# CIPOS™ IPM Motor Drive Simulator User Manual

## General Guide

## About this document

### Scope and purpose

To provide guidance for the CIPOS™ IPM Motor Drive Simulator Tool

### Intended audience

Any user that needs help with CIPOS™ IPM Motor Drive Simulator Tool

## Table of contents

# 1 Introduction

The CIPOS™ 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.

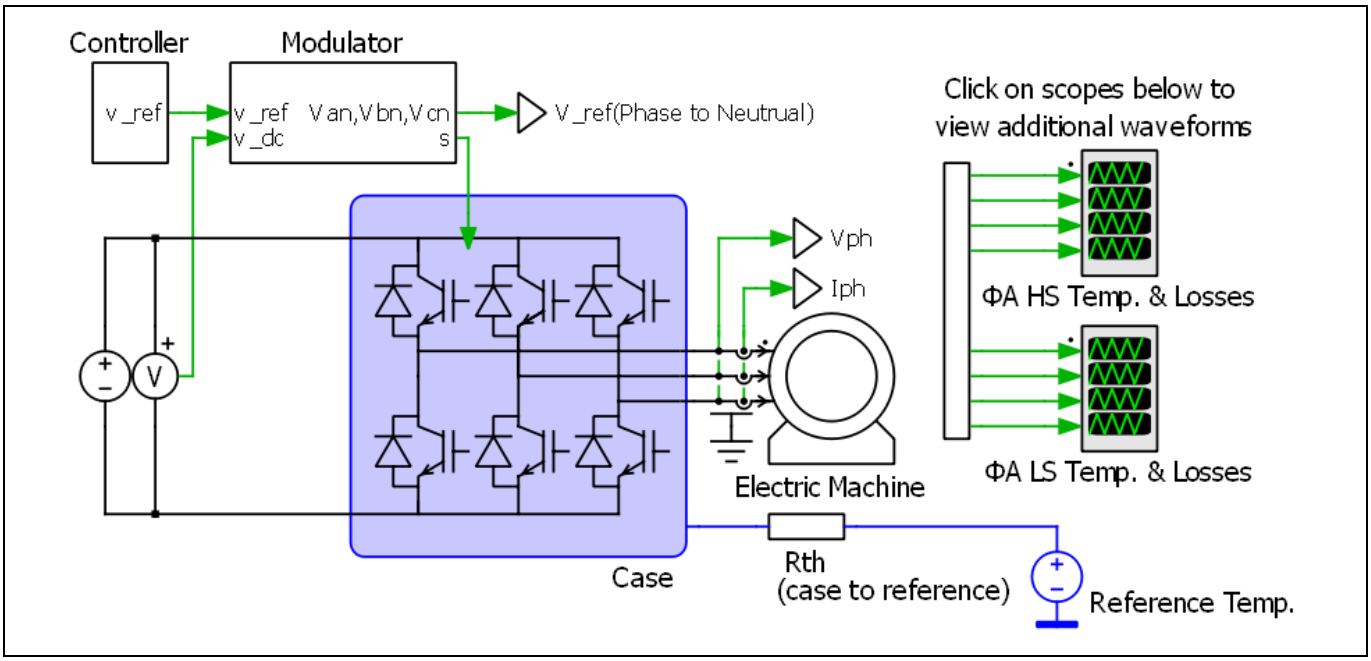



**Figure 1 Motor Drive Schematic**

# 2 Input Parameters

The Simulator Tool allows the user to input parameters for system and PWM frequency, modulation scheme, input and output voltage, current, power factor, thermal interface material, mounting option, thermal resistance, and reference temperature. Family and Package option can be used to filter parts and the DC Bus Voltage is 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:<br>▪ Sine PWM<br>▪ Space-Vector PWM<br>▪ Space-Vector PWM (2 Phase 60°)<br>▪ Trapezoidal 120°<br>▪ Space-vector PWM (2 Phase 120° High Side Clamp)<br>▪ Space-vector PWM (2 Phase 120° Low Side Clamp) |
| DC Bus Voltage: | Input Voltage<br>**This selection is used to filter parts** | Between 10V and 1200V |
| Voltage to motor, line to line: | Output AC Voltage<br>See note below table 1* | Limited by DC Bus Voltage<br>Vrms, (Vpeak for Trapezoidal) |
| Motor Drive Phase Current RMS: | | Between 0.1A and 50A |
| Power Factor: | | Between -1 and 1 |
| Thermal Interface Material: | | Options:<br>▪ Yes<br>▪ No |
| Thermal Interface Resistance: | Thermal resistance of Grease, Silicon Pad, etc.<br>Will only display if Thermal Interface Material is being used | Between 0 and 10°C /W |
| Mounting Option: | | Options:<br>▪ Mounted Heatsink<br>▪ In Free Air<br>▪ Fixed Reference |
| Temperature: | Will display as Ambient or Reference Temperature depending on Mounting Option | Between -65°C and 150°C |
| Thermal Resistance | Will display as Heatsink, Case to Amb, or none depending on Mounting Option | Between 0 and 100°C /W for all cases |
| Family and Package: | **This selection is used to filter parts** | Options:<br>▪ All Packages<br>▪ Micro DIP23<br>▪ Micro DIP23A |

### Input Parameters

| Parameter | Description | Allowed Selection |
|---|---|---|
| | | ▪ Micro SOP23<br>▪ Mini MDIP-24 DCB<br>▪ Mini MDIP-24 Fullpack<br>▪ Nano PQFN 7x8<br>▪ Nano PQFN 8x9<br>▪ Nano PQFN 12x12 |

*Note: 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,

$$Voltage\ to\ Motor\ (Vpeak) = Mi \bullet V_{DC}$$

For sinusoidal modulation schemes,

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

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 package filtering option.

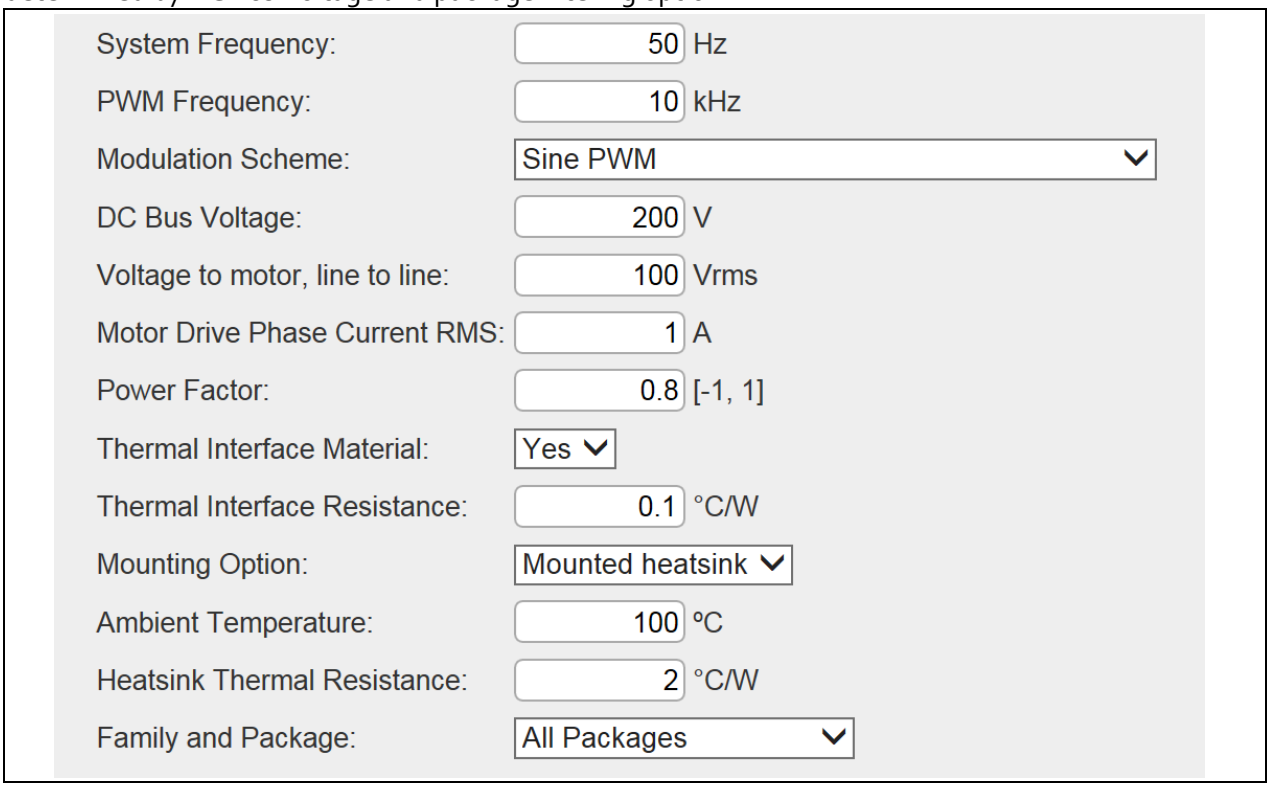



**Figure 2 Input Parameters**

# 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 may be overcrowded.

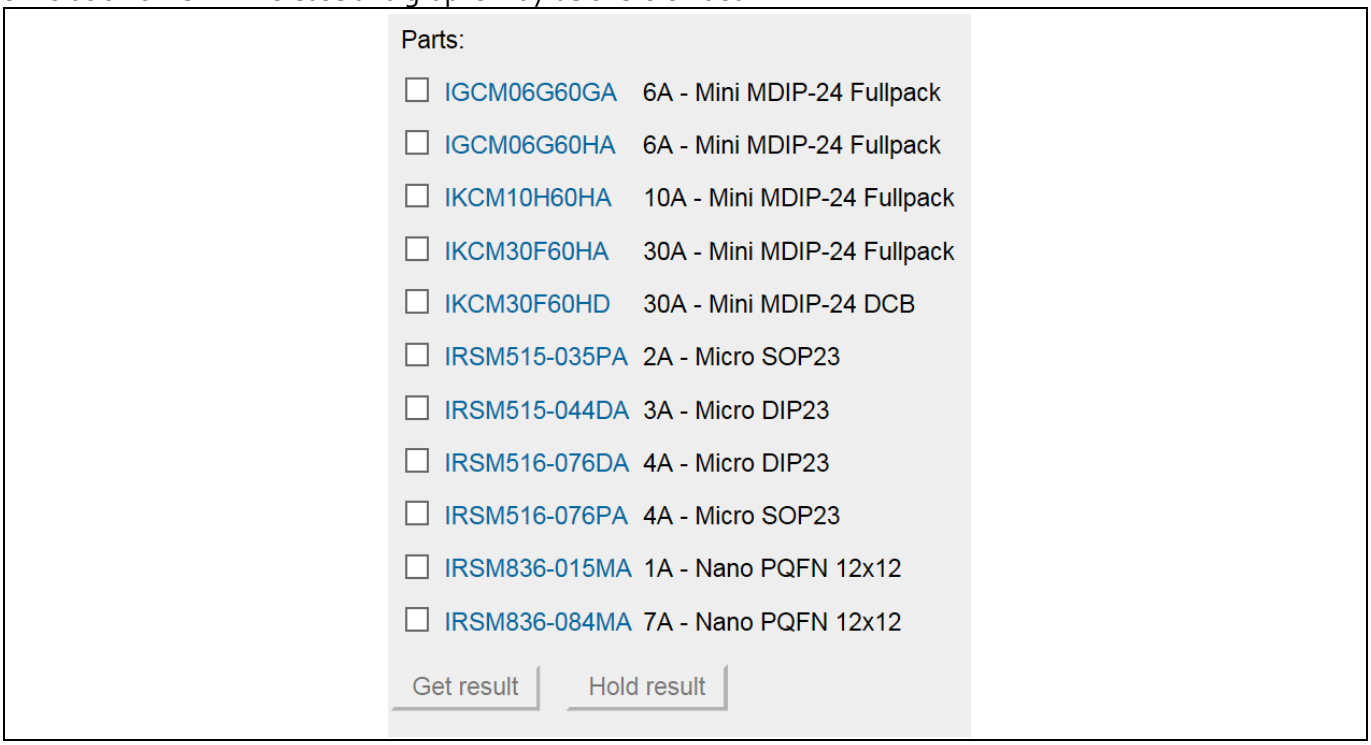



**Figure 3 Parts List Example**

# 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 as desired. This is beneficial as the user can add information from the input parameters to represent each trace.

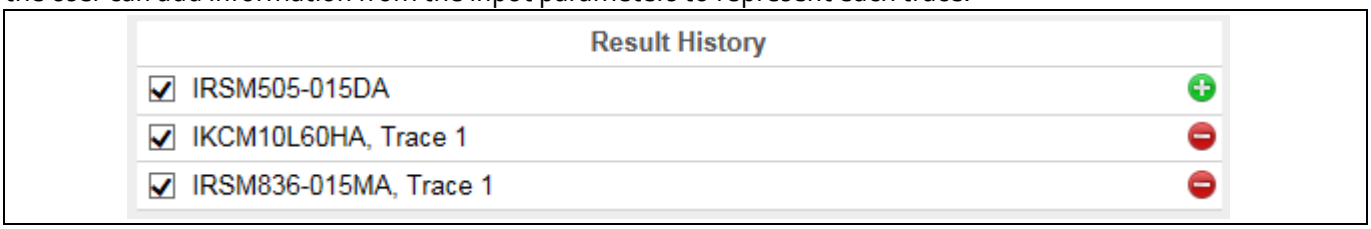
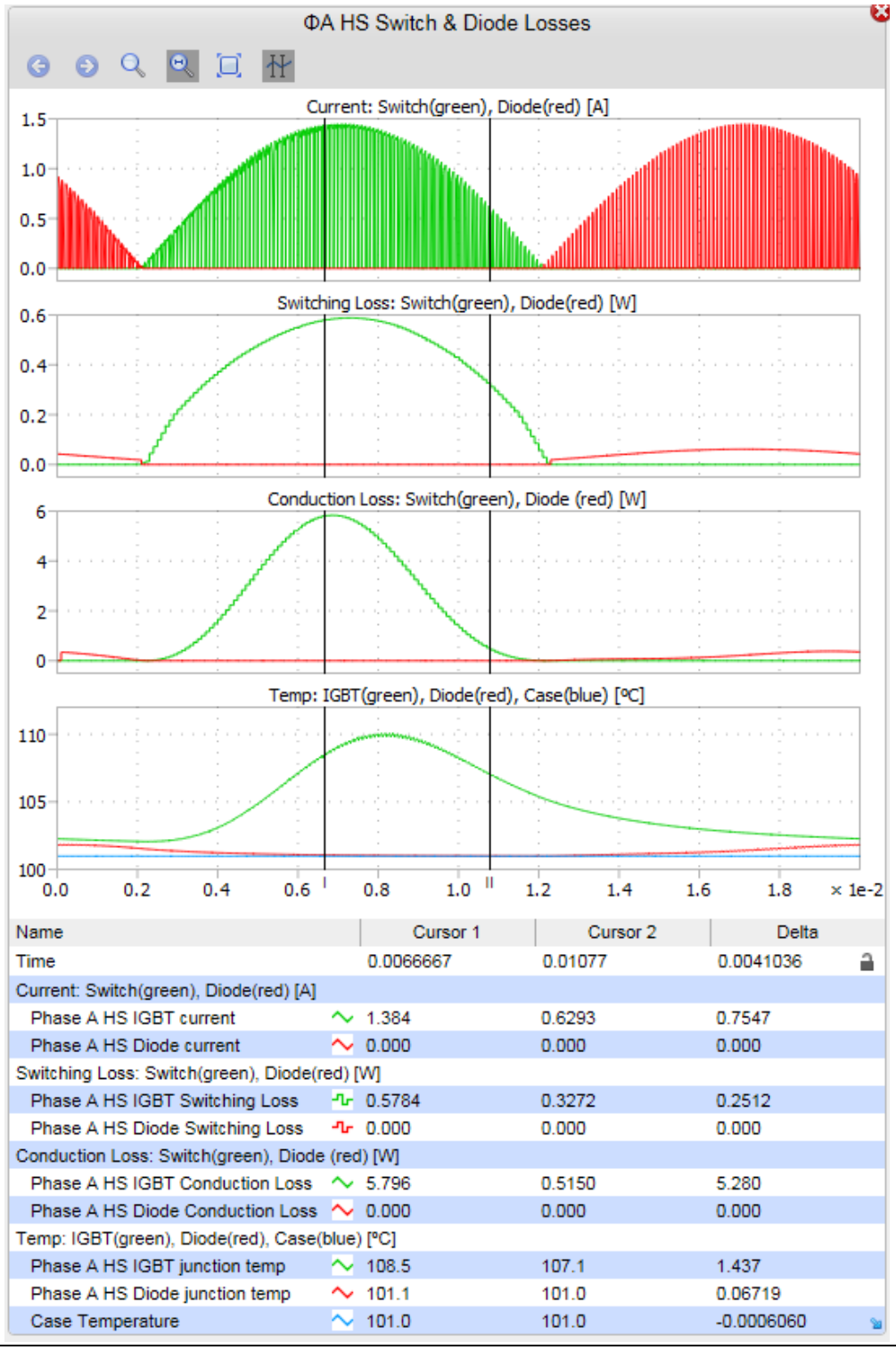



**Figure 4 Results History Example**

# 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.

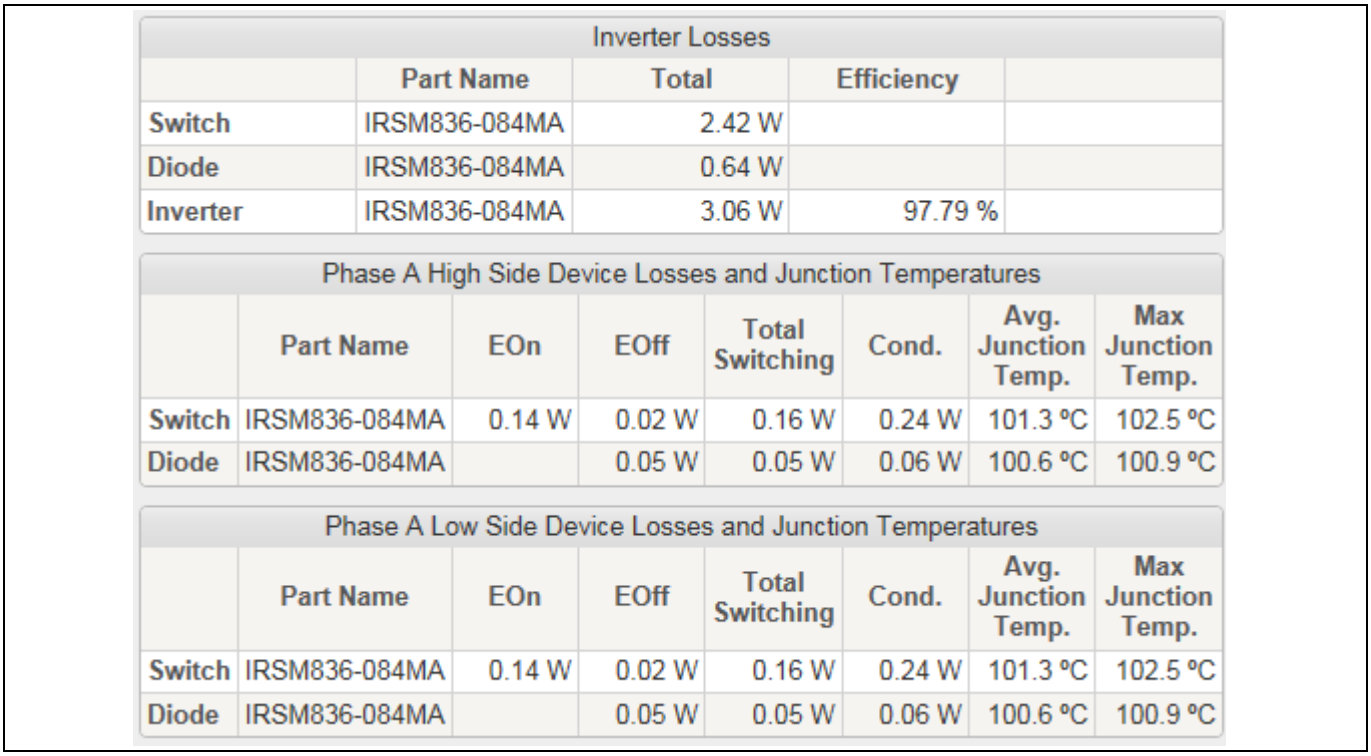



| Name | Cursor 1 | Cursor 2 | Delta |
|---|---|---|---|
| Time | 0.0066667 | 0.01077 | 0.0041036 |
| Current: Switch(green), Diode(red) [A] | | | |
| Phase A HS IGBT current | 1.384 | 0.6293 | 0.7547 |
| Phase A HS Diode current | 0.000 | 0.000 | 0.000 |
| Switching Loss: Switch(green), Diode(red) [W] | | | |
| 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) [°C] | | | |
| 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 °C | 102.5 °C |
| Diode | IRSM836-084MA | | 0.05 W | 0.05 W | 0.06 W | 100.6 °C | 100.9 °C |

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 °C | 102.5 °C |
| Diode | IRSM836-084MA | | 0.05 W | 0.05 W | 0.06 W | 100.6 °C | 100.9 °C |

**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 |
| 1.1 | 11/27/2017 | Updated to include new parameters and schematic |
| | | |

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