IGBT and MOSFET Loss Calculation in the Thermal Module

Altair PSIM Tutorial

The Thermal Module is an add-on option to PSIM. Its purpose is to simulate the losses of semiconductor devices and inductors quickly from manufacturer device datasheets.

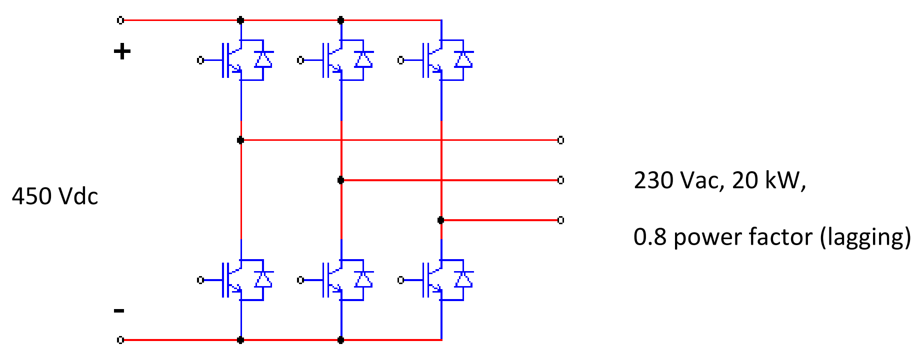
In this tutorial, the process of how to use the Thermal Module for power loss calculation of IGBT and MOSFET is described. The loss calculation of SiC and GaN devices is covered in the tutorial "Tutorial – SiC and GaN loss calculation and transient analysis.pdf", and the loss calculation of inductors is covered in another tutorial "Tutorial – Inductor loss calculation in the Thermal Module.pdf".

From PSIM 2022.1 release, the semiconductor device database files in the .xml text format are supported. The .xml files can be created and edited by PSIM's Device Database Editor PcdEditor or by any text editors (such as Notepad).

The legacy device database files in the .dev binary format are still supported by PSIM for simulation. PcdEditor in the 2022.1 release can still load the .dev files, and can convert a .dev file to a .xml file. However, it cannot create new .dev files or edit existing .dev files which can only be done by the previous versions of the PcdEditor.

1. IGBT Loss Calculation

To illustrate how IGBT losses and junction temperature are calculated in PSIM's Thermal Module, the datasheet of Semikron's IGBT Module SEMiX151GD066HDs (600V, 150A) is used in a 3-phase voltage source inverter example, as shown below:



In this example, the inverter operating conditions are:

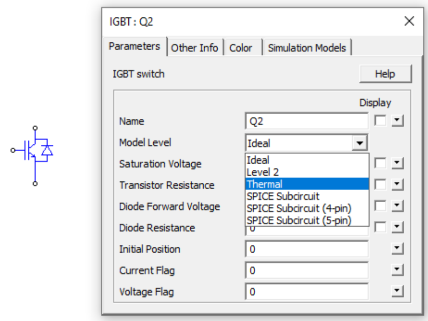
DC Bus Voltage: 450 Vdc
AC Output: 230 V (line-line, rms), 60 Hz, 20 kW, 0.8 power factor (lagging)
Switching Frequency: 8 kHz

From the values above, the ac output current is calculated as: Io = 62.75 A.

1.1 Simulation of IGBT Losses in PSIM

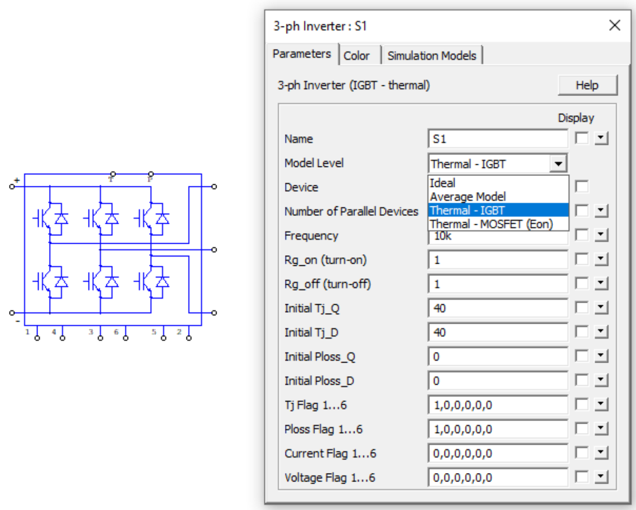
Assuming the IGBT XML file is already available in PSIM's device database, it can be placed in a PSIM schematic for the calculation of losses. To choose a device, in PSIM, select **Elements** >> **Power** >> **Switches**>> **IGBT**.

Place the discrete IGBT element on the schematic. Double click on the IGBT element to open the parameter dialog window. Click on the **Model Level** drop down box, and choose the switch level as **Thermal**, as shown below.

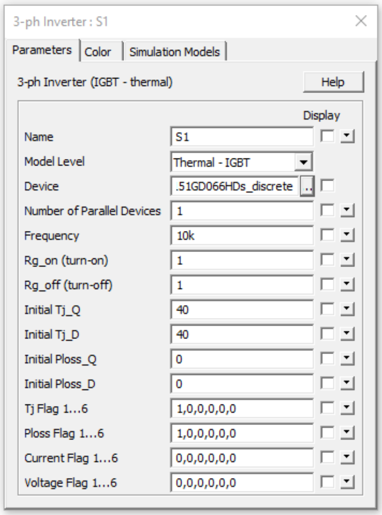


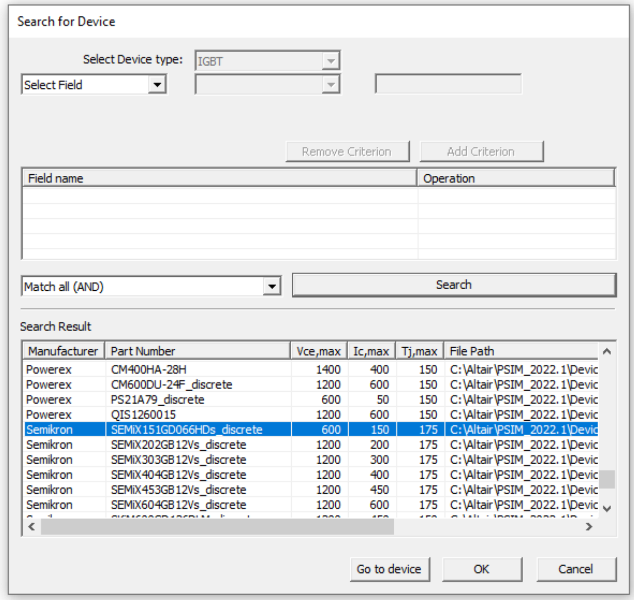
To choose a 6-pack IGBT for a 3-phase inverter system, select **Elements >> Power >> Switches>>Switch Modules>>3-ph Inverter.**

Place the 3-ph Inverter element on the schematic. Double click on the 3-ph Inverter element to open the parameter dialog window. Click on the **Model Level** drop down box, and choose the switch level as **Thermal-IGBT**, as shown below.

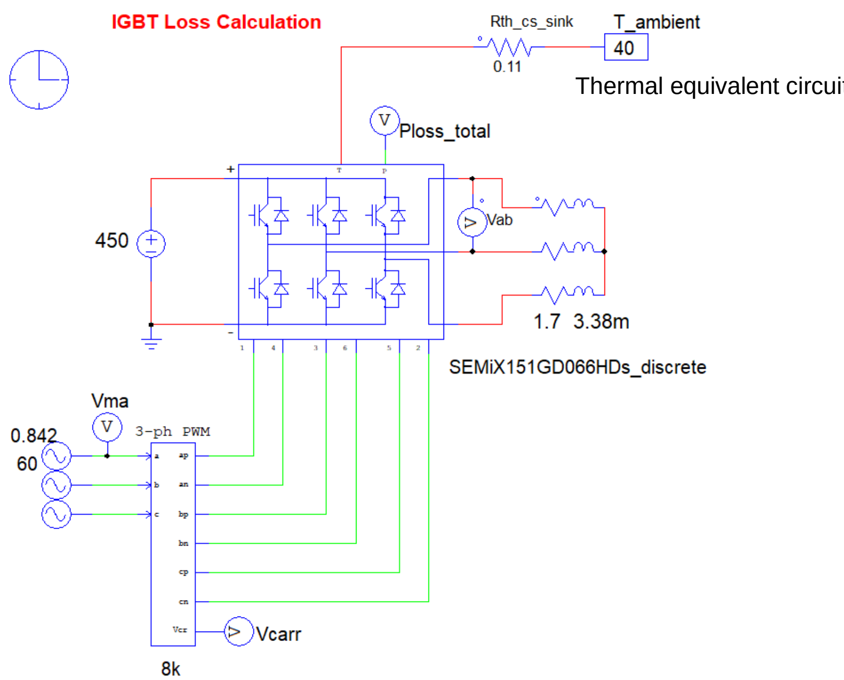


Once the Thermal-IGBT is selected as the Model Level, the IGBT (database) will pop up, as shown below. Click on the Browser button next to the “Device” input field, and choose the device “Semikron SEMiX151GD066HDs_discrete.xml”, as shown below.





The circuit below shows the completed inverter circuit using the 6-pack IGBT Module “SEMiX151GD066HDs_discrete.xml”. The load resistances and inductances and the modulation index are selected such that the circuit operates under the specified conditions (output of 230 Vac, 20-kW, 0.8 power factor (lagging)).



The IGBT module image has one node T on the top. The voltage at this node represents the module’s case temperature, and the current flowing out of this node represents the total power losses of the whole module (all 6 devices).

This node should be connected to an external thermal equivalent circuit representing the dynamic thermal impedance between the case of the module and the ambient. In this example, the resistor

Rth_cs_sink is the sum of the thermal resistances between the case and heat sink, and between the heat sink and the ambient.

The node P is the probe node for measuring the total power loss.

The parameters of the IGBT (database) are defined as below:

The parameter ***Frequency*** defines the interval under which the losses are calculated. For example, if the frequency is 60 Hz, the losses results are the average value for an interval of 16.67 ms. If the frequency is set to be the same as the switching frequency, the losses in each switching cycle are obtained.

Parameters ***Rg_on*** and ***Rg_off*** are the gate resistances at turn-on and turn-off. Note that they must be defined correctly to reflect the actual operating conditions.

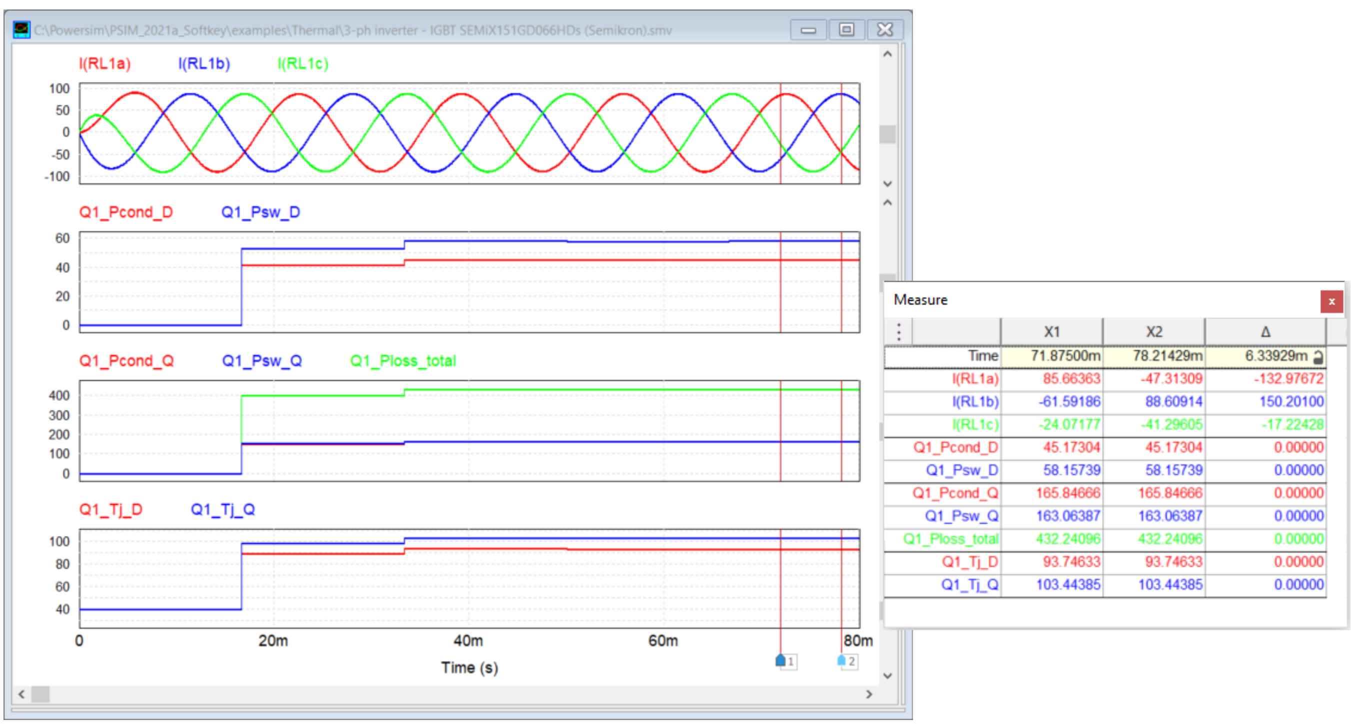
Calibration Factors are used to scale the calculation results against experimental results. For example, for a specific device, if the datasheet losses are 10 W, but the measured losses from the experiments are 12 W, the calibration factor should be set to 1.2.

If the ***flags*** are for the monitoring of the device's thermal behaviour. When the flags are set, the following thermal related characteristics of each device can be monitored:

- transistor junction temperature Tj_Q
- diode junction temperature Tj_D
- transistor conduction loss Pcond_Q
- transistor switching loss Psw_Q
- diode conduction loss Pcond_D
- diode switching loss Psw_D

The temperatures are in ^{o}C..

The simulation results displayed in SIMVIEW are shown below:



The following power loss and temperature results are obtained from the simulation results:

Diode junction temperature (^{o}C):	93.7
Transistor junction temperature (^{o}C):	103.4

Transistor conduction loss (W):	165.8
Transistor switching loss (W):	163.1
Diode conduction loss (W):	45.2
Diode switching loss (W):	58.2
Total loss per module (W):	432.2

1.2 Adding IGBT Devices into the Device Database

The above example shows how to run a simulation in PSIM when the device is already available in the database. However, in many cases, a device is not available in the database, and has to be entered into the database before it can be used in a PSIM schematic.

The IGBT Module SEMiX151GD066HDs is used as the example to illustrate the procedure of entering a device into PSIM's device database.

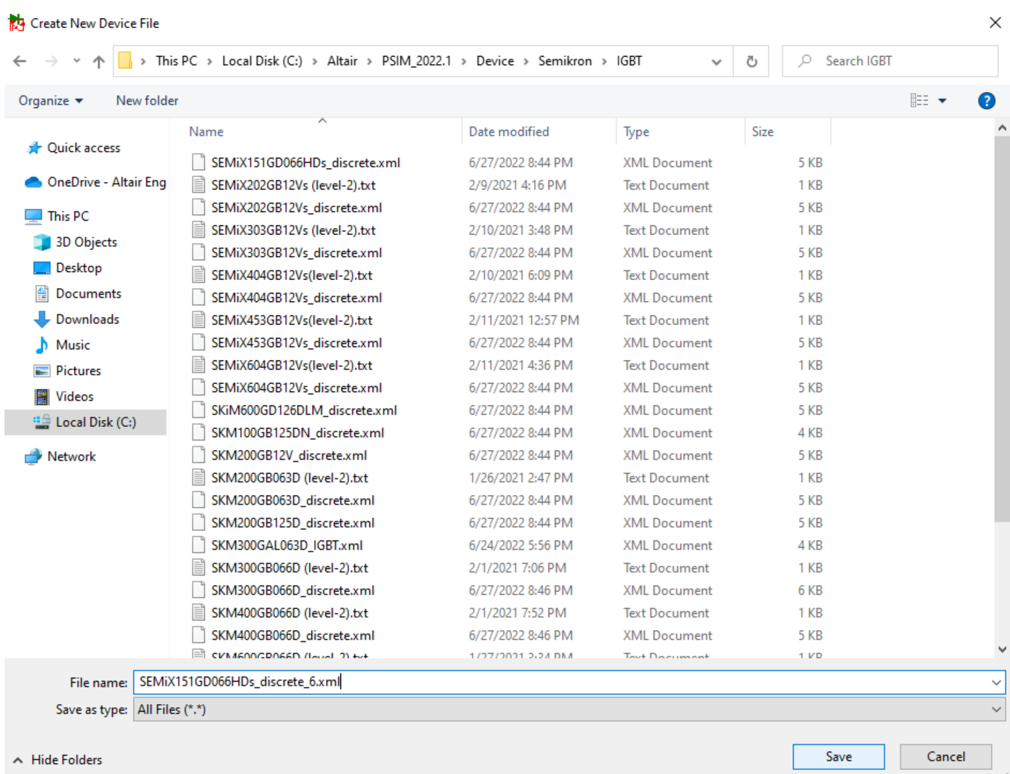
A device database file can contain one device or multiple devices. To keep things simple and to avoid confusion, it is recommended to have one device database file per each device.

Below is the procedure to add this device as a new IGBT device into a new device database file.

Step 1. In PSIM, go to **Utilities** >> **Device Database Editor** to launch the **PcdEditor**.

Step 2. Create a device database file and add the IGBT device to this device file. In PcdEditor, select **Device** >> **New IGBT.** A "**Create New Device File**" dialog will show up. Navigate through this dialog to the following folder in PSIM: **Device/Semikron/IGBT.**

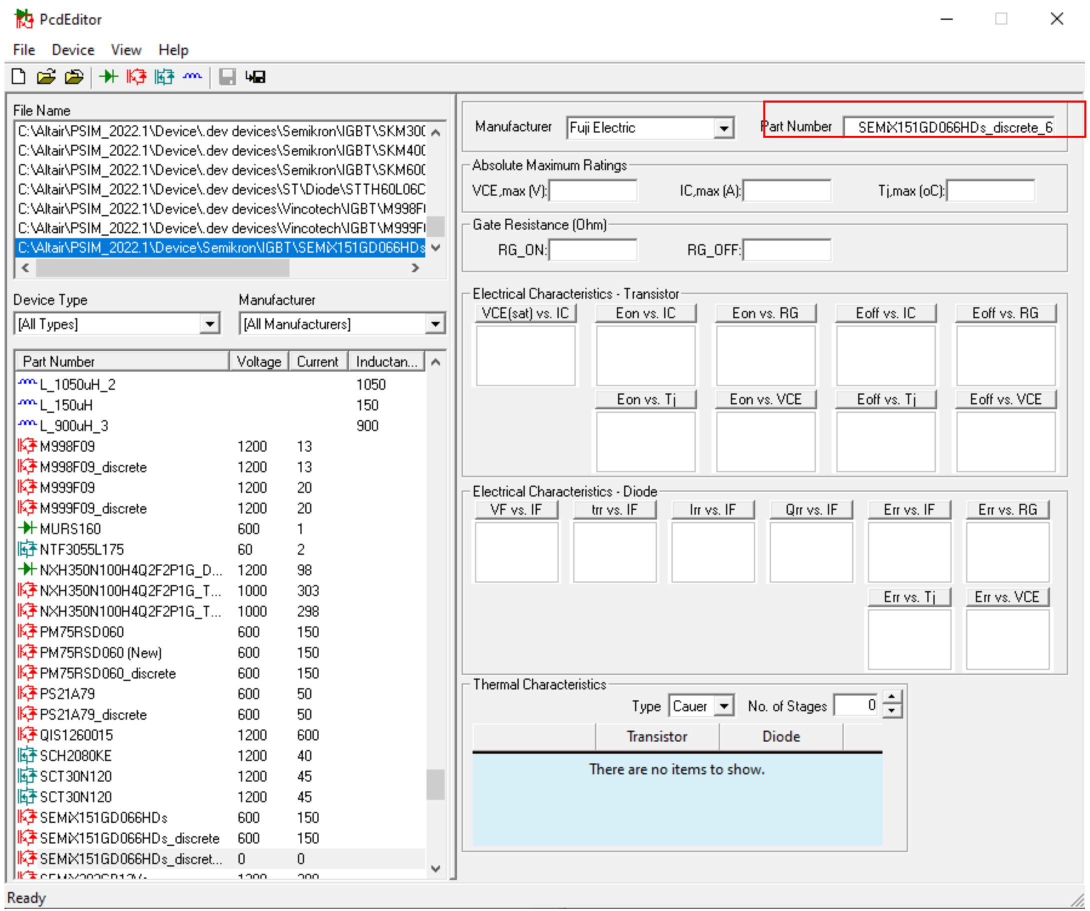
The dialog for this case is shown below:



A recommended practice is to use the device part number as the file name (for example, for this device, "**SEMiX151GD066HDs**_discrete.xml").

In order not to conflict with the existing database file “SEMiX151GD066HDs_discrete.xml”, we will give the device file a new name as “SEMiX151GD066HDs_discrete_6.xml”.

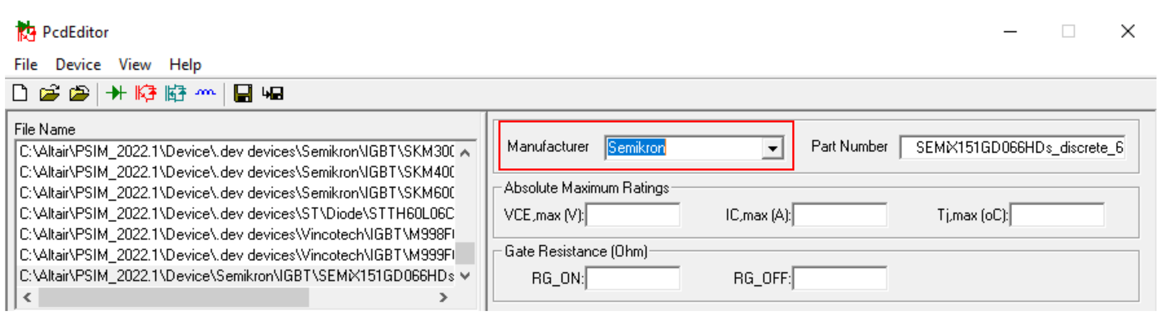
Click on **Save**, and the device file “SEMiX151GD066HDs_descrete_6.xml” will be created, and the device will appear in the Device Database Editor. The dialog is shown below.



Alternatively, one can create the device file first by selecting **File** >> **New Device File**. After the device file is selected, select **Device** >> **New IGBT**. From the dialog, select the device file just created, and add the device to the device file.

Step 3. Enter basic device information from manufacturer’s datasheet into the database. Note that the **Manufacturer** field may be incorrectly assigned, such as in this case. Click on the drop-down menu and select **Semikron** from the list. If a manufacture is new and does not exist in the list, simply type the new name in the field. The drop-down box is editable.

After the information is entered, the device database dialog appears as below.



Step 4. Use PSIM's Curve Capture Tool to enter the transistor electrical characteristics from the graphs provided in manufacturer's datasheet.

<u>Graph Vce(sat) vs. Ic</u>:

The forward conduction characteristic **Vce(sat) vs. Ic** is used as the example.

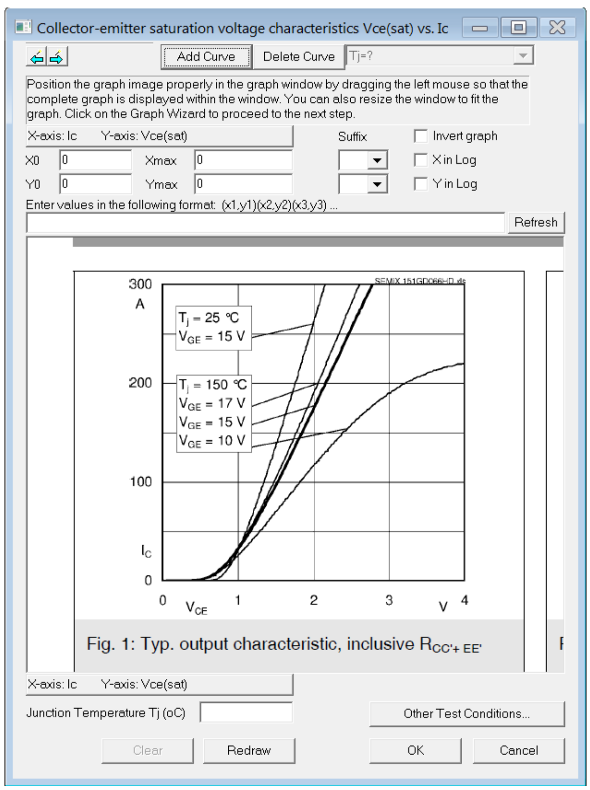
This characteristic is provided in Fig. 1 of the datasheet. Fig. 1 provides one curve at Tj=25 ^{o}C for VGE=15V, but it provides three curves at Tj=150 ^{o}C for VGE=10, 15, and 17V. We will select the curves corresponding to VGE=15V since curves of the energy losses Eon and Eoff vs. Ic are for VGE=-8/+15V.

To capture the curve from Fig. 1 of the datasheet, click on the **Edit** button of the "Vce(sat) vs. Ic" characteristics. A window for the Curve Capture Tool will open.

In the dialog window, click on **Add Curve**. We will use the Graph Wizard button  at the upper left corner to capture the 25^{o}C curve. Follow the directions as displayed in the text window. The steps are:

Display the graph of Fig. 1 on the screen. Click on the Print Screen key (PrtSc) to copy the screen to the clipboard.

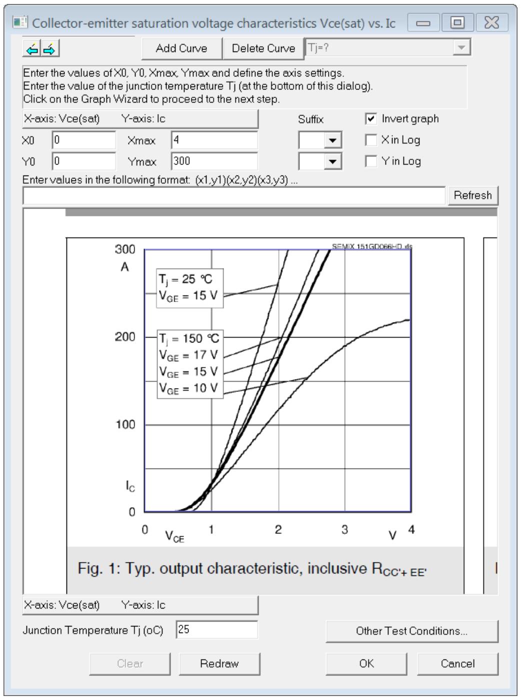
Click on the forward green arrow of the Graph Wizard. The image in the clipboard will be copied into the dialog window, as shown below.



Position the image properly within the window so that the complete graph is in full view. Click on the forward arrow. Define the border of the graph by left clicking on the graph's origin (lower left corner), and then move the cursor to the opposite corner (upper right corner) and left click. Right click to zoom in for easier cursor placement. After this, a blue frame will be superimposed on top of the original graph frame.

Click on the forward arrow. Check if the x-axis and y-axis definitions are correct.

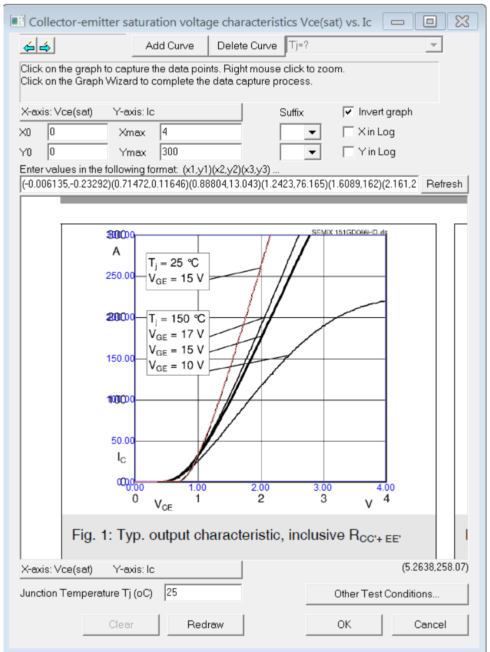
By default, the x-axis is Ic and the y-axis is Vce(sat). But the x-axis is Vce(sat) and the y-axis is Ic in the datasheet. To match the datasheet, check the box **Invert graph**. Then define the axis settings X0, Xmax, Y0, Ymax. In this case, enter X0=0, Xmax=4, Y0=0, Ymax=300. Enter the junction temperature Tj as 25 for the 25ºC curve. The dialog window will look as follows:

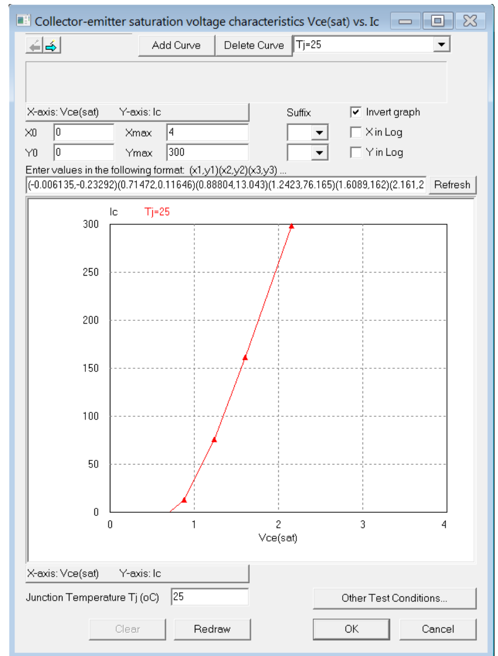


Click on the forward arrow. Starting from the origin, left click on top of the 25ºC curve to capture the data point. Right click to zoom in for easier cursor placement. As you click along the curve, a red curve will be drawn indicating the data points captured. The dialog window is shown below on the left.

Click on the forward arrow. The capture process will be completed, and the captured curve will be shown below on the right.

You can edit the captured values directly in the input field on the left of the Refresh button. For example, you can round off the first two points from (-0.006135,-0.23292) (0.71472,0.11646) to (0,0) (0.71,0.12). But avoid having sudden jump between two points, for example, (0,0) (0.71,0). PSIM uses interpolation between two points. When there is sudden jump, interpolation may not give desired result.

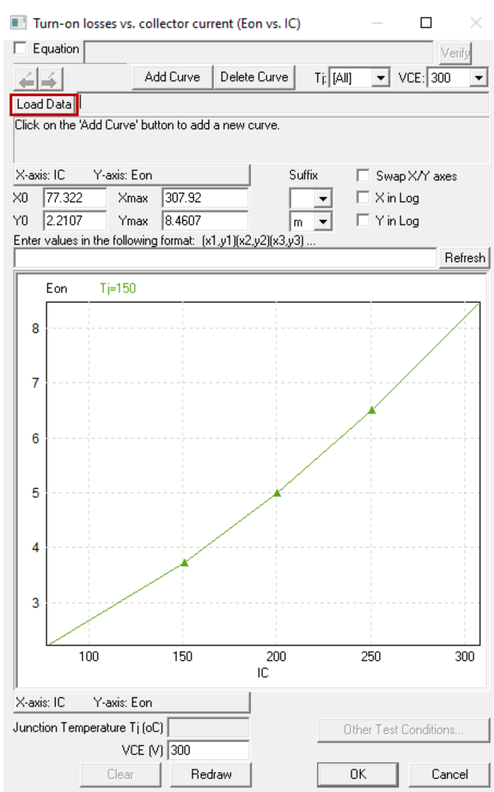


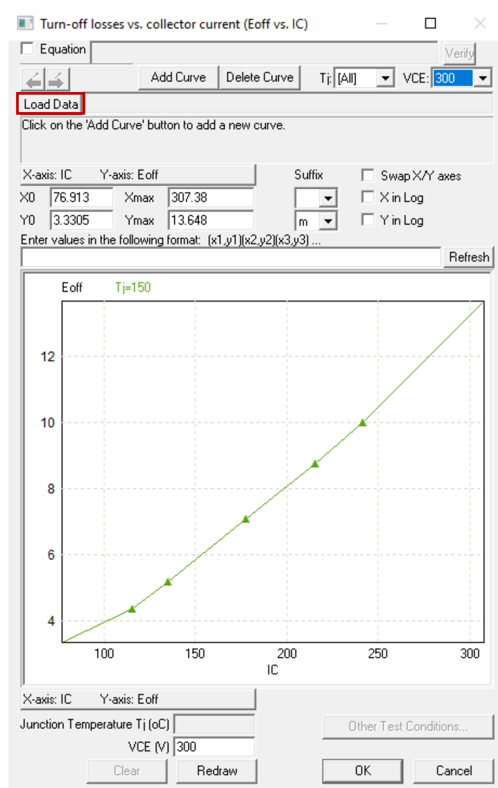


Repeat the same process to capture the 150 ºC curve.

<u>Graph Eon vs. Ic</u>:

Enter the transistor switching energy losses characteristics **Eon and Eoff vs. Ic** from the curves in Fig. 3 of the datasheet. Use the Graph Wizard and the same process as described above to capture these curves. As an example, the completed **Eon and Eoff vs. Ic** curves are shown below for VCE=300 and Tj=150.

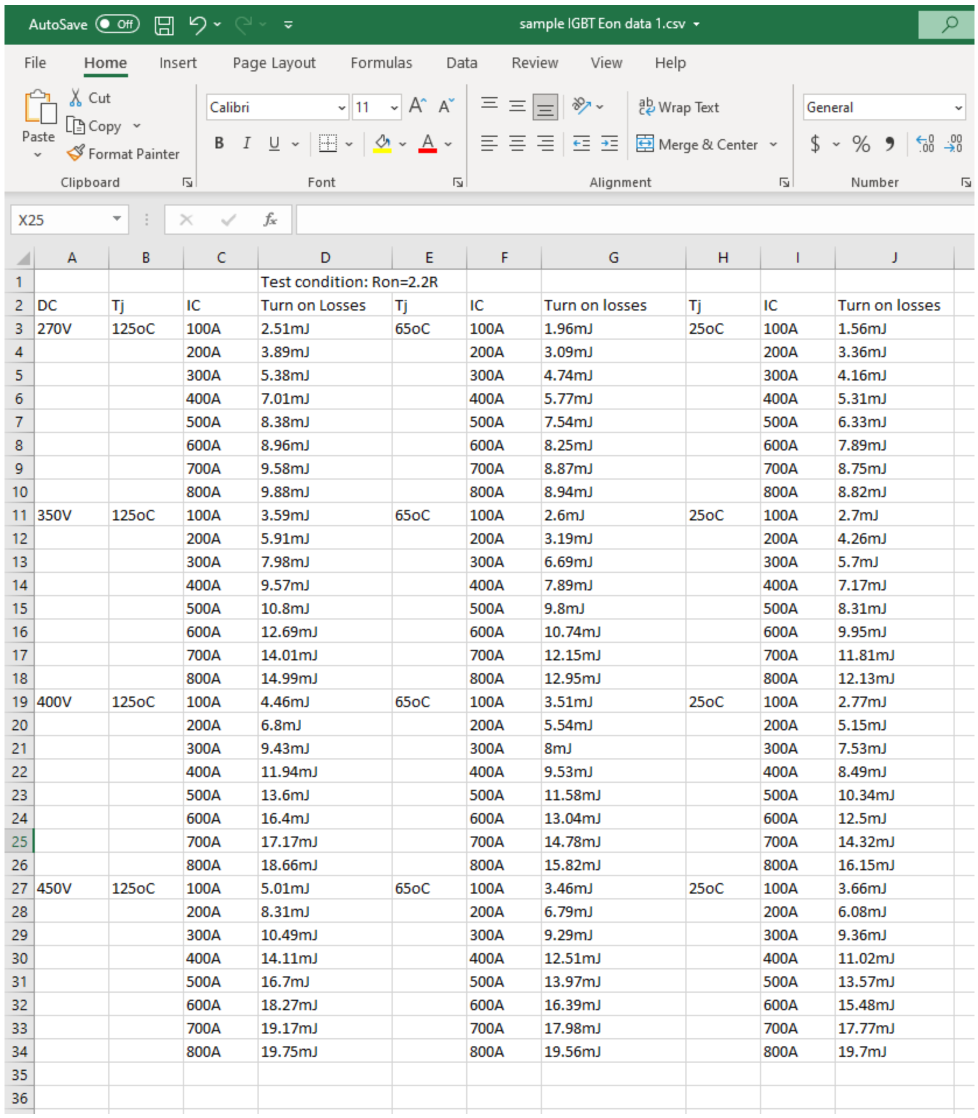




Alternatively, if the Eon or Eoff data are provided in a .csv file, the data can be directly loaded into the Device Database Editor using the **Load Data** function in the dialog, as highlighted above.

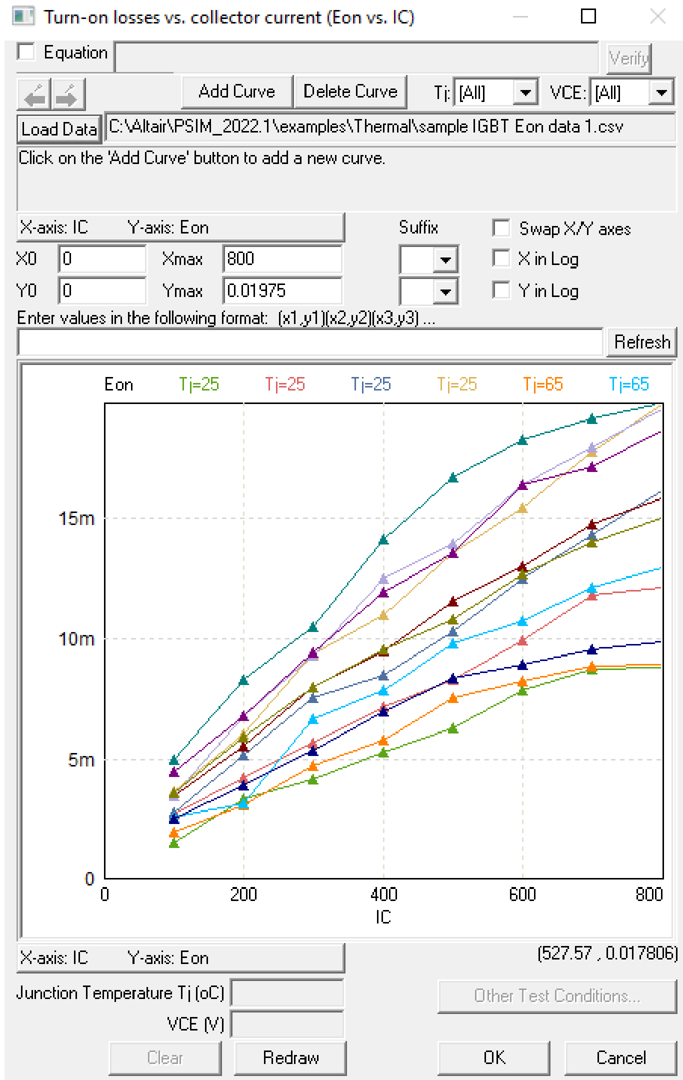
Several sample .csv files of the supported data format are provided in the “examples\Thermal” folder. Their corresponding .xlsx files are also provided for reference.

For example, the sample file “sample IGBT Eon data 1.csv” is shown below. It defines the values of Eon at different Ic, Tj, and VCE.



	A	B	C	D	E	F	G	H	I	J
1				Test condition: Ron=2.2R						
2	DC	Tj	IC	Turn on Losses	Tj	IC	Turn on losses	Tj	IC	Turn on losses
3	270V	125oC	100A	2.51mJ	65oC	100A	1.96mJ	25oC	100A	1.56mJ
4			200A	3.89mJ		200A	3.09mJ		200A	3.36mJ
5			300A	5.38mJ		300A	4.74mJ		300A	4.16mJ
6			400A	7.01mJ		400A	5.77mJ		400A	5.31mJ
7			500A	8.38mJ		500A	7.54mJ		500A	6.33mJ
8			600A	8.96mJ		600A	8.25mJ		600A	7.89mJ
9			700A	9.58mJ		700A	8.87mJ		700A	8.75mJ
10			800A	9.88mJ		800A	8.94mJ		800A	8.82mJ
11	350V	125oC	100A	3.59mJ	65oC	100A	2.6mJ	25oC	100A	2.7mJ
12			200A	5.91mJ		200A	3.19mJ		200A	4.26mJ
13			300A	7.98mJ		300A	6.69mJ		300A	5.7mJ
14			400A	9.57mJ		400A	7.89mJ		400A	7.17mJ
15			500A	10.8mJ		500A	9.8mJ		500A	8.31mJ
16			600A	12.69mJ		600A	10.74mJ		600A	9.95mJ
17			700A	14.01mJ		700A	12.15mJ		700A	11.81mJ
18			800A	14.99mJ		800A	12.95mJ		800A	12.13mJ
19	400V	125oC	100A	4.46mJ	65oC	100A	3.51mJ	25oC	100A	2.77mJ
20			200A	6.8mJ		200A	5.54mJ		200A	5.15mJ
21			300A	9.43mJ		300A	8mJ		300A	7.53mJ
22			400A	11.94mJ		400A	9.53mJ		400A	8.49mJ
23			500A	13.6mJ		500A	11.58mJ		500A	10.34mJ
24			600A	16.4mJ		600A	13.04mJ		600A	12.5mJ
25			700A	17.17mJ		700A	14.78mJ		700A	14.32mJ
26			800A	18.66mJ		800A	15.82mJ		800A	16.15mJ
27	450V	125oC	100A	5.01mJ	65oC	100A	3.46mJ	25oC	100A	3.66mJ
28			200A	8.31mJ		200A	6.79mJ		200A	6.08mJ
29			300A	10.49mJ		300A	9.29mJ		300A	9.36mJ
30			400A	14.11mJ		400A	12.51mJ		400A	11.02mJ
31			500A	16.7mJ		500A	13.97mJ		500A	13.57mJ
32			600A	18.27mJ		600A	16.39mJ		600A	15.48mJ
33			700A	19.17mJ		700A	17.98mJ		700A	17.77mJ
34			800A	19.75mJ		800A	19.56mJ		800A	19.7mJ
35										
36										

The data from the above **.CSV file** will produce the following **Eon vs Ic** curve using the “**Load Data**” function:



The **Load Data** function is also available to **Eoff vs. IC** and **Err vs. IF**.

Characteristics **Eoff vs. IC** and **Err vs. IF** are entered in a similar way as **Eon vs. IC**.

<u>Graph Eon vs. RG</u>:

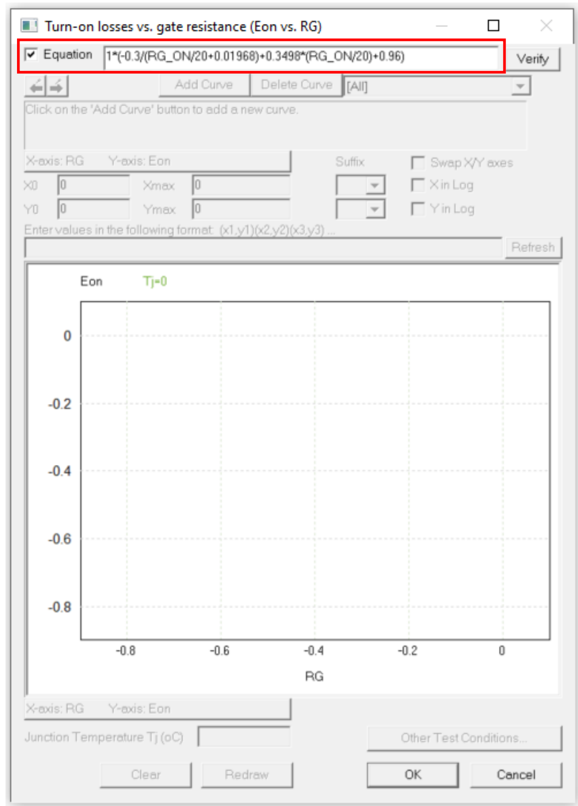
The characteristics of Eon vs. the turn-on gate resistance Rg_on can be entered in two ways. One is to enter the curve of Eon vs. Rg_on. Another is to enter the equation, as shown in the dialog below.

The equation defines Eon as a function of the turn-on gate resistance RG_ON. That is:

K_Eon = f(RG_ON)

where RG_ON represents the actual turn-on gate resistance used. The value from the Eon vs. IC curve will be scaled by K_Eon to obtain the final value in the following way:

Eon = Eon_IC * K_Eon



An equation can also be defined for Eoff vs. RG (i.e. turn-off resistance Rg_off) and Err vs. RG (i.e. turn-on resistance Rg_on).

Step 5. Use PSIM's Curve Capture Tool to enter the diode Electrical Characteristics from the graphs provided in manufacturer's datasheet.

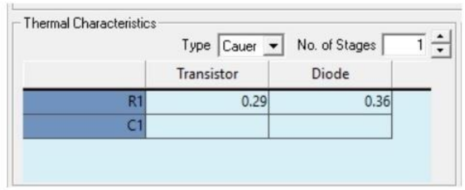
Enter the diode forward conduction characteristic **Vd vs. IF**.

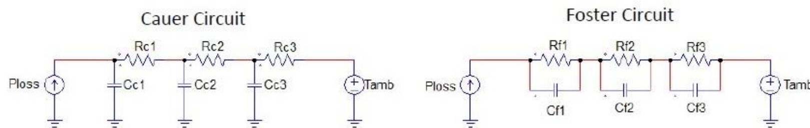
The diode forward conduction characteristics are provided in Fig. 11 in the datasheet. Use the Graph Wizard and the same procedure to capture the curves. Enter the diode switching characteristics **trr/Irr/Qrr/Err vs. IF** and **Err vs. RG**:

The diode reverse recovery characteristics trr, Irr, and Qrr vs. the current IF, and Err vs. RG, are not provided in the datasheet. Only the characteristic of the reverse recovery energy Err vs. the current IF is provided in Fig. 3 of the datasheet.

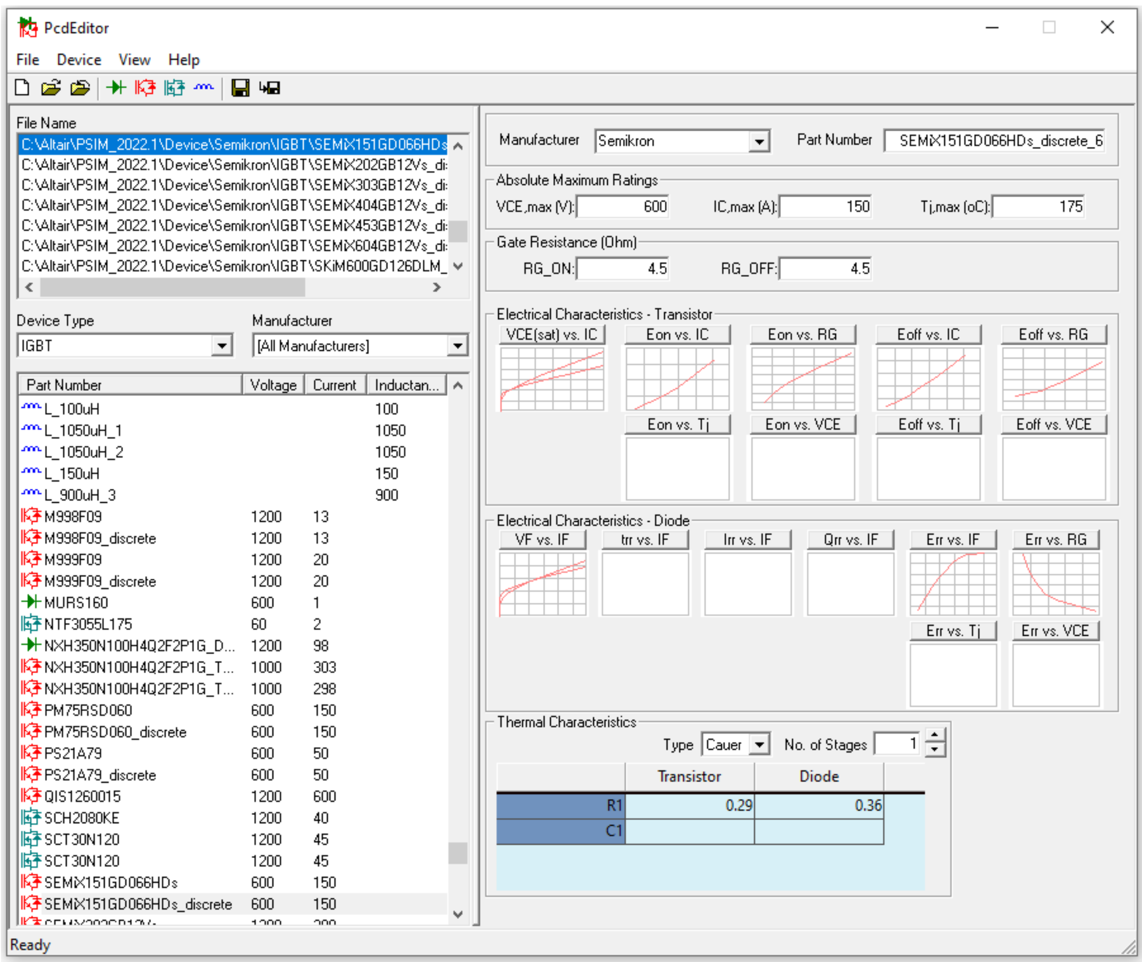
Use the same procedure to capture the curve. The test condition is the same as in Eon vs. Ic.

Step 6. Enter the thermal characteristics. Two types of the thermal impedance network are available: Cauer and Foster. For this example, the thermal impedance consists of one resister only, therefore the number of stages is 1 and the values of the capacitor is left empty. The "Tamb" in the circuits below is actually the case temperature. Between case and ambient, there might be a heatsink thermal impedance to be added, as shown in the simulation circuit of the example.





This concludes the entry of the device information into the database SEMiX151GD066HDs_descrete_6. The figure below shows the device in the **PcdEditor** after it has been added into the device file "SEMiX151GD066HDs_descrete_6.xml".



The newly created database device will be available for next PSIM session. This means, to use the new device in a PSIM schematic, one must exit and re-launch PSIM.

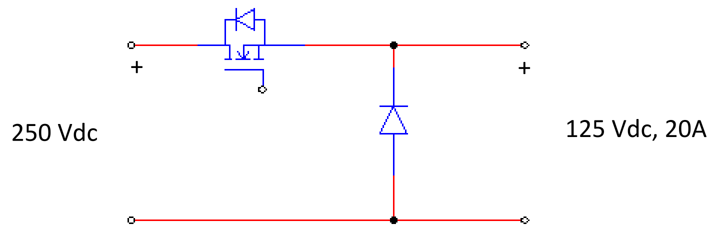
To verify this new device's thermal characteristics, in the example circuit, replace the IGBT with the newly added SEMiX151GD066HDs_descrete_6. The simulation result should be the same as before.

2. Managing User's Devices in Database

When users add their own devices, they may add these devices into one of the device files that come with PSIM. But it is strongly recommended that users save these devices in different device file names. This is because when a PSIM version is updated or upgraded, all the .xml files will be replaced by the files of the newer PSIM version. Any changes to these device files will be lost.

3. MOSFET Loss Calculation

To illustrate how to calculate MOSFET losses with PSIM's Thermal Module, the datasheet of Infineon's MOSFET IRFP460 (500V, 20A) is used in a buck converter example, as shown below:



The buck converter operating conditions are:

DC Input:	250 Vdc
DC Output:	125 Vdc, 20A
Switching Frequency:	20 kHz

3.1 Adding MOSFET Devices into the Device Database

Assuming the MOSFET device IRFP460 is not available in PSIM's device database, the first step is to add it into the device database.

Below is the procedure to add this device into the device database file "IRFP460.xml".

Step 1. In PSIM, go to **Utilities** >> **Device Database Editor** to launch the PcdEditor.

Step 2. Select **Device** >> **New MOSFET**. Choose **<New device file>.** Ceate the device file "IRFP460.xml" under the folder "Device/Infineon/MOSFET", and add the device to this file.

Step 3. Enter the required basic information from the datasheet, such as the part number, package, and maximum ratings.

Step 4. Enter the information for the Electrical Characteristics for the transistor.

Below is a screenshot of the datasheet, with required parameters highlighted in red.

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	500	—	—	V	V_{GS}=0V, I_D= 250μA
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	0.63	—	V/°C	Reference to 25°C, I_D= 1mA
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	—	—	0.27	Ω	V_{GS}=10V, I_D=12A ④
$V_{GS(th)}$	Gate Threshold Voltage	2.0	—	4.0	V	V_{DS}=V_{GS}, I_D= 250μA
g_{fs}	Forward Transconductance	13	—	—	S	V_{DS}=50V, I_D=12A ④
I_{DSS}	Drain-to-Source Leakage Current	—	—	25	μA	V_{DS}=500V, V_{GS}=0V
		—	—	250		V_{DS}=400V, V_{GS}=0V, T_J=125°C
I_{GSS}	Gate-to-Source Forward Leakage	—	—	100	nA	V_{GS}=20V
	Gate-to-Source Reverse Leakage	—	—	-100		V_{GS}=-20V
Q_g	Total Gate Charge	—	—	210	nC	I_D=20A
Q_{gs}	Gate-to-Source Charge	—	—	29		V_{DS}=400V
Q_{gd}	Gate-to-Drain ("Miller") Charge	—	—	110		V_{GS}=10V See Fig. 6 and 13 ④
$t_{d(on)}$	Turn-On Delay Time	—	18	—	ns	V_{DD}=250V
t_r	Rise Time	—	59	—		I_D=20A
$t_{d(off)}$	Turn-Off Delay Time	—	110	—		R_G=4.3Ω
t_f	Fall Time	—	58	—		R_D=13Ω See Figure 10 ④
L_D	Internal Drain Inductance	—	5.0	—	nH	Between lead, 6 mm (0.25in.) from package and center of die contact
L_S	Internal Source Inductance	—	13	—		
C_{iss}	Input Capacitance	—	4200	—	pF	V_{GS}=0V
C_{oss}	Output Capacitance	—	870	—		V_{DS}= 25V
C_{rss}	Reverse Transfer Capacitance	—	350	—		f=1.0MHz See Figure 5

Source-Drain Ratings and Characteristics

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
I_S	Continuous Source Current (Body Diode)	—	—	20	A	MOSFET symbol showing the integral reverse p-n junction diode.
I_{SM}	Pulsed Source Current (Body Diode) ①	—	—	80		
V_{SD}	Diode Forward Voltage	—	—	1.8	V	T_J=25°C, I_S=20A, V_{GS}=0V ④
t_{rr}	Reverse Recovery Time	—	570	860	ns	T_J=25°C, I_F=20A
Q_{rr}	Reverse Recovery Charge	—	5.7	8.6	μC	di/dt=100A/μs ④
t_{on}	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by L_S+L_D)				

For the parameter VGS(th), an average value of 3V is selected out of the minimum and maximum values.

Note that the parameter "Temperature Coefficient" of RDS(on) is typically not provided in a datasheet, such as in this case. It needs to be calculated from the graph "Normalized on-resistance vs. temperature" (Fig. 4 for this device), as shown below:

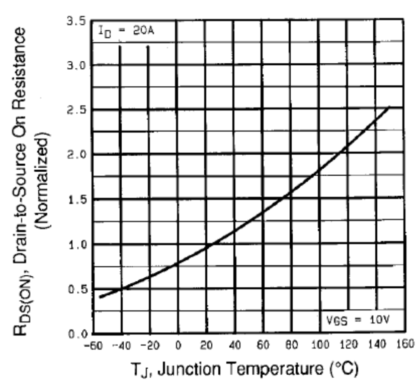


Fig 4. Normalized On-Resistance Vs. Temperature

The temperature coefficient K_T can be calculated using the expression below:

$$K_T = \frac{R_{DS(on)\_normalized} - 1}{T_j - 25}$$

From Fig. 4 of the datasheet, at Tj = 100, we obtain $R_{DS(on)\_normalized}$ = 1.8. We can then calculate K_T as: K_T = 0.01.

The on-resistance RDS(on) is calculated from K_T in the following way:

$$R_{DS(on)} = R_{DS(on)\_25\deg} \cdot (1 + K_T \cdot (T_j - 25))$$

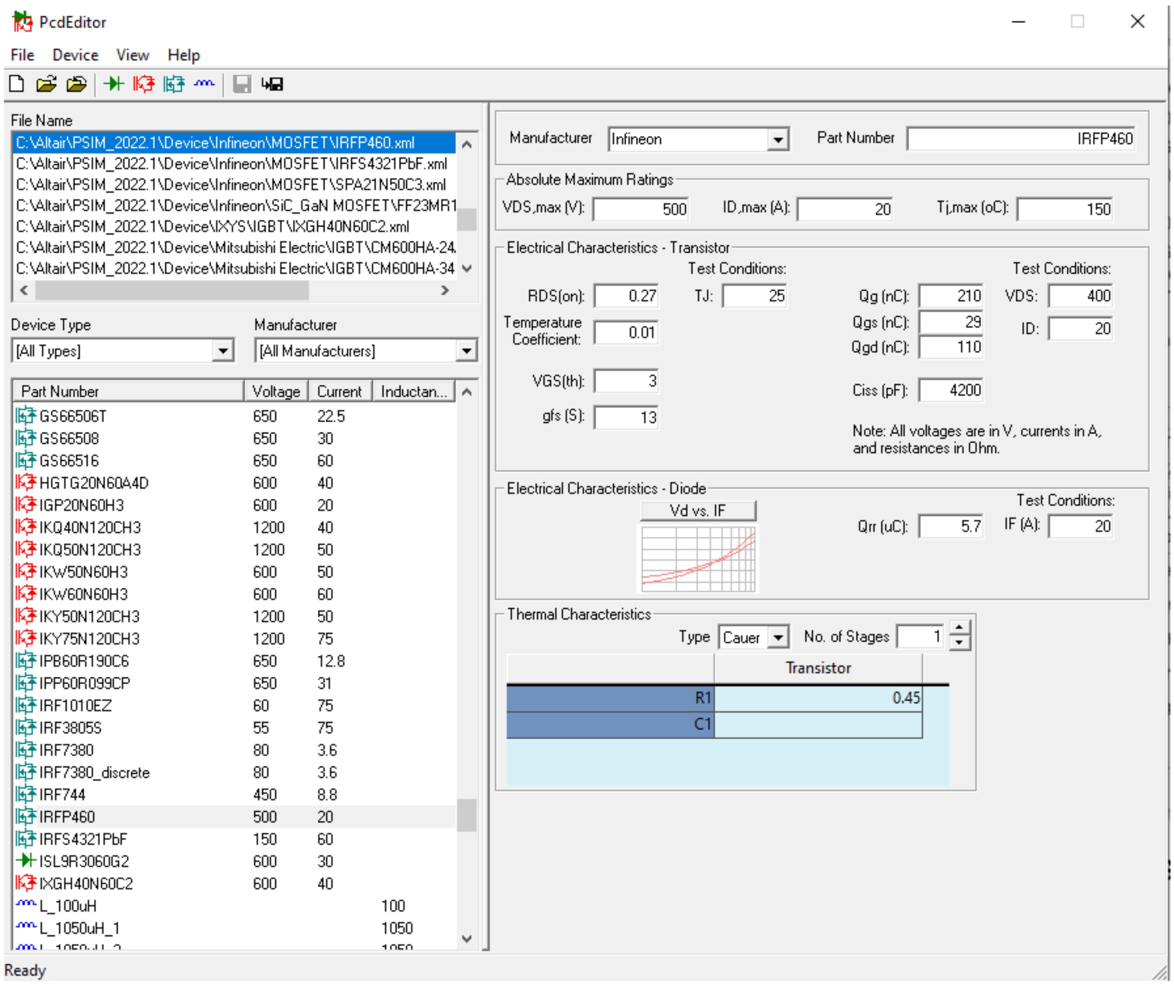
where $R_{DS(on)\_25deg}$ is the on-resistance at 25 ºC. In this example, $R_{DS(on)\_25deg}$ = 0.27 Ohm.

Step 5. Enter the electrical characteristics for the diode. The **Vd vs IF** curve can be captured as explained in the IGBT section. The test conditions must be entered, too.

Step 6. Enter the thermal characteristics, the same way as in the IGBT section.

Step 7. Enter the optional information of dimensions and weight.

This concludes the entry of the device information into the database IRFP460. The figure below shows the device in the PcdEditor after it has been added into the device file "IRFP460_descrete.xml".



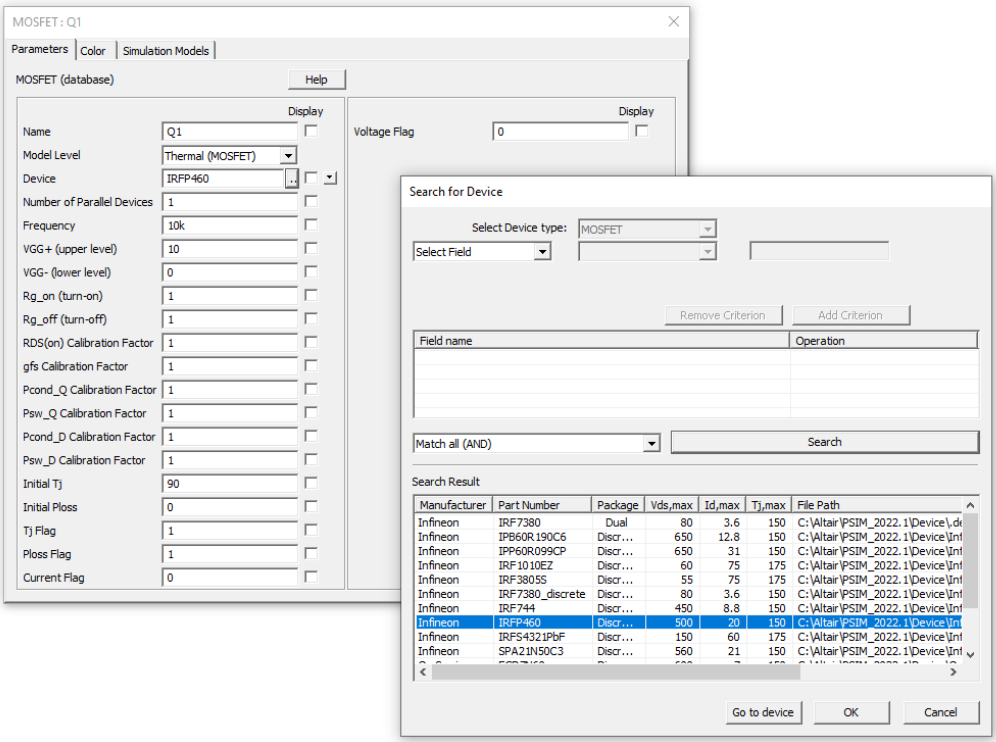
The newly created database device will be available for next PSIM session. This means, to use the new device in a PSIM schematic, one must exit and re-launch PSIM.

3.2 Simulation of MOSFET Losses in PSIM

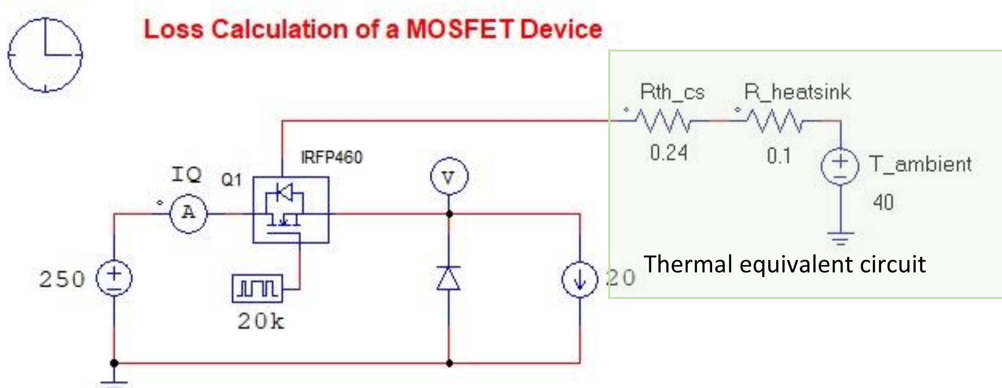
Once the device is added to the device database, it can be used in PSIM for the loss calculation. The newly added device in database should be verified with a simple example circuit before applied to a complex power system.

In PSIM, select **Elements** >> **Power** >> **Thermal Module** >> **MOSFET (database)**.

Place the discrete MOSFET element on the schematic. Double click on the MOSFET element to open the property dialog window. Click on the Browser button next to the "Device" input field, and choose the device "IRFP460". Continue to build the rest of the circuit.



The circuit below shows the completed buck converter circuit using the MOSFET IRFP460.



The MOSFET device has one extra node on the top. This node is to be connected to the external thermal equivalent circuit.

- The voltage at this node is the module's case temperature. It can be monitored with a voltage probe.

- The current flowing out of this node is the total power losses of the whole module. It can be monitored with a current probe.

This node should be connected to a voltage source representing the ambient temperature or grounded via a network representing the dynamic thermal impedance between the case of the module and the ambient. In this example, the resistor Rth_cs is the thermal resistances between the case and heat sink, and R_heatsing is the thermal resistance of the heatsink.

The parameters of the MOSFET (database) are defined as below:

The parameter **Frequency** defines the interval under which the losses are calculated. In this example, it is set to be the same as the switching frequency, and the losses in each switching cycle are obtained.

The values **VGG+** and **VGG-** are the upper level and lower level of the gate voltage source.

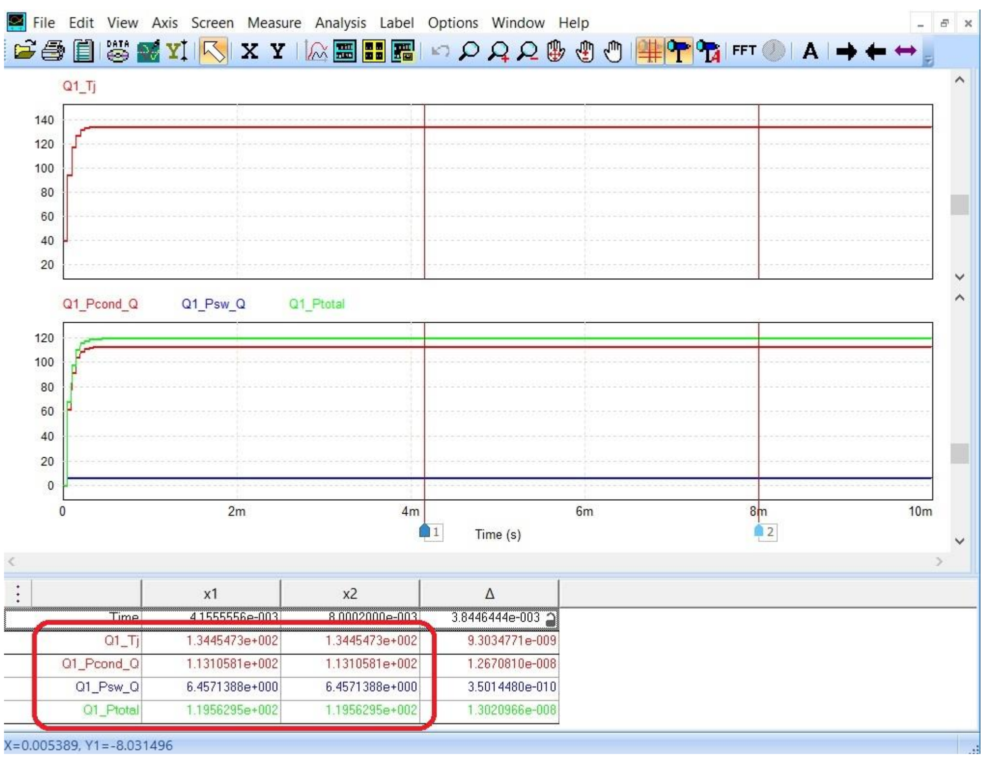
The values **Rg_on** and **Rg_off** are the gate resistances at turn-on and turn-off. They must be defined correctly to reflect the actual operating conditions. If they are not defined correctly (for example, if the gate voltage source is too low, or the load current or the gate resistance is too high), the MOSFET device may not work correctly.

The **Calibration Factors** are used to scale the calculation results against experimental results.

If the ***Flags*** are for the monitoring of the device's thermal behaviour. When the flags are set, the following thermal related characteristics can be monitored:

- transistor junction temperature Tj, in ^{o}C.
- transistor conduction loss Pcond_Q,
- transistor switching loss Psw_Q,
- diode conduction loss Pcond_D, and
- diode switching loss Psw_D.

The simulation result displayed in SIMVIEW is as below:



The following losses results are obtained from the PSIM simulation:

MOSFET Junction Temperature (^oC):	134.5
Transistor Conduction Loss (W):	113.1
Transistor Switching Loss (W):	6.5
Transistor Total Loss (W):	119.6

The loss of the diode is zero because there is no reverse conduction in this circuit.

4. Conclusion

PSIM's Thermal Module provides a quick and convenient way of estimating device conduction and switching losses. One can use the Thermal Module to study device losses under different operating conditions, and compare devices from different manufacturers.

In addition, the Device Database Editor (PcdEditor) provides an easy way to add new devices and manage devices. It also provides an easy-to-use curve capture tool that allow multiple datasheet curves to be entered into the database in minutes.