ESD Protection Diode
ESD Introduction

ESD is the discharge of static electricity. Static electricity is an excess or deficiency of electrons on one surface with respect to another surface or to ground. A surface exhibiting an excess of electrons is negatively charged, and an electron deficient surface is positively charged. Static electricity is measured in terms of voltage (volts) and charge (coulombs).

Electrostatic Discharge (ESD) frequently occurs in nature, as well in Manufacturing environments and in-use finished electronic equipments.

The Discharge occurs at our fingertips when our body is electrically charged and is in close proximity of contact points attached to electronics devices.

The latest IC technology is becoming more sensitive to these events due to the extreme complexity of circuits, and the size of the semiconductor structures used so, circuit designers must provide an effective ESD Protection.
Implications of ESD on IC industry

Major reliability threat in IC industry:
- Cause of approximately 1/3 of IC failures
- ESD protection is very challenging against rapidly changing technologies

Standard model is used to characterize ESD:
- Human Body Model (HBM)
- Machine Model (MM)
- Charged Device Model (CDM)

ESD control is indispensable throughout devices’ life:
- Eliminating static charges from the workplaces
- Proper handling from manufacturing, shipping and field handling
- On-chip protection (clamp input voltage and bypass ESD current)
ESD Requirements (U.S.A.)

**Human Body Model**
+- 2 kV Required by most customers Waivers given at 1 KV in some cases
+- 4 kV Delco (Auto Manufacturer)
+- 8 kV On Special Automotive Pins (Power Outputs)

**Machine Model**
No Standard for reliable testing Waivers given to 100 V in some cases
Protection Schemes

The solutions for avoiding or reducing ESD failures
1) identifying and rectifying possible ESD sources
2) identifying and undertaking adequate prevention measures while handling the ESD sensitive devices
3) incorporating built-in ESD protection networks in devices
4) providing awareness and training to users at all levels.

Two ways to reduce IC failures under ESD conditions:

The first approach focuses on reducing the amount of ESD induced charges and redistributing them through proper handling of devices and controlling the handling environments.

The second approach is to implement on-chip protection circuits in order to improve the circuit robustness against ESD events by improving ESD performance of the individual circuit components.
Typical Generated ESD Voltages

<table>
<thead>
<tr>
<th>Means of Generation</th>
<th>10-25% RH</th>
<th>65-90% RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking across carpet</td>
<td>35,000V</td>
<td>1,500V</td>
</tr>
<tr>
<td>Walking across vinyl tile</td>
<td>12,000V</td>
<td>250V</td>
</tr>
<tr>
<td>Worker at bench</td>
<td>6,000V</td>
<td>100V</td>
</tr>
<tr>
<td>Poly bag picked up from bench</td>
<td>20,000V</td>
<td>1,200V</td>
</tr>
<tr>
<td>Chair with urethane foam</td>
<td>18,000V</td>
<td>1,500V</td>
</tr>
</tbody>
</table>
International ESD Models

The ESD events are modeled under several industry standards, where the Most representatives and accepted are:

• IEC 61000-4-2 (Recognized internationally)
• MIL STD 883
• JEDEC A114 and A115

<table>
<thead>
<tr>
<th>Standard</th>
<th>Model</th>
<th>C, pF</th>
<th>R, Ohms</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC61000-4-2</td>
<td>HBM</td>
<td>150</td>
<td>330</td>
</tr>
<tr>
<td>MIL STD 883</td>
<td>HBM</td>
<td>100</td>
<td>1500</td>
</tr>
<tr>
<td>JEDEC A115</td>
<td>MM</td>
<td>200</td>
<td>0</td>
</tr>
</tbody>
</table>
Human Body Model (HBM)
Machine Model (MM)

Typical MM Current Waveform
Electrostatic Discharge (ESD)
IEC 61000-4-2

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>Test Voltage Air Discharge (kV)</th>
<th>Test Voltage Contact Discharge (kV)</th>
<th>First Peak Current (A)</th>
<th>Peak Current at 30ns (A)</th>
<th>Peak Current at 60ns (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
<td>7.5</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>4</td>
<td>15</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>6</td>
<td>22.5</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>8</td>
<td>30</td>
<td>16</td>
<td>8</td>
</tr>
</tbody>
</table>

τr = 0.7 to 1 ns
Electrical Fast Transient (EFT)  
IEC 61000-4-4

<table>
<thead>
<tr>
<th>Level</th>
<th>$V_{GC}$ (kV)</th>
<th>$I_{SC}$ (A)</th>
<th>$V_{GC}$ (kV)</th>
<th>$I_{SC}$ (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>10</td>
<td>0.25</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>20</td>
<td>0.5</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>40</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>80</td>
<td>2</td>
<td>40</td>
</tr>
</tbody>
</table>

EFT Burst
Surge immunity (Lighting)
IEC 61000-4-5

Voltage Impulse

Current Impulse

T1 x 1.67 = 1.2 μs

T1 x 1.25 = 8.0 μs
Transient Suppression

- Constant advances in semiconductor process technologies make the design of protection very challenging.
- Protection circuit must *divert transient current and clamp transient voltage* below the failure threshold of the protected.
ESD Testing Setup

Contact Discharge Tip

Air Discharge Tip
# ESD Protection Diode Application Field

<table>
<thead>
<tr>
<th>Digital Photography</th>
<th>Gadgets</th>
<th>Game Controllers</th>
<th>Graphics &amp; Sound</th>
<th>Input Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Digital Photo Frames</td>
<td>- FDA</td>
<td>- Gaming Pads</td>
<td>- Audio headsets</td>
<td>- Mice</td>
</tr>
<tr>
<td>- Digital Cameras</td>
<td>- GPS</td>
<td>- Joysticks</td>
<td>- Microphones</td>
<td>- Wireless Keyboard</td>
</tr>
<tr>
<td>- Portable Webcams</td>
<td>- Wii</td>
<td>- Steering Wheels</td>
<td>- Speakers</td>
<td>- Remote Control</td>
</tr>
<tr>
<td>- Webcams</td>
<td>- NES</td>
<td>- P2/S2/PS / XBOX</td>
<td>- TV Tuners</td>
<td>- Digitizing Tablets</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modems &amp; Telephony</th>
<th>Networking</th>
<th>Portable Audio Video</th>
<th>Storage</th>
<th>Printers &amp; Scanners</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Cable Modems</td>
<td>- Direct Connect</td>
<td>- MP3 Players</td>
<td>- DVD Drives</td>
<td></td>
</tr>
<tr>
<td>- Internet Telephony</td>
<td>- USB Ethernet</td>
<td>- iPods</td>
<td>- Ext Floppy Dr</td>
<td>- LaserJet</td>
</tr>
<tr>
<td>- ISDN Modems</td>
<td>- USB Phone Line Network</td>
<td>- iPods</td>
<td>- Flash Readers</td>
<td>- Photo Printers</td>
</tr>
<tr>
<td>- DSL Modems</td>
<td>- USB Wireless Network</td>
<td>- iPods</td>
<td>- Removable Disks Dr</td>
<td>- Card Readers</td>
</tr>
</tbody>
</table>

![Diagrams and illustrations of various devices including USB modems, Bluetooth adapters, and different types of printers and scanners.](image)
ESD Protection Diode for Ethernet

- AFE0504
  - SOT-363
- AFE0514
  - SOT-563

Gigabit Ethernet Protection

IEEE 1394 Firewire Protection

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ESD Protection Diode for Ethernet

AFE0505
SOT-23-6L

AFE0524
SOT-143
ESD Protection for Cell Phone / Smart Phone

AFE0514
SOT-563

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ESD Protection Diode for Cell Phone / Smart Phone

AFE0521 SOD-523

AFE0572 SOD-723
ESD Protection Diode for Cell Phone / Smart Phone

AFE0562 SOD-323

AFE6V8UW SOT-363
ESD Protection Diode for LCD TV/DVD/Set-Top Box

AFE6V8UD
DFN-10

AFE6V8UH
MSOP-10L
ESD Protection Diode for Notebook / iPad

- AFE6V8UD DFN-10 (HDMI)
- AFE0504 SOT-363 (USB 2.0)
- AFE6V8UF SOT-23-6L (USB 3.0)
- AFE6V8UW SOT-363 (USB 3.0)
- AFE0514 SOT-563 (IEEE1394)
- AFE0505 SOT-23-6L (IEEE1284)