Automatic Design Tool for PCB Embedded technology

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Guillaume LEFEVRE

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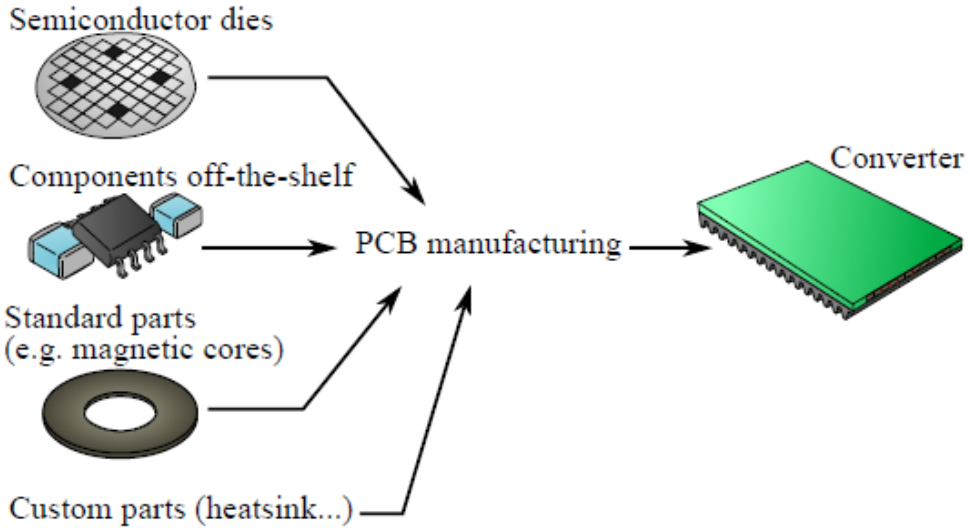
MITSUBISHI ELECTRIC R&D CENTRE EUROPE

1 Introduction

Automatic Design Tool for PCB Embedded technology

Introduction



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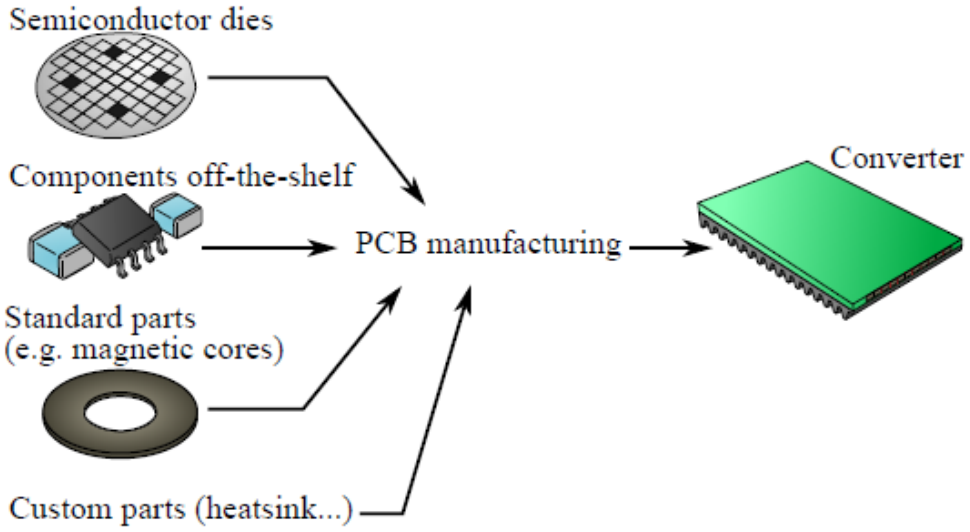

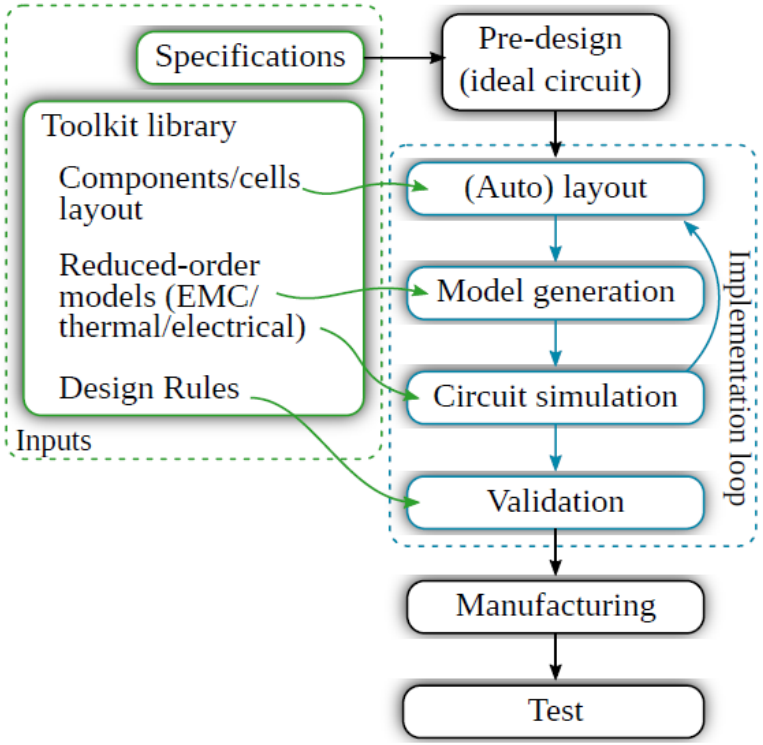

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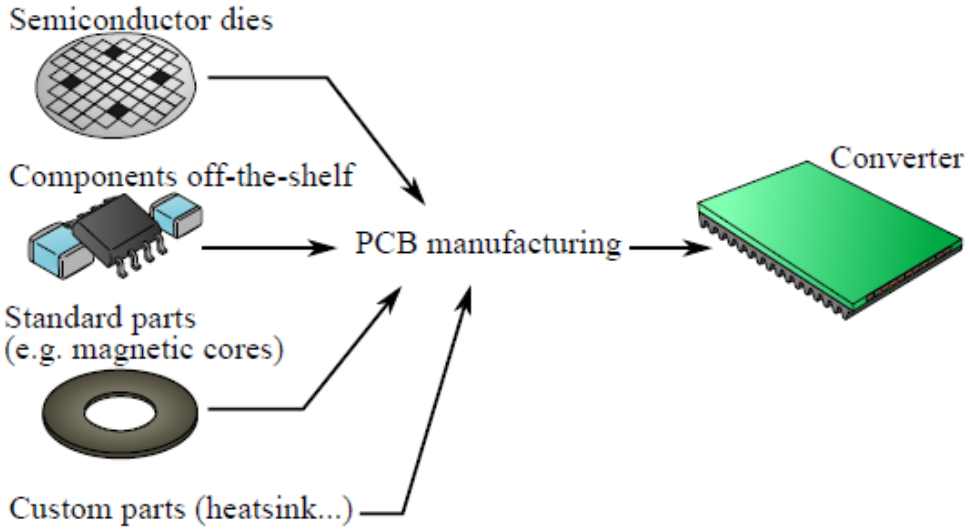
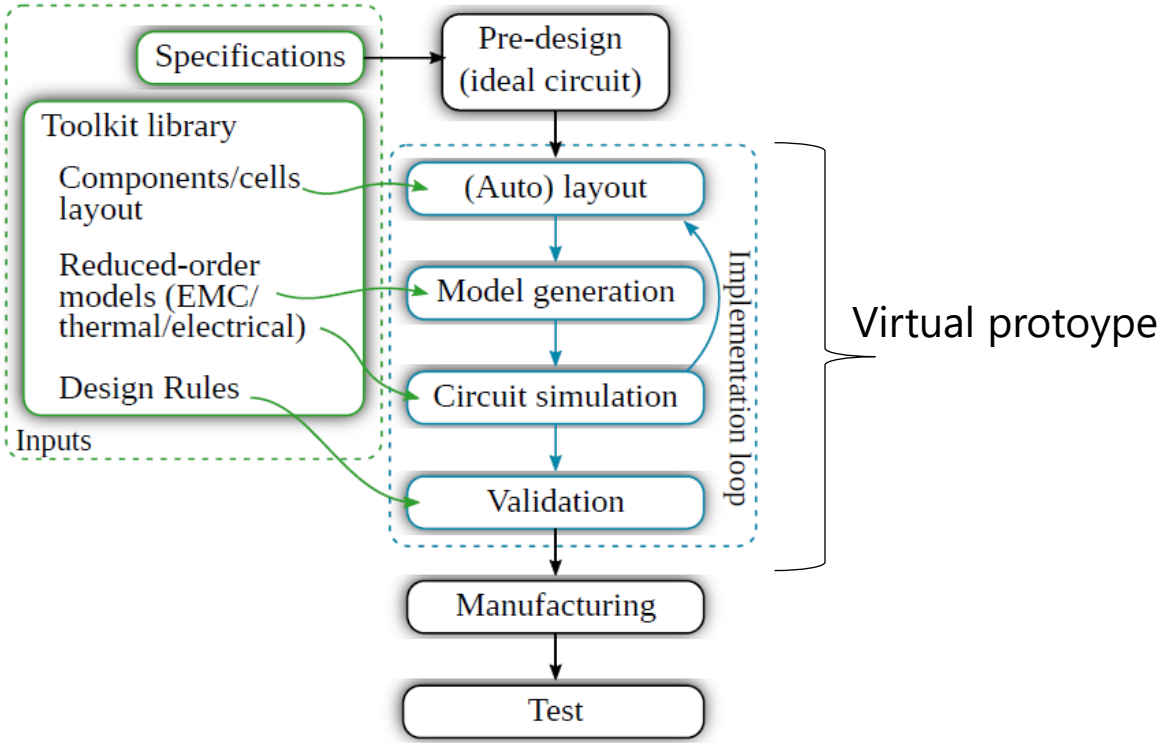
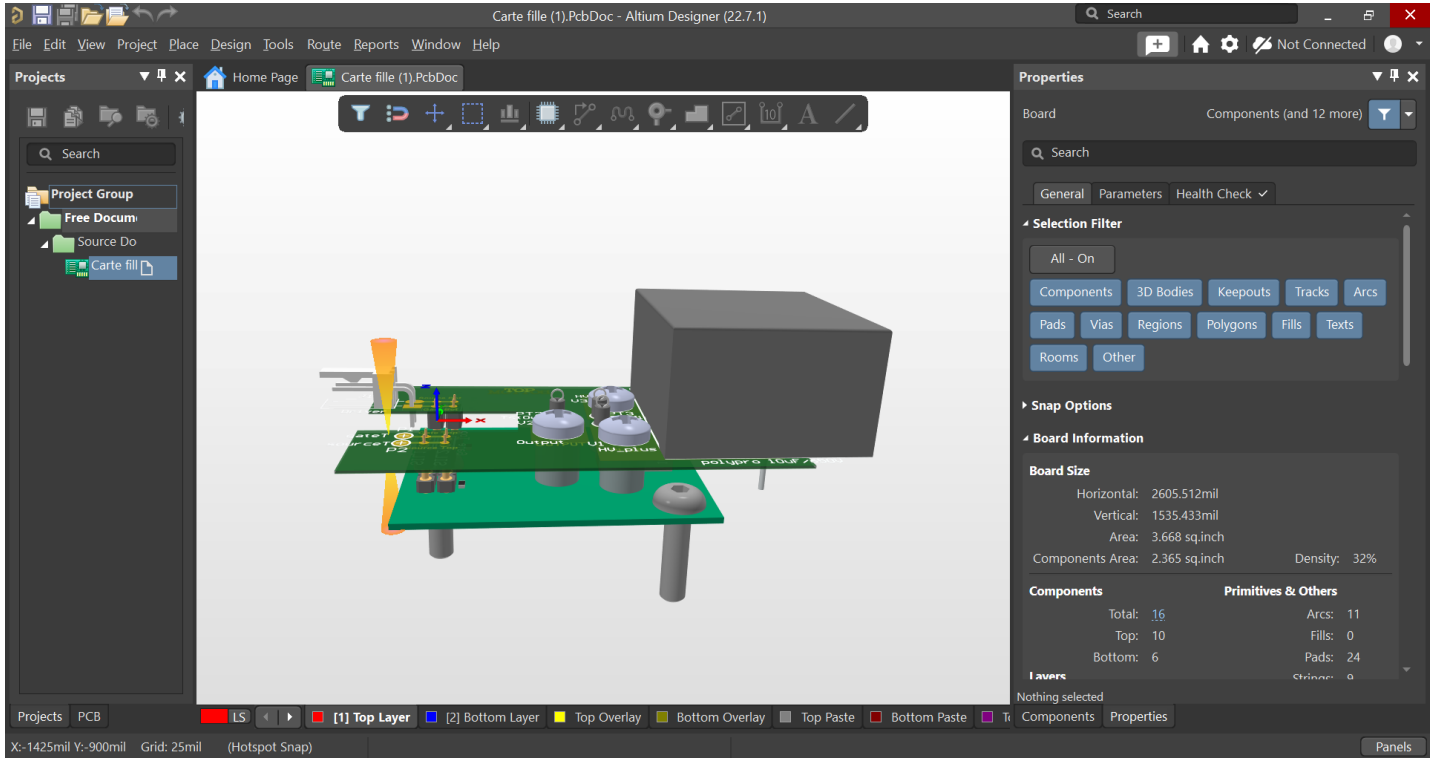




eCAD

The entire structure of a PCB-embedded converter is described in the eCAD tool



- Layout
  - Layers materials
  - Layers dimensions
- Components:
  - pins info
  - Location
  - Value
- And more : schematic …

eCAD

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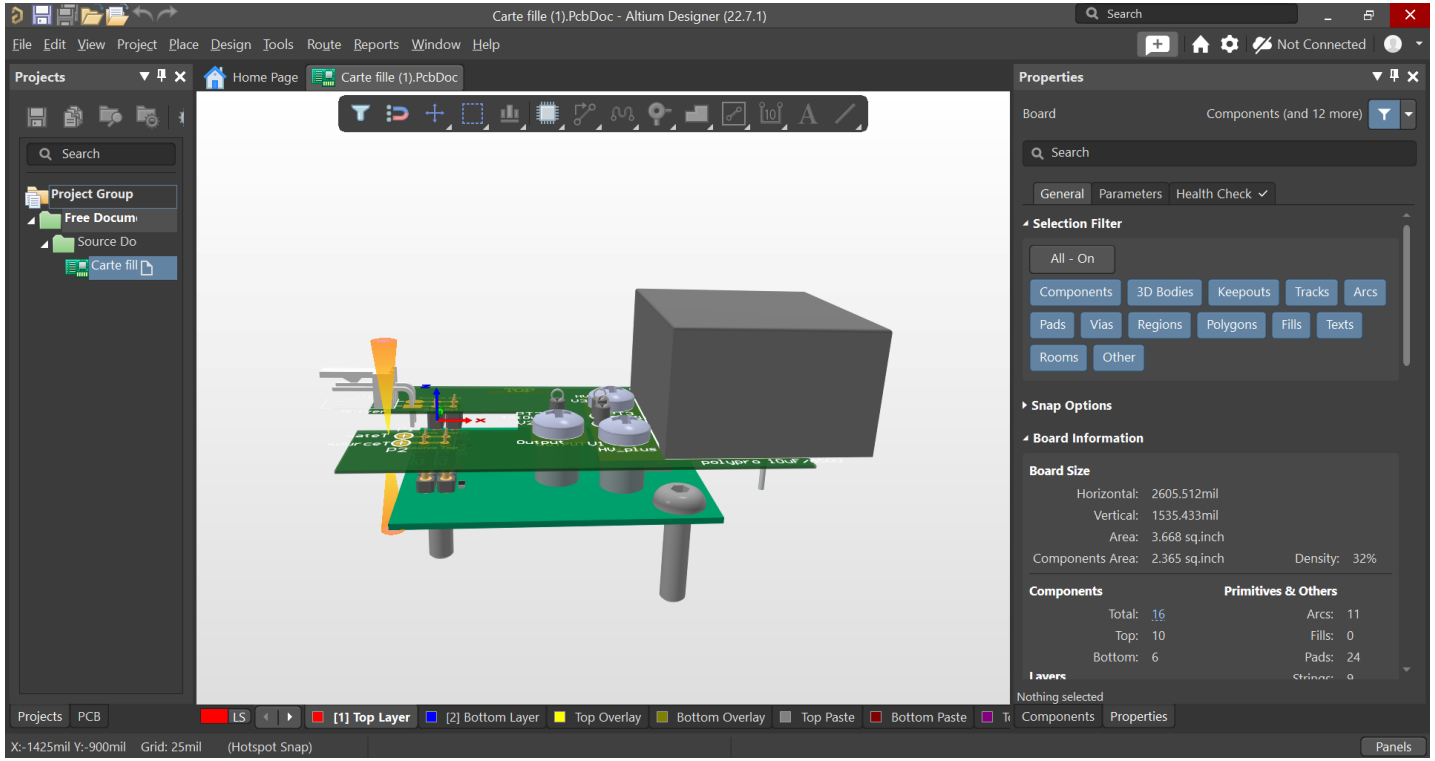


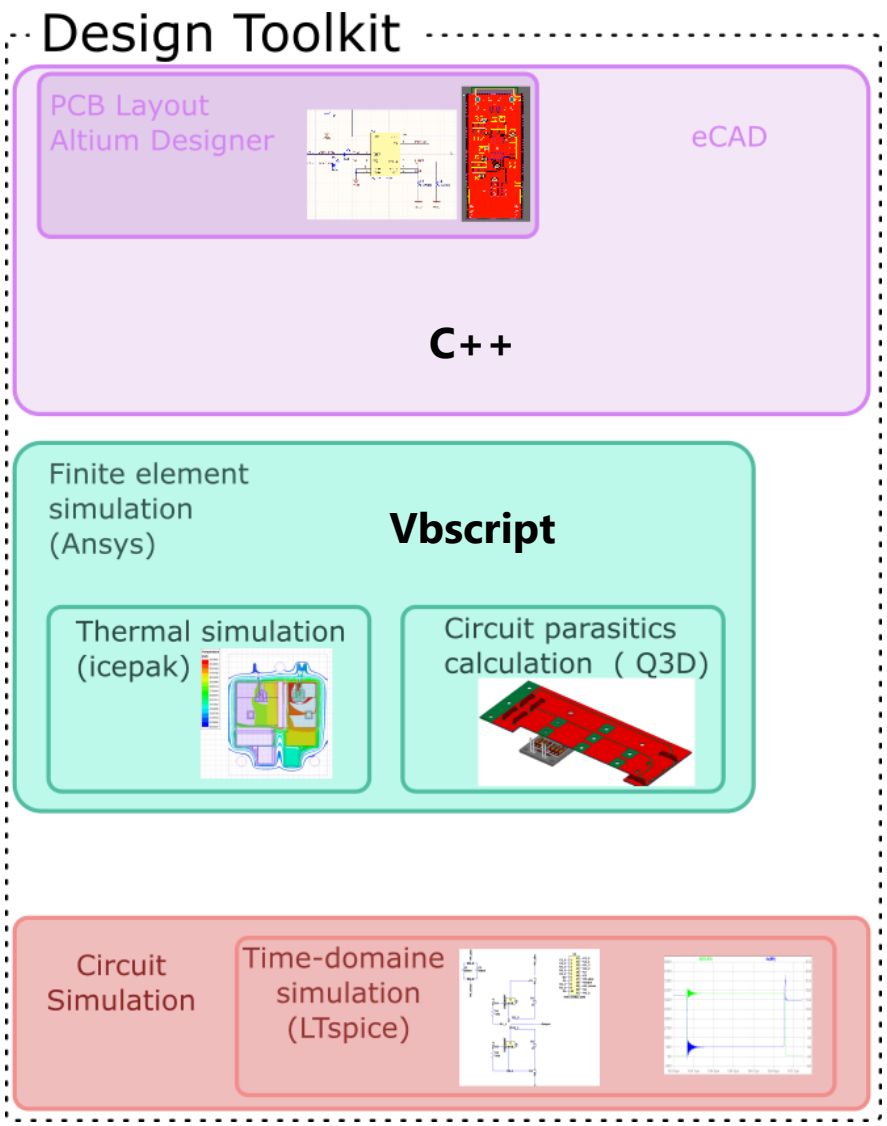
- Layout
  - Layers materials
  - Layers dimensions
- Components:
  - pins info
  - Location
  - Value
- And more : schematic …

Is-it possible to generate a virtual prototype from this description ?

Introduction

Generate a virtual prototype from the detailed circuit description available in the PCB CAD:

- Simulation of the complete PCB model (thermal, electrical & coupled models)
- Use of existing modelling software



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Generate a virtual prototype from the detailed circuit description available in the PCB CAD:

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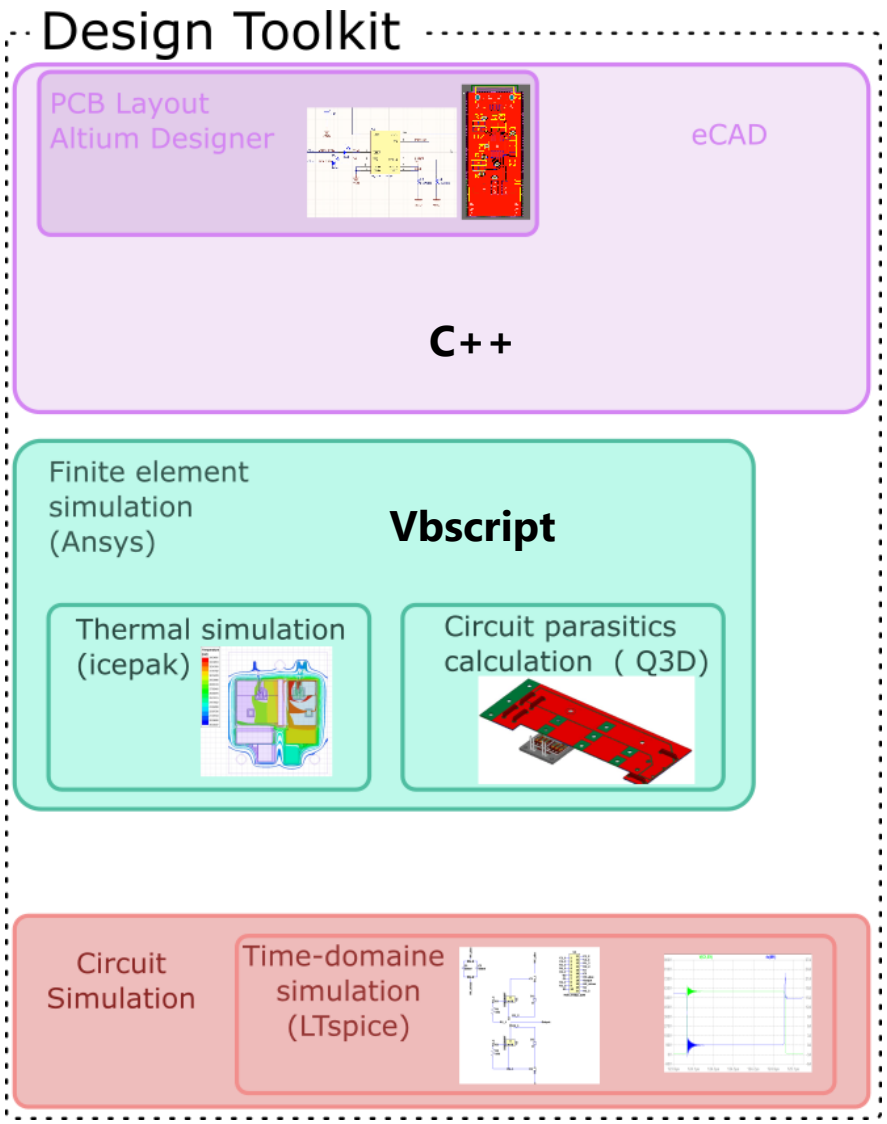
Electrical modelling approach realized:

- Generate a readable LTspice schematic which includes the parasitic effect of the interconnections
  ➔ Validation of the electrical behavior



Introduction

Generate a virtual prototype from the detailed circuit description available in the PCB CAD:

- Simulation of the complete PCB model (thermal, electrical & coupled models)
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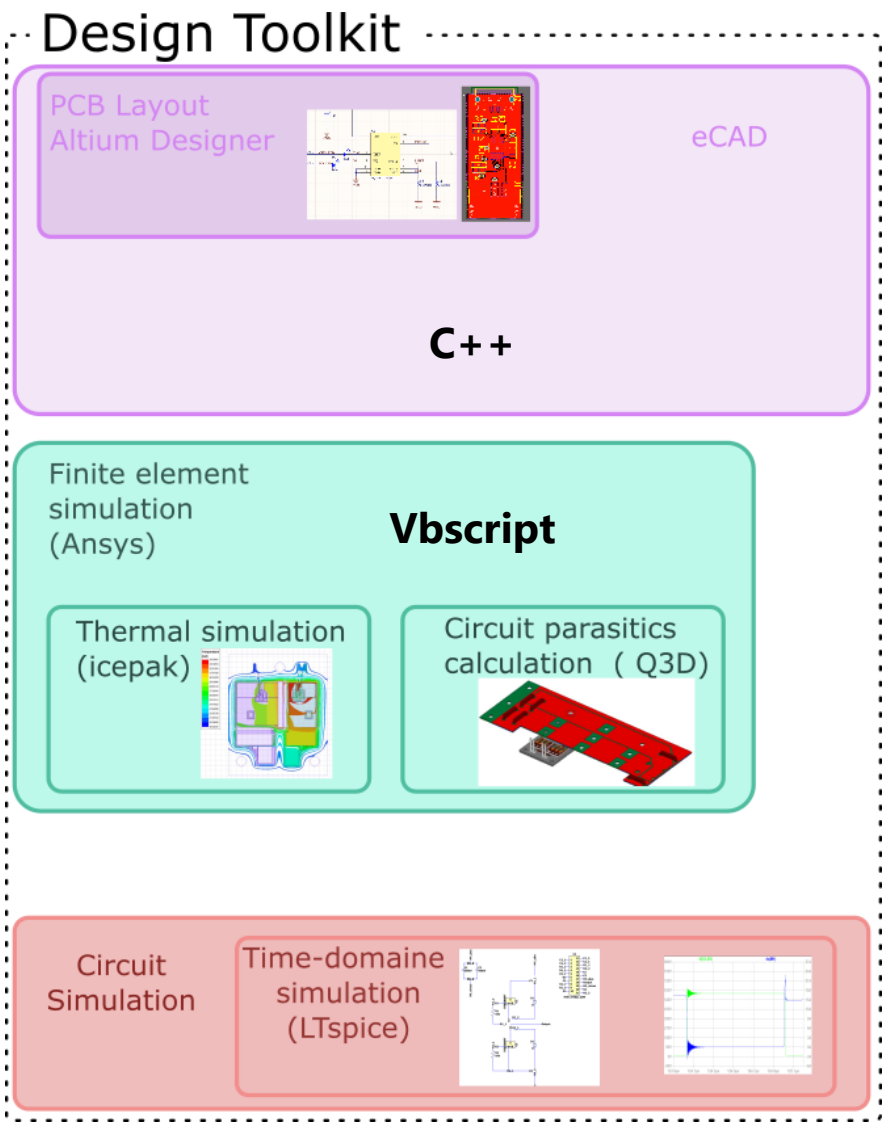
Electrical modelling approach realized:

- Generate a readable LTspice schematic which includes the parasitic effect of the interconnections
  ➔ Validation of the electrical behavior

Thermal modelling approach in progress

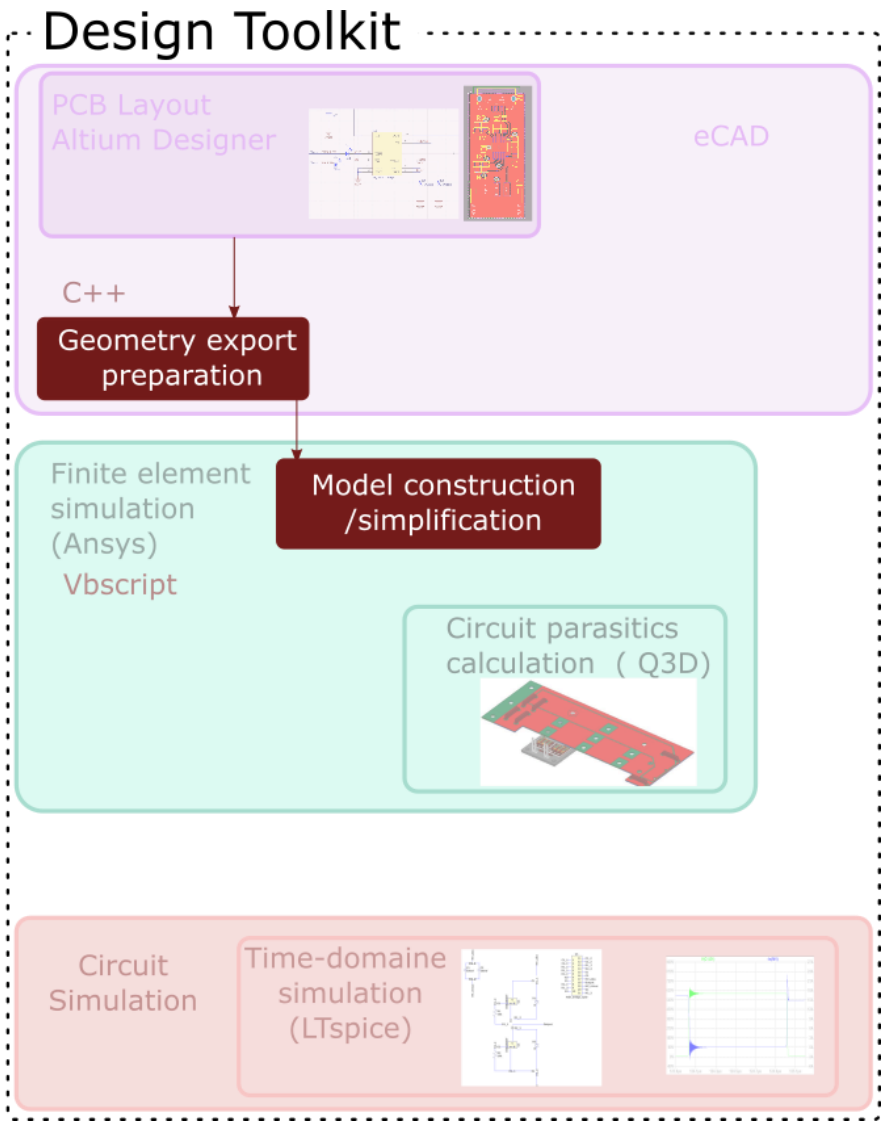
- Generate a reduced-order thermal model (RC-network equivalent thermal model)
- Add the RC-network to the LTspice schematic
  ➔Validation of the thermal behavior



2 Electrical modelling

Automatic Design Tool for PCB Embedded technology

3D-Model Construction



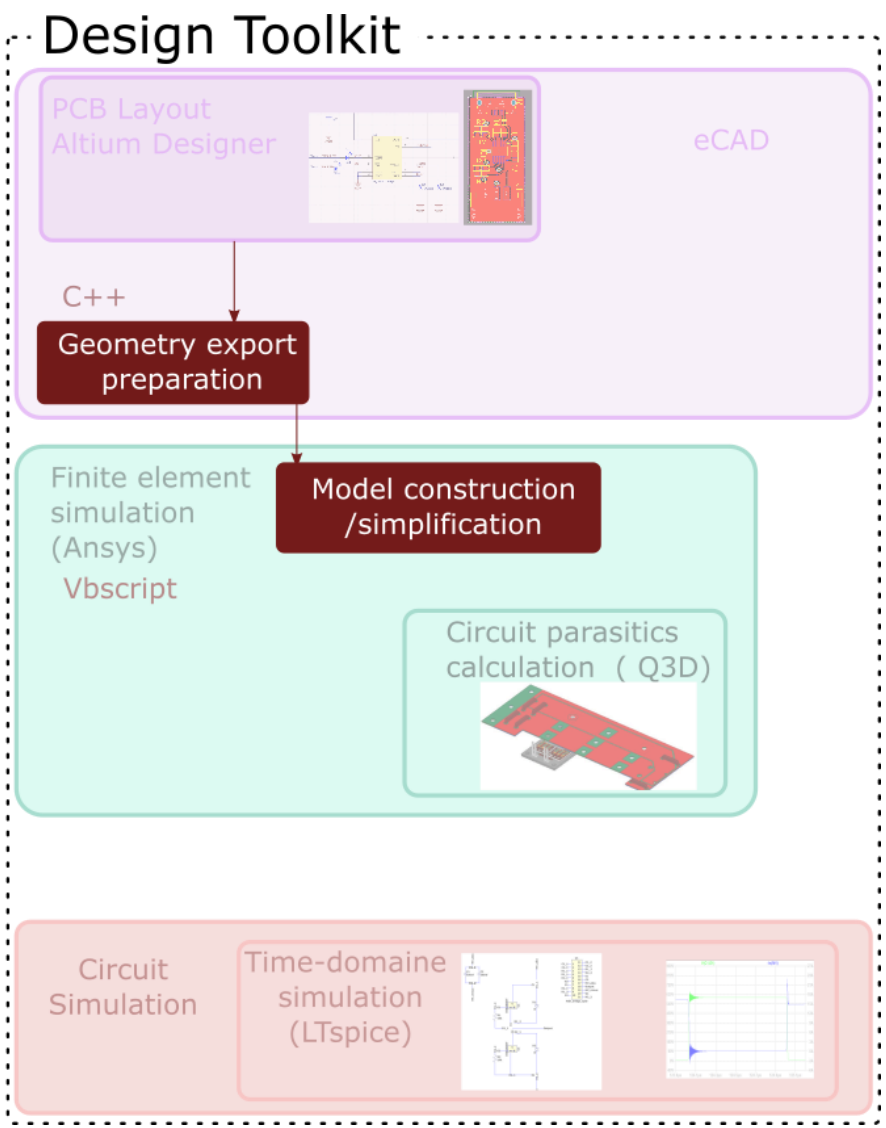
Data Export format

Many file format are available

Importing data in Ansys :

	Gerber	ODB++	IPC-2581	EDB
3D-model	--	-	-	++
Layout details (materials, Nets)	--	-	+	++
Components details	--	-	+	++

3D-Model Construction



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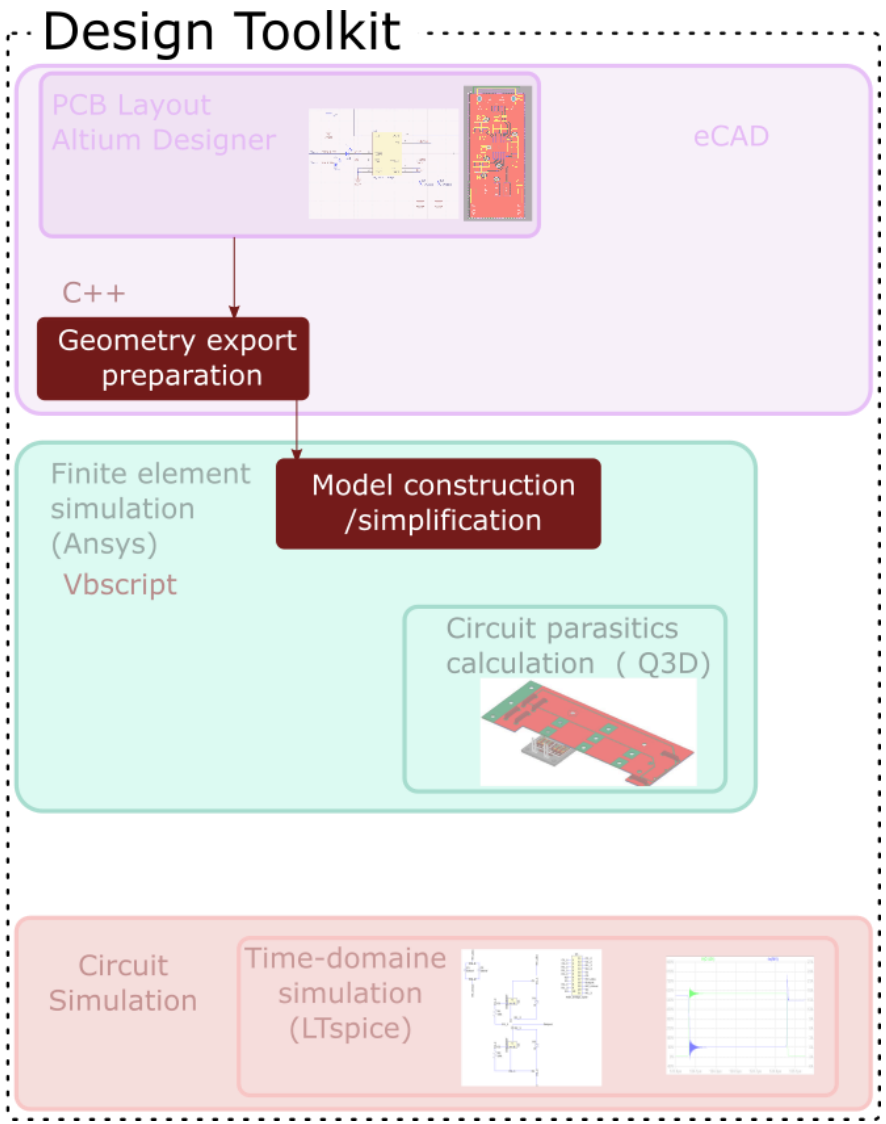
	Gerber	ODB++	IPC-2581	EDB
3D-model	--	-	-	++
Layout details (materials, Nets)	--	-	+	++
Components details	--	-	+	++

Additional data required :

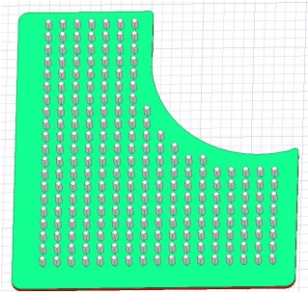
- Connection pads to be considered
- Via simplification data
- Some testbench info (e.g., Heatsink description)

3D-Model Construction

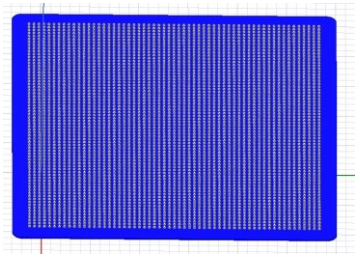


1. **Geometry import**
2. **Simplify the geometry**

- Faceting of round shapes (feature of Ansys)
- Grouping of vias

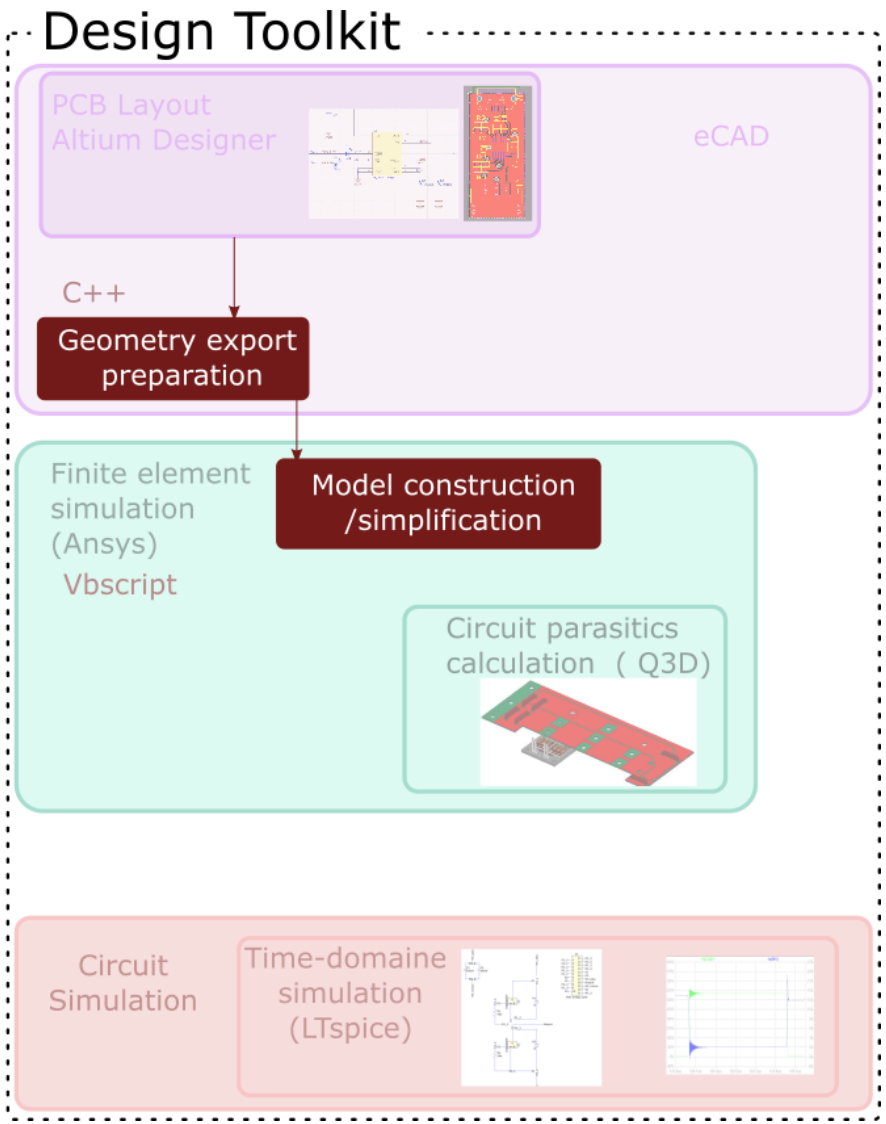


232 Via
Area= 10,44 mm^2



4012 µVia
Area=33,9014 mm^2

3D-Model Construction



1. **Geometry import**
2. **Simplify the geometry**

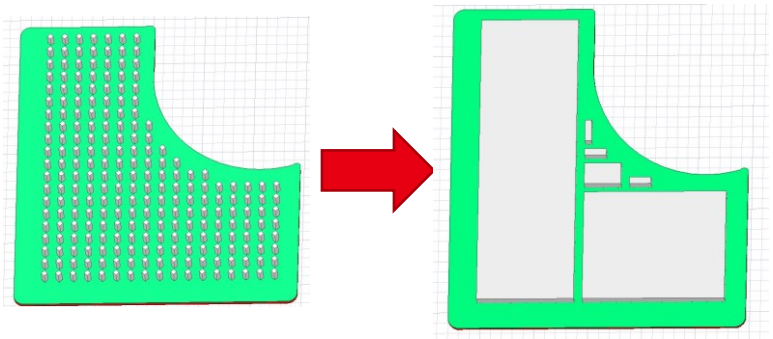
- Faceting of round shapes (feature of Ansys)
- Grouping of vias

Aims to reduce :

- the number of objects
- the complexity of the mesh

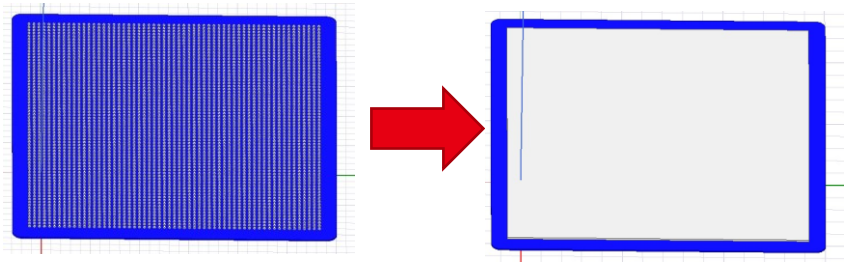
Limit the processing time & memory

Simplification



232 Via
Area= 10,44 mm^2

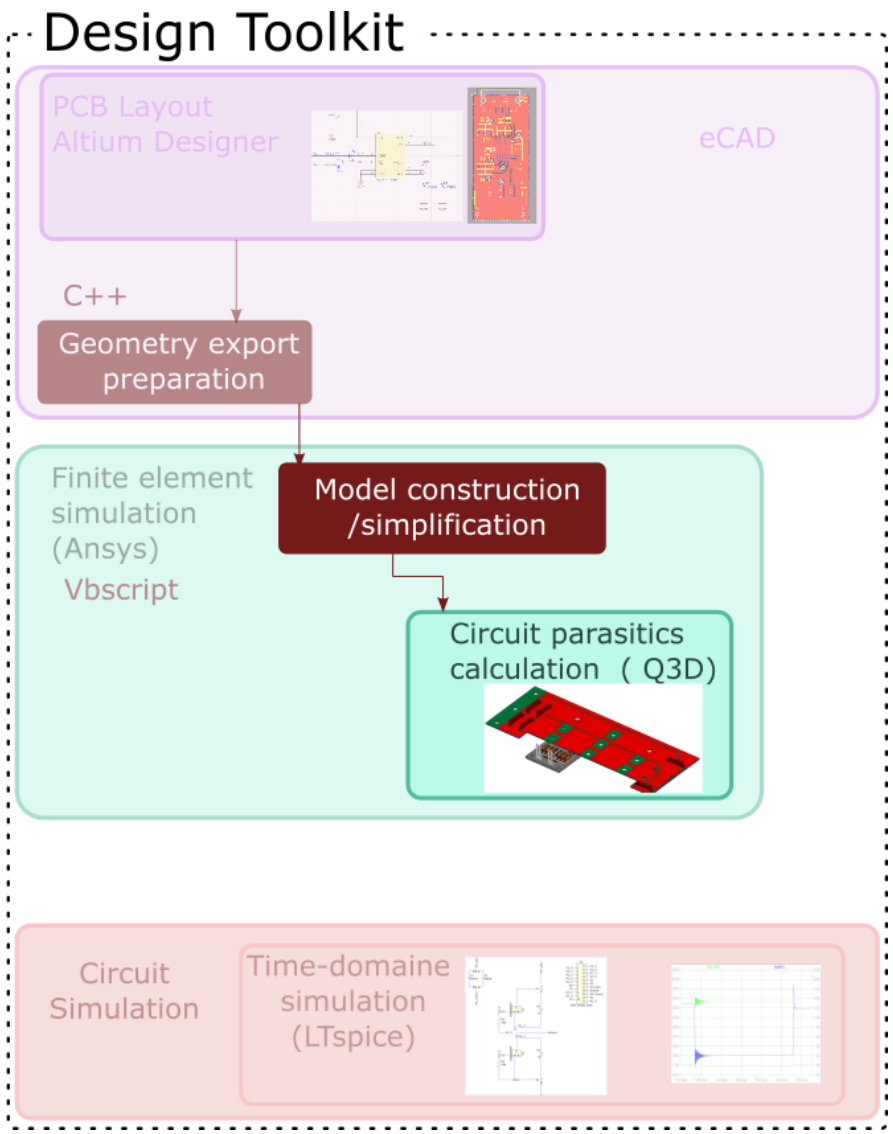
6 « Via » groups
Area= 98,12 mm^2
Ratio= 0,1



4012 µVia
Area=33,9014 mm^2

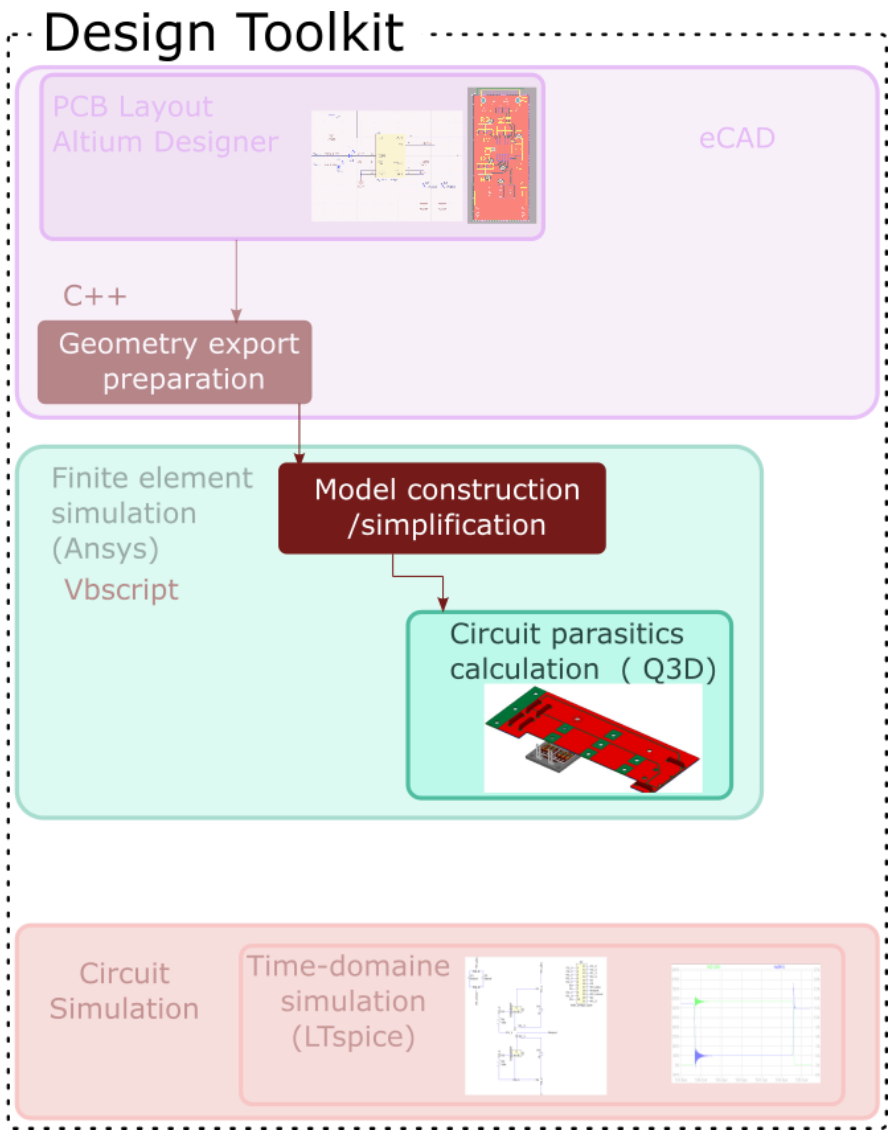
1 « Via » group
Area=254,853 mm^2
Ratio =0,133

Preparation of the 3D-Model



1. **Geometry import**
2. **Simplify the geometry**
3. **Prepare the 3D-model for Q3D**

Preparation of the 3D-Model



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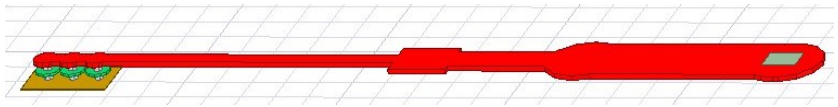
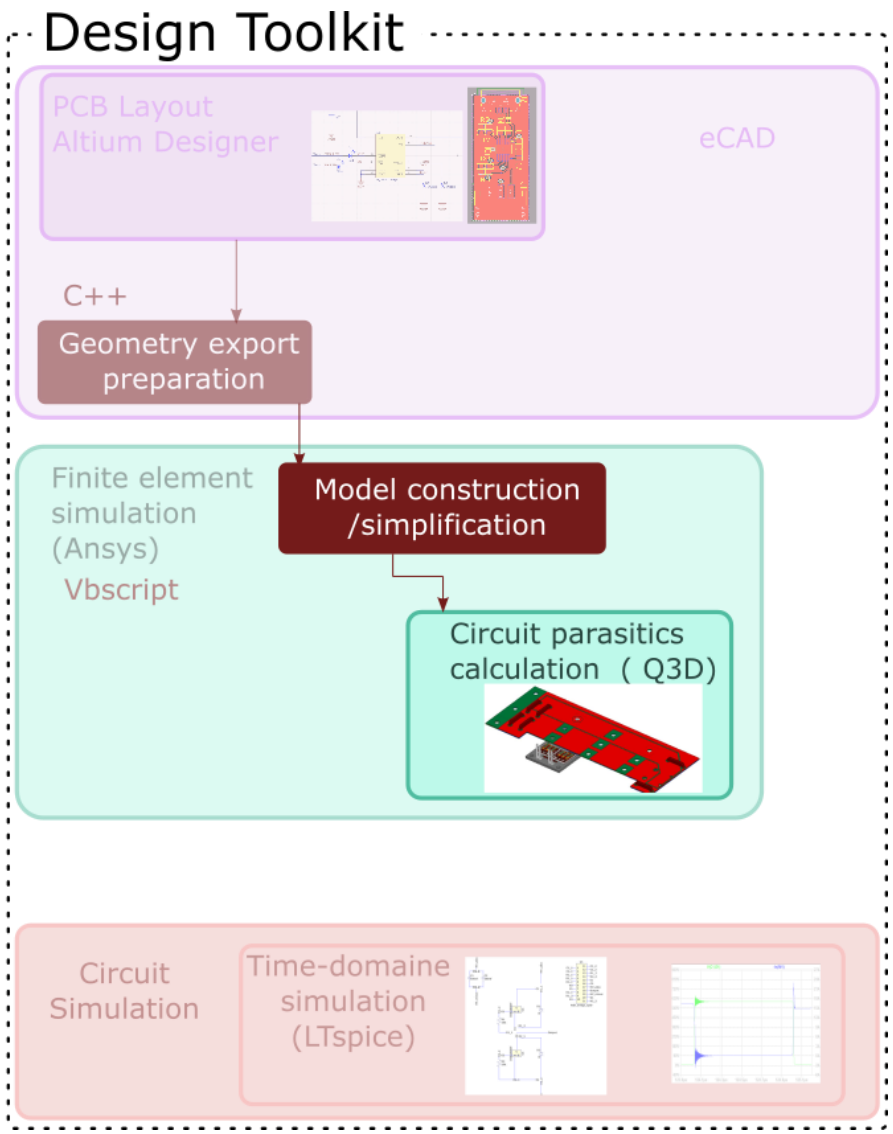
- Automatic placement of the terminals (Sink/Source)

Net = connected conductors



Preparation of the 3D-Model



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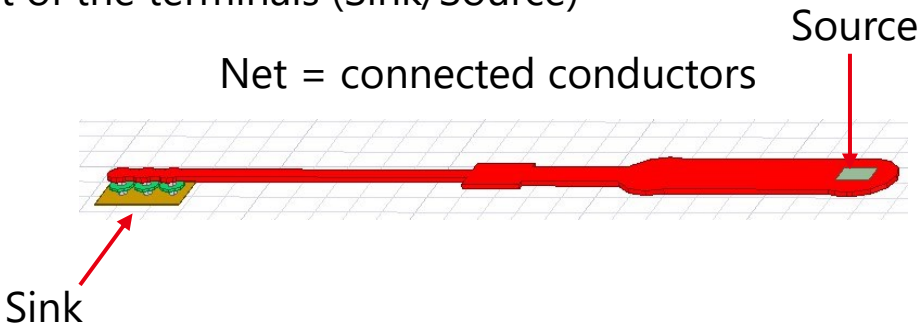
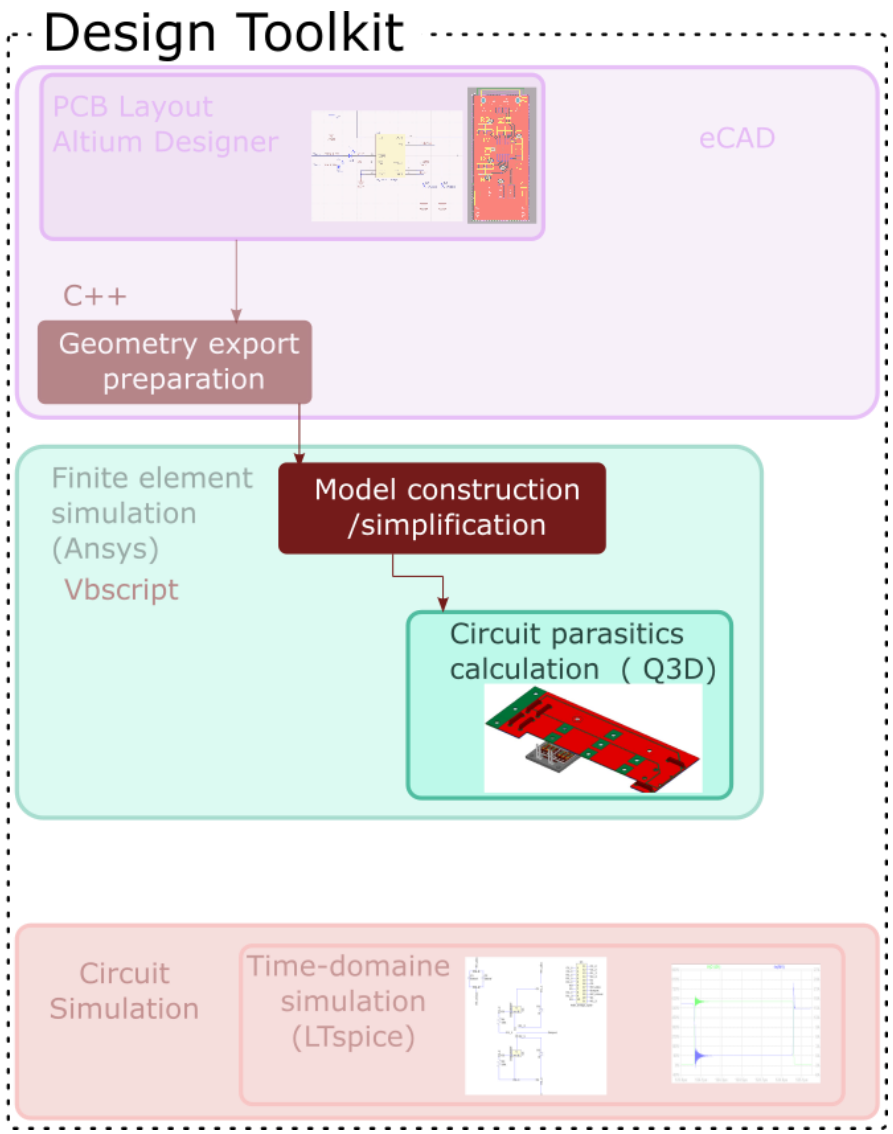


Preparation of the 3D-Model



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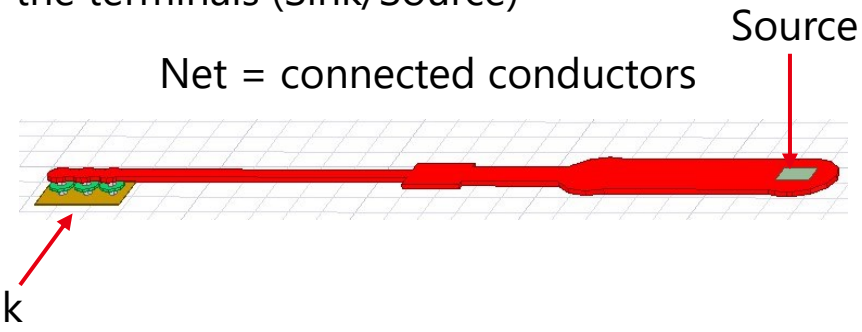
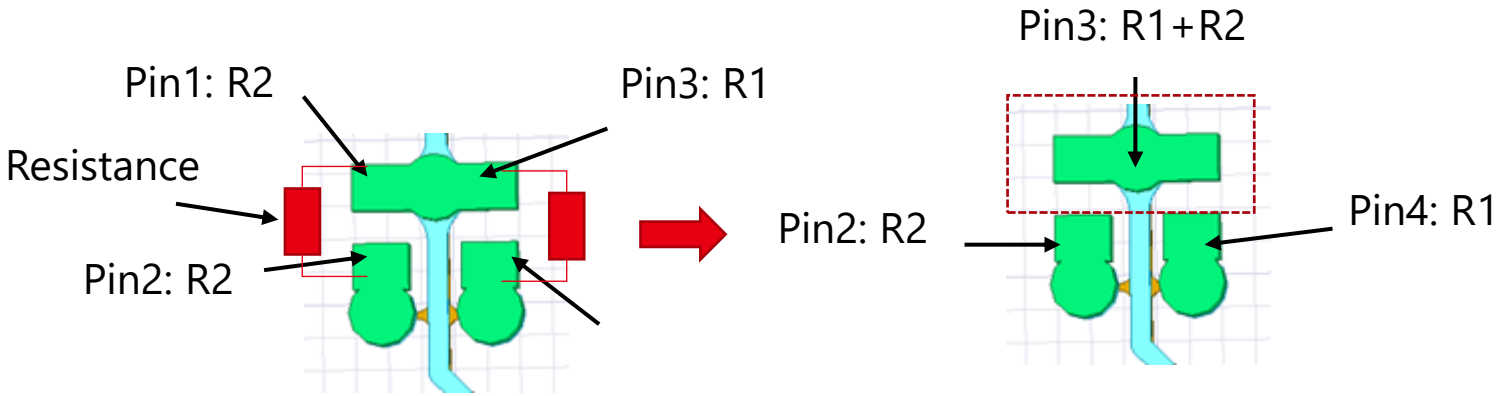
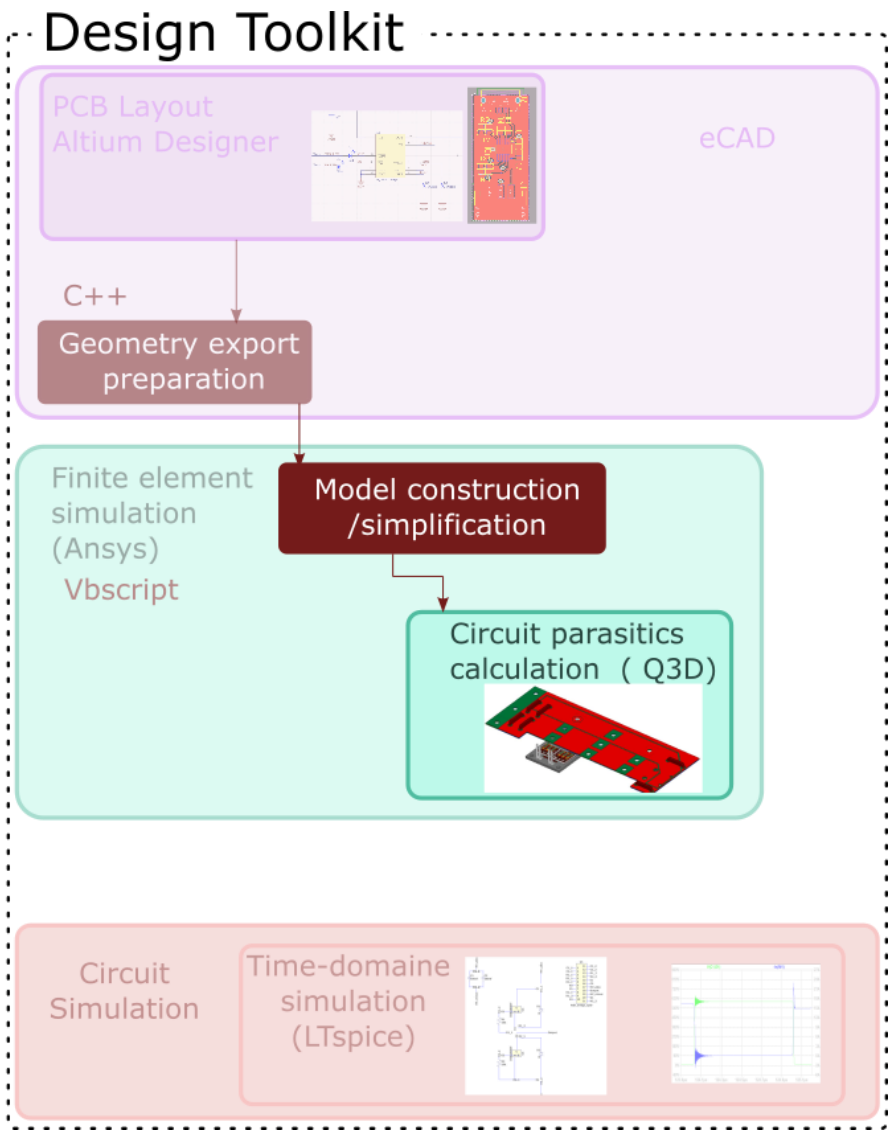


- Terminals simplifications:



Preparation of the 3D-Model



1. **Geometry import**
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3. **Prepare the 3D-model for Q3D**

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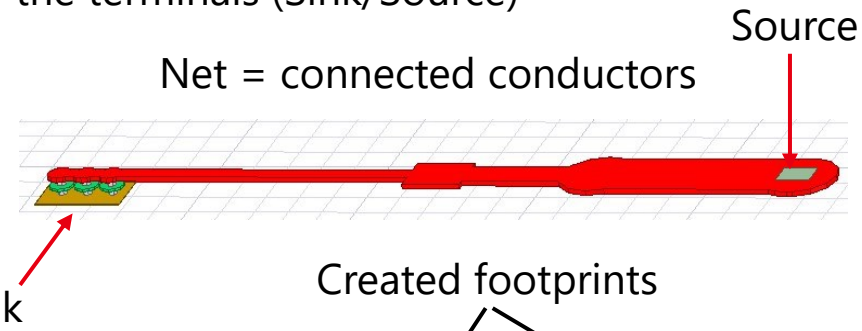

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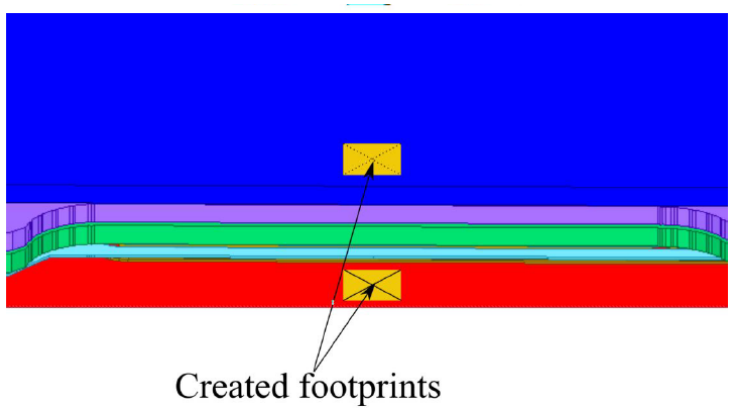
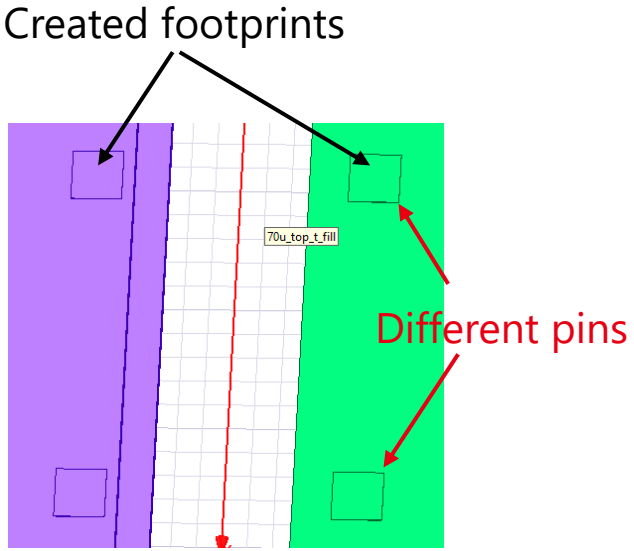
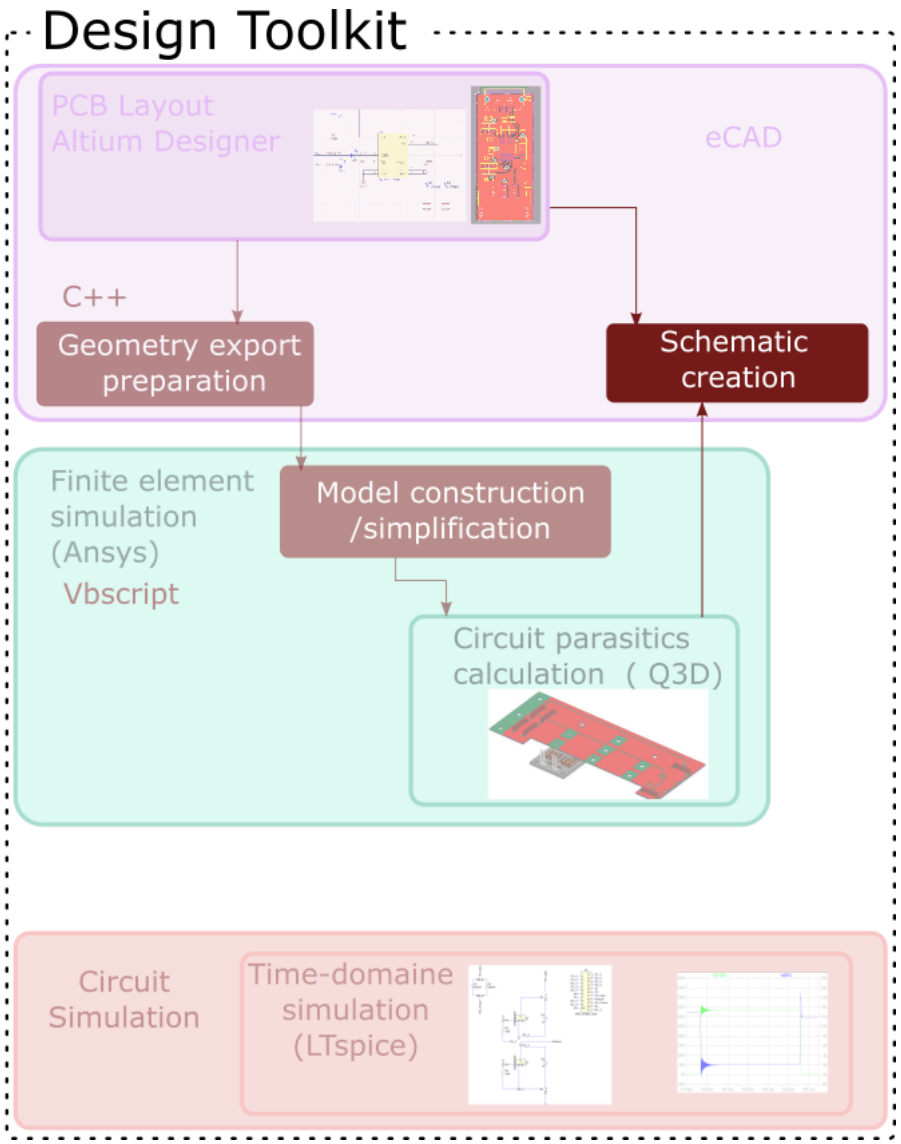


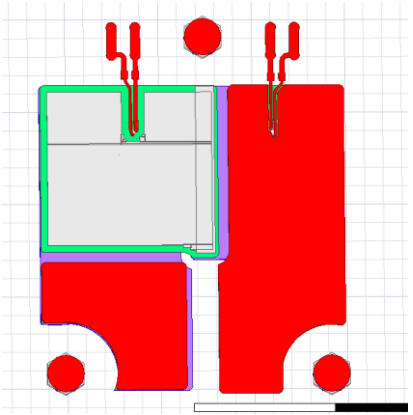


Q3D simulation



1. **Geometry import**
2. **Simplify the geometry**
3. **Prepare the 3D-model for Q3D**
4. **Run stray R,L,C calculation between all terminals**
5. **Generate the SPICE model**
6. **Export the SPICE model terminals info to the custom extension (eCAD)**

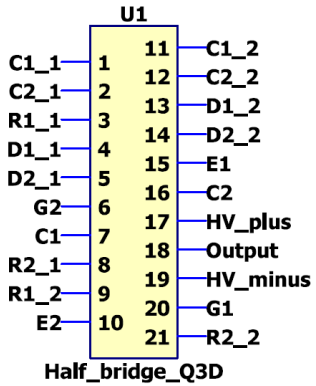
Ansys (Q3D 3D-Model)



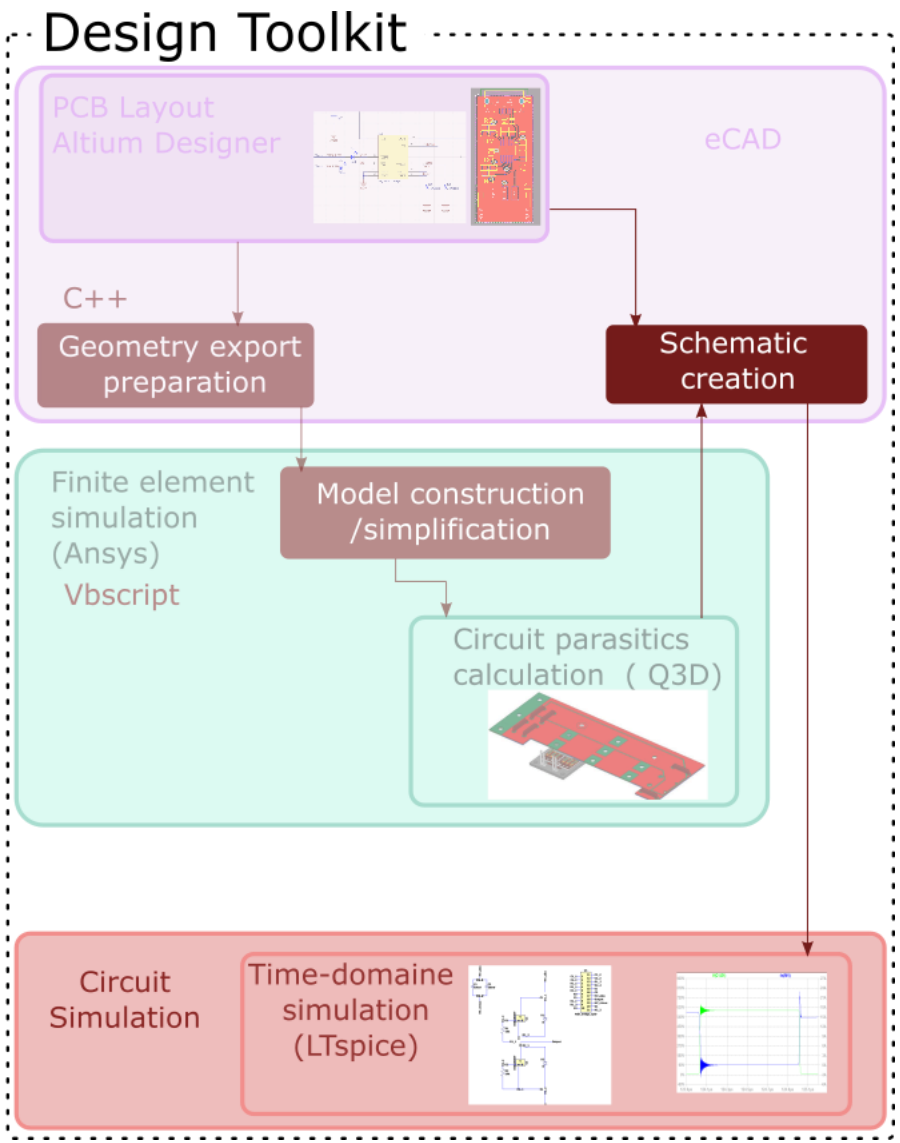
Number of VIAs : 103

Solved in ~ 4 min

Stray R,L,C equivalent circuit (LTspice)

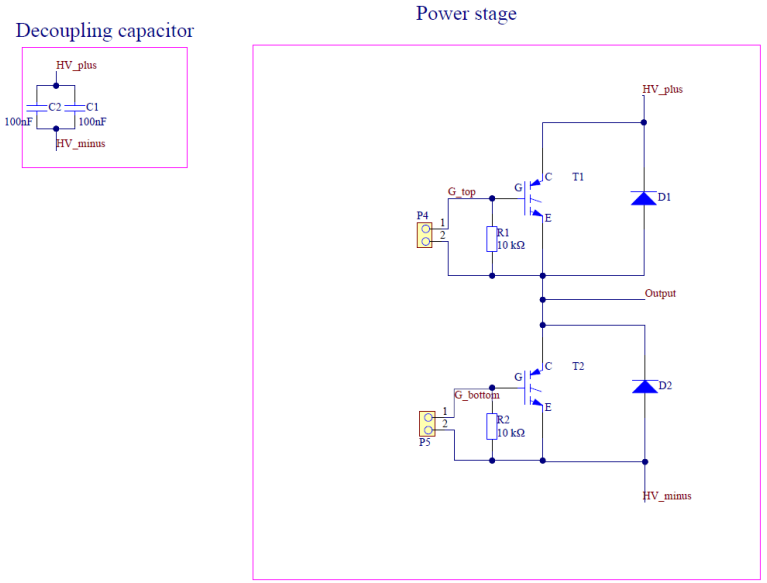


LTspice schematic generation

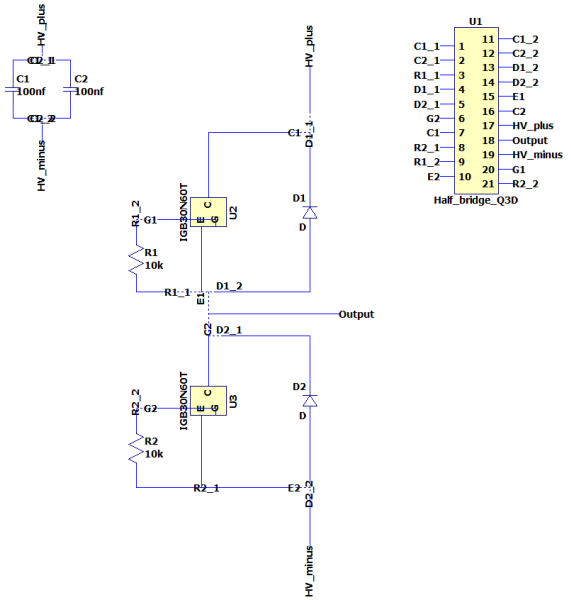


6. **Export the SPICE model terminals info to the custom extension (eCAD)**
7. **Generate the complete LTspice schematic :**
   - **Reproduce location of symbols (from Altium schematic)**
   - **Layout model as single block**
   - **Generate automatically the connections**

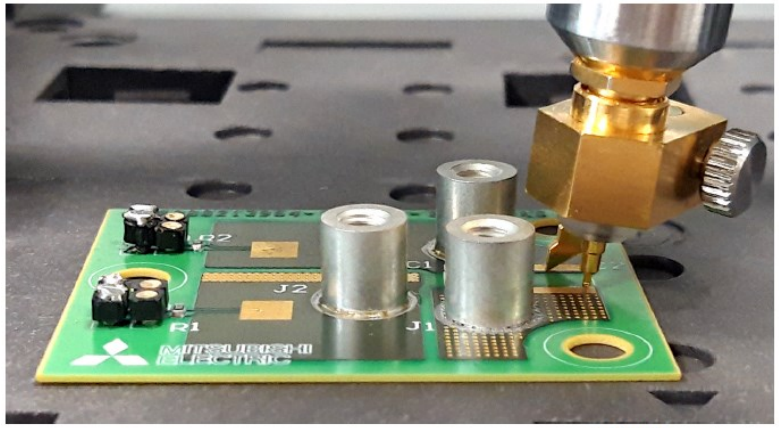
eCAD(Altium)

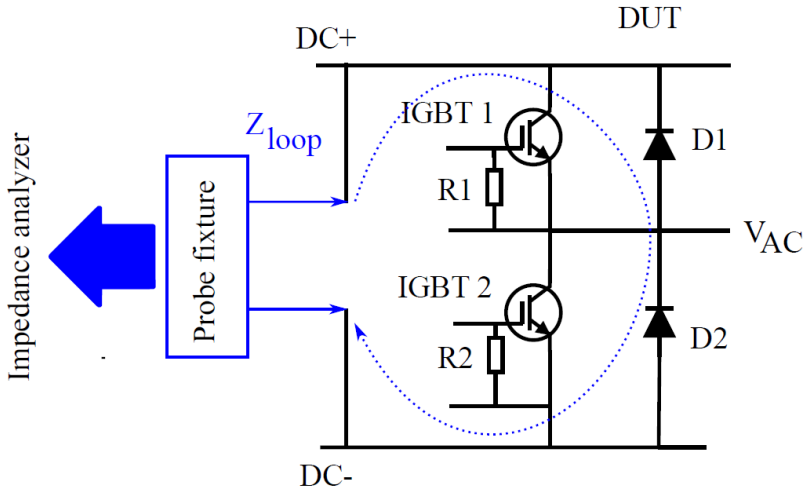


Circuit simulation(LTspice)



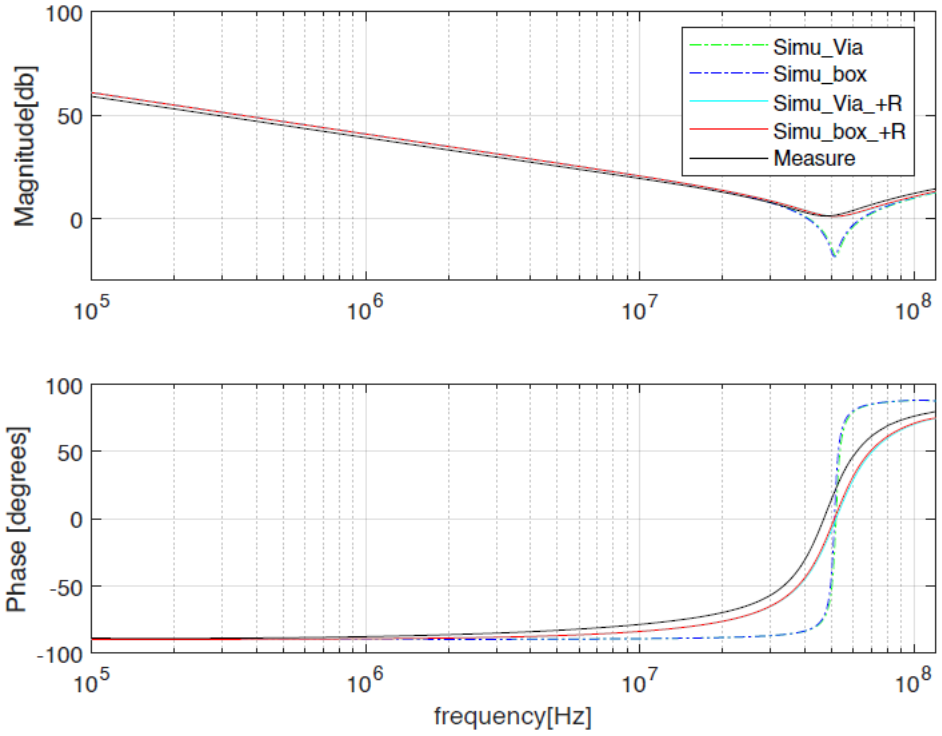
1. Characterization of circuit impedances





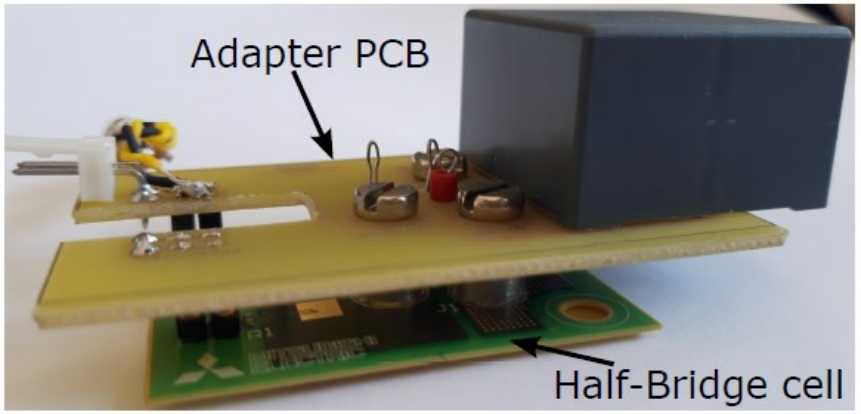
Impedance :

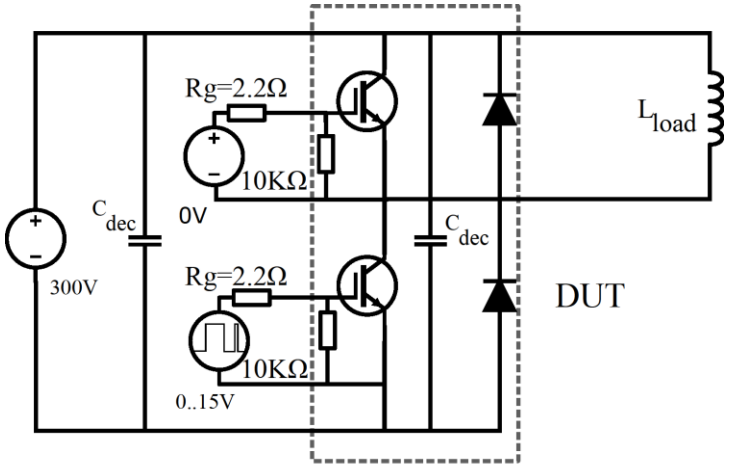
Simulation vs Measurement

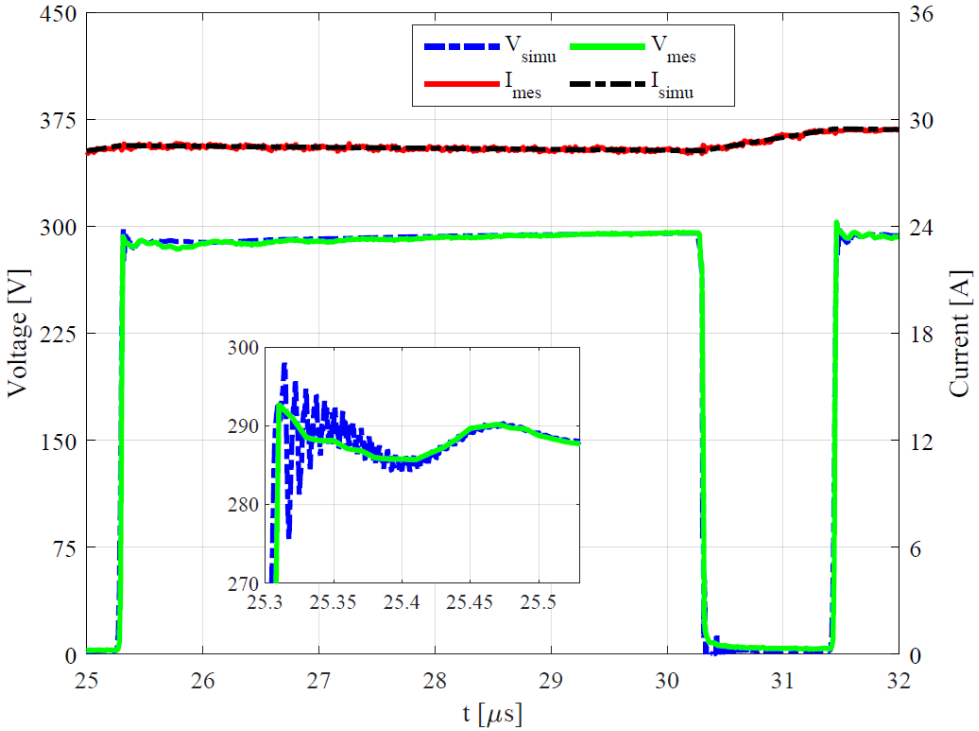


- No bad effect of the of the geometry simplification
- Measurement accuracy limited (contact prob ...)
- Good simulation/experiment agreement overall

2. Double pulse test







- Used equivalent Spice model for the IGBT & Diode
- Good match between measurement & simulation

Results validate the electrical modelling approach

3 Thermal Modelling

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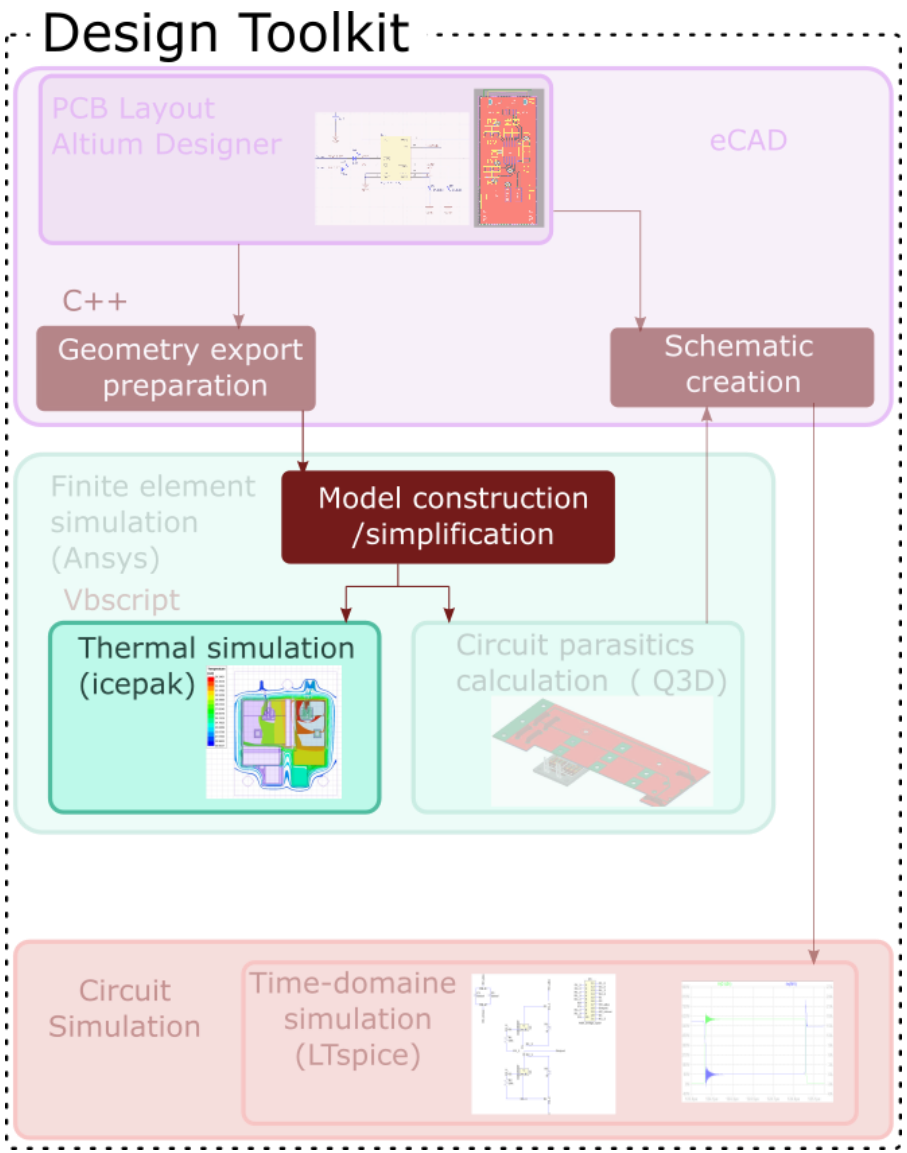
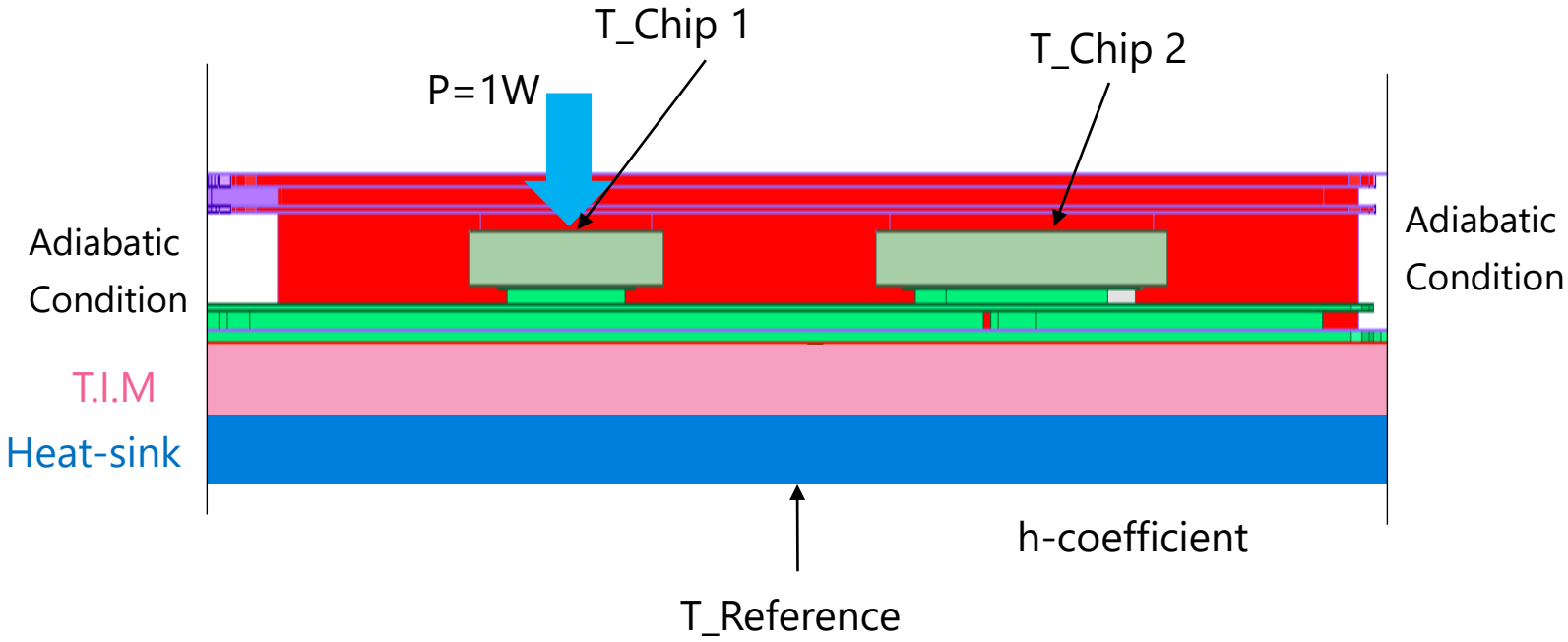
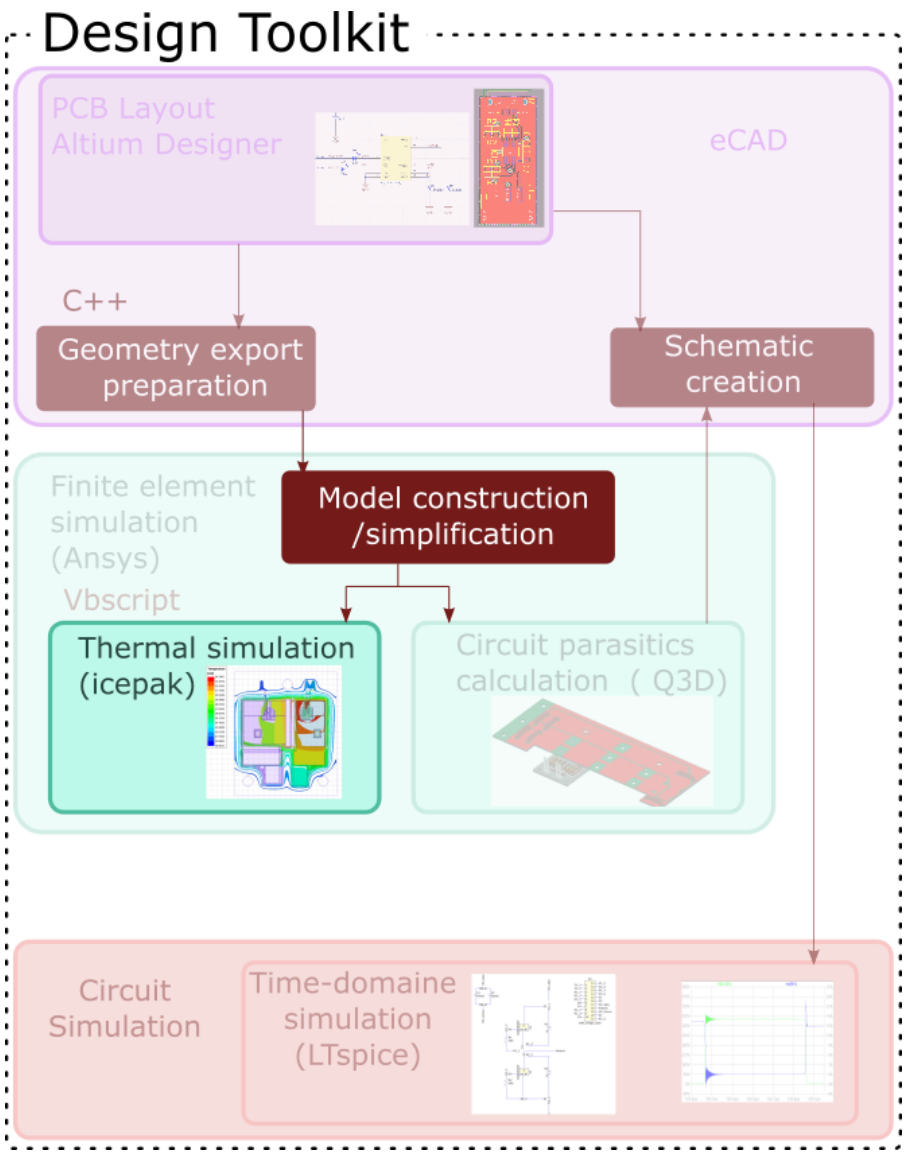
Thermal model



Run the thermal transient simulation

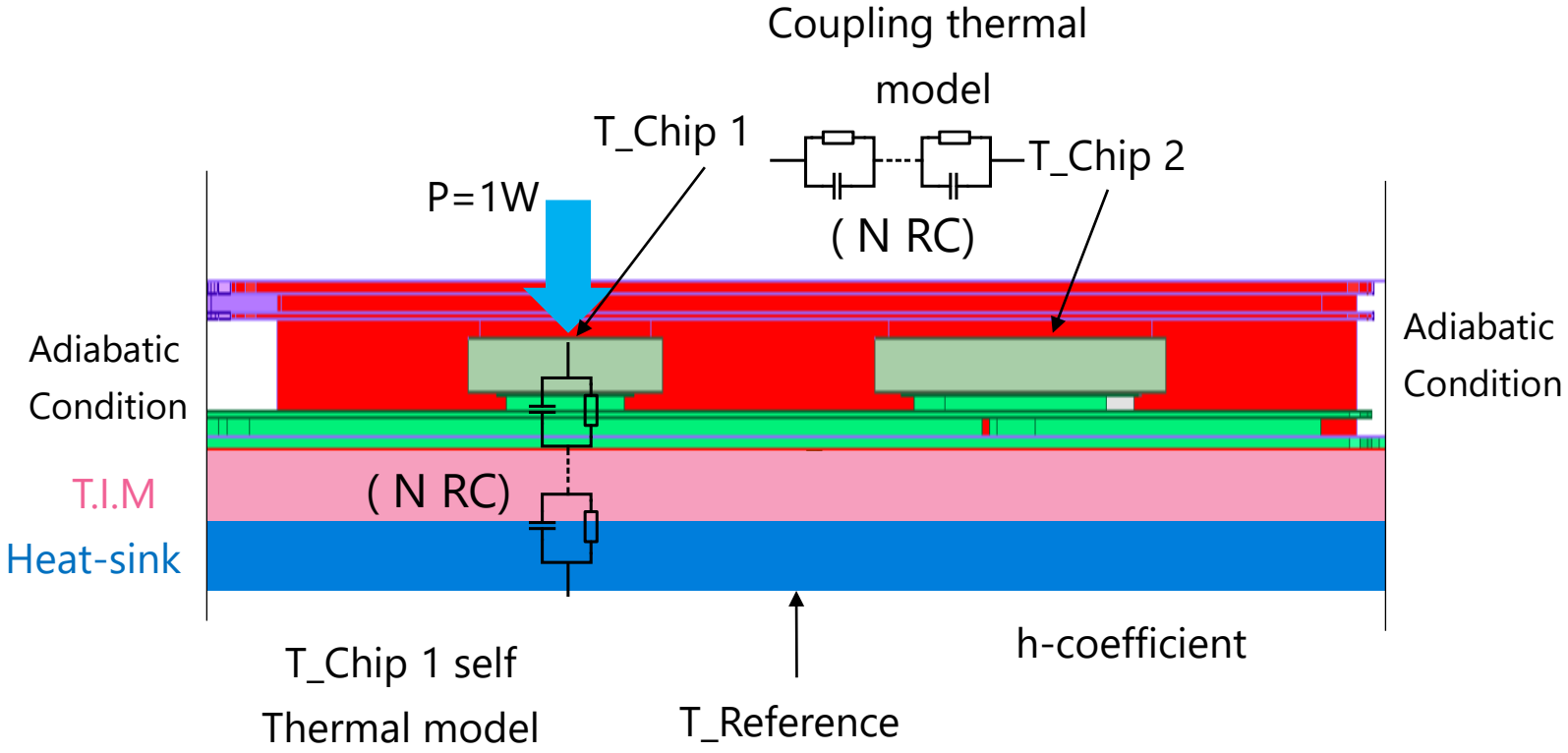


Thermal model

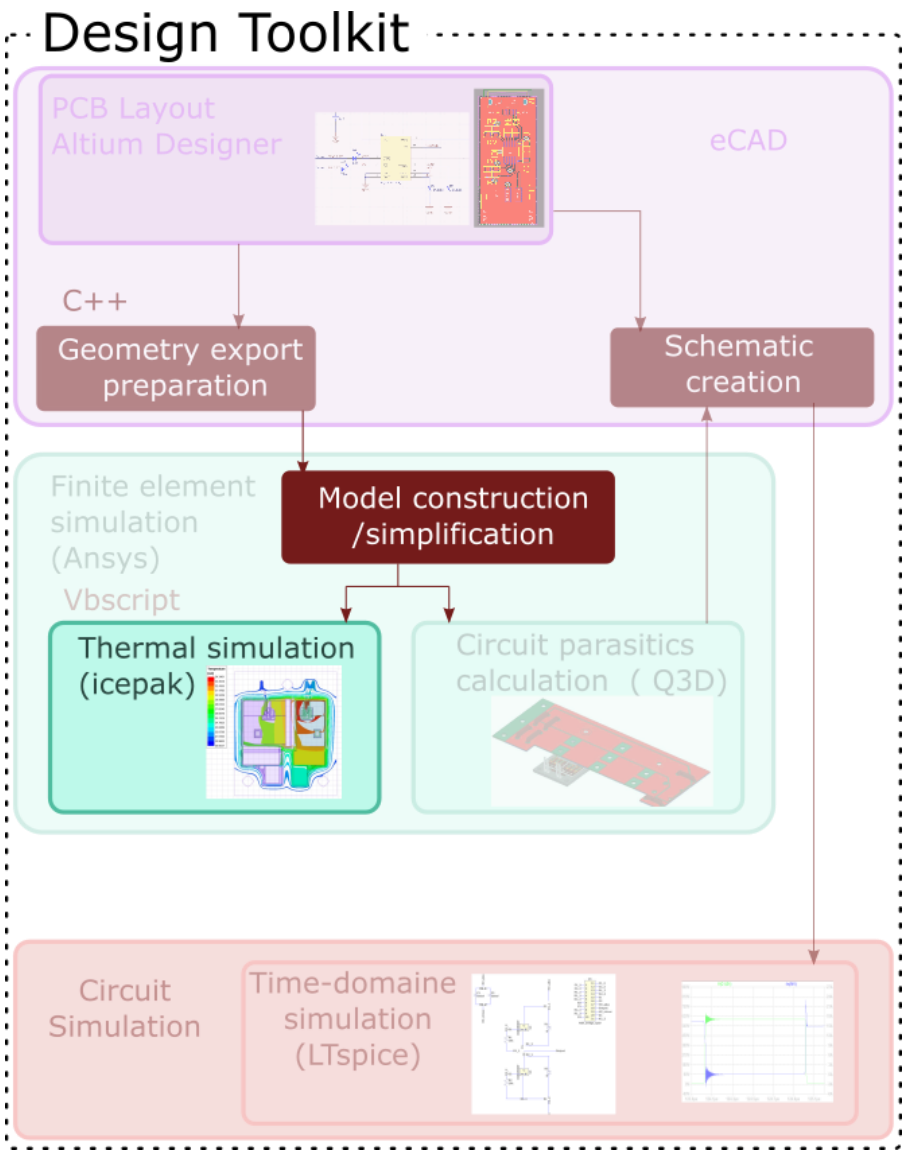


- **Objective of this simulation**

Run the thermal transient simulation



Thermal model



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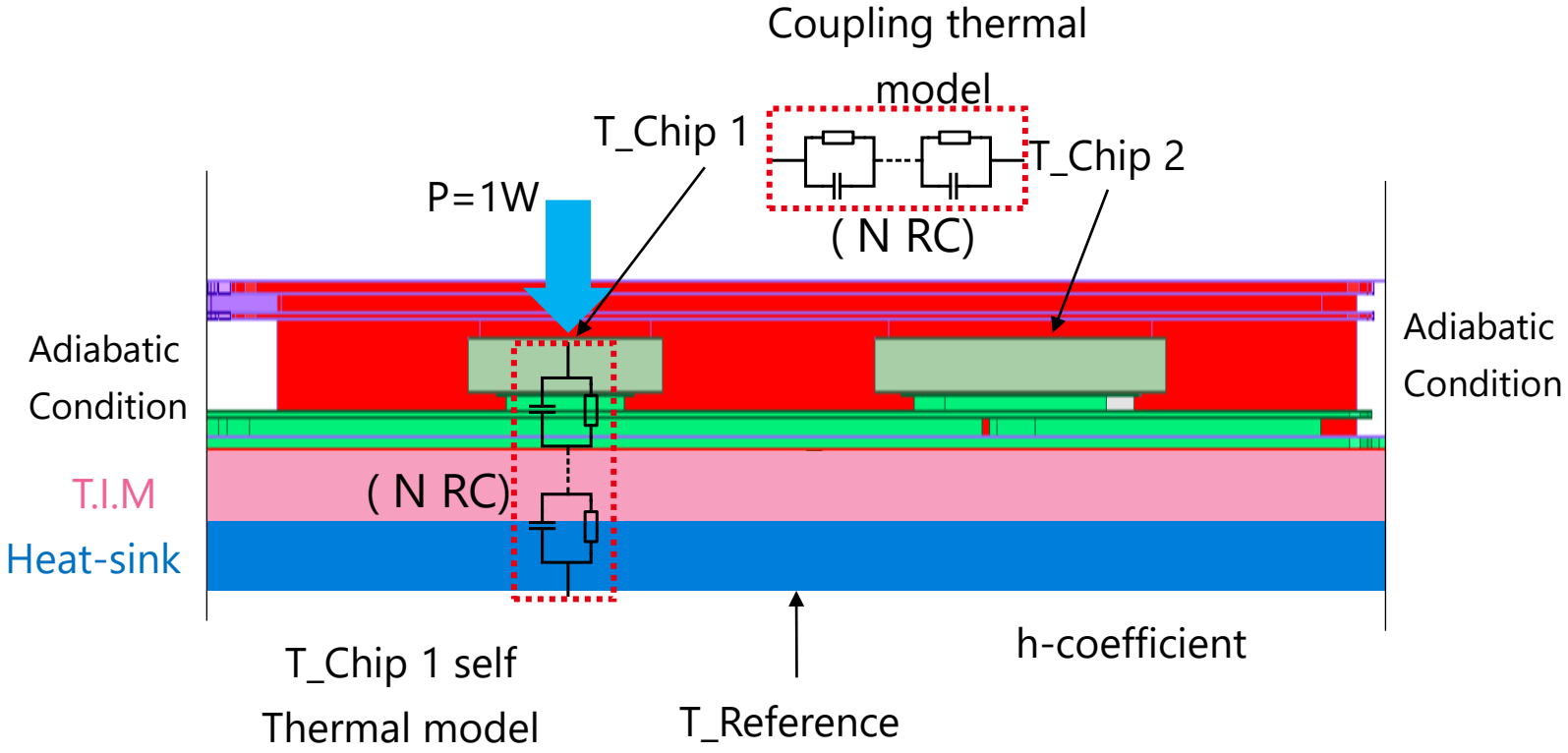
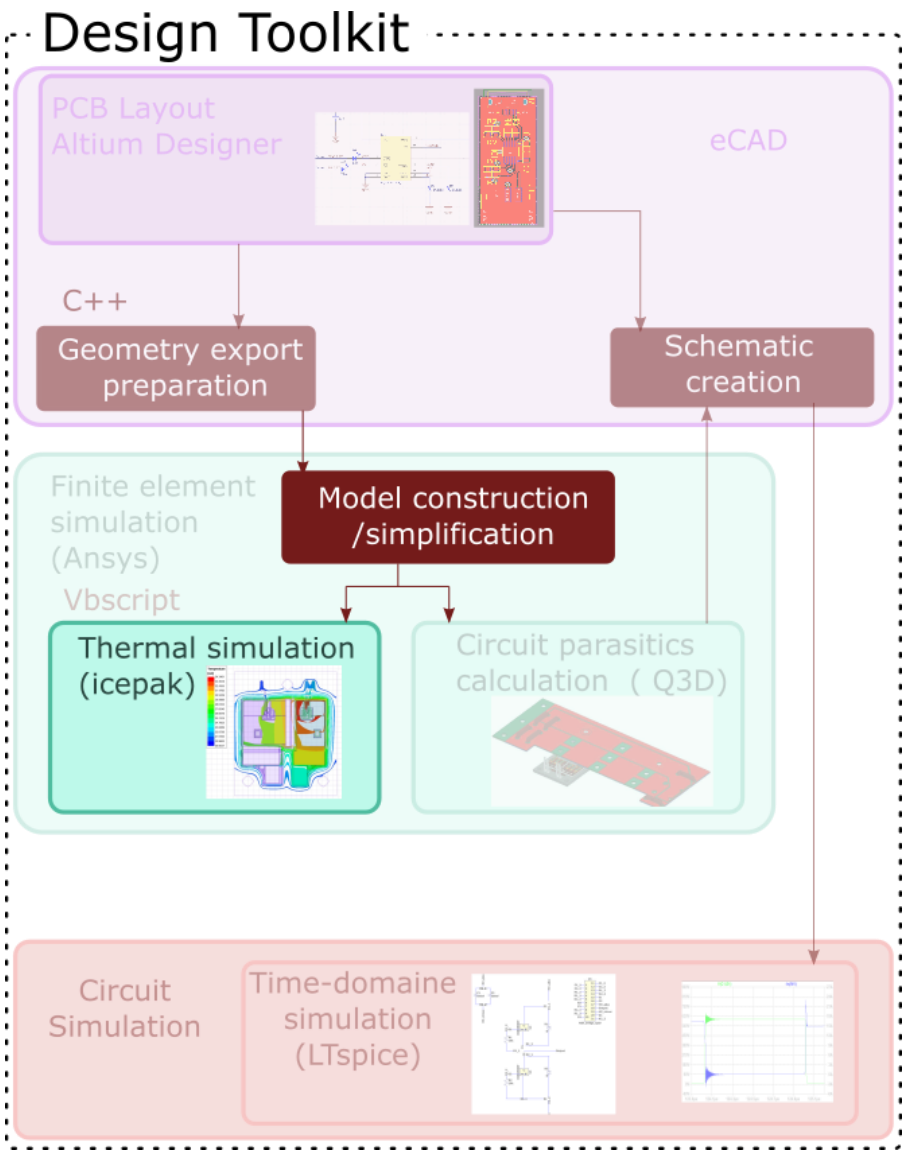


Thermal model



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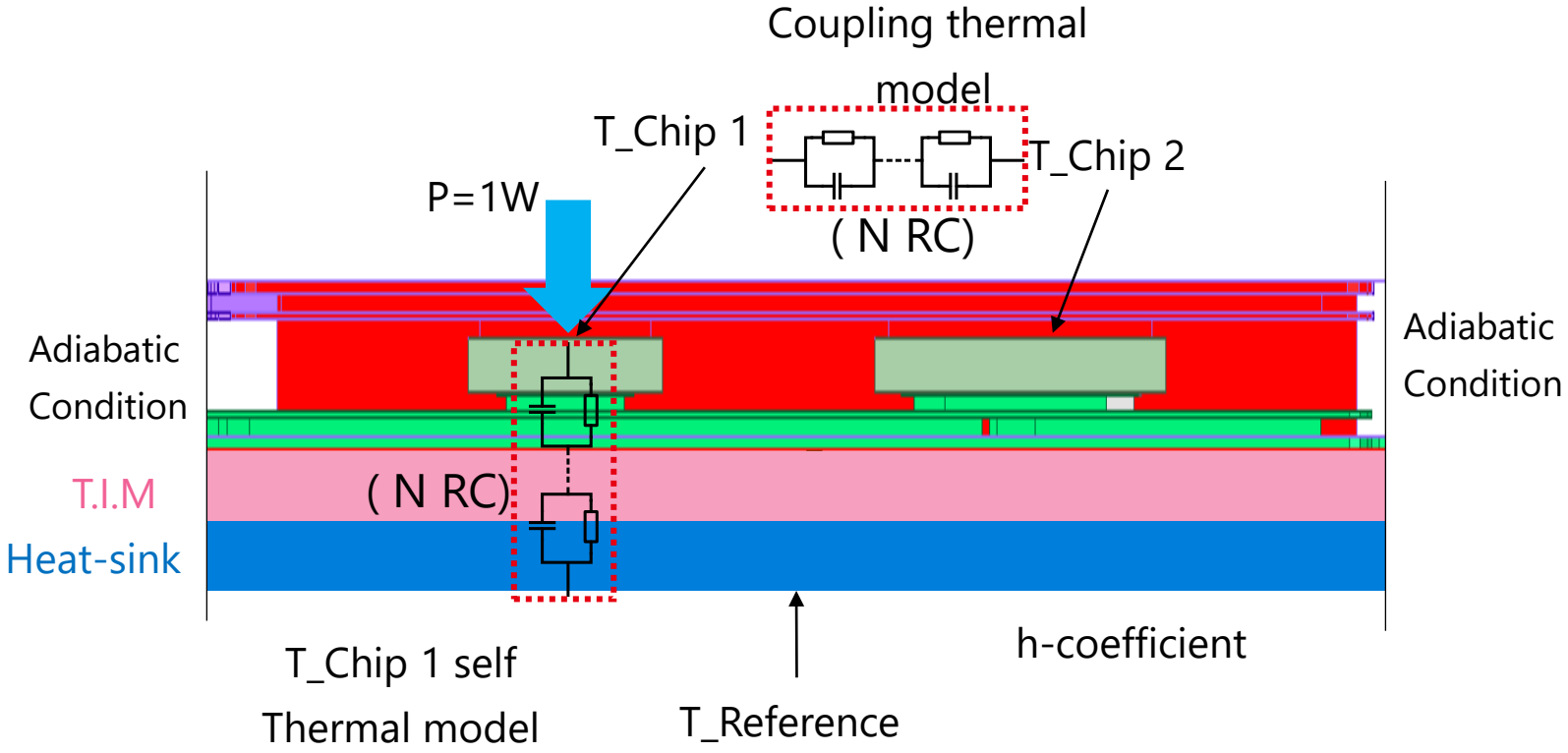
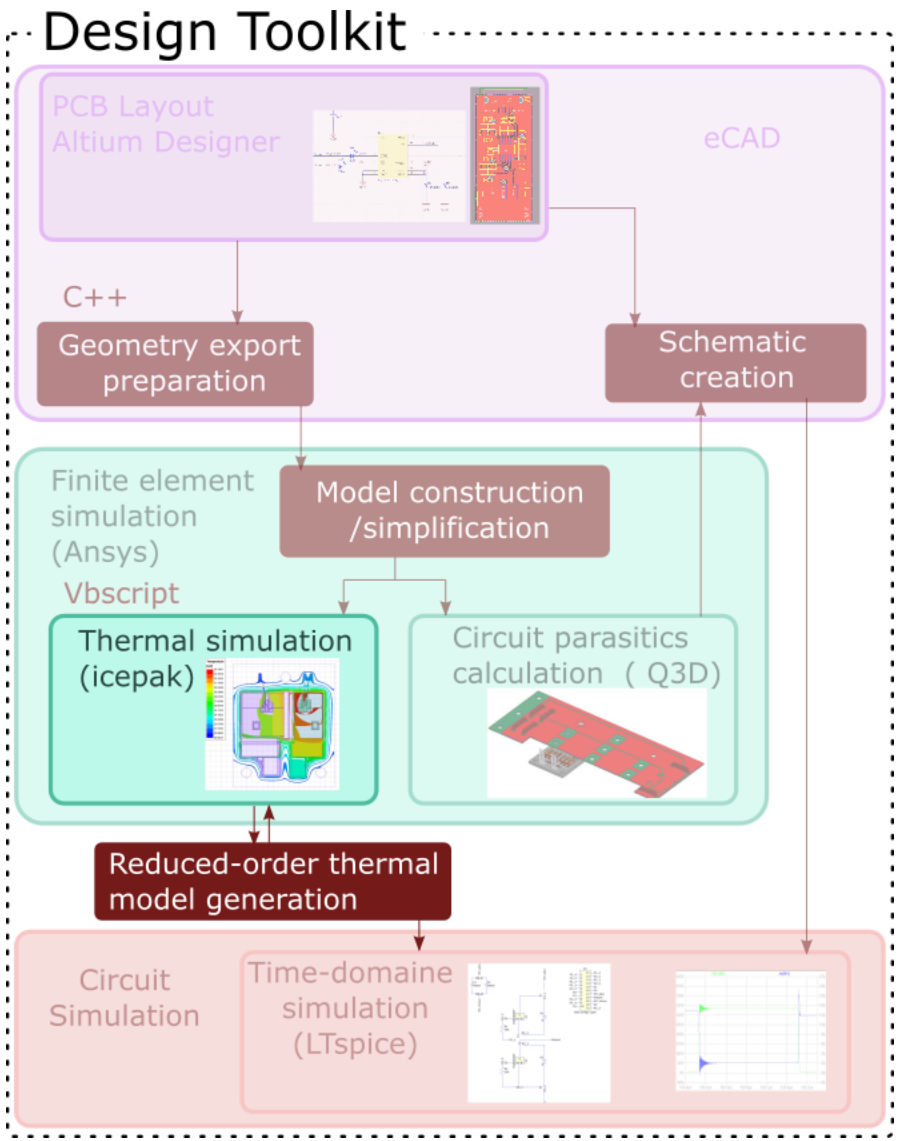


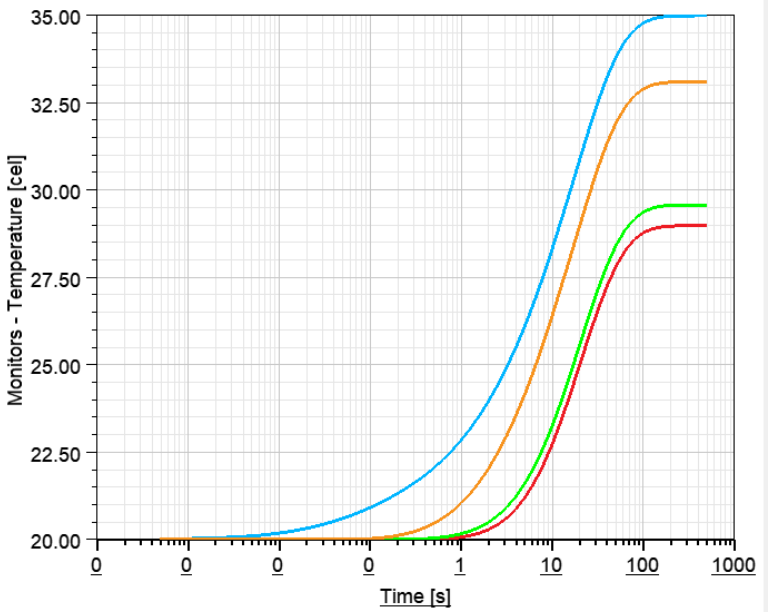
N simulations to do (where 1 Chip is active and the others are off)

Reduced-order thermal model

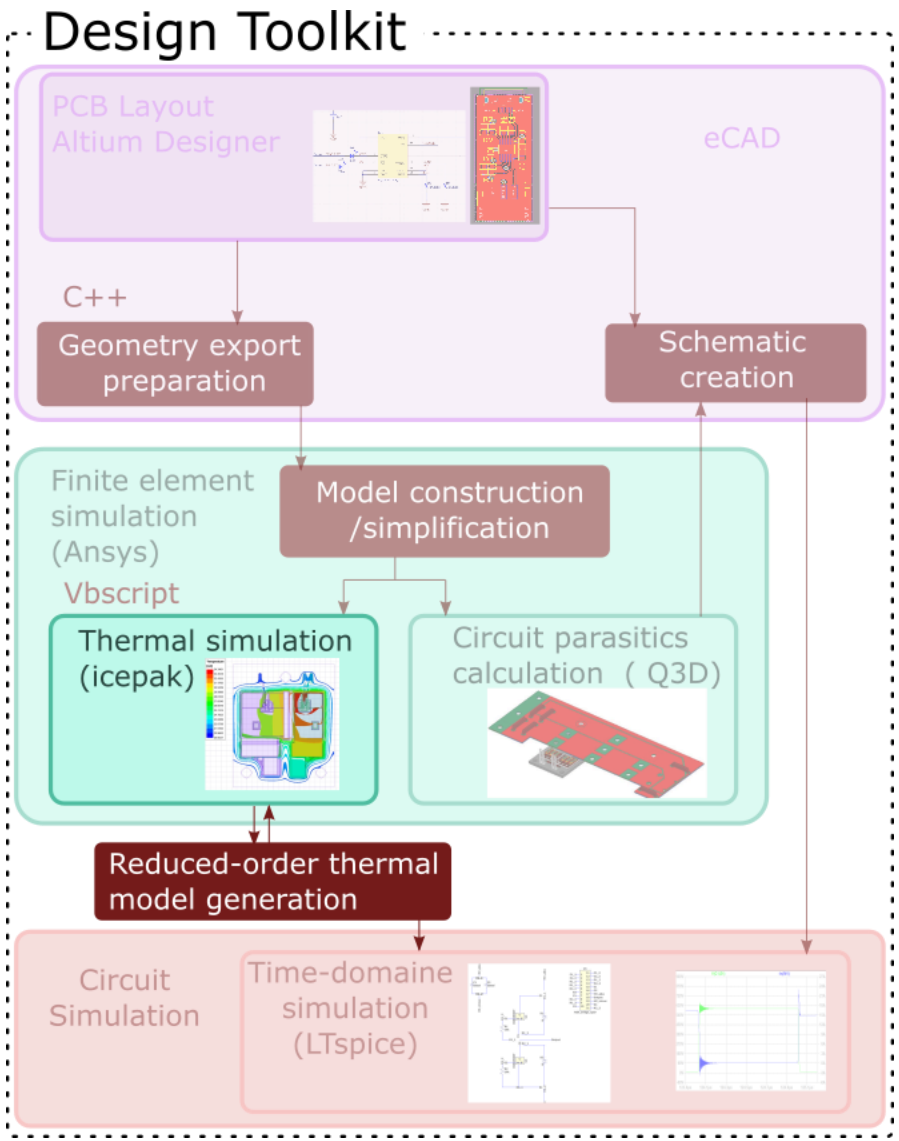


Generation of the Reduced thermal model

- From thermal transient measurement
- Self & coupling thermal model



Reduced-order thermal model



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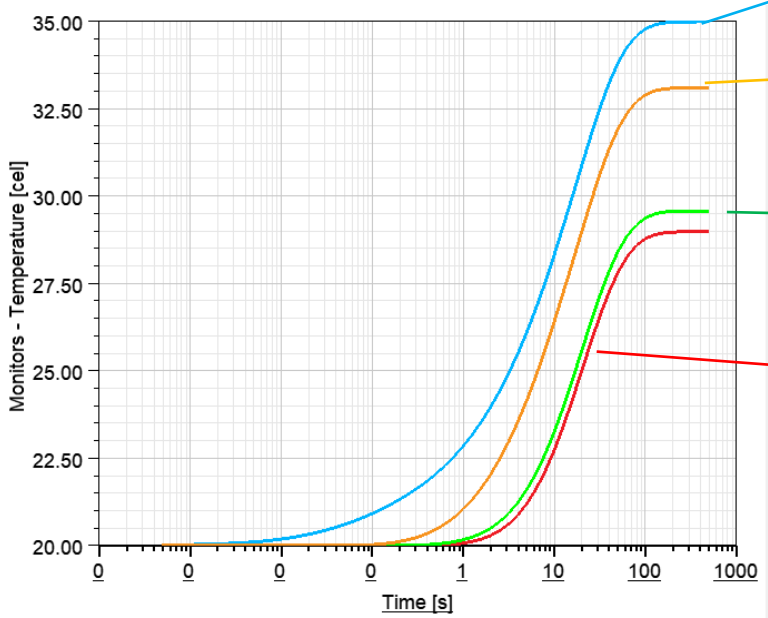
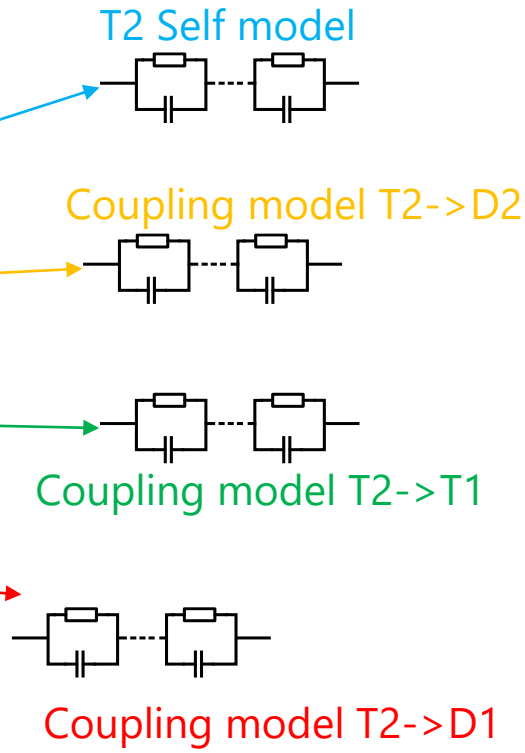
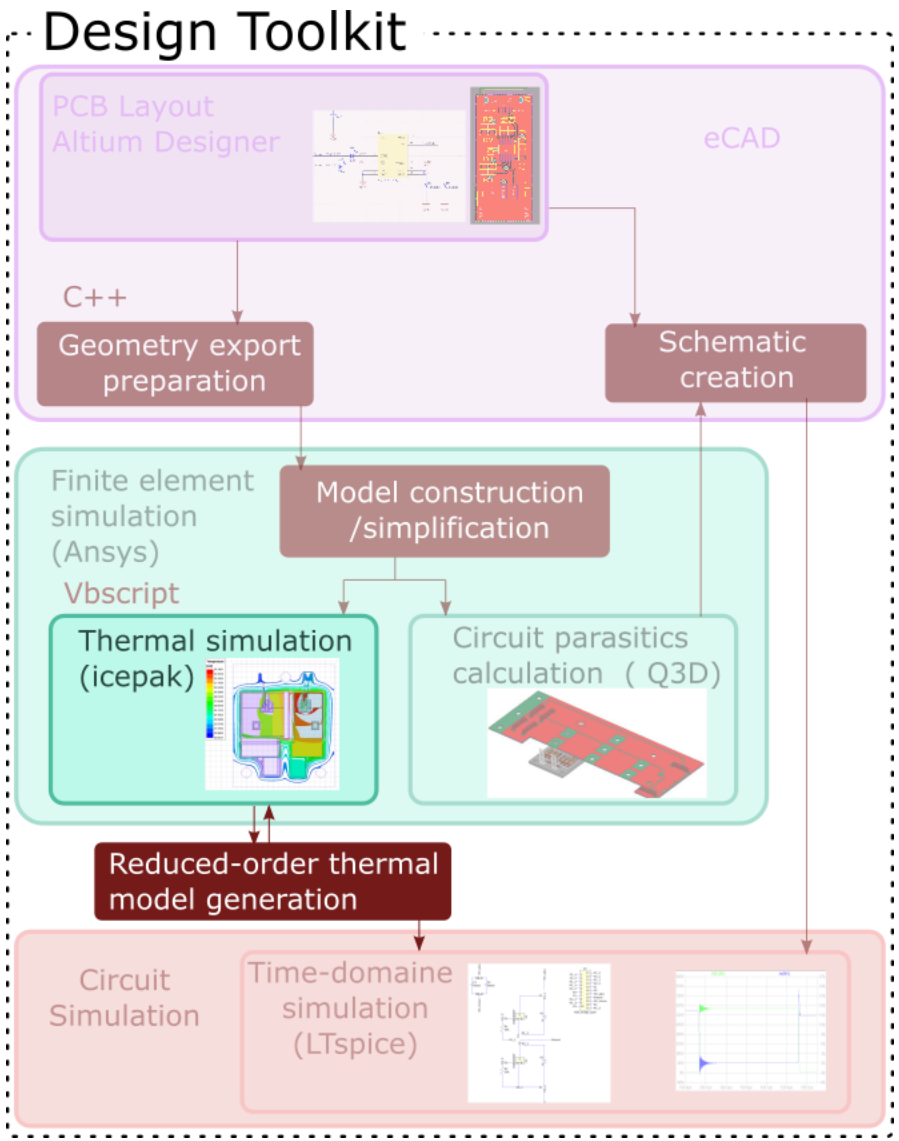




Reduced-order thermal model



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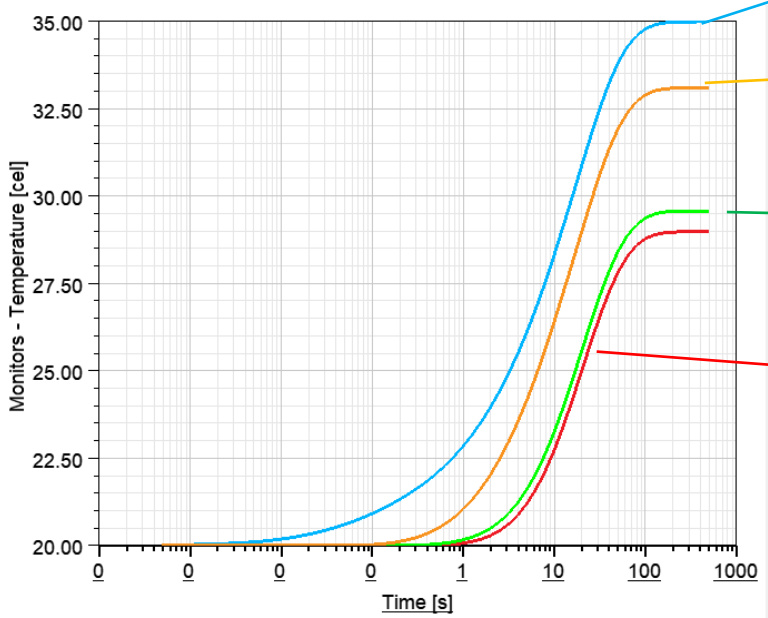
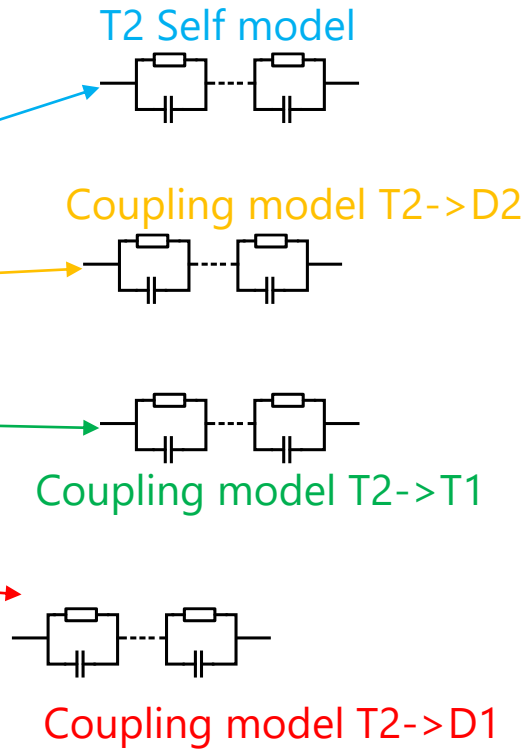
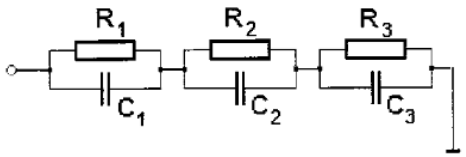




How can we Generate such model ?

Curve Fitting methods
(Not stable enough & depends a lot from the initial conditions)

Reduced-order thermal model

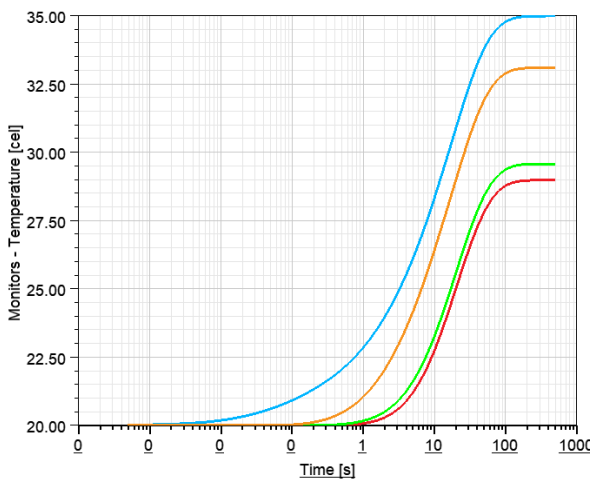


Wanted Foster model

Unit step response of the lumped circuit (P=1 W)

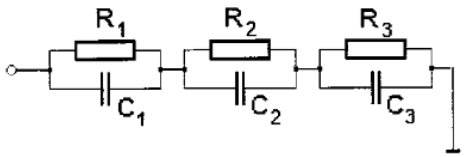
$$a(t) = P.\sum_i R_i(1 - e^{\frac{-t}{\tau_i}})$$

$With\ \tau i = Ri\ .\ Ci$



Thermal simulation output (Icepak)

Reduced-order thermal model



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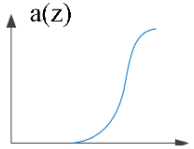
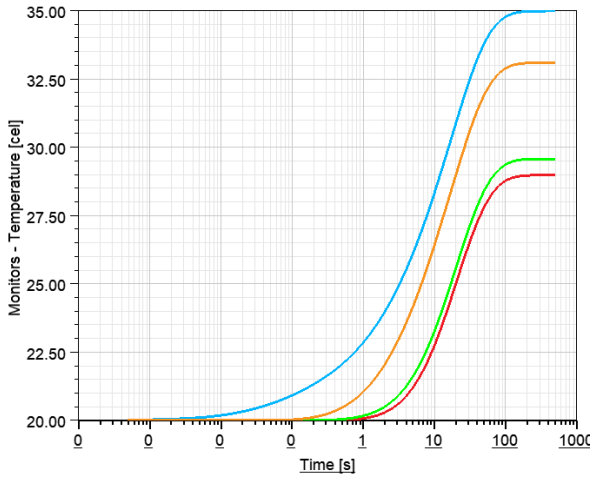
Identification of Reduced thermal model

1

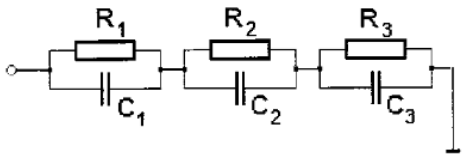




Thermal simulation output (Icepak)

Used by the JEEDEC

Reduced-order thermal model



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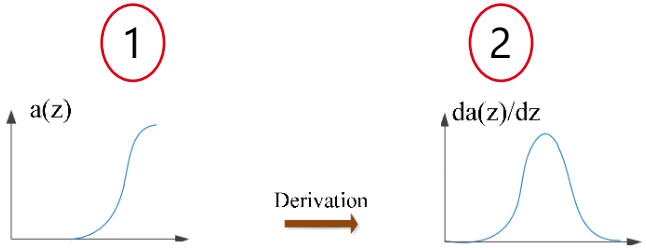

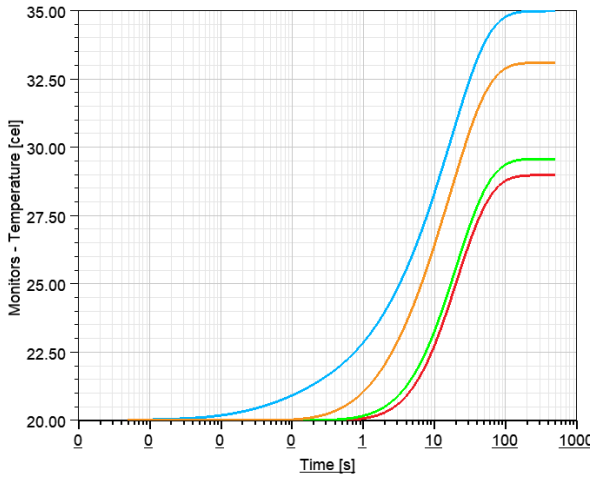

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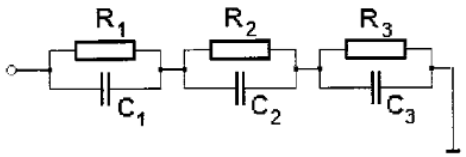

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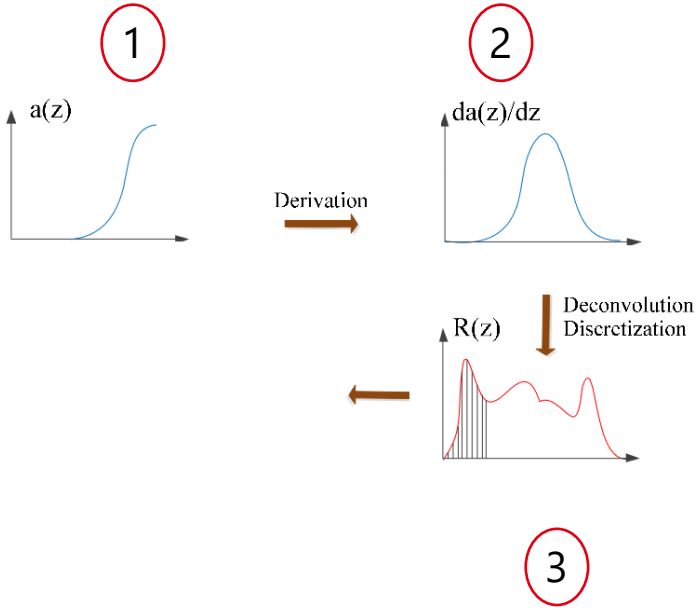

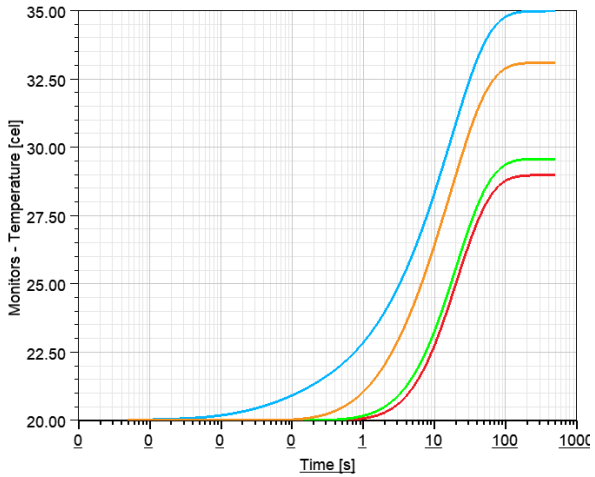

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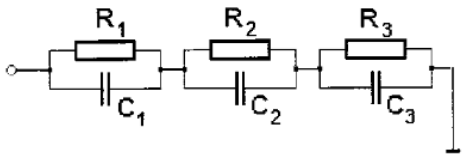

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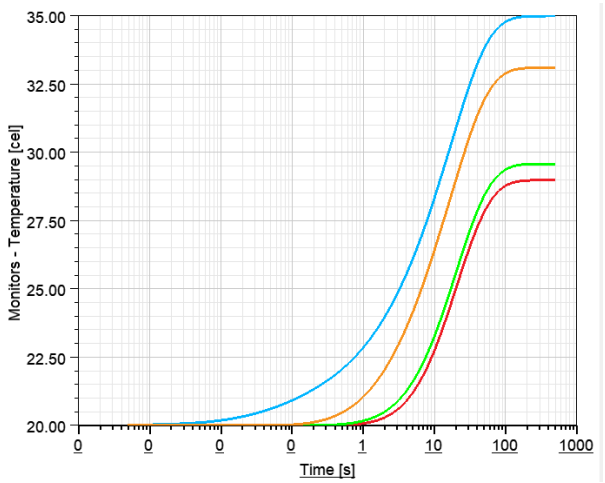

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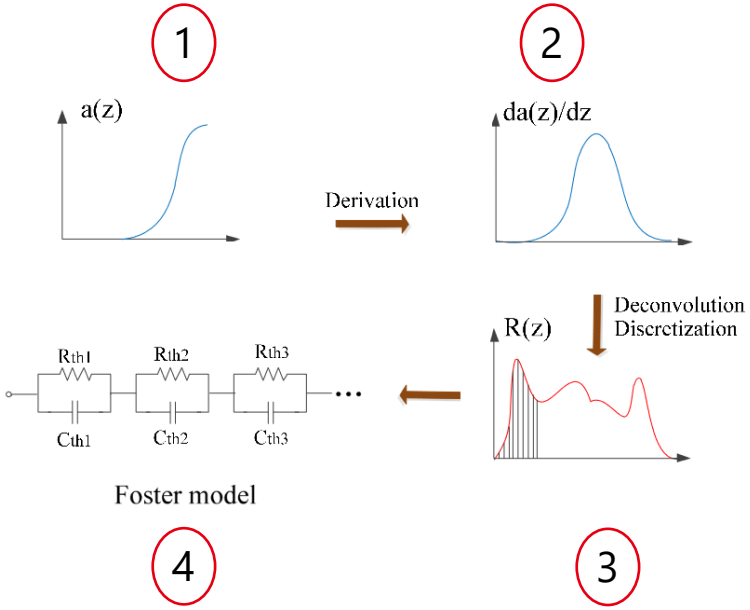

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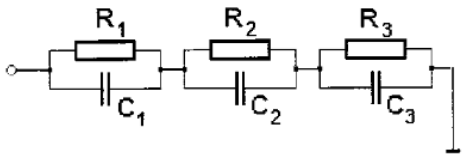

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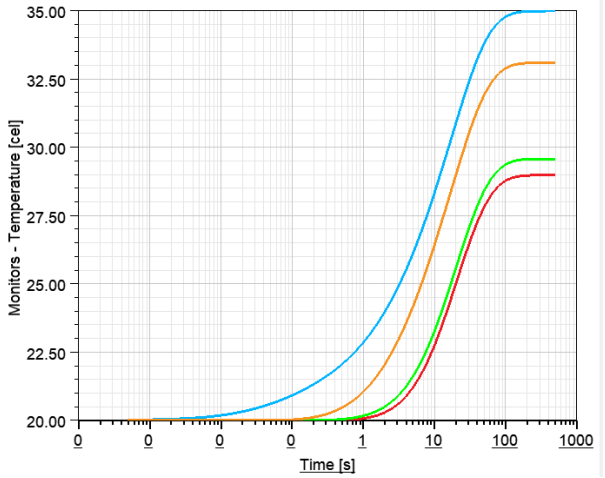

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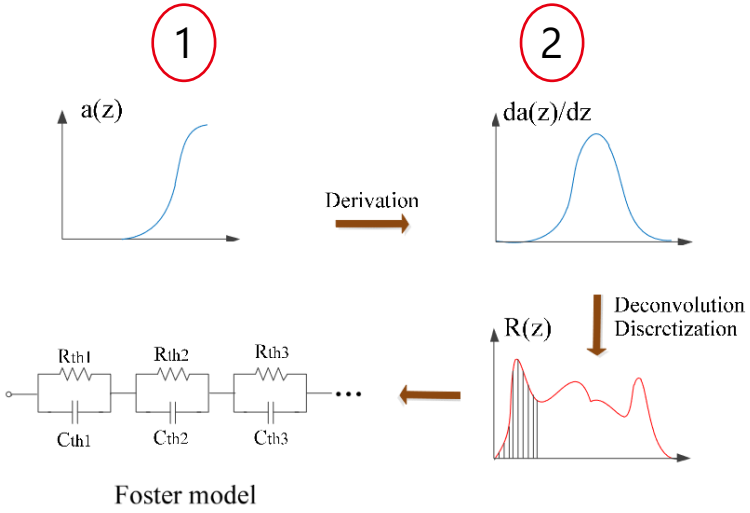

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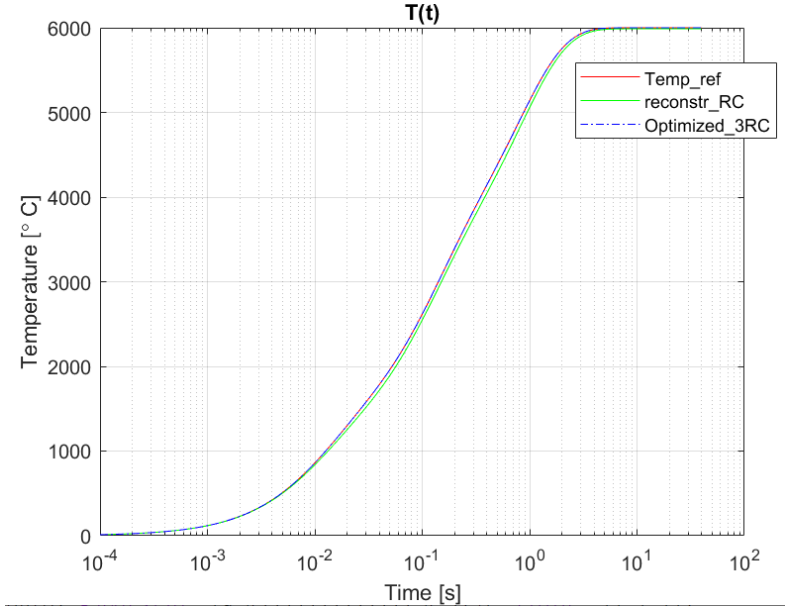


NRME = 14.4551 % ➔ 2.2652e-06 %

Least square optimization

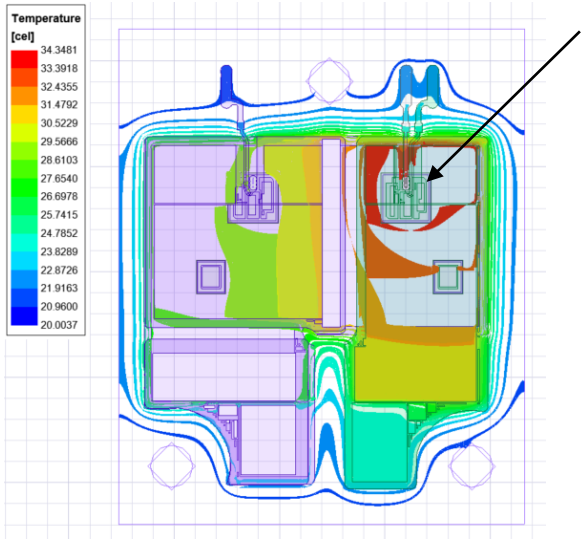
Design Toolkit: Thermal modelling Approach

Number of simulation = N

Where N is the number of Heat sources

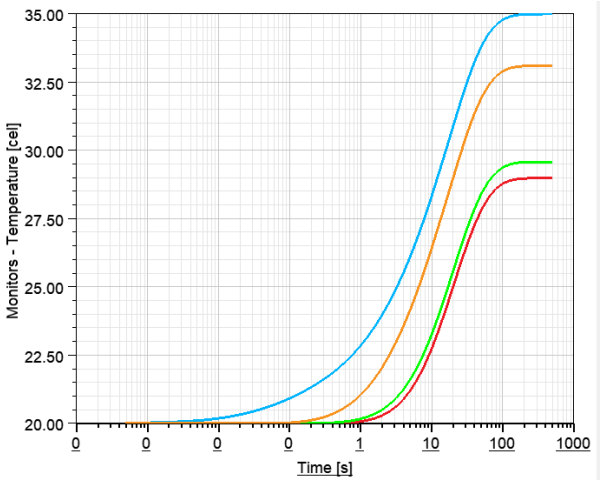
Applied on IPB1 3D model

T2 is active



Icepak simulation

Temperature extraction



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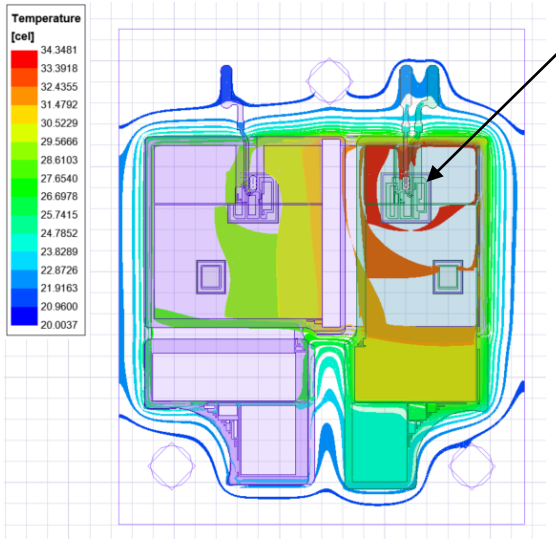

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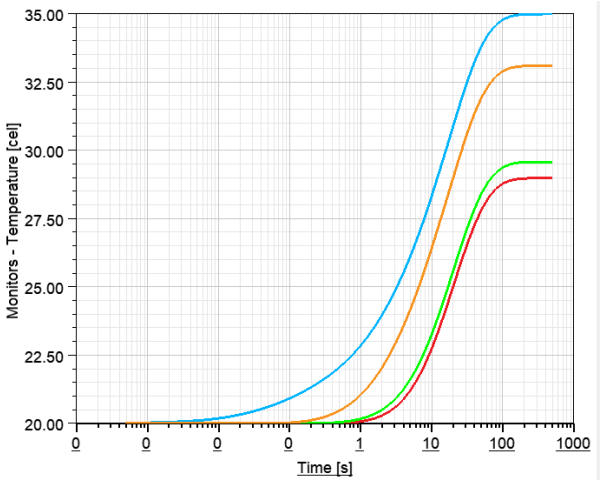
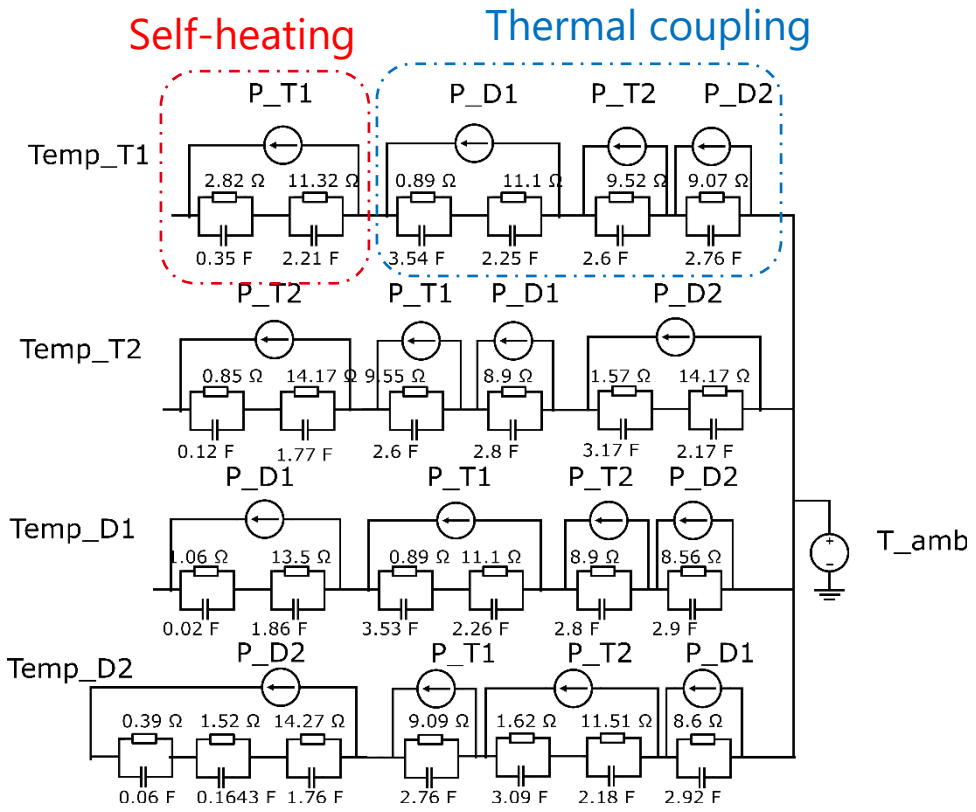
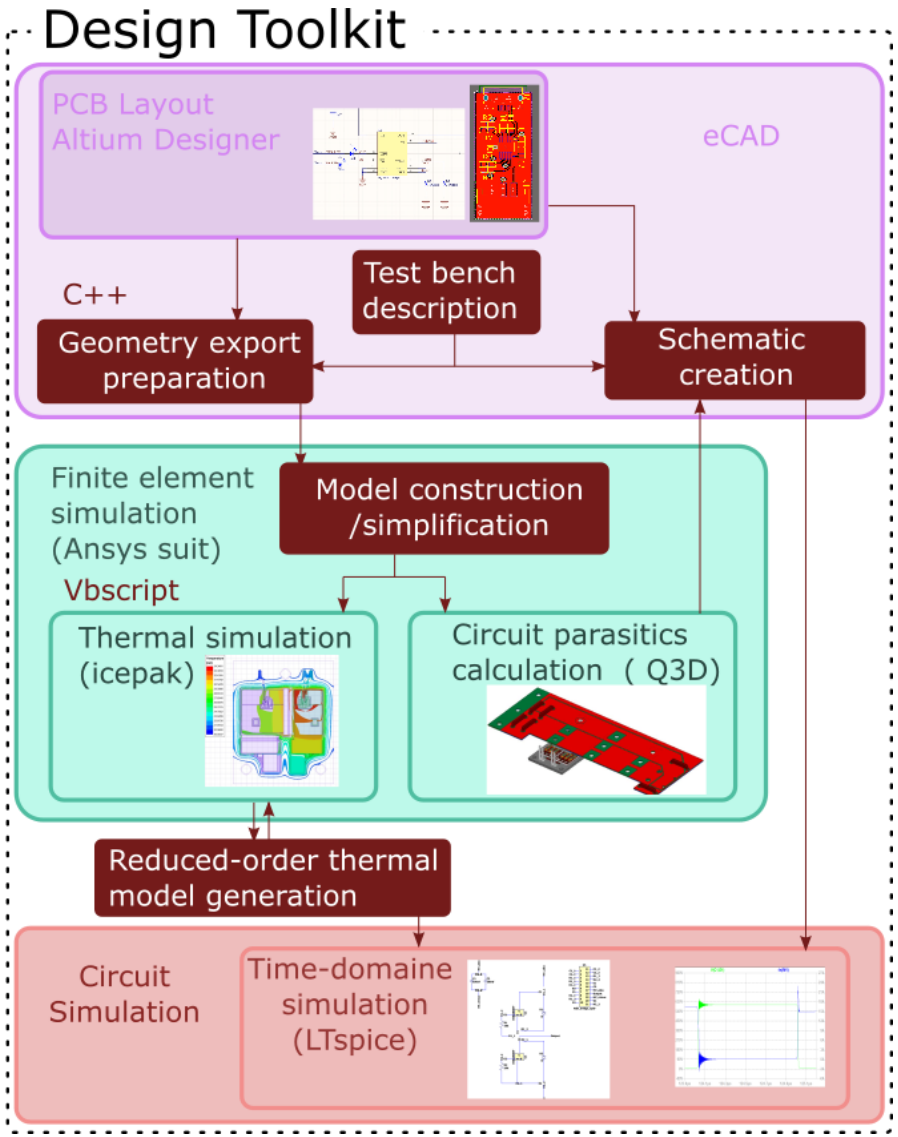




To include this thermal model to the Ltspice schematic

4 Conclusion & perspectives

Conclusion& perspectives



Toolkit:

Electrical modelling :

- Full workflow demonstrated on simple prototype
- Modelling of the external metal planes

Thermal modelling :

- 3D- model export/import & preparation done
- Working Zth calculation & reduced thermal model generation

Perspectives

- Validation thermal modelling approach
- Add the test bench ()
- Design a complete PCB-embedded converter (ANPC)
- Construction of the electro-thermal model
  - Validation (IPB1 & ANPC-prototype)

MITSUBISHI ELECTRIC

Changes for the Better