

# **FUJI IGBT Simulator Ver. 6.2**

## **User Manual**

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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

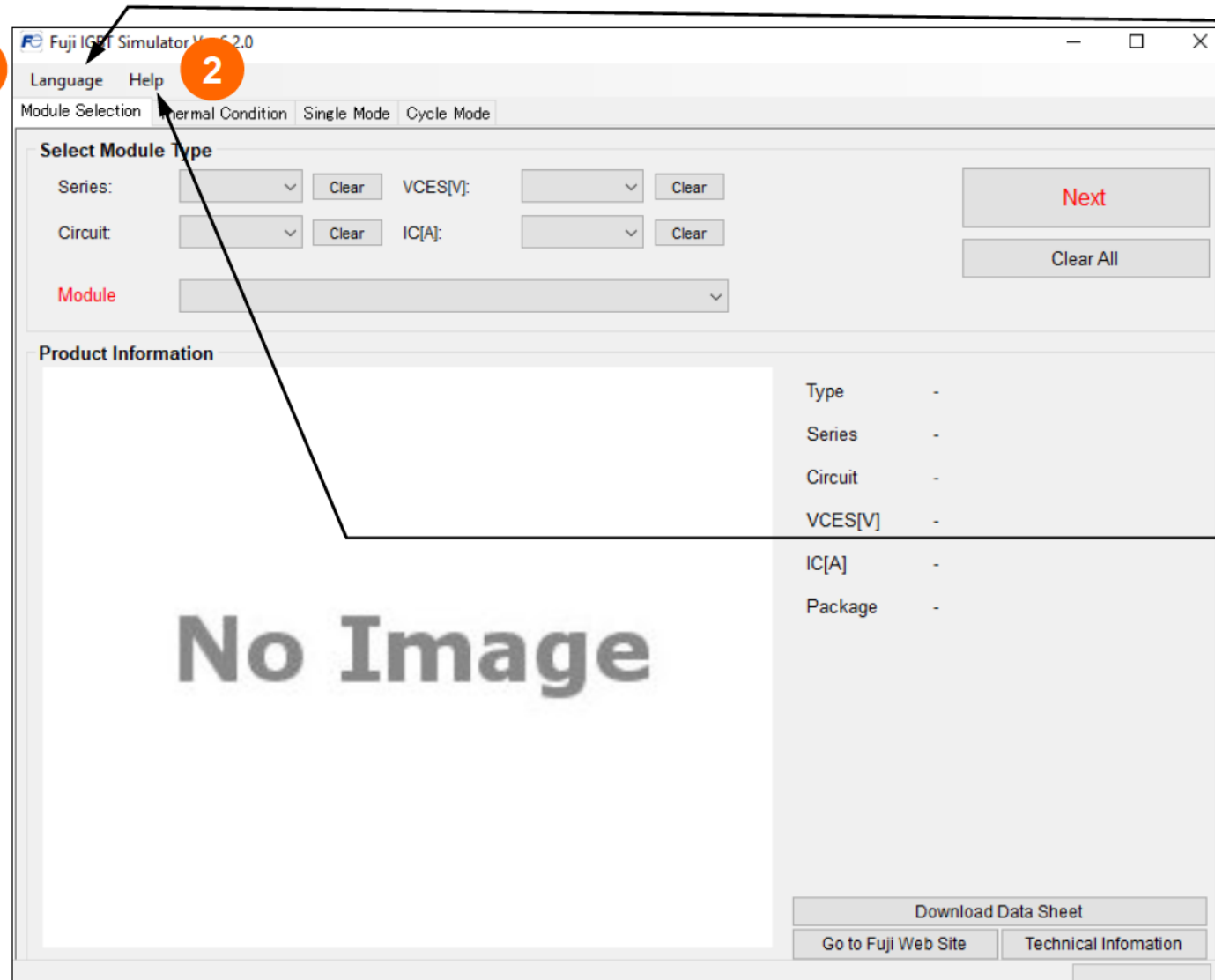
Unzip the downloaded file and copy to a custom folder.

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

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# Menu



## Select language

- English
- Japanese
- Chinese

Fuji IGBT Simulator Ver 6.2.0

- Language
- Help
- English
- Japanese
- Chinese

## Help

Visit Fuji Web site to get the latest version.

Check the version.

3T Simulator Ver 6.2.0

- Help
- Visit WEB site
- Manual

# 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. The 'Module' dropdown is set to '2MBI600XNG120-50'. Below this is the 'Product Information' section, which includes a 3D model of the M285 module (dimensions 62x150), a circuit diagram showing a thermistor and IGBTs, 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.

Additional instructions:

- Download product datasheet.
- Visit technical information page.
- Visit Fuji Semiconductor web site.

# Input thermal condition (1)

The screenshot shows the 'Thermal Condition' tab in the Fuji IGBT Simulator. The interface includes several input fields and checkboxes for defining thermal parameters. A thermal circuit model diagram is overlaid on the right side, showing the relationship between junction, case, heat sink, and ambient temperatures, connected by thermal resistances and impedances.

**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.

The diagram illustrates the thermal circuit model with the following components and connections:

- Junction temp.** ( $T_{vj}(T1)$ ) connected to **Case temp.** ( $T_{c1}$ ) via  $Z_{th(j-c)}$ .
- Case temp.** ( $T_{c1}$ ) connected to **Heat sink temp.** ( $T_i$ ) via  $Z_{th(c-f)}$ .
- Heat sink temp.** ( $T_i$ ) connected to **Ambient temp.** ( $T_a$ ) via  $Z_{th(f-a)}$ .
- The heat sink is represented by a thermal impedance model (Foster equivalent network) with parameters  $r_n$  and  $c_n$ .

# 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.  $T_{cs}$

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  $T_f$

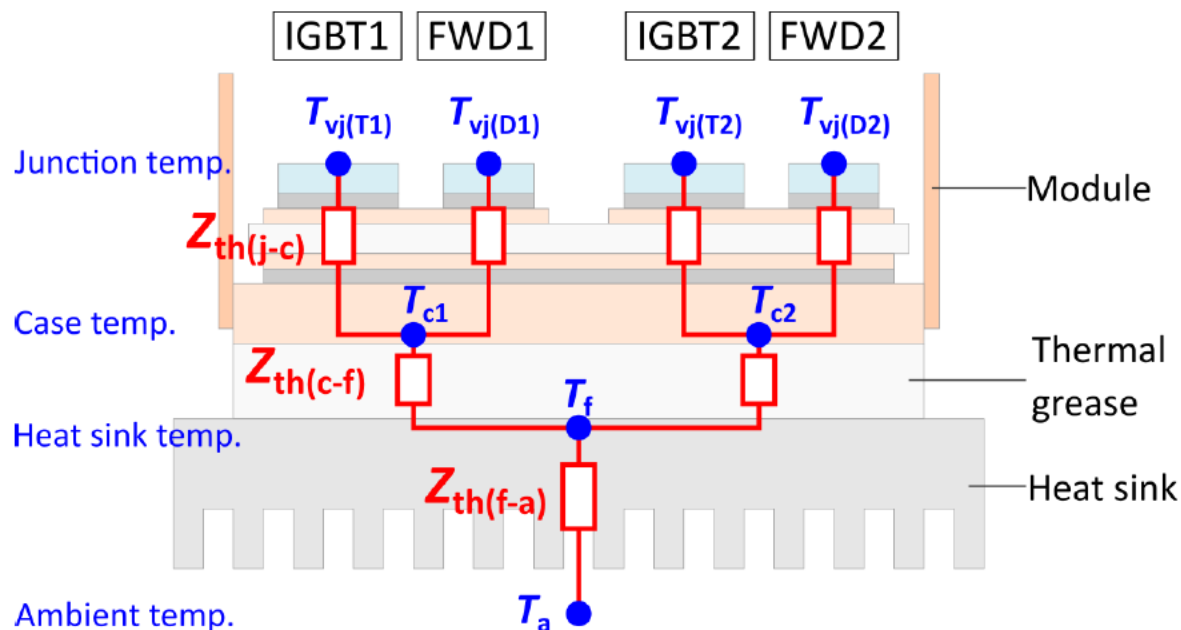
## b. Calculate heat sink temperature

$T_f$  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)

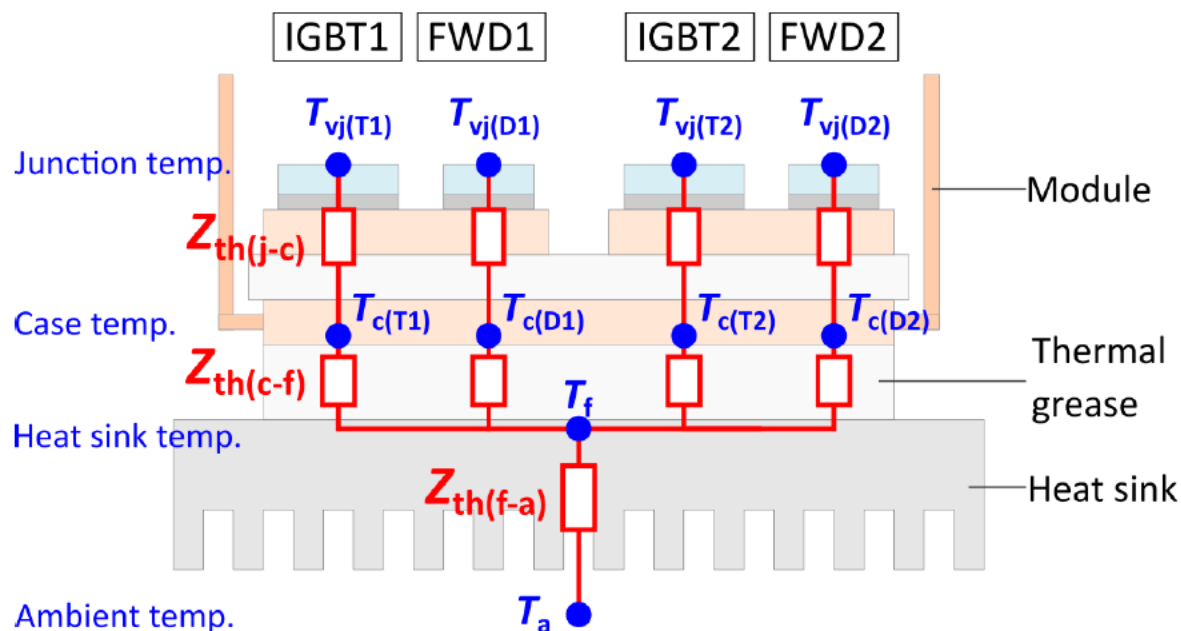
In the simulator, calculations are performed based on the following thermal circuit model.



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)

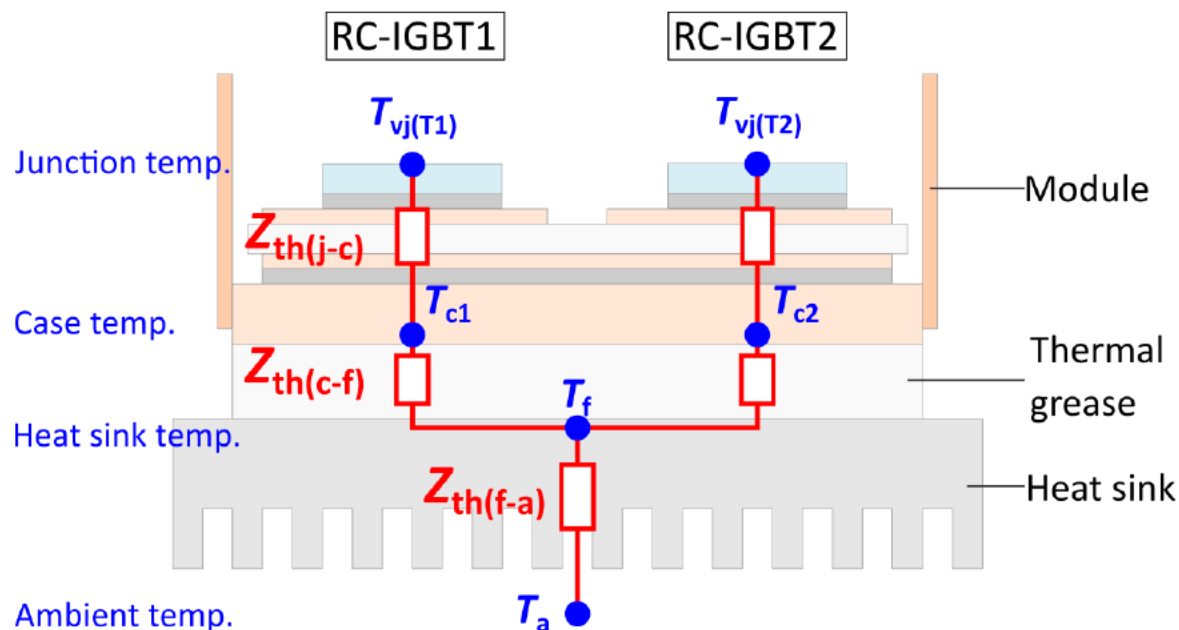
The following thermal circuit model is applied for modules without copper baseplate.



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)

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

Calculation Condition

Number of Parallel Devices 2 pcs

Output Freq.  $F_o$  50 (Hz)

Output Current  $I_o$  300 (Arms)

Switching Freq.  $F_{sw}$  5 (kHz)

Power Factor 0.8

Modulation Rate 0.9

Duty 0

DC Link Voltage VDC 0 (V)

T1 RG(ON) 0.56 ( $\Omega$ )

T1 RG(OFF) 0.56 ( $\Omega$ )

T2 RG(ON) 0.56 ( $\Omega$ )

T2 RG(OFF) 0.56 ( $\Omega$ )

Loss Calibration Factor

Thermal Condition  
Fixed Heatsink Temp.  $T_f$  90 °C

Detail Temperature Condition

Explanation

$V_{DC}$

T1 D1

All devices are mounted on a single heat sink.

# Loss Calibration Factor

The screenshot shows the Fuji IGBT Simulator Ver 6.2.0 interface. The main window has tabs for Language, Help, Module Selection, Thermal Condition, Single Mode, and Cycle Mode. The Thermal Condition tab is active, showing a Fixed Heatsink Temp. T<sub>f</sub> of 90 °C. The Calculation Condition section includes fields for Number of Parallel Devices (2 pcs), Output Freq. F<sub>o</sub> (50 Hz), Output Current I<sub>o</sub> (300 Arms), Switching Freq. F<sub>sw</sub> (5 kHz), Power Factor (0.8), Modulation Rate (0.9), Duty (0), DC Link Voltage VDC, and T1 RG(ON), T1 RG(OFF), T2 RG(ON), T2 RG(OFF). A diagram of a 3-phase 2-level inverter is shown in the center. A dialog box titled "Loss Calibration Factor" is open, showing a list of loss components with their respective calibration factors, all set to 1.00. The dialog box has a "Close" button. A text box with a red circle containing the number 6 points to the "Loss Calibration Factor" tab in the main window. Another text box with a red circle containing the number 6 points to the "Loss Calibration Factor" dialog box. A third text box with a red circle containing the number 6 points to the "Loss Calibration Factor" dialog box.

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

Fuji IGBT Simulator Ver 6.2.0

Language Help

Module Selection Thermal Condition Single Mode Cycle Mode

2MBI600XNG120-50

Circuit  
3-Phase 2-Level Inverter

PWM Modulation Method  
Sinusoidal

Thermal Condition  
Fixed Heatsink Temp.  $T_f$  90 °C  
Detail Temperature Condition

Calculation Condition

|                            |      |              |       |                          |
|----------------------------|------|--------------|-------|--------------------------|
| Number of Parallel Devices | 2    | pcs          | Sweep | <input type="checkbox"/> |
| Output Freq. $F_o$         | 50   | (Hz)         |       | <input type="radio"/>    |
| Output Current $I_o$       | 300  | (Arms)       |       | <input type="radio"/>    |
| Switching Freq. $F_{sw}$   | 5    | (kHz)        |       | <input type="radio"/>    |
| Power Factor               | 0.8  |              |       | <input type="radio"/>    |
| Modulation Rate            | 0.9  |              |       | <input type="radio"/>    |
| Duty                       | 0    |              |       | <input type="radio"/>    |
| DC Link Voltage $V_{DC}$   | 600  | (V)          |       | <input type="radio"/>    |
| T1 RG(ON)                  | 0.56 | ( $\Omega$ ) |       | <input type="radio"/>    |
| T1 RG(OFF)                 | 0.56 | ( $\Omega$ ) |       | <input type="radio"/>    |
| T2 RG(ON)                  | 0.56 | ( $\Omega$ ) |       | <input type="radio"/>    |
| T2 RG(OFF)                 | 0.56 | ( $\Omega$ ) |       | <input type="radio"/>    |

Loss Calibration Factor

Explanation

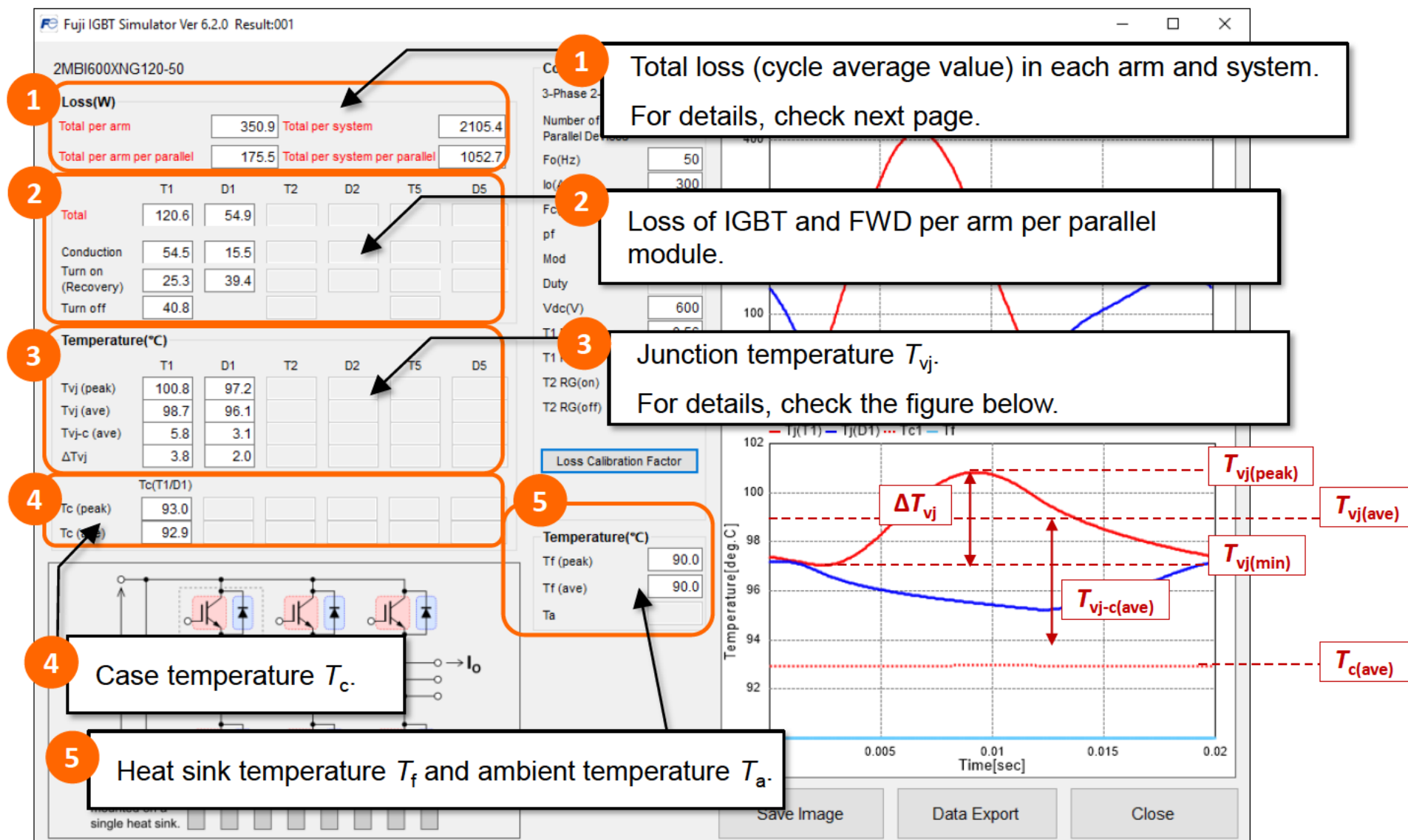
All devices are mounted on a single heat sink.

Calculate

<< Back

1 Calculation will start when you click the "Calculation" Button.

# 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 |
|--------------------|-------|------|----|----|----|
| <b>Total</b>       | 120.6 | 54.9 |    |    |    |
| Conduction         | 54.5  | 15.5 |    |    |    |
| Turn on (Recovery) | 25.3  | 39.4 |    |    |    |
| Turn off           | 40.8  |      |    |    |    |

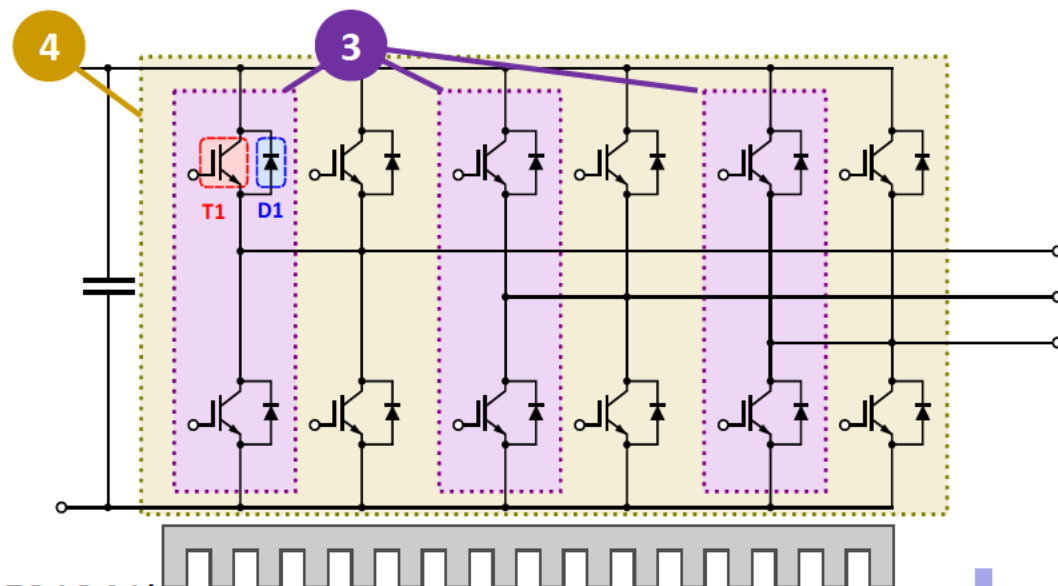
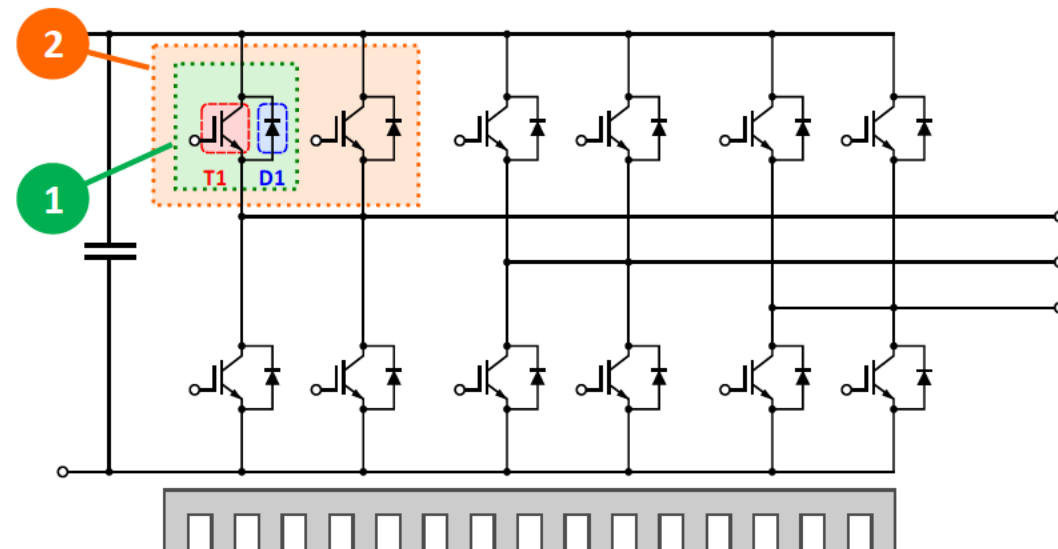
**1** Total loss per arm per parallel module  
( = T1 + D1 + T2 + D2 + D5 )

**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 )

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



# Simulation Results (Single Mode)

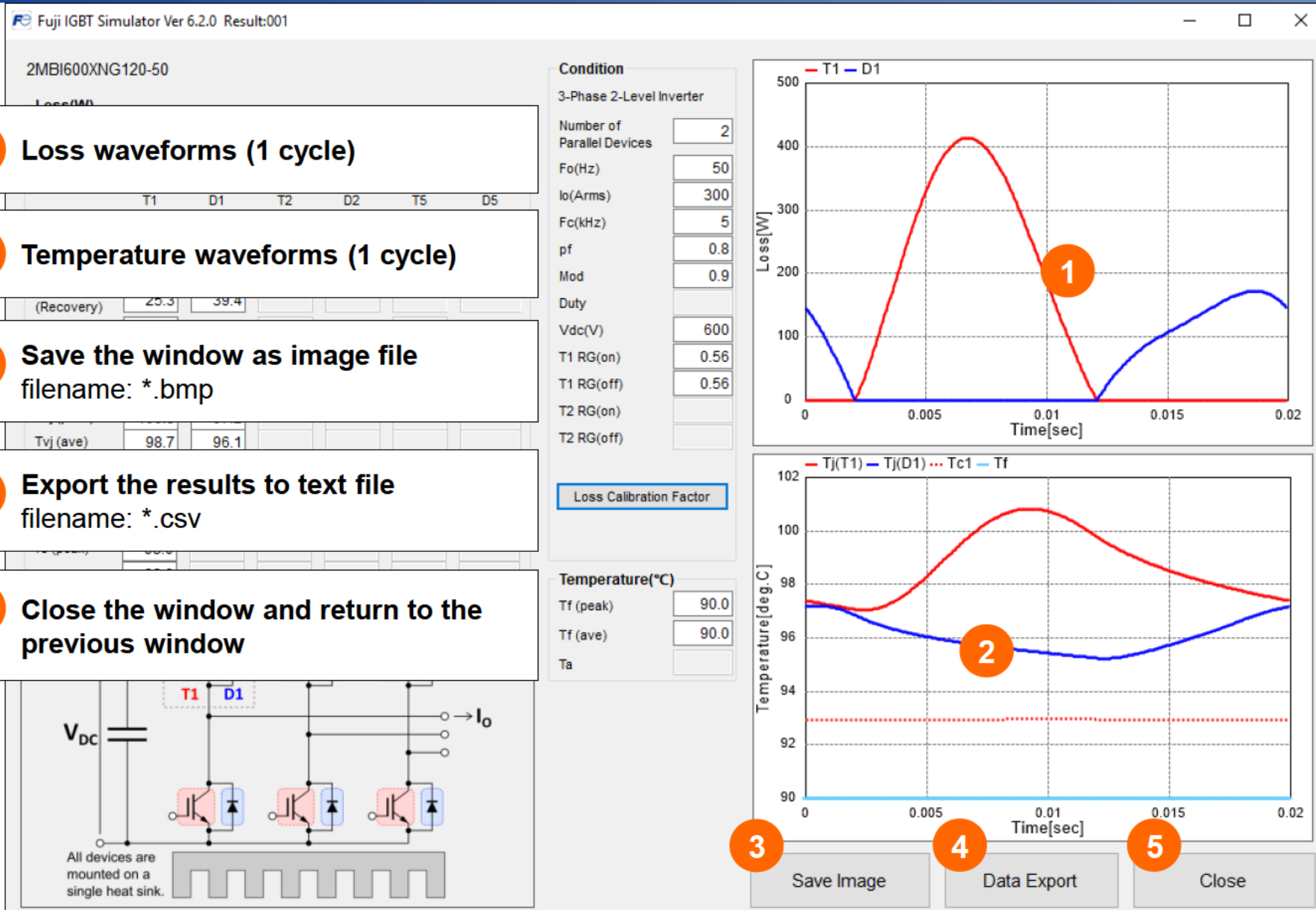
## 1 Loss waveforms (1 cycle)

## 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



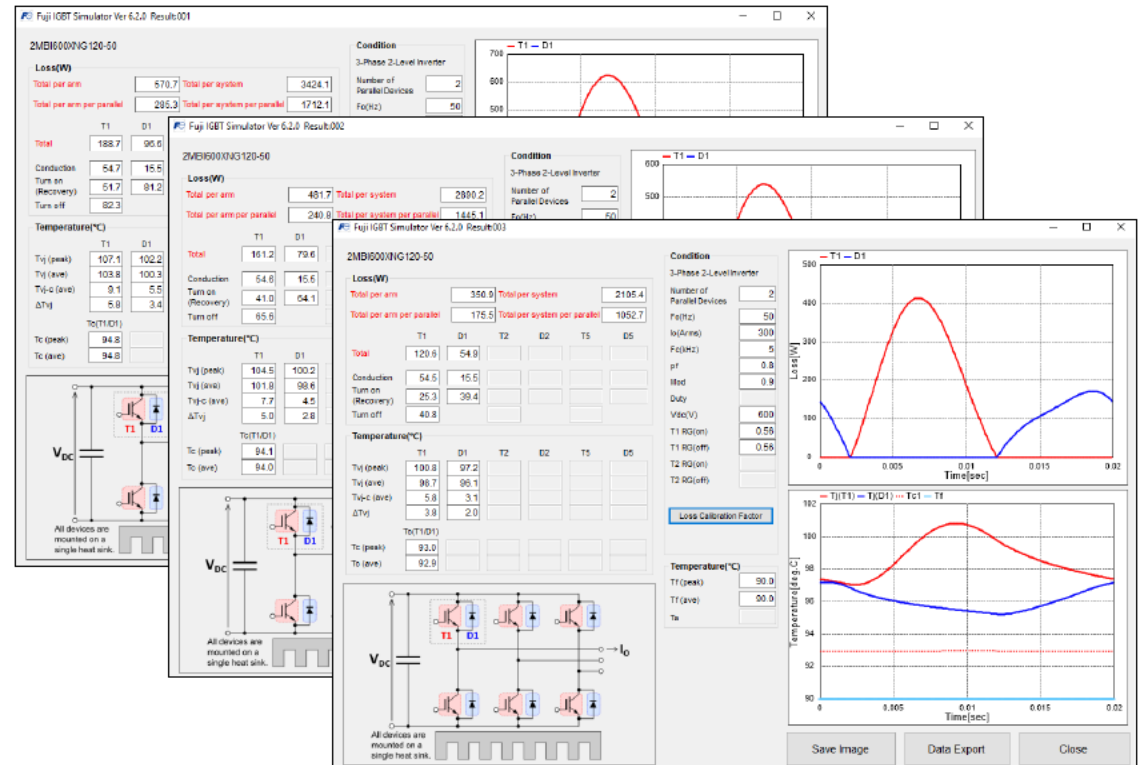
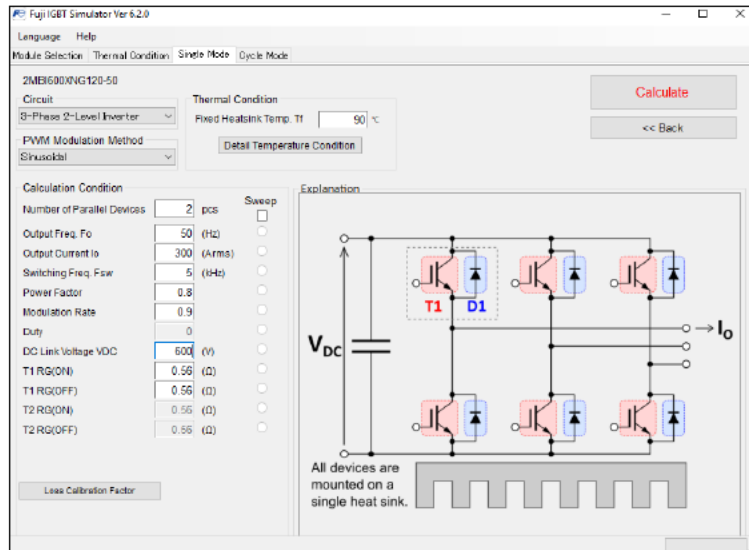


# Display Multiple Results

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

**1** Click „Single Mode“ Tab.

**2** Click „Sweep“ check box.

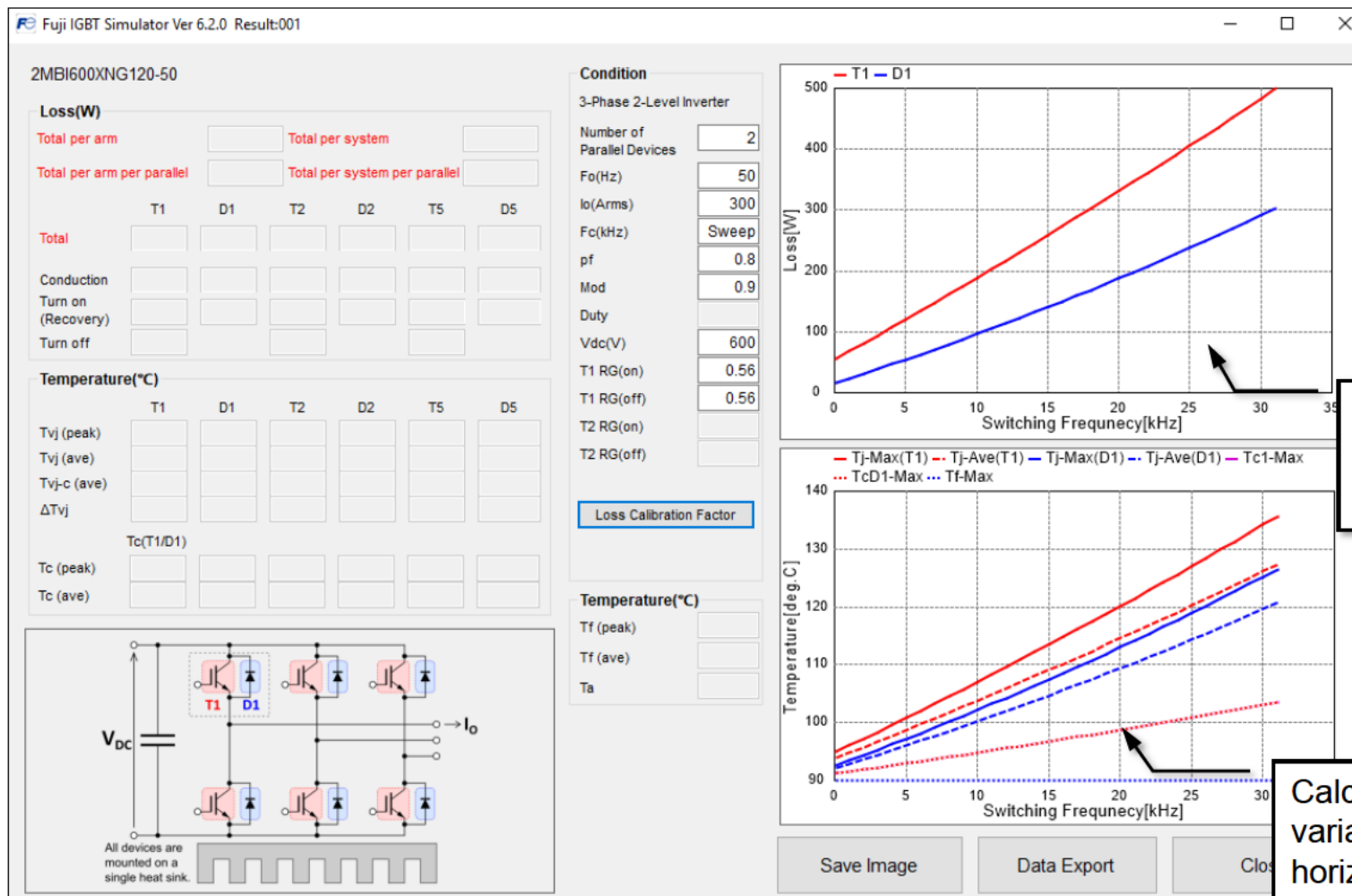
**3** Select parameter which you want to sweep by clicking radio button.

**4** Click „Calculate“ button to start the calculation.

The interface includes the following sections:

- Module Selection:** 2MBI600XNG120-50
- Circuit:** 3-Phase 2-Level Inverter
- PWM Modulation Method:** Sinusoidal
- Thermal Condition:** Fixed Heatsink Temp. T<sub>f</sub> 99 °C
- Calculation Condition:**
  - Number of Parallel Devices: 2 pcs
  - Output Freq. F<sub>o</sub>: 50 (Hz)
  - Output Current I<sub>o</sub>: 300 (A)
  - Switching Freq. F<sub>sw</sub>: 5 (kHz)
  - Power Factor: 0.8
  - Modulation Rate: 0.9
  - Duty: 0
  - DC Link Voltage V<sub>DC</sub>: 600 (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)
- Explanation:** A circuit diagram of a 3-phase 2-level inverter with a DC link capacitor V<sub>DC</sub> and output current I<sub>o</sub>. The first leg is labeled T1 and D1. A note states: "All devices are mounted on a single heat sink."

# 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

**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.  $T_f$  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

Calculate  
Partial calculation  
<< Back

Cycle Data  
Number of Parallel Devices 1 pcs  
Loss Calibration Factor

Input Default Value Delete All

\* 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]

Save Load

# Cycle Mode Calculation

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.

7

5

6

7

2MBI600XNG120-50

Language Help

Module Selection Thermal Condition Single Mode Cycle Mode

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

Cycle Data

Number of Parallel Devices 1 pcs

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 |

Fo[Hz]

Fsw[kHz]

Io[A]

P. F.

Mod. Rate

Duty

VDC[V]

Save Load

# Cycle Mode Calculation

Fuji IGBT Simulator Ver 6.2.0

Language Help

Module Selection Thermal Condition

2MBI600XNG120-50

Thermal Condition T1 RG(ON) 0.56  $\Omega$  Cyclic 1 shot

Fixed Heatsink Temp. T1

Detail Temperature Co

Cycle Data

Number of Parallel Devices 1 pcs

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      |           |         |     |           |      |         |                    |
| 4 | 2       | 50      |           |         |     |           |      |         |                    |
| 5 | 3       | 50      | 5         |         |     |           |      |         |                    |
| 6 | 4       | 50      | 5         |         |     |           |      |         |                    |
| 7 |         |         |           |         |     |           |      |         | 3-phase Sinusoidal |

Drive Condition

Fo[Hz] 53 47 5.3

Fsw[kHz] 4.7 500

Io[A] 0 1

P. F. 1 -1

Mod. Rate 1.06 0.94

Duty 0.94 630

VDC[V] 570 1.06

Mode 0.94

0 1 2 3 4

sec]

Save Load

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

Calculate

Partial calculation

<< Back

# 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 header in the table below.

The table in the dialog box has the following data:

| # | 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.

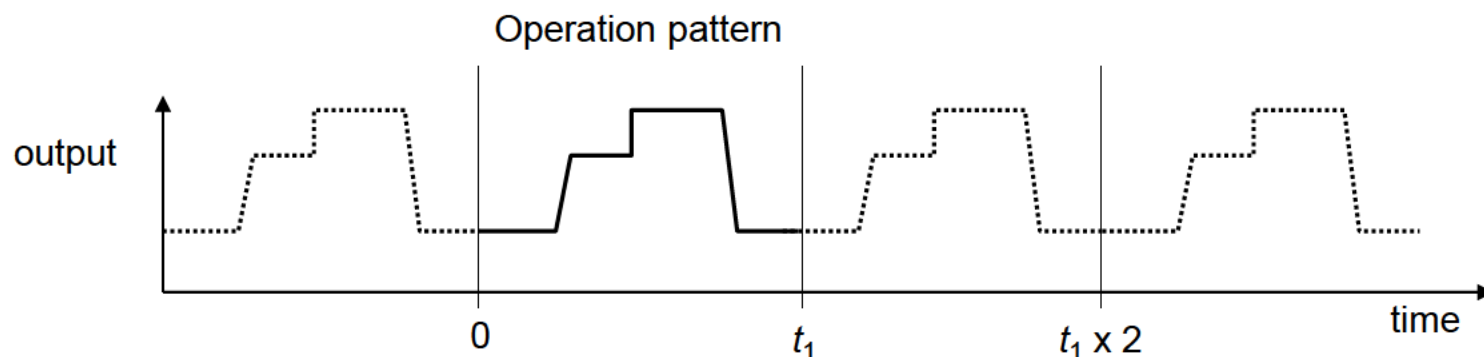


# Cycle Mode Calculation Boundary Condition

Boundary Condition

☒ Cyclic ☐ 1 shot

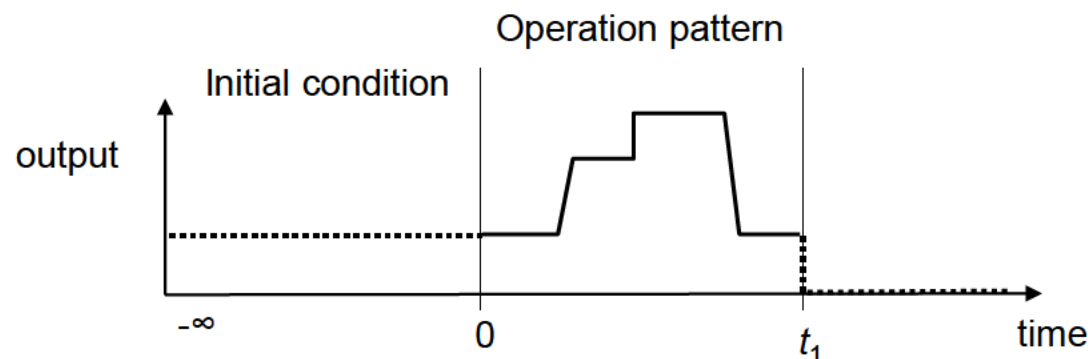
**Cyclic mode:** The load cycle pattern is repeated continuously.



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 | -∞ ≤ ... | 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 [A peak] in case of DC Lock or Chopper circuit  
\* Input [A rms] in other circuits

|    | 1<br># | t<br>[sec] | Fo<br>[Hz] | Fsw<br>[kHz] | 2<br>Io<br>[A]* | PF   | Mod.<br>Rate | 3<br>Duty | VDC<br>[V] | 4<br>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            |
|---|---------|---------|-----------|---------|------|-----------|------|---------|--------------------|
| 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.

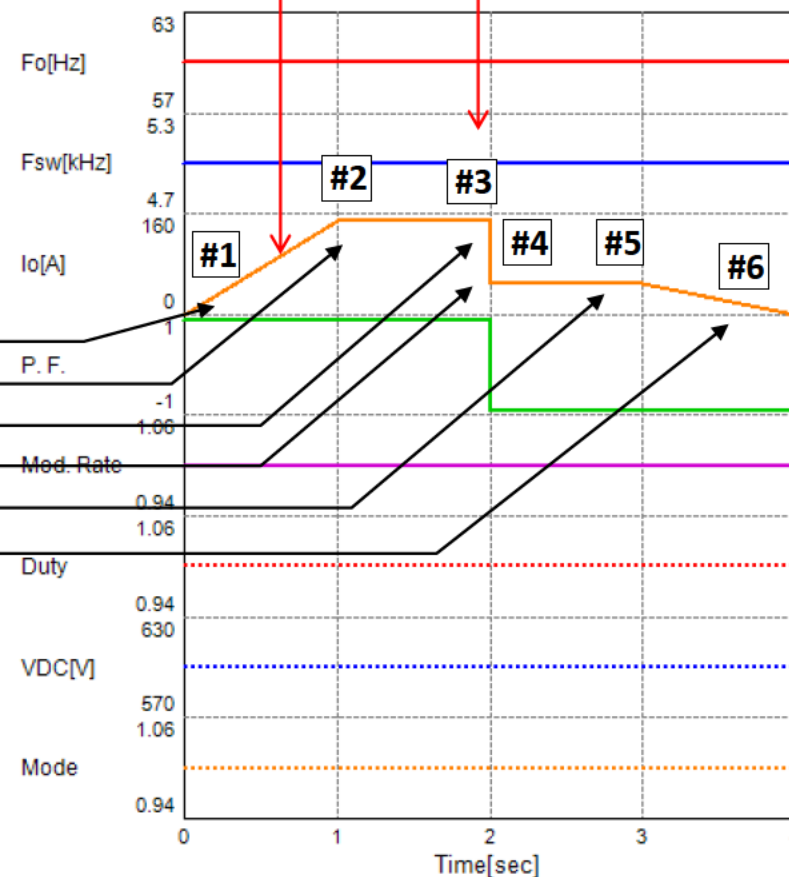
Example: #3 → #4 [Io, PF]

**A**

Linear change

**B**

Instantaneously change



## Copy & Paste cell(s) value

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

|   | # | t<br>[sec] | Fo<br>[Hz] | Fsw<br>[kHz] | Io<br>[A]* | PF   | Mod.<br>Rate | Duty | VDC<br>[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<br>[sec] | Fo<br>[Hz] | Fsw<br>[kHz] | Io<br>[A]* | PF   | Mod.<br>Rate | Duty | VDC<br>[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 1<sup>st</sup> column) → Right click  
→ Copy

|   | # | t<br>[sec] | Fo<br>[Hz] | Fsw<br>[kHz] | Io<br>[A]* | PF   | Mod.<br>Rate | Duty | VDC<br>[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 ▼ |

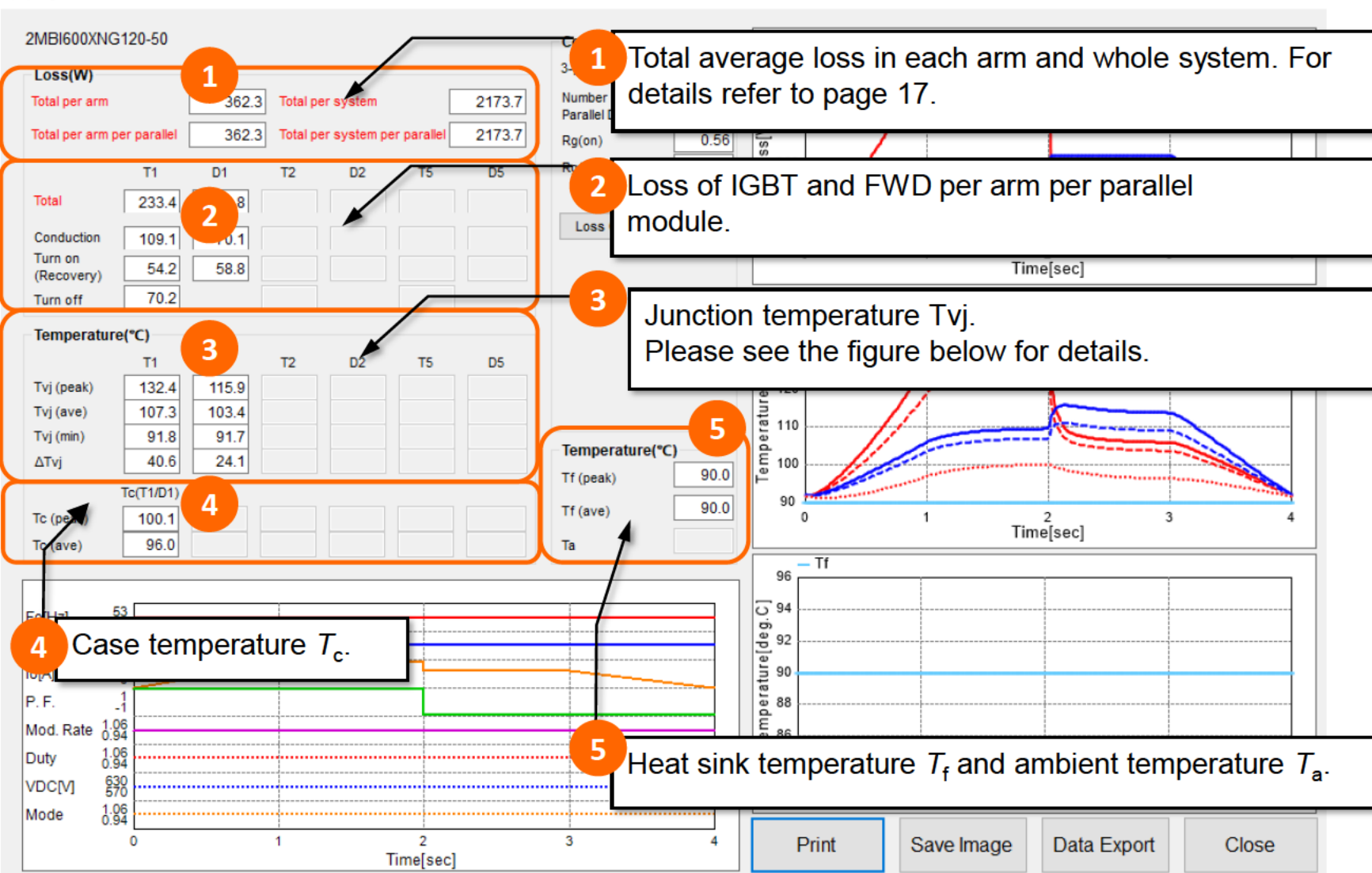


Select a line → Right click → Paste

|   | # | t<br>[sec] | Fo<br>[Hz] | Fsw<br>[kHz] | Io<br>[A]* | PF   | Mod.<br>Rate | Duty | VDC<br>[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

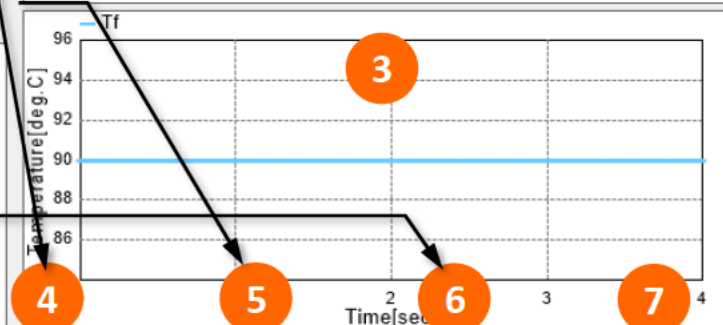
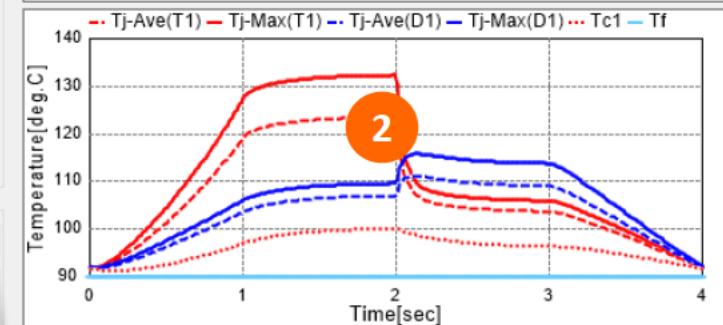
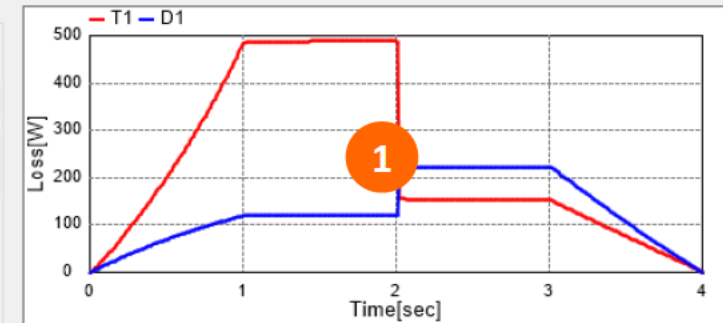
5 Save the window

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.

## Circuit

## PWM Method

### 3-Phase 2-Level Inverter

- Sinusoidal
- Space Vector
- 3<sup>rd</sup> Harmonic Injection
- 2-Phase (A)– DPWM1
- 2-Phase (B)– DPWMMin
- DC Lock

## Circuit

## PWM Method

### DC Chopper

- Boost Chopper
- Buck Chopper

### 3-Phase 3-Level I-type

- Sinusoidal
- Space Vector
- 3<sup>rd</sup> Harmonic Injection

### 3-Phase 3-Level T-type

- Sinusoidal
- Space Vector
- 3<sup>rd</sup> Harmonic Injection

### 3-Phase 3-Level AT-type

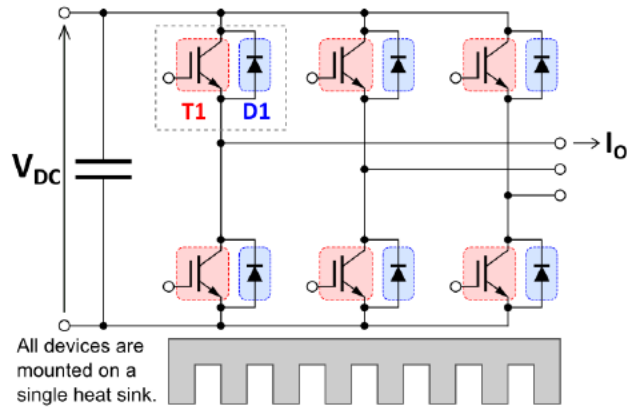
- Sinusoidal
- Space Vector
- 3<sup>rd</sup> Harmonic Injection

### 3-Phase 3-Level A-NPC-type

- Sinusoidal (PWM1)
- Space Vector (PWM1)
- 3<sup>rd</sup> Harmonic Injection (PWM1)

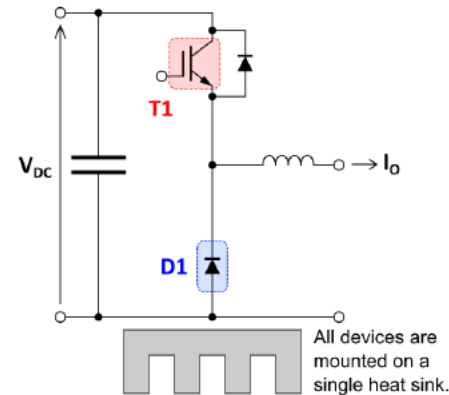


## 3-Phase 2-Level

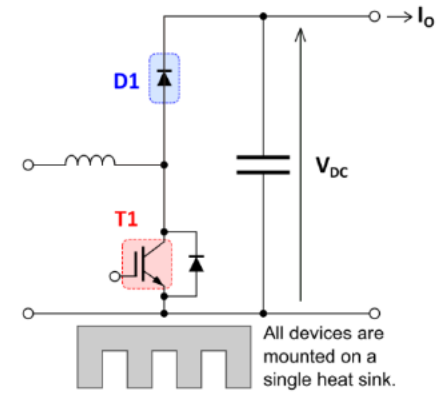


## DC Chopper

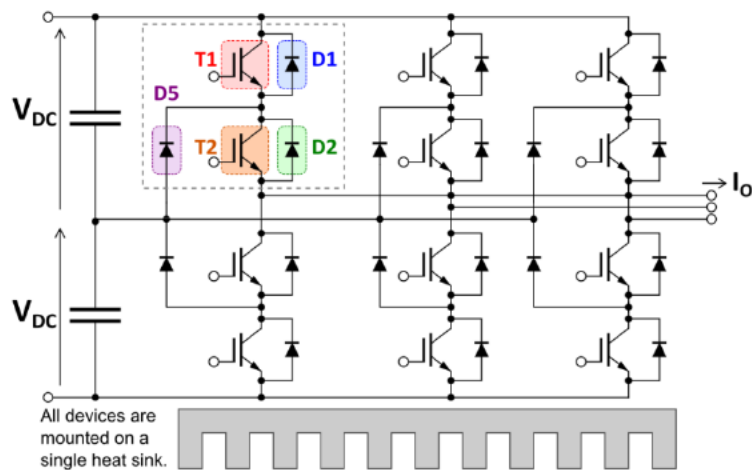
### (Buck)



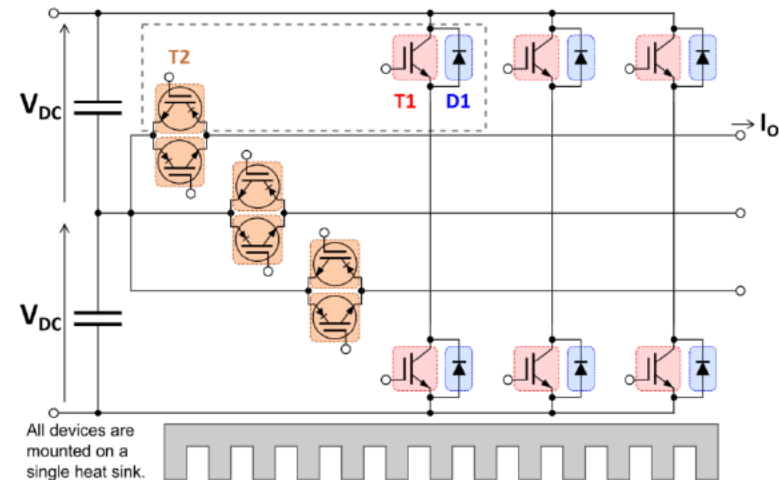
### (Boost)



## 3-Phase 3-Level I-type

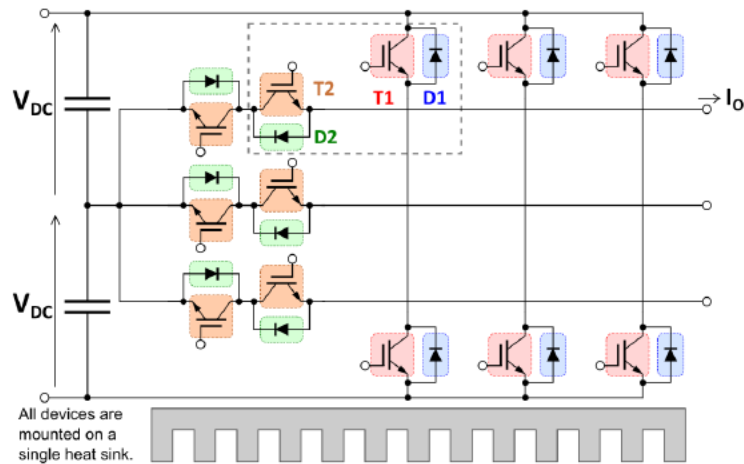


## 3-Phase 3-Level AT-type

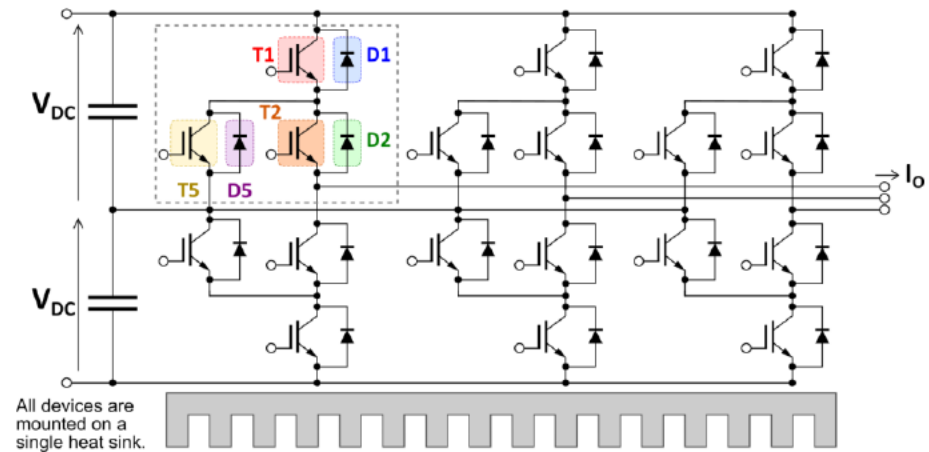


# Circuit: 3-Phase 3-Level type

3-Phase 3-Level T-type

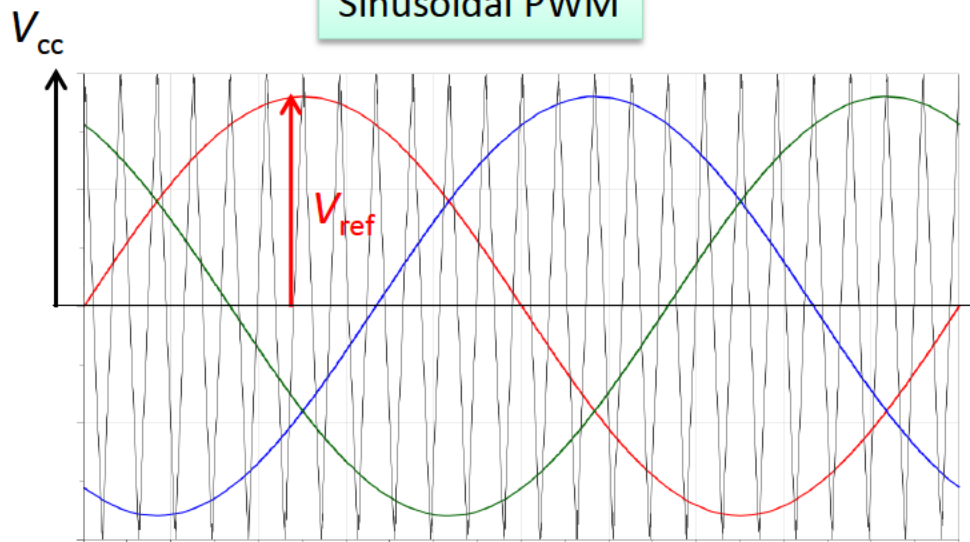


3-Phase 3-Level A-NPC-type



# PWM Method (SPWM, SVPWM)

Sinusoidal PWM



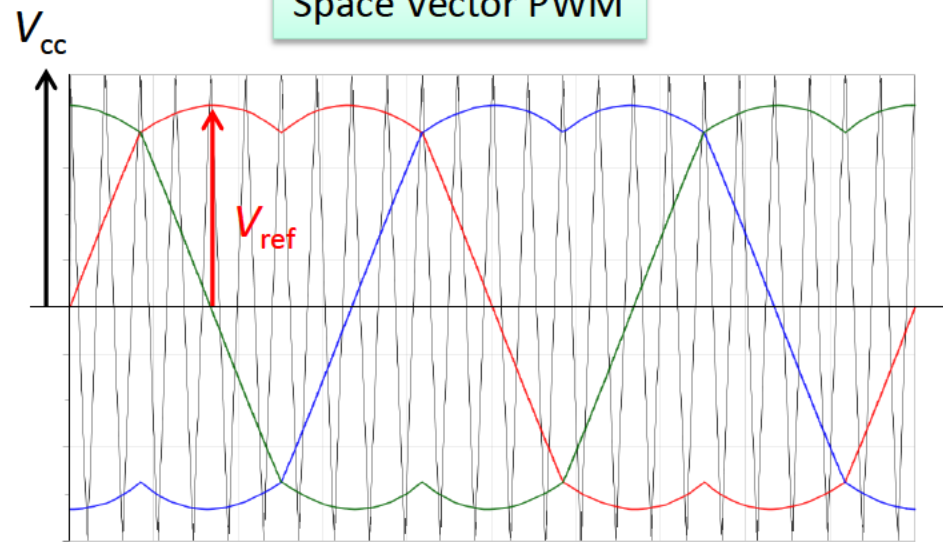
The reference voltage is a sinusoidal waveform.

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  $m$

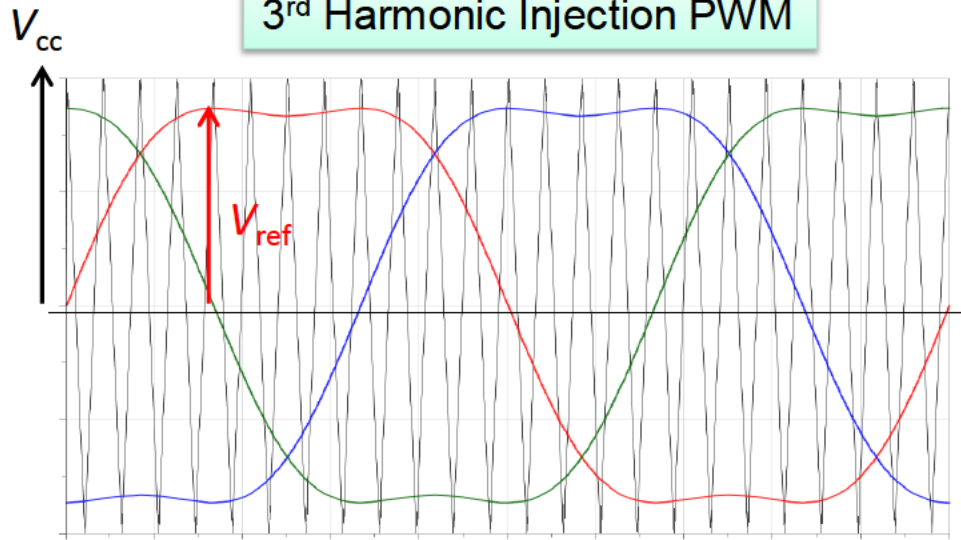
$$V_{ref} = \frac{\sqrt{3}}{2} m V_{dc}$$

$m$  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 (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  $m$

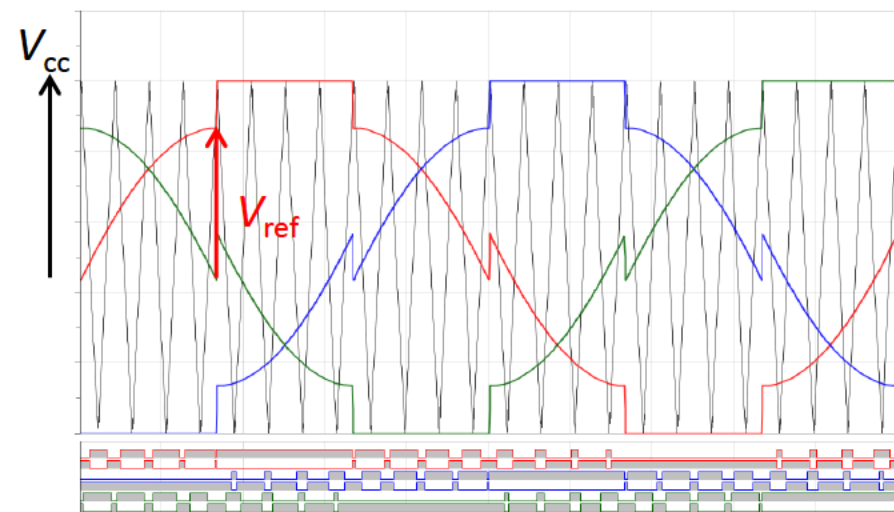
$$V_{ref} = \frac{\sqrt{3}}{2} m V_{dc}$$

$m$  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



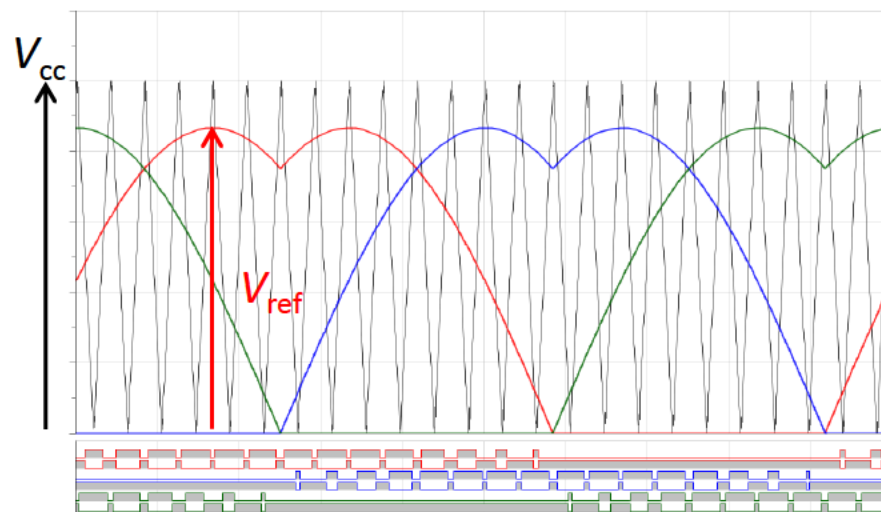
The amplitude of the reference voltage  $V_{ref}$  is defined by the following equation using modulation ratio  $m$ .

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

$m$  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  $m$ .

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

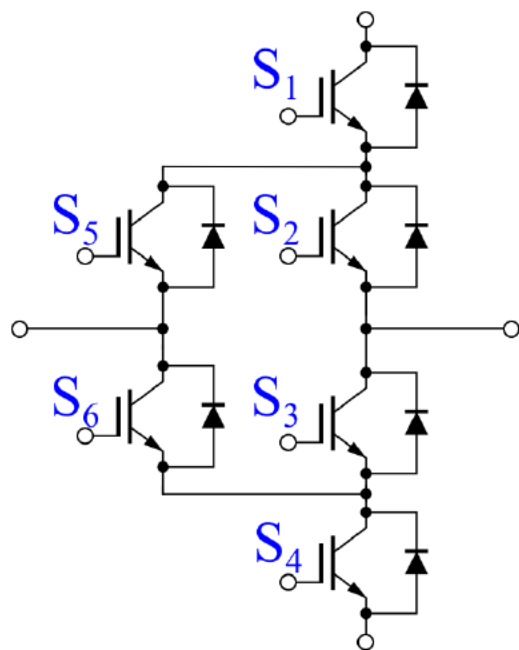
$m$  is defined to be the same output voltage to the sinusoidal PWM.

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

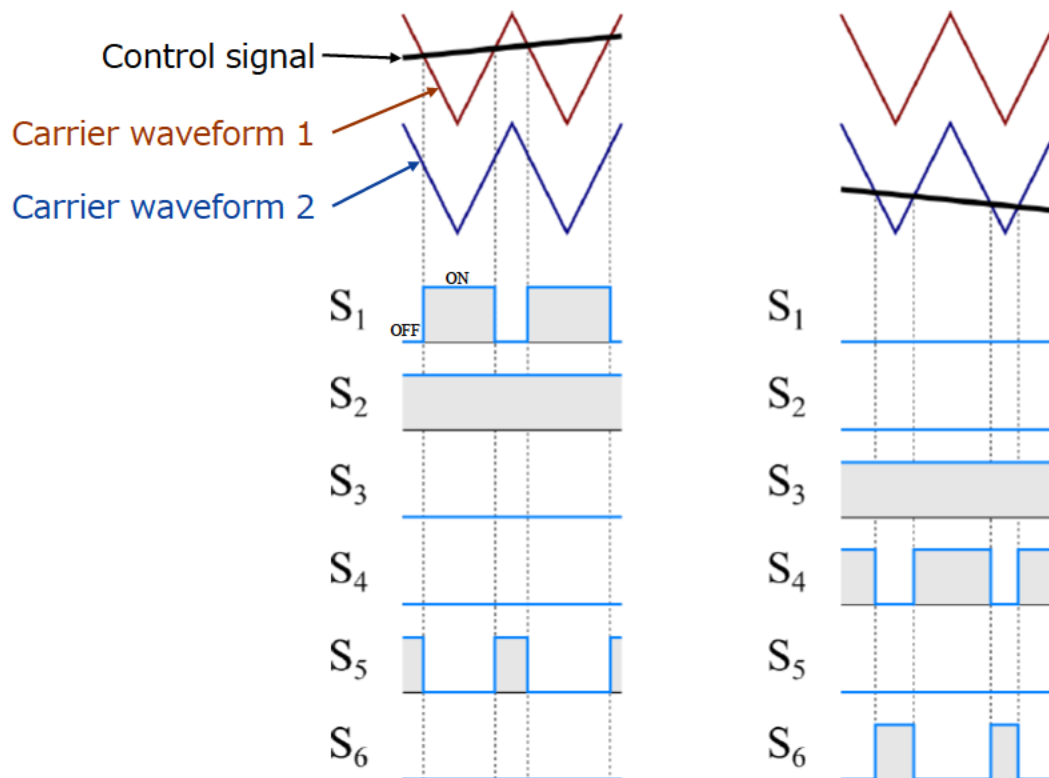
# PWM Method (A-NPC circuit)

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



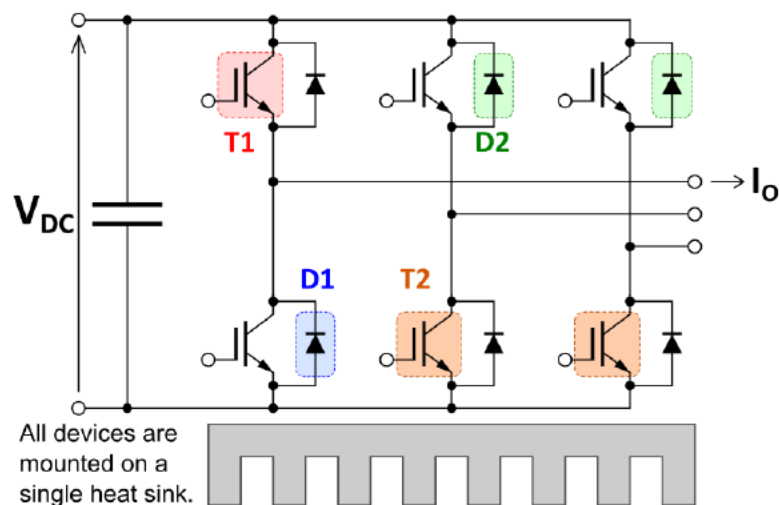
Switching pattern (PWM1)



# Motor DC Lock Operation

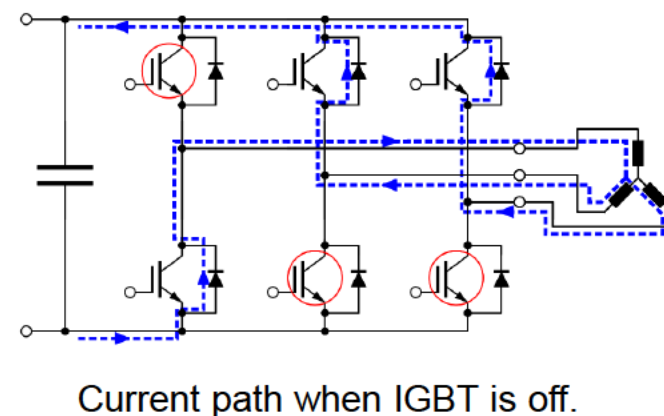
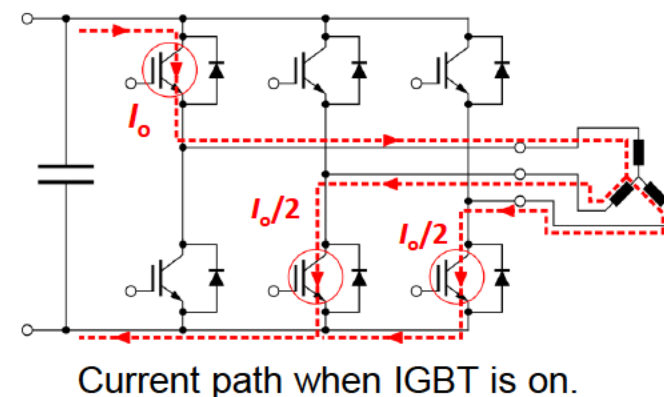
Calculate the IGBT / FWD loss when locking the motor rotation with a servo drive or the like.

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>

