results. How do we make sense of it? In this article, the authors perform a buck converter output error budget analysis. In estimating the droop amplitude, they compare a simulated result with two different back-of-the-envelope estimates and reconcile the different approaches.

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

The Engineer's Guide To EMI In DC-DC Converters (Part 2): Noise Propagation And Filtering

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: High switching frequency is the major catalyst for size reduction in the advancement of power conversion technology. It is essential to understand the EMI characteristics of high-frequency converters since the required EMI filter necessary for regulatory compliance typically occupies a significant portion of the overall system footprint and volume. In part 2 of this series, you'll gain an insight into dc-dc converter conducted EMI behavior by understanding sources and propagation paths for both the differential mode (DM) and common mode (CM) conducted emissions noise components. DM and CM noise separation from the total noise measurement is described, and a boost converter example is used to highlight the main CM noise conduction paths that exist in an automotive application.

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

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EMI For Wisdom Seekers (Part 3): Differential Mode Noise Versus Common Mode Noise

by Patrice Lethellier, Noizgon, Salt Lake City, Utah

Abstract: Having discussed why designers of power supply packaging need an understanding of electromagnetic interference (EMI) and provided a practical introduction to the topic in the parts 1 and 2, we now introduce the concepts of differential noise and common-mode noise. These two sources of EMI have different causes and different treatments.

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

Transformer Design (Part 1): Maximizing Core Utilization

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In this article, the utilization of the core in transformer design is considered by reviewing earlier work on the optimal turns that maximize use of the core in the magnetic part of coupled-inductor design. Important differences between coupled inductor and transformer design are identified and different criteria are derived for making the same maximum use of a transformer core, and for the kind of application that can make it worthwhile.

Notes: 3 pages. Read the full story…

A Power Supply Can't Fix All EMC Woes, Yet Partnering With The Right Power Supply Experts Early Can

by Kevin Parmenter, Chair, and James Spangler, Co-chair, PSMA Safety and Compliance Committee

Abstract: Recently I was called by a customer who was failing EMC in the test lab. They were using one of our competitor's power supplies and we had been talking with them about using ours because of its superior value and performance. It was hard to ascertain if our pitch was falling on deaf ears or not. But now, with their product failing compliance testing, suddenly we were important to them as evidenced by them calling me after hours. The discussion went something like "does your power supply have lower EMC than the one I'm now using?" Of course they were talking about radiated EMC as I already had helped them with selecting a line filter, which was sufficient to make sure either power supply would pass conducted EMC. With their product in the test lab there was real urgency as the money meter was running with the test lab charging them by the hour as the customer tried to get their product to pass EMC. This is their story and the lessons learned.

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

February 2018:

SEPIC Converter Simplifies Design Of Smart Electronic Loads

by Viktor Vogman, Power Conversion Consulting, Olympia, Washington

Abstract: Prior to being shipped to consumers, newly manufactured server power supplies undergo a burn-in test, which is a basic method of verifying their reliability. During this test, which generally runs for 24 hours, the unit under test is operated under supervised conditions close to its max loading capacity. To minimize the energy consumption costs of burn-in tests, which constitute a significant

portion of power supply unit development costs, the use of a smart electronic load (SEL) with energy recycling capability is recommended. However, SELs are usually expensive, sometimes to the point where makers of server power supplies will avoid their use in favor of traditional dissipative loads. This article describes a two-stage approach that combines a SEPIC converter with an off-the-shelf photovoltaic grid tie inverter to create an inexpensive, configurable SEL that can recover more than 90% of the energy supplied by the power supply during burn-in.

Notes: 7 pages, 3 figures, 2 tables. Read the full story…

Estimating Output Current Tolerance Of A Primary–Side-Regulated Constant-Current Flyback Converter (Part 2): Monte Carlo Analysis

by Stéphanie Cannenterre, ON Semiconductor, Toulouse, France

Abstract: Part 1 of this article presented an analytical model of the primary-side-regulated flyback converter operating under constant-current control. We also verified the accuracy of this model by comparing it against experimental results. This model will allow us to estimate the accuracy of the flyback output current in LED driver applications. Now in part 2, we'll begin to use the model to determine the worst-case output current accuracy of the example flyback converter design by performing a Monte Carlo analysis.

Notes: 9 pages, 5 figures, 3 tables. Read the full story…

EMI For Wisdom Seekers (Part 4): Minimizing Parasitic Current Loops

by Patrice Lethellier, Noizgon, Salt Lake City, Utah

Abstract: In this series of EMI articles targeting power supply package designers and novice EEs, we continue the discussion by looking at parasitic loops. We are going to see that the parasitic loops are not only the basic ones (where the switched currents actually flow) but also those that result from the interaction of several basic loops. Parasitic loops are responsible for generating EMI, but not all do so equally. In this article, we'll discuss which combinations contribute most to EMI and how minimizing their areas reduces the EMI. We'll also show a trick for minimizing the effective parasitic loop area in cases where the physical size of the components does not allow the loop area to actually be made smaller.

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

Transformer Design (Part 2): Aspect Ratio

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: This discussion on core utilization in transformer design continues with a study of aspect ratio. For transformer high-current primary windings, the aspect ratio of the transformer winding window is an important constraint in winding design. Here in part 2, we present an example that demonstrates how aspect ratio constrains a full winding window and how it affects power transfer. This example serves as a design template for readers looking to perform similar transformer design optimizations. This example also demonstrates how aspect ratio can affect eddy-current losses.

Notes: 6 pages, 2 figures, 1 table. Read the full story…

HOW2POWER TODAY

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PCB Board Layout Is Critical When The Power Supply And MCU Live On The Same Board

by Kevin Parmenter, Chair, and James Spangler, Co-chair, PSMA Safety and Compliance Committee

Abstract: In many simple industrial and consumer products there is printed circuit board (PCB) that contains both a microcontroller (MCU) and a simple off-line power supply. In such cases, there are typically two sources of EMI: line conducted EMI from the power supply and radiated EMI from the MCU. When there is a failure in EMC testing, the customer's first reaction is often to blame the power supply. But very likely, it is not the power supply causing the failure, but rather a poor PCB layout that caused the data lines to radiate. After reviewing some of the basic requirements of PCB design, we go step-by-step through the details of layout of a PCB for an MCU. Scans of radiated EMI for the example MCU application demonstrate how the errors in pc board layout led to compliance failures.

Notes: 8 pages, 9 figures. Read the full story…

March 2018:

Power Stage Strategies For Motor Control In Home Appliance Design

by Brian Chu, Infineon Technologies, El Segundo, Calif.

Abstract: In the design of the motor drive systems for appliances, the prevailing trend in power electronics has been in the integration of discrete components to create intelligent power module (IPM) devices. IPMs contribute in many ways to the goals of reliability and size reduction. Continued advances in this category of devices also address concerns that IPMs might limit a designer's flexibility or have a negative impact on system cost. In fact, broadening product portfolios offer more design options, while lowering parts count, simplifying assembly and reducing board area. This article discusses the different power stage options, using designs for in-room air conditioners and refrigerators to illustrate the associated electrical, thermal, size and cost tradeoffs.

Notes: 7 pages, 8 figures, 2 tables. Read the full story…

Estimating Output Current Tolerance Of A Primary–Side-Regulated Constant-Current Flyback Converter (Part 3): Extreme Value Analysis And Sensitivity Analysis

by Stéphanie Cannenterre, ON Semiconductor, Toulouse, France

Abstract: In parts 1 and 2 of this article, we derived an analytical model of the primary-side regulated (PSR) constant-current (CC) flyback and used this model to perform a Monte Carlo analysis (MCA) of the converter. In this third part, the author carries out an extreme value analysis (EVA) and a sensitivity analysis of the PSR flyback converter. For this study, only the initial tolerances of the parameters are considered (except for the controller parameters). The goal is to provide an interval for the output current value at the beginning of life of the converter. This article concludes by comparing the results of the EVA and sensitivity analysis with the MCA and determining whether we have met the goal for output current tolerance in the LED driver application.

Notes: 13 pages, 4 figures, 5 tables. Read the full story…

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The Engineer's Guide To EMI In DC-DC Converters (Part 3): Understanding Power Stage Parasitics

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: In part 3 of this ongoing series, the author provides a comprehensive illustration of inductive and capacitive parasitic elements for a buck regulator circuit that affect not only EMI performance but also switching losses. By understanding the contribution of the responsible circuit parasitics, you can take steps to minimize them and reduce the overall EMI signature. In general, a compact, optimized power-stage layout not only lowers EMI for easier regulatory compliance, but also increases efficiency and reduces overall solution cost.

Notes: 7 pages, 4 figures, 1 table. Read the full story…

To Simplify Or Not To Simplify? Take Care When Using Math Tools For Circuit Analysis

by Gregory Mirsky, Continental Automotive Systems, Deer Park, Ill.

Abstract: Occasionally when designing control systems we encounter situations where different mathematical transfer function representations of the same system may produce dramatically different results. For example, we obtain a control loop frequency response that can be mathematically described by two formulas, one of which is a simplified version produced by math analysis software, but the graphical interpretations of these functions are different. For example, there is a big class of circuits called non-minimum-phase circuits, which have a phase-frequency response that is not minimal for a corresponding amplitude response. Circuits with the right-half-plane zero (RHPZ) belong to this class of circuits and we'll use one of these circuits to highlight the pitfalls of using a math tool to analyze a circuit transfer function.

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

Modeling Of The Sen Transformer Using An Electromagnetic Transients Program

by Kalyan K. Sen and Mey Ling Sen, Sen Engineering Solutions, Pittsburgh, Penn.

Abstract: The Sen transformer (ST) is an impedance regulator that emulates an impedance in series with an electric power transmission line. The ST connects a compensating voltage in series with the transmission line to modify the magnitude and phase angle of the line voltage so that independent active and reactive power flows can be achieved. In this article, an ST model is developed using an electromagnetic transients program (EMTP) and executed in the Alternative Transients Program software package. This model preserves the details of an ST configuration that cannot be obtained from a load flow model. The operation of the EMTP model is verified with the model connected to a simple power system network that can easily be upgraded to a utility's more representative power system network. The ST model has relevance to power electronics engineers as the ST competes with power electronics-based impedance regulators.

Notes: 28 pages, 27 figures, 6 tables. Read the full story…

Winding Layering Techniques Determine Interlayer Capacitance

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Adjacent winding layers in a transformer (or coupled inductor) have capacitance between them that varies in effect depending on how the successive layers are wound and connected. This article derives the effective capacitance for successive unidirectional and bidirectional layer windings. The choice of bidirectional or unidirectional layering affects interlayer capacitance, the distribution of voltages across the layers and the storage of electric field energy in the interlayer capacitance. This article explains the origins of these differences, how to calculate the interlayer capacitances, voltages and stored energies, and a technique for emulating unidirectional layering without the mechanical drawbacks.

Notes: 6 pages, 4 figures. Read the full story…

April 2018:

The Engineer's Guide To EMI In DC-DC Converters (Part 4): Radiated Emissions

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Part 4 of this article series offers some perspective on radiated emissions from switching power converters, particularly those intended for applications in the industrial and automotive sectors. Radiated electromagnetic interference (EMI) is a dynamic and situational problem that depends on parasitic effects, circuit layout and component placement within the power converter itself as well as the overall system in which it operates. Thus, the issue of radiated EMI is typically more challenging and complex from the design engineer's perspective, particularly when multiple dc-dc power stages are located on the system board. It's important to understand the basic mechanisms for radiated EMI, as well as the measurement requirements, frequency ranges and applicable limits. This article focuses on these aspects and presents radiated EMI measurement setups and results for two dc-dc buck converters.

Notes: 14 pages, 16 figures, 6 tables. Read the full story…

Automatically Shift Seemlessly Between Peak And Valley Current Modes

by Patrice Lethellier, It Can Be Done, Salt Lake City, Utah

Abstract: At and above 50%, peak current mode control begins to show a cycle-by-cycle instability of the PWM section where the peak current stops the duty cycle. Valley current mode control is the opposite. It is unstable below 50% duty cycle and is stable above 50%. To correct either type of control, we need to introduce a slope compensation which is in fact a bit of voltage-mode control. At very large duty cycle for the peak mode or at very low duty cycle for the valley mode, the required amount of slope compensation increases and overwhelms the current mode. We are shifting to a hybrid current mode/voltage mode, which is going to show some of the 180° of dephasing coming from the output filter in the closed loop. The ideal solution to this problem is a current mode which is always stable without slope compensation. This articles describes how to achieve this goal using a very simple circuit.

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

Switching Power Supplies And EMI: Debunking The Myths About Frequency And Slew Rate

by Gregory Mirsky, Continental Automotive Systems, Deer Park, Ill.

Abstract: The majority of switching power supplies use fast switching of power components to diminish dynamic losses in these components. It is conventional to think that fast switching components may create issues with electromagnetic compatibility (EMC). It is true that short pulses with very steep edges have widespread spectra. The process of such switching may be represented as a rectangular pulse train, which may be described with a pulse repetition frequency, switching slope slew rate and duty cycle. All of these parameters affect the pulse-train spectrum but very seldom does this spectrum produce components that exceed the FCC limits for conducted and emitted EM radiation. This article tries to shed light on other aspects and culprits of the EMI tests failures. We will mathematicaly analyze how pulse-train frequency, slopes and duty cycle affect the signal spectrum and what part of the spectrum can be radiated. Ultimately, we will address the question of whether the improvement in EMI from slowing down switching edge rates is worth the added power dissipation.

Notes: 14 pages, 6 figures. Read the full story…

Inrush Current Tester Enables More Thorough Validation Of Server Power Supplies

by Viktor Vogman, Power Conversion Consulting, Olympia, Washington

Abstract: Switch-mode server power supplies that support a wide range of input voltages (90 to 264 Vac) in real applications can operate in a variety of ac transient conditions such as voltage sags and surges, dropouts, line frequency deviations, etc. Although these conditions are detailed in power supply specs and design guides it has been observed that server power supplies that pass extensive qualification tests performed with conventional programmable ac sources still have a significant failure rate in the field due to ac transients. The root cause of these failures has been isolated to overstress of the power factor correction (PFC) stage. This overstress is not detected during power supply qualification due to the limited transient current capability of the existing ac grid emulating equipment being used. This article describes the implementation of a simple technique addressing this issue.

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

Magnetizable Concrete Paves The Way For EV Charging And Low-Cost Power Magnetics

by Mauricio Esguerra, MAGMENT, Munich, Germany

Abstract: MAGMENT magnetizable concrete materials—either cement- or asphalt-based—are a patented technology displaying the mechanical properties of conventional concretes due to the embedding of ferrite particles used as magnetic aggregates. These ferrite particles are obtained from recycled material from the ferrite industry and from the rapidly growing amount of electronic waste. All chemical elements needed to produce this material belong to the most abundant metals on Earth. This article presents an introduction to the material properties and characteristics of MAGMENT MC40, a specific formulation of magnetizable concrete, and discusses its usefulness in a number of major applications. These include power inductors, wireless charging systems, inductive heating systems, and EMC filtering for HVDC power transmission systems.

Notes: 10 pages, 11 figures, 3 tables. Read the full story…

May 2018:

Dual Buck Doubles The Duty Cycle For Ultra Low-Voltage Applications

by Patrice Lethellier, It Can Be Done, Salt Lake City, Utah

Abstract: The large microprocessors (Intel, Sun, IBM) require a high current and a low voltage. A core voltage of 0.6 V at 200 A is not uncommon. It can be an even lower voltage in sleep mode. Typically the topology used to supply this voltage is a multiphase buck with 8 to 12 phases. The input voltage is 12 V and in this example where the output voltage is 0.6 V, the buck has to work at a duty cycle close to 5%. The duty cycle gets even lower in sleep mode where the output voltage can be 0.3 V. At a duty cycle below 5%, the on-time barely exists and efficiency is very low. This article presents an alternative multiphase buck topology that performs the same voltage transformation as the conventional multi-phase buck but without some of the drawbacks.

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

Analyzing The Effect of Voltage Drops On The DC Transfer Function Of The Buck Converter

by Christophe Basso, ON Semiconductor, Toulouse, France

Abstract: Switching converters combine passive elements such as resistors, inductors, capacitors but also active devices like power switches. When you study a power converter most of these components are considered ideal: when switches close they do not drop voltage across their terminals, inductors do not feature ohmic losses and so on. In reality, all these elements, either passive or active, are far from being perfect. In this article, we will study their effects on the dc transfer function of a buck converter. We will also apply this analysis to a forward converter, which is a buck-derived topology.

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

Achieve Precise High Current Monitoring Using Standard Surface-Mount Resistors

by Viktor Vogman, Power Conversion Consulting, Olympia, Washington

Abstract: In low-voltage, high-current applications, in which sensor voltage drop may noticeably impact power distribution efficiency, designers are required to use very low (sub-milliohm) resistance sensors for current sensing. High-power-rated sub-milliohm sensors often come with Kelvin connect terminals, which simplify their layout, but take up more PCB space, and are less accurate and more expensive than standard precision surface-mount (SM) parts. Designers generally prefer to select standard SM resistors. When connected in parallel, conventional SM two-terminal parts can support the sub-milliohm resistance range of the sensor. With proper PCB trace routing and summing signals of paralleled sensors a much better (1%) current signal monitoring accuracy can be achieved even without calibration.

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

Magnetic-Electric Analogs Relate Magnetic Fields To Familiar Circuit Quantities

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Circuit designers are usually able to think more easily about the circuit behavior of capacitors than inductors. Inductance is the *dual* of capacitance; exchange *v* and *i* in capacitor equations and they apply to inductors. This dualism can be extended to circuit laws too, and the three most basic laws of circuits (Ohm's Law, KVL and KCL) have magnetic counterparts. In this article, the author derives these equivalents and examines them. Finally, he explains how the magnetic counterparts to circuit laws can be applied in transformer design.

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

Beware The Pitfalls Of Power Suppy Hipot

by Kevin Parmenter, Chair, and James Spangler, Co-chair, PSMA Safety and Compliance Committee

Abstract: What is hipot (high potential) testing and what is it for? A dielectric withstanding voltage test is used to determine the ability of equipment with an installed power supply to protect against electrical shock. The dielectric withstand voltage test is typically referred to as a hipot test and involves applying a specified high voltage between the points being tested and measuring the resultant leakage current. The test has been with us a long time. However, as power supplies have developed and EMC requirements have become more stringent in, for example IEC 60601 4th edition EMC, we have seen customers needing more guidance in the proper application of the testing. Moreover, it should be emphasized that for switching power supplies, the hipot test should be considered a destructive test. What is meant by this?

Notes: 2 pages. Read the full story…

June 2018:

Lossless Method Boosts Current-Sense Signal

by Patrice Lethellier, It Can Be Done, Salt Lake City, Utah

Abstract: Inductive sensing is sensing an inductor current without incurring the losses of a sense resistor. Inductive sensing is providing a virtual signal equal to the actual current signal in the inductor, which would be obtained across the parasitic resistance of the inductance L. The sensed voltage is produced by an RC filter across the inductance. This is a lossless sense because it does not add any loss to the regulator. However, the sensed voltage signal has a small amplitude which could pick up noise that will be amplified. In this article, the author describes a modification of this current sensing method which boosts the sensed signal, while adding very little to the cost of the circuit.

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

Calibration Of Copper Sensors Enhances Accuracy Of Nonintrusive Current Monitoring

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

Abstract: Sensor calibration can be implemented with copper traces for current sensing of system loads (such as CPU, memory, hard drives, etc.) in the power distribution network. However, applying conventional calibration methods to such low-resistance copper sensors typically requires using precision high-current electronic loads that are not realizable on the PCB. This article introduces a calibration method that corrects for errors caused by copper geometry and variations in signal processing network parameters without requiring use of high-power equipment. This technique can be implemented with a miniature circuit that draws only a few tens of milliwatts when active, and can be disabled once calibration is complete. This circuit can be integrated into existing system components.

Notes: 6 pages, 4 figures, 1 table. Read the full story…

Selecting A Freewheeling Diode Solution For Lowest Losses With SiC MOSFETs

by Xuning Zhang, Monolith Semiconductor, Round Rock, Texas and Levi Gant, Littelfuse, Chicago, Ill.

Abstract: This article discusses a few of the potential configurations available to implement the freewheeling device in a SiC-based system. These include use of a discrete SiC Schottky barrier diode (SBD), a SiC MOSFET's body diode, and a SiC MOSFET in combination with an additional discrete anti-parallel SiC SBD. The main objective here is to assess the impact of adding anti-parallel SiC SBDs to SiC MOSFETs on converter losses. To that end, we've conducted a series of experiments to determine the switching losses produced by the three freewheeling device options. These experiments are described along with an analysis of the results and discussion of the tradeoffs of each freewheeling device option. Then, some guidelines are presented to help designers select the freewheeling diode solution that will minimize losses in their applications.

Notes: 10 pages, 12 figures. Read the full story…

The Engineer's Guide To EMI In DC-DC Converters (Part 5): Mitigation Techniques Using Integrated FET Designs

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: The circuit schematic and PCB are pivotal to achieving excellent EMI performance. Part 3 underscored the imperative to minimize "power loop" parasitic inductance through component selection and PCB layout. The power converter IC has an outsized impact here, in terms of its package technology and EMI-specific features. As outlined in part 2, differential-mode filtering is mandatory to reduce the input ripple current amplitude for EMI regulatory compliance. Meanwhile, common-mode filtering is generally required to curtail emissions above approx. 10 MHz and shielding also offers excellent results at high frequencies. This article delves into these aspects, offering practical examples and guidelines to mitigate EMI, specifically for converter solutions with integrated power MOSFETs and controller.

Notes: 9 pages, 10 figures. Read the full story…

Bundle Compression Overcomes Aspect Ratio Constraints On Transformer Design

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In a prior work, the impact of winding-window aspect ratio on transformer design was analyzed. This ratio is important because it imposes limits on the current density and hence the transfer power that can be achieved when using round or square wires in bundles as discussed previously. For bundles that are large relative to the window dimensions, window aspect ratio imposes a boundary effect that can reduce packing factor. Apart from resorting to foil, there is seemingly no solution to this problem—except for compressing the round bundles. In this article, we take the analysis of winding-window aspect ratio's effect on transformer design a step further, by answering this question: how much can the bundles be compressed?

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

July 2018:

Selecting An Inductor Value For A DC-DC Boost Converter

by Brian Curbo, ON Semiconductor, Phoenix, Ariz.

Abstract: The boost topology is fundamental in the field of power electronics, but selection of the inductor value is not always as straightforward as often assumed. In the dc-dc boost converter, the chosen inductor value has an impact on input current ripple, output capacitor size and transient response. Choosing the value correctly can help in optimizing the size and cost of the converter and ensure operation in the desired conduction mode. In this article, methods for calculating the inductor value to maintain the required ripple current and chosen conduction mode over a range of input voltage are described. A mathematical approach for computing the upper and lower mode boundaries of input voltage is presented, and the use of the WebDesigner online design tool from ON Semiconductor to accelerate these design steps is discussed.

Notes: 9 pages, 8 figures. Read the full story…

Accelerate Motor Mapping And Drivetrain Analysis With Advanced Power Analyzer

by Mike Hoyer, HBM Test And Measurement, Madison, Wisc.

Abstract: Evaluating motor efficiency has become extremely important since significant efforts are focused on more efficient electrical machines and drives. The main issue is how to implement an accelerated procedure that obtains the motor or drive efficiency for all operating points accurately and rapidly. Ordinary test methods using a typical power analyzer only offer inadequate numerical results. To get beyond the inadequate numerical results, all electrical, mechanical and physical signals must be acquired synchronously at high sample rates with advanced real-time custom analysis coupled with fast data transfer to automation systems. This article will outline how to accurately and significantly accelerate efficiency motor mapping; and how to speed up calculations of dq0 (Park) and space vector (Clarke) transformation or any motor, inverter and drivetrain custom analysis. As explained here, these operations can be performed in seconds instead of hours or days using HBM's eDrive solution, a power analyzer designed for motor testing.

Notes: 9 pages, 12 figures. Read the full story…

Simple Circuits Prevent Servo Overloads

by Aznan Firmansyah, Dialog Semiconductor, West Java, Indonesia

Abstract: Servos are among the most used actuators in robotics. Some servos, especially unprogrammable servos, don't have overload protection. Consequently, a user will only find that the servo was overloaded after the servo has become noticeably burned. This article describes how to protect an unprogrammable servo from overload risk caused by mechanical problems using an SLG46140V GreenPAK, a configurable mixed-signal IC. There are two servo protection circuit designs that may be implemented with the GreenPAK. The first one uses an absolute value for a failsafe PWM that will be set when overload is detected. The second uses a delay block to increase or decrease the PWM duty cycle relative to the input when overload is detected. This article describes the operation and implementation of both designs and includes the necessary design files.

Notes: 10 pages, 12 figures. Read the full story…

Strategies For Pre-compliance EMI Testing Of Radiated Emissions

by Dylan Stinson, Tektronix, Portland, Oreg.

Abstract: Radiated emissions testing is done to ensure that any electromagnetic radiation from a product during normal operation falls below limits defined for that type of product. You can often avoid multiple unwanted trips to the test house and ill-timed product delays by measuring the electrical noise emitted from your product prior to going to the test house. Not only will this type of pre-compliance testing—which is easier and more affordable than you might think—increase your chances of passing EMC compliance testing the first time out, it can help you identify potential issues early on and reduce the need for last-minute product redesigns. This article discusses the types of equipment required for performing precompliance radiated EMI testing, and offers guidelines for making the test setups and measurements.

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

The Geometry Of Twisted Wire Bundles

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Windings having bundled strands are usually twisted to minimize the interbundle proximity effect. Twisting, however, affects both the bundle diameter and the winding length. This in turn affects window utilization of transformers for a given core as twisting affects packing factor and thus current density. This article derives design formulas for both bundle radius and winding length and for calculating the bundle skin effect. The effects of bundling (including sub-bundling) on proximity and skin effects are also discussed. Understanding the impact of bundle twisting on all of these factors will enable better optimization of transformer power transfer when twisting is applied in winding designs.

Notes: 8 pages, 3 figures, 1 table. Read the full story…

August 2018:

Adaptive Overpower Protection Prevents Overheating In Power Distribution Networks

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

Abstract: Hazardous energy levels can result when high current carrying conductors at different voltage potentials are bridged or shorted. In real applications a short-circuit resistance is not zero ohms, as assumed in theory. For a low-voltage dc power distribution network (PDN) with electronically limited current capacity, a comparatively large fault resistance may be considered the most critical: at high power ratings, it may be not low enough to activate the high-power source protection. As a result, hazardous energy will be dissipated in a typically small fault area and release excessive heat, smoke and potentially an exothermic reaction. This article describes a technique to prevent hazardous conditions in low-voltage high dc power distribution networks.

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

Boost Converter Optimizes Motor Performance In Battery-Powered Applications

by Jared Becker, Texas Instruments, Detroit, Mich. and Donald Schelle, Texas Instruments, Cambridge, Ont., Canada

Abstract: Portable, battery-based motor systems are becoming more prevalent in motor-based applications. But this poses a challenge to analog system designers as battery-based operation impacts the system performance of the motor. Motor speed is proportional to the voltage applied to the motor. As a system's battery voltage decreases over time, the speed of the motor inherently decreases. One common method to combat decreasing battery voltage involves boosting the battery voltage with a switch-mode power supply. This article presents a solution based on the TPS61175 boost converter IC for maximizing motor performance, while also minimizing battery leakage currents during low-power conditions—all without the need for a microcontroller. The example system discussed here consists of a 12-V, 1-W to 3-W motor powered off of 12-V system power, which is derived from 8 AA batteries.

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

Simple Solar Tracking Sensor Is Self-Powered

by Lazo M. Manojlović, Dialog Semiconductor, Zrenjanin, Serbia

Abstract: The solar tracking sensor plays a very important role in many solar power (photovoltaic) systems where it increases the overall system efficiency by directing the solar panels toward the sun. Using the signals obtained from the solar tracking sensor, a control loop rotates the panels toward the sun. This article presents a simple, reliable and cost effective sensor circuit design that is also self-powered. The circuit consists of photodetectors and an SLG88103 operational amplifier from Dialog Semiconductor. The photodetectors, which sense the solar radiation, also power the operational amplifier. So there is no need for an additional external power supply.

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

Optimizing Regulator Output Capacitance (Part 1): Selecting Load Slammers

by David Baretich, ProGrAnalog, Portland, Oreg.

Abstract: A common practice among engineers has been to lean on capacitors to ensure adequate power supply bulk decoupling. But with the recent supply chain constraints and significant increases in capacitor pricing, the reliance on large amounts of capacitance becomes less feasible. Consequently, it becomes critical that designers carry out sophisticated testing of their voltage regulator designs to achieve the required performance with the minimum output capacitance. This article series examines the use of transient load slammers in testing regulator designs to determine the optimum capacitance. Here in part 1, the author discusses the nature of the loads themselves, how that nature affects the voltage regulators, and what load unit features are relevant to adequately stimulate the required loads. The key parameters that should be considered when choosing a load slammer are explained.

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

September 2018:

Optimizing Regulator Output Capacitance (Part 2): Using Load Slammers

by David Baretich, ProGrAnalog, Portland, Oreg.

Abstract: The first part in this series introduced the topic of load slammers, explained what characteristics should be considered when selecting them and compared some of the available options for transient load testing of voltage regulators. This second part continues by discussing how to use load slammers effectively to design, evaluate, debug, and validate your on-board power source.

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

Dynamic Torque Measurement Reveals True Electric Machine Characteristics

by Mitch Marks, HBM Test And Measurement, Madison, Wisc.

Abstract: Mechanical power measurements of an electric machine are very important to help understand what the motor is doing at any given time and operating point. Mechanical measurements help characterize the motor, build up models for the machine, ensure confidence in controllers and understand the limits of the system. Torque accuracy and bandwidth are particularly important for designing a controller and implementing an electric motor solution. Since torque is not a static value, it is preferred to have a highly accurate averaged measurement. A high-bandwidth torque measurement is also needed to understand what happens instantaneously. This could be cogging torque for a steady-state operation, torque response during loading and even torque during control changes. This article demonstrates the capabilities of using a highly accurate and high bandwidth torque sensor, such as the T12HP, in combination with the eDrive power analyzer, to make various types of high-bandwidth torque measurements.

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

The Engineer's Guide To EMI In DC-DC Converters (Part 6): Mitigation Techniques Using Discrete FET Designs

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Parts 1 through 5 of this article series offer practical guidelines and examples to mitigate conducted and radiated electromagnetic interference (EMI), specifically for dc-dc converter solutions with monolithically integrated power MOSFETs. As a sequel to those earlier parts, this article explores EMI abatement in dc-dc regulator circuits that employ a controller driving a discrete pair of high- and low-side power MOSFETs. This article provides guidelines for laying out a multilayer PCB of a half-bridge design with MOSFETs and controller to achieve excellent EMI performance. The imperative is to minimize critical loop parasitic inductances by careful power-stage component selection and PCB layout. A layout example demonstrates that it's possible to reduce the generation of conducted electromagnetic emissions without sacrificing efficiency or thermal performance metrics.

Notes: 9 pages, 8 figures. Read the full story…

Optimizing Transformer Winding Design For Max Efficiency Over Output Current Range

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In previous articles on interwinding power transfer in transformers and coupled inductors, design formulas were derived for maximum power transfer having peak winding transfer efficiency, η_{max}, using the transfer voltage ratio, υ_p and the ratio of winding to effective core resistance, β_p. In this article, some extended development of power-transfer theory applies the additional constraint of holding the secondary current (i.e. the load current) constant as β_p is varied. The migration of the operating-point (op-pt) at η_{max} on one efficiency curve to another η curve at a different β_p under constant output current shows that as winding resistance is varied in design, the η op-pt can move to either side of the new η_{max}. As current is varied, the op-pt on a given η curve also moves and efficiency changes. A slight variation in current for op-pts to the right of η_{max} causes a large change in η, especially with low winding resistance (or β_p). This article analyzes and derives the theoretical optimal peak efficiency for a power converter when its load (and that of its transformer) spans a range and uses that information to design the transformer.

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

Isolation Standards Say Little About Isolator Performance

by Kevin Parmenter, Chair, and James Spangler, Co-chair, PSMA Safety and Compliance Committee

Abstract: There is confusion concerning which standards apply to the various types of optocouplers, optodrivers, and isolators used in gate drive and power supply circuits. How do these electronic devices meet safety rules and what are some of the differences between the requirements imposed by the different safety and regulatory agencies? There is also a general misconception that isolation standards set requirements for isolator performance beyond the input-to-output voltage isolation. And even though they are called out on isolator data sheets, they are not the main standards for most applications, but rather secondary standards that are referenced in other, application standards. In this article, the authors review the different isolator device types, identify some of the major isolation standards, and then discuss the requirements imposed on the different isolator device types.

Notes: 4 pages, 1 figure, 2 tables. Read the full story…

October 2018:

Energy-Based Efficiency Metric Helps To Optimize Server Power Delivery For Dynamic Workloads

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

Abstract: Server workloads are usually highly dynamic and often spikey. Designing a server power train with continuous power ratings equal to or even exceeding workload peak power levels is not always energy efficient and cost efficient. This article studies opportunities for power architecture optimization based on an efficiency metric that accounts for dynamic energy usage, introduces potential power delivery solutions, and discusses tradeoffs for corner cases.

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

Replacing Power Supply Output Capacitors Requires Equivalent Impedances

by Gregory Mirsky, Continental Automotive Systems, Deer Park, Ill.

Abstract: Very often designers have to replace a power supply's output filter capacitors with equivalent counterparts due to the obsolescence of the original parts or because the manufacturer has gone out of business. To maintain power supply performance, the replacement capacitors should provide the same voltage ripple across the load as the original parts did. Since the voltage ripple across a capacitor is a function of the capacitor's impedance, we have to create two equivalent series

schematics of the original capacitors and replacement capacitors and equate their impedances. To find the equivalent impedance of a number of parallel-connected capacitors of different chemistries, we have to find the resulting impedance of parallel-connected capacitors. In this article, we will solve this problem in symbolic form, enabling us to plug-in parametric values when necessary. After deriving the necessary formulas, we will demonstrate their use with a numerical example.

Notes: 6 pages. Read the full story…

Random PWM Quiets Noise And Reduces Emissions In Three-Phase Inverter Applications

by Aamir Hussain Chughtai and Muhammad Saqib, Dialog Semiconductor, Lahore, Pakistan

Abstract: Conventional pulse width modulation (PWM) methods for driving three-phase inverters have been found to produce some undesirable effects in industrial applications like the production of acoustic noise, radio interference, and mechanical vibration. Traditionally, these problems are solved by employing filters that can filter out the predetermined harmonic content and mitigate electromagnetic interference. However, in such applications, random pulse width modulation (RPWM) has been found more effective than traditional methods as it spreads the harmonic content over a wide frequency range, reducing the unwanted effects in three-phase-inverter-fed systems. This article provides details of RPWM signal generation for driving three-phase inverters using the SLG46620 configurable mixed-signal IC (CMIC). This solution provides a low-cost, space-saving alternative to DSP and FPGA implementations, while also simplifying coding requirements.

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

Optimizing Regulator Output Capacitance (Part 3): Analyzing Load Slammer Results

by David Baretich, ProGrAnalog, Portland, Oreg.

Abstract: In this three-part series, the previous installment discussed types of load testing that can potentially be performed with load slammers. In this last part, we show some scope plots of actual testing using a load slammer, along with commentary on what those waveforms can tell us. After describing the voltage regulator being used in our examples, we'll demonstrate measurements of the regulator's full step and release response, response at reduced slew rate, and output ringing. The analysis of these measurements should help to illustrate the benefits of load slammers. We conclude this series by explaining how slammers can help to address capacitor sourcing challenges and their value in supporting reuse of voltage regulator designs.

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

Wire Spool Holders And Toroid Mounts Ease Prototyping Of Magnetic Parts

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Two of the practical considerations in magnetic component construction are how to hold a spool of wire so that wire can be easily dispensed from it when constructing prototype parts and how to mount small toroids on circuit boards. This article offers tips on how to make prototype magnetic component construction less cumbersome.

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

HOW2POWER TODAY

Design Article Archive

Abstracts of articles published in the January through December 2018 issues

November 2018:

Driver IC Subdues Level-Shifting Losses In Active Clamp Flybacks And Other Applications

by Dhruv Chopra, ON Semiconductor, Phoenix, Ariz.

Abstract: ZVS topologies can eliminate switching losses associated with the power switch. For popular ZVS topologies like LLC half-bridge converters, full-bridge converters, active-clamp flybacks, two-switch forward converters, etc., low−side high−side drivers are needed to perform the function of buffer and level shifter. But there are inherent losses associated with power switch drivers. In topologies like LLC, half- or full bridge converters, which have a totem-pole structure of power switches, level-shifting losses of the high-side driver are significant. These losses become even worse at higher switching frequencies. In response to this need, ON Semiconductor developed the NCP51530, a 700-V high-side low-side driver for ac−dc power supplies and inverters with very low level-shifting losses. This article describes the application of the NCP51530 driver in a 60-W USB Power Delivery (PD) adapter design based on the active-clamp flyback.

Notes: 9 pages, 7 figures, 3 tables. Read the full story…

Configurable ICs Build Versatile, Low-Cost Regulated Charge Pumps

by Vladimir Veljkovic, Dialog Semiconductor, Belgrade, Serbia

Abstract: Many battery-powered IoT applications require additional voltage levels for powering specific interface circuits, sensors, etc. Under certain operating conditions, charge pumps provide simple, efficient solutions for generating the required supply voltages. While standalone charge pump ICs can be used, charge pumps can also be implemented using a GreenPAK configurable mixed-signal IC (CMIC), which offers several advantages. These include lower cost, smaller size, multiple outputs with the same IC, programmable operating frequency, control via a serial interface, lower quiescent current, and on-chip logic for additional functions. In general, a GreenPAK solution provides the flexibility to shift the design to meet system priorities. This article explains how to design regulated capacitive charge pumps using a GreenPAK CMIC and a few low-cost external components.

Notes: 16 pages, 15 figures, 2 tables. Read the full story…

Managing Pulse Top Decay Improves Accuracy Of Current Sensing Circuits

by Gregory Mirsky, Continental Automotive Systems, Deer Park, Ill.

Abstract: When a current transformer senses current in switched-mode power supplies and other applications, the current transformer and the associated burden resistor can alter the shape of the switching waveform as seen by the current sensing circuit. This change in the shape of the switching pulse can be described as pulse top decay and it degrades the accuracy of the current sense signal. This article quantifies the effect of the current sensing circuit on the pulse decay, providing guidance on how to properly determine the value of the burden resistor. This article also aims to show that the secondary side of a current transformer should provide the inductance energy discharge through a controllable voltage limiter, which ensures the zero volt-second integral of the current transformer.

Notes: 10 pages, 5 figures, 1 table. Read the full story…

Interbundle Penetration Of Wire Bundles Improves Their Packing Factor

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: When winding transformers or coupled inductors with twisted wiring bundles, turns of adjacent wire bundles are typically wound close-packed to maximize packing factor (and in particular, porosity packing) and ultimately maximize winding current density. Bundles of a small number of strands can pack together more closely than those with a large number of strands because of the sinusoidal variation in their outside diameter. This article examines the extent to which twisted wire bundles can penetrate each other by fitting into the dips in adjacent windings and thereby increase packing factor. This analysis quantifies the relationship between the number of strands in a twisted wire bundle and the extent to which one wiring bundle penetrates or "meshes with" the other.

Notes: 4 pages, 1 figure, 1 table. Read the full story…

December 2018:

Options For Optimizing PFC Efficiency Over Wide Load And Line Ranges

by Joel Turchi, ON Semiconductor, Toulouse, France

Abstract: This extensive article will first discuss the efficiency "nibblers"—the factors that degrade efficiency in power factor correction (PFC) stages. The impact on efficiency of these nibblers, relative to one another, is not the same at low, medium and full load and also varies with line voltage. Hence, it will be seen that the PFC stage cannot be operated the same way over all operating conditions when high-efficiency ratios are sought over wide line and load ranges. Instead, as discussed in the second section of this article, the controller algorithm needs to adapt the operating mode of the PFC stage to the line and load conditions. This is a multimode approach. In the third and final section, architectural aspects of PFC stages will be considered with a focus on the bridgeless and interleaved approaches. The merits of these solutions will be compared in a 300-W, wide input voltage application.

Notes: 22 pages, 21 figures, 2 tables. Read the full story…

Optimizing Thermistor Placement For Accurate Power-Plane Current Sensing

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

Abstract: The use of copper power planes or traces as current sensors does not require adding any components in the current path and thereby presents an attractive option for power monitoring. The impact of tolerances associated with their geometric (width and thickness) variations can be minimized with calibration. However, because copper trace and plane impedances are temperature dependent, such sensors also have thermal drifts that need to be considered. These drifts can be compensated through use a small surface-mount (SM) thermistor to sense the power plane temperature. However, in cases where the power plane has noticeable temperature variation across it, the question of where to place the sensor becomes important. This article explores a simple procedure to determine the optimum sensor location on the PCB, providing minimal temperature sensing error.

Notes: 7 pages, 4 figures, 1 table. Read the full story…

Need Uninterrupted Power? Let A Supercapacitor Come To The Rescue

by Bonnie Baker, Maxim Integrated, Tucson, Ariz.

Abstract: Disconnecting or removing the power source from always-on circuits creates a blackout event. When this occurs, it is possible to lose critical data. A supercapacitor or supercap can deflect a crash condition by providing a temporary backup current source. This sounds encouraging, but some of its characteristics can inhibit a smooth recovery. This article shows how to use a supercap as a real-world charge and discharge solution in a power backup application. In particular, the use of a boost function to overcome supercap voltage limitations and extract more of the supercap's usable energy is explained. Finally, an integrated design solution based on the MAX38888 backup power regulator is presented.

Notes: 6 pages, 5 figures, 1 table. Read the full story…

The Engineer's Guide To EMI In DC-DC Converters (Part 7): Common-Mode Noise Of A Flyback

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Parts 5 and 6 of this article series offered practical guidelines and examples to mitigate conducted and radiated electromagnetic interference (EMI) for nonisolated dc-dc regulator circuits. Of course, no treatment of EMI for dc-dc power supplies would be complete without considering galvanically isolated designs, as the power transformer in these circuits plays a significant role in terms of its contribution to overall EMI performance. In particular, it's crucial to understand the impact of transformer interwinding capacitance on common-mode (CM) emissions. CM noise is mainly caused by displacement currents within the transformer interwinding parasitic capacitance and the parasitic capacitance between the power switch and chassis/earth ground. This article specifically analyzes CM noise for the dc-dc flyback converter, since it is so widely used as an isolated power supply.

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

Proper Design of the Power Supply's Input EMI Filter Protects against Power Line Transients

by Kevin Parmenter, Chair, and James Spangler, Co-chair, PSMA Safety and Compliance Committee

Abstract: In this article, author James Spangler examines the standards that address a power supply's ability to withstand ac power line transients including those induced by lightning. He shares the results of his research on what standards apply and how they were developed. He then discusses the role that the EMI filter stage plays in providing protection against power line transients and how designers can determine whether changes or additions to this protection are required to meet the applications' requirements.

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