TECHNICAL ACADEMY

WÜRTH ELEKTRONIK

Case study: How ESD could generate Electro Magnetic issues

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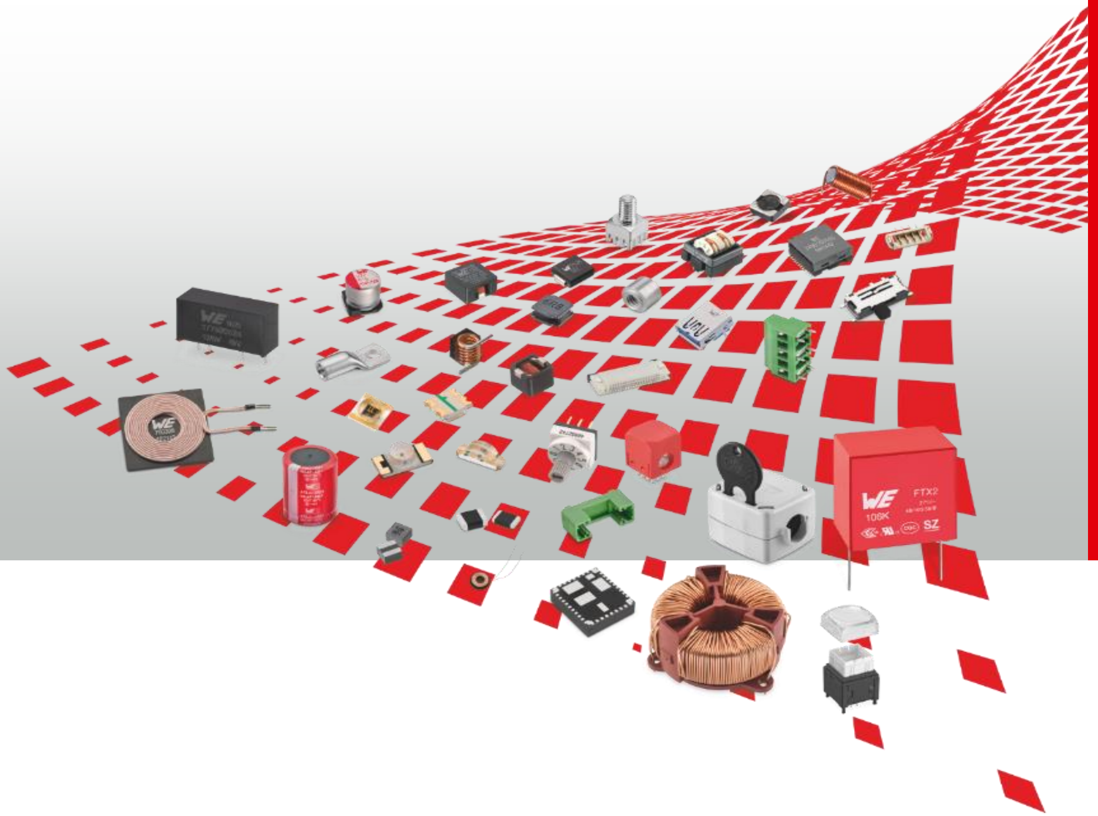
more than you expect



Agenda

- ESD Standard
- ESD Protection
- Case of Study

Types of Overvoltage: Classification

- Natural phenomena
(eg: indirect lightning strikes)

- EN 61000-4-5
High Energy Surges

- Industrial discharge
(eg: switching off inductive loads)

- EN 61000-4-4
Electric Fast Transient (E.F.T.)

- Electro-Static-Discharge
(eg: between humans and materials)

- EN 61000-4-2
ElectroStatic Discharge (E.S.D.)

EU's transient immunity standards for commercial products: The product must continue to operate as intended, without degradation or loss of function after the transient immunity test.

Types of overvoltage: characteristics of High-Voltage Transients

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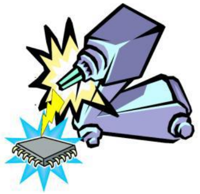
Transient	Voltage	Current	Rise Time	Pulse Width	Pulse Energy
Surge	0,5-2,0 kV	100-1000 A	1,25 µs	50 µs	10-80 J
EFT (Single)	0,5-2,0 kV	10-100 A	5 ns	50 ns	4 mJ
EFT (Burst)	0,5-2,0 kV	10-100 A	n/a	15 ms	100-1000 mJ
ESD (Contact)	2,0-8,0 kV	7,5-30 A	1 ns	100 ns	1-10 mJ

Key Parameter

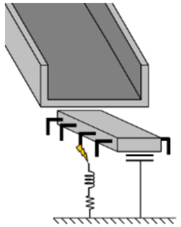
Types of ESD event: main characteristics

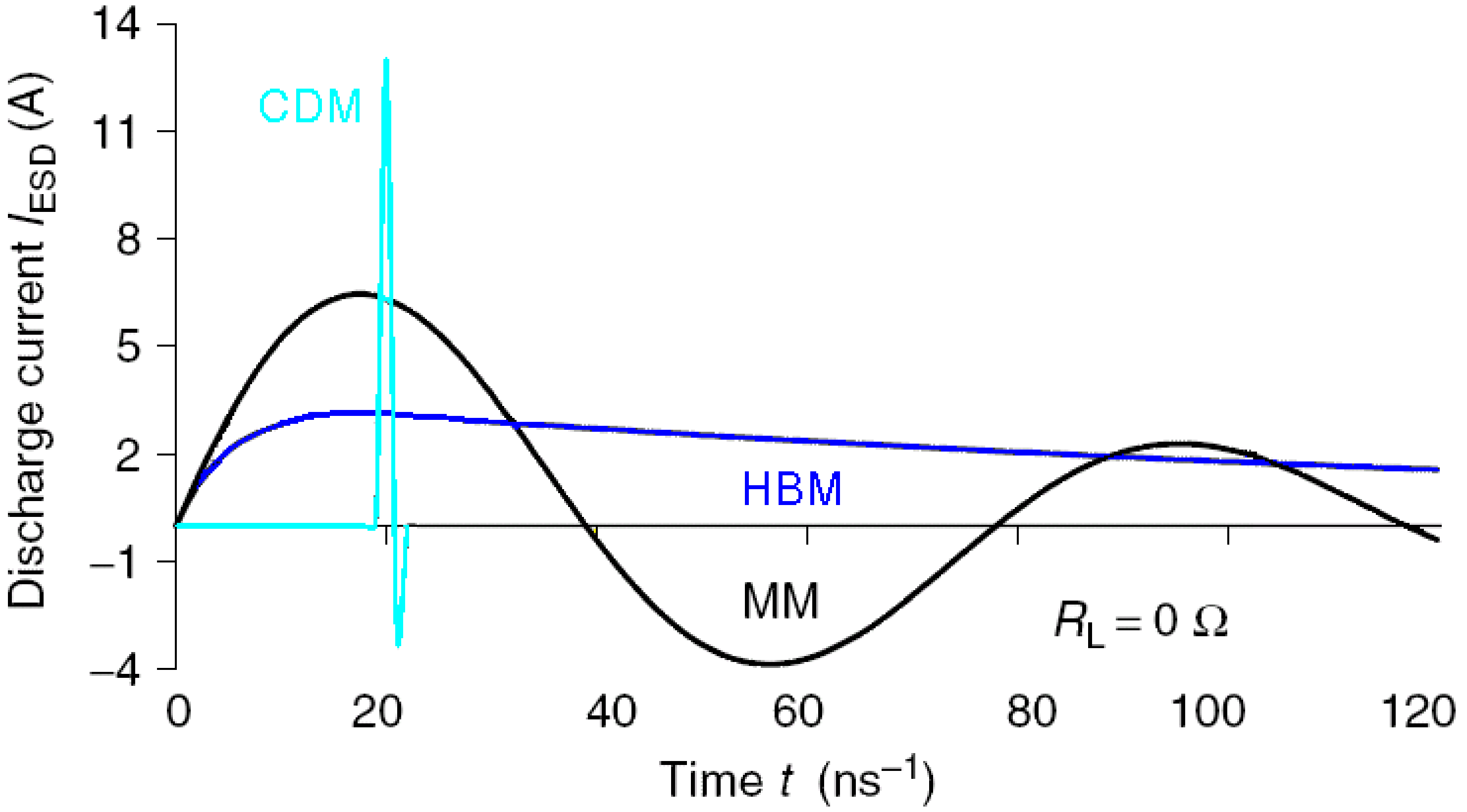
- HBM (Human Body Model)

- MM (Machine Model)



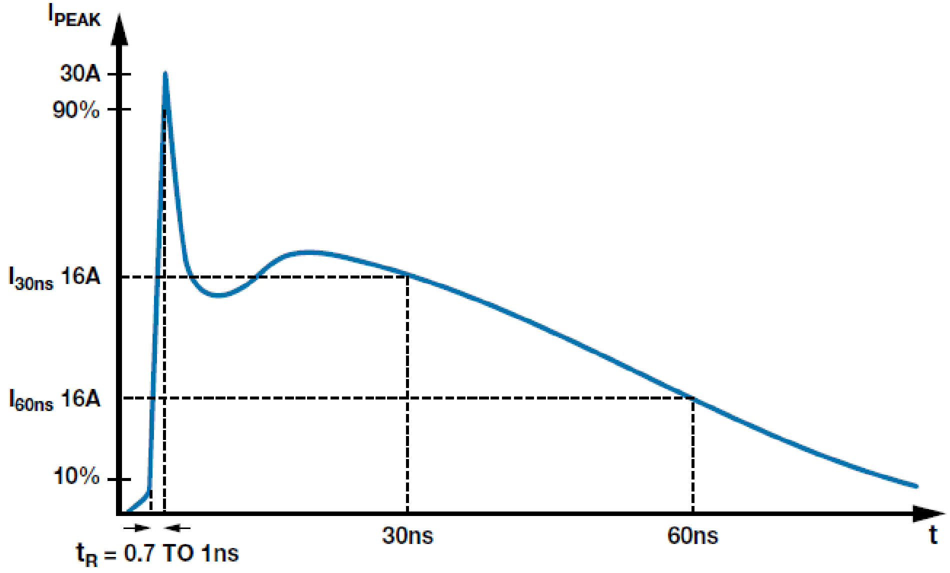
- CDM (Charge Device Model)



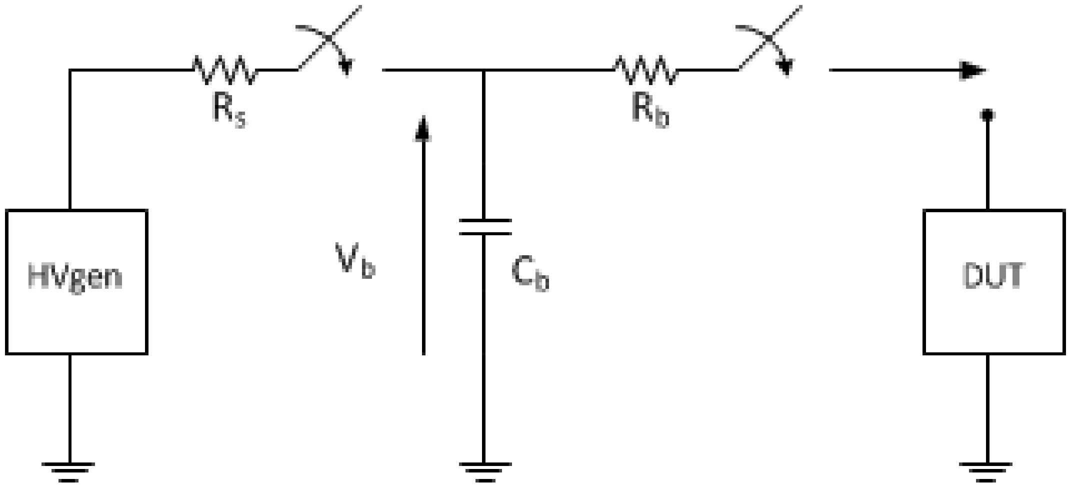


HBM: Specification

- Surge 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.



- with values for EN 61000-4-2 => Rs=50-100MΩ, Cb=150pF, Rb=330Ω, RDUT= 2Ω

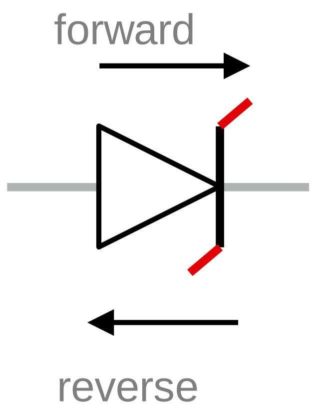
HBM: Different levels I-V pulses

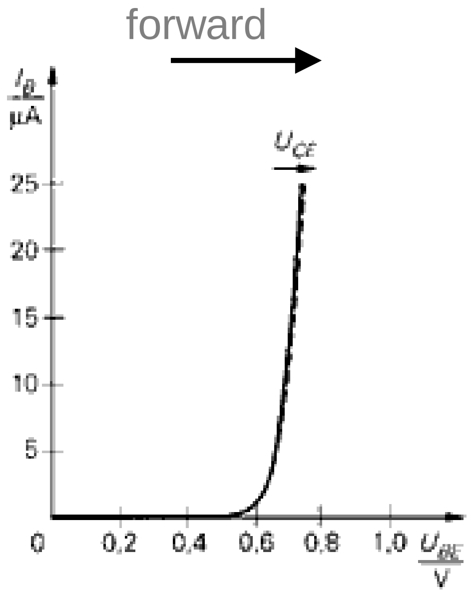
IEC 61000-4-2 Voltage Levels and Current amount during a strike

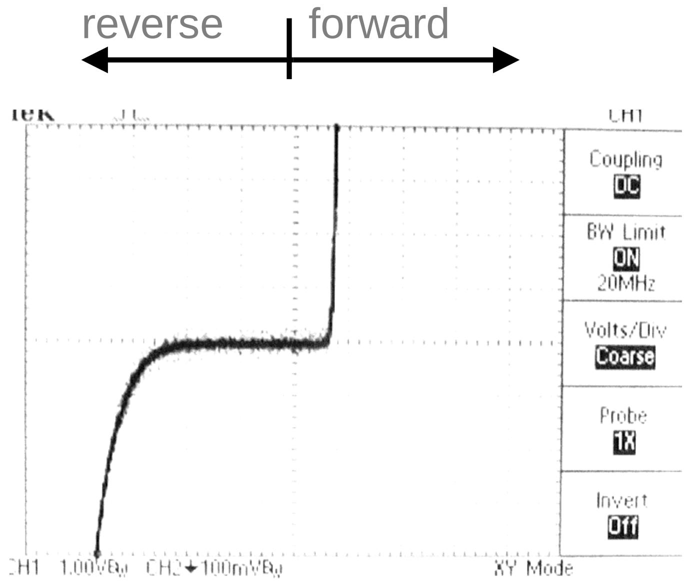
Level	Contact Discharge		Air Discharge	
	Test Voltage kV	Peak Current (A) IEC 61000-4-2	Test Voltage kV	Peak Current (A) IEC 61000-4-2
1	2	7.5	2	7.5
2	4	15	4	15
3	6	22.5	8	30
4	8	30	15	-
X*	Special	Special	Special	Special

ESD 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**

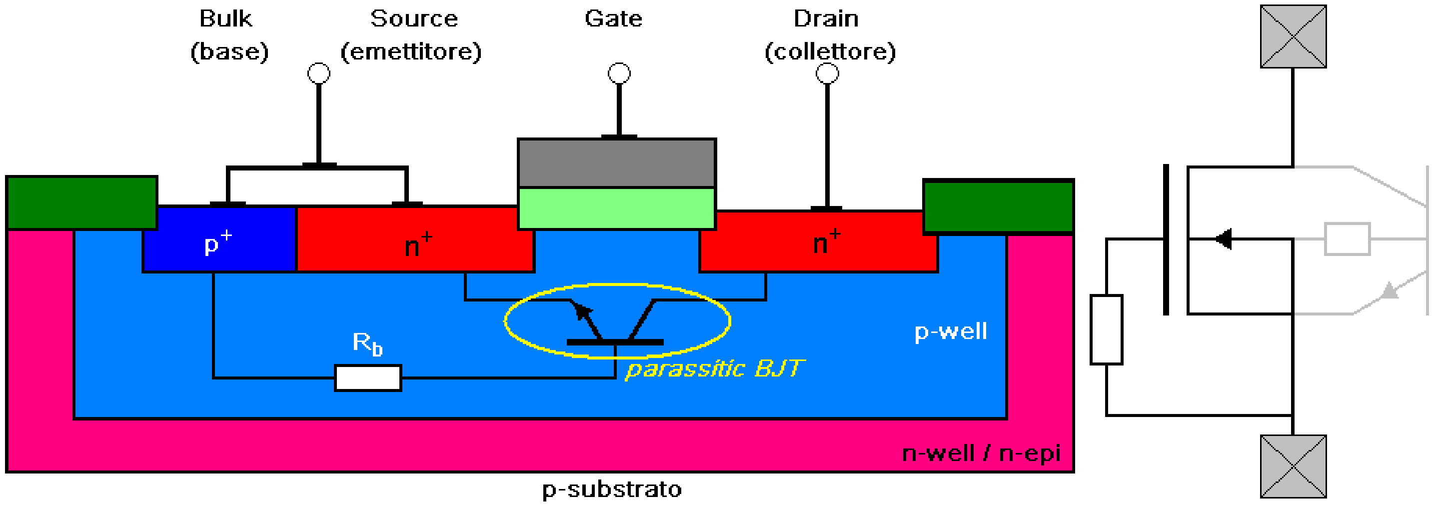






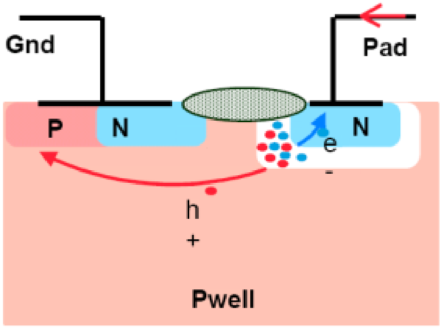
ESD protection: Inside Silicon

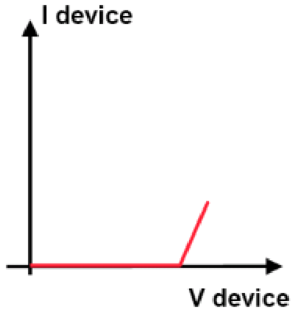
- During ESD event superficial current capability of Si-device is not enought
- Only using vertical parasitic BJT an ESD protection can be efficient
- An ESD «passive» protection, works in «snap back» configuration



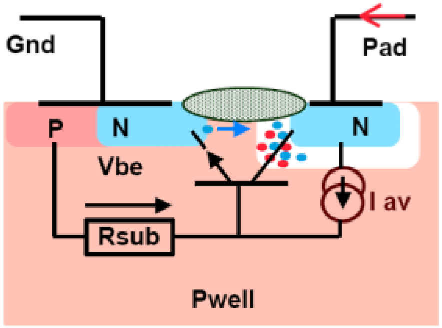
ESD protection: Snap Back Behavior

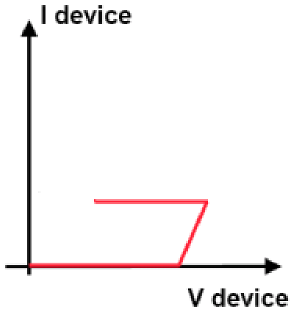
V_{pad} increase → avalanche generation due to High E Field



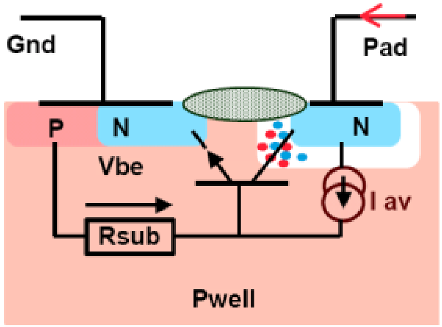


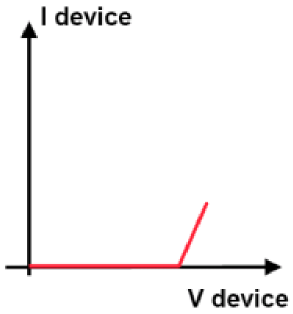
BJT starts→ more e^- from emitter to collector → decrease of voltage



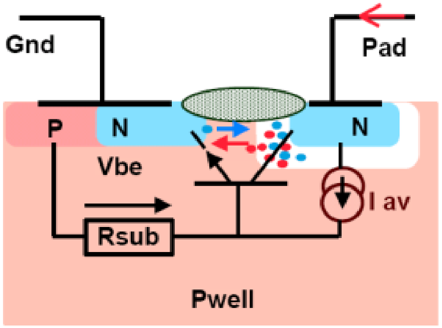


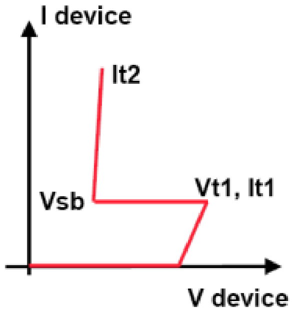
I_{Rsub} increase → start to drive the NPN when V_{BE}=0,7V





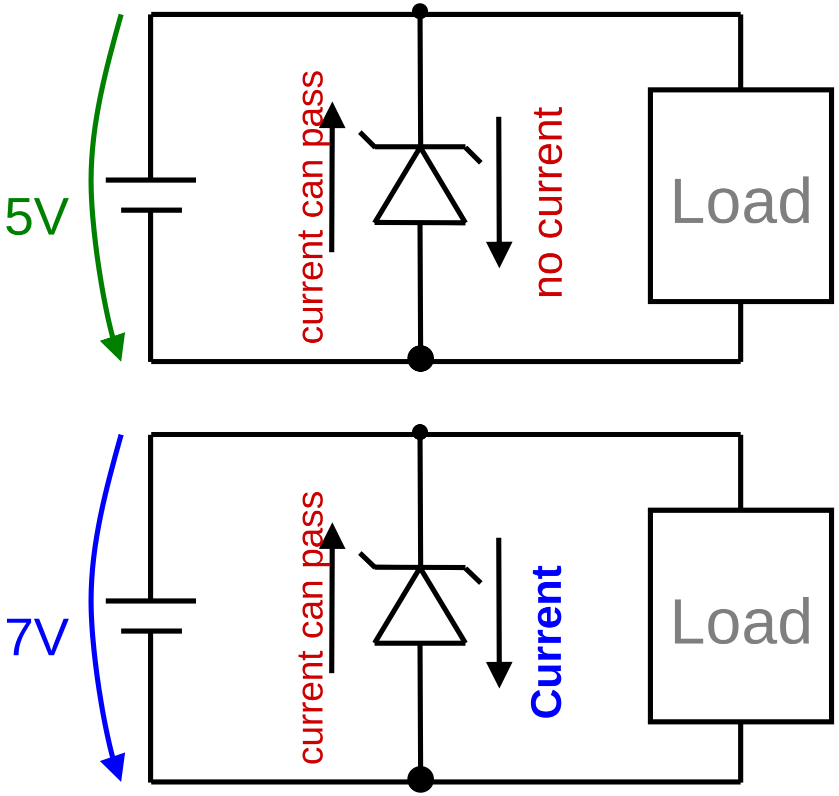
Due to high current → self polarization of the base → low R_{ON}

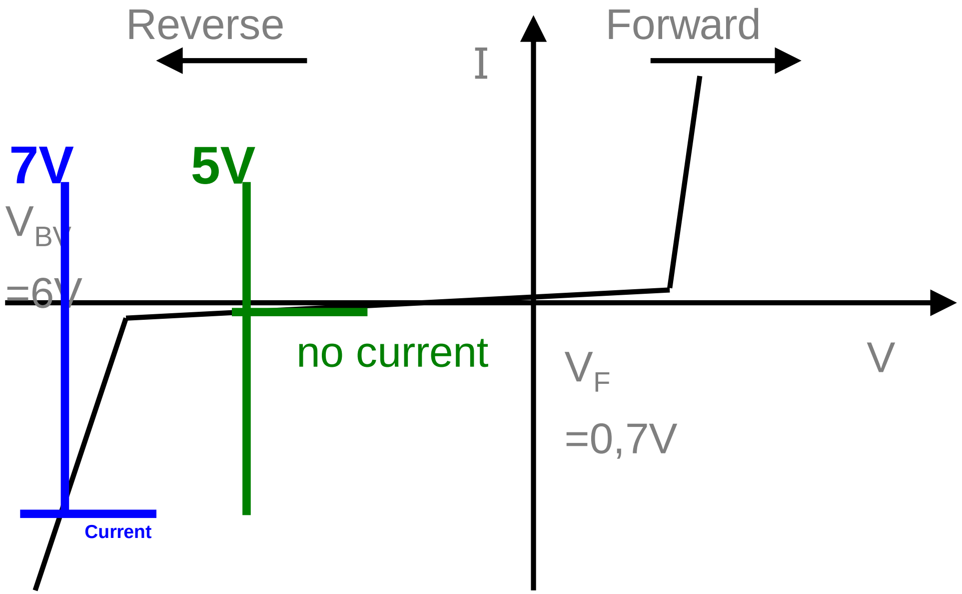




ESD protection : Diodes and Zener diodes

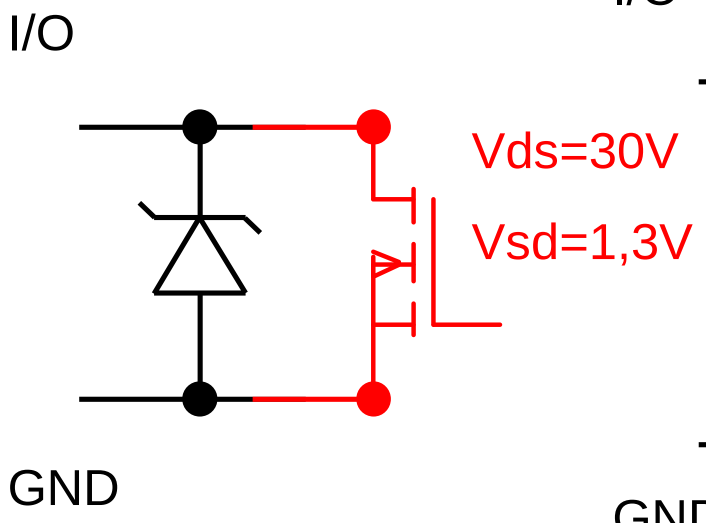
- **Zener Diodes or TVS Diodes** are connected in **reverse direction**
- There's no current through the diode due to **breakdown voltage is not exceeded**
- If **voltage is larger than breakdown voltage** there is current through diode



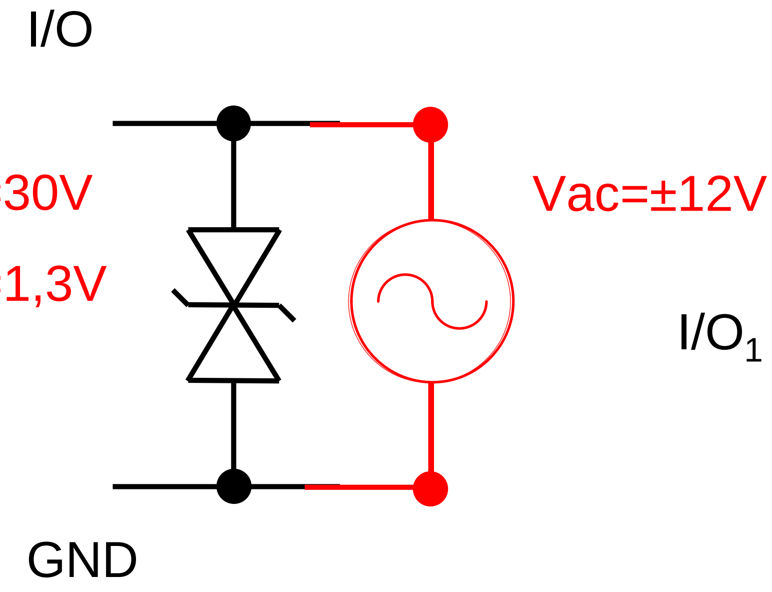


ESD: Topologies

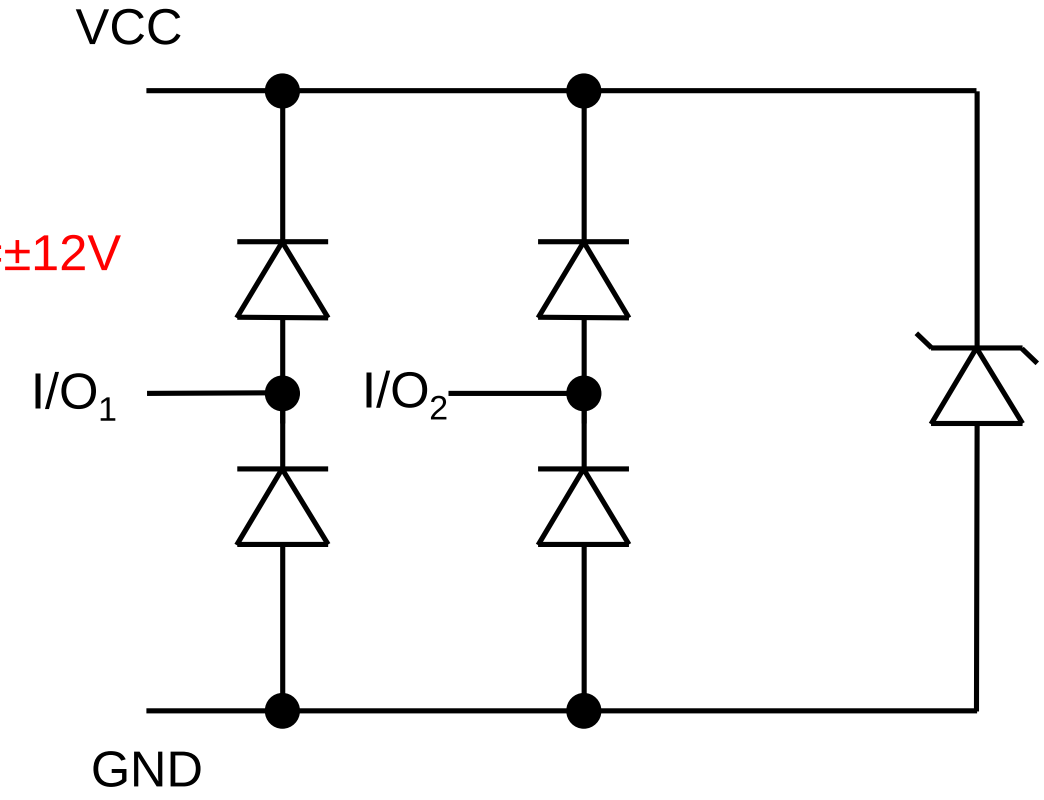
Uni-polar



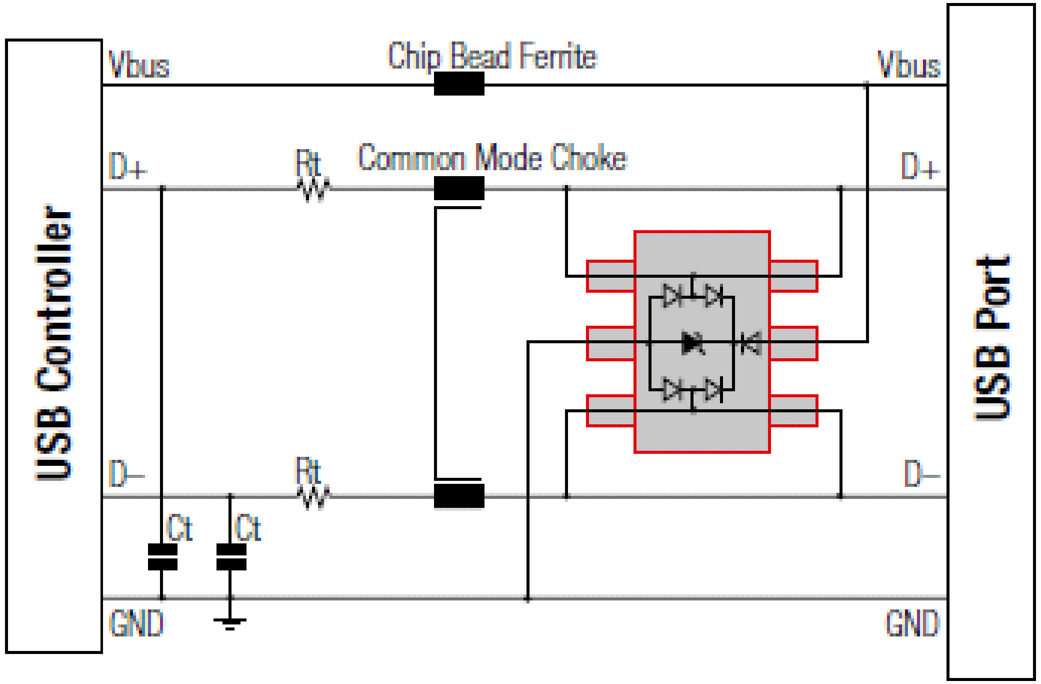
Bi-polar

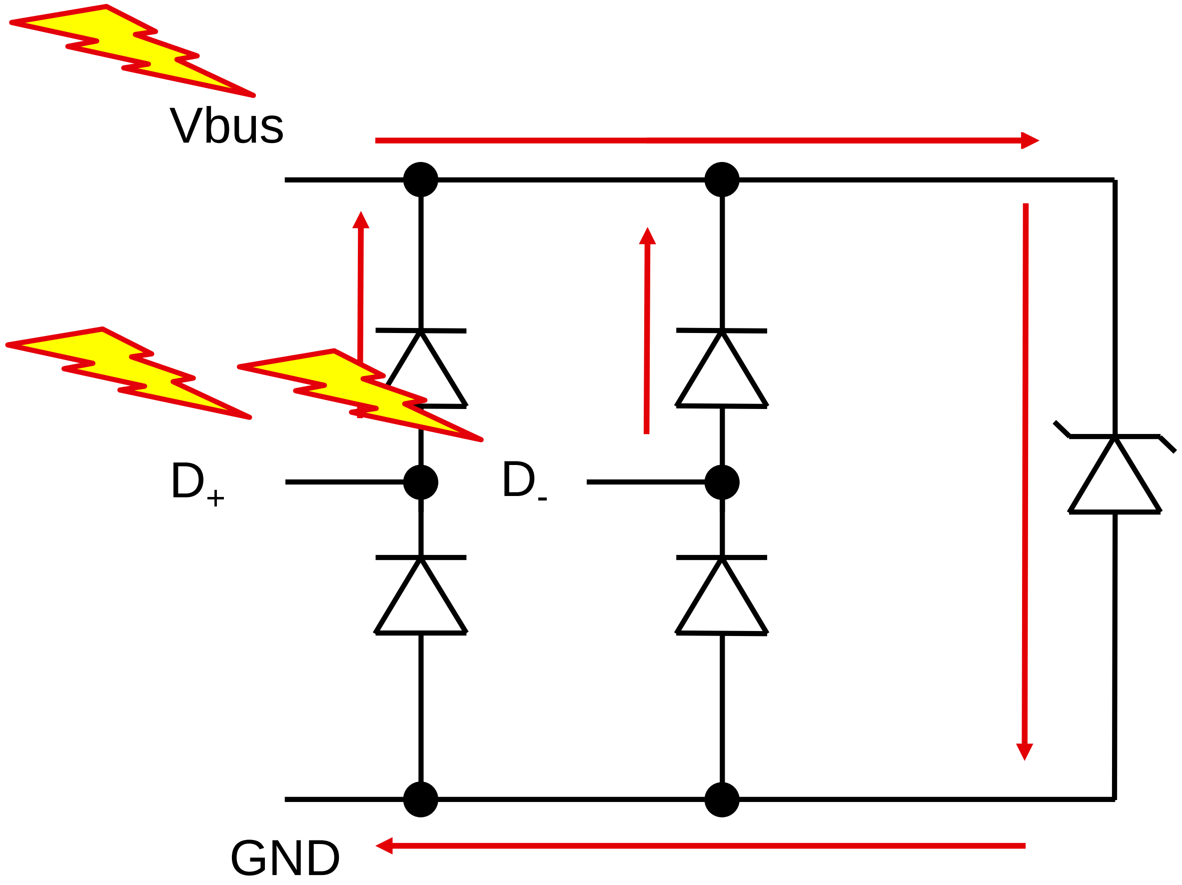


Rail-to-Rail (more ports share a single protection)



ESD: Topologies (USB 2.0)

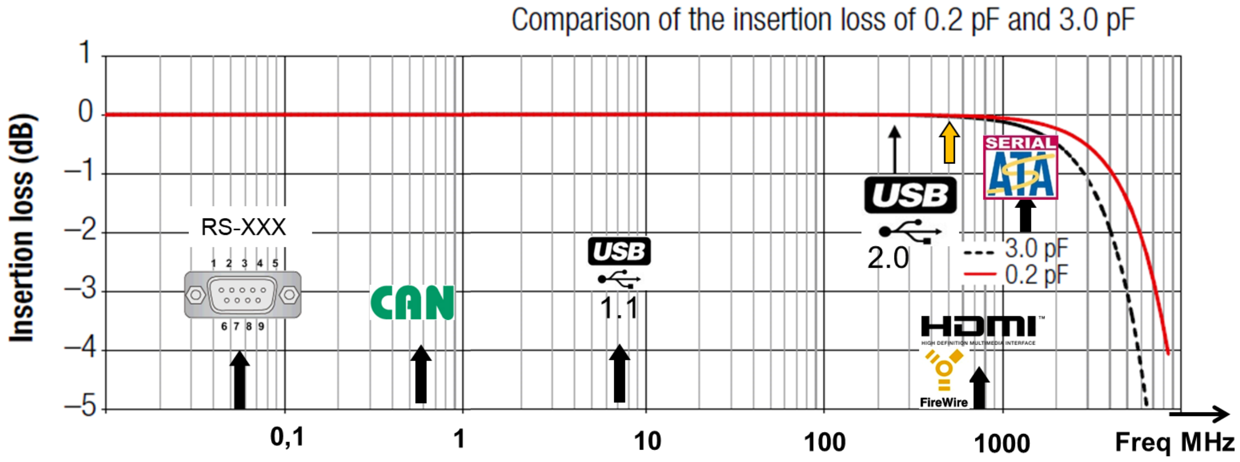




ESD: Selection process

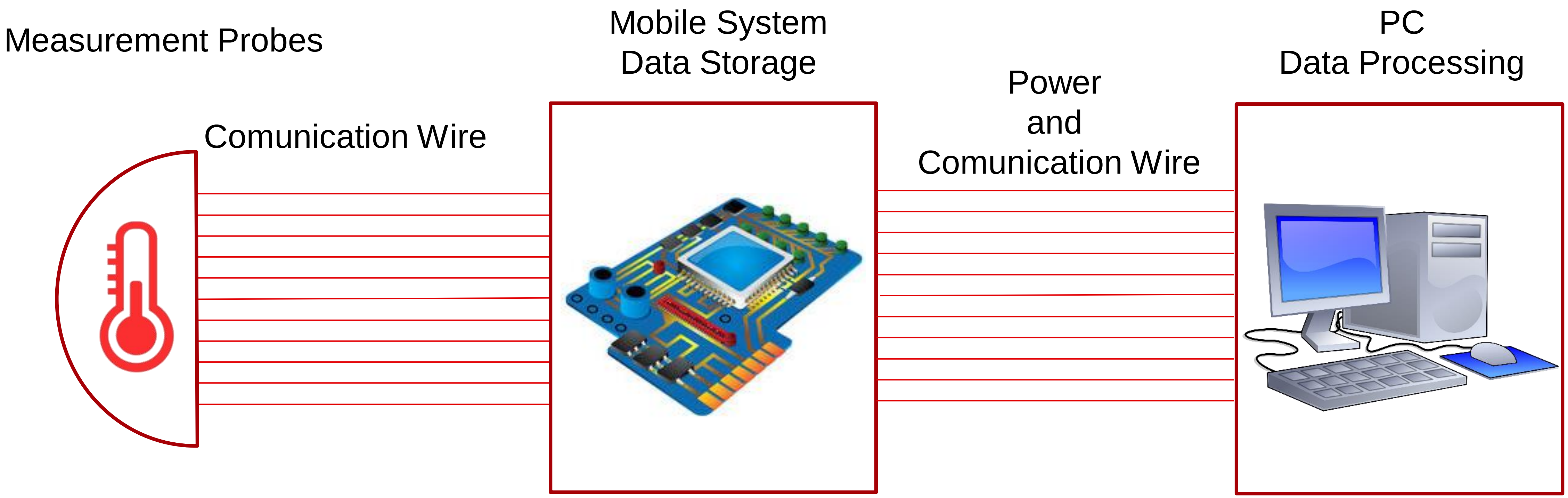
- ESD suppressor differ from SMD varistor in their lower and specified capacitance:

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

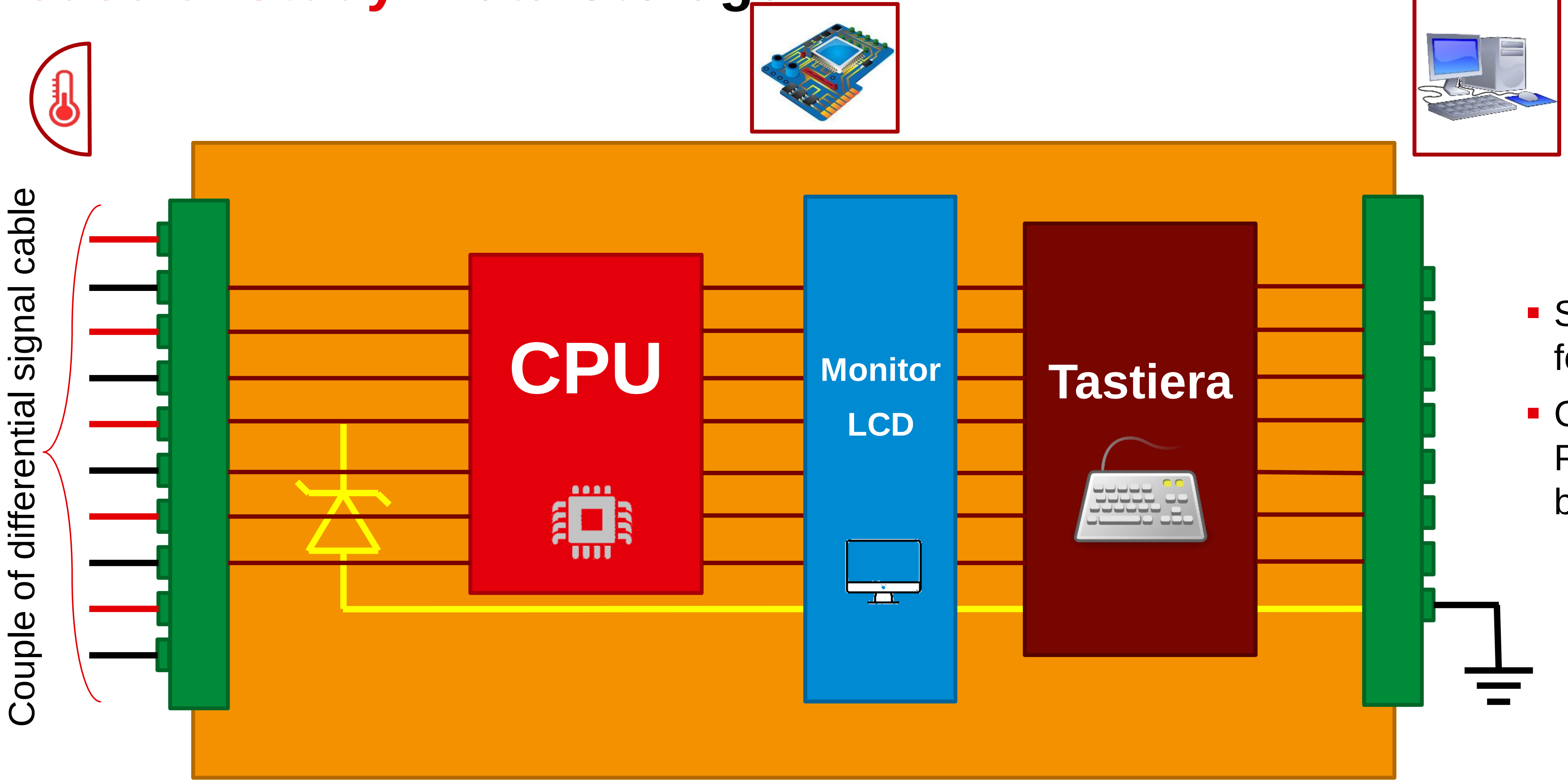


Case of Study: General Information

- Application: Industrial
  - Metering system for electrical signal (temperature, light, …)



Case of Study: Data Storage



- Same protection for all data lines
- Ground plane on PC, not on mobile board

Case of Study: ESD Protection Selection

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- Selection of the device using www.we-online.com
- Electric Parameter:
  - Line frequency: 500 kHz
  - Line Voltage: 5V

Order Code	SPEC	Downloads	V_{DC} (V)	I_{Leak} (µA)	$V_{Clamp\ typ.}$ (V)	$V_{ESD\ Air}$ (kV)	R_{ISO}	Application	Design Kit	Samples
82357050100	PDF	STP ALT EAG ZUK IGS CDS	5	1	60	15	10 MΩ	USB 1.1 RS-232 LAN 10 Mbit	–	1
82357050220	PDF	STP ALT EAG ZUK IGS CDS	5	1	55	15	10 MΩ	–	823999	1
82357050330	PDF	STP ALT EAG ZUK IGS CDS	5	1	55	15	10 MΩ	RS-422	823999	1
82357050560	PDF	STP ALT EAG ZUK IGS CDS	5	1	55	15	10 MΩ	RS-485 IrDA 1.0	–	1
82356050050	PDF	STP ALT EAG ZUK IGS CDS	5	1	75	15	10 MΩ	USB 1.1 USB 2.0	744999 823999	1
82356050100	PDF	STP ALT EAG ZUK IGS CDS	5	1	60	15	10 MΩ	–	–	1
82356050220	PDF	STP ALT EAG ZUK IGS CDS	5	1	55	15	10 MΩ	–	823999	1
82356050560	PDF	STP ALT EAG ZUK IGS CDS	5	1	55	15	10 MΩ	–	–	1
82356050101	PDF	STP ALT EAG ZUK IGS CDS	5	1	55	15	10 MΩ	RS-485 Sensors	823999	1

WE-TVS TVS Diode – Standard Series
V_{DC} 5 to 20 V | $V_{ESD\ Contact}$ 10 to 30 kV | $V_{ESD\ Air}$ 16 to 30 kV

WE-TVS TVS Diode – High Speed Series
V_{DC} 3.3 to 5 V | $V_{ESD\ Contact}$ 8 to 24 kV | $V_{ESD\ Air}$ 15 to 30 kV

WE-TVS TVS Diode – Super Speed Series
V_{DC} 1.2 to 5 V | $V_{ESD\ Contact}$ 8 to 15 kV | $V_{ESD\ Air}$ 15 to 16 kV

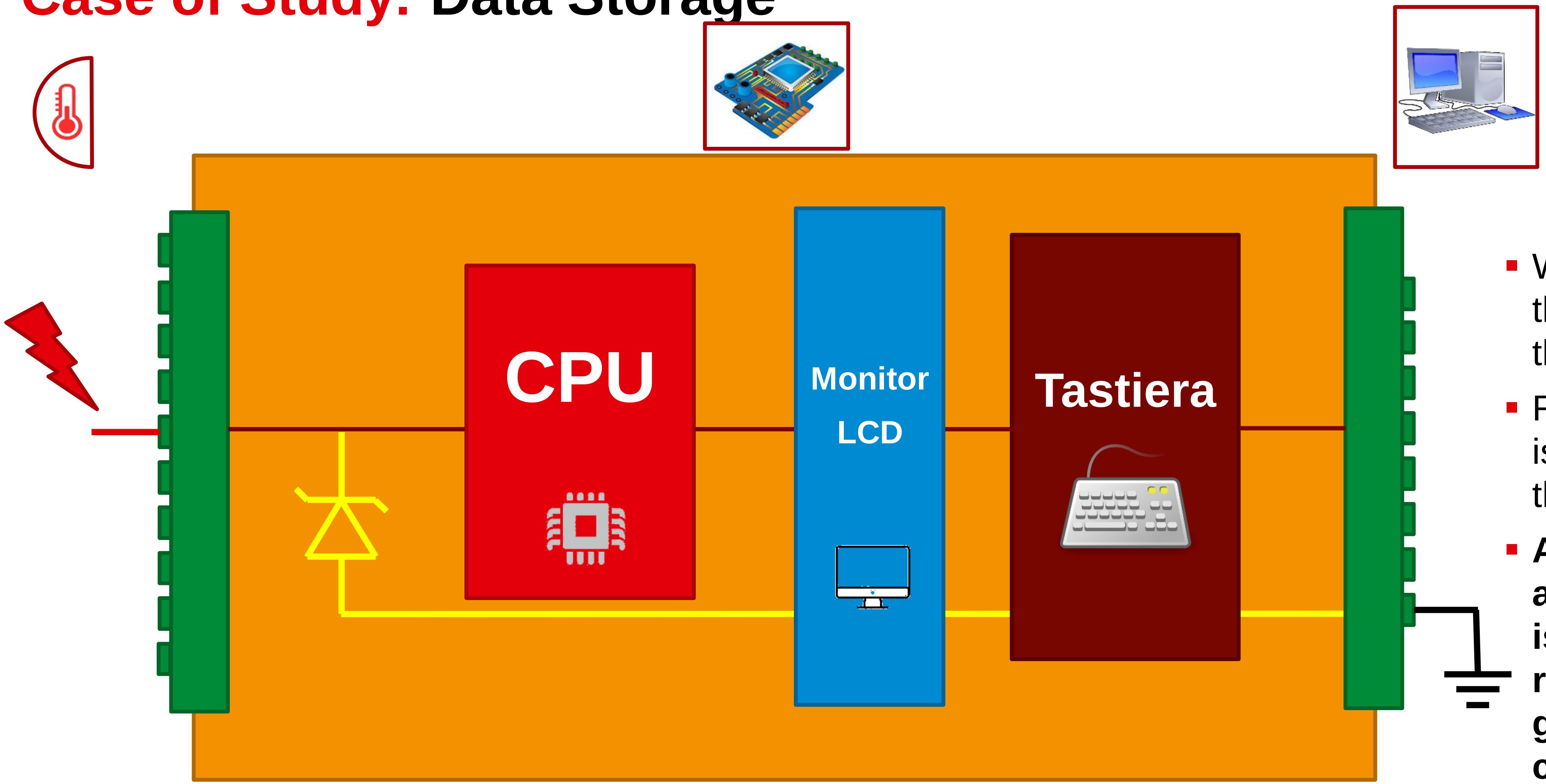
WE-VE ESD Suppressor
V_{DC} 5 to 24 V | $V_{ESD\ Air}$ 15 kV

WE-VE ULC ESD Suppressor
V_{DC} 5 to 12 V | $V_{ESD\ Air}$ 15 kV

WE-VE femtoF NEW
V_{DC} 6 to 26 V | $V_{ESD\ Contact}$ 8 kV | $V_{ESD\ Air}$ 15 kV

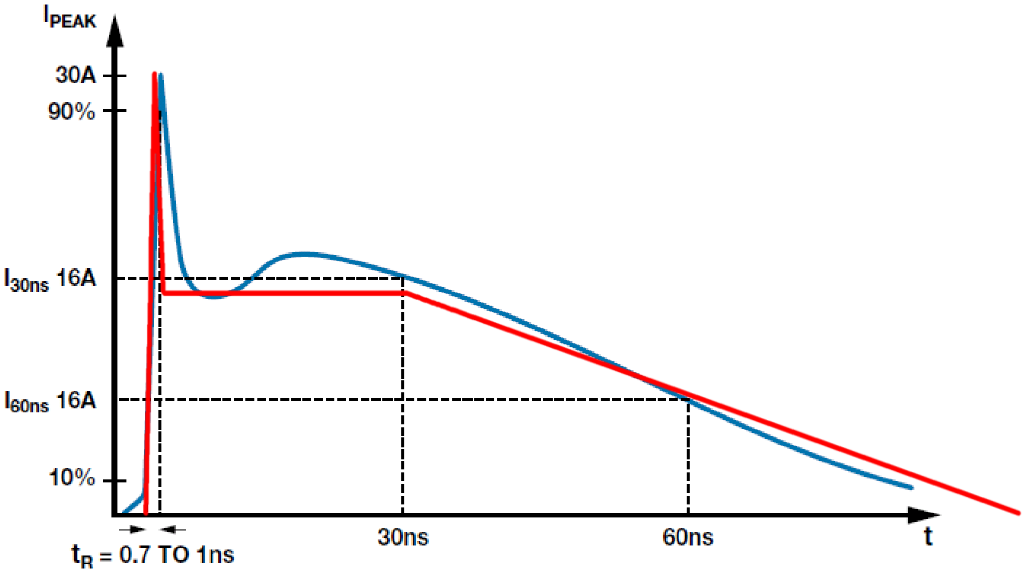
WE-VEA ESD Suppressor-Array
V_{DC} 5 to 18 V

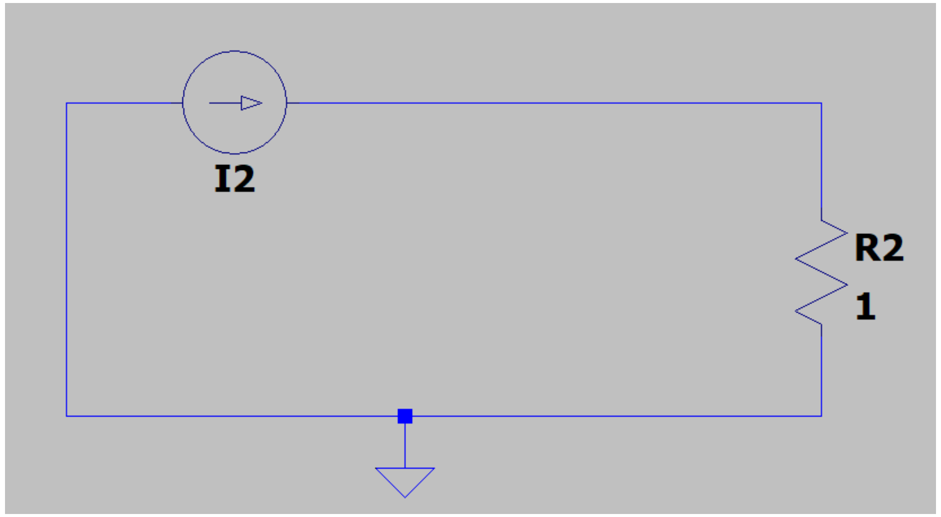
Case of Study: Data Storage



- With ESD event there is a bug on the monitor
- Removal of battery is needed to reset the bug
- **After several analisys the bug is caused by radiation on the ground connection**

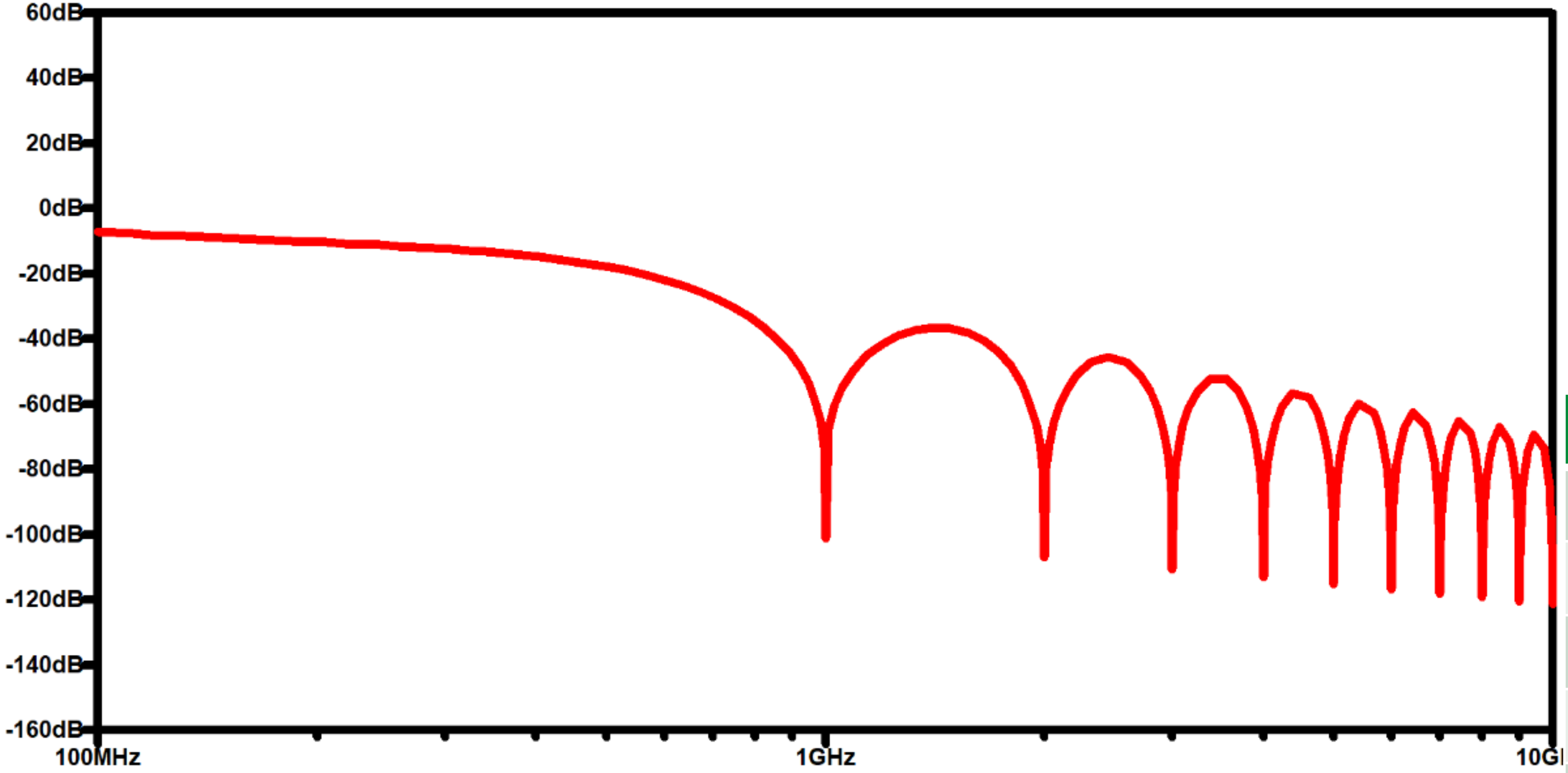
HBM Spice Simulation: Time Domain





- Simulation using LTSpice®
  - ESD pulses simulated using a current source reproducing IEC 61000-4-2 (HBM)
  - Analysis focused at frequencies between 500MHz and 10GHz

HBM Spice Simulation: Frequency Domain (FFT)



- High Noise @ 1GHz and higher order harmonics
- λ/2 antenna around cm
- Bad antennas around mm

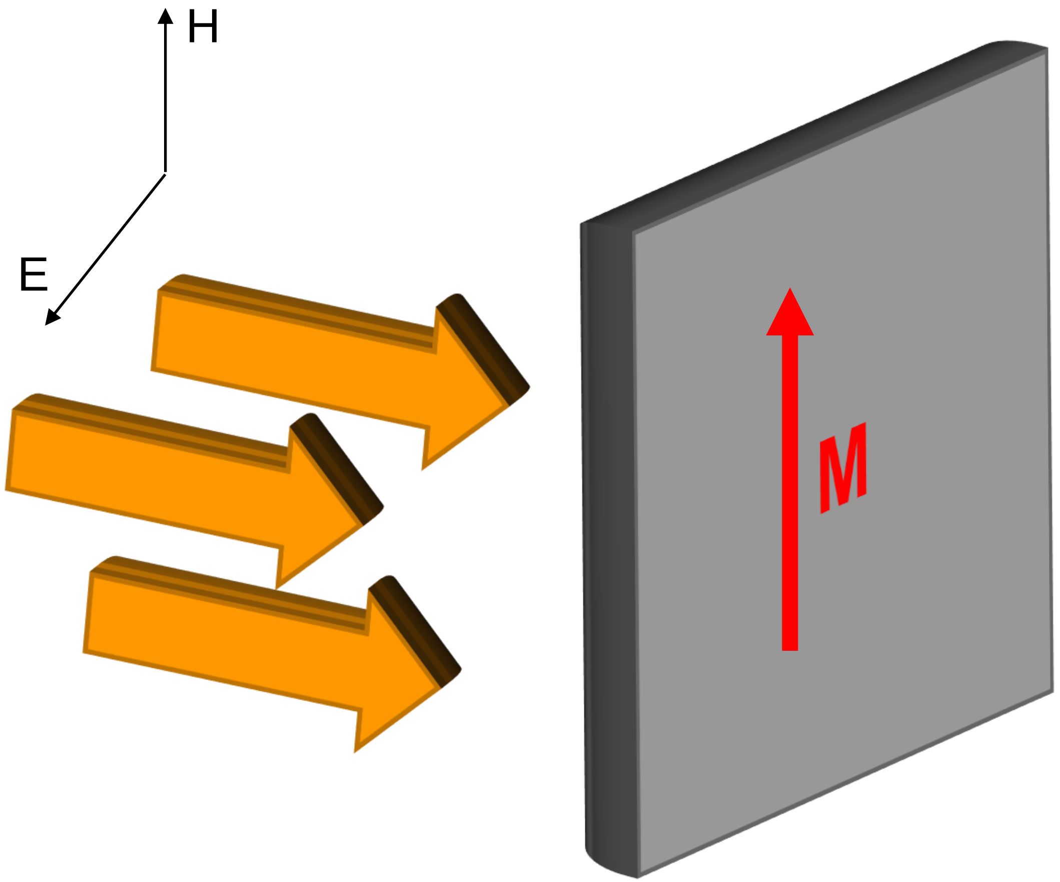
F	λ	λ/2	λ/10
1 GHz	30 cm	15 cm	3,00 cm
2 GHz	15 cm	7,50 cm	1,50 cm
4 GHz	7,50 cm	3,75 cm	0,75 cm
6 GHz	5,00 cm	2,50 cm	0,50 cm
8 GHz	3,75 cm	1,87 cm	0,37 cm
10GHz	3,00 cm	1,50 cm	0,30 cm

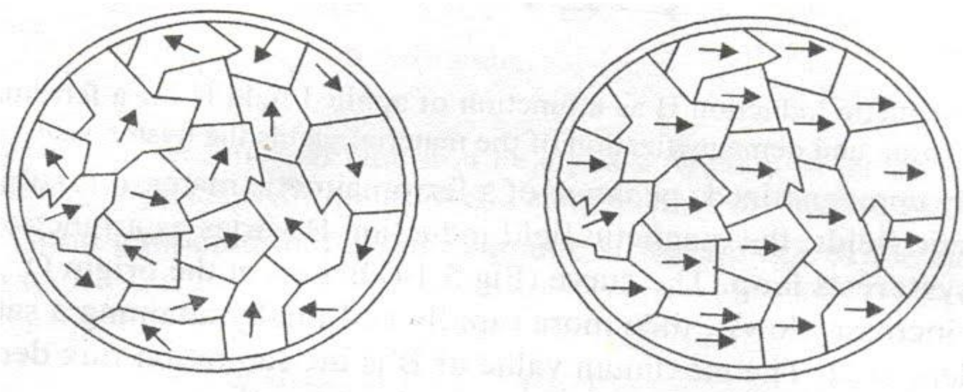
HBM Spice Simulation: High Frequency Attenuation

- To reduce high frequency noise 2 ways are possible:
  - Filtering the noise on the cable before it bacames radiation
    - Inductor and Capacitor
    - Ferrite


  - Filtering the noise alter radiation using shielding material
    - Conductive shielding
    - Magnetic shielding

Magnetic Shield with Ferrite: Losses

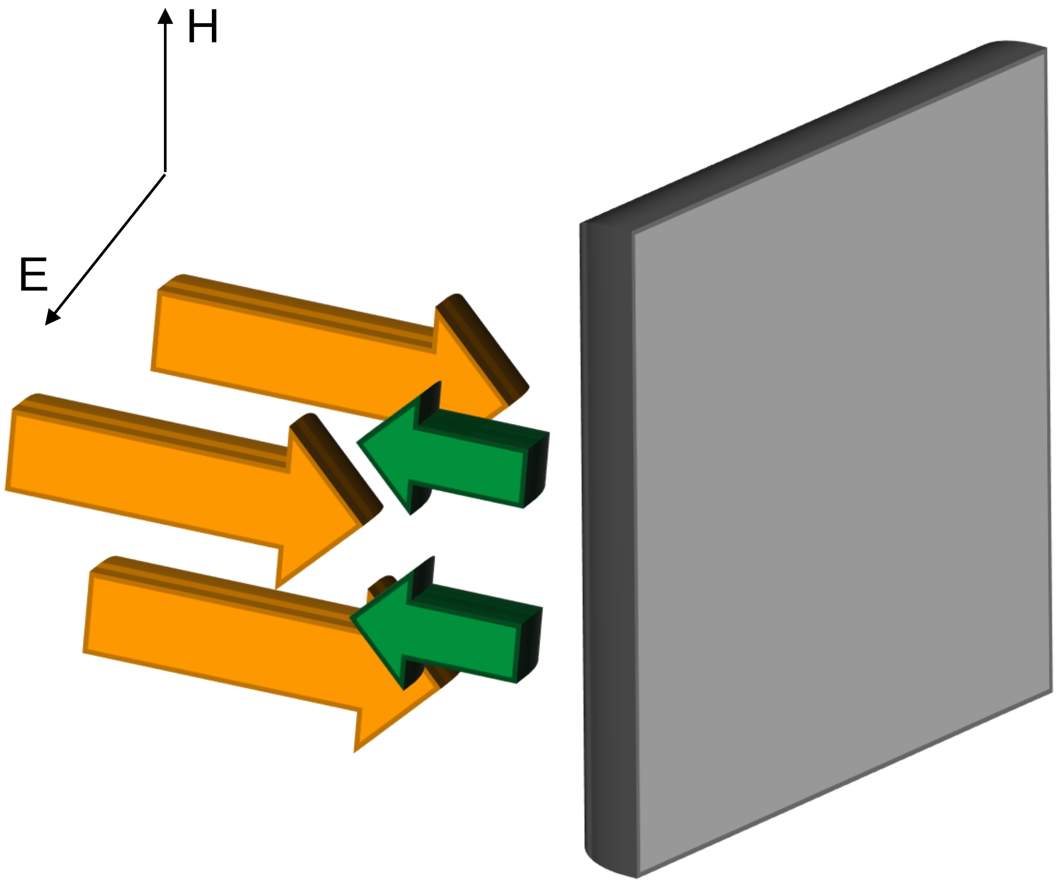


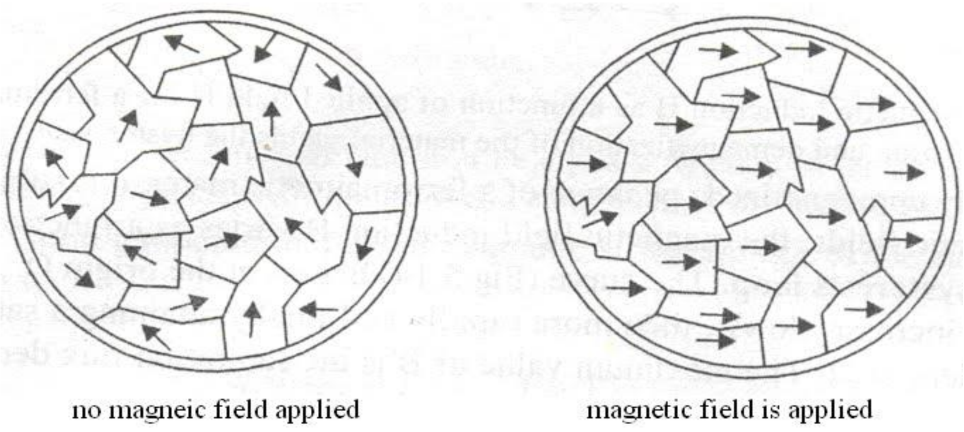


no magneic field applied   magnetic field is applied

The magnetic moments of each magnetic domain try to align with the incoming magnetic field. **Energy is lost** through mechanical torque and phase delay.

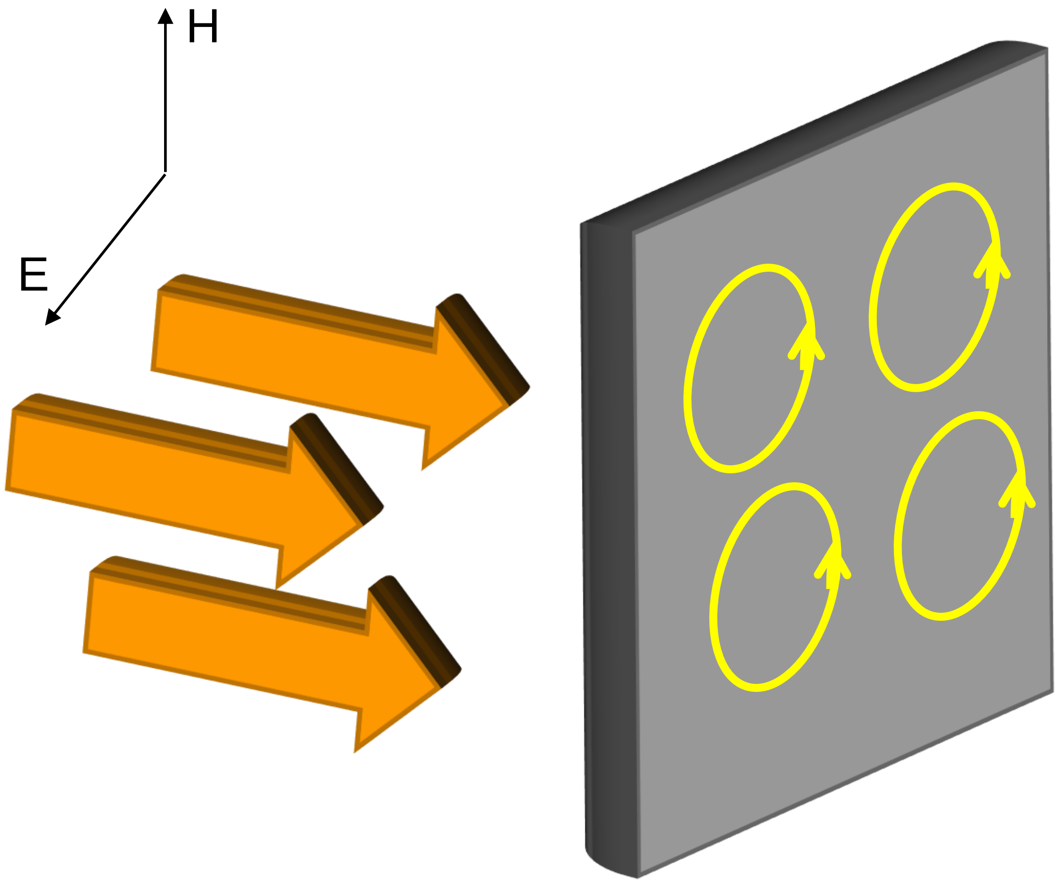
Magnetic Shield with Ferrite: Reflection





The magnetic moments of each magnetic domain try to align with the incoming magnetic field. **Energy is stored and reflected** to the source when the field is changed, “like in inductors”.

Electric Shield with Metal



An incoming EM wave will generate eddy currents on the shield. This means the energy of the EM wave is converted into electric eddy currents.

Eddy current produces an opposing field to cancel the incident field.

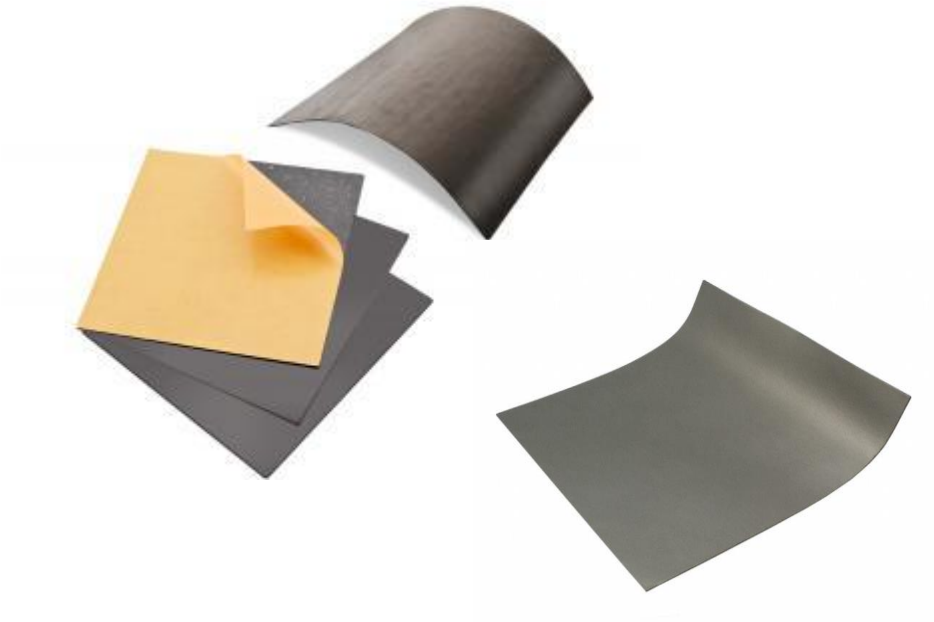
Ferrite vs. Metal

Metal (Cu, Al, Fe)

WE-LT / WE-LS / WE-TS / WE-CF

Ferrite (NiZn, MnZn, Mu-Metall)

WE-FSFS / WE-FAS



- ☹Need a connection to ground
- ☺High effectiveness in wide frequency range
- ☺High attenuation in wide frequancy

- ☺No connection to ground
- ☹Attenuation is limited in frequency
- ☹Attenuation is dependent on width of material

HBM Spice Simulation: Wire Attenuation

- Preferred to use a ferrite solution than LC filter because the ground connection was very far
- Use of RedExpert to find the correct p/n
- Primary Parameters:
  - Rated Current: 2A
  - Pulsed Current: 30A @ 10ns
  - High Attenuation @f> 1GHz
  - Size 0805

NB: The ferromagnetic material with high permeability dissipate enery into heat and it does not need ground connection to «divert»

HBM Spice Simulation: Wire Attenuation

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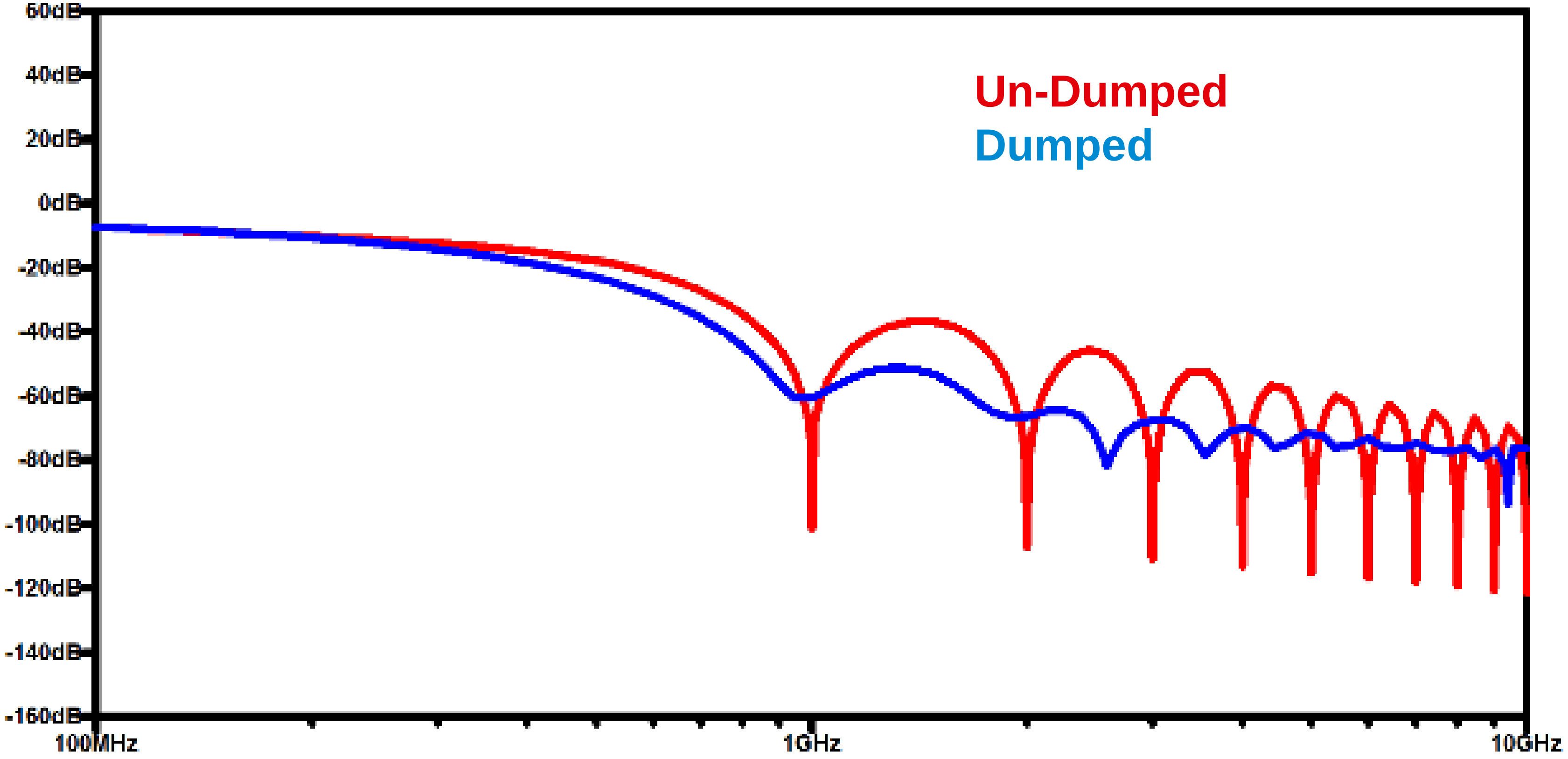
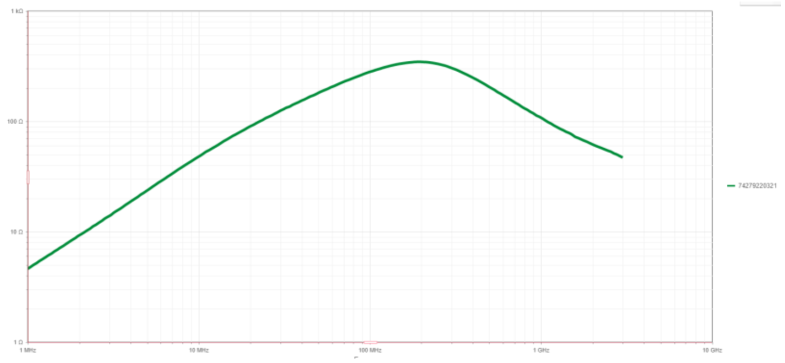
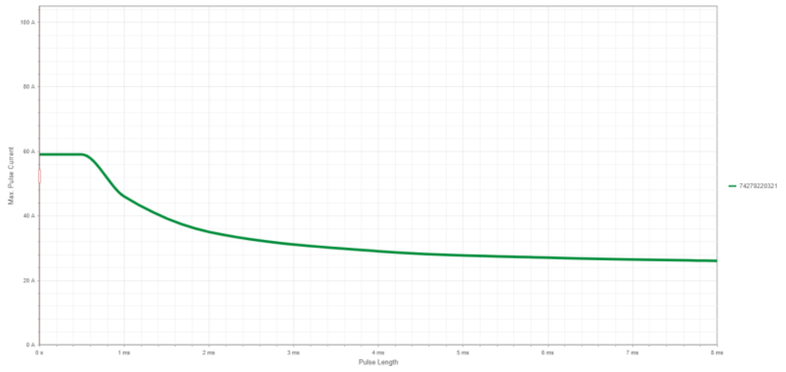


Impedance @ F



Pulse Current @ T



- Selected Code: 74279220321

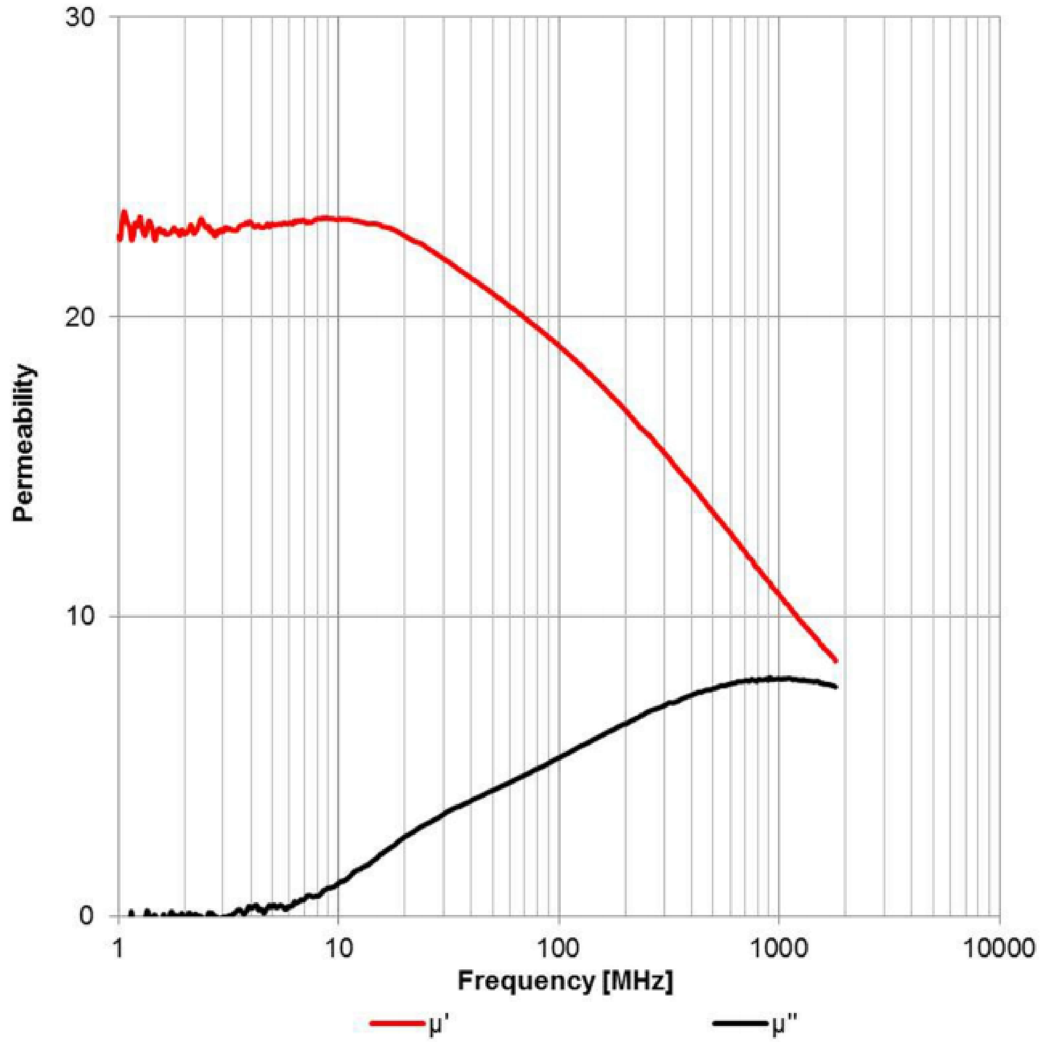
HBM Spice Simulation: Shielding Attenuation

- Preferred to use a ferrite solution than metal because the ground connection was very far
- Use of www.we-online.com to find the correct p/n
- Primary Parameters:
  - Attenuation @f > 500MHz

HBM Spice Simulation: Shielding attenuation

- Selected Code 30410S

F Permeability vs. Frequency:



Conclusions

- Both solutions are effective
- For assembly purposes the final solution was using wire components and not shielding material

That's all Folks!