OnFILTER

Electric Overstress: The Next Frontier

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Through: ASEMEP

Organized By: SEIPI

Supported By: ESD ASSOCIATION

Objectives

- Electrical Overstress (EOS) is a substantial threat for components in production environment
- EOS has long been on the "back burner" as a cause of exposure of sensitive components
- As sensitivity of components grows, EOS gains more prominence while it lags in terms of attention from manufacturing and in technical details of exposure
- Formalizing the exposure to EOS and EOS-caused damage to components will significantly benefit those dealing with sensitive components

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What is EOS?

- EOS is a signal applied to the device in excess of the device' normal operating parameters
- ESD is a partial case of EOS
- EOS, as we define it, is any overstress that is not caused by static charge

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EOS Properties

- Though EOS can have any properties, the ones below are the most typical in a manufacturing environment:
  - Duration of individual EOS Events is longer than an ESD Event (i.e. 1µS or longer)
  - Peak signal levels are typically much lower than from ESD Events
  - EOS signals can be of any type: AC, DC, EMI, transients
  - EOS signals are often periodic and/or continuous unlike ESD

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ESD vs. EOS

ESD Event	EOS Event
Caused by a rapid discharge of accumulated electrical charge. Once this accumulated charge is consumed, ESD Event can no longer manifest itself.	Caused by voltage and/or currents associated with operation of equipment or with power generating equipment. Lasts as long as the originating signal exists. There is no inherent limitation on its duration
Characterized by a specific waveform. While the waveforms of different models of ESD Events (CDM, HBM, MM and others) certainly differ in appearance, in general their properties include rapid rising edge (within few nanoseconds) and an asymptotic rear edge lasting typically less than 100nS	Can technically have any physically possible waveform – the sources of EOS are often unpredictable. There are some major categories, however, which will be described further in the text
Non-periodic and non-repeatable – accumulation of charges cannot be guaranteed	Mostly, but not always, periodic and repeatable

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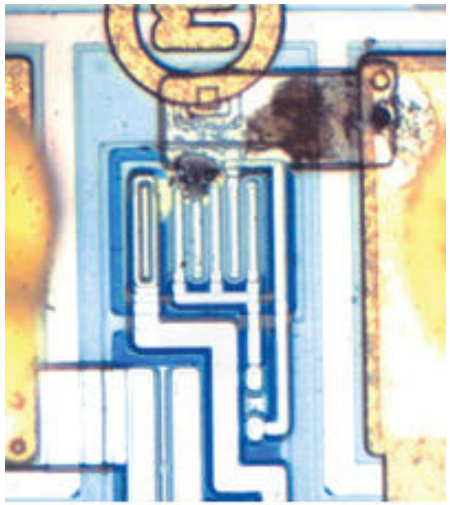

EFFECTS OF EOS ON COMPONENTS

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EOS and Component Damage

- EOS causes two basic types of failures
  - Fatal failure due to overstress
    - high levels of induced signals
  - Latch-Up
    - induced voltages outside of supply rails
    - causes overheating leading to failure
    - sometimes recoverable after power-cycling

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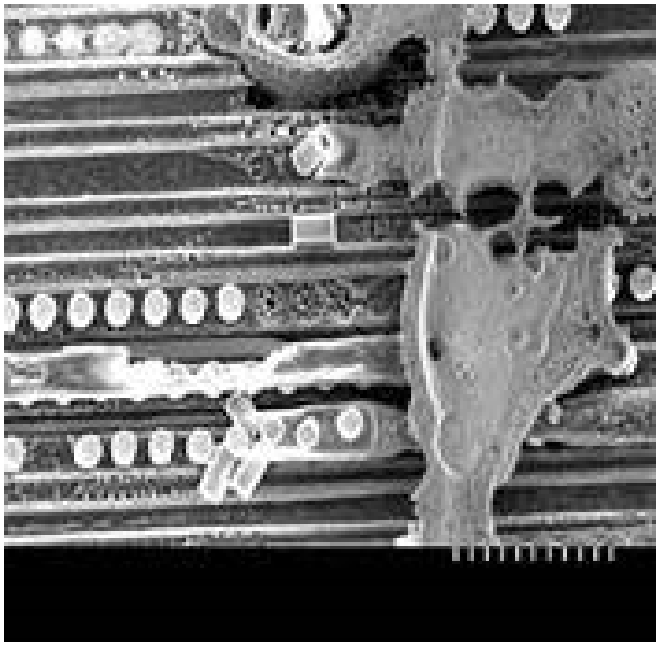
EOS and Component Damage

- EOS signals deliver significant amounts of energy to the devices
  - Virtually no limit on current
  - Relatively long duration
- Damage to the devices is often manifested as massive meltdown

- EOS Damage of IC



Source: Intel

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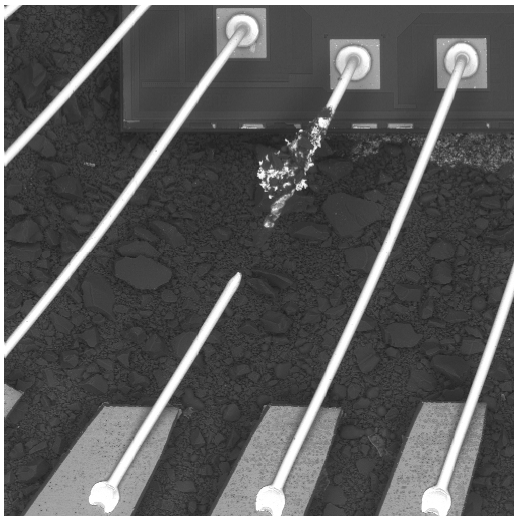
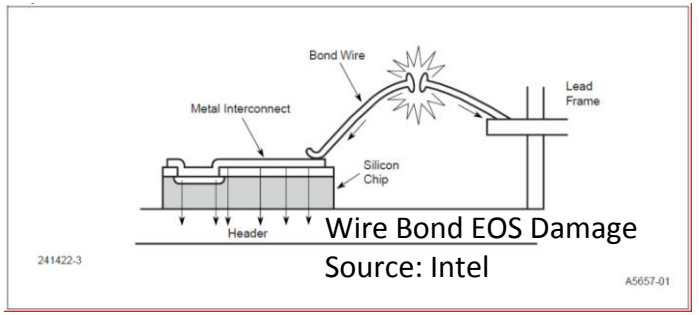
EOS and Component Damage

- Massive energy delivered by EOS can melt wires inside the packaged device
- Real danger is latent failure when the wire is weakened but the damage is not detected during the device test
- Such weakened device can fail in product' use

- EOS and Wire Bond





Wire Bond EOS Damage
Source: Intel

EOS Damage
Source: SEM Labs

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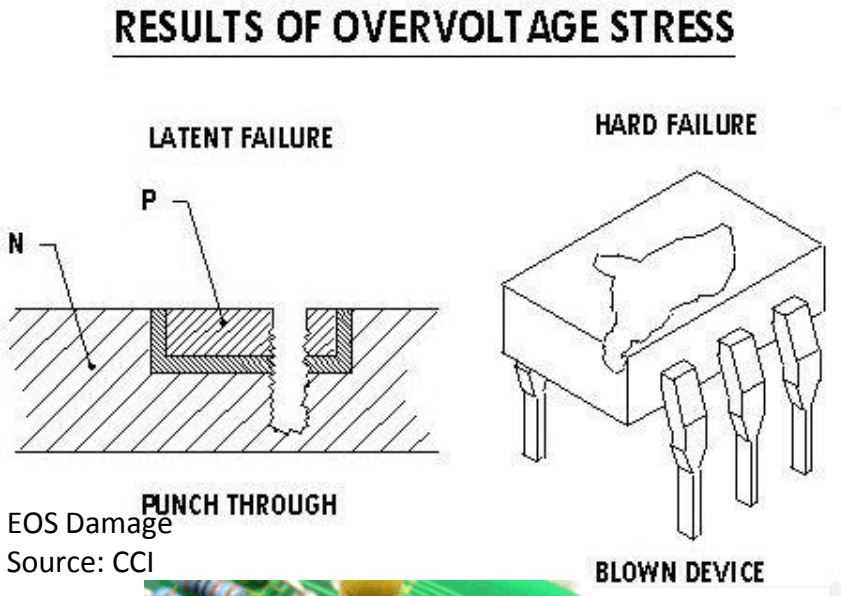
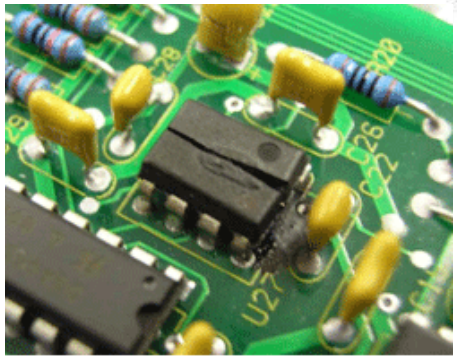
EOS and Latent Damage

- EOS can be more prone to cause latent damage than ESD
- Large energy delivered by EOS weakens the structure, the features and the geometry
- Weakened elements may still perform adequately during final test but fail in use when even the slightest normally acceptable stress is applied



EOS Damage
Source: CCI



Source: EDN Magazine

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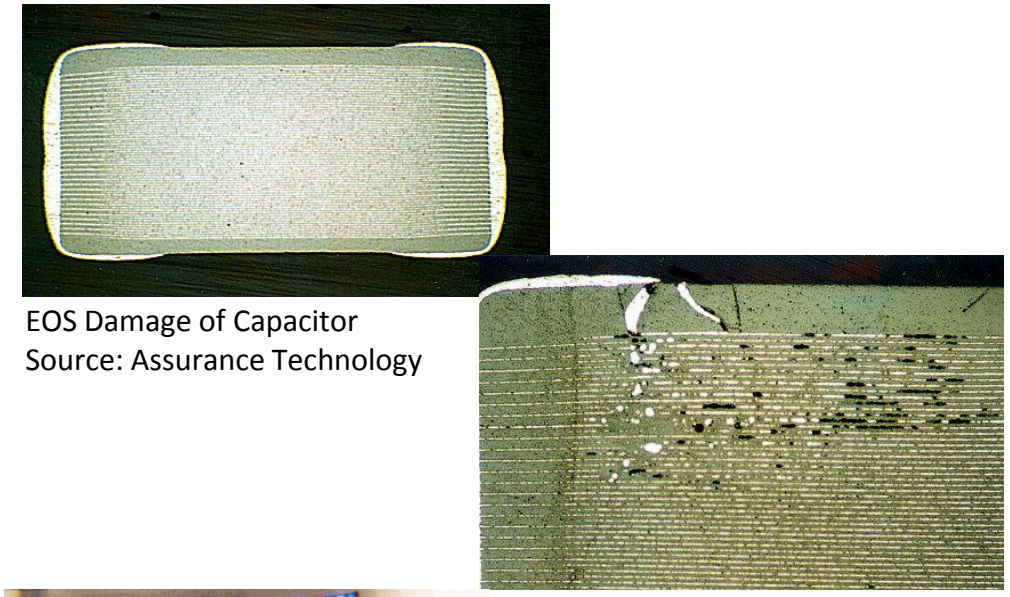
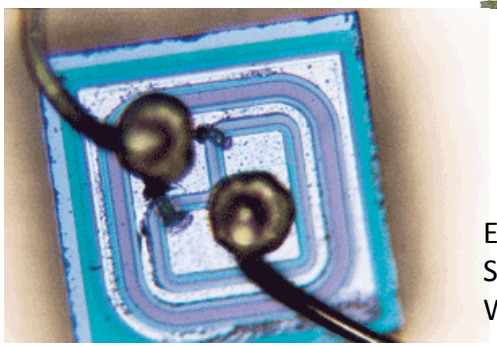
Does EOS Induce Damage only in Complex Devices, such as ICs?

- EOS is just as harmful for simple devices as for complex ones
- Capacitors and transistors can be affected by EOS as shown
- Latent damage is also a concern for simpler devices



EOS Damage of Capacitor
Source: Assurance Technology



EOS Damage of Transistor
Source: Test and Measurement World Magazine

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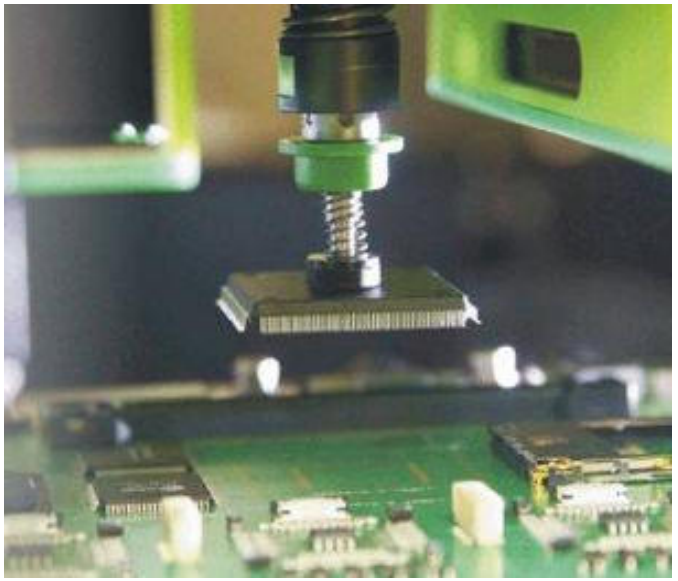
Is EOS Damage Confined only to Device Manufacturing?

- A device in the PCB assembly process can also experience electrical stress
- Board assembly steps at which EOS occurs include:
  - Soldering
  - Board test



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How Much EOS is Too Much?

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Acceptability of Electronic Assemblies

3.1.1 EOS/ESD Prevention – Electrical Overstress (EOS)

Before handling or processing sensitive components, tools and equipment need to be carefully tested to ensure that they do not generate damaging energy, including spike voltages. Current research indicates that voltages and spikes less than 0.5 volt are acceptable. However, an increasing number of extremely sensitive components require that soldering irons, solder extractors, test instruments and other equipment must never generate spikes greater than 0.3 volt.

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Why Such Huge Discrepancy in Damage Levels?

- 0.5V vs. 100V?
- The difference is in delivered energy
- ESD Event lasts few nanoseconds
- EOS Event may last microseconds or milliseconds – thousand or million times longer

vs.

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What Does This Mean?

- Conventional methods of measuring voltages in production environment, while being perfectly good for ESD, are not sufficient for EOS
- EOS is measured with high-frequency tools, not regular static instrumentation
- ESD and EOS measurements are NOT interchangeable
- EOS control is not a subset of ESD control – it is a separate entity

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EOS AND EQUIPMENT

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EMI-Caused Failures

Soft Failure

- "off-line"
- reset
- run error
- communication errors
- measurement or reading errors
- lock-up
- lost or corrupted files
- latch or lock-up
- output errors

Hard Failure

- Component damage
- PCB damage

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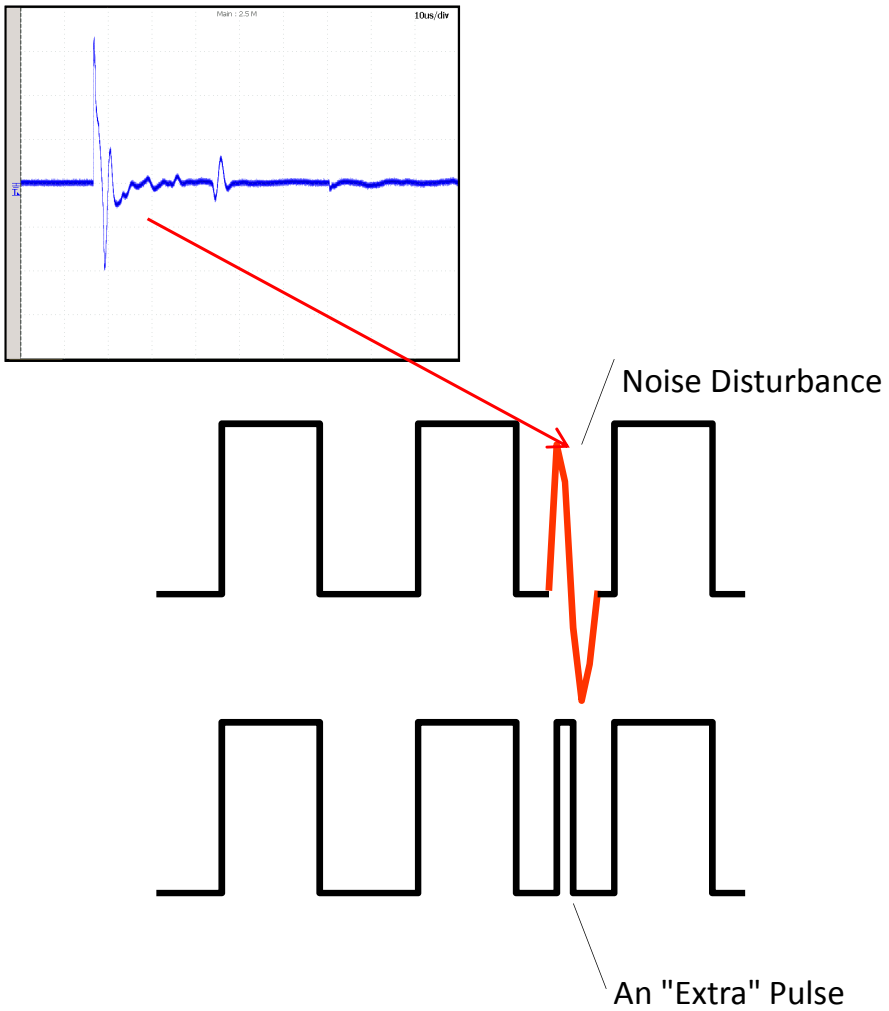
Soft Failure Example: False Signals

- Electrical noise induces seemingly legitimate signals into electronics circuits
- These types of signals cause equipment malfunction
- Often, the electronics circuit does not suspect that it is affected by noise
- Today's high-speed circuits are much more susceptible to noise



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What Equipment is Likely to be Affected by EMI?

- Data processing (computers, network equipment and alike)
  - Data processing downtime attributed to power quality is almost 50% at present (Data: CCI)
- Process control
- Sensors
- Metrology
- Any equipment with sensitive electronics
- This list is growing

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EOS SOURCES IN MANUFACTURING

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EOS Sources: Power Frequency

- Typical causes:
  - Too high of ground impedance
  - Ground and neutral are reversed
  - Faulty soldering irons
  - Faulty power adapters
- Type of signal: continuous sinewave (often distorted)

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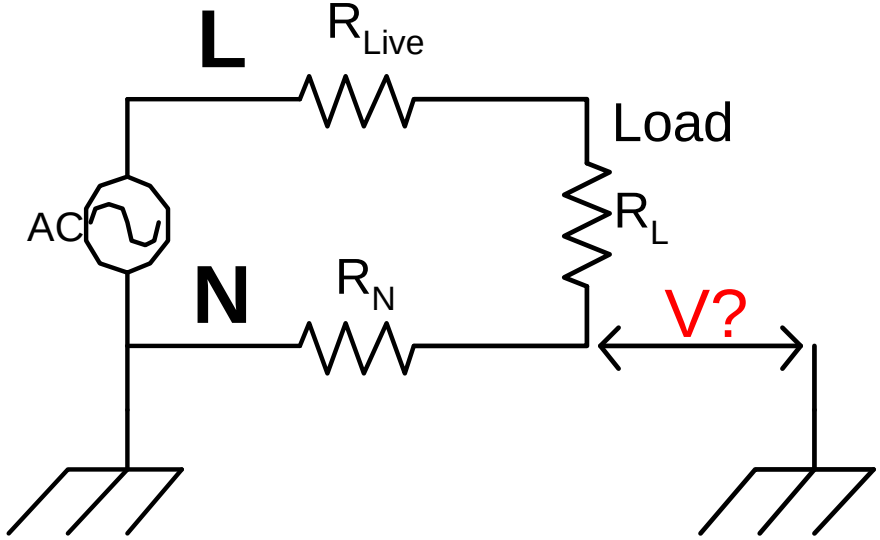
Ground Loops and Other Problems

- Ground is not always (or rather always not) the same in different locations or even within the same tool
- Often, tool design does not include best grounding practices
- The result is 50/60Hz signal applied to sensitive components



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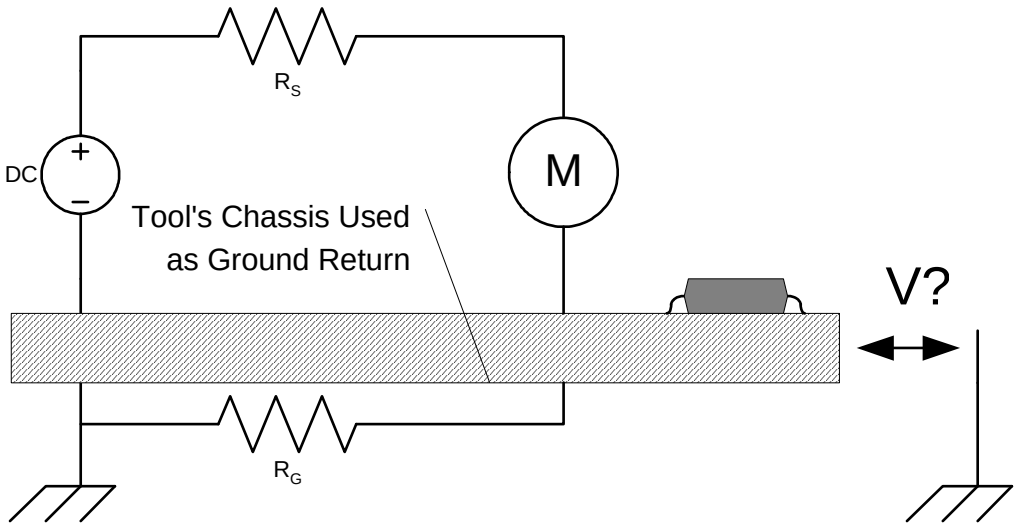
EOS Sources: DC Voltage

- DC relays, motors, lights, etc. within the tools sometimes use tool chassis as ground return
- This inevitably creates difference in voltage across the tool
- The nature of this voltage is mostly transient
- Current capacity of this voltage source is significant



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EOS Sources: Power Supply Artifacts

- DC power supplies in IC testers and other similar tools are liable to produce transients and other artifacts during commutation
- This may damage the devices during the test
- Signal type:
  - Mostly pulses and transients
  - Can reach several volts
  - Low impedance/high current capacity

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EOS Sources: EMI (Electromagnetic Interference)

- Typical causes:
  - Poorly-designed equipment
  - Poorly-maintained equipment
  - Poorly-grounded equipment
  - Ground bounce
  - Noise via power lines
  - Stepper and variable frequency motors, etc.
- Signal type:
  - Mostly pulses and transients
  - Can reach several volts
  - Low impedance/high current capacity

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EMI AS SIGNIFICANT SOURCE OF EOS

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Sources of Power Line Noise in a Factory Environment

- Equipment Turning On/Off
- Electrical Actuators
  - Stepper, servo and variable–frequency motors
  - Solenoids
  - Relays
- RF Heaters
- UPS
- Electronic Circuits
- Many Others

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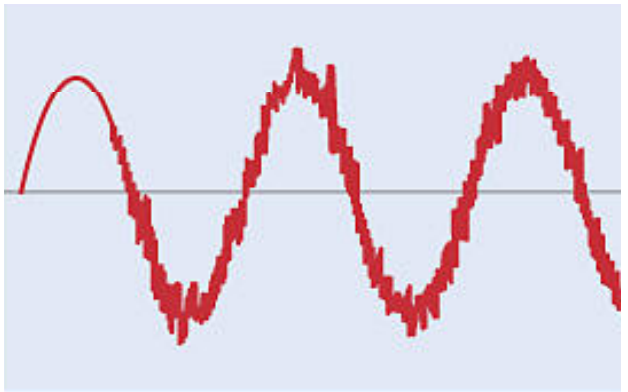
Power Line Noise

- Every electric and electronic device uses power
- Quite often, power lines also carry noise
- The noise may cause problems for equipment and components
- This noise is characterized as conducted **E**lectro**M**agnetic **I**nterference (EMI)



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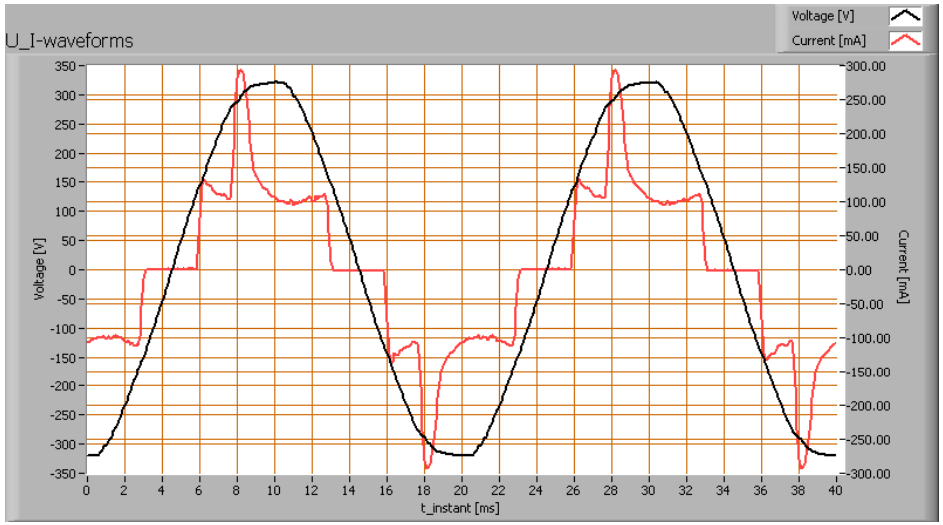
Is it Only 50/60Hz or Something Else?

- Many things are not what they appear to be
- Most of voltage on ground comes not from the 50/60Hz signal on mains but from signal artifacts on mains
- Among them:
  - Continuous noise
  - Transient noise
- These signals are impossible to recognize using "standard" ESD tools



A typical waveform of mains signal from UPS. This signal contains very significant harmonics that gets induced on ground

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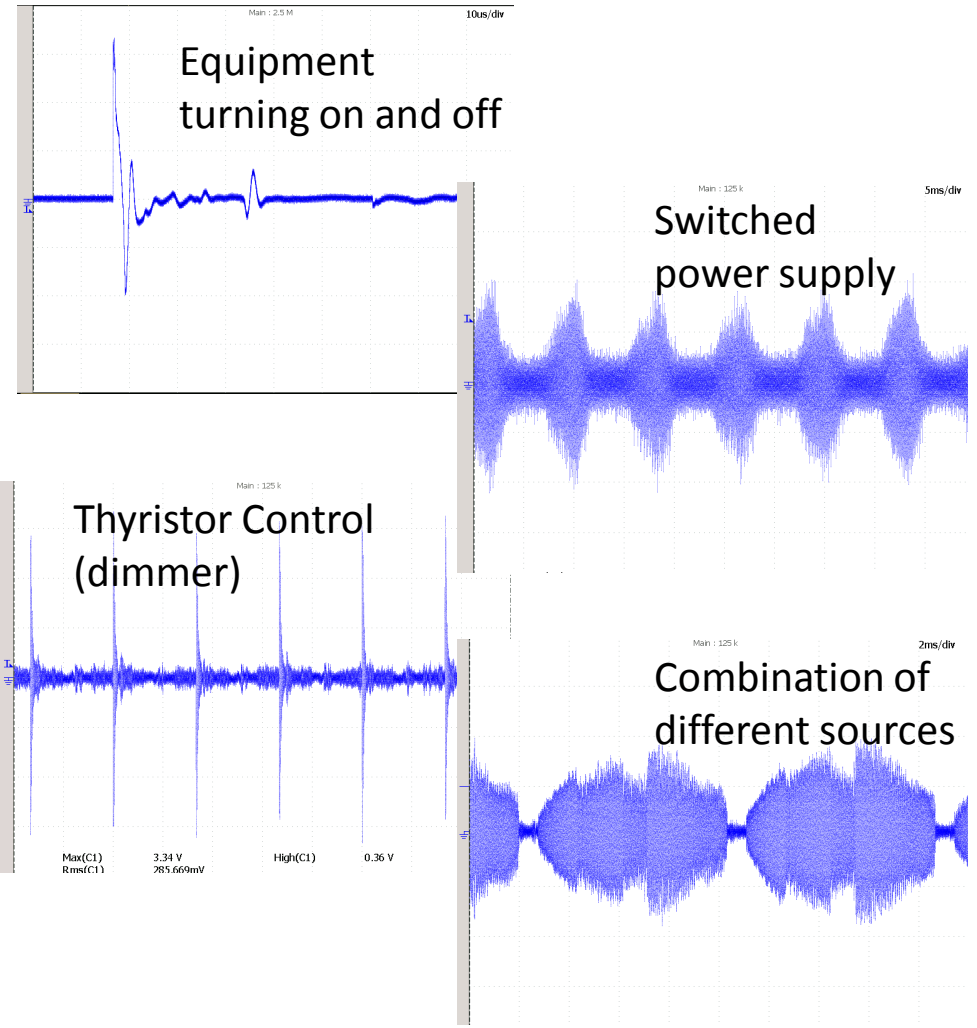
What Kind of Noise Signals Are There On Power Lines?

- Noise signals on power lines can have many different shapes:
  - Transients (pulses)
  - Ringing signals
  - Continuous signal waveforms
  - Combination of all of those
- The strongest and the most damaging signals are transients, often reaching several volts



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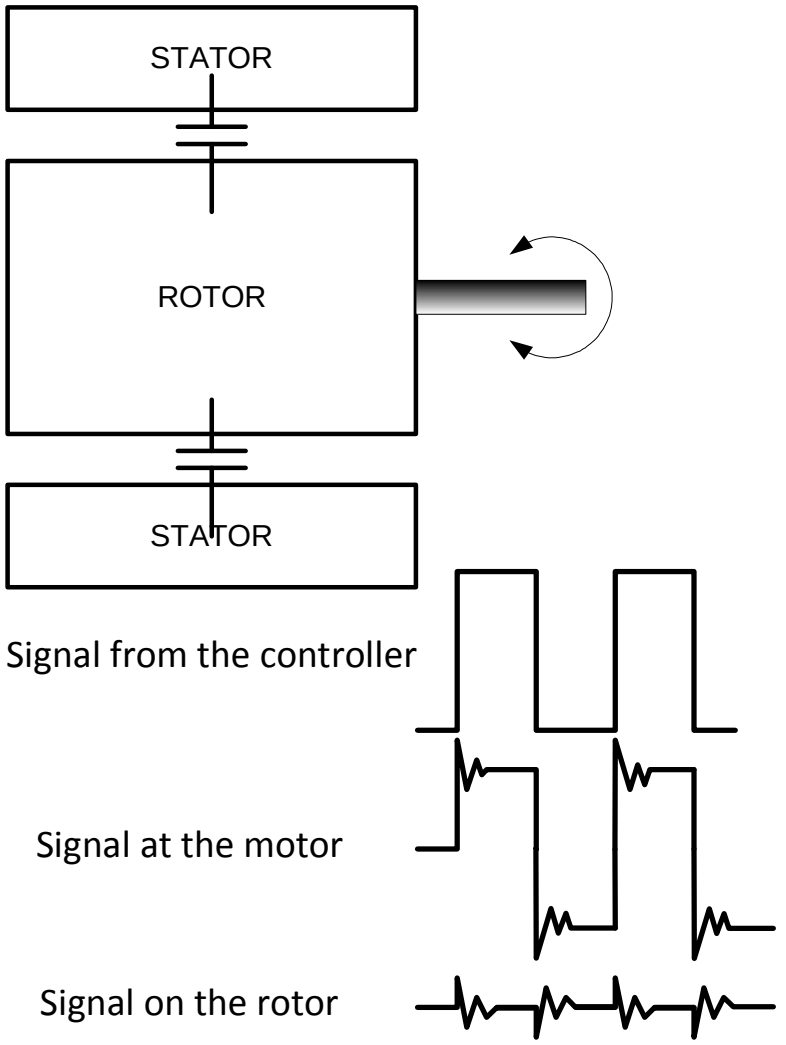
Example: Noise in Servo Motors

- Low-frequency square-wave from the servo controller gains ringing and other artifacts by the time it reaches the motor
- Via capacitive coupling these high-frequency artifacts get on the rotor
- Now your components are exposed to strong high-frequency signal
- Yet the rotor appears to be grounded



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Noise on Ground

- Ground by itself cannot generate noise
- Noise can be induced on ground by external factors
- The main source of noise on ground is power lines – AC and DC
- Because ground is common for the entire factory, once noise enters ground circuit, it spreads widely

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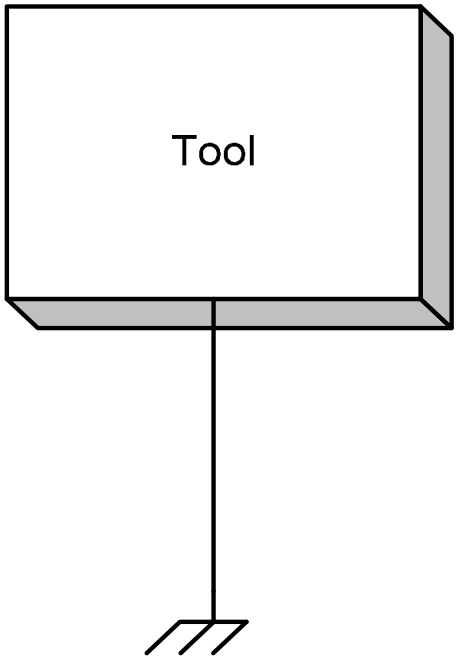
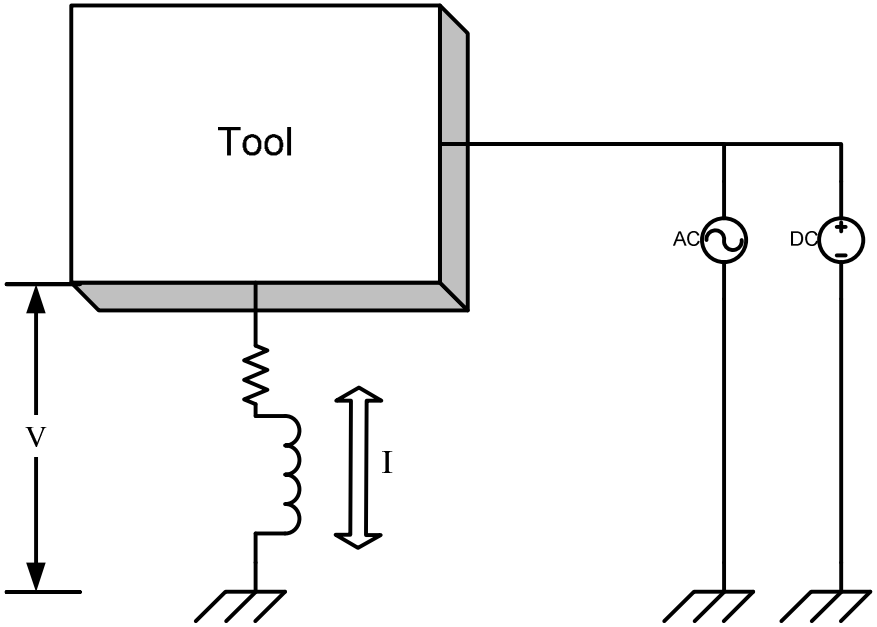
The Secret Life of Ground



Simplistic view at grounding



Realistic view at grounding

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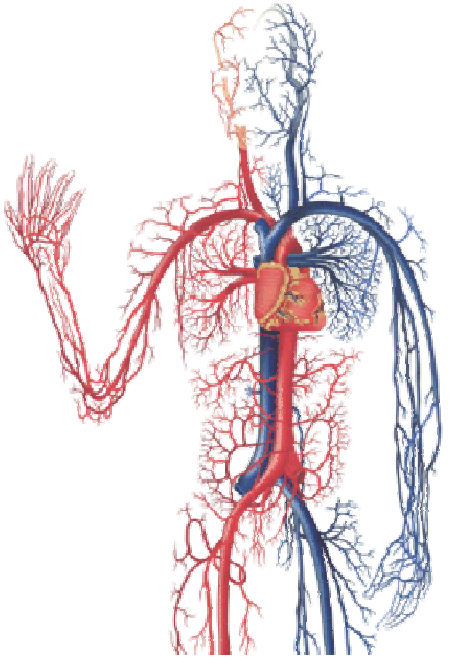
Propagation of EMI in Factories

- Conducted EMI noise propagates via
  - Power lines
  - Ground
- These lines form very complex network that channels noise from its source to many sensitive tools
- Unlike propagation via air (radiated emission), conducted emission can reach very far
- Though completely redoing power line and ground networks in a factory may help to reduce EMI propagation, it cannot prevent it. It is also very costly



Power and ground networks are similar to human blood circulation

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Equipment Design and EMI

- Electrical and electronic equipment is expected to comply with strict emission regulations (**E**lectro**M**agnetic **C**ompliance – EMC) so that it is not a source of interference
- Why then EMC-compliant equipment generates high levels of noise in real-life installations?
- Equipment is designed to satisfy compliance requirements
- There is a substantial gap between test conditions defined in the compliance standards and the "real life"

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Equipment Design and EMC: What is the Difference?

Regulatory EMC Test	Your Facility
Controlled environment	Unpredictable and variable environment
Short cables	Cables of random length
Nothing else is connected	Complex network of power and ground
50 Ohms termination input and output	Wide range of impedances from 0.1 to 1000 Ohms
Focus on continuous-type noise measurements specifically neglecting transients	Most of noise is transients, i.e. pulses and spikes

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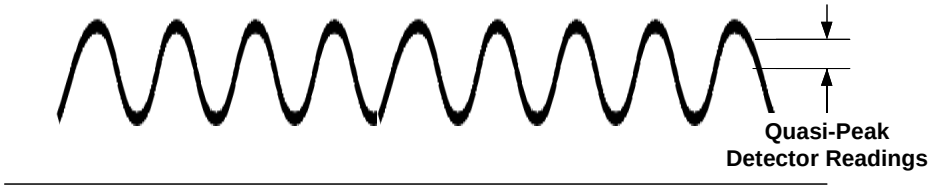
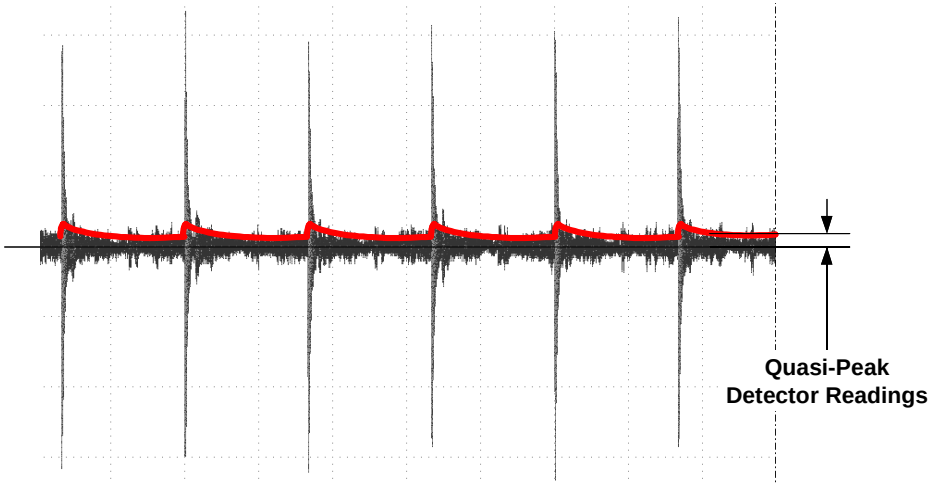
How Noise is Measured: Continuous Signal vs. Transients

- EMC Standards specify use of Quasi-Peak detector
- This detector, contrary to its name, is very slow
- It ignores short transient signals and focuses on continuous signals
- While EMC regulations are very helpful in reducing noise of certain types, other signals, i.e. transients, are left unaddressed
- This way equipment fully-compliant with EMC Standards can still be a source of noise





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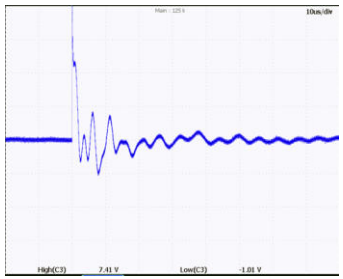
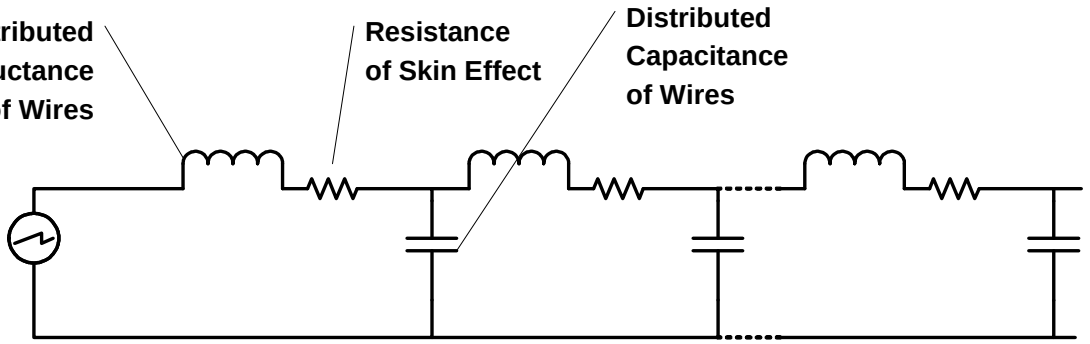
Signal Properties on Line

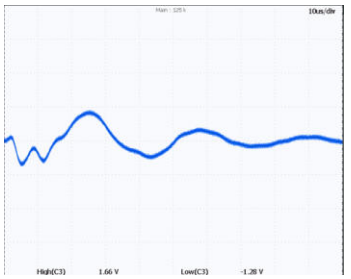
- While originating transient signal may be very short and have broad spectrum, after being affected by the distributed resistance, inductance and capacitance of the power line/ground network, the resulting signal has very different properties, most notably lower-frequency range spectrum



Typical power-on transient signal. Mostly high-frequency spectrum



From "Measurement, Simulation and Reduction of EOS Damage by Electrical Fast Transients on AC Power" *EOS/ESD Symposium 2010, A. Wallash, V. Kraz*



Signal after passing through long power line. Ringing at lower frequencies

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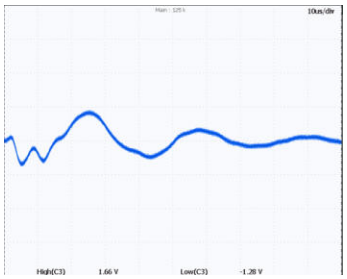
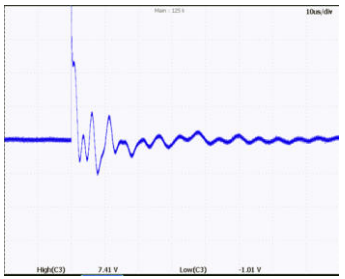
What Difference Does This Make?

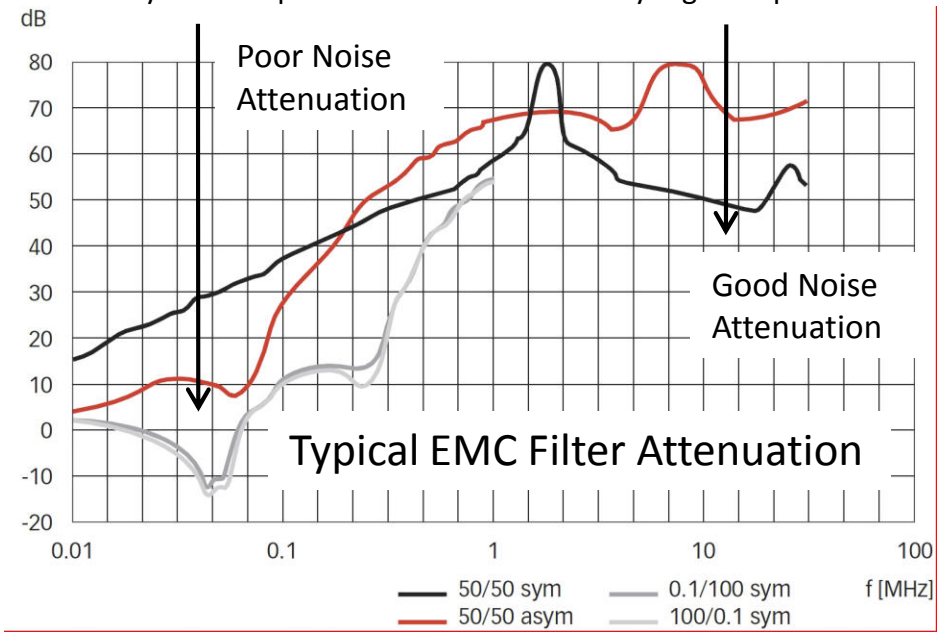
- Equipment designer optimizes his product to pass regulatory EMC test
- He knows that to pass the test he needs to worry about high frequencies and continuous signals
- His optimization does not address real-life conditions



Actual Noise Signal
Mostly Low Frequencies



Original Noise Signal
Mostly High Frequencies



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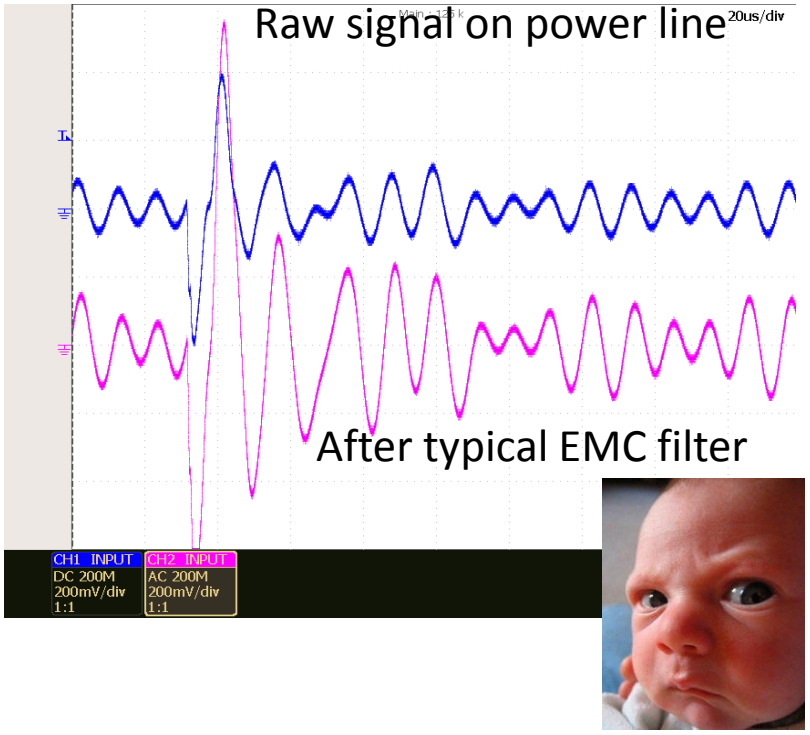
EMC vs. EMI Filter Performance

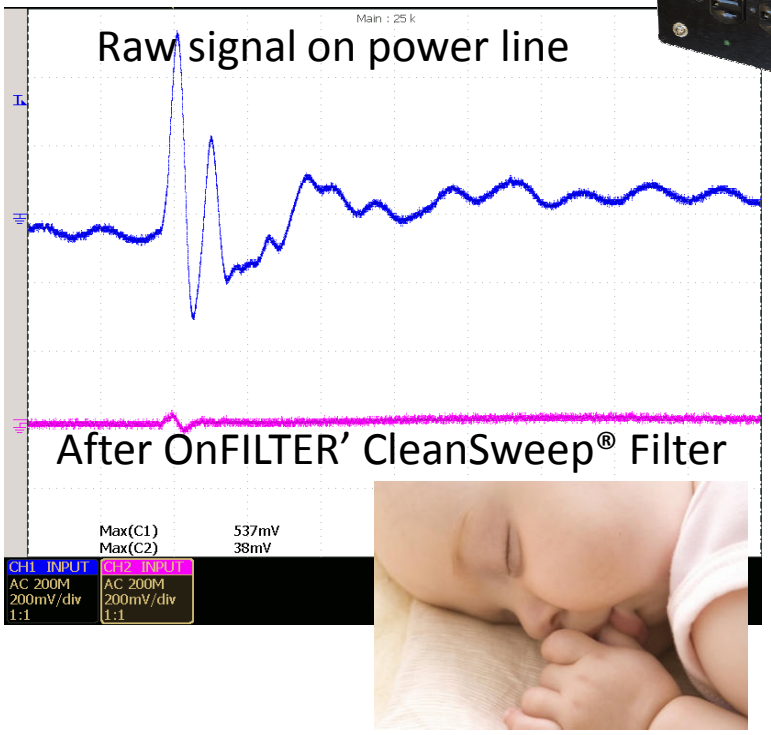
Typical EMC filter

Noise is actually amplified



CleanSweep® EMI Filter

Noise is greatly reduced



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Is EOS from Power Lines a New "Thing"?

- Hardly. Here are the recommendations from 2002 Intel' Packaging Databook:

intel®

ESD/EOS **6**

6.2.2 Common Causes of EOS

- Lack of AC line filters

6.2.3 Prevention of EOS

Establish and follow proper work procedures.

Conduct regular AC supply line monitoring and, if necessary, install EOS line control equipment such as incoming line filtering and transient suppression circuits.

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EOS: NEXT STEP

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ESDA Activities on EOS

- Recently-formed EOS Group within ESDA Standards is working on a document defining EOS
- This is the first step in standardizing Electrical Overstress which eventually bring it on par with documentation for ESD

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EOS Models? Why Not?

- Just like ESD exposure, EOS can be classified into understandable categories
- Well-defined models will help our users to deal intelligently and consistently with EOS
- A suggestion:

EOS Event Model	EOS Exposure Example
Continuous AC	Soldering iron with lost/poor ground
Continuous DC	DC soldering irons, tools
Short Transient Pulse (microseconds)	Transient signals due to EMI on ground
Transient Pulse due to DC commutation	Power supply commutation in IC handlers and alike

There is a Growing Need of Good EOS Management

- Smaller geometries of today's devices make them more susceptible to EOS
- The new circuits work at higher speeds and "notice" the short spikes that the older slower circuits ignored
- Today's circuits work at lower voltages: as low as 1.8V. Much lower levels of EOS are needed for their disturbance then before
- New equipment has much more complex electronics content – higher EOS susceptibility
- This new equipment by itself generates more noise due to higher electronic content
- The trend doesn't look promising
- Left untreated, EOS will cause more and more problems in production

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