

EOS Exposure of Components in Soldering Process

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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 soldering and shows ways of its mitigation

What is EOS?

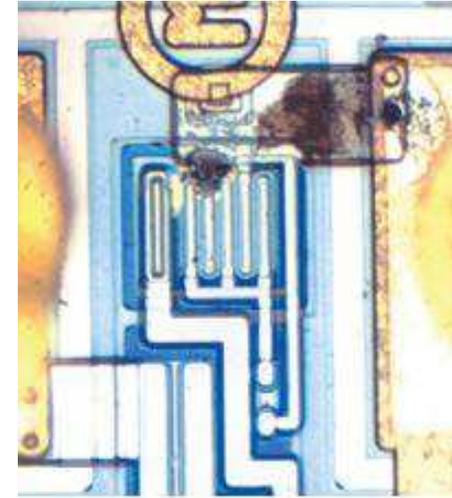
- EOS is a signal applied to the device in excess of the device' absolute maximum ratings
- ESD is a partial case of EOS
- EOS, as we define it, is any overstress that is not caused by static charge

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. 1 μ S 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

ESD vs. EOS

ESD Event	EOS Event
<p>Caused by a rapid discharge of accumulated electrical charge. Once this accumulated charge is consumed, ESD Event can no longer manifest itself.</p>	<p>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</p>
<p>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</p>	<p>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</p>
<p>Non-periodic and non-repeatable – accumulation of charges cannot be guaranteed</p>	<p>Mostly, but not always, periodic and repeatable</p>



EFFECTS OF EOS ON COMPONENTS

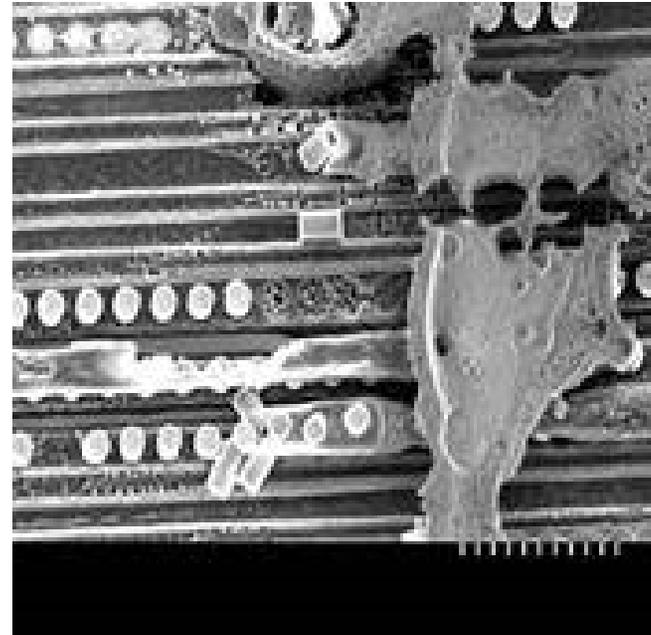
EOS and Component Damage

- 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

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

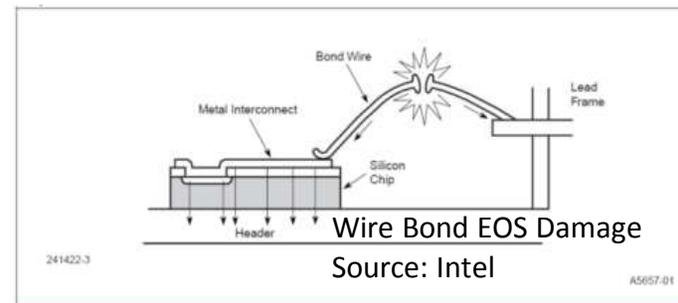
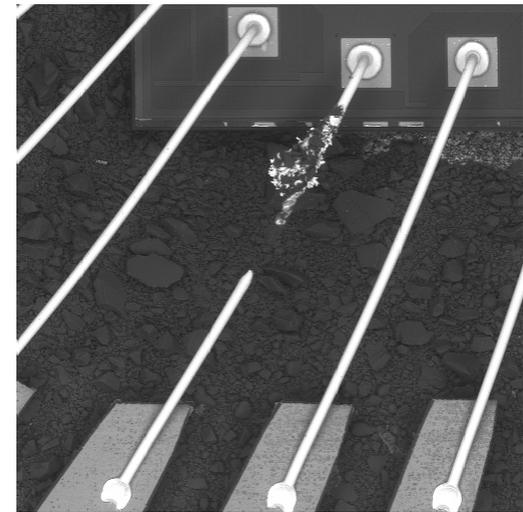


Source: Intel

EOS and Component Damage

- Massive energy delivered by EOS can melt wires inside the packaged device
- Most problematic 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

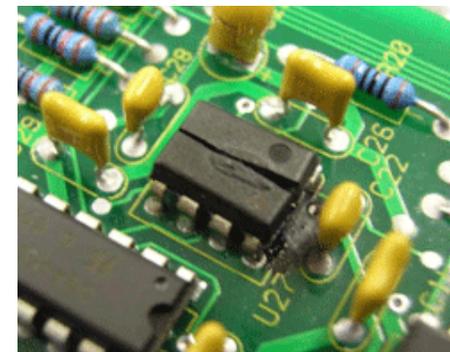
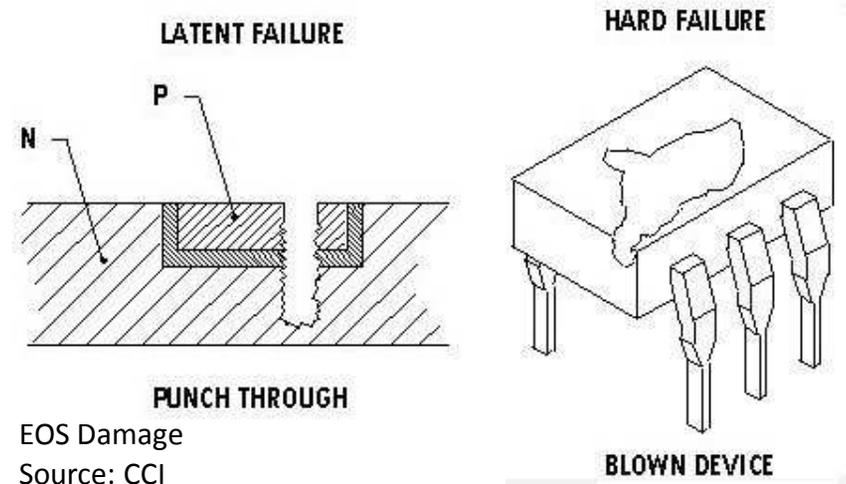


EOS Damage
Source: SEM Labs

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

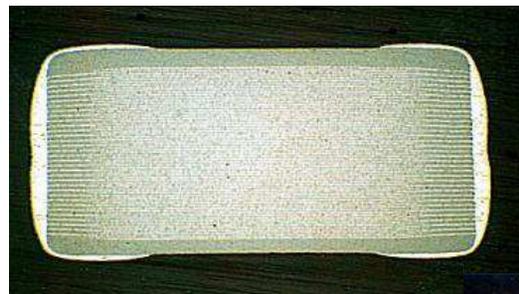
RESULTS OF OVERVOLTAGE STRESS



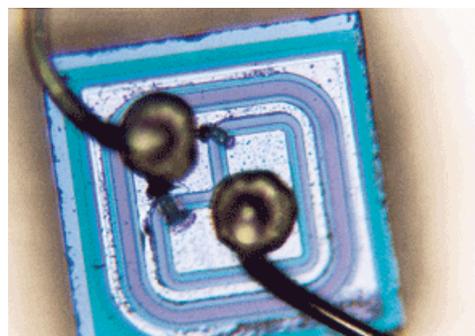
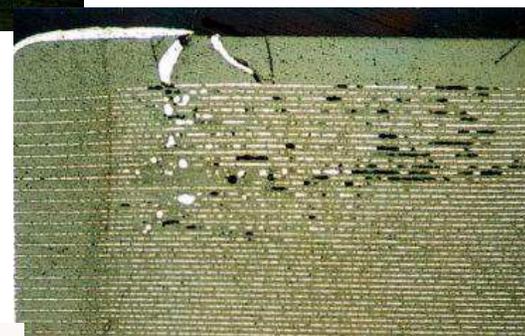
Source: EDN Magazine

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

How Much EOS is Too Much?



IPC-A-610D

3.1.1 EOS/ESD Prevention - Electrical Overstress (EOS)

Acceptability of Electronic Assemblies

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

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

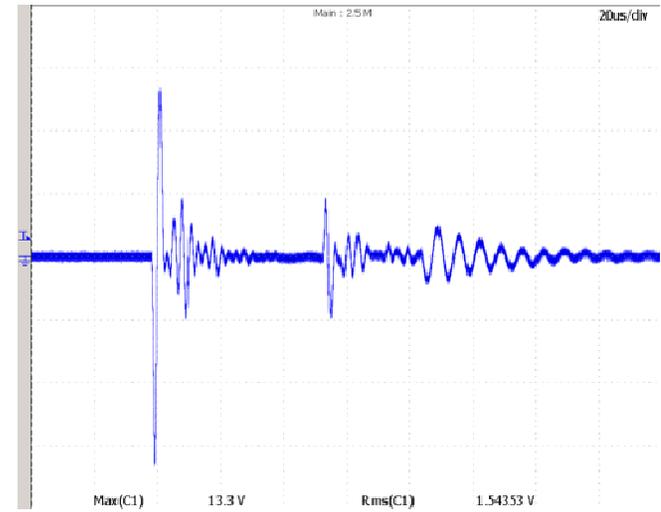


vs.



What Does This Mean?

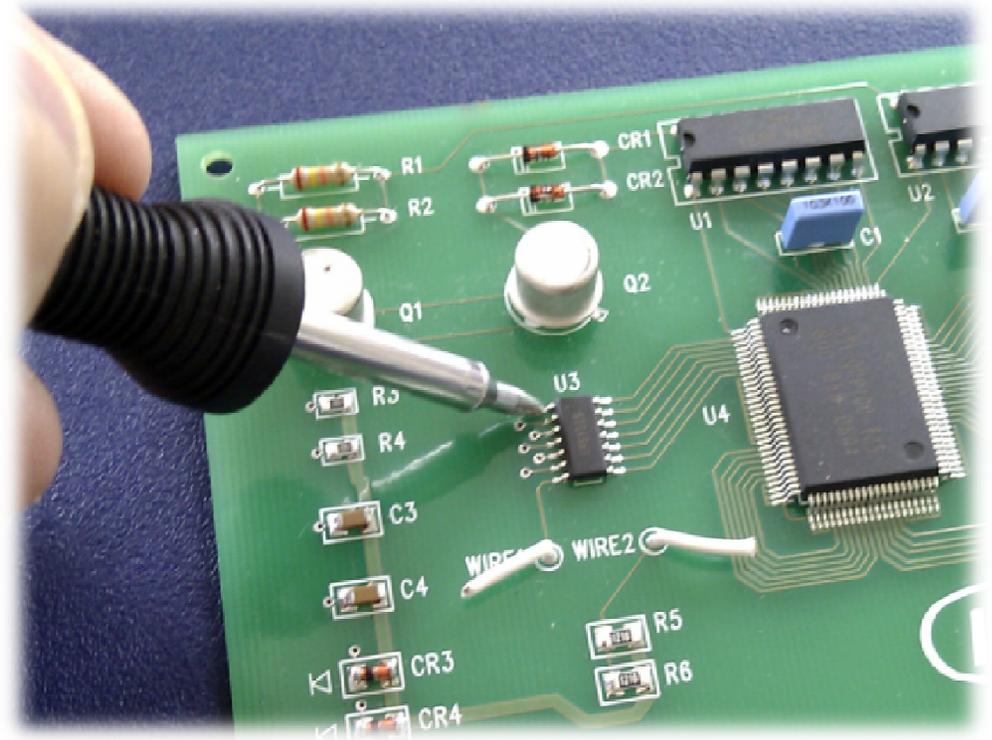
- Conventional methods of measuring voltages in production environment, while being perfectly good for ESD, are not sufficient for EOS
- EOS is measured with high-frequency tools, not regular static instrumentation
- ESD and EOS measurements are NOT interchangeable
- EOS control is not a subset of ESD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



EMI-CAUSED EOS

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?

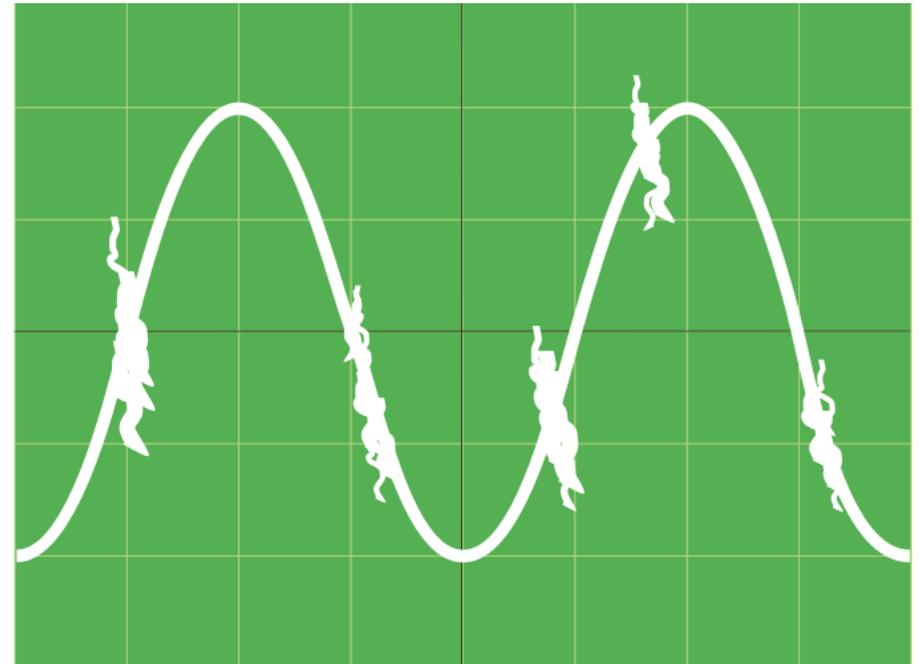
- Various industry standards and recommendations do not always agree as seen below

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	0.5V / 0.3V		Peak

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

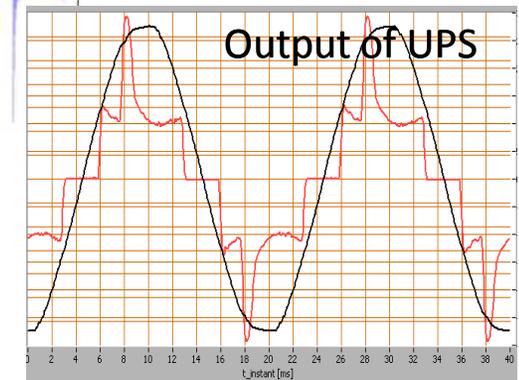
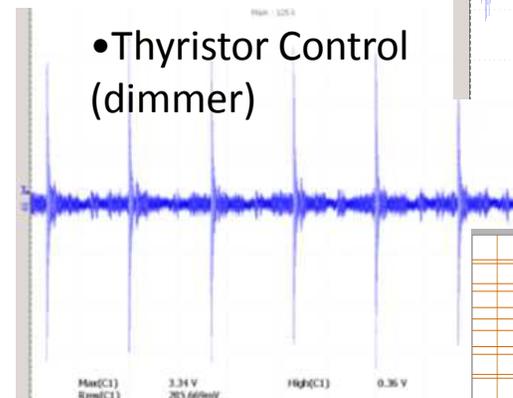
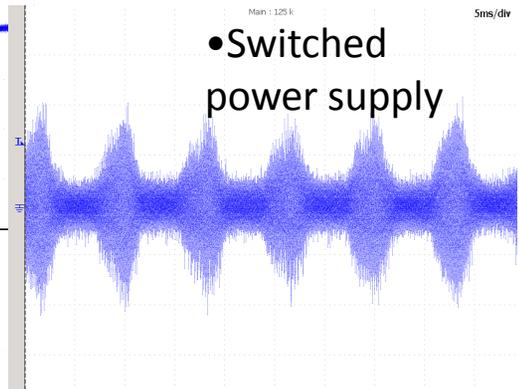
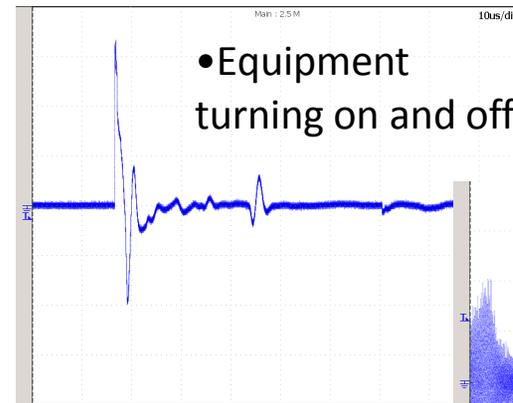
EMI-Caused EOS

- 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



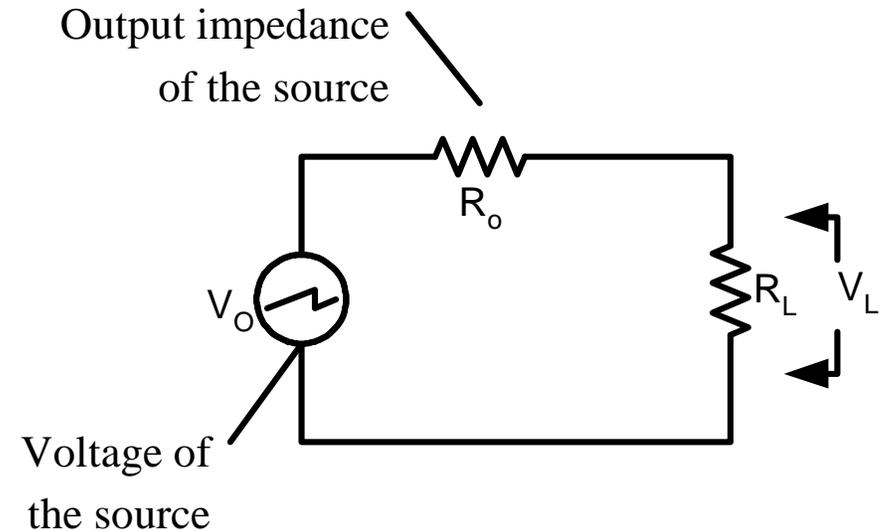
Noise From Power Lines

- 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



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

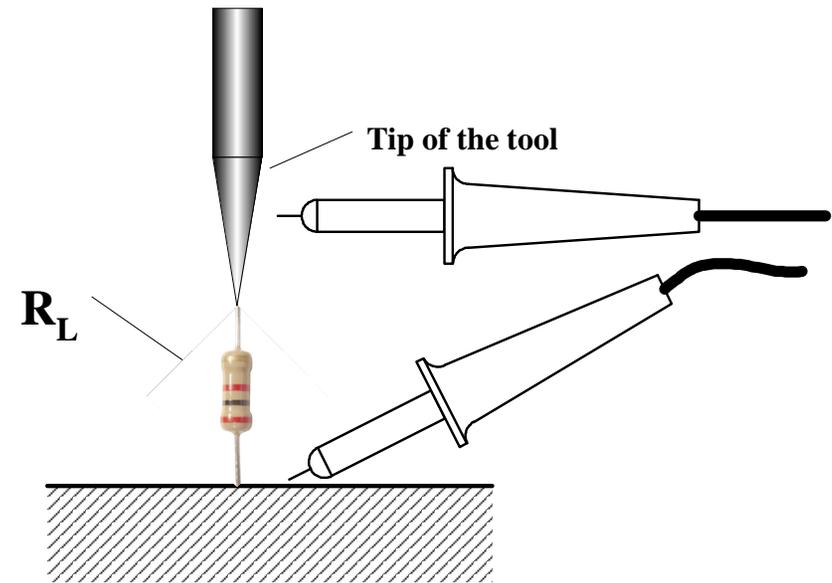
V_L – Resulting voltage on the load

R_o – Output impedance of the source

R_L – Impedance of the load

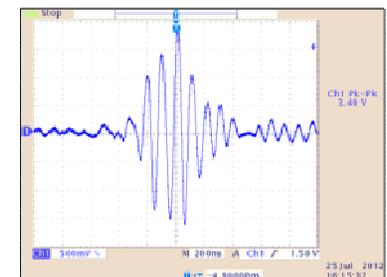
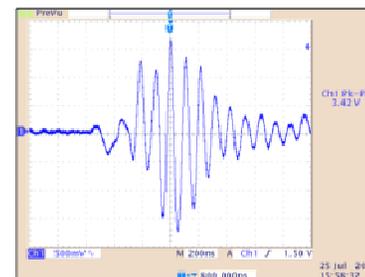
Calculating Output Impedance

- 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 supplying significant current



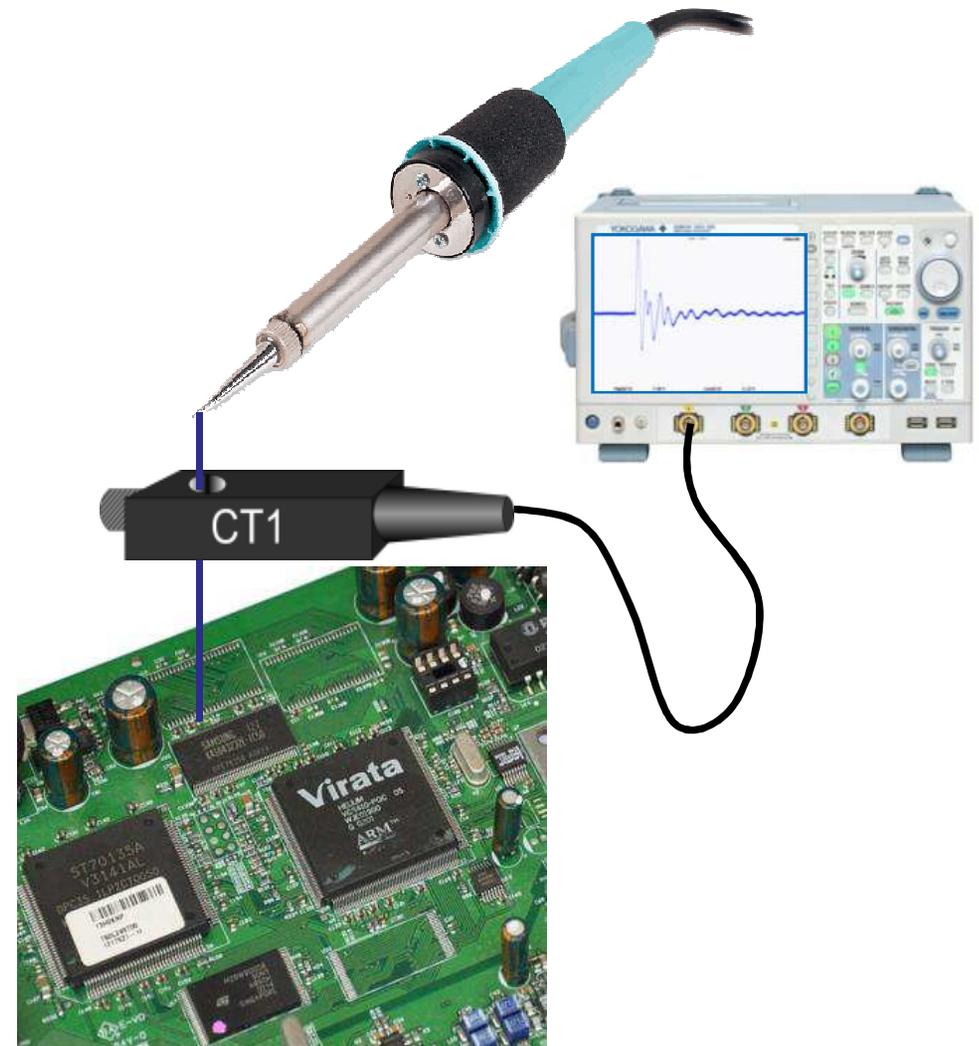
$$R_0 = R_{L1} \times R_{L2} \frac{V_{L2} - V_{L1}}{V_{L1} \times R_{L2} - V_{L2} \times R_{L1}}$$

$$R_0 = 50 \times 100 \frac{3.49 - 3.42}{3.42 \times 100 - 3.42 \times 50} = 2.09 \Omega$$



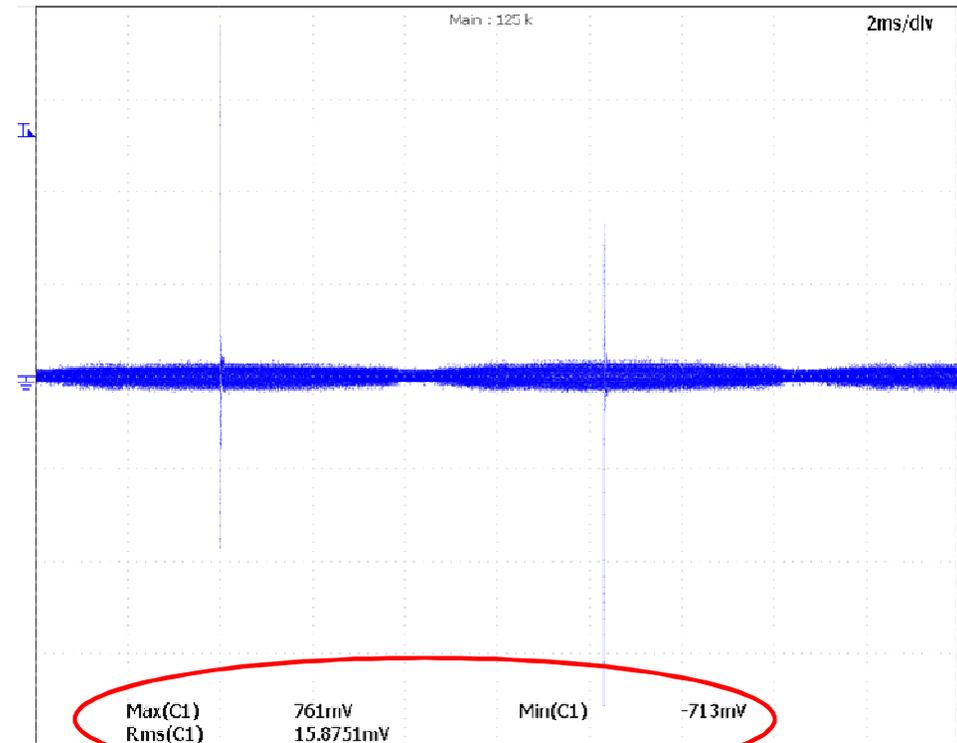
What to Measure?

- 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



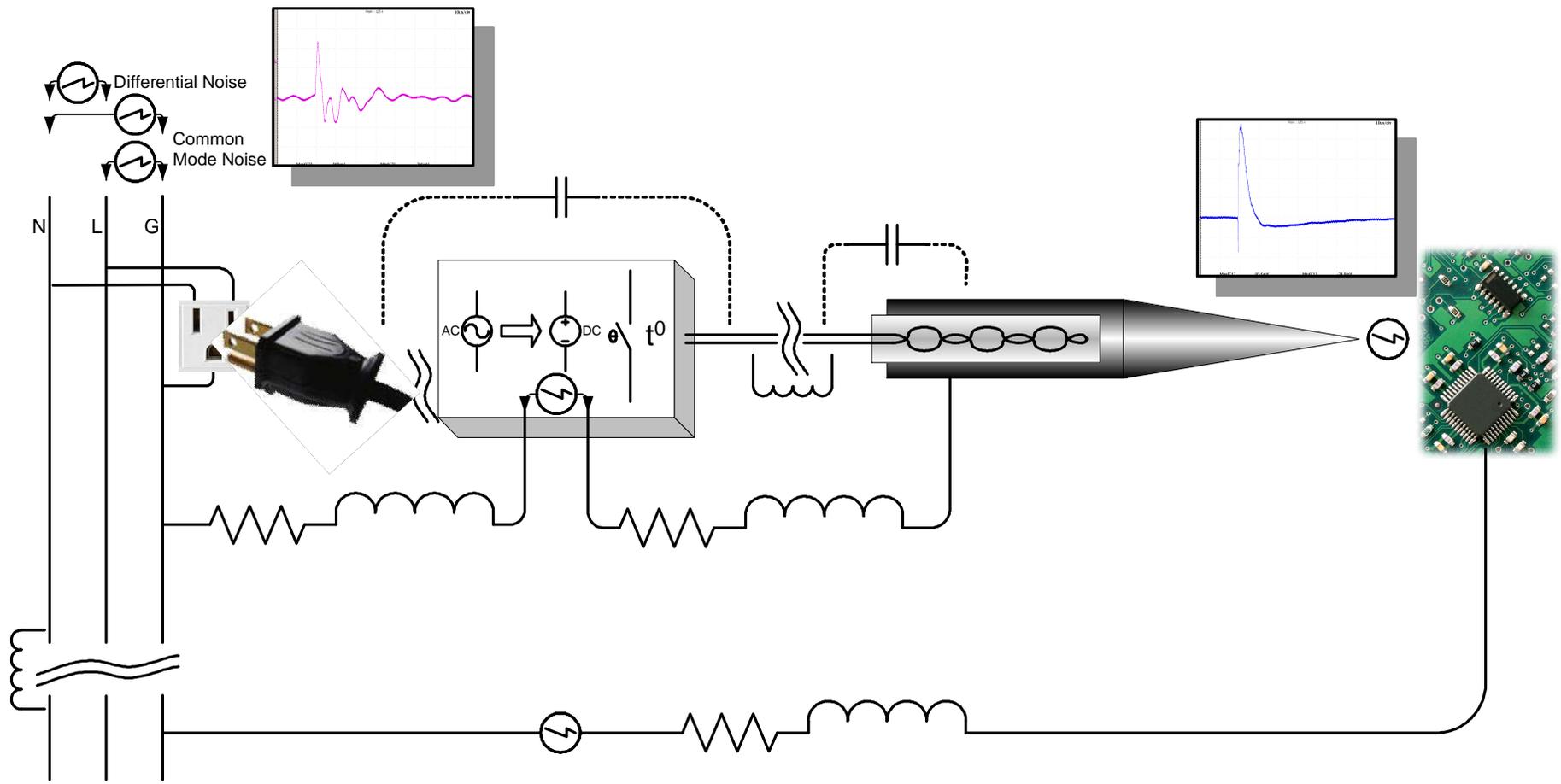
RMS or Peak?

- 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



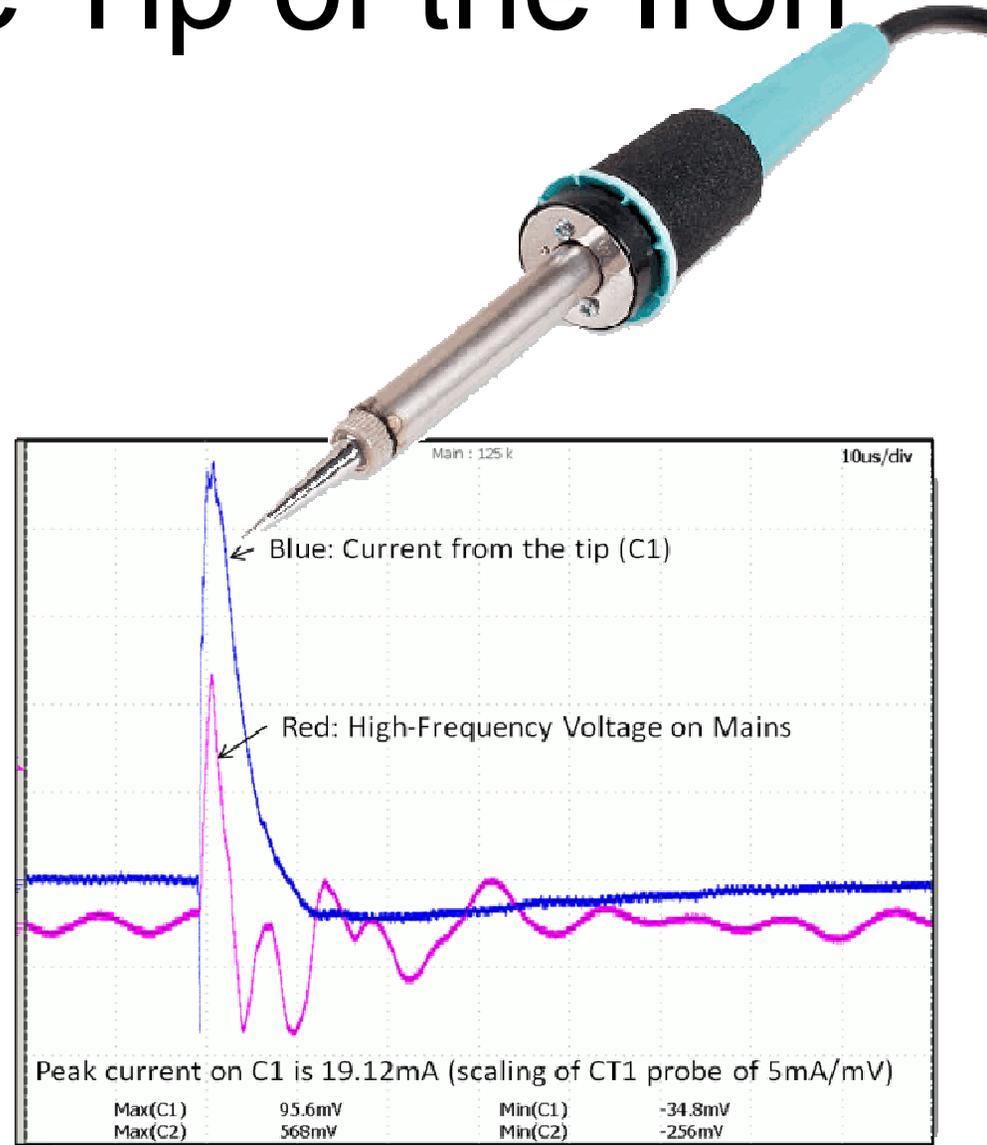
Max (C1)	761mV
Min (C1)	-713mV
RMS (C1)	15.8751mV

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



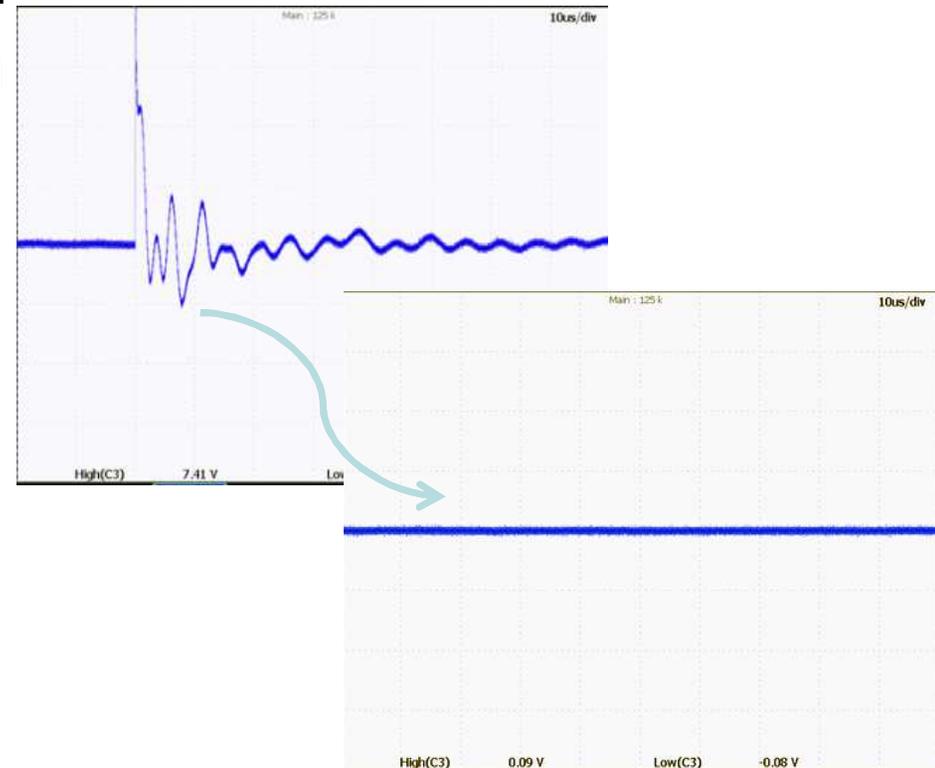
Current from the Tip of the Iron

- 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



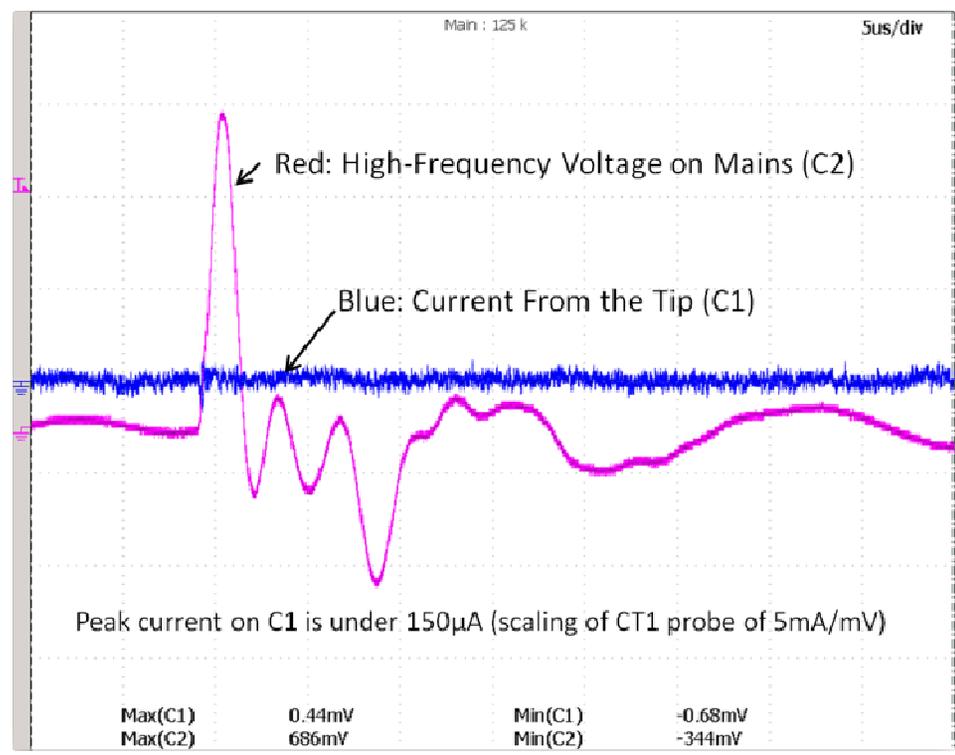
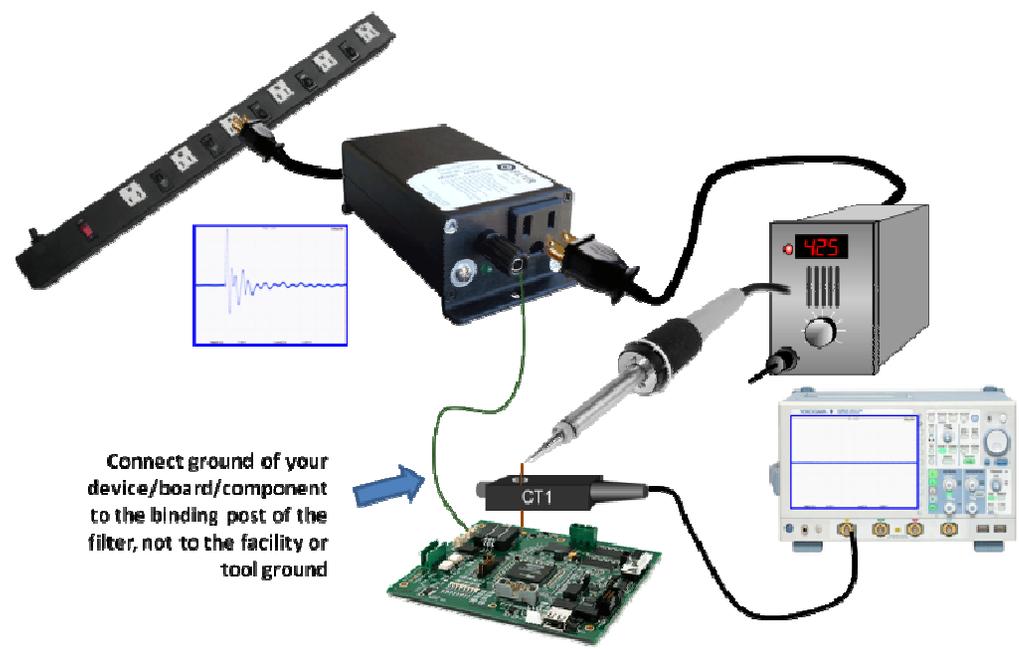
Mitigation of EOS in Soldering

- 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 add to the noise (Raytheon, 2005)



Mitigation of EOS in Soldering

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



Conclusion

- Electrical overstress is a serious problem for sensitive devices
- High-frequency noise on power lines and ground is the biggest source of EOS in soldering
- Proper measurements of high-frequency EOS current is critical in assessment of safety of soldering process
- Use of EMI-suppressing filters in soldering substantially lowers the risk of EOS



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