

Techniques for Solving EMC Problems in Various Industries

Presented by

Dr. Tom Van Doren

Electromagnetic Compatibility Laboratory

University of Missouri-Rolla

573-341-4097

vandoren@umr.edu

Techniques developed with the assistance of :

2

8 – 12 Industry Sponsors/year

12 – 18 Graduate Students/year

Faculty Members:

Dr. Jim Drewniak, Dr. Dick DuBroff, Dr. Todd Hubing

Visiting Professors:

Dr. Koledintseva, Dr. Radu, Dr. Tanaka, Dr. Sha

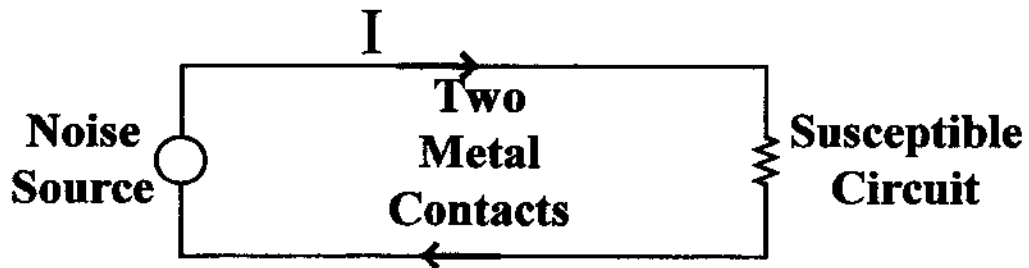
3

<u>Industry</u>	<u>Product</u>	<u>EMI Problem</u>
Computer	Handheld PC	400 MHz Radiation
Process Control	Temp. Controller	60 Hz Suscept.
Avionics	Flight Controller	RF Susceptibility
Automotive	Pressure Sensor	RF Susceptibility
Automotive	Timing Sensor	Self Induced Noise

<u>Noise Coupling Mechanisms</u>	<u>Key Requirements</u>
Conducted (Common Impedance Coupling)	Two metal contacts
Magnetic Field (Mutual Inductance)	$dI/dt + 2$ loop areas
Electric Field (Mutual Capacitance)	$dV/dt + 2$ surface areas
Electromagnetic Wave (Far-field Radiation)	Distance $> \lambda$

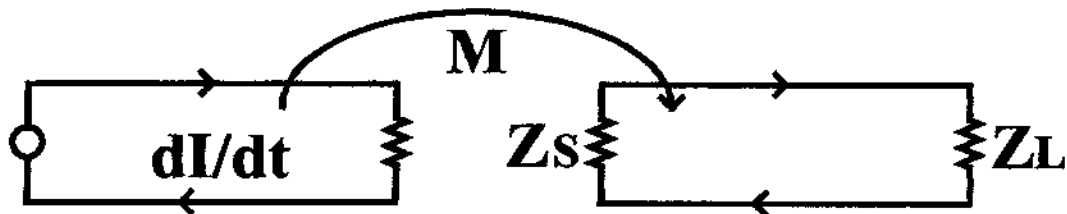
5

Conductive Coupling Equivalent Circuit



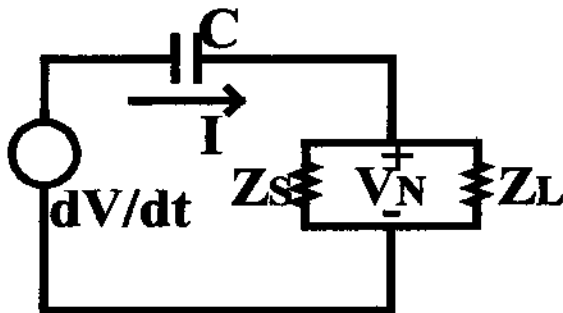
6

Magnetic-Field Coupling Equivalent Circuit



$$V_{\text{Induced}} = M dI/dt$$

Electric-Field Coupling Equivalent Circuit



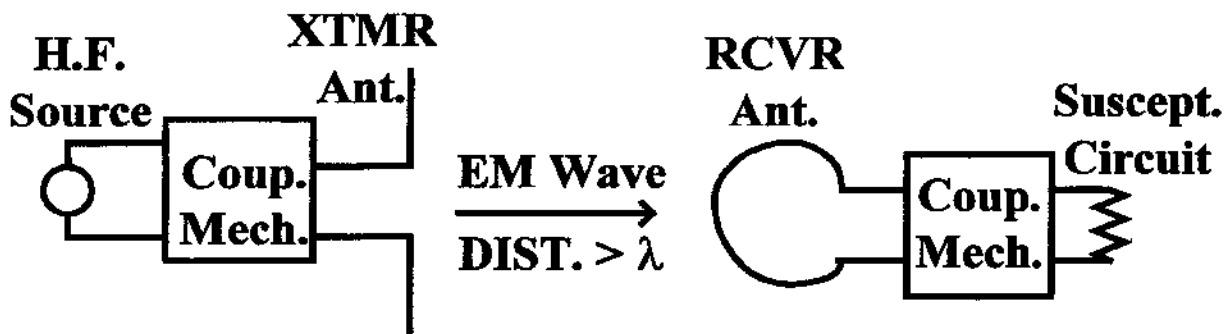
$$I_{\text{Induced}} = C dV/dt$$

$$I = \omega C V$$

$$Z_{\text{EQ}} = Z_S // Z_L$$

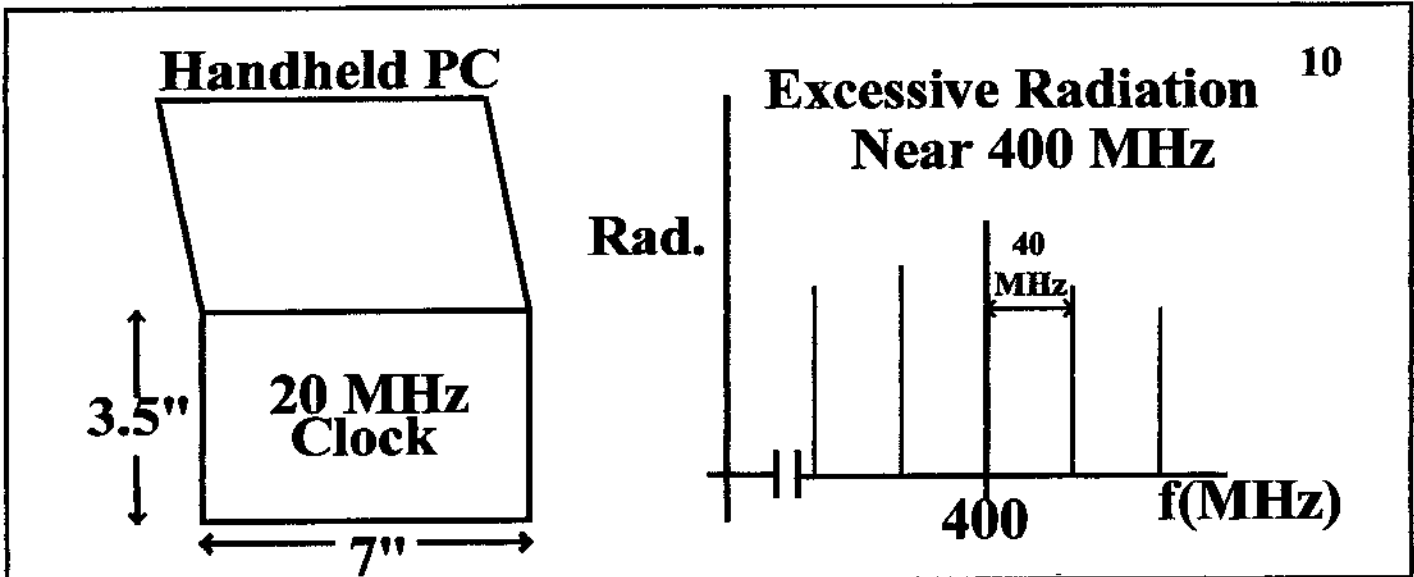
$$V_N = I Z_{\text{EQ}}$$

Electromagnetic Wave Equivalent Circuit



Some causes of electromagnetic interference problems:

- Current taking an unintended path.
- Poor electric or magnetic field containment.
- Resonance
- Impedance imbalance causing DM \Leftrightarrow CM conversion.



11

Radiation Peak \Rightarrow Resonance $\Rightarrow \lambda/2$ Antenna

$$f\lambda = v = c/\sqrt{\epsilon_r}$$

400 MHz $\Rightarrow \lambda/2 = 14.8$ inches in air

OR $\lambda/2 = 7$ inches in FR4 ($\epsilon_r = 4.5$)

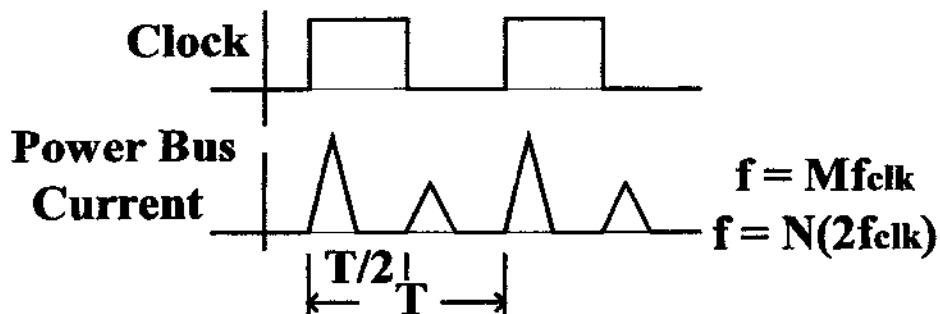
***Only the 3.3 VDC digital bus was 7" long.**

Dominant radiated spectral lines 40 MHz apart:

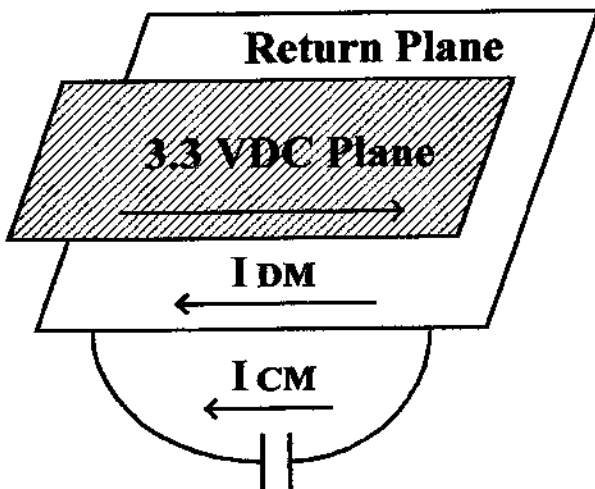
12

\Rightarrow Even harmonics of f_{clk} (20 MHz), OR

\Rightarrow Every harmonic of $2xf_{clk}$ (40 MHz).



13

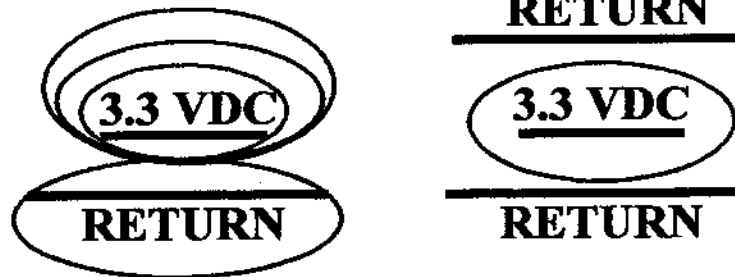


1. Resonance
2. Poor Magnetic Field Containment
3. Imbalance

Solutions

14

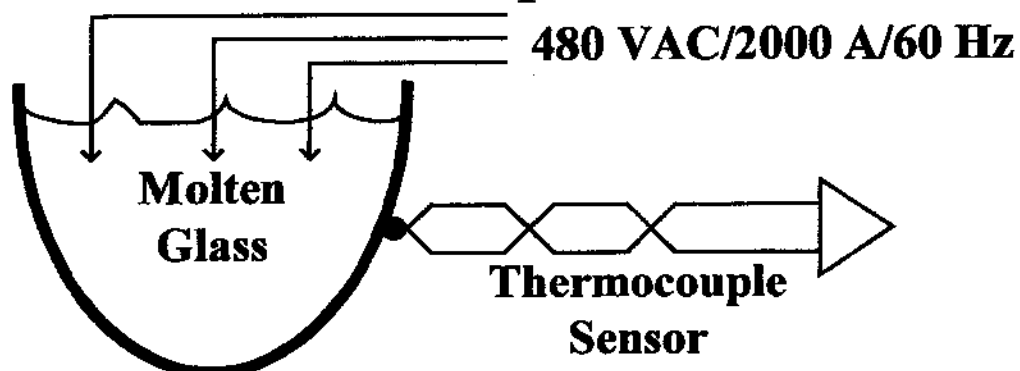
1. Improve magnetic-field containment with 3 layers.



2. Supply more current from decoupling capacitors.
(Reduce self inductance of connections.)

15

60 Hz Noise in Temperature Controller



60 Hz \Rightarrow Noise from AC Source

Electric field $\propto dV/dt$

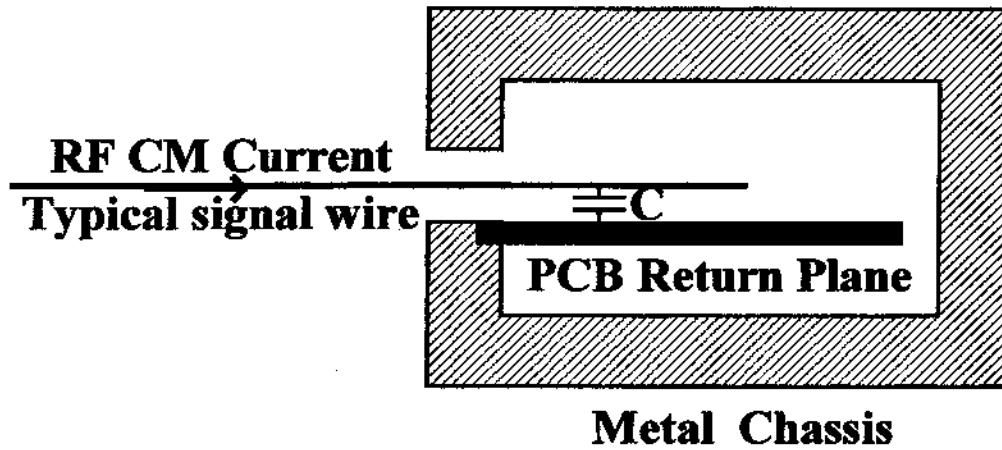
Magnetic field $\propto dI/dt$

$$\frac{dV/dt}{dI/dt} \Rightarrow \frac{V(f)}{I(f)} = \frac{480 \text{ V}}{2000 \text{ A}} = 0.24 \Omega \ll 377 \Omega$$

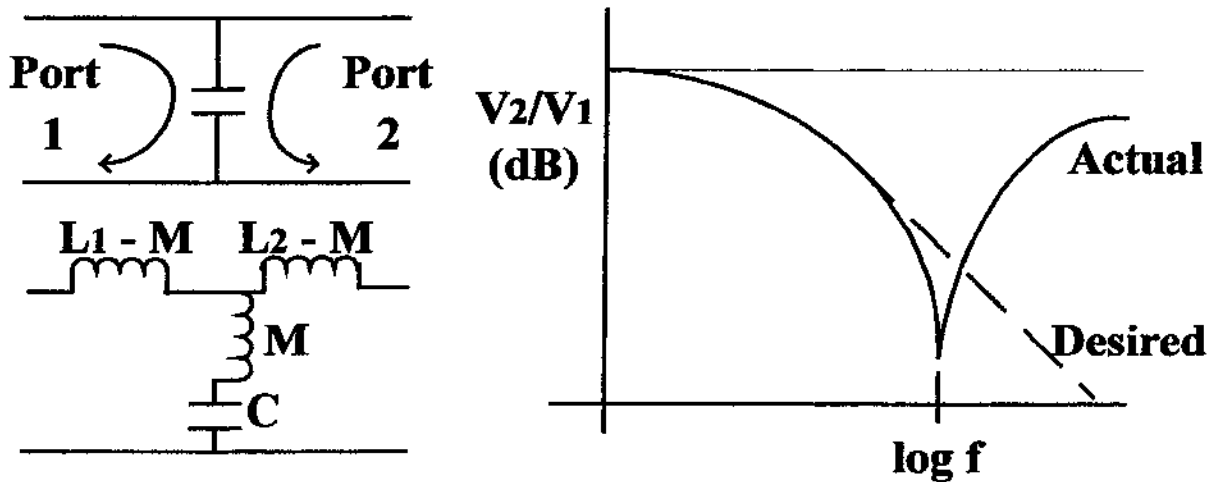
Conclusion: Magnetic-field coupling.

Solution: Reduce loop area in thermocouple circuit.

RF Susceptibility of Flight Controller



The problem is mutual inductance not self inductance



Problem: Mutual Inductance

19

Solution: Reduce Mutual Inductance

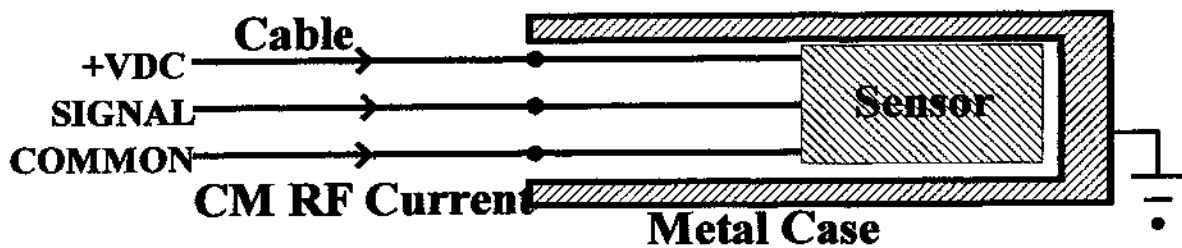
1. Minimize length and maximize diameter of the boundary between the two loops.

OR

2. Use a 3-terminal, feed-thru like capacitor.

RF Susceptibility of Automotive Pressure Sensor

20



Problem: Rectified RF shifts DC signal level.

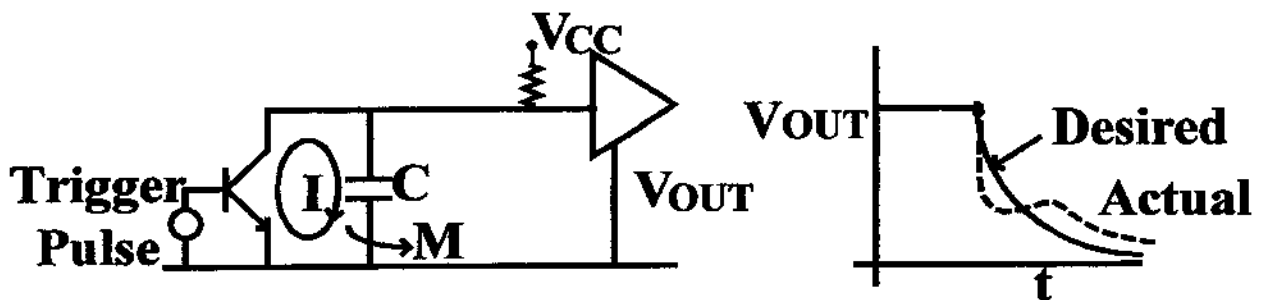
**RF Current passes through the sensor
in route to the metal case.**

21

**SOLUTION: Provide a CM capacitive bypass path
for the RF current from the cable to the metal case.**

**Capacitor connection must minimize
mutual inductance.**

Automotive Timing Sensor Has Self-Induced Noise



Timing Sensor Self-Induced Noise

Problem: Mutual Inductance

Solution: Reduce length of conductor common to both loops.

Techniques for solving EMC problems are essentially the same for all industries.

1. **Locate where the noise couples in or out.**
2. **Determine the coupling mechanism**
 - Conducted (on wires)**
 - Magnetic Field (MdI/dt)**
 - Electric Field (CdV/dt)**
 - Electromagnetic Wave (Distance $> \lambda$).**

25

Frequency identifies the noise source.

Loop Areas & $dI/dt \Rightarrow$ Magnetic-Field Coupling.

Surface Areas & $dV/dt \Rightarrow$ Electric-Field Coupling.

(EX: Heat Sinks)

Source: $(dV/dt)/(dI/dt) \Rightarrow$ Electric or Magnetic

RCVR: Z_S & $Z_L \Rightarrow$ Electric or Magnetic

26

Resonance can cause part of the current to take an unintended path.

Resonance identifies critical dimensions.

Impedance imbalance causes

DM \Leftrightarrow CM conversion.

Balance means that the signal outgoing and return paths are electrically identical.

27

Electric- & Magnetic-Field Containment

1. Self Shielding:

a. The return path surrounds the outgoing path.

b. The metal is an intentional part of the signal path.

2. Externally Added Shielding:

The metal is not a part of the signal path.