

# KIMMEL GERKE



## Bullets

Summer , 1999

### Welcome to KGB...

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

**This issue discusses grounding and EMC.** This is probably the most important, yet least understood, aspect of EMC. As such, we'll only be able to scrape the surface of this important topic.

Several years ago we discussed grounding, but we only addressed different types of grounds - safety, power, ESD, EMI, etc. In this issue, we'll try to resolve the dilemma between "single point grounds" and "multi-point grounds". Yes, both are correct... under the right circumstances.

A key difference is frequency (and the associated parasitic inductances, capacitances, and wavelengths.) At low frequencies (such as 50/60 Hz), we can usually ignore these effects. At higher frequencies (beginning at about 10 kHz), these effects become very significant.

While we're at it, we'll look at "ground loops", and you'll see why these are not always something to be feared. We'll also look at "hybrid grounds", often a good compromise in complex EMI situations.

As always, give us a call if we can help you with any of your EMI problems, from circuit boards to full systems.

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

### emicalog.com

Looking for an EMI part, but don't know who has what you need? Trying to find a test lab with special capabilities? Tired of paging through directories just to find a (large) list of company names?

Well, we were too, and so was a friend and colleague, Patrick Conway (Conway Technology Associates.) That's why we put our heads together and started the *emicalog.com*, an on-line database with search capabilities, plus a few new wrinkles. **Details Inside.**

### Shows and Conferences...

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

**IEEE International EMC Symposium..** August 2-6, 1999, at the Washington State Trade & Convention Center in Seattle, WA. We'll both be there, of course. Daryl will be presenting "*Diagnosing & Troubleshooting EMI Problems - Tips & Techniques*" during the Monday tutorial workshops. Come visit us at booth #204.

**Fourteenth Annual Minnesota EMC Event..** Moved back to the fall for 1999. Combined day of training and exhibitions. It takes place Thursday, September 9, 1999 at the Thunderbird Hotel in Bloomington.

**Arizona EMC-99 a Success...** Bill and Daryl both participated in this one day colloquium, held in Scottsdale, Arizona in early May. Other speakers included Henry Ott, Dan Hoolihan, Bill Ritenour, and Scott Roleson. Thanks to all who supported this effort — Janet O'Neil, Terry Donohoe, Harry Gaul, all the vendors, and the local Phoenix EMC Society Chapter members.

**Area Code Changes...** Once again, please note that both Bill and Daryl have new area codes. Here are our new direct numbers:

—Bill Kimmel - 651-457-3715 (Was 612)

—Daryl Gerke - 480-755-0080 (Was 602)

Of course, you can always reach us through our **Toll Free "888" number - 1-888-EMI-GURU**. This reaches our answering service in Minnesota, so please leave a message and we'll get back to you. For calls from outside the US, please use 612-330-3728 (*Note this area code stays the same.*) You can also contact us at the following:

**E-Mail..** A preferred way of reaching us if you don't need a "real-time" answer. We both check our mail boxes regularly, and it works out well. Addresses are:

Bill Kimmel - [bkimmel@emiguru.com](mailto:bkimmel@emiguru.com)

Daryl Gerke - [dgerke@emiguru.com](mailto:dgerke@emiguru.com)

**World Wide Web** — Visit our "home page" at <http://www.emiguru.com>. You'll find back issues of the *KGB (Kimmel Gerke Bullets)*, plus other information.

## Focus on Grounding...

When we first looked at grounding in 1992, we promised to provide more details in a future issue. Well, after seven years, it's probably time to revisit this topic. After all, grounding is probably one of the most important, yet most misunderstood, aspects of EMI/EMC. (For the original grounding discussion, see past KGBs at [www.emiguru.com](http://www.emiguru.com). See the Spring 1992 issue.)

**What is a ground, anyway?** While there are many possible definitions, the one we like best for analyzing EMI problems is "ground is a return path for current." Thanks to "ground symbols" on a schematic, we sometimes forget that current flows in a complete circuit, and must return to its source.

At KGA, we often refer to this as the "sewer system" model for grounding. (Daryl's brother is a civil engineer, which may explain the origin of this analogy.)

In a sewer, we are concerned about two vital issues: low impedance to flow, and low impedance connections to the "big sewers." So it is with a ground system — we need to maintain low impedance to minimize the voltage difference across the ground system, and we need to maintain low impedance connections. Yes, Ohm's Law still applies to ground systems —  $E=IZ$ .

In a sewer, another concern is unwanted mixing of waste. That's why most cities today have separate sanitary and storm sewers — to minimize unwanted mixing. In a ground system, different currents may be mixed together in a single ground path. That's why we often use separate "analog" and "digital" grounds.

But enough sewer talk. Let's look at several key grounding issues, and what they mean to EMI problems.

**Grounds are very frequency dependent** Since all ground systems must have some finite impedance (even if it is low), there must be a resulting voltage difference between different points in a ground system. The lower the impedance, the lower the voltage for a given current. So if we just use bigger wire, we'll be OK, right?

### A KGB Bullet...

Here are some guidelines for power line filter design:

- Differential mode (DM) predominates < 1 MHz
- Common mode (CM) predominates > 1 MHz
- Broadband (BB) noise is typically high impedance
- Narrowband (NB) noise is typically low impedance

Thus, the following strategies are suggested:

- DM/NB = use differential mode chokes
- DM/BB = use differential mode (X) capacitors
- CM/BB = use common mode chokes
- CM/NB = use common mode (Y) capacitors

Keep in mind there will be exceptions, but this is a good place to start.

Unfortunately, as frequency increases, the impedance of a ground system changes. These changes are due to two phenomena: *inductance*, and *transmission line effects*.

*Inductance* is a bit easier to visualize. Every wire has resistance, as well as inductance. From DC to about 10 kHz, the resistance is usually the predominant factor for typical round wires. Thus, we are usually most concerned about ground "resistance" at frequencies under 10 kHz. This factor leads to *single point grounds* for low frequency threats, such as 60 Hz in analog or audio circuits. It also leads to *ground planes* or *ground straps* for high frequency threats, such as RF or digital circuits.

*Transmission line effects* are a bit trickier to visualize, but still easy when you consider transmission line transformers. If you travel  $\frac{1}{4}$  wavelength from a "short" on a transmission line, the impedance looks like an "open" circuit, and vice-versa. If you travel  $\frac{1}{4}$  wavelength from a low impedance "ground connection", the impedance is a high impedance, not a low impedance. This factor leads to *multiple point grounds* for RF and digital circuits. (At 60 Hz a wavelength is 5000 km, while at 300 MHz it's only a meter... and only 30 cm at 1 GHz.)

**What about ground loops?** A ground loop occurs whenever unwanted ground currents can enter and leave a victim circuit at two different points. In large systems, this often occurs with different signal/chassis/facility ground connections. In circuit boards, this often occurs with shared planes or traces for digital and low level analog circuits. The latter are the typical victims, since they can not tolerate much "noise voltage" in their ground paths.

Many people worry needlessly about "ground loops". They are primarily a low frequency problem (50/60 Hz power or other threats under 10 kHz), so analog and audio designers pay a lot of attention to them. For these low frequency threats, *single point grounds* are very effective.

At higher frequencies, however, parasitic capacitance provided alternate "ground paths", so even if you think you have a "single point ground", in reality you do not. At higher frequencies we accept these parasitic ground loops, and concentrate on lowering ground path impedances through *planes*, *grids*, *straps*, and other *low inductance structures*.

**So what is best... single point or multi-point?** It depends on the threat, and the victim. You need to consider both the frequency, and the victim circuit threshold levels.

For *low frequency* threats (50/60 Hz power or power harmonics) and low level analog circuits, single point grounds are preferred. Ground loops are a big problem here. In fact, getting rid of a 60 Hz ground loop can reduce EMI levels by a factor of a million or more.

For *high frequency* threats (emissions, RF immunity, or transients) multiple point grounds combined with low impedance structures (planes, grids, straps) are preferred. Ground loops are not a key concern here... they will exist no matter what you do, thanks to parasitic capacitance and inductance.

**What if I need to address both low and high frequency threats?** Then consider *hybrid grounds*. Multiple high frequency connections can be made with capacitors. Two examples are: (1) using multiple caps for PCB/chassis connections with a single DC connection, or (2) using a cap at one end of a cable shield while providing a solid DC connection at the other.

In both examples, the *hybrid* provides a multi-point connection at high frequencies, while maintaining a single point connection at low frequencies. We often use 1000 pF caps — at 100 MHz they look like about 1.5 ohms, while at 60 Hz they look like several million ohms.

Alternately, low frequency connections with high frequency isolation can be achieved with inductors or ferrites. We've used this approach with success on a number of sensitive analog systems.

Incidentally, remember that transients often look like "high" frequencies. With a 1 nanosecond rise time, ESD transients look like about 300 MHz, definitely a "high" frequency threat. But even power transients with 1 microsecond rise time look like about 300 kHz. We've solved a number of transient induced problems in mixed analog/digital instrumentation systems with hybrid approaches on cable shields.

**Summary:** We hope this second installment on grounding has proved helpful. There are still a few things we could discuss, so we'll try not to wait another seven years discuss grounding again. In the meantime, give us a call if we can help with your grounding, or any other EMI problems.

"Learn from the mistakes of others. You can't live long enough to make them all yourself."  
**—Unknown**

## Engineers frustrated by EMI...

So says a survey taken at the *Printed Circuit Board Design Conference* earlier this year, as reported in *EE Times* and *Conformity Magazine*.

Apparently 20% of those surveyed deal with EMI issues on a daily basis, and wish they had better tools and insights to address the problems during the design stage. Also, the general consensus was that EMI issues (and related *Signal Integrity* issues) are both complicated and changing.

So, if you are frustrated with EMI/SI, you're not alone. If you're in the business (as we are), think "job security." And seriously, if you need help, give us a call... we deal with EMI/SI frustration and ambiguity all the time.

## emicatalog.com...

By the time you read this, our "experiment in EMC" should be available. We invite you to try it out, at [www.emicatalog.com](http://www.emicatalog.com). Then let us know what you think.

This is not just another data base. Rather, it includes several features that we, as EMC engineers, have found useful to us. (By us, we means Bill, Daryl, and Patrick Conway of Conway Technology Associates, our very capable partner in this venture.)

Our objective was to help design, systems, and test personnel find quick information for solving their EMI/EMC problems. This is done two ways:

- (1) By guiding you to appropriate *vendors* or *test labs*
- (2) By providing some tools for in-depth comparisons

The *vendor search* works like a "buyer's guide" but with computer enhanced search capabilities. You can search for components, shielding materials, test labs, test equipment, and specialty items. Numerous parameters let you narrow your search to give you more precise results. At that point, you can click on the vendor name for more information, or jump directly to their web site.

The *design tools* help you make detailed comparisons on select components. The first two tools available are *Ferrite-Finder*, and *Gasket-Finder*, with more planned in the future. (By the way, these are Patrick's brainchildren, based on his many years experience as an EMC engineer at Compaq.)

We all hope you enjoy using *emicatalog.com*. The best part of all this... it's FREE. We'll be interested in hearing what you think about our latest EMC (ad)venture.

**Book Review...** If you are like us, you occasionally get questions on the possible health effects of 60 Hz magnetic fields. Here is a book that provides some good engineering information on this topic.

**Power Frequency Magnetic Fields and Public Health...** by William Horton and Saul Goldberg, published by CRC Press, 1995. It is impartial, and the authors state in their preface, "To date, there is no convincing argument that it does or does not" have a health impact. A good technical resource if you are interested in this subject.

### A KGB Bullet...

Here is some advice from on power transients Alex McEachern of BMI...

"As a rule, if the peak amplitude (in volts) is less than 100% of the rms voltage in a circuit, then the impulsive generally won't do any damage. However, it is greater than 200% of the rms voltage of a circuit, it may disrupt sensitive loads."  
**(EC&M Magazine)**



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**Public EMC Classes...** We are now starting to set up our fall schedule for the ever popular EMI Made Simple classes sponsored by Tektronix. Here are the tentative cities for Fall 1999:

- Denver, CO
- Santa Clara, CA
- Phoenix, AZ
- Los Angeles, CA
- Portland, OR
- Albuquerque, NM

As you may have noted if you've been to a recent class, we are emphasizing Signal Integrity issues, and showing how they complement good EMC design. Of course, EMC issues go beyond SI, as they also must address grounding, shielding, and filtering in addition to PCB issues.

Check our web site ([www.emiguru.com](http://www.emiguru.com)) or watch for a mailer on the exact details on classes in your area. Watch also for an important change in class format.

**Reprints...** EDN Magazine's Designer's Guide to Electromagnetic Compatibility...

This popular EMC design guide (written entirely by us) is still available. For your copy, call Cahners Reprint Services at 1-800-523-9654. Only \$19.95+ shipping.

## EMI Suppression Handbook ... by

Bill Kimmel and Daryl Gerke, and edited by our good friend and Associate, Dr. Tom Chesworth. This is a collection of articles written over the past ten years for Electromagnetic News Report. The book includes numerous "war stories" on various aspects of EMC — most with a lesson or moral.

Only \$20 plus shipping. To order, contact Seven Mountains Scientific at 814-466-6559, or visit their web site at [www.7ms.com](http://www.7ms.com).



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