ROHM Solution Simulator

PTC Heater Thermal Simulation

This documents introduces and describes the use of a simulation environment that allows simultaneous electrical simulation of PTC (Positive Temperature Coefficient) heaters and temperature simulation of built-in devices. By changing the parameters of the components, it is possible to simulate a wide range of conditions.
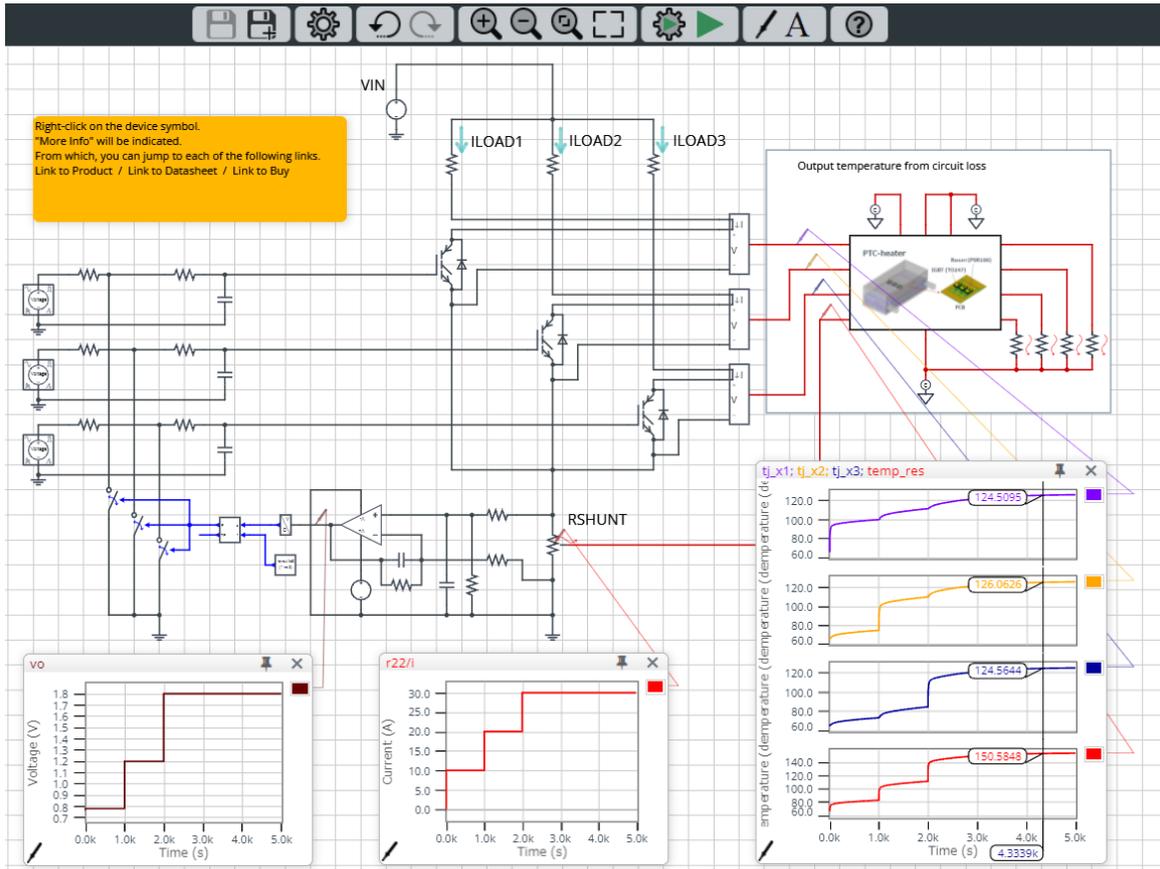
1 Simulation circuit

Figure 1. Simulation circuit

In this circuit diagram, the black and blue lines show the electrical simulation circuit and the red lines show the thermal simulation circuit.

The circuit consists of three IGBTs connected in parallel, which function as switches. A load resistor (heater) is connected to each IGBT and is driven independently. The load current is adjusted in three steps only by turning the three IGBTs on and off; no fine-tuning via switches is envisaged. The total current of the three loads is detected by a shunt resistor and a circuit is provided to prevent over current.

The thermal simulation circuit creates a thermal simulation model (ROM[*1]) of the device losses calculated in the electrical simulation and a typical PTC heater (including a water-cooled environment), and calculates the temperature of the IGBTs and shunt resistor.

*1 ROM (Reduced Order Model): A model created by 3D-CAE using a technique to reduce the dimensionality to 1D.

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2   Simulation method

Simulation settings such as simulation time and convergence options can be set from "Simulation Settings" shown in Figure 2, and the initial simulation settings are shown in Table 1.

If you are having problems with the convergence of the simulation, you can change the advanced options to fix the problem. The simulation temperature and various parameters of the electrical circuit are defined in "Manual Options".
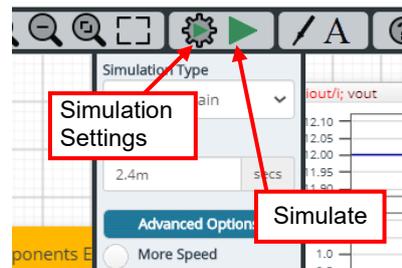
Figure 2. Simulation Settings and execution

Table 1. Initial values for Simulation Settings

Parameters	Initial values	Remarks
Simulation Type	Time-Domain	Do not change the simulation type
End time	5000 secs	
Advanced Options	More Speed	
Manual Options	.TEMP 100	Simulation temperature of the circuit Set to around the convergence temperature of the IGBT
	.PARAM …	See Table 2 for details

3   Simulation conditions

3.1   Definition of parameters

The parameters for the components shown in blue in Figure 3 are defined in the manual options as they need to be set in the simulation conditions.

Table 2 shows the initial values of the parameters. These values are written in a text box in the "Manual Options" section of the simulation settings, as shown in Figure 4.
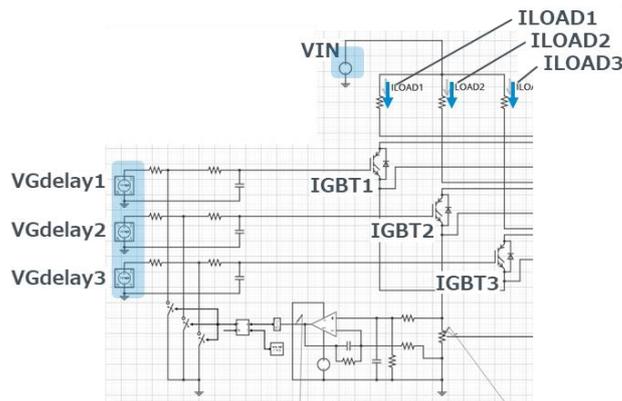
Figure 3. Definition of component parameters

Table 2. Simulation conditions

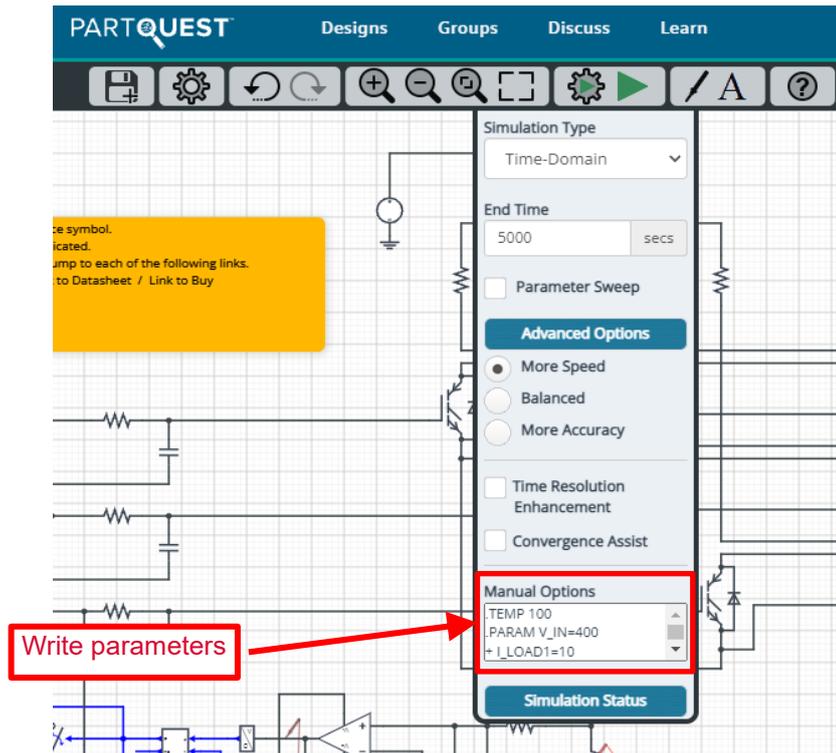| Parameters	Variable names	Initial values	Unit	Description
V_{IN}	V_VIN	400	V	
I_{LOAD1}	I_LOAD1	10	A	
I_{LOAD2}	I_LOAD2	10	A	
I_{LOAD3}	I_LOAD3	10	A	
VG_{delay1}	VG_delay1	0	sec	When IGBT1 is on
VG_{delay2}	VG_delay2	1000	sec	When IGBT2 is on
VG_{delay3}	VG_delay3	2000	sec	When IGBT3 is on

Figure 4. Definition of parameters

3.2　Over current protection

Figure 5 shows the over current protection circuit. The load current is detected by a low-side sense circuit using a shunt resistor and an op-amp. The total current flowing through the load generates a voltage of ΔV_{SHUNT} via the shunt resistor. This voltage is differentially amplified by the op-amp and if it exceeds the threshold of the "Voltage to Digital" stage, the next stage turns on and protection begins. If the input offset voltage of the op-amp is ignored, the output VO of the op-amp can be expressed by the following equation.

$$V_O = I_{LOAD} \times R_{SHUNT} \times \frac{R2}{R1} \quad [V]$$

The default circuit is I_{LOAD}=30 A, R_{SHUNT}=1 mΩ, R1=2 kΩ, R2=120 kΩ, so the output V_O=1.8 V. The threshold value for "Voltage to Digital" is set to 2 V (over current ≈ 33.3 A), so the protection is not activated.
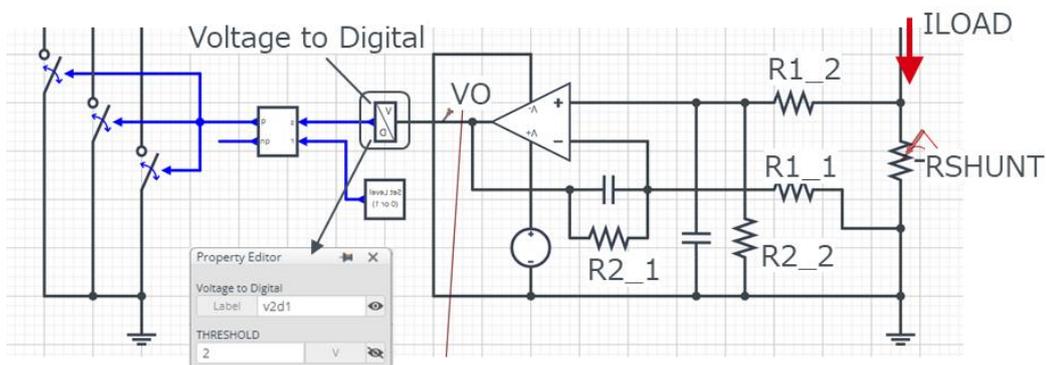

Figure 5. Over current protection circuit

3.3 Thermal circuit

The "PTC-heater" symbol in Figure 6 is the thermal simulation model of the PTC heater (ROM). Also, Table 3 shows the terminal description for the PTC heater thermal simulation model.
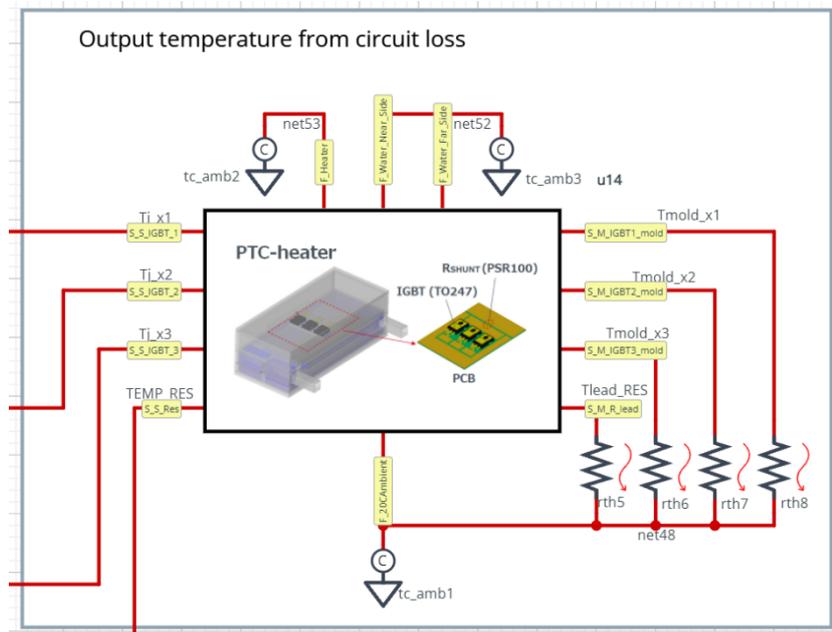

Figure 6. PTC heater thermal simulation model

Table 3. Terminal description of the thermal simulation model

Terminal name	Description
S_S_IGBT_1	Inputs the losses of IGBT1 and monitors T_J
S_S_IGBT_2	Inputs the losses of IGBT2 and monitors T_J
S_S_IGBT_3	Inputs the losses of IGBT3 and monitors T_J
S_S_Res	Inputs the losses of RSHUNT and monitors T_J
F_Heater	Heater temperature
F_Water_Near_Side	Cooling water temperature (inlet)
F_Water_Far_Side	Cooling water temperature (outlet)
F_20CAmbient	Ambient temperature
S_M_IGBT1_mold	Monitors the mold temperature of IGBT1 (received at high impedance)
S_M_IGBT2_mold	Monitors the mold temperature of IGBT2 (received at high impedance)
S_M_IGBT3_mold	Monitors the mold temperature of IGBT3 (received at high impedance)
S_M_R_lead	Monitors the lead temperature of RSHUNT (received at high impedance)

• The S_S_xxxx pin allows monitoring of the device temperature by inputting the device losses.

• The F_xxxx pin is connected to "tc_amb" and is set to the temperature at that location.

• The S_M_xxxx pin allows monitoring of the temperature of the IGBT mold and the lead temperature of the shunt resistor.

4   Parts list

Figure 7 shows the main component names. The initial values for each component can be found in Table 4. Some components allow the user to select the component to be used from a predetermined list of component names. The components that can be changed and the component name list are shown in Table 5. To change the name of a component, right-click on the component and select "Properties" as shown in Figure 8. In "Property Editor", select "Spicelib Part" and choose the name of the component you want to use.
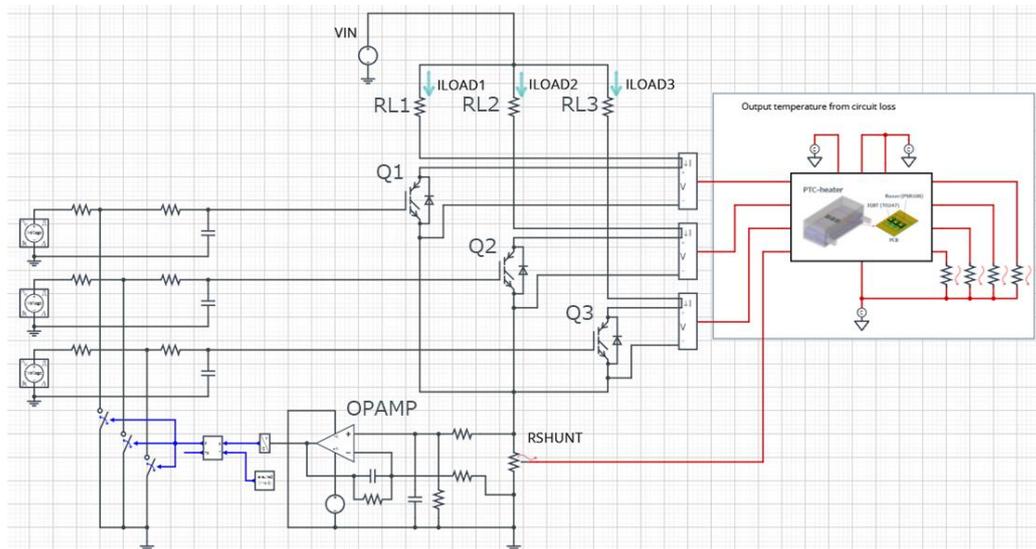

Figure 7. Main component names

Table 4. Initial values of components

Component name	Function	Initial values	Remarks
Q1, Q2, Q3	IGBT	RGS00TS65D	Can be changed
RSHUNT	Resistor	1mΩ	PMR100
RL1, RL2, RL3	Load Resistor	{Vin/ILOADx}	Fixed
OPAMP	Opamp	Parameter model	LMR1802G-LB

Table 5. List of components that can be changed and component names

| Component name	Function	Product name	Specifications
Q1, Q2, Q3	IGBT	RGC80TSX8R	1800V, 40A
		RGCL60TS60D	600V, 30A
		RGCL80TS60D	600V, 40A
		RGS00TS65D	650V, 50A
		RGS00TS65E	650V, 50A
		RGS50TSX2DHR	1200V, 25A
		RGS60TS65D	650V, 30A
		RGS80TS65D	650V, 40A
		RGS80TSX2DHR	1200V, 40A
		RGT00TS65D	650V, 50A
		RGT16TM65D	650V, 5A
		RGT30TM65D	650V, 8A
		RGT40TS65D	650V, 20A
		RGT50TS65D	650V, 25A
		RGT60TS65D	650V, 30A
		RGT80TS65D	650V, 40A
		RGT8TM65D	650V, 3A
		RGTH00TS65D	650V, 50A
		RGTH40TS65D	650V, 20A
		RGTH50TS65D	650V, 25A
		RGTH60TS65D	650V, 30A
		RGTH80TS65D	650V, 40A
		RGTV60TS65D	650V, 30A
		RGW00TS65D	650V, 50A
		RGW60TS65D	650V, 30A
		RGW80TS65D	650V, 40A
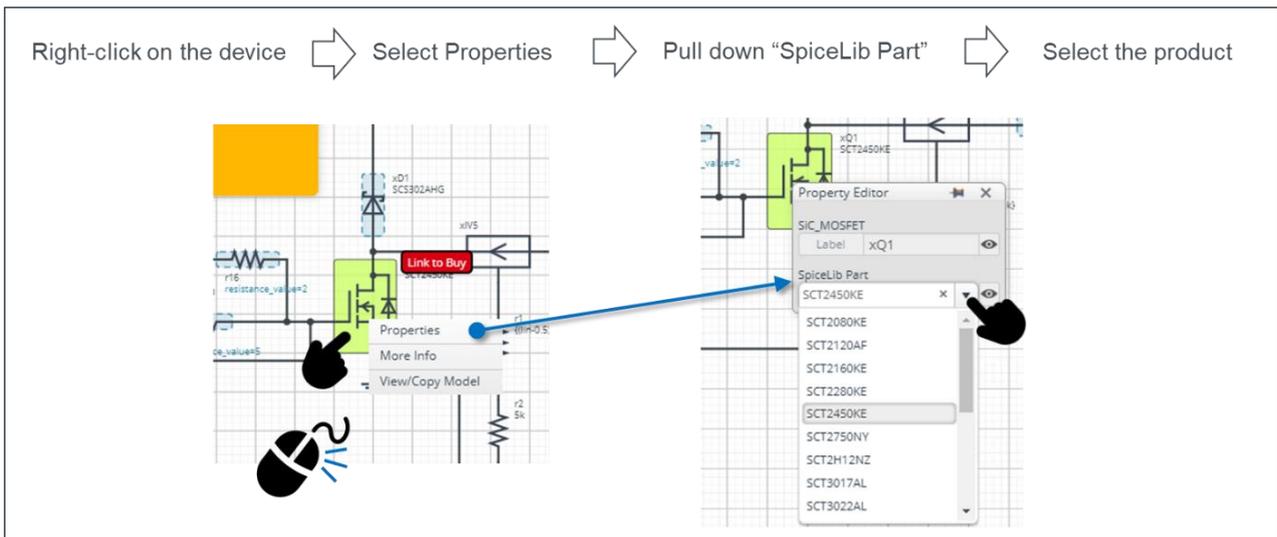
Figure 8. Changing the name of the component to be used

5　Links to related documents

5.1　Products

IGBT (TO247 package)

Shunt Resistors_PSR series

Ground Sense Operation Amplifier

5.2　Application Note

Low-Side Current Sensing Circuit Design

Reference: About the PTC heater thermal simulation model

An image of the 3D model used to create the thermal simulation model (ROM) is shown in Figure A. Structural information is also shown in Table A.
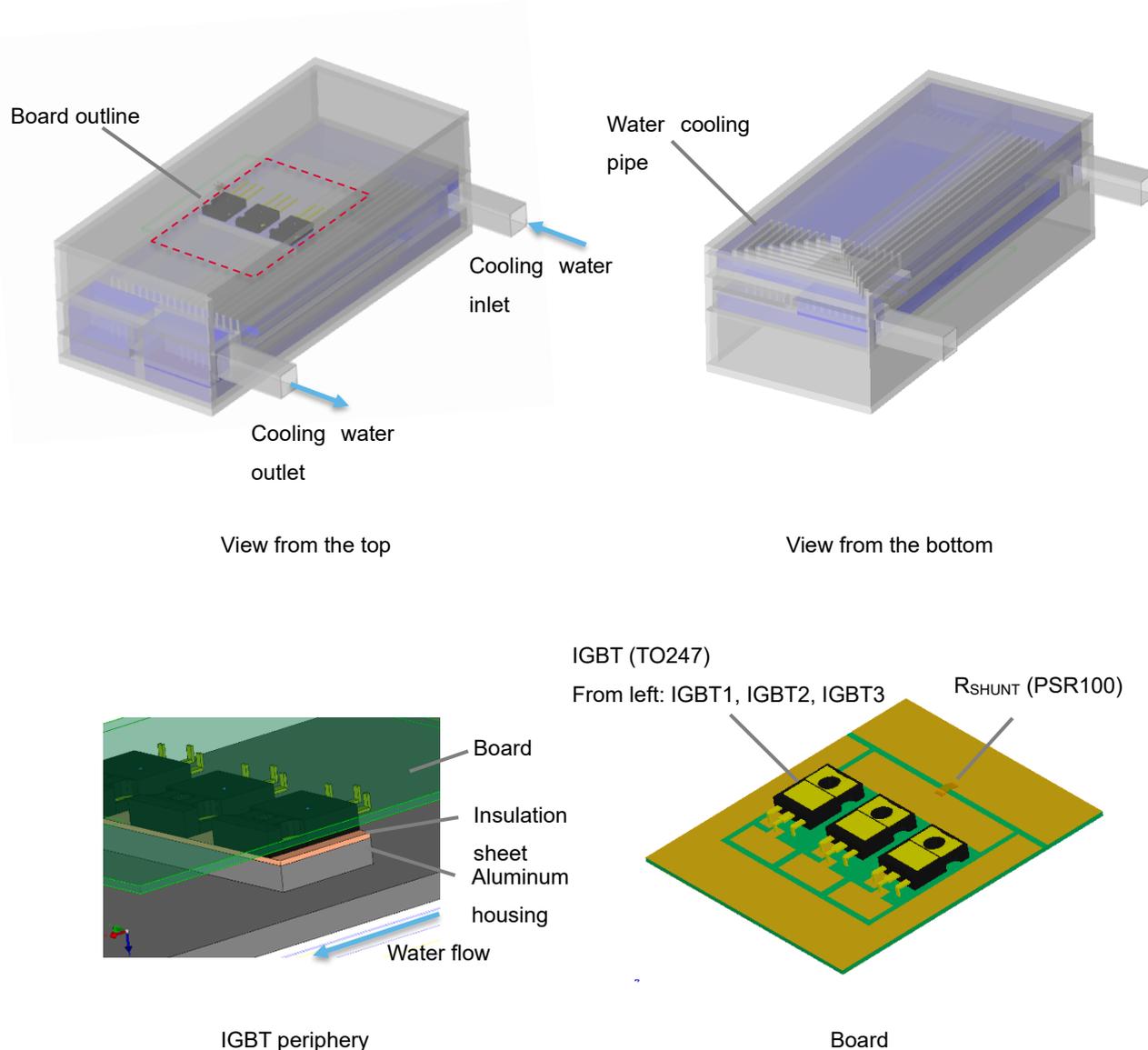

View from the top

View from the bottom

IGBT periphery

Board

Figure A. 3D image of the PTC heater

Table A. Structural information

Structural parts	Description
Aluminum housing	Outline dimensions: 250mm × 110mm × 120mm
Board	Outline dimensions: 100mm × 90mm × 1.6mmt Board material: FR-4 Copper foil thickness: 70 µm (2 oz copper foil)
Insulation sheet	Thickness: 1mm

*In order to save simulation time, the thermal capacity of the aluminum housing is not taken into account.

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