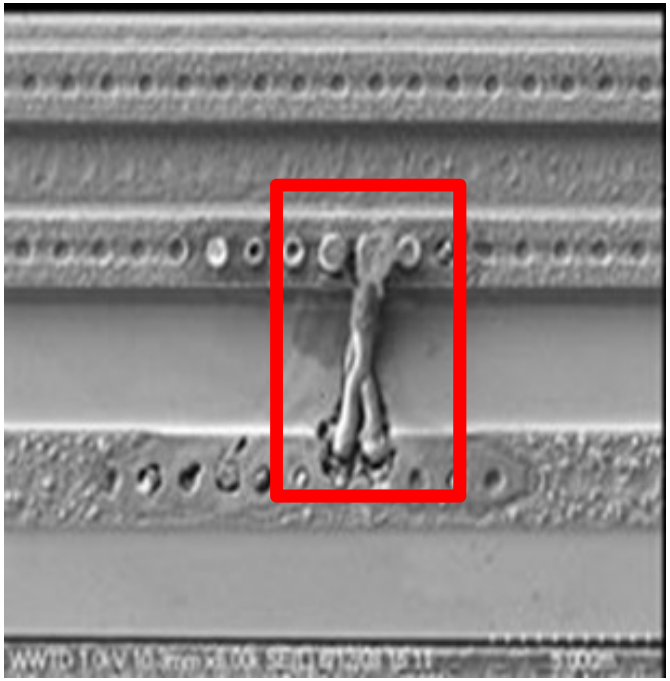
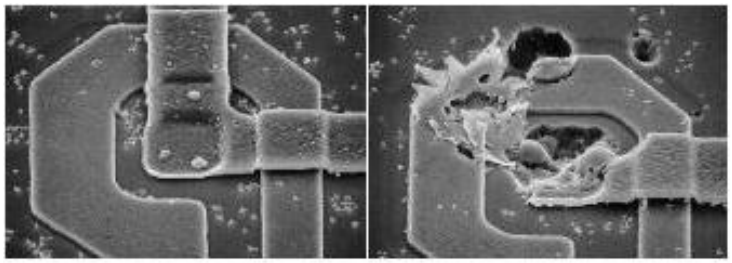
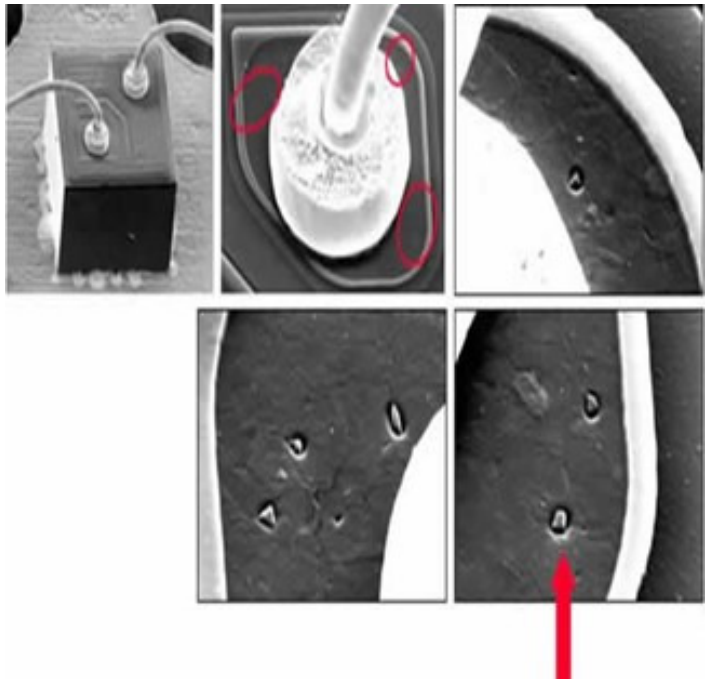
Effective ESD Protection with TVS Diodes

Dipl. Ing. (FH) Robert Demharter

ESD / Transient protection: Damaged Circuits







ESD / Transient protection: Sources of ESD

Typical Electrostatic Voltages comes from Triboelectric phenomena:

ESD source	ESD Voltage 10% to 20% Relative Humidity	ESD Voltage 60% to 90% Relative Humidity
Walking across carpet	35 kV	1500 V
Walking on vinyl floor	12 kV	250 V
Worker moving at bench	6 kV	100 V
Opening a vinyl envelope	7 kV	600 V
Picking up common polyethylene bag	20 kV	1200 V
Sitting on chair padded with polyurethane foam	18 kV	1500 V

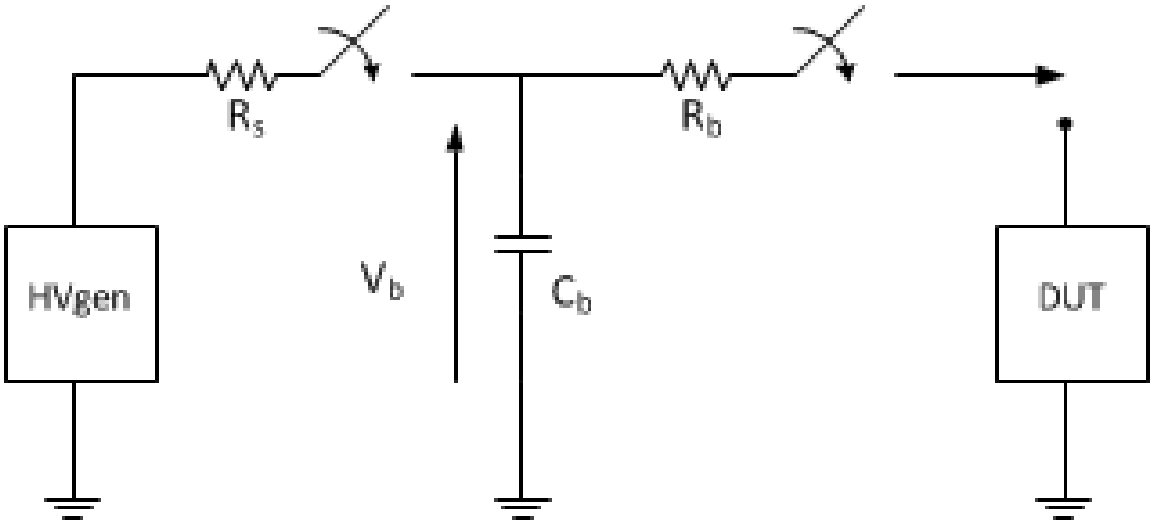
Source: EMC Engineering - Henry W. Ott (Chapter #15-1- Electrostatic Discharge pag582)

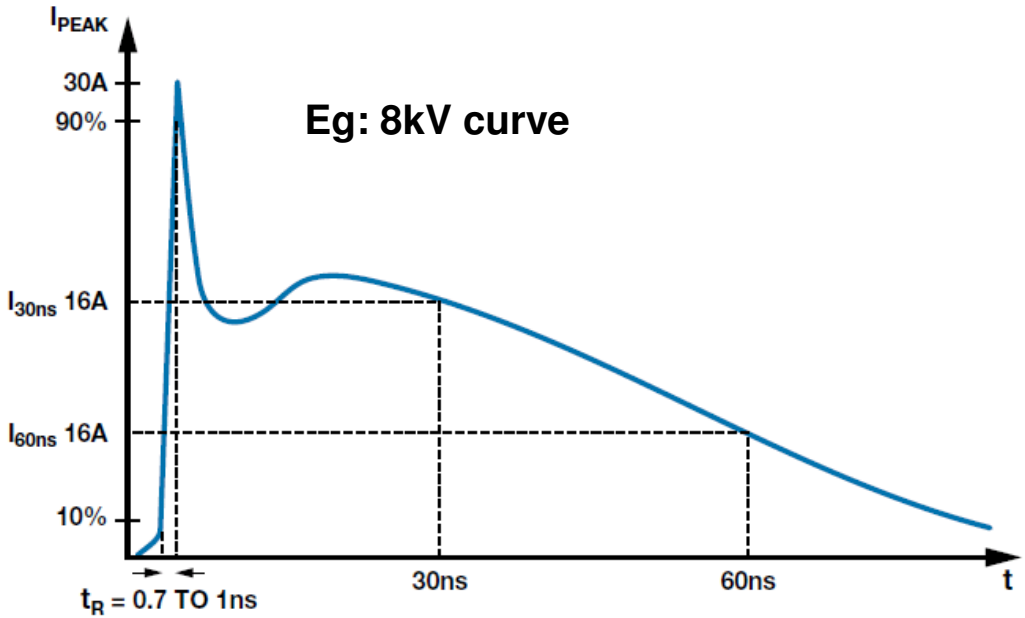
ESD / Transient protection: Test Pulse Setup

- ESD Test Generator is able to produce:
  - Contact discharge/Air discharge
  - 10 positive and 10 negative strikes (int. std)

  Starting from lower level of pulse voltage.

- The curves come out from HBM circuit:



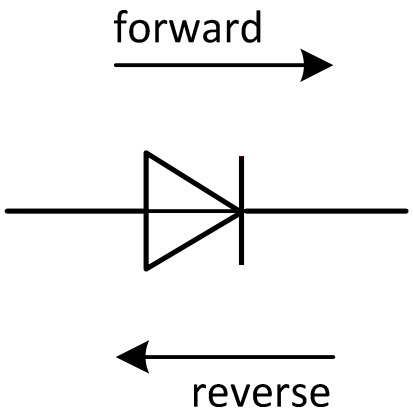


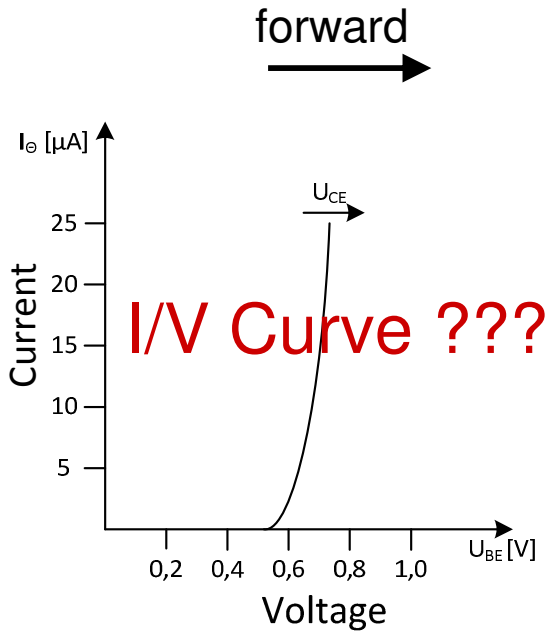
with values for EN 61000-4-2 => R_s=50-100MΩ, Cb=150pF, R_b=330Ω, R_{DUT}= 2Ω

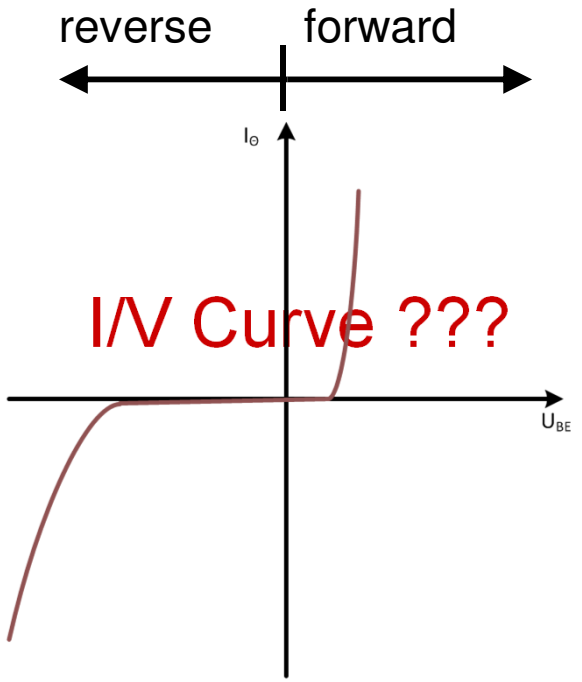
ESD / Transient protection: Diodes and Zener diodes

A **Diode** is an electrical component, which **lets pass current only in one direction** and blocks current in reverse **direction**.

Z-Diodes have same behavior in forward direction, but **in reverse direction they get conducting at defined voltage.**

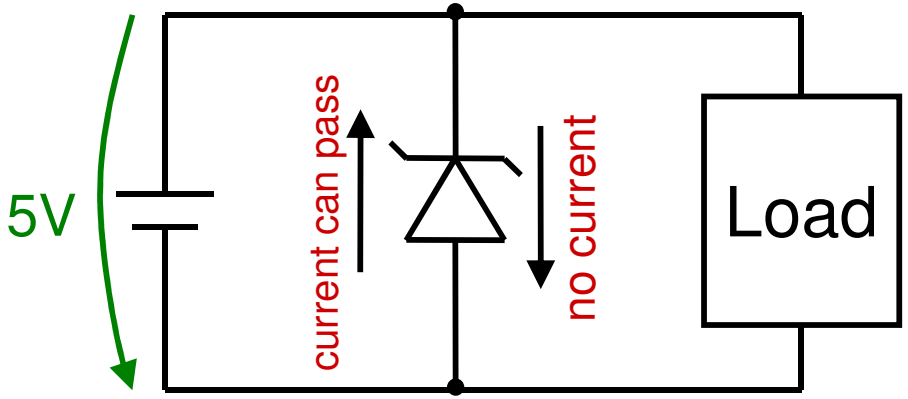




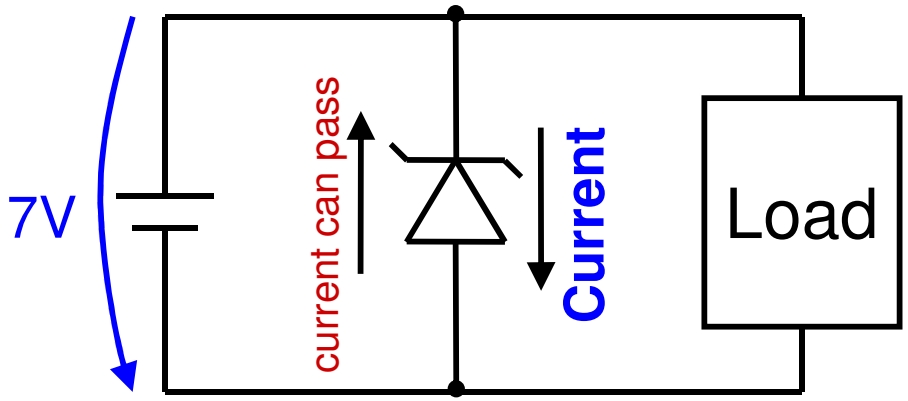


ESD / Transient protection: Diodes and Zener diodes

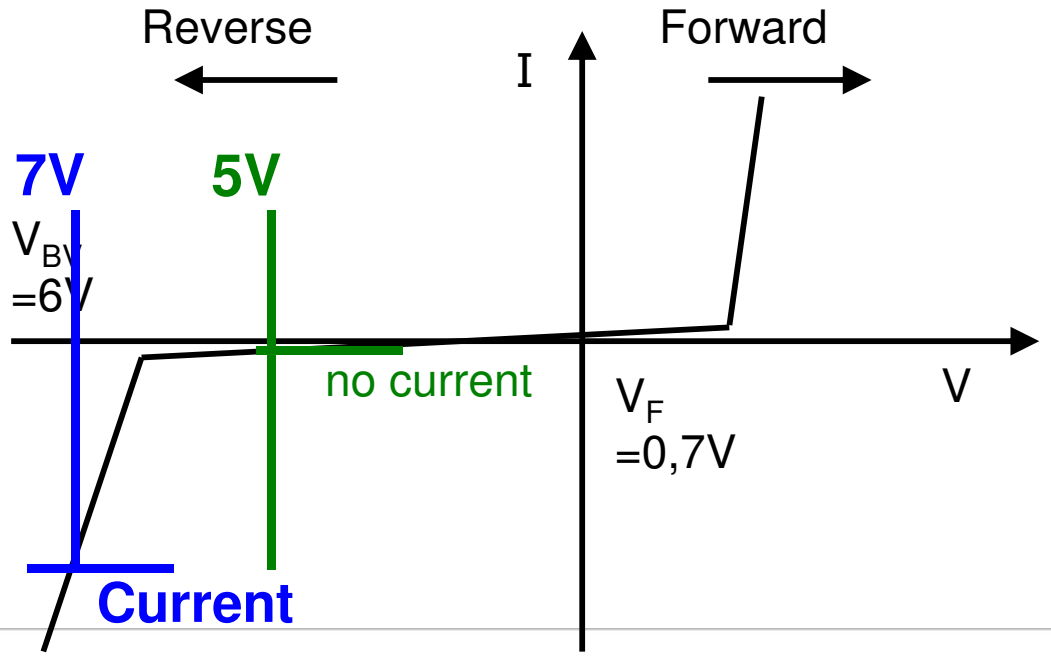
Zener Diodes or TVS Diodes are connected in reverse direction.



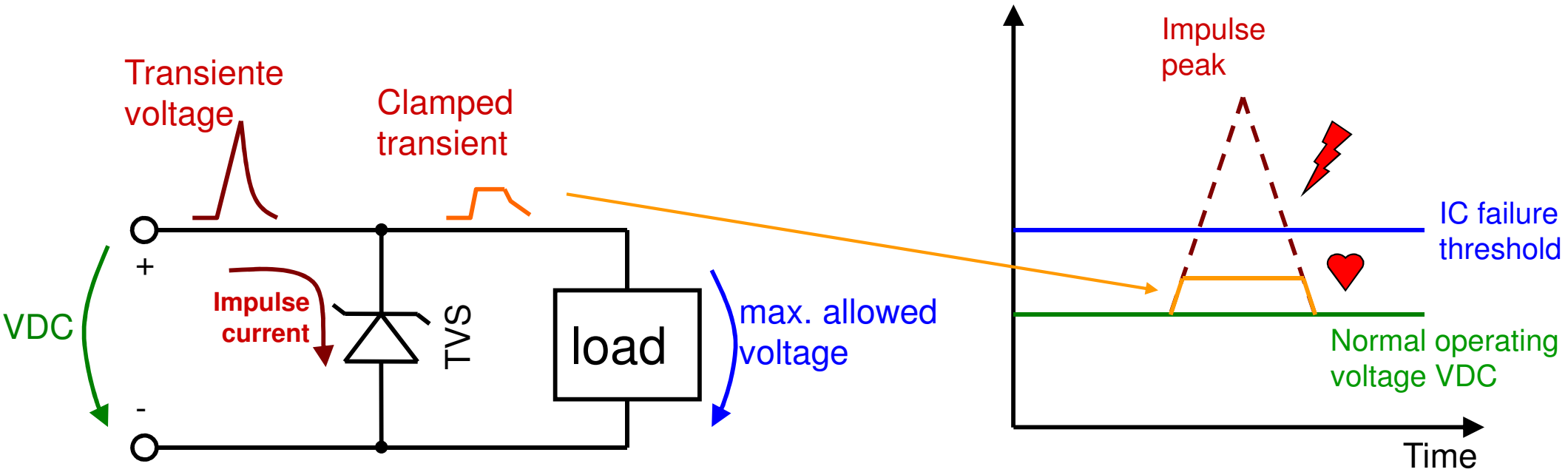
There's no current through the diode due to breakdown voltage is not exceeded.



If voltage is larger than breakdown voltage there is current through diode.

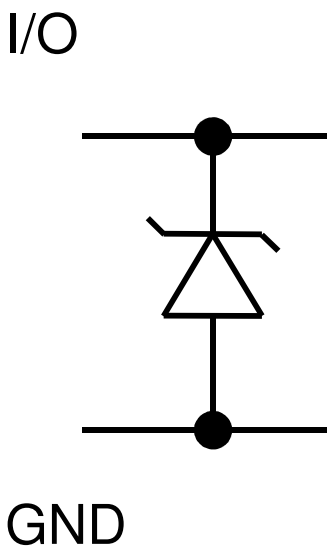


ESD / Transient protection: Scenario

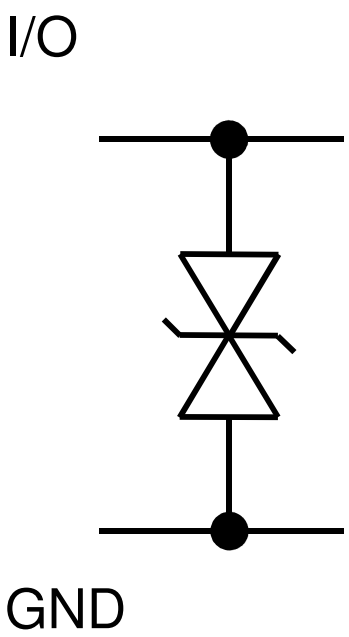


ESD / Transient protection: Topologies

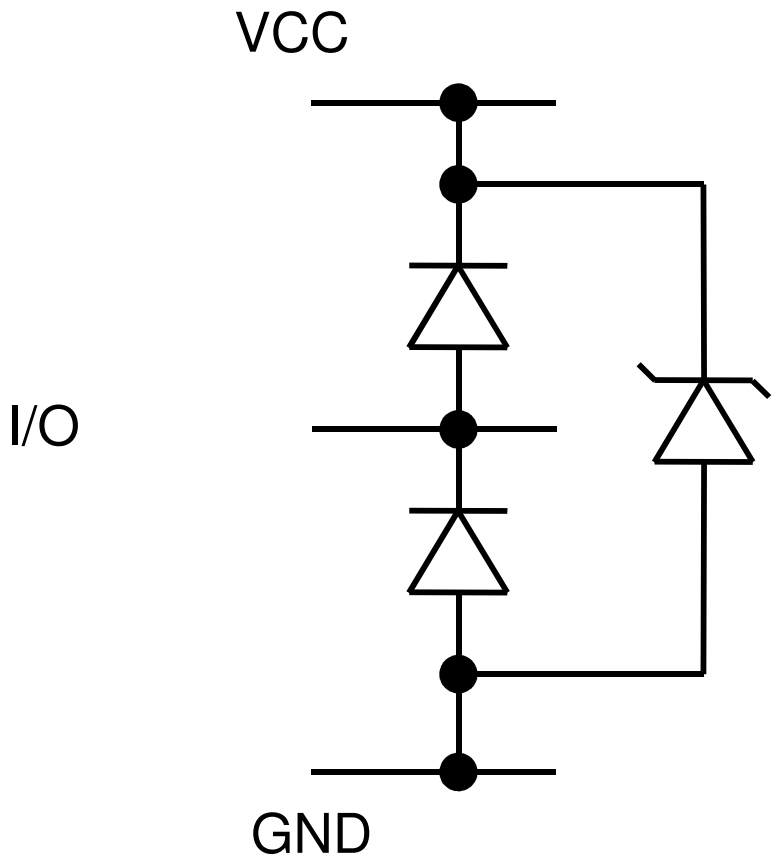
Uni-polar



Bi-polar



Rail-to-Rail



ESD / Transient protection: Topologies differences

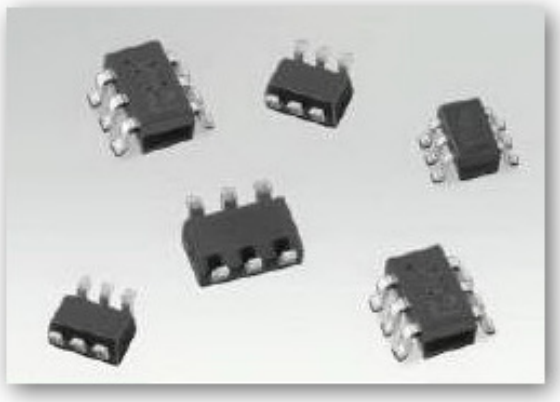
Uni- / Bi-directional Protection 824 02x 824 04x	**Rail-to-Rail Protection** 824 00x 824 01x
Very good ESD Protection Capability	Very good ESD Protection Capability
Good Surge Protection Capability	Poor Surge Protection Capability
Medium- to High-Speed Data Lines	Ultra-High-Speed Data Lines
One Reference Voltage needed	Two Reference Voltages needed
Lower Price per Protected Line	Higher Price per Protected Line

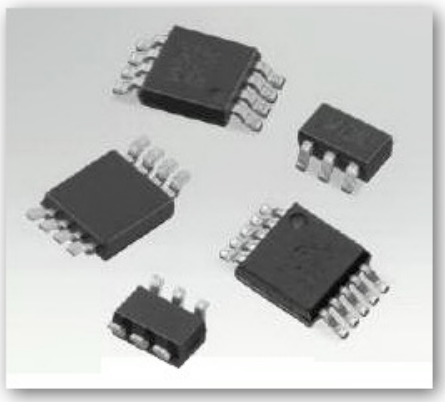
Typical applications: Interface protection

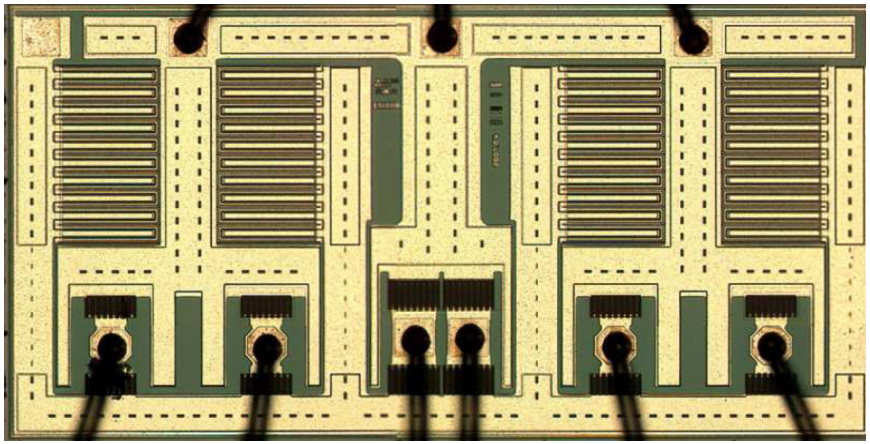
- USB 1.0 / 2.0 / 3.1
- Ethernet
- RS-232 / RS-485
- CAN
- PROFIBUS
- Serial ATA
- FireWire
- DVI
- HDMI
- …

ESD / Transient protection: WE products

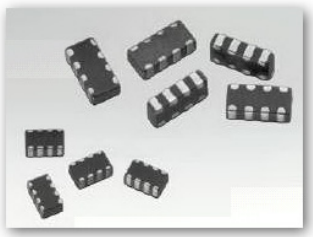
WE-TVS
(Standard Series / High Speed / Super Speed)

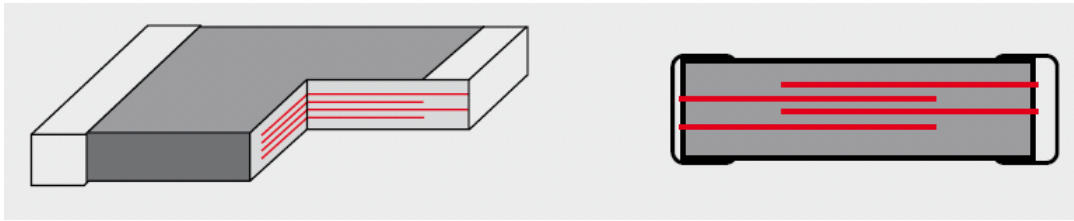






WE-VS / WE-VE(ULC)/ WE-VEA(ULC)





ESD / Transient protection: Selection process

ESD suppressor differ from SMD varistor in their lower and specified capacitance.

1. **Determine the Operating Voltage**
   Checking the typical application
2. **Selection of the correct value of capacitance**
3. **Checking the max clamping voltage**

The selection of a TVS diode is the same as above with the following differences:

1. TVS can be uni or bi-directional
2. V_{DD} pin has to be connected in some cases

ESD / Transient protection: Selection process

1. Determine the Operating Voltage
Checking the typical application

Is it possible to choose a component with a higher permissible op Voltage: the leakage current will be lower but Clamping voltage higher.

Checking the application, will let the choice easier.

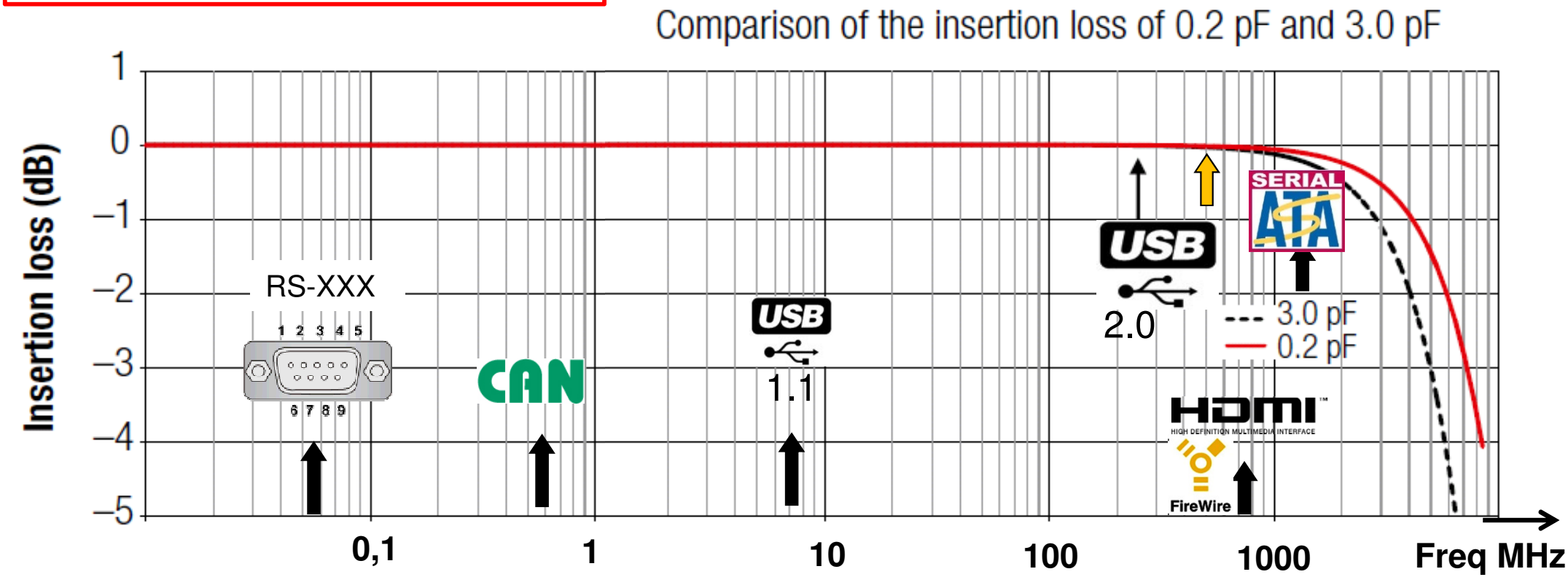
Electrical properties: Size 0402

Order Code	V_{DC} (V)	C (pF)	V_C (V)	I_{Leak} (µA)	R (MΩ)	Typical Applications	Qty.
823 57 050 100	5	10	60			USB 1.1/RS-232/LAN 10 Mbit	
823 57 050 220	5	22	55			CAN Bus	
823 57 050 330	5	33	55			RS-422	
823 57 050 560	5	56	55			RS-422 & IrDA 1.0	
823 57 120 050	12	5	80	1	10	USB 1.1/USB 2.0	10000
823 57 120 100	12	10	60			USB 1.1/RS-232/LAN 10 Mbit	
823 57 120 220	12	22	55				
823 57 240 010	24	1	200				
823 57 240 030	24	3	180			USB 2.0/LAN 100 Mbit	

ESD / Transient protection: Selection process

2. Selection of the correct value of capacitance

For signal integrity, it is important to select a capacitance to match the data rate.



ESD / Transient protection: Selection process

3. Checking the max clamping voltage

The Clamping Voltage is a measure for the protection of the ESD suppressor.
This should be lower than the voltage stability of the circuit to be protected.

Electrical properties: Size 0402

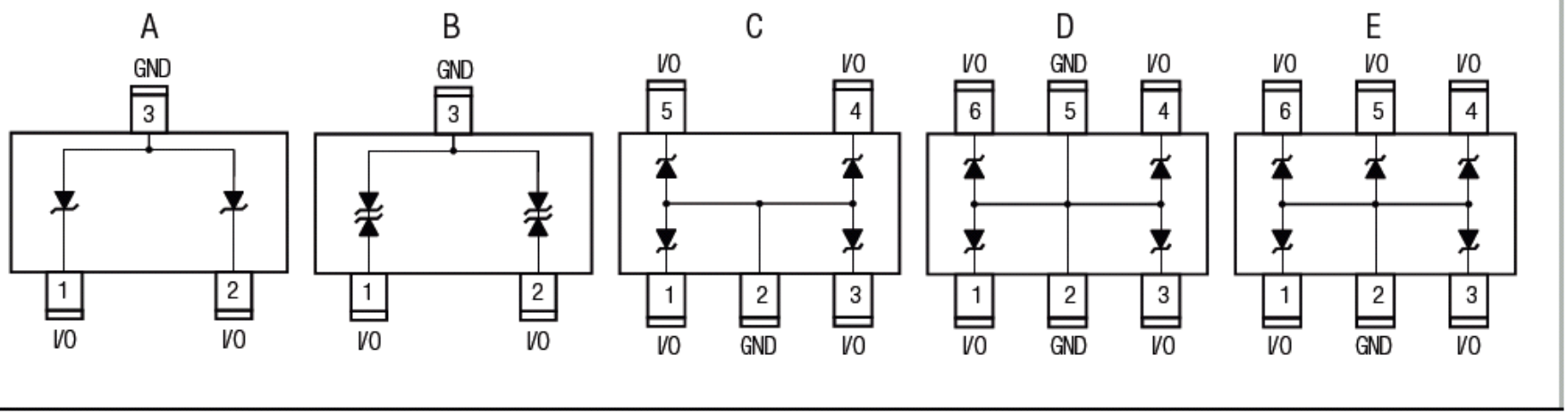
Order Code	V_{DC} (V)	C (pF)	V_C (V)	I_{Leak} (µA)	R (MΩ)	Typical Applications	Qty.
823 57 050 100	5	10	60			USB 1.1/RS-232/LAN 10 Mbit	
823 57 050 220	5	22	55			CAN Bus	
823 57 050 330	5	33	55			RS-422	
823 57 050 560	5	56	55			RS-422 & IrDA 1.0	
823 57 120 050	12	5	80	1	10	USB 1.1/USB 2.0	10000
823 57 120 100	12	10	60			USB 1.1/RS-232/LAN 10 Mbit	
823 57 120 220	12	22	55				
823 57 240 010	24	1	200				
823 57 240 030	24	3	180			USB 2.0/LAN 100 Mbit	

ESD / Transient protection: TVS Selection process

The selection could be done also for uni- or bi-directional behaviour.

Schematic A for unidirectional
Schematic B-C-D-E for bi-directional

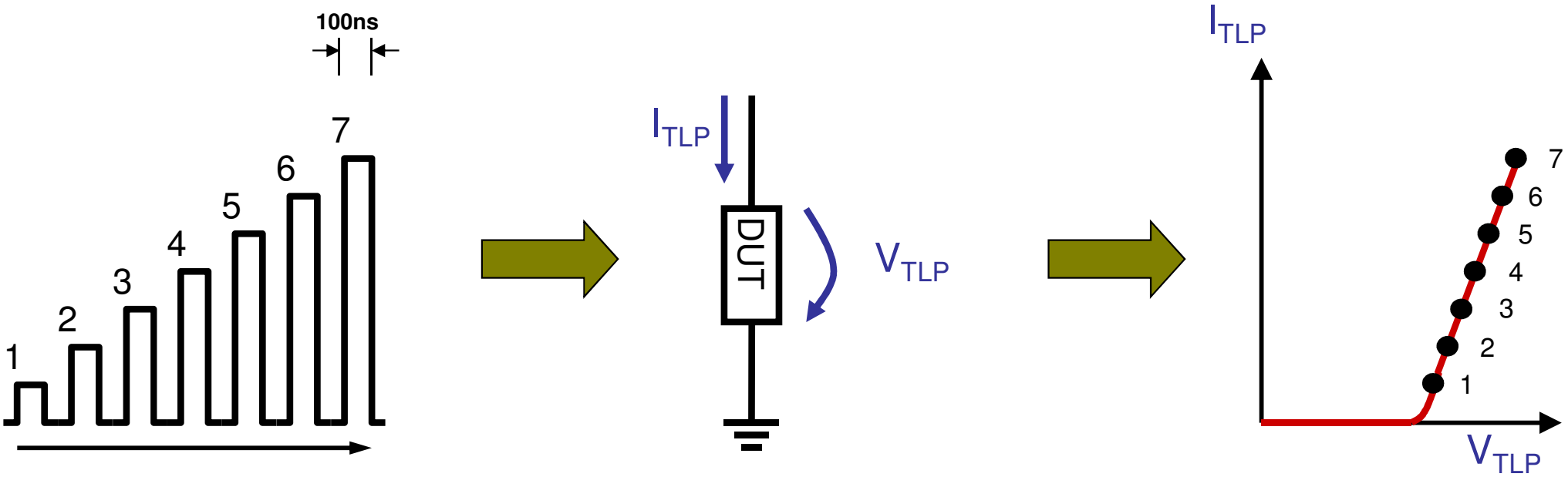
Schematics



Electrical properties (3.3 V Operating Systems)

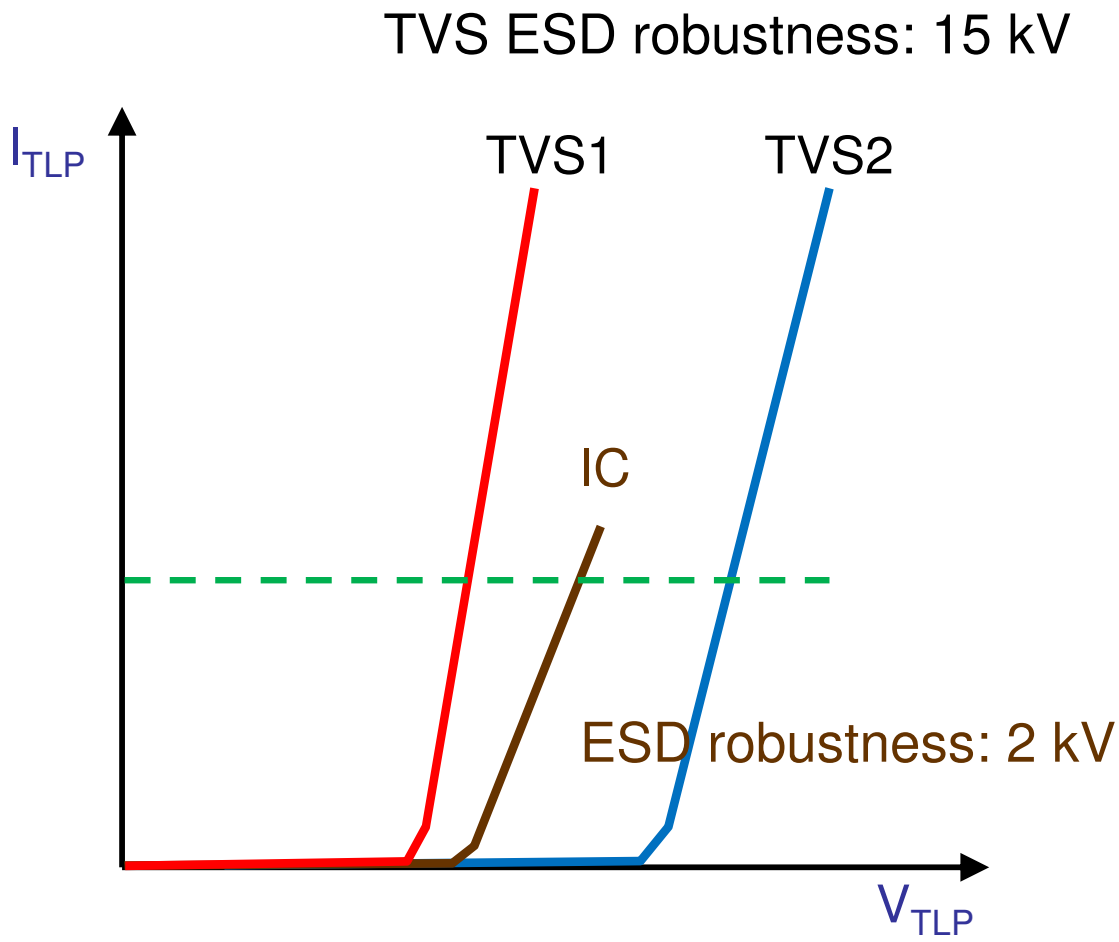
824 001	SOT23-6L				6.2	1.0		5	2		9.0	14	15/8

TLP – Transmission Line Pulsing



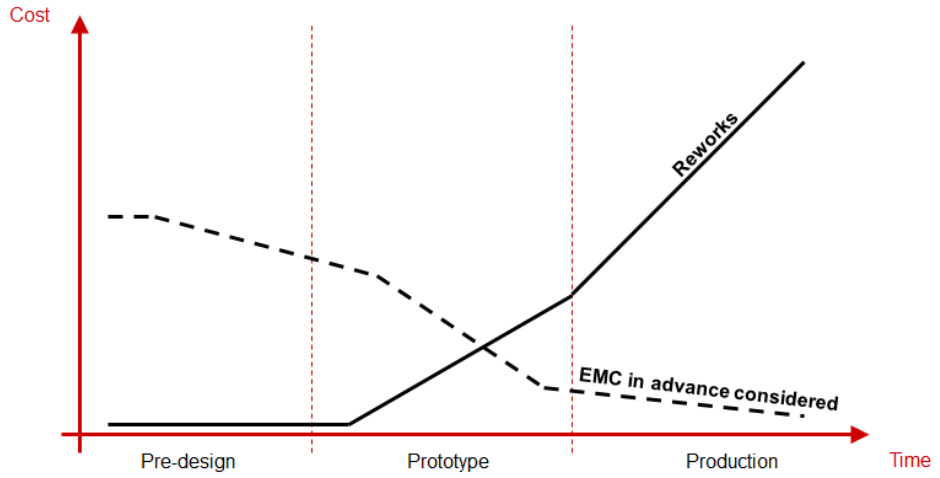
TVS vs IC: Improve ESD Robustness
Theory vs. Reality

Who protects who ??



ESD / Transient protection: Rationale

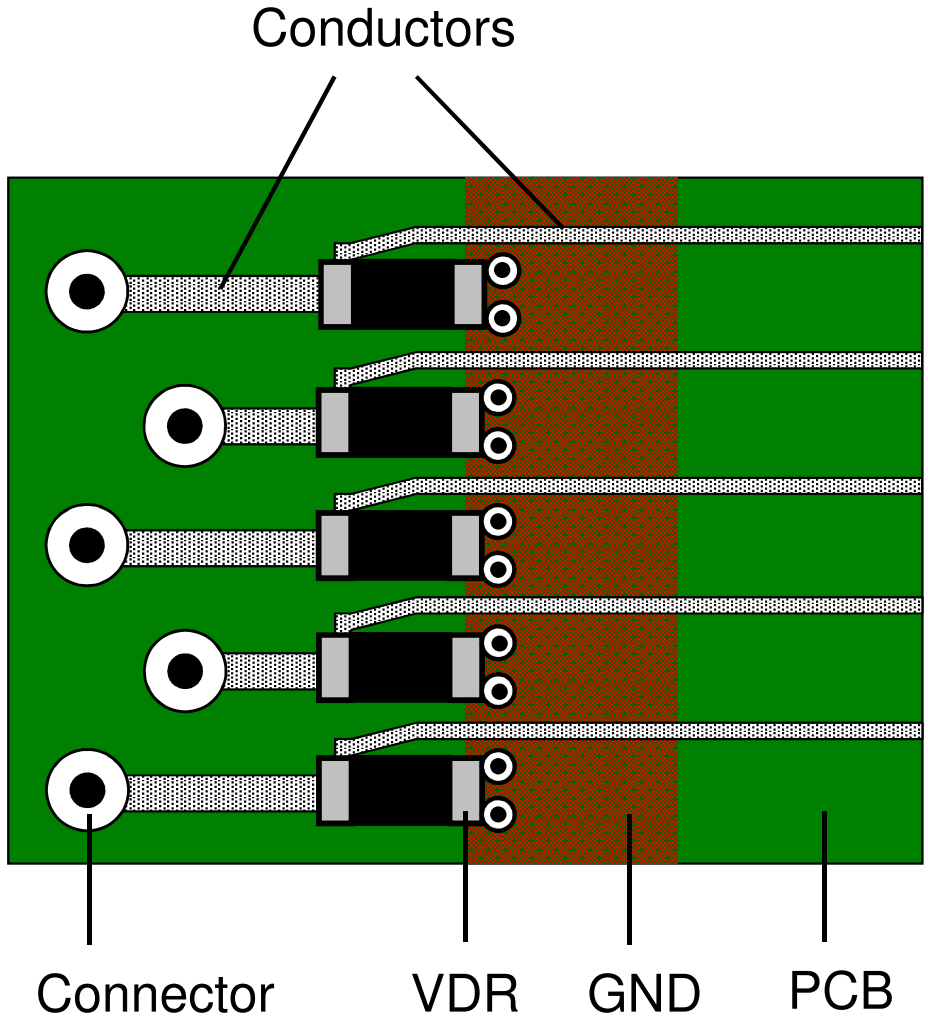
- ESD protection should be part of the original system design
- ESD hardening of a system involves the electrical, mechanical
- Digital circuits are more sensitive to ESD upset than analog circuits
- ESD has a spectral content until 4 GHz frequency range
- Ribbon cables are especially susceptible to ESD (textile WE-TS could be useful)
- All loop areas on PCB should be kept as small as possible
- Ferrites can be effective in limiting ESD currents



ESD
PCB LAYOUT RECOMMENDATIONS

PCB Layout recommendations: Suppressors placing

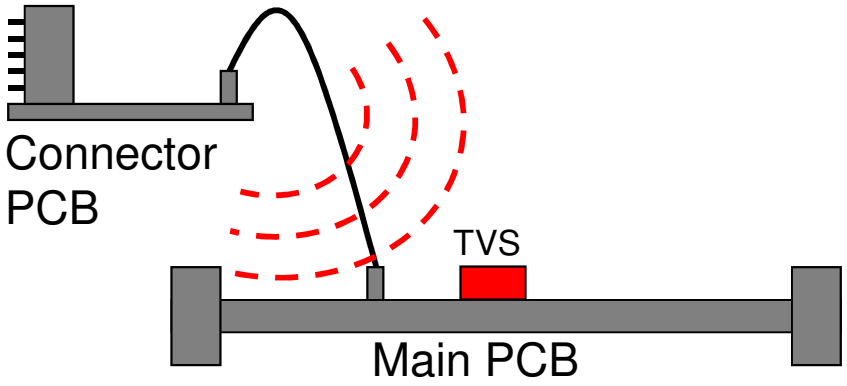
- The conductor tracks from the connector to the ESD suppressor are short and wide, if possible => low inductance.
- ESD suppressor is connected with the other pin onto a big ground plane to operate properly.
- No other conductor track is allowed to cross between the connector and the ESD suppressor => no superimposed ESD pulse to be transferred and propagate on the circuit board.



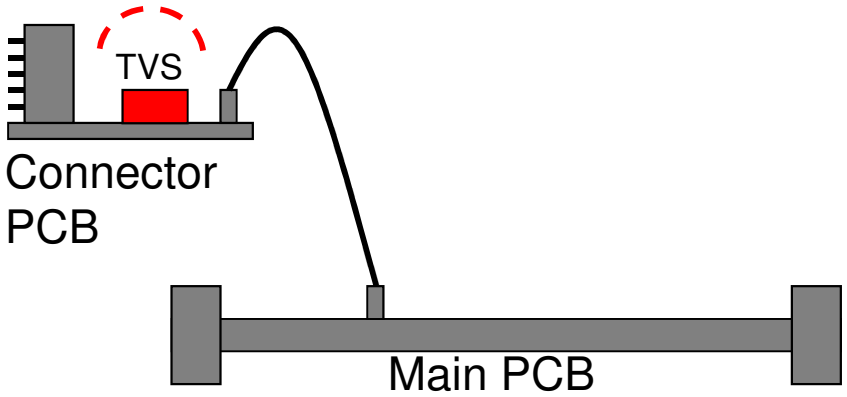
D-SUB connector layout

PCB Layout recommendations: TVS placing

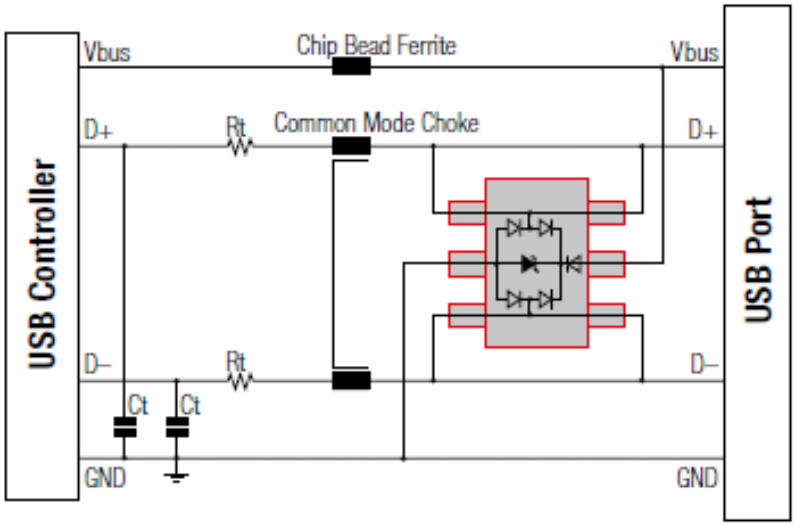
Not good



Good

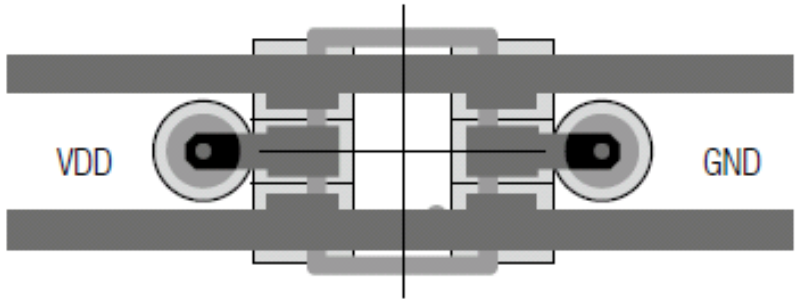


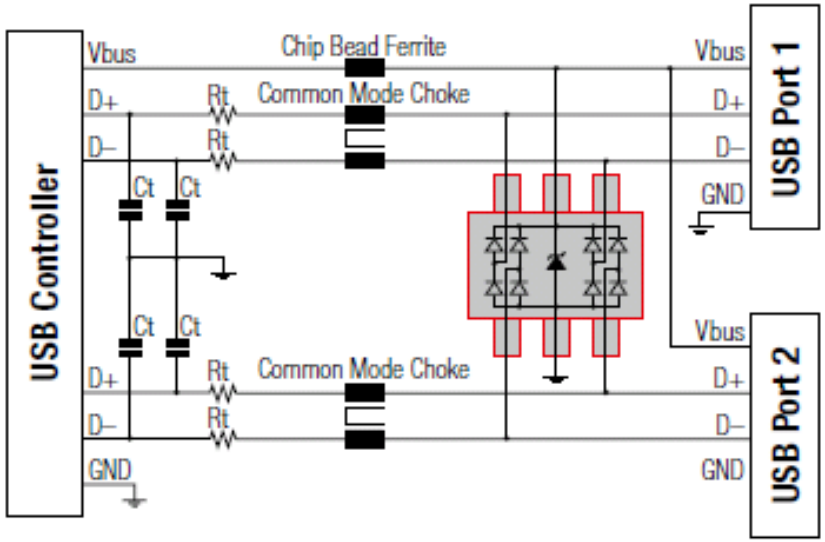
USB 2.0 : With TVS

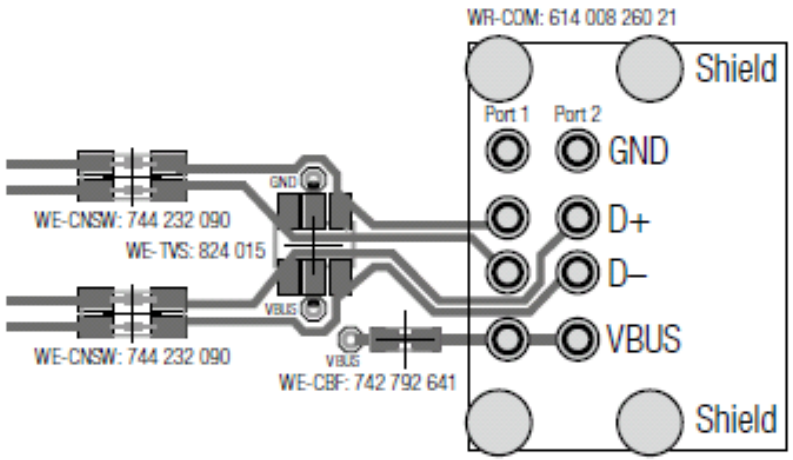


Flow Thru Design

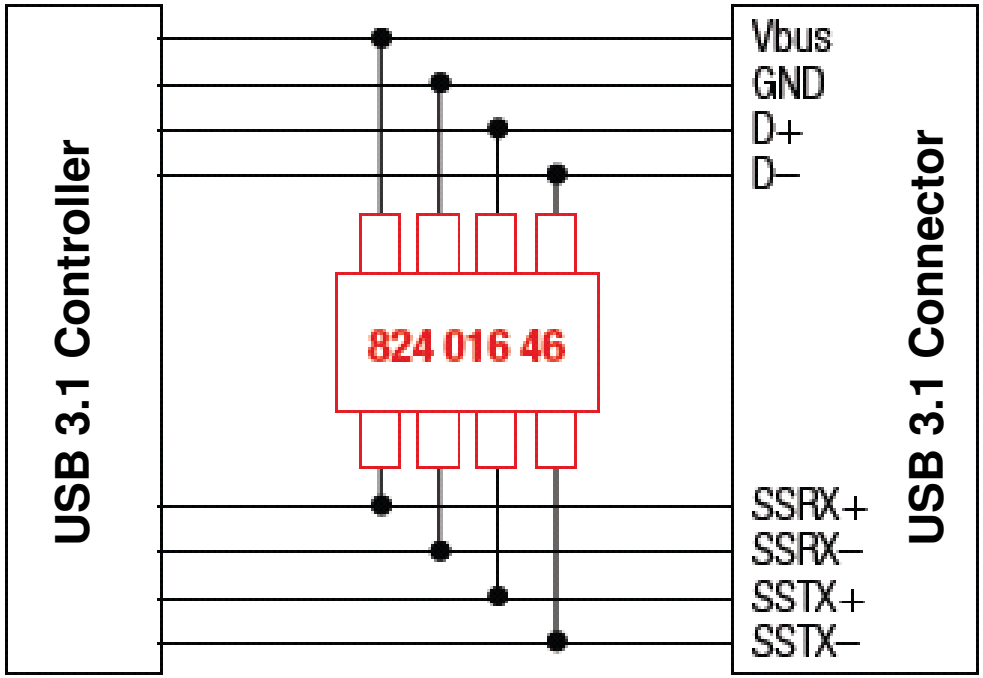
WE-TVS: 824 001x

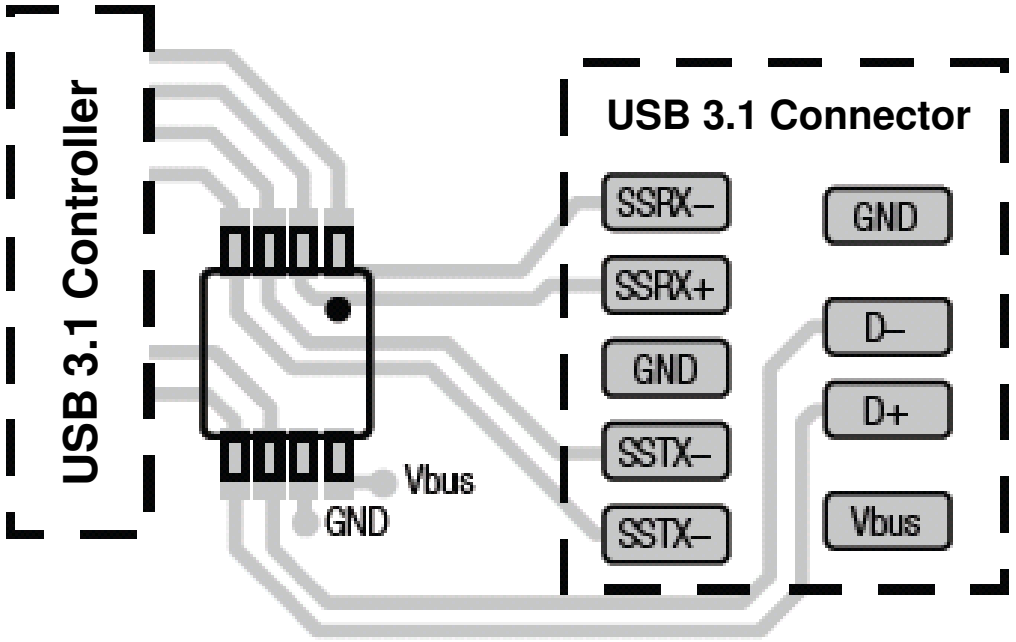






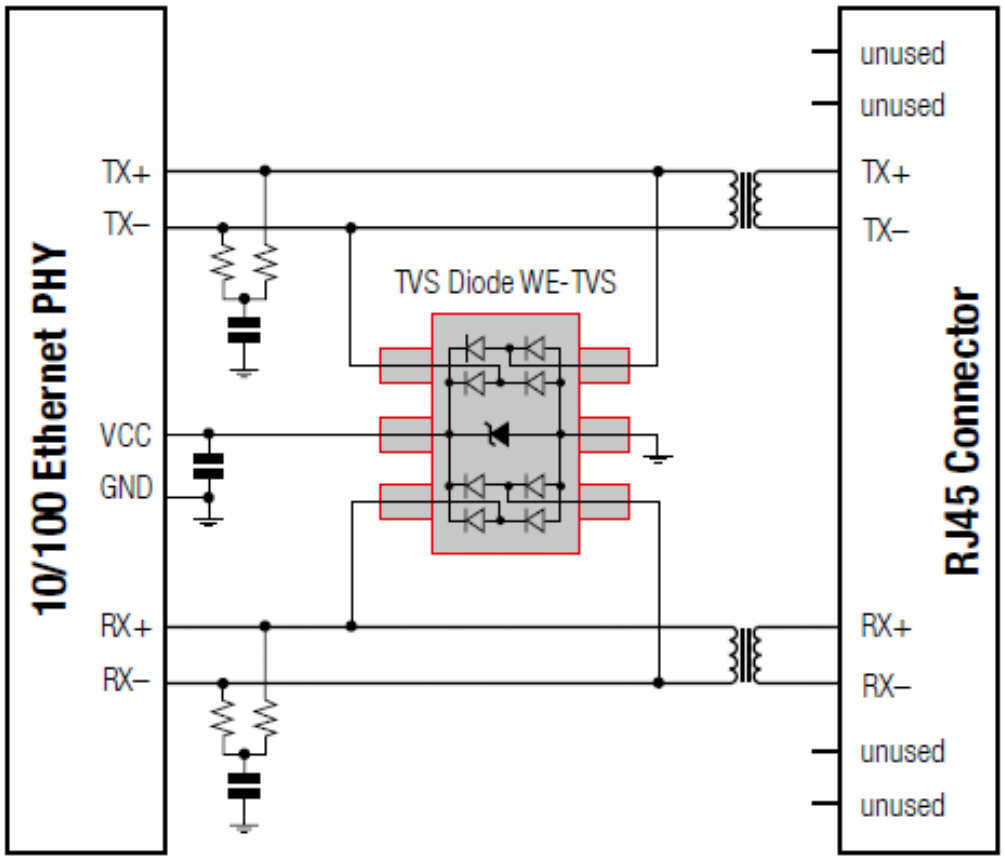
USB 3.1 : with TVS



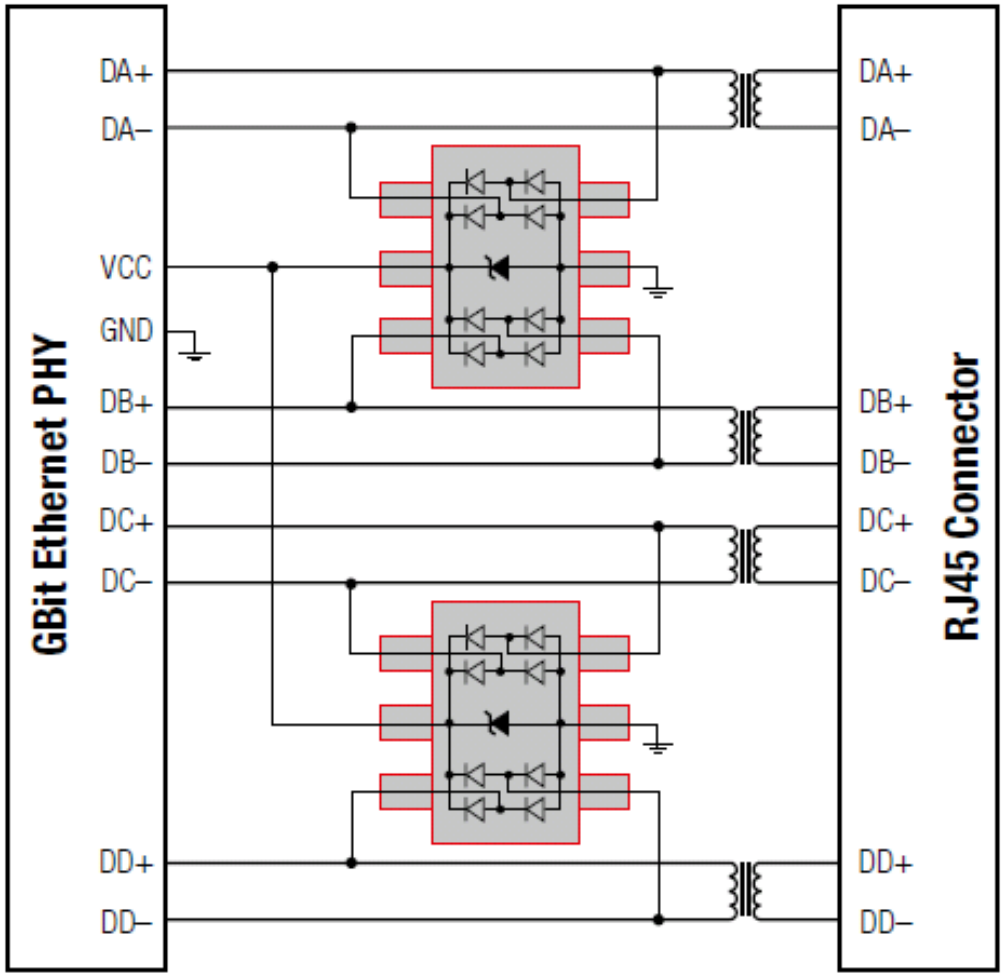


Ethernet: with TVS

10/100BaseT



1000BaseT



Thank you for your attention!
Any questions?

Bibliography

- **1)Protek Device website** (http://www.protekdevices.com/Knowledge_Base/technical_articles.php)
- **2)EMC Engineering - Henry W. Ott** (Chapter #15)
- **3)EMC Engineering - Henry W. Ott** (Chapter #14.3 - Transient Immunity pag557-575)
- **4)Trilogy of Magnetics** (from page 311 up to 349)
- **5)(only Images) Analog Devices - Safeguard Your RS-485 Communication Networks from Harmful EMC Events**(http://www.analog.com/library/analogdialogue/archives/47-05/rs485_emc.pdf)
- **6) Glen Wallis - EMC presentation november 2010**
- **7) Designers Maximize TVS Diode Performance - Jim Lepkowski** (http://powerelectronics.com/site-files/powerelectronics.com/files/archive/powerelectronics.com/mag/603PET25.pdf)
- **8)(only Images) http://www.scantech7.com/esd-electrostatic-discharge-testing-sensitive-equipment-electronics/ (transistor damage)**
- **9)(only Images)http://slideplayer.com/slide/6051683/**