KIMMEL GERKE Bullets

EMI GURU®

Fall 2005

Welcome to KGB...

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

This KGB discusses "critical circuits." In our EMC classes, we are fond of saying that "95% of the problems are caused by 5% of the circuits." While our statistics are only a crude guestimate, experience has taught us that we do need to pay close attention to a few critical circuits.

We were reminded of this concept in a recent consultation. After fixing some ESD problems, we did a quick "EMC Design Review" on our client's circuit boards, addressing other potential problems (RF, emissions, transients, etc.) This is in keeping with our philosophy of not only helping solve your current EMI problems, but also helping prevent future EMI problems.

In any event, our client liked the idea of focusing on "critical circuits" so much that we decided to discuss this in our next KGB. As always, give us a call if we can help you out with any of your EMI problems - from individual circuits to full blown systems.

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

EDN Magazine Designer's Guide for EMC

As many of you may have noticed, this classic design guide (written entirely by Kimmel and Gerke, and updated in 2001) is no longer being offered by Cahner's Publications.

Don't despair! We have made arrangements to print it ourselves, and will soon be offering it on our web site. It will include all the same text and figures, but will not be in color. By going to B&W, we can offer it at a lower price as well - $25 (+$3 S&H) instead of $50.

We will also have special pricing for multiple copies, so you can equip ALL your engineers with this practical EMC guide. (Several companies have already done this .)

For more details, watch our web site – *www.emiguru.com*. Or give us a call 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. Daryl will be doing a tutorial on Monday *(How to Diagnose EMI Design Problems... And Find Their Fixes)* as a part of Maqsood Mohd's ever popular session on the *"Fundamentals of EMC Design."* Hope to see many of you at the show!

Public EMC Courses...

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

- **– Portland, OR – September 13-14-15, 2005 (T-W-Th)**
  Tektronix Campus, Beaverton, OR
- **– Denver, CO – September 21-22-23, 2005 (W-Th-F)**
  Courtyard by Marriott, Louisville, CO
- **– Minneapolis, MN – September 27-28-29, 2005 (T-W-Th)**
  Hampton Inn, Bloomington, MN
- **– Detroit, MI – October 11-12-13, 2005 (T-W-Th)**
  Hotel Baronette, Novi, MI
- **– Milwaukee, WI – October 17-18-19, 2005 (M-T-W)**
  Courtyard by Marriott, Brookfield, WI
- **– Los Angeles, CA – November 1-2-3, 2005 (T-W-Th)**
  Courtyard by Marriott, Irvine, CA
- **– San Jose, CA – November 8-9-10, 2005 (T-W-Th)**
  Courtyard San Jose Airport, San Jose, CA
- **– Phoenix, AZ – November 14-15-16, 2005 (M-T-W)**
  Residence Inn, Chandler, AZ

Please note that days of the week vary. *By the way, four or more students from the same company qualify for a discount.* All classes are conducted by either Bill or Daryl.

In-House EMC Courses...

Our on-site classes are as popular as ever, and we can tailor them for your specific needs – *military, commercial, medical, automotive, industrial, telecomm, and more*. We can address *design, systems, and troubleshooting issues.*

Most classes run two days, but some opt for a third day for more details. You supply the meeting space...we supply the materials and instructor (either Bill or Daryl.) Flat rate for up to 30 students, but even 12 students make sense.

Kimmel Gerke Bullets is a free newsletter on Electromagnetic Interference/Compatibility (EMI/EMC).
Published by Kimmel Gerke Associates, Ltd., 300 Christine Lane, W. St. Paul, MN 55118 • 1-888-EMI-GURU • http://www.emiguru.com

Focus on "Critical Circuits" for EMC...

We've all heard of the 80/20 rule (Pareto's Law), which can be paraphrased for EMC to say that 80% of the problems are caused by 20% of the circuits. In our experience, it often seems more like 95/5 when dealing with EMI problems. But b paying attention to a few "critical circuits," we can often achieve EMC success.

In this issue, we'll look at six different "critical circuits," and how they are affected by EMI. We'll also make recommendations on how to prevent or fix problems with these circuits at the PCB (printed circuit board) level. While this approach won't assure 100% success, it can certainly raise you EMC "batting average."

– Clocks – Clocks and other highly repetitive signals are the main source for radiated and conducted emissions. As a rule of thumb, we usually assume that the first 20 harmonics will cause problems. Thus, a 50 MHz clock can easily contribute radiated emissions up to 1 GHz. Alternately, a 500 kHz switch mode power supply can easily contribute conducted emissions up to 10 MHz. By the way, we've seen emissions well above the 20th harmonic, but the first 20 are definitely the troublemakers.

PCB design solutions include risetime controls, careful clock trace routing, and paying attention to circuit location. Clock circuits next to I/O circuits are just asking for trouble, as are clock traces running over splits in planes.

Good high frequency power decoupling is also important — the "pulsing DC" on the power distribution is often a bigger problem than the clock traces. We often refer to the power/ground distribution as the "back door" for emissions.

– Resets – These circuits are very vulnerable to "spiky" interference, such as ESD (electrostatic discharge) or its cousin EFT (electrical fast transient.) Both can cause unwanted reset conditions to occur, the most common upsets due to ESD/EFT.

PCB design solutions include filtering of reset inputs, outputs, and power decoupling. The input is the most critical, but a series ferrite or 100 ohm resistor and a shunt 1000 pF capacitor can work wonders. Sometimes the capacitor alone is enough, but you MUST keep the leads short to minimize unwanted inductance. Like the clock circuits, you should also keep reset circuits away from I/O circuits to prevent unwanted coupling from I/O lines.

– Control Circuits – These include interrupts, memory read/write, chip enables, etc. Like reset circuits, these circuits are also vulnerable to ESD/EFT events. You want to pay particular attention to non-maskable interrupts (NMI), as they often behave like reset circuits.

Often times you can match the symptoms to the vulnerable circuit. For example, if the memory is scrambled, you should suspect the memory read/write lines.

PCB design solutions are similar to reset circuits - 1000 pF capacitors at critical inputs, which may need to be augmented with series resistors or series ferrites (100 ohms typical.) Once again, keep the capacitor leads SHORT.

– Voltage Regulators – These circuits are vulnerable to RF, and often fail in the 10-100 Volts/meter range. The symptoms include bizarre behavior, as the DC Vcc is driven out of the specified range by the unwanted RF interference.

These circuits can also cause unwanted radiated emissions, typically in the 100-500 MHz range. These are parasitic oscillations, which are unrelated to clock frequencies. In fact, that is a useful clue — any emission that is not clock related, and also tends to "wander" is likely a such an unwanted oscillation.

PCB design solutions include 1000 pF ceramic capacitors placed directly across the input and output of voltage regulators. Keep the leads SHORT, and make the connection to the regulator neutral pin, which may or may not be at "ground" potential. The objective is to provide a good "high frequency short" across the inputs and outputs. Note that the lower frequency capacitors (tantalum or aluminum) are ineffective at VHF frequencies. — that is why you need the ceramic capacitors as well.

– Low Level Analog Circuits – These circuits are very vulnerable to RF, and often fail in the 1 Volt/meter range or below. As such, they are typically 10 times more vulnerable than the voltage regulators circuits, and they deserve attention anytime RF immunity is involved. Like the voltage regulators, these circuits can also cause unwanted emissions due to parasitic oscillations.

PCB design solutions include high frequency filtering of the inputs, outputs, as well as high frequency decoupling of the power circuits. Remember, low frequency circuits can have high frequency EMI problems. Thus, high frequency protection may be necessary. Ferrite beads and 1000 pF capacitors can work EMC wonders with these circuits.

If you have remote analog circuits (such as active sensors), you may need to apply the same type of fixes to those circuits as well.

A KGB Bullet...

Here are some "rules of thumb" we picked up along the way on power line THD (total harmonic distortion), that may be useful if you are involved with power issues.

— At the *service entrance*, there is little to worry about as long as the voltage THD is less than 4%, and the current THD is less than 10%.

— At a *branch circuit*, there is little to worry about as long as the voltage THD is less than 6%, and the current THD is less than 20%.

Note that very sensitive circuits may still need lower levels of THD to function properly.

– Input/Output Circuits – Last, but certainly not least, are the I/O circuits. Since these circuits are often connected to cables, they can both radiate and receive unwanted energy. This energy includes both RF and transients, such as ESD and EFT. I/O circuits in avionics and industrial control systems are also vulnerable to lightning surges on the cables, which can be a very nasty problem.

PCB design solutions include transient protection, filtering, isolation transformers, current limiting resistors, etc. When dealing with I/O circuits, you are often concerned with permanent circuit damage, as well as simple upsets.

Summary - We hope this quick look at "critical circuits" has helped. Consider these circuits the next time you review your PCB design for EMC. Finally, give us a call if we can help you - from PCB circuits to full blown systems.

> Blessed are the young, for they shall inherit the national debt.
>
> — *Herbert Hoover* (U.S. President 1929-1933)

Engineering Humor...

Four surgeons were taking a coffee break, and were discussing their work.

The first said, "I think accountants are the easiest to operate on. You open them up, and everything inside is numbered."

The second said, "I think librarians are the easiest. You open them up, and everything inside is in alphabetical order."

The third said, "I like to operate on electricians. You open them up, and everything is color coded."

The fourth said, "Well, I prefer engineers. They always understand when you have a few parts left over at the end."

Application Note...

Although we first posted this notice some time ago, 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 some years back, now out of print. We have a PDF version, so if you need a copy, e-mail Daryl at *dgerke@emiguru.com*.

NARTE Announcement...

As NARTE Certified Engineers (both EMC and ESD), we were recently asked to "spread the word" on a special NARTE testing session.

It will be held on Friday, September 16, at the Southern California Institute of Technology in Anaheim, CA. For more information, go to *www.narte.org*.

The NARTE Certification is a worldwide recognized credential for EMC and ESD engineers and technicians.

Book Review...

Electromagnetic Compatibility Handbook, by Kenneth Kaiser. Over 2500 pages of details on EMC, and endorsed by the IEEE EMC Society Newsletter. At $150, it may seem a bit pricey, but if you are serious about EMC, you should check it out. ISBN 0-08493-2097-9. CRC Press, 2005. For more info, go to *www.crcpress.com*.

From the E-Mail Bag...

Here is a question we recently received., that may be of interest to others: *I am looking for a low cost solution for surge protection on my PCB. Other than MOVs, is there anything else?*

There are three popular types of surge protection that can be applied at the PCB level. They each have advantages and disadvantages, so the final choice if often a tradeoff.

– *Gas tubes* – These are arc devices, and as such are very robust, but relatively slow. As such, they are best for "slow" transients such as lightning surges or other power line transients. They are usually not fast enough for ESD or EFT events.

Gas tubes are often used as "primary" protection for power or signal interfaces. At the PCB level, they are often supplemented with "secondary" protection, such as MOVs or Zener devices.

– *MOVs* – These are clamp devices, and are also relatively slow. They also work well for lightning or power transients, but are not generally fast enough for ESD or EFT events. They are relatively inexpensive, and provide a high degree of protection in a small package. MOVs can degrade with time, due to the cumulative effects of transients on the devices.

Discrete MOVs are quite popular on power interfaces in cost sensitive applications, such as consumer products. As far as the cumulative effects are concerned, the consumer product is often thrown away before the MOV wears out anyway.

There are some surface mount MOV devices that are fast enough for ESD and EFT, thanks to their small size. The SMT devices do not handle a lot of energy, but they are well suited for moderate protection on PCB I/O interfaces.

– *Zener Devices* – Like MOVs, these are also clamp devices, but they can operate at sub-nanosecond speeds. As such, they are suitable for all types of transients, including ESD and EFT. They are physically larger for the given amount of protection, and typically cost more than other devices.

The Zener devices are widely used in industrial, military, and medical power and signal interfaces, where long term reliability is more important than the lowest component cost.

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*.

EMI Toolkit V2.0...

Want a bunch of useful EMI information at your fingertips? Then check out our popular software package. Includes tables, calculators, frequency assignments, and more. All in an easy to use, Windows based format.

If you are heavy into regulations, 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...)

Both V2.0 and Plus come on CD, and run under Windows 95/98/NT/2000/XP. V2.0 is $150 for single users, $750 for site licenses. (*Plus* is higher.) Discounts apply if you are a V1.0 user. For more details, *visit www.emiguru.com*.

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