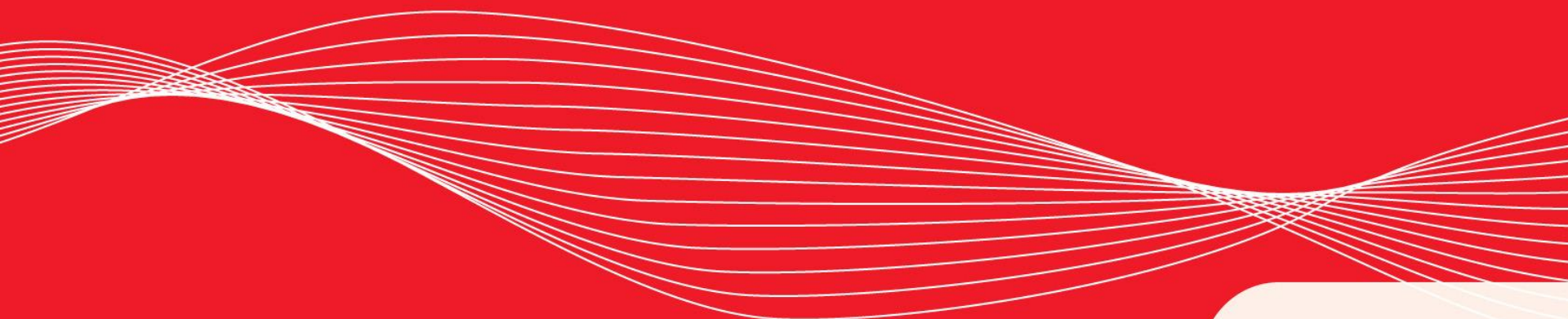


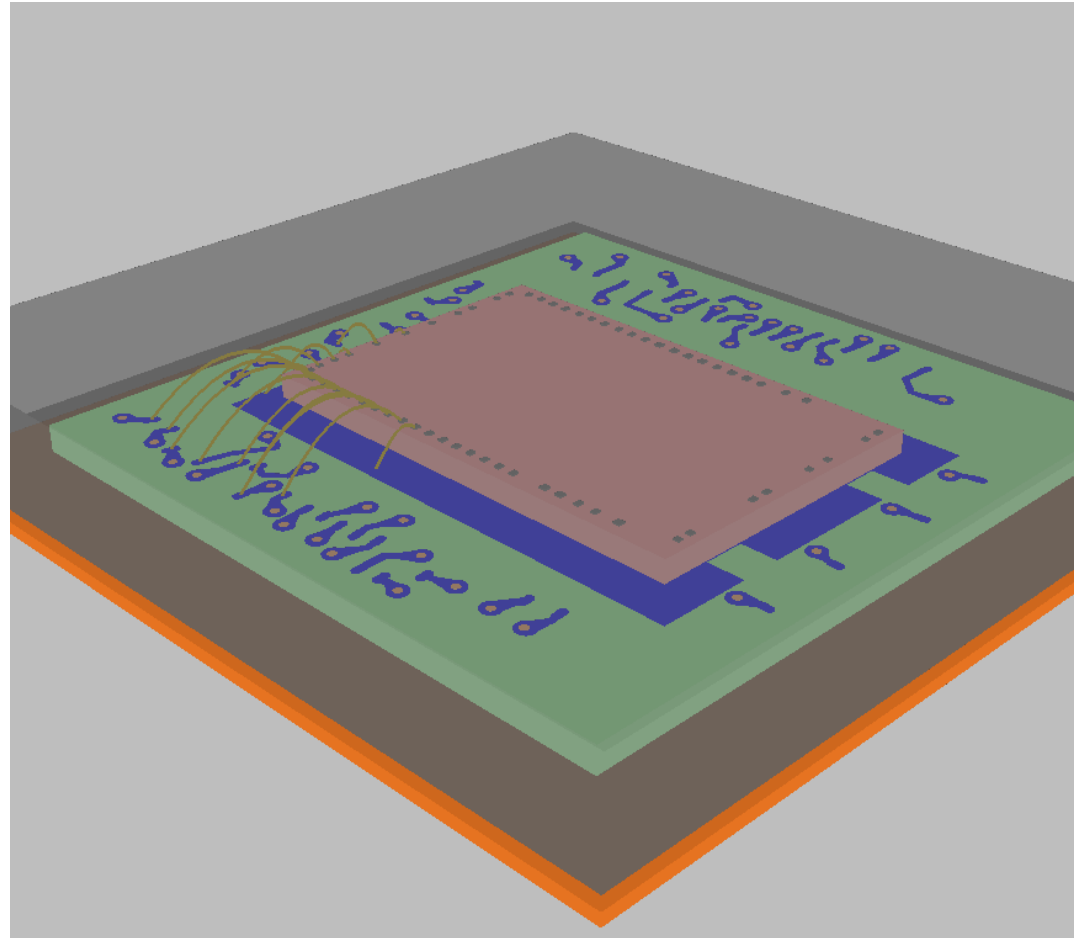
# EMPIRE XPU Tutorial

## Signal Integrity of a BGA Package



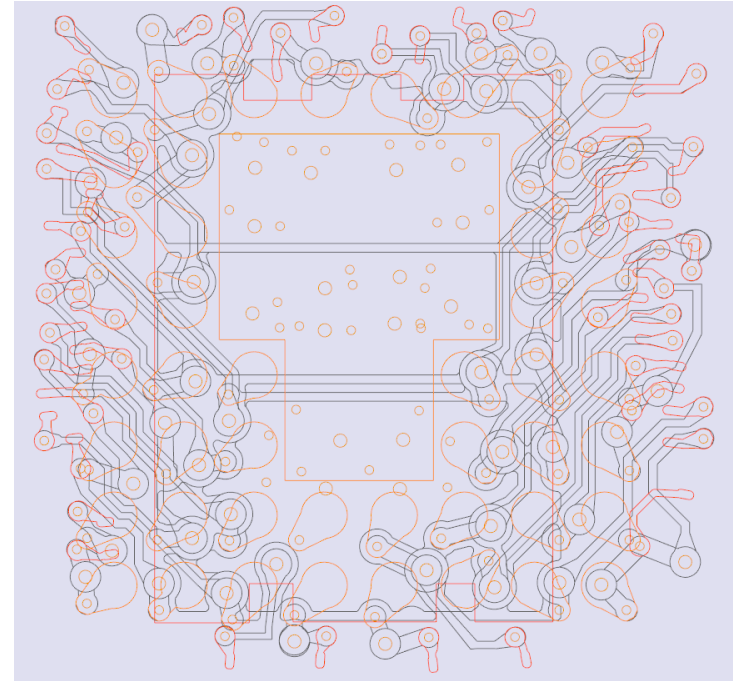
# Overview: Topics

- Basic Features
- Layout import
- Bond wires
- Array generation
  
- Preprocessing
- Pulse definition
- Simulation Control
- Postprocessing



# Step 1: Layout Import

- Open Empire XPU on Desktop
- Select “New Project”, OK
- Select File - Save As
- Create new folder “bga”
- Switch to “2D Design” Tab
- Select File → Import → 2D Layout → Import DXF (2D)
- Select data\layout.dxf \*



\* C:\EMPIRE XPU 8.00\Tutorials\2D Design\07 Ball Grid Array Package

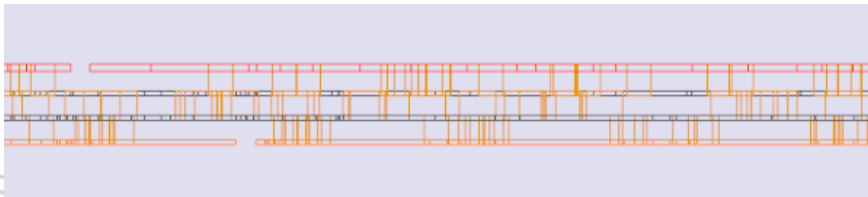
*Comment: Layout data does not contain height information.*

# Step 2: Layer Stack

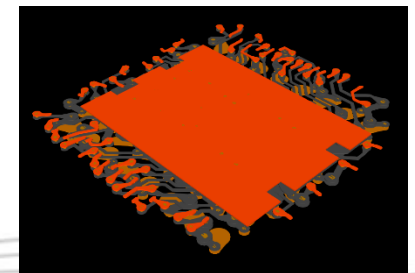
2D Layout Import

Name	Orig. Name	New	Type	Obj./Vias	Dir.	Start	Stop	Physical Property
Groups								
✓ V34	V34	✓		64/0	z	200	330	conductor
✓ V23	V23	✓		64/0	z	100	220	conductor
✓ V12	V12	✓		64/0	z	0	120	conductor
✓ L4	L4	✓		49/0	z	300	330	conductor
✓ L3	L3	✓		51/0	z	200	220	conductor
✓ L2	L2	✓		50/0	z	100	120	conductor
✓ L1	L1	✓		49/0	z	0	20	conductor
#001				0	z	0	1000	conductor

- Set Start / Stop according to image
- Click OK at the bottom



2D Design: Front view after layer stack definition (detail)



3D Result: Iso-z-view

# Step 3: Setup

- Click "Simulation Setup"

## Tab: „EM Setup“

- Set „Limit for Number of Steps“: 8000

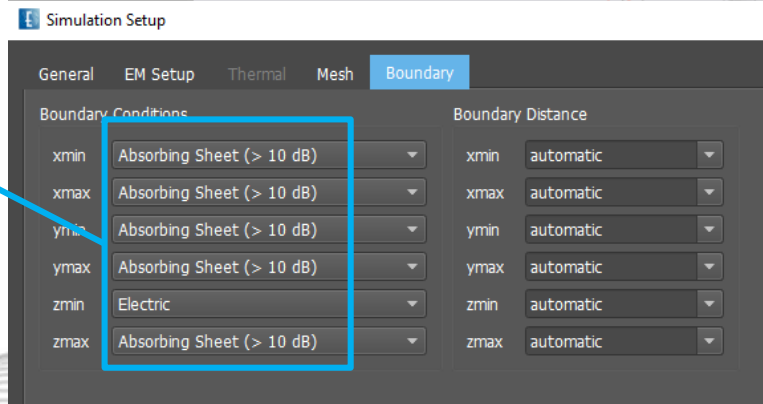
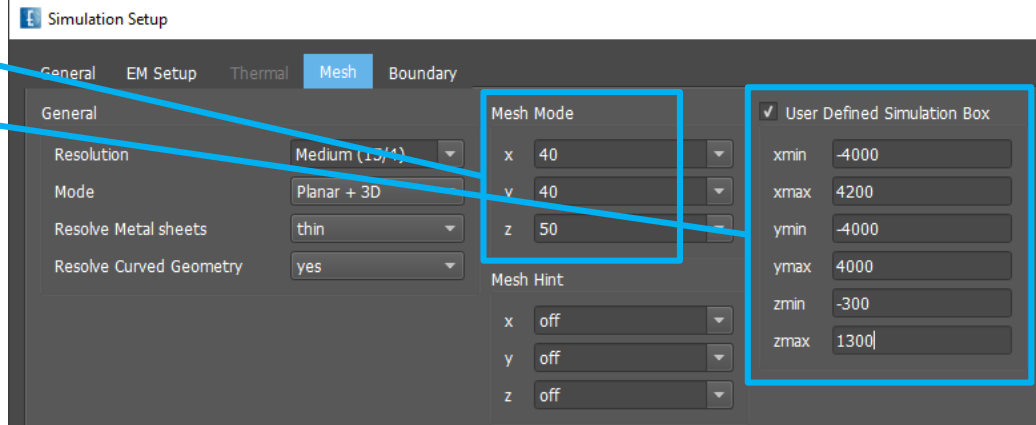
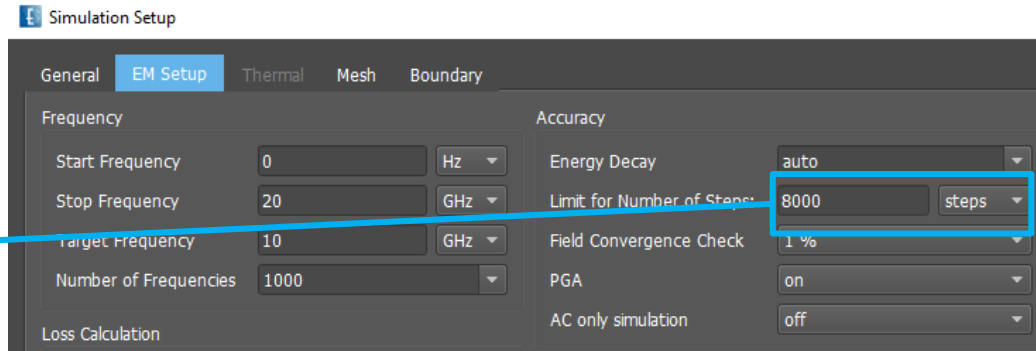
## Tab: „Mesh“

- Set „Mesh Mode“: x=40, y=40, z=50
- Enable „User defined Simulation Box“
- Set
  - Xmin = -4000 Xmax = 4200
  - Ymin = -4000 Ymax = 4000
  - Zmin = -300 Zmax = 1300


## Tab: „Boundary“

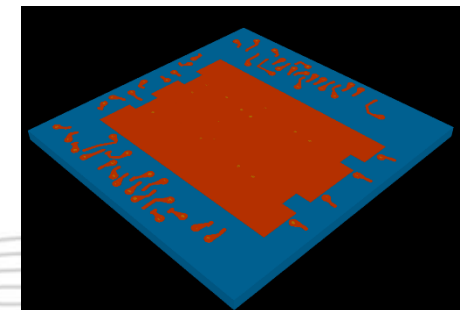
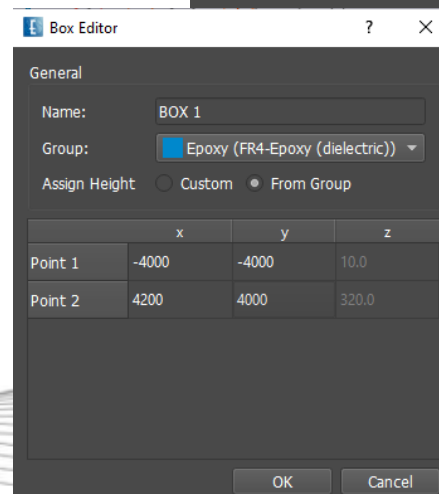
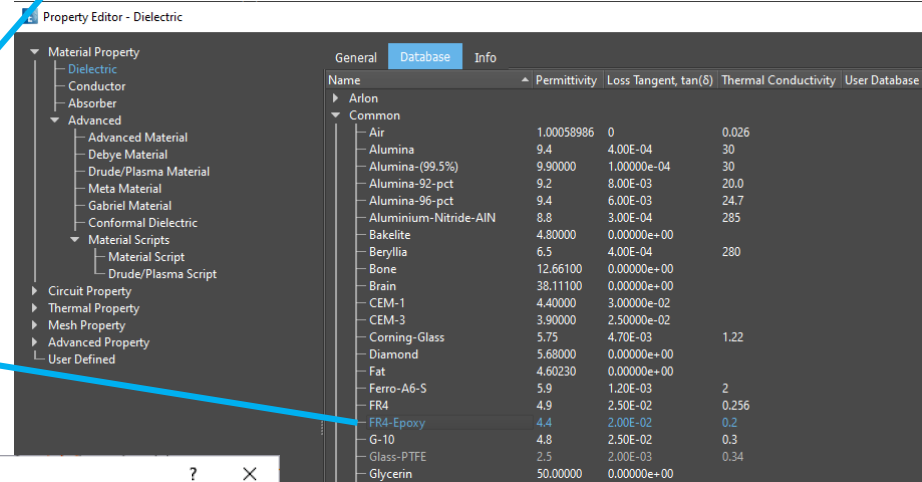
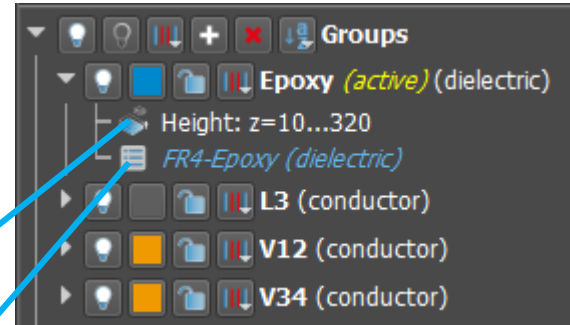
- Set xmin: Electric
- Set others: Absorbing sheet
- OK
- Click Create Mesh

*Comment: An equidistant grid is created*



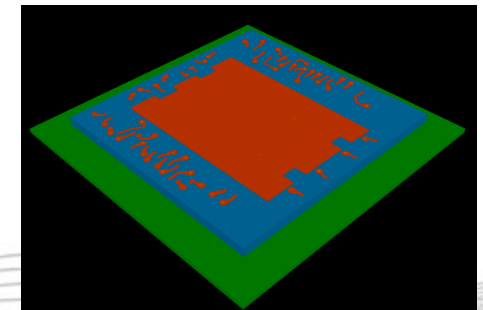
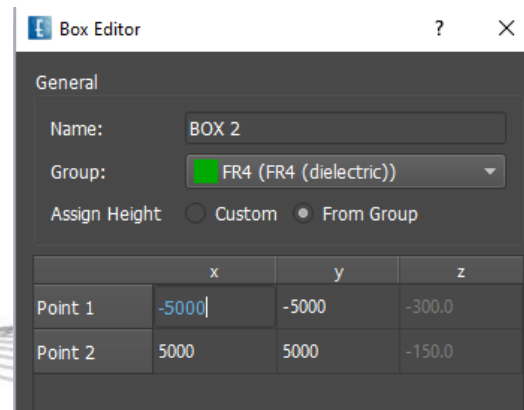
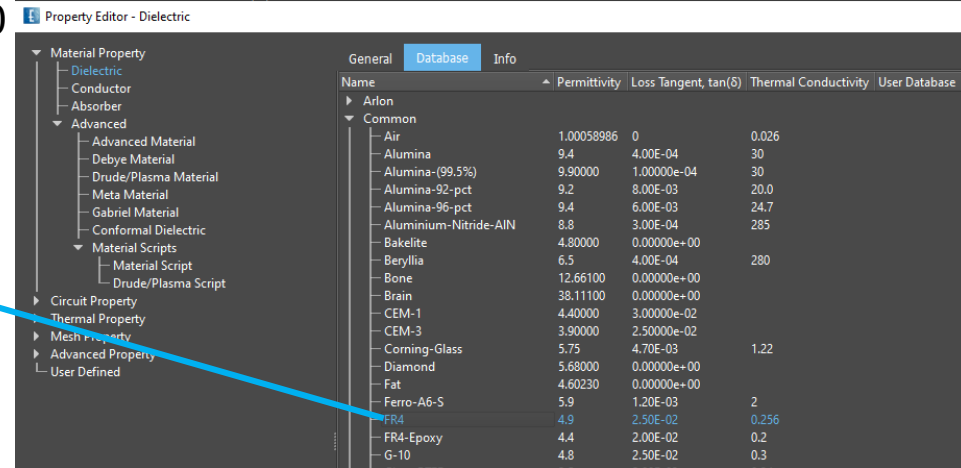
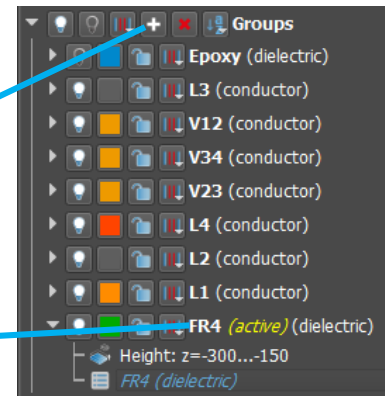
# Step 4: Substrate

- Right click on group #001 – “Set Active”
- Right click on group #001 – “Edit Name”: Epoxy
- Open group, double click “Height”, Set  $z=10\dots320$
- Double click on “conductor” to change Property
- Select Dielectric → Database Common → FR4-Epoxy
- OK
- “Create Box” 
- Point 1:  $x=-4000, y=-4000$
- Point 2:  $x=4200, y=4000$
- OK



# Step 5: Board

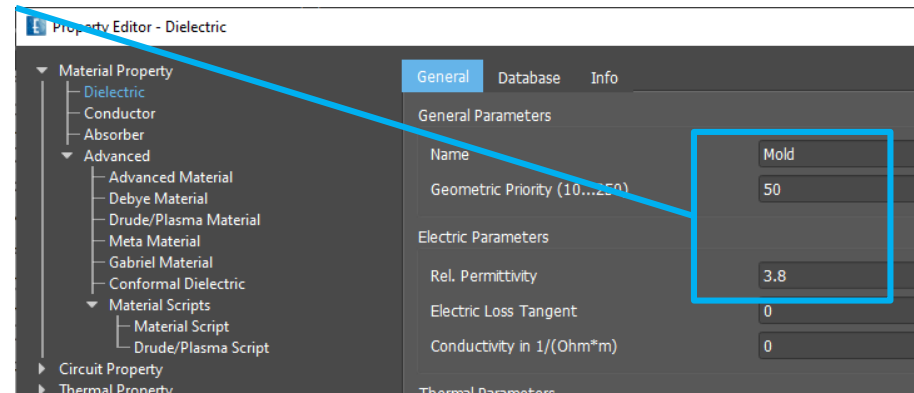
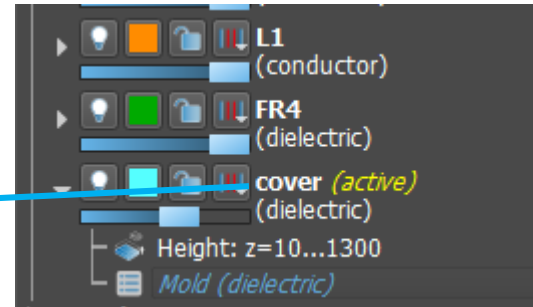
- Create new group
- Name: "FR4"
- Double click Height: z=-300...-150
- Double click "Conductor":
- Select Dielectric → Database → Common → FR4
- OK, close groups
- Click "Create Box"
- Point 0: x=-5000, y=-5000
- Point 1: x=5000, y=5000
- OK



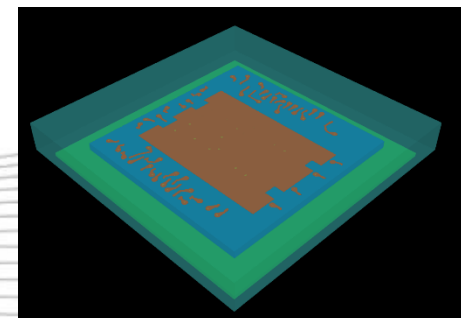


# Step 6: Cover

- Create and open new group 'cover'
- Double click Height: z=10...1300
- Double click "conductor"
- Select Dielectric, enter Name: Mold
- Set Geometric Priority 50
- Rel. Permittivity 3.9
- OK, close groups
- Click "Create Box"
- Point 0: x=-5500, y=-5500
- Point 1: x=5500, y=5500
- OK



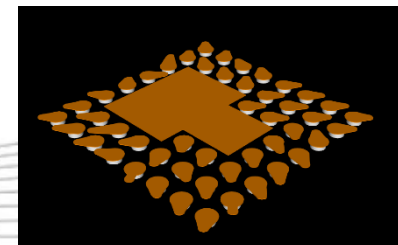
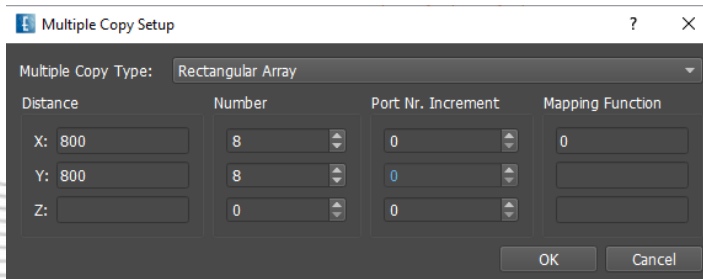
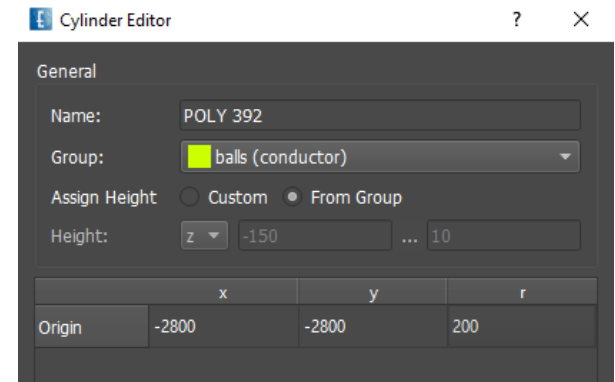
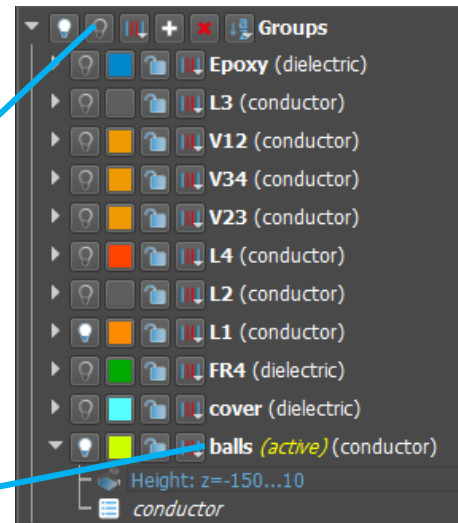
*Comments: Intersecting Dielectrics need priority specification.*





# Step 7: Ball Grid

- Create and open new group “balls”
- Set height  $z=-150...10$
- Switch off all groups but ‘L1’, ‘balls’
- Click “Create Cylinder” (default circular)
- Point 0:  $x=-2800, y=-2800, r=200$ , OK
- Select new object (left click on lower left circle)
- Click “Multiple Copy”
- Enter ‘Distance’  $x,y = 800,800$  and ‘Number’ for  $x,y = 8,8$ , OK



Only groups L1 and balls visible

# Step 8: Die and Pads

2D Layout Import

Name	Orig. Name	New	Type	Obj./Vias	Dir.	Start	Stop	Physical Property
V12				64	z	0	120	conductor
L4				49	z	300	330	conductor
L3				51	z	200	220	conductor
L2				50	z	100	120	conductor
L1				49	z	0	20	conductor
FR4				1	z	-300	-150	dielectric name FR4 prio 100 epsr 4.9 tand 0.02
Epoxy				1	z	10	330	dielectric name FR4-Epoxy prio 100 epsr 4.1 tand 0.02
diepad	diepad	✓		60/0	z	580	620	conductor
die	die	✓		1/0	z	300	600	dielectric name Silicon prio 100 epsr 11.9 tand 0.02
cover				1	z	10	1500	dielectric name mold prio 50 epsr 3.8 tand 0.02
balls				64	z	-150	10	conductor

- Select File → Import → 2D Layout → Import DXF (2D)
- Select “data/die-pad.dxf”
- In “2D Layout Import” window:
- Group “die”:  
 “Start” = 320 “End” = 600, “Property  
 “conductor” → Select Dielectric, browse  
 Common database for “Silicon”
- Group “diepad”:  
 “Start” = 580 “Stop” = 620
- OK

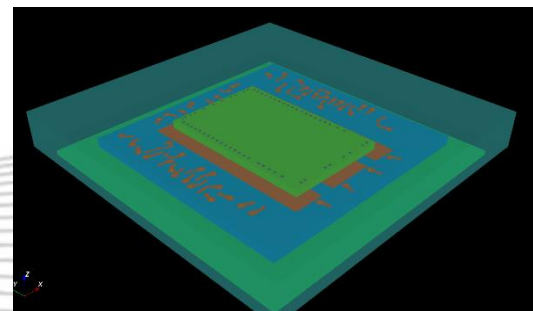
Property Editor - Dielectric

Material Properties

- Dielectric
- Conductor
- Absorber
- Advanced
  - Advanced Material
  - Debye Material
  - Drude/Plasma Material
  - Meta Material
  - Gabriel Material
  - Conformal Dielectric
  - Material Scripts
    - Material Script
    - Drude/Plasma Script
- Circuit Property
- Thermal Property
- Mesh Property
- Advanced Property
- User Defined

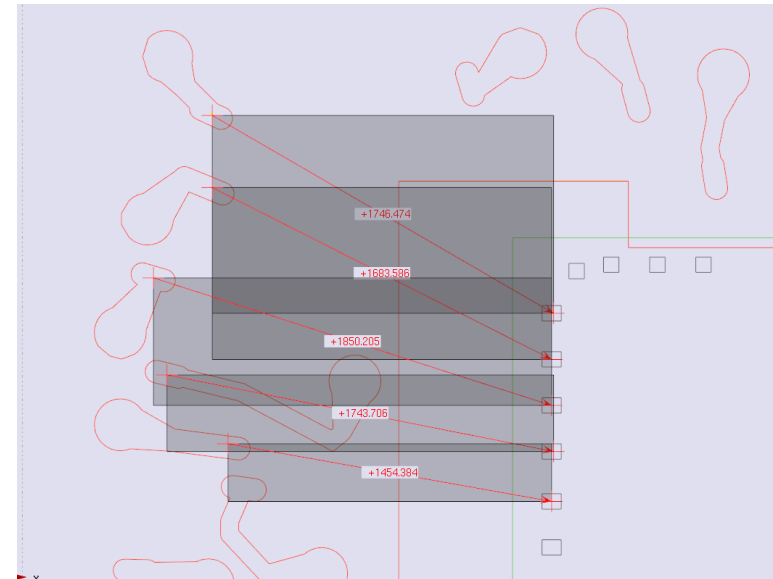
General Database Info

Name	Permittivity	Loss Tangent, tan(δ)	Thermal Conductivity	User Database
Arlon				
Common				
Air	1.00058986	0	0.026	
Alumina	9.4	4.00E-04	30	
Alumina (99.5%)	8.90000	1.00000E-04	30	
Alumina-92-pct	9.2	8.00E-03	20.0	
Alumina-99-pct	9.4	6.00E-03	24.7	
Aluminium-Nitride-AIN	8.8	3.00E-04	285	
Bakelite	4.80000	0.00000E+00		
Beryllia	6.5	4.00E-04	280	
Bone	12.66100	0.00000E+00		
Brain	38.11100	0.00000E+00		
CEM-1	4.40000	3.00000E-02		
CEM-3	3.90000	2.50000E-02		
Corning-Glass	5.75	4.70E-03	1.22	
Diamond	5.68000	0.00000E+00		
Fat	4.60230	0.00000E+00		
Ferro-A6-S	5.9	1.20E-03	2	
FR4	4.9	2.50E-02	0.256	
FR4-Epoxy	4.4	2.00E-02	0.2	
G-10	4.8	2.50E-02	0.3	
Glass-PTFE	2.5	2.00E-03	0.34	
Glycerin	50.00000	0.00000E+00		
Mica	6.00000	0.00000E+00		
Oil	2.33000	0.00000E+00		
Paper	2.31000	0.00000E+00		
Plexiglass	3.4	1.00E-03	0.17	
Polyamide	4.3	4.00E-03	0.25	
Polyester	3.2	3.00E-03	0.3	
Polyethylene	2.25	1.00E-03	0.3	
Polyimide	3.5	3.00E-03	0.2	
PVC	2.91	2.50E-02	0.14	
Quartz	3.78	1.00E-04	5	
Rubber	3.00000	0.00000E+00		
ShieldHI-ComClad-HF	2.6	3.30E-03	0.19	
Silicon	11.9	1.00E-02	148	
Skin	31.29000	0.00000E+00		

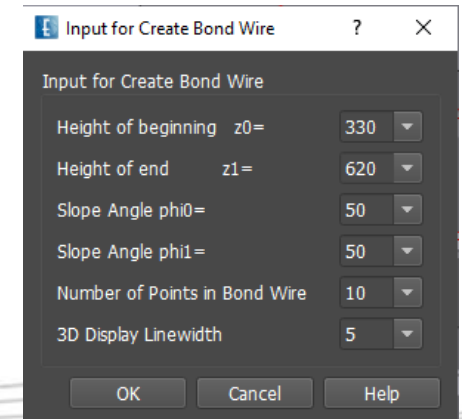


# Step 9: Bond Wires



- Create new group “wires”
- Switch off all groups but
- L4, die, diepad, wires
- Zoom into upper left corner
- Draw arrows to die pads\*
- Press “Advanced”
- → “Linpolys-Bondwire“
- → “Create Bondwire“
- Height of beginning = 330
- Height of end = 600, OK
- Switch off all groups but
- L1, balls, die, diepad

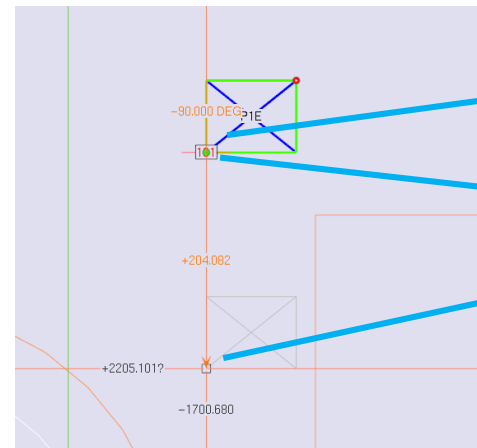
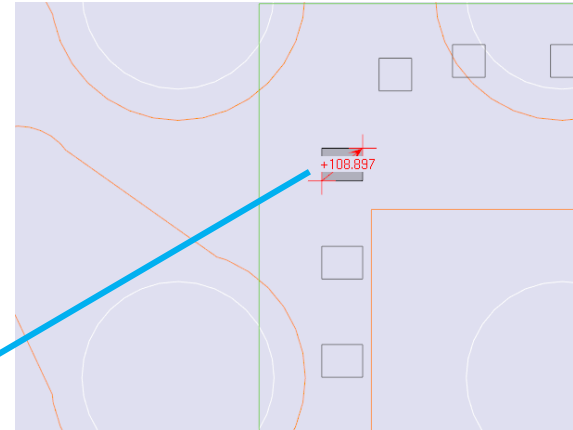


*Comment: \* Press and drag left mouse button, start at L4 pads, end at die pads. Only do this for 5 pads.*



# Step 10: Inner Ports

- Create and Open new group “iports”
- Set height z=330...580, close Groups list
- Create diagonal arrow in top pad
- Create “Perpendicular port”  →  , OK
- Copy\* port to other pads (5 ports)
- Create and Open new group „oports”
- Set height z=-300...-150, close group list

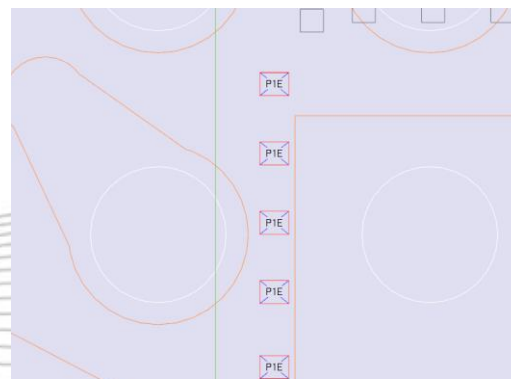


\* Copy port:



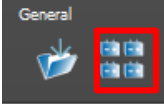
- Select port (left mouse button)

- Move cursor to green handle

- Drag middle mouse button



# Step 11: Outer Ports

- Create “Perpendicular port”  → 
- Point 0:  $x=-2875, y=2875$
- Point 1:  $x=-2700, y=2700$ , OK
- Copy port to other pads (as before, see picture)
- Click Port Setup Wizard 
- Select “Array View”
- Enter new port numbers as shown
- Select Excitation
- Keep excitation port 11, deselect others
- OK

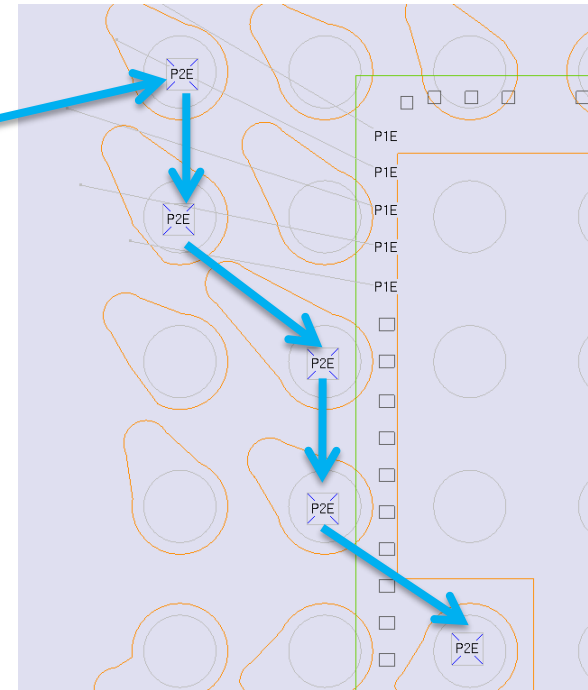

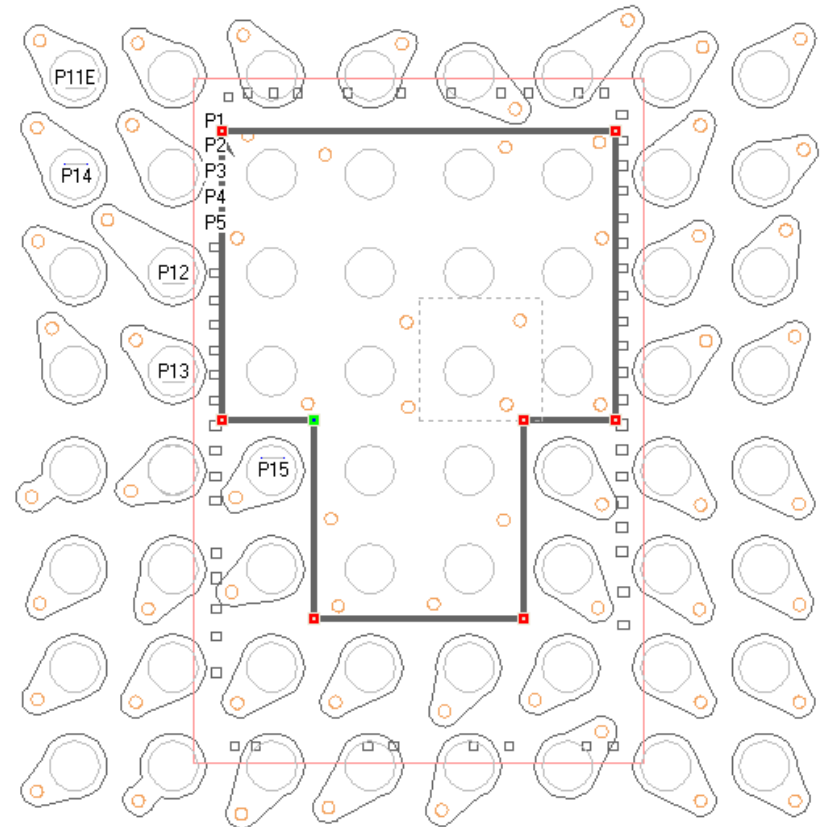


Table Style:	Array View	Parameter:	Excitation	✓ Show Port Numbers
	-2787.5	-1987.5	-1658.2	-1187.5
2787.5	✓ 11: N/A			
2443.2		<input type="checkbox"/> 1: N/A		
2239.1		<input type="checkbox"/> 2: N/A		
2035		<input type="checkbox"/> 3: N/A		
1981.5	<input type="checkbox"/> 14: N/A			
1831		<input type="checkbox"/> 4: N/A		
1609.9		<input type="checkbox"/> 5: N/A		
1187.5		<input type="checkbox"/> 12: N/A		
387.5		<input type="checkbox"/> 13: N/A		
-412.5		<input type="checkbox"/> 15: N/A		

Table Style:	Array View	Parameter:	Number	Calculator
	-2787.5	-1987.5	-1658.2	-1187.5
2787.5	11			
2443.2		1		
2239.1		2		
2035		3		
1981.5	14			
1831		4		
1609.9		5		
1187.5		12		
387.5		13		
-412.5			15	

# Step 12: Ground Connection

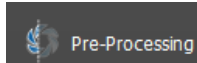
- Create and Open new group “gnd”
- Keep property conductor
- Set group height  $z=-300\dots-150$
- Select large polygon (see picture)
- Right click on Group – Select  “Copy and set height for selected Objects”
- Press Esc



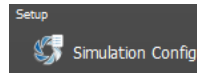
# Step 13: Simulation Setup

- Switch to Simulation Tab

- Click “Pre-Processing”



- Click “Simulation Config”

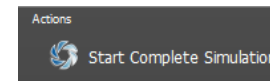
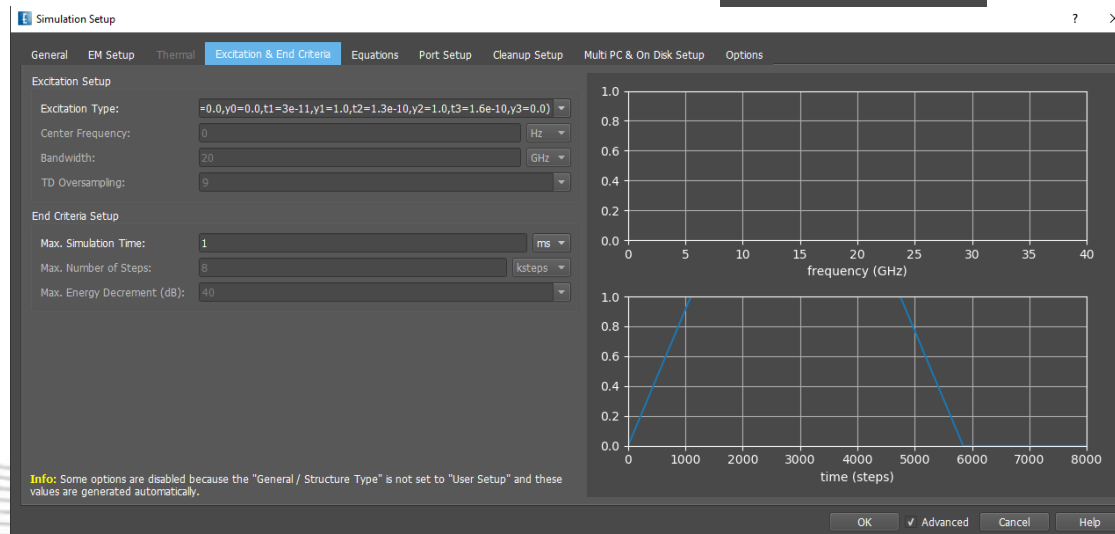


- Select “Excitation & End Criteria”

- Excitation Type: Select “linear” and edit t1,t2,t3:

$\text{linear}(t, t_0=0, y_0=0, t_1=3e-11, y_1=1, t_2=1.3e-10, y_2=1, t_3=1.6e-10, y_3=0)$

- OK, Click “Start Complete Simulation”

**Excitation Setup**

Excitation Type:  $\text{linear}(t, t_0=0, y_0=0, t_1=3e-11, y_1=1, t_2=1.3e-10, y_2=1, t_3=1.6e-10, y_3=0)$

Center Frequency: 0 Hz

Bandwidth: 20 GHz

TD Oversampling: 9

**End Criteria Setup**

Max. Simulation Time: 1 ms

Max. Number of Steps: 8 ksteps

Max. Energy Decrement (dB): 40

Info: Some options are disabled because the "General / Structure Type" is not set to "User Setup" and these values are generated automatically.

OK Advanced Cancel Help



# Step 14: Simulation Results

- After Simulation: Switch to 2D Results
- Plot Type: Voltage (Time Domain)
- Right click on Curves: Show all
- Reload Data, Autoscale

