EMI-Caused EOS Exposure of Components and Its Mitigation

Vladimir Kraz\textsuperscript{1}, Patsawat Tachamaneeekorn\textsuperscript{2}, Dutharuthai Napombejara\textsuperscript{3}
\textsuperscript{1}OnFILTER, Inc., Soquel, CA \texttt{vkraz@onfilter.com}
\textsuperscript{2}Seagate Technology, Thailand, \texttt{patsawat.tachamaneeekorn@seagate.com}
\textsuperscript{3}Seagate Technology, Thailand, \texttt{dutharuthai.napombejara@seagate.com}
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.”
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

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

\[
R_O = 50 \times 100 \frac{3.49 - 3.42}{3.42 \times 100 - 3.42 \times 50} = 2.09\Omega
\]
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
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

Slide 10
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
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

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

- 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 a 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