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, 628 LeVander Way, So. St. Paul, MN 55075
– 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.

EDN Designer's Guide to EMC...

Written entirely by Kimmel Gerke Associates. First published in 1994, and updated in 2001 (three new chapters.) Now available – *at a reduced price* – directly from Kimmel Gerke Associates.

Order on-line at *www.emiguru.com*, for $29 (includes US shipping.) Call for special pricing on multiple copies. *Attend a class and get a FREE copy of this book.*

In-House EMC Courses...

Our on-site classes are very popular. Here are some recent classes we have done for clients:

-Design for EMC (2 days)
-EMC Grounding & Shielding (2 days)
-EMC in Military Systems (2 ½ days - 3 days)
-EMC in Avionics Systems (2 days)
-EMC in Medical Devices (2 days)
-EMC in Vehicular Electronics (2 days)
-EMC and Signal Integrity in PCBs (1 day)
-EMC for Mechanical Engineers (1 day)

We can customize to meet your special needs. Flat rate for up to 30 students, but with even a dozen students, an in-house class makes sense. Call *888-EMI-GURU* for more information on an in-house class at your facility.

Kimmel Gerke Associates, Ltd.
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Winter 2009/2010

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 focuses on frequency, probably the most important (yet often misunderstood) parameter when dealing with EMI issues. Different frequencies usually mean different strategies and design rules – for grounding, shielding, cables, components, circuit boards, and more.

As frequency increases, higher order effects can no longer be ignored. Parasitic inductance and capacitance often become significant parts of the "hidden schematic." Traces, wires, and cables often become "hidden transmission lines and antennas." In short, simple schematic representations fall apart at high frequency.

Regardless of your frequency concerns – from DC to daylight – give us a call if you need EMI help. Happy Holidays, and Best Wishes for 2010!

Bill Kimmel, PE, and Daryl Gerke, PE

EMC Winter Workshops 2010

San Diego, CA - February 9-10-11, 2010
Orlando, FL - February 16-17-18, 2010

Need a winter break, and some fun in the sun? Want to learn more about EMC design or troubleshooting? Then join us in San Diego or Orlando for our annual "EMC Winter Workshops."

In addition to our regular *Design for EMC class* (2 days), you can attend our *EMC Troubleshooting* class (1 day). The troubleshooting class is offered ONLY at these locations, as an optional extension to the two day class. If you have already attended a two day class, you are welcome to join us for this additional day.

For more details, visit our website (*www.emiguru.com*) or call us toll free at 1-888-EMI-GURU. (Inquire about our special hotel rates in Orlando.)

Free Copy of Useful Bits of Info...

Want your own copy "UBI," the little shirt pocket sized "cheat sheet" for EMI? Just e-mail *dgerke@emiguru.com*, with your snail mail address, and we'll send you one.

Public EMC Classes...

Here are the cities for the Winter/Spring 2010 schedule for the EMC seminar series co-hosted by Tektronix and Kimmel Gerke Associates, Ltd.

–San Diego, CA - February 9-10-11, 2010
Arrow Electronics Inc., San Diego, CA
–Orlando, FL - February 16-17-18, 2010
Best Western Lakeside, Kississimme, FL
–Dallas, TX - March 8-9, 2010
Tektronix Region Office, Richardson, TX
–Washington, DC - March 16-17, 2010
Washington Labs, Gaithersburg, MD
–Boston, MA - April 2010
(Exact date & location TBD)
–Rochester, NY - April 2010
Courtyard by Marriott, Greece, NY (Exact date TBD)

For more information on any of these locations, please visit our web site, *www.emiguru.com*. Call for discounts for multiple students.

For larger groups (12 or more students), it often makes sense to hold an in-house class. These are done at a fixed cost, with up to 30 attendees. This can really drop the cost per student. You can even co-share with another company– we've had several firms do this in the past.

Some thoughts on EMC training... We know times are tight, but EMC training is still a very good investment. Consider how much even ONE extra trip to the EMC test lab costs, and it just makes sense to prevent the problems in the first place. We'll give you and your colleagues the tools to *identify, prevent, and fix* EMC problems at the design stage, when the fixes are the most cost effective.

Incidentally, all classes are conducted by either Bill or Daryl, so you get the benefit of our many years of dealing with EMC issues. We've already taught thousands the intricacies of EMC – put that experience to work for you.

Watch for our Webinars and Blog...

As part of our ongoing educational efforts to share our (often hard earned) EMI experience and knowledge, we plan to offer some short webinars on select subjects to supplement our regular class offerings. We also expect to have a blog in January 2010. More details inside. Check our web site, *www.emiguru.com*, for schedules.

Kimmel Gerke Bullets is a free newsletter on Electromagnetic Interference/Compatibility (EMI/EMC).
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Focus on Frequency...

When dealing with EMI issues, we usually look at five key parameters – frequency, amplitude, time, impedance, and dimensions – which we have dubbed "FAT-ID." Of these, frequency is probably the most important, and yet most misunderstood parameter.

Multiple order effects... As frequency increases, so do the high order effects. Parasitic inductance and parasitic capacitance become significant, and can no longer be ignored. Distributed effects become significant as wires/traces/cables behave as transmission lines and antennas. Simple schematic representations often fall apart at higher frequencies.

Three broad ranges... We like to divide the frequency world into three simple ranges – low, medium, and high. This is just a starting point, and further subdivisions may become necessary.

Low frequencies – DC to 10 kHz. This is the traditional AF (audio frequency) range. Simple "lumped component" schematic representations work fine here. Parasitic and distributed effects are so small that they can be ignored.

This is the world of audio, linear power supplies, and low frequency analog instrumentation.

Medium frequencies – 10 kHz to 1 MHz. This is where the RF (radio frequency) range traditionally begins. At about 10 kHz, parasitic inductance rears its ugly head, and the inductive reactance starts to exceed the resistance of traces and wires. We often assume 20 nH/inch for wires/traces, since the inductance is relatively insensitive to wire size.

Parasitic capacitance starts to be a problem, particularly with high impedance circuits.

This is the world of switch mode power supplies, power electronics, motor drivers, and power transients.

High frequencies – 1 MHz and up. Depending on the physical dimensions, distributed effects begin to show up. We often assume anything longer than 1/20 wavelength can act as a transmission line or antenna. At 1 MHz, that would be 15 meters (about 50 feet), and by 100 MHz that distance is only 15 cm (about 6 inches.)

A KGB Bullet... Due to losses, a coax cable behaves like a low-pass filter whose cutoff frequency decreases with length. For example, here are the approximate -3dB power points for RG-58A/U:

Cable Length	Frequency
100 feet	25 MHz
200	6
500	2
1000	1.5

Cable losses increase above these levels with high VSWR.

This is the world of digital electronics and radios. In fact, most modern electronics fall in this category.

A helpful hint... As a troubleshooting method, we often recommend looking at a circuit or system at least three frequencies: DC (or maybe 60 Hz), 1 MHz, and 100 MHz or more. This is like adjusting the magnification on a microscope. You are still looking at the same phenomena, but with a different focus. By doing this, the underlying problems and solutions often become obvious.

Equivalent frequencies... Since many of us live in a digital "time-domain" world, it is helpful to be able to quickly convert to the "frequency-domain" world. Rise/fall times (edge rates) are the key parameter, *not* clock rates. We typically use 1/(pi x risetime), or if we are really lazy, we just multiply the risetime by about 0.3 (the answer is certainly close enough for our needs.)

Here are typical "equivalent frequencies" for transients:

– Lightning – 1 usec nominal – 300 kHz
– Power transients – 300 nsec nominal – 1 MHz
– EFT (Electrical Fast Transient) – 5 nsec – 60 MHz
– ESD (Electrostatic Discharge) – 1 nsec – 300 MHz

Here are typical "equivalent frequencies" for logic:

– 10 nsec rise/fall – 30 MHz
– 3 nsec rise/fall – 100 MHz
– 1 nsec rise/fall – 300 MHz
– 300 psec rise/fall – 1 GHz
– 100 psec rise/fall – 3 GHz

At the above edge rates, the clock rates are typically 10-20 times slower. As a result, we often just multiply the clock rate by 10 or 20 to give us a first approximation. This can be helpful if you don't know the exact rise/fall times.

Design Solutions... By now it should be apparent that one set of design rules may not work over the entire frequency range. In fact, the rules often conflict – low frequency rules may not work at high frequencies, and vice versa. Here are some quick thoughts on how to apply design rules in a multi-frequency world.

Grounding – At *low frequencies* (under 10 kHz), single point grounds are usually preferred, particularly when analog circuits are present. This strategy applies to both signal returns and cable shields.

By carefully steering currents, the dreaded "ground loop" can be avoided. A classic example of this is 60 Hz hum in an audio or telephone system. Unfortunately, the single point ground falls apart at higher frequencies due to both parasitic and transmission line effects, often rendering it ineffective at 1 MHz and above.

At *high frequencies* (above 1 MHz), multi-point grounds are usually preferred, coupled with low inductance paths such as planes, grids, and straps. By reducing the ground impedance, the resulting noise voltages can be controlled.

Kimmel Gerke Associates, Ltd. Winter 2009/2010

At *medium frequencies* (10 kHz-1 MHz), you may need to experiment to find the best approach. That is why power electronics grounding is often so challenging.

Cables – Here are some general "frequency dependent" guidelines for shielding, grounding, and terminations.

For signal *shielding*, most materials work fine from DC to 1 MHz, where non-solid shielding starts to degrade. Thus, for frequencies above 10 MHz, we recommend high quality braids with high optical coverage.

For cable *grounding*, single-point ground shields for low frequencies (<10 kHz), but multi-point ground shields for high frequencies (>1 MHz). Capacitive (hybrid) grounds or multiple shields may be necessary to cover the full ranges.

For cable *terminations*, drain wires ("pigtails) are fine for low frequencies (<10 kHz), but should be replaced by circumferential terminations for high frequencies (>1MHz.)

Circuit Boards – At low frequencies (audio and power circuits), single or double layer boards work well. An exception is low frequency circuits that are exposed to high frequency threats, such as RF immunity or ESD testing.

At high frequencies (digital and RF), multi-layer boards with power and ground planes are highly recommended. An exception can be made for simple embedded controllers, typically operating at clock speeds under 5 MHz. Even so, multi-layer boards still provide significant ESD protection.

We hope we have helped demystify and clarify with the wide world of frequencies. Call us if you need help!

Alcohol & calculus don't mix. Never drink & derive.
– Author Unknown

You Might Be an Engineer If...

–You see a good design, and still need to change it. .
–You save the power cords from broken appliances.
–Everyone else on the cruise is looking at the scenery, and you are still on a personal tour of the engine room.
–You wife has no idea what you do at work.
–You know what http:// stands for.
–Your laptop computer cost more than your car.
–You have calculated how much you make per second.
–You still own a slide rule – and know how to use it.
–You window shop at Radio Shack.
–You have ever repaired a $5 radio.

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 you need a copy, e-mail Daryl at *dgerke@emiguru.com*.

Book Review...

Electromagnetic Compatibility Engineering, by Henry Ott. This started out as a third edition of Ott's very popular book, *Noise Reduction Techniques in Electronic Systems,* but ended up as much more. At over 800 pages, this new book has much new and revised material, all written in Ott's practical, easy-to-read style.

We believe this will be Henry Ott's lasting legacy to the EMC community. Available from John Wiley & Sons. ISBN 978-0-470-18930-6. $96 at *www.amazon.com*.

New EMC magazine...

From the former staff of *Conformity* (now defunct) comes a new magazine, *IN Compliance Magazine*. According to Lorie Nichols, publisher/editor, she and her colleagues (Sharon Smith and Erin Feeney) are following a long time dream. We certainly understand those sentiments, and wish them all the best!

For more information, go to *www.incompliancemag.com*. According the press release we got, the digital edition is free, and the print edition is $24.95 per year (12 issues) for North American subscriptions.

Kimmel Gerke Webinars...

While we don't have a firm schedule in place, we plan to begin with our webinar program prior to the next KGB. The immediate goal is to offer some focused topics that we don't cover in depth at our public EMC seminars. Here are several topics under consideration:

– ESD as an EMI Problem - Causes and Solutions
– Design Impact of MIL-STD-461 & MIL-STD-464
– EMI in Power Electronics - Design & Systems
– Systems Engineering & Military EMC
– How to Identify and Fix EMC Problems in the Field

Let us know if you have a topic idea, and watch our website, *www.emiguru.com*, for schedules and details. We are looking forward to this "EMC Experiment."

EMI-Toolkit (R) 2.0...

The updated version of our popular *EMI-Toolkit (R)* software 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 (R) Plus*. All the neat features of V2.0, plus additional information on most relevant EMC standards (MIL-STD-461, DO-160, FCC, CISPR)

For more information on either version, call us at 1-888-EMI-GURU, or e-mail *bkimmel@emiguru.com**

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