# Discussion for the Interface between PMT base and HV, electronics

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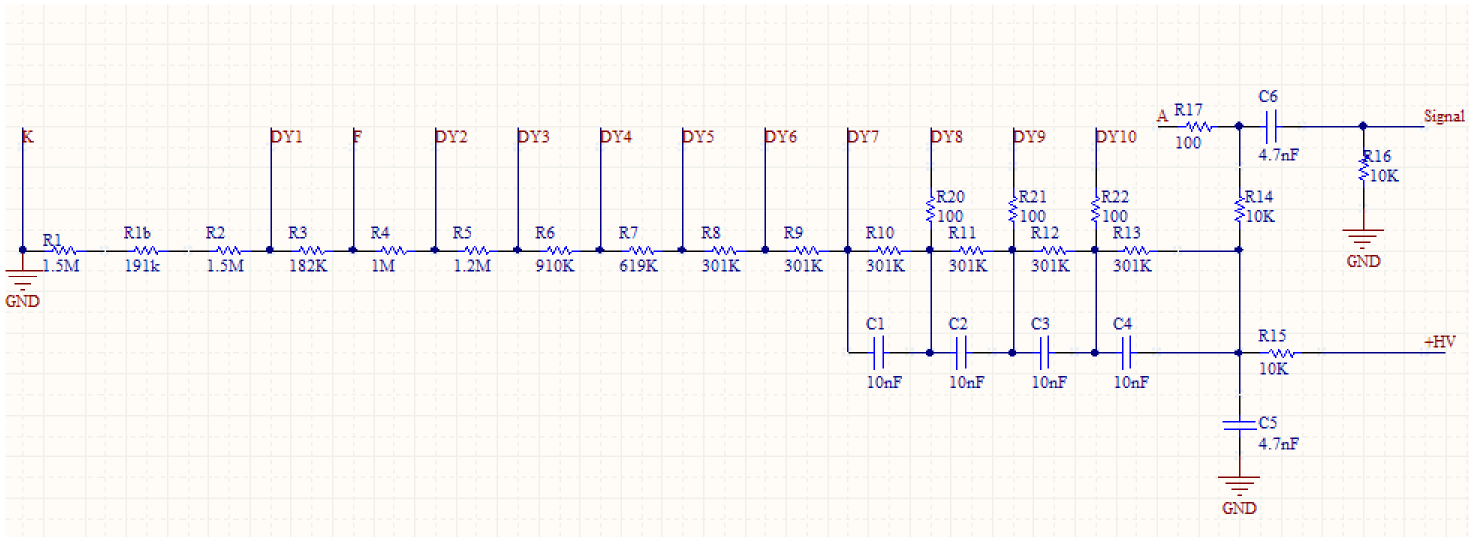
Gain: output gain on load resistor

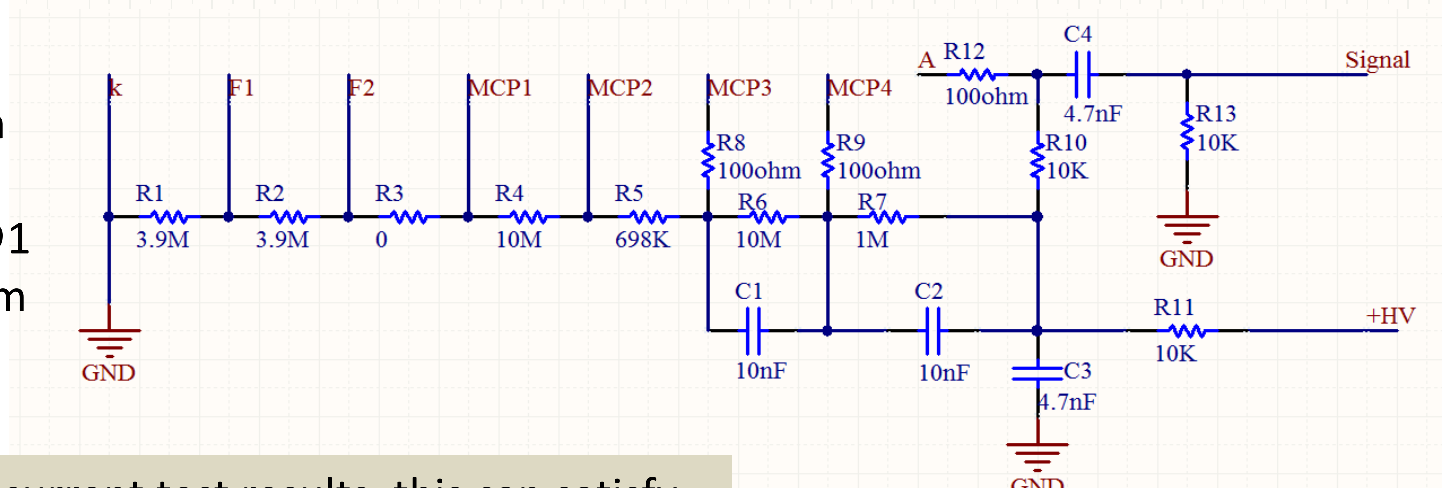
# HV base current

HV unit: 300uA@3000V

Hamamatsu 20" Version 1.2
~2000V, ~200uA@1e7 gain, ~10Mohm

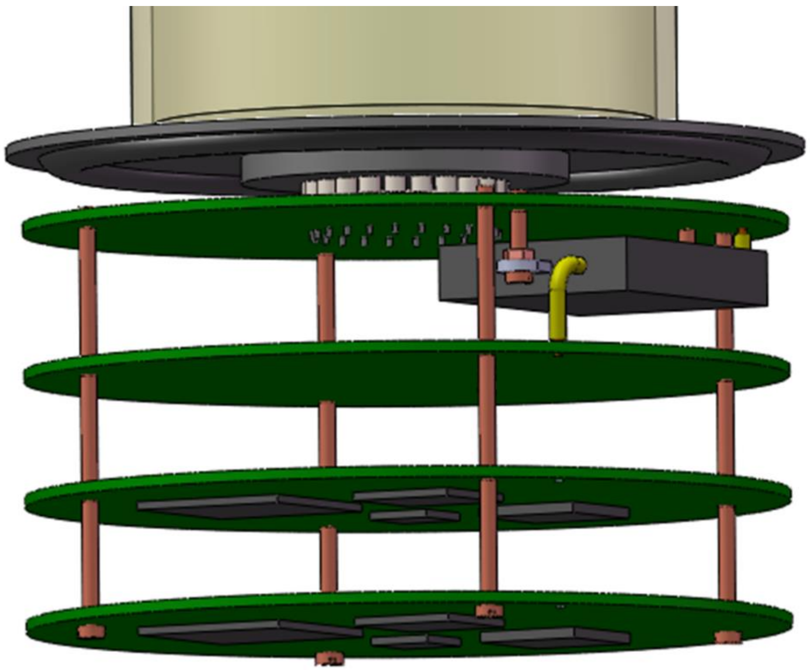


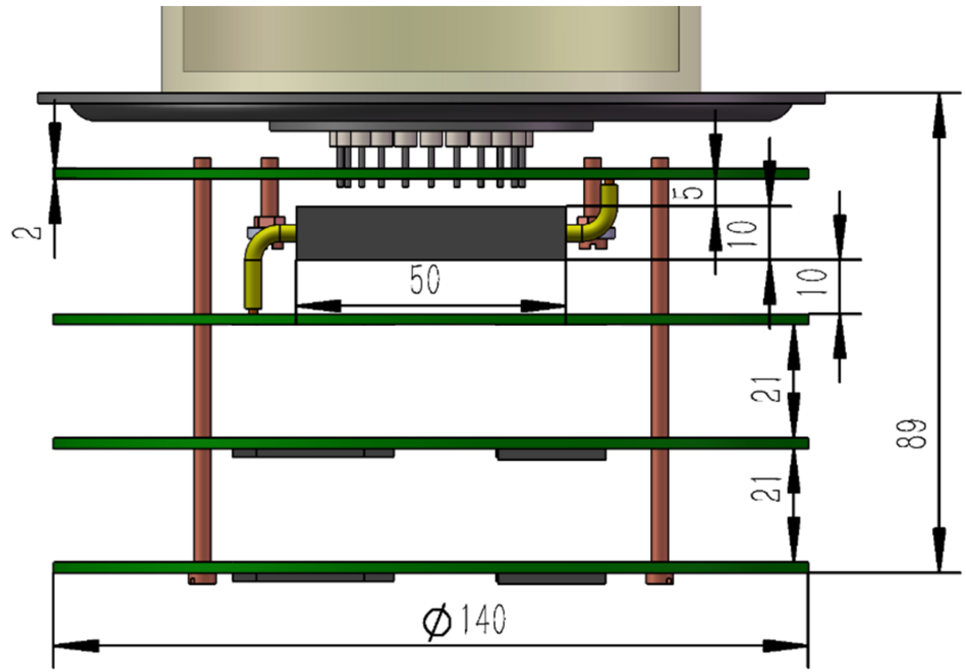

MCP 20" version 2.0
~1600V,~100uA@1e7 gain, ~28Mohm



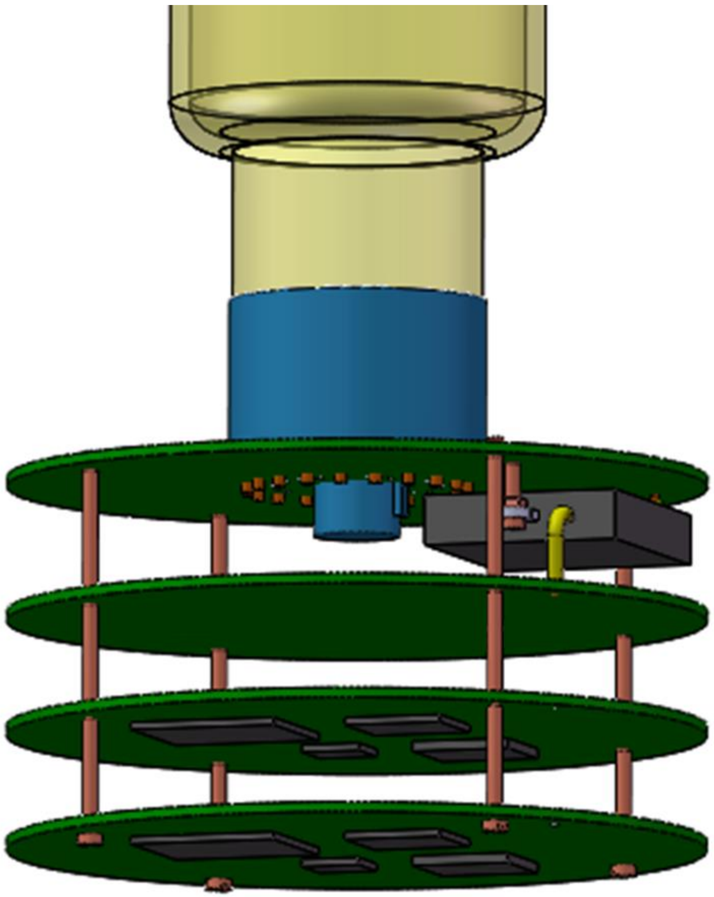

According to current test results, this can satisfy JUNO linearity requirements

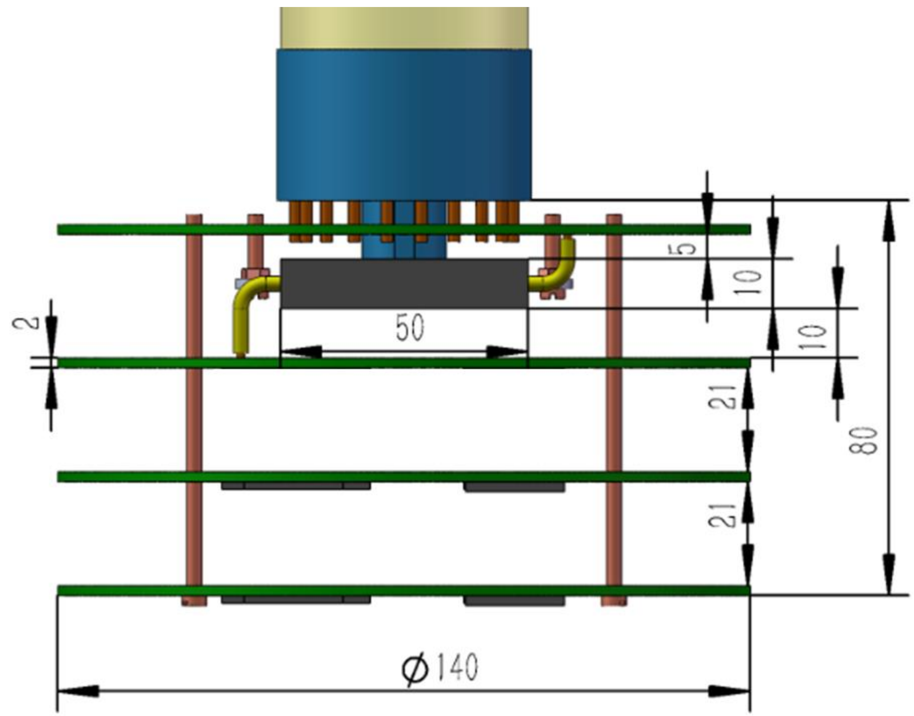
# MCP





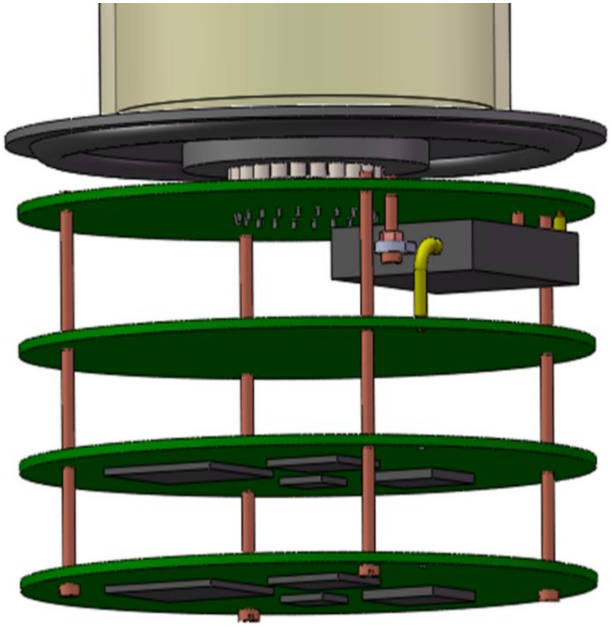
# HAMAMAZU





# HV base connections

- Possible installation procedure
  - 1. PMT base
  - 1.5 potting bottom structure located.
  - 2. signal, ground, HV cables soldered to PMT base PCB onsite, and HV unit screwed PMT base PCB with HV cable soldered. (all the connection should cables or pins with length tolerance. Do we need separate grounding for HV and signal? Or only need signal grounding?)
  - 3. PMT base PCB soldered to PMT pins
  - 4. isolation PCB screwed to PMT base PCB, and cables get through
  - 5. electronics PCB (ADC board) screwed and soldered with cables, and HV power and control cable get through out
  - 6.  GCU board screwed, control, signal cable and HV power and control cable soldered. GCU cable
  - 7. potting



# Electrostatic Discharge (ESD)

From **Juin J. Liou**

…is the a sudden transfer of charges between 2 objects at different static potentials. It's caused by direct contact or induced by an electric field.

## Electrical Overstress (EOS) in General

### ESD

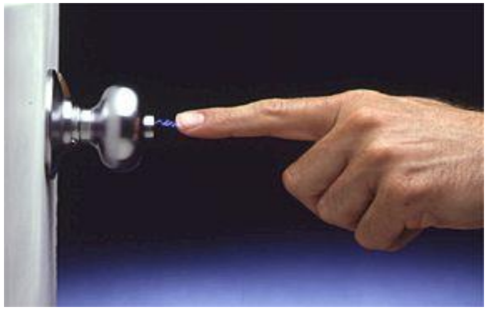
High voltage (1V ~ 15 kV)
Short duration (nano~microseconds)
Very low power (several μJ)
Fast rise time (0.2 ns~10 ns)

### EOS Specific

Low voltage (30 V)
Longer duration (last several μs to ms)
High power ($10^6$ μJ)
Long rise time (>1000 ns)

### Lightning

Extremely high voltage
Extremely high power



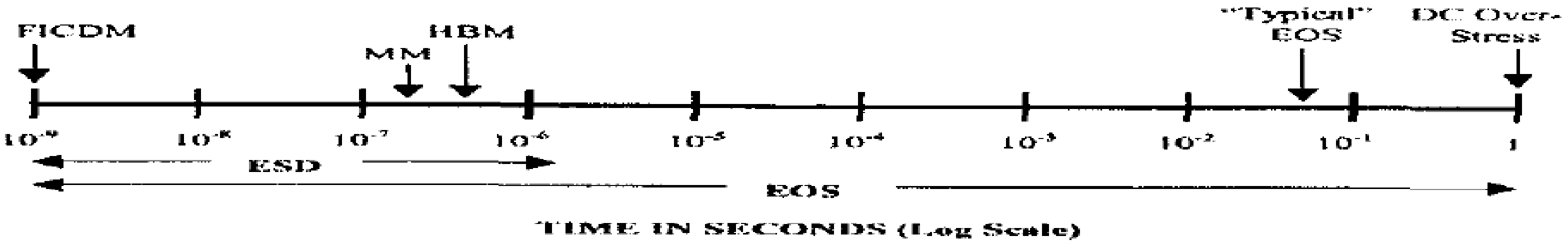
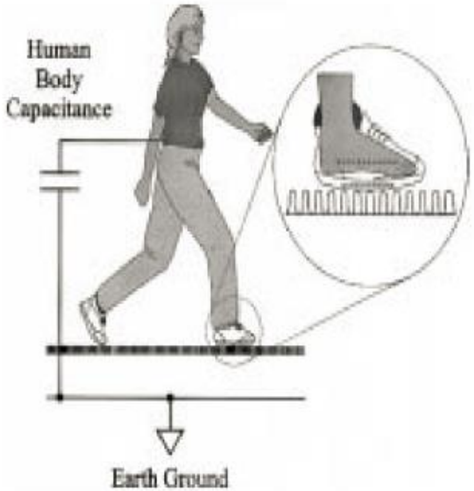



图 1　各种电浪涌脉冲宽度（或频谱）分布




# Electrostatic Charge Generated on Human Body

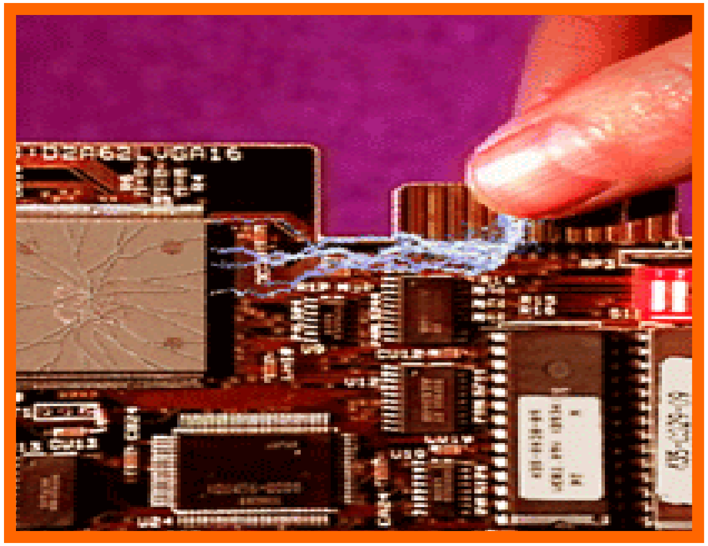
Triboelectrification process

| *Source* | *< 25% RH* | *65-90% RH* |
|---|---|---|
| Walking across carpet | 35,000 V | 1,500 V |
| Walking across vinyl tile | 12,000 V | 250 V |
| Worker at bench | 6,000 V | 100 V |
| Poly bag picking up from bench | 20,000 V | 1,200 V |
| Chair w/ urethane foam | 18,000 V | 1,500 V |

**V = Q/C, so for a small capacitance, the voltage can be very high even if the amount of charge is small.**

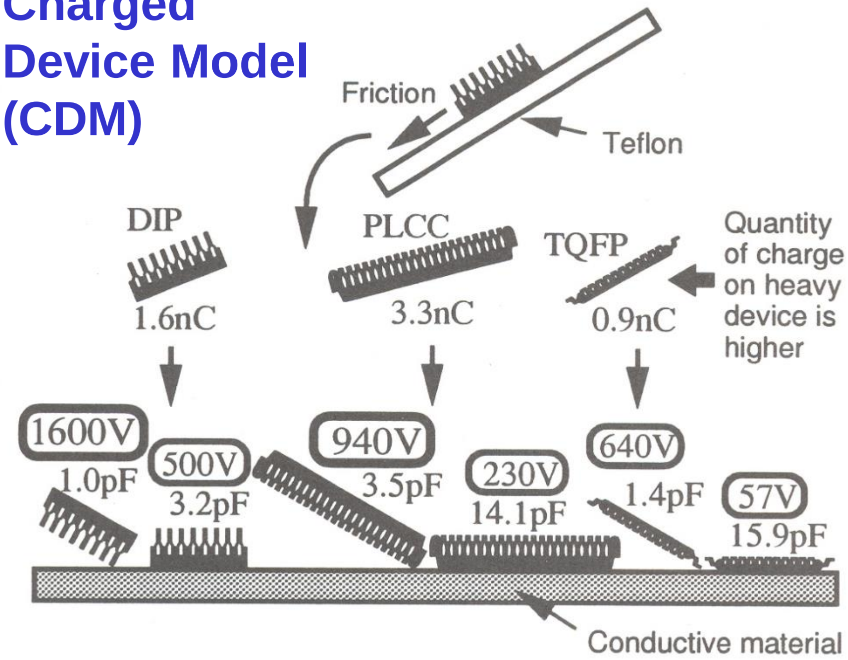
**The danger of ESD is everywhere!**

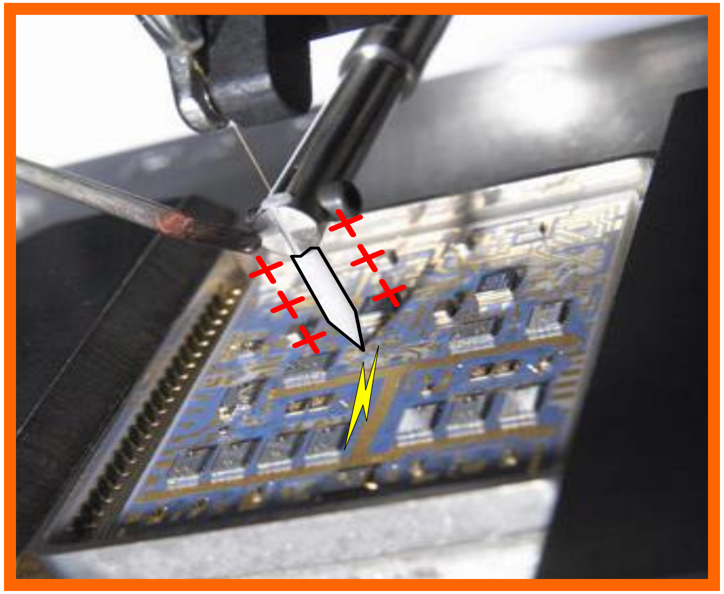
# Various ESD Events on Microchips



Human Body Model (HBM)

Charged Device Model (CDM)



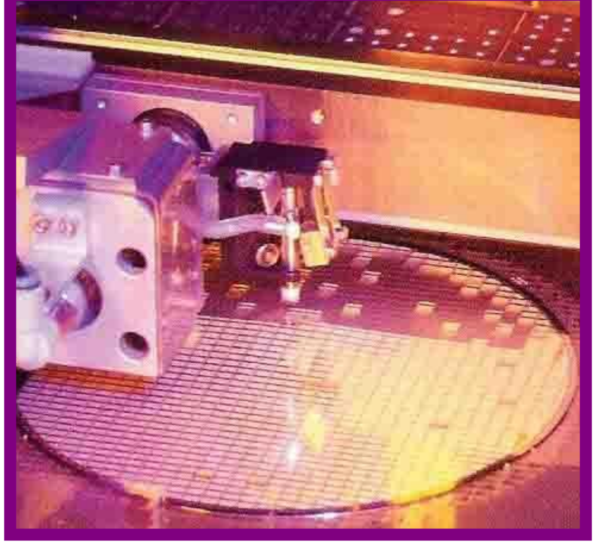
Machine Model (MM)

# *Charged Device Model (CDM) is increasingly important!*

## *IC Shipping Tubes*

- An IC becomes charged by sliding down a plastic shipping tube and then a corner pin discharges to a grounded bench mat.

## *Die Picking*



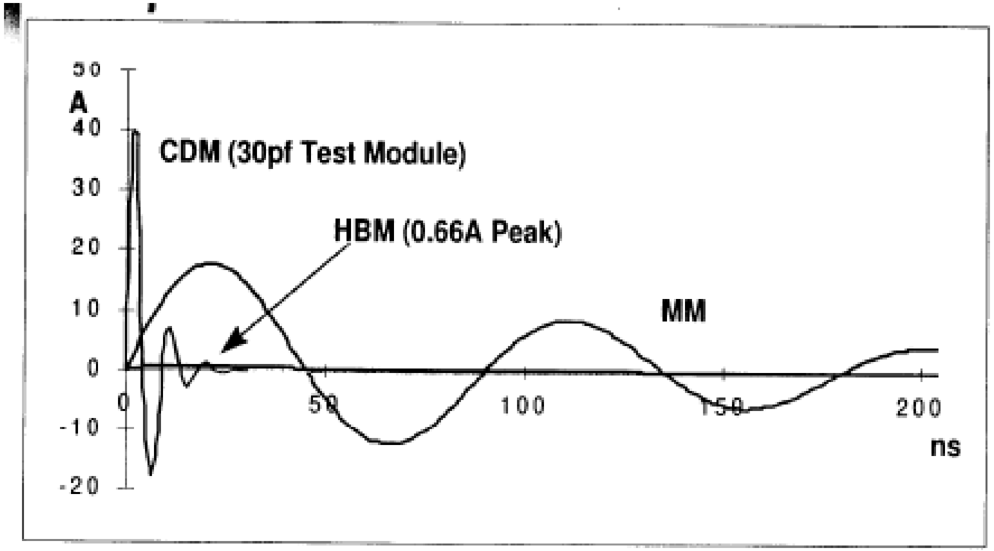
- Most documented CDM damage in IC manufacturing.
- Die separates from tape – places charge on die and inductively charges tape.
- Discharge from die to collet

## *Conveyor Belt*

- Charged by friction – discharged to conductor

# ESD Standards

| Models | Rise Time (ns) | Decay Time (ns) | Voltage Level (V) | Standard Waveform Load | Ipeak for Short (A) |
| --- | --- | --- | --- | --- | --- |
| Human Body Model (HBM) | 2 - 10 | 130 - 170 | 250 - 15k | Short/ 500Ω | 0.60-0.74 at 1kV |
| Machine Model (MM) | 6 - 7.5 | 66 - 90 (Ring period) | 100 – 400 | Short/ 500Ω | 5.80-8.00 at 400V |
| Charged Device Model (CDM) | < 0.2 - 0.4 | 0.4 - 2 (Oscillations) | 250 - 2k | brass disc | 9.78-13.22 at 1kV |
| International Electrotechnical Commission (IEC) | 0.7 - 1 | 80 | 2k - 15k | Air gap/ Discharge 50MΩ-100MΩ | - |




Comparison of 1kV CDM, HBM and MM discharges

- The CDM discharge is 50x faster than HBM or MM.
- The peak current of CDM can be 20x that of HBM pulse.
- The severeness of ESD is determined by the current, not the voltage.

By JEDEC standard

# ESD Testing Classification

| Class | Voltage Range |
|---|---|
| Class C1 | <125 volts |
| **Class C2** | **125 volts to < 250 volts** |
| Class C3 | 250 volts to < 500 volts |
| Class C4 | 500 volts to < 1,000 volts |
| Class C5 | 1,000 volts to < 1,500 volts |
| Class C6 | 1,500 volts to < 2,000 volts |
| Class C7 | =>2,000 volts |

Charged Device Model

| Class | Voltage Range |
|---|---|
| Class M1 | < 100 volts |
| **Class M2** | **100 volts to < 200 volts** |
| Class M3 | 200 volts to < 400 volts |
| Class M4 | > or = 400 volts |

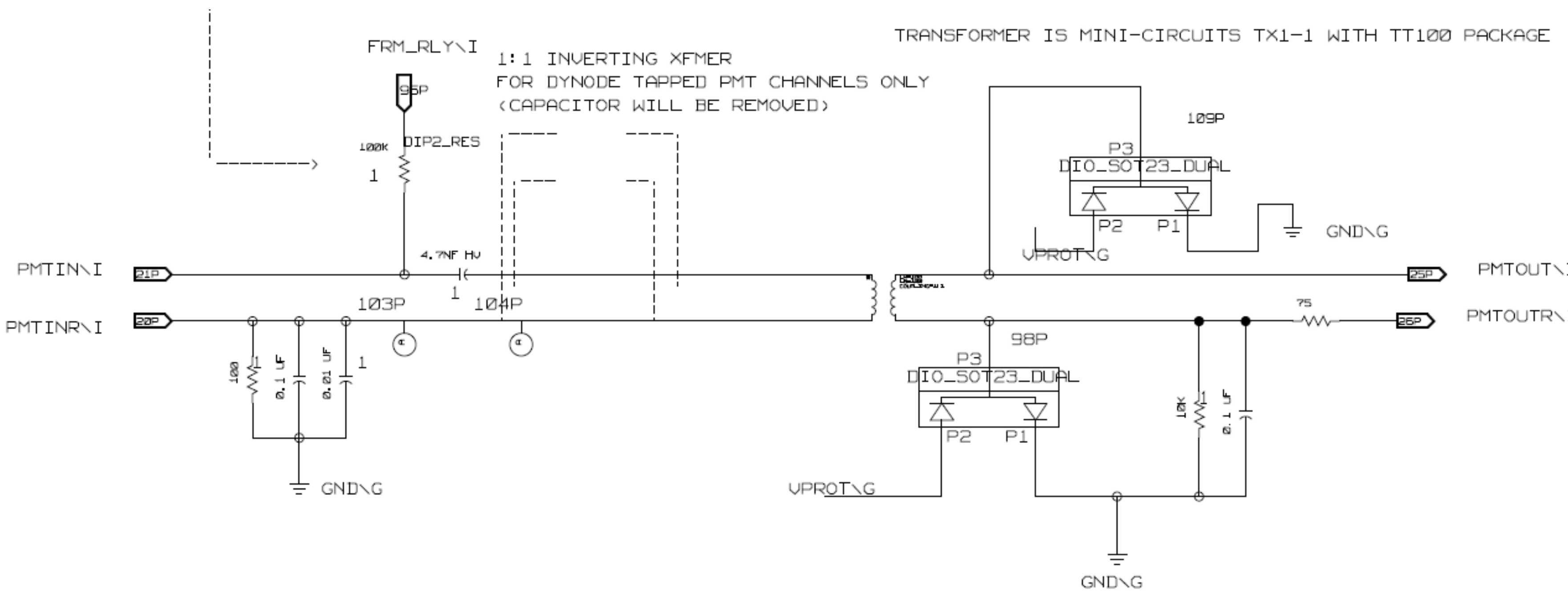
Machine Model

| Class | Voltage Range |
|---|---|
| Class 0 | < 250 volts |
| Class 1A | 250 volts to < 500 volts |
| Class 1B | 500 volts to < 1,000 volts |
| Class 1C | 1000 volts to < 2,000 volts |
| **Class 2** | **2000 volts to < 4,000 volts** |
| Class 3A | 4000 volts to < 8000 volts |
| Class 3B | > = 8000 volts |

Human Body Model

**Boldfaces are the typical ESD protection levels found in commercial microchips**

# SNO HV divider and protection



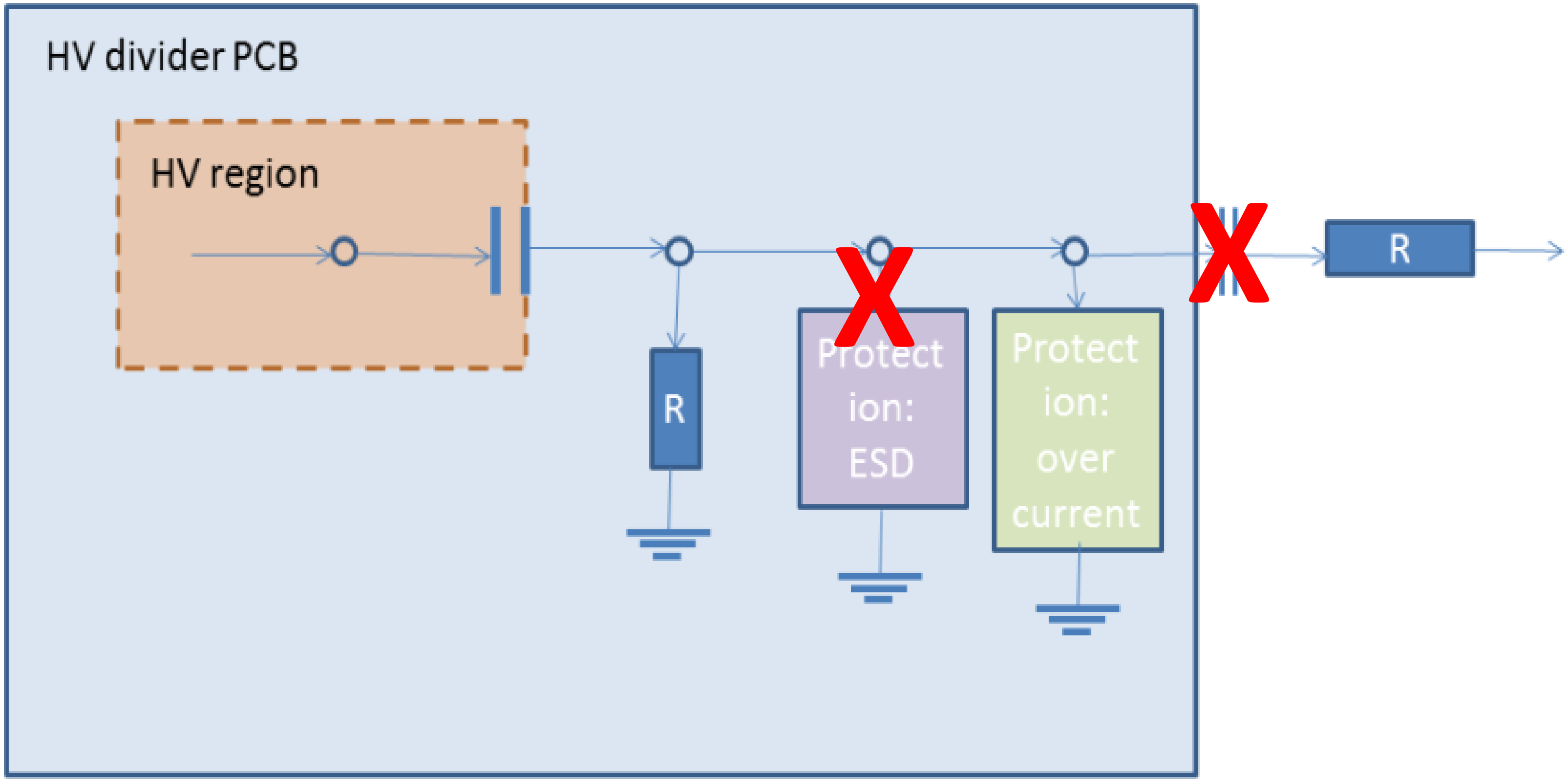

From SNO **Peter Skensved**

# Requirements of JUNO HV divider

- ESD protection for following electronics
  - MM, CDM
  - **Should located at electronics board**
- EOS: signal clamping
  - 0~-160mA (tolerance to ~200mA)
  - Or 0~-7.5V@50ohm
  - **Located at HV divider**
- No distortion to PMT raw signal or non-linearity effect
  - Signal bandwidth <200MHz

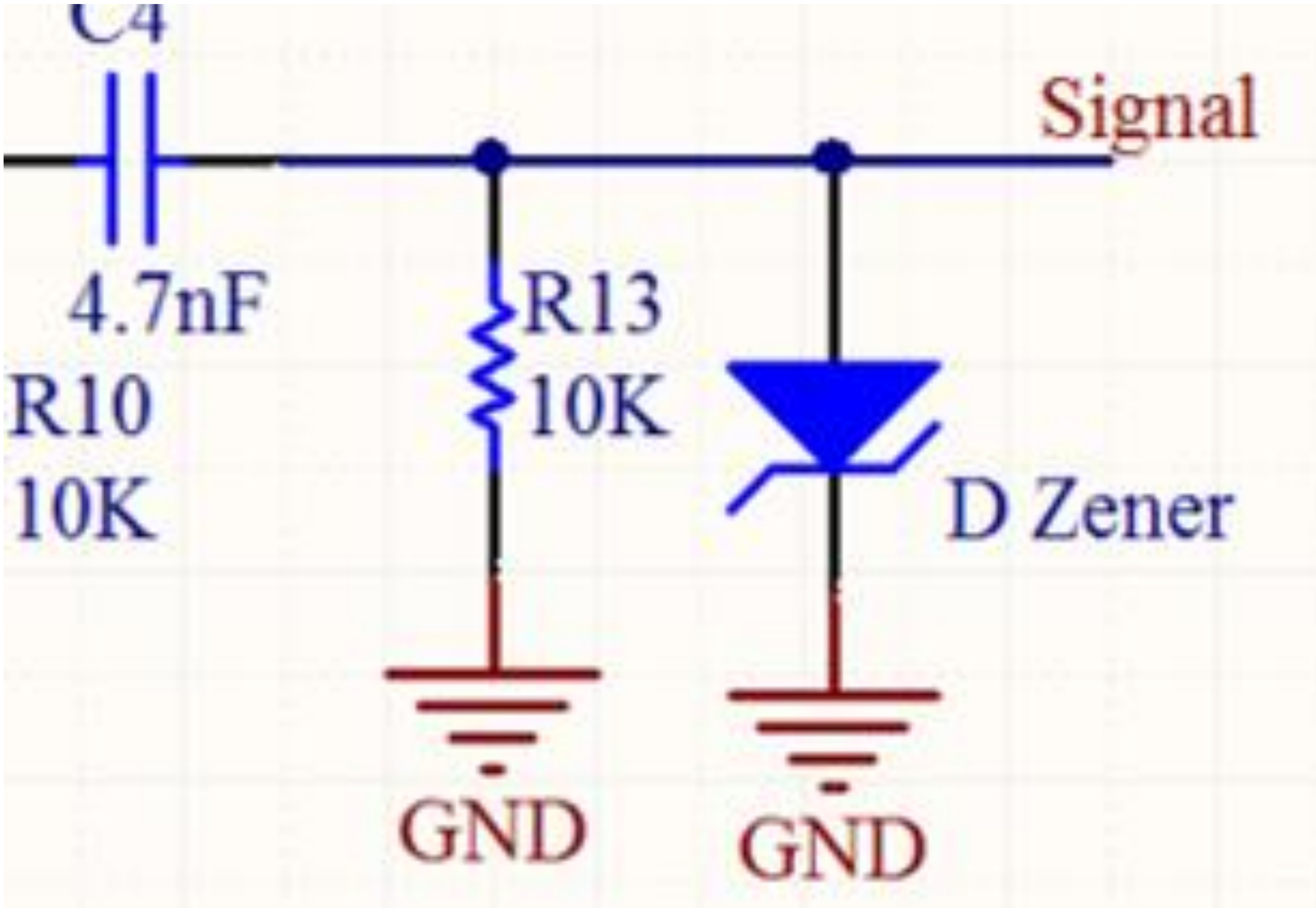
| RF Interface<br>（参考判据：50Ω系统，端口驻波系数由1退化到1.5） | | | |
|---|---|---|---|
| Frequency | $C_p$（近似值） | Frequency | $C_p$（近似值） |
| 100MHz | ≤16pF | 1.8GHz | ≤0.9pF |
| 450MHz | ≤3.5pF | 2.1GHz | ≤0.7pF |
| 800MHz | ≤2pF | 3GHz | ≤0.5pF |
| 1GHz | ≤1.5pF | 5GHz | ≤0.33pF |

# Ideas for JUNO




Ordered several diodes and coils, preliminary test shows few types of Zener diode can clamp the PMT output signal less than 7~8V@50ohm (max to ~9V) with tiny waveform distortion. More detailed effect still under test.

# Zener Diode test



# Diode test

- **Fairchild Semiconductor BZX85C8V2 1 Zener Diode 8.2V 5% 1 W**
- **Test with MCP PMT maximum signal to 28V, real output is clamped to 7.7V~9.5V.**

**Absolute Maximum Ratings *** $T_A$ = 25°C unless otherwise noted

| Symbol | Parameter | Value | Units |
|---|---|---|---|
| $P_D$ | Power Dissipation @ TL ≤ 75°C, Lead Length = 3/8" | 500 | mW |
| | Derate above 75°C | 4.0 | mW/°C |
| $T_J$, $T_{STG}$ | Operating and Storage Temperature Range | -65 to +200 | °C |

* These ratings are limiting values above which the serviceability of the diode may be impaired.

**Electrical Characteristics** $T_A$=25°C unless otherwise noted

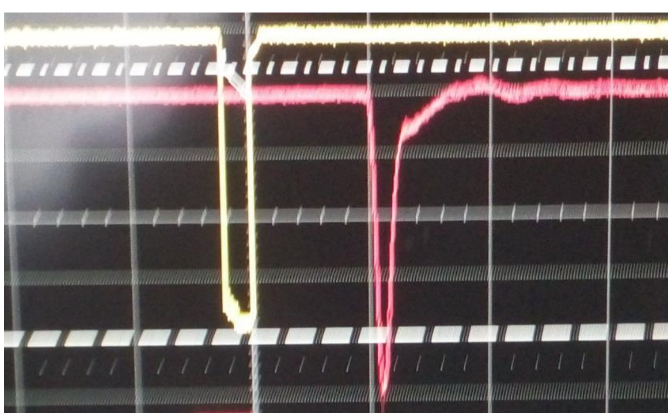
| Device | Zener Voltage (Note 1) | | | $Z_Z$ @ $I_Z$ (Ω) | Leakage Current | | $T_C$ (mV / °C) | | C (pF) |
|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | $I_Z$ (mA) | Max. | $I_R$ (µA) | $V_R$ (V) | Min. | Max. | $V_Z$ = 0, f = 1MHz |
| BZX79C2V4 | 2.2 | 2.6 | 5 | 100 | 100 | 1 | -3.5 | 0 | 255 |
| BZX79C2V7 | 2.5 | 2.9 | 5 | 100 | 75 | 1 | -3.5 | 0 | 230 |
| BZX79C3V0 | 2.8 | 3.2 | 5 | 95 | 50 | 1 | -3.5 | 0 | 215 |
| BZX79C3V3 | 3.1 | 3.5 | 5 | 95 | 25 | 1 | -3.5 | 0 | 200 |
| BZX79C3V6 | 3.4 | 3.8 | 5 | 90 | 15 | 1 | -3.5 | 0 | 185 |
| BZX79C3V9 | 3.7 | 4.1 | 5 | 90 | 10 | 1 | -3.5 | +0.3 | 175 |
| BZX79C4V3 | 4 | 4.6 | 5 | 90 | 5 | 1 | -3.5 | +1 | 160 |
| BZX79C4V7 | 4.4 | 5 | 5 | 80 | 3 | 2 | -3.5 | +0.2 | 130 |
| BZX79C5V1 | 4.8 | 5.4 | 5 | 60 | 2 | 2 | -2.7 | +1.2 | 110 |
| BZX79C5V6 | 5.2 | 6 | 5 | 40 | 1 | 2 | -2 | +2.5 | 95 |
| BZX79C6V2 | 5.8 | 6.6 | 5 | 10 | 3 | 4 | 0.4 | 3.7 | 90 |
| BZX79C6V8 | 6.4 | 7.2 | 5 | 15 | 2 | 4 | 1.2 | 4.5 | 85 |
| BZX79C7V5 | 7 | 7.9 | 5 | 15 | 1 | 5 | 2.5 | 5.3 | 80 |
| BZX79C8V2 | 7.7 | 8.7 | 5 | 15 | 0.7 | 5 | 3.2 | 6.2 | |
| BZX79C9V1 | 8.5 | 9.6 | 5 | 15 | 0.5 | 6 | 3.8 | 7 | |

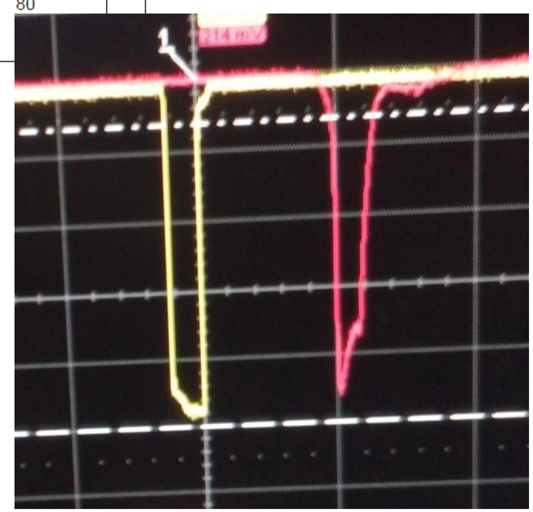
**Tolerance = 5%**

**DO-35 Glass case**

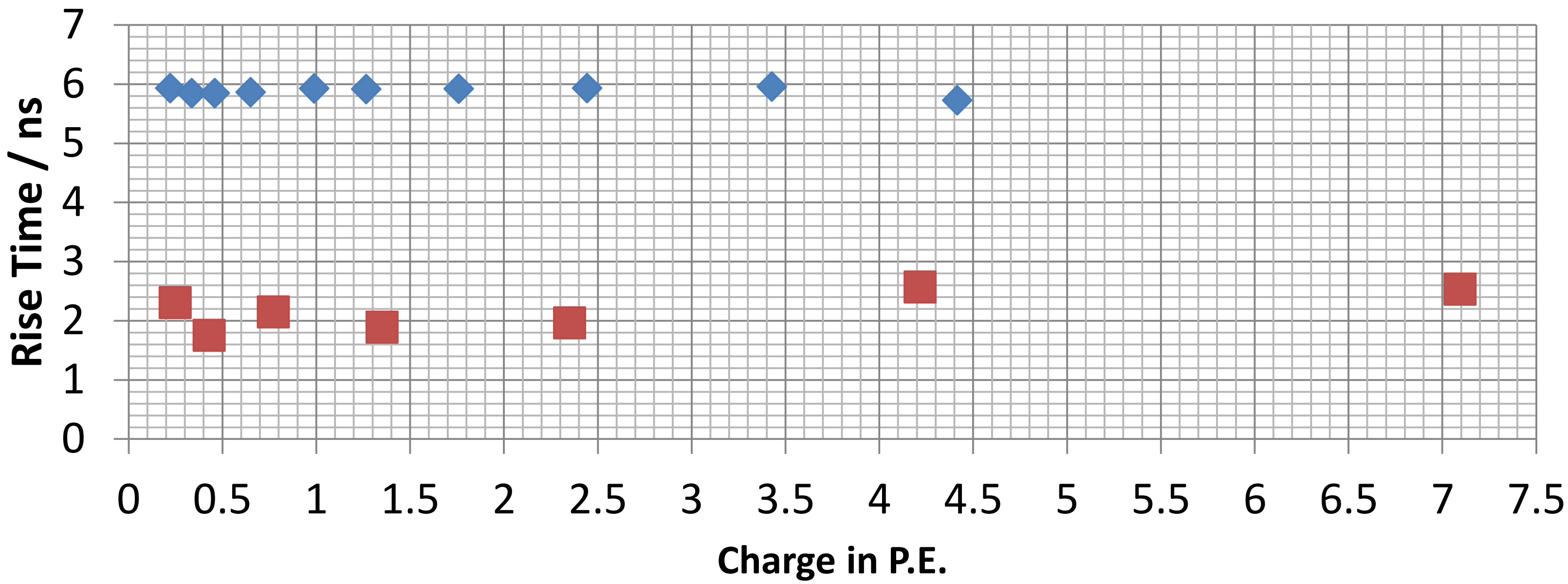
COLOR BAND DENOTES CATHODE

But has a big influence to pulse timing, a little bit to pulse charge measurement.

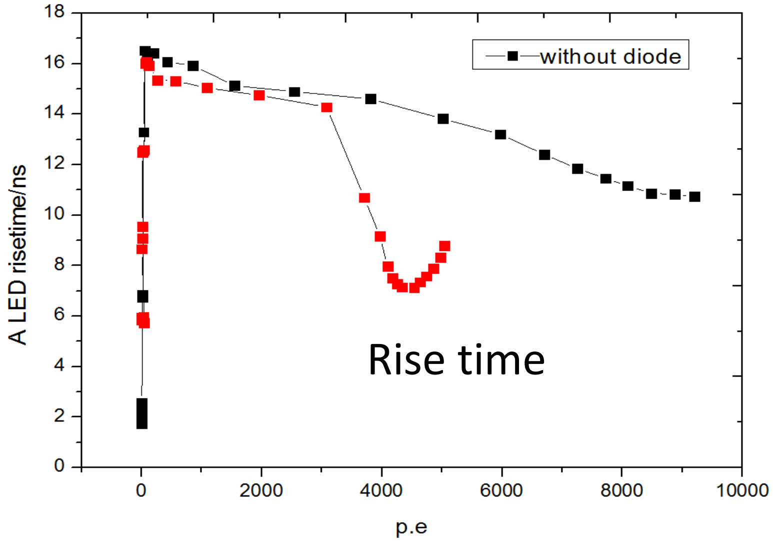





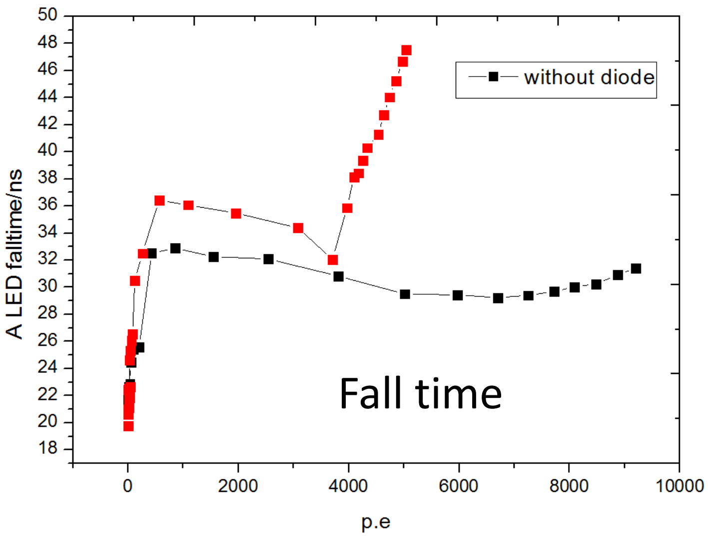
# Rise Time



Rise Time / ns
Charge in P.E.
0
1
2
3
4
5
6
7
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5

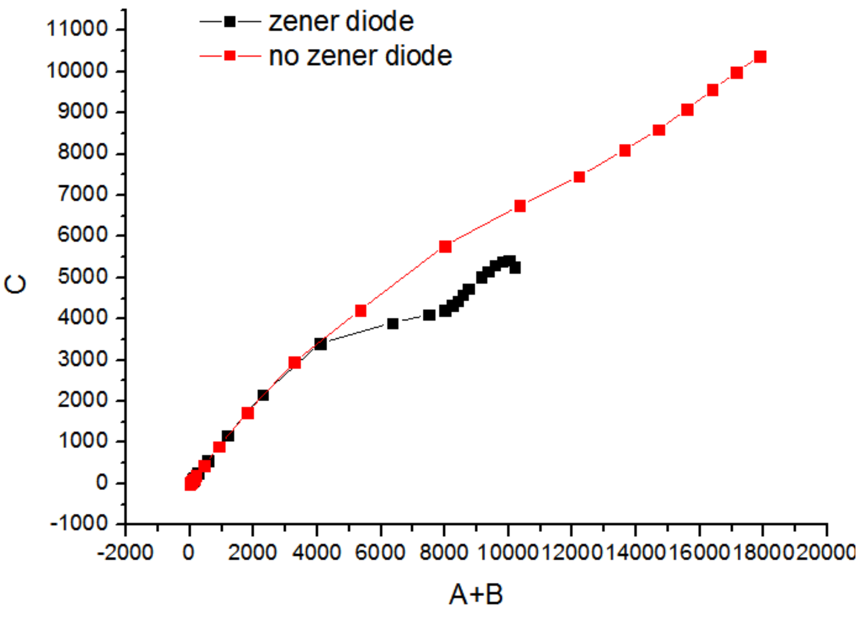



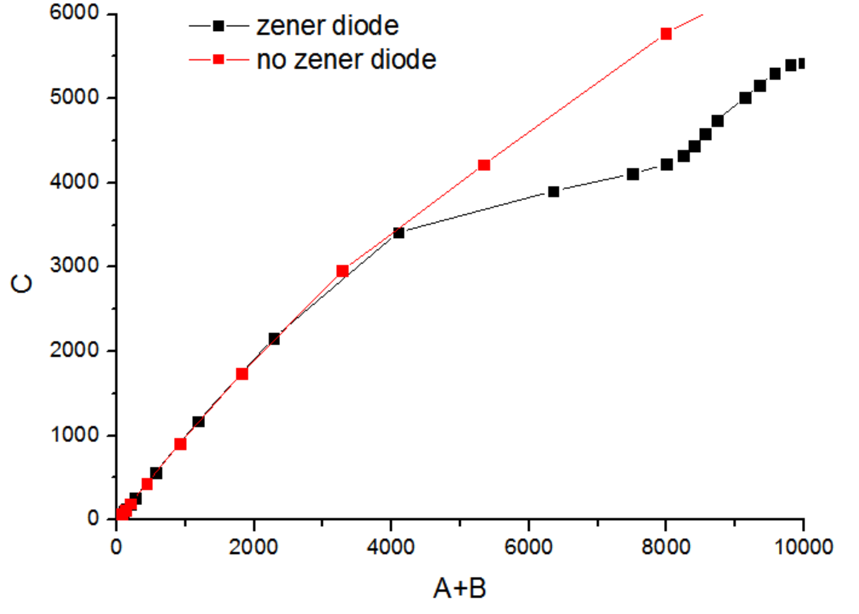
without diode
Rise time
A LED risetime/ns
p.e
0
2
4
6
8
10
12
14
16
18
0
2000
4000
6000
8000
10000

without diode
Fall time
A LED falltime/ns
p.e
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
0
2000
4000
6000
8000
10000

# Linearity test

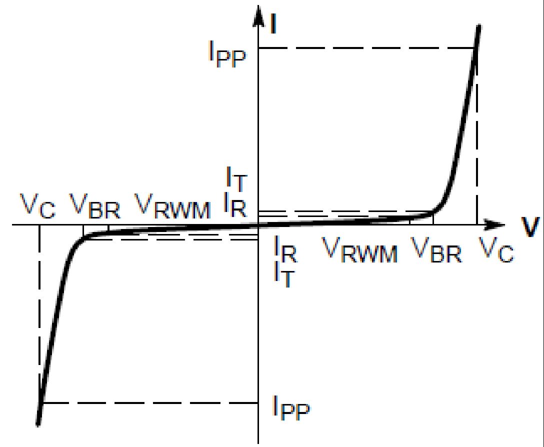


**ELECTRICAL CHARACTERISTICS**
($T_A$ = 25°C unless otherwise noted)

| Symbol | Parameter |
|---|---|
| $I_{PP}$ | Maximum Reverse Peak Pulse Current |
| $V_C$ | Clamping Voltage @ $I_{PP}$ |
| $V_{RWM}$ | Working Peak Reverse Voltage |
| $I_R$ | Maximum Reverse Leakage Current @ $V_{RWM}$ |
| $V_{BR}$ | Breakdown Voltage @ $I_T$ |
| $I_T$ | Test Current |

*See Application Note AND8308/D for detailed explanations of datasheet parameters.

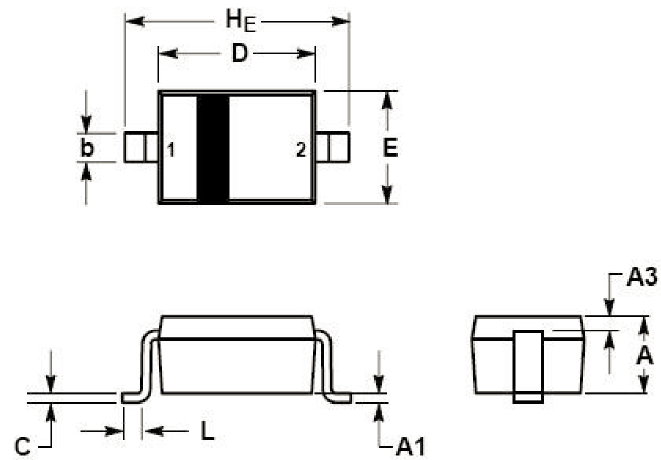


Bi−Directional ESD

**ELECTRICAL CHARACTERISTICS** ($T_A$ = 25°C unless otherwise noted)

| Parameter | Symbol | Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Reverse Working Voltage | $V_{RWM}$ | | | | 7.0 | V |
| Breakdown Voltage | $V_{BR}$ | $I_T$ = 1 mA (Note 1) | 8.0 | | | V |
| Reverse Leakage Current | $I_R$ | $V_{RWM}$ = 7.0 V, I/O to GND | | | 200 | nA |
| Clamping Voltage | $V_C$ | $I_{PP}$ = 8 A − (IEC61000−4−2 Level 2 Equivalent (±4 kV Contact, ±8 kV Air)) | | 18 | | V |
| ESD Clamping Voltage | $V_C$ | Per IEC 61000−4−2 | See Figures 1 and 2 | | | |
| Junction Capacitance | $C_J$ | $V_R$ = 0 V, f = 1 MHz | | | 0.5 | pF |
| Dynamic Resistance | $R_{DYN}$ | TLP Pulse | | 1 | | Ω |

# ESD08V32D-LC




| ELECTRICAL CHARACTERISTICS PER LINE (@ 25 Unless Otherwise Specified) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PART NUMBER | DEVIC EMARKING | $V_{RWM}$ (V) (max.) | $V_B$ (V) (min.) | $I_T$ (mA) | $V_C$ @1A (max.) | $V_C$ (max.) | $V_C$ (@A) | $I_R$ (µA) (max.) | $C_T$ (pF) (typ.) |
| ESD03V32D-LC | CC | 3.0 | 4.0 | 1 | 5.15 | 13.9 | 8 | 20 | 1.2 |
| ESD05V32D-LC | AC | 5.0 | 6.0 | 1 | 9.80 | 18.3 | 8 | 5 | 1.2 |
| ESD08V32D-LC | BC | 8.0 | 8.5 | 1 | 13.40 | 18.5 | 8 | 2 | 1.2 |
| ESD12V32D-LC | DC | 12.0 | 13.3 | 1 | 19.00 | 28.6 | 6 | 1 | 1.2 |
| ESD15V32D-LC | EC | 15.0 | 16.7 | 1 | 24.00 | 31.8 | 5 | 1 | 1.2 |
| ESD24V32D-LC | HC | 24.0 | 26.7 | 1 | 43.00 | 56.0 | 3 | 1 | 1.2 |

***Thanks***