How2Power's Power Supply EMI Anthology

A select list of design-oriented articles and videos discussing electromagnetic interference (EMI) and electromagnetic compliance (EMC) issues as related to power supply design. These articles and videos were published in the How2Power Today newsletter. This list includes abstracts and links for these materials plus information on where to find more EMI and EMC-related articles, books, and other resources.

Table of Contents

How2Power's Power Supply EMI Anthology

1. Measuring And Troubleshooting EMI

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…

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…

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…

2. Reducing Power Supply EMI By Design

Common-Mode Transformer Aids Noise Reduction In High-Power Supplies

by Dennis Feucht, Innovatia Laboratories, Cayo, Belize

Abstract: In a typical switched-mode power supply transformer, the capacitance between primary and secondary windings is distributed along the windings. This interwinding capacitance can be represented by an equivalent capacitor, C_{seq}, across the middle of the primary and secondary windings. This interwinding capacitance offers a path for parasitic currents, which result from voltage differences across the primary and secondary windings. Those parasitic currents, in turn, can become a source of noise, which is particularly troublesome in power supplies with higher power output. However, these parasitic currents can be avoided with the addition of a common-mode transformer as explained in this article.

Notes: 3 pages, 1 figure. 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…

Reducing Noise Generated By Switching Regulators

by Frederik Dostal, Analog Devices, Munich, Germany

Abstract: Switched-mode power supplies generate noise. In many applications this noise needs to be limited so that analog data integrity is not compromised and also to pass certain EMI requirements. This article will introduce different types of noise we find in switched-mode power supplies (SMPSs), discuss different noise-coupling mechanisms and ultimately present solutions to reduce the generation of noise and to filter remaining disturbances with the best strategies. While the concepts discussed here are generally applicable to all SMPS designs, the focus here is mainly on the type of nonisolated, dc-dc converters or point-of-load converters (POLs) that are used to generate the various low-voltage supply rails in electronic systems.

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

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

How2Power's Power Supply EMI Anthology

by Timothy Hegarty, Texas Instruments, Phoenix, Ariz.

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

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

Take The Edge Off High dV/dt Supplies

by Rob McCarthy, Maxim Integrated, San Jose, Calif.

Abstract: High dV/dt rise times on the power supply can cause problems with downstream components. This is especially true in 24-V powered industrial and automotive systems with high-current output drivers. This design idea describes how to control the rise time while limiting the power loss through the control FET. Rather than using a p-channel MOSFET as the current-limiting element, this circuit employs an n-channel MOSFET, which offers lower on-resistance and therefore limits power dissipation better. This capability makes the circuit well suited for applications where supply current is 8 A or higher. The circuit is built around the MAX16127 controller, which was developed to provide overvoltage protection but serves well in this role in controlling power supply rise time.

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

Livin' On The Edge: Switching Converter Slew Rate Is Key To Mitigating EMI In Automotive Environments

by Matt Jenks and Paul L. Schimel, International Rectifier, El Segundo, Calif.

Abstract: The state-of-the-art automobile can be viewed as a common chassis that attempts to enclose the RF soup that is radiated and conducted by an increasing plethora of onboard electronics. This spectral soup sees noise contributions from dc-dc converters running processors and computers, inverters running traction motors, choppers running pumps and many assorted motors, class D audio amplifiers, and switching converters for LED lighting and brush motor commutation to name a few. The primary focus of this piece is on the brushed dc motors and the choppers or drivers that run them. This article will discuss the noise output of these circuits, the applicable EMI standards and the points of sensitivity that drove those standards. The focus here will be on the edges of the switching converter waveforms and their impact on radiated noise.

Notes: 5 pages, 1 figure, 2 tables. Read the full story…

How To Control Phase Voltage Ringing In Synchronous Buck Converters

by Suresh Kariyadan, International Rectifier, El Segundo, Calif.

Abstract: In synchronous buck converters, fast switching of the MOSFETs can cause high-voltage spikes and ringing at the phase node. These effects are undesirable because they can cause increased

power dissipation, higher voltage stress on the switching devices, higher EMI, and higher peak-to-peak output ripple and noise at higher bandwidth. In this article, an integrated buck converter is used to study the undesired voltage spikes and ringing at the phase node caused by fast switching. The focus here is mainly on the peak-to-peak output ripple voltage that occurs at higher bandwidth. Experiments are conducted to gauge the impact of different methods used to control this ringing, and the pros and cons of these methods are discussed.

Notes: 11 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…

3. Filtering And Suppressing EMI

A Guide To The Operation And Use Of Input EMI Filters For Switching Power Supplies

by Anastasios Simopolous, Beta Dyne, Bridgewater, Mass.

Abstract: The noise generated by power supply switching is a problem in electrical and electronic systems. But at least in terms of conducted EMI, the switching noise can be controlled with an input filter placed between the power lines, neutral and chassis. Despite the widespread use of switching power supplies, many engineers are not clear on how input filters operate, their capabilities and their limitations, how to specify them, and how to apply them. This article aims to address all of these issues, primarily with the non-power supply designer in mind, but in a way that will also inform new power supply designers about key aspects of filter design and application. Understanding input filters is not only about knowing when and how to specify them, but also when not to use them. For example, some power supplies have built-in input filters, making it unnecessary to add input filtering to the customer's board. But to begin the filter discussion, this article looks at regulatory requirements for emissions, which will dictate the minimum required filter performance.

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

Using Ruggedized EMI Filters To Pass The CS101 Requirement Of MIL-STD-461D-F

by Kevin Seaton and Leonard Leslie, VPT, Blacksburg, Va.

Abstract: Power systems designed for military applications that require compliance to MIL-STD-461D-F must use an input EMI filter that contains adequate damping to meet the conducted susceptibility requirements of CS101. The risk of failing the CS101 test is often highest in the mid-frequency range, which includes the EMI filter cutoff frequency (typically 1 kHz to 10 kHz) where some filters exhibit peaking in their responses. In this article, the CS101 requirements are examined and its implications for the design of the power system—the combination of input EMI filter plus power converter—specifically a dc-dc converter in this case—are discussed at length. Finally, a discussion of the CS101 test methods is presented, including a number of testing precautions that designers should observe.

Notes: 6 pages, 4 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…

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…

Beyond Power Management: Power Engineers Must Also Solve ESD, EMI, And RFI Problems

by Bill Laumeister, Maxim Integrated Products, San Jose, Calif.

Abstract: The label "one size fits all" is rarely true when used to describe clothing and it most certainly does not apply to power management in ICs. Knowing that, we can focus attention on the 20%/80% rule to produce a well-designed power-management circuit. Following this principle, the power designer must consider all the potential disruptions to a steady flow of power and the various ways to mitigate them. These disruptions include overvoltage, overcurrent, and interference conditions due to RFI, EMI, EMS, and ESD. This article, suggests voltage- and current-limiting devices and risetime reducers to manage the power. It also points to free and low-cost software tools to help design lowpass filters, check capacitor self-resonance, and simulate circuits.

How2Power's Power Supply EMI Anthology

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

Frequency Dithering: A Tool For Overcoming Last-Minute EMC Hurdles

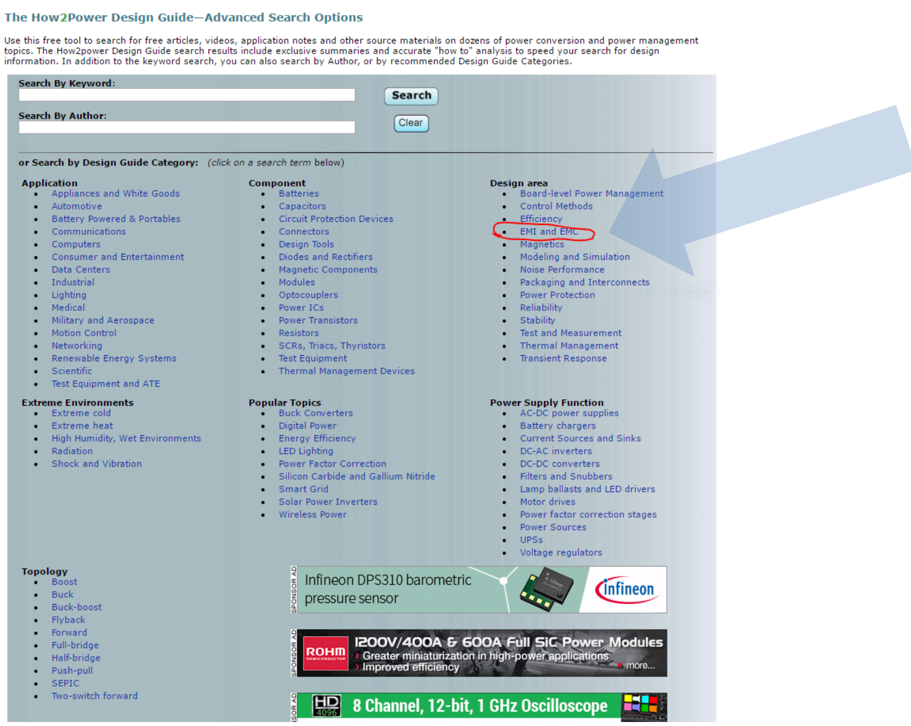
by Bob Bell and Ajay Hari, National Semiconductor, Phoenix, Ariz.

Abstract: When designing a power converter to meet electromagnetic compatibility (EMC) requirements there is no substitute for good layout, design and filtering practices. But, often the emissions of the power converter are not measured until late in the development process when the power converter is integrated into the final assembly. Usually, at that time there is limited space to add filtering components and no time for re-design. As the authors discuss in this feature, one relatively simple but controversial way to reduce a converter's peak emissions and possibly pass the EMC requirements is to enable a clock-dithering circuit, which dithers the converter's switching frequency.

Notes: 5 figures [Read the full story…]

4. More EMI/EMC articles And Resources

See the How2Power Design Guide for more articles on dealing with power supply EMI and EMC issues including articles from other free sources.



The following book review offers an overview of a valuable EMI reference.

How2Power's Power Supply EMI Anthology

Highly Practical EMC Book Will Pay For Itself

EMC for Product Designers, 5th Edition, Tim Williams, Newnes (Elsevier), September 2016, 564 pages, $85.95.

Reviewed by Kevin Parmenter, Contributor, How2Power Today

If you can have only one text on EMC in your library, "EMC for Product Designers, 5th Edition," by Tim Williams, should be it. This book is one of the most—if not *the* most—practical works I've seen on the subject. For years I've relied heavily on the previous editions of this book when working on systems, and I've frequently referred to it when teaching EMC for power electronics designers in Asia and other regions. Williams' book offers a comprehensive text on EMC that is truly practical.

Read this EMC book review…