FUJI IGBT Simulator Ver. 6.2
User Manual

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Contents

Software Setup

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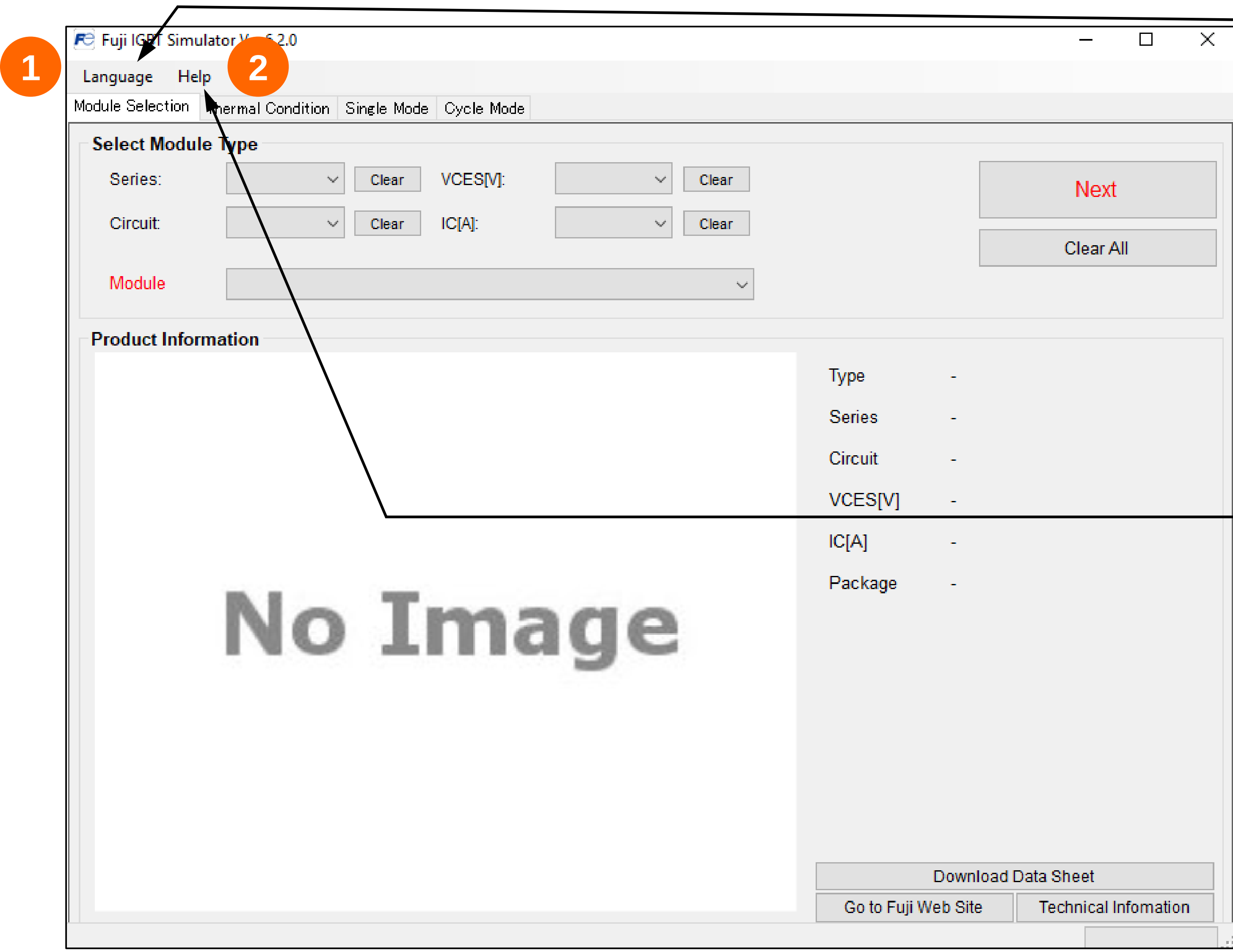
This software is suitable for Microsoft® Windows® Windows7, Windows & Windows10.

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.

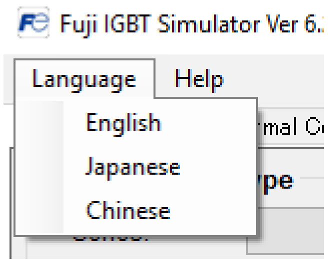
Menu



1

Select language

- English
- Japanese
- Chinese

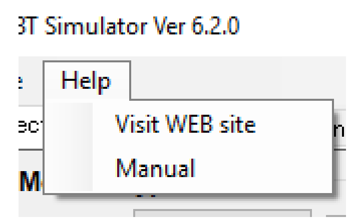


2

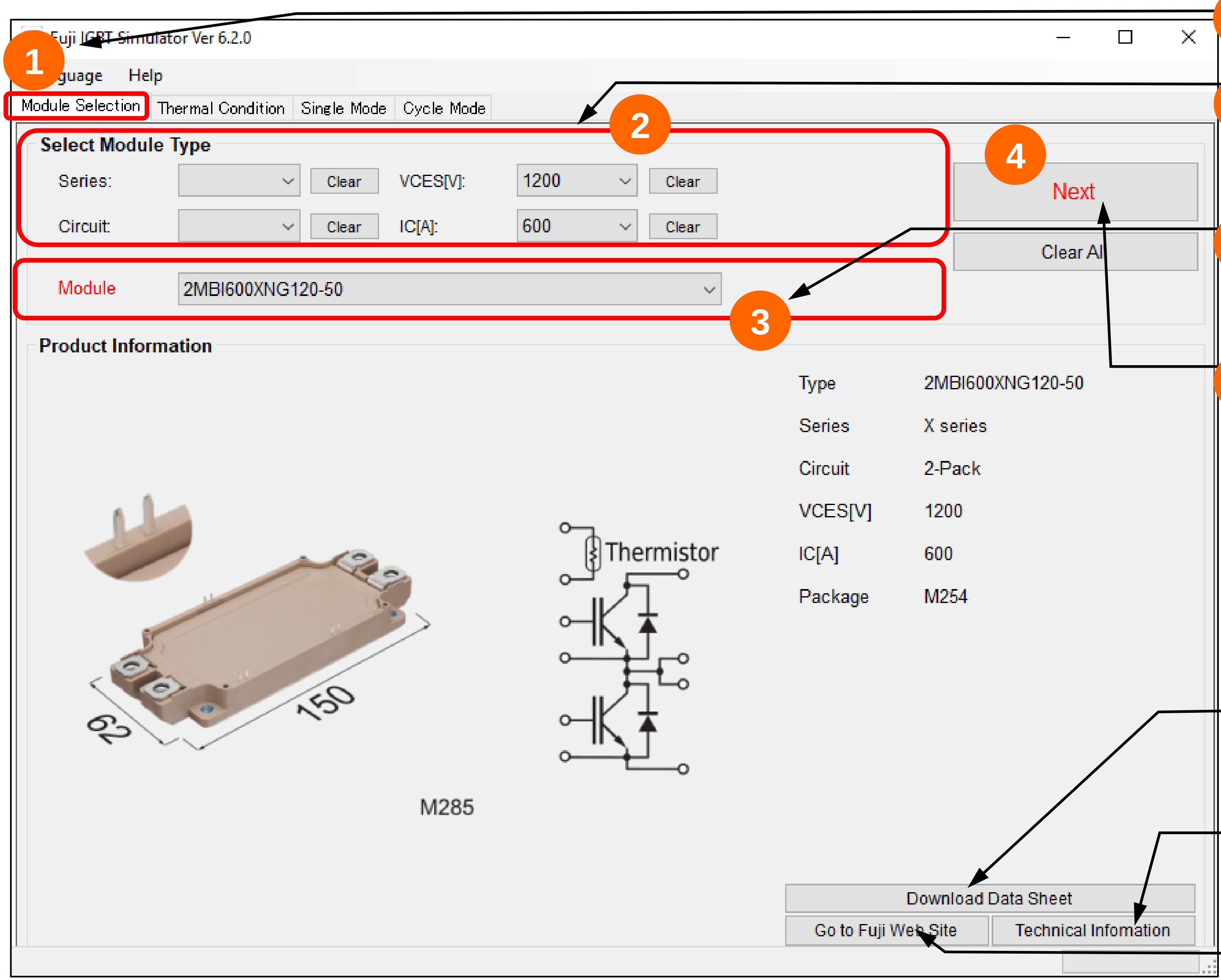
Help

Visit Fuji Web site to get the latest version.

Check the version.



Module Selection



1 Click "Module Selection" tab.

2 Select "Series, Circuit, VCES, IC" from each dropdown list.

3 Select module from the dropdown list.

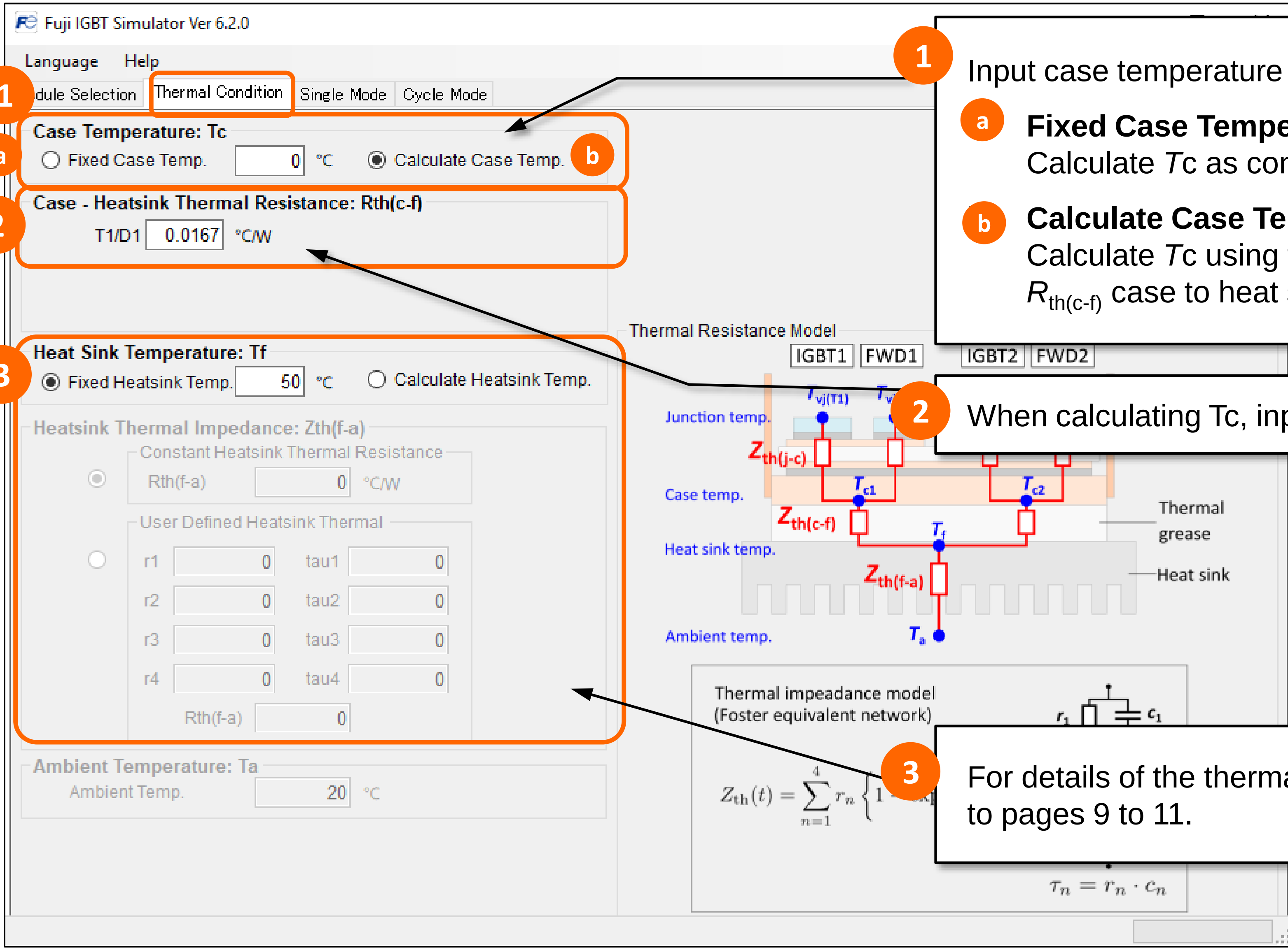
4 Click "Next" button.

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 T_c as constant

b **Calculate Case Temperature**
Calculate T_c 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)

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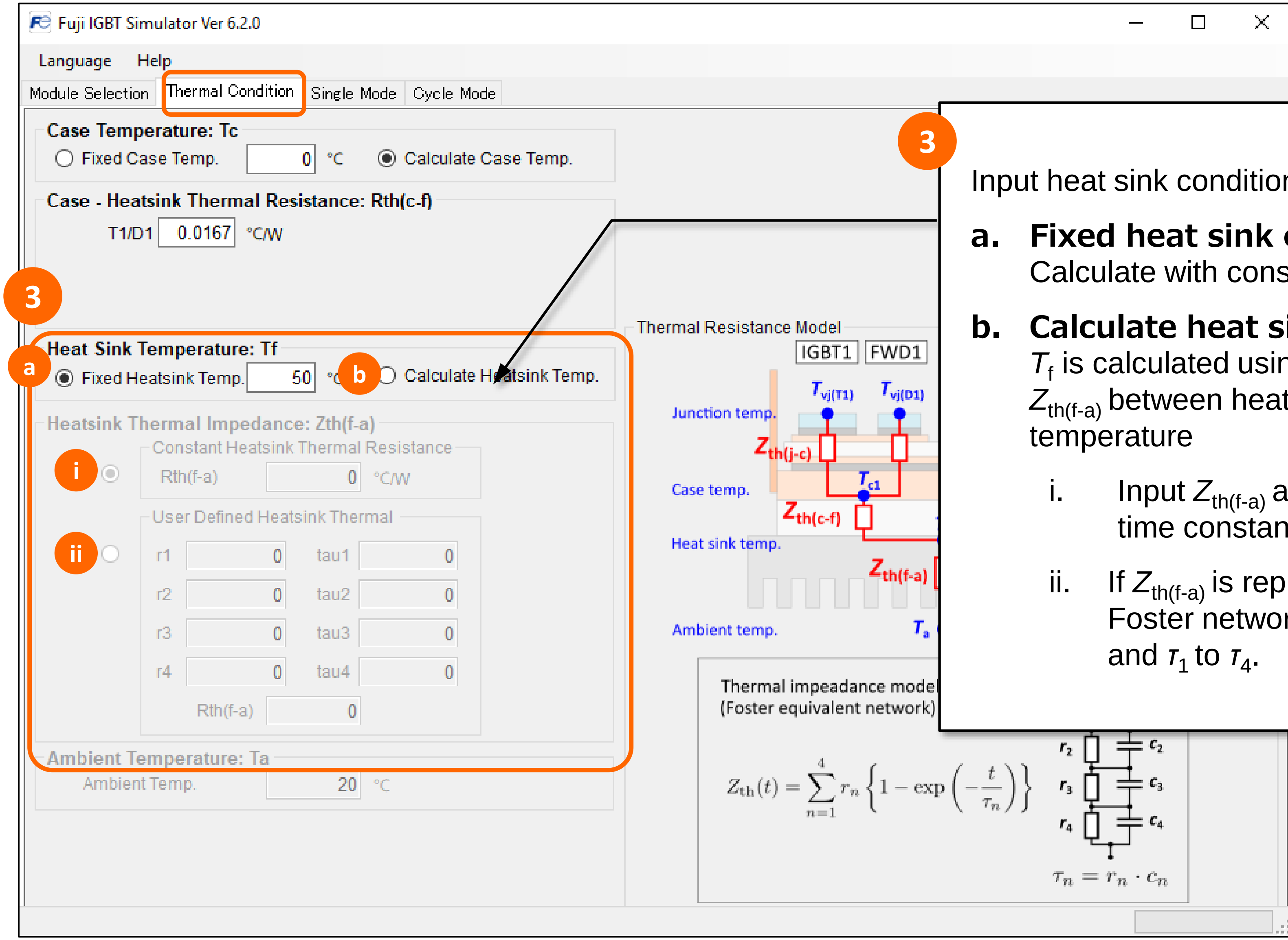


3

Input heat sink condition

a. Fixed heat sink condition
Calculate with constant T_f

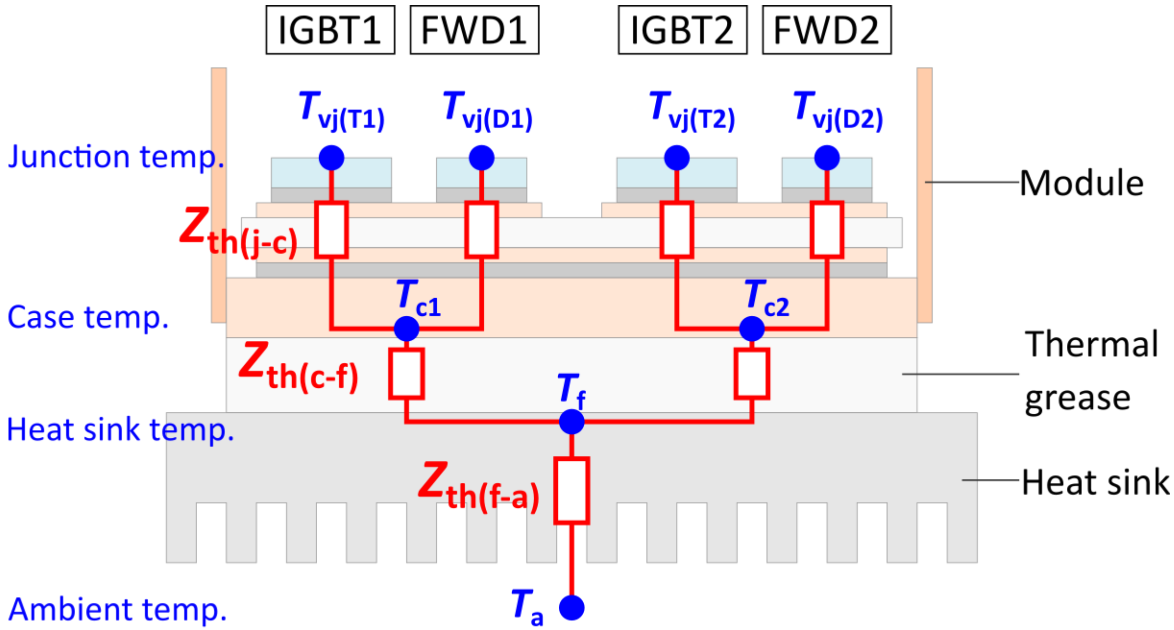
b. Calculate heat sink temperature
T_f is calculated using thermal impedance $Z_{th(f-a)}$ between heat sink and ambient temperature

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)

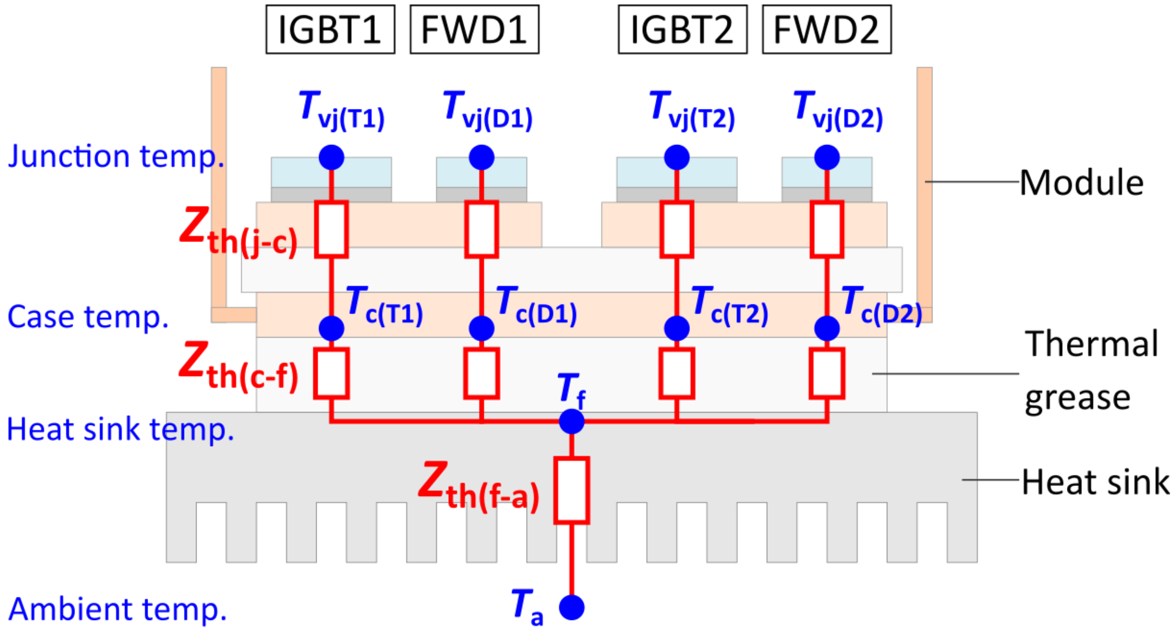
In the simulator, calculations are performed based on the following thermal circuit model.



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)

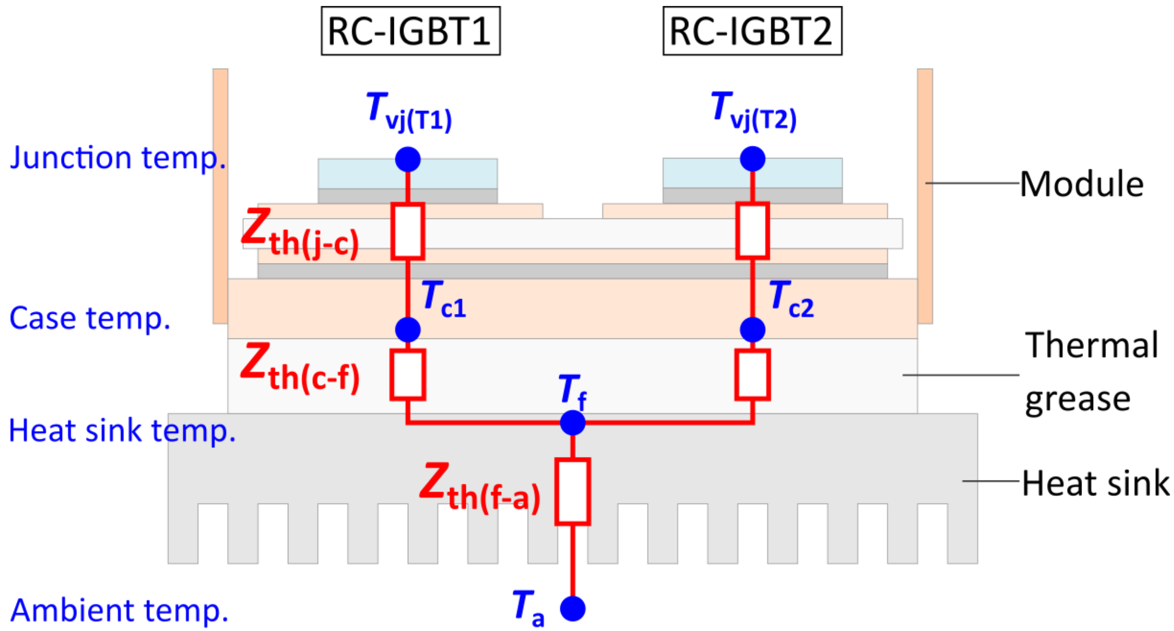
The following thermal circuit model is applied for modules with copper baseplate.



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)

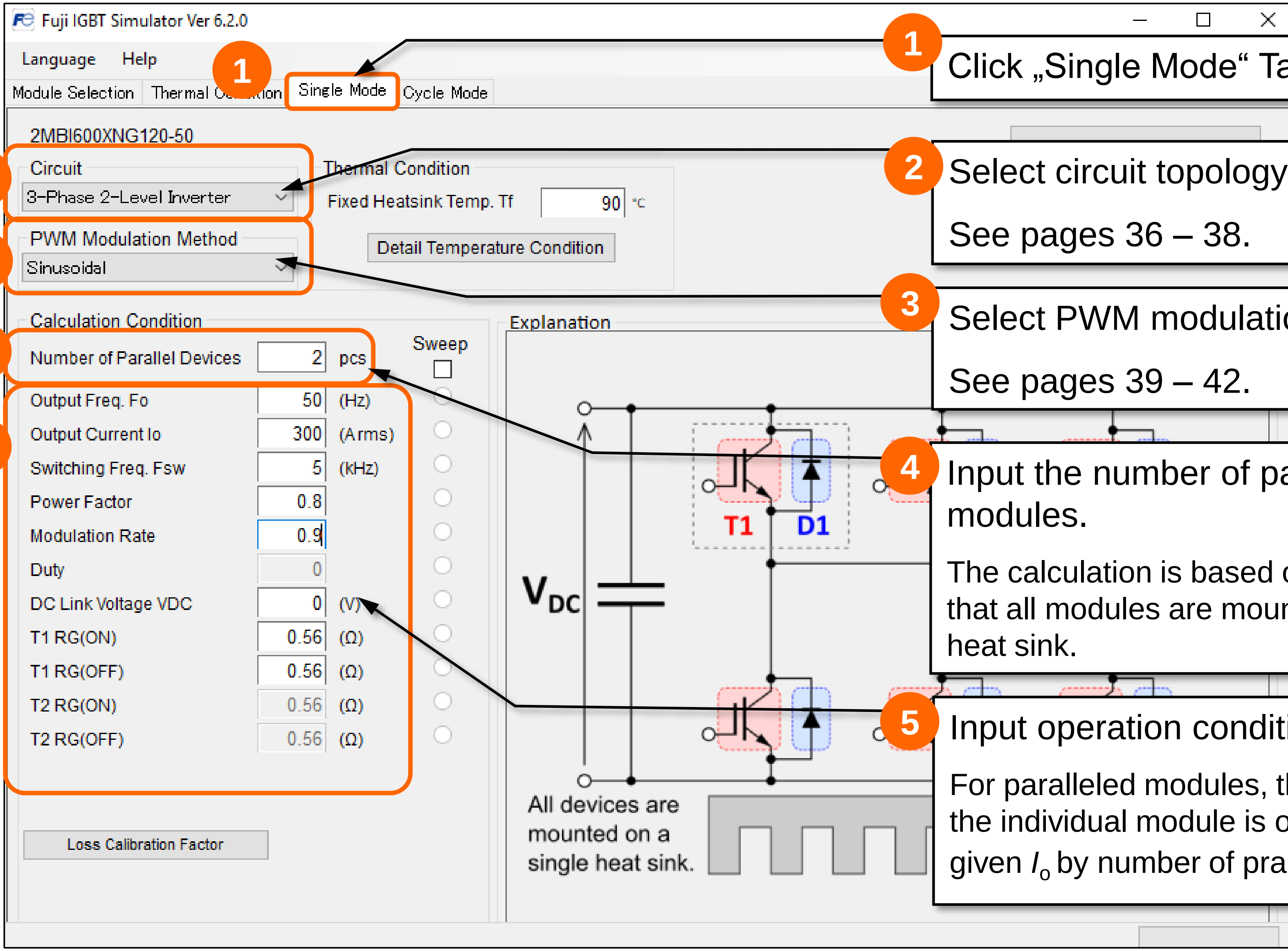
The following thermal circuit model is applied for RC-IGBT modules.



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.

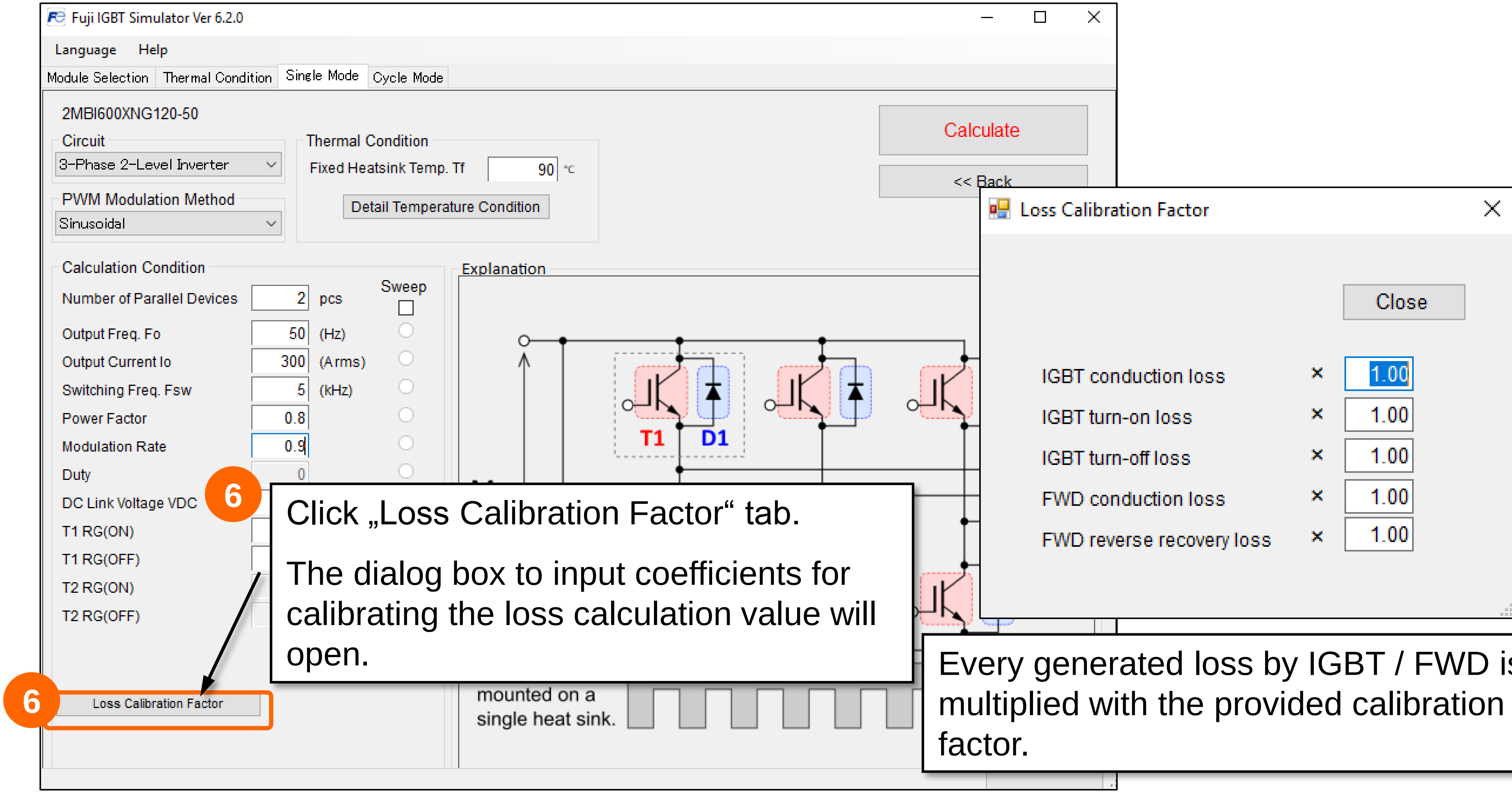
4. Input the number of parallel connected modules.

   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

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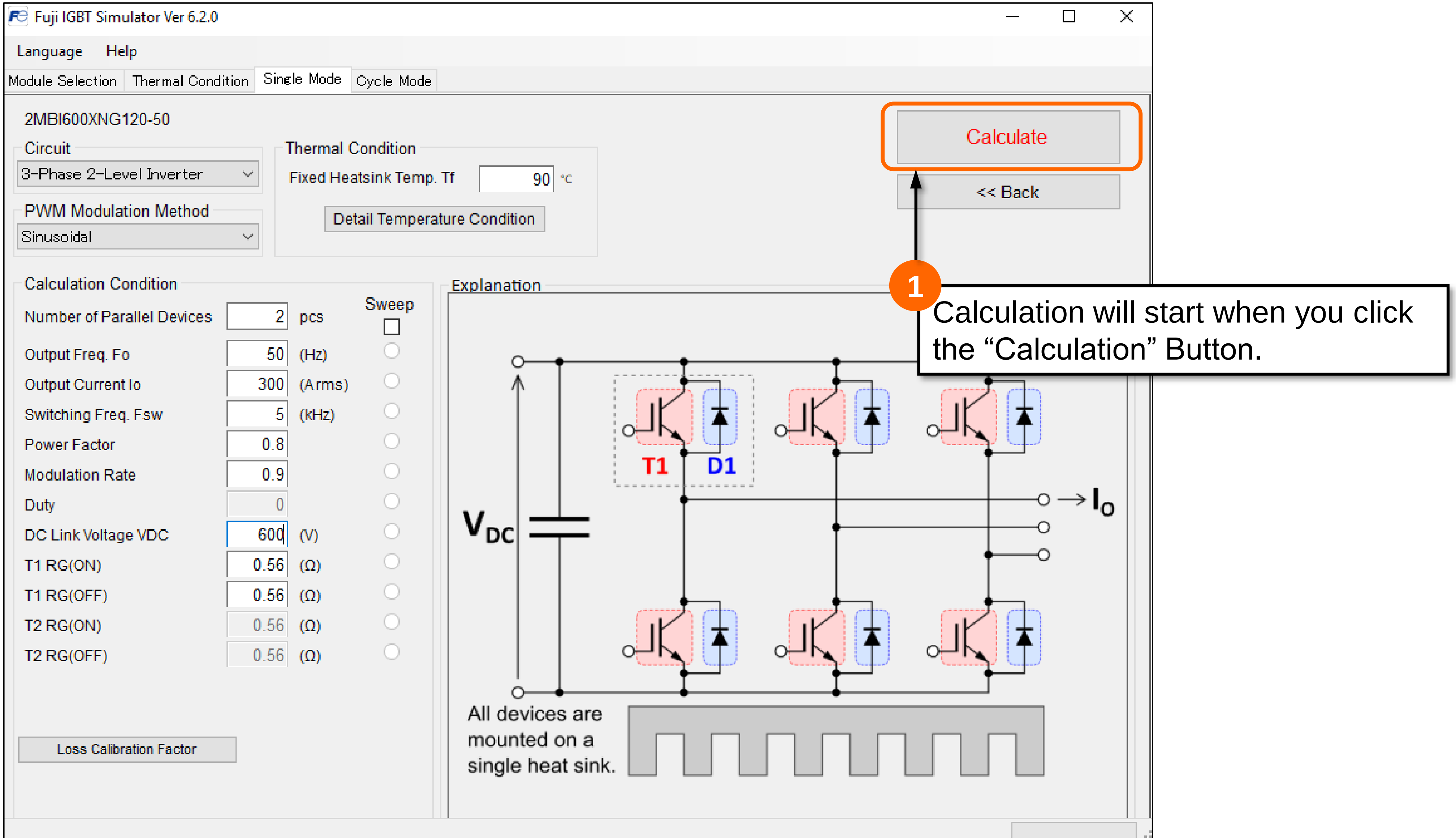

Simulation Results (Single Mode)

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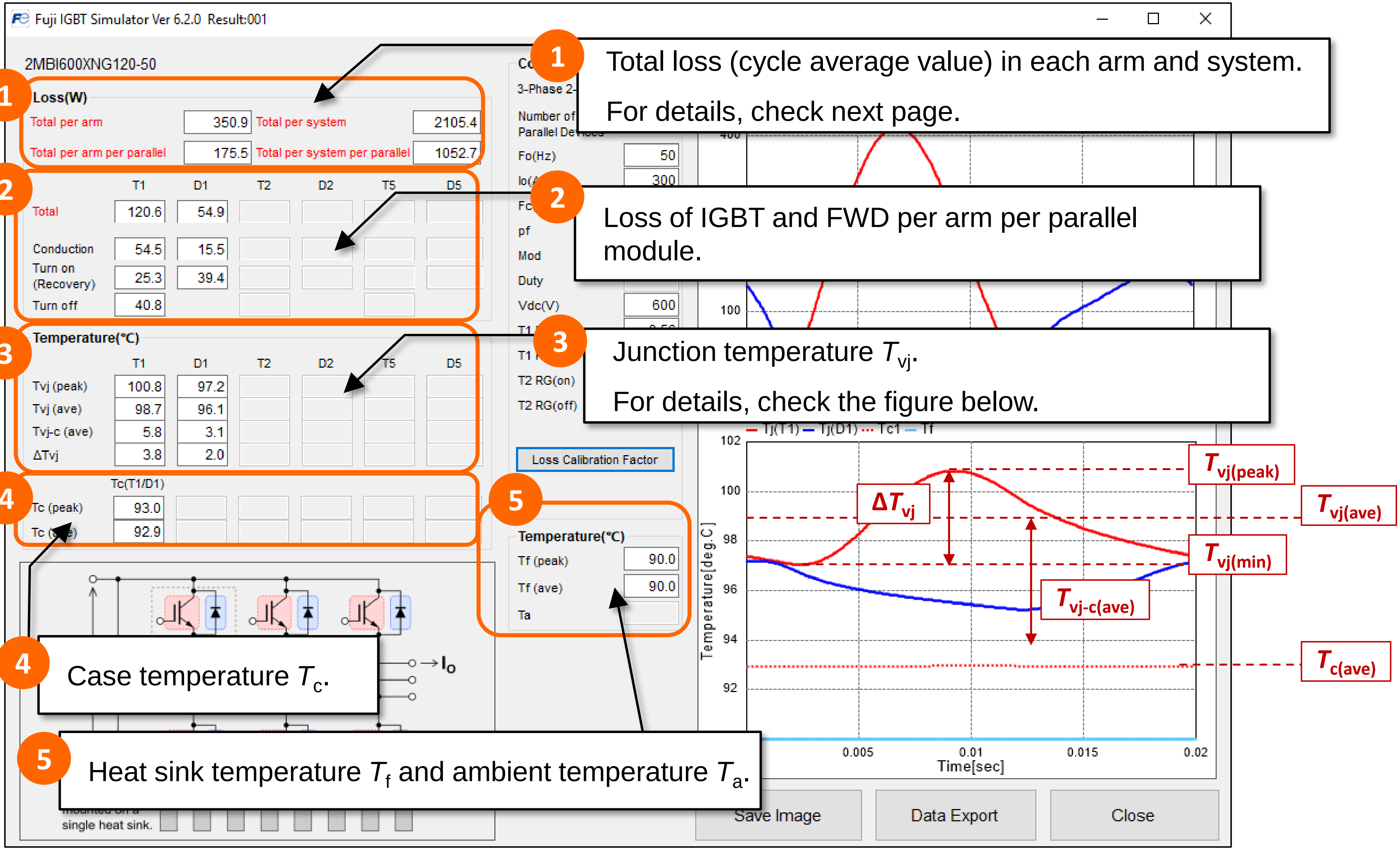
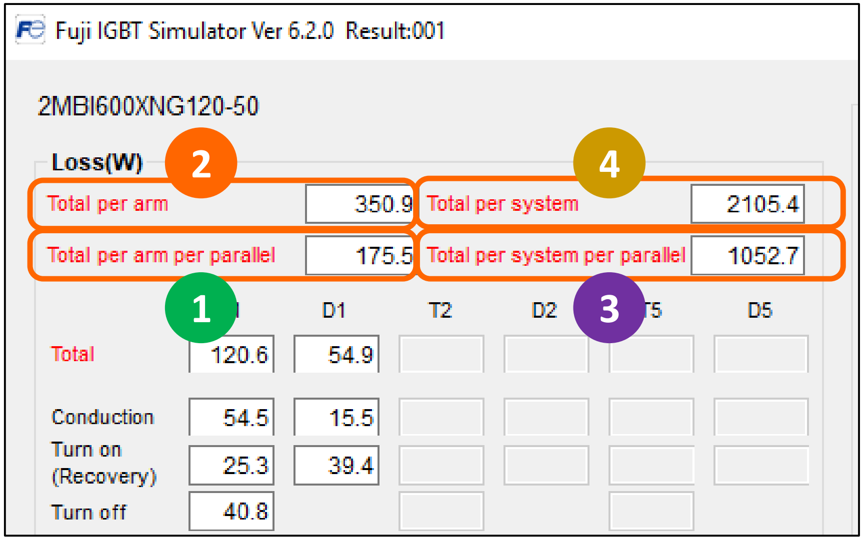
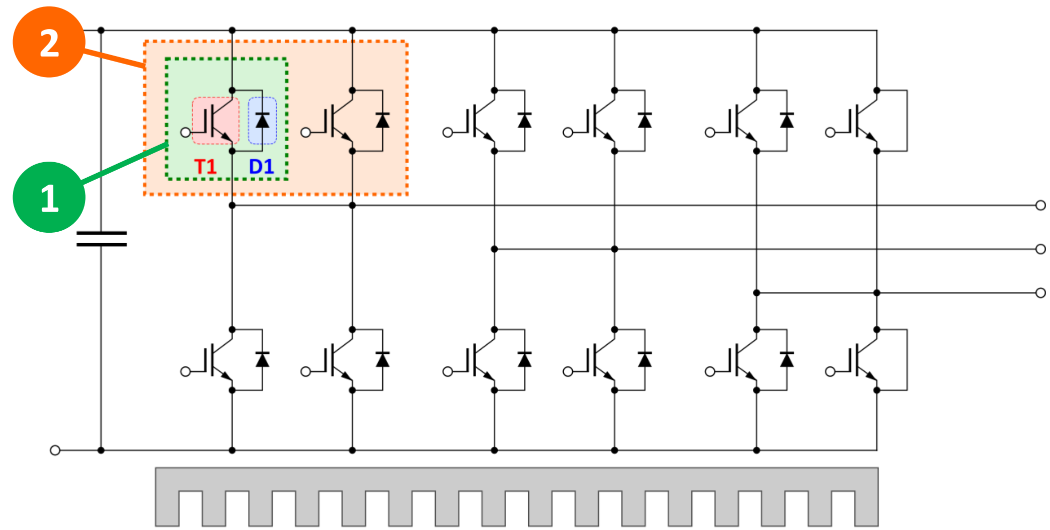


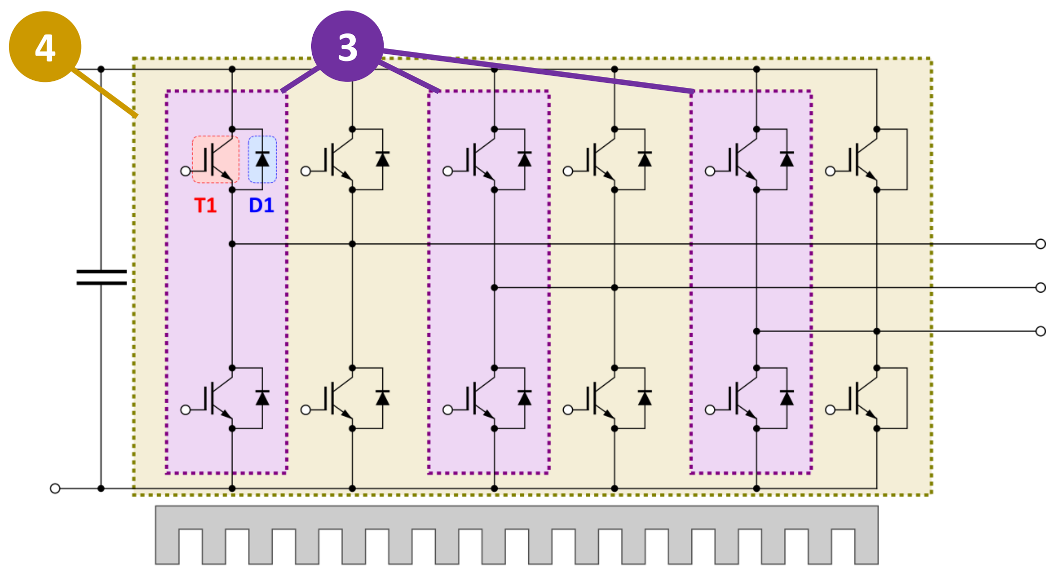
Simulation Results (Total Loss)



	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)

Simulation Results (Single Mode)

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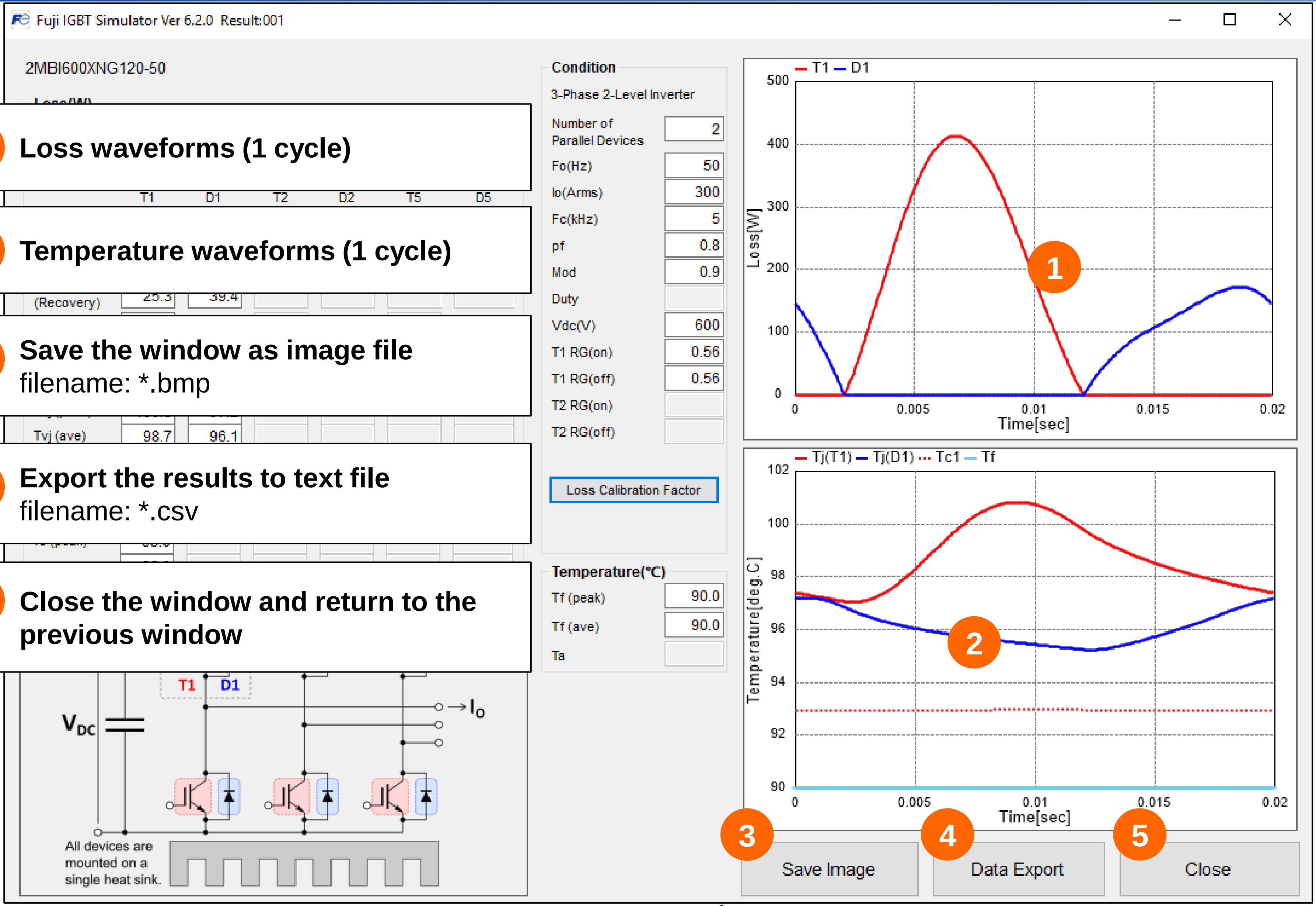


1 **Loss waveforms (1 cycle)**

2 **Temperature waveforms (1 cycle)**

3 **Save the window as image file**
filename: *.bmp

4 **Export the results to text file**
filename: *.csv

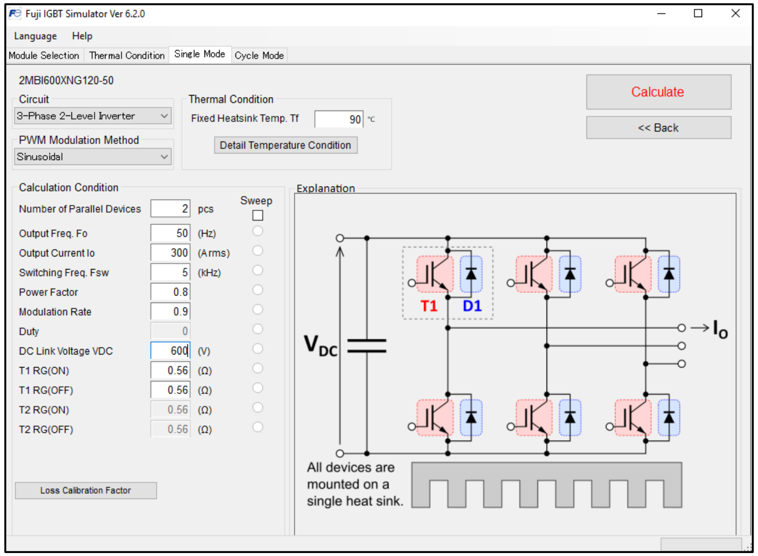
5 **Close the window and return to the previous window**

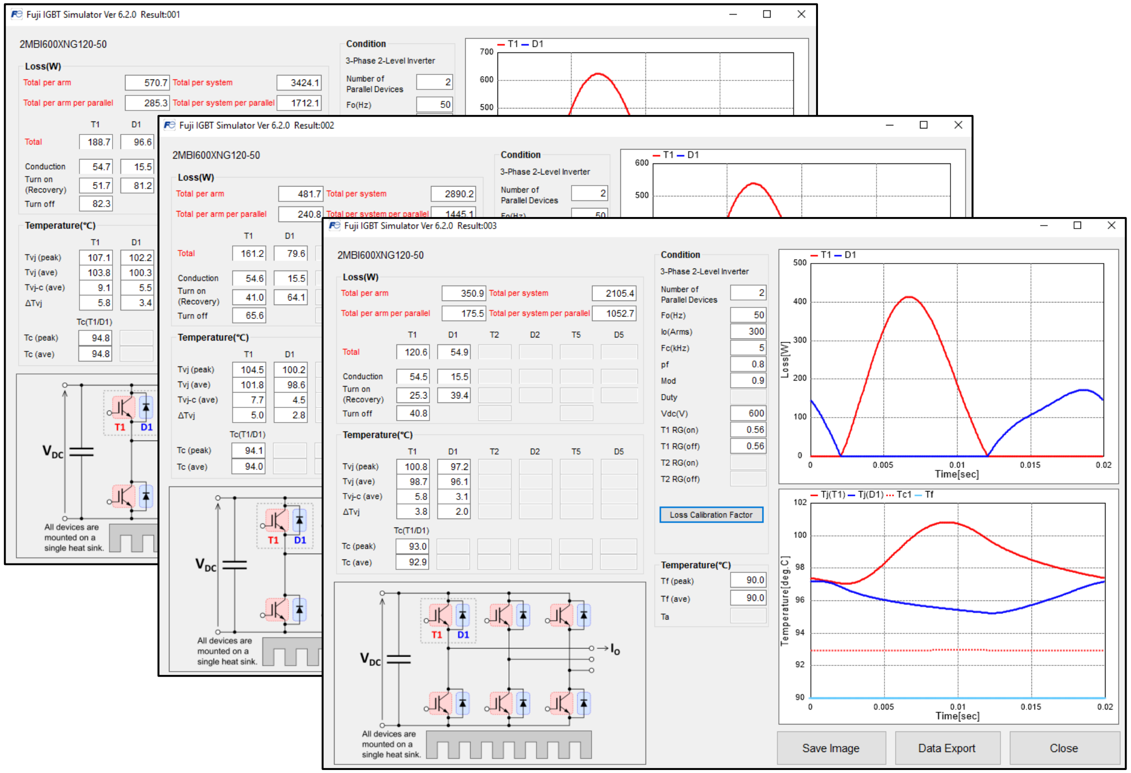
Display Multiple Results

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.



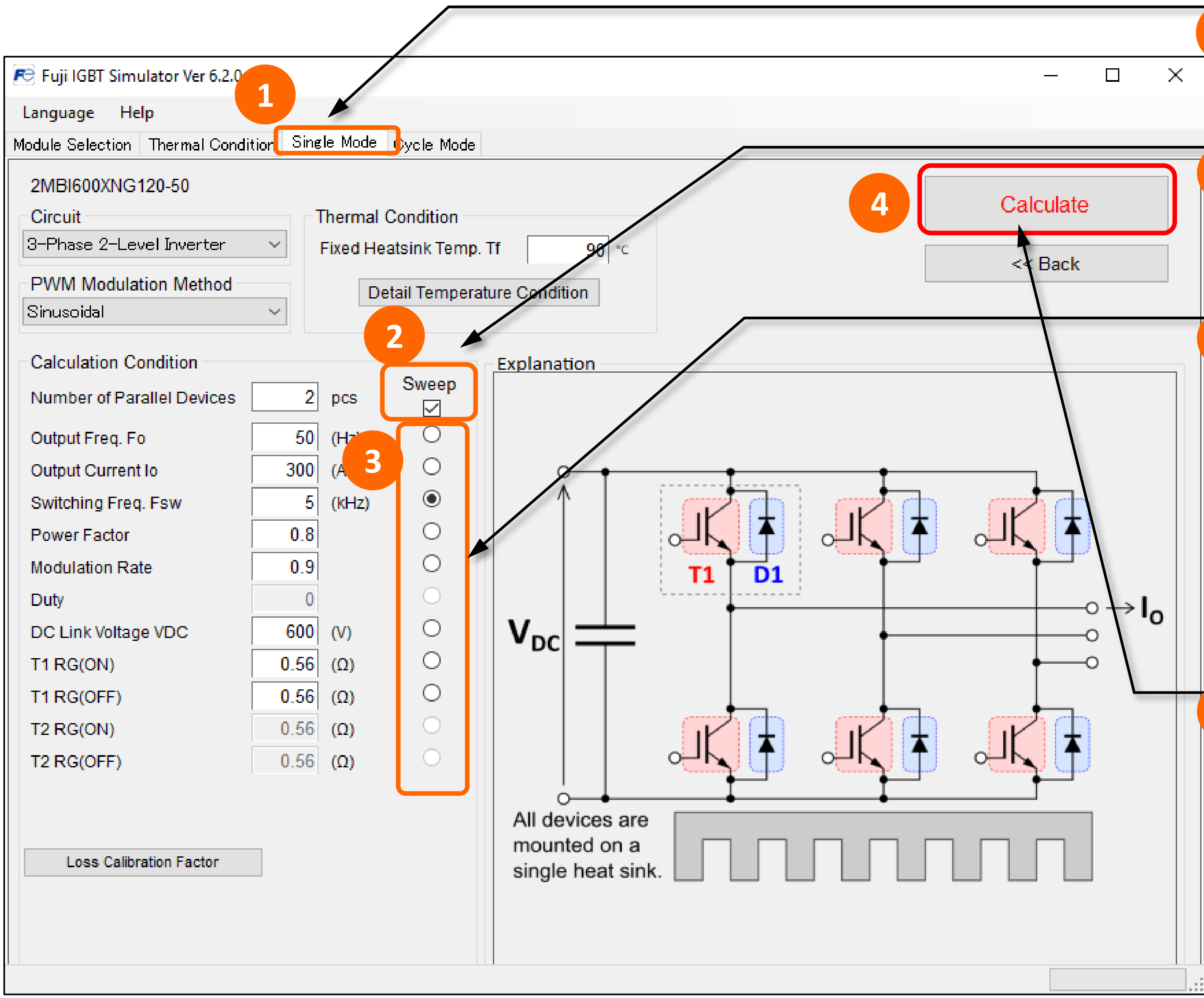


Parameter Sweep Calculation

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



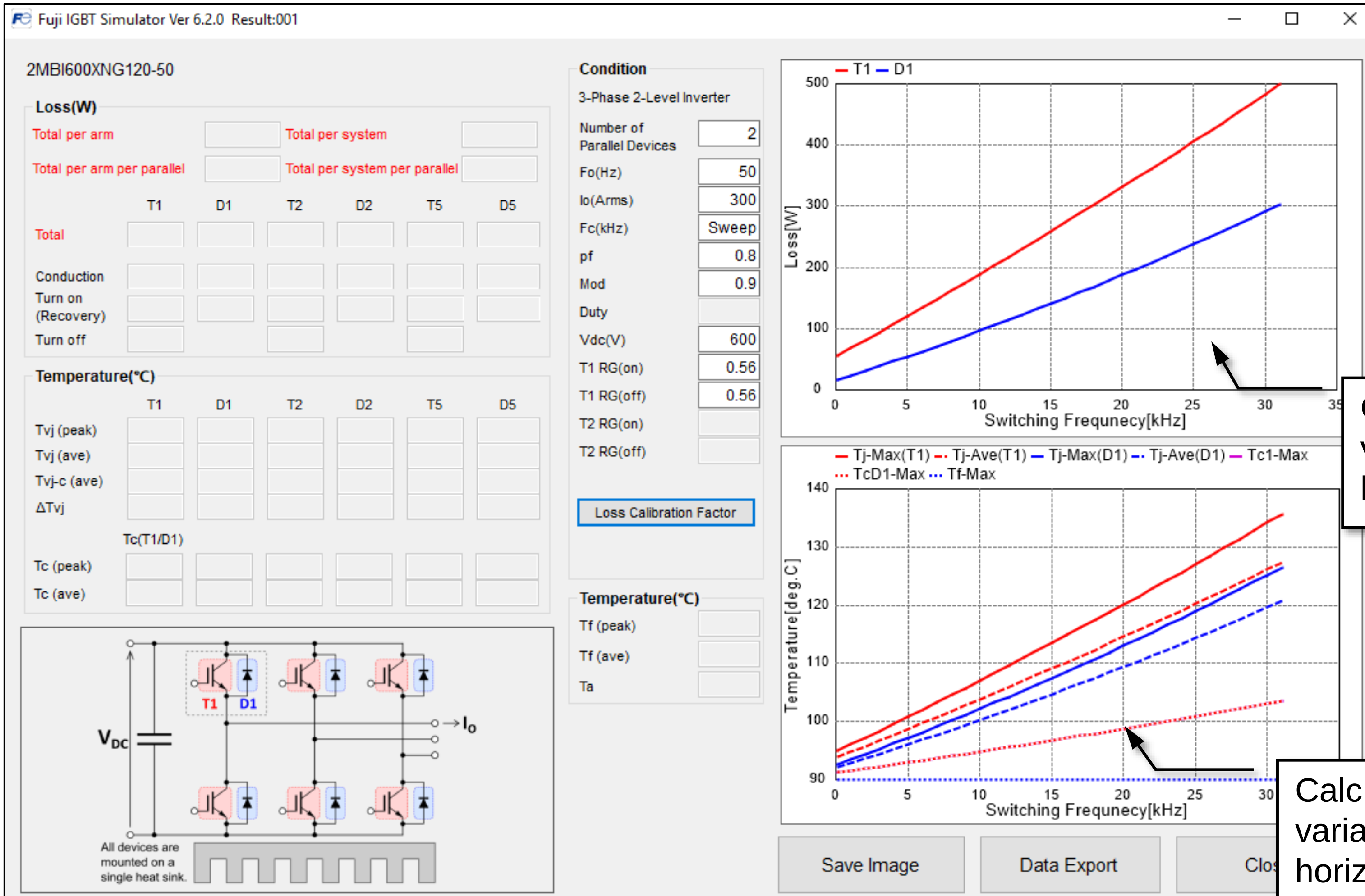
1 Click „Single Mode“ Tab.

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



Calculated losses with variable parameter on horizontal axis.

Calculated temperature with variable parameter on horizontal axis.

Cycle Mode Calculation

Cycle Mode Calculation

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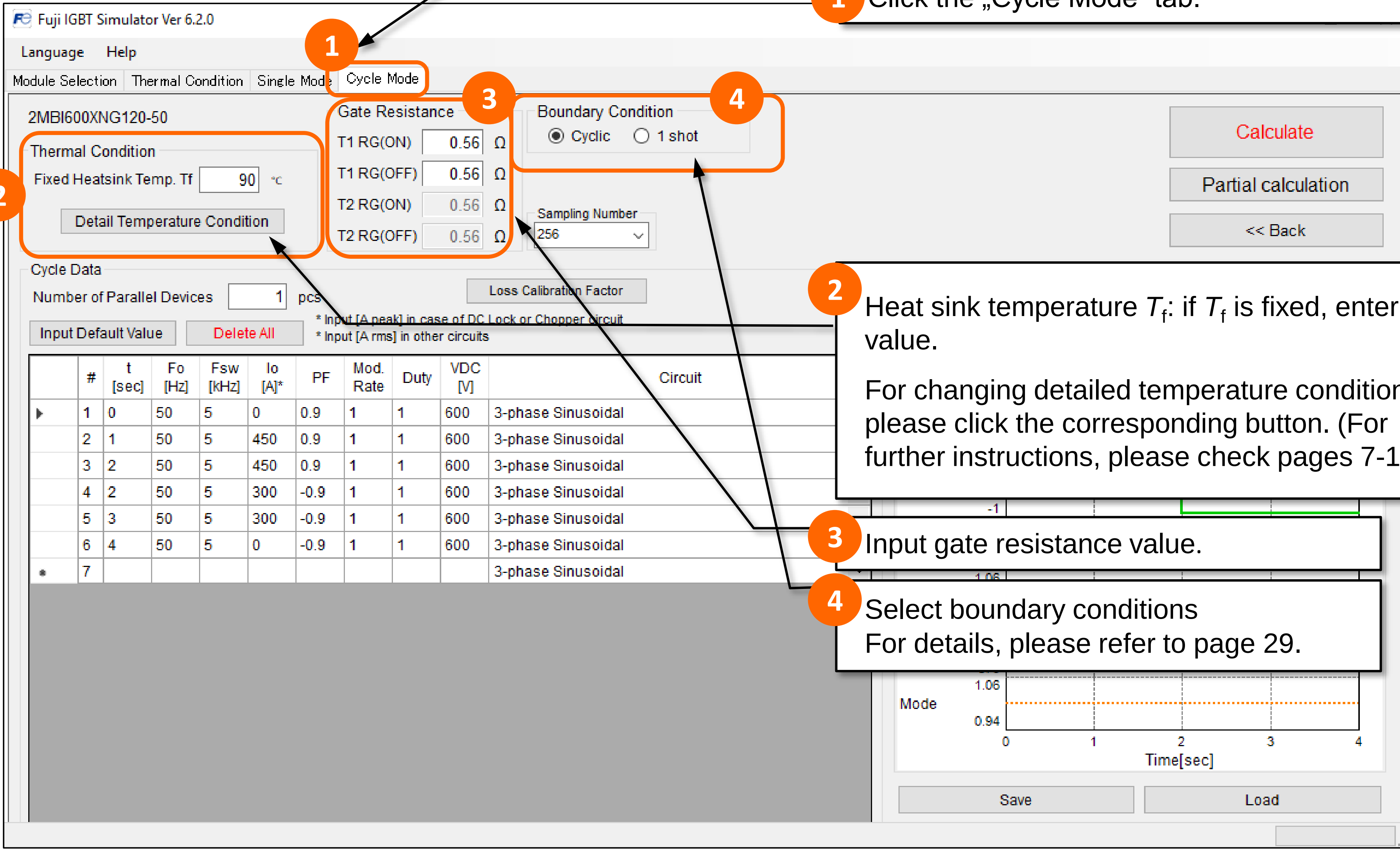


1. Click the „Cycle Mode“ tab.

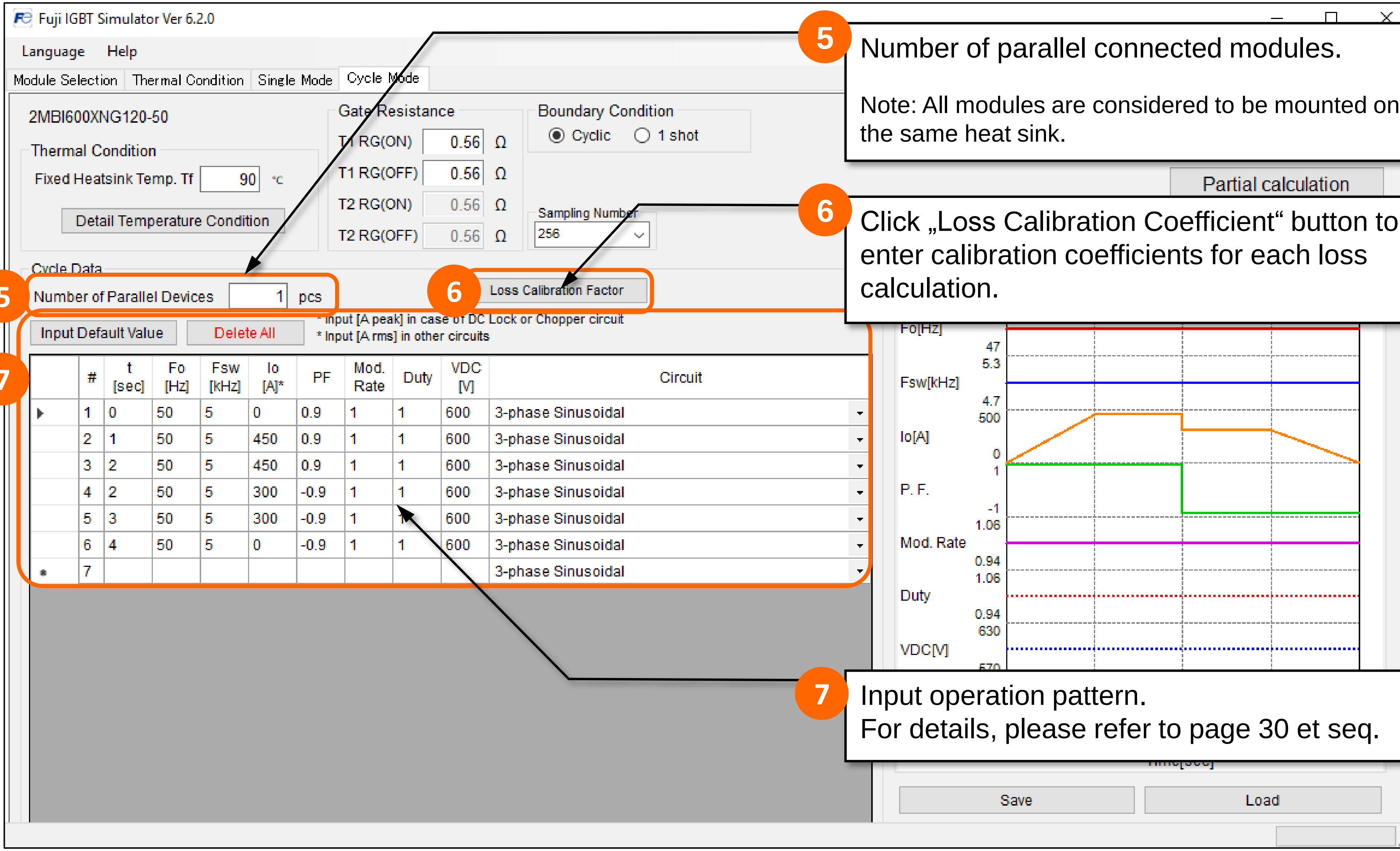
2. Heat sink temperature T_f: if T_f is fixed, enter value.

   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

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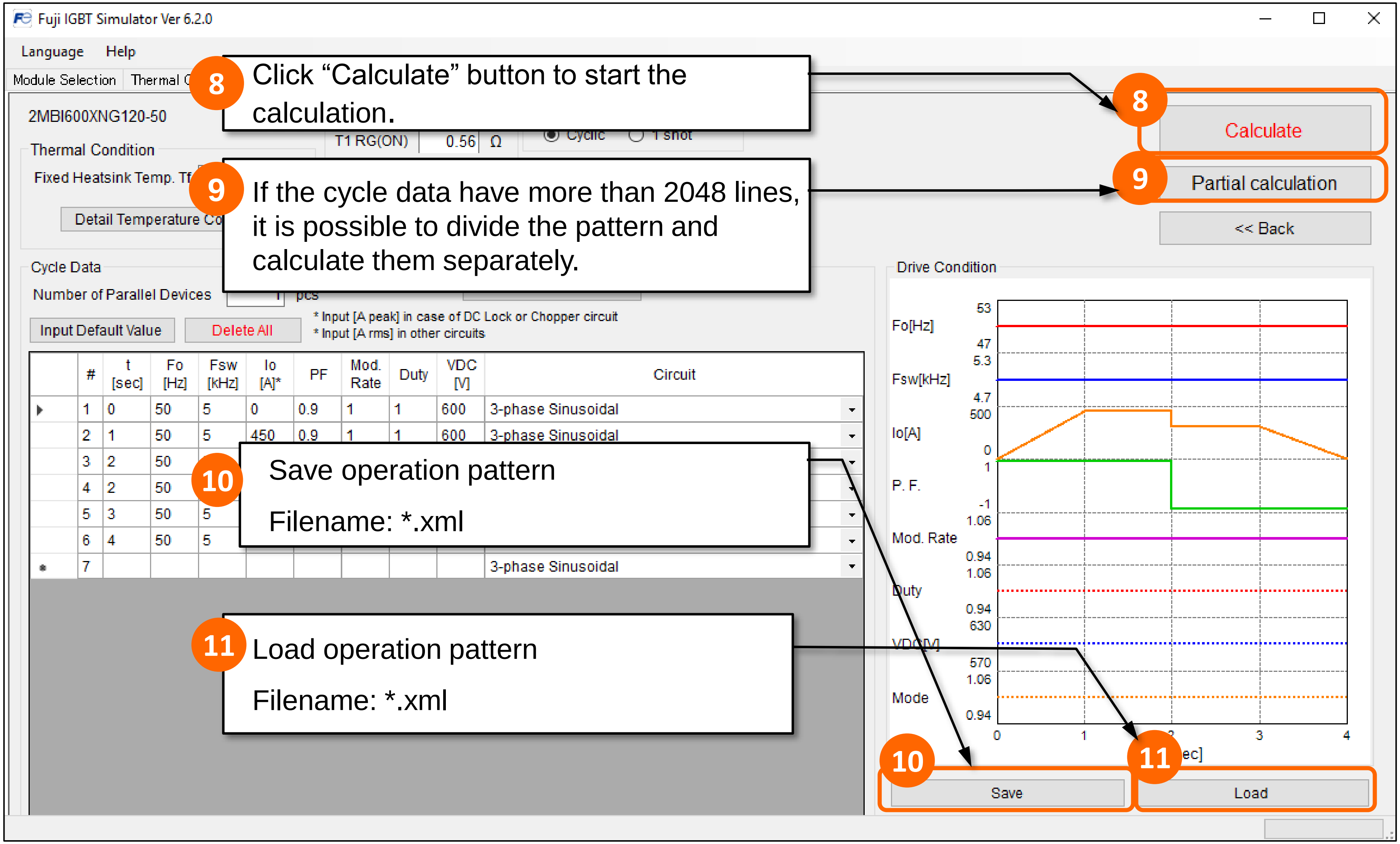
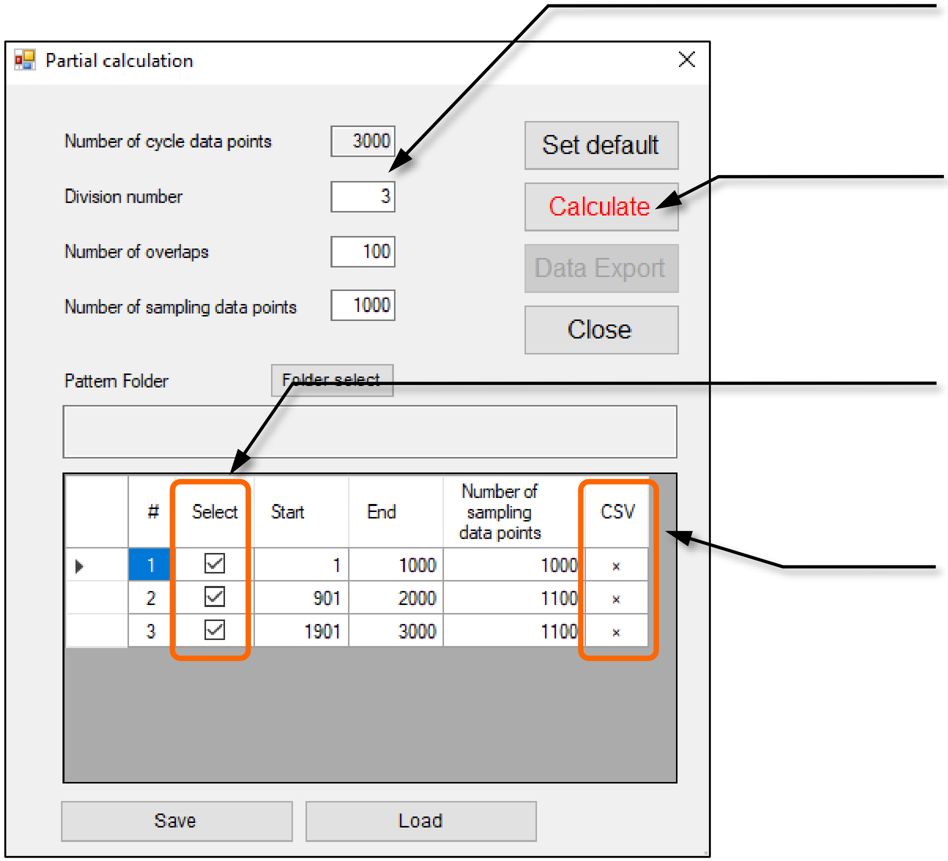


Partial Calculation



Number of splits of cycle data.

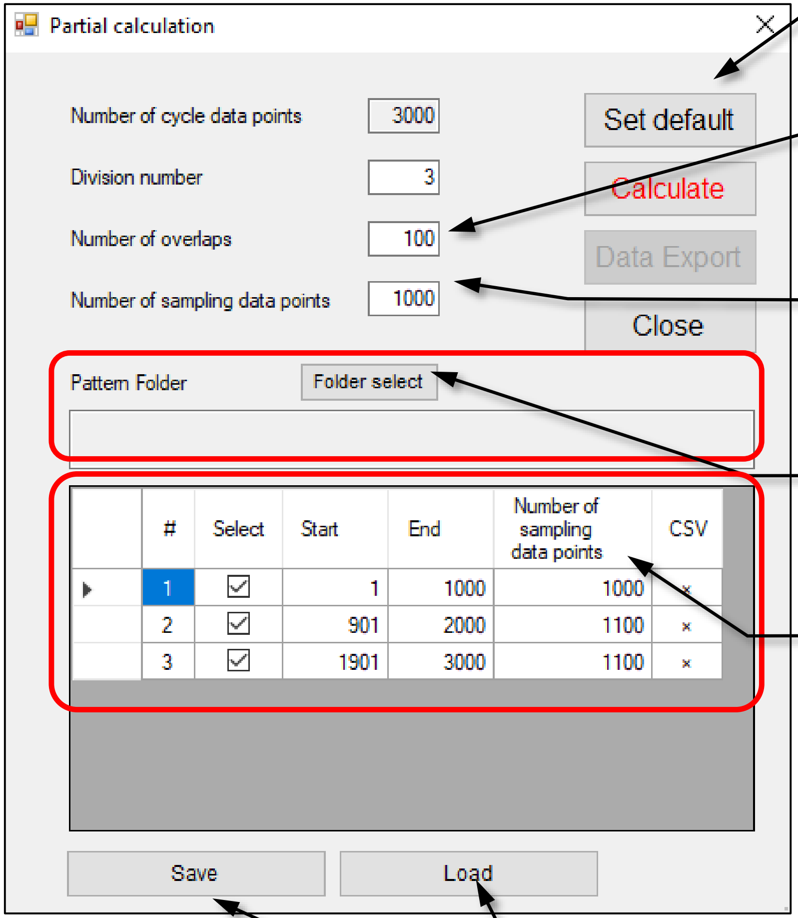
Calculate the splitted data.

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.

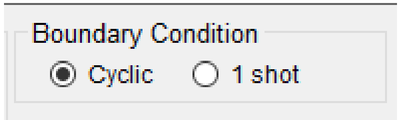
The information in the partial calculation table are based on the entered division number, number of overlaps and number of sampling data points.

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

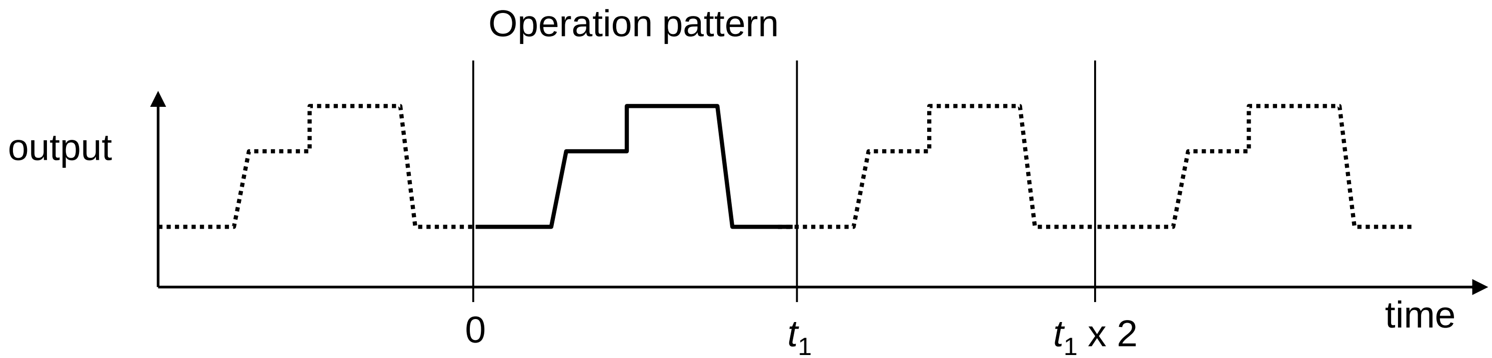
Save partial calculation table.

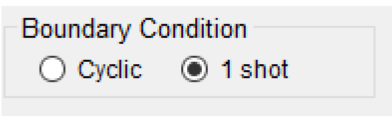
Load the saved partial calculation table.

Cycle Mode Calculation Boundary Condition

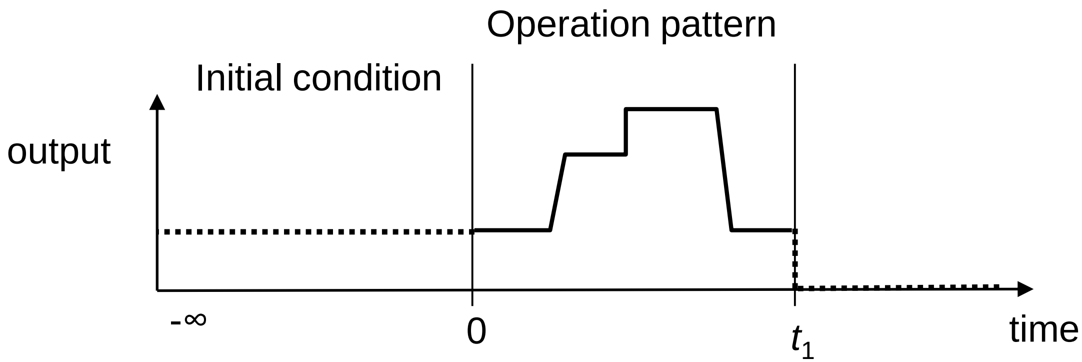


Cyclic mode: The load cycle pattern is repeated continously.





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

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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

A

Parameter values linearly change between two operation points.

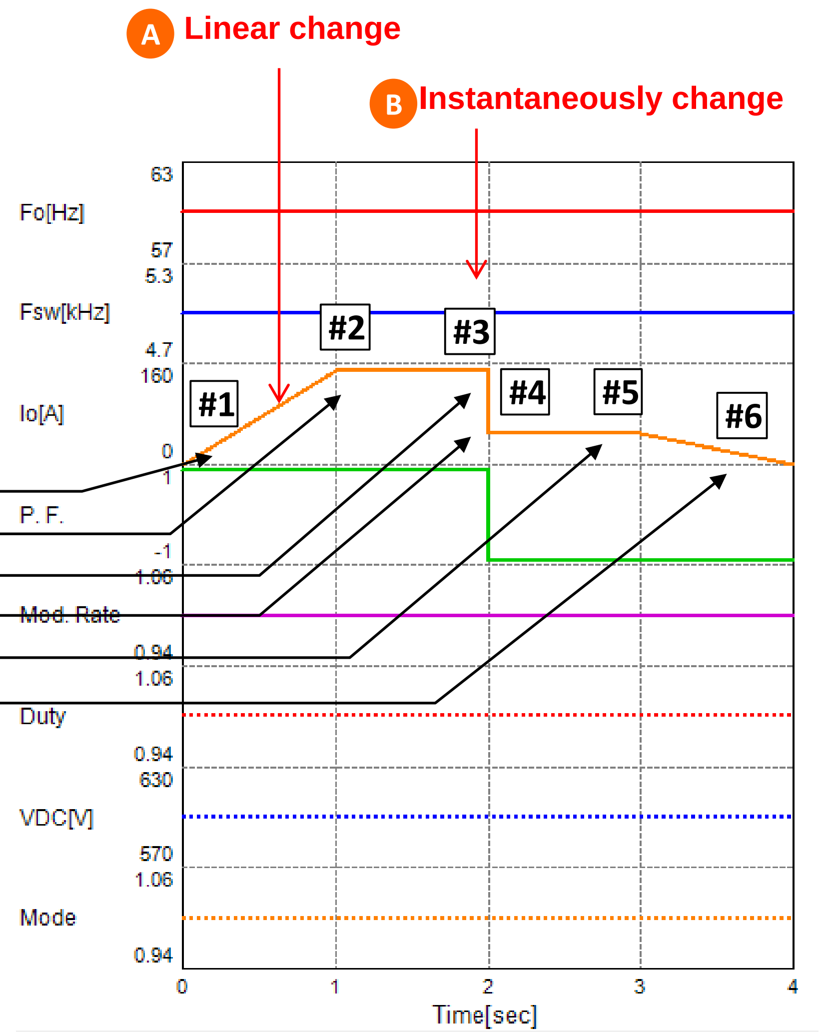
Example: #1 → #2 [Io]

	#	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]



Set Load Cycle

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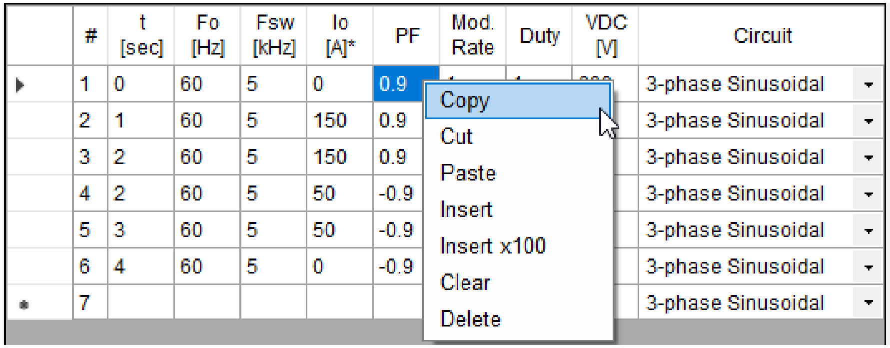
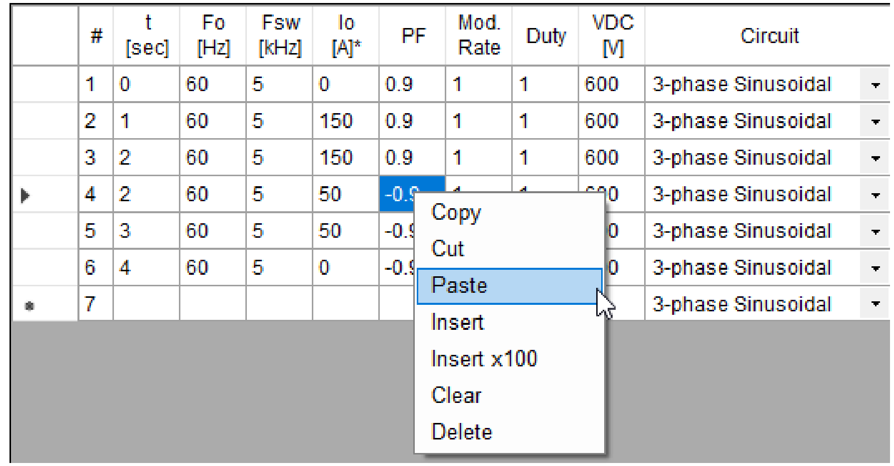
Copy & Paste cell(s) value

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

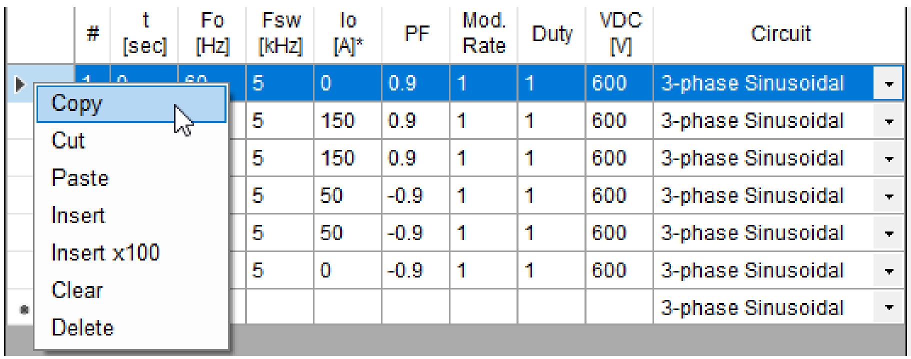


Select cell(s) → Right click → Paste

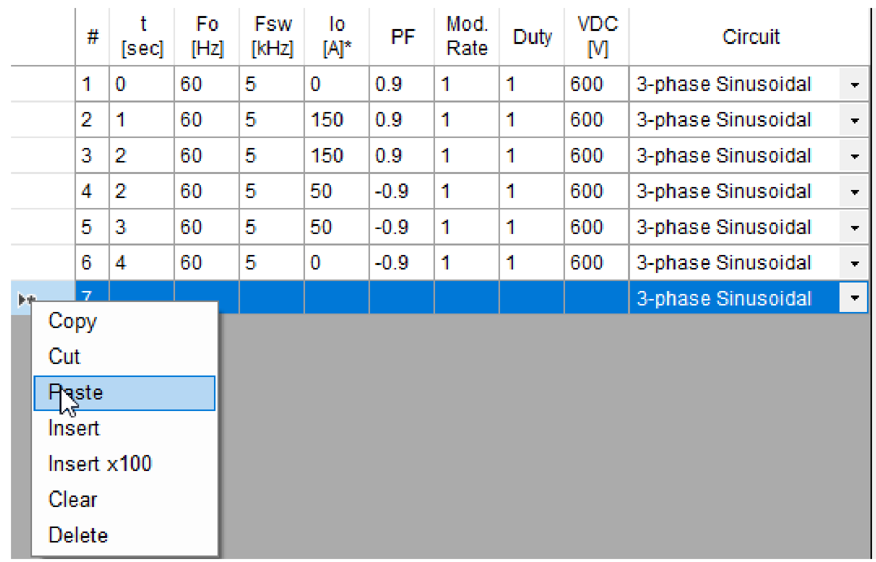


Copy & Paste line

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



Select a line → Right click → Paste



Simulation Results (Cycle Calculation)

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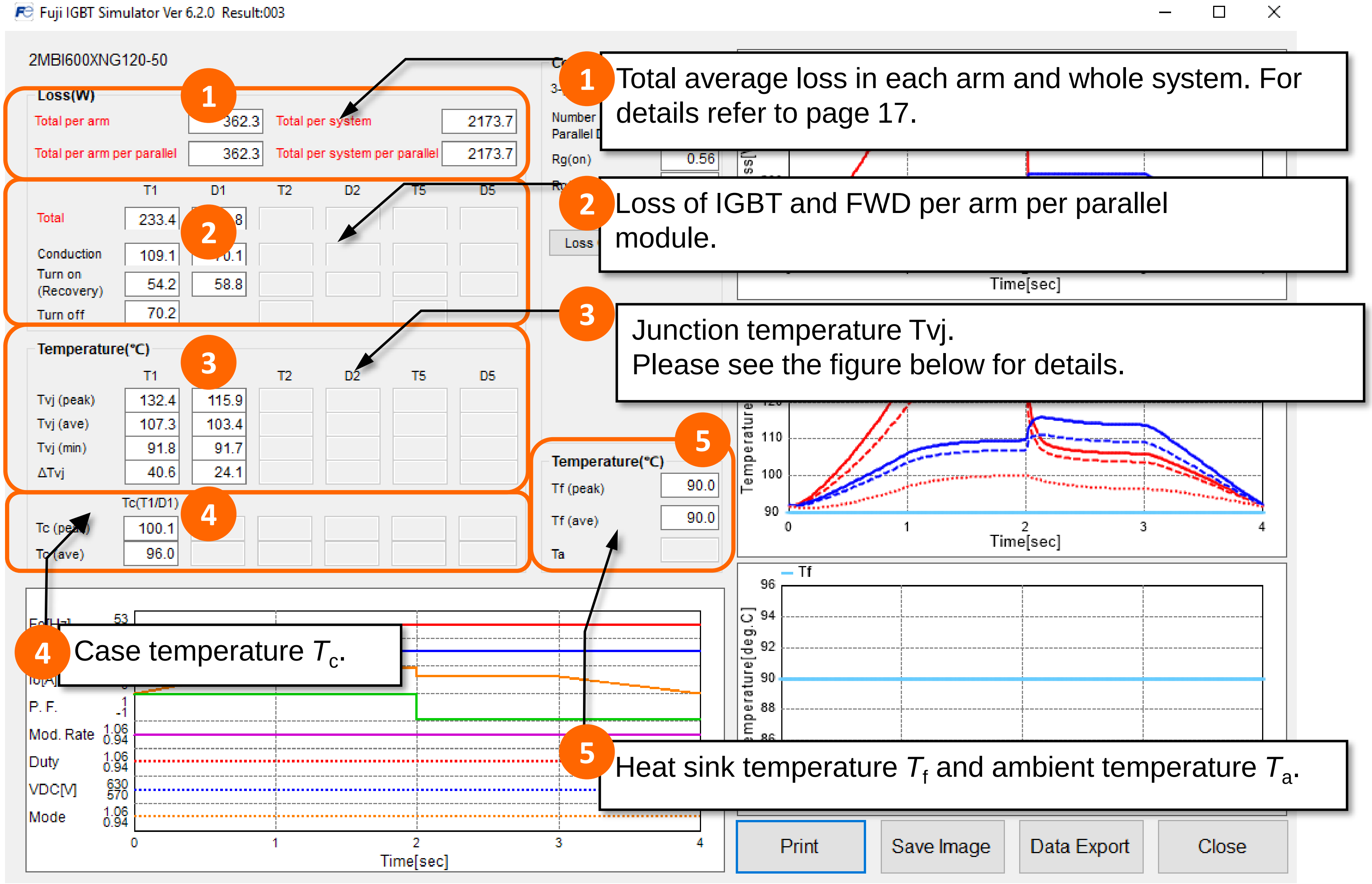

1. Total average loss in each arm and whole system. For details refer to page 17.
2. Loss of IGBT and FWD per arm per parallel module.
3. Junction temperature Tvj. Please see the figure below for details.
4. Case temperature T_c.
5. Heat sink temperature T_f and ambient temperature T_a.

Simulation Results (Cycle Calculation)

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1 **Loss curves**

2 **Temperature curves**

3 **Temperature curves**

4 **Print the window**

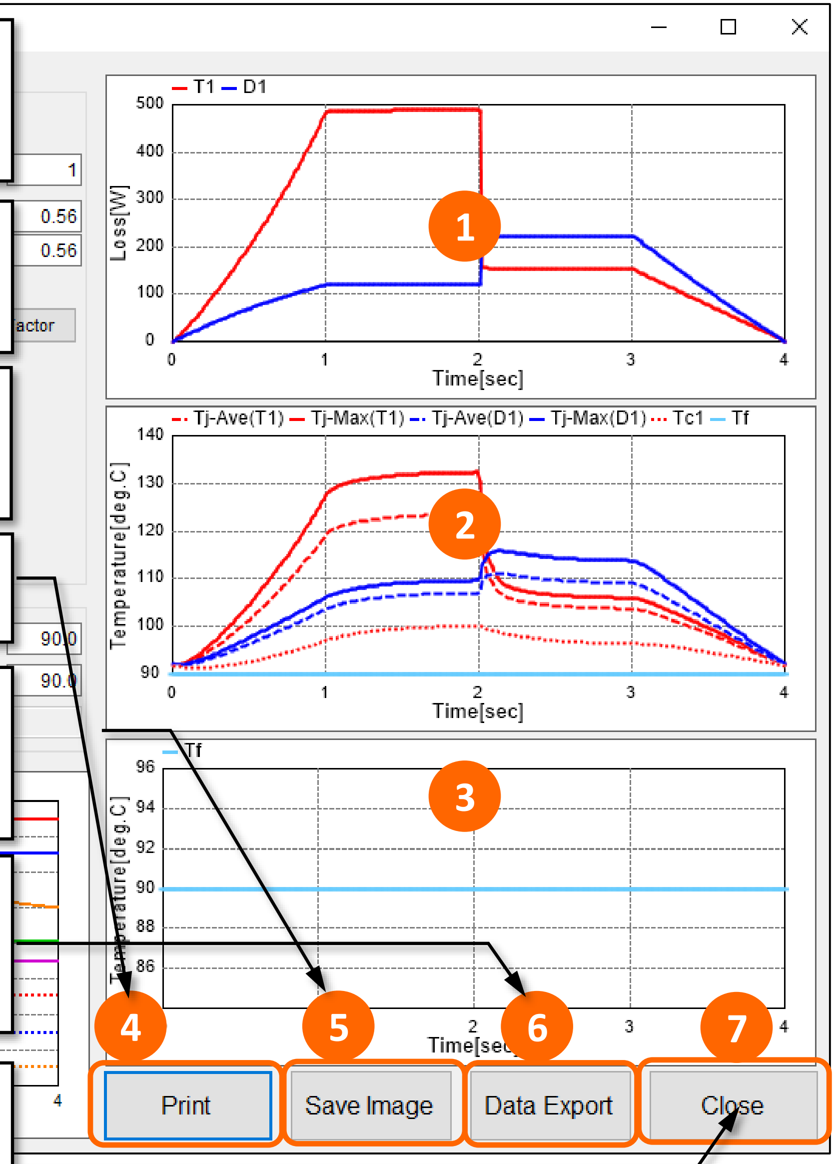
5 **Save the window**

Filename: *.xml

6 **Export the results**

Filename: *.csv

7 **Close the window**



Circuits & PWM Methods

Circuits & Modulation Methods

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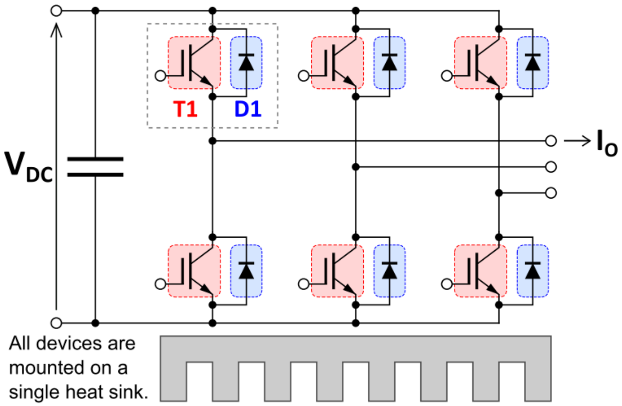
This page shows a list of circuits and PWM methods that are supported by the simulator.

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

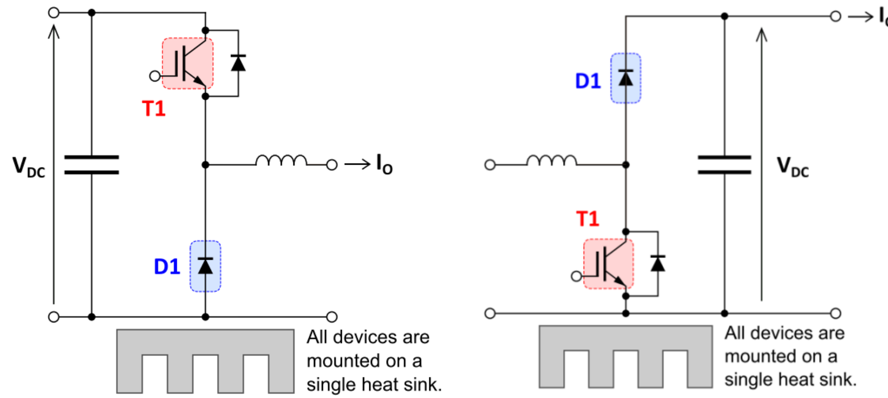
3-Phase 2-Level



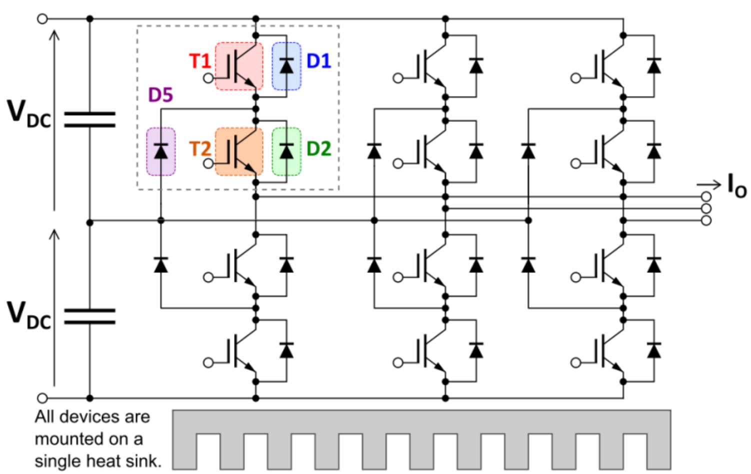
DC Chopper

(Buck)

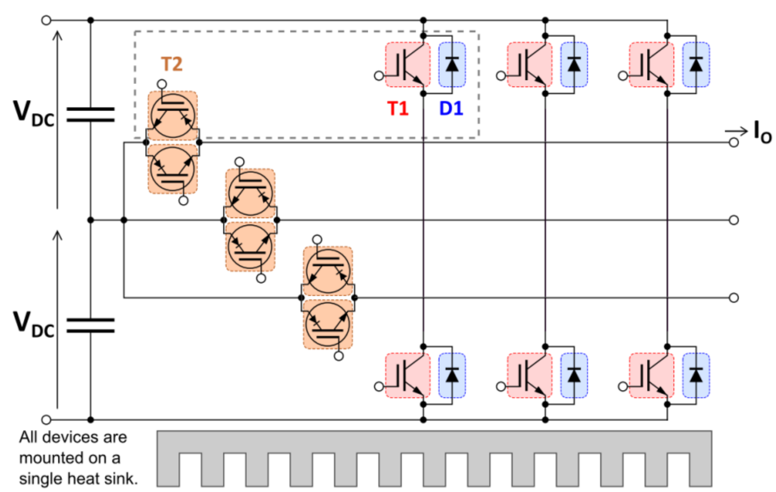
(Boost)



3-Phase 3-Level I-type



3-Phase 3-Level AT-type



Circuit: 3-Phase 3-Level type

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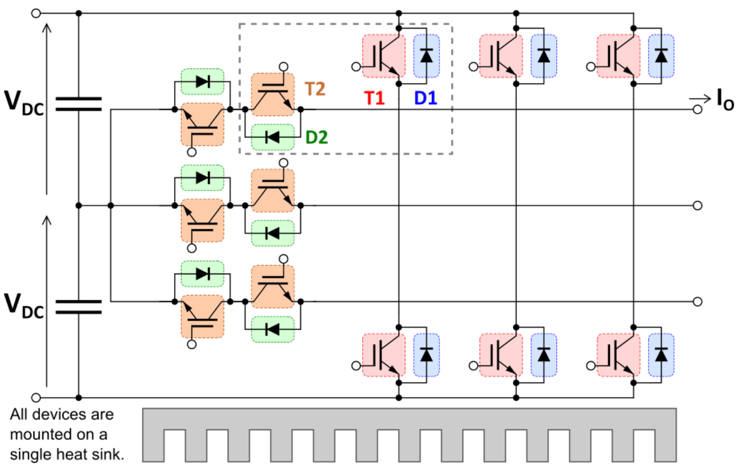
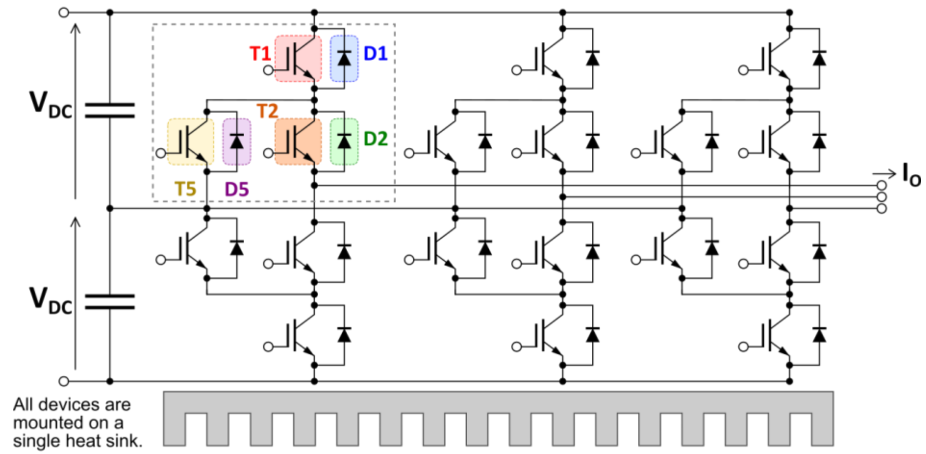
3-Phase 3-Level T-type



3-Phase 3-Level A-NPC-type



PWM Method (SPWM, SVPWM)

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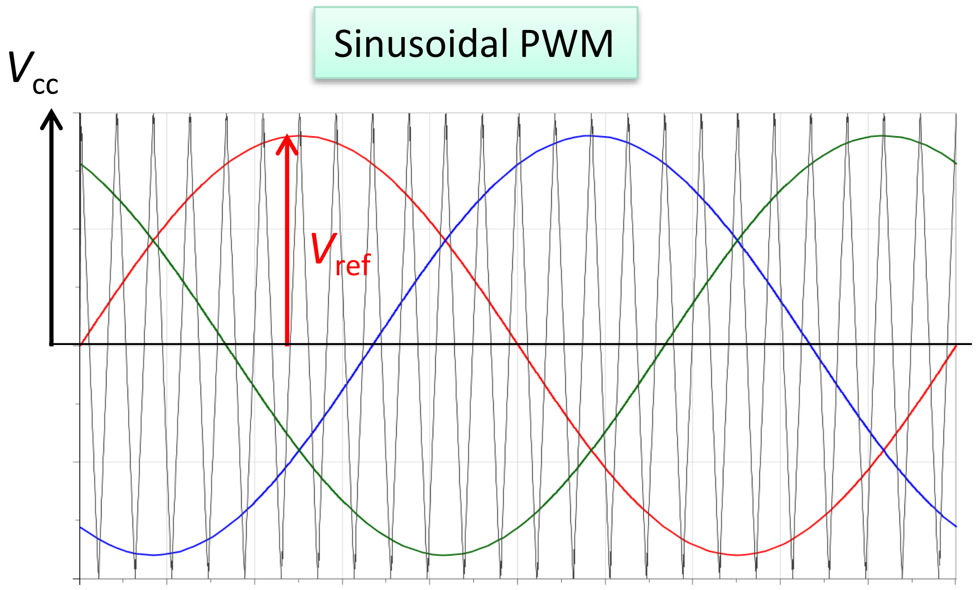
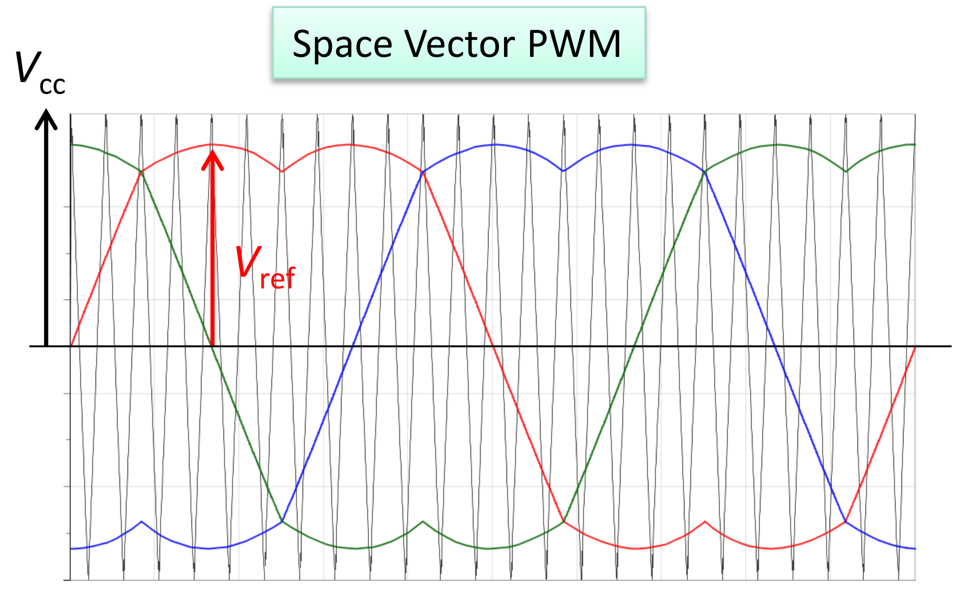


The reference voltage is a sinusoidal waveform.

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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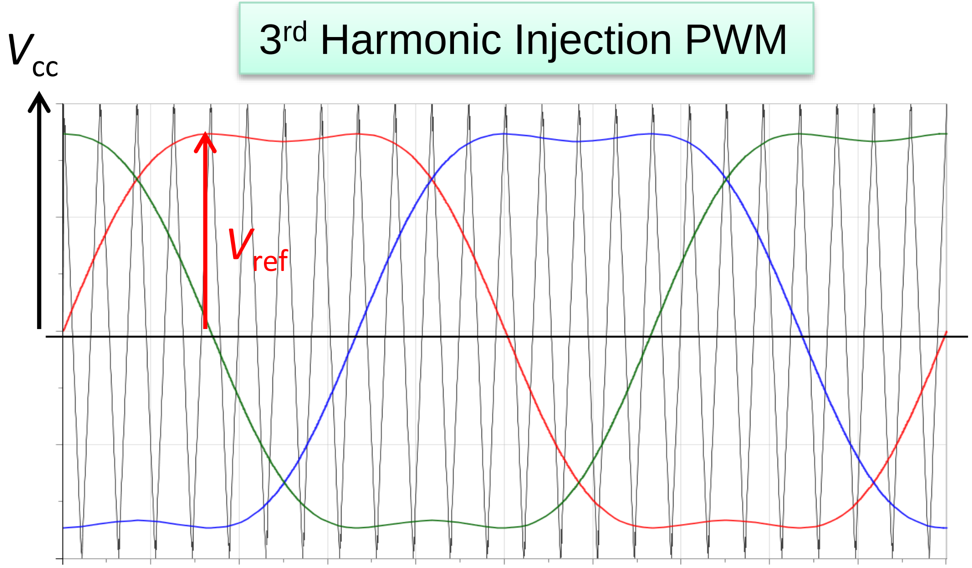


The amplitude of the reference voltage Vref is defined by the following equation using modulation ratio *m*

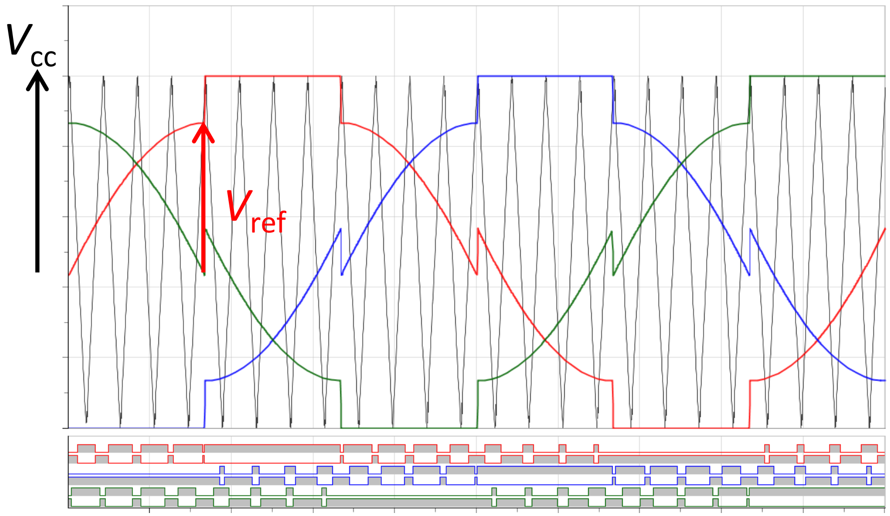
$$V_{\mathrm{ref}} = \frac{\sqrt{3}}{2} m V_{\mathrm{dc}}$$

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



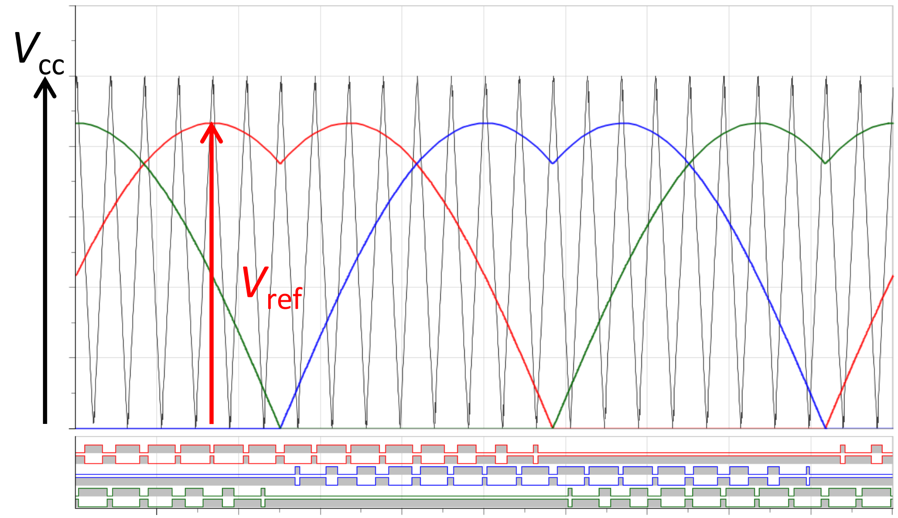
The amplitude of the reference voltage Vref is defined by the following equation using modulation ratio *m*.

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

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*.

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

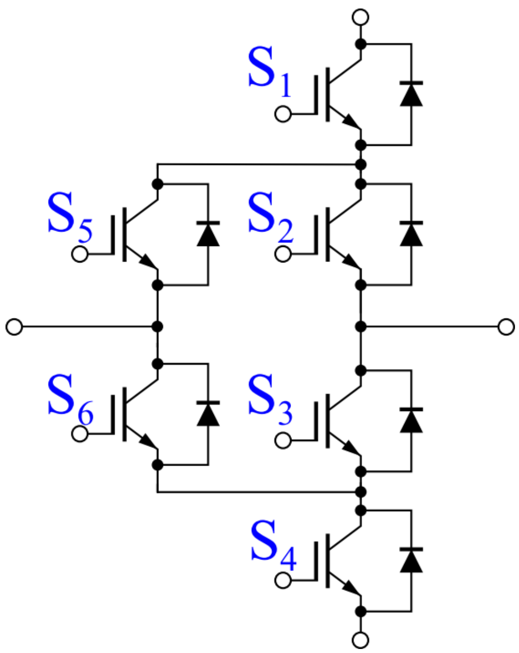
m is defined to be the same output voltage to the sinusoidal PWM.

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

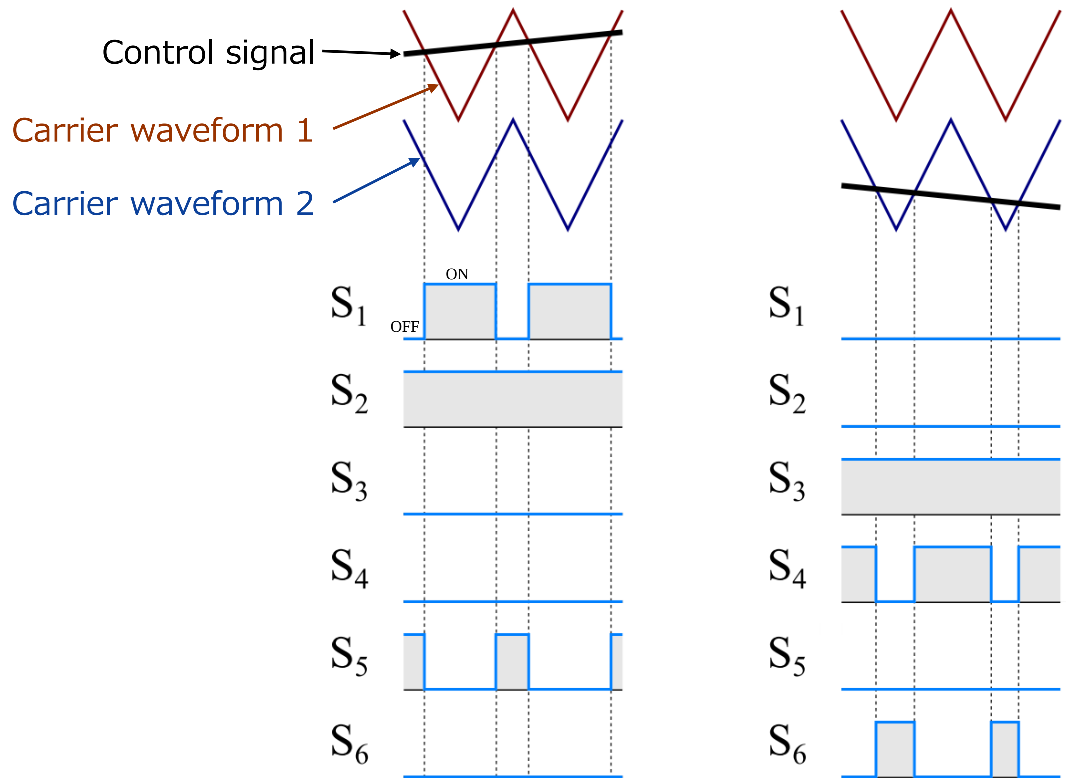
PWM Method（A-NPC circuit）

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)



Motor DC Lock Operation

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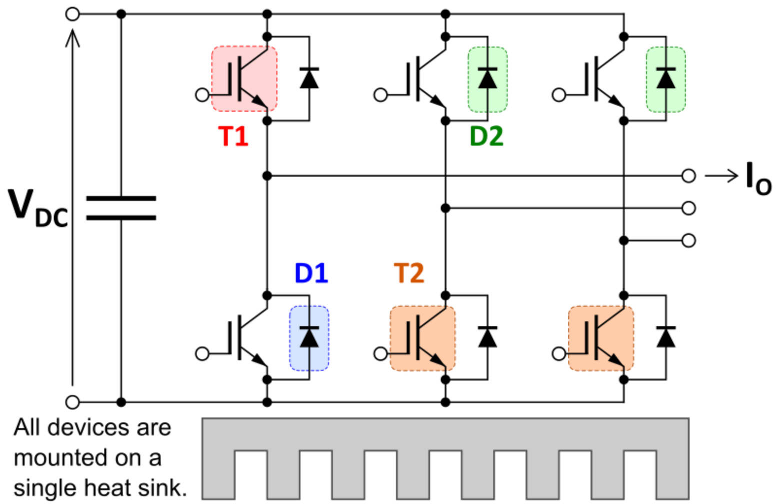
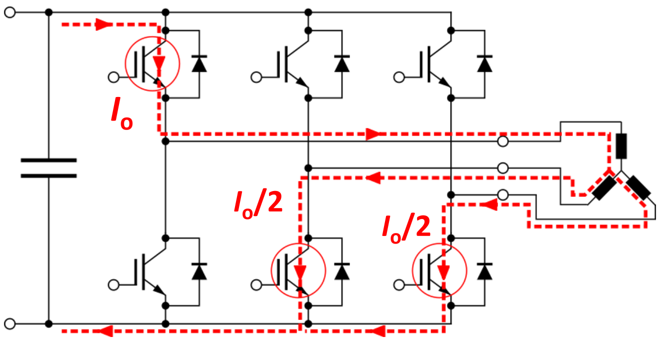
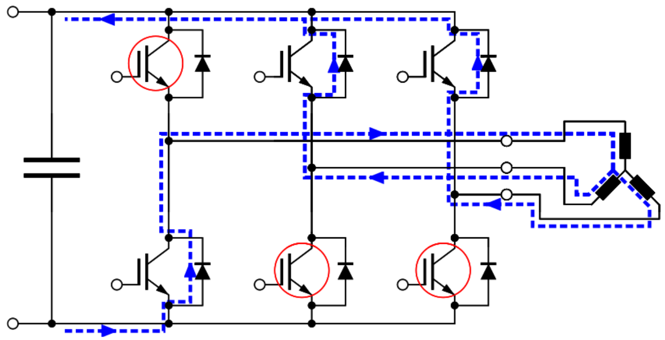
Calculate the IGBT / FWD loss when locking the motor rotation with a servo drive or the like.

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.



Current path when IGBT is off.

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.

If you have any questions, please contact us.

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

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