

KIMMEL GERKE



Bullets

Fall/Winter 2004

Welcome to KGB...

And to this issue of our "personal communications" to our friends, clients, and colleagues about EMI issues, problems and solutions.

This KGB discusses EMC in power electronics. Upon reflecting on the hundreds of EMC problems we have worked on over the years, we were surprised at how many were related to power electronics. These have included power supplies, motor drives, battery charging circuits, and UPS systems, among others. These projects included design, troubleshooting, and even a couple of legal "expert witness" cases.

In this KGB, we'll share some insights based on our EMC related "power electronic" experiences. As always, give us a call if we can help you with any of your EMI problems... power, digital, analog, systems, or facilities... in the military, commercial, medical, industrial, telecom, avionics, automotive industries, and more...

Best Regards... Bill Kimmel, PE, and Daryl Gerke, PE

Seasons Greetings...

Our sincere best wishes to you and your families this holiday season, and the best to you in 2005... *Daryl & Bill*

EMC Winter Workshops 2005

San Diego, CA – February 7-10, 2005

Orlando, FL – February 14-17, 2005

Need a winter break, and some fun in the sun? Want to learn more about EMC design, systems, or troubleshooting? Then join us in Orlando or San Diego in February for our "once a year" expanded seminar series. (This includes the *EMC Troubleshooting*, which we offer only at the Winter Workshops.)

Here are the class offerings:

- Two days on *EMC Grounding & Shielding*
- One day on *EMC & Signal Integrity in PCBs*
- One day on *EMC Troubleshooting*

Take only what you need to get up to speed on EMC.

For more details, visit our website (www.emiguru.com) or call us toll free at 1-888-EMI-GURU.

Shows and Conferences...

Here are some shows and meetings on EMC that may be of interest. Call us if you'd like more details.

- **IEEE Symposium on EMC...** August 8-12, 2005, at Navy Pier in downtown Chicago, IL, USA.

Public EMC Courses...

Here are the cities selected for the Winter/Spring 2005 EMC seminar series **hosted by Tektronix and Kimmel Gerke Associates, Ltd.** For more information, please visit our web site, www.emiguru.com.

- **San Diego, CA – February 7-8-9-10, 2005**
Doubletree Club Hotel Circle, San Diego, CA
- **Orlando, FL – February 14-15-16-17, 2005**
LaQuinta Inn Lakeside, Kissimmee, FL
- **Austin, TX – March 7-8-9, 2005**
Courtyard Austin Central, Austin, TX
- **Atlanta, GA – March 15-16-17, 2005**
Hampton Inn Perimeter, Atlanta, GA
- **Baltimore, MD – April 18-19-20, 2005**
Courtyard by Marriott, Columbia, MD
- **Boston, MA – April 25-26-27, 2005**
Courtyard by Marriott, Westborough, MA
- **Newark, NJ – May 9-10-11, 2005**
Hampton Inn, Somerset, NJ
- **Rochester, NY – May 16-17-18, 2005**
Courtyard by Marriott West, Greece, NY

By the way, four or more students from the same company qualify for a 10% discount. If you have 12 or more, an in-house class may make sense. All classes are conducted by either Bill or Daryl.

In-House EMC Courses...

Our on-site classes are ever popular, and we can tailor for your specific needs. We can address *design, systems, and troubleshooting issues*. Most classes run two days, but some opt for a third day for more details. Most clients have us stay an extra day for one-on-one design review meetings.

Its simple... you supply the meeting space...we supply the materials and the instructor (either Bill or Daryl.) Flat rate for up to 30 students, but with even a dozen students, an in-house class often makes sense.



Focus on "EMI in Power Electronics..."

Power electronics, like EMI, is often considered to have elements of "black magic." As a result, EMI in power electronics (power supplies, motor drives, and other pulse power circuits) can be particularly vexing. They account for some of the more interesting (and challenging) EMI problems we have faced over the years.

Multiple effects — Before we begin, let's briefly look at three key effects — frequency, amplitude, and time.

Frequency effects — Many power electronic problems range between DC and about 1 MHz. The latter are due to switching harmonics and transient rise times. A notable exception is the EFT (Electrically Fast Transient) that behaves more like 60 MHz, due to 5 nsec rise/fall times.

Simple *low frequency* circuit rules usually work from DC to about 10 kHz. More complex *high frequency* rules (due to transmission line effects, or parasitic inductance and capacitance) often become necessary above about 1 MHz. Thus, the range between 10 kHz and 1 MHz (the realm of power electronics) can cause confusion.

These frequency effects are particularly important with power grounding. For frequencies under 10 kHz (DC, or 60/400 Hz and harmonics), *single point grounds* are preferred. For frequencies 1 MHz and above (transients and EFT), *multipoint grounds* are preferred. For power frequencies between 10 kHz and 1 MHz, we often need to experiment to find the best grounding solutions. We may also need *hybrid grounds* — capacitors and inductors — to get the job done.

Amplitude effects — While most digital and analog circuits deal with milliAmps and milliVolts, even lower level power electronics are often dealing with tens or hundreds of Amps, and perhaps thousands of Volts, particularly with transients. These power levels are often well outside normal operating levels. As a result, we often need to worry about breakdown voltages of filters or capacitors, and saturation of inductors or transformers.

Time effects — The key parameter here is rise/fall time. As rise/fall times decrease, harmonics levels and parasitic coupling increase. As FETs and transistors get faster, we've seen a big increase in these types of problems.

A KGB Bullet...

"The general rule of thumb is that if you do the hardening during the design phase, it increases the cost roughly one percent. If you do it afterward, it may cost as much as 30 percent more."

A quote by Howard Seguire, weapons expert in "The Dawn of the E-Bomb," IEEE Spectrum, November 2003. (Probably applies to EMI in general as well.)

Power electronics designers are constantly striving for faster edge rates, since this improves efficiency. They often pay for this efficiently in increased EMI problems, both emissions and susceptibility. Fortunately, even small sacrifices in efficiency mean big improvements in EMI. Simple engineering tradeoffs can often solve the problems.

Conducted emissions — Since most modern high power electronics use high power switching circuits, *primary sources* are the fundamental switching frequency and the first 10-20 harmonics. Thus, a 50 kHz switcher is often a problem into the 1 MHz range, while a 500 kHz switcher is often causing problems at 10 MHz and beyond.

A *low frequency source* of emissions is harmonics of the input power frequency. Since switching power supplies are "non-linear" loads, the non-linear currents cause low frequency harmonics, which can put severe stresses on the power distribution systems. As a result, the European Union EMC requirements now addresses these concerns, as do most military and avionic requirements.

A *sneak source* of conducted emissions is parasitic coupling in power electronics circuits. The primary path is between switching transistors and heat sinks, but secondary paths also exist across transformers, or even to windings and shafts in motor drive circuits. Incidentally, these problems can result in conducted emissions of 20-40 dB or more above test limits.

Design solutions include filtering (both local and at the input power leads) for emissions; special pre-regulators or transformers for power harmonics; and Faraday shields and/or decoupling capacitors for parasitic coupling.

Conducted susceptibility — Since most power supplies are connected to the input power mains, the *primary concerns* are for external transients and other power perturbations (sags, outages, etc.) *Secondary concerns* are for internal transients, due to motors, relays, solenoids, etc. Both types often result in system damage.

A particularly insidious problem is EFT, which is often caused by arcing at power contacts. Often referred to as the *showering arc*, it can cause both damage and upset. In fact, the EFT is rapidly becoming a major source of unwanted system resets, right along with ESD.

Design solutions include filtering and transient protection. For momentary power outages (such as the common half cycle loss of 50/60 Hz power) additional energy storage may suffice, while for longer term outages battery backup may be necessary. Another key point — since EFT behaves like 60 MHz, your "standard" EMI power filters and transient protectors may not be adequate. You may need ferrites and fast transient devices.

Radiated emissions and susceptibility — Until recently, these problems have been of secondary concern for power electronics. Thanks to speed increases in power electronic devices, you can no longer safely ignore these issues.



In the past, we rarely saw power supply radiated emissions above 30 MHz. Now, we often see direct contributions from switching harmonics up to 100 MHz and beyond. We've also seen indirect contributions in the 200-400 MHz range due to parasitic oscillations of power regulator circuits. Incidentally, those same regulator circuits are vulnerable to moderate levels of RF (10-100 Volts/meter).

Design solutions include high frequency filtering, decoupling, and snubbing. We regularly recommend 1000 pF capacitors across regulator inputs and outputs. We often recommend small caps or ferrites to slow down switching edge rates. In this latter case, we typically slow the edge rates by tens of nanoseconds, which usually has little if any significant affect overall system efficiency.

Well, we hope you have found this discussion interesting and useful. Please call us if we can help you with any of your EMI needs — from DC to daylight — from design concepts to EMI testing or troubleshooting.

No matter how low you think politics has sunk, it can always sink even lower.

— Harry Browne

Application Note...

We still get requests for a copy of the Intel Application Note (AP711-EMI Design Techniques for Microcontrollers in Automotive Applications) that we helped write a few years ago, and is now out of print. We have a PDF version, so if need a copy, e-mail Daryl at dgerke@emiguru.com.

Some Engineering Humor...

Here are some terms you may find useful in your next engineering project:

- *Blamestorming* — Sitting around in a group, discussing why a deadline was missed or why a project failed, and who was responsible.
- *Ohnosecond* — That minuscule fraction of time in which you realize that you've just made a really BIG, uncorrectable mistake.
- *Percussive Maintenance* — The fine art of whacking the heck out an electronic device to get it to work again.
- *Cube Farm* — An office filled with cubicles.
- *Prairie Dogging* — When someone yells or drops something in a cube farm, and people's heads pop up over the walls to see what is going on.
- *Adminisphere* — The rarefied organizational layers beginning just above the rank and file. Decisions that fall from the adminisphere are often irrelevant to the problems they were designed to solve in the first place.

Book Reviews...

ESD Design & Analysis Handbook, by James Vinson, Joseph Bernier, Gregg Croft and Juni Liou. These four semiconductor industry engineers provide insights into ESD at the IC level, and discuss failure analysis techniques, environmental protection, and chip level design solutions. Kluwer Academic Publishers, 2003. ISBN 1-4020-7350-X.

E-Mail vs. Snail Mail...

Most of you now receive the KGB by e-mail, which makes it easy for you to archive or forward the KGBs. We do get quite a few returns, however, due to bad addresses or company firewalls. We then send the KGB by snail mail. *If you want to receive the KGB by e-mail, contact Bill at bkimmel@emiguru.com. — we will do the rest.* By the way, our mail lists (both e-mail and snail-mail) are PRIVATE, so you don't need to worry about spam from us.

Questions from the mailbag...

We recently had this question in an e-mail: "You mentioned (in a recent article) that photodiodes can rectify radiated electromagnetic energy, producing a demodulated output. How likely is this to occur, and at what levels?"

Yes, photodiodes can, and do, rectify RF energy that reaches the diode. The diode behaves just like a diode in a crystal radio, so even low levels can cause problems.

The actual failure level depends on field strength, components, cable/wiring lengths (hidden antenna effects,) and frequency. Nevertheless, a good rule of thumb is to expect problems at levels above 1 volt/meter, and cable or wiring lengths greater than 1/20 wavelength (about 4 inches at 150 MHz.)

For comparison, unprotected power circuits (regulators, etc.) are usually about 10 times more robust, often working fine up to 10 volts/meter. Unprotected digital circuits are usually about 10 times more robust than that, often working fine up to 100 volts/meter. Thus, you can see that diodes and low level analog circuits are often quite vulnerable to RF energy.

A small capacitor across the diode is often enough to solve or prevent this problem. For 100 MHz and higher, a 0.001 uF capacitor works fine. At 1 MHz, a 0.1 uF capacitor is more appropriate. In either case, keep the cap leads short! The goal is to shunt the diode with a reactance of no more than a few ohms, thus providing an RF "short" across the diode. Above 100 MHz, augmenting the shunt cap with a series ferrite can provide significant additional protection.

In summary, the bad news is that unprotected diodes and analog circuits are vulnerable to RF. The good news is that protection right at the circuit is usually very effective in mitigating these problems.



How to Contact Us...

Telephone... Toll Free or Direct...

- Answering Service – 888-EMI-GURU (Toll Free)
- Bill Kimmel – 651-457-3715 (Minnesota Office)
- Daryl Gerke – 480-755-0080 (Arizona Office)

E-Mail... A preferred way of reaching us, if you don't need a "real time" answer. Addresses are:

- Bill Kimmel – bkimmel@emiguru.com
- Daryl Gerke – dgerke@emiguru.com

Snail Mail... If you need to mail or Fed-X something...

- Bill Kimmel, 300 Christine Lane, W. St. Paul, MN 55118
- Daryl Gerke, 2538 W. Monterey, Mesa, AZ 85202

Web Site... Please visit our web site (www.emiguru.com) for class schedules, back issues of the KGB, and other useful EMI stuff. We've also included detailed information on our firm, such as our consulting and training brochures.

EMI Suppression Handbook...

The little red book with the great EMI war stories, written by us and edited by our good friend, Dr. Tom Chesworth. Only \$25 (plus shipping.) To order, contact Seven Mountains Scientific at 814-466-6559, or visit their web site at www.7ms.com. Another thought... attend one of our classes and get this book FREE — it is included with the class.

EMI-Toolkit® 2.0...

Check out the updated version of our popular *EMI-Toolkit®* software. The new version includes many useful features, plus an improved format. Comes on CD, and runs under Windows 95/98/NT/2000/XP. \$150 single user, \$750 for site license. Discounts apply for V1.0 users.

If you are heavy into the EMC standards, consider *EMI-Toolkit® Plus*. All the neat features of V2.0, plus additional information on most relevant EMC standards (MIL-STD-461, DO-160, FCC, CISPR, and more...)

For more information on either version, call us at

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