IPM Motor Drive Simulator User Manual

General Guide

About this document

Scope and purpose

To provide guidance for the IPM Motor Drive Simulator Tool

Intended audience

Any user that needs help with IPM Motor Drive Simulator Tool

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1 Introduction

The IPM Motor Drive Simulator was designed for the user to simulate and compare IPM parts with their three-phase motor conditions to determine which part best suits their needs. This tool shows expected temperature of the selected IPM, the approximate losses of the system, and also generates output voltage, output current, junction temperature and loss waveforms.

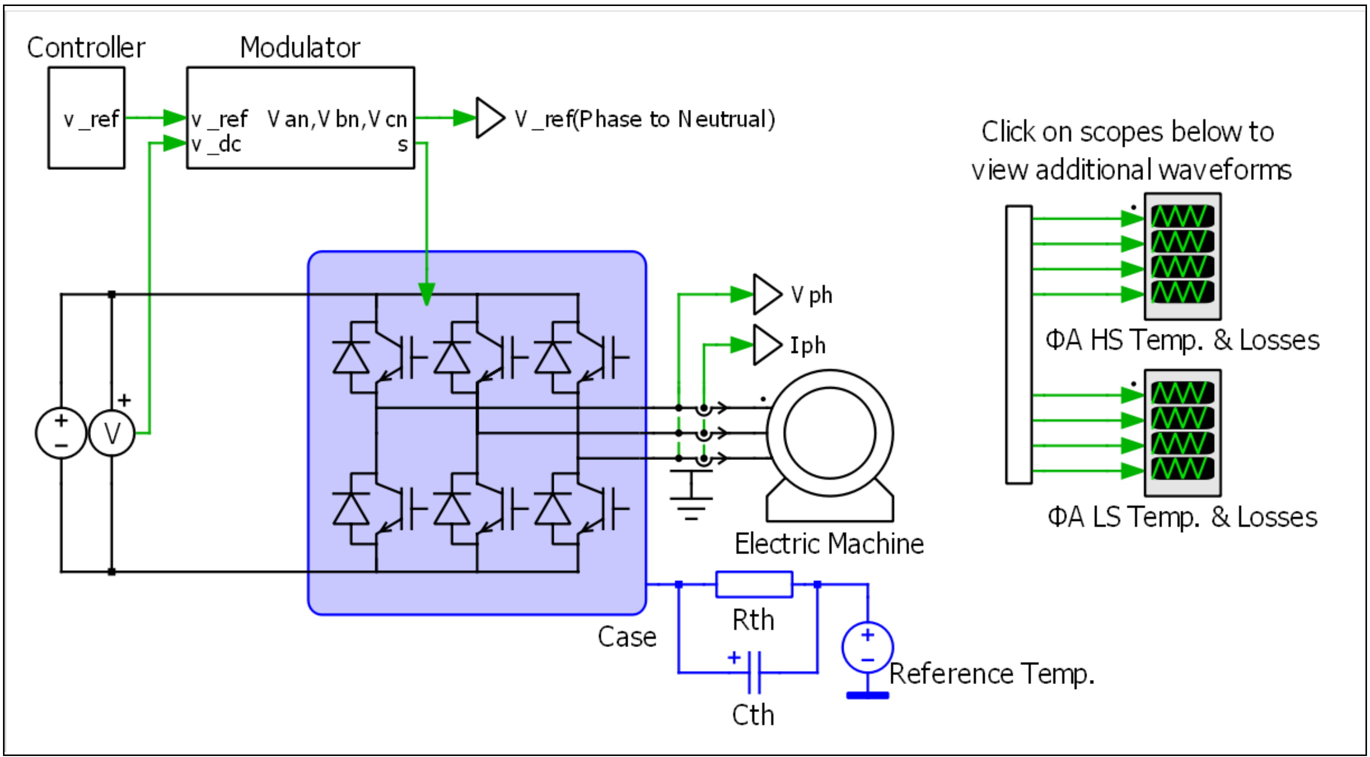


Figure 1 **Motor Drive Schematic**

2 Inputs

The Simulator Tool allows the user to input parameters for system and PWM frequency, modulation scheme, input and output voltage, current, power factor, thermal resistance, and reference temperature. There is also another selection for a heat sink option and family and package to filter parts. The "DC Bus Voltage" is also used to filter the shown parts to those that can operate at the required voltage. Default values are auto-filled and the user can overwrite them with their own parameters as needed. The input parameters have range limits to prevent unrealistic outputs. These range limits are as follows:

Table 1 Allowed Input Parameters

Parameter	Description	Allowed Selection
System Frequency:	Inverter Output Frequency	Between 0.1Hz and 1000Hz
PWM Frequency:	Switching Frequency	Between 0.1kHz and 100kHz
Modulation Scheme:		Options: ▪ Sine PWM ▪ Space-Vector PWM ▪ Space-Vector PWM (2 Phase 60°) ▪ Trapezoidal 120° ▪ Space-vector PWM (2 Phase 120° High Side Clamp) ▪ Space-vector PWM (2 Phase 120° Low Side Clamp)
DC Bus Voltage:	Input Voltage **This selection is used to filter parts**	Between 50V and 1200V
Voltage to motor, line to line:	Output AC Voltage	Limited by DC Bus Voltage Vrms, (Vpeak for Trapezoidal)
Motor Drive Phase Current RMS:		Between 0.1A and 50A
Power Factor		Between -1 and 1
Thermal Resistance (case to reference)	Thermal Resistance of heatsink and/or thermal grease	Between 0°C/W and 500°C /W
Reference Temperature	Lowest temperature seen by the system, normally ambient or case temperature	Between -65°C and 150°C
Heat Sink Option:	Module mounting option, free air or with heatsink **This selection is used to filter parts**	Options: ▪ With or Without Heat Sink ▪ Heat Sink Needed ▪ No Heat Sink Needed
Family and Package:	**This selection is used to filter parts**	Options: ▪ All Packages ▪ Micro DIP23 ▪ Micro SOP23 ▪ Mini MDIP-24 DCB ▪ Mini MDIP-24 Fullpack ▪ Nano PQFN 12x12

If Modulation Index (MI) is known instead of Voltage to motor, it can be easily converted to the needed output voltage:

For trapezoidal modulation scheme,

$$Voltage\ to\ Motor\ (Vpeak) = MI * V_{DC}$$

For sinusoidal modulation schemes,

$Voltage\ to\ Motor\ (Vrms) = \frac{\sqrt{3}}{\sqrt{2}*2} MI * V_{DC}$, where Vrms is referencing the RMS voltage of the first harmonic.

The reference temperature and thermal resistance can be calculated by the user in several ways.

1. The reference temperature equals the temperature of the case. In this method, the thermal resistance should be set to 0.
2. The reference temperature equals the temperature of the heatsink. In this method, the thermal resistance is then given by the thermal grease or silicon pad used between the IPM and the heatsink.
3. The reference temperature equals ambient temperature. The thermal resistance is then calculated by adding the heatsink thermal resistance and thermal grease together.

See table below for summary of explanation:

Table 2 Temperature Reference and Thermal Resistance Calculation

Method	**Reference Temperature**	**Thermal Resistance (case to reference)**
Method 1:	Case Temperature	Zero
Method 2:	Heatsink Temperature	Thermal Grease or Silicon Pad Thermal Resistance
Method 3:	Ambient Temperature	Heatsink Thermal Resistance + Thermal Grease

Inputs

All input parameters must be filled out before parts are selected to simulate as the available parts list is determined by DC Bus Voltage and Heat Sink option.

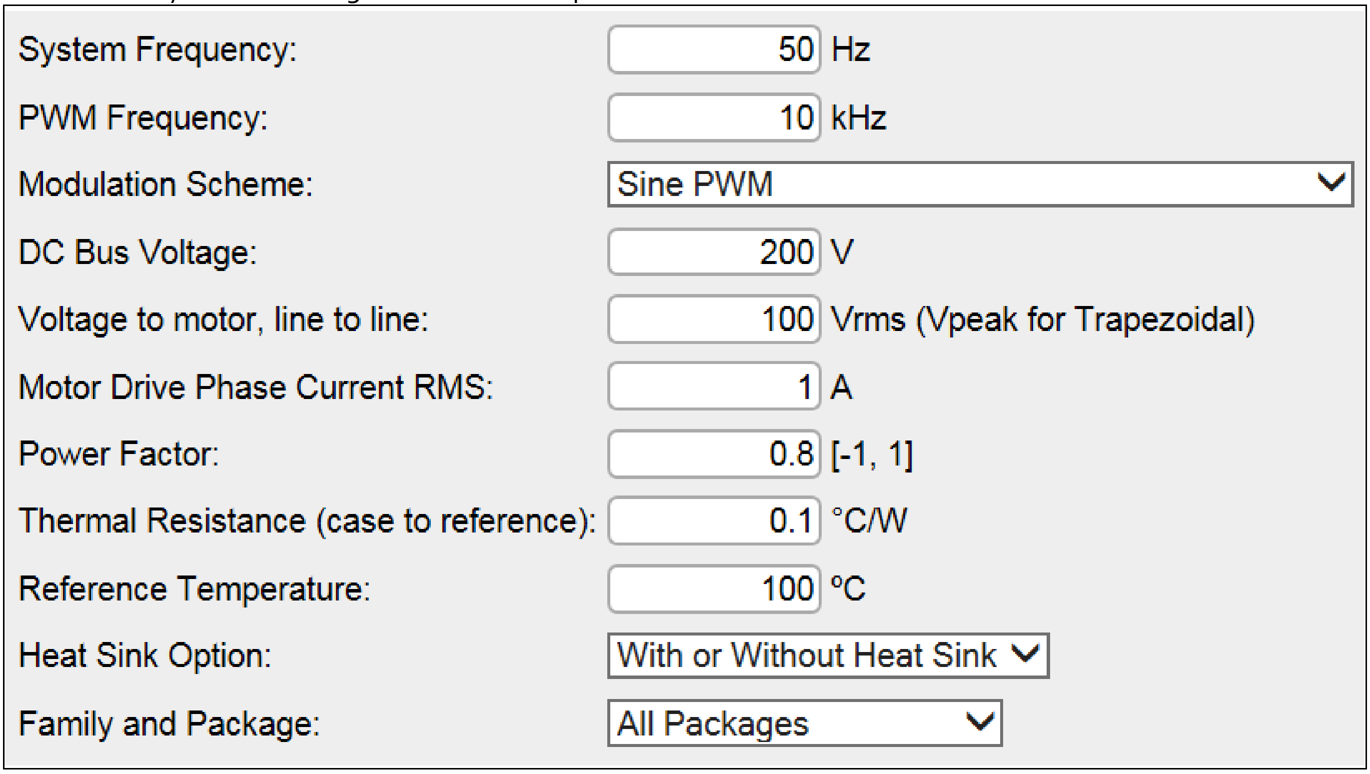


Figure 2 Input Parameters

3 Selecting Parts

Once all input parameters have been entered, the user can now select a part. The list of parts available depends on the parameters the user has entered. Highlighted in blue is the part's name. Clicking on this name will direct the user to the part's datasheet. Next to the part number is the headline current of the part and its package name. Knowing the motor current, the user can select a part that best meets the needs of the application. The tool calculates the operating conditions for the parts selected. As many parts as desired can be selected, but simulation time will increase and graphs will be overcrowded.

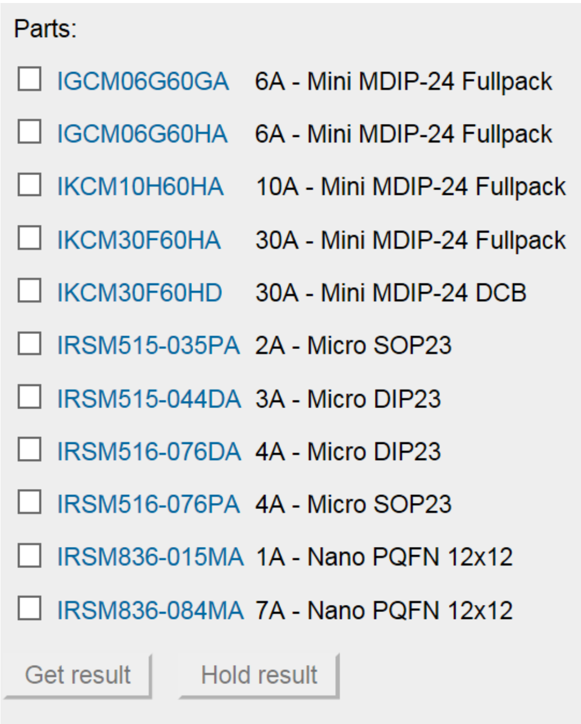


Figure 3 Parts List Example

4 Running Simulation

Once parts have been selected, the simulation can be run by clicking “Get result”. A purple loading bar will appear next to the button to show simulation is running and will read “Calculating Jacobian: X/46” below. Once finished, “Analysis completed” will appear in its place. Pressing the “Get Result” button when simulation is calculating will abort the calculation. The user can save the current simulation by pressing the “Hold Result” button. This will open a Result History log below to show all traces saved. Clicking the (-) next to the Part will remove its simulation results. Clicking a (+) next to the part will hold the simulation results until removed. “Trace #” refers to which simulation the result was held. If results are saved again in another simulation the results will be labeled “Trace 2”. By clicking on the name in the trace, the user can rename it as desired. This is beneficial as the user can add information from the input parameters to represent each trace.

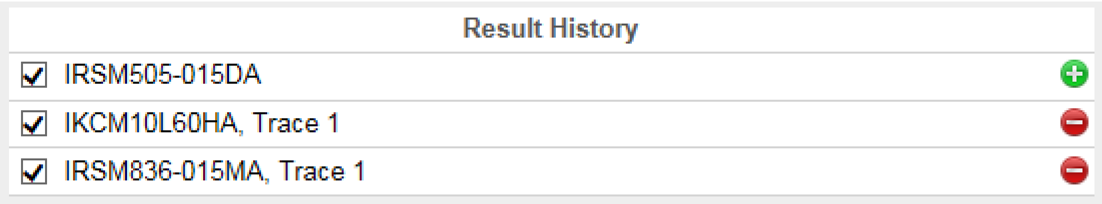
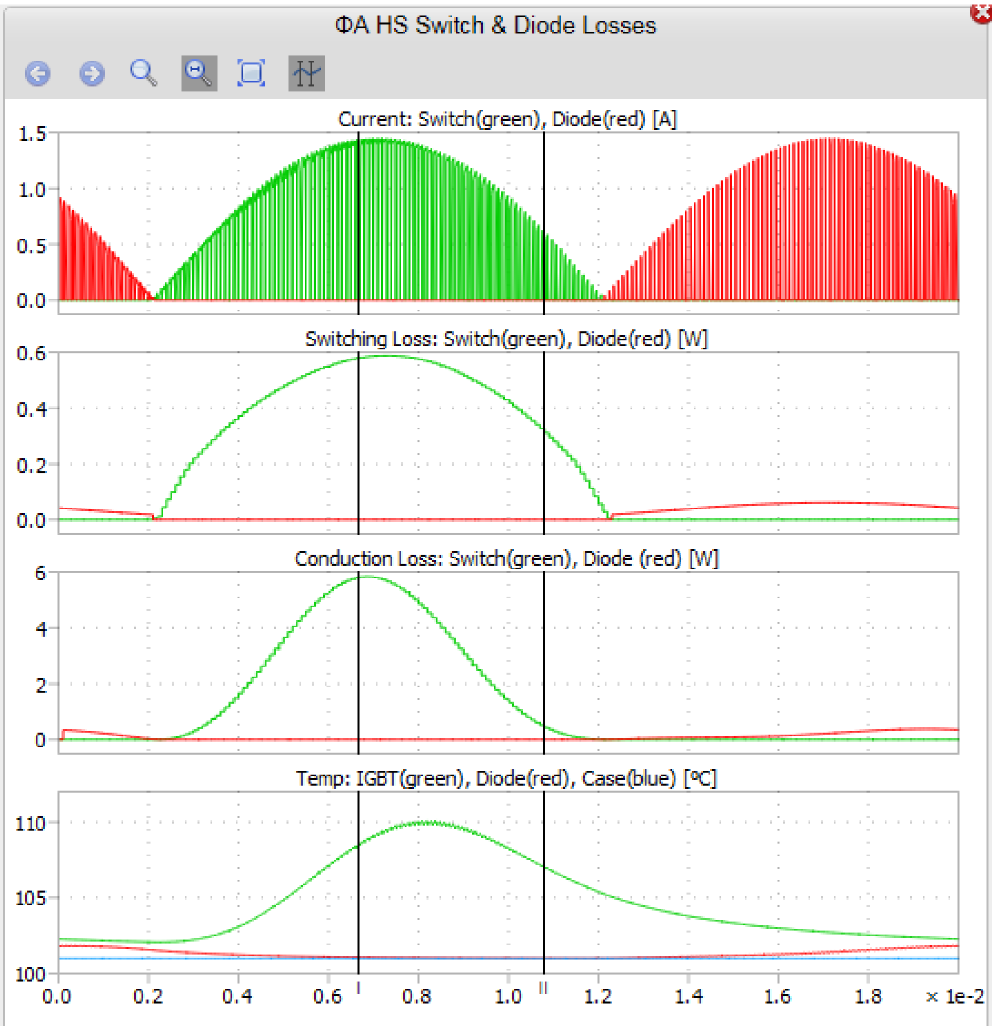


Figure 4 Results History Example

5 Simulation Results

IPM Motor Drive Simulator outputs a total of 11 graphs in 3 scopes for the user to view. These include Inverter Output waveforms, High Side temperature and losses, and Low Side temperature and losses for both the switch and diode. The Inverter Output graph shows automatically, and the other graphs can be viewed by clicking their corresponding waveform scopes in the schematic. These scopes can be reordered by dragging the title bars. They can also be resized by dragging the small blue arrow in the bottom of each scope. The simulation offers many tools for analysis located on the title bar of each of the three scopes. Free zoom and fixed zoomed can be used to better view each graph. The cursor tool allows the user to move two cursors to measure voltage, current, losses, and temperature at any given time in the scope.



Name	Cursor 1	Cursor 2	Delta
Time	0.0066667	0.01077	0.0041036
Current: Switch(green), Diode(red) [A]			
Phase A HS IGBT current	1.384	0.6293	0.7547
Phase A HS Diode current	0.000	0.000	0.000
Switching Loss: Switch(green), Diode(red) [W]			
Phase A HS IGBT Switching Loss	0.5784	0.3272	0.2512
Phase A HS Diode Switching Loss	0.000	0.000	0.000
Conduction Loss: Switch(green), Diode (red) [W]			
Phase A HS IGBT Conduction Loss	5.796	0.5150	5.280
Phase A HS Diode Conduction Loss	0.000	0.000	0.000
Temp: IGBT(green), Diode(red), Case(blue) [ºC]			
Phase A HS IGBT junction temp	108.5	107.1	1.437
Phase A HS Diode junction temp	101.1	101.0	0.06719
Case Temperature	101.0	101.0	-0.0006060

Figure 5 ΦA HA Scope Example

6 Results Tables

The Inverter Losses result table displays the total losses for the switch, diode, and the whole IPM part under the given conditions and also the efficiency. The Phase A High Side and Low Side result tables show switching losses, conduction losses, average temperature and max temperature of both the switch and diode inside the IPM device.

Inverter Losses				
	Part Name	Total	Efficiency	
Switch	IRSM836-084MA	2.42 W		
Diode	IRSM836-084MA	0.64 W		
Inverter	IRSM836-084MA	3.06 W	97.79 %	

Phase A High Side Device Losses and Junction Temperatures							
	Part Name	EOn	EOff	Total Switching	Cond.	Avg. Junction Temp.	Max Junction Temp.
Switch	IRSM836-084MA	0.14 W	0.02 W	0.16 W	0.24 W	101.3 ºC	102.5 ºC
Diode	IRSM836-084MA		0.05 W	0.05 W	0.06 W	100.6 ºC	100.9 ºC

Phase A Low Side Device Losses and Junction Temperatures							
	Part Name	EOn	EOff	Total Switching	Cond.	Avg. Junction Temp.	Max Junction Temp.
Switch	IRSM836-084MA	0.14 W	0.02 W	0.16 W	0.24 W	101.3 ºC	102.5 ºC
Diode	IRSM836-084MA		0.05 W	0.05 W	0.06 W	100.6 ºC	100.9 ºC

Figure 6 Results Table Example

In case of IGBT devices, the IGBT losses are listed under "Switch" while the diode losses are listed under "Diode".

In case of RC-IGBT (reverse conducting) the split is similar although the IGBT and diode are placed on the same physical switch.

In case of MOSFET the forward conduction losses, Eon and Eoff are grouped under "Switch" while the reverse conduction losses and reverse recovery losses are grouped under "Diode". For MOSFET products the "Switch" and "Diode" temperatures are the same as is physically on one die.

Revision history

Document version	Date of release	Description of changes
1.0	08/07/2017	Initial Document

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Email: erratum@infineon.com

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