Design Article Archive

Abstracts of articles published in the January through December 2016 issues

January 2016:

Tips And Tricks For High-Speed, High-Current Measurement

by Grant Smith, Texas Instruments, Santa Clara, Calif.

Abstract: Accurate high-speed, high-current measurement is a key requirement for power supply designers. Today's 1200-V, high-current SiC FETs are capable of switching on and off in as little as 5 ns. Changes in current over the change in time (di/dt) can exceed 10 A/ns, and peak currents ca n exceed 100 A. Complicating matters further are the space restrictions that stem from use of the higher switching frequencies supported by SiC transistors. So, current measurement circuits embedded in high-frequency SiC-based power converters need to be as small as possible. This article describes requirements for measuring current in SiC-based power converters, discusses two measurement options—current transformers and current-sense resistors—and gives tips for applying them. Finally, it presents two high-speed, high-current current measurement circuits using current-sense resistors and wideband differential amplifiers.

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

Modeling The Effects of Leakage Inductance On Flyback Converters (Part 3): The Small-Signal Model

by Christophe Basso, ON Semiconductor, Toulouse, France

Abstract: In the final part of this article series, the author studies the small-signal response of the CCM flyback converter operated in voltage mode as affected by the leakage inductance. The large-signal model of this converter, which was introduced in part 2, is transphormed or *linearized* in a step-by-step process into a simplified small-signal model. From this final circuit, the author extracts a control-to-output transfer function that shows how the leakage inductance affects the quality factor of the transfer function's denominator.

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

Optimal Switch Timing Circuits (Part 1): The Relationship Between Switch Timing And Available Energy

by Ernie Wittenbreder, Technical Witts, Flagstaff, Ariz.

Abstract: One of the important benefits of leakage inductance is its use in realizing simple, single-magnetic isolated soft-switching converters. In these converters, leakage inductance provides the energy needed for soft switching. But to achieve soft switching over a broad range of line and load conditions an adaptive switch timing circuit is necessary. In part 1 of this article series, the author describes switch timing issues and the relationship of switch timing to stored energy. This lays the groundwork for a discussion of adaptive switch timing circuits in part 2.

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

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Medical AC-DC Power Supplies Are Becoming More Specialized

by Ron Chiang, Enargy Power, Shenzhen, China and Todd Hendrix, Enargy Power, San Ramon, Calif.

Abstract: In the past, medical ac-dc power supplies were primarily defined by creepage and clearance requirements, which were imposed to achieve lower leakage and greater isolation safety as a means to protect both the operator and patient. Soon medical power supply performance will have to be even more differentiated. That's because the requirements are being upgraded to reflect changes in the way that health care is delivered. Many procedures and treatments that were here-to-for provided in controlled environments with professional medical supervision, like hospitals and physicians' offices, are increasingly moving into the home and other non-classical sites. The new 4th edition IEC/EC/UL 60601-1-2 standard released in 2014 addresses these changes as explained here by the authors.

Notes: 3 pages, 2 figures, 1 table. Read the full story…

Power Transformer Design Simplified—Really!

by Martin Kanner, KEMCO, Power Controls Div., Plainview, N.Y.

Abstract: Many engineers who have had formal training and/or experience in the field of electrical engineering, including magnetics, may draw a blank if asked this simple question: how big is a 15-W, 60-Hz transformer? And if asked to design that transformer for a 115-V ac input and an output of 15 V ac, the same individuals might respond "what for, I can simply pick it out of a catalog." As the author explains, this article does not intend to instantly make the reader a magnetics expert. Instead, it aims to provide non-magnetics specialists with a more fundamental understanding of the power transformer so that they can better interface with the specialists and not shy away from an ideal application of a transformer.

Notes: 5 pages. Read the full story…

February 2016:

A Practical Primer On Motor Drives (Part 1): What New Design Engineers Need To Know

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

Abstract: Many excellent textbooks have been written on the subject of motor drives. But most of these require prerequisite knowledge and/or are difficult sources of basic understanding for newcomers. While there is also useful information on the internet, such material is typically aimed at narrow applications or specific products and markets. In addition, many of the public domain materials lack "real-world" examples that are vital to gain a full understanding of the topic. Both textbooks and the internet are more useful references given a broad overview. This extensive article series aims to provide such an overview by explaining the basics of a motor drive from the input signals (ac line inputs) through motor shaft sensing (mechanical power) and all relevant areas in between. It targets newcomers to these fields desiring a broad overview before seeking deeper technical information from other sources. Part 1 offers an introduction to this series including an outline of the topics that will be addressed in the upcoming parts.

Notes: 4 pages. Read the full story…

How It Works: The Current Doubler Demystified

by Bob Zwicker, Consultant, Olympia, Wash.

Abstract: The current doubler is a particularly useful rectifier configuration for low-voltage or high-current outputs. It combines two advantages—efficient usage of the transformer secondary winding (like a bridge rectifier) and easy self-drive of two n-channel MOSFET synchronous rectifiers (like a full-wave center tap). It has the disadvantage of needing two inductors, but because the transformer is usually more critical, this tradeoff is usually favorable. However, some engineers may be confused as to how the current doubler works. Fortunately, there are similarities between the current doubler and the dual-phase buck converter. In this article, an analogy with the dual-phase buck converter is used to explain how the current doubler operates.

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

Optimal Switch Timing Circuits for Soft-Switching Converters (Part 2): Circuits for Different Switch Functions

by Ernie Wittenbreder, Technical Witts, Flagstaff, Ariz.

Abstract: In part 1 of this article series, the need for adaptive switch timing in soft-switching circuits was explained. Here in this second and final part of the article, the author describes circuits that can be used to accomplish optimal switch timing. Requirements differ to some extent depending on what a switch is being used for. For example, optimal switch timing for a main switch is different than optimal switch timing for a clamp switch and from that required for a synchronous rectifier. The author explains the various switch-timing problems that need to be overcome and the circuit solutions that might be applied in each case.

Notes: 13 pages, 14 figures. Read the full story…

Custom UPS Software Allows Greater System Control For Pipeline Clients

by William Fox and John Ely, AMETEK Solidstate Controls, Columbus, Ohio

Abstract: Customization is nothing new to most UPS manufacturers, but developing an entire new line of products to meet the special needs of a customer in a particular field is not a common practice. That was the case recently when the authors' company tailored a UPS software package to meet a customer's rigorous specifications and ended up with new hardware, software and system design suitable for widespread use. Specifically, custom software was developed to address system failures in the remote pumping station of an oil pipeline. This article presents a case study in how the problem was diagnosed and the types of diagnostic and control features that were implemented in the UPS software to prevent the problem from recurring in the future.

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

Four-Terminal Inductor Achieves High-Accuracy Current Measurements For POLs (Part 1): Inductor Design

by Ron Vinsant, Vishay Siliconix, Santa Clara, Calif.

Abstract: This is the first of a three-part series which will discuss the application of a single-phase synchronous rectifier that is capable of high currents and high efficiency combined with a four-terminal inductor used for sensing output current. This combination results in a simple, small, highly efficient point of load regulator (POL). The focus here will be on current accuracy. The four-terminal inductor is based on a novel construction that allows a close tolerance on DCR and little drift with temperature. These performance parameters are utilized by the POL regulator's A-D converter to allow a highly accurate read back of output current that maintains its accuracy over temperature and time. In this first segment of the series, the four-terminal inductor and its use in measuring current are discussed.

Notes: 10 pages, 18 figures. Read the full story…

March 2016:

Clearing Up Confusion About GaN Power Transistors (Part 1): Marketer, Scientist Or Engineer—Who Should You Believe?

by Carl Blake, Transphorm, Goleta, Calif.

Abstract: This two-part article series is a response to questions raised by experienced and knowledgeable power circuit designers who were confused by the apparently contradictory information that has been published about gallium nitride (GaN) power devices. This article is not a detailed analysis of all of the existing literature. Rather, it's an attempt to offer some guidance to design engineers that may help them separate fact from fiction as it applies to their design applications. Here in part 1 of this article, the author explains the importance of boundary conditions in evaluating published research on GaN. Design engineers tend to assume that many of the boundary conditions used in research articles are consistent with those used within a specific industry segment. But in reality, they can be quite different whether the source of the testing or publication comes from academia, industry or a government research laboratory.

Notes: 5 pages. Read the full story…

A Practical Primer On Motor Drives (Part 2): Single-Phase AC Line Voltage

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

Abstract: This article series explains the basics of motor drives from the input signals (ac line inputs) through motor shaft sensing (mechanical power) and all relevant areas in between. It targets newcomers to these fields desiring a broad overview before seeking deeper technical information from other sources. Here in part 2 of this series, concepts relating to ac line voltage are explained, starting with a broad discussion on voltage, current and power, leading to a more detailed discussion on single-phase ac line voltage.

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

Design Article Archive

Abstracts of articles published in the January through December 2016 issues

Improving Loop-Gain Performance In Digital Power Supplies With Latest-Generation DSCs

by Alex Dumais, Microchip Technology, Chandler, Ariz.

Abstract: In a digital power supply unit (PSU) there are several factors that impact loop-gain performance that are specific to the microcontroller. These factors include maximum sampling rate, time required to execute compensator algorithm(s), sampling/conversion time of the analog-to-digital converter (ADC), and microcontroller operating speed. For converters employing peak-current-mode control, the speed of the comparator and the accuracy/speed of the control digital-to-analog converter (DAC) will also have an impact on the PSU loop-gain performance. All of these factors need to be considered when selecting a microcontroller for a given application. This article examines how the dsPIC33EP 'GS' series of digital signal controllers can help improve loop-gain performance for the next generation of power supplies.

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

Vertically Stacked MOSFETs And Other Tricks For Building A High-Density 30-A Point-of-Load Regulator

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: This article tackles the challenge of fitting numerous dc-dc regulators onto a dense system motherboard to power various high-current loads. One solution lies in a point-of-load regulator (POL) module that is designed to parallel stack onto a system motherboard in a mother-daughter configuration. This article delves into an example of a modular POL implementation with high density that provides 30 A of output current. This design uses 3D-integrated MOSFETs, an efficient shielded inductor, ceramic capacitors and voltage-mode controller with integrated gate drivers. High density (200 A/in^3) and a sub-$5 bill-of-materials cost are the main tenets of this design. The circuit schematic, board layout and experimental waveforms are provided, and relevant features of the major active and passive components are outlined.

Notes: 8 pages, 6 figures, 4 tables. Read the full story…

This Misconception About Power Integrity Can Cost You Big

by Steven M. Sandler, Picotest, Phoenix, Ariz.

Abstract: Many power supply engineers mistakenly believe that power integrity (PI) is mainly a system-level issue and not a concern for the power supply design. But the reality is very different. If you're developing power solutions while working under this misconception, the resulting problems can be both hard to find and intractable to fix. When power integrity problems occur, they can cost your company big bucks and significant schedule delays. Ignoring PI issues when developing voltage regulators or when designing them into systems can lead to malfunctioning designs, time consuming design iterations and board spins to fix problems, stoppages in production, and other costly scenarios. These problems can be avoided if designers of voltage regulators, designers of the power distribution networks (PDNs) that carry the power and designers of the circuits that use the power take time to consider the impact that these power generating circuits will have on PI in the intended applications.

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

Design Article Archive

Abstracts of articles published in the January through December 2016 issues

April 2016:

Beware Of Zero-Voltage Switching

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

Abstract: "High frequency? No problem! We do resonant switching" is an often heard mantra in the design of power converters today. Zero-voltage switching (ZVS) is considered the panacea for all the challenges posed by high frequency and higher efficiency requirements. While ZVS is indeed a blessing, designers need to be aware of its limitations and also watch out for a whole range of traps in the implementation. And while there is an enormous amount of literature on how to implement ZVS, very little has been written from the perspective of the device that is actually doing the switching. In this article the author looks at zero-voltage switching from the MOSFET's point of view.

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

A Practical Primer On Motor Drivers (Part 3): Three-Phase AC Line Voltage

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

Abstract: In part 2 of this article series, the focus was on distribution and measurement of single-phase ac voltages. Now, in part 3, the discussion continues with details on the distribution and measurement of three-phase ac voltages. Most of this discussion simply reframes the concepts and techniques discussed in part 2 on single-phase waveforms as they apply to three phase. However, this part 3 article extends the discussion with a section explaining the utility voltage classes as defined by ANSI/IEEE and other organizations. Some differences in voltage classes between the U.S., Canada and Europe are noted and some related measurement implications are discussed.

Notes: 10 pages, 13 figures. Read the full story…

Clearing Up Confusion About GaN Power Transistors (Part 2): Proving Power GaN Reliability

by Carl Blake, CBK Market Consulting, Fountain Valley, Calif.

Abstract: In part 1 of this series, the author explained how different sources of published information about GaN technology seem to offer contradictory information to the design engineer. By comparing academic and industry approaches to research, he argued that presenting unclear boundary conditions can confuse the engineer who might be coming to the research with different assumptions. In this second part of the article, the author uses a paper by Transphorm as an example of how a company can apply scientific research on GaN power transistors to prove the reliability of its devices.

Notes: 11 pages, 7 figures, 1 table. Read the full story…

Gate Driver ICs Enable Higher Efficiency In Air-Conditioning Systems

by Nagarajan Sridhar, Texas Instruments, Dallas, Texas

Abstract: The advent of VFD and PFC circuits in air conditioning systems creates specific requirements for power controllers, gate drivers and power switches. Gate drivers in particular play an important role in achieving superior performance and efficiency in these applications. In addition to supporting design for high efficiency, gate drivers must be sufficiently robust to handle the harsh environments and noisiness in air conditioning systems. In this article, the author discusses the types of gate driver ICs that are available for use in modern-day air conditioners. The application focus here is on the split air conditioners used in residential and commercial applications, specifically on the PFC and VFD power stages found in the outdoor units.

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

Sizing Your Power Converter's Magnetics (Part 1): Inductor Power Rating With Fixed Input Voltage

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: When designing inductors and transformers for PWM-based power converters, engineers may rely on published formulas or design tools provided for a specific topology when determining the power rating of the power magnetic component. Or they may run simulations to determine the amount of power handled by the inductor or transformer. However, a more analytical approach gives designers greater insight when the objective is optimizing the magnetics design for size, efficiency, cost or other goals. The methods of analysis described in this series are applicable to inductors and transformers for the three PWM-switch configurations and their derivatives. With this approach, the rating of the inductor or transformer can be determined at the start of the inductor design, rather than after the fact. This gives designers a powerful tool for evaluating which topology offers the edge in terms of magnetic component size.

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

May 2016:

Smart Inrush Current Limiter Enables Higher Efficiency In AC-DC Converters

by Benoît Renard, STMicroelectronics, Tours, France

Abstract: Inrush current limiting is required in a wide spectrum of electronics applications, from appliances to automobiles, especially in systems where ac-dc conversion is performed to supply a dc load. This current limiting function satisfies the limits set forth in the EN61000-3-3 EMC standard. It also permits the management of overcurrent through a rectifier bridge and ultimately an increase in the reliability of the converter's bulk capacitor thanks to a smooth charge. To implement inrush current limiting, the topology described in this article uses a mixed-bridge—two diodes and two SCRs. This approach represents an all-silicon alternative to the classic solution consisting of a standard diode bridge with thermistor and relays in series to limit the inrush current.

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

Subharmonic Behavior In Current-Mode Control (Part 1): The Causes And Cure At High Duty Cycles

by Ernie Wittenbreder, Technical Witts, Flagstaff, Ariz.

Abstract: In peak and average current-mode control there are well known problems that can cause subharmonic behavior associated with operation above 50% duty cycle. Less well known and less reported are the subharmonic operating states associated with low duty cycle operation. This article series will address the subharmonic issues of peak current-mode control at both high and low duty cycles. The issues described here for peak current mode control apply as well to average current-mode control. In this first part of the article series, the problem of subharmonic behavior at high duty cycles will be examined. This discussion may be helpful for new designers and a welcome refresher for more experienced designers.

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

A Practical Primer On Motor Drives (Part 4): Single-Phase AC Line Current

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

Abstract: Having concluded the discussion of ac line voltages in the previous sections, here in part 4 the focus shifts to measurement of ac line currents. Specifically, this part explains the basics of making current measurements in single-phase systems.

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

Metal Alloy Resistors Offer Robustness And Other Benefits For Current Sensing

by Bryan Yarborough, Vishay, Wendell, N.C.

Abstract: For current-sensing applications, metal alloy resistors provide a more robust technology than thick film devices. This is due to the large current-carrying mass of their bulk alloy, which provides higher surge capability. Although metal alloy resistors have been around for decades, their capabilities have evolved to offer higher power ratings, extended resistance ranges, and Kelvin connections for increased accuracy. Vishay's Power Metal Strip resistors feature the Kelvin connection in combination with the ability to operate at very high temperature (275°C) and tight tolerance (0.1%). This article offers background on how the different resistor technologies compare with respect to current sensing and discusses the specific features of the Power Metal Strip series.

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

Sizing Your Power Converter's Magnetics (Part 2): Inductor Power Rating With An Input Voltage Range

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In part 1 of this article, the author explained how the power rating of a given inductor or transformer could be determined based on the PWM switch configuration in which it was being used. This analytical approach offers certain advantages in terms of optimizing the size of the magnetic component. In that part, he derived the formulas for the inductor current rating in each of the three switch configurations for the case where input voltage V_g is fixed. However, the determination of inductor power rating is complicated somewhat when V_g is not fixed, but rather varies over a range of input voltage values. So, here in part 2, the author derives design formulas for inductor power ratings given a converter V_g range.

Notes: 9 pages, 4 figures, 2 tables. Read the full story…

June 2016:

Meeting The Standby Power Specification In LED TVs With A Single Power Supply

by Jean-Paul Louvel, ON Semiconductor, Toulouse, France

Abstract: The improved efficiency of today's switched-mode power supplies (SMPSs) under light loads has helped designers to eliminate the need for a dedicated standby power supply in LED TVs. However, new features such as Internet-connected TV are driving this standby power back up, creating new challenges. If improving light-load efficiency is relatively straightforward for a flyback converter used to supply limited power (<100 W) in up to 42-in. screen size TVs, this task becomes much more complex for resonant LLC converters used to deliver higher output power in larger TVs. This article is intended to help SMPS designers get the best possible overall performance when they have to design an LED TV with a single SMPS that still meets standby requirements.

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

Optimize Half-Bridge Circuit Designs Through Accurate V_{GS} Measurements

by Tom Neville, Tektronix, Beaverton, Ore.

Abstract: This article looks at the use of an innovative new galvanically isolated measurement system for improving the accuracy of high-side gate-source voltage measurements, which in turn opens up new opportunities to optimize half-bridge circuit designs. The standout feature of the IsoVu measurement system is its high common-mode rejection across its entire bandwidth. The measurements described in this article are shown on a half-bridge configuration with eGaN FETs on both the high-side and low-side switch. While high-side gate measurements are the focus of this article, the low-side gate will also be examined. In addition, examples of how these measurements can be used to gain insights never possible before will be discussed.

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

A Practical Primer On Motor Drives (Part 5): Three-Phase AC Line Current And Winding Configurations

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

Abstract: In the previous part, the measurement of single-phase ac currents was described. The discussion continues here with a description of the current vectors in three-phase ac systems, how current flows in wye and delta winding configurations, and how it is measured.

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

Conventional Buck Vs. High-Frequency Series-Capacitor Buck: Who Wins?

by Ryan Manack, Pat Hunter, and Rich Nowakowski, Texas Instruments, Dallas, Texas

Abstract: High switching frequency, multi-phase dc-dc converters are beginning to take hold in the point-of-load (POL) marketplace, allowing much smaller input and output filters to save space. This article compares and contrasts a high-frequency series-capacitor buck converter, operating at 4 MHz, with a traditional single-phase synchronous buck converter operating at 500 kHz. We compare size, efficiency, thermals, external components, ripple and transient response. We also demonstrate a 12-V input design methodology for the inductor and capacitor selection, while bounding the design's output-voltage variation supporting advanced processor core voltage requirements up to 10 A.

Notes: 11 pages, 13 figures, 5 tables. Read the full story…

Sizing Your Power Converter's Magnetics (Part 3): Transformer Power Rating With An Input Voltage Range

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: The previous inductor power-rating exercise of parts 1 and 2 can be extended to transformers. As a starting point, note that the waveforms present in power electronics heavily affect the power ratings for transformers. Because inductor and transformer waveforms differ, transformers will naturally require a different derivation of the power formulas for the three PWM switch configurations.

Notes: 5 pages, 2 figures, 1 table. Read the full story…

July 2016:

Subharmonic Behavior In Current Mode Control (Part 2): The Causes And Cures At Low Duty Cycles

by Ernie Wittenbreder, Technical Witts, Flagstaff, Ariz.

Abstract: Part 1 discussed the subharmonic behavior that occurs in power converters operating under

current-mode control at high duty cycles and how this problem can be remedied with slope compensation. At low duty cycles we often do not expect to see subharmonic behavior. So when it arises we may take the step of designing in slope compensation after the fact, which often resolves the problem, but not always. So now what do we do? This second and final part of the article answers that question. The causes of subharmonic behavior at low duty cycles are explained along with techniques to counteract them. This discussion culminates in the description of circuits that generate a precise analog of the inductor current, which is then combined with slope compensation to eliminate the subharmonic behavior.
Notes: 8 pages, 8 figures. Read the full story…

Four-Terminal Inductor Achieves High-Accuracy Current Measurements For POLs (Part 2): Sources Of Error

by Ron Vinsant, Vishay Siliconix, Santa Clara, Calif.

Abstract: The first segment of this series introduced Vishay's four-terminal inductor and discussed its use in measuring current in point-of-load regulators (POLs). This second article discusses the current measurement performance of the four-terminal inductor under various use scenarios in a synchronous rectifier that is capable of currents up to 40 A. The focus here will be on current accuracy. This part begins by explaining our goals for ac and dc current measurement accuracy and describing the test setup that will be used to measure these accuracy terms. Then a series of measurements and simulations are performed to show the influences of various component values and tolerances, instrument specifications, load values and environmental conditions such as temperature and noise on measurement accuracy.

Notes: 17 pages, 24 figures. Read the full story…

A Practical Primer On Motor Drives (Part 6): AC Line Power Calculations

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

Abstract: Having discussed measurement of voltages and currents in previous chapters, the discussion now turns to calculation of power as encountered in motor drives. This part reviews the relationships between voltage and current in linear and nonlinear loads, relationships between real and reactive power and how these parameters are calculated including the significance of phase angle and power factor. Requirements for sampling of voltage and current waveforms to enable accurate power calculations are also reviewed and measurement examples demonstrate how the power-related parameters are calculated by instruments such as the Motor Drive Analyzer. This section focuses specifically on power calculations in single-phase systems.

Notes: 11 pages, 19 figures, 1 table. Read the full story…

August 2016:

Open HW/SW Platform Accelerates Development Of Control Solutions For Power Electronics

by Marko Vekic, Vlado Porobić and Evgenije Adzic, PERUN Technologies, Novi Sad, Serbia

Abstract: Developing a controller at the power electronics (PE) or power systems (PS) level requires a great deal of versatility and expertise in various engineering areas. This is especially true for many large, high-power applications such as motor drives, active filters, PV inverters, and flexible ac transmission systems (FACTS). Controller development is very time-consuming, laborious and expensive and yet very inflexible if a traditional testbench approach is applied. To cope with these challenges, PERUN Technologies has developed a comprehensive open platform known as the LARA-100. After describing the LARA-100's features, this article explains how this hardware/software platform can be used for controller development, to supplement an existing development platform (with LARA-100 emulating a source or load) or as a combination of these uses. Two case studies are presented to illustrate the first two use scenarios.
Notes: 12 pages, 13 figures. Read the full story…

Wide Voltage Trim Power Supplies: The Benefits Of Linear Supplies Without The Drawbacks

by Kevin Parmenter, Excelsys Technologies, Chandler, Ariz.

Abstract: Since the beginning of the electronics industry one of the desirable attributes of a power source was its ability to vary its output voltage from close to zero up to a maximum desirable voltage for the intended application. In the old days of linear power supplies, this capability was easily accomplished. But with the advent of switched-mode power supplies (SMPSs) design engineers gave up the voltage-range feature as a compromise to gain the higher efficiency and other attributes of SMPSs. Nevertheless, many applications still require wide voltage adjustment. After discussing these applications, a series of recently introduced power supply modules with wide output trim capability are described with details on how they achieve their wide output ranges and the benefits of using these modules in place of laboratory-style or custom power supplies.

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

A Practical Primer On Motor Drives (Part 7): Power Calculations In Three-Phase Systems

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

Abstract: In this part, the discussion moves on to power calculations in three-phase systems as encountered in motor drive applications. After reviewing the basics of calculating power values in systems with resistive and non-resistive loads, techniques are explained for measuring power given various three-phase system configurations including four-wire and three-wire wye-connected systems, as well as three-wire delta-connected systems. Both line-to-neutral and line-to-line measurements techniques are discussed as they apply to these configurations as is the conversion of line-to-line voltage measurements to their line-to-neutral equivalents for the purpose of calculating power per phase. Both the two-wattmeter and three-wattmeter methods of measuring power are explained. As in previous parts, the Motor Drive Analyzer is used to demonstrate the various measurement

techniques on an example motor drive and how the MDA's built-in functions automate the power calculations described.

Notes: 13 pages, 24 figures. Read the full story…

Eddy-Current Effects In Magnetic Design (Part 1): The Skin Effect

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: One of the more troublesome aspects of transductor (magnetic component) design is the winding design—the electrical aspect of transductor design. What complicates it the most are eddy-current effects: the skin and proximity effects. The goal of this six-part article series—a mini-course—is to explain and clarify eddy-current effects, provide some useful graphs and design equations, and explain how to use them in winding design for a more optimized transductor. This material is adapted from a book by the author, *Power Magnetics Design Optimization*. Part 1 of this series explains the origin of the skin effect and analyzes some key expressions related to it that will aid designers in the sizing of wires for inductor and transformer designs.

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

September 2016:

Multi-Output Fly-Buck Regulator Offers Wide V_{IN}, Isolation And Low EMI

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: The power management requirements in industrial, medical, automotive and transportation end markets are setting new challenges for design engineers. System performance requirements for the power converters dictate high density and high switching frequency coupled with increasing emphasis on a wide input voltage range, multiple output rails, galvanic isolation, and compliance with EMI regulations and, in many cases, stringent transient and safety standards. The Fly-Buck converter has gained prominence as a solution to provide low-current auxiliary and bias outputs from a widely-ranging input supply up to 100 V, especially if both isolated and non-isolated rails are required. In comparison with conventional flyback or push-pull topologies, the Fly-Buck offers simplicity, versatility, small size, high reliability, and low BOM cost. This article discusses the advantages of the Fly-Buck in the context of a multi-output Fly-Buck design example

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

Performance Parameters Lead To The Optimal Converter

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: This article explains the performance parameters that guide power converter design toward the ideal, and how they point toward certain features of optimal converter circuits. Our starting point for this discussion is an explanation of the inherent tension in converter design goals arising from the desire to convert one constant voltage to another, yet needing changing waveforms to do it. From there, we'll explore a few measures of optimal converter design—form factor, form factor product, and ripple factor—that use ratios of waveform characteristics to assess the efficiency of different power

circuit topologies across the range of duty cycles. The article concludes by explaining two other waveform-based parameters—utilization and crest factor—which represent metrics for component sizing or rating.

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

A Practical Primer On Motor Drives (Part 8): Power Semiconductors

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

Abstract: Here in part 8, we begin to look inside the motor drive to understand its operation by introducing the power semiconductors that control the flow of power to the drive. This section on power semiconductor device physics will be a review for most power electronics engineers. However, for those new to the motor drive field, this section lays the groundwork for a discussion of the power conversion topologies and circuits discussed in subsequent parts of this series.

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

Eddy-Current Effects In Magnetic Design (Part 2): The Proximity Effect

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Having introduced the skin effect in part 1, this article now turns its attention to the other eddy-current effect, which is the proximity effect. Skin effect is the eddy-current effect within a conductor; its counterpart, the proximity effect, occurs *between* conductors and dominates over the skin effect for multiple winding layers. Before describing the proximity effect, this part will establish the general equations for frequency-dependent resistance as these will be useful later in determining power loss caused by skin effect and proximity effect.

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

October 2016:

Meeting High Altitude Requirements For Power Supplies: A Guide For Designers And Specifiers

by Kevin Parmenter, Excelsys Technologies, Chandler, Ariz.

Abstract: Regulations such as China's GB 4943.1-2011 standard as well as other regional and application needs require power supplies to operate reliably in high altitude environments. After briefly discussing some of the market drivers for high altitude performance, this presentation describes the impact of high altitude on power electronics, explaining key principles such as Paschen's Law and the impact of the high altitude environment on power supply design. High altitude affects the three Cs—creepage, cleerance and cooling—as the author discusses in detail. He also explains the meaning of the relevant power supply specifications. Finally, he presents an example of a new power supply series developed to meet the high altitude requirements and how specific performance capabilities of this series support compliance with the high altitude specs.

Notes: 63 slides. View the presentation*…
**For best viewing, select "Fit to width" and use the page down key to advance the slides.*

Design Article Archive

Abstracts of articles published in the January through December 2016 issues

A Practical Primer On Motor Drives (Part 9): Power Semiconductors As Implemented In Power Conversion Systems

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

Abstract: The review of power semiconductor physics in the last part set the stage for a discussion of the power electronics circuitry found in motor drives. This section does not provide exhaustive technical detail regarding power-electronic designs. Rather, it introduces the common power conversion topologies, explaining in broad terms how they work and the types of outputs they produce. The topology discussion begins with single-device configurations of buck and boost stages, then moves onto the multi-device topologies—the half-bridge and full bridge (H-bridge). The latter subject covers both the standard (single-phase) and cascaded (three-phase) H-bridges with descriptions of both the sine-modulated and six-step commutated PWM control techniques. For those drive applications requiring even greater control over these parameters or the ability to reach higher output voltages, there are multi-level topologies, which are also introduced here.

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

Tradeoffs In Digital, Analog, And Hybrid Power Supply Control

by Fionn Sheerin, Microchip Technology, Chandler, Ariz.

Abstract: Most power conversions are (and always will be) implemented in dedicated hardware. However, as digital signal processors (DSPs) and digitally configured controllers become more capable, this does expand the options and power conversion capabilities available to a savvy power designer. Especially if that designer is not scared to play around in a firmware compiler. The big question is when; when is it worth it to add firmware to the design process, and when is it better to use traditional analog power conversion? The answer varies depending on the application needs. However, there are four primary reasons currently driving investment in digital power conversion: reporting, reliability, dynamic load management, and total cost of ownership. This article discusses each of these reasons, citing application examples that illustrate how digital control is beneficial and in some cases mandatory.

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

Eddy-Current Effects In Magnetic Design (Part 3): Conductor Cross-Sectional Geometry

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In transformer or coupled-inductor (i.e. transductor) design, we need expressions that account for the combined skin and proximity effects. Such formulas have already been developed through field derivations, but those formulas are not entirely adequate for transductor winding designs. The field solution to the eddy-current problem was worked out by P. J. Dowell and published in 1966. Dowell solved the field problem for two planar parallel conductors, such as two parallel metal bars. For any other conductor shape, the field problem must either be solved or else the Dowell formula for parallel bars is adapted to them. Part 3 addresses the adaptation from parallel bars to foil to square wire and round wire conductors. Interestingly enough, there is no general agreement in the magnetics industry or academia on exactly how to do this.

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

Design Article Archive

Abstracts of articles published in the January through December 2016 issues

November 2016:

Surges and Transients Can't Read Specifications! How to Protect Power Supplies Against Real-World Threats

by Kevin Parmenter, Excelsys Technologies, Chandler, Ariz. and Tim Patel, Littelfuse, Chicago, Ill.

Abstract: There are numerous standards and specifications in the industry regarding electrical overstress. Unfortunately, transients and surges cannot read! In the real world, transients and surges often exceed the test specifications and damage the power supply. However, the specifications and circuit protection techniques used to protect against surges and transients in outdoor LED lighting are extremely robust, yet highly cost effective. This presentation explains why circuit protection techniques developed for LED power supplies are suitable for most other power supply applications, describes global safety and surge immunity standards in the lighting field, and offers detailed discussion and guidance on the use of MOVs for surge protection.

Notes: 119 slides. View the presentation*…

**For best viewing, select "Fit to width" and use the page down key to advance the slides.*

A Practical Primer On Motor Drives (Part 10): Motor Background

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

Abstract: The last two installments in this series reviewed power semiconductor devices and power conversion topologies, providing foundational knowledge for understanding how motor drives work and how they are designed. Equally important to understanding motor drives is a knowledge of how the load (i.e. the motor) works. In this part, we begin that discussion, providing an overview of the popular motor types and the basics of how motors work.

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

Generate Hysteresis Curves From Magnetic Core Datasheet Parameters

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

Abstract: Those who are involved with the design of magnetic components know that it is desirable to have a hysteresis curve available for accurate calculations and, in general, to have a better understanding of a magnetic core's capabilities. However, magnetic core manufacturers very seldom provide full hysteresis loops for their products, limiting the parameters to the saturation flux density, remanence and permeability. Despite that limitation, it is possible to build a hysteresis curve based on these parameters. Moreover, it is possible to predict the magnetic parameters' behavior at different magnetizing currents. This is very helpful in designing transformers, inductors and electric magnets (including solenoids.) In a previous work it was shown that a hysteresis curve going through the zero point of the coordinates and describing materials having negligible coercive force, may be represented with an exponential function. This article introduces analysis for a hysteresis curve describing materials having substantial coercive force.

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

How To Calculate Winding Packing Factor

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: How does the space between wires in transformer or inductor windings affect magnetic design? The short answer is that it affects a variable known as packing factor, which in turn, is useful in selecting a transformer or inductor core with an eye toward optimizing the efficiency or power transfer of the magnetic component. The role of packing factor k_p has been discussed in previous articles in this column and other literature. In those earlier discussions, the role of k_p has been touched on to varying degrees, and the factors influencing k_p have only been discussed in passing. This article explores the interplay between wire size, wire geometric configuration and window end effects for magnetic components wound with round wire.

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

December 2016:

Correct Snubber Power Loss Estimate Saves the Day

by Rayleigh Lan and Nazzareno (Reno) Rossetti, Maxim Integrated, San Jose, Calif.

Abstract: Your customer is worried. He believes the resistor in your voltage regulator's snubber network is overheating and suspects it is causing reported field failures. At stake are millions of products already in the field. Now the customer is at your door step asking for help. Should a recall be issued? What are you going to recommend? This article looks at the assumptions behind the formula for resistor power dissipation in an RC snubber ($P=CV^2f$), and then does an analysis to determine the true power dissipation based on actual circuit conditions. A new equation is derived that accounts for the fact that the voltage seen by the snubber is not always a step function. Results are verified by performing a SIMPLIS simulation.

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

A Practical Primer On Motor Drives (Part 11): AC And DC Motor Types

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

Abstract: In the previous part in this series, the basic principles of motor operation were explained and the main categories of motors were introduced. This part 11 takes a closer look at the different motor types including ac induction motors, ac permanent magnet synchronous motors, and brushless and brushed dc motors. It also offers more details on universal motors, ac synchronous motors, and switched reluctance motors. Finally, this part concludes with some comments on servo motors and stepper motors.

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

Creating A Complex Multi-Load Power Solution In Minutes

by Ron Johnson, Intersil, Melbourne, Fla.

Abstract: Intersil's PowerCompass simplifies the power design process by presenting users with the right groups of parts from the company's catalog of power supply ICs based on user-specified requirements. From these parts, designers are presented with the data needed to make an informed choice on which power device to use in their applications. PowerCompass currently supports Intersil's nonisolated dc-dc controllers and regulators, including buck, boost and buck-boost configurations as well as positive output linear regulators. This article explains and demonstrates how to use

PowerCompass. The five simple steps described here create a custom design from initial definition to reference design schematics and a bill of materials (BOM). Also, note there are two versions of this tool available, one is an online app version that runs in a web browser and the other is an offline Excel version.

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