

# **FUJI IGBT Simulator Ver. 6.2 User Manual**

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1. Software Setup	----- p.4
2. Menu	----- p.5
3. Module Selection	----- p.6
4. Set temperature condition	----- p.7
5. Single Mode Calculation	----- p.12
6. Parameter Sweep Calculation	----- p.20
7. Cycle Mode Calculation	----- p.23
8. Application circuit and PWM control	----- p.35

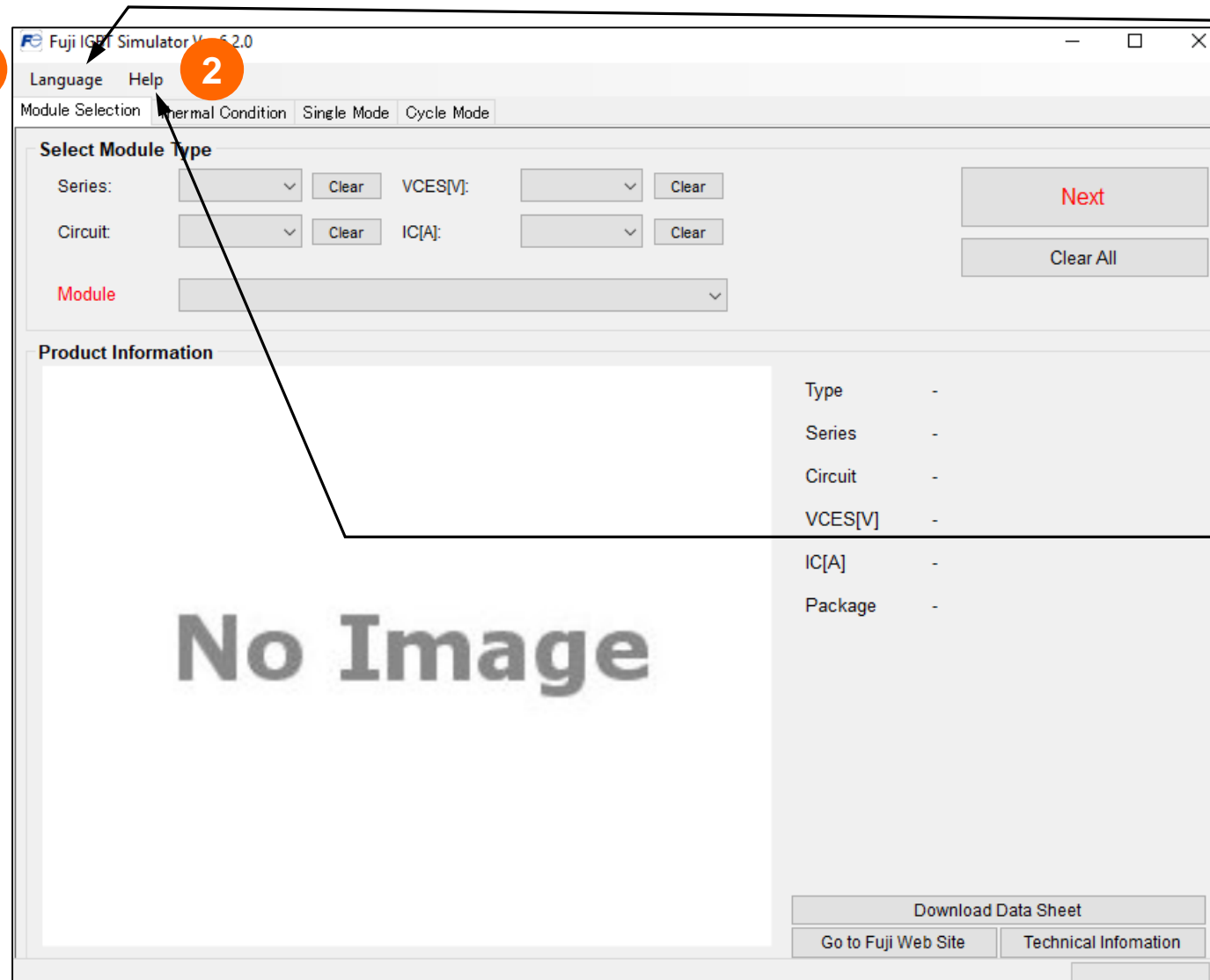
This software is suitable for Microsoft® Windows® Windows7, Windows & Windows10.

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.

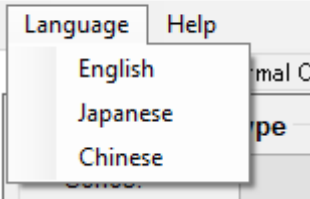
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## Select language

- English
- Japanese
- Chinese

Fuji IGBT Simulator Ver 6.2.0

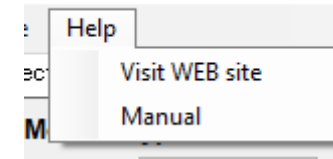


## Help

Visit Fuji Web site to get the latest version.

Check the version.

IGBT Simulator Ver 6.2.0



# Module Selection

The screenshot shows the 'Module Selection' tab in the Fuji IGBT Simulator. The interface includes a 'Select Module Type' section with dropdowns for Series, Circuit, VCES[V], and IC[A], each with a 'Clear' button. A 'Module' dropdown is set to '2MBI600XNG120-50'. A 'Next' button is visible. Below this is a 'Product Information' section showing a 3D model of the M285 module (dimensions 62x150), a circuit diagram with a thermistor, and a table of specifications.

Parameter	Value
Type	2MBI600XNG120-50
Series	X series
Circuit	2-Pack
VCES[V]	1200
IC[A]	600
Package	M254

At the bottom, there are three buttons: 'Download Data Sheet', 'Go to Fuji Web Site', and 'Technical Information'.

- 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  $T_c$

a **Fixed Case Temperature**  
Calculate  $T_c$  as constant

b **Calculate Case Temperature**  
Calculate  $T_c$  using thermal resistance  $R_{th(c-f)}$  case to heat sink

2 When calculating  $T_c$ , input  $R_{th(c-f)}$  ( $^{\circ}\text{C/W}$ )

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

Thermal Resistance Model

IGBT1 FWD1 IGBT2 FWD2

Junction temp.  $T_{vj}(T1)$   $T_{vj}(T2)$

Case temp.  $T_{c1}$   $T_{c2}$

Heat sink temp.  $T_f$

Ambient temp.  $T_a$

Thermal grease

Heat sink

Thermal impedance model (Foster equivalent network)

$$Z_{th}(t) = \sum_{n=1}^4 r_n \left\{ 1 - \exp\left(-\frac{t}{\tau_n}\right) \right\}$$

$$\tau_n = r_n \cdot c_n$$

# Input thermal condition (2)

**Case Temperature:  $T_c$**

☐ Fixed Case Temp.  °C ☒ Calculate Case Temp.

**Case - Heatsink Thermal Resistance:  $R_{th(c-f)}$**

T1/D1  °C/W

**Heat Sink Temperature:  $T_f$**

☒ Fixed Heatsink Temp.  °C ☐ Calculate Heatsink Temp.

**Heatsink Thermal Impedance:  $Z_{th(f-a)}$**

**i** ☒ Constant Heatsink Thermal Resistance

$R_{th(f-a)}$   °C/W

**ii** ☐ User Defined Heatsink Thermal

$r_1$	<input type="text" value="0"/>	$\tau_1$	<input type="text" value="0"/>
$r_2$	<input type="text" value="0"/>	$\tau_2$	<input type="text" value="0"/>
$r_3$	<input type="text" value="0"/>	$\tau_3$	<input type="text" value="0"/>
$r_4$	<input type="text" value="0"/>	$\tau_4$	<input type="text" value="0"/>

$R_{th(f-a)}$

**Ambient Temperature:  $T_a$**

Ambient Temp.  °C

**Thermal Resistance Model**

IGBT1 FWD1

Junction temp.  $T_{vj}(T1)$   $T_{vj}(D1)$

Case temp.  $T_{c1}$

Heat sink temp.  $T_a$

Ambient temp.  $T_a$

**Thermal impedance model (Foster equivalent network)**

$$Z_{th}(t) = \sum_{n=1}^4 r_n \left\{ 1 - \exp\left(-\frac{t}{\tau_n}\right) \right\}$$

$$\tau_n = r_n \cdot c_n$$

Input heat sink condition

## a. Fixed heat sink condition

Calculate with constant  $T_f$

## b. Calculate heat sink temperature

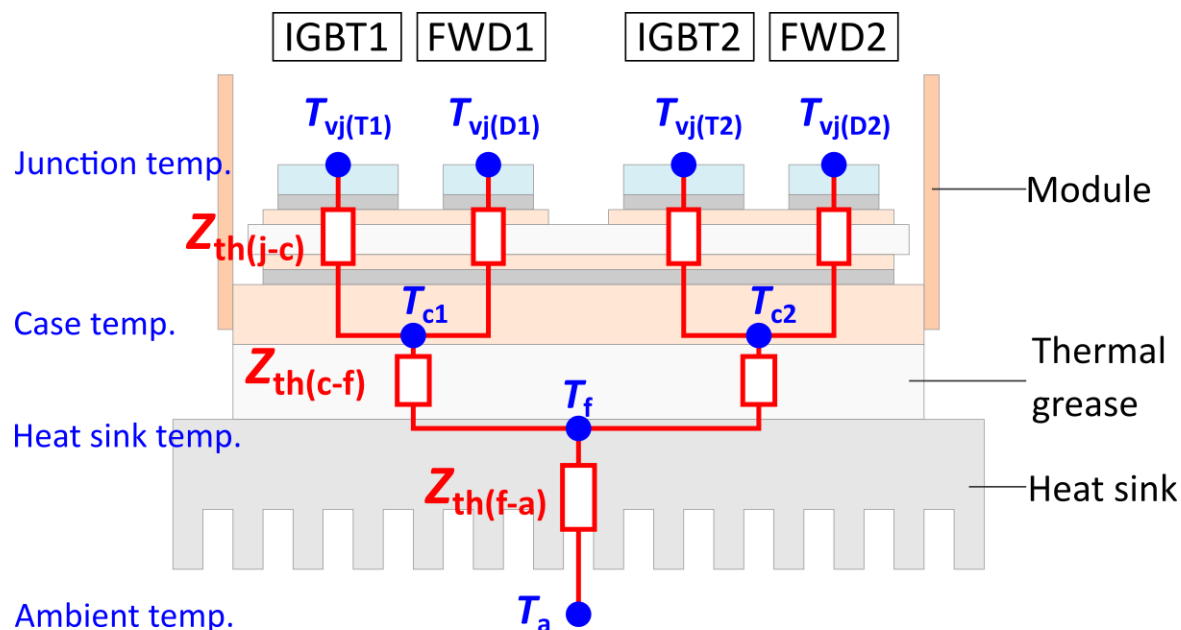
$T_f$  is calculated using thermal impedance  $Z_{th(f-a)}$  between heat sink and ambient temperature

- Input  $Z_{th(f-a)}$  as constant without any time constants.
- If  $Z_{th(f-a)}$  is represented by a 4<sup>th</sup> order Foster network model, input  $r_1$  to  $r_4$  and  $\tau_1$  to  $\tau_4$ .



# Thermal Circuit Model (1)

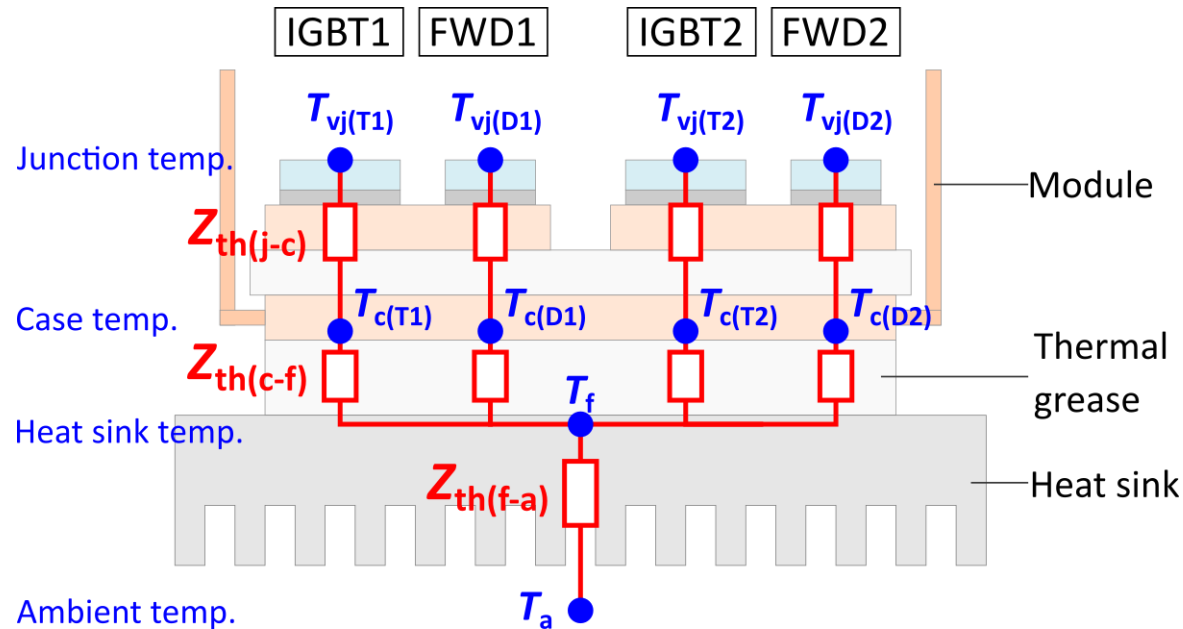
In the simulator, calculations are performed based on the following thermal circuit model.



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)

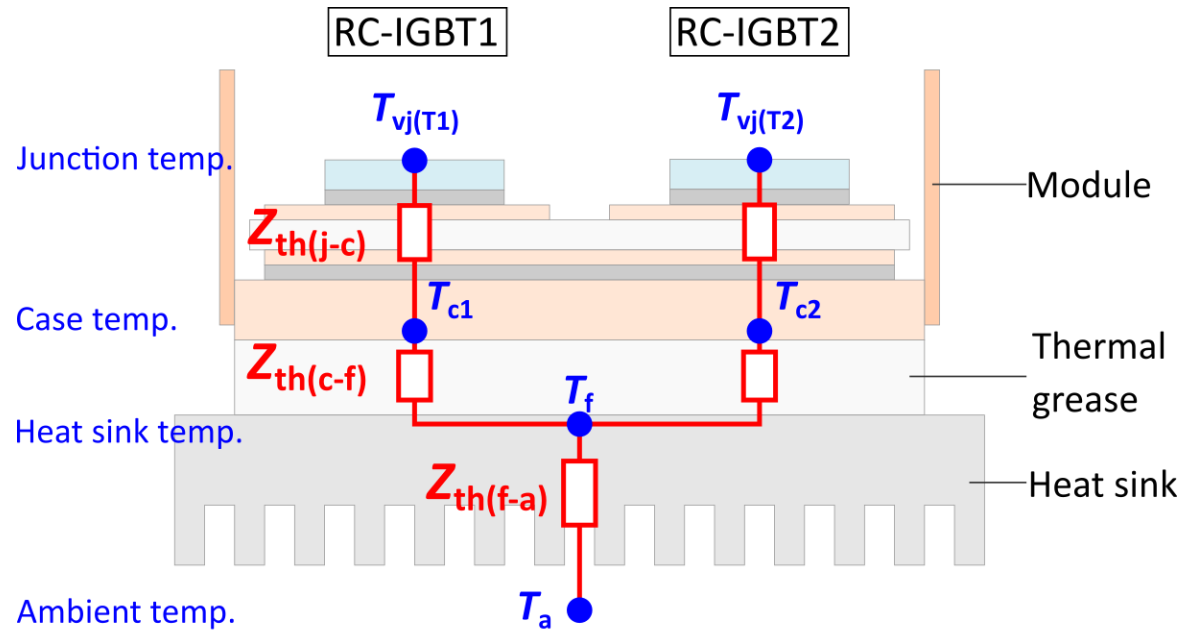
The following thermal circuit model is applied for modules with copper baseplate.



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 parallel modules.

2MBI600XNG120-50

Language Help

Module Selection Thermal Condition **Single Mode** Cycle Mode

Circuit  
3-Phase 2-Level Inverter

PWM Modulation Method  
Sinusoidal

Thermal Condition  
Fixed Heatsink Temp. Tf 90 °C

Detail Temperature Condition

Calculation Condition

Number of Parallel Devices 2 pcs

Output Freq. Fo 50 (Hz)

Output Current Io 300 (Arms)

Switching Freq. Fsw 5 (kHz)

Power Factor 0.8

Modulation Rate 0.9

Duty 0

DC Link Voltage VDC 0 (V)

T1 RG(ON) 0.56 (Ω)

T1 RG(OFF) 0.56 (Ω)

T2 RG(ON) 0.56 (Ω)

T2 RG(OFF) 0.56 (Ω)

Loss Calibration Factor

Explanation

V<sub>DC</sub>

T1 D1

All devices are mounted on a single heat sink.

# Loss Calibration Factor

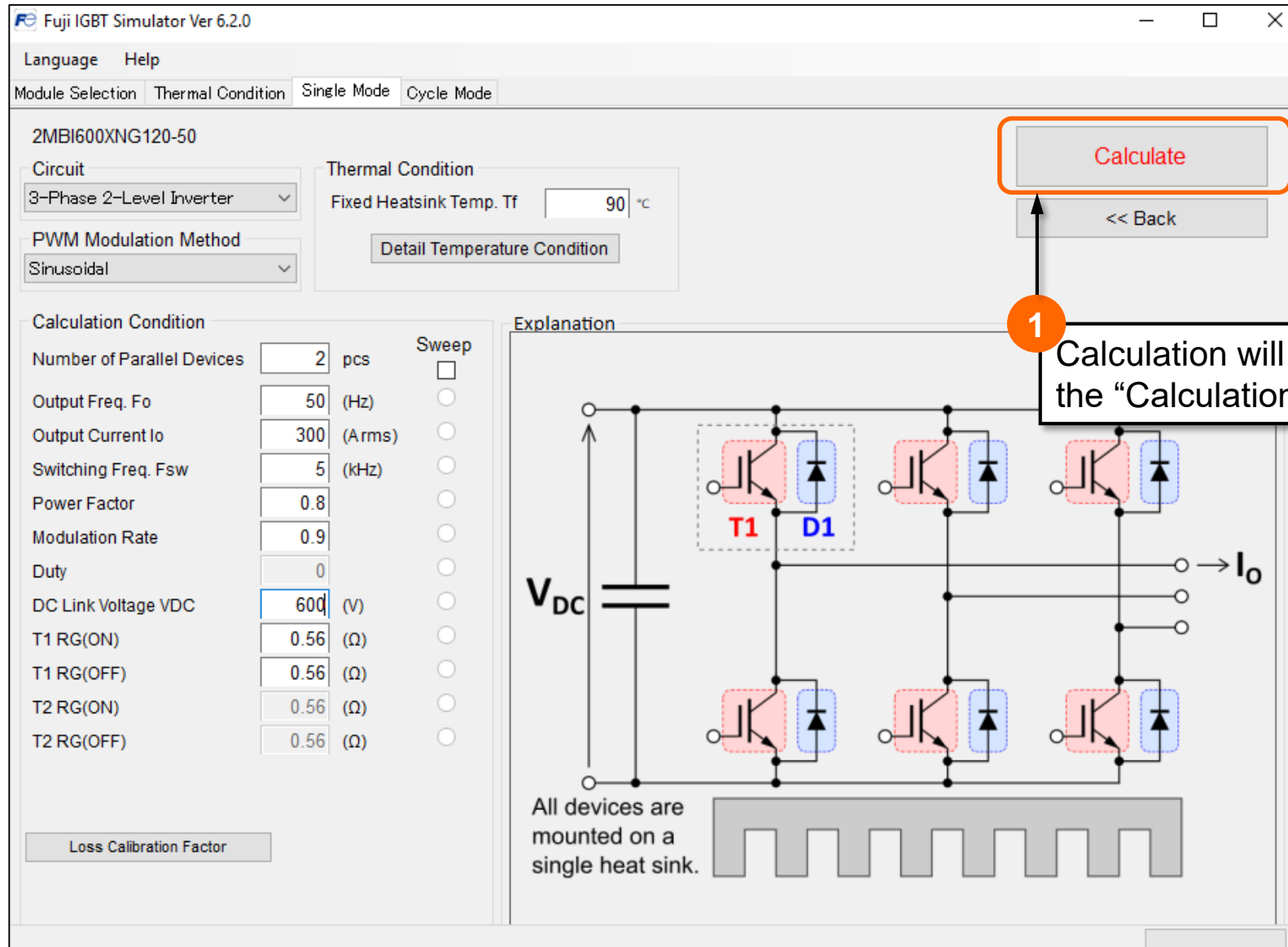
The screenshot displays the Fuji IGBT Simulator Ver 6.2.0 interface. The main window shows various configuration tabs and parameters. A callout box with the number 6 points to the 'Loss Calibration Factor' tab in the bottom left. Another callout box with the number 6 points to the 'Loss Calibration Factor' dialog box, which is open on the right side of the screen. The dialog box contains a list of loss components and their corresponding calibration factors, all set to 1.00. A third callout box explains that every generated loss by IGBT / FWD is multiplied with the provided calibration factor.

Click „Loss Calibration Factor“ tab.  
The dialog box to input coefficients for calibrating the loss calculation value will open.

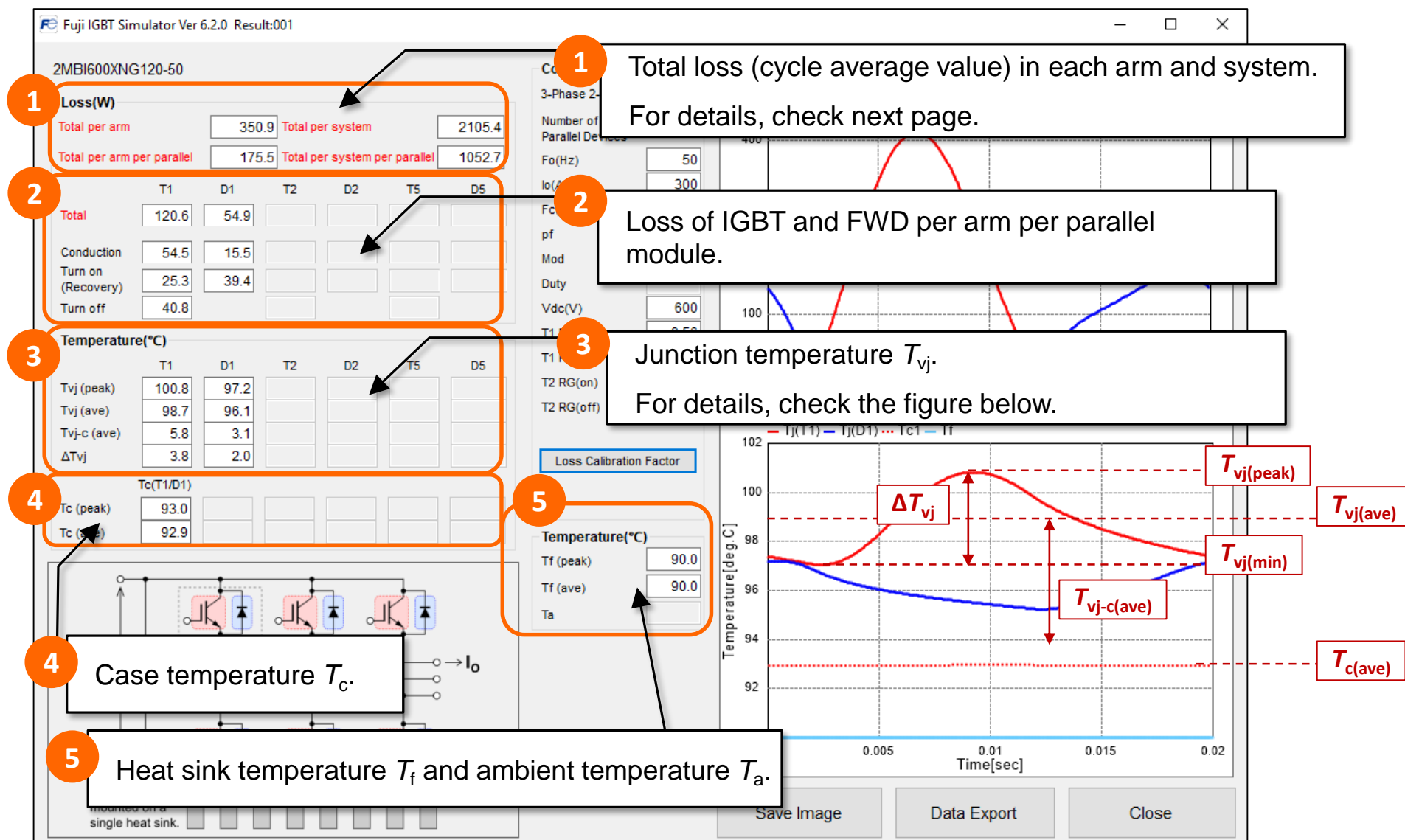
Every generated loss by IGBT / FWD is multiplied with the provided calibration factor.

Loss Component	Calibration Factor
IGBT conduction loss	1.00
IGBT turn-on loss	1.00
IGBT turn-off loss	1.00
FWD conduction loss	1.00
FWD reverse recovery loss	1.00

# Run Calculation



# Simulation Results (Single Mode)





# Simulation Results (Total Loss)

Fuji IGBT Simulator Ver 6.2.0 Result:001

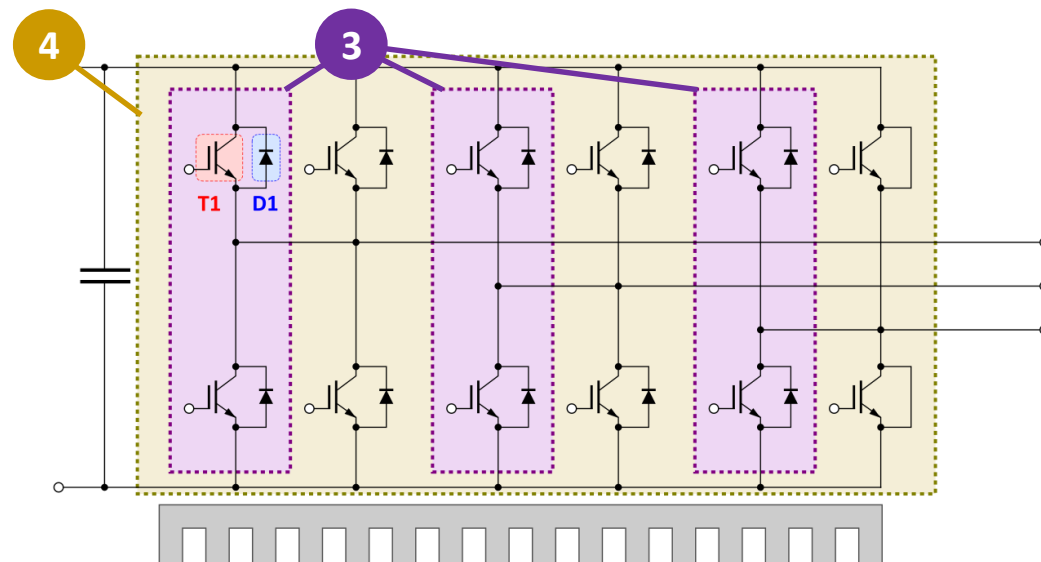
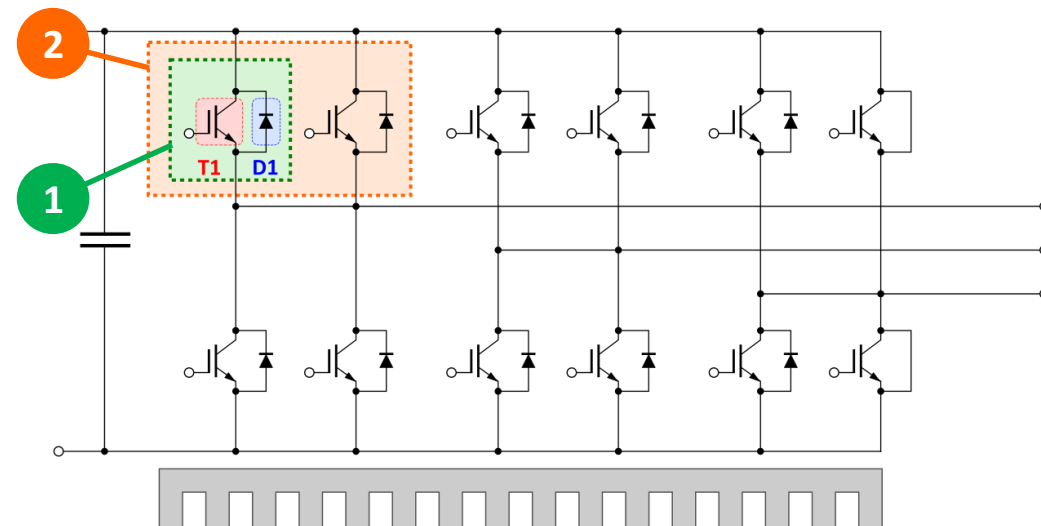
2MBI600XNG120-50

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

	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)

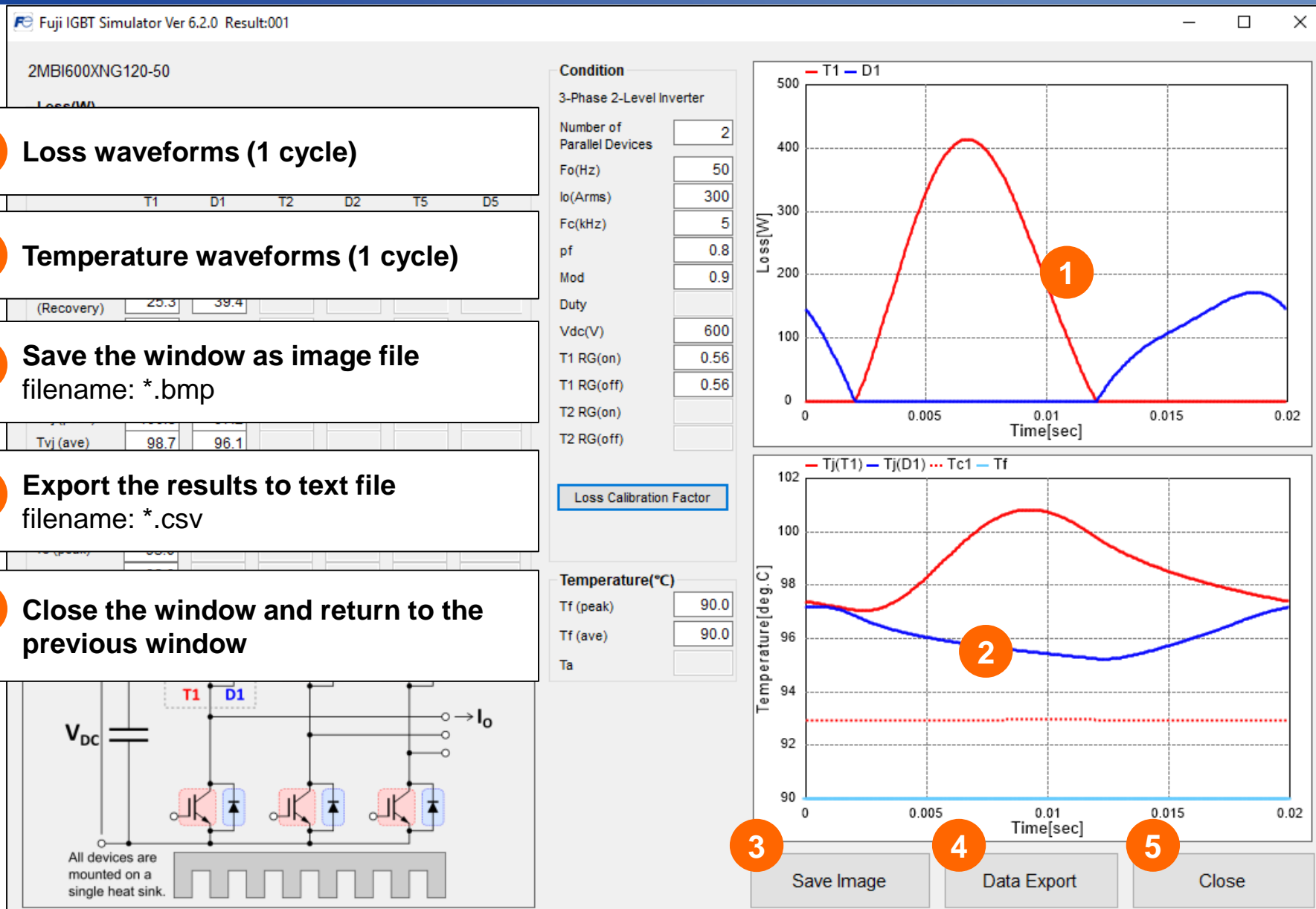
1 Loss waveforms (1 cycle)

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



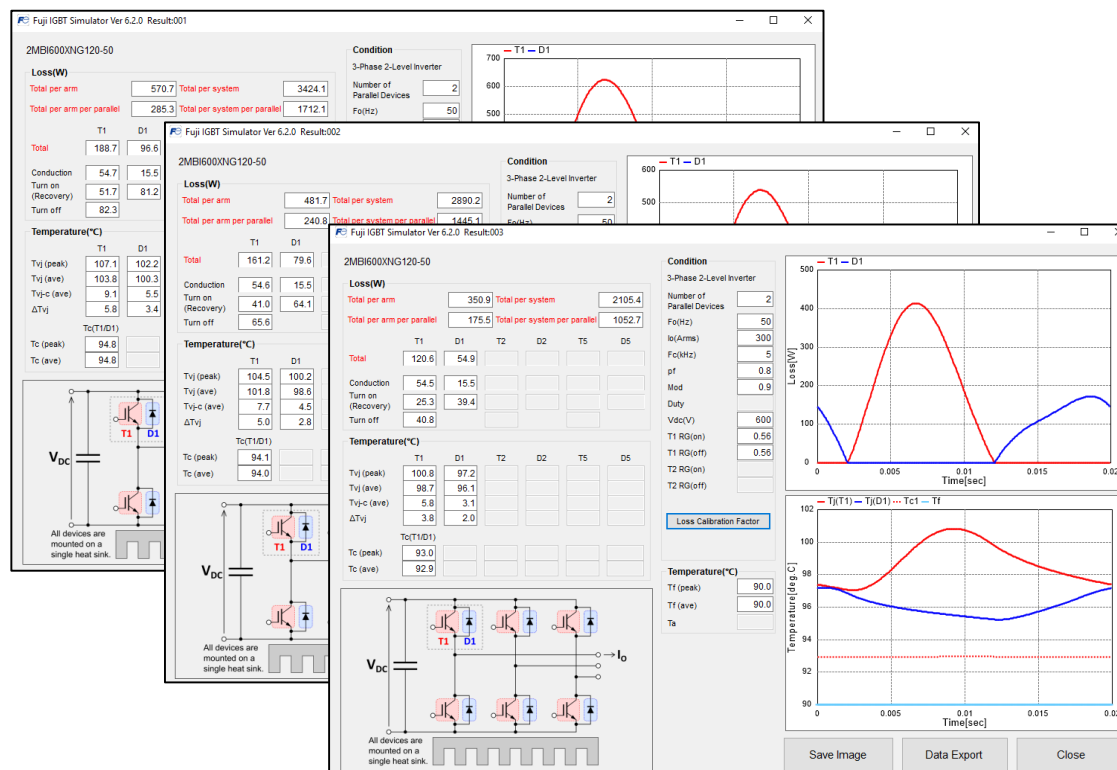
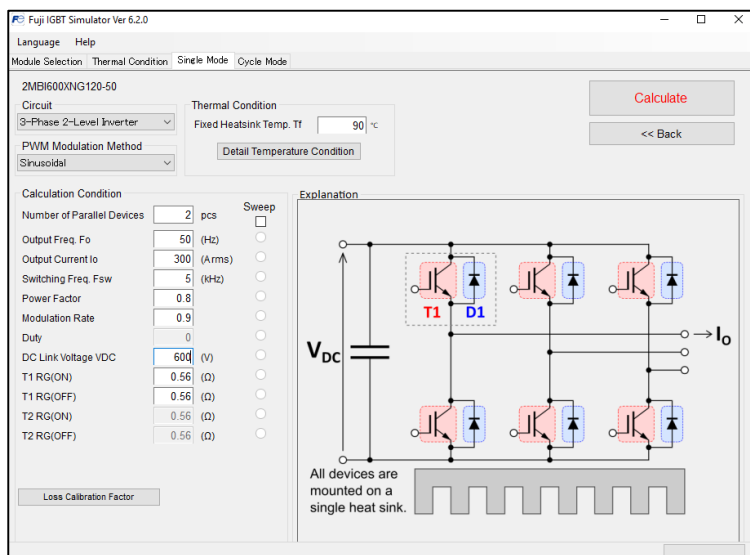
# Display Multiple Results

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, ... continuous numbering

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



# Parameter Sweep Calculation

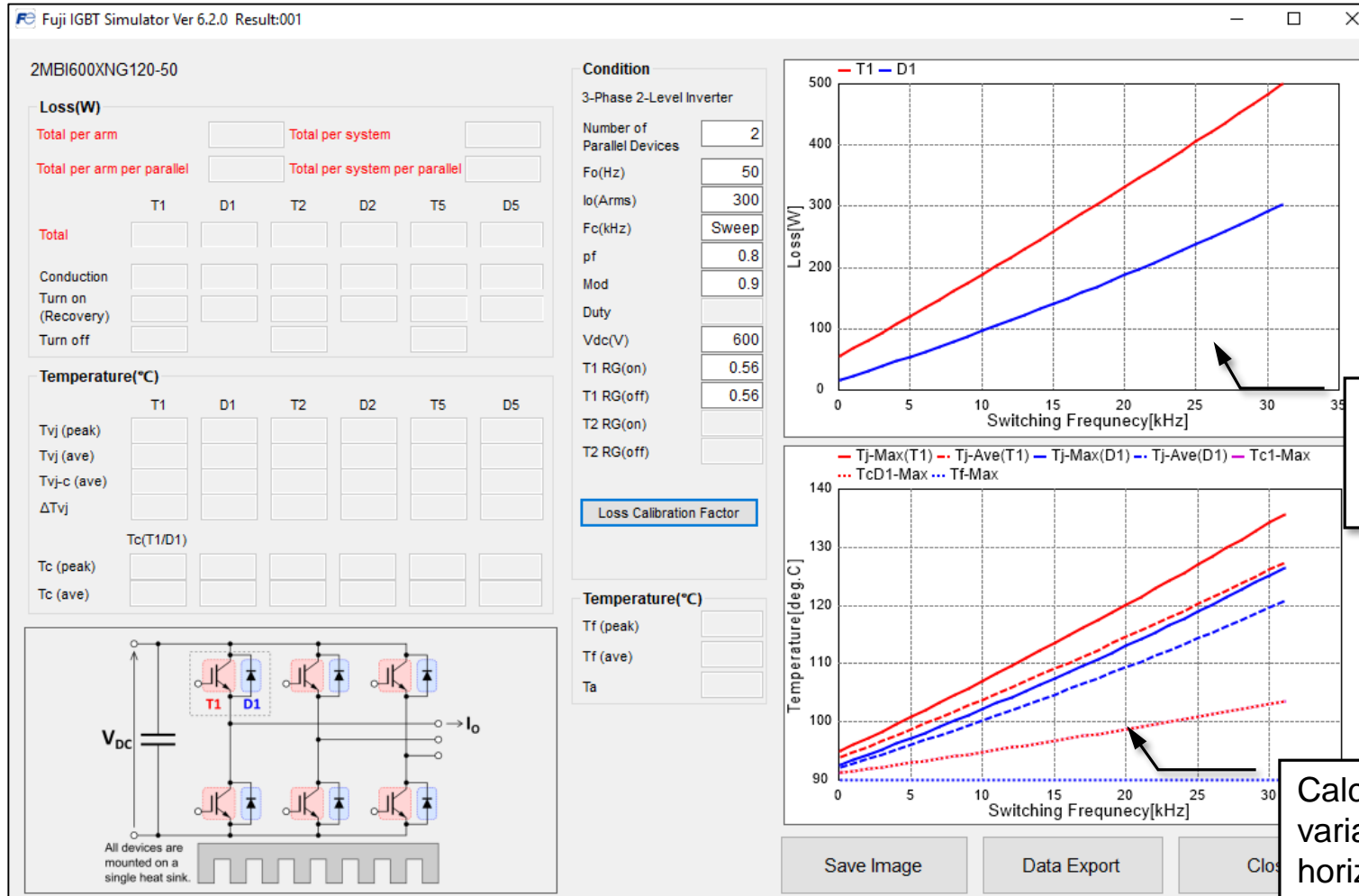
In the parameter sweep calculation one of the simulation parameter is variable.  
It is possible to calculate the change of losses and temperatures.

# Parameter Sweep Calculation

The screenshot displays the Fuji IGBT Simulator Ver 6.2.0 interface. The 'Single Mode' tab is selected. The 'Calculation Condition' section on the left lists various parameters for a 3-Phase 2-Level Inverter, including Output Freq.  $F_o$ , Output Current  $I_o$ , Switching Freq.  $F_{sw}$ , Power Factor, Modulation Rate, Duty, DC Link Voltage  $V_{DC}$ , and thermal parameters for T1 and T2. The 'Sweep' checkbox is checked. The 'Calculate' button is highlighted in red. The circuit diagram on the right shows a 3-phase inverter bridge with IGBTs and diodes, labeled T1 and D1, connected to a DC link and a load. The output current  $I_o$  is indicated. The text 'All devices are mounted on a single heat sink.' is visible at the bottom of the diagram.

- 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

**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.

**2MBI600XNG120-50**

Language Help

Module Selection Thermal Condition Single Mode **Cycle Mode**

Thermal Condition  
Fixed Heatsink Temp.  $T_f$   °C

Gate Resistance  
T1 RG(ON)  Ω  
T1 RG(OFF)  Ω  
T2 RG(ON)  Ω  
T2 RG(OFF)  Ω

Boundary Condition  
☒ Cyclic ☐ 1 shot

Sampling Number  
 ▼

Cycle Data  
Number of Parallel Devices  pcs

\* Input [A peak] in case of DC Load 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 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

Mode  
1.06  
0.94  
0 1 2 3 4  
Time[sec]



# Cycle Mode Calculation

Fuji IGBT Simulator Ver 6.2.0

Language Help

Module Selection Thermal Condition Single Mode **Cycle Mode**

2MBI600XNG120-50

Thermal Condition  
Fixed Heatsink Temp. Tf 90 °C  
Detail Temperature Condition

Gate Resistance  
T1 RG(ON) 0.56 Ω  
T1 RG(OFF) 0.56 Ω  
T2 RG(ON) 0.56 Ω  
T2 RG(OFF) 0.56 Ω

Boundary Condition  
☒ Cyclic ☐ 1 shot

Sampling Number 256

**5** Number of Parallel Devices 1 pcs

**6** Loss Calibration Factor

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 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.

Partial calculation

Waveform plots:  
Fo[Hz]: 47, 5.3  
Fsw[kHz]: 4.7, 500  
Io[A]: 0, 1  
P. F.: -1, 1.06  
Mod. Rate: 0.94, 1.06  
Duty: 0.94, 630  
VDC[V]: 630, 670

Save Load

# Cycle Mode Calculation

8 Click "Calculate" button to start the calculation.

9 If the cycle data have more than 2048 lines, it is possible to divide the pattern and calculate them separately.

10 Save operation pattern  
Filename: \*.xml

11 Load operation pattern  
Filename: \*.xml

The screenshot shows the Fuji IGBT Simulator Ver 6.2.0 interface. The 'Cycle Data' table is visible, showing parameters for 7 cycles. The 'Drive Condition' graph displays various waveforms over time. The 'Calculate' button is highlighted with a red box and a callout. The 'Partial calculation' button is highlighted with a red box and a callout. The 'Save' and 'Load' buttons are highlighted with red boxes and callouts. The 'Save' button is labeled '10' and the 'Load' button is labeled '11'.

#	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

Drive Condition

Graph showing Fo[Hz], Fsw[kHz], Io[A], P.F., Mod. Rate, Duty, VDC[V], and Mode over time (0 to 4 seconds).

# Partial Calculation

The screenshot shows the 'Partial calculation' dialog box. It contains several input fields and buttons. Annotations with arrows point to specific elements:

- An arrow points to the 'Number of cycle data points' input field, which contains the value '3000'.
- An arrow points to the 'Calculate' button, which is highlighted in red.
- An arrow points to the 'Folder select' button, which is located next to the 'Pattern Folder' label.
- An arrow points to the 'CSV' column in the table, which contains 'x' for all three rows.

The table in the dialog box is as follows:

#	Select	Start	End	Number of sampling data points	CSV
1	<input checked="" type="checkbox"/>	1	1000	1000	x
2	<input checked="" type="checkbox"/>	901	2000	1100	x
3	<input checked="" type="checkbox"/>	1901	3000	1100	x

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

Partial calculation

Number of cycle data points: 3000

Division number: 3

Number of overlaps: 100

Number of sampling data points: 1000

Buttons: Set default, Calculate, Data Export, Close

Pattern Folder: Folder select

#	Select	Start	End	Number of sampling data points	CSV
1	<input checked="" type="checkbox"/>	1	1000	1000	×
2	<input checked="" type="checkbox"/>	901	2000	1100	×
3	<input checked="" type="checkbox"/>	1901	3000	1100	×

Buttons: Save, Load

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.

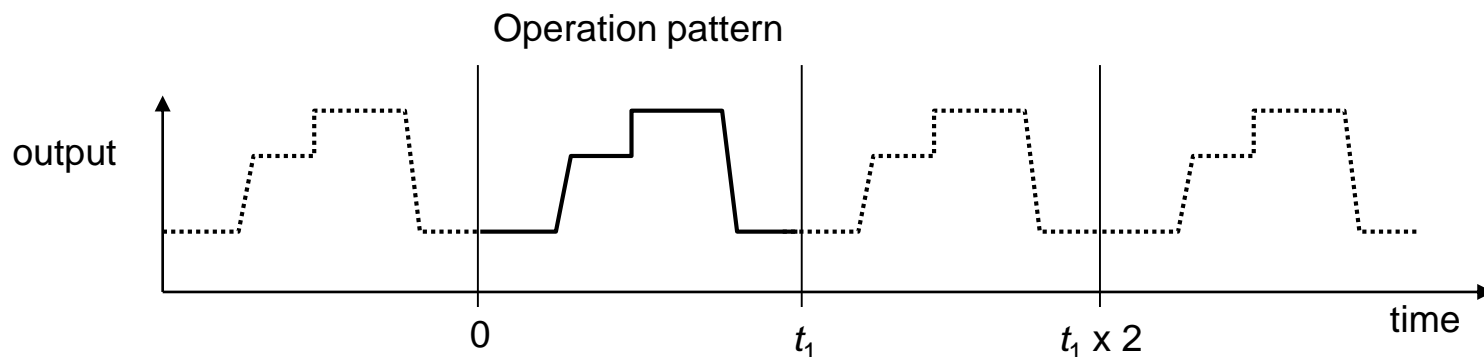
Load the saved partial calculation table.

# Cycle Mode Calculation Boundary Condition

Boundary Condition

☒ Cyclic ☐ 1 shot

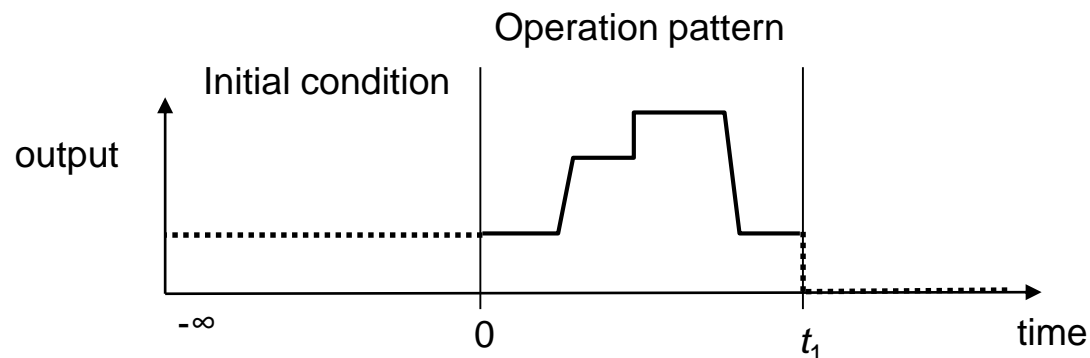
**Cyclic mode:** The load cycle pattern is repeated continuously.



Boundary Condition

☐ Cyclic ☒ 1 shot

**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	$-\infty \leq \dots$	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

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

A

B

B

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

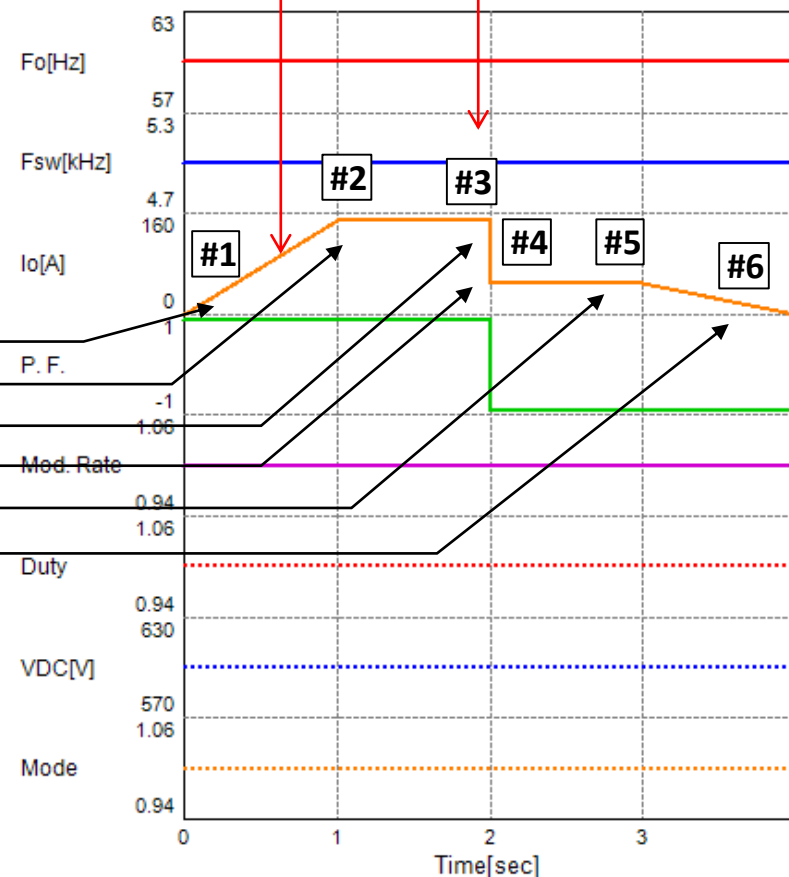
Example: #3 → #4 [Io, PF]

A

Linear change

B

Instantaneously change



# 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			600	3-phase Sinusoidal
	2	1	60	5	150	0.9			600	3-phase Sinusoidal
	3	2	60	5	150	0.9			600	3-phase Sinusoidal
	4	2	60	5	50	-0.9			600	3-phase Sinusoidal
	5	3	60	5	50	-0.9			600	3-phase Sinusoidal
	6	4	60	5	0	-0.9			600	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	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

## Copy & Paste line

Select a line (click 1<sup>st</sup> column) → 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	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



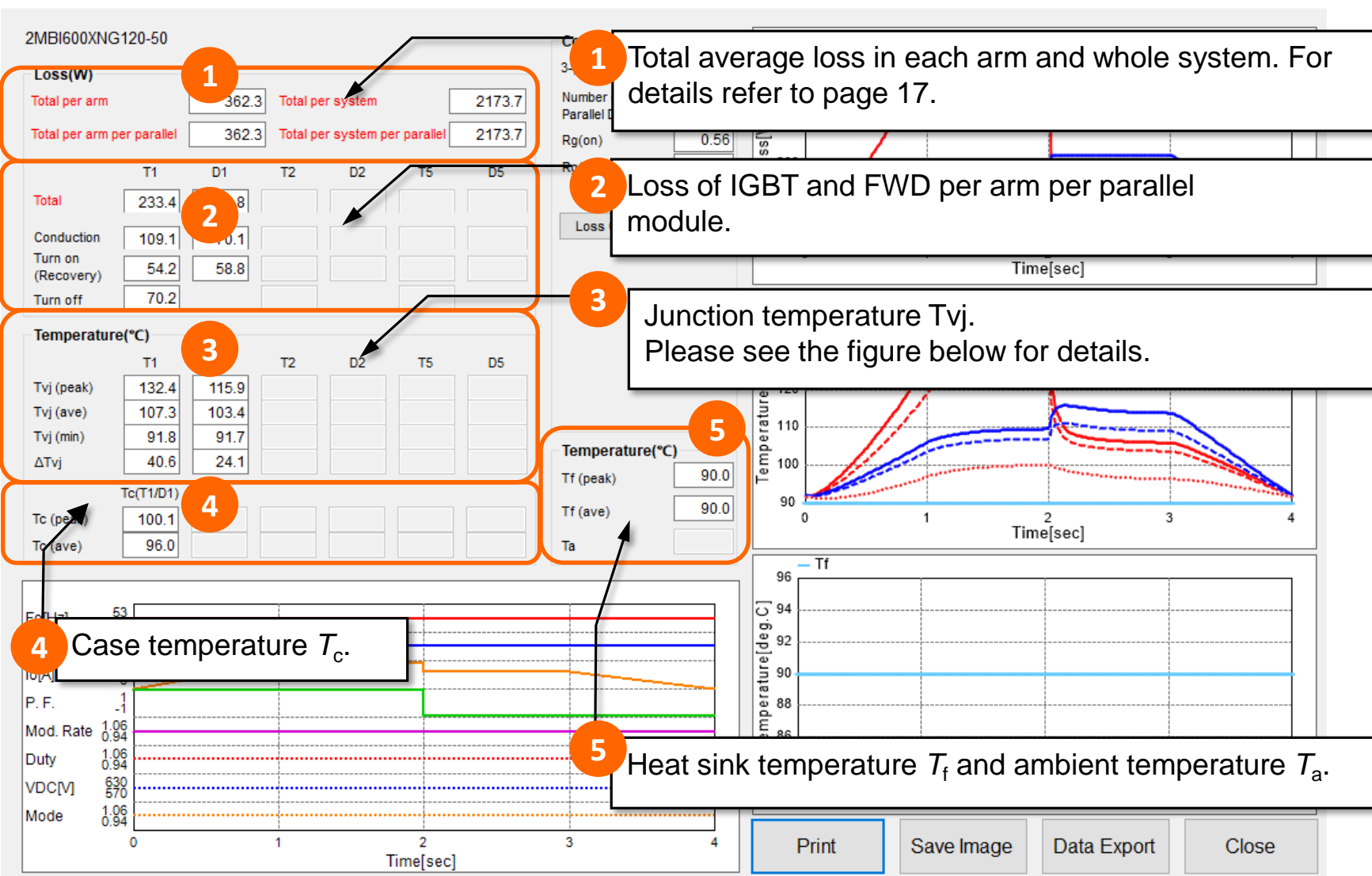
Select a line → Right click → Paste

	#	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)

Fuji IGBT Simulator Ver 6.2.0 Result:003



# Simulation Results (Cycle Calculation)

1 Loss curves

2 Temperature curves

3 Temperature curves

4 Print the window

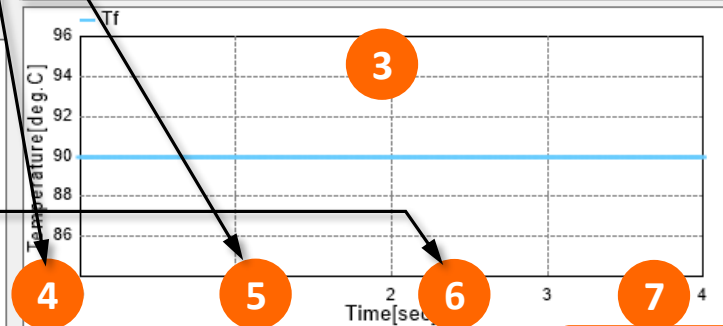
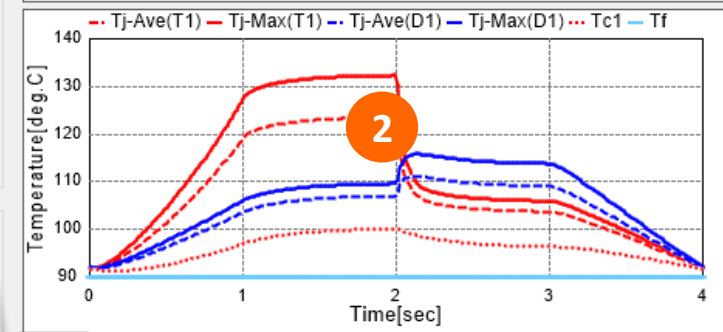
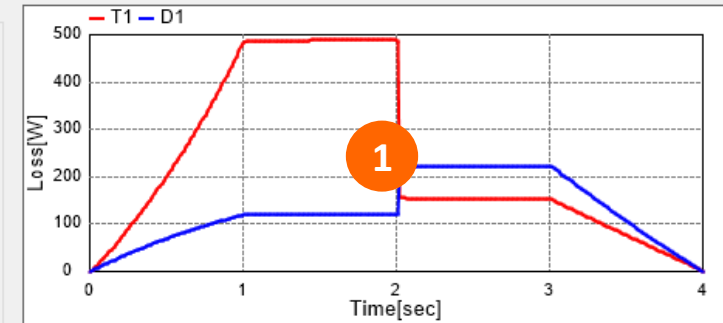
5 Save the window

Filename: \*.xml

6 Export the results

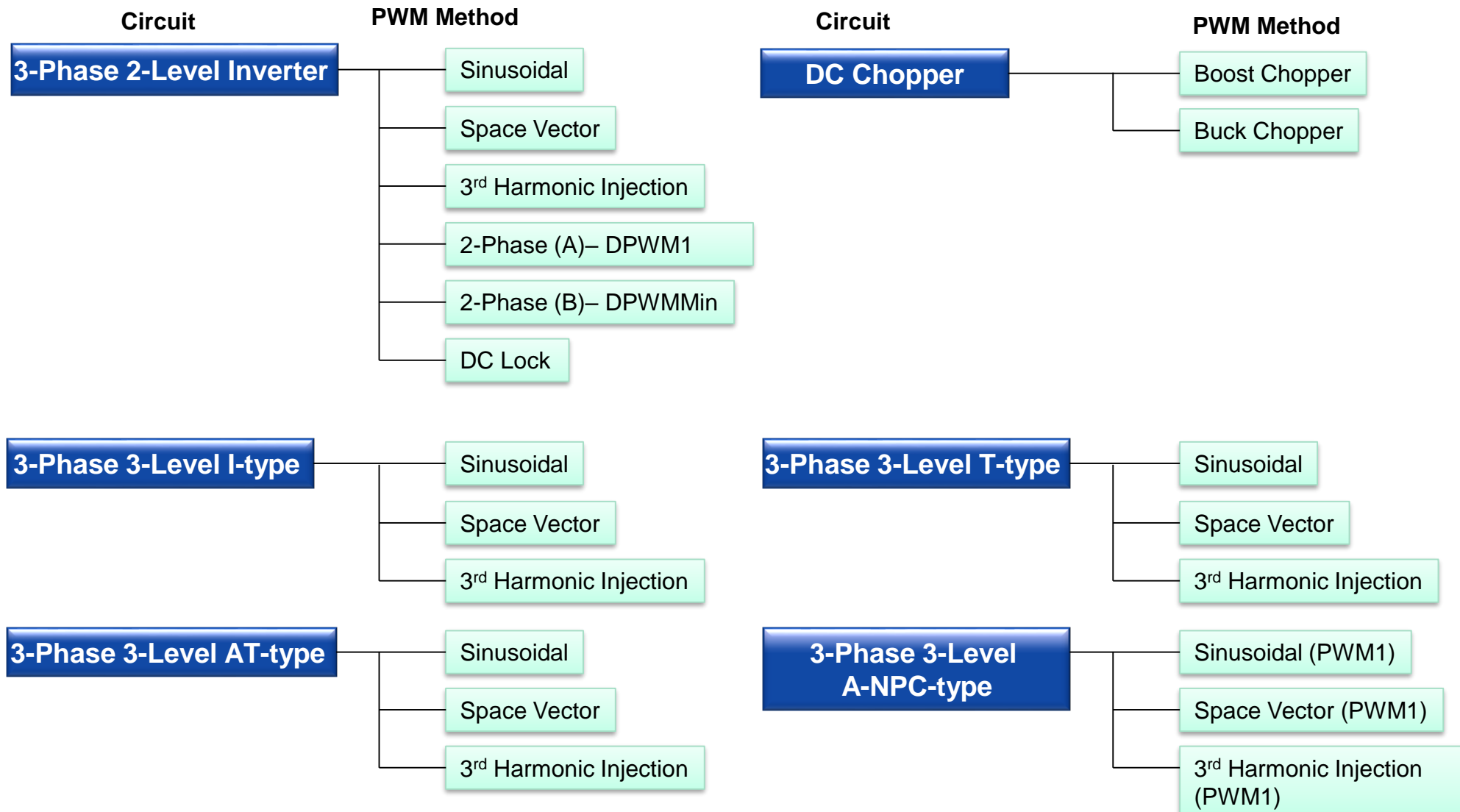
Filename: \*.csv

7 Close the window

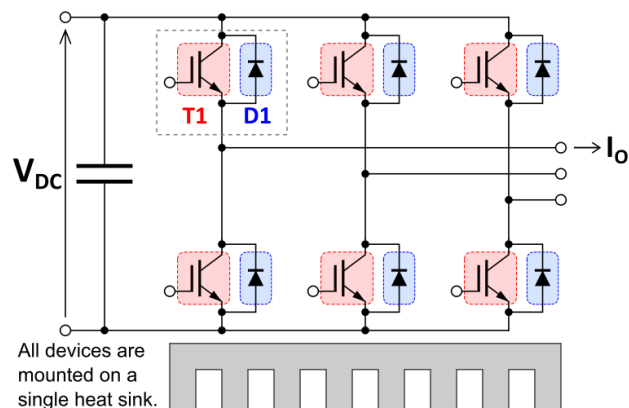


# Circuits & PWM Methods

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

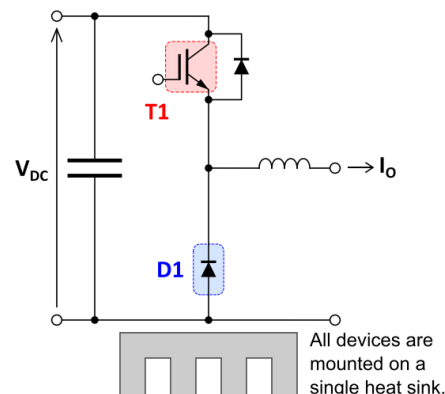


## 3-Phase 2-Level

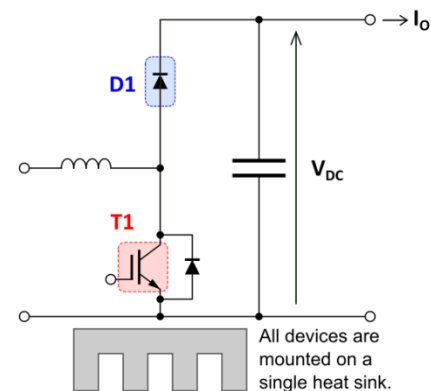


## DC Chopper

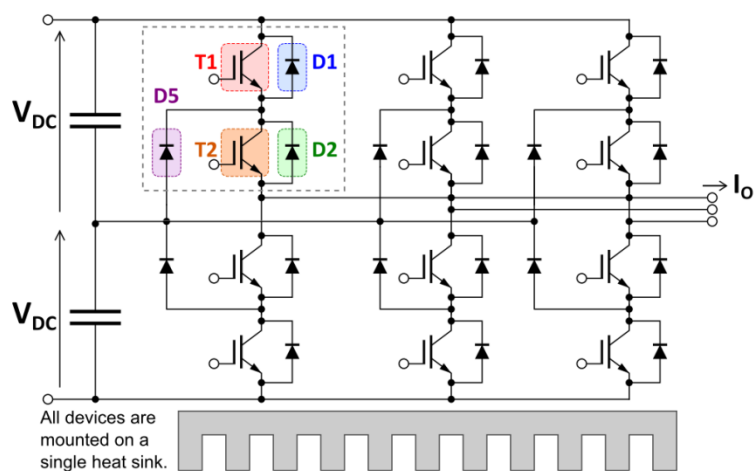
(Buck)



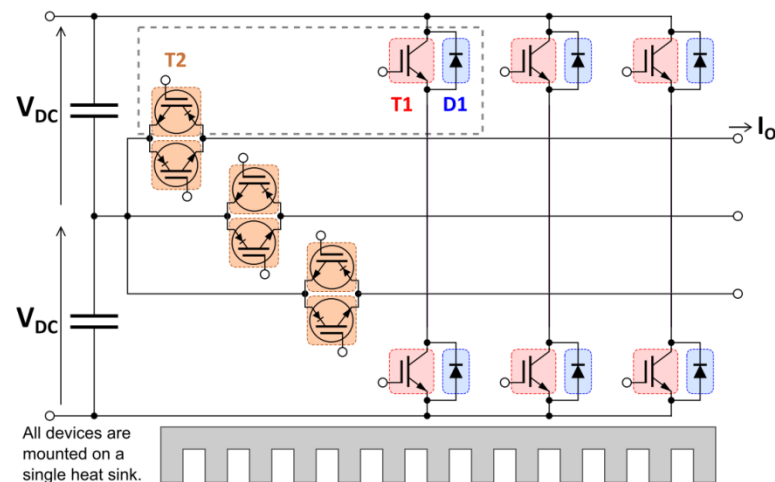
(Boost)



## 3-Phase 3-Level I-type

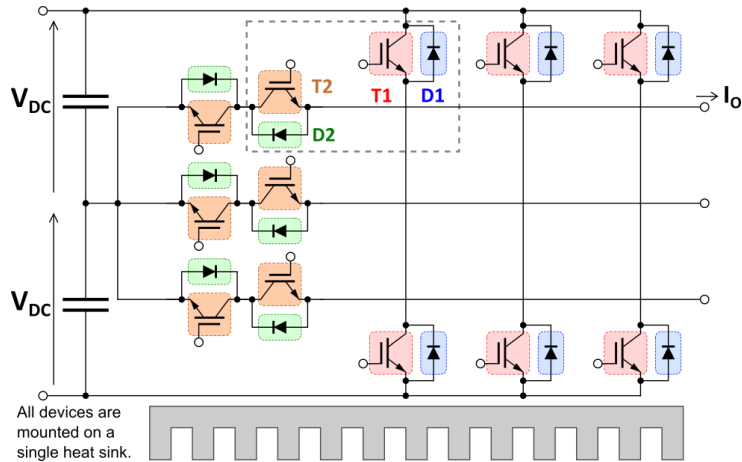


## 3-Phase 3-Level AT-type

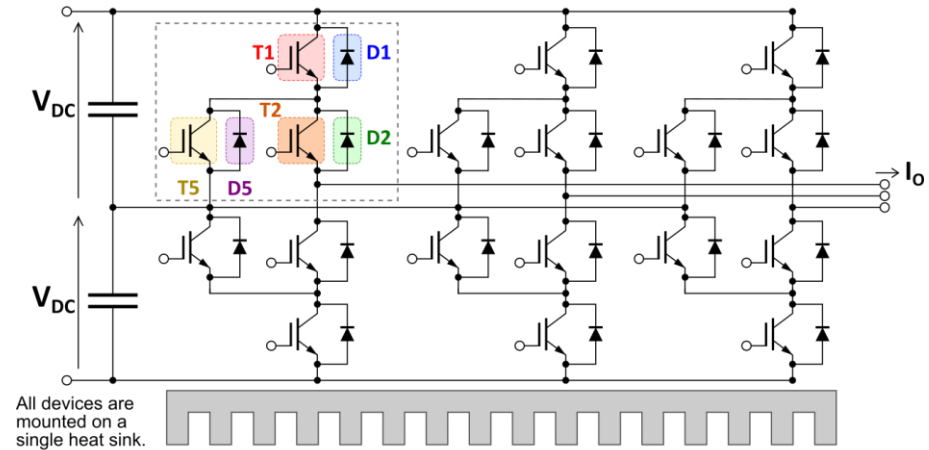


# Circuit: 3-Phase 3-Level type

3-Phase 3-Level T-type

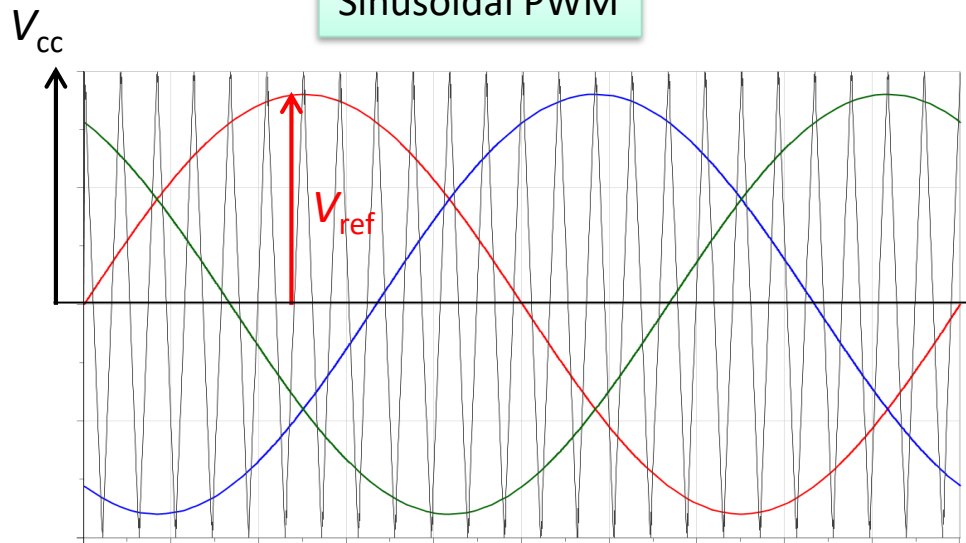


3-Phase 3-Level  
A-NPC-type



# PWM Method (SPWM, SVPWM)

Sinusoidal PWM



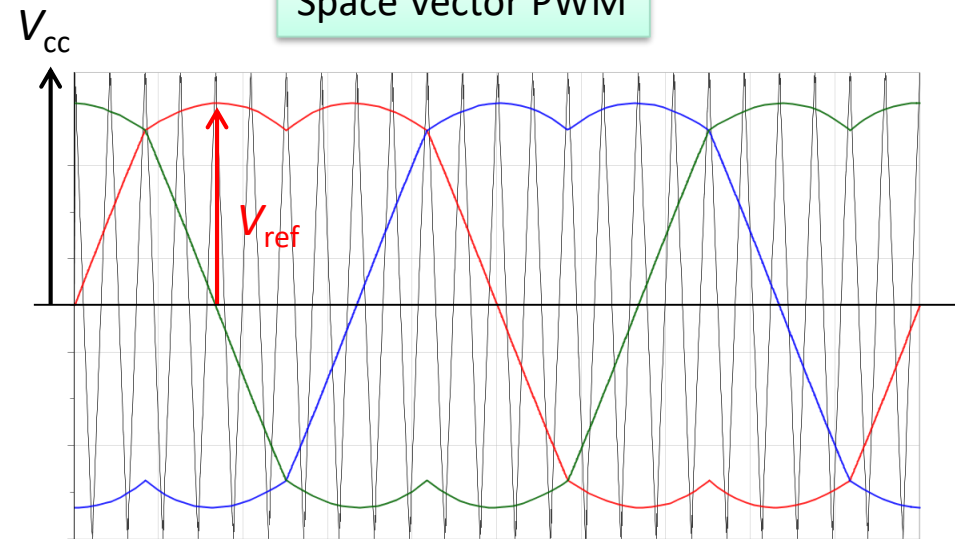
The reference voltage is a sinusoidal waveform.

The amplitude of the reference voltage  $V_{ref}$  is defined by the following equation using modulation ratio  $m$ .

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

The maximum value of  $m$  is 1.

Space Vector PWM



The amplitude of the reference voltage  $V_{ref}$  is defined by the following equation using modulation ratio  $m$

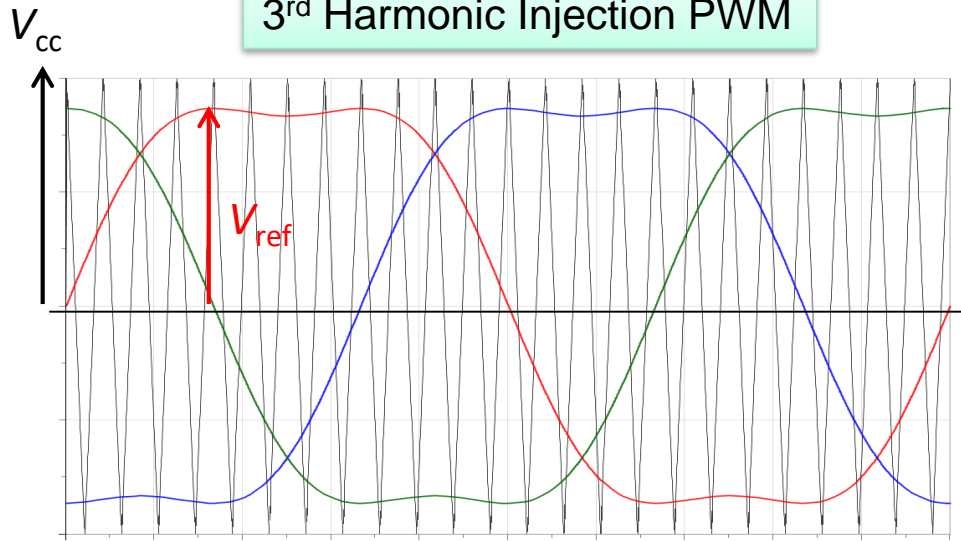
$$V_{ref} = \frac{\sqrt{3}}{2}mV_{dc}$$

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

The maximum value of  $m$  is  $2/\sqrt{3} = 1.1547$

# PWM Method (3<sup>rd</sup> harmonic injection)

## 3<sup>rd</sup> Harmonic Injection PWM



The amplitude of the reference voltage  $V_{ref}$  is defined by the following equation using modulation ratio  $m$

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

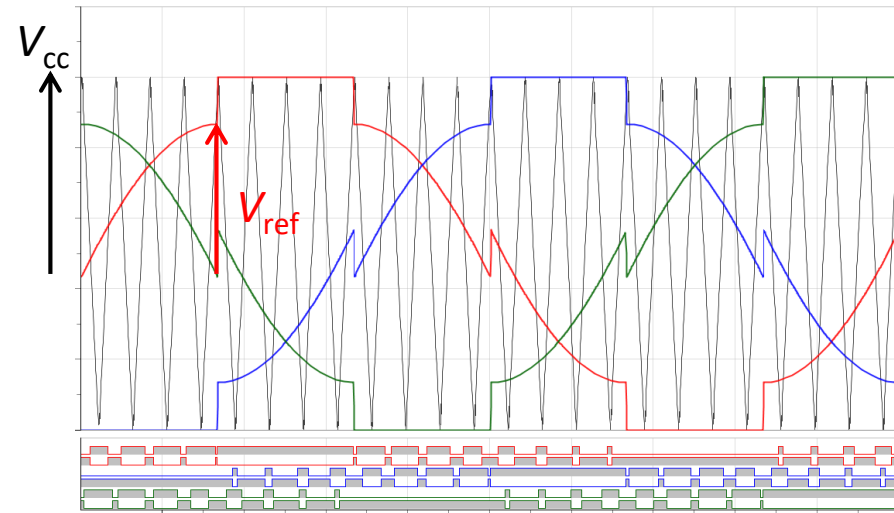
$m$  is defined to be the same output voltage to the sinusoidal PWM.

The maximum value of  $m$  is  $2/\sqrt{3} = 1.1547$



# 2-Phase Modulation

2-Phase (A) – DPWM1



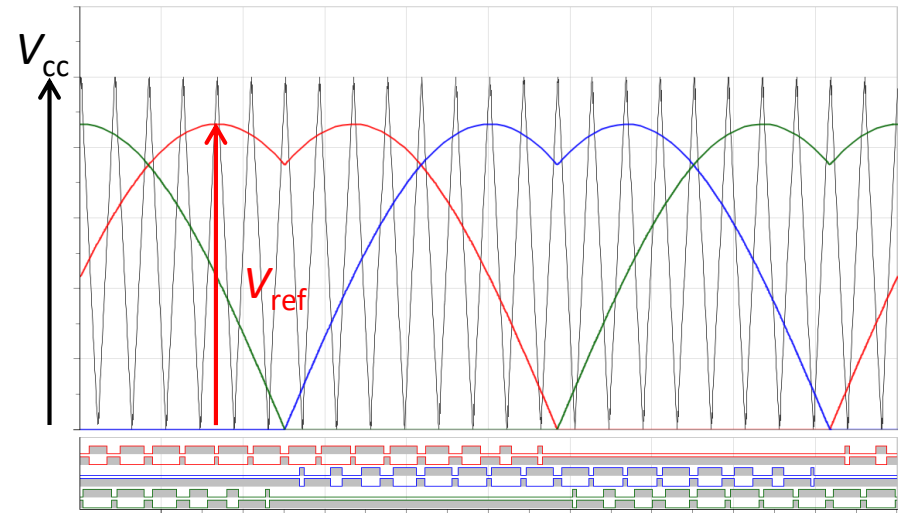
The amplitude of the reference voltage  $V_{ref}$  is defined by the following equation using modulation ratio  $m$ .

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

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

The maximum value of  $m$  is  $2/\sqrt{3} = 1.1547$

2-Phase (B) – DPWMMin



The amplitude of the reference voltage  $V_{ref}$  is defined by the following equation using modulation ratio  $m$ .

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

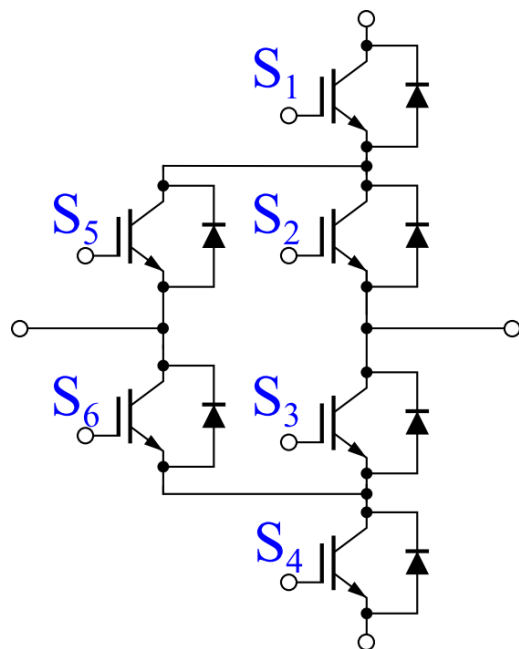
$m$  is defined to be the same output voltage to the sinusoidal PWM.

The maximum value of  $m$  is  $2/\sqrt{3} = 1.1547$

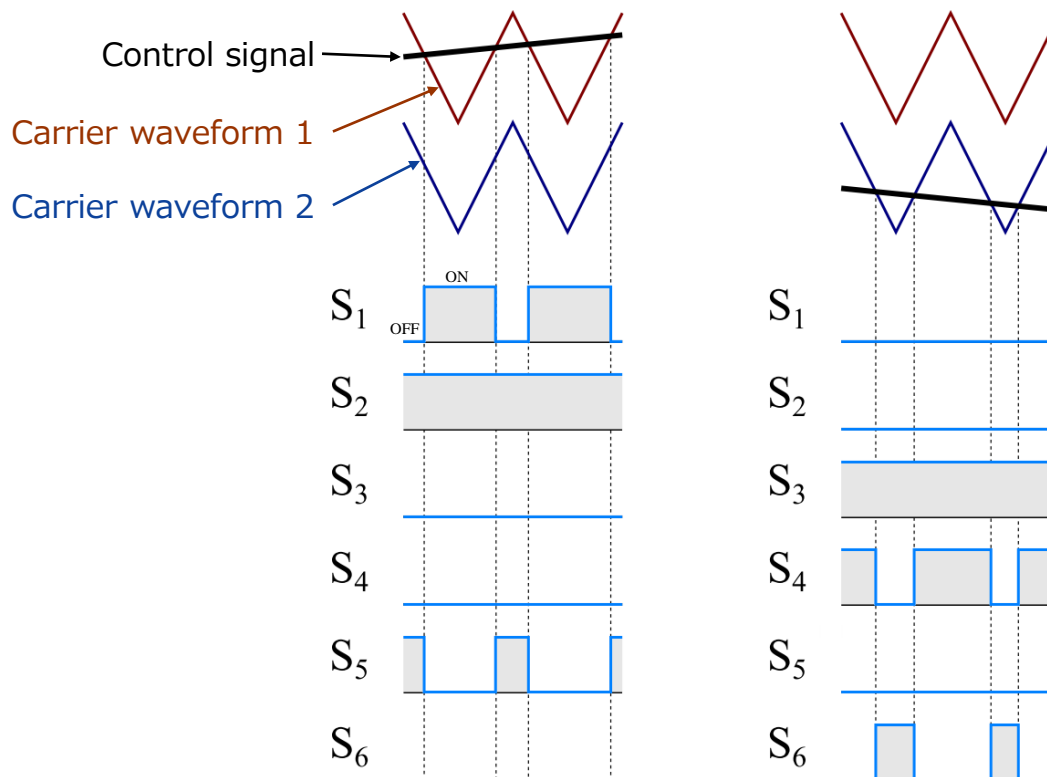
# PWM Method (A-NPC circuit)

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



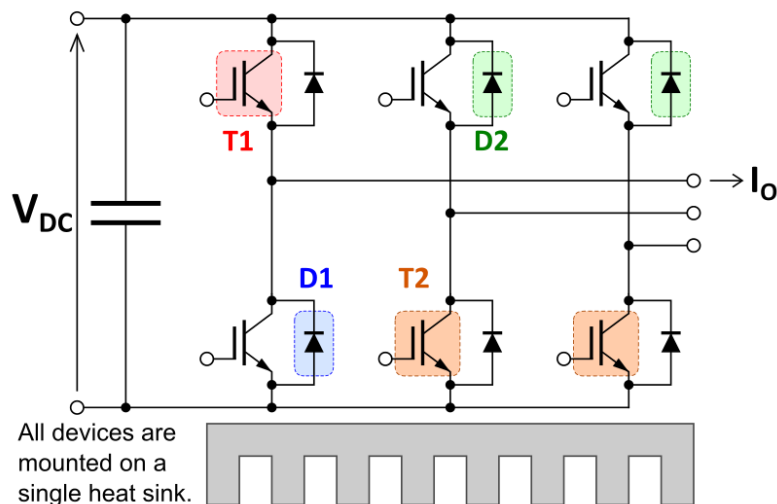
Switching pattern (PWM1)



# Motor DC Lock Operation

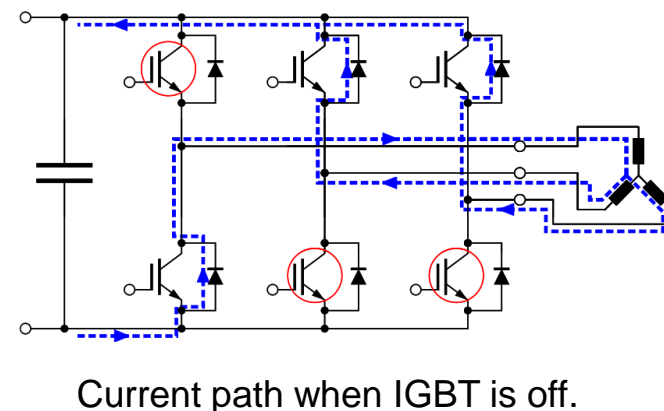
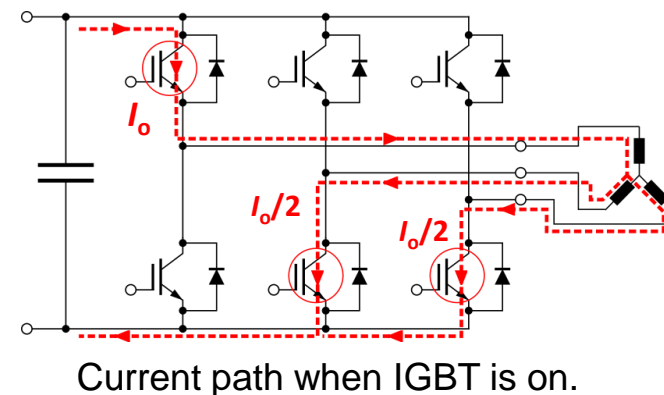
Calculate the IGBT / FWD loss when locking the motor rotation with a servo drive or the like.

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.



**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,  $T_f$  and  $T_c$  might become high.



If you have any questions, please contact us.

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

