Design Article Archive

Abstracts of articles published in the January through December 2017 issues

January 2017:

Understanding Op Amp Dynamic Response In A Type-2 Compensator (Part 1): The Open-Loop Gain

by Christophe Basso, ON Semiconductor, Toulouse, France

Abstract: A compensator is an electronic filter tuned to make a control system fast and stable during dynamic operation. In most studies, the compensator is an active circuit built around an ideal op amp. If this approach suffices in low-bandwidth systems, nowadays power converters cross over at or beyond 100 kHz to ensure a transient response that is fast enough to limit the output voltage drop in spite of a small output capacitive bank. In these applications, calculations considering a perfect op amp no longer work and induce severe gain and phase distortions. However, by accounting for the effects of the finite open-loop gain and the two low- and high-frequency poles of the op amp on the compensator's response, you can select the right op amp without altering the gain and phase you need at crossover.

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

A Practical Primer On Motor Drives (Part 12): Variable Frequency Motor Drives

by Ken Johnson, Teledyne LeCroy, Chestnut Ridge, N.Y.

Abstract: To combine the reliability of an ac induction motor or permanent-magnet synchronous motor with the variable speed and precise torque control of a brushed dc motor, we use a complex electronic control. Such a control modulates the duty cycle of a pulse-width "digital" voltage signal applied to the stator winding(s) of the motor, and manages the period during which the digital pulse width's alternate polarity is controlled. By precisely controlling both the pulse-width durations and period, we achieve precise control of the applied stator voltage and frequency. The systems that provide these pulse-width-modulated (PWM) outputs and control capabilities are known as variable frequency drives (VFDs), variable-speed drives (VSDs), inverter drives, or, more commonly, motor drives. After a brief discussion of VFD uses, this section explains VFD operation including a discussion of VFD architecture and topologies.

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

Automotive Front-End Buck-Boost Regulator Actively Filters Voltage Disturbances

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: In most vehicles, a centralized passive circuit protection network consisting of a low-pass LC filter and TVS diode is used as a first line of defense for transient disturbance rejection. Automotive electronics located downstream from the protection network are then rated to survive up to a 40-V transient without damage. However, the cutoff frequency required of the LC filter to attenuate disturbances at low frequencies makes the required footprint and profile of the filter inductor and electrolytic capacitor undesirable. This article details an active filter implementation using a four-switch synchronous buck-boost dc-dc regulator with high power supply rejection ratio (PSRR) that offers a high-density and cost-effective solution. This approach eliminates the need for bulky passive filter components while simultaneously providing both battery voltage regulation and rejection of voltage transients.

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

Eddy-Current Effects In Magnetic Design (Part 4): Dowell's Formula

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: This article series began with a discussion of the skin and proximity effects as they relate to transductors (transformers and coupled inductors). It continued by converting ξ, the penetration or skin-depth ratio, to forms suitable for different wire shapes, so that real wire types can be analyzed using Dowell's equation. Here in part 4, we examine Dowell's equation to gain an understanding of how it illustrates the impact of skin effect and proximity effect at different frequencies by plotting wire resistance for different numbers of wire layers over frequency. This analysis will lead to some conclusions about where (in the frequency range) skin effect or proximity effect dominates, and how the physical winding of the transductor (spacing of turns and layers) affects the accuracy of Dowell's formula.

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

February 2017:

Understanding Op Amp Dynamic Response In A Type-2 Compensator (Part 2): The Two Poles

by Christophe Basso, ON Semiconductor, Toulouse, France

Abstract: In part 1 of this article, we have shown the impact of the operational amplifier open-loop gain AOL on the response of a type-2 compensator. Pushing the analysis further, a closer look at the magnitude and phase response of an op amp reveals the presence of two poles—one low frequency and one high frequency. While these poles can be neglected in low-bandwidth compensator designs, you must account for the distortion they produce when you need gain and phase boost in high-bandwidth systems. In this second part, we will see how to determine the transfer function of the type-2 compensator accounting for these poles and how they distort the response of the filter. As we will see, the op amp's poles and finite gain produce distortions in the gain and especially the phase characteristics of the compensator. Fortunately, these distortions can be minimized by appropriate selection of the op amp and we'll present a method for doing so.

Notes: 19 pages, 22 figures. Read the full story…

Fast, Simple Solenoid Driver Saves Power In Industrial Applications

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

Abstract: Conventional solenoid drivers have uncontrollable current decay arrangements. If a fast current decay is required, a higher supply voltage is used, which results in high power dissipation. Alternatively, an extra Zener diode may be connected in series with the solenoid recuperating diode. In that case a special external signal clamps the Zener diode during the driver active mode and releases it when its operation is necessary. Typically, a microcontroller is needed to control the Zener, which adds complexity. Or, if the Zener diode is connected on a permanent basis, the solenoid operates in a discontinuous conduction mode—this approach also dissipates a lot of power, creating heat and substantial EMI. To overcome these limitations, a new solenoid driver arrangement is proposed.

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

A Practical Primer On Motor Drives (Part 13): Motor Drive Control Architectures And Algorithms

by Ken Johnson, Teledyne LeCroy, Chestnut Ridge, N.Y.

Abstract: Part 12 began the explanation of how VFDs operate by describing their overall operation and architecture, dc bus link topologies, and pulse-width modulation techniques. In this part, the discussion continues with an introduction to the popular VFD control architectures and algorithms. There are three primary methods for achieving variable-frequency motor control: scalar V/Hz, six-step commutation (also known as trapezoidal control), and vector control. One may implement all of these methods in an open loop (few or no sensor feedback signals from the motor) or closed loop (significant sensor feedback required from the motor) with various algorithms. Each of these control methods will be explored here.

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

Phase Angle Regulation Versus Impedance Control: Which Offers Greater Control Of Power Flow On the Grid?

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

Abstract: Power flow control in electric transmission lines has long been attempted with the use of a phase angle regulator (PAR). But PARs have performance limitations. Two decades ago, a new impedance regulation method was attempted using a mostly power electronics-based controller called a UPFC. Although the UPFC was not commercially successful due to high cost and component obsolescence issues, experience with this technology led to the development of the Sen Transformer (ST). This article presents a comprehensive comparison of PARs and the ST, which will help utilities to make informed decisions when choosing power flow control solutions and may inspire power electronics engineers to develop more practical UPFCs.

Notes: 15 pages, 15 figures, 4 tables Read the full story…

Eddy-Current Effects In Magnetic Design (Part 5): Winding Design Optimization

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In part 4, Dowell's equation was presented. It provides a graphic way of determining winding loss for a given wire size and number of layers. Having that capability, we now progress to the problem of how to optimize wire size for minimum winding resistance. Given the two winding design parameters, ξ and M (with frequency, f given), the winding design goal is not to minimize F_R in itself but to minimize winding loss, $\overline{P}_w(\xi)$. To achieve this goal, we will transition from F_R to F_r, which is proportional to $\overline{P}_w(\xi)$. Whereas F_R is the resistance ratio with constant wire size and varying frequency, F_r instead has constant frequency with varying wire size. We can thereby find the optimal wire size using F_r. Ultimately, we will find there are two possible solutions for minimizing eddy-current effects—a low-ξ *solution* involving a smaller wire size and a high-ξ solution involving a larger wire size.

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

Design Article Archive

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March 2017:

Dealing With Nonlinear MOSFET Capacitances

by Sanjay Havanur, Vishay Siliconix, Santa Clara, Calif.

Abstract: Two major developments in MOSFET technology that enabled improvements in on-resistance were the trench gate, and the charge balancing structures. Originally developed for high-voltage devices that resulted in superjunction MOSFETs, charge balancing is now getting extended to lower voltages as well. While it reduces both R_{DSON} and all the junction capacitances dramatically, charge balancing makes the latter much more nonlinear. The effective stored charge and energy in the MOSFET is indeed reduced, and significantly so, but calculating these parameters or comparing different MOSFETs for optimum performance has become a rather complicated exercise. As a result, the conventional approach to understanding MOSFET parameters such as C_{OSS} and C_{RSS} is no longer valid. This article explains why and presents some guidance on how to better evaluate a MOSFET's performance within its operating environment based on principles of stored charge and energy.

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

Building An Average Model For Primary-Side Regulated Flyback Converters

by Yann Vaquette, ON Semiconductor, Toulouse, France

Abstract: Primary-side-regulated (PSR) controllers can reduce the size and cost of flyback-based ac-dc adapters by simplifying the feedback chain. These controllers are now found in a variety of applications and compete against existing optocoupler-based designs. This article will describe the main differences between a classical flyback converter with optocoupler and a PSR flyback. Then we will see how we can build an average model for the PSR flyback—one that includes a sample-and-hold network—and simplify it without impacting the transfer function. The transfer function will be evaluated and results obtained with Mathcad plots of the transfer function will be compared with simulations of the converter. Finally, the loop compensation will be plotted and calculations needed to adjust the phase margin detailed.

Notes: 19 pages, 27 figures. Read the full story…

A Practical Primer On Motor Drives (Part 14): Power Measurements On Distorted Signals

by Ken Johnson, Teledyne LeCroy, Chestnut Ridge, N.Y.

Abstract: Power conversion systems and drives do not output sinusoidal signals—they are PWM signals and they have high harmonic content. This high harmonic content can be thought of as a multi-vector system, with one rotating voltage vector and one rotating current vector (for each phase) for "N" harmonics, with each voltage and current vector system associated with a given harmonic having a unique phase angle. We cannot directly measure the phase angle between distorted voltage and current waveforms. We must use a digitally sampled waveform technique, as described previously, for accurate calculation of the power values for these waveforms. In this part we will discuss some additional considerations such as advanced cyclic period detection and display, harmonic filtering of power measurements, and the impact of line-to-reference voltage probing, which will aid in correct measurement of power.

Notes: 12 pages, 17 figures. Read the full story…

Eddy-Current Effects In Magnetic Design (Part 6): Winding Bundles

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: This article series closes with an additional design consideration when multistrand windings or *bundles* are used to reduce winding resistance because of eddy-current effects. Strands have an equivalent number of layers within a bundle and the layer value for use in the Dowell formula (and graphs) of the previous part 5 can be approximated from the number of strands with the same current polarity. This part derives the formula for that approximation, which allows calculation of the layer value, *M*, from parameters such as number of strands, strands per layer, and strand packing factor. Then, we delve into eddy current effects encountered in the special case of unibundle construction where primary and secondary strands are all twisted in the same bundle.

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

April 2017:

Using Duty Cycle To Detect Power Supply Overload (Part 1): Why It's Needed

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

Abstract: A majority of switching power supplies use sensing resistors to detect overloads and output shorts. At high output current a sense resistor value becomes comparable to the resistance of the board traces and wires as well as the diode bonding wire resistances, which reduces the overload detection circuit accuracy. If the power supply is made correctly, its feedback sensing node would be placed on or near the output terminals to efficiently compensate for the voltage drop across the printed board foil, inductor winding resistance, control MOSFET $R_{DS(ON)}$, etc. In this case, when the load current changes, the feedback loop commands the control PWM duty cycle to compensate for the voltage drop. At very heavy loads or shorts the feedback may increase the control PWM signal duty cycle to very high values. This effect is used in the proposed protection circuit.

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

Programmable Devices Implement Highly Accurate Optical Tachometer

by Bilal Ahmed, Silego Technology, Santa Clara, Calif.

Abstract: Hall Effect sensors are commonly used in tachometers, which measure the speed of a rotating object in RPM. While these tachometers are highly accurate over most of their operating range they are known to give false readings at low speeds. That's because at low speeds the vibration of the motor/rotational objects causes the magnetics-based Hall sensor to behave erratically. This article describes an optical contactless tachometer that achieves better accuracy at all speeds through the use of an infrared sensor. The design described here is based on three GreenPAK SLG46533V ICs. Described as a programmable mixed-signal matrix, the SLG46533V integrates a variety of functions including 18 GPIOs, four analog comparators, an 8-state asynchronous state machine, I^2C interface, and 25 combination function macrocells.

Notes: 13 pages, 7 figures, 2 tables. Read the full story…

A Practical Primer On Motor Drives (Part 15): Low-Pass And Harmonic Filtering Of Power Measurements

by Ken Johnson, Teledyne LeCroy, Chestnut Ridge, N.Y.

Abstract: Most power analyzers utilize an analog-to-digital conversion system to digitize the voltage and current waveforms, and then perform power calculations on each acquired cycle. By default, the instrument's analog bandwidth and digital sample rate combine to determine the maximum (full-spectrum) frequency of the acquired voltage and current signals, and thus the number of harmonic orders present in the power calculations. One may employ analog or digital low-pass filters, complex harmonic filters, or any combination of these, to achieve filtering of the acquired full-spectrum signals. This part explains how these different filtering options work and shows how they are configured on Teledyne LeCroy's Motor Drive Analyzer. Measurement examples of motor drive waveforms that have been processed using a discrete Fourier transform (DFT) digital harmonic filter demonstrate the impact of filter settings on calculated power values.

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

Magnetics Optimization (Part 3): Maximum Power Transfer Of Magnetics Circuit Model

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: The first two parts of this four-part article showed the inadequacy of primary- or secondary-referred circuit models of transductors (transformers or coupled inductors) for deriving the condition of maximum power transfer across windings. This third part introduces a more general yet simple circuit model, and from it derives the ratio of winding to core loss for which power transfer is maximum. This derivation is quite lengthy and before tackling that, this part presents an approximation of the winding loss to core loss ratio for maximum power transfer. This approximation is itself a practical result that designers can use to optimize efficiency of transformers and coupled inductors.

Notes: 16 pages, 10 figures. Read the full story…

May 2017:

A Practical Primer On Motor Drives (Part 16): Torque, Speed, Position, And Direction Sensing

by Ken Johnson, Teledyne LeCroy, Chestnut Ridge, N.Y.

Abstract: Depending on the application and the required complexity of control, a motor may be instrumented with or without sensors for detection of rotor speed and position, and the control system may be a closed-loop or open-loop design, depending on the application. In most cases, optimal operation of the motor by the variable-frequency drive requires some direct sensing of the motor operation (sensored) or control system calculation of these quantities from other known data (sensorless). A motor running in a sensorless mode in normal operation would likely still be instrumented during design testing, or instrumented differently. This part 16 discusses the different parameters that are measured in motor applications—namely torque, speed, and rotor shaft position—and describes operation of the various types of analog and digital sensors used to measure these

variables. This section also demonstrates various measurements of sensor outputs that can be performed using an instrument such as Teledyne LeCroy's Motor Drive Analyzer.

Notes: 20 pages, 30 figures. Read the full story…

Mixed-Signal Matrix IC Eases Control Of Three-Phase AC Systems

by Bilal Ahmed, Silego Technology, Santa Clara, Calif.

Abstract: This article will demonstrate how to control each phase of a three-phase ac system using a Silego GreenPAK SLG46140 programmable mixed-signal matrix IC. We will do this by turning on and off three TRIACs at precise time intervals that are synchronized with a corresponding ac phase. In the design presented here, the GreenPAK device controls three different-colored incandescent lightbulbs. Each TRIAC is turned on for a certain part of the ac sine wave, a technique called leading-edge cutting. This technique allows us to dim the lightbulbs by creating an ac PWM signal to reduce their duty cycle. This technique can also be used to control other types of loads. Although similar functionality could be achieved using multiple discrete devices, the GreenPAK IC enables a more integrated and compact design.

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

Using Duty Cycle To Detect Power Supply Overload (Part 2): A Practical Implementation

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

Abstract: Part 1 of this article introduced the concept of using the duty cycle of a power supply's PWM control signal to detect and protect the power supply against overload and short circuit conditions. The easiest way to carry out this idea is to compare the duty cycle of the signal created by the power supply controller to a reference duty cycle whose value corresponds to the overload condition. Here, in part 2 we will discuss how to design the needed circuitry. After explaining how the reference pulses are generated, we'll present a design example that illustrates how a phase-discriminator built on a D-flip flop can be used to compare the reference signal to the PWM control signal to detect a power supply overload condition.

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

Magnetics Optimization (Part 4): Minimization Of Transductor Power Loss

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: The previous parts of this series explained the shortcomings of existing transformer and coupled inductor (transductor) models for determining the condition of maximum power transfer through these devices and then derived a model that gives the ratio of winding to core loss for which power transfer (i.e. efficiency, η) is maximum. But maximum power transfer through a transductor is not the only design criterion. Another important form of optimization is the minimization of power loss, P_t. In this part 4, minimum-P_t optimization is derived and compared to maximum η to arrive at an overall optimization method.

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

June 2017:

Digital Controller Eases Design Of Interleaved PFC For Multi-kilowatt Converters

by Rosario Attanasio, Giuseppe Di Caro, Sebastiano Messina, and Marco Torrisi, STMicroelectronics, Schaumburg, Ill. and Catania, Italy

Abstract: In power supply applications requiring higher power up to and beyond a kilowatt, the design of power factor correction (PFC) boost converters using interleaved stages rather than a single stage becomes advantageous. However, the controller IC options that have been available to date have required specialized design and programming skills to implement PFC at the kilowatt level, while also imposing bandwidth limitations associated with digital control of the compensation loop. To overcome these difficulties, a new digital controller has been developed that is suitable for multi-channel interleaved PFC topologies operating in CCM. The operation and application of this IC are presented in detail in this article. Experimental results for a 3-kW three-channel interleaved PFC prototype show the suitability of the proposed approach and the benefits of combining digital and analog control techniques.

Notes: 23 pages, 26 figures, 1 table. Read the full story…

Development Tools Aim to Overcome Designers' Hesitation About SiC MOSFETs

by Levi Gant, Monolith Semiconductor, Round Rock, Texas, and Kevin Speer, Littelfuse, Chicago, Ill.

Abstract: Thanks to improvements in material quality and device maturity, additions to the supplier base, and falling prices, it is now generally accepted that wide-bandgap materials such as silicon carbide (SiC) will play a major role in the future of power electronics. However, some power converter designers remain hesitant to use SiC devices because it requires changes in the techniques used to design a power converter. To counter designers' hesitation, device suppliers are developing reference designs and demo boards. This article describes two of these tools and discusses the reductions in inductance and capacitance that can be achieved by raising the switching frequency over a range of power levels up to 5 kW.

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

Using Duty Cycle To Detect Power Supply Overload (Part 3): Accounting For A Variable Input Voltage

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

Abstract: Part 2 discussed the use of duty cycle as a means of protecting an SMPS from overload and the application of this method in a buck converter. It showed how to calculate a reference threshold value for a specific maximum load current. This works well for an SMPS operating with a constant input voltage. However, if the input voltage is not fixed, but varies within some range, then the maximum output current limit may require adjustment since the input and output power does not usually change. Thus, for a variable input voltage, the reference threshold voltage should change. This article describes a method for making this adjustment of the reference threshold value in a new circuit that may be used in combination with the one described in part 2.

Notes: 10 pages, 7 figures. Read the full story…

Magnetic Component Theory Is Simpler If You Grasp Reference Frames

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Engineers sometimes avoid the study or application of magnetics theory because it seems too abstract compared to the more familiar aspects of electronics. Magnetics theory as it applies to transformers and inductors is simpler to understand by categorizing the quantities involved as being related either to the circuit at the winding terminals or to the magnetic field inside the core. These categories are "frames of reference." This article explains the concepts of electrical or *circuit* and magnetic or *field* reference frames as they apply to inductors, transformers, and coupled inductors. The key parameters in the circuit and field frames of reference are identified and the relationships between them are described.

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

July 2017:

Boosting Efficiency, Reliability And Affordability Of EV-Drivetrain Power Modules

by André Christmann and David Levett, Infineon Technologies North America, El Segundo, Calif.

Abstract: As the markets for EVs continue to expand, suppliers must work to satisfy stringent end-user demands. In the private-car and commercial, construction and agricultural vehicles (CAV) sectors, these include longer driving range, increased ease of use, and greater reliability and safety assurances. Above all, electric motoring must be affordable, which demands minimizing the cost of new electric drivetrain technologies, all the way through to the module and component level. This article describes how improvements in IGBT device design and module packaging design associated with Infineon's EDT2 IGBT/diode chipset and its HybridPACK Drive package enable reductions in switching and conduction losses, greater ability to withstand thermal stresses, and use of smaller, lighter baseplates. In the targeted EV applications, these improvements can be leveraged either to create IGBT modules with smaller size or higher current rating.

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

Smart High-Side Switches Ease Safety Compliance For Industrial IoT

by Giuseppe Di Stefano and Michelangelo Marchese, STMicroelectronics, Catania, Italy

Abstract: IEC 62061 is the international norm that identifies the safety rules for industrial machinery. This standard defines the safety integrity level (SIL) concept as the safety requirements for a machine's safety control system, and the established time interval and conditions in which the assigned safety functions must be performed. To design the system according to the required SIL level, appropriate electronic components that allow the whole system to achieve functional safety must be used. Because of their embedded protection and diagnostic features, the IPS160H and IPS161H single-switch high-side drivers enable designers to realize functional safety in machinery more easily. This article describes the protection and diagnostic functionality offered by these ICs, and demonstrates their key functions.

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

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Optimize Power MOSFET Performance In Motor Drive Designs

by Nicholas Oborny, Texas Instruments, Dallas, Texas

Abstract: This article provides a look into several MOSFET properties and how they affect the performance of a motor drive design. For those familiar with MOSFET operation and three-phase motor drives, this article will be mostly a review of fundamentals. Parameters that influence MOSFET selection are explained, equations are given for calculating conduction and switching losses in the motor drive applications, and factors such as switching frequency and edge rates, which influence both switching losses and EMI, are discussed. Tradeoffs in the different performance factors and in performance versus device cost are noted. Finally, this article points to a gate drive IC with adjustable drive current architecture, which makes it easier for designers to assess the impact of higher MOSFET switching speeds and their parasitic effects in three-phase motor drive designs.

Notes: 7 pages, 5 figures, 2 tables. Read the full story…

Using Duty Cycle To Detect Power Supply Overload (Part 4): The Circuit Block Diagram

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

Abstract: In previous parts of this article we learned how a switching power supply's duty cycle can be used to trigger overload protection. In parts 1 and 2, we described the concept and a circuit implementation that is suitable for the case where V_{IN} is a relatively stable or unchangeable input. Then in part 3, we extended the concept to accommodate the more-complex case where the supply voltage may change within wide limits. While we described the techniques and circuits for implementing these two forms of duty cycle-based overload protection, we did not show how both of these forms of overload protection can be implemented in the same circuit. In this part 4, we provide a more-complete circuit implementation, presenting a buck converter in which overload protection circuits for both the fixed input voltage and wide ranging input voltage cases are included and are switch selectable.

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

Ferrite Core Magnetics (Part 1): Ungapped Ferrite Cores

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Ferrite cores have distinct characteristics from iron-powder cores, which leads to their usage in different power conversion applications with different requirements. These differences also dictate some different considerations when selecting and designing transformers with ferrite cores. This two–part article discusses the qualities of both ungapped and gapped ferrite cores, and techniques for achieving best results in transformer designs. This part 1 examines ungapped ferrite cores, which find optimal use in transformers. This article explains ferrite saturation and power-loss characteristics, and presents the outline of a method for optimizing transformer design with ferrite cores, with emphasis on the design parameter, γ, the ripple factor for the purpose of either maximizing core utilization or power transfer.

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

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August 2017:

Circumventing Loss In An RC Circuit Leads To More Efficient Power Converters

by Nihal Kularatna, University of Waikato, Hamilton, New Zealand; Kosala Gunawardane, Auckland University of Technology, Auckland, New Zealand; and Thilanga Ariyarathna, University of Waikato, Hamilton, New Zealand

Abstract: The charging of a capacitor in a simple RC loop incurs losses in the resistive portion of the circuit. However, the efficiency of the charging circuit varies widely with the initial voltage on the capacitor at the start of charging. If the capacitor in question is a supercapacitor, which results in long time constants, we can take advantage of this relationship between circuit efficiency and capacitor voltage to create novel ac-dc converters with improved efficiency. This article describes two novel ways in which the RC circuit can be combined with power converters to negate the resistive loss of the RC circuit. One approach replaces the resistive part of the circuit with a useful resistance such as a loaded dc-dc converter or voltage regulator. The other approach places a supercapacitor ahead of a linear voltage regulator as a lossless voltage dropper.

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

Receiver Chip Implements Efficient, Flexible Wireless Charging For Wearables

by Scott Kim, Nazzareno (Reno) Rossetti, Raymond Park, Maxim Integrated, San Jose, Calif.

Abstract: Wireless charging is the next big wave in portable electronics. But the field is still young, with competing technologies and no definitive standard. Like other critical blocks for portable gadgets, the wireless power receiver must utilize minimal space while operating on a single charge for a long time. Accordingly, the receiver must be very small, highly efficient, and compliant with multiple standards. This article discusses the challenges of designing an inductive charging wireless power receiver in today's climate and introduces an innovative wireless charging solution based on the MAX77950 wireless power receiver IC. This device incorporates features that improve efficiency while accommodating both WPC and PMA protocols. The IC also enables wireless power transfer to a peer device.

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

A Guide To Selecting Industrial Battery Chargers For Material Handling Applications

by Jeff Harrison, AMETEK Prestolite Power, Troy, Ohio

Abstract: Specifiers of industrial battery chargers need to understand how the requirements of their particular application influence the choice of charger type. This article outlines the key considerations including what questions need to be asked, and describes at a high level the differences between the three major charger technologies—ferroresonant, high-frequency and SCR. In addition to providing an overview of the internal power supply technology found within these chargers, this article also calls out some of the typical charger specifications. Furthermore, it introduces the concept of opportunity charging. While this article is aimed primarily at specifiers of industrial battery chargers, it may also be useful to novice designers of these chargers.

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

Ferrite Core Magnetics (Part 2): Gapped Ferrite Cores

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Gapped ferrite cores are used to store transfer energy, as are iron powder cores. Yet they differ in important ways. This article describes how the differences affect the design of inductors, transformers and coupled inductors, and how transfer power is maximized for high-ripple cores. Transformer optimization results from part 1 are also derived from the standpoint of large-ripple design. We begin by explaining how calculation of the operating point H differs for ferrite gapped cores versus powder cores, and how to find the operating point and the saturation limited turns for gapped ferrite cores.

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

September 2017:

Control Method For Quasi-Resonant Flyback Converters Achieves Unity Power Factor With Zero THD

by Claudio Adragna and Giovanni Gritti, STMicroelectronics, Agrate Brianza, Italy

Abstract: The high-power-factor (Hi-PF) quasi-resonant (QR) flyback converter is a popular choice in cost-sensitive applications like solid-state lighting because it achieves two objectives using a single conversion stage: compliance with harmonic current emission regulations such as IEC61000-3-2 and the generation of a bus voltage isolated from the mains. But with the conventional control scheme, the primary current flows only during the on-time of the power switch, making it difficult to meet the THD spec required in some areas. This distortion can be prevented if the flyback is operated with a fixed switching frequency in DCM, but then some benefits of QR operation are lost. This article describes in-depth a novel control method that achieves the advantages of QR operation yet obtains a sinusoidal input current.

Notes: 18 pages, 13 figures, 3 tables. Read the full story…

Rapid Prototyping Platform Eases Development Of Grid-Connected Converters

by Stevan Grabić, PERUN Technologies, Novi Sad, Serbia

Abstract: For a single development platform to provide rapid prototyping of power electronics, it needs to satisfy several HW and SW design criteria. On the circuit side, the power stage HW needs to be maximally reconfigurable to accommodate different topologies and application-specific demands while the control stage must be open access, i.e. reprogrammable. The accompanying SW toolset has to provide plug-and-play functionality for all application-specific components. It also has to support rapid prototyping development of control code and provide all necessary manipulation and testing resources including scope and debugging tools. Additionally, the system must address all functionality, safety and design challenges. This article describes the characteristics of the LARA-100 platform that enable it to serve as a comprehensive solution for rapid prototyping development and validates the platform in a grid-connected converter application.

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

Cut Your Losses–With an Active Diode

by Nazzareno (Reno) Rossetti, Steve Logan and Stuart Smith, Maxim Integrated, San Jose, Calif.

Abstract: The popular use of an ORing function—the electrical connection of two or more power sources, which ensures that when one fails, the other intervenes—has made the Schottky diode the component of choice for most implementations. But in low-voltage applications, the supposedly low dropout voltage of the Schottky is not so low after all, causing high-power losses compared to the rest of the electronics. The Schottky's reverse leakage current is also a concern, as it can drain the main power source, and try to charge a nonrechargeable battery. This article reviews ORing techniques used to switch between two power sources in four popular low-voltage applications, and introduces a monolithic solution—the MAX40200 ideal diode IC— which overcomes the limitations of the existing techniques.

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

A New Method Of Winding Design Optimization (Part 1): Window Geometry And Eddy-Current Plots

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: This article series presents new advances in the simplification and refinement of winding design, and also its conceptual extension into new territory. At first, winding design seems unduly complicated by fields equations and winding geometry. However, the right paths through the mathematics can greatly simplify the derivation of algebraic design equations that can then be used with a calculator. The article begins by reviewing the use of Dowell-equation graphs to minimize winding losses due to eddy-current effects in transformer and inductor design through selection of wire size, number of strands per bundle, and indirectly, the number of winding layers. The rest of the article then discusses how these three parameters are constrained while attempting to minimize winding resistance. It also analyzes how holding certain factors constant such as winding area, number of strands, and number of strand layers affects the choice of operating points on the Dowell-equation graphs.

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

Power Supply Standards: Which Ones Apply In Your Application?

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

Abstract: When an engineer begins a program, one confronting issue emerges—which standards or regulations must the product meet? The number of potentially applicable standards is quite large, covering a range of issues including safety, energy efficiency, electromagnetic compatibility, material toxicity and environmental considerations. In many instances, multiple standards apply, are sometime conflicting, and are often changing. These challenges motivated creation of the PSMA's Safety and

Compliance database. As co-chairs, authors Kevin Parmenter and James Spangler oversaw the development of this database and now coordinate efforts to maintain up-to-date information on the standards. In writing this new monthly column, they aim to help inform power supply and power system designers of changes to the standards that may affect their designs, as well as information that may help designers overcome compliance challenges. Here in this first Spotlight on Safety & Compliance Column, Kevin and Jim take readers on a tour of the database.

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

October 2017:

Modeling The Input Step Response Of A Power Converter

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

Abstract: Conventional methods of defining power converter stability are based on the analysis of the frequency response of the unlocked feedback loop. This is a straightforward way of obtaining the gain and phase margins, and says something about how the converter will respond to a load step, but says nothing about how the power converter output reacts to an input voltage step. Knowledge of the control system reaction to the input voltage step is extremely important because it allows the designer to immediately define whether the power converter will work correctly or not. This can be done by obtaining the closed-loop system response to an input voltage step. The derivation of the needed transfer function is described here for the familiar buck converter.

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

Thermocouple And Conditioning Circuits Enable Accurate Temperature Monitoring Over Wide Range

by Robin Yang, Microchip Technology, Chandler, Ariz.

Abstract: Accurate temperature measurement over an extensive range has attracted increasing interest in various engineering applications such as industrial thermal management and hazardous environmental monitoring. To achieve precise calculations over the entire temperature range, both the sensor and the signal conditioning circuit must be meticulously adapted and adjusted. This article presents an analysis of the key factors that have the most significant impact on the accuracy of temperature measurement, and offers technical solutions to guarantee an accurate and cost-effective thermocouple-based temperature monitoring device. The article compares the four common types of temperature sensors (thermocouples, thermistors, resistive thermal detectors and temperature sensor ICs) with a focus on thermocouples including techniques for mitigating their sources of error. Finally, this article discusses the operation of a sensor conditioning IC, the MCP9600, which integrates the various functional blocks needed to convert a thermocouple's EMF to a temperature reading in Celsius.

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

A New Method Of Winding Design Optimization (Part 2): Optimal Window Magnetic Operating Points

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In part 1, the influence of various winding design parameters on eddy current effects was analyzed and expressed as F_r. the constant-frequency resistance ratio for wire strands. However, for actual design purposes, what's needed is a version of this resistance ratio that applies to the bundles of strands that comprise the winding turns. This parameter is known as f_r and in this part the author presents two methods for achieving minimum f_r in winding designs. The first method is a graphical approach in which Dowell's equation is expressed as f_r and plotted under different design constraints such as constant number of layers, constant number of strands, and constant area. The graph is then used to identify ξ_r operating point (op-pt) values. The second method derives design formulas that can be used to calculate the ξ_r op-pt values. Finally, a winding design procedure is described that makes use of the op-pt formulas.

Notes: 11 pages, 2 figures, 1 table. Read the full story…

Understanding LISNs Is Essential To EMI Pre-Compliance Testing

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

Abstract: A line impedance stabilization network (LISN) is a circuit used for testing power supply line conducted emissions produced by either a power supply or some other type of product that contains a power supply. The network is inserted into the power supply lines to determine if the product is emitting unwanted high frequencies that will interfere with other products plugged into the same outlet or power source. Since there are multiple standards that require conducted emissions testing, if you are designing power supplies, chances are you'll need to meet some of these requirements and you'll need to know enough about LISNs to perform pre-compliance testing of your product. The same may be true even if you're applying someone else's power supplies in your system designs. In this column, the authors explain the basics of how LISNs work and are used, identify some of the applicable standards, and then analyze the differences between the LISNs specified by two FCC standards to help engineers understand when these differences affect testing and when they don't.

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

November 2017:

EMI For Wisdom Seekers: (Part 1): What New EEs And MEs Need To Know

by Patrice Lethellier, Noizgon, Salt Lake City, Utah

Abstract: Much has already been written on the subject of EMI/EMC. Is another primer on the subject really needed? Yes! First of all, new EEs are always coming into the field for whom EMI/EMC is a new subject. But there are also many non-EEs who need basic knowledge of this subject, in particular the mechanical engineers (MEs) who design the packaging for power converters, supplies or systems. The impact of their work on EMI performance becomes especially significant at higher power levels. Yet so often these MEs do not receive adequate guidance from the EEs and the packaging design wreaks havoc on the system's EMI performance. So this EMI primer is written with both the novice EEs and the MEs in mind. It is hoped that experienced power electronics designers, who already know the subject well, will also read this material and use it as a tool for educating their mechanical engineering colleagues. To explain why packaging design is so critical to EMI performance in high-power applications, this article discusses how designing high-power power electronics differs from designing low-power power electronics.

Notes: 4 pages. Read the full story…

Configurable IC Implements Low-Cost Class D Audio Amplifier For IoT Devices

by David Riedell, Dialog Semiconductor, Santa Clara, Calif.

Abstract: In the consumer market, there are numerous battery-powered devices containing buzzers and inexpensive speakers and with the growth of the internet of Things (IoT) we can expect to see more such devices. Because battery runtime is critical in such applications, many of these devices could benefit from the high efficiency of class D audio amplifiers. Typically, sound quality is not a concern in the targeted applications, but issues such as design size and cost are important. As the author explains, GreenPAK configurable mixed-signal ICs are ideal solutions for such applications because they allow designers to implement various custom functions in a tiny IC. In this article, the author uses a GreenPAK SLG46140 to create a simple, low-cost class D audio amplifier that is small in size. Because just a portion of the chip's resources are required to build the amplifier, it has the added benefit that other functionality and glue logic can be implemented within the same chip, providing additional space and cost savings.

Notes: 10 pages, 14 figures. Read the full story…

A New Method Of Winding Design Optimization (Part 3): Magnetic Operating Points For Toroidal Windings

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In part 2 of this article, the magnetic operating points (op-pts) useful for winding design were identified and derived for linear layering (constant turns per layer, N_l). To complete the set of winding design formulas, corresponding equations for toroidal windings are included in this part 3. They are similar to those for linear layering, but are constrained by $\hat{M}$, the maximum number of layers for a toroid, and wire insulated radius, r_{cw}. These design formulas are also harder to derive, and though the reader is spared much of the math, the resulting formulas presented here require more calculator button-pushing. Yet even for toroids, an optimal winding design can be achieved using a calculator. The equations are, of course, also suitable for a computer math program such as Mathcad or Matlab.

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

December 2017:

High-Power Wireless Charging Of Heavy Duty EVs: Techniques, Challenges And Limitations

by John M. Miller and John Wolgemuth, Momentum Dynamics, Malvern, Penn.

Abstract: Commercial high-power wireless charging equipment for light duty (LD) electric vehicles (EVs) has been available for several years. Suppliers now offer wireless EV supply equipment in power ratings from 3.7 kW to 11.1 kW, and up to 22-kW developmental systems that are designed per SAE

J2954. Also in development is a sister standard, SAE J2954/2 Wireless Power Transfer of Heavy Duty Plug-In Electric Vehicles and Positioning Communication, which addresses wireless charging up to 200 kW. This article evaluates the practical and safety related limitations to high-power WPT, especially for heavy duty (HD) vehicles such as shuttle and transit bus, material handling, truck, rail, aerospace and marine types.

Notes: 20 pages, 15 figures, 5 tables. Read the full story…

EMI For Wisdom Seekers (Part 2): Keeping It Simple

by Patrice Lethellier, Noizgon, Salt Lake City, Utah

Abstract: In part 1 of this series, we explained why mechanical designers need an understanding of electromagnetic interference to create standards-compliant mechanical designs for high-power power electronics and how high power designs differ from low power designs. Here in part 2 we turn to the main focus of this series—explaining the causes of EMI and how to minimize its generation. EMI is considered to be a difficult subject but it is not unsolvable or impossible to understand. EMI is not incompatible with conventional packaging wisdom. It is not something exclusive. It is possible to optimize a packaging design for both mechanical and electrical considerations. Nevertheless, the causes of EMI must be addressed at the beginning of the design as it may be almost impossible to implement the necessary changes down the road.

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

The Engineer's Guide To EMI In DC-DC Converters (Part 1): Standards Requirements And Measurement Techniques

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Although the emergence of faster-switching power devices for dc-dc converters provides an opportunity for increased switching frequency and smaller size, the higher switch voltage and current slew rates that occur during switching transitions often exacerbate EMI, causing problems in the overall system. For example, the high-switching speed of GaN power devices can raise EMI by 10 dB at high frequencies. EMI filters are inevitably part of a power electronic system, but since filtering adds unwanted size and cost, it's incumbent on the power designer to focus on system EMI noise reduction and mitigation. This article, the first in a multipart series on EMI, reviews relevant standards for both industrial and automotive end equipment. This part also explains the associated measurement techniques with an eye toward pre-compliance testing. The focus here and throughout the series is mainly on conducted emissions.

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

The Next Stage Of The Design Specification For Production: Energy Efficiency

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

Abstract: This article is written to supply information on energy efficiency standards, which may be needed to complete the design of your product. Marketers and anyone who creates new product specifications need to review the energy efficiency specifications, before sending the document(s) to the engineering department. Many of these rules, regulations, guidelines, etc. will require additional engineering design time and testing time prior to sending the product to the qualifying test lab for approval. In this article, we introduce a specialized, free energy efficiency database that engineers can access to determine which energy efficiency requirements apply in their power supply or end equipment applications and also to keep up-to-date on changes in these requirements.

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