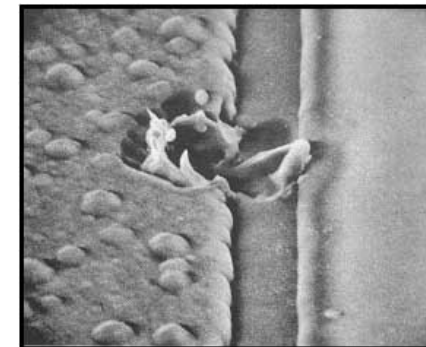
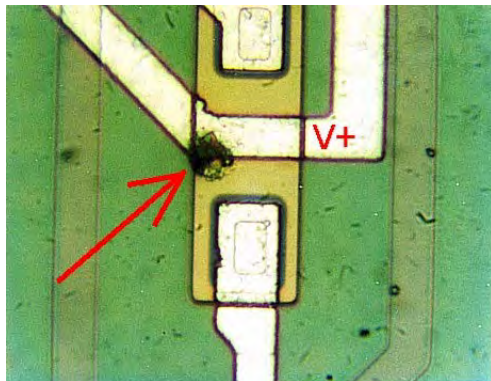


ESD Protection

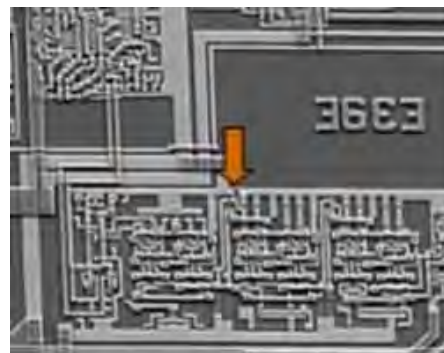
Kenneth Toomey
Field Application Engineer
AEM Electronics (USA), Inc.
ktoomey@aemcomponents.com

Effect ESD has on IC's?

- **Electrostatic Discharge is the transfer of static charge between two objects of different potential that come in to contact**
- **Can generate between 1,500V to 35,000V**
- **Leading cause of device failure**



Surface damage at 4300X



New ESD Challenges

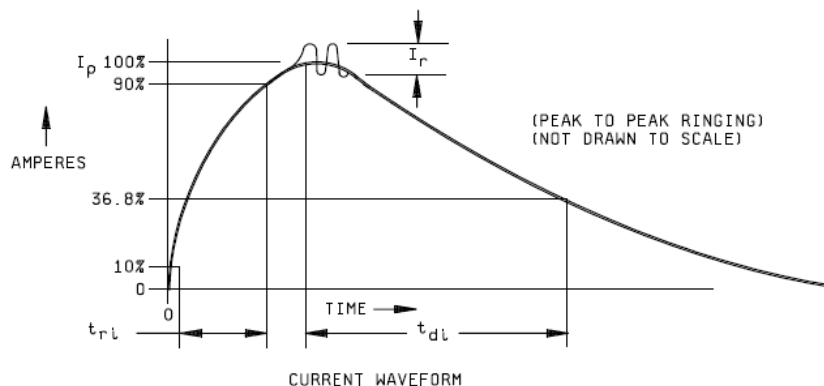
- **IC nanometer technology is more vulnerable to ESD**
- **High speed interfaces and data ports**
 - USB 3.0 - 5Gbit/sec
 - HDMI 1.3 - 3.4Gbit/sec
 - IEEE 1394 - 400/800/3200Mbit/sec



ESD Standards

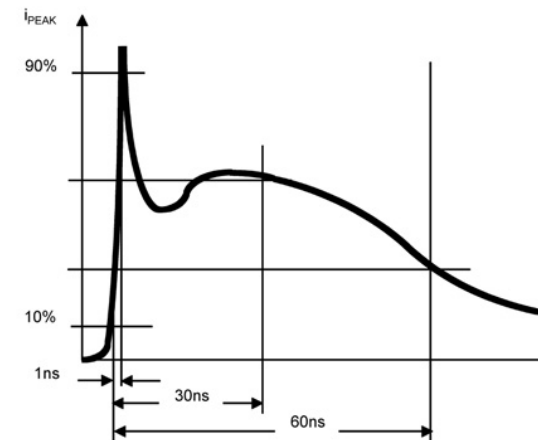
MIL-STD-883, Method 3015

- Required for “on-chip” ESD protection during chip manufacturing
- Also known as the “Human Body Model” (HBM)
- Discharges a 100pF capacitor into a 1500Ω resistor
- HBM Level 4: Peak Current 2.67A at 4kV
- Rise time: 10ns



IEC61000-4-2

- Required by equipment manufacturers for system or application level testing
- Discharge a 150pF into a 330Ω resistor
- IEC Level 4: Peak Current 30A at 8kV
- Rise Time: 1ns

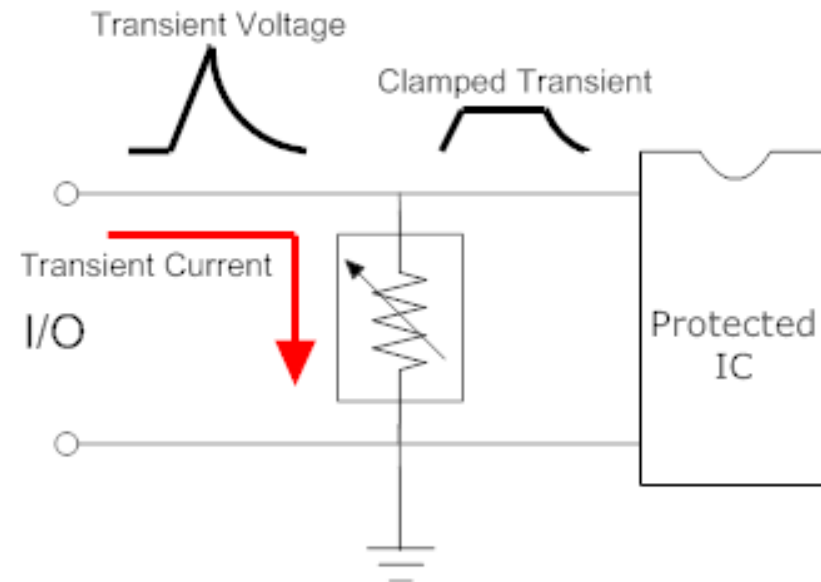


ESD Standards Comparison

Level	HBM		IEC	
	Contact Discharge (kV)	Peak Current (A)	Contact Discharge (kV)	Peak Current (A)
1	0.5	0.33	2	7.5
2	1	0.67	4	15
3	2	1.33	6	22.5
4	4	2.67	8	30

ESD Protection

- Non-linear voltage-current characteristic
 - Low voltage high resistance
 - High voltage low resistance
- Provides low impedance shunt path to ground



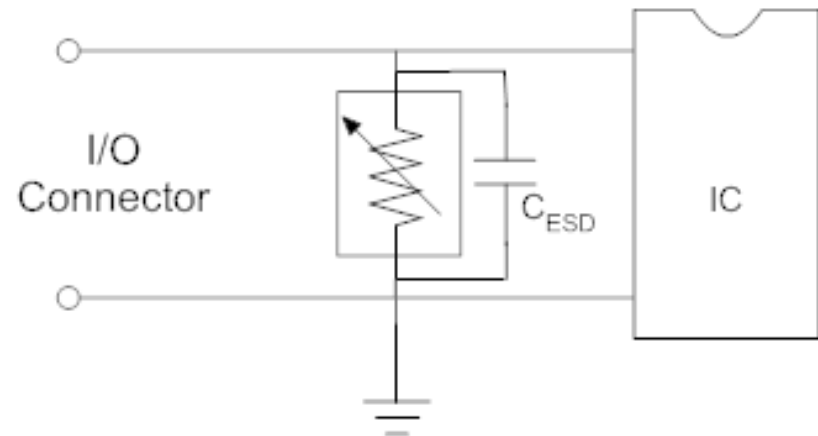
Design Considerations

- Capacitance and signal integrity
- Max ESD withstanding capability of protected device
- Min ESD shot withstanding cycle of ESD device
- Package size and PCB layout
- Clamping Voltage
- Breakdown/Trigger voltage



Capacitance and Signal Integrity

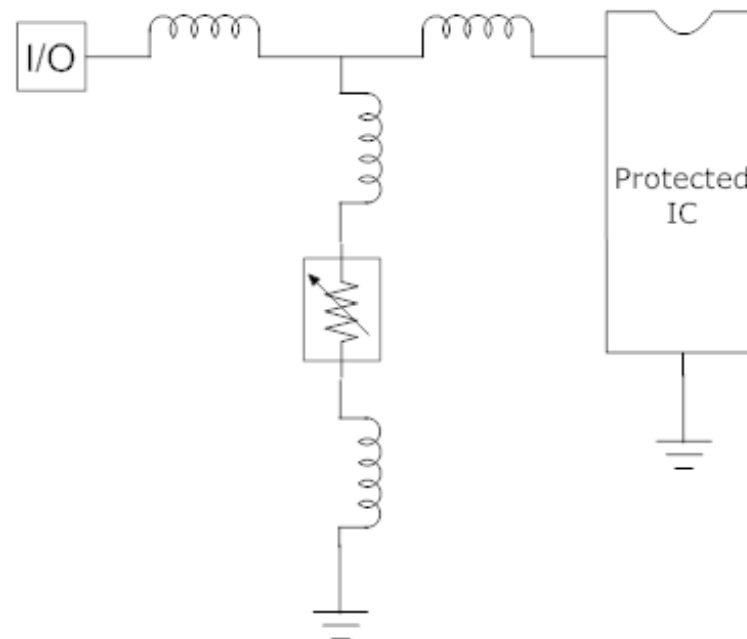
- All ESD device have some level intrinsic capacitance
- Parallel capacitance attenuates high frequency signals
- High capacitance causes signal degradation as signal frequencies increase



Board Layout

- Place ESD device as close as possible to I/O port or source of ESD entry
- Reduce trace length to minimize parasitic inductance
- Parasitic inductance can cause a large voltage spike and increase clamping voltage through the relationship:

$$V = L \frac{di}{dt}$$

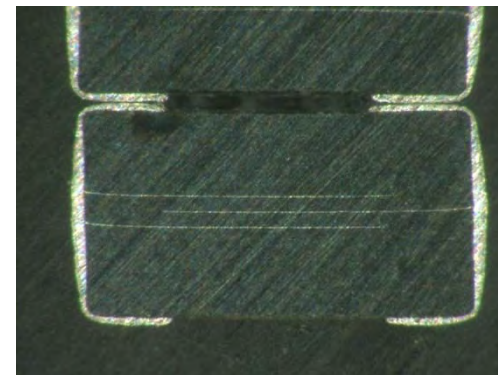


ex. A trace that measures just 2nH will produce a 60V spike for an 8kV ESD strike.

$$L \frac{di}{dt} = 2\text{nH} \left(\frac{30}{1\text{ns}} \right) = 60\text{V}$$

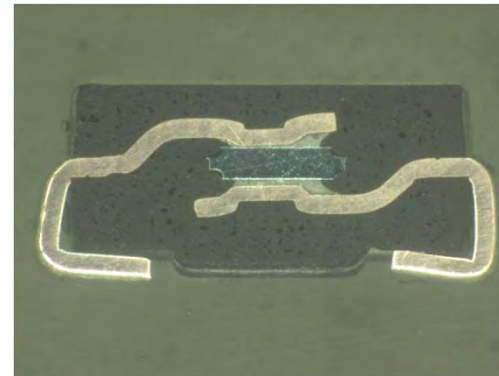
Types of ESD Devices

- Polymer Based
 - Pros:
 - Ultra low cap - 0.05pF to 0.5pF
 - Low cost
 - Cons:
 - High trigger and clamping voltage
 - Low ESD strike withstanding capability
- Low Cap MLV
 - Pros:
 - Low cap – 0.1 to 1pF through sorting
 - Low cost
 - Cons:
 - High clamping voltage
 - High leakage current
 - Low ESD strike withstanding capability



Types of ESD Devices

- TVS Diode
 - Pros:
 - High ESD strike withstanding capability
 - Cons:
 - High cost

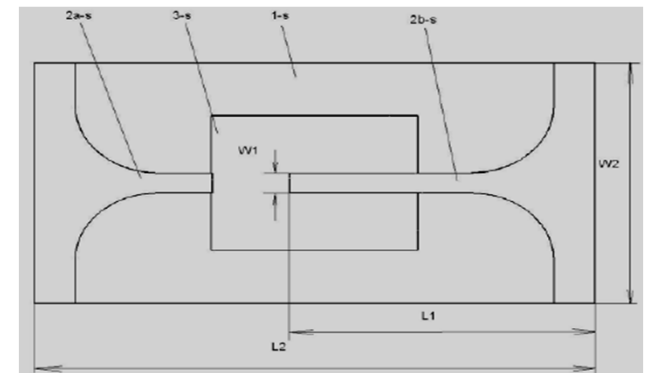
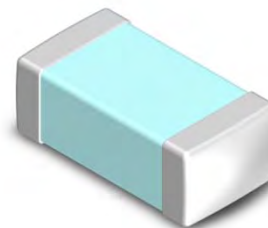
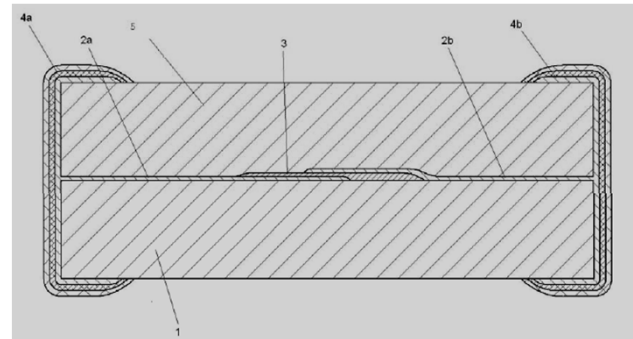


AEM GcDiode™

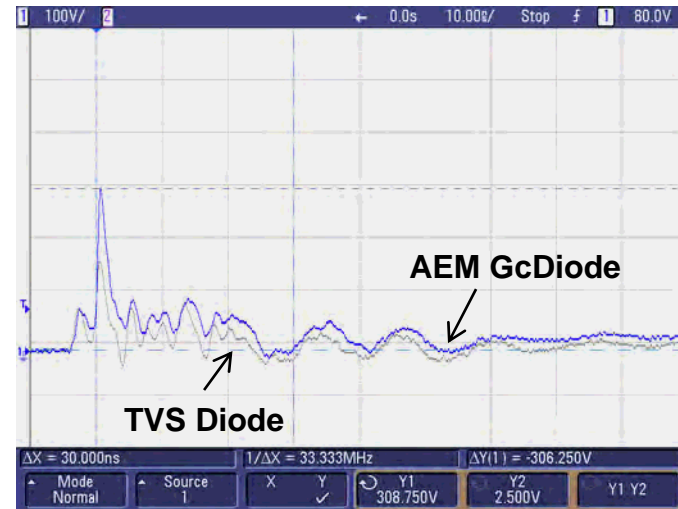
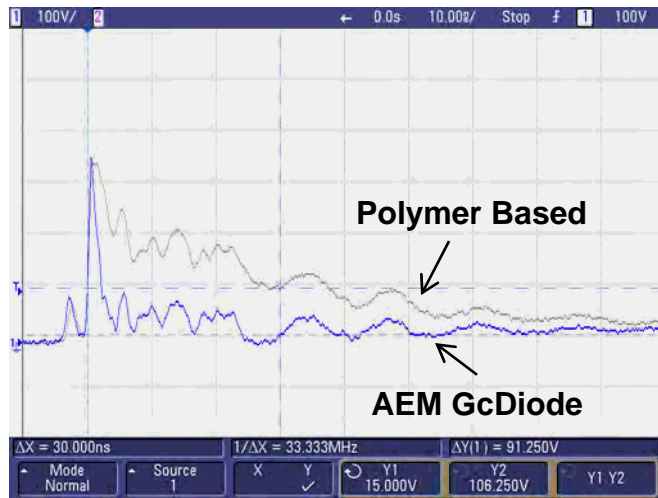
The GcDiode is based on a glass-ceramic dual phase material system with proprietary ESD functional material that provides non-linear resistance at different voltage conditions

Key Features

- Low clamping voltage (30V)
- Low capacitance (0.25pF)
- Low leakage current (0.1nA)
- Fast response time (1ns)
- High ESD shot withstanding capability
- Bi-Directional



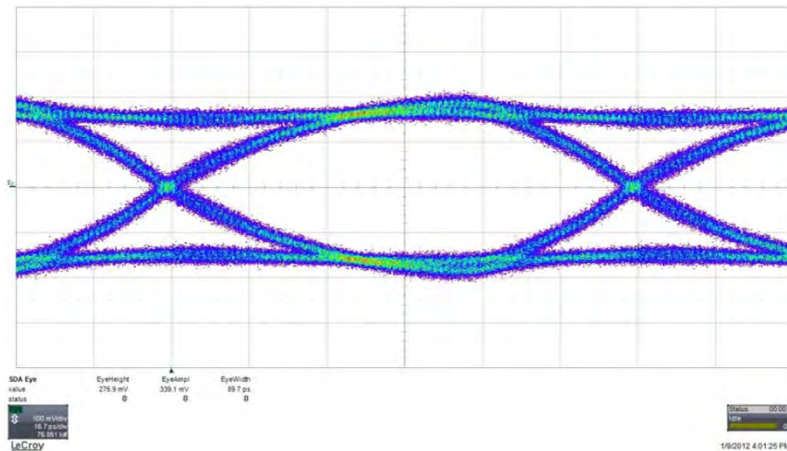
Comparison ESD Suppression



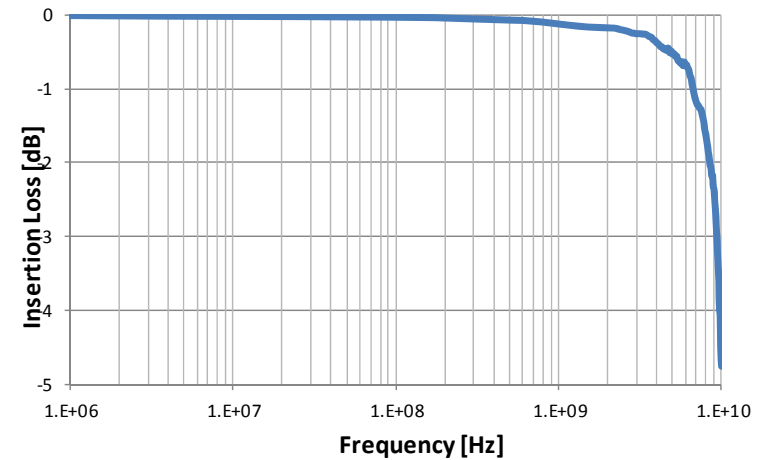
- Typical IEC61000-4-2 level 4 contact discharge (8kV) suppressed waveform.
- GcDiode has similar performance as the TVS Diode

GcDiode™ Signal Integrity 10Gbit/sec

Eye Diagram

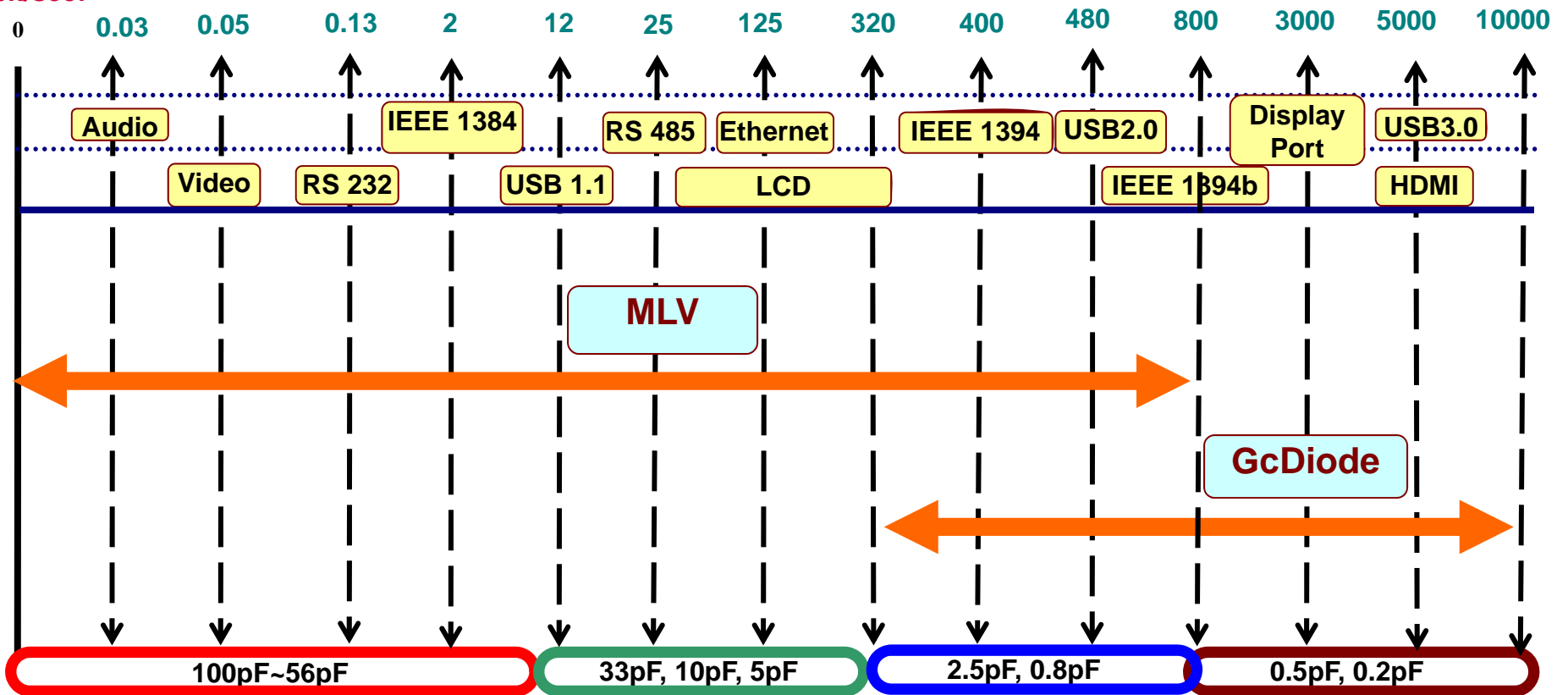


Insertion Loss (S21)



ESD Selection

DATA Rate
(M bit/sec)



Conclusion

- **The main purpose of “On-Chip” ESD protection is to protect the IC against an ESD event during the manufacturing environment of the IC**
- **Supplementary ESD protection is required for system level/application ESD events**
- **Low capacitance to maintain signal integrity for high speed data ports**
- **Minimize parasitic inductance to maximize performance of ESD device**
- **GcDiode™ is similar in performance to the TVS Diode**