KIMMEL GERKE Bullets

MEMBER AMERICAN CONSULTING ENGINEERS COUNCIL

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Welcome to KGB. . .

And to the first issue for 1994 of our "personal communications" to our friends, clients, and colleagues about EMI problems and solutions.

This issue focuses on EMI in printed circuit boards. Nowhere else can you get so much EMI protection for so little cost. Remember, all EMI problems begin and end at a circuit, so good EMI engineering at the PCB level can pay big dividends. As we like to say, *"An ounce of prevention is worth a pound of shielding."*

As always, give us a call if we can help you with your EMI problems, circuit board related or otherwise.

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

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

Those of you who read *EDN* have already received your own copy of the 116 page guide to EMC design, which was included with the January 20, 1994 issue of *EDN Magazine.*

We wrote the entire design guide — 12 chapters that deal with *EMI design & troubleshooting issues* and how to prevent & solve EMI problems during design.

Our goal was to provide an original "design oriented" approach to EMI, rather than to write just another book on EMI. We wanted to capture and share our insights and many years of experience as EMI design consulting engineers.

If you don't read *EDN*, and you can't beg, borrow, or steal your own copy, contact Kathy Leonard with *EDN Magazine* at 617-558-4405 about reprints. (Note — there will be a nominal cost for reprints.)

Thanks to all of you who wrote or called, and thanks to both *EDN Magazine* and the vendors who supported this design guide with their advertising.

Shows and Conferences. . .

Here are some shows and conferences in which we'll participate. Call if you want details on any of these.

EMC/ESD International. . . April 12-15, 1994, which moves this year to Anaheim, California, after two years in Denver. This show is a favorite of ours, as it focuses on practical sessions. Great for the EMI newcomer. We'll be doing two sessions this year:

- *ESD Design Tutorial* (Repeat By Popular Demand)
- *EMI Troubleshooting* (New Session)

Hope to see many of you there.

Medical Design & Manufacturing East 94 Conference. . . May 23-26, 1994, at the Jacob Javits Convention Center in New York City, and sponsored by *Medical Devices and Diagnostics Industry* magazine. This show is very popular with medical equipment designers.

Daryl will present a tutorial on *"Designing for EMI/EMC in Medical Devices,"* and Bill will present a tutorial on *"Designing to Prevent ESD Upsets in Medical Electronics."* Our friend and colleague Dr. Bill Duff will also be presenting papers on medical EMI regulations at this show.

IEEE 1994 International Symposium on EMC. . . August 22-26, 1994, in Chicago. Technical sessions, plus three days of exhibits. A must for the EMI guru.

Bill will present a paper on *"Wide Frequency Impedance Modeling of EMI Ferrites."* This reports on some original work done at Kimmel Gerke Associates, the results of which have also been incorporated in the *EMI-Toolkit*™ software.

EMC Design Seminars. . .

We continue to receive very good reviews on our *Designing for EMC* seminars. Two versions are available — through Tektronix at selected cities around the U.S., and in-house at your facility. Call for details.

Kimmel Gerke Bullets is a newsletter on electromagnetic interference/compatibility (EMI/EMC). Published by Kimmel Gerke Associates, Ltd., 1544 North Pascal, St. Paul, Minnesota 55108 (612) 330-3728.

Focus on Printed Circuit Boards. . .

All EMI problems ultimately begin and end at the circuit level. Thus, it makes a lot of sense to address EMI problems at the printed circuit board, or PCB. Many circuit board EMI solutions are even free, and most are usually much less costly than "external" fixes like shielding and filtering.

While we can't begin to cover PCB design in great detail in a single issue of the KGB (after all, entire books have been written on the subject), perhaps we can share a few key concepts on EMI prevention at the PCB level. Here are several ideas to consider.

Identify Critical Circuits. . . We estimate that over 90% of the EMI problems are caused by less than 10% of the circuits. Thus, by identifying and treating the critical 10%, many EMI problems can be prevented or solved with minimal effort and expense.

The most critical circuits for *emissions* are the highly repetitive signals like clock and busses. These signals are rich sources of high frequency harmonics that result in high frequency emissions. We advocate high frequency filters such as ferrites or damping resistors on clock lines, with special attention given to clock routing. We also like to see good high frequency power decoupling of these critical circuits.

The most critical circuits for *immunity* are resets, interrupts, and control lines. If these signals are corrupted by EMI, the whole system can be brought to a halt. We advocate high frequency filtering (RCs or ferrite-cap filters) of these signal lines. And watch out for the new "Watchdog-Reset" chips — you need to protect their inputs as well.

Consider multi-layer boards. . . If everyone used multi-layer boards, we'd see a lot less EMI problems. As a rule of thumb, we figure a multi-layer board is at least 20 dB, or ten times better than a two layer board for both emissions and immunity.

The miracle occurs due to the "image" effect of a ground plane near the traces, which results in high frequency currents returning in the "image plane" under the wire. In simple terms, the trace "antennas" are turned into "transmission lines" which do not radiate nearly as well as the "antennas."

Watch out, though, as it is still easy to mess up a multi-layer board. This often occurs when cuts are made for traces, connectors, or isolation.

Pay attention to power decoupling. . . It's amazing how many board level problems are caused by poor power decoupling. While almost everyone understands the need to filter signal traces, they often forget about the power perturbations. This can be a key leakage path for emissions, as the high frequency noise just blows out the "back door."

Remember that every digital circuit that is switching is also "gulping" current at a high frequency rate. These power pulses can radiate just like signal pulses.

In fact, the power current pulses are often higher than signal current pulses, so they actually cause higher levels of emissions. This is particularly true with high speed CMOS devices, which have very high peak power currents, but very low average currents.

We advocate decoupling all IC devices on a board, with high frequency capacitors (0.01-0.1 uf typical) located right at each chip. We also advocate the same high frequency caps (0.01-0.1uf) at each power input to the board. These should be in parallel with the larger bulk 1-10 uf "energy storage" caps.

In single chip microcontroller cases, we often provide additional power isolation with a ferrite bead in series with the VCC trace. This is very effective if only one device is clocked, since it confines the current pulses to the to the "noisy" component.

Focus on Printed Circuit Boards. . .

continued

Use Care in Component Layout. . .Separate the high speed and low speed circuits. (Obvious advice, but too often overlooked.) Watch out for routing between sections, and pay particular attention to clocks and crystals. We like to keep these lines and devices at least one inch or more away from I/O circuits, connectors, and even internal cables.

Hand route critical lines if necessary, and stay involved with the PCB layout process. Don't just throw the design "over the wall." In fact, most PCB layout personnel will welcome your input. And watch out for autorouters. Remember, "Autorouters will always try to route to maximize EMI. . ."

Test early and often. . . Don't wait until the end of the project to do all your EMI testing. In fact, you can begin EMI testing on the first prototype boards.

For *emission* requirements, the board doesn't even need to be fully functional, as long as the clocks run. We've had several cases where EMI disasters were avoided by getting this information early.

For *immunity* requirements, the boards will need to be functional, so you can recognize failures. You may even need to develop some special diagnostic software to help you here. We had one client who subjected all boards to a modified set of "indirect ESD" tests, which resulted in a much easier final integration of the system.

Summary. . .This quick introduction just barely touched on PCB issues. For more details, see the *EDN Designer's Guide to EMC,* described on page 1. Read Chapter 6, titled "Circuit Boards. . . How to Bulletproof Yours Against EMI."

If you need serious help, give us a call — we do a lot or EMI work at the printed circuit board level, ranging from design reviews to EMI fire-fighting.

Ignore EMI Panics. . .And Repent at Leisure.
Thanks to Al Wollscheidt of Cummins Electronics

EMI Test & Measurement Software. . .

Here is a resource if you need special help setting up test site software (or other EMI test software applications). Call our friend and colleague Bob Swarts in Oregon at 503-662-3931. Bob is a former Tektronix spectrum analyzer guru who now offers his talents and experience to the "EMI public."

EMI Site Surveys. . .

In addition to our regular EMI design and troubleshooting services, we also provide the following special EMI services for our clients.

Radio Frequency (RF) Surveys — Measure and assess levels of radio frequency fields from nearby radio or television transmitters that might affect humans, or might affect the operation of electronic equipment (computers, industrial controls, medical devices).

Power Line RF Surveys — Measure and assess levels of radio frequency fields from nearby power lines that might affect radio and television communications.

Power Disturbance Monitoring — Measure and assess levels of power line transients, sags, surges, etc. that might affect operation of electronic equipment.

Magnetic Field Measurements — Measure and assess levels of 60 Hz magnetic fields that might affect electronic equipment.

Incidentally, as consulting engineers, we don't just take measurements and give you the data — rather, we help you identify the problems and then recommend the appropriate solutions.

Book Reviews. . .

Electromagnetic Compatibility, by Jasper Goedbloed, Prentice Hall, 1990. This is the English version of a Dutch book written by an EMC expert with the Phillips Research Laboratories in the Netherlands. Well written, with fresh information and a strong design focus.

MECL System Design Handbook, by Bill Blood, and published by Motorola Semiconductor Products. First printed in 1980, this handbook is a must if you are designing high speed digital equipment. Learn the tricks the ECL designers have been using for years to improve "signal integrity" and to reduce EMI.

A KGB Bullet. . .

Here is the definition of "Antenna Factor", used to convert from voltage levels measured by a spectrum analyzer or receiver to radiated electric field levels.

AF (dB/m) = E (dB uv/m) – V (dB uv)

AF = Antenna Factor in dB/m
E = Electric Field Strength at antenna in dB uv/m
V = Voltage at the terminals of the antenna in dB uv

Note: For voltage measurements in dBm, add 107 to convert to dB uv in a 50 ohm system.

About Kimmel Gerke Associates. . .

Often we are asked to give a quick description of what we do. If you are asked by someone needing EMC help, here are six key points about KGA . . .

Key Point I. . . We are a two-man **electrical engineering firm that specializes in electromagnetic interference and compatibility (EMI/EMC) issues.** These include five areas:

- **Regulatory Compliance** (FCC, FDA, IEC, MIL-STD-461, etc.)
- **Radio Frequency Interference** (Communications systems)
- **Electrostatic Discharge** (ESD)
- **Power Disturbances** (Transients, magnetic fields, etc.)
- **Self-compatibility** (High speed digital, analog, etc.)

Key Point II. . . We are Registered Professional Engineers (PE) and NARTE Certified EMC Engineers. Between us, we have **over 55 years of industry experience.**

Key Point III. . . We are not a test lab — **our emphasis is on EMC design and troubleshooting.** While we are knowledgable about key EMC tests and regulations, our focus is on design issues, and how to identify, prevent, and fix EMC problems. **This includes training as well as engineering help.**

Key Point IV. . .We serve many industries, and our support ranges from individual equipment to large systems. We've helped clients in the following areas:

- **Computers** (PCs to supercomputers)
- **Industrial Controls** (Individual controls to full systems)
- **Vehicular** (Automotive, railroad, heavy machinery)
- **Medical** (Diagnostic, clinical, patient connected)
- **Telecommunications** (Small and large system)
- Military (MIL-STD-461, EMP, TEMPEST, etc.)
- **Architecture** (Shielded rooms, lightning, power)

Key Point V. . . We are an independent firm with no outside affiliations. **Our advice and recommendations are free from any bias or other business interests.**

Key Point VI. . .All client projects are treated in complete confidence. Unlike many other consulting firms, you won't even see our clients named in our brochure.

Please give us a call if we can help you with your EMI/EMC problems or training needs. **And please pass our name along to your colleagues. . .your referrals are always sincerely appreciated.**

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