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Electromagnetic Simulation Software

Simulation of Electrostatic Discharge (ESD) Testing with XFdtd®

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This material is based upon work sponsored by the U.S. Department of Energy, Office of Science, Office of Advanced Scientific Computing Research, under Award Number DE-SC0017164.

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Overview

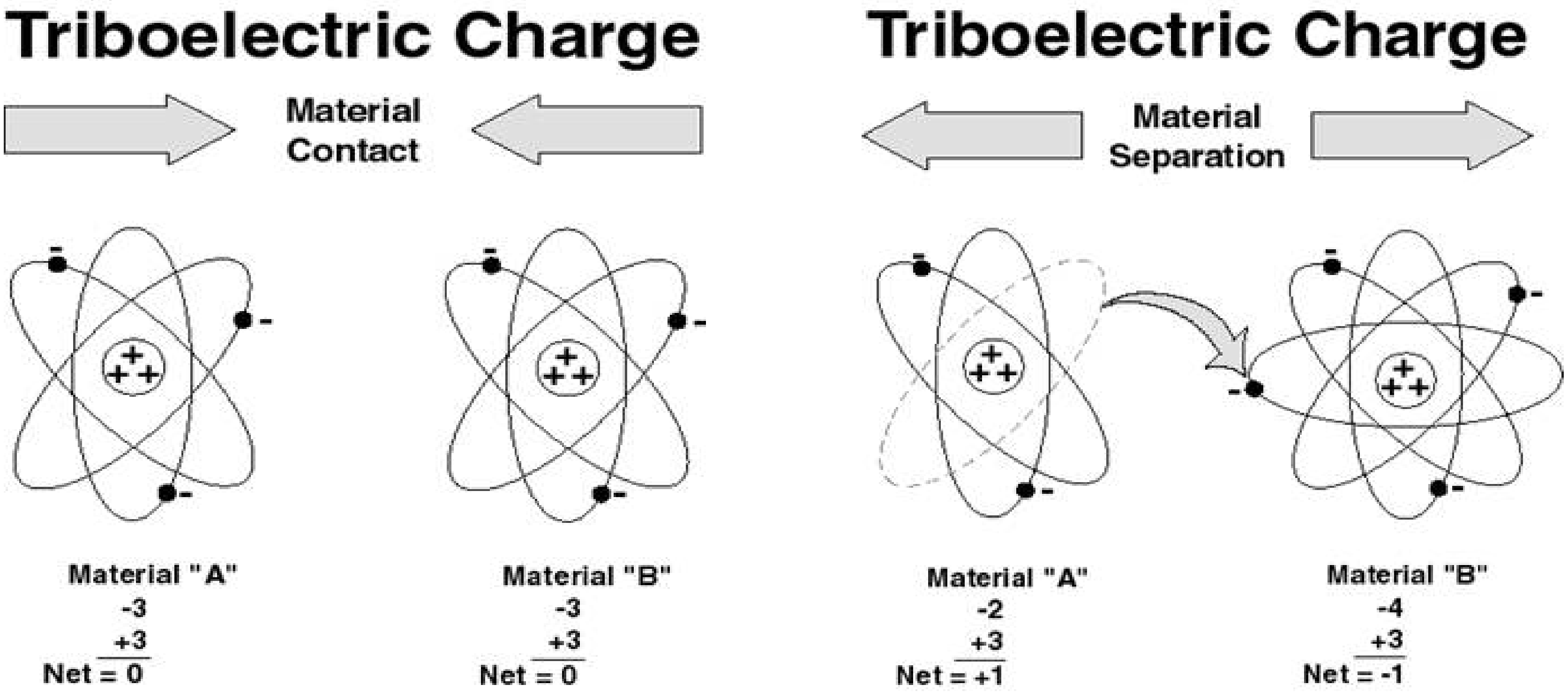
1. Static Electricity and Electrostatic Discharge (ESD)
2. Electrostatic Discharge Testing
3. ESD Testing Simulation with XFdtd
4. Conclusions

Static Electricity

Causes:

- Contact / Triboelectric
- Pressure / Piezoelectric
- Temperature / Pyroelectric
- Charge / Electrostatic Induction

Triboelectric Charge



Source: [1]

Triboelectric Charge

$$q = CV$$

q – Charge (Coulombs)

C – Capacitance (Farads)

V – Voltage (Volts)

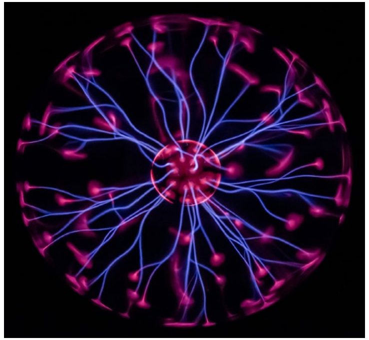
$$E = \frac{1}{2}CV^2$$

E – Energy (joules)

Examples of Static Generation - Typical Voltage Levels		
Means of Generation	**10-25% RH**	**65-90% RH**
Walking Across Carpet	35,000V	1,500V
Walking Across Vinyl Tile	12,000V	250V
Worker at a Bench	6,000V	100V
Poly Bag Picked up from Bench	20,000V	1,200V
Chair with Urethane Foam	18,000V	1,500V

Source: [1]

Electrostatic Discharge

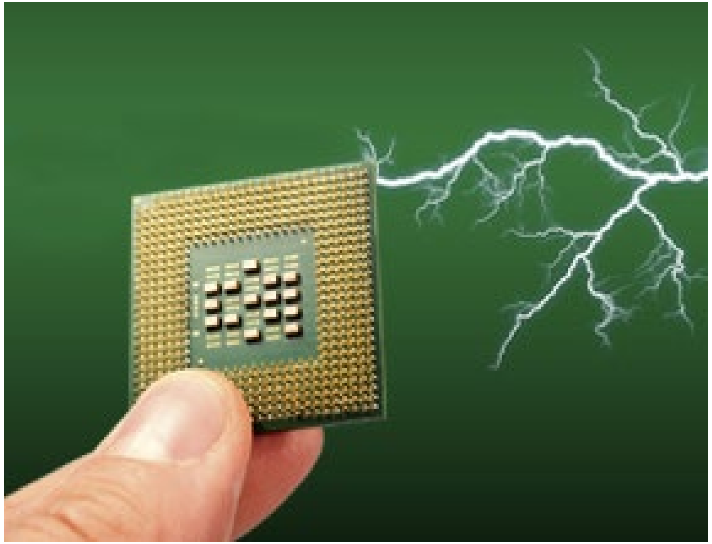


ESD Cost

"… in the electronics industry, losses associated with ESD are estimated at between a half billion and five billion dollars annually."

- In reality, total ESD cost is very difficult to determine.
- Facts:
  - Multiple Prototypes
  - Warranty Claims
  - Loss of Consumer Confidence

Reference: [2]



ESD Testing

Standards:

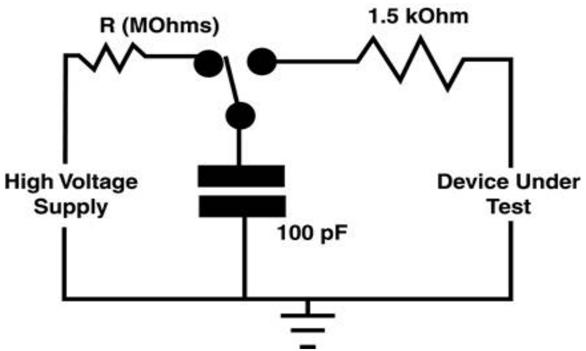
- ANSI/ESD, IEC, JEDEC, MIL, etc.

Common Test Models:

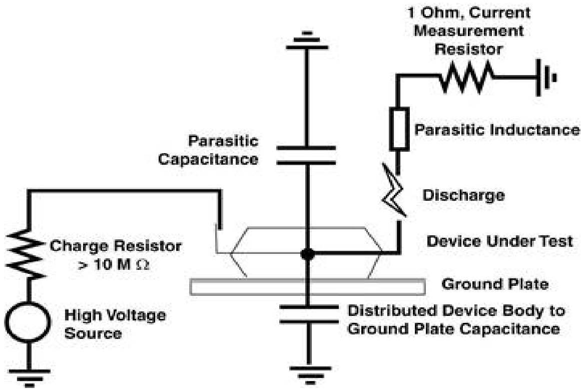
- Human Body Model (HBM)
- Charged Device Model (CDM)
- Machine Model (MM)

HBM & CDM Models

HBM



CDM



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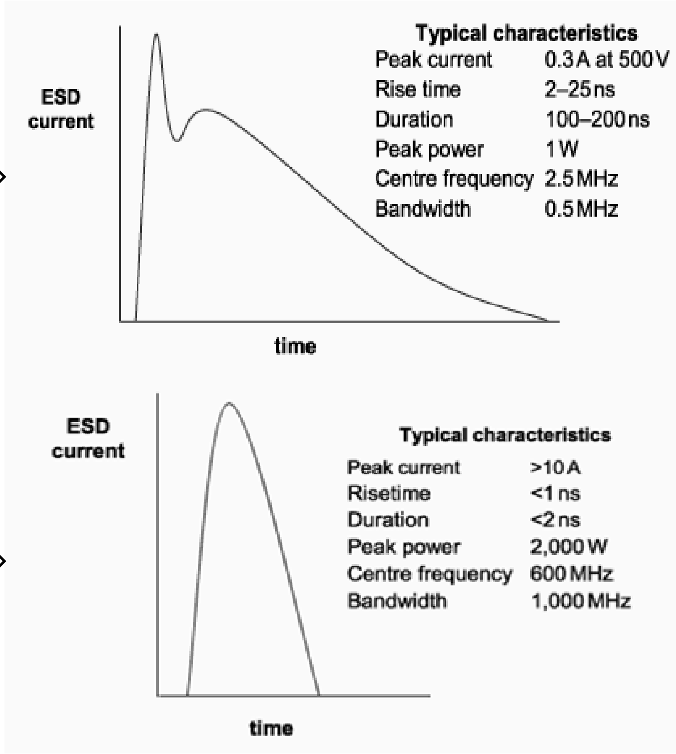

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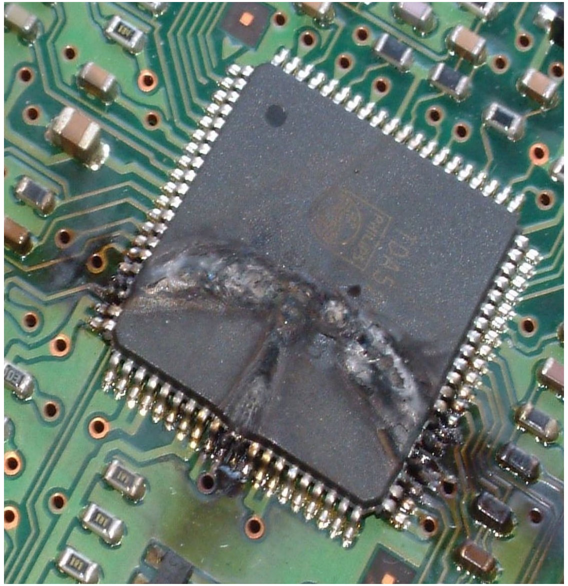
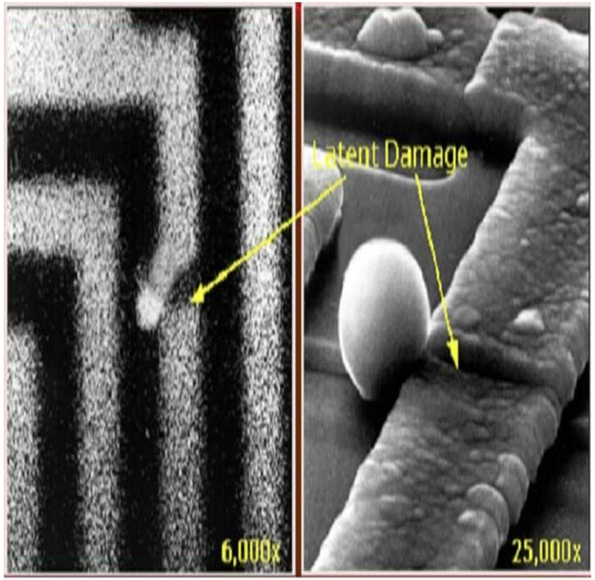
ESD Damage

Catastrophic



Latent



Upset

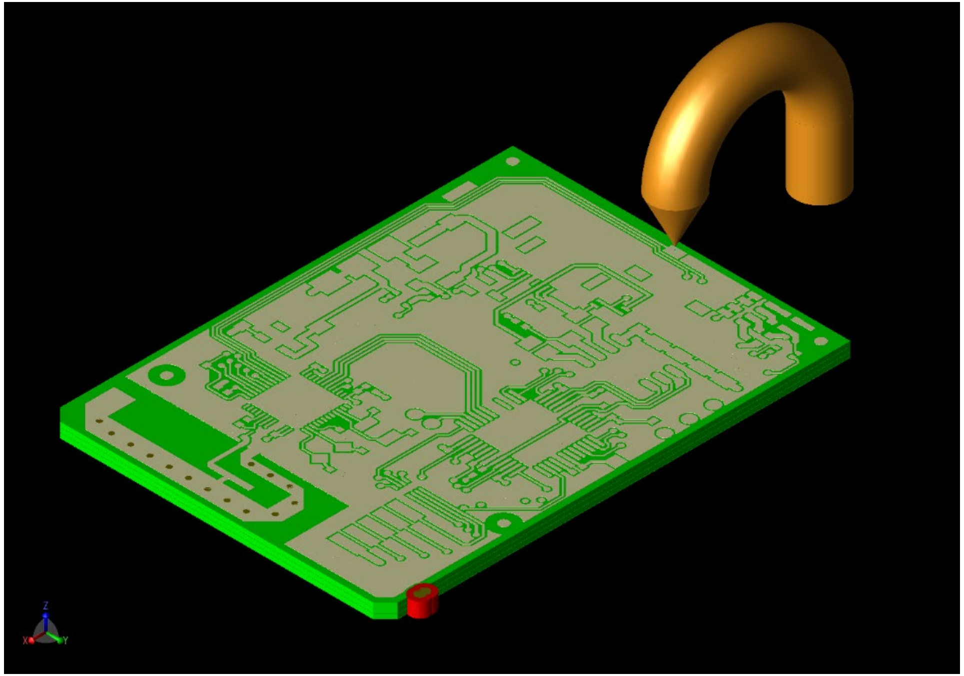
XFdtd ESD Simulation

Goals:

- Help engineers pinpoint locations in their designs at risk of experiencing dielectric breakdown during ESD testing.
- Help engineers pinpoint components at risk of damage during ESD testing.
- Allow engineers to optimize their ESD mitigation designs prior to hardware prototyping.
- Reduce product development costs and time to market.
- Improve product reliability and consumer confidence.

New XFdtd Functionality

- ESD Waveforms
  - HBM, CDM, MM, etc.
- Material Parameter
  - Dielectric Strength
- Result Sensor
  - Dielectric Breakdown
- Circuit Components
  - Rated Voltage/Current



ESD Waveforms

- ESD waveforms can be imported using XFdtd's improved User Defined Waveform feature.
- Waveform References:

  [5] – Cerri et al., 1996

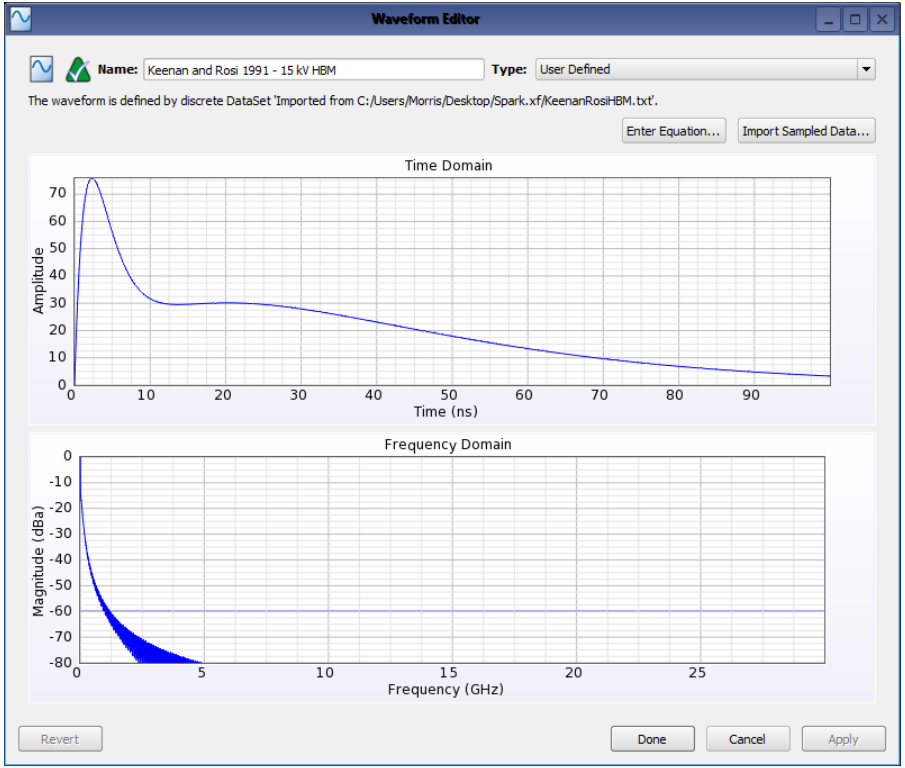
  [6] – Keenan and Rosi, 1991

  [7] – Songlin et al., 2003

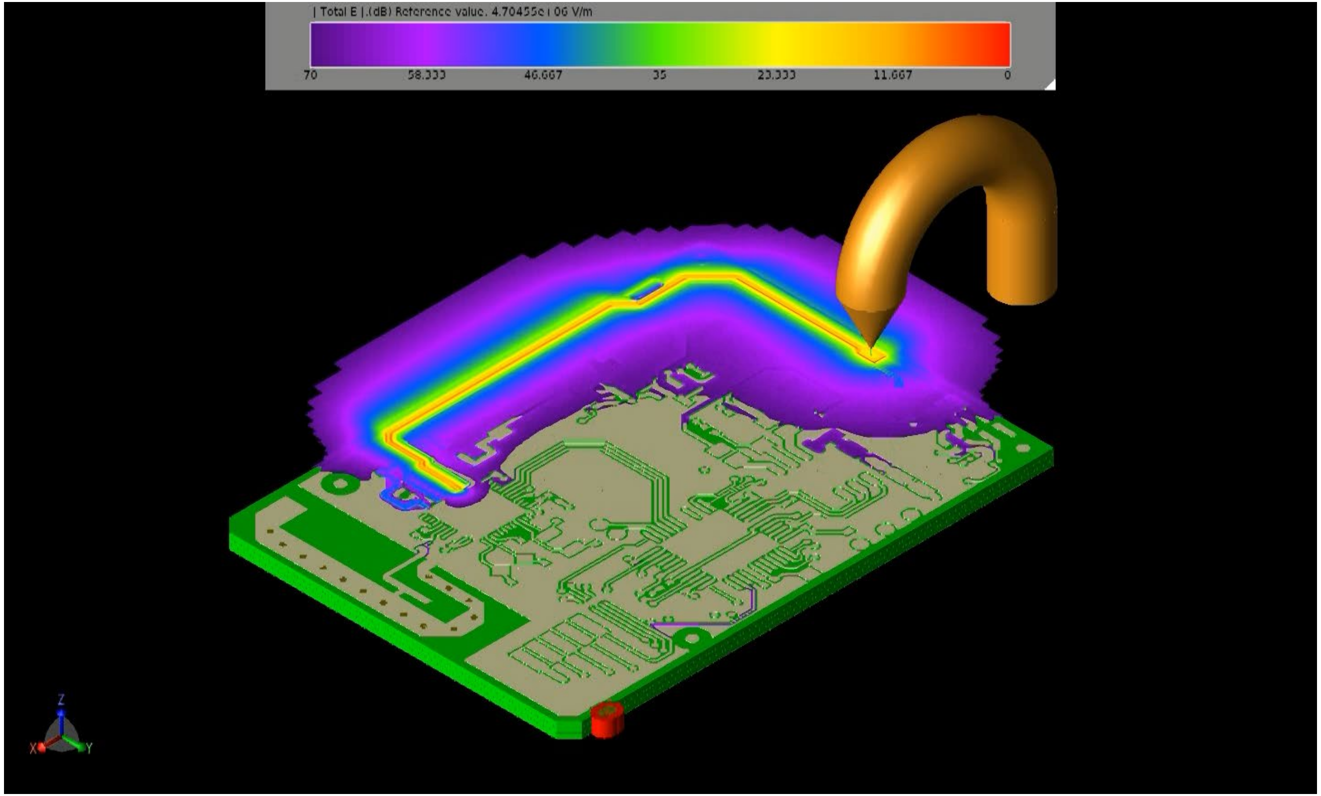
  [8] – Yuan et al., 2006

  [9] – Wang et al., 2003

  [10] – Berghe and Zutter, 1998

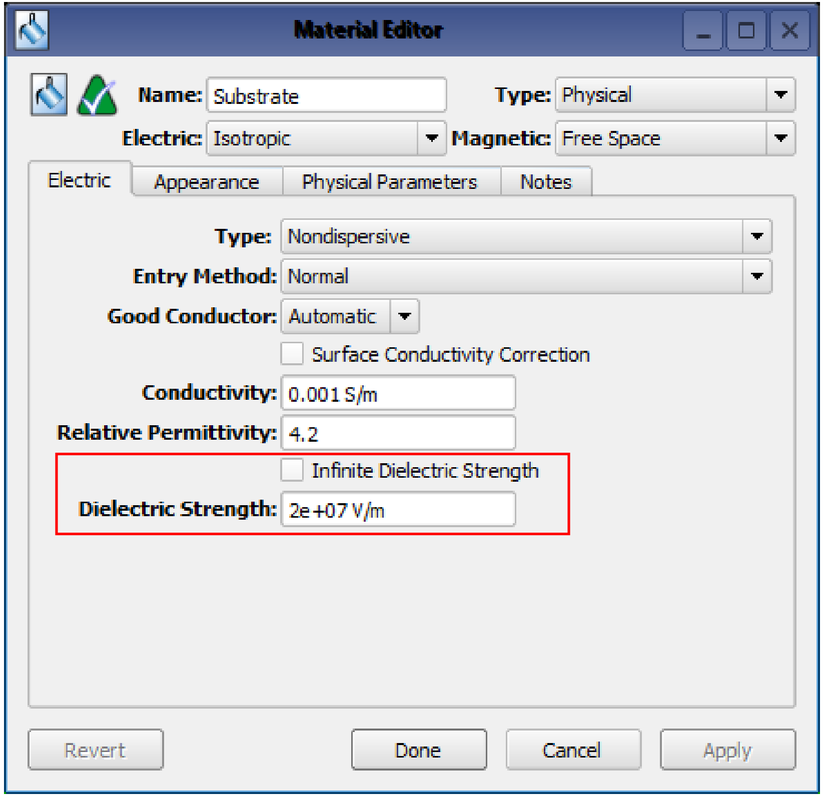


ESD Testing Electric Fields



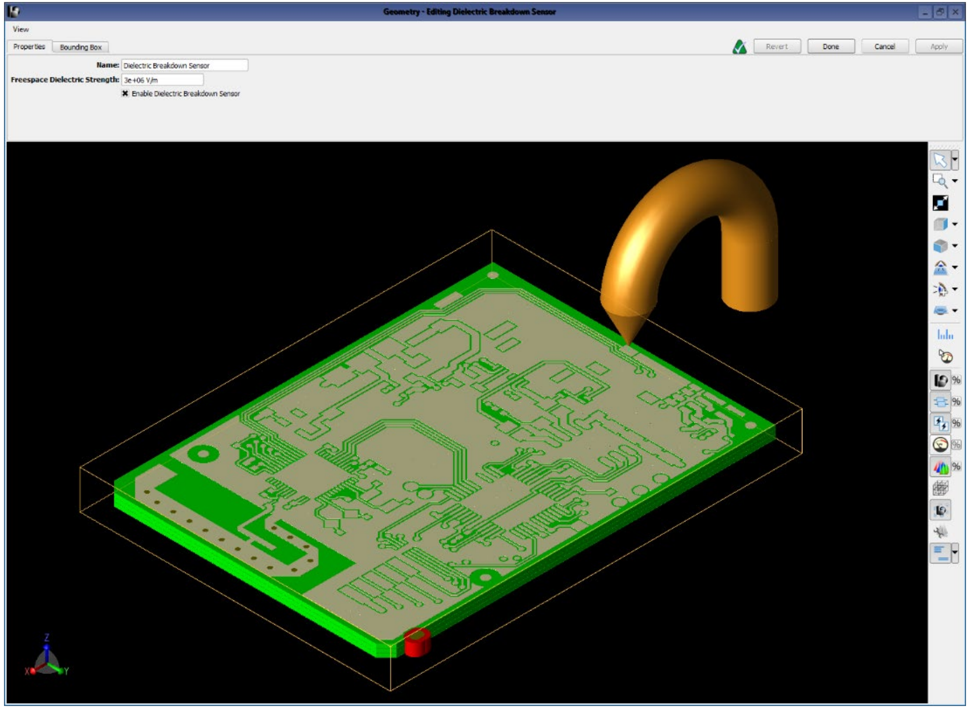
Dielectric Strength

- Defines the maximum electric field a material can withstand without experiencing dielectric breakdown and losing its insulating properties.
- Materials with an infinite dielectric strength will be ignored by the Dielectric Breakdown Sensor.

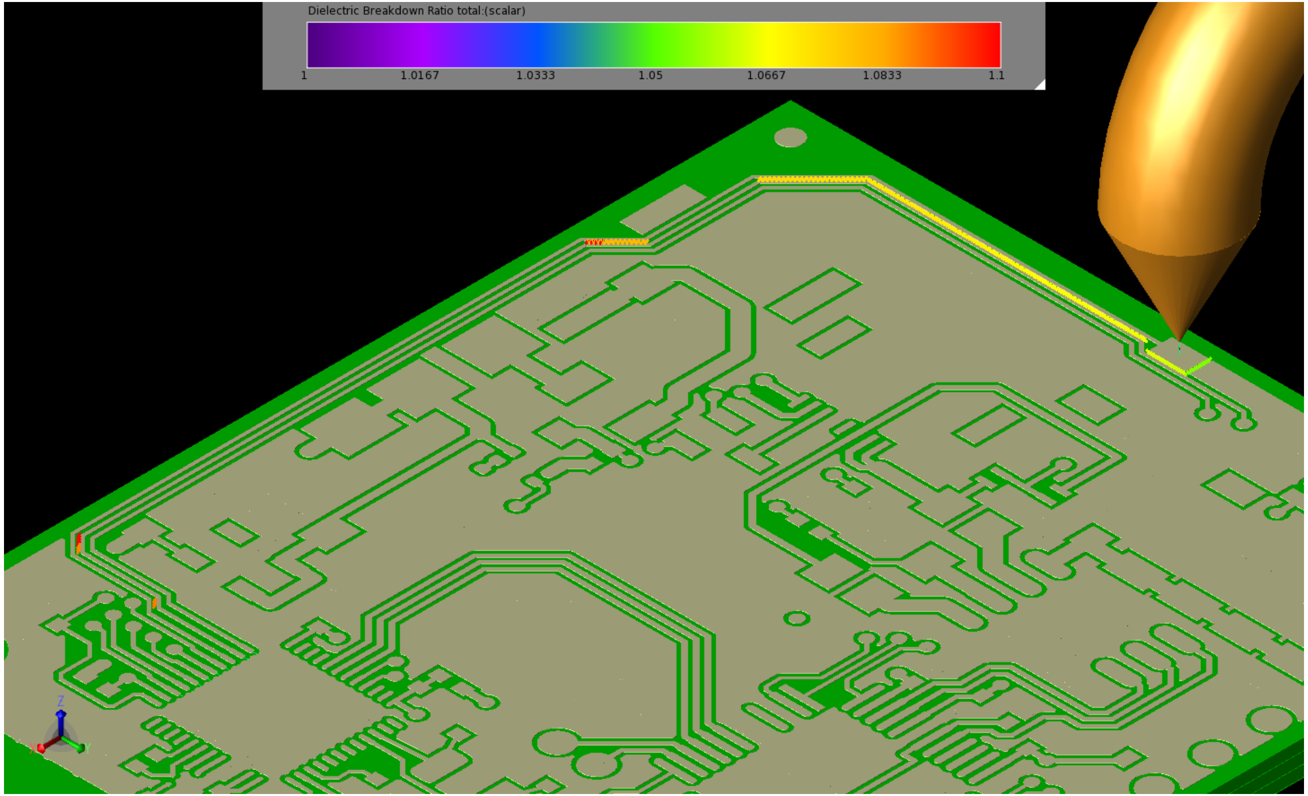


Dielectric Breakdown Sensor

- Computational savings can be obtained by reducing the size of the sensor to the geometry's bounding box or to specific regions of interest.
- The default dielectric strength of free space is set to 3.0 MV/m corresponding to air at sea level.

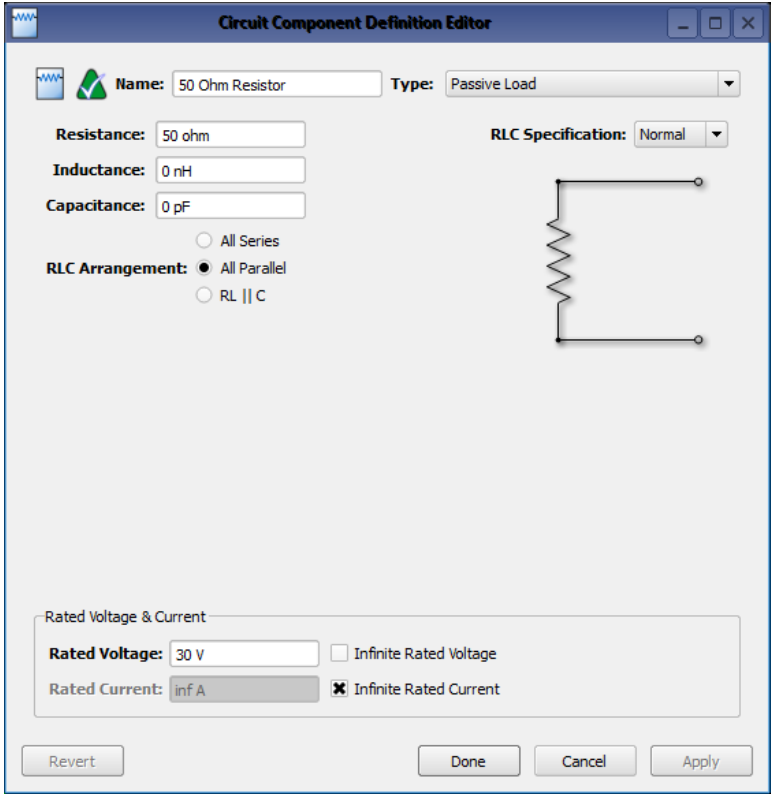


Dielectric Breakdown Risk



Rated Components

- Rated peak voltages and currents can be obtained from a circuit component’s data sheet and entered into its Circuit Component Definition.
- Infinite rated voltages and currents will be ignored by XFdtd’s System Sensor.



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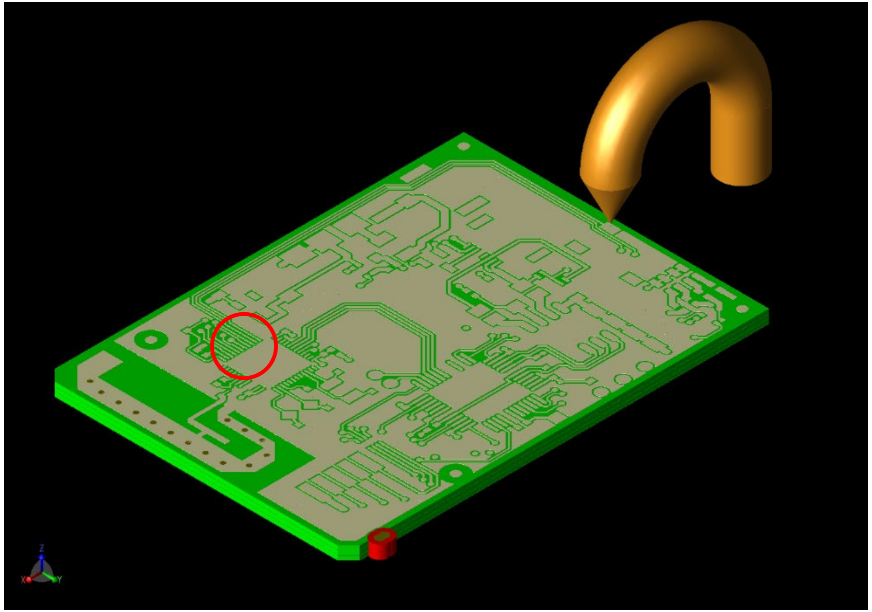
Exceeded Design Specs

MFM 2019



Max Component Voltages and Currents Results for Remote : 000008 : 1

File

Run Details

Max Component Voltages and Currents Results for:

Project Name: Remote
Simulation: HBM Test (Coarse Staircase, Reduced Dielectric Strength)
Run Number: 1

Component Name	Max Voltage	Rated Voltage	Max Current	Rated Current
C1	17.7892 V	16 V	0.170955 A	--
C2	2.55162 V	16 V	0.0439905 A	--
C3	9.12234 V	16 V	0.154973 A	--
ESD Feed	392.368 V	--	5.34214 A	--
L1	1.42421 V	--	0.572944 A	0.44 A
L2	0.9173 V	--	0.268556 A	0.44 A
L3	1.08432 V	--	0.134515 A	0.44 A
R1	20.1895 V	30 V	0.40379 A	--
R2	64.1534 V	30 V	1.28307 A	--
R3	278.358 V	30 V	5.56717 A	--

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Optimize ESD Mitigation

- Once locations and components at risk of suffering ESD damage are pinpointed, the ESD mitigation design can be optimized:
  - Increase distance between traces
  - Reduce sharp angles and edges
  - Use materials with higher dielectric strength
  - Introduce ESD protection circuits and/or suppressors
  - Improve shielding
  - Use quality components with higher rated values

Conclusions

- ESD simulation does not replace hardware testing.
- ESD simulation does allow engineers to predict potential ESD problems and optimize ESD protection in the design phase.
  - Reduce number of hardware prototypes
  - Reduce product development cost
  - Reduce time to market
  - Improve product reliability
- This is only beginning…Multiphysics ESD Analysis
  - Spark Discharge Simulation
  - Thermal Damage Simulation

References

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10. Berghe, S. V., and D. Zutter, “Study of ESD signal entry through coaxial cable shields,” *J. Electrostat.*, 44, pp. 135 – 148, 1998.

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