FUJI WEB SIMULATION TOOL: PLECS BASED POWER ELECTRONIC APPLICATION SIMULATOR

USER MANUAL

End-User Software License Agreement

Fuji Electric
Innovating Energy Technology

(Caution) Before downloading and using the software, please read the following “End-user Software Agreement”. By downloading the software, you agree to be bound by the terms of the following agreement. If you don’t agree the agreement, remove the software and erase all copies of the software and the related documents.

End-User Software License Agreement

This is a software license agreement (the “Agreement”) between you (“Customer”) and Fuji Electric Co. Ltd. (“Fuji”) with regard to the use of Fuji IGBT Simulator (“Software”).

1. **(Right of Use)** This software is available to use without paying additional fees to Fuji.
   No right or license, either express or implied, under any patent, copyright, trade secret or other intellectual property right owned by Fuji Electric Co., Ltd. is (or shall be deemed) granted.
2. **(Copyright)** Fuji retains the copyright, title and ownership of the software, the manual and related documents.
3. **(Prohibitions)** You may not reverse engineer, decompile, or disassemble this software.
4. **(Limited Warranty)** Fuji makes no representation or warranty, whether express or implied, relating to the infringement or alleged infringement of other's intellectual property rights which may arise from the use of the applications described herein.
   Fuji pays close attention to the quality of the contents on this simulator. However, such continents are provided “as is “ without guarantees of any kinds.
5. **(Program update)** The program specification of this software is subject to change without any notice.

Contents

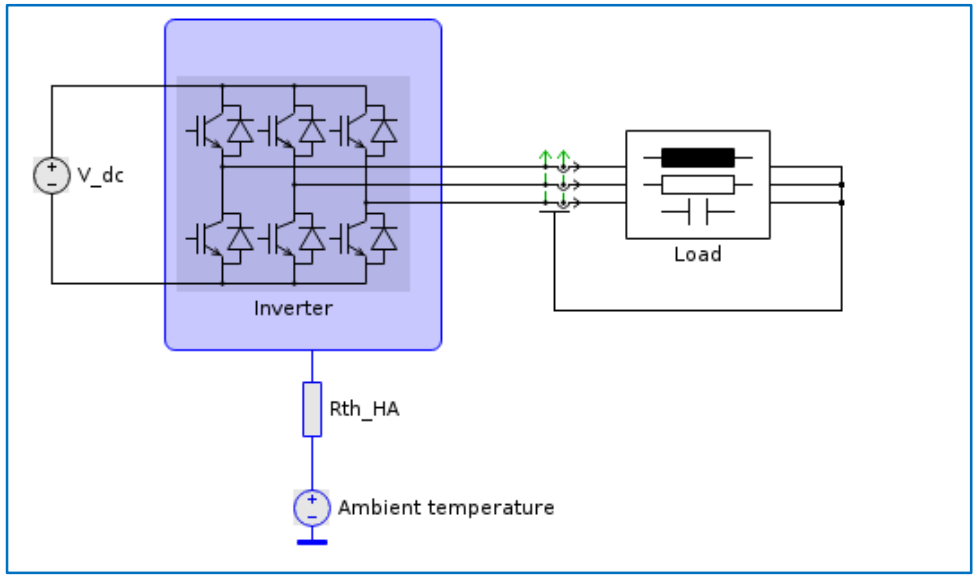
Fuji Electric
Innovating Energy Technology

How to Start

Fuji Electric
Innovating Energy Technology

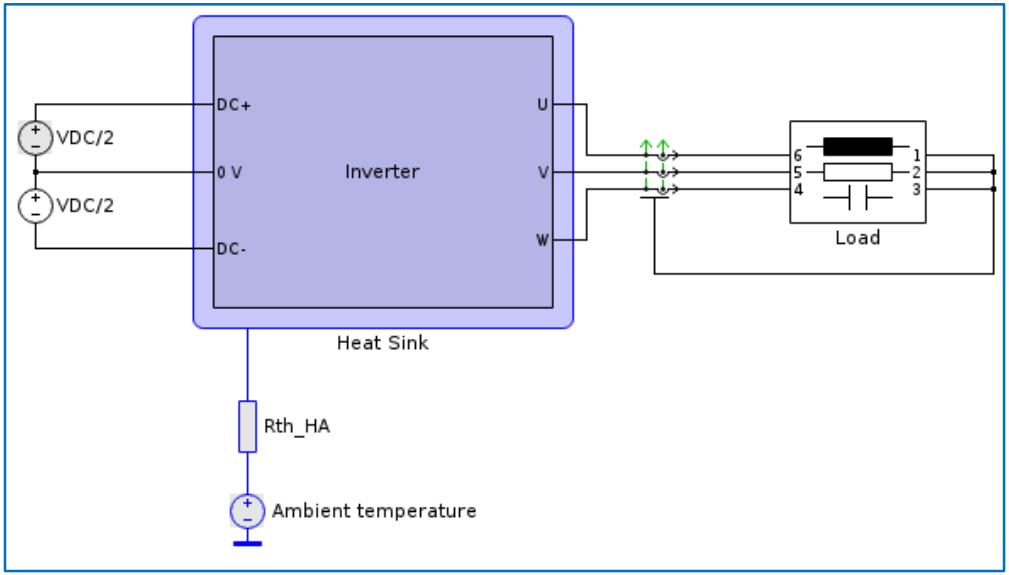
Choose between two different models:

3 Phases 2 Level Inverter



http://simu.fujielectric-europe.com/2_level_inverter.html

3 Level T type Inverter



http://simu.fujielectric-europe.com/3_level_inverter_t_type.html

3 Phases 2 Level Inverter

3 Phases 2 Level Inverter

Fuji Electric
Innovating Energy Technology

Explanation of start page

Variable Parameters for Simulation

Modulation rate:	1	
Modulation strategy:	Sinusoidal	
Inverter output current:	100	A
Inverter output frequency:	50	Hz
Switching frequency:	5000	Hz
Power factor:	0,9	

Module Selection

Module type: Single IGBT

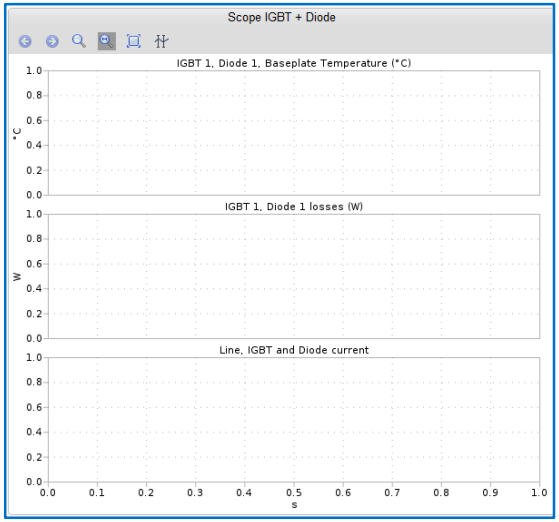
Blocking voltage: 1200 V

Package: High Power Module

IGBT Module:

- ○ 1MBI1200VC-120P V Series, 1200 A
- ○ 1MBI1600VC-120P V Series, 1600 A
- ○ 1MBI2400VC-120P V Series, 2400 A
- ○ 1MBI2400VD-120P V Series, 2400 A
- ○ 1MBI3600VD-120P V Series, 3600 A

Scope



Numerical results from Scope

Temperatures	Max temperature	Min temperature	Avg temperature
IGBT			
Diode			
Case			
Heat sink			

Losses	Cond. losses	Turn-on losses	Turn-off losses	Reverse recovery losses	Total losses
IGBT					
Diode					

Variables Parameters in the Circuit

Fuji Electric
Innovating Energy Technology

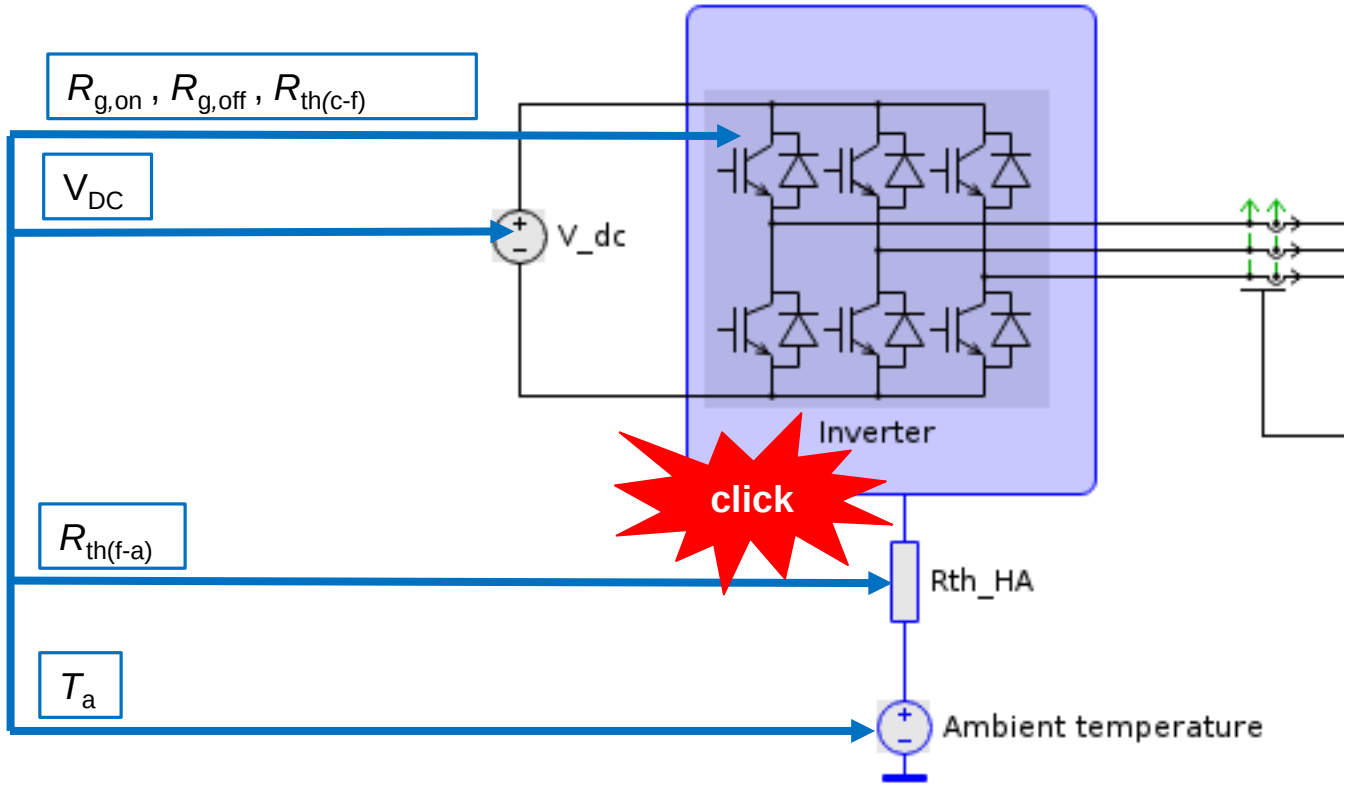
Components highlighted in **grey** contain adjustables parameters

Thermal Settings

- $R_{th(c\text{-}f)}$ case to heat sink
- $R_{th(f\text{-}a)}$ heat sink to ambient
- Ambient temperature T_a

Electrical Settings

- Rg,on and Rg,off
- Vdc



Thermal Conditions: Overview

Fuji Electric
Innovating Energy Technology

Different scenarios in the thermal calculation can be considered:

1) Calculate case temperature

- Input $R_{th(c\text{-}f)}$
- Input $R_{th(f\text{-}a)}$
- Set ambient temperature

Refer to next page how to input the values!

2) Fixed case temperature

- $R_{th(c\text{-}f)} = R_{th(f\text{-}a)} = 0$
- Set ambient temperature

3) Fixed heat sink temperature

- Set $R_{th(f\text{-}a)} = 0$
- Set heat sink temperature = ambient temperature
- Provide Rth_c-h

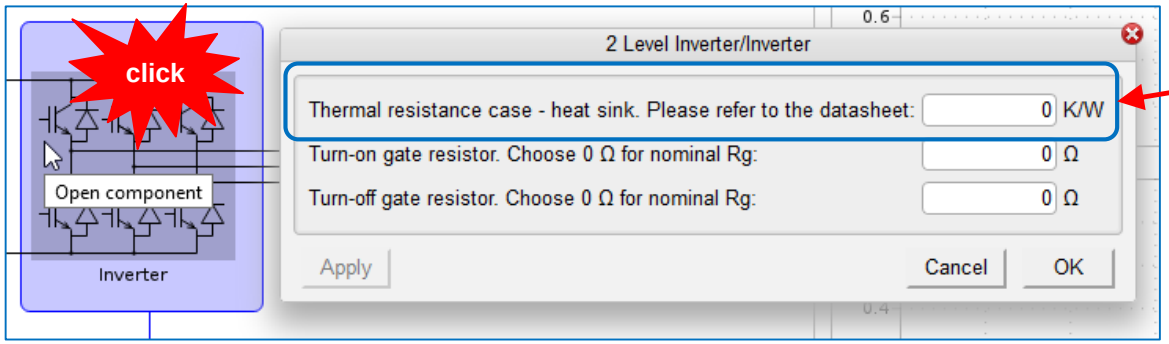
Thermal Conditions: Settings

Fuji Electric
Innovating Energy Technology

$R_{th(c-f)}$

Click on the grey box in the inverter model.

A drop down menu will open.

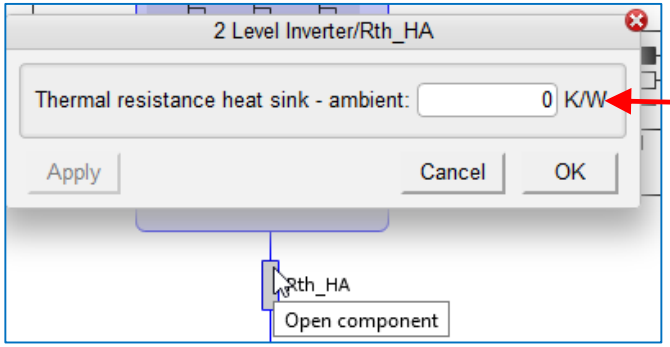


Input $R_{th(c-f)}$ here.

Please check the datasheet for the value.

$R_{th(h-a)}$

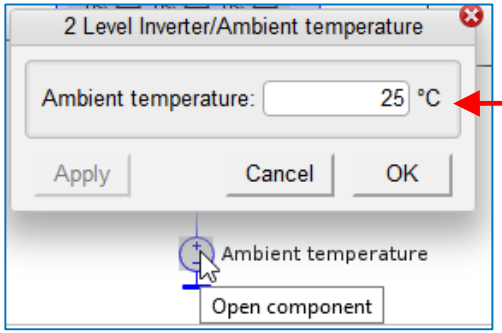
Click on the resistor "Rth_HA"



Input $R_{th(h-a)}$ here.

T_a

Click on the constant temperature symbol "Ambient temperature"



Input ambient temperature.

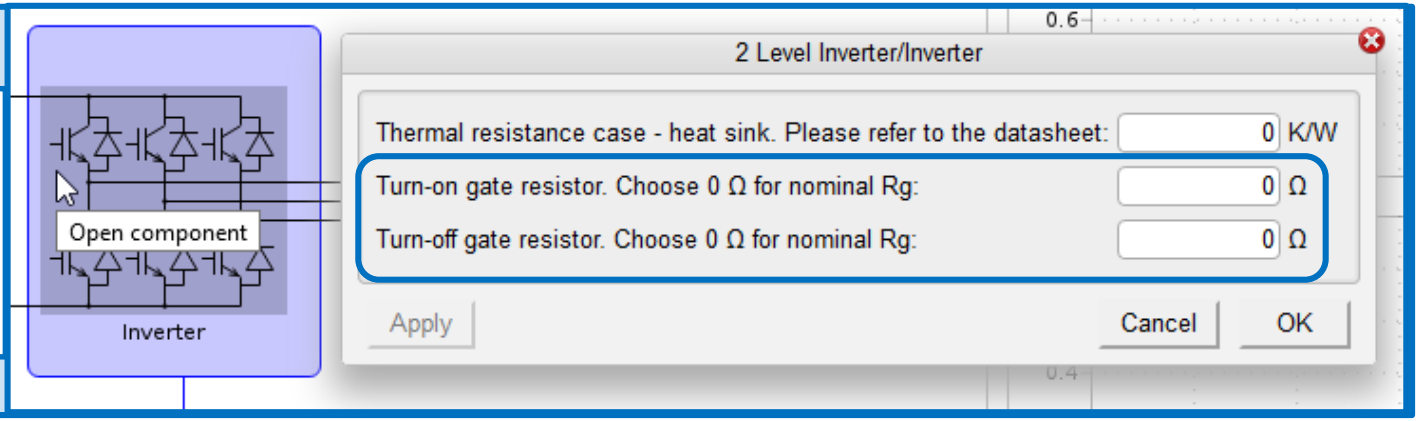
Electrical Conditions

Fuji Electric
Innovating Energy Technology

$R_{g,on}$ and $R_{g,off}$

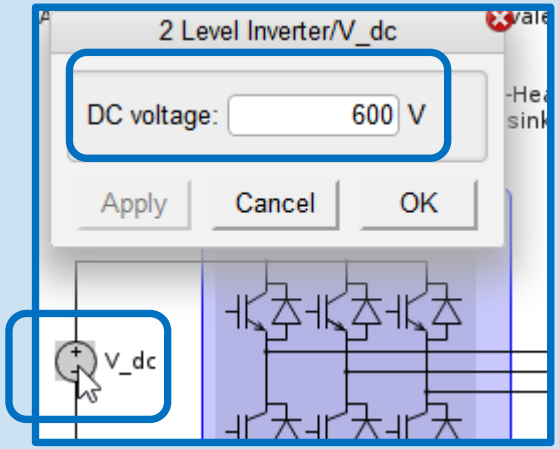
Click on the grey inverter part and the menu will open.

Input $R_{g,on}$ and $R_{g,off}$. Set them to 0 if you want to use the datasheet values.



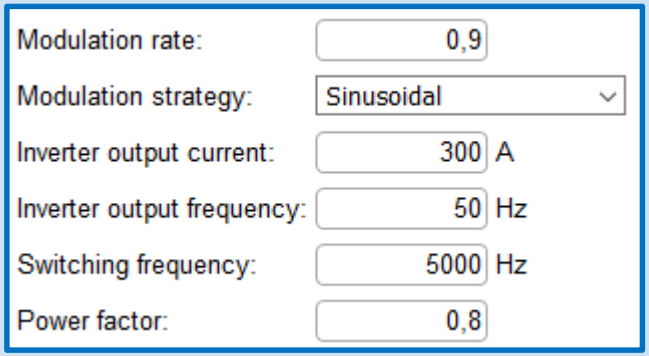
V_{DC}

Drop Down Menu when clicking on the voltage source "V_dc".



m, PWM, I_{out}, f_{out}, f_{sw}, pf

Input the simulation parameters.



3 Level T Type Inverter

Variables Parameters in the Circuit

Fuji Electric
Innovating Energy Technology

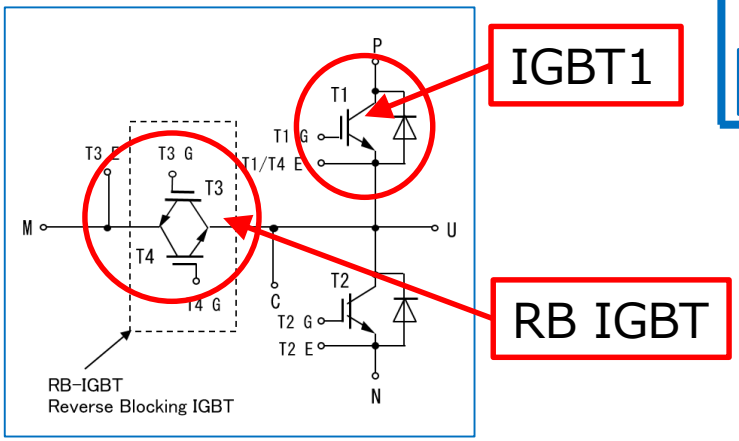
Components highlighted in **grey** contain adjustables parameters

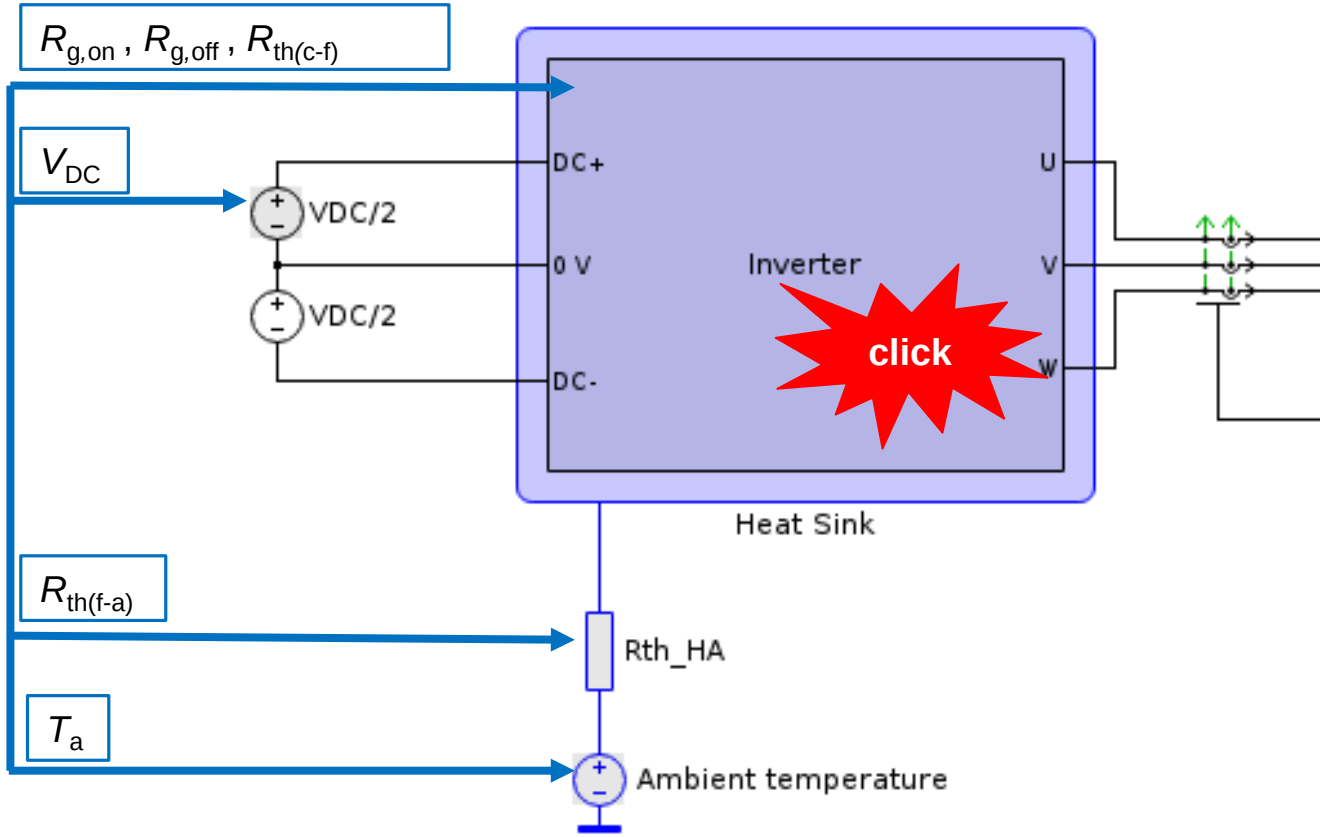
Thermal Settings

- $R_{th(c-f)}$ case to heat sink
- $R_{th(f-a)}$ heat sink to ambient
- Ambient temperature T_a

Electrical Settings

- IGBT1 $R_{g,on}$ and $R_{g,off}$
- RB IGBT $R_{g,on}$ and $R_{g,off}$
- V_{DC}





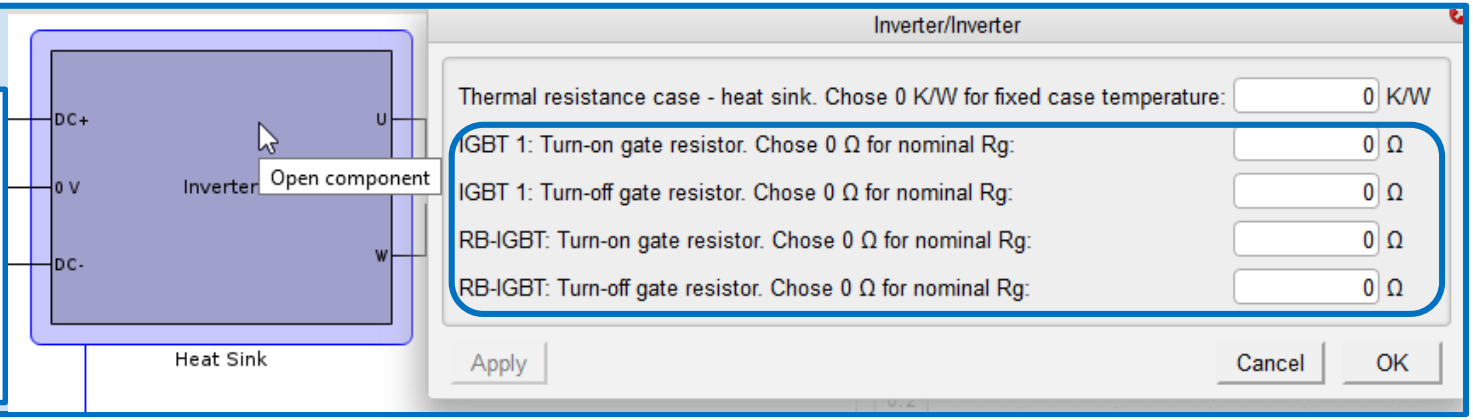
Electrical Conditions

Fuji Electric
Innovating Energy Technology

$R_{g,on}$ and $R_{g,off}$

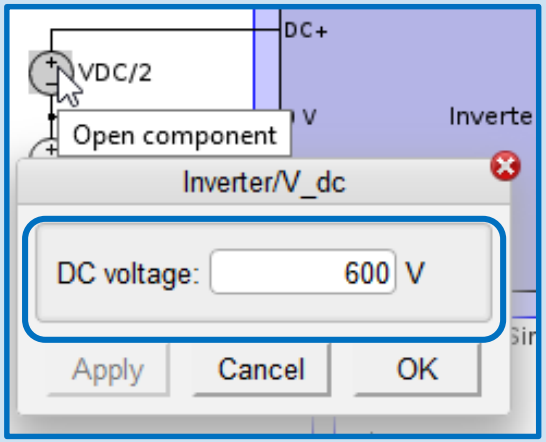
Click on the grey inverter part and the menu will open.

Input $R_{g,on}$ and $R_{g,off}$ for IGBT and RB IGBT. Set them to 0 if you want to use the datasheet values.



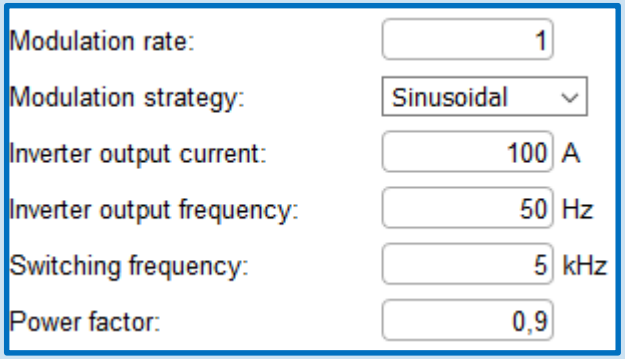
V_{DC}

Drop Down Menu when clicking on the voltage source "V_DC/2".



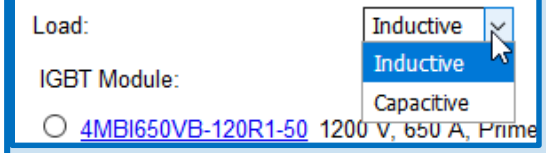
m, PWM, I_{out}, f_{out}, f_{sw}, pf

Input the simulation parameters.



load

Choose load type.

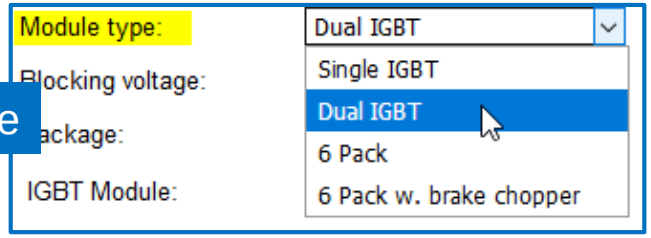


General Settings

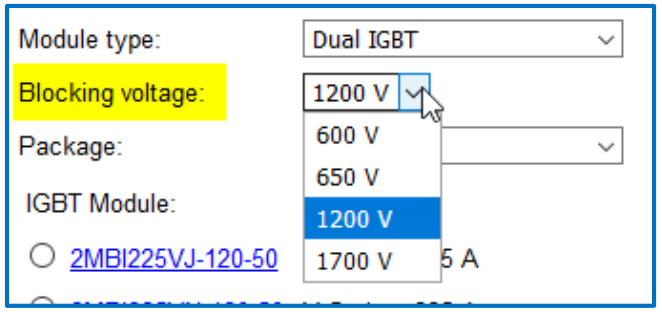
Module Selection

Fuji Electric
Innovating Energy Technology

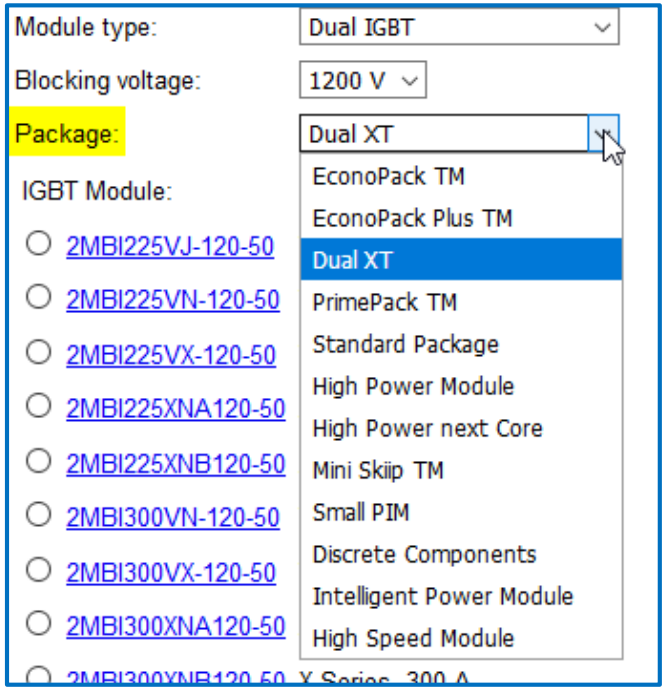
1 Module type



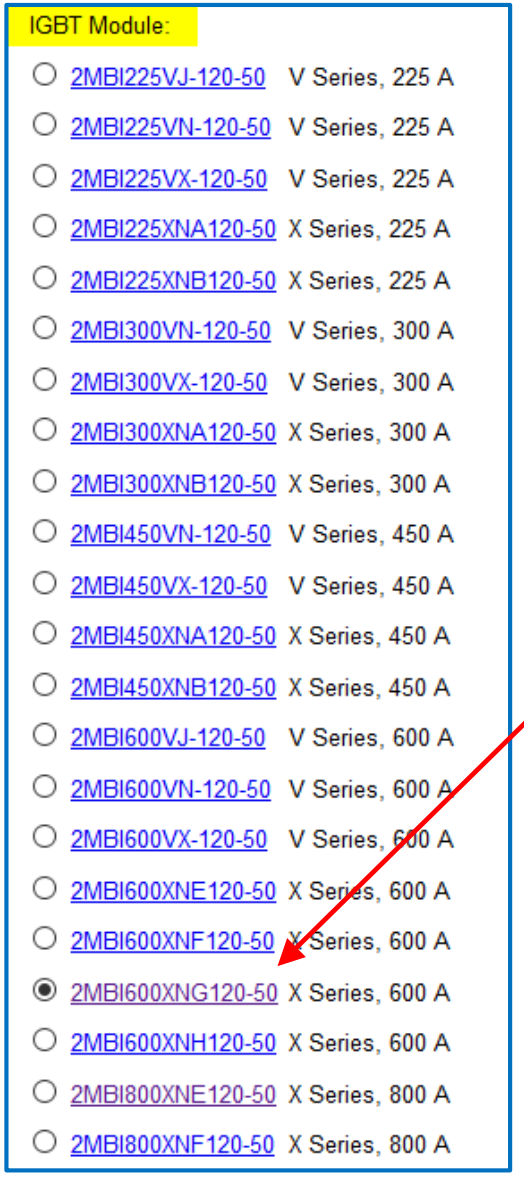
2 Blocking voltage



3 Package



4 Modules



Link to data sheet on www.fujielectric.com

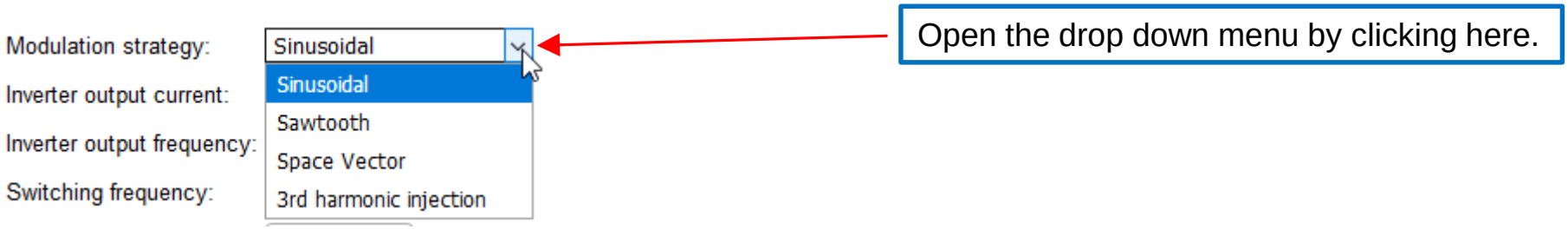
MT5F39886

PWM Methods

Fuji Electric
Innovating Energy Technology

Currently the following modulation methods are available:

- Sinusoidal
- Sawtooth
- Space Vector
- 3rd harmonic injection



Run Simulation

Fuji Electric
Innovating Energy Technology

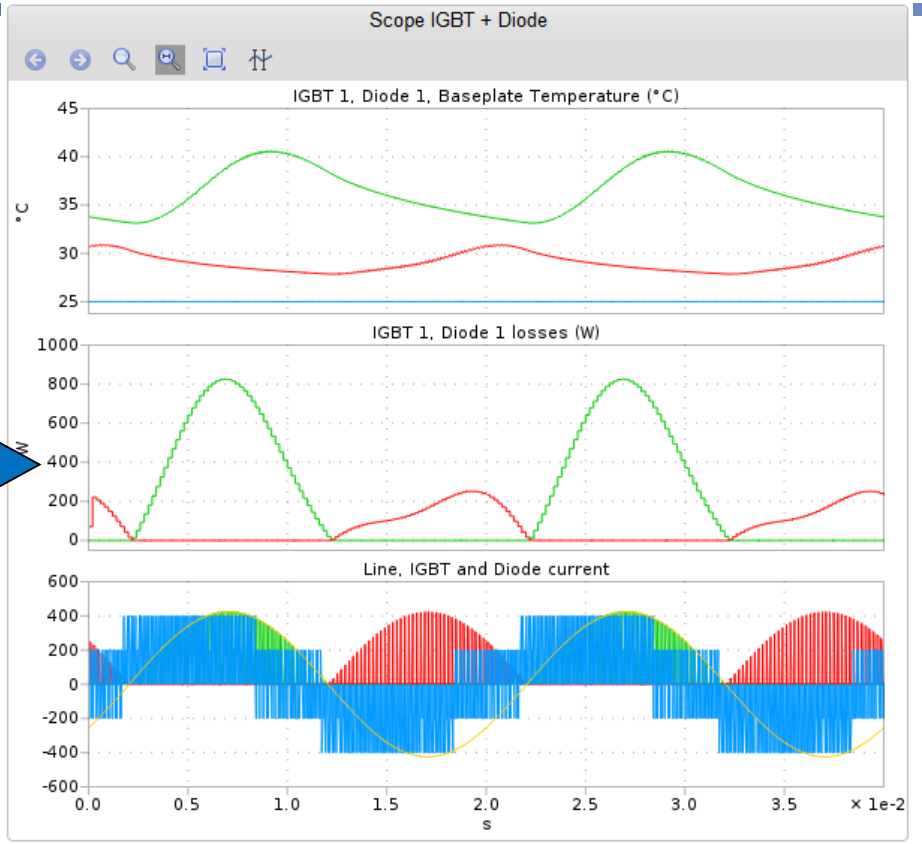
- 2MBI600XNE120-50 X Series, 600 A
- 2MBI600XNF120-50 X Series, 600 A
- (•) 2MBI600XNG120-50 X Series, 600 A
- 2MBI600XNH120-50 X Series, 600 A
- 2MBI800XNE120-50 X Series, 800 A
- 2MBI800XNF120-50 X Series, 800 A

Steady-State Analysis | Hold result

click

Simulation will start when you click the “Steady-State Analysis” button

Simulation Results



The resulting waveforms will be displayed in the screen of the scope.

Corresponding numerical values are shown in the Temperatures / Losses windows.

Temperatures	Max temperature	Min temperature	Avg temperature
IGBT	40.6 °C	33.1 °C	36.4 °C
Diode	30.9 °C	27.8 °C	29.0 °C
Case	25.0 °C		
Heat sink	25.0 °C		

Losses	Cond. losses	Turn-on losses	Turn-off losses	Reverse recovery losses	Total losses
IGBT	129.7 W	39.6 W	68.2 W		237.5 W
Diode	37.5 W			33.0 W	70.5 W

Simulation Results

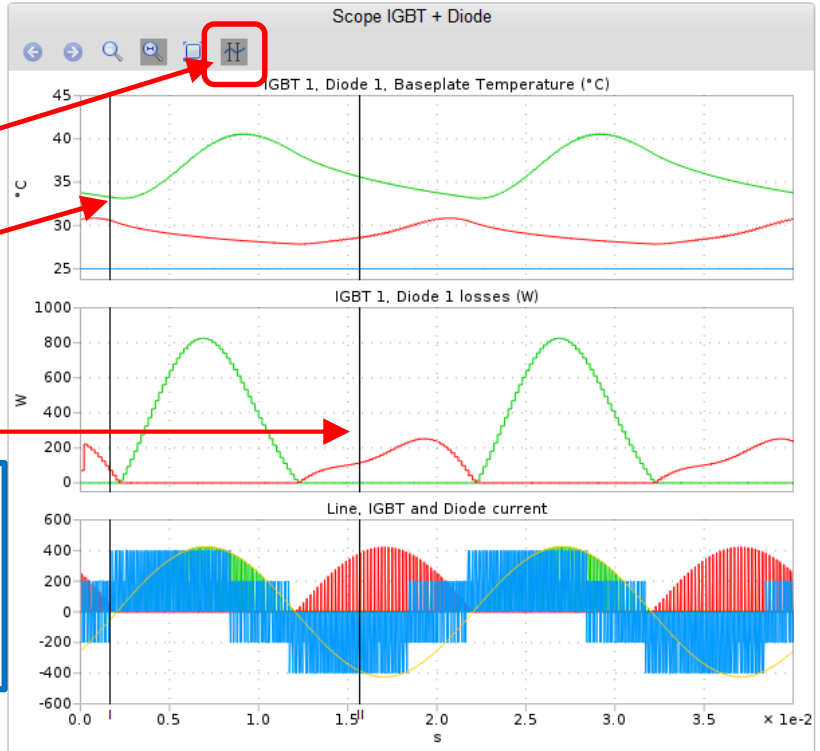
Fuji Electric
Innovating Energy Technology

click

Using Cursors

Cursors will firstly appear at the edges. Use mouse cursor to move them to the right position.

New window will open



Name	Cursor 1	Cursor 2	Delta	Min	Max	Mean	
Time	0,001695	0,015712	0,014017				
IGBT 1, Diode 1, Baseplate Temperature (°C)							
IGBT 1 junction temperature	33.27	35.60	-2.326	33.12	40.65	37.29	3
Diode 1 junction temperature	30.56	28.68	1.881	27.84	30.56	28.63	2
Case temperature	25.00	25.00	0.000	25.00	25.00	25.00	2
IGBT 1, Diode 1 losses (W)							
IGBT losses	0.000	0.000	0.000	0.000	825.8	338.8	4
Diode losses	71.52	115.0	-43.50	0.000	115.0	19.77	4
Line, IGBT and Diode current							
IGBT 1 current	0.000	0.000	0.000	0.000	424.3	151.5	2
Diode 1 current	47.00	0.000	47.00	0.000	387.1	4.853	3
Output voltage	200.0	-400.0	600.0	-400.0	400.0	40.66	2
Output current	-47.00	-387.4	340.4	-387.4	424.3	135.0	2

Analysis window:

Characteristics

IGBT & Diode:
- Tj, losses, current

Module:
- Tc

Inverter:
- Iout, Vout

Values
- Delta, min, max, mean, rms

Simulation Results: Comparison

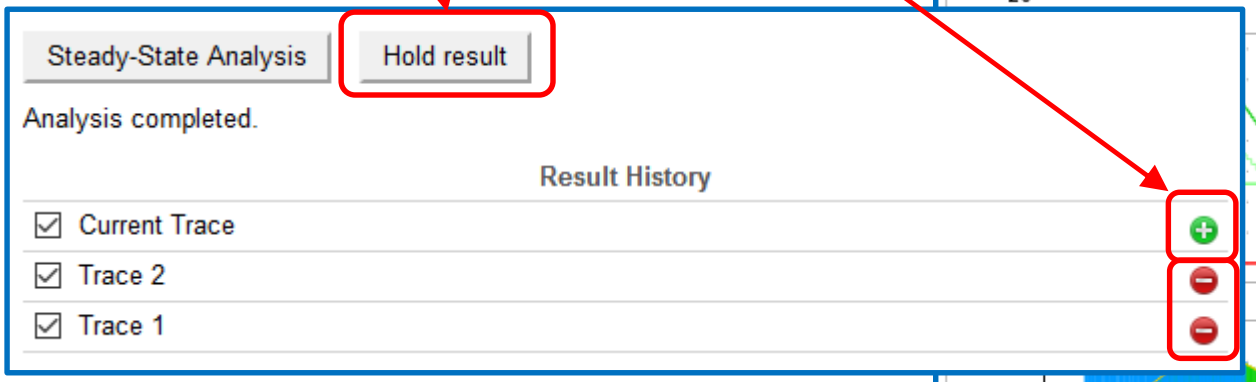
Fuji Electric
Innovating Energy Technology

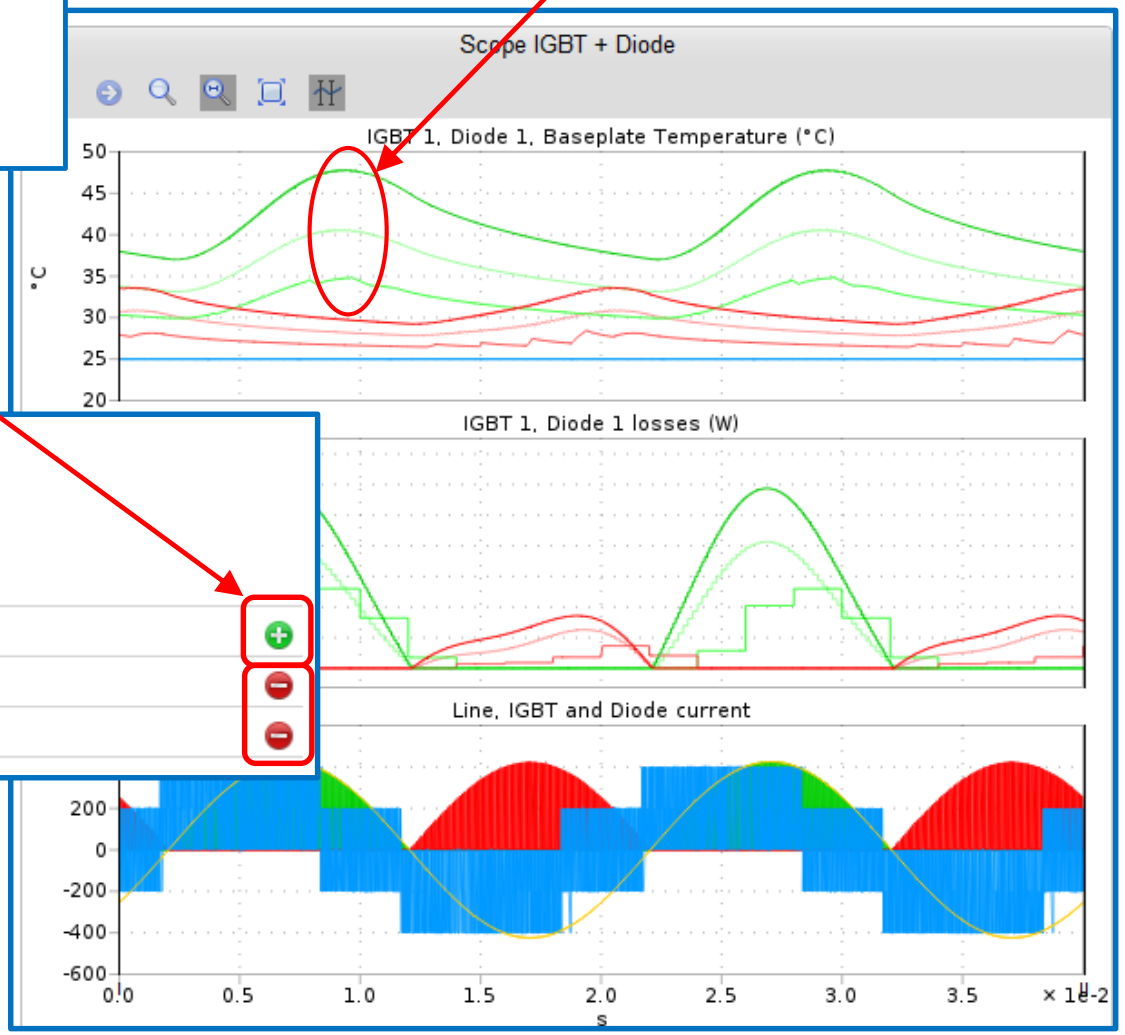
Use „hold result“ to easily compare different simulations:

The first result will be kept automatically. For more please use ⊕ when the simulation is finished.

To remove a result from the history, please click ⊖

3 different simulation results





Comparison: Multiple results

Fuji Electric
Innovating Energy Technology

Results of all 3 traces are displayed.

Scope values

Temperatures			
	Max temperature	Min temperature	Avg temperature
IGBT	47.8 °C 34.9 °C 40.6 °C	37.0 °C 29.9 °C 33.1 °C	41.8 °C 31.9 °C 36.4 °C
Diode	33.6 °C 28.5 °C 30.9 °C	29.2 °C 26.5 °C 27.8 °C	31.0 °C 27.1 °C 29.0 °C
Case	25.0 °C 25.0 °C 25.0 °C		
Heat sink	25.0 °C 25.0 °C 25.0 °C		

Losses					
	Cond. losses	Turn-on losses	Turn-off losses	Reverse recovery losses	Total losses
IGBT	130.5 W 133.6 W 129.7 W	82.1 W 3.6 W 39.6 W	137.4 W 7.1 W 68.2 W		350.0 W 144.3 W 237.5 W
Diode	37.8 W 33.5 W 37.5 W			67.8 W 3.1 W 33.0 W	105.7 W 36.6 W 70.5 W

Analysis result between the Cursors

Name	Cursor 1	Cursor 2	Delta	Min	Max	Mean	
Time	0,0054617	0,025726	0,020264				
IGBT 1, Diode 1, Baseplate Temperature (°C)							
IGBT 1 junction temperature	41.67	42.40	-0.7326	37.01	47.84	41.80	4
	31.90	32.20	-0.3025	29.92	34.91	31.93	3
	36.45	36.82	-0.3757	33.12	40.65	36.40	3
Diode 1 junction temperature	30.85	30.76	0.09595	29.23	33.62	31.02	3
	27.11	27.07	0.03669	26.47	28.46	27.08	2
	28.96	28.89	0.06622	27.84	30.90	29.02	2
Case temperature	25.00	25.00	0.000	25.00	25.00	25.00	2
	25.00	25.00	0.000	25.00	25.00	25.00	2
	25.00	25.00	0.000	25.00	25.00	25.00	2
IGBT 1, Diode 1 losses (W)							
IGBT losses	1019	1076	-57.23	0.000	1175	359.1	5
	114.7	114.7	3.965e-10	0.000	519.8	143.9	2
	712.4	741.9	-29.49	0.000	825.8	243.8	3
Diode losses	0.000	0.000	0.000	0.000	342.8	104.3	1
	0.000	0.000	0.000	0.000	146.2	36.09	5
	0.000	0.000	0.000	0.000	251.8	69.58	1
Line, IGBT and Diode current							
IGBT 1 current	372.6	388.2	-15.54	0.000	424.3	109.2	1
	372.6	388.2	-15.54	0.000	424.3	113.8	1
	372.6	388.2	-15.54	0.000	424.3	109.5	1
Diode 1 current	0.000	0.000	0.000	0.000	424.3	28.74	9
	0.000	0.000	0.000	0.000	424.3	25.80	8
	0.000	0.000	0.000	0.000	424.2	28.52	9
Output voltage	200.0	400.0	-200.0	-400.0	400.0	3.728	2
	400.0	400.0	1.128e-7	-400.0	400.0	5.218	2
	400.0	200.0	200.0	-400.0	400.0	2.899	2
Output current	372.6	388.2	-15.54	-424.3	424.3	4.965	3
	372.6	388.2	-15.54	-424.3	424.3	4.965	3
	372.6	388.2	-15.54	-424.3	424.3	4.965	3

More Scope Functions

Fuji Electric
Innovating Energy Technology

You can use different kind of zoom functions. Please note that (according to your hardware / internet connections etc.) the responding time might be slow.

Free zoom:

Zoom in x and y direction possible

1

Constrained zoom:

the whole y-axis range is fixed.
Zoom in x direction

2

Zoom to fit:

resets all zoom operations

3

Previous / next view