EMI and Equipment Malfunction in Cleanroom Environment

Credence Technologies, Inc.

Why Control of EMI is Important on Your Production Floor?

- EMI causes equipment lock-up
- EMI causes equipment and sensor malfunction
- EMI may cause component damage
- EMI is extremely difficult to diagnose using conventional methods

All of the above causes losses and downtime that nobody can afford today

What is EMI?

- **E**lectro**M**agnetic **I**nterference is negative influence of electromagnetic emission on equipment
- Until equipment is affected by electromagnetic emission in any way, that emission is not EMI, no matter how strong it is
- A very weak emission can be EMI and a very strong one may be not

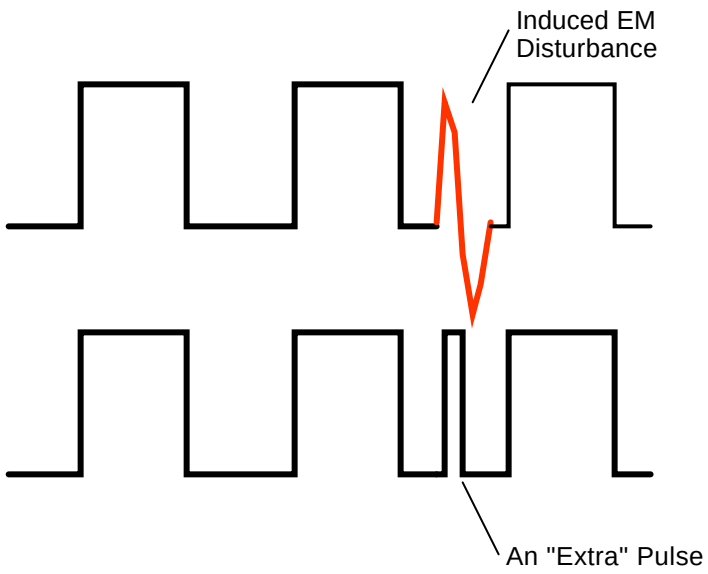
EMI-Caused Equipment Failures

Three Basic Types of Failures

- Fatal failure due to overstress
  - direct ESD discharge
  - very high EMI-induced signals
- Latch-Up
  - induced voltages are outside of supply rails
  - often recoverable after power-cycling
  - sometimes causes overheating and failure
- Injection of false signals
  - Induced signal is comparable to legitimate signals

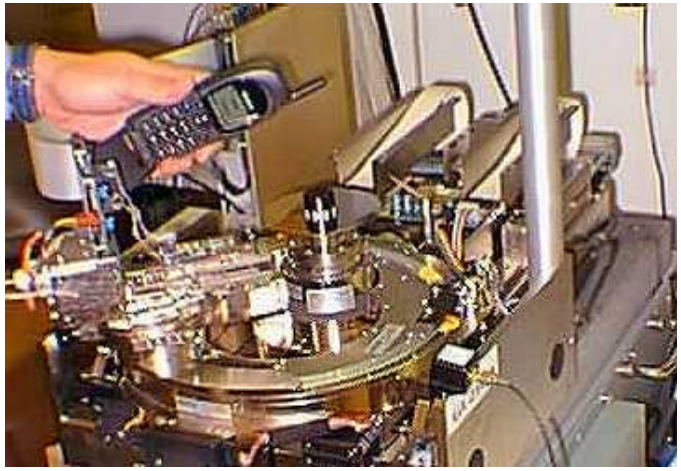
Equipment Lock-Up: False Signals

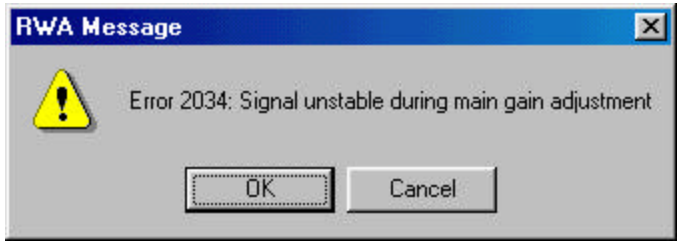
- Electromagnetic fields induce seemingly legitimate signals into electronics circuits which leads to circuit malfunction
- Often, the electronics circuit does not suspect that it was affected by EMI
- Today's high-speed circuits are much more susceptible to ESD-induced high-speed transients
- Virtually impossible to reproduce – difficult to diagnose



Sensor Malfunction

- Strong electromagnetic fields induce voltages and currents in circuits
- In sensors such signals can affect legitimate signals and cause false readings
- Consequences:
  - disrupted process
  - good components failed
  - bad components passed





TDMA mobile phone caused false readings in sensor of magnetic head tester and finally caused error message after failing several good GMR heads

ESD-Caused EMI

- ESD Event is rapid current surge: causes magnetic field
- ESD Event is rapid drop of voltage: causes electric field
- In the far field: electromagnetic field
- ESD Events cause strong ground and power line currents -- EMI via conductive path
- ESD-induced EM fields have broad spectrum, high energy and rapid rise time -- good candidates for EMI

EMI: The Path to Destruction

- Charge is created
- Charge results in ESD Event
- ESD Event causes strong electromagnetic emission
- This emission propagates across the cleanroom and reaches the “victim”
- Equipment malfunction

Propagation of Electromagnetic Emission

- **Radiated**
  - Electromagnetic field composed of electric and magnetic fields propagates via air path just as emission from a mobile phone would reach the base station
  - This field would create voltages and currents in any metal object, i.e. wire, PCB trace, etc.
- **Conducted**
  - The most neglected type of propagation
  - High-frequency currents move via power, ground and data cables and inject undesirable signals into equipment
- **Mixed**
  - Radiated emission generates signals in wires and cables. These signals are then injected into equipment via conductive path

How Equipment Receives Electromagnetic Waves

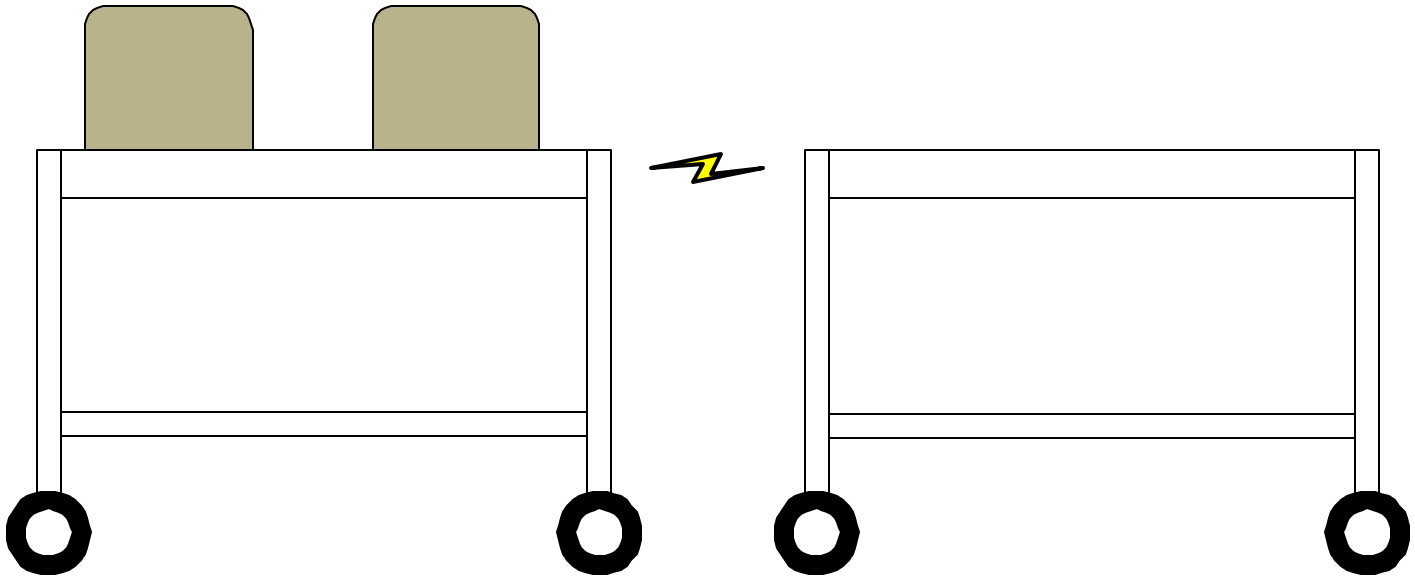
- Any piece of wire is an antenna
- Any antenna will convert electromagnetic field into voltage and/or current
- A signal wire, a data cable, a ground wire, a power cable, a trace on the circuit board -- they are all antennae
- In order for antenna to be efficient, it needs to be 1/4 of the wavelength of the electromagnetic field
- With the rise time of ESD Events of 1nS or less, the energy spectrum of the rising front lies in the range of 500MHz to 2GHz or even higher
- At these frequencies the efficient antenna would be 1.5” to 6” long
- This covers most of the traces on the circuit boards

Charge in FABs

- Wafers
  - Wafers get charged by handling
  - 300mm wafer can carry plenty of charge
  - Wafers are insulators that cannot be discharged by grounding
  - Wafers cannot be discharged by ionization while in pods due to lack of air flow
  - Highly-charged wafers induce charge on metal surfaces
- Anything Moving
  - Carts
  - Insulated rollers
- Other
  - Improperly installed or out of balance ionizers

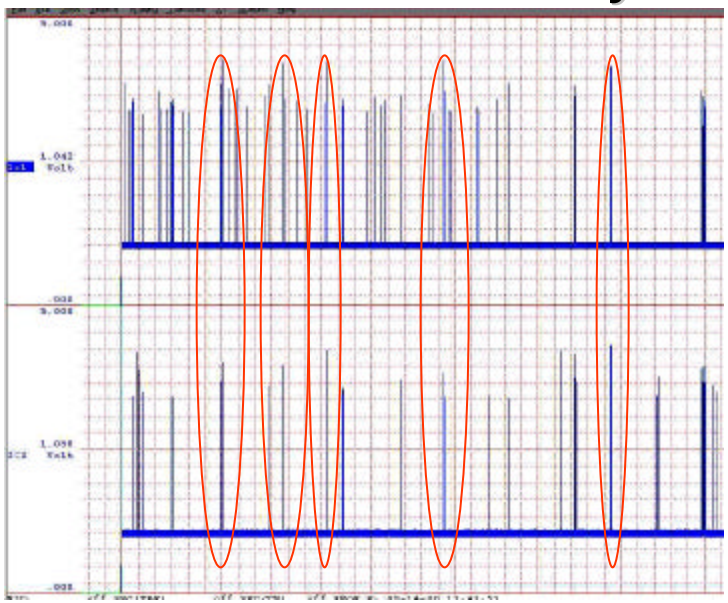
Isolated Metal Carts: Armed Bombs

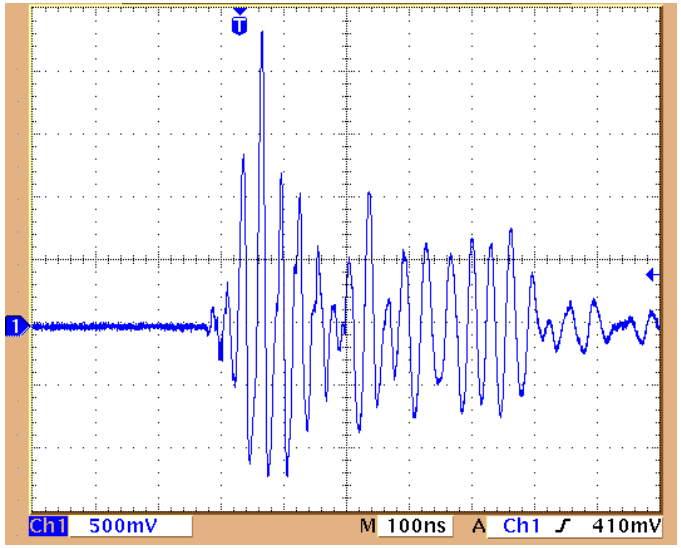
- Wafers are charged to the limit
- SMIF pods with wafers are placed on steel cart
- Cart is charged by the wafers via inductance
- Wheels are insulators



EMI Environment Inside the Tool

- Extraneous EMI Events are out of sync with the operation of equipment
- EMI Events from the carts was extremely strong even from far away





Induced Charge Issues

- The most harmful ESD Events are metal-to-metal
- Highly-charged wafers in pods induce charge on metal objects
- Metal-to-metal contact releases high levels of EMI energy that propagates across the fab causing equipment malfunction
- Large-mass metal object do not have to be charged to very high voltage to generate high energy EMI
- It is next to impossible to discharge wafers in pods in a normal production process
- What can be done:
  - Dissipate induced charges on metal objects
  - Prevent metal-to-metal contact

Grounding from EMI Point of View

- Traditionally, ground quality is measured with a multimeter at DC or at very low frequencies
- At high frequencies this method is useless
- It is mostly high-frequency signals that cause equipment malfunction

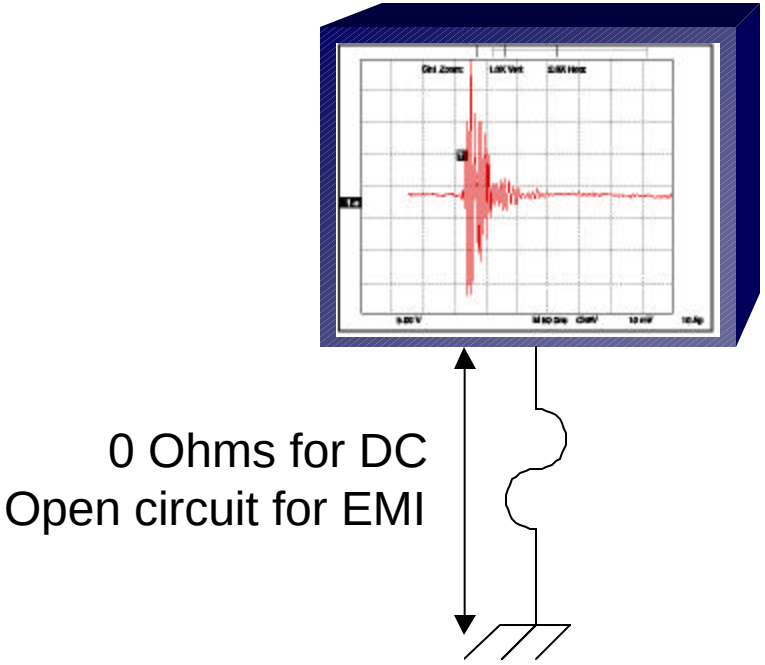
Mochi Moqui sacred shaman stones balls for “energy grounding” (Navaho Tribe)

Electrical Circuits Behavior at Low and at High Frequencies

Examples:	**Capacitor**	**Long Wire**
		
Low frequencies and DC:	Open circuit (infinite resistance)	Short circuit (low resistance)
High frequencies (MHz and GHz):	Short circuit (low impedance)	Open circuit (high impedance)

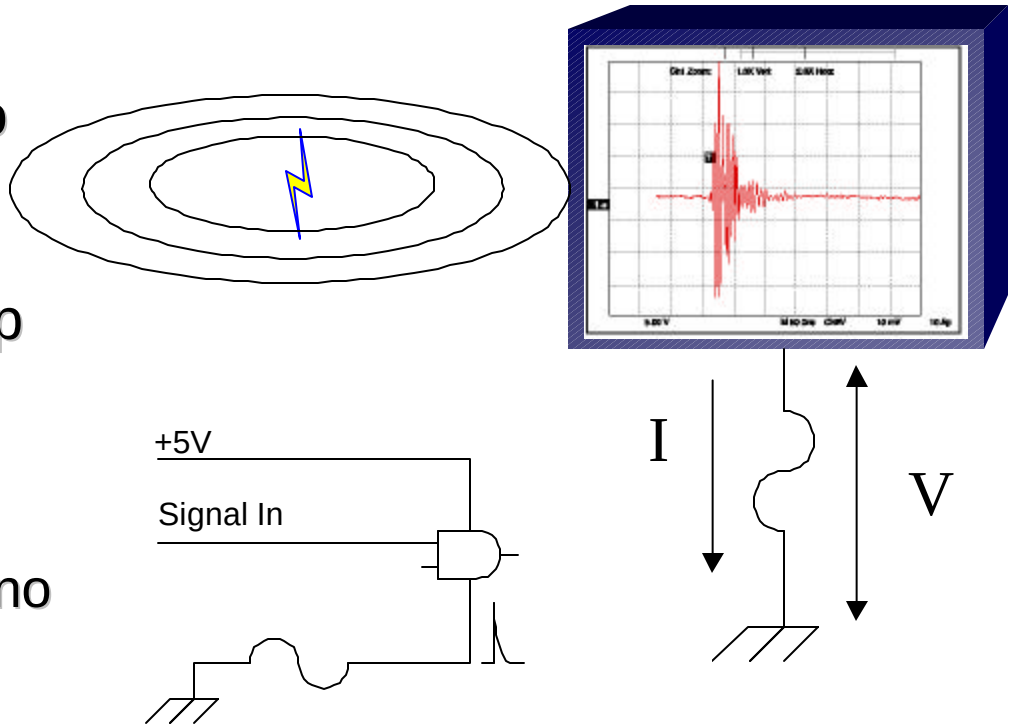
Grounding at Low and High Frequencies

- If ground is done improperly, a ground wire acts as an inductor with high impedance at EMI frequencies
- High-frequency “junk” doesn’t dissipate into the ground and resides on a workbench or on a tool
- Conventional methodology and tools provide false assurance of “good ground”



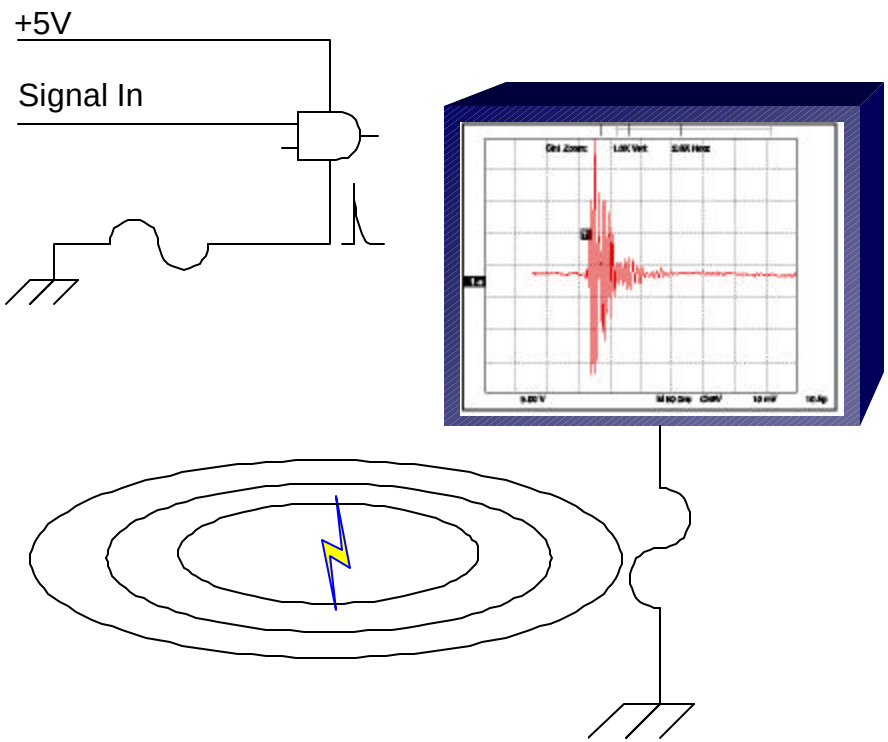
Equipment Lock-Up: Ground Bounce

- EMI induces voltages in equipment's ground
- Current flows from equipment's ground to facility's ground
- If ground path is imperfect, voltage drop develops
- Equipment ground "bounces"
- Circuit signal levels are no longer valid
- Equipment malfunctions



Equipment Lock-Up: Injection of EMI into Ground Wires

- EMI induces voltages in long and poorly-done ground wires
- Equipment ground “bounces”
- Circuit signal levels are no longer valid
- Equipment malfunctions



Checking for Good Ground

- Good ground is an “infinite sink.” It should have NO voltage on it. Just like a multimeter or a static field voltmeter shouldn’t see any DC voltage on a good ground, there should be no high-frequency voltages as well

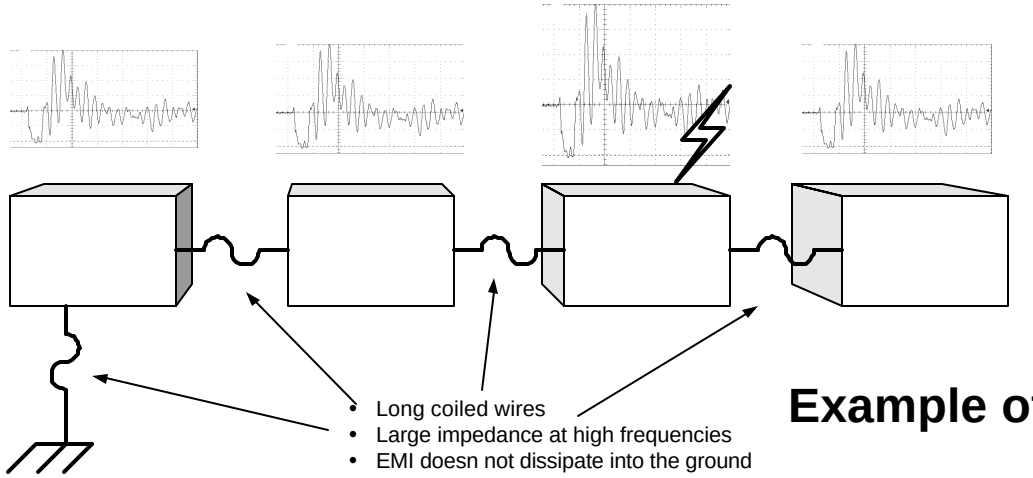
- Voltage causes electric field. High-frequency EMI can be easily measured.
- Bring EMI meter (not static field meter!) close to the grounded surface of your equipment or a workbench. Measure peak signals (very important for ESD-caused transients)
- If the equipment or the workbench is well-grounded, the emission level will drop
- OK ground will cause emission level to raise slightly
- Poor ground will cause emission level to raise several times

Things to Do to Improve Your Ground

- Don't Panic
- Shorten your ground wires
- Straighten your ground wires
- Use large gauge braided cable
- Connect it to known good ground
- Do not chain-link many workstations
- Always verify ground quality for EMI
- Do it on a regular basis

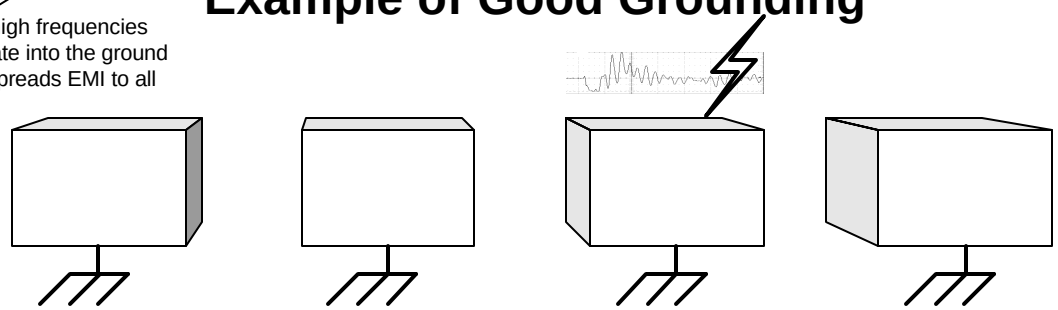
Do Not Use Long Ground Links

Example of Poor Grounding



- Long coiled wires
- Large impedance at high frequencies
- EMI doesn not dissipate into the ground
- Chained connection spreads EMI to all devices in the chain

Example of Good Grounding

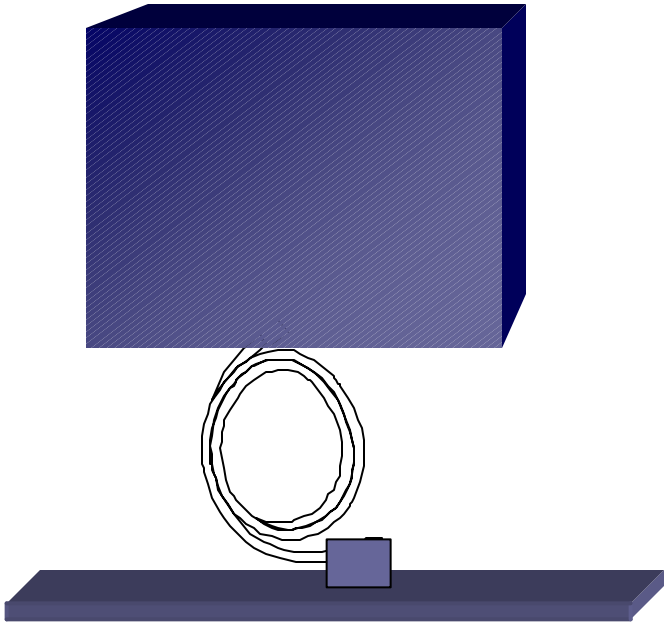


- Short straight wires
- Low impedance at high frequencies
- Most of EMI dissipates into the ground
- Individual grounding prevents spreading of EMI to devices in the chain

Short Straight Ground Wires Reduce Effects of EMI

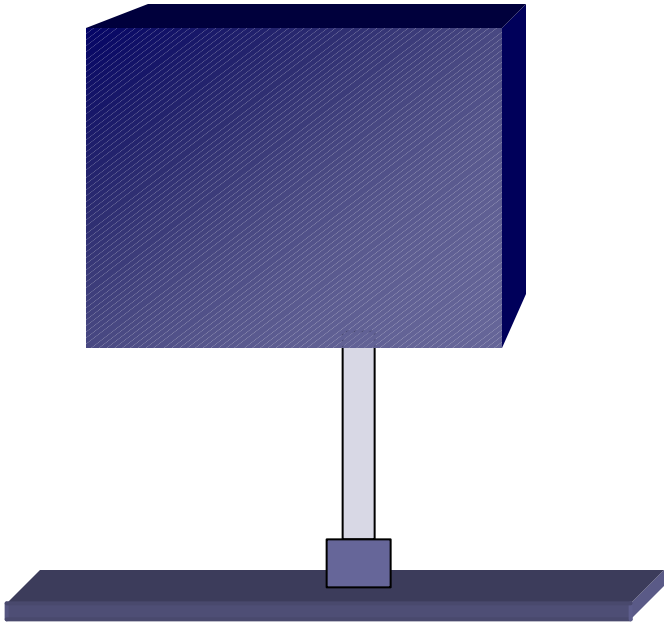
Bad for EMI

Long coiled solid wire



Good for EMI

Short straight stranded cable



How to Minimize Effect of EMI on Operation of a FAB -- 1

Reduce charge	Proper choice of materials Reduce contact between dissimilar materials Provide static-dissipative path Provide ionization wherever appropriate
Avoid discharges	Avoid metal-to-metal contacts Provide for slow dissipation rather than discharges
Reduce propagation of EMI	Improve and maintain EMI-valid ground throughout the facility Use EMI filters on power and data lines

How to Minimize Effect of EMI on Operation of a FAB -- 2

EMI-harden your equipment	Make sure that equipment you install in your facility was tested for EMI susceptibility (IEC 1000-4-2, IEC 1000-4-3 and IEC 1000-4-4) Apply proper grounding techniques Decouple long data cables Implement ferrite chokes on cables (not ground!)
Know your EMI environment	Monitor EMI environment Do EMI audit Have EMI specification (max. levels) Keep record of EMI environmental data for correlation of failures

EMI: Verification Approach

- EMI is continuously monitored at the most vulnerable area of a tool
- If EMI is detected, the tool is instructed not to do anything new
- If EMI is detected, its presence is datalogged for future analysis
- If EMI is detected, alarm is issued
- If EMI is detected, tool can be checked

The Last Line of Defense: EMI Protection Devices

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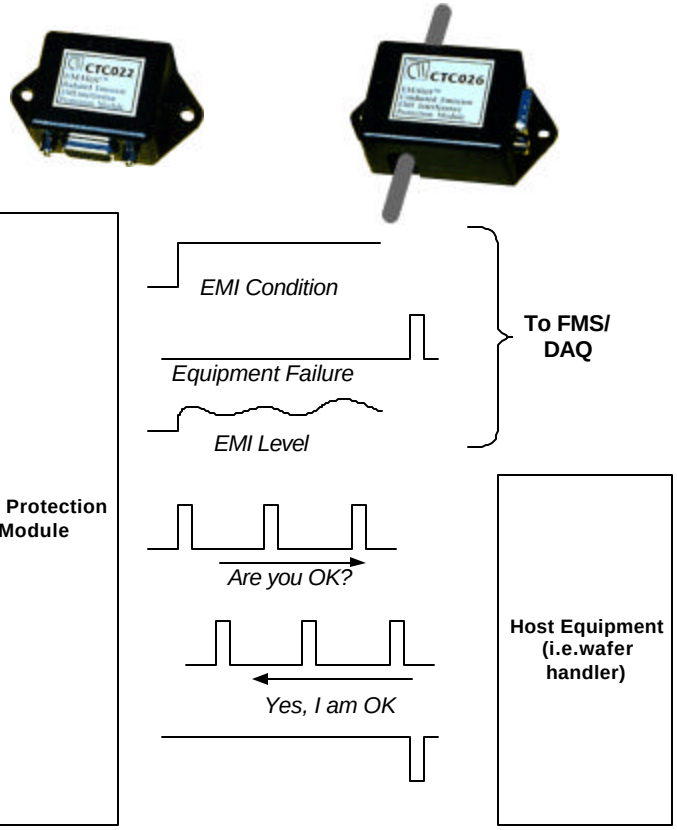
- When strong EMI is present, EMAlert issues a signal indicating strong EMI conditions
- Based on that, equipment can be set to idle until the EMI condition goes away
- A remote warning of EMI condition is possible
- It is possible to test lock-up condition of equipment and even reset it
- EMI environment can be datalogged for failure correlation and improvement verification



EMI Protection Devices -- the last line of defense against EMI

- Case Study
  - A lumber company in Canada was using metal detectors in their saw mill operation in order to find nails in logs so that the saw blade is not damaged
  - Workers are using walkie-talkies that caused malfunction of the metal detector
  - EMAlert® CTC022 installed next to the metal detector stops log advancement when the EMI is above the set threshold

EMI Monitoring -- Hidden Problems Revealed

- Don’t let your equipment failures due to ESD and EMI catch you by surprise
- Know the real cause of failure (whether it is ESD/EMI related or not) -- no need to guess
- Real-time response to EMI/ESD condition is possible
- Address the root cause of the problem and prevent it from happening again.

Why EMI Matters Now More than Ever?

- Smaller geometries of today's devices make them much more susceptible to ESD and EMI
- The new circuits work at higher speeds and now "notice" the ultra-short spikes that older slower circuits ignored
- Higher frequencies used in today's electronics create more emission due to better antenna factor
- Today's circuits work at lower voltages: as low as 1.8V. Much lower levels of EMI are needed for their disturbance.
- **The trend doesn't look promising.**

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