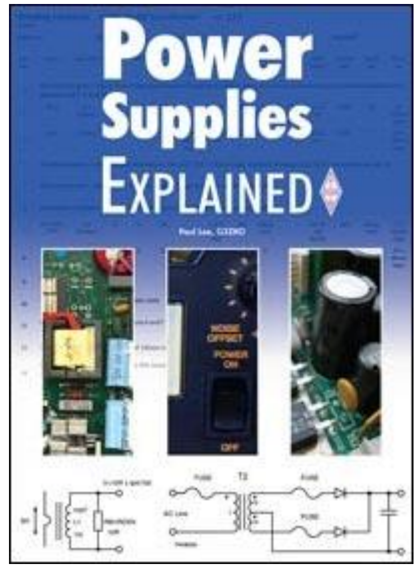
Power Supply Book Also Explains EMI And EMC Requirements

Power Supplies Explained, Paul Lee, G3ZKO, published by the Radio Society of Great Britain, September 11, 2018, 531 pages, ISBN number 978-1-91019-364-8, item number 5010, $24.95 from ARRL, also available for Kindle from Amazon.

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



I (Kevin) am in the process of reviewing a great book "Power Supplies Explained" by Paul Lee, G3ZKO, and I'll be sharing my thoughts on the book as a whole in an upcoming article in this newsletter. However, the information provided on EMI and EMC in chapter 11 of this book, deserves some special attention on its own because of its very practical approach to these topics.

It's refreshing to review a practical book which serves to assist engineers in getting their products to production faster rather being an academic work that reads as if the author is trying to impress his or her fellow professors by solving Maxwell's equations to the 9th decimal place for fun with no practical guidance offered. Fortunately, Lee's book is definitely the former type—the information presented is highly usable by working engineers, especially the discussion on EMI and EMC. What follows here is a summary of that discussion, combined with my experience in making power converters pass regulatory requirements.

To start with, the purpose of EMC and EMI regulations and design techniques are to ensure that the electronic equipment operates satisfactorily in its intended environment. This means not only does it have to pass the required compliance testing but it must be self-compatible—i.e., not interfere with itself— and it must not interfere with other proximate equipment and thus co-exist peacefully if you will, while also tolerating neighboring interference.

All this includes conducted as well as radiated EMI. Some typical regulations include FCC Part 15, the European EN55022 and EN55011 and EN61000-4-X, medical 4th edition EMC under 60601 now mandatory, Belcore–Telecordia GR1089, MIL STD 461, and RTCA-DO-160 (avionics) Vehicular SAE J551 and J1113. The author makes reference to these documents in his text. The objectives are to protect nearby radio communications equipment, protect from ESD and EFT-surges, EN61000-x-x, proximate lightning, and other situations.

As the author discusses, any interference problem can be broken down to source, receptor, and path. The interference must have a source and it much have a receptor to be interfered with and finally it must have a path to couple the source to the receptor. Typical internal and equipment sources include oscillators, transmitters, fast clock rates, fast edge rates resulting in harmonics, RF transmitters—purposeful as well as accidental—and of course power conversion circuits. Switching power supplies are unintentional transmitters. External sources of EMI include natural ones such as lightning, ESD as well as manmade, switching on power lines and other power disturbances, power conversion circuits, RF transmitters, bad design or inadequate filtering or snubber-protection components.

With finance people running everything these days it's often common to reduce component count to the point that possibly the protection and/or "what if" components are missing. Many companies have different philosophies to catch issues before they occur, as I've observed in my roles in industry.

Lee describes the different forms of testing that companies can use to identify EMI problems. Compliance testing is intended to gather data proving a product or design meets EMI compliance requirements. Pre-compliance testing is intended to gather data in the design phase so less time and money is spent during compliance testing—catching and fixing issues in the early design stages of a product. Troubleshooting is the process of forcing failures to identify EMI issues and then finding ways to mitigate the issue so that passing compliance testing can be done more easily.

As an aside, I believe there's a common misconception among engineers that purchasing a power converter rather than designing and building one yourself will excuse you from having to do much EMI and EMC work. Nothing could be farther from the truth. Many to most store-bought power converters in my experience—both dc-dc and ac-dc—rely on proper filtering, grounding, and shielding to meet global regulatory requirements. The physical placement of the converter in the product also will cause differences in EMC performance. The fine print in the specifications for ac-dc power supplies will often indicate that to meet various global EMC requirements a certain model or type of filter must be used.

While buying rather than designing and building the power converter is often the right approach, due diligence is still needed to ensure that EMI compliance is achieved. Buying a power subsystem either—ac-dc or dc-dc—does not excuse the user from taking note of proper application precautions and adding appropriate filtering, protection, physical placement and so forth.

As the author discusses, when dealing with EMI issues it's best to consider frequency, amplitude, impedances, and dimensions. We all know what the frequency, amplitude and impedances are all about. But what about dimensions? This relates to the unintended antennas and transmission lines that can occur in wires and other objects in the area which can radiate and/or re-radiate signals.

In other words, conducted radiation can and often does become radiated emissions and radiated emissions can and do become conducted emissions in systems. Transmission lines often become antennas and resonances can "amplify" problems on a routine basis. The system does not know that you bought a power converter or designed one. It can and will misbehave anyway if you do not take precautions in the implementation.

Having said all that, in many cases purchased power converters will get you closer to your target faster than the unknowns of a home-grown design. This is because the power converter designer has already taken precautions and testing because they don't know what you are likely to do with the power system so they design in and test for EMC before you get hold of it. Thus there are fewer unknowns starting with something that has already been made to meet specification. I know some of you will argue the point, however that has been my experience.

Lee discusses PCB layout in power conversion, as this subject is critical to lowering EMI and passing regulatory and compliance testing. First and foremost, turn off the auto-router—that's for digital designs. That auto router does not know about EMC and will hurt you more than help you. If you are good at RF circuit design, you are probably good at power PCB layout. Why do RF designers make good power electronics PCB layout designers? Because they are used to the PCB being part of the design and they treat traces as transmission lines versus assuming they are perfect lossless interconnections.

Kelvin connections are typically the way to go on critical traces if you can use them at every opportunity. It's best to identify critical traces and pay close attention to the PCB layout. Component placement is critical as well and it's also critical to protect the peripheral of the design and use multilayer PCBs when possible paying close attention to decoupling and watch out for cross talk on low impedance versus high impedance signal lines. Finally, we all know it's kind of cheating but dithering the power supply clock might be a good option.

Inductors couple magnetically to adjacent inductors and PCB traces, so separation and orientation of inductors and critical components is key. Magnetics radiate capacitively and inductively to heat sinks, traces, other magnetics, and components. Local shielding might be necessary to make the design meet standard.

From a store-bought power converter and system design perspective, it's useful to know that the filter placement in the system is also important and Lee addresses this issue. Filter entry modules are often used in systems on the ac line because they provide five-sided shielding of the power inlet and filter both radiated and conducted EMI right at the product entry in both directions.

If a chassis-mounted filter is used, the wiring and placement in the system is highly critical and consulting with the filter maker is likely a great idea sooner rather than later. Usually, mounting the filter in the corner of the chassis with wiring along the interior metal chassis is the correct approach.

In my work, I have found that the filter manufacturers can be a big help not only with filter placement but also with other tasks. Many filter makers have compliance labs where they can advise on filter selection and placement, perform pre-compliance testing and even offer guidance on grounding, and shielding, which are also critical. These companies have experience with thousands of products and testing and if their testing is free, why not use them?

Additionally, over the years I have noticed that many designers assume that the store-bought converter is perfectly protected from any line surge or transient known to man. In most cases they are protected up to a reasonable level. However, it might be necessary to add MOVs and/or gas tubes or other clamping devices externally to extend the level of protection to meet the market regulatory standards you are looking to meet. Note that if you add transient protection to your system before hi-pot testing in production, you are guaranteed to fail the test. Many production applications first build, then hipot test and finally add overvoltage surge protection as the last step before shipping the product to the customer.

One trend that I see causing issues for all manner of EMC design—power and otherwise—is the tendency for companies to fall in love with industrial design that only uses plastic chassis materials, which offer no electrical shielding. Managers are often surprised when they discover that expensive spray coatings or subshielding must be bought to make the system pass EMC after the fact.

The EMC compliance lab will not be impressed with your slick plastic sweeping mechanical-industrial design and will want you to knock down the radiated emissions regardless of how cool it looks. I have seen this happen more times that I can remember. That should be considered up front rather than as an afterthought.

In summary, and we have said it before, the sooner EMC and EMI and all regulatory compliance issues are considered in the design cycle, the lower the development cost and overall impact on the project. Thirty years from now people will probably be saying the same thing. However, it seems to me that rule is violated more than any other.

Over the course of multiple projects, experienced managers eventually learn to let the engineers pursue pre-compliance testing early and often rather than waiting until the project end to be surprised. The inexperienced managers tend to want to control everything and will spare no expense to save money rather than let the engineers do the right thing unimpeded. In my experience, this generally holds true for all compliance considerations including safety, materials compliance, EMI and EMC, and all other regulatory and compliance considerations. The longer the wait until the end of the project to address these issues, the more added delays and associated costs are involved. The sooner that lesson is learned the better for the organization.

At a later time I will review the rest of this wonderful book. In the meantime, I recommend you pick up a copy of "Power Supplies Explained" by Paul Lee. Though the title makes it sound basic in nature, it's really not. This book is worthwhile reading for any engineer involved with solving power electronics issues and tasked with implementing power electronics in practical applications.

About the Authors

Kevin Parmenter is an IEEE Senior Member and has over 20 years of experience in the electronics and semiconductor industry. Kevin is currently director of Field Applications Engineering North America for Taiwan Semiconductor. Previously he was vice president of applications engineering in the U.S.A. for Excelsys, an Advanced Energy company; director of Advanced Technical Marketing for Digital Power Products at Exar; and led global product applications engineering and new product definition for Freescale Semiconductors AMPD - Analog, Mixed Signal and Power Division.

Prior to that, Kevin worked for Fairchild Semiconductor in the Americas as senior director of field applications engineering and held various technical and management positions with increasing responsibility at ON Semiconductor and in the Motorola Semiconductor Products Sector. Kevin also led an applications engineering team for the start-up Primarion.

Kevin serves on the board of directors of the PSMA (Power Sources Manufacturers Association) and was the general chair of APEC 2009 (the IEEE Applied Power Electronics Conference.) Kevin has also had design engineering experience in the medical electronics and military electronics fields. He holds a BSEE and BS in Business Administration, is a member of the IEEE, and holds an Amateur Extra class FCC license (call sign KG5Q) as well as an FCC Commercial Radiotelephone License.

Jim Spangler is a Life Member of the IEEE with over 40 years of electronics design experience and is president of Spangler Prototype Inc. (SPI). His power electronics engineering consulting firm's priority is helping companies to place products into production, assisting them to pass government regulations and agency standards such as UL, FCC, ANSI, IES, and the IEC.

For many years, he worked as a field applications engineer (FAE) for Motorola Semiconductor, *On Semiconductor, Cirrus Logic, and Active Semiconductor, assisting customers in using semiconductors. He published numerous application notes and conference papers at a variety of conferences: APEC, ECCE, IAS, and PCIM. Topics included power factor correction, lighting, and automotive applications. As a FAE, he traveled internationally giving switch-mode power supply seminars in Australia, Hong Kong, Taiwan, Korea, Japan, Mexico, and Canada.*

Jim has a master's degree from Northern Illinois University (NIU) and was a PhD candidate at Illinois Institute of Technology (IIT). He taught senior and first-level graduate student classes: Survey of Power Electronics, Fields and Waves, and Electronic Engineering at IIT and Midwest College of Engineering. Jim is a member of the IEEE: IAS, PELS, PES; the Illuminating Engineering Society (IES), and the Power Sources Manufacturers Association (PSMA) where he is co-chair of the Safety and Compliance Committee.

For further reading on power supply-related safety and compliance issues, see How2Power's special section on Power Supply Safety and Compliance.