A Very Down To Earth Treatment Of Grounding For Power Electronics Designers

Grounding and Bonding for the Radio Amateur, published by The American Radio Relay League (ARRL), copyright 2017, 176 pages, available in softcover or Kindle edition, ISBN number 978-1-62595-065-9, item number 0659, $22.95 from ARRL.

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When the subject of ground comes up in power supply design, it's usually in the context of circuit design or measurement, and the discussion often concerns noise issues in some way. How to layout ground traces and planes to avoid crosstalk, EMI, groundbounce and similar effects. But there's another side to ground that concerns the safety of equipment, and more importantly, the safety of its operators. This is where the related subjects of grounding and bonding come in, and these are the focus of the book being reviewed here. They're important because safety, lightning protection, emissions–immunity EMI-EMC and proper system operation overall will depend on how well grounding is done.

This topic is relevant to anyone in the power electronics field who is designing or testing systems that connect to the ac power line or the "mains", or to similar sources of high voltage ac or dc for that matter. So, for example, if you are doing any high voltage work or ac off line designs related to grid-tied alternative energy, solar, EV, HEV, bi-directional converters and so on, you need to know about grounding and bonding.

If that explanation helps to address your concerns over the relevance of "Grounding and Bonding for the Radio Amateur," to your work in power electronics, you may still wonder why I (Kevin) might be reviewing a book written not for engineers, but for *hams*. Will the materials presented in the book be sufficiently mathematically vigorous? Will they be more relevant to RF design than power electronics design? For those familiar with amateur radio and power electronics, the answers may be obvious, but others may wonder. So let me take a step back…

I've been involved with ham radio since before I was a teenager and this was the path to my career. In my experience, this hobby offers a few important benefits to practicing engineers. 1. It teaches you practical applications-oriented aspects of electronics. If you are going to get a station on the air it's all practical electronics work. 2. The radio art just like most things taught in this book are aspects of electronics they are not teaching in school any longer. Yet these are things you need to know to make equipment work safely, properly and without interference. For instance, where is lightning protection taught any longer? Nevertheless, our systems must be able to withstand proximate lighting strikes and their effects.

Grounding and Bonding for the Radio Amateur extensively covers the subject of ac safety, explaining how to protect against shock hazards from ac power systems and how to provide a safe path for current when a fault occurs. Additionally a great deal of information is provided on lightning protection and strikes. It teaches how to design systems that dissipate transients to earth, routing it away from systems and equipment so they can continue operating or to minimize damage. Finally, it addresses RF management and RFI, describing how to prevent unwanted RF current and voltage from disrupting normal functions of equipment.

This book provides valuable information on topics that are not common knowledge among EEs. Typically this information is not passed down well via tribal knowledge from engineer to engineer. What makes this book so valuable is that it not only gives you information and tips on how to do things properly, it also provides resources on where to obtain further information that power electronics engineers should have access to anyway. I'll give some examples of these resources in a bit.

But getting back to the issue of things that are just not taught any more, here are a few examples: proper bonding of equipment in systems, the differences between grounding vs. "earthing," "protective earth conductor," and "counterpoise". Another mystery to some is the difference between ground vs. common reference voltage. These two things are often very different. Similarly, RF grounds and dc grounds are often at quite different potentials.

This book provides a fascinating explanation on how to properly install ground rods, covering what gauge the ground wiring should be along with how to connect the wires to the ground rod. How many of us have done CADWELDING before? This involves an exothermic product used to permanently bond the copper wires to each other as well as to the ground rods by heat fusing them together.

Additionally, the text's coverage of how to properly provide a ground connection when using a portable generator was also fascinating reading.

As I mentioned above, *Grounding and Bonding for the Radio Amateur* points readers to other valuable resources we all should have and be aware of. One is the national electrical code[1] which covers the safety and regulatory issues required to tie equipment to the power grid.

Another less familiar document is Motorola publication R56 Standards And Guidelines for Communications Sites.[2] This publication covers best practices for installing RF and communications equipment safely and in a way that insures that the system will work properly in the application.

While you might not be designing a communications site, the principles and guidelines will help no matter what you are designing. Finally this book references MIL Handbook 419A Grounding, Bonding And Shielding For Electronic Equipments And Facilities. [3] This publication details the way the military requires their systems to be installed. This represents a high standard because they have equipment that must work and last in hostile environments and be safe for the operators. To this end, the military has developed this handbook to document their best practices.

Overall the book emphasizes safety and responsibility for doing things properly. One skill, which was taught to me when I first started working on electronics, was to keep one hand in your pocket while working on energized high voltage equipment. Years ago (circa the 1970s) this was essential because there was very little low voltage equipment at the time. So the one hand rule was a common practice. Yet I suspect it's not as widely known today. Those of us working on offline power electronics should follow this practice.

There are several nuggets of wisdom in *Grounding and Bonding for the Radio Amateur*, any one of which likely justifies the cost of this book, which at the ARRL's list price is a relative steal anyway. For example, if you are going to install ground rods or trench for additional ground wires you should obtain a survey of what is in the ground already.

As you can imagine driving a ground rod into a water line, gas pipe or utility electrical service will have negative consequences. Many states and most locations have a free service to survey and mark where these are located. The website call811.com has a list or you can simply call 811 on your phone and arrange a non-emergency survey.

Once you have your ground rods installed or if you want to bond heavy gauge wire together permanently, the CADWELD kits are available to perform these welds. If you choose to use this method vs. ground clamps, watch the video.[4] In any case safety first—wear heavy gloves and safety glasses while you are working with the CADWELD products.

I would highly recommend this ARRL publication to have on your library shelf or hard drive, whatever your area of interest in power electronics. I believe this should be in every practicing power electronics engineer's library as a ready reference along with the other references recommended in the book.

References

1. Free online access to the NEC and other electrical standards
2. Motorola Standards And Guidelines For Communication Sites
3. Military Handbook Grounding, Bonding, And Shielding For Electronic Equipments And Facilities, Volume 1 of 2, Basic Theory, MIL-HDBK-419A, 29 December 1987.
4. Cadweld How-To

About The Authors

Kevin Parmenter is an IEEE Senior Member and has over 20 years of experience in the electronics and semiconductor industry. Kevin was recently vice president of applications engineering in the U.S.A. for Excelsys, an Advanced Energy company. Previously, Kevin has served as 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 based in Tempe, Arizona.

Prior to that, he 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 where he worked on high-speed electro-optical communications and digital power supply semiconductors.

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 an 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.

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