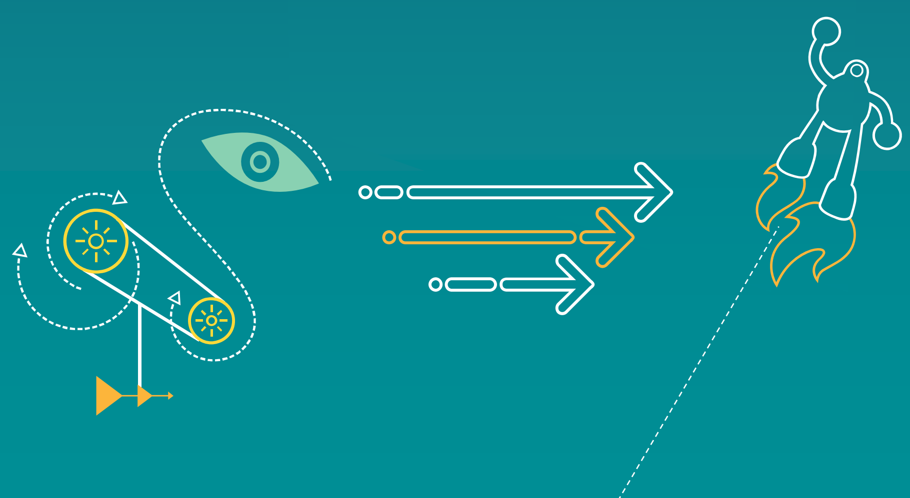
Thermal Simulation Example

Using FloTHERM – SW Tool
(Based on QRD Reference Design with MSM8x26 Chipset)

Qualcomm Technologies, Inc.



80-VU794-13 Rev. B

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Revision History

Revision	Date	Description
A	September 2013	Initial release
B	January 2014	Slides 7 and 8: Added additional *Forward* content Slide 10: Updated content for clarity Slide 56: Added *Visual Editor: Viewing Thermal Simulation Results* Slide 57: Added *Viewing Thermal Simulation Results* Slides 58-60: Added the *Visual Editor/FloVIZ* slides Slide 61: Updated content for clarity

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* Based on FloTHERM V9.2 *

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Section 1

Forward

Forward (1 of 3)

This application note provides an example of performing thermal simulation for a smartphone. The example is based on the Qualcomm Technologies, Inc. (QTI) handset reference design as illustrated below:

- The example uses the following QTI:
  - MSM8x26 chipset suite
  - QRD-China handset reference design
  - QTI IC package thermal models
- The purpose of this example:
  - Introduce thermal simulation to customers through simplified methods.
  - Help customers understand the process and reduce the learning curve through a validated example.
  - Encourage customers to adopt the thermal simulation approach for their own handset designs so they can predict the outcome of their product's thermal health.
  - To compliment the efforts that QTI is providing to customers which includes:
    - Providing **thermal models** for all chipsets
    - Providing **thermal power concurrencies for challenging handset use cases**

Forward (2 of 3)

What is included in this document? This document discusses the following:

- Step-by-step method of building the thermal simulation model for a handset – QTI reference design in the FloTHERM thermal simulation tool. The procedures illustrate two sub-models:
  - PCB only thermal model extracted from an EDA tool
  - Entire smartphone thermal model that includes:
    - QRD enclosure/housing for the entire handset extracted from MCAD design tool (Pro Engineer), including battery and any other necessary hardware for the handset.
    - Components packages thermal models – downloaded from QTI documents and downloads website at CDMATech https://support.cdmatech.com.
    - QRD reference design PCB extracted from Cadence EDA tool.
  - Thermal simulation set up procedures for the QRD reference design in FloTHERM Rev10.0. The procedures include problem parameters, thermal power input, boundary conditions, etc.
  - Visualization editor (VE) (FloViz Rev10.0 – free download from Mentor Graphics). The VE allows users to view the results files for the pre-performed simulation.

Forward (3 of 3)

The below files are available at the Qualcomm documents and downloads website at CDMATech https://support.cdmatech.com:

- *Thermal Simulation Example using FloTHERM – SW Tool* (80-VU794-13); this document
- *Qualcomm Handset Thermal Model Example FloTHERM* (HS11-NJ902-6HW); a zipped folder containing the following files:
  - NC002_MSM8x26_System-Thermal-Model.pack; Qualcomm reference design “Thermal Model”
  - Thermal simulation results files that can be viewed by the VE:
    - HeatFlux_Vectors_and_Shortcut_Opportunities
    - Outer_Surface_Temperature
    - PCB_Components_Surface_Temperature
    - Temperature_Plane_Components_Board
    - Temperature_Plane_Junction_Hotspot

Note: For all questions related to the FloTHERM tool (installation, license, revisions, operating instructions, etc.), please contact Mentor Graphics at www.mentorgraphics.com.

Section 2

Preparation

Preparation

Materials needed for the QRD8x26 reference design thermal simulation:

- QRD8x26 PCB layout source file
- IC thermal power information of different use cases
- QTI thermal models for the MSM8x26 chipset IC packages
- Phone mechanical 3D native data and material information

PC requirements for thermal simulation:

- 3.6 GHz quad core with high GPU performance (two per simulation run)
- 32 GB physical memory recommended

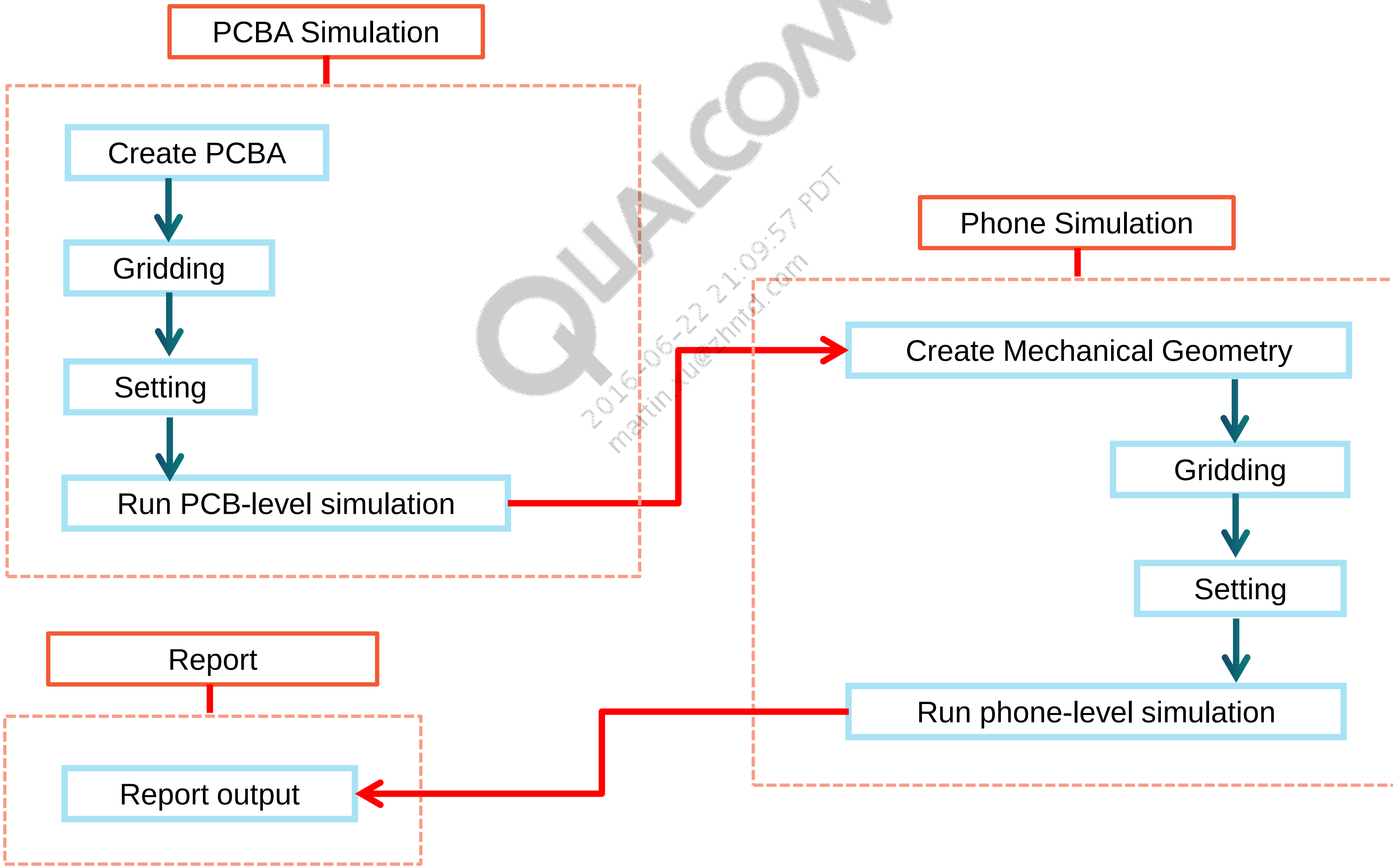
Section 3

Thermal Simulation Procedure Overview

Thermal Simulation Procedure Overview (1 of 2)

Simulation flow chart:

The below flow chart is a simplified representation of the necessary steps to build the thermal simulation model and perform the desired thermal analysis.



Thermal Simulation Procedure Overview (2 of 2)

Task list in main processes

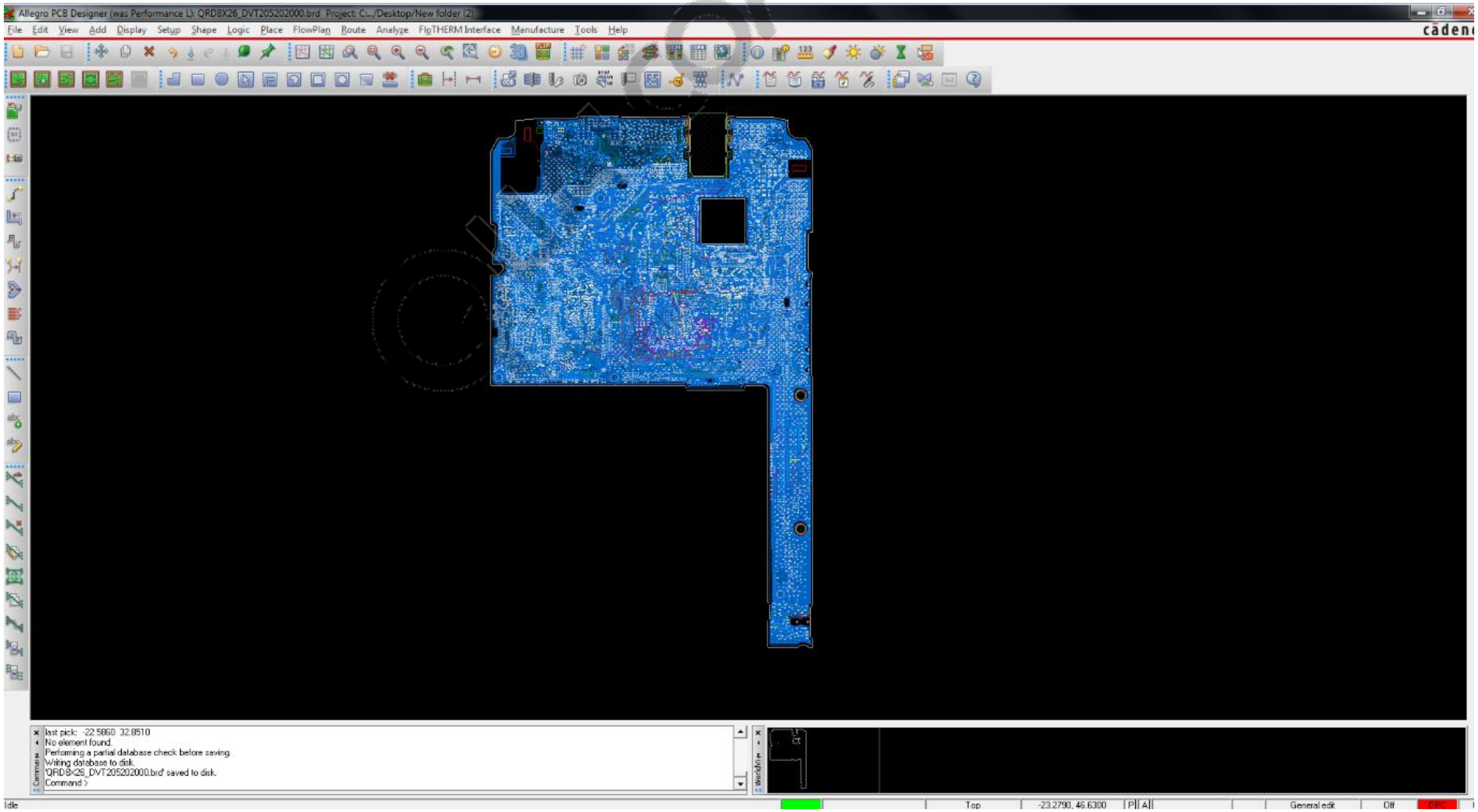
Task list	Details
Create PCBA	Generate .floeda file Import PCB Import/position the shields/components
Setting	Set material properties Set radiation Set thermal power
Gridding and convergence	Define system parameters Define region parameters Run simulation Analyze the convergence Adjust and re-run
Create mechanical geometry	Import parts by using MCAD tool exported data Create simplified parts
Gridding and convergence	Define system parameters Define region parameters Run simulation Analyze the convergence Adjust and re-run
Report output	Report template Further Iterations (run simulation)

Section 4

PCBA Thermal Simulation

- Generate .floeda file

1. Load the 8x26 PCB source file in Cadence Allegro.

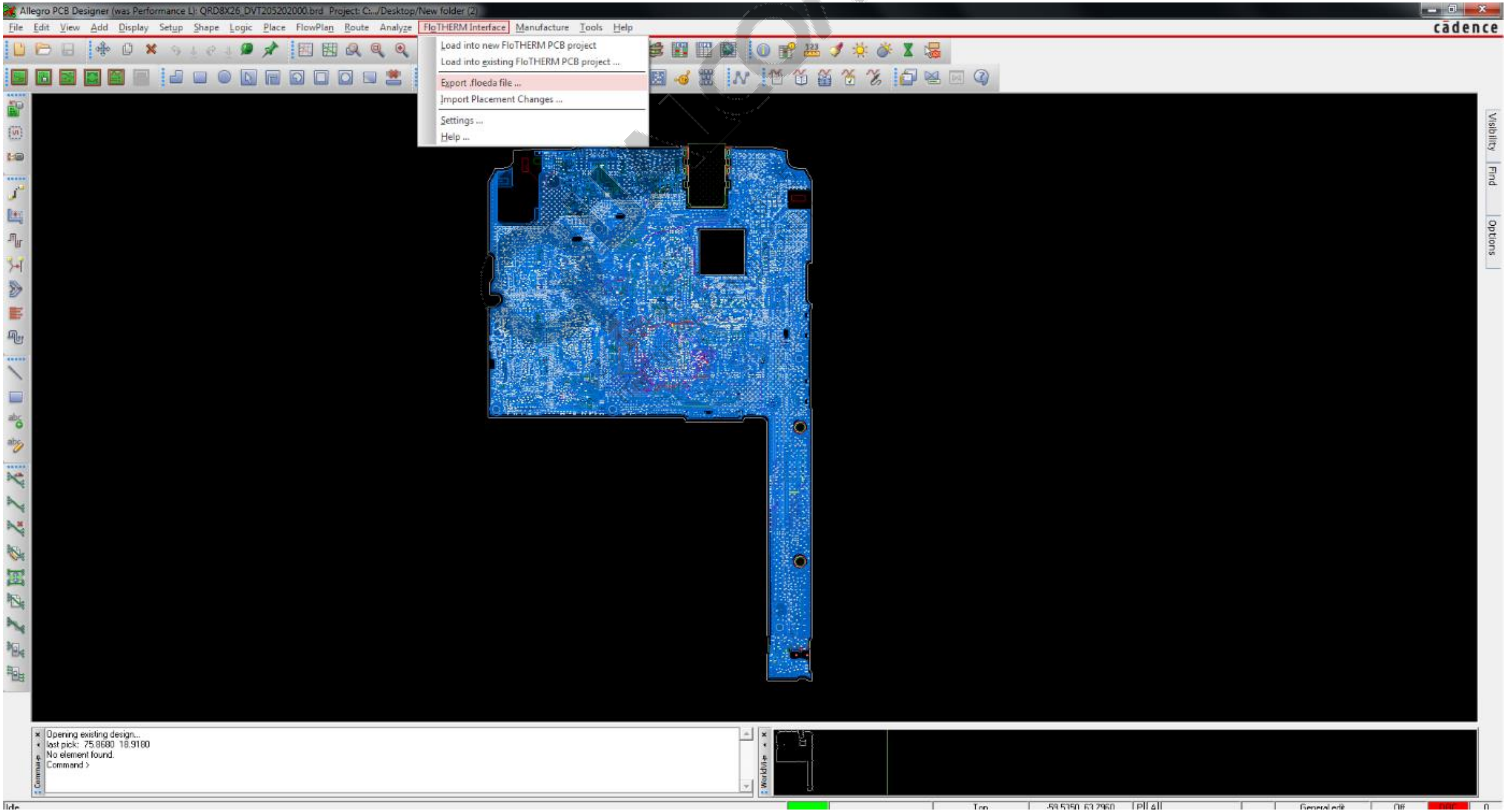


Note: An EDA interface software needs to be installed before exporting a .floeda file from Allegro.

PCBA Thermal Simulation – Create PCBA (2 of 15)

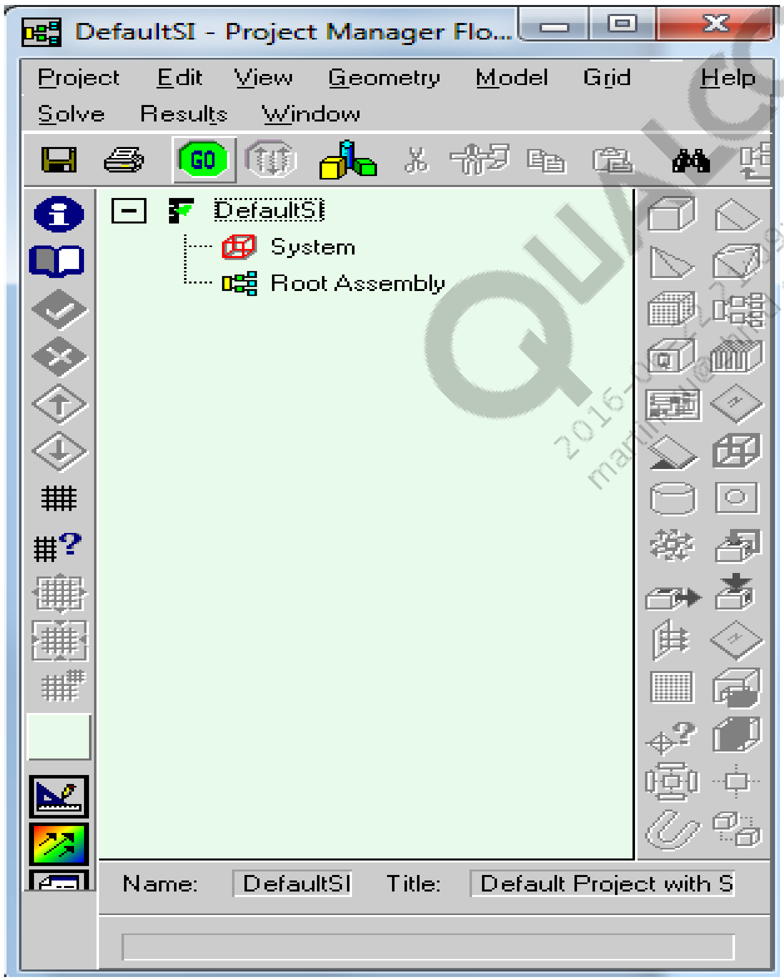
- Generate .floeda file

2. Export .floeda file from Allegro.

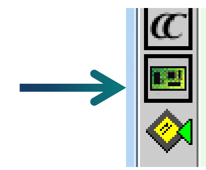


- **Import PCB**

1. Open a new FloTHERM project.

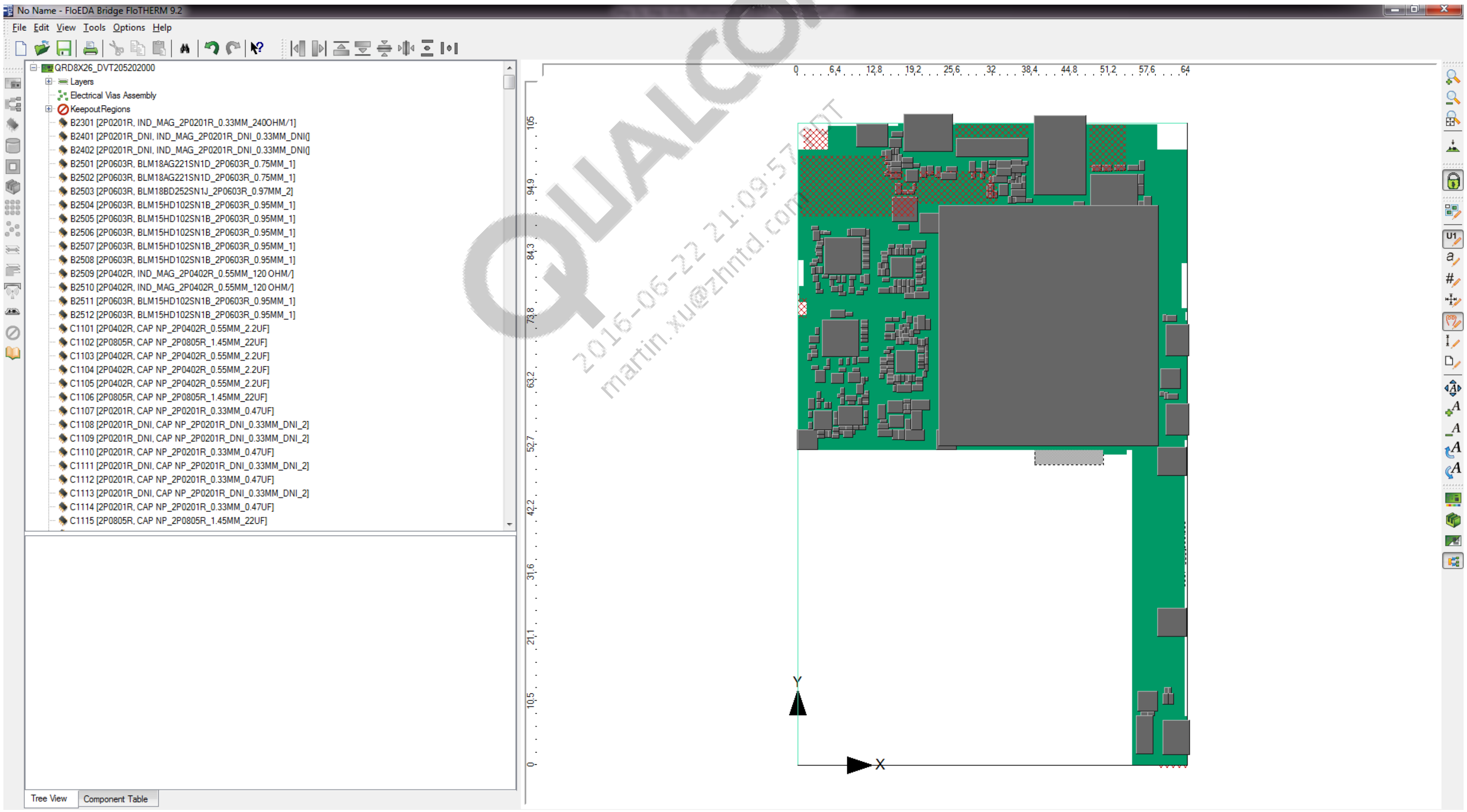


2. Open Floeda bridge.



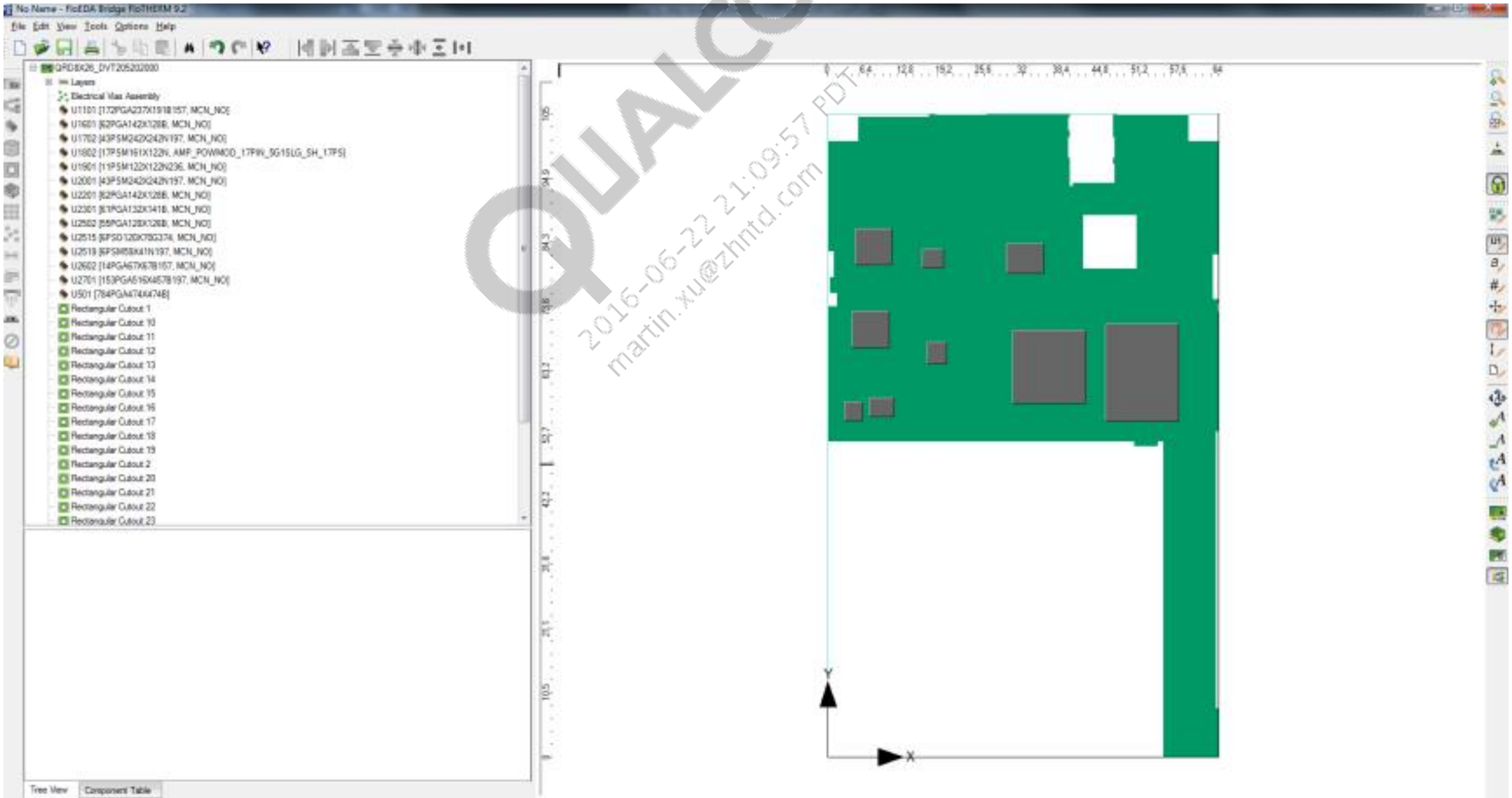
Import PCB

3. Import .floeda file into Floeda bridge.



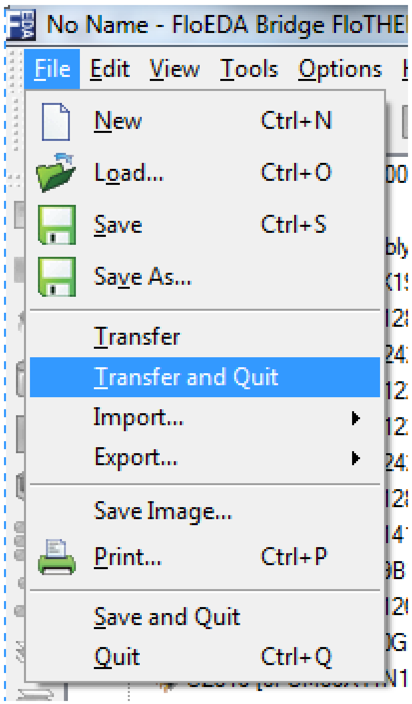
Import PCB

4. Delete the lower power ICs like resistors, capacitors, inductors, etc. QTI provides package thermal models for major components that can be imported to the PCB thermal model. Therefore, only keep EMMC/PA/transceiver/etc., on the board.

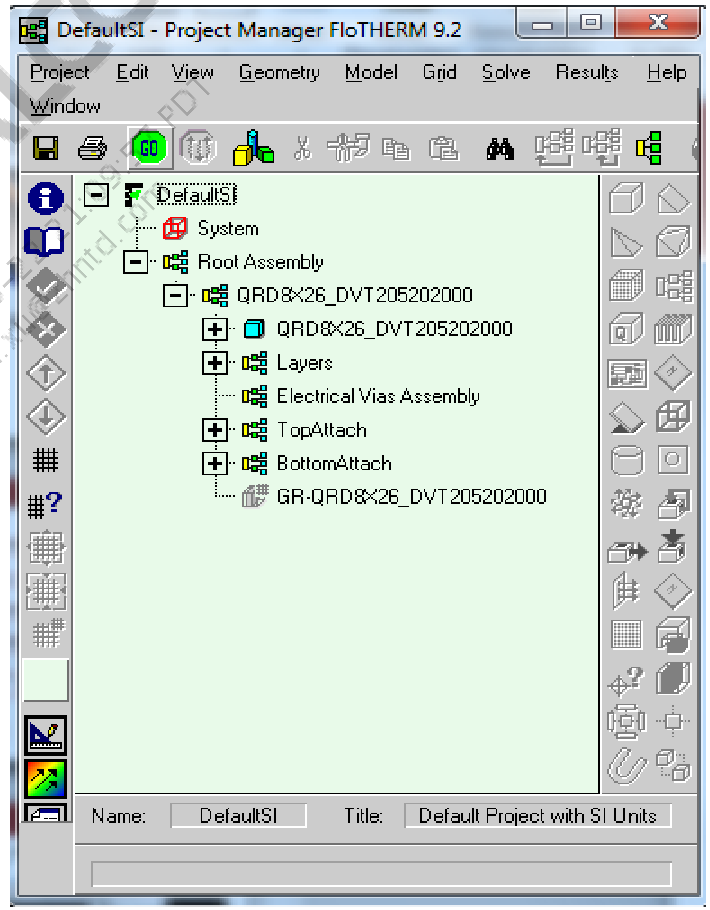


Import PCB

5. Transfer to FloTHERM.

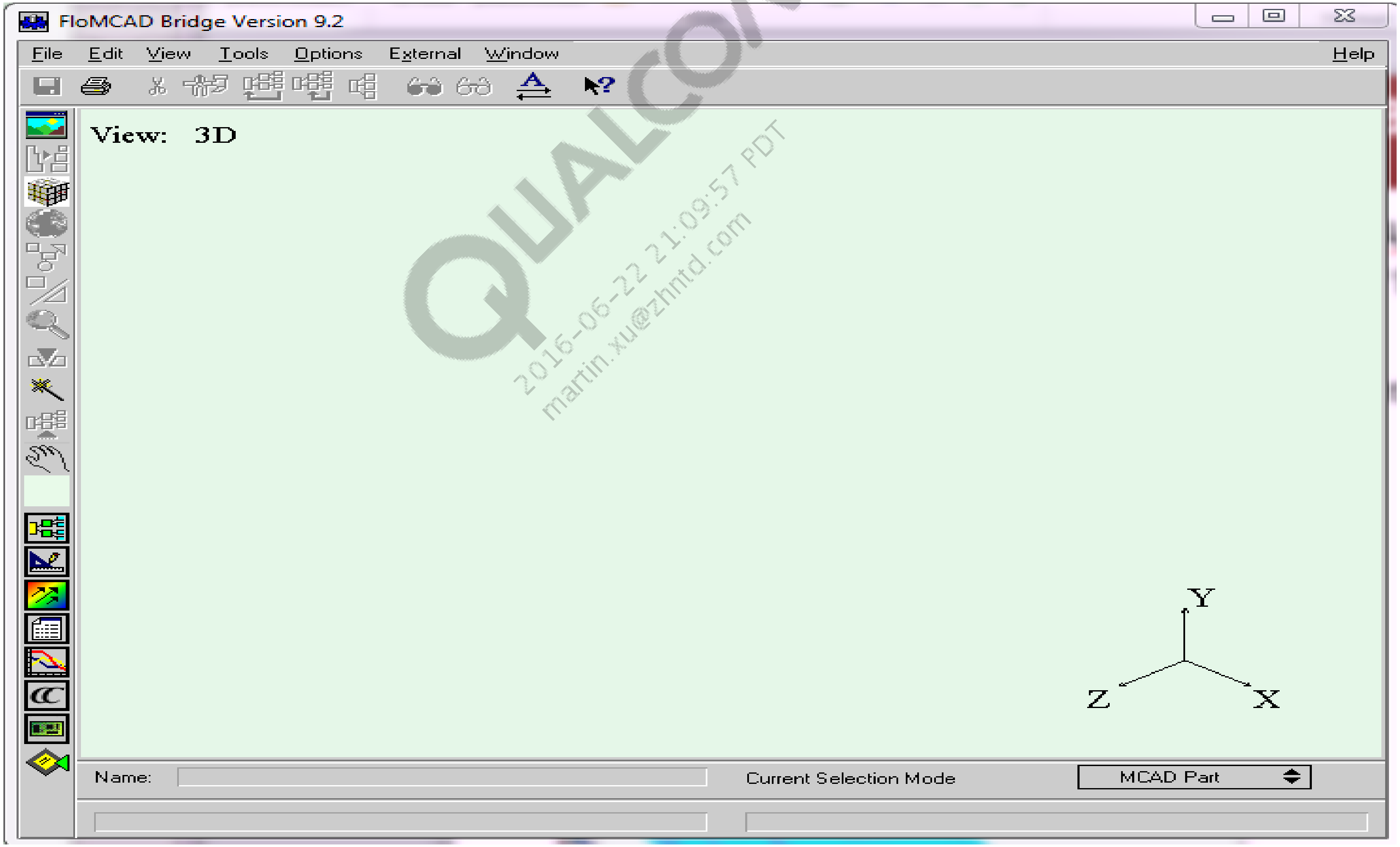


6. The QRD8x26 model in FloTHERM model tree.



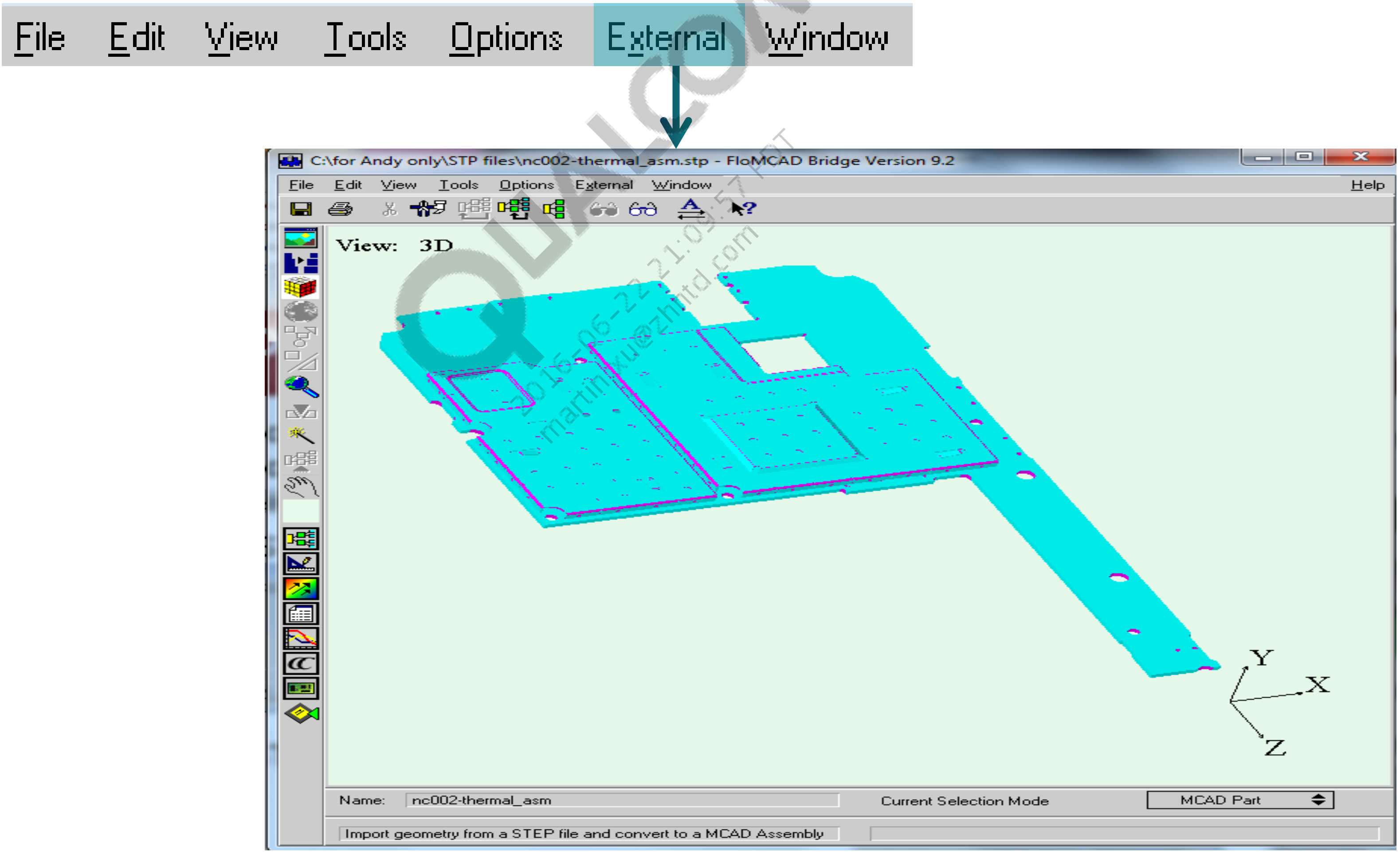
- Import shields

1. Click to open FloMCAD.



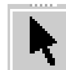
- **Import shields**

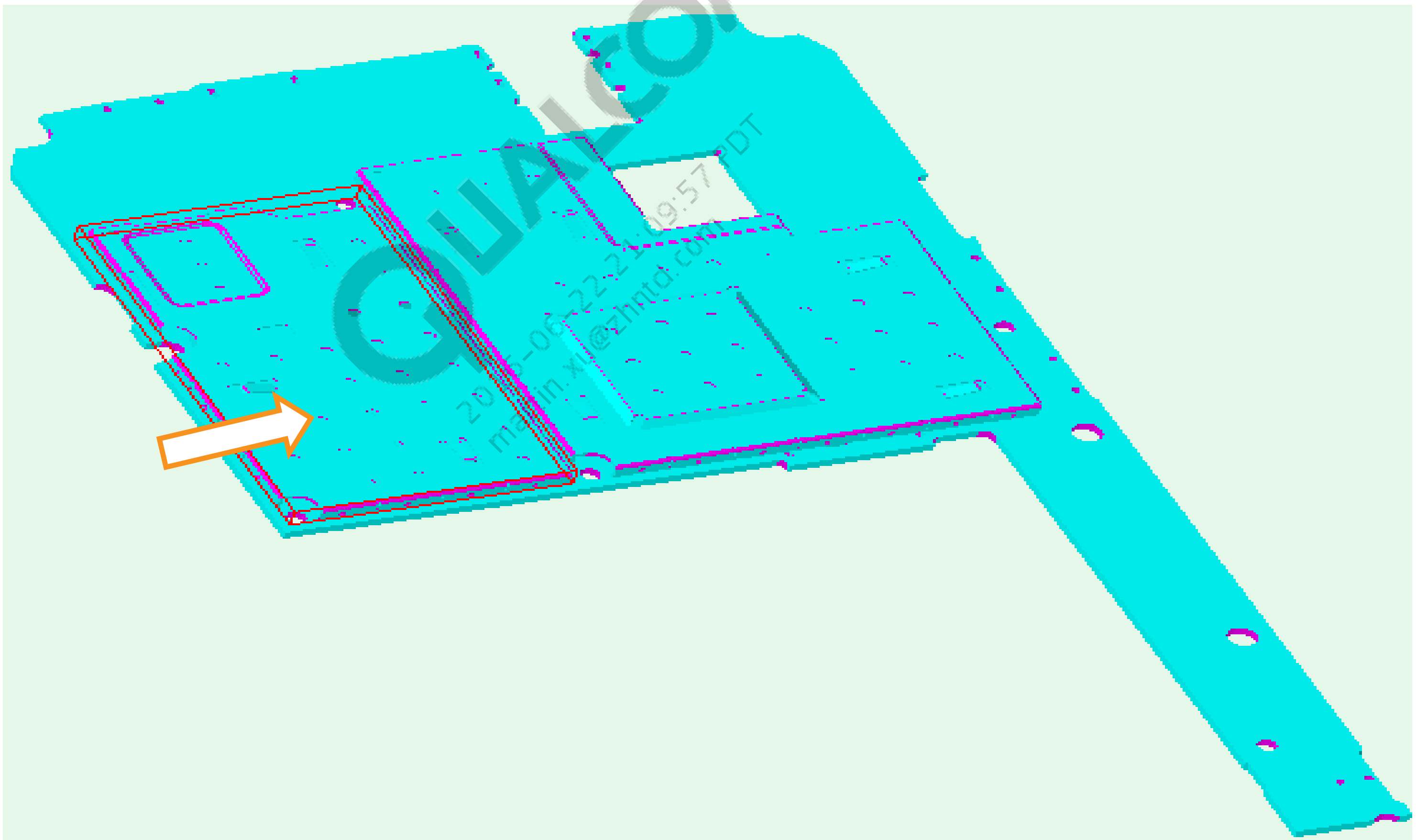
2. Click External tab to import the STEP file.



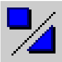
PCBA Thermal Simulation – Create PCBA (9 of 15)

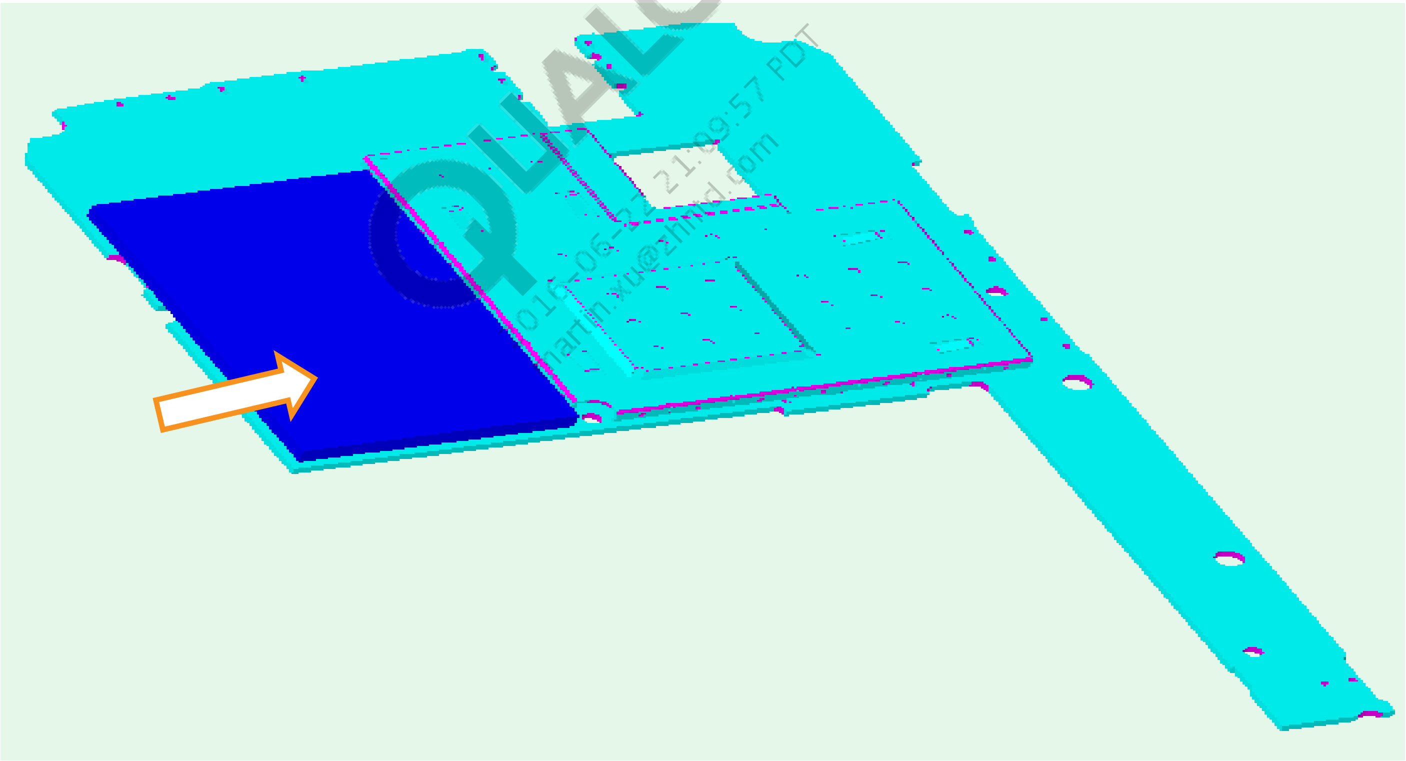
- Import shields

3. Click “Toggle mouse mode”  and select the object.

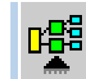


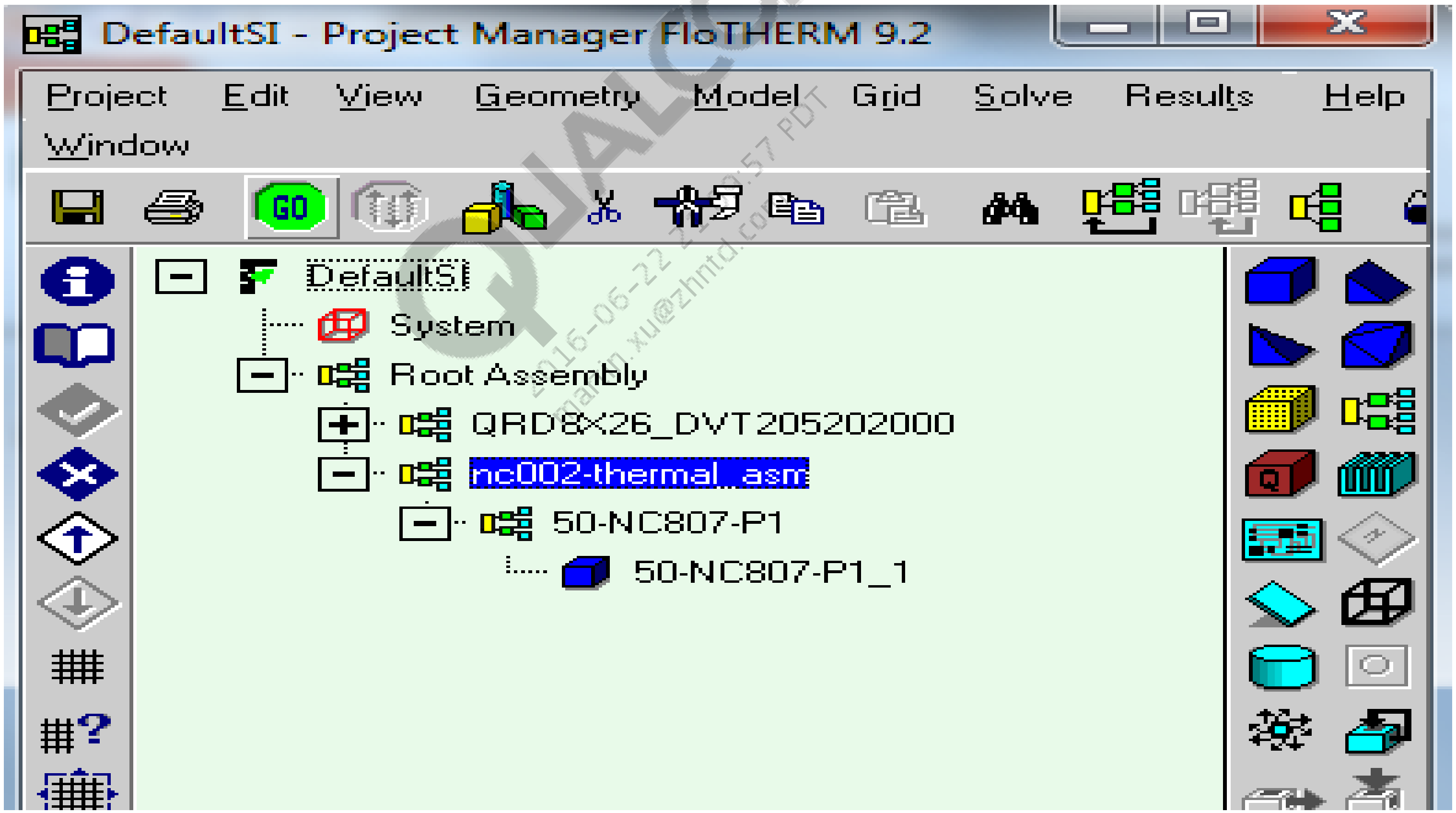
- **Import shields**

4. Click “Replace with single object”  to replace the imported shield.



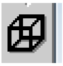
- Import shields

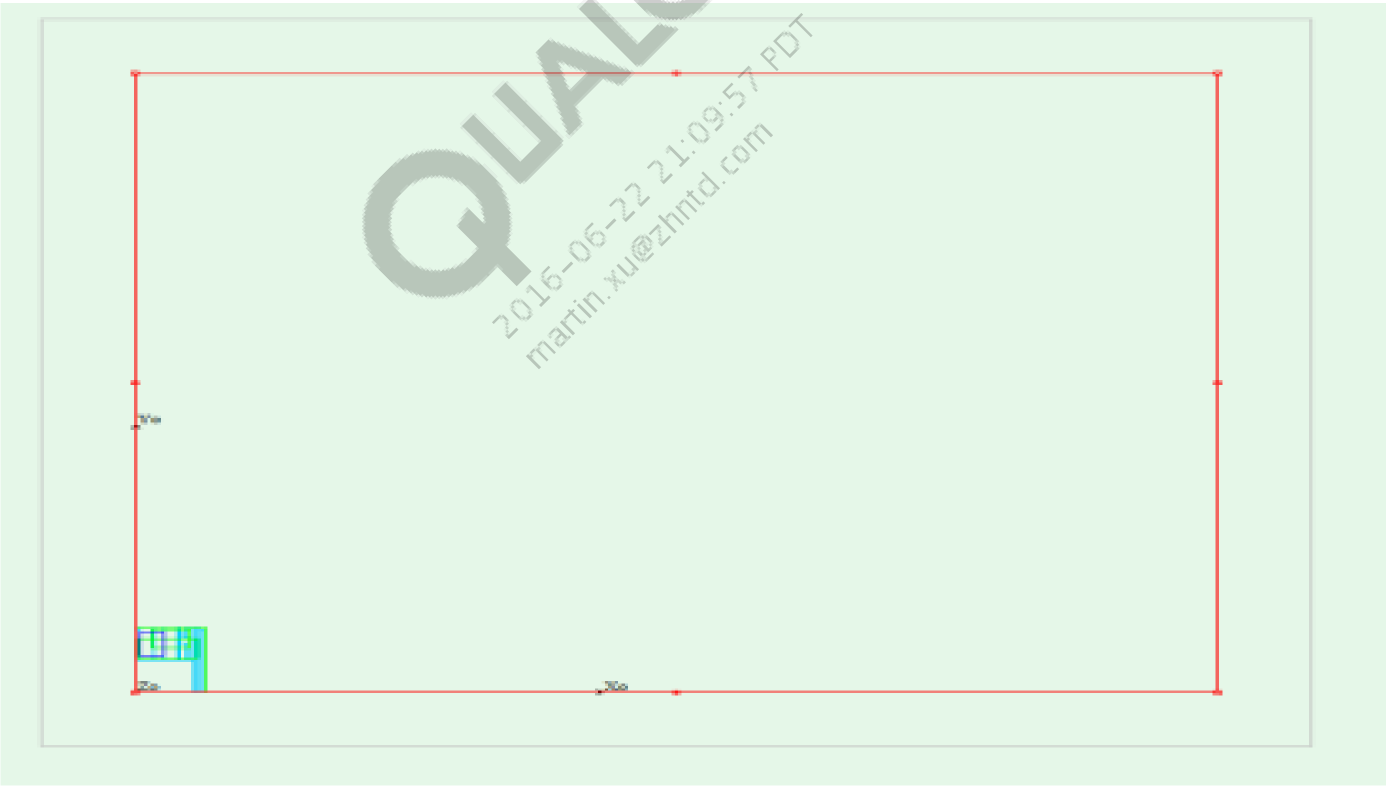
5. Click “Transfer MCAD Assembly”  .



PCBA Thermal Simulation – Create PCBA (12 of 15)

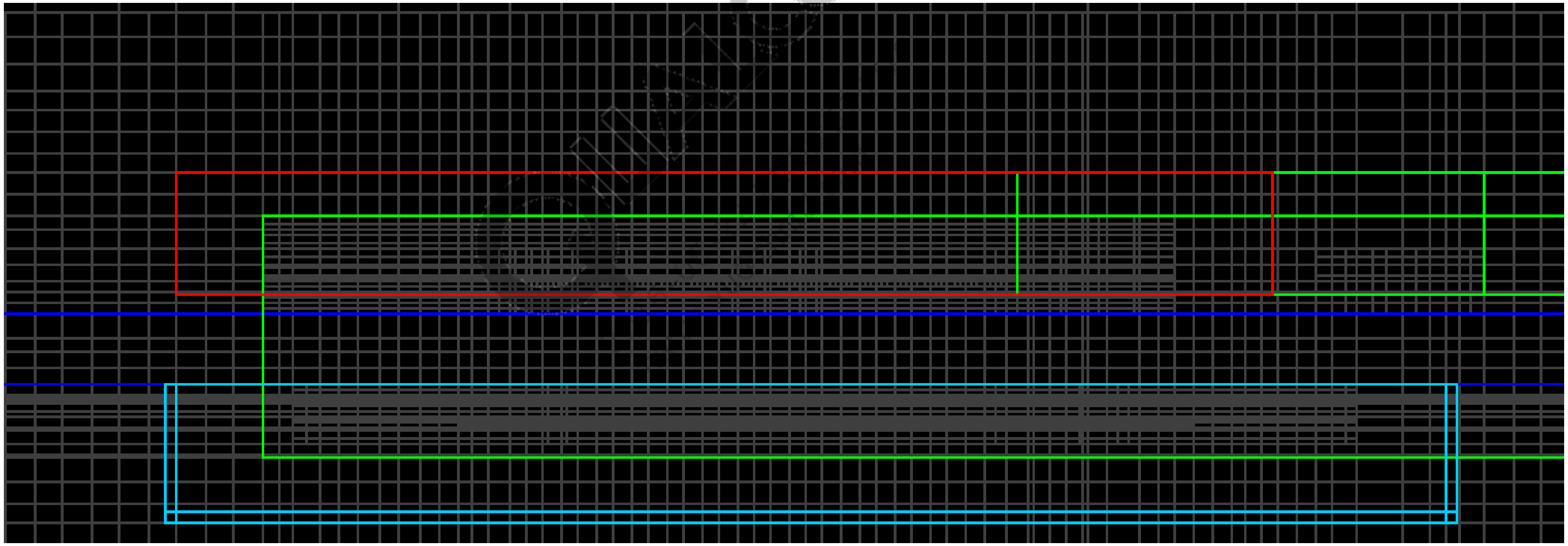
- **Import shields**

6. Click  and replace the shield with the enclosure.



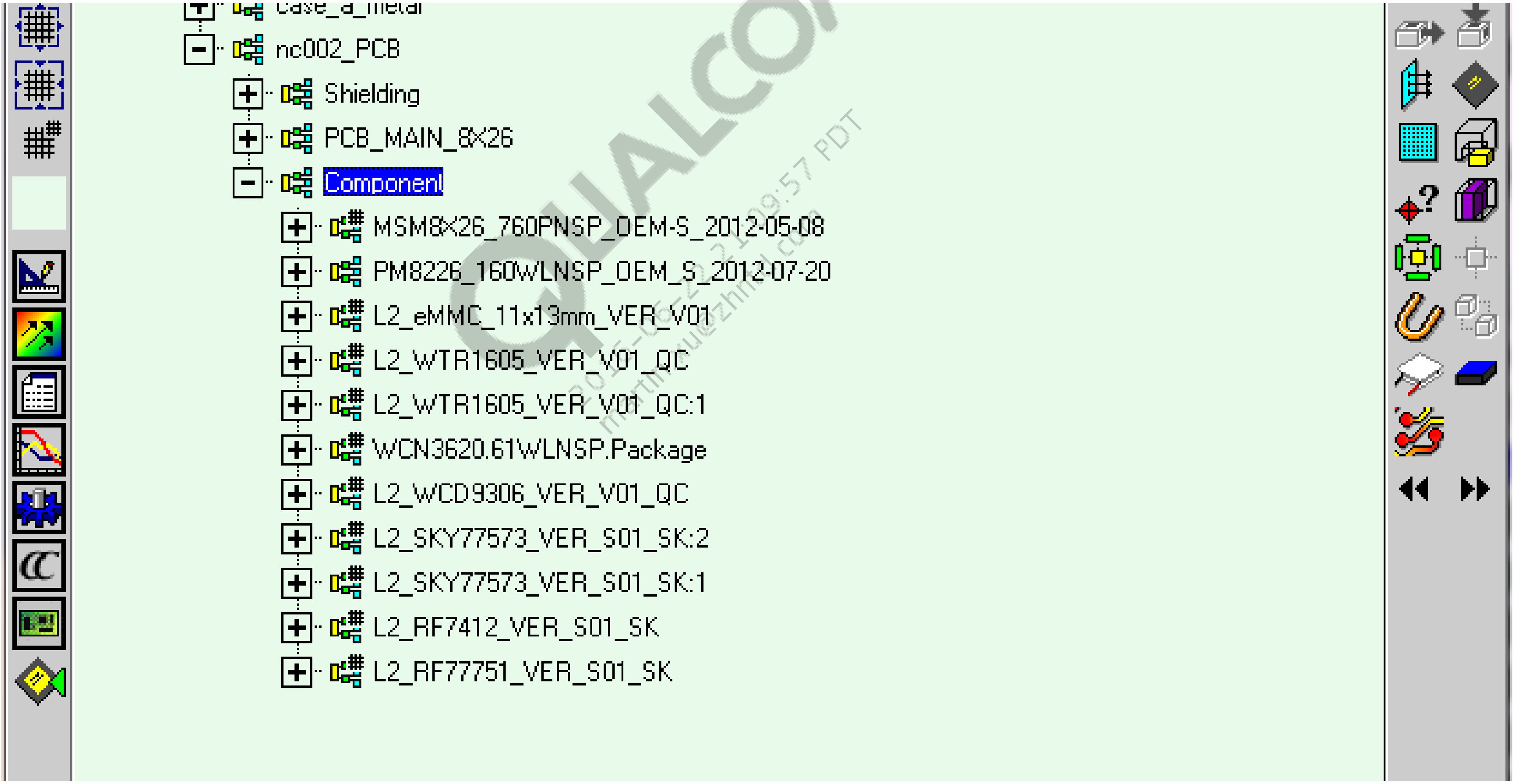
- **Import shields**

7. Adjust the size of the enclosure and position it with the original location.



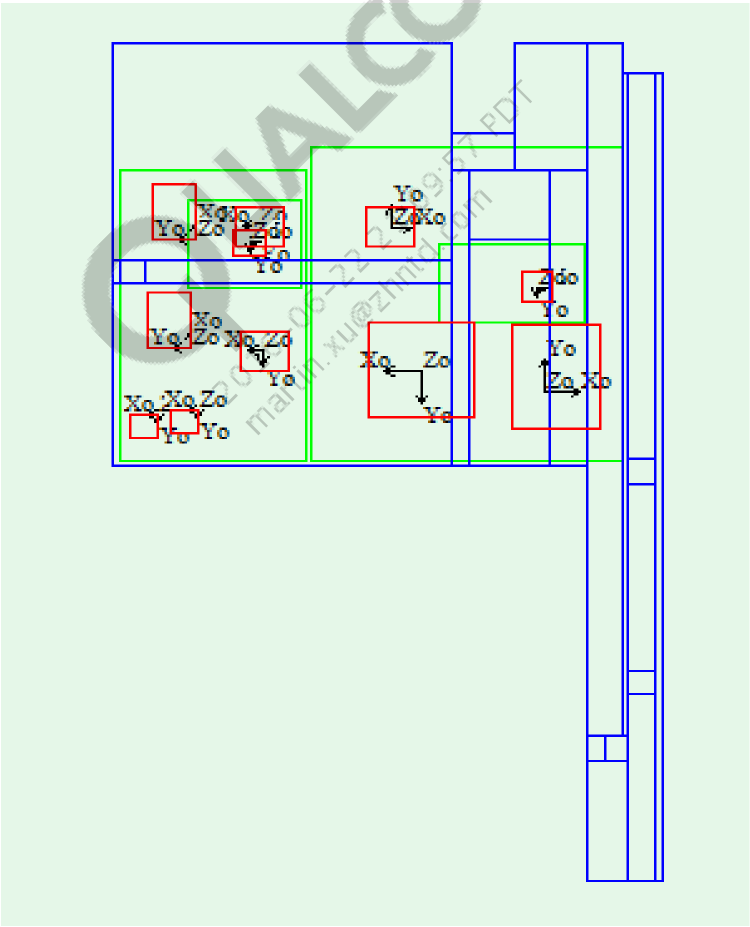
- **Import components**

1. Import .pdml files of the components into FloTHERM.

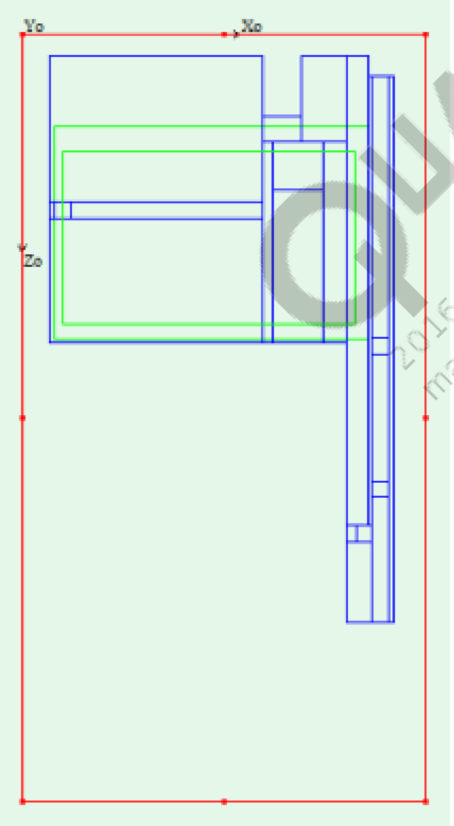


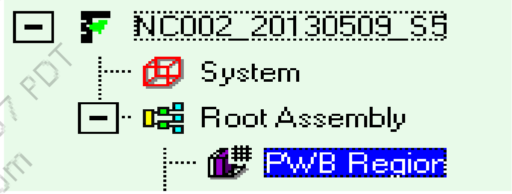
- **Import components**

2. Adjust the position of the component to ensure having the same position with the imported ICs from .floeda.

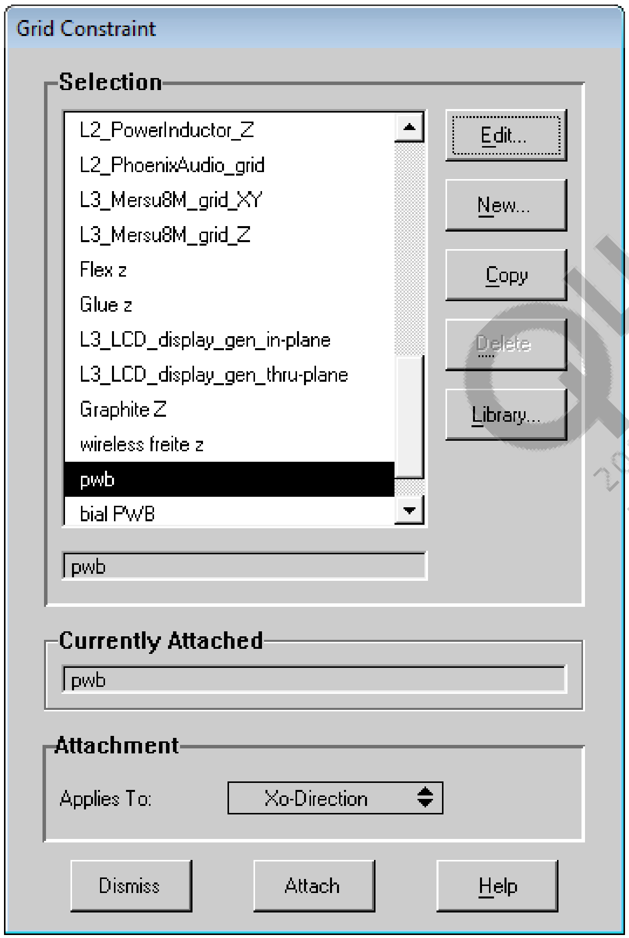


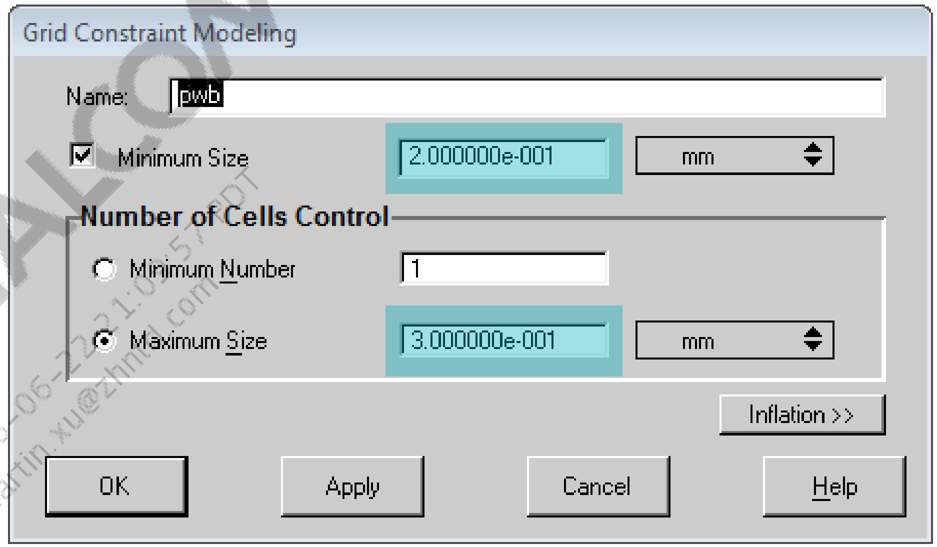
1. Click “Volume region”  to set the volume region for the PCB board.



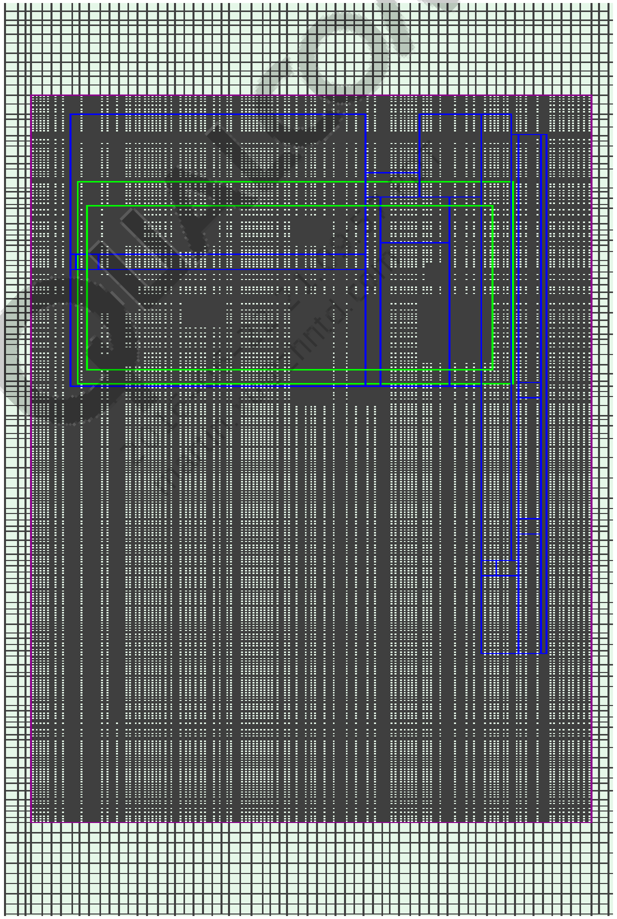


2. Set up the grid constraint of the volume region.





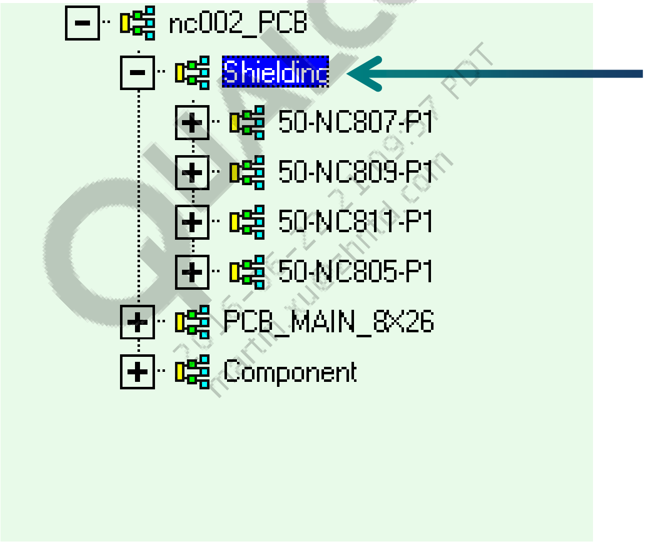
3. Set the volume region and the grid constraint for the whole PCBA.



PCBA Thermal Simulation – Setting (1 of 8)

- Setting shield material and radiation

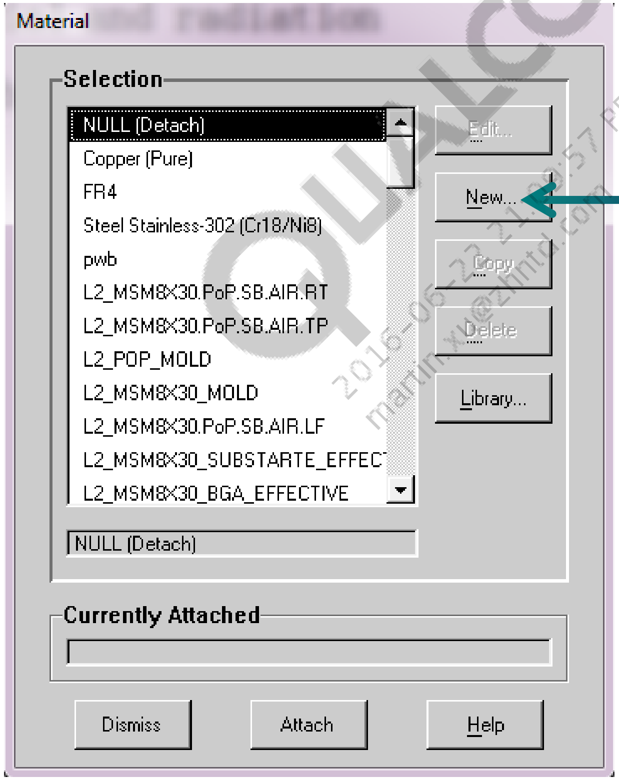
1. Right click the object and open the “Material” window.



PCBA Thermal Simulation – Setting (2 of 8)

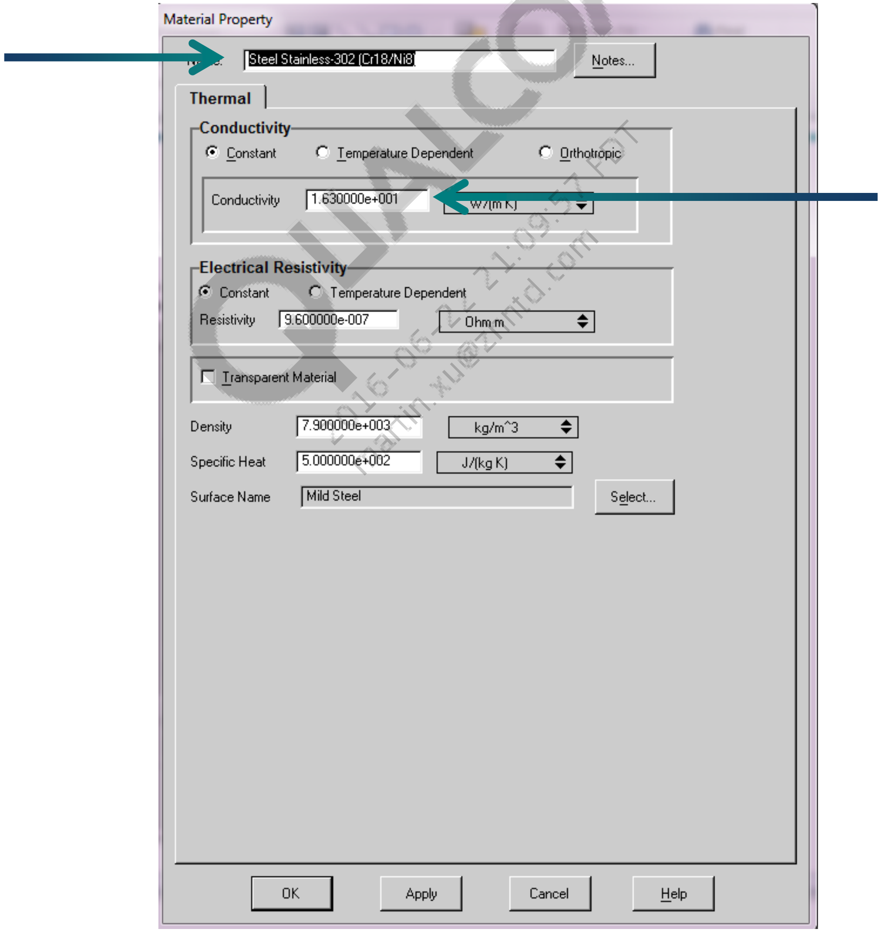
- Setting shield material and radiation

2. Select the property of the object or create a new one.



- Setting shield material and radiation

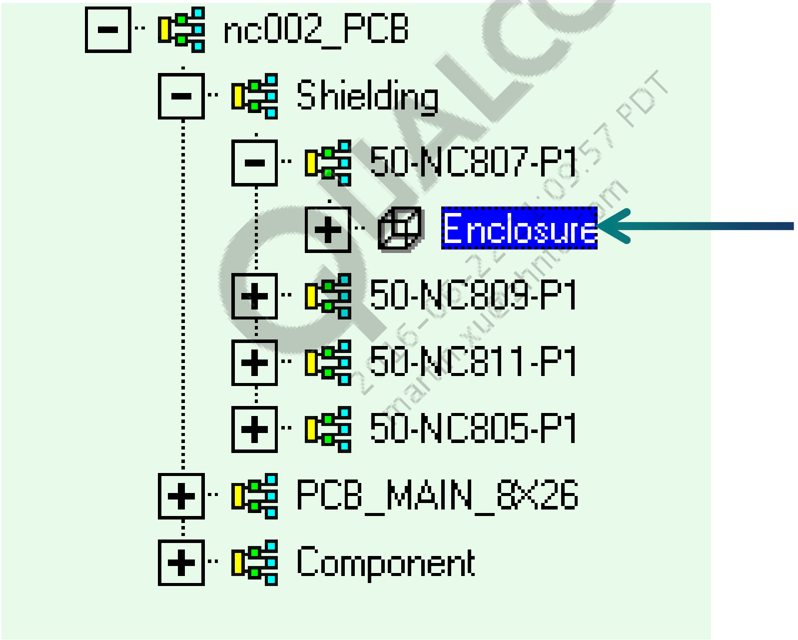
3. Define the name and set the thermal conductivity to “16.3”.



* See common Parameters Set in the Appendix *

- Setting shield material and radiation

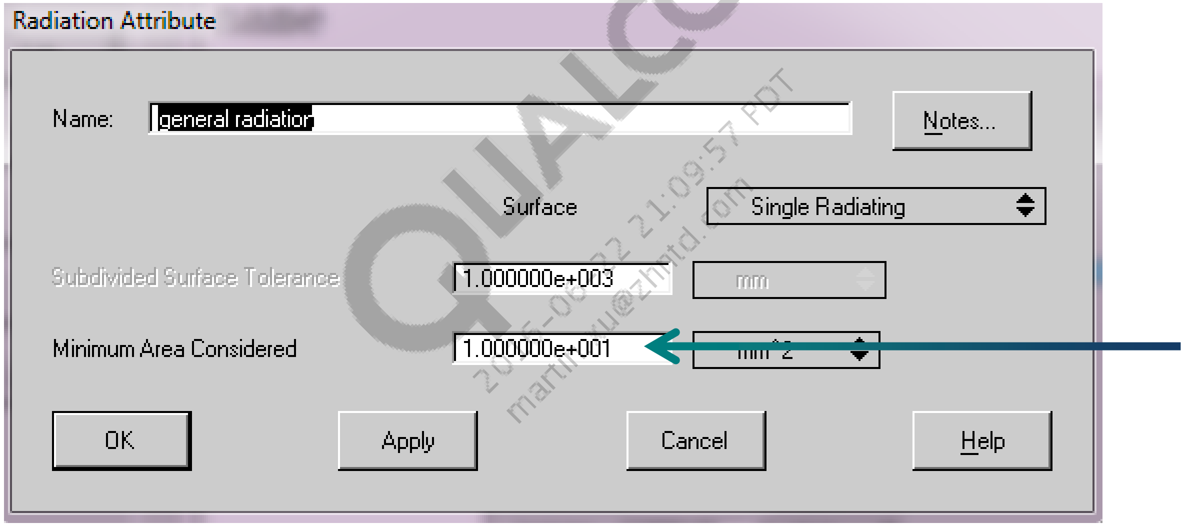
4. Right click the object and open the “Radiation” window.



PCBA Thermal Simulation – Setting (5 of 8)

- Setting shield material and radiation

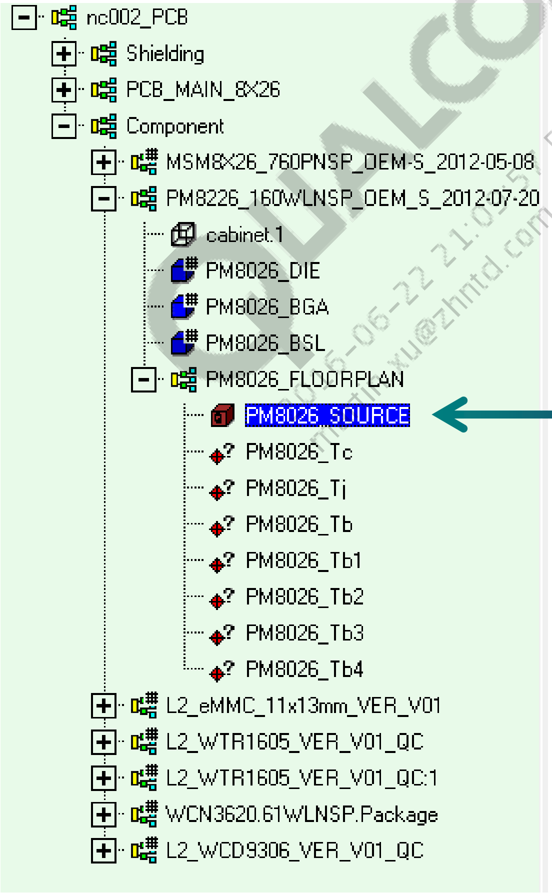
5. Define the name and set the number “10”.



PCBA Thermal Simulation – Setting (6 of 8)

- Setting IC thermal power

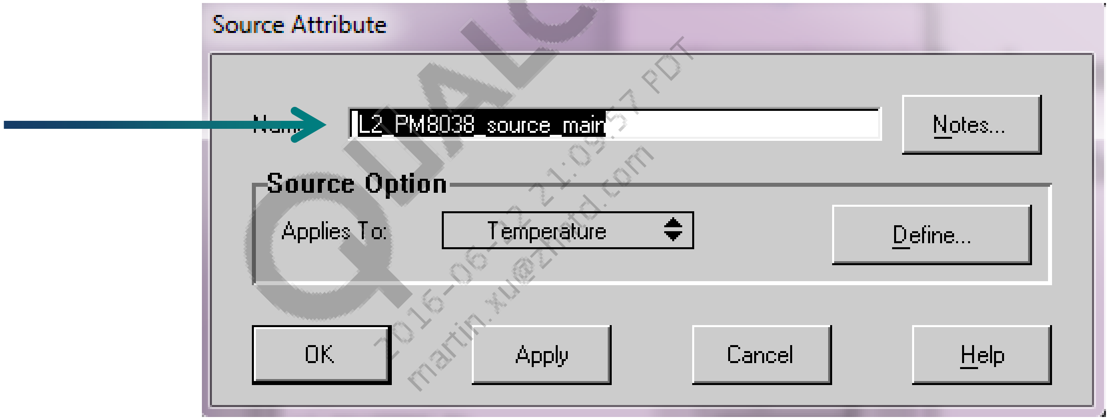
1. Right click the object and open the “Source” window.



PCBA Thermal Simulation – Setting (7 of 8)

- Setting IC thermal power

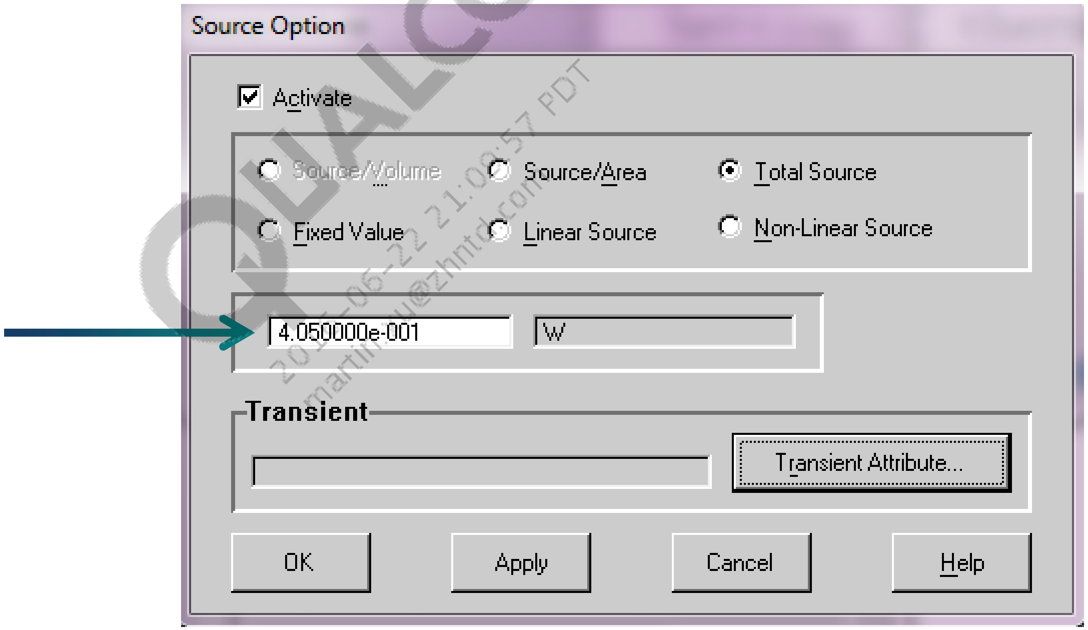
2. Define the name, and then click Define.



PCBA Thermal Simulation – Setting (8 of 8)

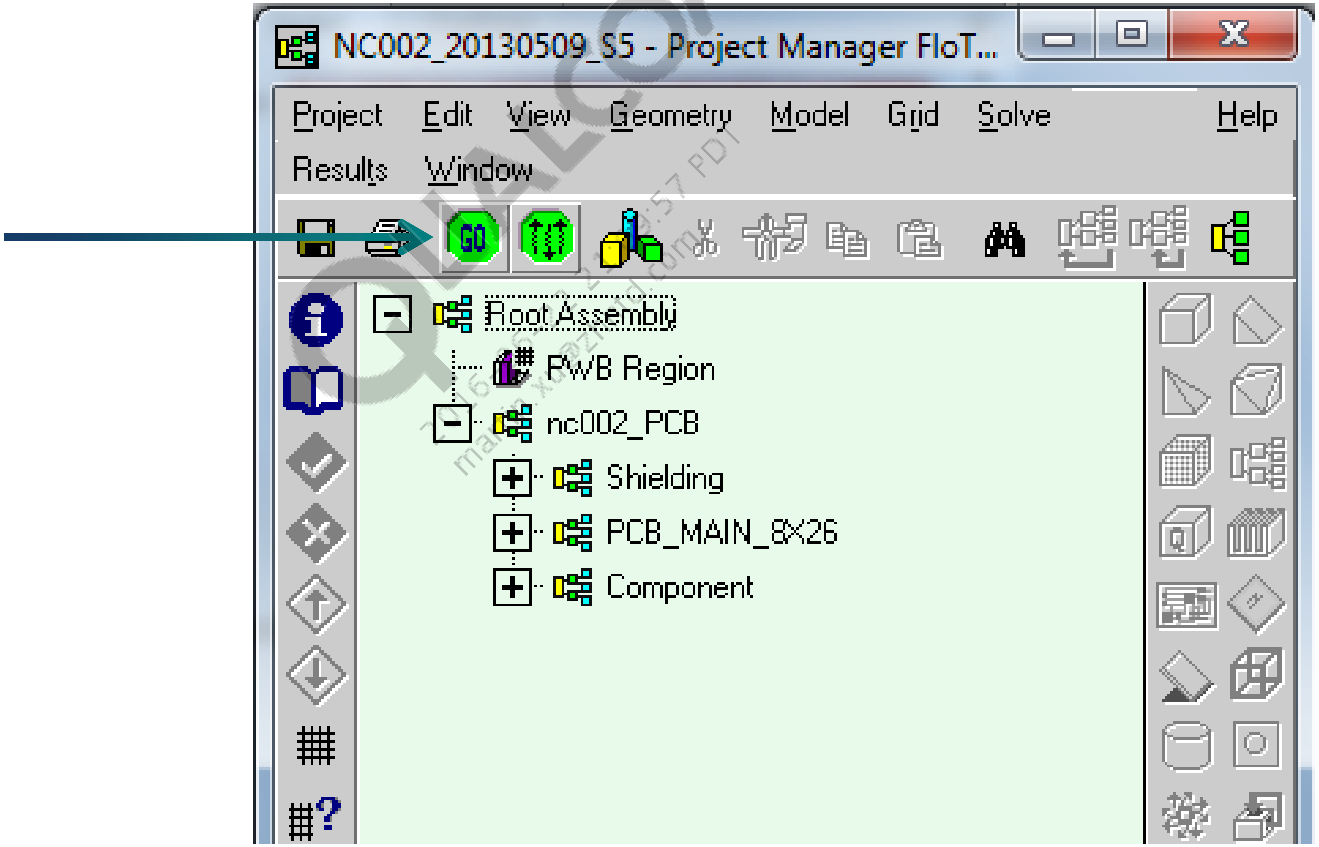
- Setting IC thermal power

3. Type in the thermal power.



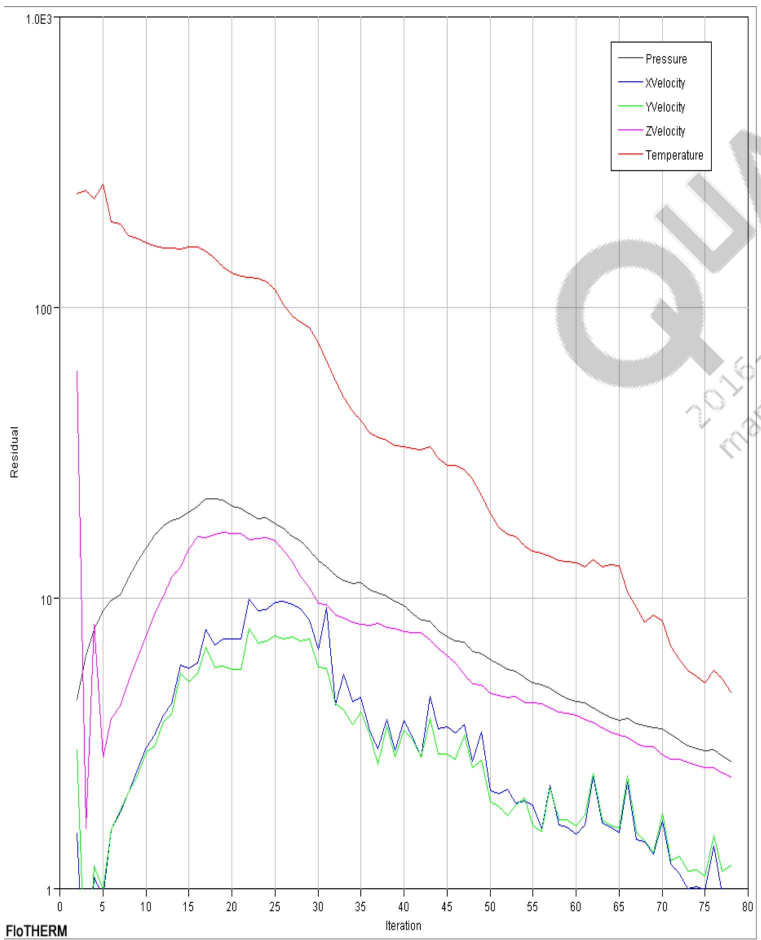
PCBA Thermal Simulation – Run Simulation (1 of 2)

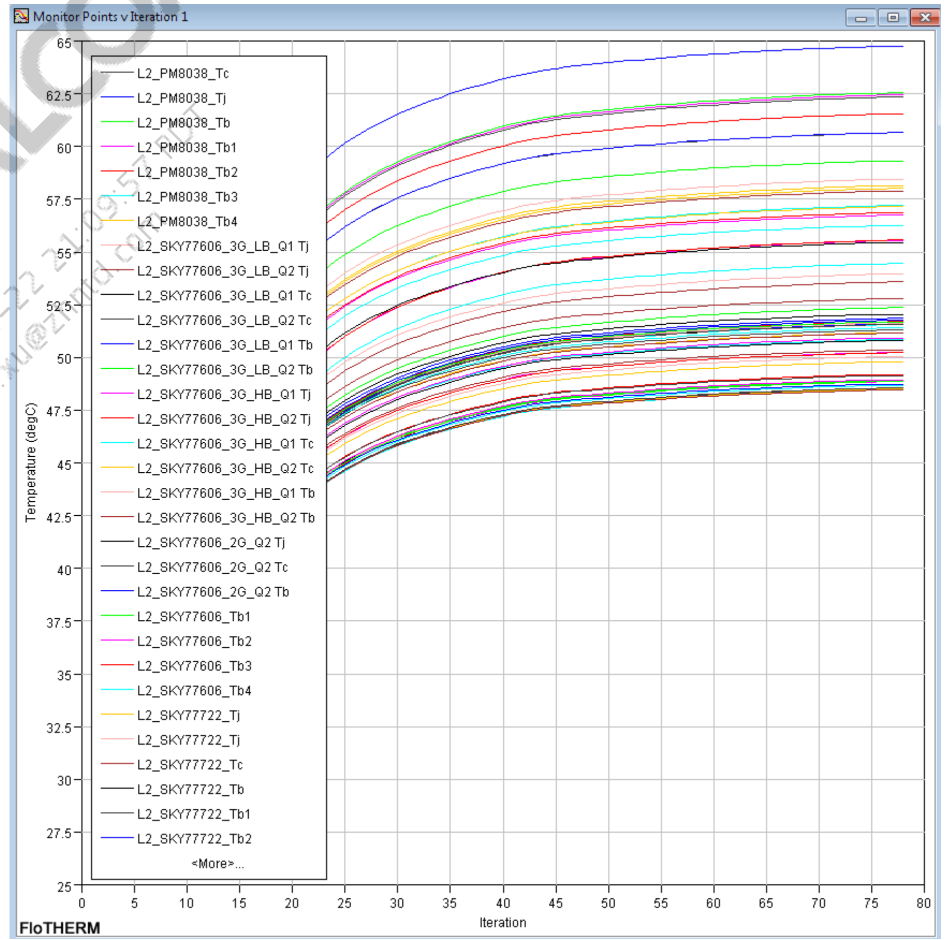
1. Click Go to run the simulation.



PCBA Thermal Simulation – Run Simulation (2 of 2)

2. If the (residuals) vs.(iteration) line is under 10 and all monitor-point temperatures are stable, the simulation result is considered to be reasonable.

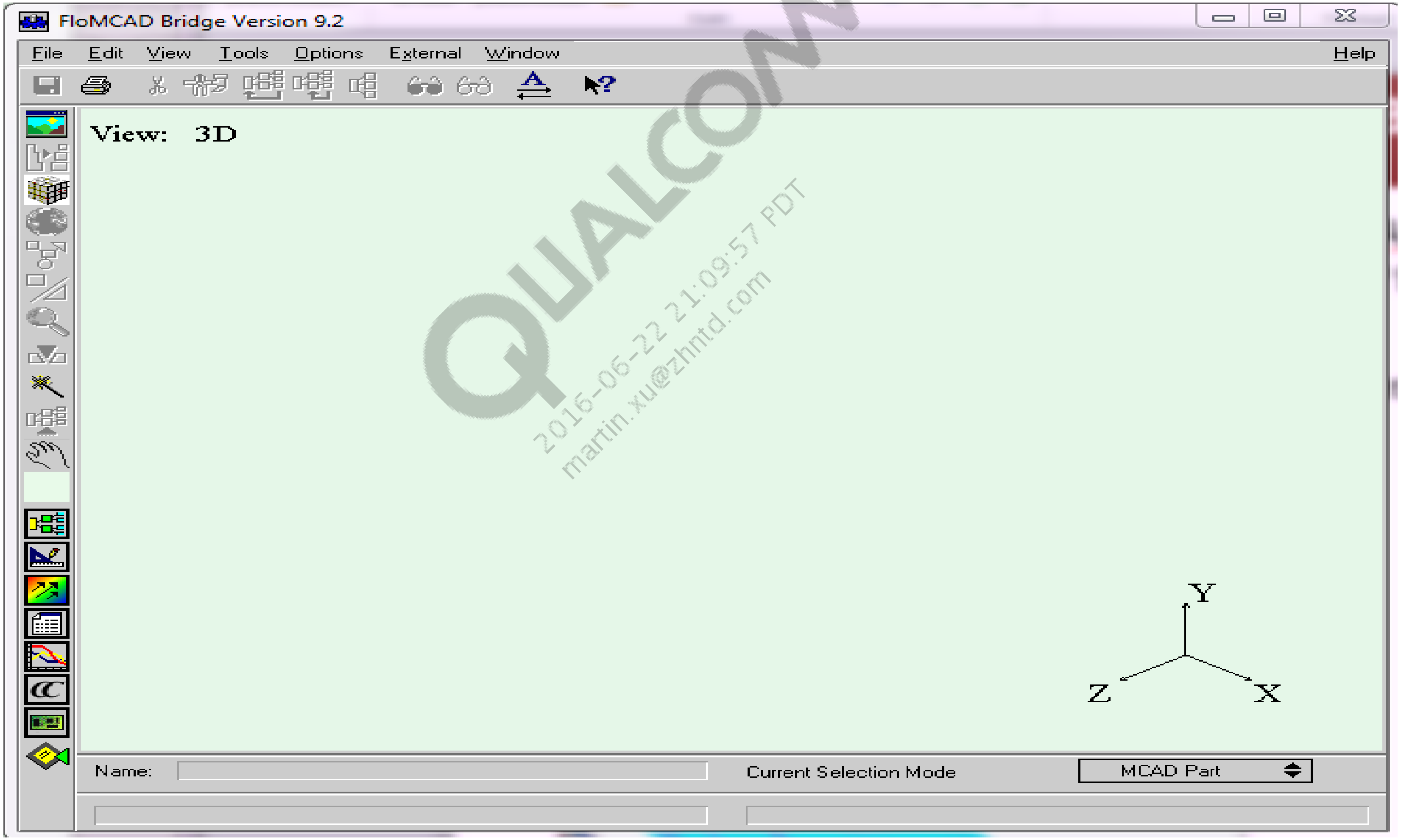




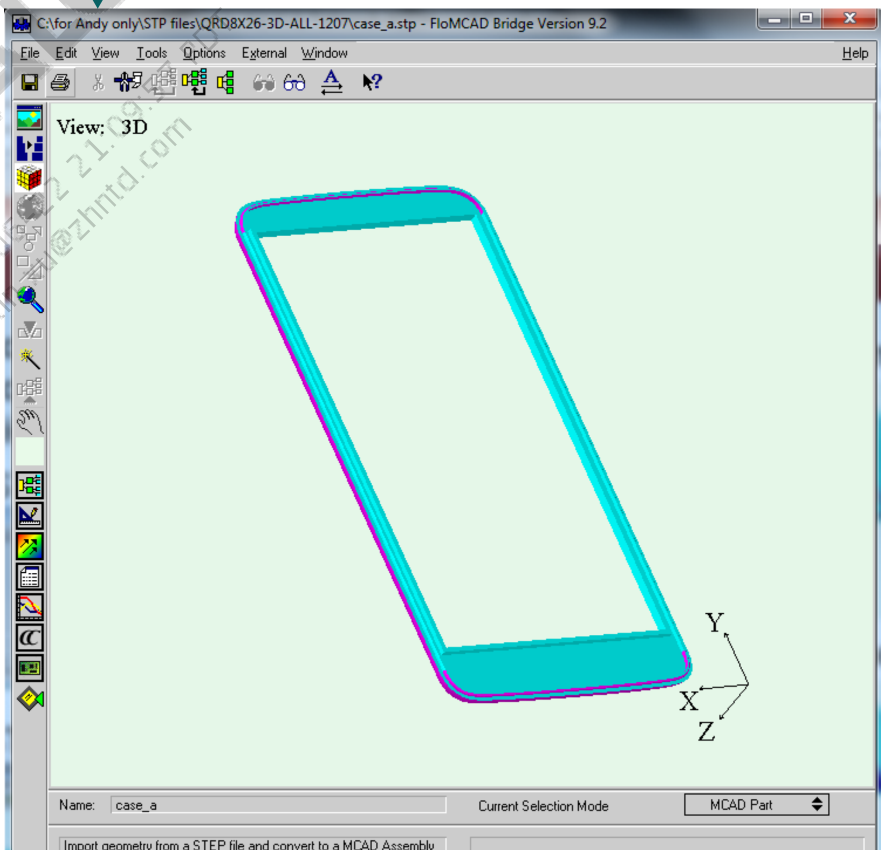
Section 5

Overall Handset System Thermal Simulation

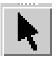
1. Click  to open the FloMCAD window.

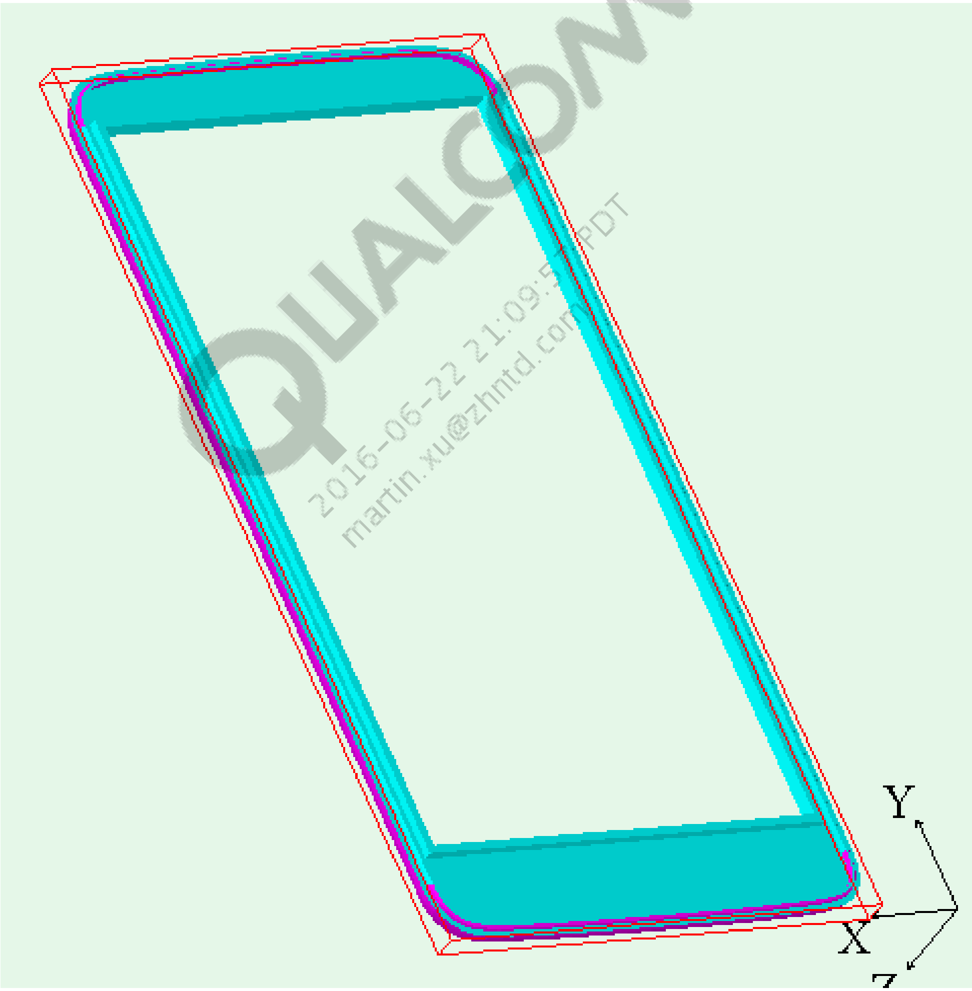


2. Click the External tab to import the STEP file.

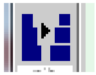


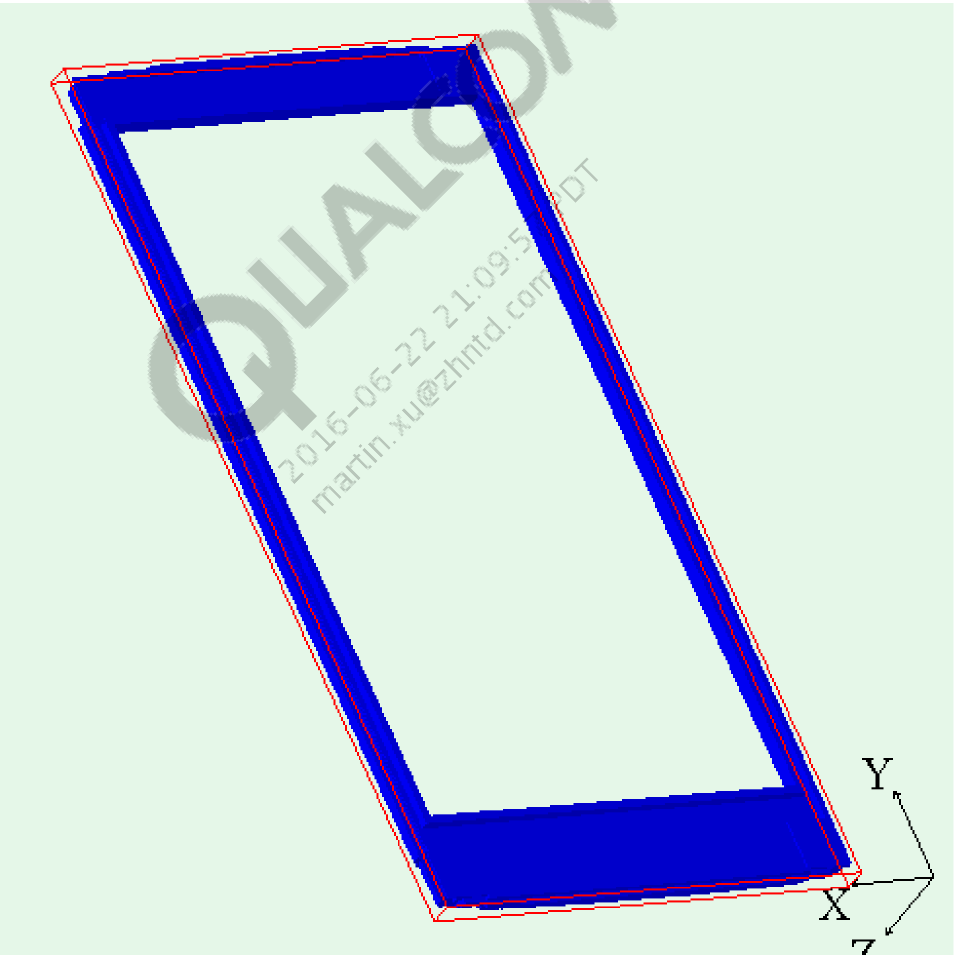
* Take the CASE-A (front housing) Importing Process, for example *

3. Click “Toggle mouse mode”  and select the object.

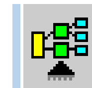


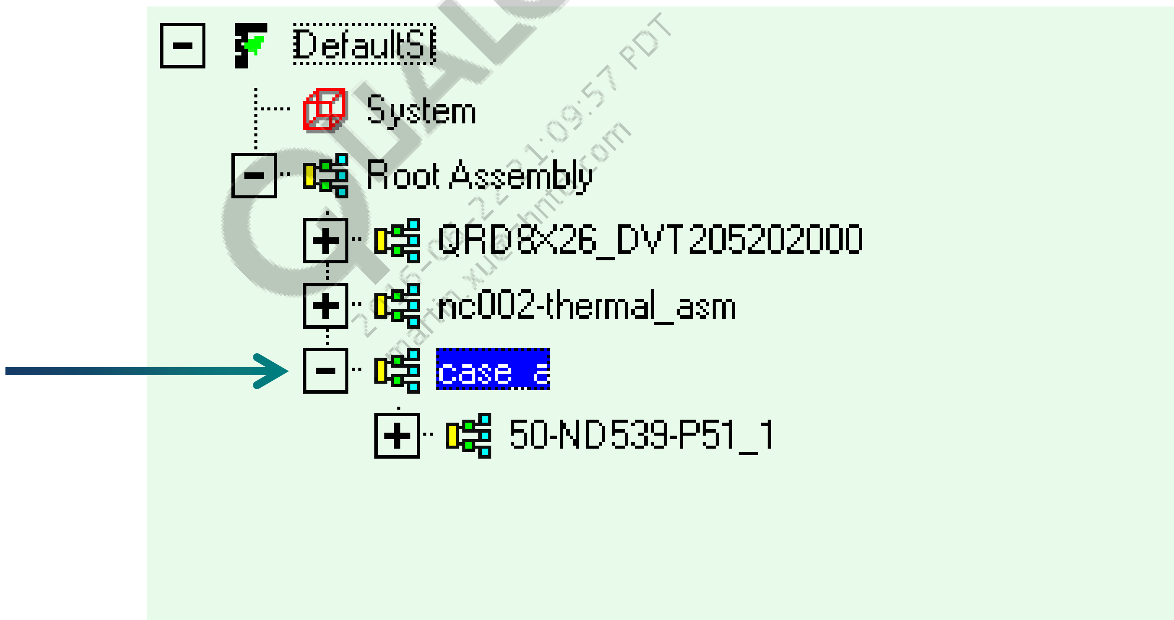
Overall Handset System Thermal Simulation – Create Mechanical Geometry (4 of 6)

4. Click “Decompose”  .

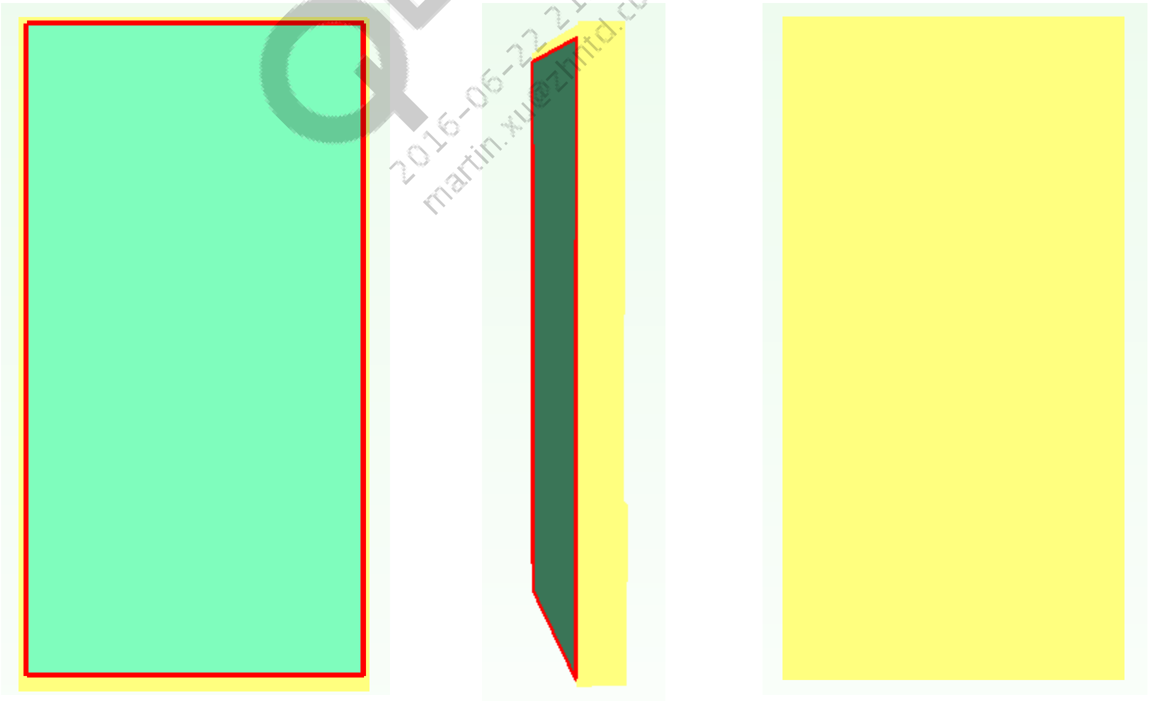


Overall Handset System Thermal Simulation – Create Mechanical Geometry (5 of 6)

5. Click “Transfer MCAD Assembly”  .

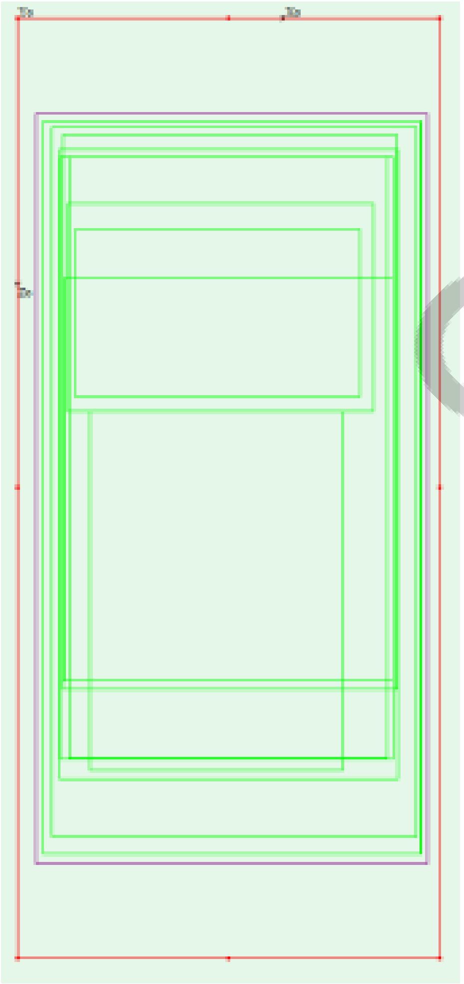


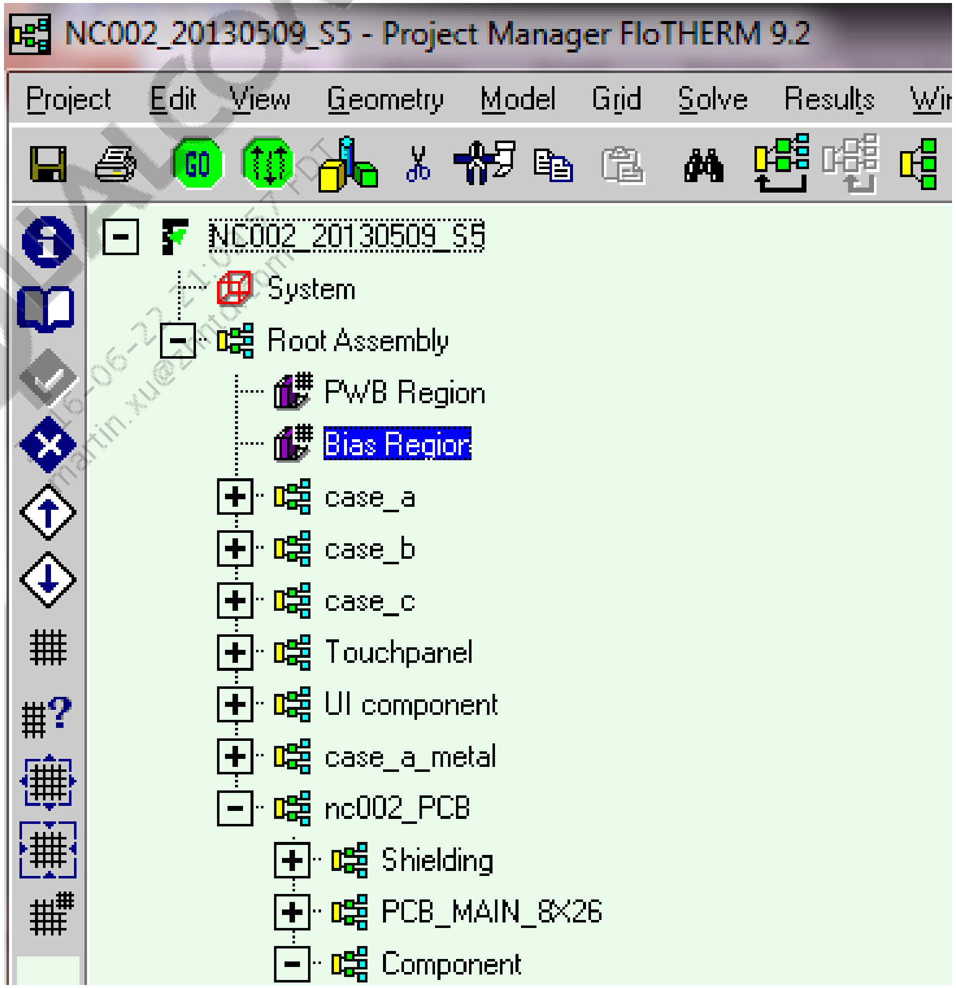
6. Import the other mechanical parts, shown below, by repeating steps 1-5:
- Case B
- Case C
- LCD metal support
- Touch panel



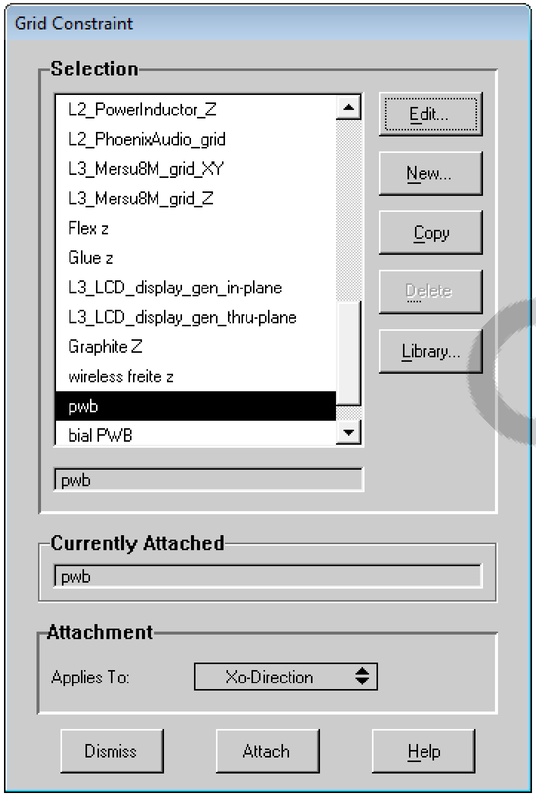
Overall Handset System Thermal Simulation – Gridding (1 of 3)

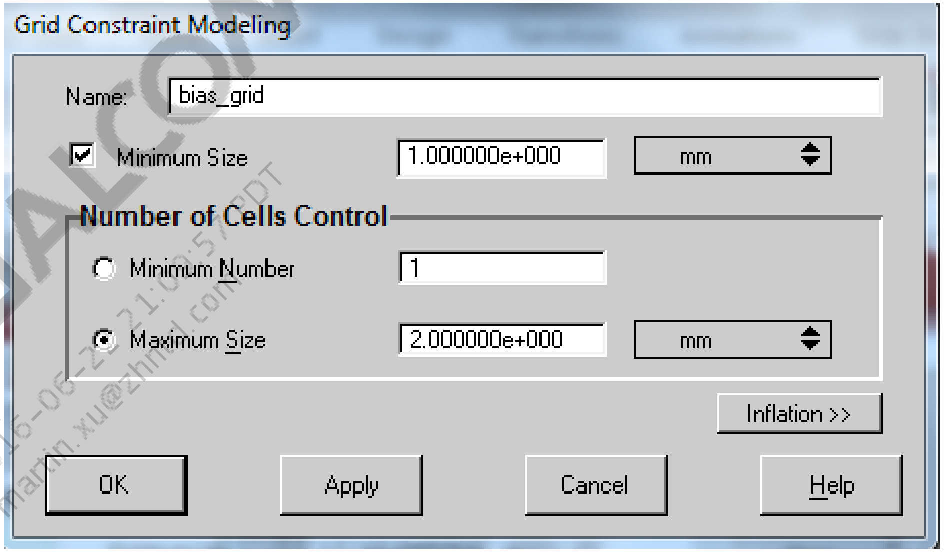
1. Click “Volume region” to set the volume region for the phone-level “Bias Region”.



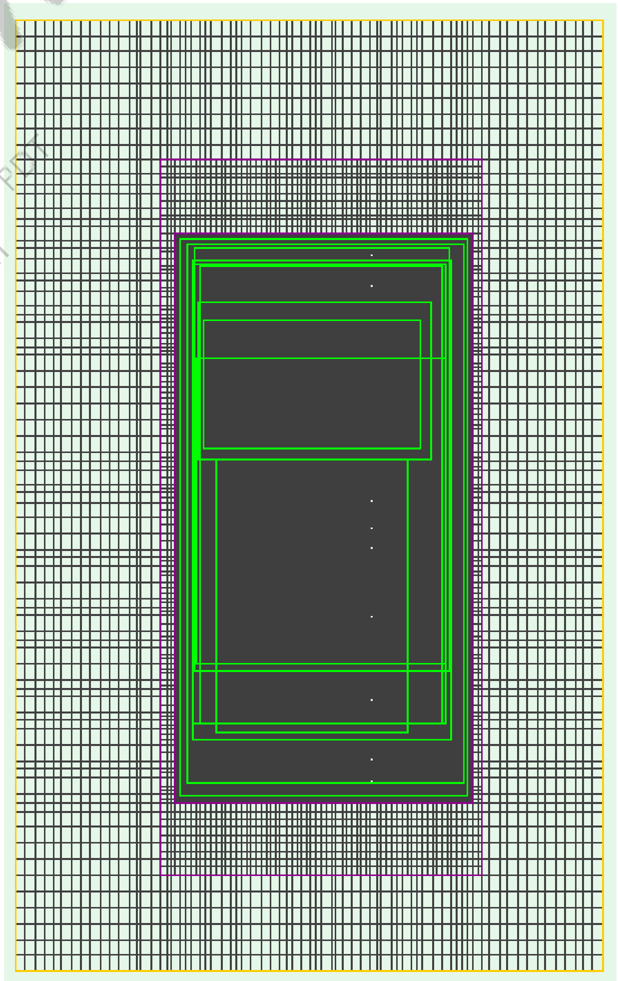


2. Set up the grid constraint of the volume region.





3. Set the volume region and the grid constraint for the whole phone.



* Common grid number
  – Four million cells
* Required grid quality
  – Maximum aspect ratio 20
* Run time (design iteration)
  – About 1 hour for each use case

Overall Handset System Thermal Simulation – Setting

* Same process as the *PCBA Simulation – Setting* section *

* Also see the common Parameters Set in the Appendix *

Overall Handset System Thermal Simulation – Run Simulation

* Same process as the *PCBA Simulation – Run Simulation* section *

Section 6

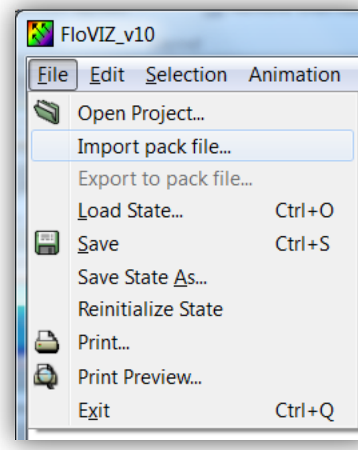
Visual Editor: Viewing Thermal Simulation Results

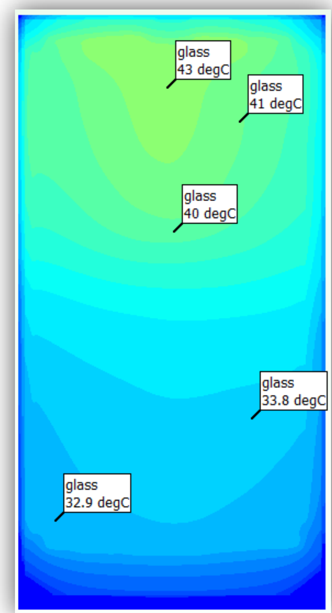
Visual Editor: Viewing Thermal Simulation Results

- The next few slides illustrate how to download and view an example of thermal simulation results of a QTI handset reference design based on the MSM8x26 chipsets.
- By default, the thermal simulation can be viewed in FloTHERM (for those with a license). However, for those without a license, results can also be viewed in FloViz, a free tool made available by Mentor Graphics.
- FloViz reads thermal simulation results of temperature and other parameters obtained from the simulation.
- All results files from this example are available on the QTI document and downloads at CDMATech https://support.cdmatech.com.
- See the next slide for procedures.

Viewing Thermal Simulation Results

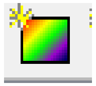
- Click “Visual Editor” to view the simulation results.
- If you do not have access to FloTHERM, download the free FloTHERM results viewer, FloVIZ, here: http://www.mentor.com/products/mechanical/downloads/floviz-viewer/
  - Load the provided model into FloVIZ using “File – Import pack file” to load the provided NC002_2013.12.23_AT_Rev3.pack file
- In Visual Editor or FloVIZ, use “File - Load State” to load any of the five provided state .xml files, to look at the predefined results setups:
  - Temperature_Plane_Junction_Hotspot.xml
  - Temperature_Plane_Components_Board.xml
  - HeatFlux_Vectors_and_Shortcut_Opportunities.xml
  - PCB_Components_Surface_Temperature.xml
  - Outer_Surface_Temperature.xml



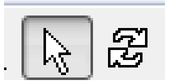


Visual Editor/FloVIZ (1 of 3)

Some commonly used tools in the Visual Editor/FloVIZ:

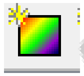
 – Creates a contour plane showing a selected variable (temperature/speed, etc.) and/or a selected vector (velocity, heat flux, etc.).

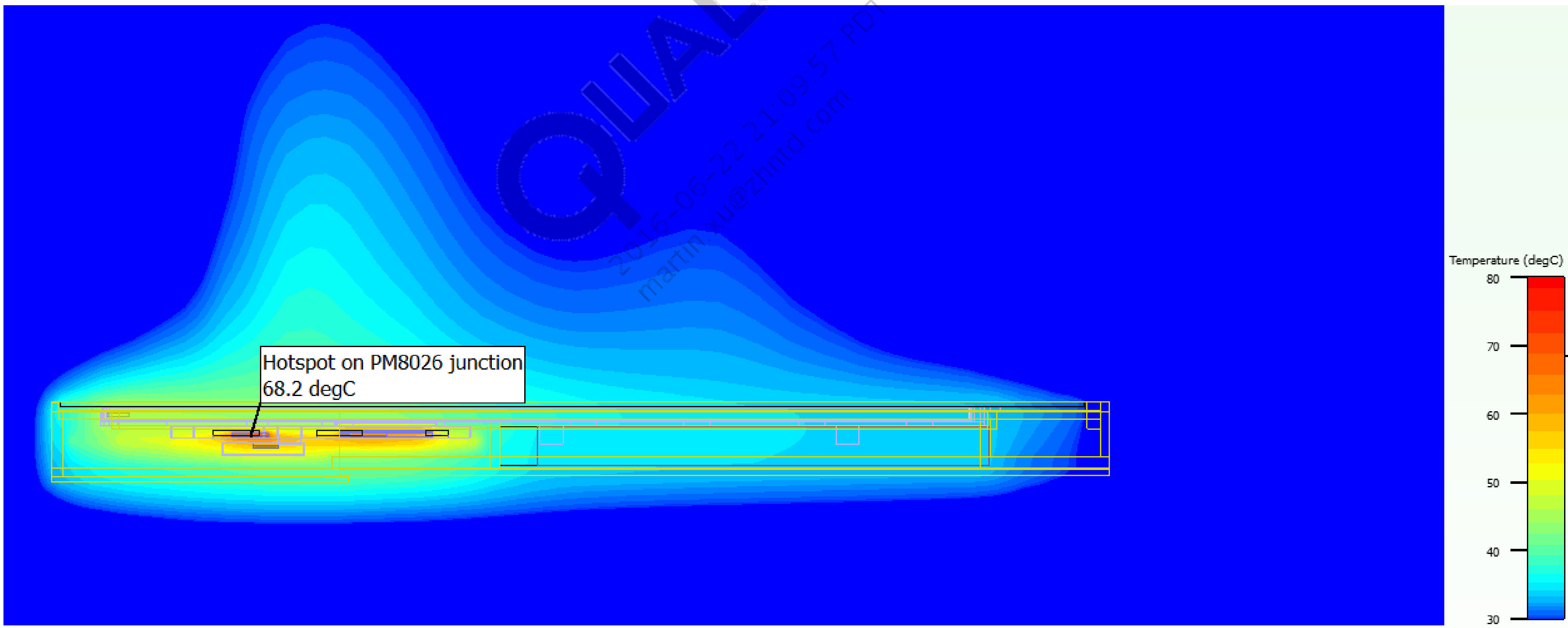
 – Wireframe/Solid/Surface Temperature. Select the geometry, then click the icon for the style you would like to view in.

 – Mouse Select Mode/Mouse View Manipulate Mode. The arrow is for selecting geometry. The manipulator allows rotating, panning (with Ctrl key), and zooming (scroll or center mouse).

Note: In FloVIZ, some toolbars may need to be expanded to show all available tool icons.

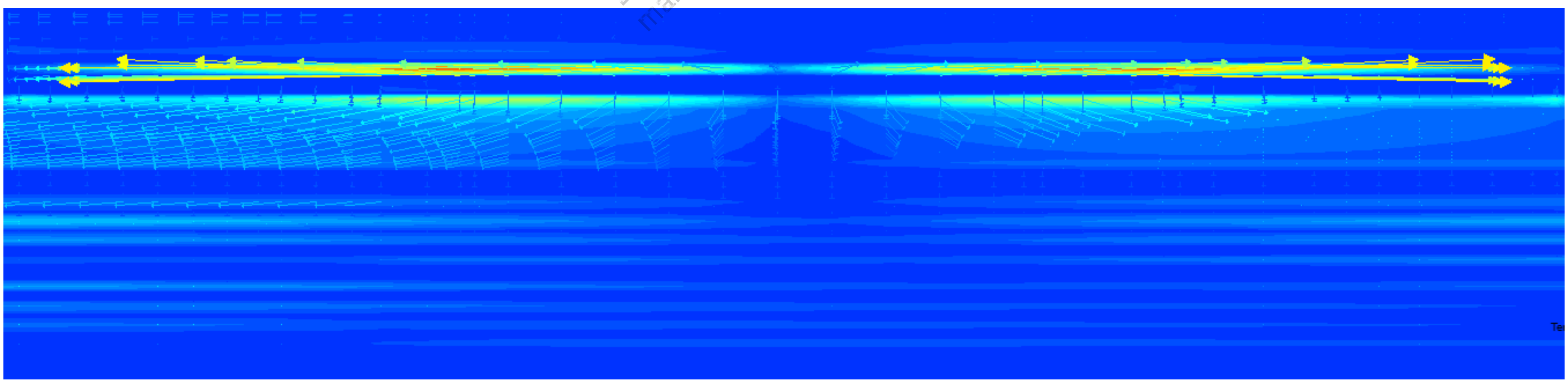
Visual Editor/FloVIZ (2 of 3)

- The contour plane shown below can be viewed using the provided visual state, “Temperature_Plane_Junction_Hotspot.xml.”
- You may create such a plot using the Contour Plane tool  .

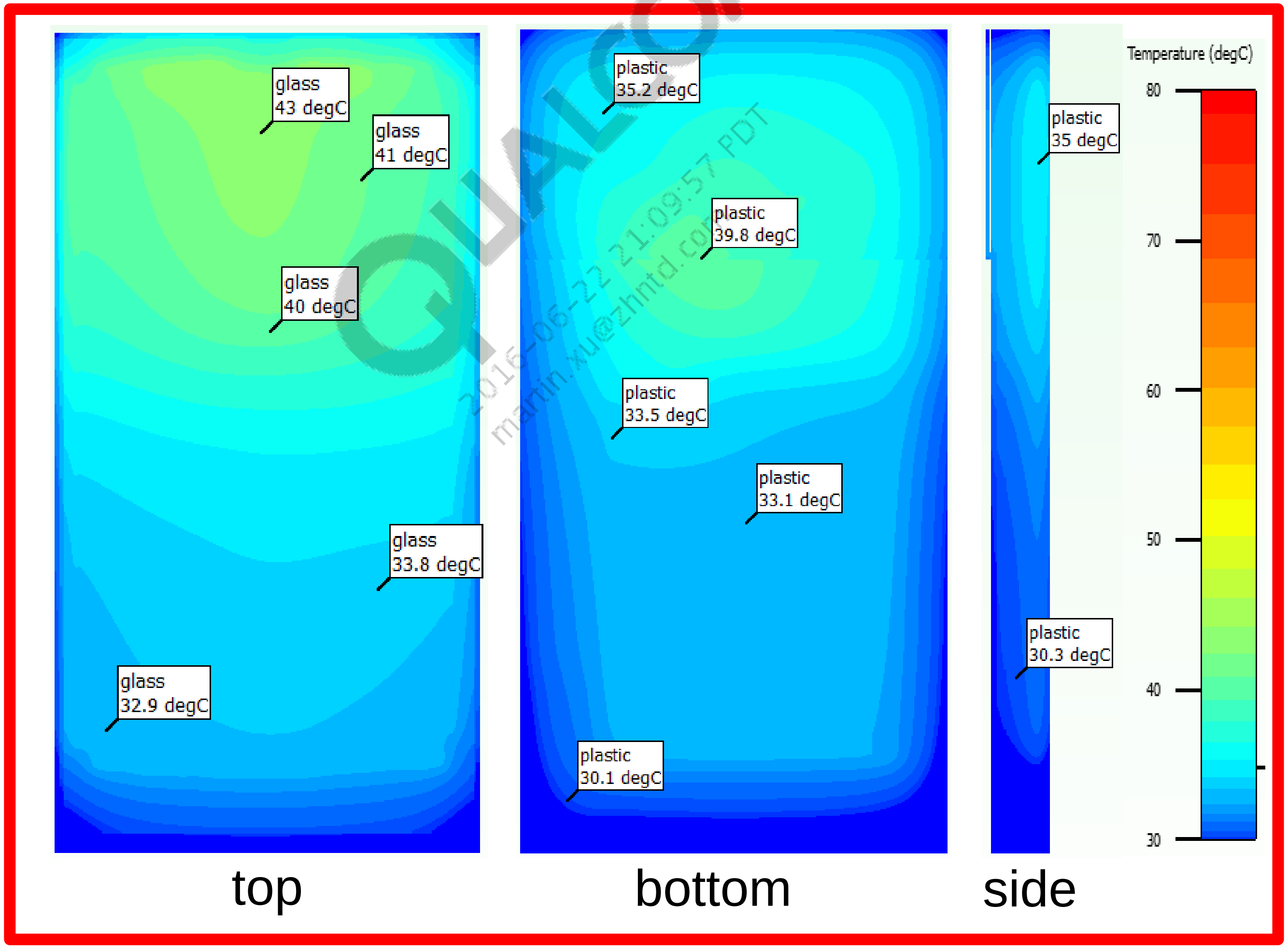


Visual Editor/FloVIZ (3 of 3)

- For the example contour plane shown below, the contour plane is showing the heat flux vector arrows leaving the MSM8x26 component.
  - The majority of the heat flows down into the PCB.
- The contour plane is colored with the Thermal Shortcut parameter, which helps show where thermal design improvements can be made.
  - In this example, the copper planes of the PCB are colored a high value, indicating there is a thermal shortcut available. Since a lot of heat is moving into the PCB, the thermal improvement to be made is to add vias under the component to help move the heat into the power/ground planes more easily.



The images below can be viewed using the provided visual state, “Outer_Surface_Temperature.xml.” The images show temperature contours on the outer surface of the device. The value at any point on a plot can be viewed and annotated using the annotate tool .



Section 7

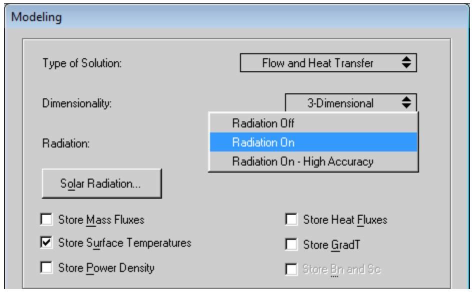
Appendix

Thermal Conductivity Set for QRD8x26 Thermal Model

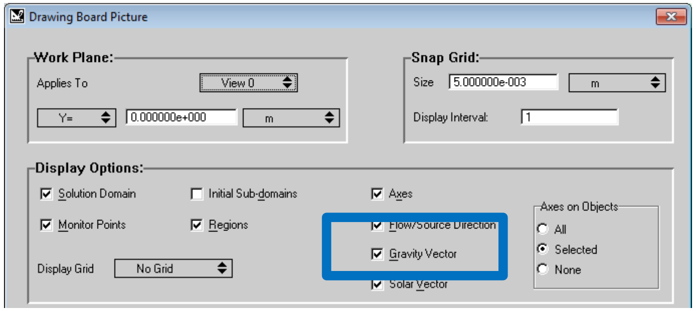
Mechanical parts	Materials
Shields	Steel Stainless-302 (Cr18/Ni8) = 16.3 W/mK
LCD support	Steel Stainless-302 (Cr18/Ni8) = 16.3 W/mK
Touch panel	Glass = 1.07 W/mk
Plastics (case A/B/C)	Polycarbonate (typical) = 0.2 W/mk
Screw	Steel Stainless-302 (Cr18/Ni8) = 16.3 W/mK
LCD shield	Steel Stainless-302 (Cr18/Ni8) = 16.3 W/mK

FloTHERM (1 of 2)

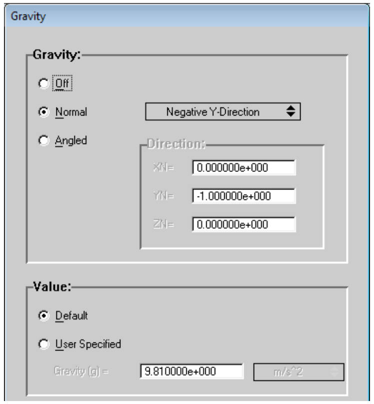
System simulation setup



- Natural convection system
  - Activate Radiation Solver in Model – Modeling Menu



  - Check gravity orientation
    - Display gravity vector in the drawing board in the Edit – Modify Picture Menu
      - Can also be shown in the Visual Editor

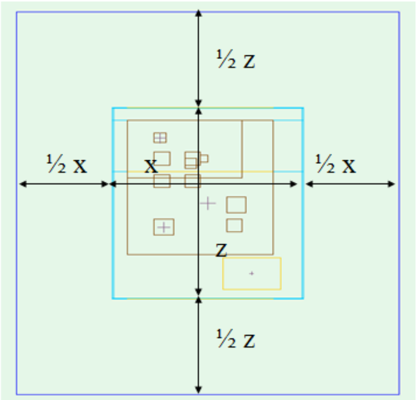


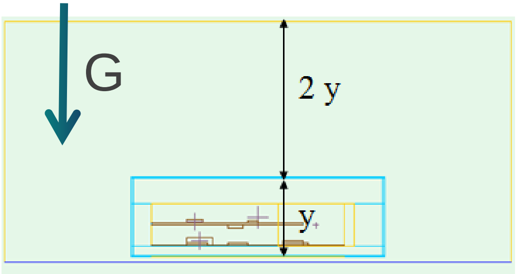
    - Change gravity direction in Project Manager, Model – Gravity Menu

Natural convection system

- The solution domain should be bigger than the geometry, so the natural convection air flow outside can be solved
- How big?
  - Rule of thumb
    - Half the assembly width away from the geometry in the non-gravity directions
    - Twice the assembly height above device in the gravity direction
    - One assembly height bigger below the device, or
    - If applicable, model the surface below device (e.g., desktop)
      - This will affect the airflow to the device and is important to capture
      - Then solution domain does not need to be extended below this surface

Solution domain size

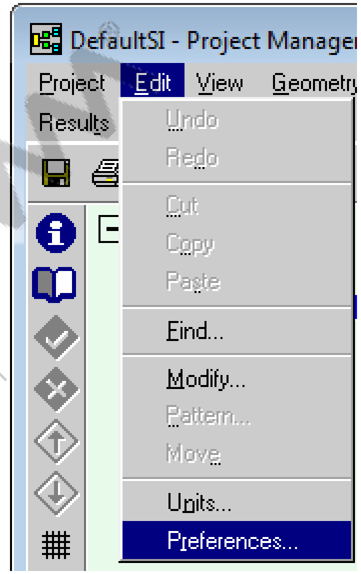


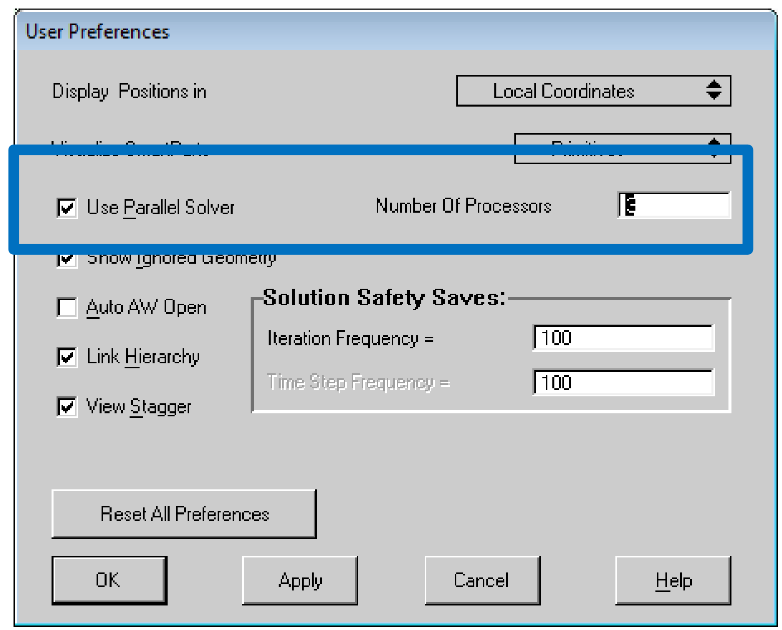


FloTHERM Hints/Tips (1 of 5)

Parallel Solver

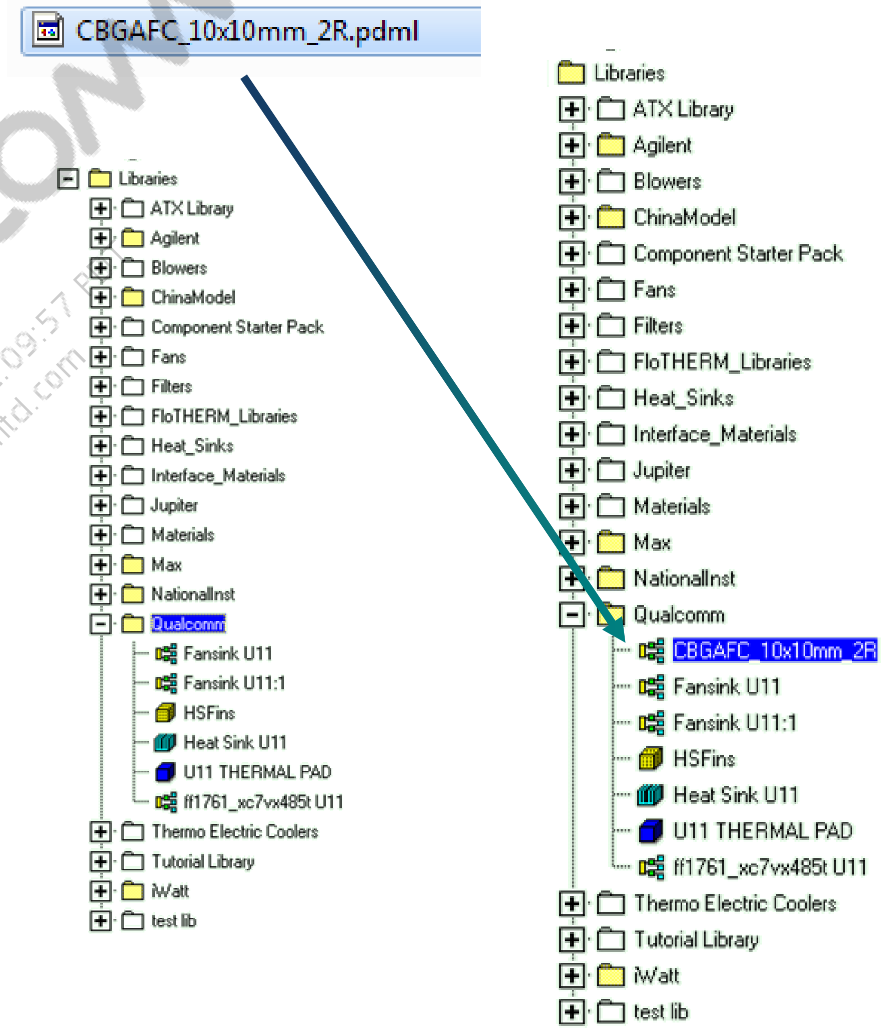
- Activating the Parallel Solver will reduce the solve time by allowing multiple cores to work on the simulation
  - Requires a parallel solver license
- Activate in the Project Manager, Edit – Preferences menu





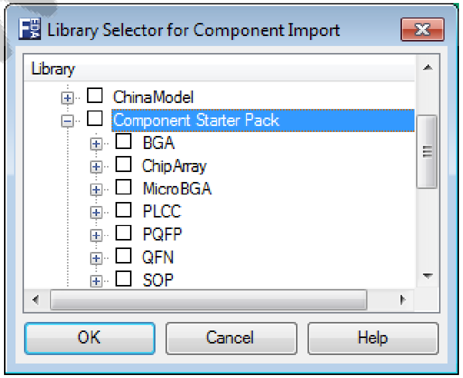
- Library Manager is drag and drop
- User can drag and drop
  - Objects
  - Subassemblies
  - Attributes
  - From project into library for future use
- User can drag .pdml models from Windows Explorer/desktop into library folder as well

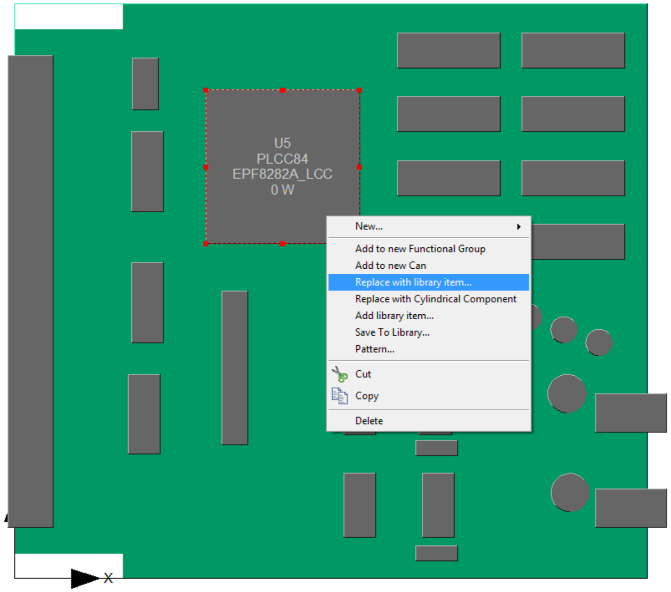
Library Manager



- If IC package models are already in the library manager, FloEDA Bridge can automatically swap them in during the PCB import
- Use the Library Swap tool
  - Automatically appears during import
  - Also available in Tools – Component Library Swap menu
- Will match package names with names in the selected library folder
  - Ensure library component are saved with package names to use this feature
  - It will use a partial match if an exact match is not found
- Manual library swap is also available

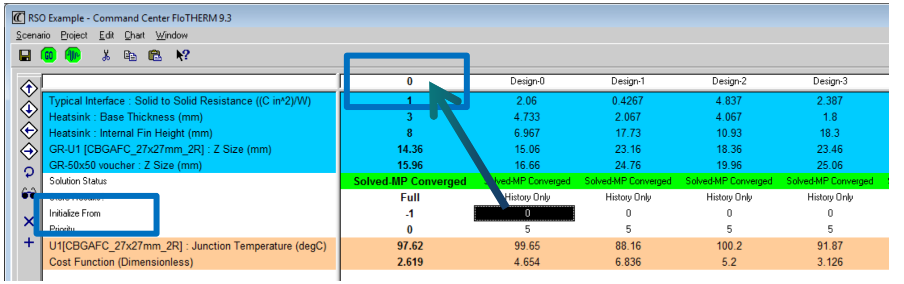
Library Manager and FloEDA Bridge





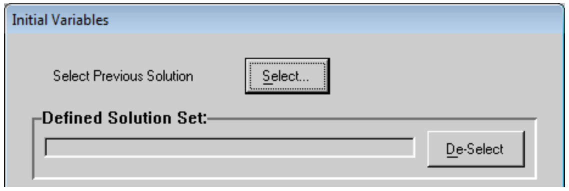
- Reduce model complexity
  - Complex models need more grid cells and take longer to solve
  - Remove thermally insignificant geometry like screws and resistors, reduces grid count and improves grid quality
  - Do not model every IC in detail
    - Only the most critical components need to be modeled to this high level
- Leverage existing results
  - Command center can be used to optimize the design, or to run the design through various studies
  - Command center will use the results from the base case model as a starting point for the other simulations
    - Reduces solve time
  - Can manually point to previous results in Project Manager as well
    - Model – Initial Variables menu

Reducing solution time


RSO Example - Command Center FloTHERM 9.3
Scenario Project Edit Chart Window

	0	Design-0	Design-1	Design-2	Design-3
Typical Interface : Solid to Solid Resistance ((C in^2)/W)	1	2.06	0.4267	4.837	2.387
Heatsink : Base Thickness (mm)	3	4.733	2.067	4.067	1.8
Heatsink : Internal Fin Height (mm)	8	6.967	17.73	10.93	18.3
GR-U1 [CBGAFC_27x27mm_2R] : Z Size (mm)	14.36	15.06	23.16	18.36	23.46
GR-50x50 voucher : Z Size (mm)	15.96	16.66	24.76	19.96	25.06
Solution Status	Solved-MP Converged	ved-MP Converged	Solved-MP Converged	Solved-MP Converged	Solved-MP Converged
[illegible]	Full	History Only	History Only	History Only	History Only
Initialize From	-1	0	0	0	0
Priority	0	5	5	5	5
U1[CBGAFC_27x27mm_2R] : Junction Temperature (degC)	97.62	99.65	88.16	100.2	91.87
Cost Function (Dimensionless)	2.619	4.654	6.836	5.2	3.126

Design-X initializes from the base case #0 results



FloTHERM Hints/Tips (5 of 5)

Reducing solution time

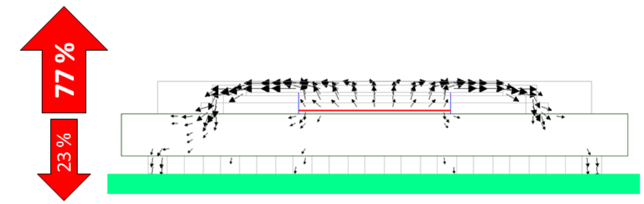
Best advice?

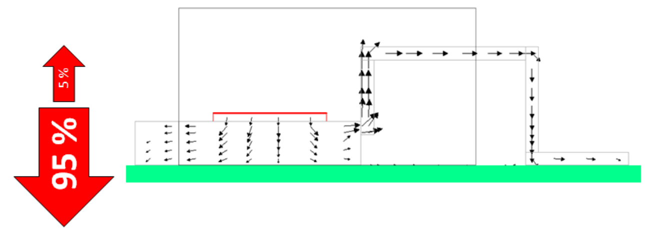
- Attend a FloTHERM introduction training class
- Computational fluid dynamics requires a good knowledge foundation to achieve consistently accurate results
- Mentor Graphics offers standard training classes at our offices, but also offers onsite customized trainings

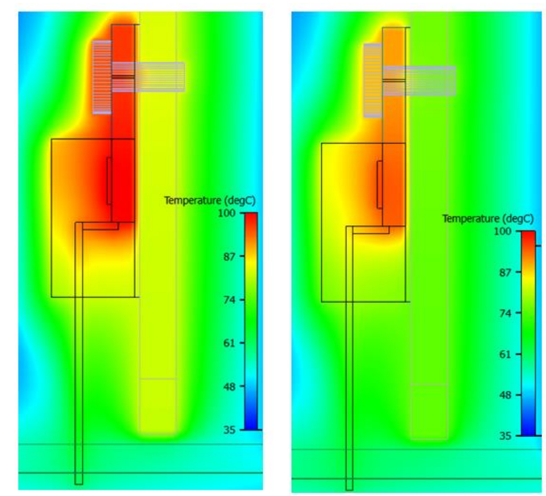
FloTHERM (1 of 2)

- Simulation allows user to
  - See results that are difficult/impossible to measure, like heat flux vectors within the PCB
  - See the full spectrum of results, not just a spot temperature from a thermocouple
  - Analyze many variants very quickly
    - Compared to an experiment, which takes time to instrument and requires a prototype built for each design variant to be tested.
  - Analyze designs early in the design process to eliminate bad design concepts early and focus time and effort on the best design concepts
    - Costs increase to fix designs later in the design cycle
  - Analyze the design in the operational environment
    - Typically experiments are on lab benches and may not exactly approximate the operating conditions of the device

Simulation vs. experiments







Original Design Thermally Relieved Design

Simulation vs. experiments

- FloTHERM has been well validated over 25 years of existence
  - FloTHERM is used in 19 of the top 20 electronics companies in the world
  - FloTHERM is the clear market leader in electronics cooling
  - Many papers published by customers using FloTHERM to conferences like IEEE's Semi-Therm, and IMAPS
    - FloTHERM is cited 537 times in IEEE's paper citation index
    - Nearest CFD competitor – 28 citations

Thank You.