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EMI-Caused EOS Exposure of Components and Its Mitigation

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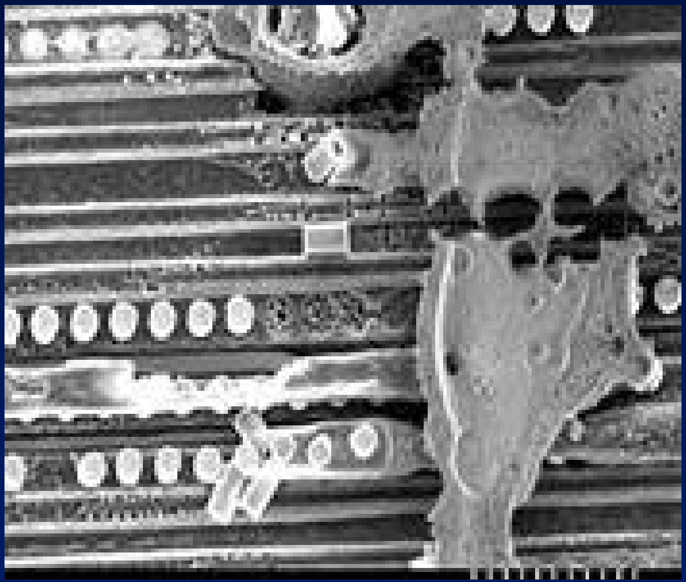
Objectives

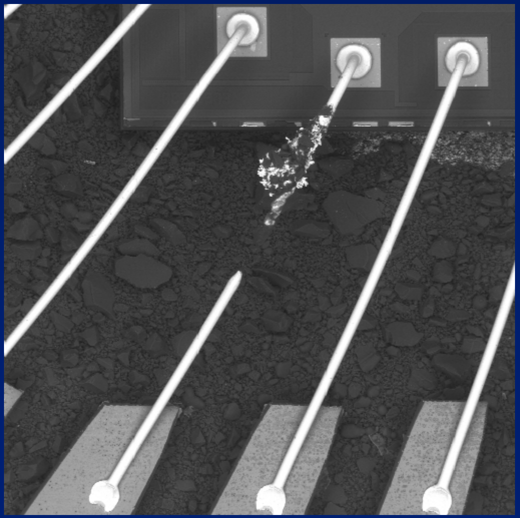
- Electrical Overstress (EOS) is a substantial threat for components in production environment
- As sensitivity of components grows, EOS gains more prominence while it lags in terms of attention from manufacturing and in technical details of exposure
- Understanding the exposure to EOS and EOS-caused damage to components will significantly benefit those dealing with sensitive components
- This paper describes the nature of EMI-caused EOS in two typical manufacturing processes and shows ways of its mitigation

EOS Effect on Devices

- 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 a massive meltdown
- According to Intel, "EOS is the number one cause of damage to IC components."



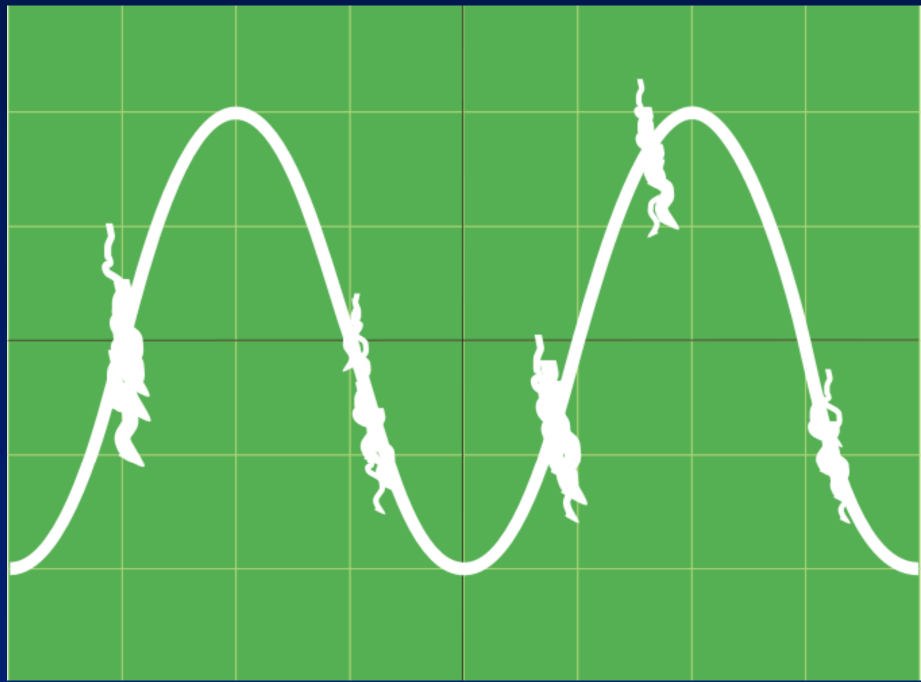
Source: Intel



Source: SEM Labs

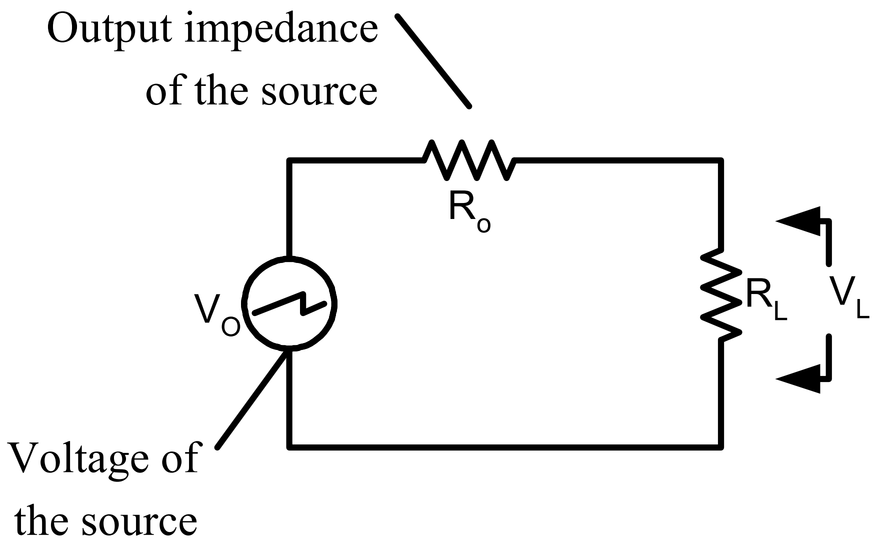
EMI-Caused EOS

- Significant proportion of electric overstress in manufacturing is caused by high-frequency transient signals
- This phenomenon is called conducted emission, or EMI – electromagnetic interference
- EOS-generating EMI in production environment comes from power lines and from equipment within tools



How Much Current can EMI Source Provide?

- Ability of EMI source to provide current is determined by its output impedance
- The lower the output impedance, the higher the current capabilities of the source
- Since EMI is caused by power elements, it appears that output impedance is low



Equivalent Schematic of EMI Source

V_O – Source of EMI signal

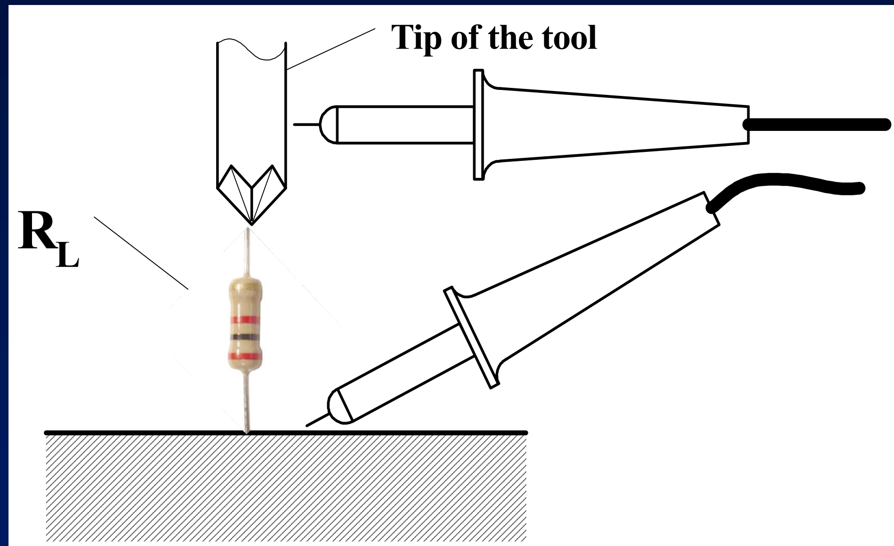
V_L – Resulting voltage on the load

R_O – Output impedance of the source

R_L – Impedance of the load

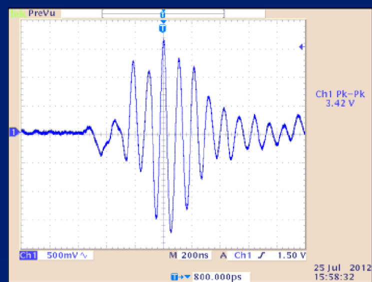
Calculating Output Impedance

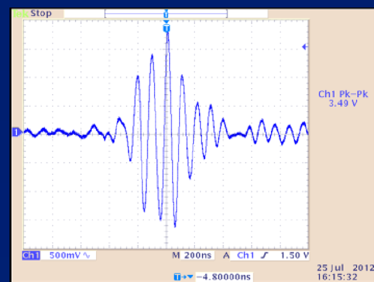
- EMI source is loaded with two different resistors
- Voltage across load resistors is measured
- Output impedance is calculated with the formula shown
- Two resistors – 50Ω and 100Ω - were used
- Voltage values were very close: 3.49V and 3.42V
- Output impedance of the source in this case is 2.09Ω
- Such low impedance is capable of outputting significant current



$$R_O = R_{L1} \times R_{L2} \frac{V_{L2} - V_{L1}}{V_{L1} \times R_{L2} - V_{L2} \times R_{L1}}$$

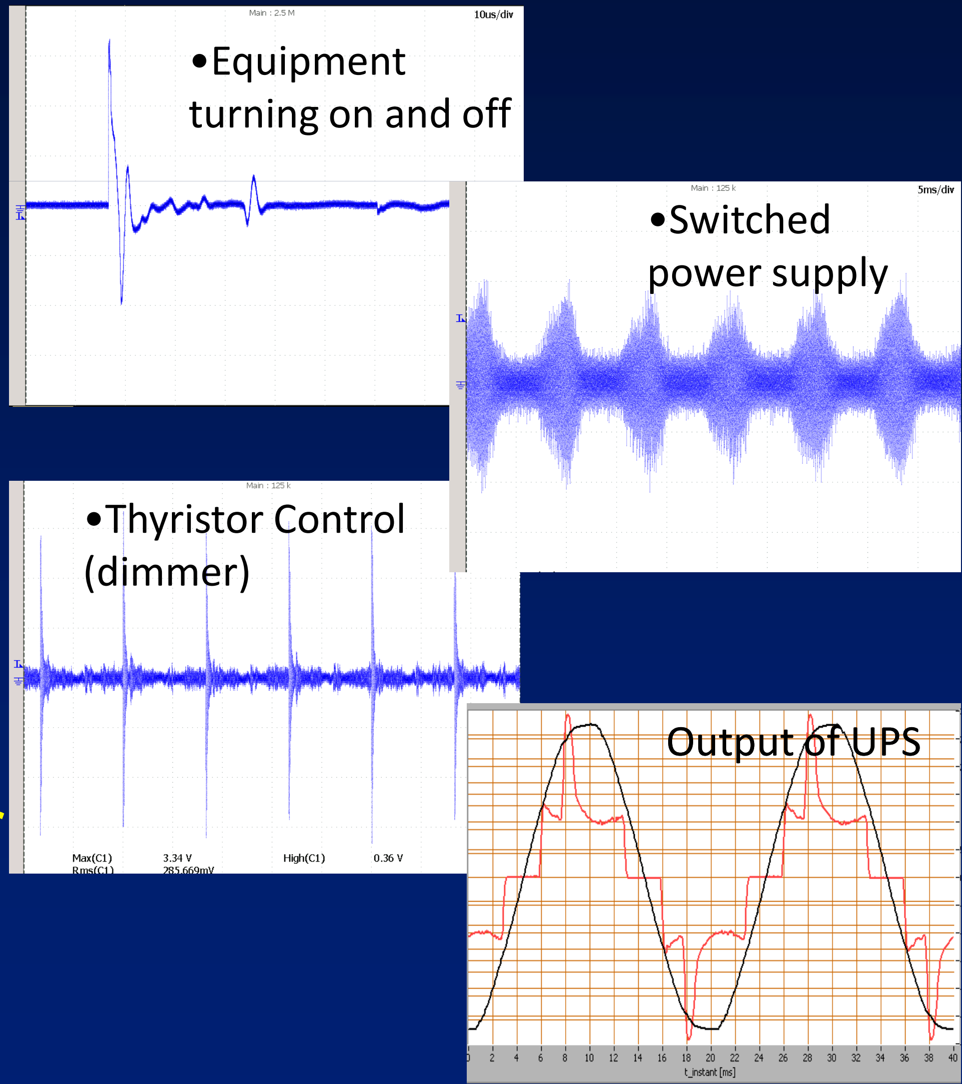
$$R_O = 50 \times 100 \frac{3.49 - 3.42}{3.42*100 - 3.42*50} = 2.09\Omega$$





Noise From Power Lines

- Ideal power line (mains) provides sinusoidal voltage
- Every device consuming electricity loads power line and alters its voltage
- Most of noise is spikes and transient signals
- This noise travels from one tool to another and enters facility ground, propagating far
- These spikes enter other tools and may cause EOS in devices

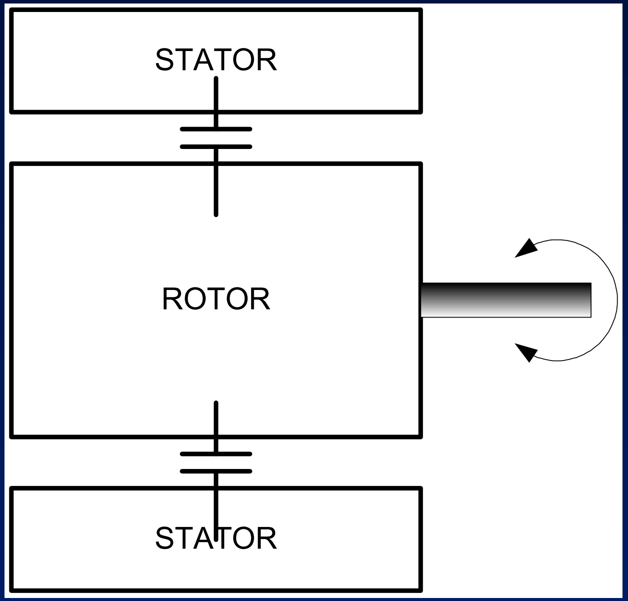


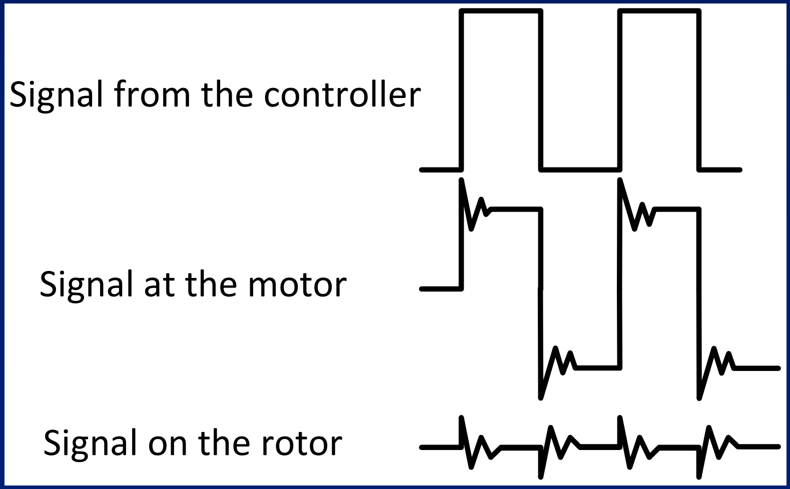
EMI From Sources Within the Tools

- There are several sources of EMI within the manufacturing tools:
  - Servo and variable frequency motors
  - Solenoids and other actuators
  - Switched mode power supplies
  - UPS
- All of them consume energy in “bursts”
- This variable load in combination with finite impedance of wiring and power sources affects power voltage
- The higher their current draw, the higher level of EMI they are capable of providing

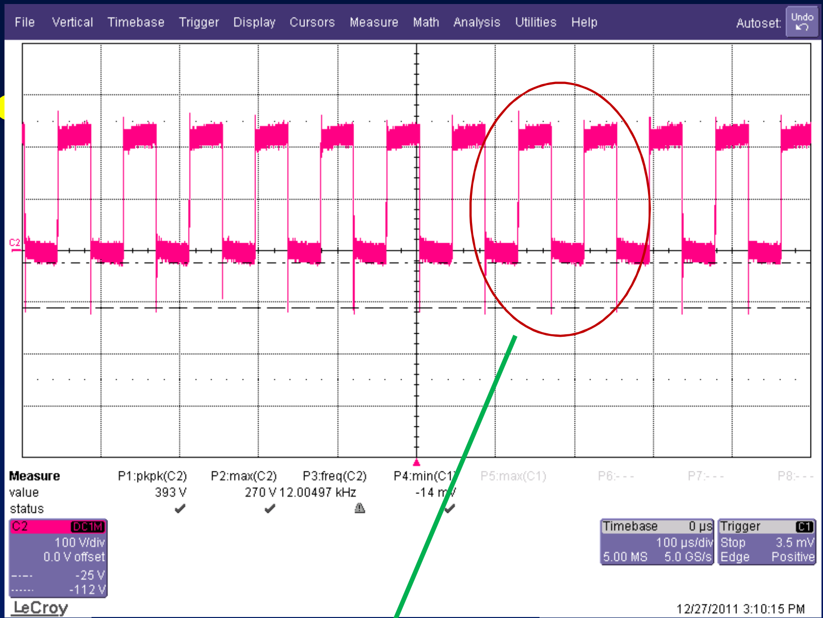
EMI Source Example: Servo Motor

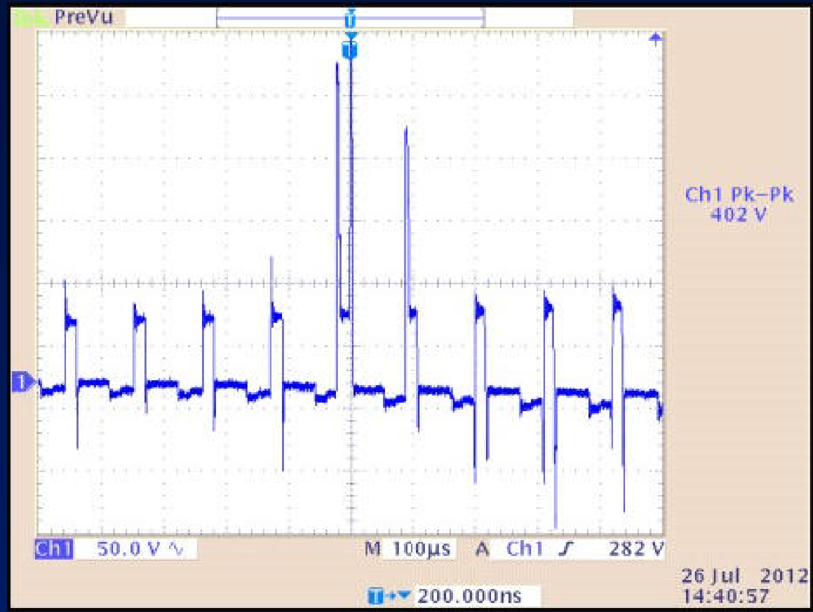
- Low-frequency (up to 20kHz) square-wave power signal from the servo controller gains ringing and other artifacts due to RF mismatch with the motor and wiring
- Via capacitive coupling these high-frequency artifacts get on the rotor
- High-frequency leakage pollutes ground of the tool
- Now your components are exposed to strong high-frequency signal

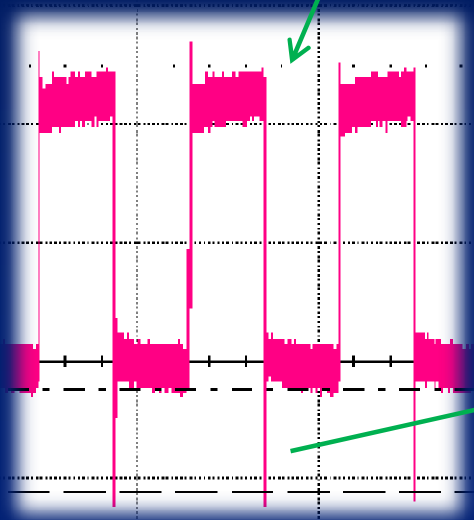


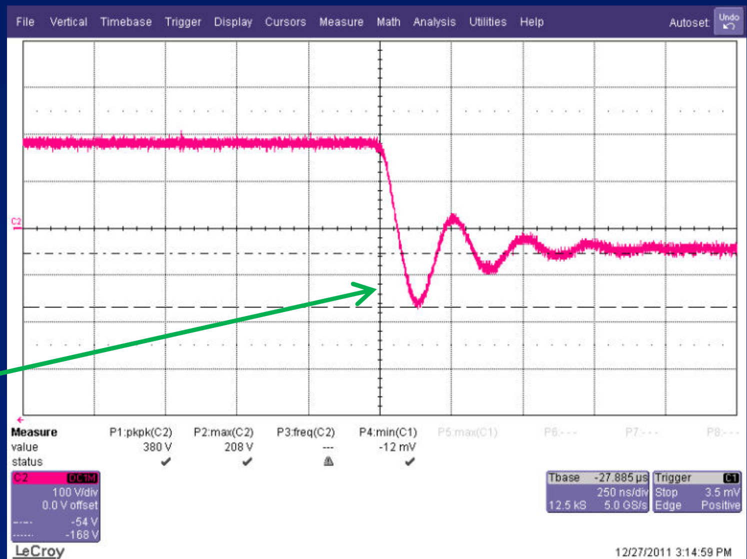


Examples of Waveforms of Servo Motors



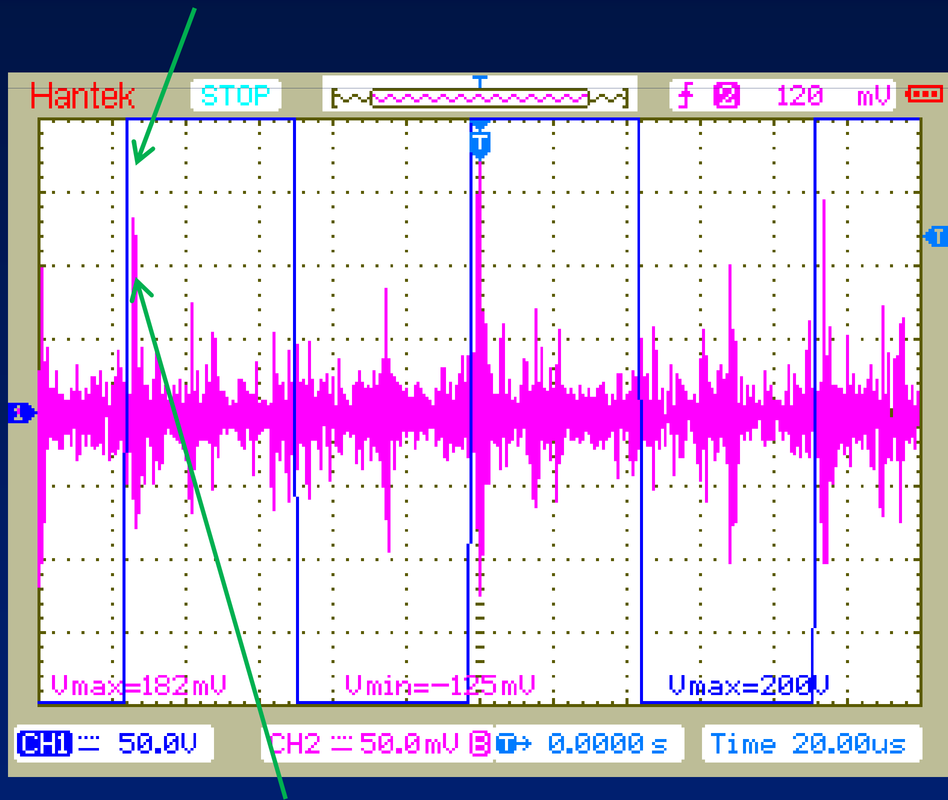






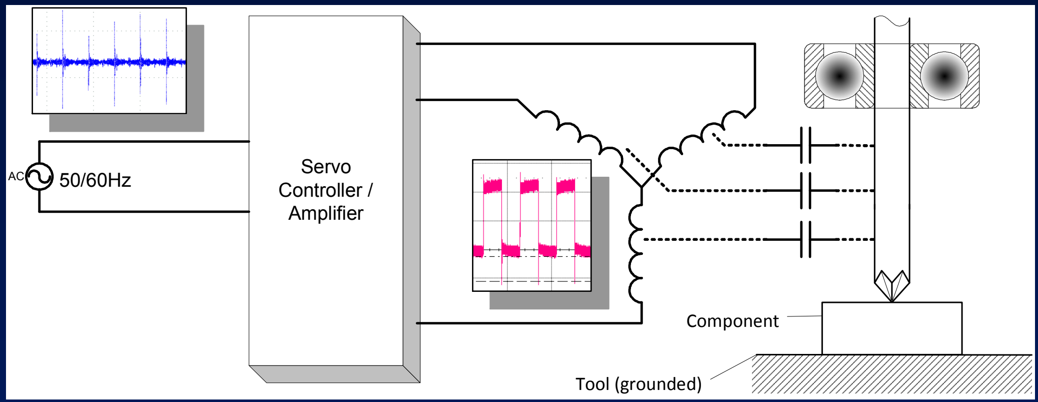
Servo Motor and EOS Current

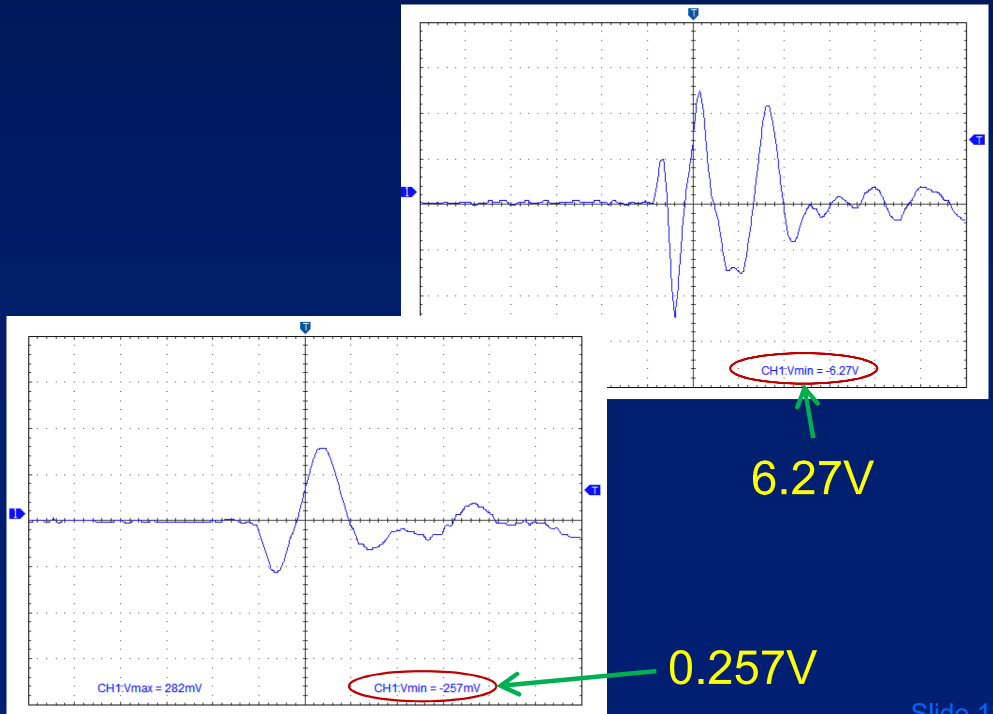
- Spikes from servo motors are synchronized with the current spikes through the device
- The figure shows drive pulses of a servo motor and current between the robotic arm and ground of the test socket
- As seen the current spikes are synchronized with the rise time of drive pulses
- Other spikes are synchronized with the pulses on other phases of the motor



Mitigation of EOS from Servo Motor

- Several basic ways of reducing transient signals:
  - Improve wiring
  - Employ special EMI filtering
- Change of wiring is often impractical since the wiring is an integral part of the tool
- This leaves EMI filtering as the main method of mitigation of noise

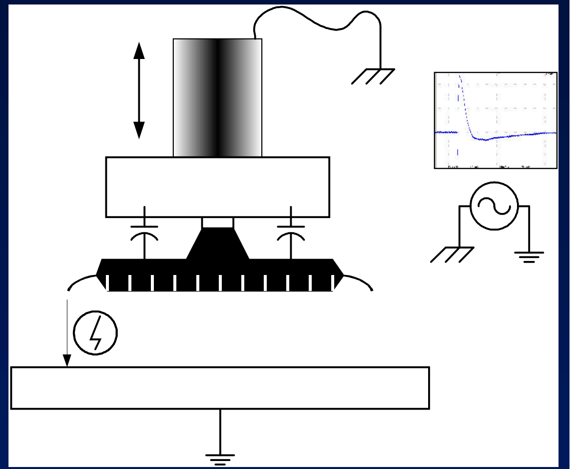




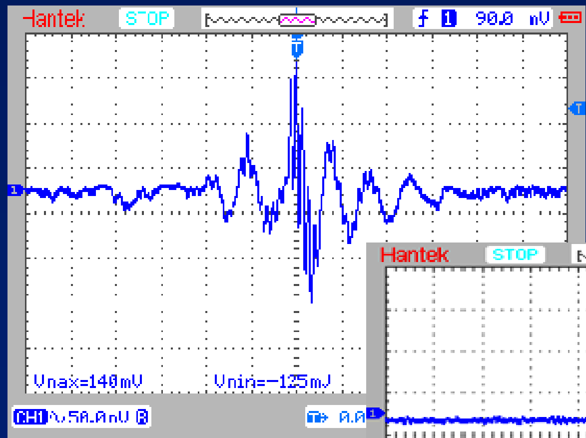
Mitigation of EOS from Servo Motor

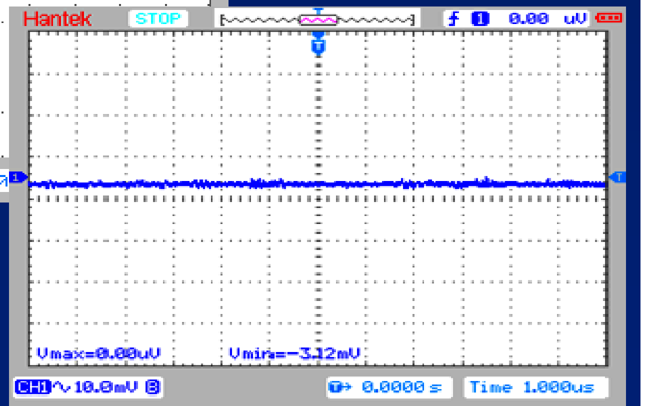
- Different “grounds” have different high-frequency voltage
- Devices are capacitively coupled to the shaft of the robotic arm.
- The result is high current when the device comes in contact with the test socket or shuttle
- Special EMI filters can greatly reduce EOS current as shown

Model of high-frequency current through the device



Current before mitigation

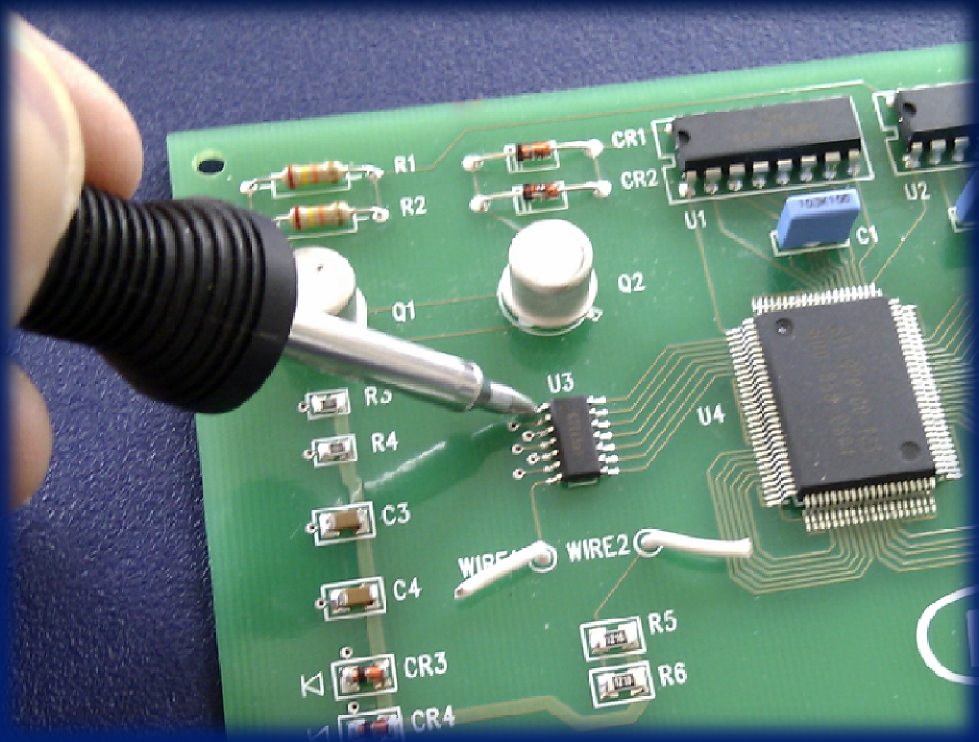




Current after implementation of EMI filter

EMI-Caused EOS in Soldering Process

- Soldering irons come in direct electrical contact with sensitive components
- Any voltage residing on soldering irons causes unwanted current into sensitive devices
- This current causes electrical overstress (EOS) that damages sensitive devices



What EOS Exposure is Safe?

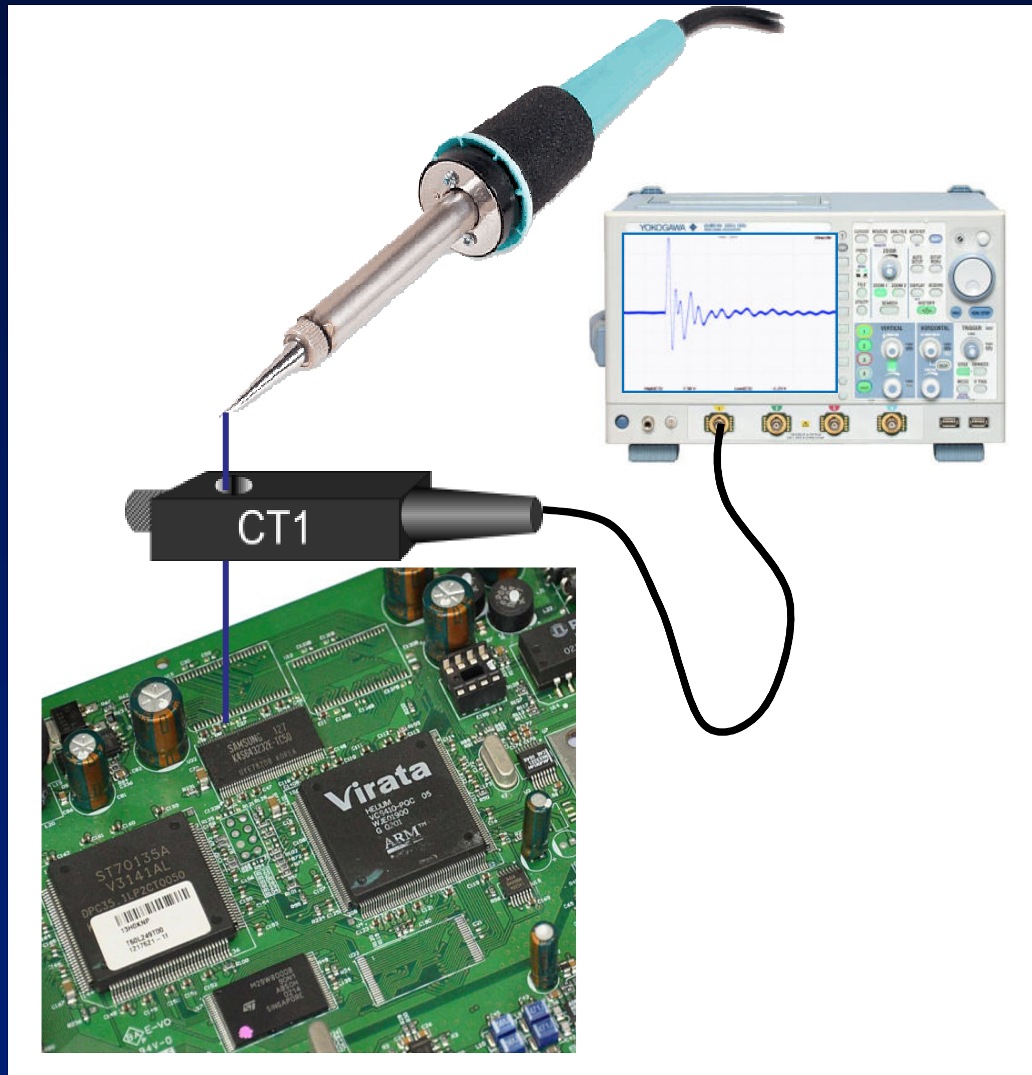
- Various industry standards and recommendations do not always agree as seen below

Standard / Organization	Voltage	Current	Comment
ESDA STM13.1-2000	20mV	10mA	
MIL-STD-2000	2mV		RMS
IPC-TM-650 Sec.2.5.33.2	2V		Peak
IPC-TM-650 Sec.2.5.33.2		1µA	RMS
IPC-A-610-E	0.5V / 0.3V		Peak

- Ultimately, it is the users who has to set EOS requirements for their devices
- Guideline: no component got damaged from reduced levels of EOS

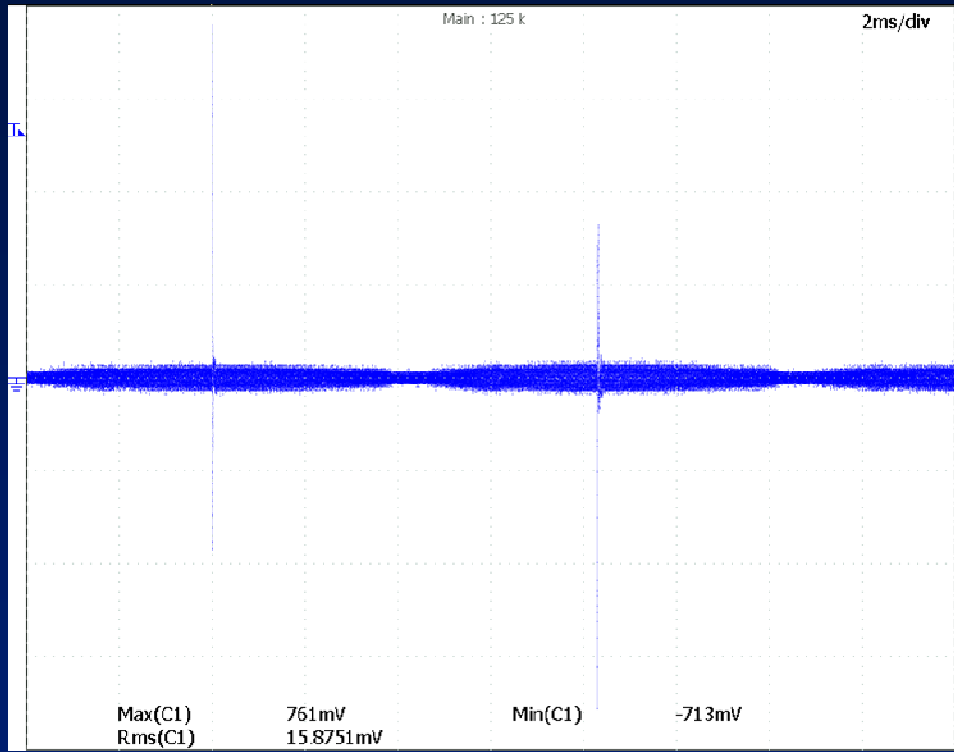
What to Measure?

- Typical specification for signal on soldering irons is in voltage
- Transient voltage measurements may be subject to radiated EMI distorting the data
- More accurate are current measurements
- It is current that damages the devices, not voltage



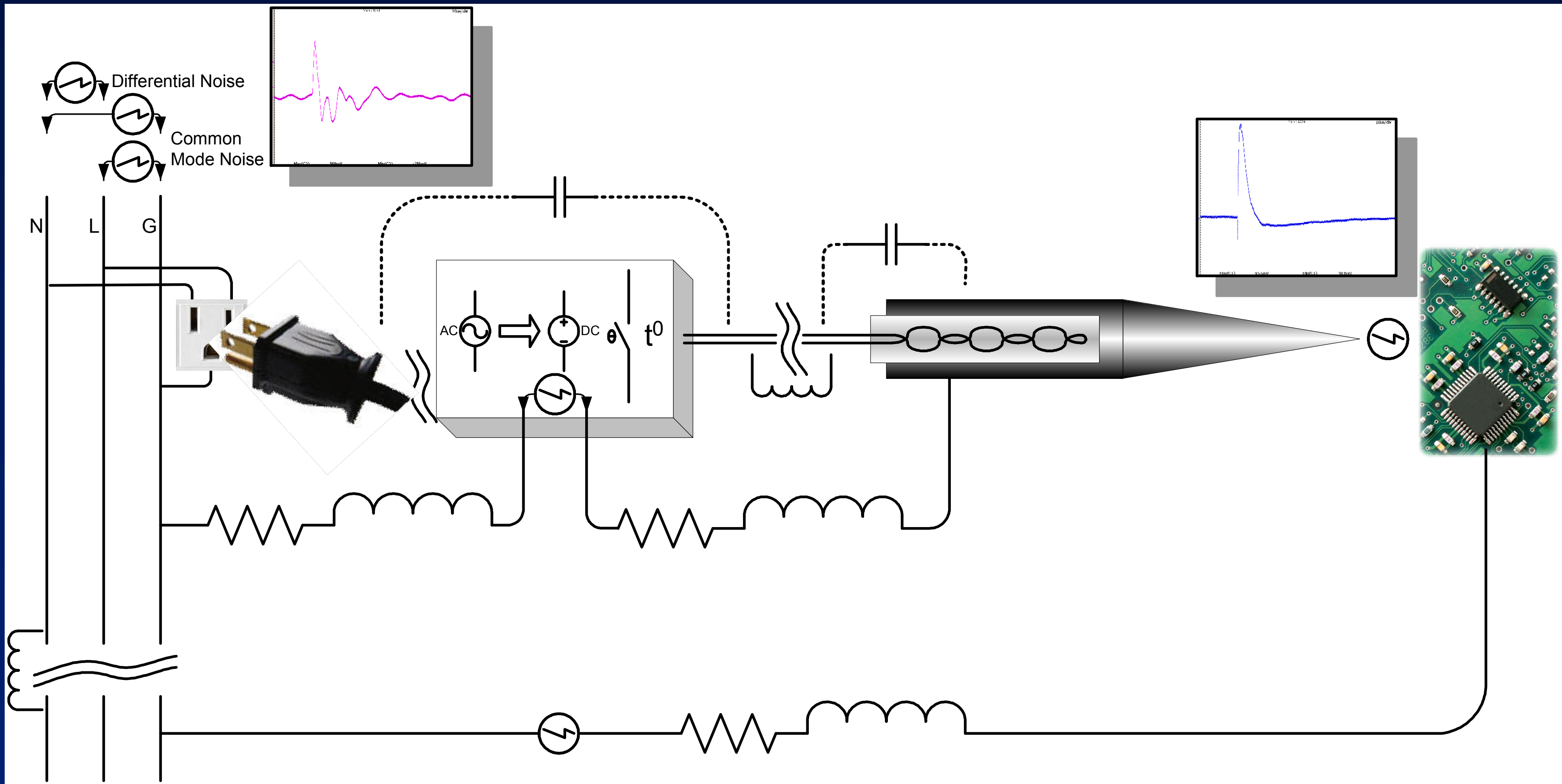
RMS or Peak?

- Most of EMI-caused EOS are transient in nature
- Measurement of such signals using RMS or average data is meaningless
- Figure to the right shows transient signals with peak values of over 700mV but RMS values of only 15.8mV
- Use only peak values obtained with appropriate instruments



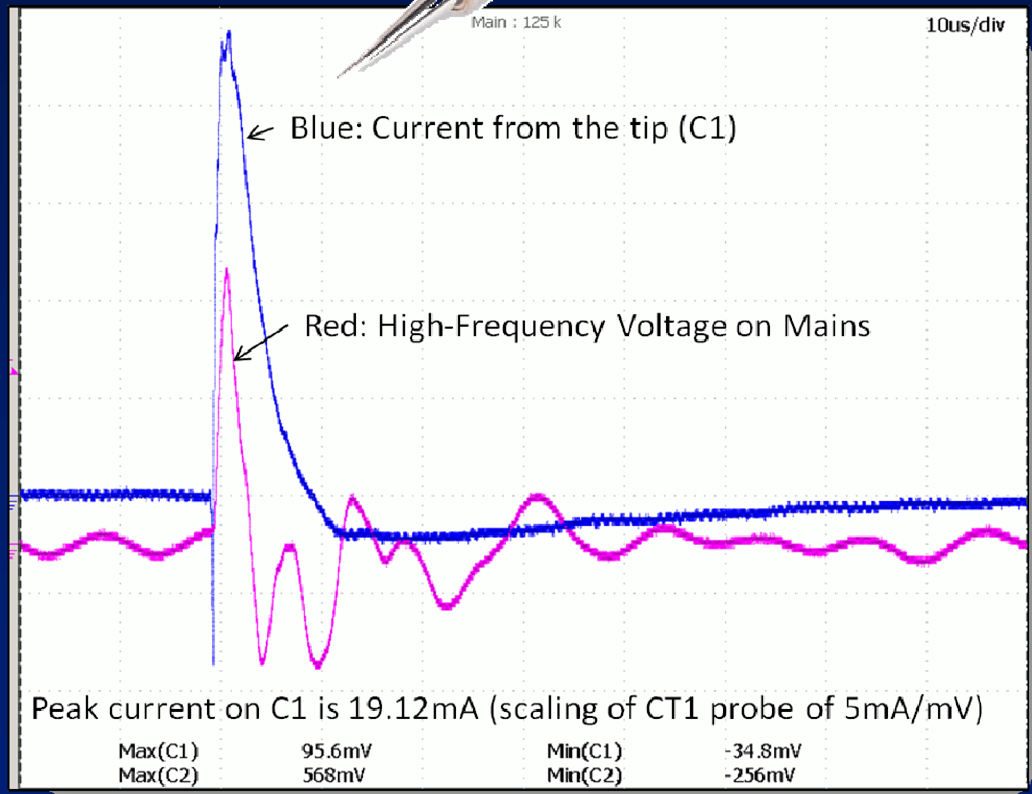
Max (C1)	761mV
Min (C1)	-713mV
RMS (C1)	15.8751mV

How the EMI Voltage Gets to the Tip of the Soldering Iron



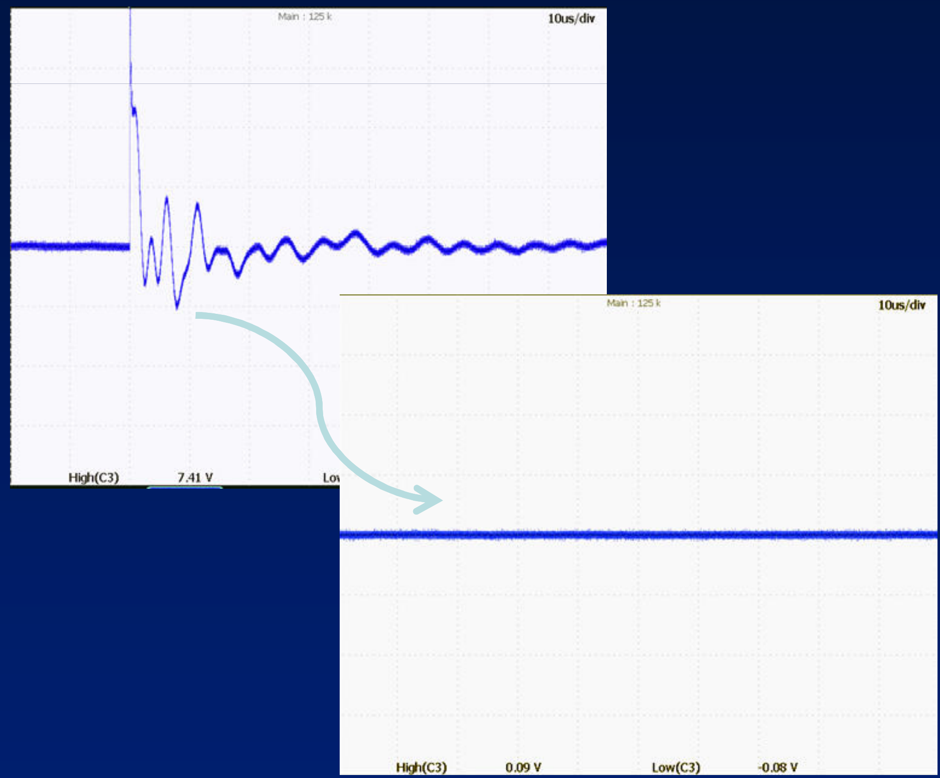
Current from the Tip of the Iron

- EMI-caused EOS here comes largely from noise on power lines and ground
- Even though both the tip of the iron and the board are grounded, from high frequency point of view they are different circuits
- The high-frequency voltage differential between the tip and the board creates EOS current



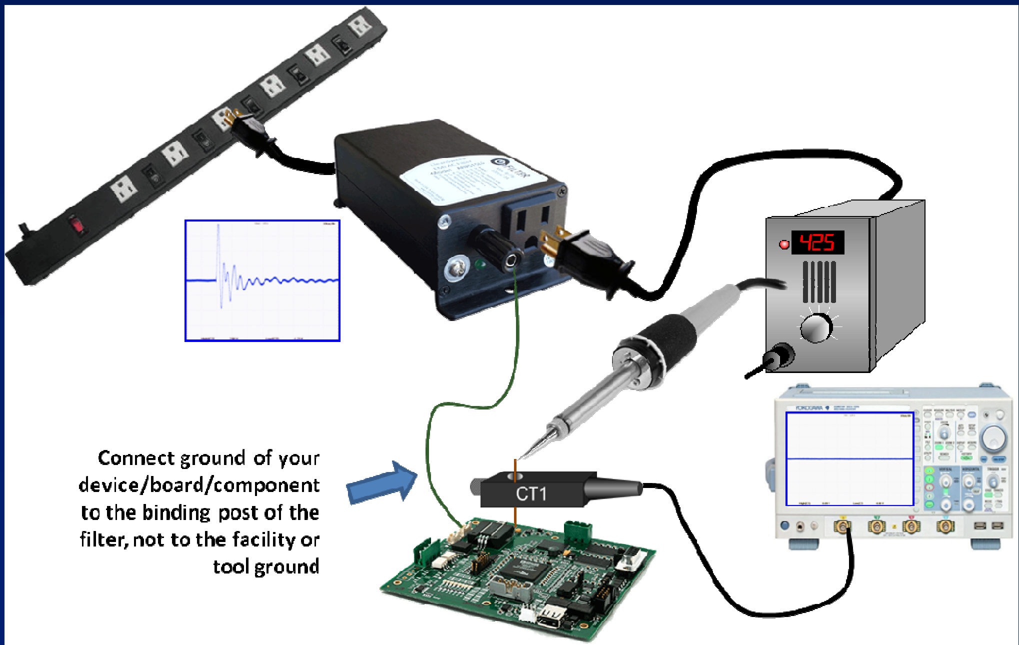
Mitigation of EOS in Soldering

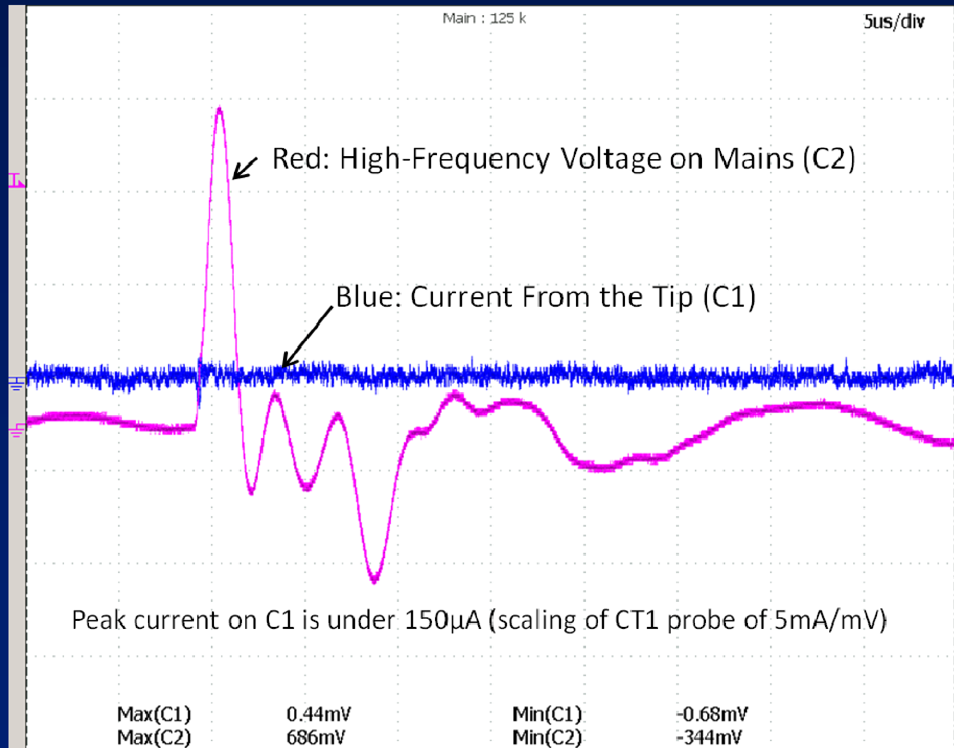
- The way to prevent EMI-caused EOS current from soldering iron is to put the circuit in the EMI-protective environment using special EMI filters
- Intel: “…install EOS line control equipment such as incoming line filtering …”
- Regular EMI filters do not provide noticeable advantage and may increase noise (Raytheon, 2005)



Mitigation of EOS in Soldering

Specially-designed EMI filters create EMI-protective environment for the soldering process





Conclusion

- "EOS is the number one cause of damage to IC components"
- Significant proportion of EOS is caused by EMI
- Mitigation of EMI-caused EOS is critical for consistent high yield
- Necessary elements for successful mitigation of EOS:
  - Understanding of origins and propagation of EMI on a facility level
  - Understanding of origins and propagation of EMI in tools
  - Proper implementation of EMI-suppression means