

KIMMEL GERKE



Bullets

Winter, 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 crosstalk, an important concern for both EMC and signal integrity. As we discussed in the Spring 1999 *KGB*, signal integrity deals with millivolts and milliamps, while EMC often deals with microvolts and microamps. Crosstalk is often a critical "sneak path" for both signal integrity and EMC emissions/immunity.

We'll look at two coupling mechanisms for crosstalk, and then give you several "fixes" as well as some proven "rules of thumb" for determining if and when crosstalk might pose a problem. These can be applied at both the circuit board and the cable levels.

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

Seasons Greetings... Our sincere best wishes to you and your families this holiday season, and all the best to you in the year 2000... *Bill, Daryl, and our Associates.*

EMC Winter Workshops 2000

San Diego, CA - February 14 - 17, 2000

Orlando, FL - February 7 - 10, 2000

Need a winter break, and some fun in the sun? Want to learn more about EMC design, systems, or troubleshooting? Then join us in San Diego or Orlando in February for our "once a year" expanded seminar series, sponsored by Tektronix.

This year we have one day on systems, two days on design, and one day on troubleshooting. Take only what you need to get up to speed on EMC issues.

See the insert for details, or call us toll free at 1-888-EMI-GURU. (*Inquire about special hotel rates if you reserve by January 1.*)

EMC Calendar...

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

IEEE International EMC Symposium... August 21-25, 2000, in Washington, DC. We'll both be there, of course. More details in a future issue.

Fifteenth Annual Minnesota EMC Event... Fall of 2000, exact date to be determined. Combined day of EMC training and exhibitions in the Twin Cities.

EMC Courses... These are the very popular seminars sponsored by Tektronix and presented by Kimmel Gerke Associates, Ltd.

- Orlando, FL - February 7-10, 2000
 - San Diego, CA - February 14-17, 2000
 - Dallas, TX - March 2000
 - Raleigh, NC - March 2000
 - Washington, DC - March 2000
 - Rochester, NY - April 2000
 - Newark, NJ - April 2000
 - Boston, MA - April 2000
 - Chicago, IL - May 2000
 - Detroit, MI - May 2000
 - Minneapolis, MN - May 2000
- For more details, visit our web site, www.emiguru.com.

emicatalog.com...

Have you visited our new web site yet? It is an on-line database with search capabilities for finding special EMC components or EMC test labs.

This is a joint venture with a friend and EMC colleague, Patrick Conway (*Conway Technology Associates*). It has over 300 vendors and almost 100 test labs listed. Very easy to use, with hot links to vendor web sites. Best of all, it is FREE to users, as costs are supported by vendors. (Be sure to mention you saw them on the *emicatalog.com*.)

We introduced the *emicatalog.com* at the 1999 IEEE EMC Symposium in August, and since then we have had thousands of hits. If you haven't visited it, please do so, and let us know what you think about it. (*If you are a vendor, please call for information on how to get your company listed in emicatalog.com.*)



Focus on Crosstalk...

We often refer to crosstalk as a "hidden transmission line" that can inadvertently couple unwanted energy between traces on a circuit board, wires in a cable, or even between separate cables. It is a key concern for Signal Integrity (SI) in high speed digital systems, and it is often a critical "sneak path" for EMI into or out of a system.

As we mentioned in the Spring 1999 *KGB*, there is a lot of overlap between SI and EMI issues. The methods to prevent and fix are often the same, but the levels are usually different. Thus, good SI design is a good start, but still may not solve EMI problems.

For SI, we are usually dealing with millivolts or millamps, levels that are large enough to upset a circuit. For EMI emissions, we are sometimes dealing with microvolts and microamps, so the EMI levels of concern are often several orders of magnitude below SI levels. For EMI immunity, on the other hand, the levels may be well above circuit thresholds — i.e. kilovolts for ESD. Regardless of levels, crosstalk is a very common culprit for both EMI and SI.

Two Coupling Mechanisms - Crosstalk is the result of both parasitic mutual capacitance and parasitic mutual inductance between traces, wires, or cables. The actual levels are dependent on several factors - distance, spacing, and circuit impedance levels.

The last parameter, impedance, often determines which mode predominates — in high impedance circuits (including most digital and analog circuits), the capacitive mode predominates, while in low impedance circuits (power supplies, low impedance audio) the inductive mode usually predominates. We'll soon see why this distinction is important.

The actual levels can be calculated, but the formulae are a bit complex, and the errors are often quite large, particularly at higher frequencies. In this article, we'll give you some quick "rules of thumb" that we often use for a quick assessment.

For those of you who relish details and equations, we recommend Dr. Clayton Paul's book, *Introduction to Electromagnetic Compatibility*. (Visit our web site, emiguru.com, and click on EMI Publications for more details on this book.) Another good source is our own software package, *EMI-Toolkit*[®], which includes a crosstalk predictor

A KGB Bullet...

Interested in Power Factor Correction? Here are four IC vendors that offer components that can help:

- Cherry Semiconductor - www.cherry-semi.com
- Unitrode - www.unitrode.com
- Motorola - www.mot.com
- Micro Linear Corp.

With the right design, you should be able to achieve power factors corrected to 0.98 or 0.99.

—"*Factor in Power Factor*", *EDN Magazine*, 2/4/99

based on the standard two wire pair model that has been around for many years. Plug in the dimensions, and it will give you a prediction.

Reducing Crosstalk - There are several ways to reduce crosstalk. Some work for both mechanisms, while others are specific for either mutual inductance or capacitance. Generally, PCB crosstalk is capacitive, so the common and capacitive methods are preferred for circuit boards. Cables, on the other hand, can have both modes present, so don't ignore inductive crosstalk in systems.

-Common methods - *Reducing common length* and/or *increasing the spacing* between "culprit" and "victim" traces or wires are very effective against both modes. In addition, *moving traces closer to a ground plane* (or return trace on one or two layer boards), or *moving wires closer to their returns in a cable* are also effective. For cable-to-cable crosstalk, moving cables closer to a "ground plane", such as cabinet metal, can also be effective. Finally, *decreasing edge rates* is also effective for both modes.

-Capacitive mode - *Inserting a grounded guard trace* between the "culprit" and "victim" traces can be effective at the PCB level. (The ground trace should be grounded at both ends, and/or stitched to the ground plane at least every $\frac{3}{4}$ inch.) For cables, *a shield over the wires or cables* can be very effective against capacitive crosstalk. *Lowering the circuit impedance* can also be effective. (If you use "far end" terminations on transmission lines, you usually reduce the capacitive crosstalk at the same time.)

-Inductive mode - *Twisting wire pairs* can be very effective for inductive crosstalk. (A guard trace is usually ineffective against inductive crosstalk, since it is a capacitive shield, not an inductive shield.) Generally speaking, the tighter the twist, the better the protection. For low frequencies such as 60 Hz, however, even simple twists can be effective. For example, telephone wiring is often twisted at about one twist per foot, which protects well against 60 Hz fields. "Data grade" telephone wiring is often twisted at about one twist per inch, to limit crosstalk from audio and digital signals in the kHz and perhaps low MHz range.

Raising circuit impedances may be necessary if inductive crosstalk predominates. This is often done with an inductor, which increases impedance with frequency.

Predicting crosstalk - As mentioned earlier, crosstalk calculations can be cumbersome and inaccurate. Here are the "quick and dirty" methods we use to predict crosstalk. These work at both the PCB and cable levels.

First, we assess the "common length" versus the circuit edge rates (rise/fall times). The worst case would be 100% coupling, which would require a "common length" equal to the length associated with the edge rate. In free space, the propagation velocity is about 1 foot/nsec, and on a circuit board or ribbon cable, it is about 6 inches/nsec. Thus, if we have 1 nsec edge rates (very typical today) and traces close together for six inches or more, we suspect crosstalk. For multilayer circuit boards, we often derate by a factor of 10, and for buried traces (stripline) by a factor of 100.

Next, we assess the "spacing between traces or wires" vs. the "height above a ground plane" or "spacing between signal wires and their returns." If the "spacing to height" ratio is less than 3:1, we become concerned. At 3:1 or greater, the crosstalk has already decreased by about a factor of 10. This results in a popular "3:1" rule that many EMC engineers use for crosstalk.

Several years ago, an EMC engineer giving a talk at a conference introduced the "fat trace" concept for clock lines. He said that his company routed the clock trace first, as a fat trace (typically 6 times wider than normal). Then, when the routing was done, they rerouted the trace "skinny" leaving an "open area" on both sides of the trace. He claimed their emissions problems were significantly reduced, supporting the theory that crosstalk is a common "sneak path" for emissions. In any event, paying attention to crosstalk is certainly worthwhile for both SI and EMI.

Summary: We have used these methods for many years with good success, at both the PCB and cable level. We hope this quick overview has given you some insights into this important EMI issue.

EMI-Toolkit® 2.0... Now available, an updated version of our very popular *EMI-Toolkit®* software. The new version includes many new useful features, plus an improved format of previous features.

Comes on CD, and runs under Windows 95/98. \$150 for single license, \$750 for site license. Discounts for upgrades. *EMI-Toolkit® Plus* available soon, which will include summary information on most EMI standards.

About Our Congress...

Based on records prior to the summer break, here are some interesting statistics about members of the US Congress:

- 29 members have been accused of spousal abuse
- 7 members have been arrested for fraud
- 19 have been accused of writing bad checks
- 117 have bankrupted at least two businesses
- 3 have been arrested for assault
- 71 have credit reports so bad they can't get credit cards
- 14 have been arrested on drug related charges
- 8 have been arrested for shoplifting
- 21 are defendants in lawsuits
- 84 were arrested in 1998 alone for drunk driving, but released after they claimed Congressional immunity.

Politicians and diapers have one thing in common - they should be changed regularly and for the same reason.

(From an e-mail on the Internet.)

On-Site EMC Classes...

Our in-house EMC classes continue to be very popular. Here are several standard classes we have done:

- Design for EMC (2 days)**
- Systems Grounding & Shielding (2 days)**
- Medical Design for EMC (2 days)**
- EMC in Telecommunications (2 days)**
- EMC Troubleshooting (1/2 to 1 day)**
- Understanding EMC Regulations (1 day)**

We can also custom tailor classes to your needs. For example, we recently did a class that was "half design/ half systems", and we have done several that included the "troubleshooting workshop."

Another possibility is "sharing" a class with another company. One client in a small "non-electronic" city even formed a consortium with several other companies. In addition to our seminar, they have hosted several other technical seminars.

We can handle up to 30 attendees, but even if you have a dozen, an in-house class may make sense. Call 1-888-EMI-GURU for more details.

"The word bipartisan usually means some larger than usual deception is being carried out."

-George Carlin

Book Review... Here is a new book by a popular EMC author who always provides some fresh insights.

EMI Troubleshooting Techniques... by Michel Mardiguian, published by McGraw Hill, 2000. A thorough treatment of EMI troubleshooting at the prototype, qualification, and field levels. Discusses diagnosing techniques, instrumentation needs, and necessary components and materials. Very practical and unique. We are not aware of any similar book on the subject.

A KGB Bullet...

Here are some popular ESD "rules of thumb"...

- Rise time of 1 nanosecond (or less)
 - Equivalent frequency of 300 MHz (or more)
 - Critical distance of 2 inches (slots, seams, etc.)
 - Peak currents of 10 amps (human model)
- To be more conservative, you may want to use 300 picoseconds, 1 GHz, and 3/4 inch.

Design Reviews... Many of our clients now include *EMI Design Reviews* as part of their design process. They know that the earlier you address the problems, the more options you have, and the lower the overall costs.

A typical design review examines the printed circuit board, interconnect, power supplies, cable & I/O, and mechanical packaging, with an emphasis on your EMC requirements and cost constraints. Typical times are 1-2 days, with typical costs of \$2-3000 plus travel expenses.



Electronic Communications...

Thanks to the "wireless explosion", both Bill and Daryl have new area codes. Here are our new direct numbers:

—Bill Kimmel - 651-457-3715 (Was 612, Minnesota)

—Daryl Gerke - 480-755-0080 (Was 602, Arizona)

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 old area code.)

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

Daryl Gerke - dgerke@emiguru.com

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.

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An EMI Software "Reference Handbook"

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