Design Article Archive

Abstracts of articles published in the January through December 2020 issues

January 2020:

Injecting Noise In Power Supplies Improves Security For Communications Devices

by Gregory Mirsky, Vitesco Technologies, A Spinoff Of Continental Automotive Systems, Deer Park, Ill.

Abstract: In communication devices such as cell phones, voice-generated audio signals that pass through audio amplifiers modulate the dc supply voltage and thus they also modulate the switching waveforms that control and regulate switching power supplies. As any switching power supply has some electromagnetic emission at the switching frequency and its harmonics or unwanted derivatives (ringing), the modulating voice-generated information is emitted as well. There is a very simple way of safeguarding this audio information. This method hampers eavesdropping of any emitted signal, can be used with practically any existing switching power supply and is applicable to any device processing information, both digital and analog. The proposed method uses noise to modulate the power supply switching signal.

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

The Engineer's Guide To EMI In DC-DC Converters (Part 11): Input Filter Impact On Dynamic Performance

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Meeting electromagnetic interference (EMI) standards requires the insertion of an EMI filter between a switching-mode power converter and its source. As described in part 10 of this series, a dynamic coupling between a converter and its EMI filter effectively creates a feedback loop, where the source-side "minor-loop" gain is the ratio of the filter's output impedance to the converter's closed-loop input impedance. Given the negative input impedance behavior of a regulated, high-loop-gain dc-dc converter, part 10 showed that impedance shaping (via passive damping of the input filter to reduce its output impedance peaking) is normally required to ensure robust stability. However, there's another concern as input-filter interactions may severely affect the transfer functions related to dynamic performance of the converter, particularly the loop gain and output impedance characteristics. The impact of those input-filter interactions on the converter's dynamic performance are considered here.

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

A Guide To Second Sourcing Rectifiers

by Jos van Loo, Taiwan Semiconductor Europe, Zorneding, Germany and Kevin Parmenter, Taiwan Semiconductor America, Chandler, Ariz.

Abstract: Rectifiers are usually not very high on the priority list of most designers. Once designed-in on a PCB and qualified, the sources of these components are rarely changed to other suppliers. However, if problems happen in the supply chain or a supplier "end of lifes" parts, then attempts will be made to second source them. This article describes some of the problems that can occur when you second source rectifiers. Although testing is necessary in many cases, by better understanding the manufacturing processes, datasheets and technology, the testing can be more focused and failures in mass production can be avoided. Test programs and statistics provided by the manufacturer should also be considered. We will start by discussing some general issues that arise when cross referencing standard rectifiers. Afterwards we will go into the details that apply when looking specifically at bridge

rectifiers, fast recovery and fast efficient rectifiers, Schottky diodes, TVS diodes, small-signal products and zeners.

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

Deflux Windings Benefit Forward Converters But Not Flybacks

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: A circuit technique that increases the efficiency of low to medium-power (<1 kW) converters with transductors (multiple-winding magnetic components) is to add a winding that conducts current during the on-time to off-time transition, returning the leakage-inductance energy to either input or output port. This article demonstrates how this technique for *defluxing* the primary winding works in the forward converter and also, why it is not feasible for flyback converters. This discussion thereby demonstrates the more detailed magnetics behavior of deflux circuits. For those familiar with active-clamp "reset" techniques, the method described here for recovering the transformer's leakage energy is similar in function, but simpler in that it only requires the addition of a small winding and a diode.

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

February 2020:

GaN-Based Wireless Power Enables Efficient, Seamless Multi-Device Charging

by Daniel Costinett, Jie Li, Jingjing Sun and Peter Pham, The University of Tennessee, Knoxville, Tenn.

Abstract: At present, commercial implementations of wireless power transfer (WPT) are largely limited to low power, low efficiency, and a charging paradigm where each device must be well aligned with a dedicated charger. This approach fails to capitalize on the promise of spatial freedom and effortless, pervasive charging which makes WPT attractive. In this article, the authors describe the design of a WPT system for a workstation in which a single transmitter seamlessly charges electronic devices of varying power levels, simultaneously, when placed in arbitrary coplanar positions above a 0.5-m x 0.5-m charging area. This work, in collaboration with Power America, leverages the capabilities of GaN transistors to enable new design paradigms for WPT systems.

Notes: 20 pages, 30 figures, 2 tables. Read the full story…

Transmitting Overpower Alert Signals With Low Latency Boosts Reliability Of Bus-Bar Power Lines

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

Abstract: For server racks with dc bus-bar power distribution, the power supply is usually sized for a full-rack configuration running software that generates the highest power consumption. Such overly conservative power delivery architectures present an opportunity for significant reduction in power supply size and cost. For example, when operating in a failure/nonredundant mode, smaller power supplies can detect an anomalous excessive power condition and then generate a fast interrupt in the form of an overpower alert that signals to the servers to throttle back until the redundancy gets restored and/or power comes back into an acceptable range. This article presents a study of the

conditions necessary for reliable transmission of overpower alert signals across a dc bus-bar power delivery network (PDN) in a high-power server rack. It also introduces a simple technique for broadcasting the alert logic signal across such PDNs with a small transmitter/receiver and with minimal latency in node throttling.

Notes: 10 pages, 7 figures, 1 table. Read the full story…

More-Efficient Boost Converter Extends Battery Life For Wearable Medical Patches

by Eddie Lee and Nazzareno (Reno) Rossetti, Maxim Integrated, San Jose, Calif.

Abstract: With their ability to continuously record and transmit a patient's state of health, wearable medical devices are transforming the healthcare industry. But these devices pose some difficulties in power management. This article reviews the challenge of powering a wearable medical patch placed on a patient's chest while meeting the requirement to operate for five days on a single disposable zinc-air battery. When regulated by a typical boost converter, the battery voltage fails to meet the device operating time requirement. However, when powered by a high-efficiency, low-quiescent boost converter such as the MAX17224, the same device meets and exceeds the five-day runtime demand.

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

Debunking The Gapped Inductor Myth

by Gregory Mirsky, Vitesco Technologies, A Spinoff Of Continental Automotive Systems, Deer Park, Ill.

Abstract: While browsing the Internet, the author recently discovered that many engineers do not treat gapped magnetics correctly: some state that an air gap increases the saturation flux density, others say that inductors based on an air gap in the magnetic core store energy in the gap only. Neither statement is true because the gap in the core just lowers the core's effective permeability, leaving the core material saturation flux density intact. And the energy is stored in the whole gapped magnetic, with the energies stored in the gap and the rest of the core in reverse proportion to the permeabilities of air and the magnetic material. Sometimes, the energy stored in the core may be substantial. Anyway, we have to deal with all possible cases of magnetic energy storage distribution over the gapped core as will be explained and illustrated in this article. A new approach to designing gapped-core inductors is also presented.

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

Power Factor Correction (Part 1): Why We Need It And How It Evolved

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

Abstract: The application of power factor correction (PFC) in switched-mode power supplies is well established and the circuits used to implement active PFC are widely known. Along with knowledge of PFC circuits and components, many engineers likely have an awareness of the PFC standards that govern product compliance. But when it comes to why these PFC requirements are in place and what were the industry or market conditions that drove their adoption, the record is not so clear. Here in part 1 we review the history of how PFC evolved and the technical requirements it produced. This discussion includes a review of the IEC 61000-3-2 power factor standard and the limits it imposes on harmonics generated by non-resistive loads, and where PFC is currently required.

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

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March 2020:

Current Drive Can Overcome Pitfalls Of Class D Audio Amplifiers

by Anthony Esposito, Avatar Engineering, Fountain Hills, Ariz.

Abstract: My background includes over a decade in the design of medical MRI digital gradient amplifiers. In many ways, MRI gradient amplifiers perform similarly to class D audio amplifiers except that the high power and absolute accuracy is well beyond what commercial audio amplifiers can achieve. In the MRI, the drive employs a controlled current to create an accurate magnetic field gradient across the patient without direct feedback of the magnetic field. The driven gradient coils are complex loads and are typically modeled as third- or fifth-order impedances. Driving these complex impedances with a controlled current rather than voltage, results in greater accuracy. The same benefit can be obtained when driving a loudspeaker with a current and this approach also eliminates many of the errors associated with using class D amplifiers to drive speakers. It can also override the need to migrate from silicon to GaN power transistors in these amplifiers.

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

Determining Whether A Film Capacitor Can Handle One AC Voltage Imposed On Another

by Samuel Accardo, KEMET, Boston, Mass.

Abstract: Customers reach out to KEMET on a daily basis to help them determine whether or not a particular capacitor series or an individual part number will work in their circuit. More often than not, answering the question requires us to learn a little about the circuit and the type of environment in which the capacitor is expected to operate. A recent, but common type of question is along these lines, “Can I use a C44BXFP4100ZB0J, C44BXFP4150ZA0J or C44BXGP4200ZA0J with a 60-Hz 720-Vrms ac voltage imposed on 10% 16-kHz pk-pk ripple?” To determine whether a capacitor can handle two applied ac voltages, we need to know more about the operating conditions in the application and its life expectancy as will be explained in this article.

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

How To Choose Magnetics Materials—Beyond Ferrites And Iron-Powder

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: The simple and well known rule in designing transformers and coupled inductors is *ferrites for transformers; iron-powder for inductors*. While following this rule of thumb gives designers a starting point in selecting a core material, it does not enable the designer to choose the optimal core material within the ferrite and Fe-pwd classes of materials. Nor does it allow them to take advantage of the other core materials whose properties fall between those of Fe-pwd and ferrites. Depending on circuit operating conditions, it may be another core material such as NiFe, FeSiAl or NiFeMo that offers optimal performance in the application. Or a gapped ferrite may be best. This article describes the use of ripple factors to achieve optimal selection of core materials among the various ferrite, iron-powder and other core material options.

Notes: 5 pages, 1 figure, 3 tables. Read the full story…

PFC (Part 2): How Current Harmonics Cause Distortion And The Role of the Delta-Wye Transformer

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

Abstract: The first part of this article reviewed the evolution of power factor correction (PFC) requirements and discussed the IEC 61000-3-2 PFC standard. Here in part 2, the relationship between line frequency harmonics and distortion is analyzed, and we explain how the delta-wye transformer corrects this distortion on the power grid.

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

April 2020:

The Engineer's Guide To EMI In DC-DC Converters (Part 12): Predicting The Differential-Mode Conducted Noise Spectrum

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: In general, complying with EMC standards is an increasingly important task for switching power supplies, not because of excessive total spectral energy but more so the concentrated energy in specific narrow bands at the fundamental switching frequency and its harmonics. Custom-designed passive filtering at the input of a dc-dc regulator is the most common approach for mitigating EMI. To this end, part 12 now examines the modeling of differential-mode (DM) noise, including the converter, passive EMI filter and measurement equipment. This article takes into account the modeling of the converter and the measurement equipment, such as the line impedance stabilizing network (LISN) and the EMI test receiver (TR), in order to streamline and better predict the effectiveness of the DM filter design. The converter input current is modeled as a current source and its harmonic content is estimated by Fourier analysis.

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

How To Make Sense Of Sense Resistors

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: This article is a mini-tutorial on fundamental concepts for power-circuit design involving sense resistors. This article discusses a variety of problems that must be understood to obtain accurate measurements with sense resistors including temperature effects, properties of resistor materials, make-versus-buy options, and Kelvin sensing. The explanations on those topics set the stage for the more-detailed discussions that follow on how to measure resistor parasitics. Two methods for measuring the parasitic series inductance of sensor resistors on the bench—frequency sweep and pulse-response methods—are explained to enable designers to properly evaluate and characterize sense resistors for use in power supply circuits. These methods are highly accessible in that they employ an oscilloscope, sine and square-wave generators, and basic probing accessories.

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

Choosing The Best Operating Mode In An Ultra-Low-I_Q Buck Converter

by Chris Glaser, Texas Instruments, Dallas, Texas

Abstract: Through ultra-low-power techniques and ultra-low quiescent current, a stepdown converter extends the battery run time for many portable devices, such as earbuds, sensors and smart meters. But to be useful, a buck converter must still meet the performance needs of the system, such as responding to load transients from the radio or generating low-enough noise for a data converter. To do this, the TPS62840 ultra-low-power buck converter has numerous operating modes. This article describes each of its five operating modes: shutdown, power-save, forced pulse-width modulation, 100% and stop mode. Furthermore, the article explains their impact on I_Q, their system benefits, and how each mode supplies the required performance while drawing appropriately low currents.

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

Optimize Inductor Design To Minimize Output-Filter Size

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In the converter PWM-switch CP (buck) and CA (boost) configurations, the PWM-switch inductor, L, is in series with the input and output ports. The output capacitor, C_o, is in parallel with the output port. Actual L and C_o components have parasitic series resistance which causes power loss. Both the inductor and the output storage capacitor are subject to either design or component selection by which the loss in each can be determined. It's common that they are the largest components in a converter. Their combined component size can be minimized by not allowing either component to become much larger than the other. In this article, equations are derived to enable the inductor and capacitor to be similarly sized in order to minimize overall filter size (volume).

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

May 2020:

Designing An Ultra-Thin Stepdown Converter: Multiphase Vs. Multilevel

by Jianjing Wang, Efficient Power Conversion, El Segundo, Calif.

Abstract: This article examines the feasibility of adopting various nonisolated dc-dc stepdown topologies for an ultra-thin 48-V to 20-V, 250-W power solution. After some comparison of several topology options, two of these converter topologies, namely the two-phase buck and the three-level buck, were selected for comparison. Converters based on these topologies were then designed, built and tested. GaN FETs were used in these designs to further reduce the converter size and improve efficiency beyond what could be achieved using silicon MOSFETs. This article describes each design and evaluates the experimental results obtained in each case to determine which approach offers the optimal solution for this demanding application.

Notes: 9 pages, 8 figures, 3 tables. Read the full story…

Inductorless Heater Switch-Mode Control Enhances Configurability Of Server Motherboards

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

Abstract: The increase in server complexity has resulted in a growing need for better and easier motherboard (MB) configurability. To meet this requirement, server MB developers recently unveiled a new technology that facilitates MB reconfiguration with a so-called rework grid array (RGA) interposer. Such an interposer is composed of a ball grid array or an IC package support structure, which has electric heaters embedded in its foundation layer. The heaters supply heat locally to reflow solder and thereby enable attachment or detachment of the IC or the processor package. This RGA-based reconfiguration method provides cost advantages over sockets or desoldering/resoldering equipment. The power required to activate the RGA heater can be supplied from the MB power supply, e.g. a 12-V bus. This article studies the electrical design of the RGA heater control to make this circuitry highly efficient, as well as cost- and size-optimized.

Notes: 11 pages, 5 figures, 1 table. Read the full story…

Novel 54-V to 12-V Buck Topology Eases Efficient Power Delivery In Data Centers

by Paolo Sandri, STMicroelectronics, Santa Clara, Calif.

Abstract: Power consumption from hyperscale data centers poses numerous challenges to the design community to deliver power more efficiently to meet continuously growing demand. One key means to address this challenge is to move the rack bus bar power distribution from the traditional 12 V to 48 V (54 V nom.) as this offers lower distribution losses. Changing the dc input bus requires developing new topologies to efficiently manage the conversion from the 54-V/48-V bus and "smoothly merge" with the current 12-V ecosystem in the least invasive way while delivering the best overall power efficiency gain. This article presents the details of the newly developed ST Stacked Buck topology (STB), which delivers a high-efficiency, high-density, regulated 12-V bus.

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

Understanding Core Magnetization In Current Transformers—Avoiding Saturation And Dangerous Output Voltage

by Gregory Mirsky, Vitesco Technologies, A Spinoff Of Continental Automotive Systems, Deer Park, Ill.

Abstract: Current transformers (CTs) are used as ac current sensors and power handling devices in current-fed power supplies. Very often CTs operate in circuits where the primary current has a dc component. This dc magnetization adds more magnetic flux to the core, leaving less headroom for the ac magnetizing. Therefore the CT design or selection should be based on the maximum or peak operating flux density of the core. It is also important to note that the CT is supplied from a very high impedance current source and has just one turn (usually) on the primary winding. This makes the primary turn(s) a magnetizing winding. Meanwhile, the output is a parallel connection of the secondary winding and load. This creates very high voltage at no load and zero secondary volts with a load short. Therefore no-load operation may pose a danger to an operator or destroy equipment if the load resistor does not have a low enough value

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

June 2020:

The Power Supply Designer's Guide To Radiation Effects in Power Semiconductors

by Paul L. Schimel, Microchip Technology, Chicago, Ill.

Abstract: Let's pretend that in a parallel universe our predecessors who knew the ins and outs of radiation hardened semiconductors retired, but left no succession plan. New engineers would have a

lot of questions and no answers, as would tenured staffers. Not that any of this would be possible in *our* universe. But if it were, maybe the brief ramblings to follow would help fill that cosmic gap and offer a bit of utility. So why is radiation hardened needed? What of the fundamentals of radiation hardness? How do you design for this? How can a 2N2222A be $0.60 in single pieces while a JANSR2N2222A is $165.00? What do these things do and how do they work? How are they tested and validated? These are the types of questions this article will answer.

Notes: 13 pages, 11 figures, 2 tables. Read the full story…

How Application-Driven Performance And Reliability Requirements Shape Design and Qualification Of GaN Power Devices

by Sam Abdel-Rahman and Deepak Veereddy, Infineon Technologies, El Segundo, Calif.

Abstract: The structures of GaN devices and their operating mechanisms differ from those of the more familiar silicon (Si) power MOSFETs. These differences account for the performance advantages of the GaN transistors, but also impose different gate-drive requirements and imply different failure mechanisms. This article describes how GaN power transistors differ in structure and performance from their Si counterparts, the different approaches to achieving normally off operation, gate structures used to design enhancement-mode GaN power transistors and gate-drive requirements, particularly as they relate to Infineon's CoolGaN devices. The last part of this article describes the extensive tests conducted by Infineon to confirm the robustness of the gate structure and to qualify these new devices for in-field applications, particularly telecom power supplies which represent the most stringent requirements.

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

The Engineer's Guide To EMI In DC-DC Converters (Part 13): Predicting the Common-Mode Conducted Noise Spectrum

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Part 1 of this article series reviewed the applicable EMI standards and measurement approaches for conducted and radiated interference from dc-dc converters. Part 2 then studied the noise propagation and separation of differential-mode (DM) and common-mode (CM) currents to understand the requisite attenuation from the EMI filter. More recently, part 12 reviewed the DM noise spectrum and streamlined models to predict it, at least from a low-frequency standpoint as it pertains to DM filter design. The analysis considered the converter and passive EMI filter stage as well as the measurement equipment, specifically the line impedance stabilization network (LISN) and the EMI test receiver. Part 13 now takes a similar approach for the CM conducted noise spectrum, again referring to the behaviors of the converter, the passive EMI filter and the LISN.

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

July 2020:

Analysis, Simulation And Experimentation Enable Successful Design Of Power Supply Compensation

by Christophe Basso, ON Semiconductor, Toulouse, France

Abstract: Loop control represents an important aspect of the design of a switching power supply. However, for various reasons, its study is often relegated to the end of the project when the main components have already been selected. Through simple trial and error, it is sometimes possible to get the impression that a design delivering an acceptable transient response on the oscilloscope is ready for production but this is a very unwise and potentially costly attitude. Without a thorough analysis backed up by simulations and loop measurements, you have no idea what phase and gain margins look like and how solid they are. It is very likely that such a loosely designed converter will fail in production or shortly after being powered in the field. To keep you away from such situations, this article reviews some of the tools currently available to let you calculate, simulate and measure your prototype's control loop before safely pressing the production start button.

Notes: 19 pages, 24 figures, 1 table. Read the full story…

Different Approaches To Learning And Applying Digital Signal Processing In Power Electronics

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: One of the early confusion factors in learning digital signal processing (DSP) is the rather different emphases placed upon it in DSP books. If you learn DSP from a book like the Prentice-Hall classic, *Digital Signal Processing*, by Oppenheim and Schafer (or from Alan Oppenheim's excellent MIT video course), or even more so, from another Prentice-Hall book, *Digital Filters*, by R.W. Hamming, you will get a filter-oriented view of DSP. On the other hand, if you learn it by reading digital control books, you will acquire a control-oriented view. And more basically, if you learn it by reading numerical analysis books of mathematics, you might wonder how it is related to electronics (or engineering). What then is the best approach to an efficient acquisition of the subject? In this article, the author explores this issue from a power electronics perspective.

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

Interstitial Wire Interleaving Packs More Conductor Into Magnetic Windings

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: One of the limitations on winding efficiency is the *packing factor*, k_p, the fraction of winding area that is conductor. Ideally the conductive part of a winding—the copper or aluminum part of the wire turns—would completely fill the area allotted to a particular winding, and the current and power density would then be maximum. However, gaps between round wires result in areas not conducting current. This article proposes a way to reduce gaps and thus increase the winding *fill factor*, k_f by filling these gaps with smaller wires. After reviewing the various packing factor components that quantify winding density, we'll analyze how to determine the optimum wire size for the smaller wire in square-layered and hexagonal-layered winding configurations. We'll also determine the improvement in fill factor obtained in each case.

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

Mounting Bridge Rectifiers: Compliance Needs Make It Complicated

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

Abstract: Among the various types of semiconductor devices, bridge rectifiers are somewhat unusual in that they are subject to safety agency certifications such as UL. These devices have agency

approvals because they often connect to the ac mains in their applications. In addition, higher-power bridge rectifiers are usually mounted on a chassis or heatsink, such that they become part of the isolation safety barrier and therefore subject to creepage and clearance considerations as well as hi-pot testing. There are also maximum touch temperatures that affect rectifier usage. The requirements for isolation and heat removal are often in conflict. This article discusses techniques and strategies for satisfying these requirements—real world best practices—and highlights some of the pitfalls to avoid when mounting bridge rectifiers in your applications.

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

August 2020:

Highly Efficient LED Driver Tackles COVID But Also Benefits Lighting Applications

by Gregory Mirsky, Vitesco Technologies, A Spinoff Of Continental Automotive Systems, Deer Park, Ill.

Abstract: This article describes the design of a very efficient current source intended for supplying a pre-determined current to LEDs, which can be connected in various configurations. It has no expensive current sensors like conventional LED drivers. This LED power supply can provide an output voltage that is completely defined by the overall voltage drop across the series-connected LEDs and can be higher than the supply voltage. Operation of this current source is based on series resonance, which makes the MOSFETs switch at zero current, thus reducing power loss. The author originally designed this current source to supply UV-C LEDs used in a device intended for exterminating bacteria and viruses (including COVID-19) on flat surfaces like boxes and office and laboratory tables. However, this circuit can also be used to power LEDs that produce visible light in conventional lighting applications.

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

The Engineer's Guide To EMI In DC-DC Converters (Part 14): Behavioral Noise Modeling

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Modeling is an advantageous way to evaluate system performance in the early stages of the design process. EMI modeling usually involves the characterization of noise sources and the essential coupling paths, and these models can be physics-based or behavioral models. Part 14 of this series provides an introduction to and overview of behavioral EMI models, where a compact association of noise sources and impedances identifies the dc-dc converter and its external EMI behavior. This article will discuss two types of behavioral models—two-terminal (one-port), decoupling-mode models and three-terminal (two-port) models. Since the latter type provides greater accuracy, details on how to extract parameters for the three-terminal models will be presented. There are two methods for extracting these parameters and both will be described here.

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

More About No-Load Operation In Current Transformers—Creating Real World Models

by Gregory Mirsky, Vitesco Technologies, A Spinoff Of Continental Automotive Systems, Deer Park, Ill.

Abstract: A previous article analyzed the operation of a current transformer (CT) in idle mode (i.e. with no load) with the goal of determining whether the CT was in danger of experiencing core saturation or a dangerously high secondary voltage. In this article, the author continues the discussion by clarifying various aspects relating to his modeling of the CT secondary voltage under no load. He elaborates on the choice of the exponential function for the rectangular-shaped primary current waveform, the meaning of those unitless constant terms, and how the timing parameters equate to readily available data sheet parameters for power MOSFETs and CTs. Finally, he plugs in some actual component values for a design example, to see how the model for the CT secondary voltage under no load can be applied in the real world. As part of this discussion, he considers the real world case where rise and fall times of the pulse are different, discussing some tips for making the analysis easier.

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

September 2020:

Using Forced-Frequency Resonant Zero-Voltage Switching In USB PD Adapters

by Jimmy Wang, Infineon Technologies, Shenzhen, China

Abstract: Capable of supplying anything from 5 to 20 V and supporting power levels up to 100 W, USB-C cables may be the only thing we need to power our laptops, as well as to connect a wide range of peripherals to them. It also breaks the previous 7.5-W power limit at 5 V, opening up the possibility of charging smartphone batteries even faster. This article discusses some of the challenges in designing USB PD-based power adapters and how they can be addressed using a switching technique known as forced-frequency resonant zero voltage switching (ZVS) in a DCM-operated flyback topology. A reference design based on a controller developed to implement this technique, the XDPS21071, is presented, its principles of operation and other circuit details are explained, and a prototype and measurements of its efficiency are provided and discussed.

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

Using Local Energy Storage For Organized System Shutdown Simplifies Power Supply Hold-Up Time Requirements

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

Abstract: Traditionally, the energy needed for organized system shutdown is stored in the PSU bulk capacitor, which supplies power to the entire system during an ac fault event. When warning and/or hold-up time needs to be significantly extended (5 to 10 ms) for organized shutdown mode, a straightforward solution is to increase the PSU bulk cap size. But this greatly increases power supply size and cost, especially in server redundant subsystems using two or more PSU modules. This article studies an opportunity for easing the PSU hold-up time requirements for applications that require significantly extended warning time intervals. It shows how a local buffer cap can supply power just to the components critical to the organized system shutdown while increasing system immunity to indiscriminate power faults.

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

A Flexible Design For Fast Charging Supercapacitors In Industrial Applications

by Nazzareno (Reno) Rossetti and John Woodward, Maxim Integrated, San Jose, Calif.

Abstract: With their short charge and discharge cycles, supercapacitors require chargers that can handle high current. The chargers must work smoothly in constant current (CC) mode during a charge, which often starts at 0 V, and in constant voltage (CV) mode once the final output value is achieved. In high-voltage applications, many supercapacitors are connected in series, requiring chargers to manage high input and output voltage. In this article, the authors discuss two use cases for supercapacitors: automatic pallet shuttles in storage facilities and short-duration backup systems in fail-safe valve actuators. They then introduce a synchronous stepdown supercapacitor charger (the MAX17701) that can handle a large number of industrial and consumer applications, using the two use cases to demonstrate its capabilities.

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

Why Magnetics Design Has Progressed So Slowly

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: This article contrasts the development of the magnetics industry, particularly power magnetics as applied in electronic power supplies, with that of the semiconductor industry by giving an overview of the history of each. The objective of this comparison is to analyze why the semiconductor electronics technology has grown so much quicker than the magnetics technology. Why have the theory, terminology and industry practices underlying power transformer and inductor design and development for power electronics failed to keep pace with that of power semiconductors and ICs, and semiconductors in general?

Notes: 6 pages, 1 figure. Read the full story…

October 2020:

Increasing Power Density In Three-Phase Inverters With Direct-Cooled SiC Power Modules

by Matthew Feurtado, Matt Reeves, Daniel Martin, and Ty McNutt, Wolfspeed, Fayetteville, Ark. and Wieland Microcool, Bend, Ore.

Abstract: Wolfspeed has developed a next-generation module that has been highly optimized to achieve the maximum performance out of Wolfspeed Generation 3 SiC MOSFETs. The XM3 half-bridge power modules offer the capability to carry high currents (300 to >600 A) in a small footprint (53 mm x 80 mm). Due to the high current density of SiC power devices the thermal performance of the module and cold plate is critical to maximizing heat flux and reducing system size and cost. The XM3 modules are offered in both a conventional flat baseplate version, which mounts to a liquid-cooled heatsink, and a direct-cooled baseplate which essentially integrates liquid cooling within the baseplate. In this article, the characteristics of both module types are described and the performance and manufacturing benefits of the direct-cooled modules are explained and demonstrated.

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

Improving Reliability Of Low-Cost Power-Source Inverters

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In hardware and automotive stores you can find inverters that supply 120 V ac rms from your vehicle's 12-V battery bus. Various brands exist at various power outputs. The consumer market

is flooded with such low-cost inverters. Many of these inverters have one characteristic in common. To be price competitive, they have cut corners in the design, resulting in unreliable products. Engineers and others with electronics knowledge may be tempted to repair these products when they fail, and may even want to make upgrades to improve their reliability. However, the manufacturers do not support either of these activities. In this article, the author examines some inverter product examples, discusses why they are unreliable, and proposes some possible solutions with the ultimate goal of enabling more robust low-cost inverter designs.

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

Avoiding Thermal Runaway In Schottkys Is Key To More Reliable And Efficient Designs

by Jos van Loo, Taiwan Semiconductor Europe, Zorneding, Germany and Kevin Parmenter, Taiwan Semiconductor America, Chandler, Ariz.

Abstract: Schottky diodes are used more and more in applications where there is a combination of high ambient temperatures and higher voltages present. This means it is time to revisit thermal runaway in Schottky diodes. By better understanding how the maximum T_j of a Schottky diode is defined and why thermal runaway happens, design engineers will be able to build more efficient and more reliable products. This article looks at the factors that lead to thermal runaway and describes its two forms—static and dynamic. It also discusses the importance of reliability testing and thermal modeling in avoiding thermal runaway. Much of this discussion revolves around a Schottky rectifier's forward voltage and leakage current specifications, how they influence thermal performance, junction temperatures, reliability, efficiency, and aspects of Schottky device structure that influence these two specifications.

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

The Engineer's Guide To EMI In DC-DC Converters (Part 15): Differential-Mode Input Filter Design

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: Due to their high efficiency, small solution size and low component count, you'll find modern dc-dc converters in almost all electronic systems in the automotive, communications infrastructure, enterprise/data center and industrial sectors. Yet these converters generate substantial conducted electromagnetic interference (EMI), both differential mode (DM) and common mode (CM), as a side effect of high-frequency and high-edge-rate switching. This article reviews theoretical concepts related to input filter design to minimize DM noise specifically, including selecting the filter topology, estimating the required filter attenuation and calculating the filter component values. A simulation provides the expected attenuation based on an input filter for conducted emissions from an automotive synchronous buck converter.

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

Foil Vs. Wire Windings—How Do They Differ?

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: The two most common conductor shapes for windings are round wire and flat foil. This article assesses the merits of round wire and foil in winding magnetic components. Four comparisons are made to describe the impact of conductor shape on winding loss, with three involving eddy-current

resistance. The article begins by comparing foil windings with round-wire and square-wire windings in terms of their effect on packing factor. Next it looks at how wire geometry affects the penetration ratio and winding resistance ratios used in Dowell's equations, and then goes further to explore 1D and 2D skin resistance effects. Finally, Dowell's curves are generated to show how winding resistance due to eddy current effects varies with wire thickness and number of layers.

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

November 2020:

Evaluating Fuses, Breakers, PTCs And Electronic Fuses For Automotive Applications

by Jerry Steele, Red Hill Labs, Tucson, Ariz.

Abstract: This article explains the differences between the popular circuit protection devices available to electronics designers including fuses, circuit breakers, PTCs and electronically assisted circuit breakers also known as electronic fuses or eFuses. Their tripping mechanisms and other characteristics such as isolation, accuracy, reset ability and programmability are discussed with an eye toward evaluating their flexibility and reliability, and helping designers to select the right device type for their applications. This article uses examples from industrial devices to illustrate the functionality that is needed for automotive applications and functional safety. It concludes by looking ahead to the next step in the evolution of electronic fuses—a device that can meet functional safety requirements.

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

A Quick Way To Determine Power Supply Output Resistance

by Gregory Mirsky, Vitesco Technologies, A Spinoff Of Continental Automotive Systems, Deer Park, Ill.

Abstract: When dealing with slow-changing dc loads, like solenoids, brushed motors, heaters, etc., it is necessary to rapidly define a power supply output resistance in order to correctly assess the power supply load capability and tweak the feedback loop if necessary. There are diverse methods for defining the output impedance of a power supply, but some of these methods involve test instruments that may not always be available and/or produce more information than is needed for the loads in question. This article presents a highly simplified method. It needs only a multimeter and a resistor of any resistance close to the load resistance.

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

Configurable IC Enables Flexible And Efficient LED Lamp Driver

by Serhiy Prykhodko, Dialog Semiconductor, Lviv, Ukraine

Abstract: LEDs have high efficiency and brightness, which makes them the performance leaders in many lighting applications. However, the LED driver can also play a key role in the performance of these applications. Among the many LED driver ICs available to designers, a new, high-voltage version of Dialog Semiconductor's GreenPAK configurable, mixed-signal matrix IC, the SLG47105, offers particular advantages when configured as an LED driver. This chip, which is also known as the HV PAK, enables a very compact driver design that is simultaneously very flexible and highly efficient. This article describes the configuration of the HV PAK as an LED driver with brightness and color temperature control.

Notes: 7 pages, 12 figures, 1 table. Read the full story…

Determining Design Power Over An Input Voltage Range (Part 1): Maximum Inductor Power

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: Designs are often rated based on a fixed input voltage, V_g but for many applications with a variable input voltage, the power requirements increase. This is typically the case with inductors and transformers used in power supply designs, and it results in oversizing or undersizing of these components. However, if the inductor and transformer transfer power are evaluated for a given PWM-switch configuration, it's possible to specify the device's power rating more accurately and better optimize component size. Yet, determining the magnetic component's maximum power consumption alone is not quite sufficient for optimizing the power rating and therefore the device size. With that in mind, this article series introduces a new concept that the author refers to as *design power*, which is the product of the max current seen by the component across the voltage range and the maximum range voltage.

Notes: 5 pages, 3 figures, 1 table. Read the full story…

EMC+SIPI Talks Reveal More About EMI Filter Design For Flyback Converters

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

Abstract: While many of the presentations at EMC+SIPI 2020 addressed EMI and EMC issues broadly, some of the talks had a power electronics focus. This article focuses on two such presentations on EMI filter design by Michael Schutten and Cong Li of GE Research, which offered practical information on filter design for low-power flyback converters. Not only were these talks interesting on their own, they also were similar to work that I (Jim) and my co-authors presented at the Power Electronics Technology conference in 2002. All of these talks explained and demonstrated how the various components used in an EMI filter affect the line-conducted noise. In this article, we'll discuss and compare these presentations to highlight what power supply designers can learn from them.

Notes: 10 pages, 13 figures, 1 table. Read the full story…

December 2020:

Modeling Digitally Controlled PFCs Made Easy

by Nikhilesh Kamath, ON Semiconductor, Phoenix, Ariz.

Abstract: Simulation of digitally controlled power supplies has its challenges. For example, it is easy to lose track of the gain at various points in the system such as may occur while converting floating-point compensator coefficients to fixed-point representation. This article discusses how to address these types of challenges in a specific application of digital control—power factor correction (PFC) circuits. In particular, this article aims to serve as a guide for designing a digital average-current-mode control scheme, a popular choice for high-power PFC applications. This article discusses the steps involved in modeling a 500-W average-current-mode-controlled PFC circuit using MATLAB, which features a SPICE-like circuit solver. A switching model is simulated using power stage components from the Simscape Electrical toolkit. The Simscape toolkit provides a convenient means to model a physical system.

Notes: 16 pages, 17 figures, 6 tables. Read the full story…

The Engineer's Guide To EMI In DC-DC Converters (Part 16): Common-Mode Input Filter Design

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

Abstract: CM noise current flows through the earth or system chassis ground (GND) connection and current magnitudes are dictated by the voltage slew rates at the power semiconductor terminals. The CM noise propagation path of a nonisolated converter comprises mainly stray capacitances to GND from the output bus connections and the parasitic capacitance brought by the switching device(s) and heatsink structure to GND. This article reviews theoretical concepts related to dc-dc converter input filter design to minimize CM noise specifically, including selecting the EMI filter topology, estimating the required filter attenuation, calculating the filter component values, and integrating the CM filter stage to reduce the volume and weight of the EMI filter design. A simulation using a SIMPLIS model estimates the expected CM noise based on an input filter for conducted emissions from an automotive synchronous buck converter design.

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