# Articles And Videos By Consultants Corner Engineers

## From Anthony Esposito of Avatar Engineering:

### *Synergy: SEPIC-Cuk Combo Illustrates Benefits of Creative Thinking*

*by Anthony Esposito, Avatar Engineering, Scottsdale, Ariz.*

**Abstract:** Synergy is the combining of two or more things to create something new. In this article, the author presents an example of how the term can be applied to power supply design. In the design described here, the author combines two converter topologies, Cuk and SEPIC, to create a tracking dual supply with performance benefits and greater simplicity than other more-conventional approaches. In this case, the benefits include low-noise operation (which eases filtering requirements), integration of magnetics, and use of a single MOSFET power switch. This article is not a scholarly review, but rather an encouragement to think creatively and move beyond "cut and paste" circuits from vendor-supplied application notes.

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

### *Advantages Of GaN FETs Versus "Best Of Breed" Silicon MOSFETs*

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

**Abstract:** It's just good engineering to scrutinize the hype that follows the introduction of any new technology. GaN power FETs are an excellent example where the caveats are less exposed than their benefits. When should we abandon the established recent generation of silicon MOSFETs with proven reliability, high performance, and low cost for the claims made about GaN devices? In this article, the author examines some of the claims made about GaN power transistors from his perspective as a power system designer and development consultant for a large semiconductor corporation.

Notes: 8 pages, 4 figures, 1 table. Read the full story…

## From John Dunn of Ambertec:

### *Use Exponential Equations And A Simple Program To Solve Power Supply Problems*

*by John Dunn, Ambertec, Merrick, New York*

**Abstract:** Many physical processes in which some parameter changes value from one number to another will undergo transitions between those numbers which may be described by exponential equations. Temperature excursions in most electronic equipment often proceed that way. The coefficients of those equations can yield valuable insight into the underlying physical processes and can sometimes predict if a product will work properly or whether it will catastrophically fail. Unfortunately, the software for doing that analysis can be a bit costly. But you can avoid that cost for some purposes with a little mathematics for which you can write your own code in a language of your choosing. In this article, the author presents a power supply case history in which a thermal runaway problem was diagnosed, a failure analysis was performed and a remedy was achieved— all using this analysis method.

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

## *From Steve Sandler and others of AEi Systems:*

### *Debunking Transformer Performance Myths*

*by Steven M. Sandler and Danny Chow, AEi Systems, Los Angeles, Calif.*

**Abstract:** There are three common myths regarding transformers, and more generally, magnetic coupling. Surprisingly, these myths concern fundamental concepts in transformer design, and perhaps they're a source of unexpected results in your design work. One myth concerns how you measure the turns ratio. Another relates to the meaning of leakage inductance. The third myth deals with the role of inductance factor (AL) in calculating transformer inductance. To dispel these myths, the authors conducted a series of experiments on transformers with different winding configurations.

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

### *Lost in Space:*
### *Unpredictable Aging Can Send Resistor Accuracy Way Off Course*

*by Steve Sandler and Charles Hymowitz,* AEi Systems, Los Angeles, Calif..

**Abstract:** Commercially available M55342 chip resistors specify tolerances as tight as 1% with aging on the order of 0.2% after 10,000 hours. Unfortunately, such specifications do not predict how resistors will age when subjected to the extreme temperatures encountered in space. So what is an appropriate aging tolerance for film resistors? To answer this question, designers may turn to the many specification and guideline documents that offer aging tolerances for resistors in space applications. Unfortunately, these specifications are often ambiguous, arbitrary or even contradictory. In this article, an attempt is made to analyze the aging tolerance of M55342 chip resistors from different perspectives, assess the validity of the different guidelines on resistor aging, dispel common myths, and suggest possible solutions for dealing with the unpredictability of resistor aging.

Notes: 12 pages, 3 figures. Read the full story…

### *Powering RF Systems: Why So Many Power Supply Designs Have Problems And What IC Suppliers Should Do About It*

*by Steve Sandler and Charles Hymowitz, AEi Systems, Los Angeles, Calif.*

**Abstract:** Many power supply designs used to power microwave and RF applications simply don't work as well as they need to. From the simplest linear regulators, to the switching converters, all the way up to the complete distributed power systems, these designs often fail to meet key specifications such as stability, regulation, ripple, and headroom. This feature examines the variety of technical reasons why these power supply designs perform poorly. It also demonstrates that, in many cases, the problems can be traced back to a lack of adequate information from the power component vendors. Their datasheets simply don't tell RF system designers what they need to know to develop power conversion circuitry. Nevertheless, this problem presents a great opportunity. And as the authors comment, power IC developers and FAEs—if they are willing—can do a lot to help. The article

concludes with an intriguing list of "The Top Ten Things RF Engineers Should Know About Voltage Regulators."

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

### An Accurate Method For Measuring Capacitor ESL

*by Steve Sandler, Picotest, Phoenix, Ariz.*

**Abstract:** The equivalent series inductance (ESL) of chip capacitors is becoming an increasingly important parameter as bandwidths and switching frequencies rise in many high-performance systems. The stability and high-frequency dynamic performance of these systems is dependent, in part, on capacitor ESL. Manufacturers of ceramic and tantalum capacitors have been working hard to reduce the ESL of their components. However, system designers cannot simply rely on the capacitor vendors' published data for ESL, which is limited at best. It's important that designers be able to make their own ESL measurements. Yet, with values typically in the range of 1 nH to 5 nH, measuring the ESL of chip capacitors is not a trivial task. This article presents an ESL measurement method using a network analyzer in combination with an impedance adapter to measure the device impedance over frequency. This approach specifically addresses the issue of test-fixture parasitics, accurately measuring both the capacitance and inductance of the device under test.

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

### Component Aging Is Primary Hurdle In Design Of High-Temperature Power Converters

*by Steve Sandler, AEi Systems, Los Angeles, Calif.*

**Abstract:** Extreme environments such as oil drilling, deep sea exploration, and space applications present daunting power supply design challenges. Power converters used in these applications, especially in "down-hole" drilling, may be subject to temperatures in excess of 200°C, while also facing extreme pressure. Relatively few electronic components are rated for such high-temperature operation, and even when they are, their useful operating life may be only a matter of hours. In most cases, the culprit is aging, which is accelerated by temperature. This article explores the impact of temperature on the aging of resistors and capacitors with an eye toward assessing the useful life of these components at high temperatures (200°C and beyond) using the Arrhenius equation. It also discusses component options for achieving longer component life in severe operating environments.

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

### Video: Troubleshooting EMI: Use Versatile Instrument And Preamp To Search For Embedded Noise

*by Steve Sandler, Picotest, Phoenix, Ariz.*

**Abstract:** Most engineers do not have convenient access to the equipment necessary for electromagnetic compliance (EMC) or electromagnetic interference (EMI) testing. Certified test labs, while readily available, and necessary for conformance testing, are a very expensive solution for troubleshooting EMI/EMC issues that ought to be addressed during product development. In this video, Steve Sandler demonstrates a test-setup that may be used to troubleshoot EMI during product design and development using readily accessible test equipment. While these same tests may be

performed with various test instruments, two of the instruments selected for use in this demo—the LeCroy Waverunner 610Zi oscilloscope with built-in spectrum analyzer and the Picotest J2180A preamp—offer a mix of performance, versatility, and cost that justifies their use in these measurements.

Notes: 2 minutes. View the Video…

### *Making Sense of Two-Wire Current-Sense Resistors*

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

**Abstract:** Four-wire sense resistors provide two power connections and two sense wires in order to make a precision measurement. Newer two-wire devices are available in values as low as 250 micro-ohms (μΩ), with wide pads to minimize inductance. In the most simplistic case, we could assume that a device such as this can be represented as a single resistor with two connections. But in real applications that assumption could lead to incorrect measurements as demonstrated in this article. Using a simple, but precise test set up, measurements are taken on a 1-mΩ 5% metal-foil current-sense resistor mounted to a small PCB. These measurements enable development of a finite element analysis model, which provides insights into the PCB's influence over the resistor's actual value in an application and what steps designers can take to obtain the desired or specified value.

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

### *Video: Troubleshooting Distributed Power Systems (Part 1): Why Stability Matters*

*by Steve Sandler, AEi Systems and Picotest, Phoenix, Ariz.*

**Abstract:** Control-loop stability impacts power supply performance in multiple ways. Even if the control loop is not oscillating, poor stability—as evidenced by low phase margin—in voltage regulator and reference circuits can lead to problems such as poor PSRR or reverse transfer performance. What's more, many system-level problems such as clock jitter, noise-induced degradation of circuit performance, and EMI can be traced back to poor control-loop stability in the power supply. In this 5-minute video presentation, Steve Sandler discusses how stability impacts circuit performance, offering examples that demonstrate the effects of stability problems on both power supply and system performance. This video is part one of an ongoing series.

Notes: 5-min. 31-sec. runtime. Watch the video…

### *Video: Troubleshooting Distributed Power Systems (Part 2): Impedance Is The Critical Measurement*

*by Steve Sandler, AEi Systems and Picotest, Phoenix, Ariz.*

**Abstract:** Whether your goal is to optimize system performance or to troubleshoot issues in distributed power systems, impedance measurement is an indispensable tool. That's because there is a direct correlation between impedance, which is a highly observable characteristic, and two key measures of system performance—noise and stability. In this 10-minute video, Sandler discusses the value of impedance measurements and demonstrates their usefulness with two examples: one using vendor-supplied data for a voltage reference and another using ADS-generated data for a second-order control loop. As Sandler explains, analysis based on impedance measurements can more

thoroughly assess control-loop stability than Bode plot measurements, and can do so more conveniently for control loops that are hard-to-access in system, and for devices (like some voltage regulators) that do not allow access to the feedback path. This video is part two of an ongoing series.

Notes: 9-min. 57-sec. runtime. Watch the video…

## *Video: Troubleshooting Distributed Power Systems (Part 3): Measuring Impedance Using Vector Network Analyzers (One-Port Tests)*

*by Steve Sandler, AEi Systems and Picotest, Phoenix, Ariz.*

**Abstract:** Vector network analyzers (VNAs) have always had measurement capabilities that looked like they would be particularly useful in assessing the performance of analog and power components and circuits. Unfortunately, the input range of these instruments did not extend low enough in frequency for many power and analog applications. However, two of the more recently introduced VNAs—Omicron Lab's Bode 100 and Agilent's E5061B—have changed this situation, making it possible to measure the impedance of many types of power components and circuits as Steve Sandler explains in this 10-minute video. This video focuses on single-port measurements, describing how they can be applied to low power circuits such as linear regulators, voltage references and op amps as well as semiconductors, capacitors, and inductors. Test set up requirements are discussed and example measurements are presented. This video is part three of an ongoing series.

Notes: 9-min. 31-sec. runtime. Watch the video…

## *Video: Troubleshooting Distributed Power Systems (Part 4): Measuring Impedance Using Vector Network Analyzers (Two-Port Tests)*

*by Steve Sandler, AEi Systems and Picotest, Phoenix, Ariz.*

**Abstract:** In the previous installment in this video series, Sandler discussed the benefits of using VNAs to measure the impedance of devices encountered in distributed power systems, providing details on how to perform and interpret one-port measurements. In this video, the focus shifts to making and interpreting two-port impedance measurements, particularly those in which the device under test is connected "in shunt through" with the VNA ports. Shunt through, wideband measurements can be made from approximately 100 microohms to a few ohms. This is the measurement performed by designers for the power distribution network (PDN) assessment of VRMs and POLs. This technique may also be used to measure the impedances of batteries, dc-dc converters, EMI filters, and other functions. Setup requirements such as 4-wire connections, a common-mode transformer, dc blockers, and ac versus dc coupling are explained in this video. Also discussed is the use of a preamp to measure impedances below 1 milliohm. In addition, the video presents impedance measurement examples such as a POL output, a motherboard PDN and a 250-microohm resistor. This video is part four of an ongoing series.

Notes: 13-min. 12-sec. runtime. Watch the video…

# Articles And Videos By Consultants Corner Engineers

## Video: Troubleshooting Distributed Power Systems (Part 5): Using Current Injectors

*by Steve Sandler, AEi Systems and Picotest, Phoenix, Ariz.*

**Abstract:** Previous videos in this series discussed the use of vector network analyzers (VNAs) to measure impedance using one- or two-port configurations. This video discusses another method of measuring impedance—the current injector method. Although not quite as accurate as the two-port VNA impedance measurement, the current injection technique has advantages including wide range (approx. 1 milliohm to thousands of ohms), the ability to measure in-system, and a suitability for measuring low-power devices such as op amps, voltage references, and voltage regulators. In addition, current injectors can be used to carry out other types of tests such as non-invasively measuring PSRR, determining power integrity and signal integrity sensitivity, and in generating high-speed load steps. In this video, Steve Sandler discusses each of these current injector measurement capabilities and presents test examples that illustrate how designers can perform and interpret these measurements. Along the way, Sandler offers many test tips to help the engineer obtain the most accurate results.

Notes: 11-min. 23-sec. runtime. Watch the video…

## Video: Troubleshooting Distributed Power Systems (Part 6): The Switch

*by Steve Sandler, AEi Systems and Picotest, Phoenix, Ariz.*

**Abstract:** System and power converter issues are frequently related to a converter's switching characteristics, which are most easily observed at the switching node. In this video, Steve Sandler discusses the measurement and interpretation of switch-node waveforms as observed in point-of-load regulators (POLs). He discusses the instrumentation requirements for measuring switch-node waveforms, why these waveforms should be viewed using different time scales, and the impact of scope probes on these measurements. With those measurement requirements as background, Sandler examines how switching frequency and duty cycle affect power supply stability as well as EMI.

Notes: 9-min. 36-sec. runtime. Watch the video…

## Video: Troubleshooting Distributed Power Systems (Part 7): Measuring Ripple

*by Steve Sandler, AEi Systems and Picotest, Phoenix, Ariz.*

**Abstract:** Circuit designers, particularly power supply designers, are frequently required to measure power supply ripple. Nevertheless, many engineers struggle with this measurement as sensitivity, selectivity, and bandwidth limitations degrade the accuracy of oscilloscope results. But as Steve Sandler explains in this 7-minute video, specialized probes and adapters can improve the results obtained from the conventional time-domain approach to measuring ripple, while other approaches to measuring ripple—involving the spectrum and impedance domains—can yield more-accurate and more-insightful results. Various test setups and measurement techniques are described in this video and example results obtained from testing different point of load regulators are discussed. Sandler also provides tips to help designers avoid common measurement pitfalls.

Notes: 6-min. 42-sec. runtime. Watch the video…

# Articles And Videos By Consultants Corner Engineers

### *Video: Troubleshooting Distributed Power Systems (Part 8): Making Time Domain Measurements*

*by Steve Sandler, AEi Systems and Picotest, Phoenix, Ariz.*

**Abstract:** There are inherent challenges in measuring power supply waveforms in the time domain. Limitations in oscilloscopes and probes, difficulties imposed by linear time and amplitude scales, and even seemingly helpful scope features can either degrade measurement fidelity or hide "glitches" and waveform anomalies that can wreak havoc with system performance. In previous videos, Steve Sandler discussed measurement of power supply signals such a switch-node waveforms and output ripple. Here in this last installment of the video series, he delves further into the subject of how to make time-domain measurements of power supply signals, providing further discussion on the sources of measurement error and many examples of noise and stability problems that engineers may be missing. Sandler dispenses techniques and tips on how to observe hard-to-spot problems and how to make higher-fidelity measurements in general. Even experienced power supply designers may be disappointed to hear that their oscilloscopes are underpowered with respect to bandwidth and sampling speeds, but then this video may help them to justify requests for better instruments. As with the earlier videos, this one is not just for power supply designers, but for any circuit designers concerned with power integrity in their system designs.

Notes: 9-min. 14-sec. runtime. Watch the video…

### *Video: Inside the 21st Century Power Test Lab*

*with Steve Sandler of AEi Systems and Picotest, Phoenix, Ariz. Video courtesy of SpinQ Studios (**SpinQ.com**).*

**Abstract:** Making high-fidelity measurements on high-performance power converters—when measured alone or in distributed power systems—can require a number of different test instruments encompassing multiple measurement domains. And with the performance of these converters and systems on the rise, the performance required of the test instruments is growing too. In this 5-minute video, Steve Sandler takes you on a tour of an advanced power test lab that contains a wide assortment of instruments for measuring various power supply waveforms and troubleshooting various power-related problems, particularly those encountered in power distribution networks or PDNs. Sandler introduces a number of different test instruments that he has used to make various measurements, and discusses their measurement capabilities. In the process, he provides some guidance on the instrument specs required to measure power converters and PDNs, today and in the future.

Notes: 5-min. 31-sec. runtime. Watch the video…

### *Video: PDN Basics For Power Designers*

*by Steve Sandler, Picotest, Phoeniz, Ariz.*

**Abstract:** In modern electronic systems, the performance of FPGAs, CPUs, and other high-speed logic devices depends on the power distribution networks or PDNs that power these devices. Within these PDNs, power converters in the form of point-of-load regulators (POLs), voltage regulator modules (VRMs), dc-dc converters, and linear regulators play a crucial role. Yet, many engineers who develop these power converters may be unfamiliar with PDN concepts and how power converters affect PDN

and system performance. In this three-part video series, Steve Sandler introduces three basic PDN concepts that developers of board-level power solutions need to understand.

***Part 1: What's A PDN?*** In this 4-min. video, Steve explains what PDNs are and why they matter, particularly to developers of POLs and VRMs. Watch the part 1 video…

***Part 2: Keep Impedance Flat.*** In this 6-min. segment, Steve discusses power converter output impedance and why designers of board-level power converters need to keep their output impedance curves flat. Watch the part 2 video…

***Part 3: Impedance Matching Is Critical.*** In the last video, which runs 3 min., Steve explains why the output impedance of a power converter needs to be matched to the impedance of the PDN in which it is used. Watch the part 3 video…

### *Voltage References Behaving Badly: Output Caps Are Key Source Of Poor Stability*

*by Steve Sandler, Picotest, Phoenix, Ariz.*

**Abstract:** The purpose of a voltage reference is to provide a very precise dc voltage level, which in turn will be used by other circuitry. By its very nature, a voltage reference is quite susceptible to control loop issues. This is due in part to the low dc output resistance of the reference and its low power circuitry, which generally results in a relatively high effective output inductance. Furthermore, the low dc output resistance results in this output inductor being a high Q inductor that is very sensitive to external capacitance. Yet many voltage reference manufacturers recommend the use of an output capacitor. In this article, a series of measurements are presented to highlight issues resulting from the addition of the output capacitor to the voltage reference circuit or, in some cases, the selection of an inappropriate output capacitor value.

Notes: 6 pages, 6 figures. 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…

# Articles And Videos By Consultants Corner Engineers

## From Harold Eicher of Champs Technologies:

### Embed Your Planar Magnetics To Maximize DC-DC Converter Performance (Part 1)

*by Harold Eicher, Champs Technologies, East Setauket, N.Y.*

**Abstract:** Compared with wire-wound magnetic devices, planar magnetics offer advantages such as low profile, improved efficiency, and easier thermal management. However, the time is now for many design engineers to contemplate the switch from the discrete planar magnetic devices to embedded magnetics structures. With embedded planar magnetics, the copper windings for inductors or transformers are formed directly on the user's PCB and magnetic cores are then assembled over these windings. This approach enables a higher level of design optimization than the discrete planar approach. In this article, the author demonstrates how embedded planar magnetics can be applied to achieve enhanced performance in a digitally controlled dc-dc converter design. The magnetics design described here was originally developed as part of Microchip Technology's reference design for a dc-dc converter based on the dsPIC33F digital signal controller. In part 1 of this article, procedures are described for designing the main transformer.

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

### Embed Your Planar Magnetics To Maximize DC-DC Converter Performance (Part 2)

*by Harold Eicher, Champs Technologies, East Setauket, N.Y.*

**Abstract:** In this article series, the author argues that the time is now for many design engineers to switch from discrete planar magnetic devices to *embedded* magnetics structures. With embedded planar magnetics, the copper windings for inductors or transformers are formed directly on the user's PCB and magnetic cores are then assembled over these windings. This approach enables a higher level of design optimization than the discrete planar approach. Here in Part 2, the author continues to explain the procedures used to design the main transformer TX1 that was developed for use in a digitally controlled dc-dc converter. This part of the article focuses on estimating ac copper losses in the PCB windings for TX1.

Notes: 10 pages, 2 figures, 1 table. Read the full story…

### Embed Your Planar Magnetics To Maximize DC-DC Converter Performance (Part 3): The Bias Supply

*by Harold Eicher, Champs Technologies, East Setauket, N.Y.*

**Abstract:** This article continues the discussion on embedded planar magnetics and how its use enhances the performance of a digitally controlled dc-dc converter design. Here in part 3, the focus is on the design issues faced when implementing a bias supply as part of the embedded dc-dc design. At the center of this bias supply design is embedded planar transformer TX3. This article also considers alternative magnetic solutions based on wound components and discusses the tradeoffs between the embedded-planar and wound-component approaches.

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

# Articles And Videos By Consultants Corner Engineers

## From Ed Walker of Design/Analysis Consultants:


### Use Worst-Case Analysis Tool To Efficiently Validate Your Designs

*by Ed Walker, Design/Analysis Consultants, Tampa, Fla.*

**Abstract:** When it's time to validate their electronic circuit designs, many engineers depend on testing of prototypes and running of Monte Carlo simulations, believing that these two methods are sufficient to ensure design reliability. However, bench measurements and Monte Carlo analysis will not catch all potential design problems and the potential field failures that they miss can prove to be very costly. To truly validate a design, worst-case analysis is required. Design Master software allows engineers to efficiently and thoroughly validate their designs, using an advanced form of worst-case analysis called WCA+. This program provides a fully integrated set of analysis tools, including a worst-case solver, probability estimates for out-of-spec results, sensitivities, and optimum values. This article demonstrates how to use Design Master by going step-by-step through a simple analysis example.

Notes: 9 pages, 18 figures. Read the full story…

## From Bob White of Embedded Power Labs:

### High Step-Down Ratio Buck Converters With eGaN Devices

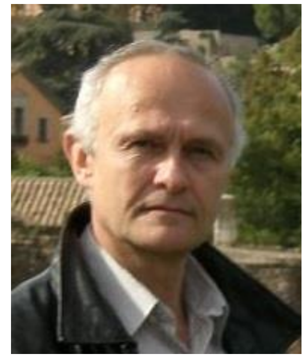
*by Johan Strydom, Efficient Power Conversion, El Segundo, Calif. and Bob White, Embedded Power Labs, Highlands Ranch, Colo.*

**Abstract:** The intermediate bus architecture (IBA) is currently the most popular power system architecture in computing and telecommunications equipment. However, it is coming under scrutiny. Some companies using a +48 V system power distribution bus with on-board bus converters and point-of-load regulators (POLs) are wondering if they can simplify their systems. For them, a single "POL" that converts the +48 V system bus directly to the load voltages is a very intriguing idea. Until now, the limitations of silicon MOSFET technology have made it impractical to design such a POL and produce it commercially. This article discusses how recently introduced gallium-nitride (GaN) power devices have overcome these hurdles, making it feasible to build POLs with the high stepdown ratios needed to generate 1 V or less directly from a 48 V bus. Experimental results are presented for two high-stepdown-ratio buck converters—one built with state-of-the-art 60 V silicon devices and another built with eGaN devices.

Notes:  15 pages, 15 figures, 3 tables. Read the full story…

# Articles And Videos By Consultants Corner Engineers

## From Peter Markowski of Envelope Power:



### Power Supply Control With FPGAs: Model-Based Design With Matlab, Simulink And DSP Builder

*by Peter Markowski, Envelope Power, Chebeague Island, Maine*

**Abstract:** Digital control has taken the power supply industry by storm and today almost no one needs to be convinced of its merits. But in the low to medium ranges of power and cost, this digital revolution is largely focused on implementations using microcontrollers, DSPs or ASICs, entirely neglecting programmable logic devices like FPGAs and CPLDs. However, a methodology know as Model-Based Design (MBD) has lowered the barrier to applying FPGA-based digital controllers in power conversion. Correctly applied, MBD reduces design time and the number of errors, while also enabling higher performance. After briefly explaining the benefits of FPGA-based design in power conversion, this article presents a step-by-step example of how to design a basic FPGA-based power supply controller using the MBD methodology.

Notes: 13 pages, 15 figures. Read the full story…

### FPGA-Based Power Controllers Offer Greater Speed And Computational Power Than Microcontrollers And DSPs

*by Peter Markowski, Envelope Power, Ansonia, Conn.*

**Abstract:** In this article, the discussion of digital power control continues by exploring the specific advantages of using an FPGA rather than a microcontroller or DSP as the power supply controller. After a brief explanation of the differences in structure that distinguish FPGAs from microcontrollers and DSPs, this article will describe how those differences lead to specific benefits for FPGAs when applied in power supply designs. The long list of benefits relates mostly to the higher bandwidth and faster dynamic response enabled by the speed and computational power of FPGAs. The article concludes by discussing a number of applications that could potentially benefit from the superior speed and computational power offered by an FPGA.

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

### Simple Method Of Implementing Digital Loop Compensation In An FPGA

*by Peter Markowski, Envelope Power, Ansonia, Conn.*

**Abstract:** Previous articles in How2Power Today presented the Model-Based Design methodology for implementing a digital power supply controller in an FPGA and discussed examples of engineering challenges that might be addressed effectively with FPGA controllers. Here the author explains how a standard linear compensator can be implemented digitally in an FPGA. While there are already many references available on this subject, most of them are unnecessarily complex and rely too much on the theory of discrete circuits. However, by applying the Model-Based Design methodology and using Matlab, Simulink and DSPBuilder, the whole task of implementing digital loop compensation in an FPGA can be shown to be relatively straightforward and reliable. This particular design example will apply type III compensation.

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

# Articles And Videos By Consultants Corner Engineers

## *FPGA-Based Controller Plus Integrated Power Stage Builds Envelope Tracking Modulator With No Compromises*

*by Peter Markowski, Envelope Power, Ansonia, Conn.*

**Abstract:** This article presents an example of a high-performance FPGA-based digital power supply controller used in an envelope tracking (ET) voltage modulator. The ET modulator design discussed here takes advantage of a new integrated power stage component with very high switching frequency capability, practically no dead time, very low delay and excellent timing accuracy—all critical in high-bandwidth voltage modulation applications. The combination of a low-cost FPGA controller with the integrated power stage enables design of a new topology multilevel converter that overcomes the limitations of other circuit solutions for ET, which sacrifice efficiency gains in order to limit switching frequency to a manageable level. Those alternative approaches are briefly discussed before the author describes implementation of a 16-level envelope tracking power converter.

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

## *Latest Generation Of 3D Electromagnetic Finite Element Analysis Software With Breakthrough Simplicity Facilitates Magnetic Component Design*

*by Peter Markowski, Envelope Power, Ansonia, Conn.*

**Abstract:** Finite element analysis (FEA) software is a great tool for simulating electromagnetic fields in chokes and transformers, allowing accurate computation of the spatial distribution of the current, flux density, associated losses and resulting temperature rise as well as the impact of the magnetic component on the efficiency of the converter. By manipulating dimensions and geometrical arrangements we can arrive at the most compact, efficient and lowest-cost structure. Unfortunately, 3D FEA software gained the reputation of being expensive, tedious and requiring a highly skilled operator to obtain sufficiently accurate results. Consequently, practicing power supply designers were forced to resort to simpler methods. However, FEA vendors have been busy trying to improve the ease of use, accuracy, stability and versatility of their tools. And as the author explains in this article, some of them have become truly practical design tools for hands-on power supply designers with general knowledge of magnetic components.

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

## *3D FEA Software Solves Tough Inductive Noise Problems*

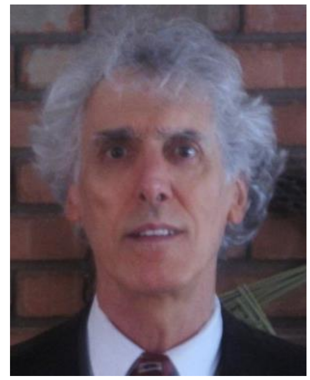
*by Peter Markowski, Envelope Power, Ansonia, Conn.*

**Abstract:** Switched-mode power supplies are notorious for hard-to-eliminate noise problems simply because we cannot completely avoid proximity of high-power switching circuits and sensitive controls. Good engineering practices such as minimizing high-frequency current loops and voltage surfaces, perpendicular arrangement of potential source-target sets and using large copper planes for shielding are naturally a must. But without any way of quantifying problematic phenomena it is impossible to know if we are pushing our luck and if we did the best we could within the given constraints. However, as the author explains here, dangerous noise can be reduced and many layout re-spins avoided if we model potential trouble spots with the latest-generation 3D FEA software, which has the necessary modeling power and user friendliness to be applied in power supply design.

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

# Articles And Videos By Consultants Corner Engineers

## *From Ernie Wittenbreder:*



### *Leakage Inductance (Part 1): Friend Or Foe?*

*by Ernie Wittenbreder, Technical Witts, Flagstaff, Ariz.*

**Abstract:** There are situations in which leakage inductance in a transformer or coupled inductor creates power losses and generates unwanted noise. In these situations, the designer seeks to minimize leakage inductance as much as possible. There are other situations in which leakage inductance provides a benefit. Moreover, in certain situations leakage inductance plays a critically important role in the operation of the circuit to great benefit. This three-part article series will attempt to foster a better understanding of leakage inductance, how to design around problems that leakage inductance creates, and how to use leakage inductance to advantage, to reduce power losses, size, and cost. Part one describes leakage inductance and the science and math behind it.

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

### *Leakage Inductance (Part 2): Overcoming Power Losses And EMI*

*by Ernie Wittenbreder, Technical Witts, Flagstaff, Ariz.*

**Abstract:** Leakage inductance is our foe when it creates problems such as power losses, EMI, or degraded regulation. In most isolated converters, leakage inductance contributes to both power losses and EMI, but there are ways in which power losses and EMI can be avoided by design. The first course of action is to design the transformer for low leakage inductance, but sometimes that approach is too costly or requires more space than is available, so other methods are needed. In this part 2, the various clamp and snubber options are discussed including RCD clamp, RC snubber, LCD clamp and active clamps. The pros and cons and varying requirements of the different approaches are discussed mainly within the context of the flyback topology, but also touching on the LCD clamp in the single-ended forward converter, and active clamps in the coupled-boost converter. Finally, this part looks at techniques for improving load regulation degraded by leakage inductance.

Notes: 17 pages, 9 figures. Read the full story…

### *Leakage Inductance (Part 3): Improving Power Supply Filtering, Efficiency And Density*

*by Ernie Wittenbreder, Technical Witts, Flagstaff, Ariz.*

**Abstract:** Part 1 of this article series focused on the science and math of leakage inductance and described methods for calculating leakage inductance and related quantities. Part 2 showed how leakage inductance creates EMI, power losses, and load regulation problems, and also described some remedies for these problems. This final installment of the series describes some of the ways that leakage inductance is a friend, offering benefits in filter and power converter circuits. In EMI filters, leakage inductance can enhance the filter's attenuation of both differential- and common-mode noise. And in multi-output forward converters and other topologies, leakage inductance in coupled inductors can provide filtering of output ripple. Leakage inductance also aids zero voltage switching (ZVS) in the active-clamp flyback converter, enabling lower switching losses and/or use of higher switching frequencies. Similar benefits are obtained in the active-clamp coupled-boost converter.

Notes: 14 pages, 10 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…

## 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…

## 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…

# Articles And Videos By Consultants Corner Engineers

## *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…

### *From Andrew Ferencz of Ferencz Consulting:*

## *Magnetically Isolated Digital Coupling Circuit Solves Gate Drive and Communications Dilemmas*

*by Andrew Ferencz, Ferencz Consulting, Southborough, Mass.*

**Abstract:** Power engineers often need digital isolation for a variety of reasons including controlling switches on the other side of an isolation barrier, driving high-side switches, passing communication signals, and using digital methods to encode analog signals such as a PWM signal. A variety of solutions exist in packaged form including optical, magnetic and even capacitive isolators. Each solution has some type of tradeoff in performance or key technology that differentiates it from its peers albeit at a cost. This article describes a simple digital isolation circuit based on a tiny toroidal pulse transformer. It achieves safety isolation by using triple-insulated wire and appropriate spacing between the terminals. Though comparable to a gate-drive transformer, the transformer developed for this digital isolation circuit is much simpler, smaller, and lower in cost.

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

### *From Gregory Mirsky:*

## *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…

## *Fast, Simple Solenoid Driver Saves Power In Industrial Applications*

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

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

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

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

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

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

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

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

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

**Abstract:** Part 1 of this article introduced the concept of using the duty cycle of a power supply's PWM control signal to detect and protect the power supply against overload and short circuit conditions. The easiest way to carry out this idea is to compare the duty cycle of the signal created by the power

supply controller to a reference duty cycle whose value corresponds to the overload condition. Here, in part 2 we will discuss how to design the needed circuitry. After explaining how the reference pulses are generated, we'll present a design example that illustrates how a phase-discriminator built on a D-flip flop can be used to compare the reference signal to the PWM control signal to detect a power supply overload condition.

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

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

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

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

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

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

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

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

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

## *Modeling The Input Step Response Of A Power Converter*

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

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

obtaining the closed-loop system response to an input voltage step. The derivation of the needed transfer function is described here for the familiar buck converter.

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

## *From Martin Kanner of KEMCO—Power Controls:*

### *Everything You Wanted To Know About Copper Wire But Didn't Know To Ask*

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

**Abstract:** Many of you reading this article have had formal training and or experience in the field of electrical engineering. Yet if you had to select the wire size for an electrical cable, it might be a mystery to you or you might have to guess at it. Selecting wire for a transformer or an inductor might be a more formidable task too. Or, how would you answer a question on how wide a copper run should be on a printed circuit board? It is the purpose of this article to make these simple tasks, just that.

Notes: 2 pages. Read the full story…

### *Testing What You Know About Copper Wire*

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

**Abstract:** For those who enjoyed Martin Kanner's article, "Everything You Wanted To Know About Copper Wire But Didn't Know To Ask" in the December 2013 issue, and want to test their understanding of the material, take this short exam.

Notes: 2 pages. Read the full story…

### *Testing What You Know About Copper Wire - The Answers*

**Abstract:** For those who enjoyed Martin Kanner's article, "Everything You Wanted To Know About Copper Wire But Didn't Know To Ask" in the November 2013 issue, and took the exam on this material presented in the December 2013 issue, we now provide the **answers** to that test.

### *Cutting Power Transformer Size In Half While Doubling Transistor Efficiency: It's All In The Topology*

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

**Abstract:** Once upon a time, I was designing switching power supplies for a highly secure military communication system. Initially the requirements for the supplies were not unusual. They called for multiple regulated dc outputs generated from a 28-V dc supply specified by Mil-Std-704. Naturally the supplies had to satisfy the EMI requirements of Mil-Std-461 for conduction and radiation and be reasonably efficient. The various modules ranged from 10 W to 200 W with size and weight appropriately specified. But sometime after the project was underway, the program manager said he

needed an another power supply—one with a regulated 40-V dc, 1500-W output, and at least 90% efficiency, plus tight size and weight specs. This is the story of how I met these requirements using a nonisolated push-pull topology that performed voltage doubling while maximizing efficiency and minimizing transformer size.

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

### *Power Transformer Design Simplified—Really!*

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

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…

## *From Patrice Lethellier of Noizgon:*

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Turn your Red into Green

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

*by Patrice Lethellier, Noizgon, Salt Lake City, Utah*

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

Notes: 4 pages. Read the full story…

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

*by Patrice Lethellier, Noizgon, Salt Lake City, Utah*

**Abstract:** In part 1 of this series, we explained why mechanical designers need an understanding of electromagnetic interference to create standards-compliant mechanical designs for high-power power

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

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

## *From Franki Poon of PowerELab:*

### *Web-Based Toolset Accelerates Power Supply Design For Both Power Electronics Experts And Non-Experts*

*by Franki Poon, PowerELab, Shatin, N.T., Hong Kong*

**Abstract:** Functionality, ease of use, and simulation speed have been optimized in a free online, power supply design and simulation toolset called PowerEsim. Within PowerEsim, there are several tools including ones for circuit simulation, loss analysis, thermal simulation, input harmonic analysis, and Monte Carlo analysis. There's also a very popular Magnetic Builder tool, among others. These individual tools are seamlessly integrated so that the users feel as if they are using a single tool. Furthermore, PowerESim has been optimized to perform very fast simulations. With some topologies, it can run hundreds of simulations per second. These simulations include accurate models of magnetic components that have been designed using Magnetic Builder. And by offering three different options for starting a power converter design, PowerESim accommodates the varying skill levels and requirements of both power supply and non-power supply designers. After briefly describing these options, this article demonstrates how a power supply designer could use this tool to design a power factor correction (PFC) stage.

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

### *The Most Important Concept In EMI Diagnosis*

*by Franki N.K. Poon, PowerELab, Shatin, N.T., Hong Kong*

**Abstract:** After all the work that has been done to analyze and treat EMI in power supplies, it is about time we stop describing the analysis and treatment of EMI as a "black art." Clearly, EMI topics have been studied to the point where the underlying issues are understood, techniques for dealing with EMI are well established, and this knowledge is readily available to the engineering community. Nevertheless, EMI engineers still feel frustrated at times with theories and real world measurements. One of the sources of this frustration is the conflict between the log scaling required to measure and assess EMI and the engineer's "linear" mindset. It is important for engineers to adapt to log scales in order to apply EMI theories on diagnostic techniques effectively, gain valuable experience in these areas, and to obtain more consistent results. This article discusses some common mistakes that engineers make in interpreting log-scale EMI measurements, explains why different engineers performing similar tests draw different conclusions about the causes of EMI, why the search for a "dominant" noise source is counterproductive, and describes a more effective approach to addressing EMI issues in power supply designs.

Notes: 8 pages, 10 figures. Read the full story…

### *Free Tool Takes The Drudgery Out Of Designing EMI Filters*

*by Franki N.K. Poon, PowerELab, Shatin, N.T., Hong Kong*

**Abstract:** A free online power supply design tool available at the PowerEsim website provides a very simply way to predict the EMI caused by the line ripple. This tool contains a complex model that considers all the parasitic elements of the input filter and an equivalent arbitrary current source. Engineers can change those parameters to predict the EMI that will be observed on the input of the power supply. If this level of simulation of EMI is not enough, engineers can go a step further and use PowerEsim's converter build. This will allow engineers to immediately see the EMI result under any operating conditions. This article will explain how engineers can use PowerEsim's EMI simulation tool to predict the EMI that will be generated by their power supply designs and to optimize their input EMI filters for maximum attenuation of this EMI.

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

## *From Rakesh Dhawan and others of Strategic Technology Group:*

### *Integrating Statistics And Manufacturing Data Into Simulation of Permanent Magnet Motor Drives*

*by Rakesh Dhawan and Amitabh Mallik, Strategic Technology Group, Pune, India*

**Abstract:** Simulating motor drives using Spice, Simulink or other tools is a great way to verify a concept or basic system performance. And through the use of Monte Carlo (MC) and worst-case analysis (WCA), a reasonable estimate of the performance probability distribution can be made. However, MC and WCA techniques are based on assumptions of a normal probability distribution and linear correlations between various system parameters. These techniques are not sufficient in predicting realistic system performance. In this paper, we propose techniques to modify MC and WCA through the integration of manufacturing data to explain and predict abnormal correlations between various system parameters such as those that occur when a production ramp up takes place. These techniques are tested and verified on a permanent magnet brushless motor drive system.

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

### *Current Flow Analysis in Permanent Magnet Brushless DC Motor Control Using PSpice*

*by Amitabh Mallik and Rakesh Dhawan, Strategic Technology Group, Pune, India*

**Abstract:** A brushless dc motor has a permanent magnet rotor and a wound stator. The windings are connected to an inverter and the inverter energizes the windings in a pattern that rotates the magnetic field around the stator. The energized stator winding causes the PM rotor to rotate in a synchronous fashion around the stator. So it is important to know the perfect sequence to energize

the stator windings. Simulation could offer a convenient means for determining the optimum sequence for energizing the windings. However, methods for performing this type of simulation using popular tools such as Spice are not widely known in the industry. In this article, we describe a step-by-step procedure for simulating a BLDC motor control system using PSpice.

Notes: 15 pages, 10 figures. Read the full story…

### *Selecting A DSP Controller For Brushless Permanent Magnet Motor Drives*

*by Mala D. M., Varun Kumar H., Sudharshana, and Rakesh K. Dhawan, Strategic Technology Group, Ashburn, Va, U.S.A. and Pune, Maharashtra, India*

**Abstract:** The selection of a proper controller for a motor drive application is one of the critical decisions that determines the success or failure of a project. There are numerous criteria to consider when choosing a controller and this article enumerates most of them. Specifically, this discussion focuses on the selection of a controller for applications employing brushless permanent magnet (PM) motors. Following a brief review of the operating principles of these motors and an overview of motor control requirements, the authors discuss controller selection criteria in depth while comparing the ability of MCUs and DSPs to meet these criteria. Ultimately, the authors make the case that DSP-based control is preferable to MCU-based control in brushless PM motor applications because of the special capabilities offered by digital signal controllers (DSCs.)

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

## *From Robert (Bob) M. Zwicker:*

### *More Boost With Less Stress: The SEPIC-Multiplied Boost Converter*

*by Bob Zwicker, Analog Devices, Olympia, Wash.*

**Abstract:** The SEPIC-multiplied boost is a novel and tested topology for boost converters with moderately high boost ratios in the range of 10:1 to 50:1. This topology is suitable for applications with voltages ranging from as low as about 1.8 V on the input, up to perhaps 500 V on the output. The SEPIC-multiplied boost overcomes many of the disadvantages presented by other methods. For example, this topology significantly reduces the voltage stress on the main and rectifier switches without any accompanying significant increase in current stress. This widens and improves the choices in MOSFETs and Schottky rectifiers, where high voltage is often a problem. This article describes the origins and operation of the SEPIC-multiplied boost converter, compares this topology with other boost topologies for obtaining high boost ratios, presents test results for an actual design example, and provides additional information about design variations and component considerations.

Notes: 19 pages, 20 figures, 6 tables. Read the full story…

### *Topology Twists And Circuit Tricks Improve Performance Of Multi-Output Converters*

*by Bob Zwicker, Analog Devices, Olympia, Wash.*

**Abstract:** SEPIC, Ćuk, Zeta, flyback and inverting buck-boost converters are some of the most common "go-to" topologies when the buck and boost cannot quite do what is needed. After allowing for turns ratios and voltage inversion, they are all governed by the same relationship between voltage and duty cycle. While there are many useful variations for producing one output, the group is particularly well-suited for generating two or more outputs. The author has been working with these converters for many years, and in the process has developed some topology variations and techniques that can improve performance. This article describes some common and some less-well-known multiple-output buck-boost topologies, along with three favorite "tricks" that improve their performance. It also explains why these tricks work.

Notes: 25 pages, 27 figures, 4 tables. 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…