FUJI IGBT Simulator Ver. 6.2
User Manual

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Innovating Energy Technology

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5. **(Program update)** The program specification of this software is subject to change without any notice.

Contents

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Software Setup

This software is suitable for Microsoft® Windows® Windows7, Windows & Windows10.

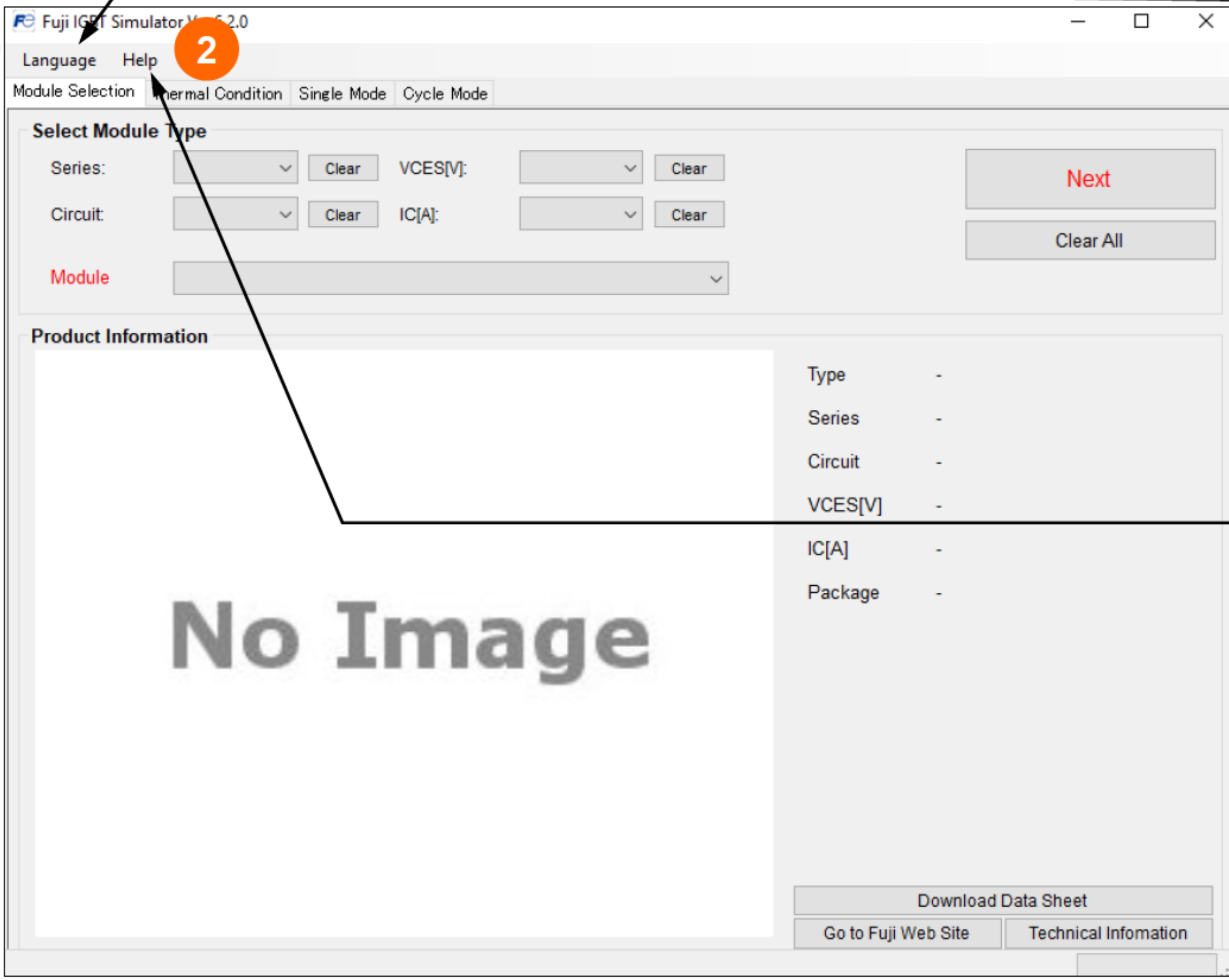
In order to operate, Microsoft .NET Framework 3.5 or later is required

Unzip the downloaded file and copy to a custom folder.

Please double-click the file “IGBTSim.exe” to start the simulator.

Windows is a registered trademark of Microsoft Corporation in the United States and other countries.

Menu



1

Select language

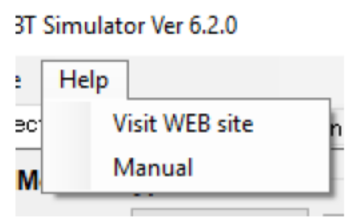
- English
- Japanese
- Chinese

2

Help

Visit Fuji Web site to get the latest version.

Check the version.



Module Selection

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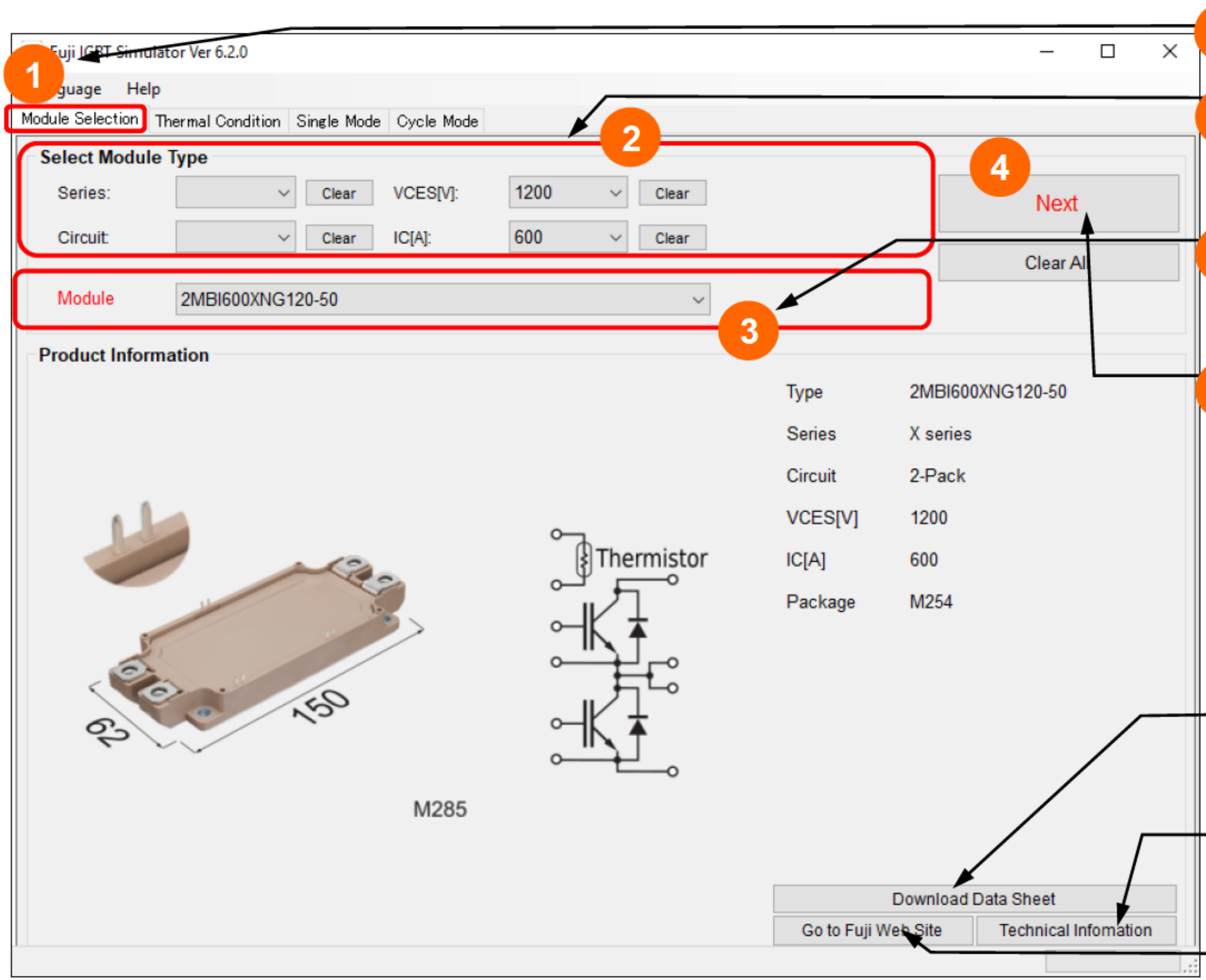


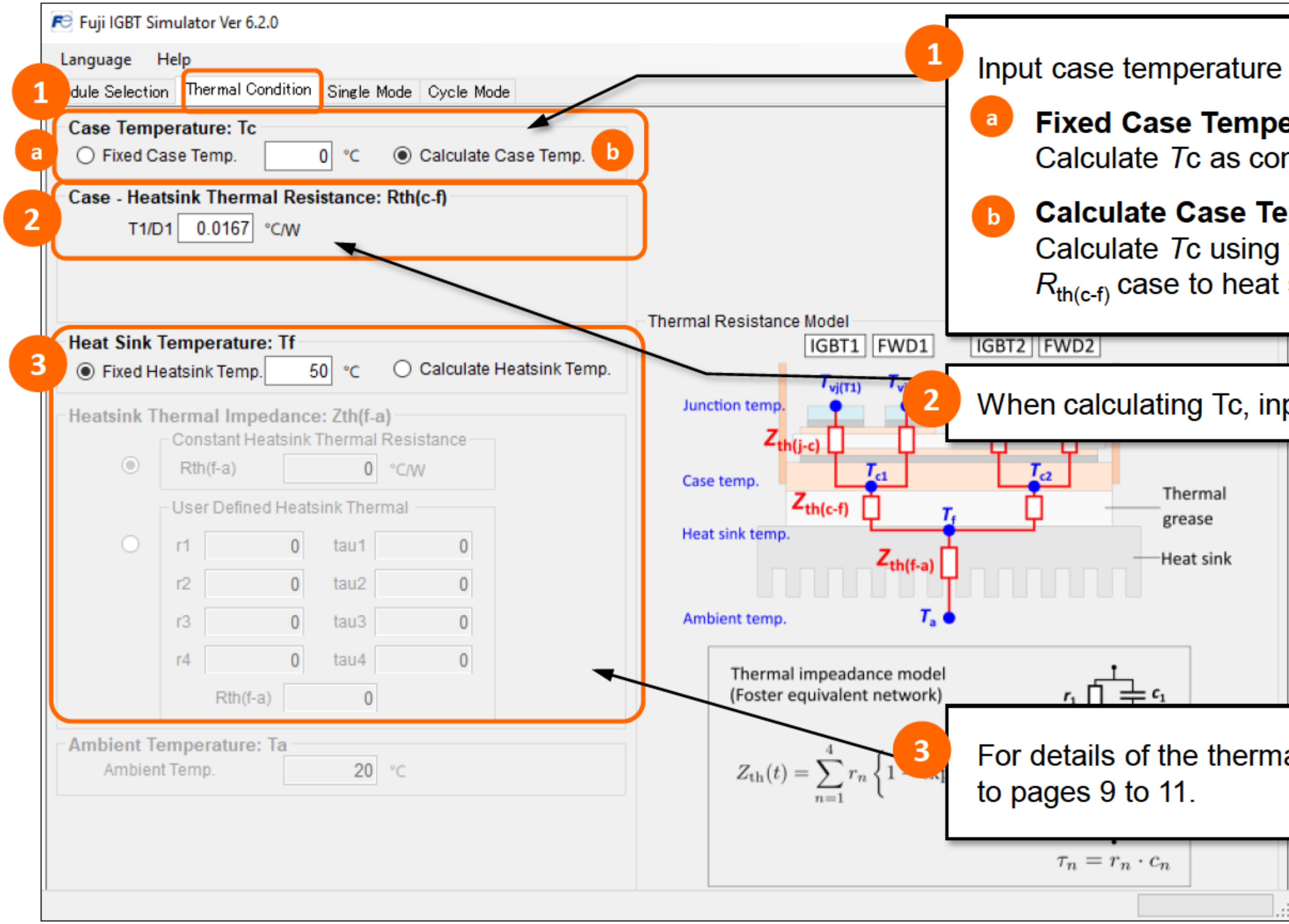
1. Click "Module Selection" tab.
2. Select "Series, Circuit, VCES, IC" from each dropdown list.
3. Select module from the dropdown list.
4. Click "Next" button.

Download product datasheet.

Visit technical information page.

Visit Fuji Semiconductor web site.

Input thermal condition (1)



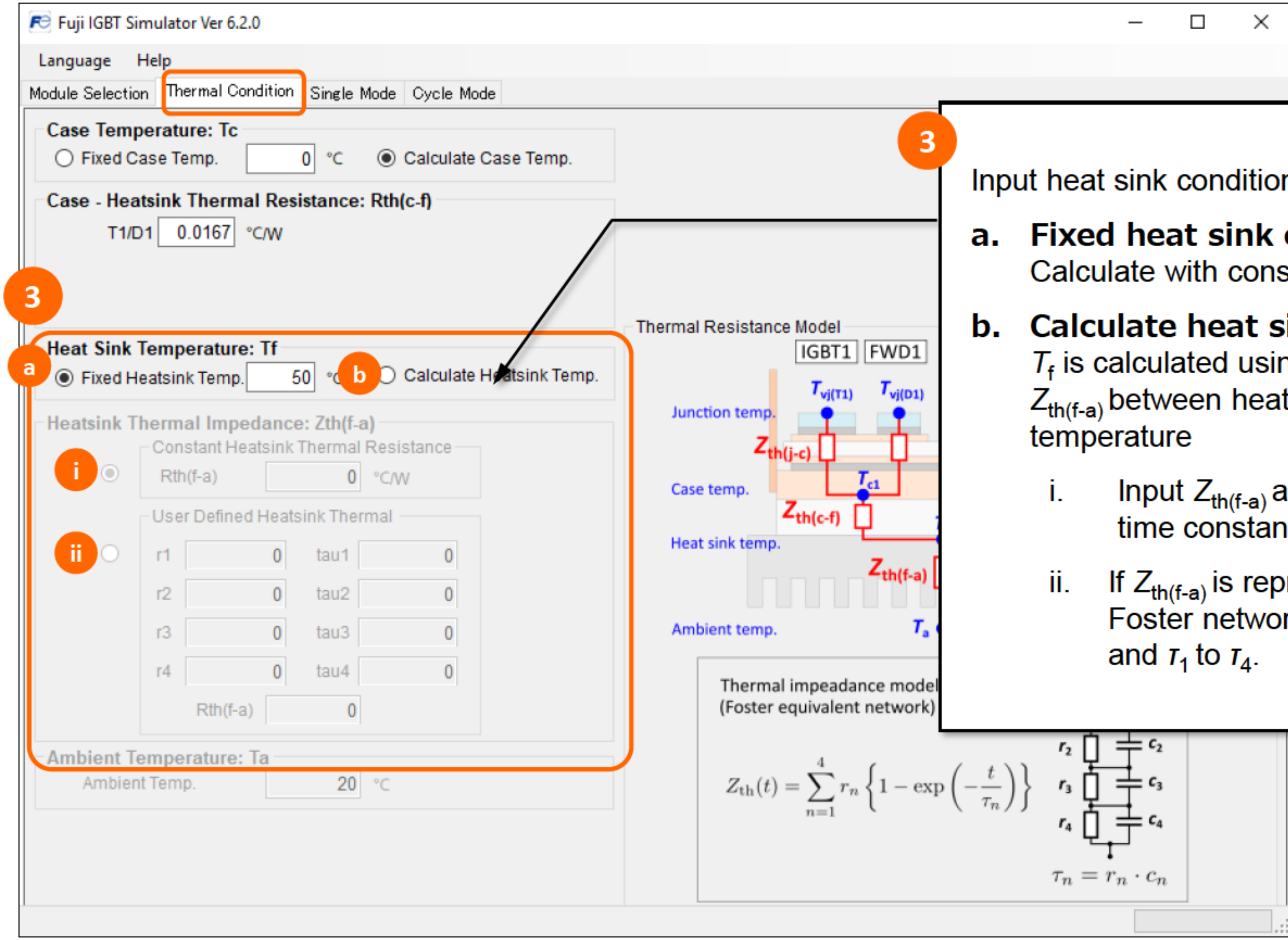
1 Input case temperature Tc

- **a** **Fixed Case Temperature**
  Calculate *Tc* as constant
- **b** **Calculate Case Temperature**
  Calculate *Tc* using thermal resistance $R_{th(c\text{-}f)}$ case to heat sink

2 When calculating Tc, input Rth(c-f) (°C/W)

3 For details of the thermal circuit model, refer to pages 9 to 11.

Input thermal condition (2)



3

Input heat sink condition

a. Fixed heat sink condition
Calculate with constant T_f

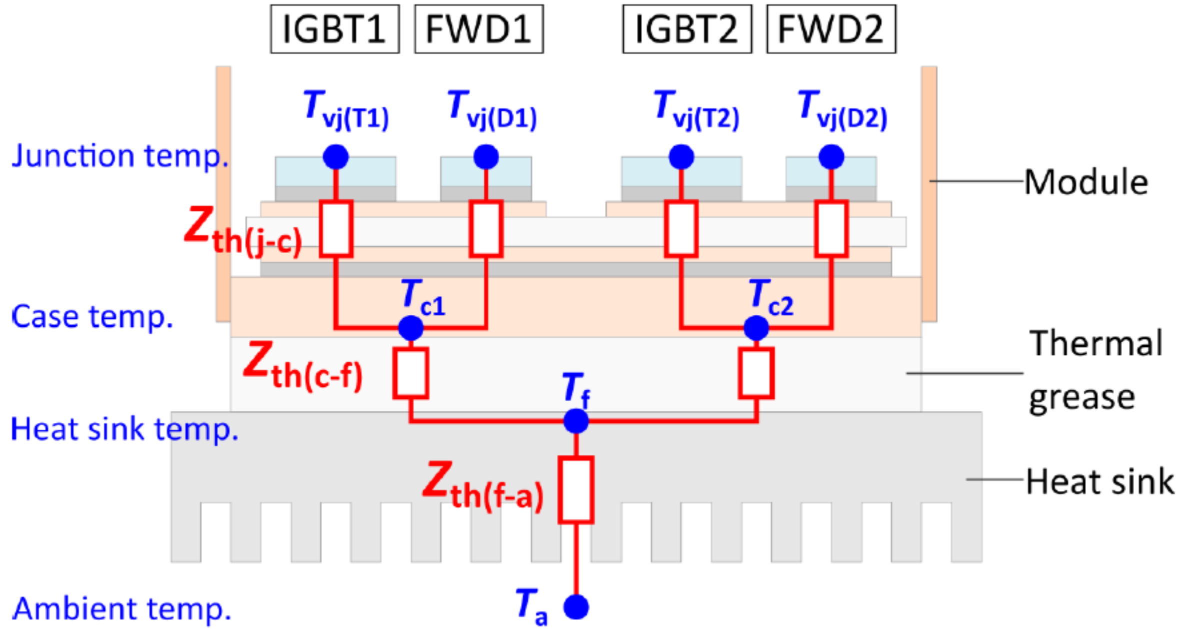
b. Calculate heat sink temperature
T_f is calculated using thermal impedance $Z_{th(f-a)}$ between heat sink and ambient temperature

i. Input $Z_{th(f-a)}$ as constant without any time constants.

ii. If $Z_{th(f-a)}$ is represented by a 4th order Foster network model, input r_1 to r_4 and τ_1 to τ_4.

Thermal Circuit Model (1)

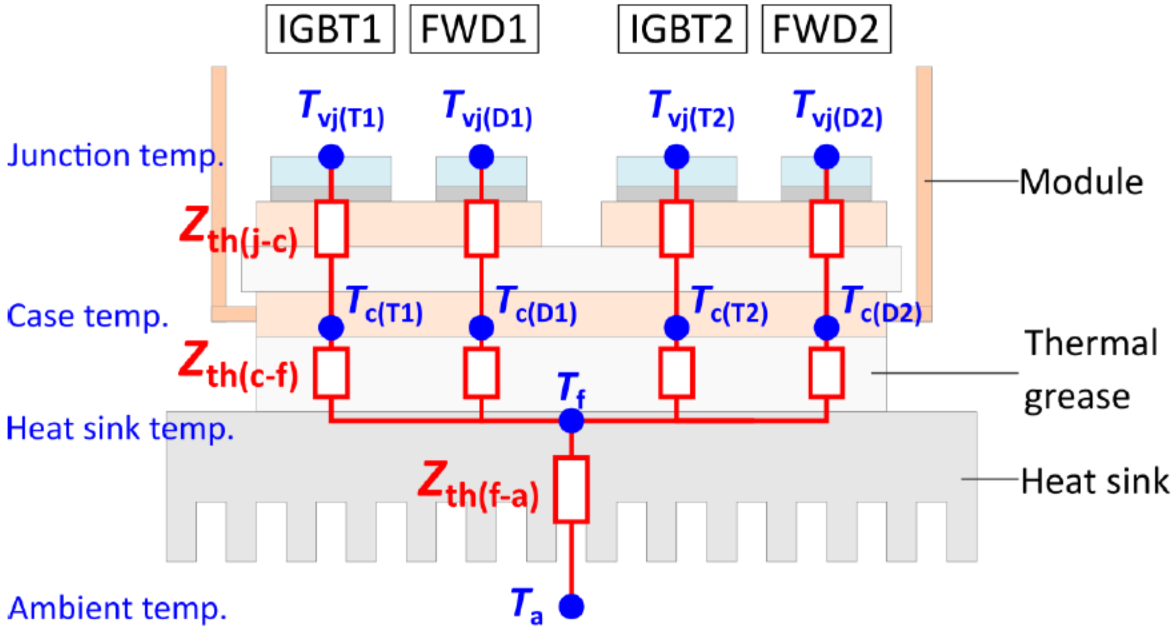
In the simulator, calculations are performed based on the following thermal circuit model.



The heat sink temperature T_f is calculated based on the assumption that the surface temperature distribution of the heat sink's area, which is in contact with the module, is uniform. If there is a deviation in the real temperature distribution, the calculated value might be different to the real one.

Thermal Circuit Model (2)

The following thermal circuit model is applied for modules without copper baseplate.



The heat sink temperature T_f is calculated based on the assumption that the surface temperature distribution of the heat sink's area, which is in contact with the module, is uniform. If there is a deviation in the real temperature distribution, the calculated value might be different to the real one.

Thermal Circuit Model (3)

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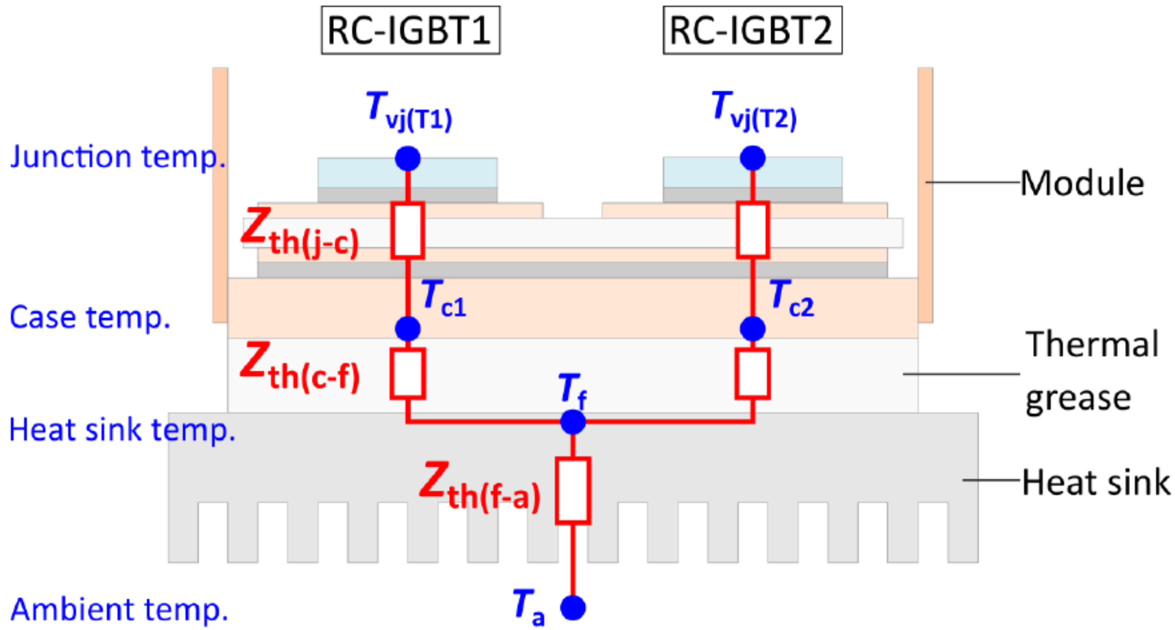
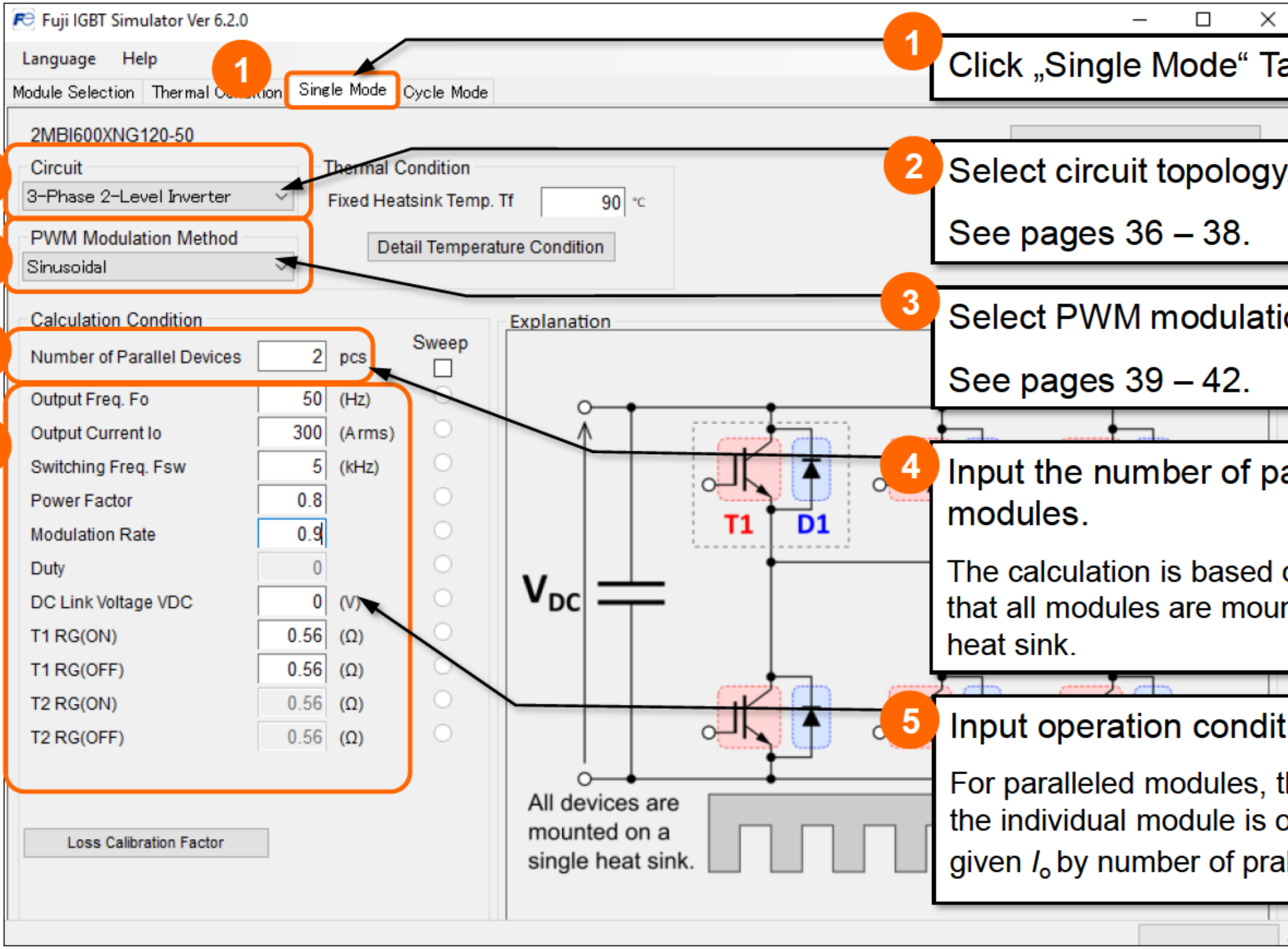
The following thermal circuit model is applied for RC-IGBT modules.



The heat sink temperature T_f is calculated based on the assumption that the surface temperature distribution of the heat sink's area, which is in contact with the module, is uniform. If there is a deviation in the real temperature distribution, the calculated value might be different to the real one.

Single Mode Calculation

Input simulation condition (Single Mode)



1. Click „Single Mode“ Tab.

2. Select circuit topology.

   See pages 36 – 38.

3. Select PWM modulation method.

   See pages 39 – 42.

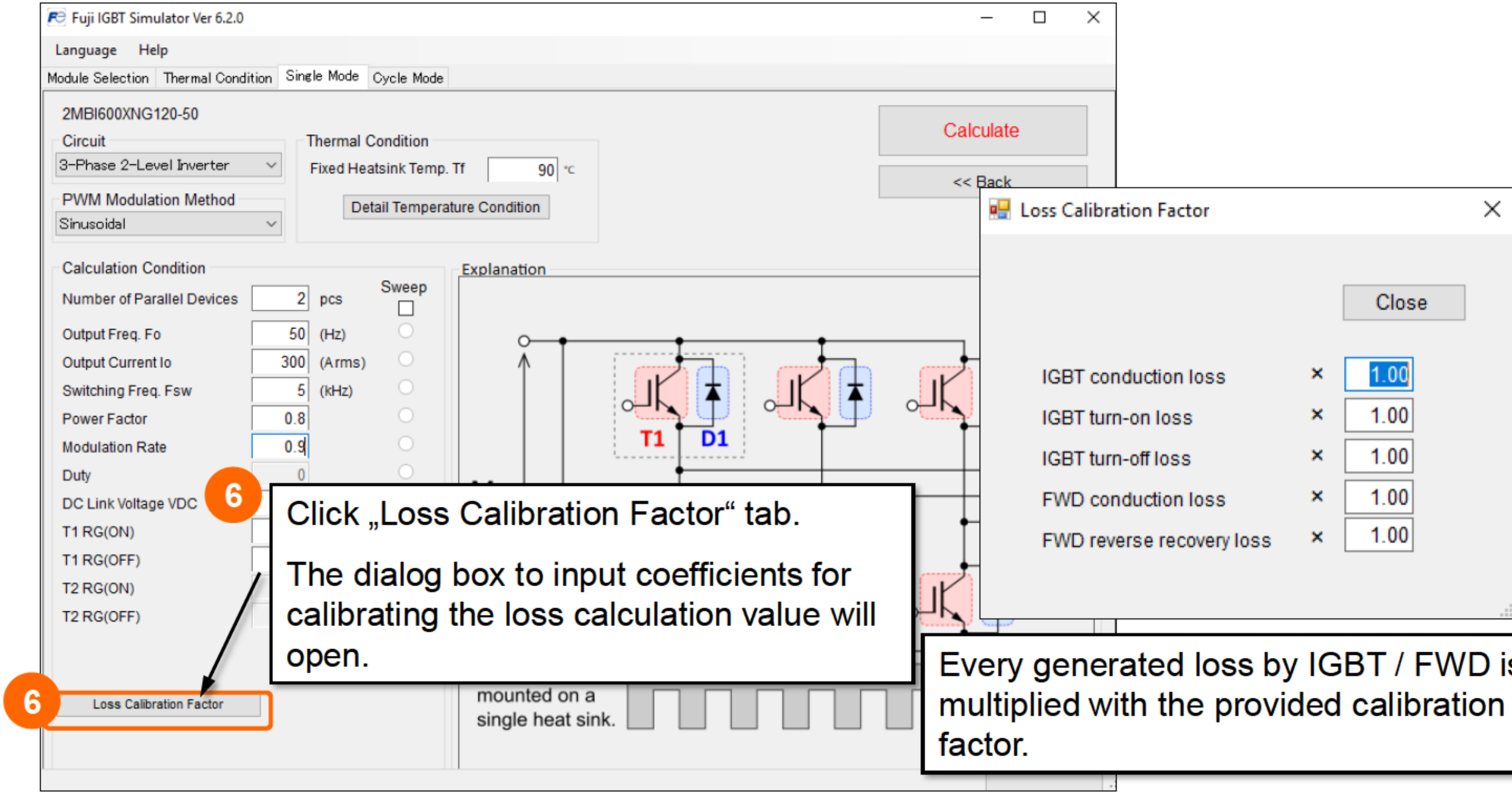
4. Input the number of parallel connected modules.

   The calculation is based on the assumption that all modules are mounted on the same heat sink.

5. Input operation condition.

   For paralleled modules, the current through the individual module is obtained by dividing given I_o by number of prallel modules.

Loss Calibration Factor

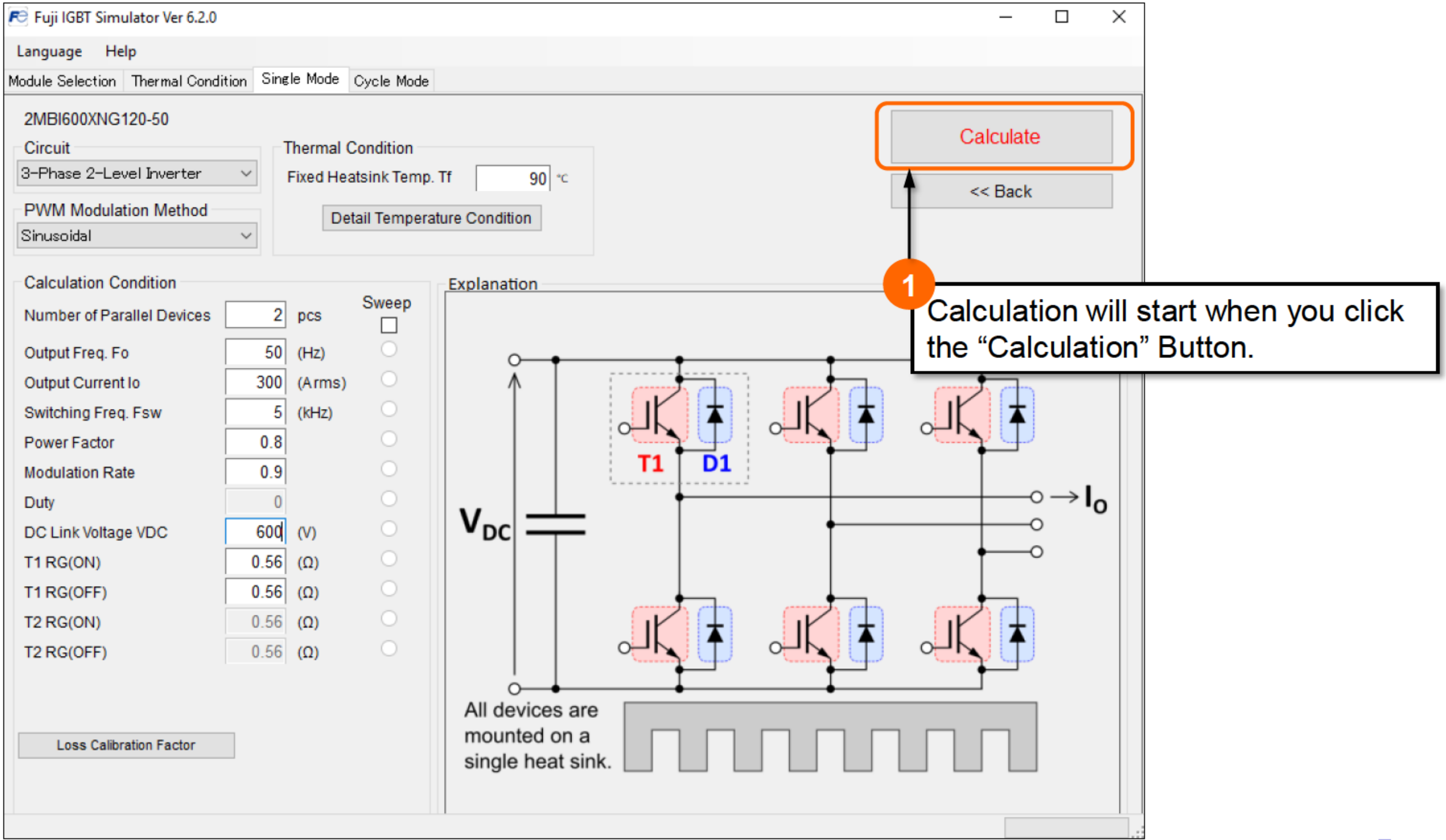


6 Click „Loss Calibration Factor“ tab.

The dialog box to input coefficients for calibrating the loss calculation value will open.

Every generated loss by IGBT / FWD is multiplied with the provided calibration factor.

Run Calculation



Simulation Results (Single Mode)

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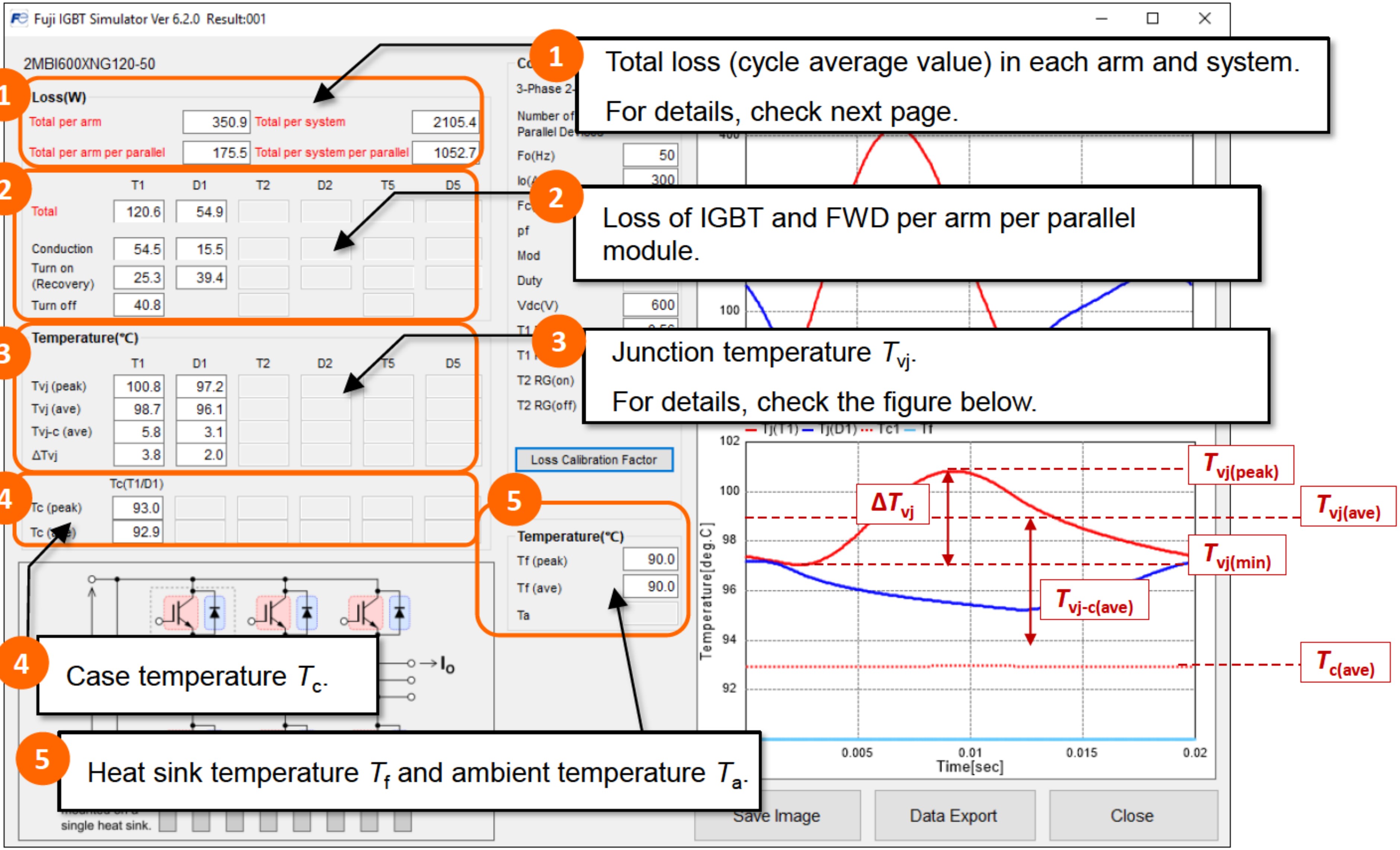

Simulation Results (Total Loss)

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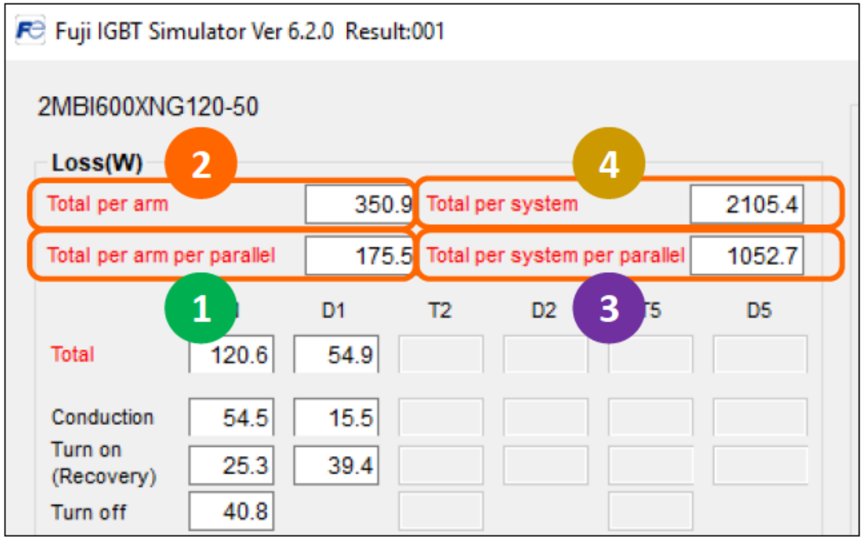

Fuji IGBT Simulator Ver 6.2.0 Result:001

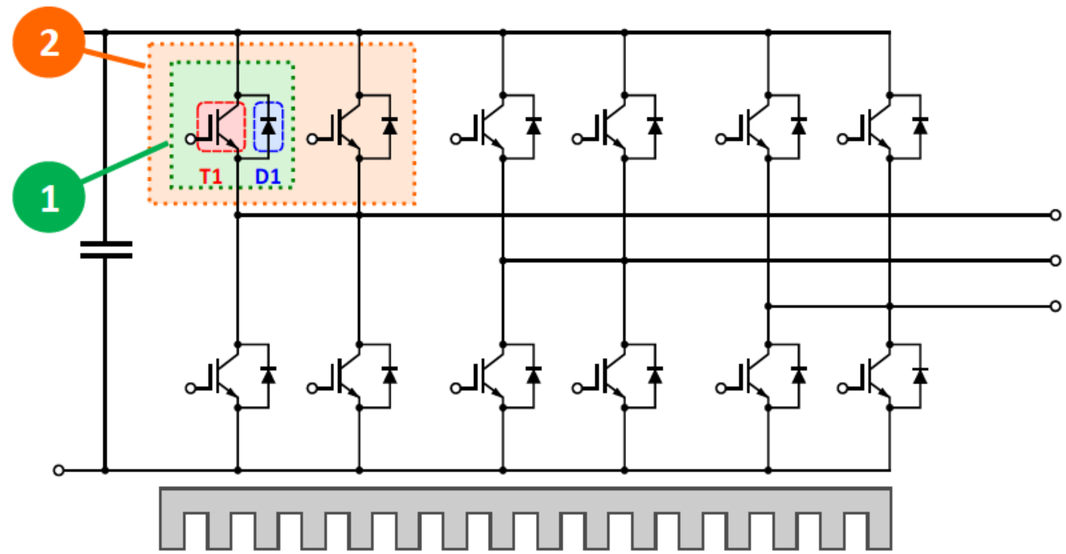
2MBI600XNG120-50

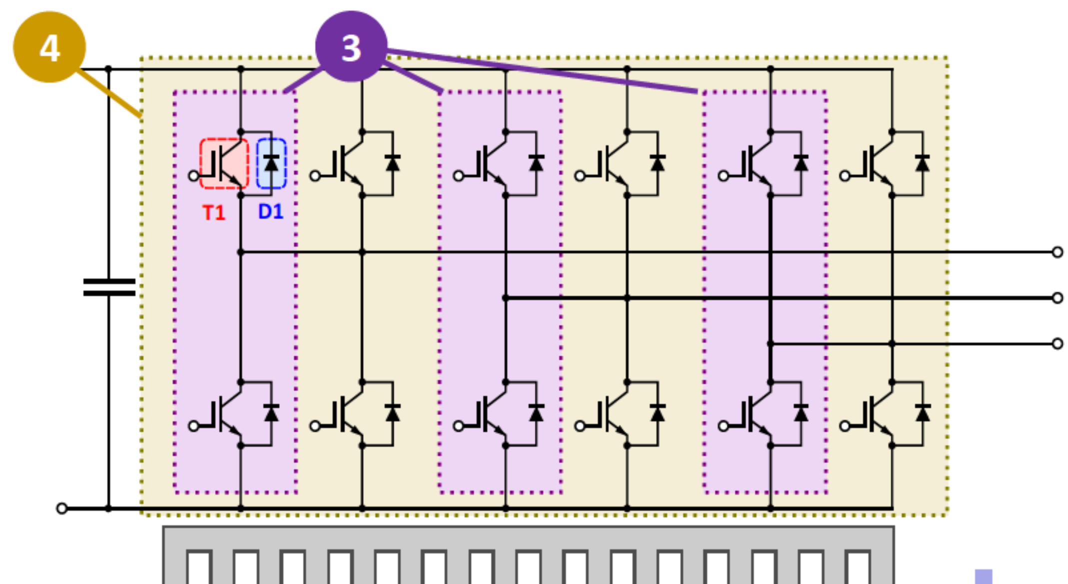
Loss(W)

Total per arm	350.9	Total per system	2105.4
Total per arm per parallel	175.5	Total per system per parallel	1052.7

	T1	D1	T2	D2	T5	D5
Total	120.6	54.9				
Conduction	54.5	15.5				
Turn on (Recovery)	25.3	39.4				
Turn off	40.8					

Example: 3-Phase 2-Level Inverter; 2 modules in parallel





1. Total loss per arm per parallel module (= T1 + D1 + T2 + D2 + D5)
2. Total loss per arm (= 1 × # of parallel modules)
3. Total loss of system per parallel module (3-Phase 2-Level Inverter: 1 × 6)
4. Total loss of the sytem (= 3 ×# of parallel modules)

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Simulation Results (Single Mode)

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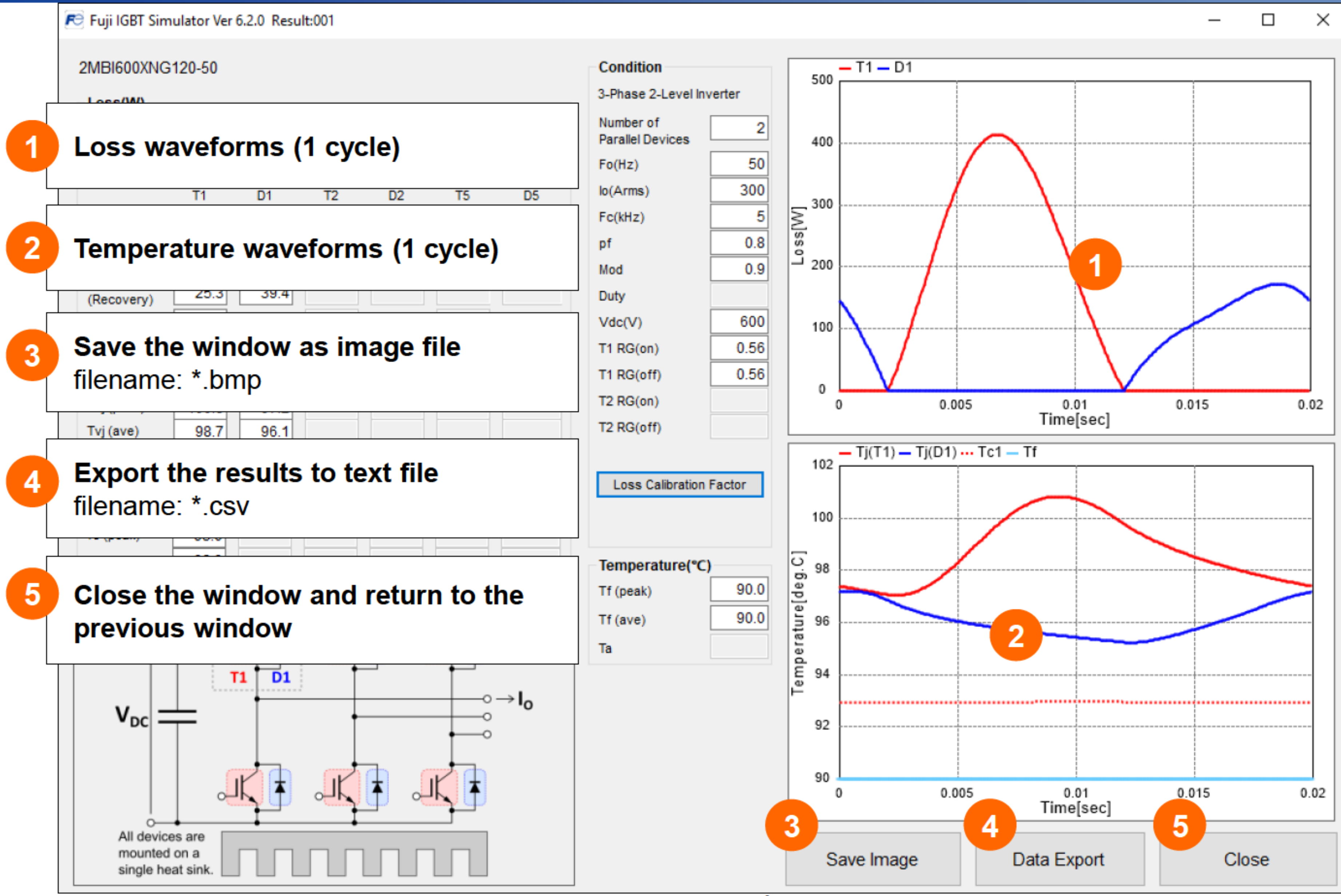

Display Multiple Results

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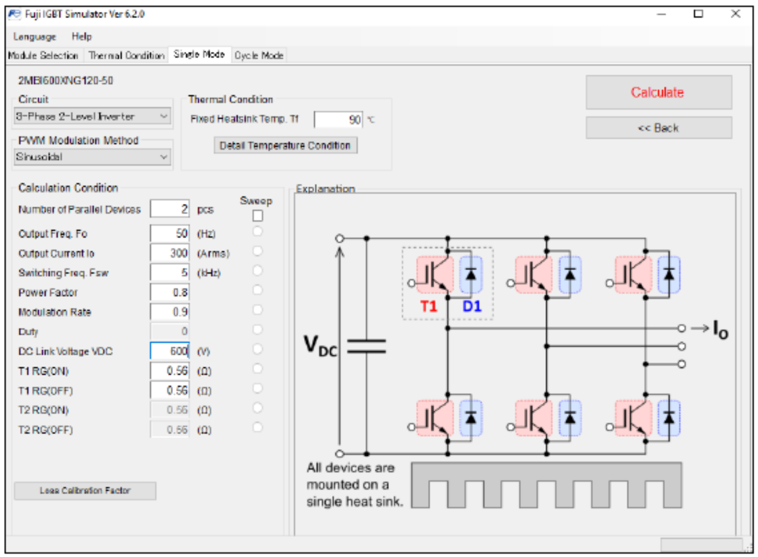
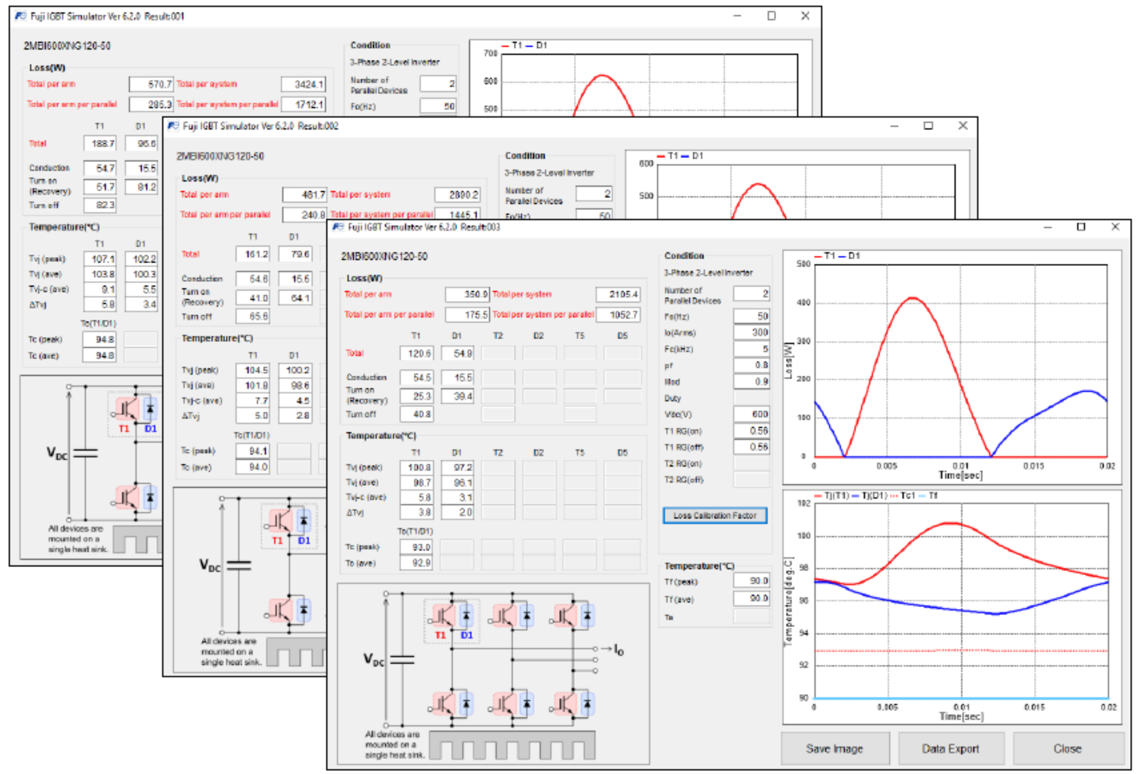
Multiple windows of calculation result can be displayed at the same time (max. 40).

A new calculation result window is displayed each time the calculation execution button is pushed.
The windows will be displayed in order Result001, Result002, … continous numbering

Please use this function for comparative examination when changing the calculation conditions.



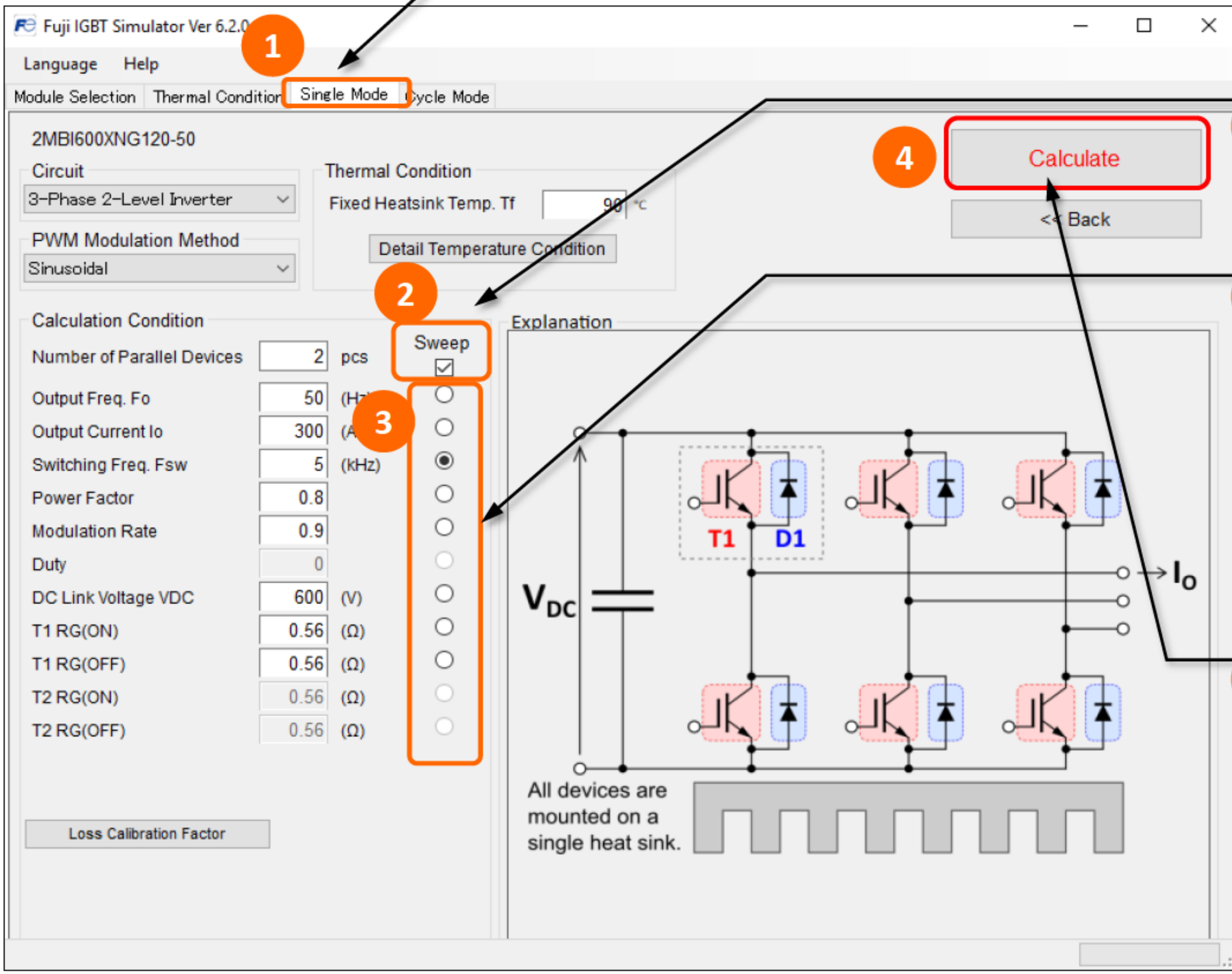


Parameter Sweep Calculation

In the parameter sweep calculation one of the simulation parameter is variable.

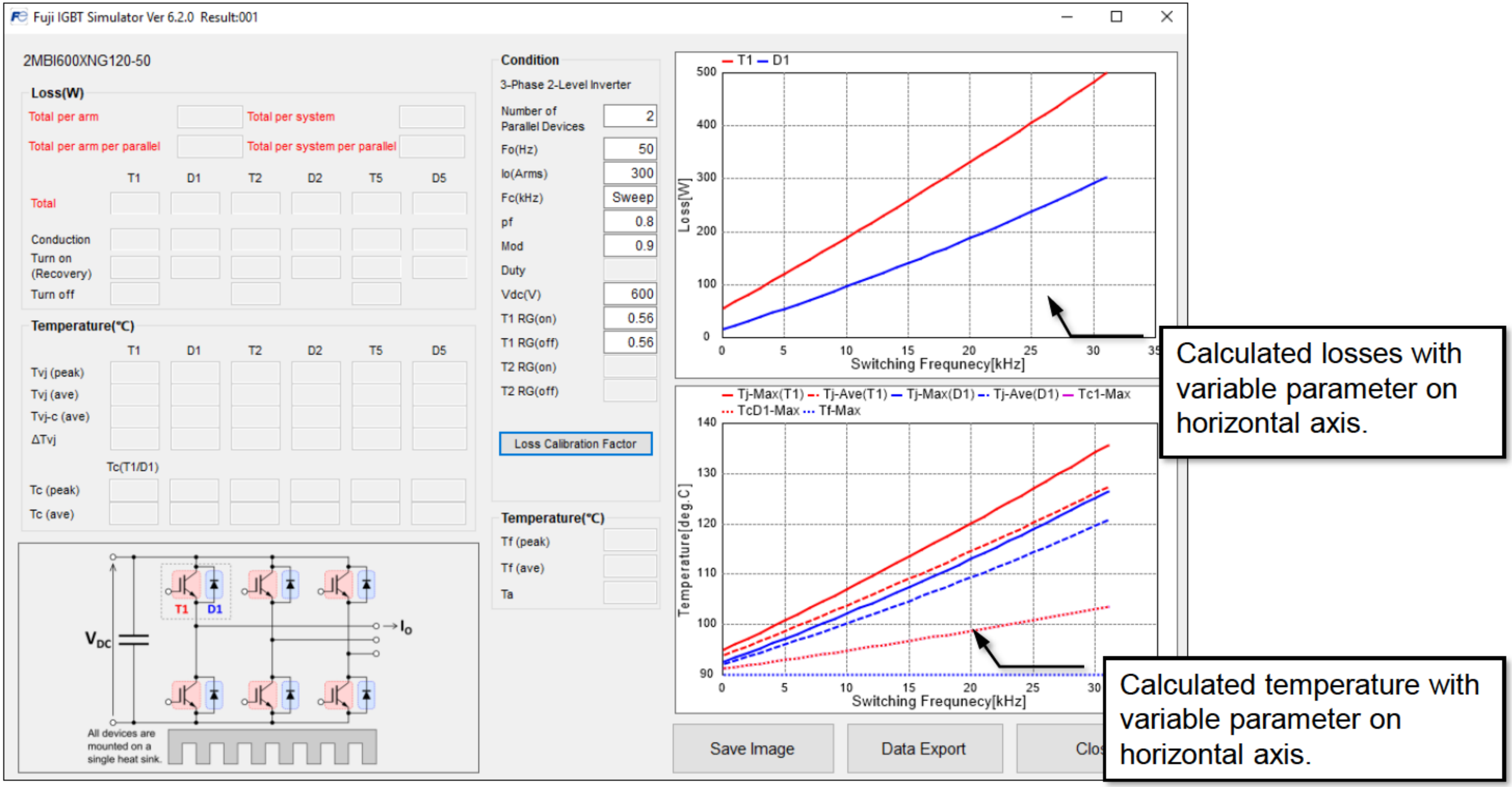
It is possible to calculate the change of losses and temperatures.

Parameter Sweep Calculation



1. Click „Single Mode“ Tab.
2. Click „Sweep“ check box.
3. Select parameter which you want to sweep by clicking radio button.
4. Click "Calculate" button to start the calculation.

Parameter Sweep Calculation Result



Cycle Mode Calculation

Cycle Mode Calculation

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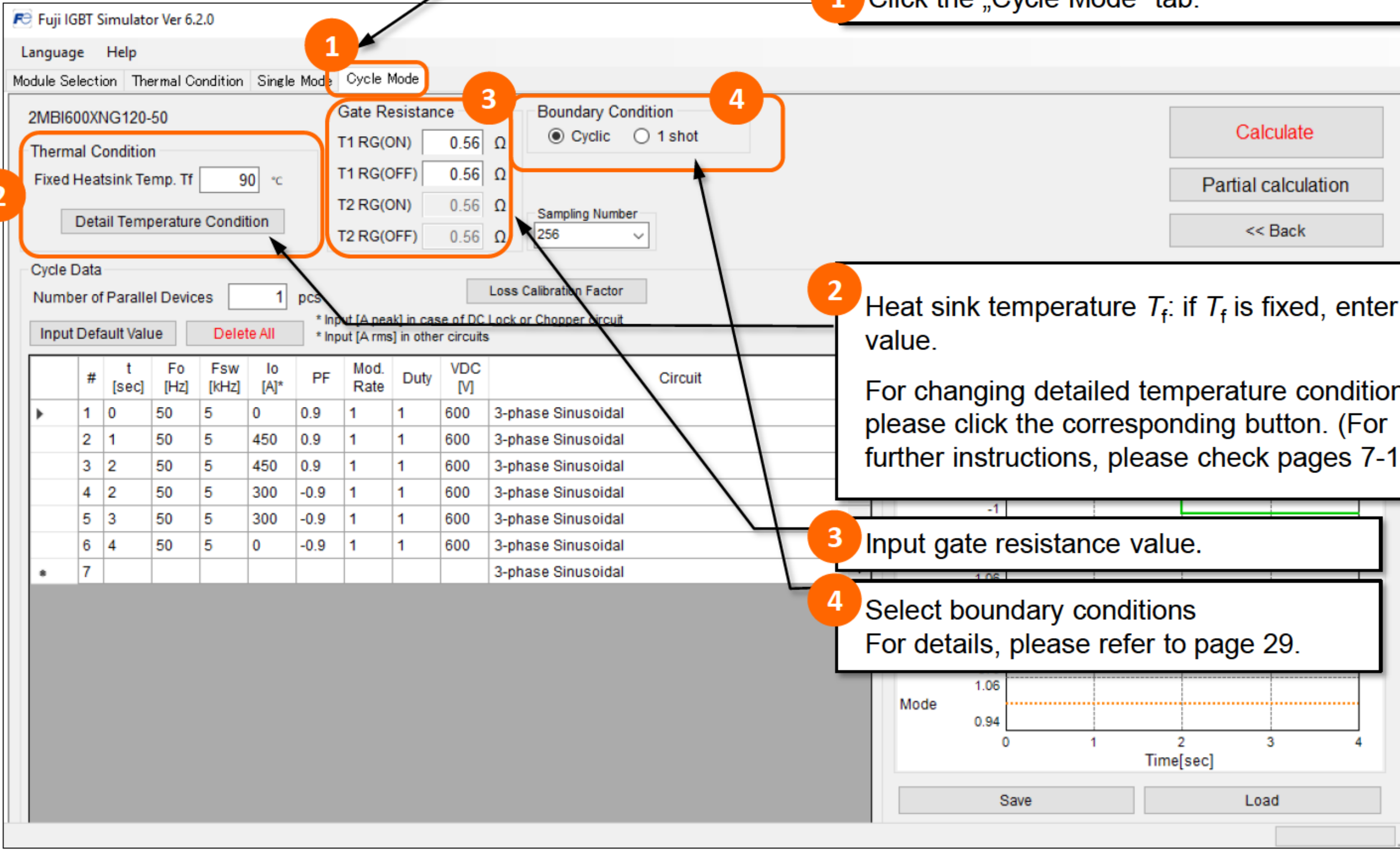


1. Click the „Cycle Mode“ tab.

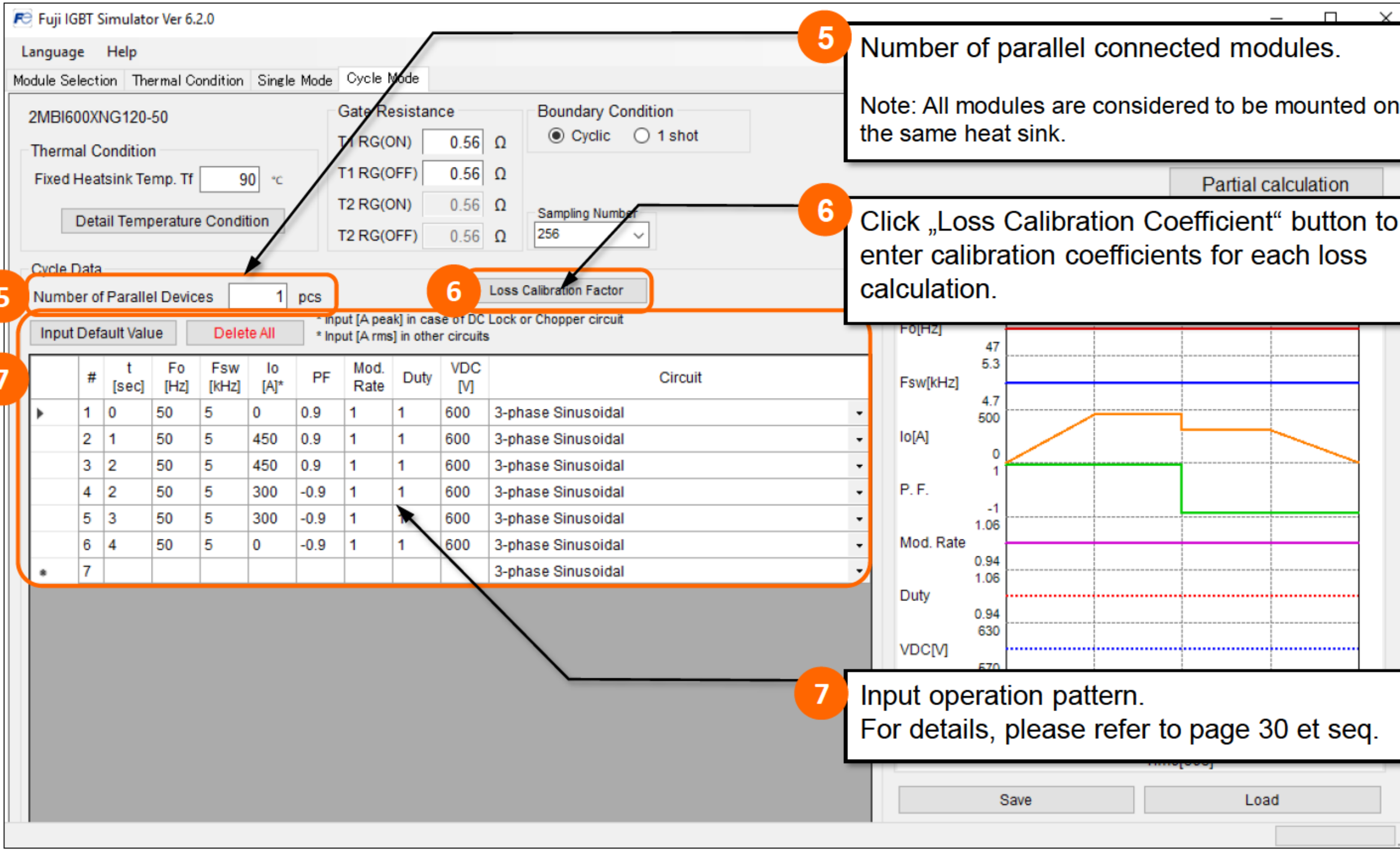
2. Heat sink temperature T_f: if T_f is fixed, enter value.

   For changing detailed temperature condition, please click the corresponding button. (For further instructions, please check pages 7-11.)

3. Input gate resistance value.

4. Select boundary conditions
   For details, please refer to page 29.

Cycle Mode Calculation



	#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
▸	1	0	50	5	0	0.9	1	1	600	3-phase Sinusoidal
	2	1	50	5	450	0.9	1	1	600	3-phase Sinusoidal
	3	2	50	5	450	0.9	1	1	600	3-phase Sinusoidal
	4	2	50	5	300	-0.9	1	1	600	3-phase Sinusoidal
	5	3	50	5	300	-0.9	1	1	600	3-phase Sinusoidal
	6	4	50	5	0	-0.9	1	1	600	3-phase Sinusoidal
*	7									3-phase Sinusoidal

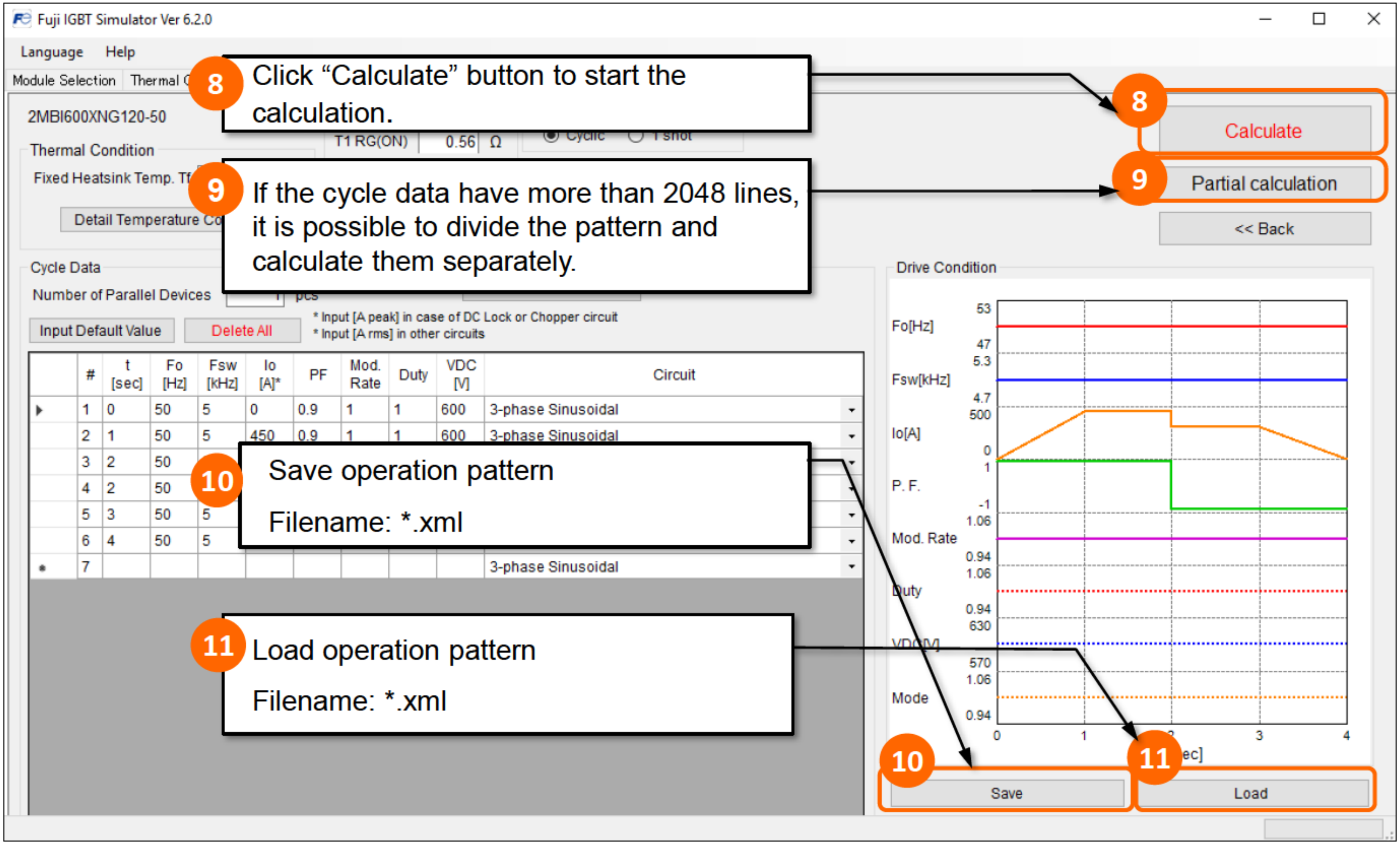
5 Number of parallel connected modules.

Note: All modules are considered to be mounted on the same heat sink.

6 Click „Loss Calibration Coefficient“ button to enter calibration coefficients for each loss calculation.

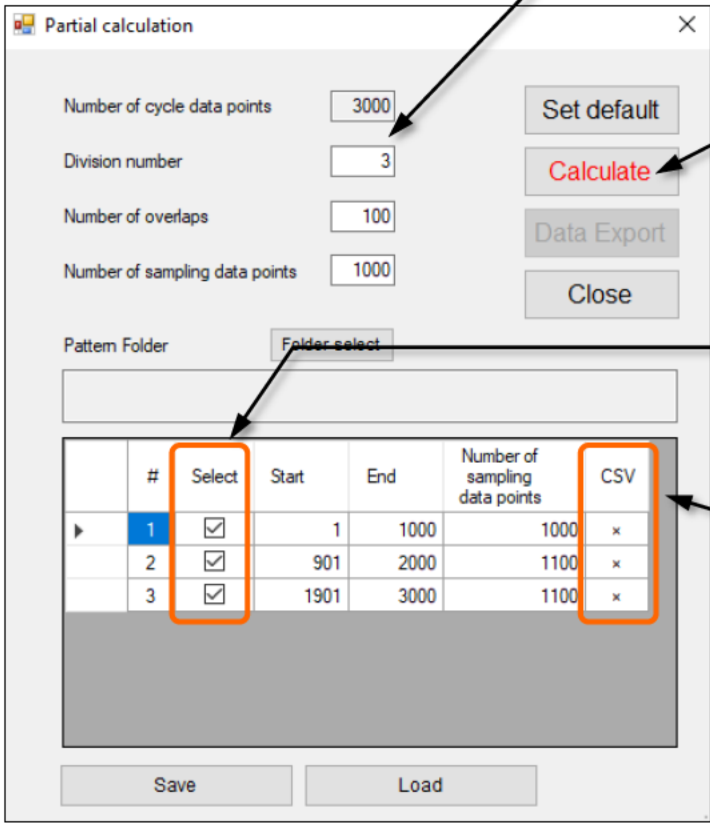
7 Input operation pattern.
For details, please refer to page 30 et seq.

Cycle Mode Calculation



	#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
▸	1	0	50	5	0	0.9	1	1	600	3-phase Sinusoidal
	2	1	50	5	450	0.9	1	1	600	3-phase Sinusoidal
	3	2	50							
	4	2	50							
	5	3	50	5						
	6	4	50	5						
*	7									3-phase Sinusoidal

Partial Calculation



Number of splits of cycle data.

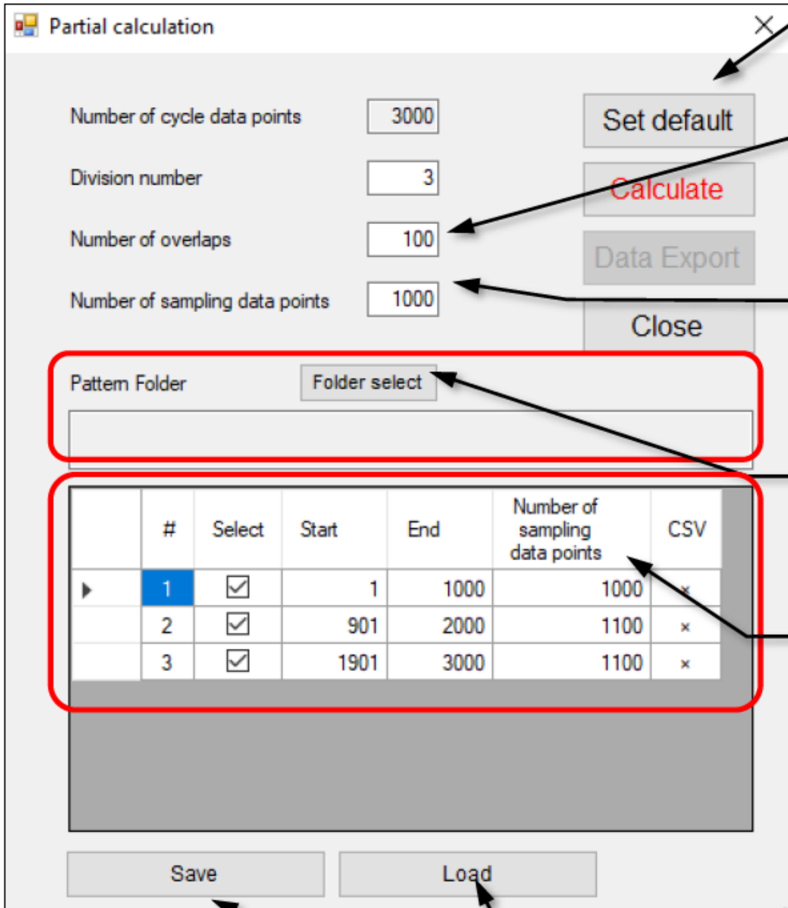
Calculate the splitted data.

Select the parts which have to be calculated.

„o“: calculation result does exist in the pattern folder

„x“: result does not exist

Partial Calculation



Reset partial calculation table.

When dividing cycle data, enter the number of lines to be overlapped before and after.

Enter the number of sampling date points for the calculation of the divided cycle data.

Select a specific folder to save the pattern file.

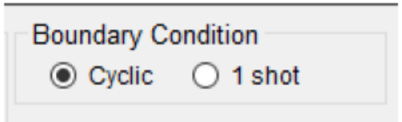
The information in the partial calculation table are based on the entered division number, number of overlaps and number of sampling data points.

It is also possible to enter values directly in the table.

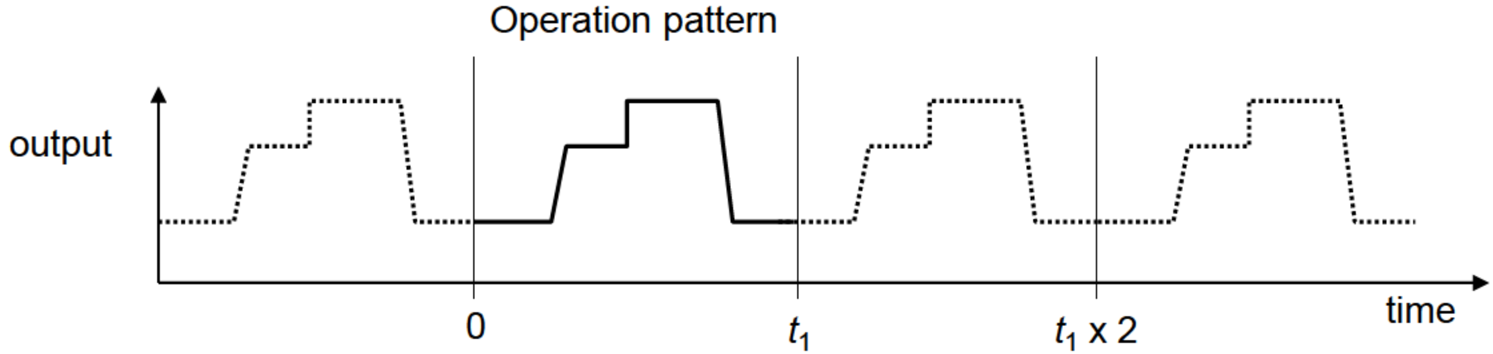
Save partial calculation table.

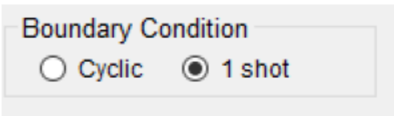
Load the saved partial calculation table.

Cycle Mode Calculation Boundary Condition

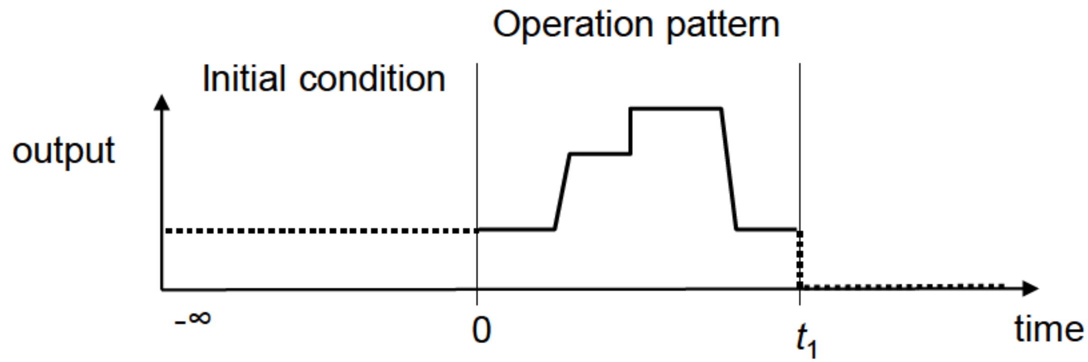


Cyclic mode: The load cycle pattern is repeated continously.





1 shot mode: The load cycle pattern is not repeated



#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
1	-∞≤...	50	5	0	0.9	1	1	600	3-phase Sinusoi...
2	1	50	5	450	0.9	1	1	600	3-phase Sinusoi...
3	2	50	5	450	0.9	1	1	600	3-phase Sinusoi...

Enter the initial conditions in first line.

Set Load Cycle

Input Default Value | Delete All

* Input [A peak] in case of DC Lock or Chopper circuit
* Input [A rms] in other circuits

	#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
	1	0	50	5	0	0.9	1	1	600	3-phase Sinusoi...
	2	1	50	5	150	0.9	1	1	600	3-phase Sinusoi...
	3	2	50	5	150	0.9	1	1	600	3-phase Sinusoi...
	4	2	50	5	50	-0.9	1	1	600	3-phase Sinusoi...
	5	3	50	5	50	-0.9	1	1	600	3-phase Sinusoi...
	6	4	50	5	0	-0.9	1	1	600	3-phase Sinusoi...
▸*	7									3-phase Sinusoi...

1 Time

For details, please refer to page 31.

2 Output Current

[A peak] in case of DC Lock or Chopper circuit.
[A rms] in case of other circuits.

3 Duty

For DC Lock or Chopper: please insert the duty value in this column.

All other cases: column will be ignored.

4 Circuit

Select circuit and PWM method from the dropdown list.

Set Load Cycle

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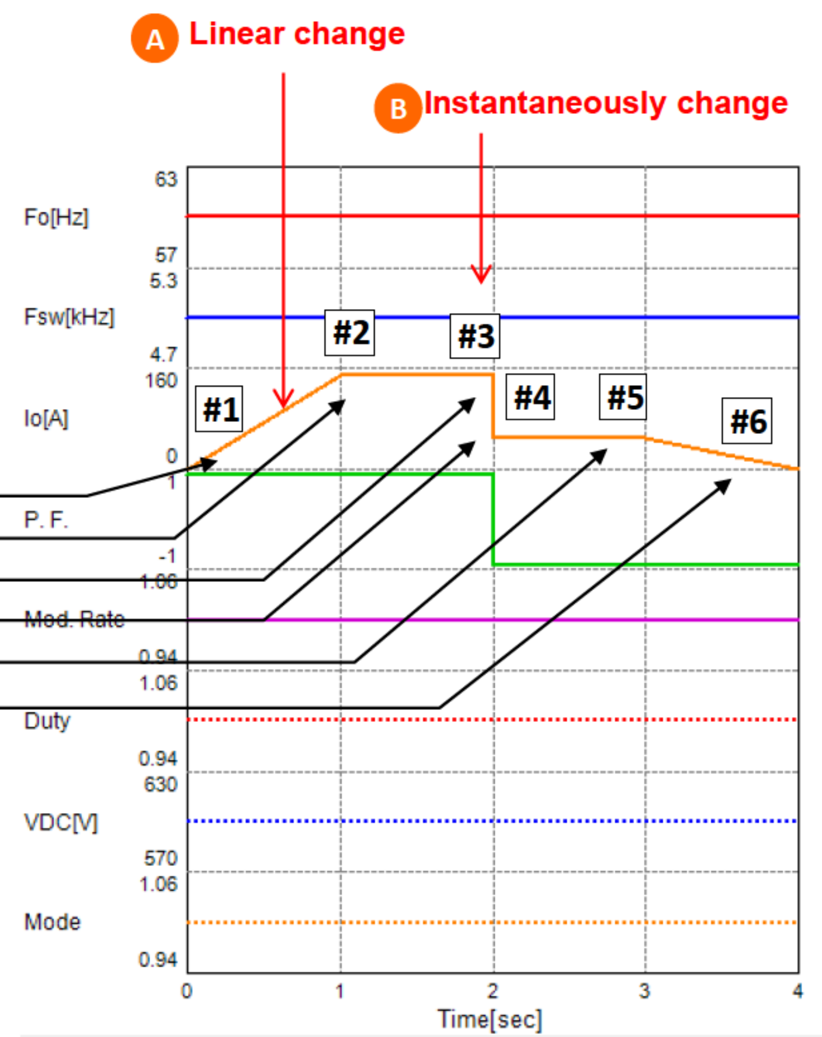
A **Parameter values linearly change between two operation points.**

Example: #1 → #2 [Io]

	#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
A	1	0	60	5	0	0.9	1	1	600	3-phase Sinusoi...
A	2	1	60	5	150	0.9	1	1	600	3-phase Sinusoi...
B	3	2	60	5	150	0.9	1	1	600	3-phase Sinusoi...
B	4	2	60	5	50	-0.9	1	1	600	3-phase Sinusoi...
	5	3	60	5	50	-0.9	1	1	600	3-phase Sinusoi...
	6	4	60	5	0	-0.9	1	1	600	3-phase Sinusoi...
▸*	7									3-phase Sinusoi...

B **Parameter values change instantaneously if two operation points have same time t.**

Example: #3 → #4 [Io, PF]



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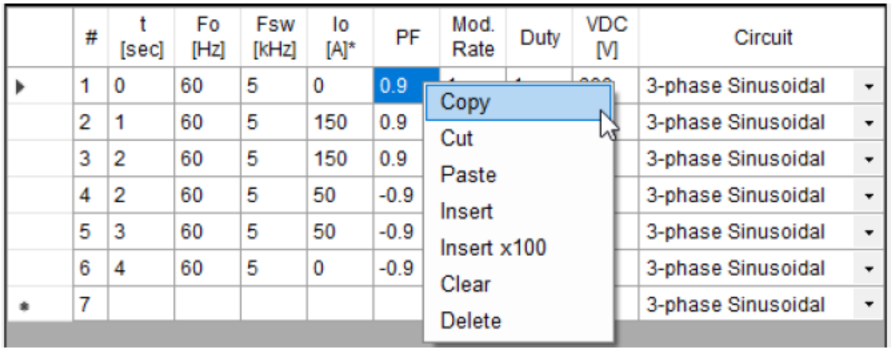
Set Load Cycle

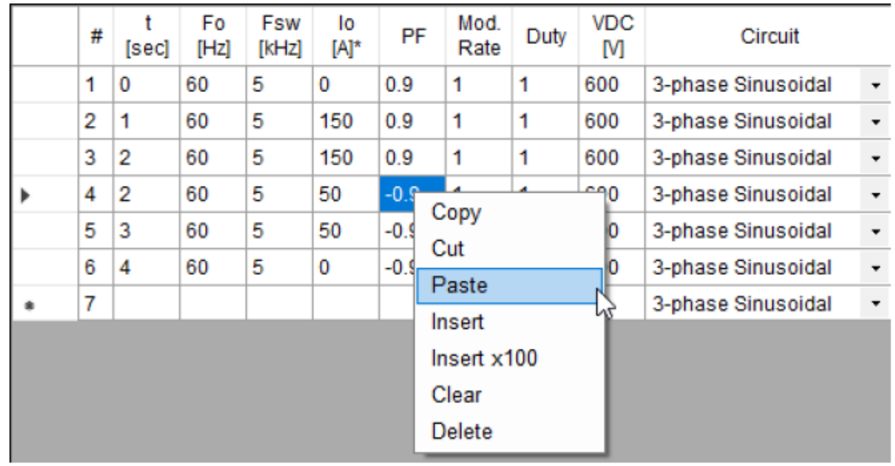
Copy & Paste cell(s) value

Select a cell or range of cell(s) → Right click
→ Copy



	#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
▶	1	0	60	5	0	0.9				3-phase Sinusoidal
	2	1	60	5	150	0.9				3-phase Sinusoidal
	3	2	60	5	150	0.9				3-phase Sinusoidal
	4	2	60	5	50	-0.9				3-phase Sinusoidal
	5	3	60	5	50	-0.9				3-phase Sinusoidal
	6	4	60	5	0	-0.9				3-phase Sinusoidal
*	7									3-phase Sinusoidal

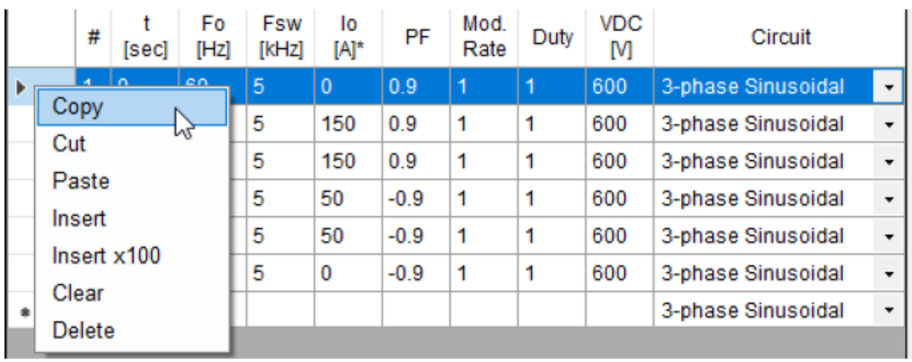
Select cell(s) → Right click → Paste



	#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
	1	0	60	5	0	0.9	1	1	600	3-phase Sinusoidal
	2	1	60	5	150	0.9	1	1	600	3-phase Sinusoidal
	3	2	60	5	150	0.9	1	1	600	3-phase Sinusoidal
▶	4	2	60	5	50	-0.9				3-phase Sinusoidal
	5	3	60	5	50	-0.9				3-phase Sinusoidal
	6	4	60	5	0	-0.9				3-phase Sinusoidal
*	7									3-phase Sinusoidal

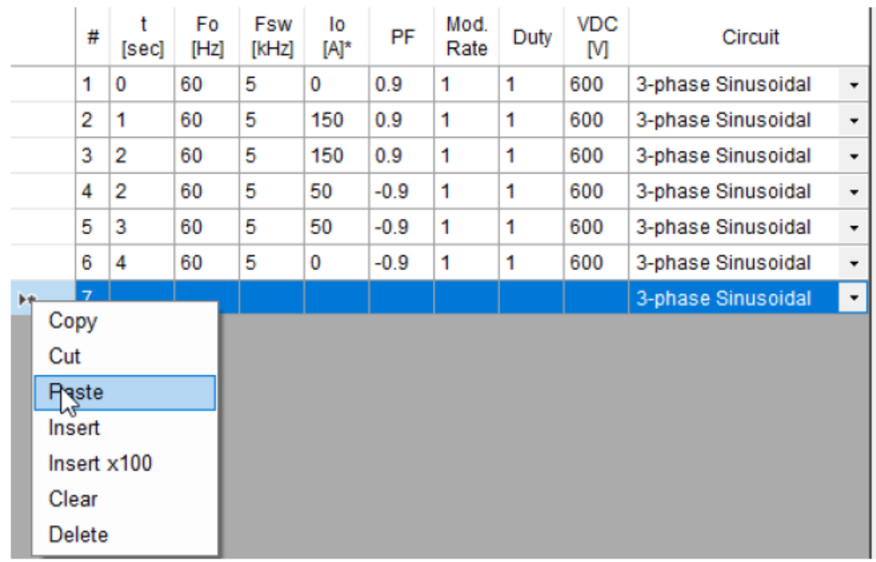
Copy & Paste line

Select a line (click 1st column) → Right click
→ Copy



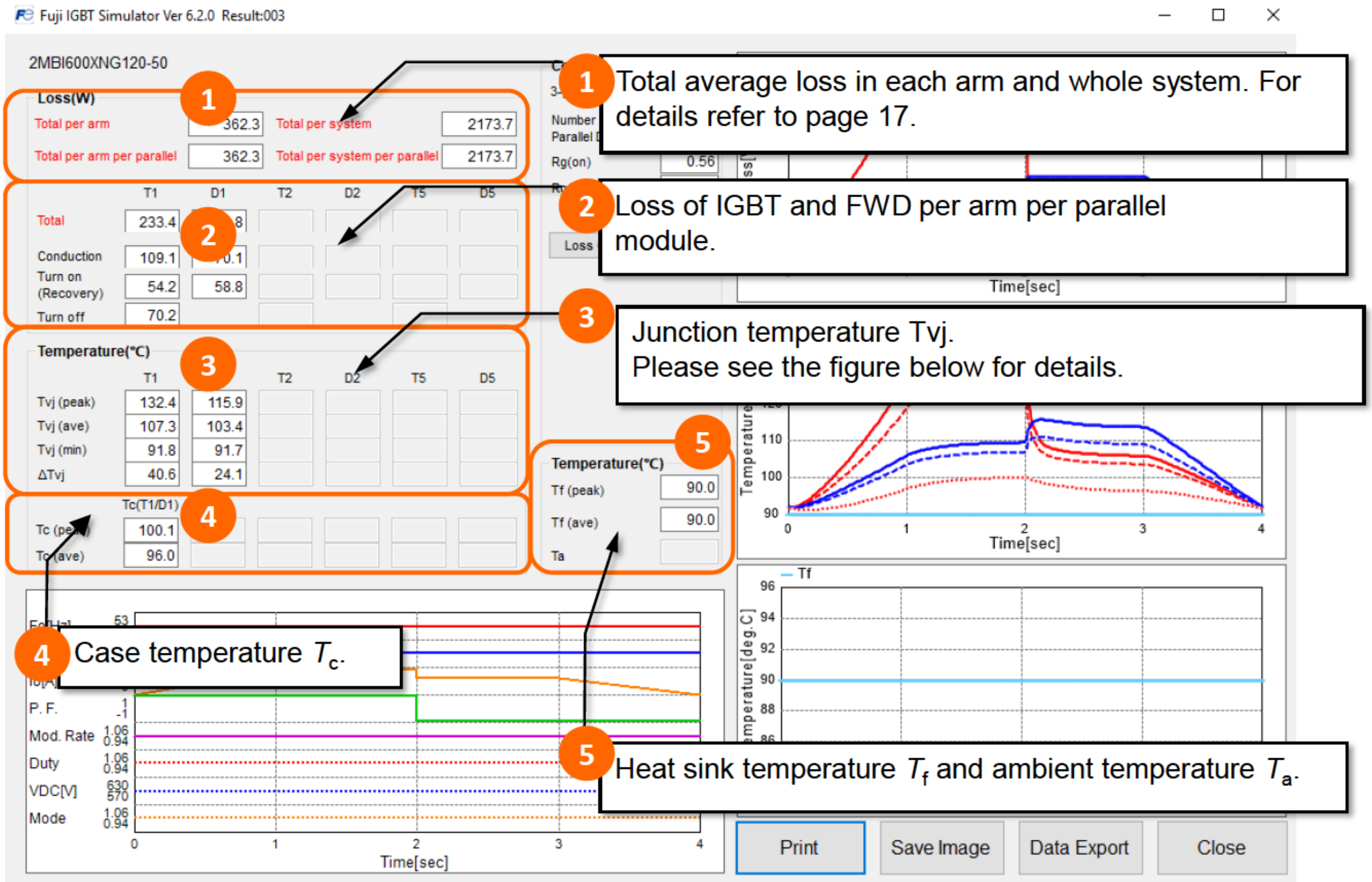
	#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
▶				5	0	0.9	1	1	600	3-phase Sinusoidal
				5	150	0.9	1	1	600	3-phase Sinusoidal
				5	150	0.9	1	1	600	3-phase Sinusoidal
				5	50	-0.9	1	1	600	3-phase Sinusoidal
				5	50	-0.9	1	1	600	3-phase Sinusoidal
				5	0	-0.9	1	1	600	3-phase Sinusoidal
*										3-phase Sinusoidal

Select a line → Right click → Paste



	#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
	1	0	60	5	0	0.9	1	1	600	3-phase Sinusoidal
	2	1	60	5	150	0.9	1	1	600	3-phase Sinusoidal
	3	2	60	5	150	0.9	1	1	600	3-phase Sinusoidal
	4	2	60	5	50	-0.9	1	1	600	3-phase Sinusoidal
	5	3	60	5	50	-0.9	1	1	600	3-phase Sinusoidal
	6	4	60	5	0	-0.9	1	1	600	3-phase Sinusoidal
▶*	7									3-phase Sinusoidal

Simulation Results (Cycle Calculation)



Simulation Results (Cycle Calculation)

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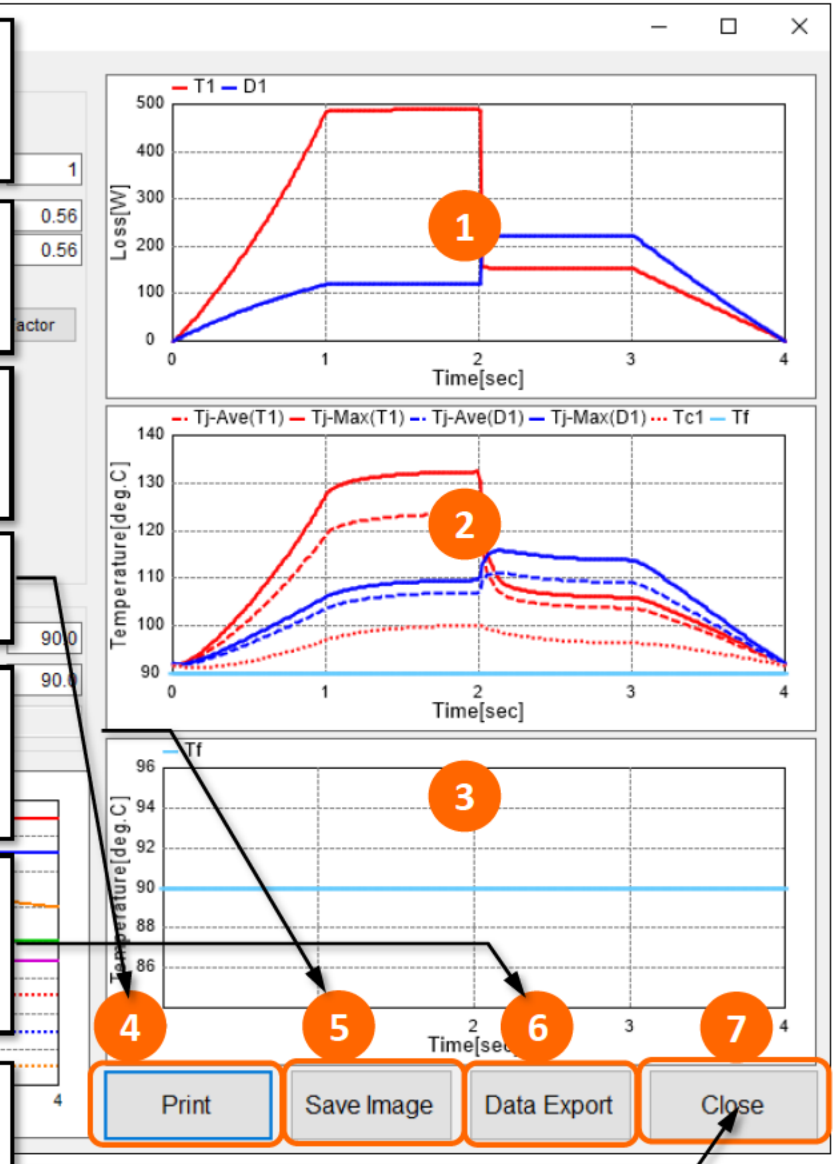
1. **Loss curves**
2. **Temperature curves**
3. **Temperature curves**
4. **Print the window**
5. **Save the window**

   Filename: *.xml
6. **Export the results**

   Filename: *.csv
7. **Close the window**



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Circuits & PWM Methods

Circuits & Modulation Methods

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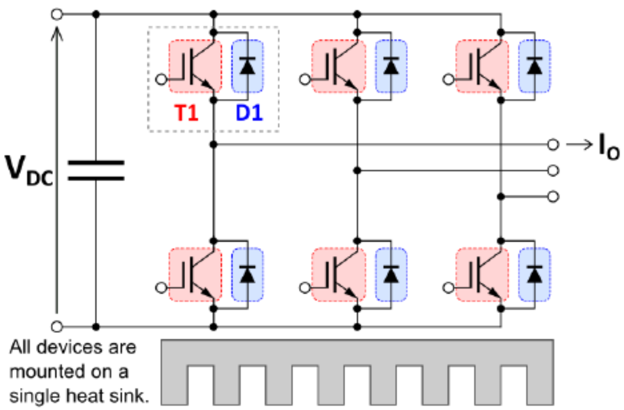
This page shows a list of circuits and PWM methods that are supported by the simulator.

Circuit — **PWM Method**

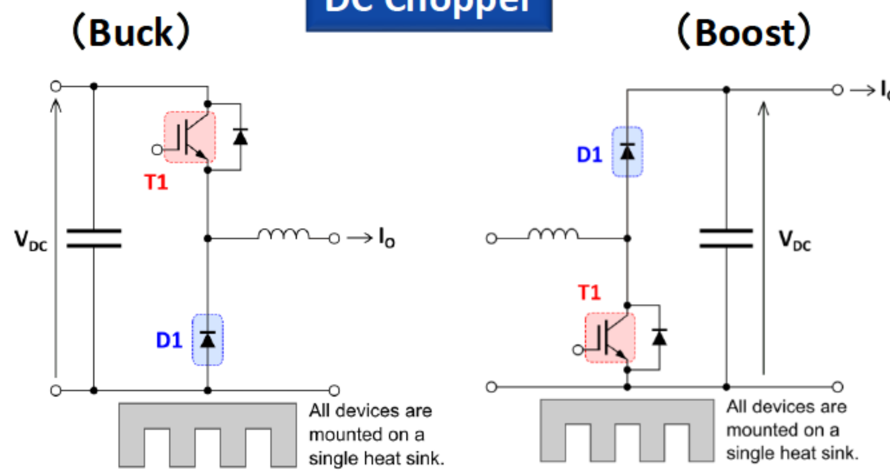
- **3-Phase 2-Level Inverter**
  - Sinusoidal
  - Space Vector
  - 3rd Harmonic Injection
  - 2-Phase (A)– DPWM1
  - 2-Phase (B)– DPWMMin
  - DC Lock
- **DC Chopper**
  - Boost Chopper
  - Buck Chopper
- **3-Phase 3-Level I-type**
  - Sinusoidal
  - Space Vector
  - 3rd Harmonic Injection
- **3-Phase 3-Level T-type**
  - Sinusoidal
  - Space Vector
  - 3rd Harmonic Injection
- **3-Phase 3-Level AT-type**
  - Sinusoidal
  - Space Vector
  - 3rd Harmonic Injection
- **3-Phase 3-Level A-NPC-type**
  - Sinusoidal (PWM1)
  - Space Vector (PWM1)
  - 3rd Harmonic Injection (PWM1)

Circuit Topology

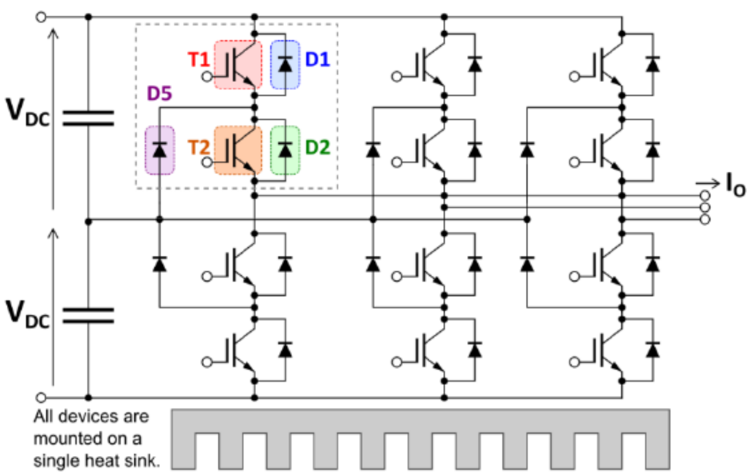
3-Phase 2-Level



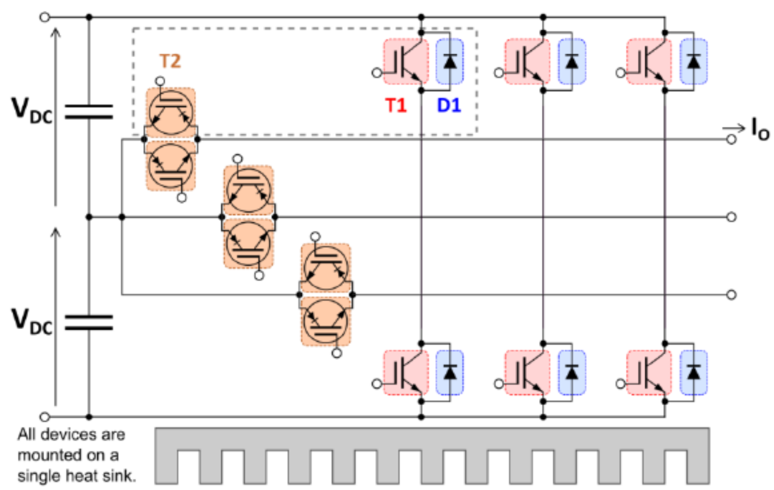
DC Chopper



3-Phase 3-Level I-type

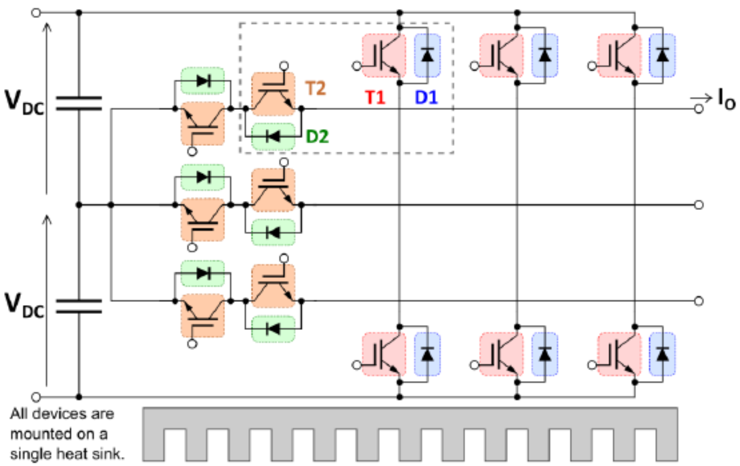


3-Phase 3-Level AT-type

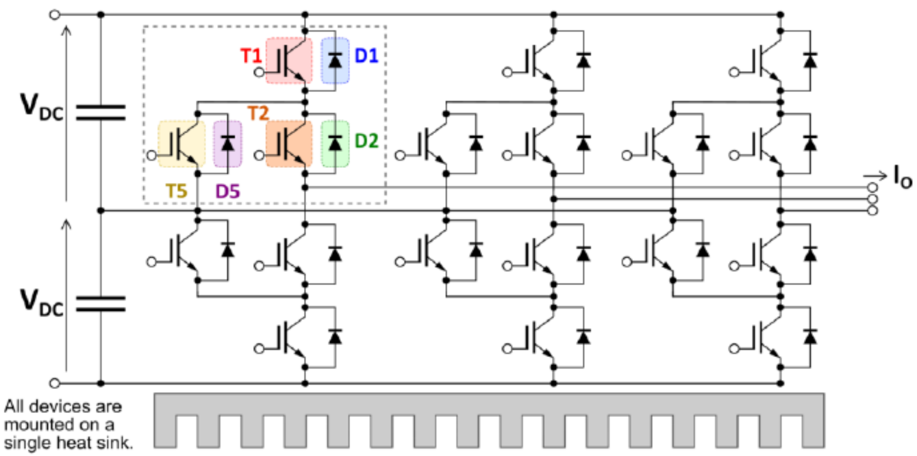


Circuit: 3-Phase 3-Level type

3-Phase 3-Level T-type



3-Phase 3-Level A-NPC-type



PWM Method (SPWM, SVPWM)

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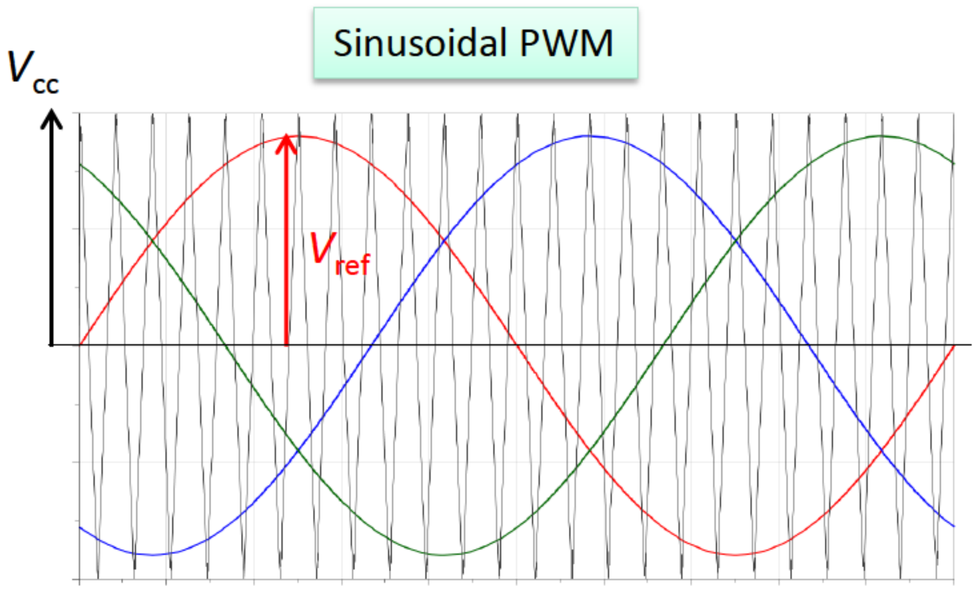
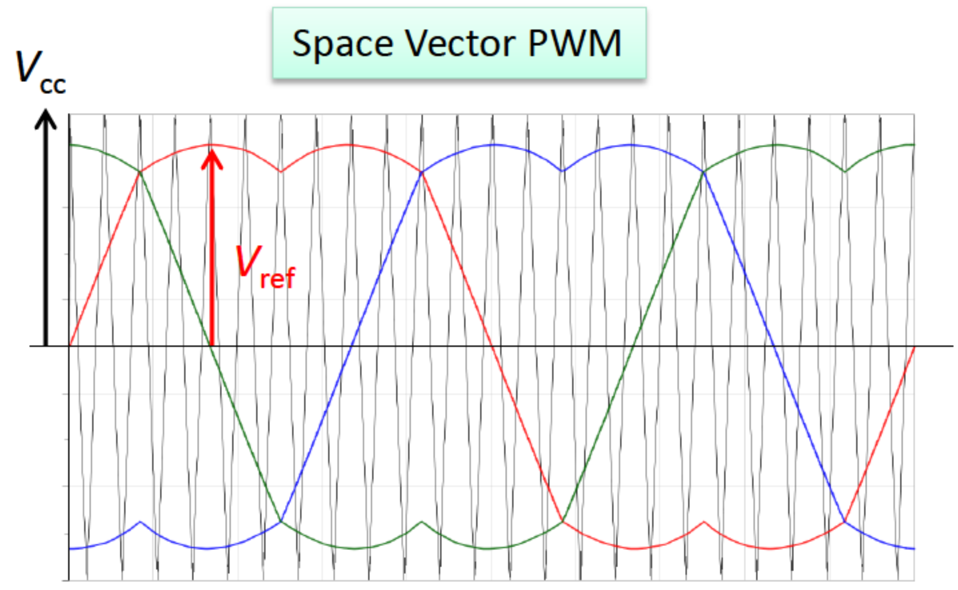


The reference voltage is a sinusoidal waveform.

The amplitude of the reference voltage Vref is defined by the following equation using modulation ratio *m*.

$$V_{\mathrm{ref}} = mV_{\mathrm{dc}}$$

The maximum value of *m* is 1.



The amplitude of the reference voltage Vref is defined by the following equation using modulation ratio *m*

$$V_{\mathrm{ref}} = \frac{\sqrt{3}}{2} mV_{\mathrm{dc}}$$

m is defined to be the same output voltage to the sinusoidal PWM.

The maximum value of *m* is 2/√3 = 1.1547

PWM Method (3rd harmonic injection)

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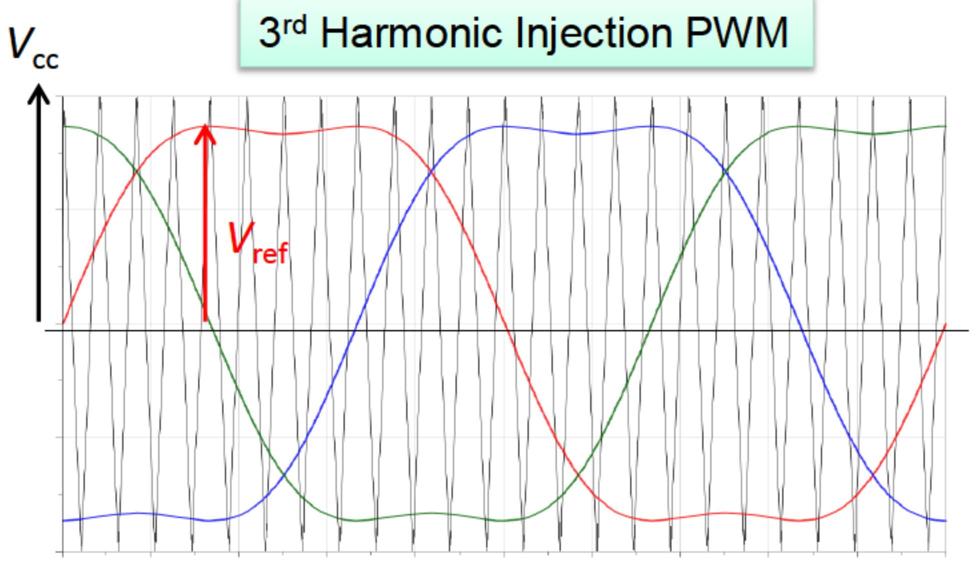


The amplitude of the reference voltage Vref is defined by the following equation using modulation ratio *m*

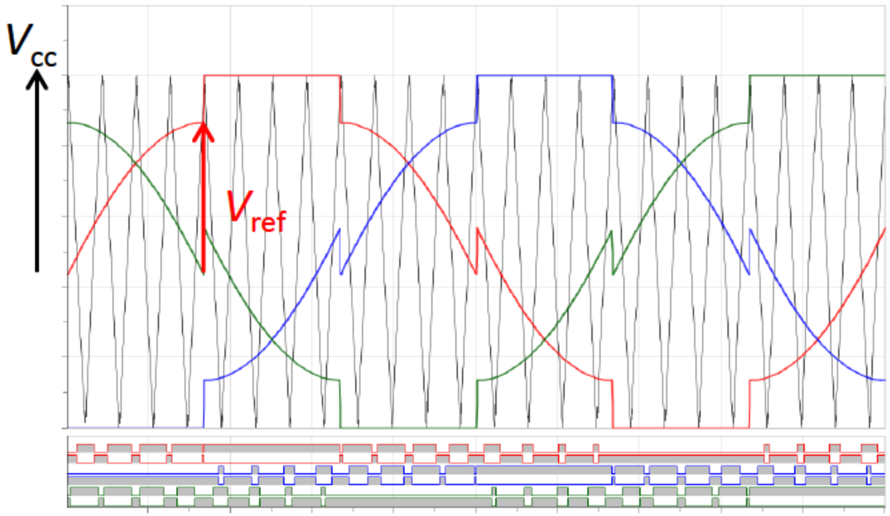
$$V_{\mathrm{ref}} = \frac{\sqrt{3}}{2} m V_{\mathrm{dc}}$$

m is defined to be the same output voltage to the sinusoidal PWM.

The maximum value of *m* is 2/√3 = 1.1547

2-Phase Modulation

2-Phase (A) – DPWM1



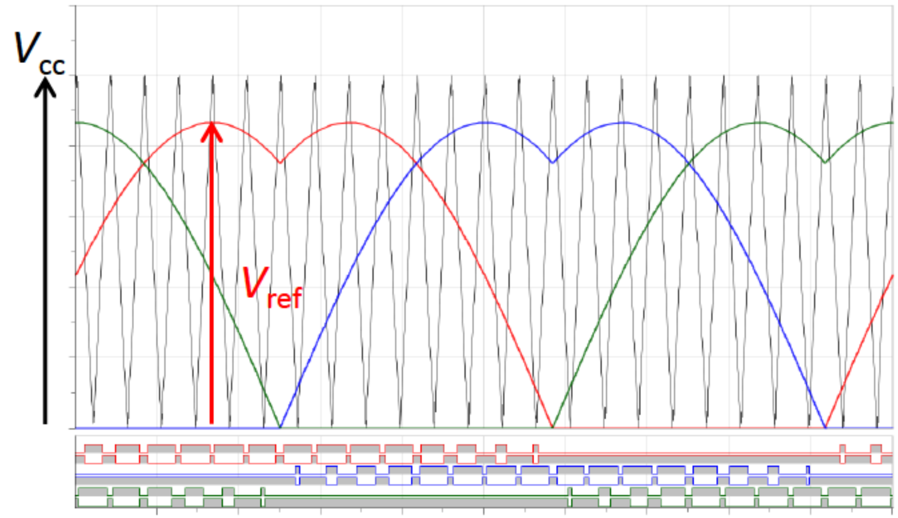
The amplitude of the reference voltage Vref is defined by the following equation using modulation ratio *m*.

$$V_{\mathrm{ref}} = \frac{\sqrt{3}}{2} m V_{\mathrm{dc}}$$

m is defined to be the same output voltage to the sinusoidal PWM.

The maximum value of *m* is 2/√3 = 1.1547

2-Phase (B) – DPWMMin



The amplitude of the reference voltage Vref is defined by the following equation using modulation ratio *m*.

$$V_{\mathrm{ref}} = \frac{\sqrt{3}}{2} m V_{\mathrm{dc}}$$

m is defined to be the same output voltage to the sinusoidal PWM.

The maximum value of *m* is 2/√3 = 1.1547

PWM Method（A-NPC circuit）

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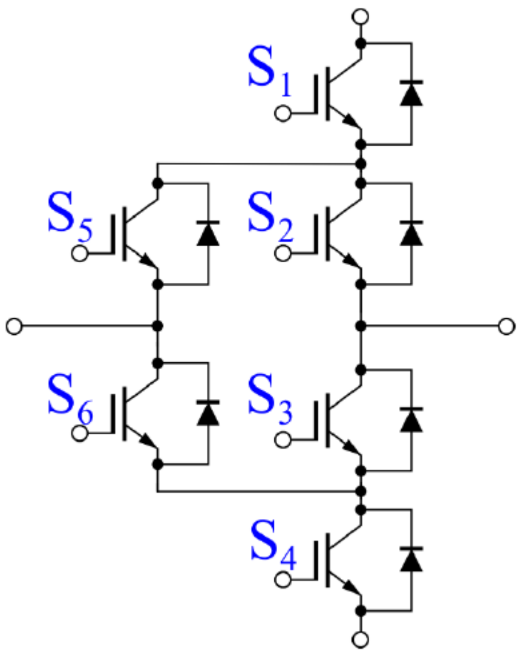
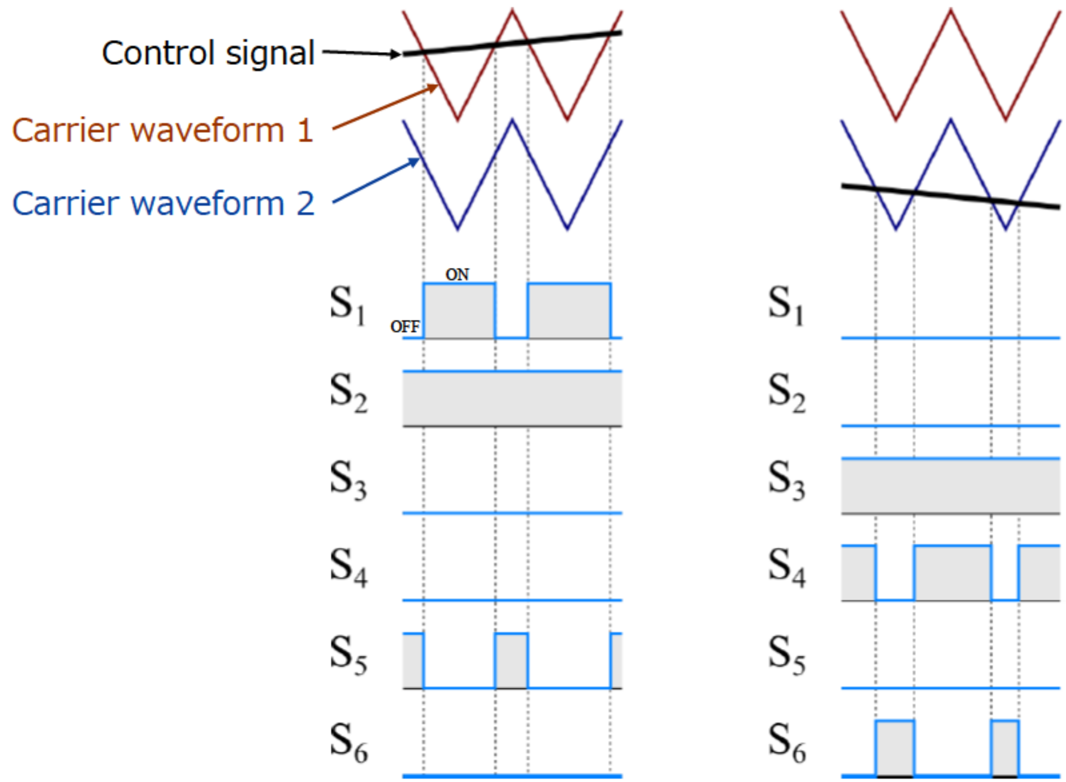
Several methods have been proposed for the PWM method of the A-NPC circuit.
This simulator performs simulation with the PWM method (PWM 1) shown below.

A-NPC circuit diagram



Switching pattern (PWM1)



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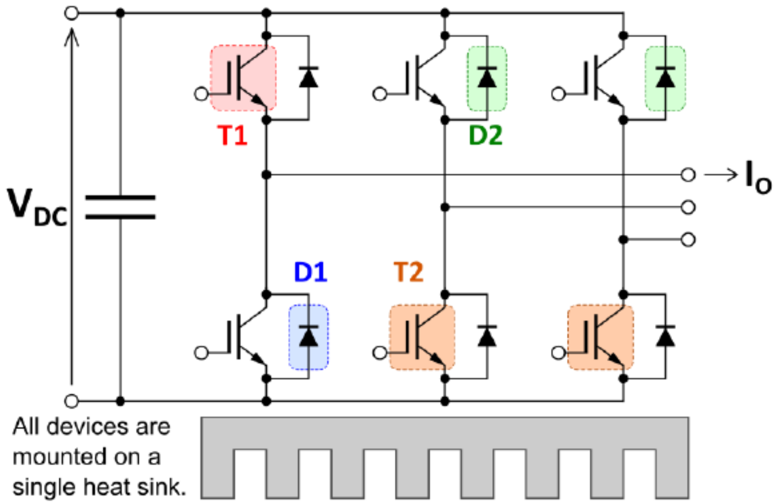
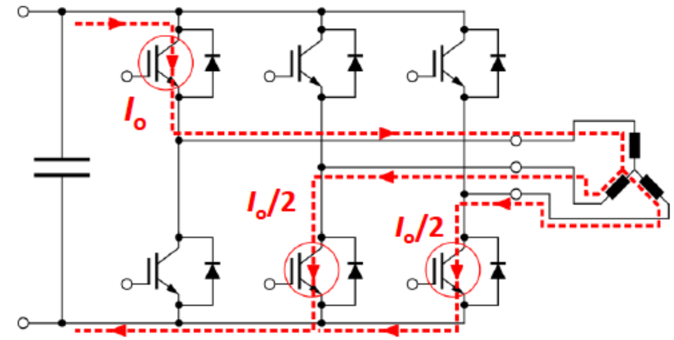
Motor DC Lock Operation

Calculate the IGBT / FWD loss when locking the motor rotation with a servo drive or the like.

As shown in the figure below, one IGBT of the upper arm (or the lower arm) of one phase and the IGBT of the other arm of the other two phases are switching controlled.

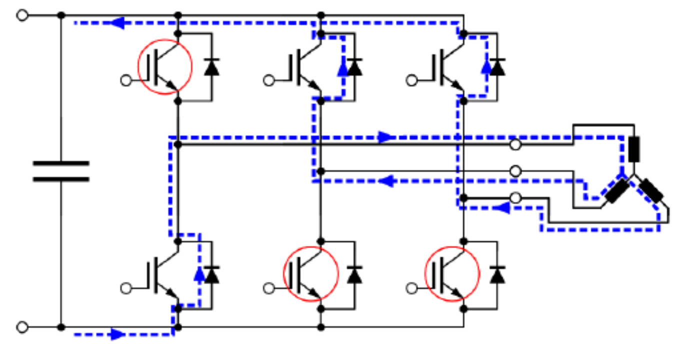




Current path when IGBT is on.

Note: The heat sink temperature T_f is calculated based on the assumption that the surface temperature distribution of the heat sink's area, which is in contact with the module, is uniform.

In the motor lock operation only specific elements generate heat. Thus the heat does not spread optimally on the heat sink's surface and the heat sink's thermal resistance increases. As a result, Tf and Tc might become high.



Current path when IGBT is off.

If you have any questions, please contact us.

http://www.fujielectric.com/products/semiconductor/contact/index.html

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