Elite Power Simulator

Powered by plecs

User Guide

onsemi

Outline of User Guide

1	Introduction to the Elite Power Simulator: What is it and What are the benefits
2	Simulator Access
3	Step by Step Tool Flow

Outline of User Guide

onsemi's online Elite Power Simulator Powered by plecs

- PLECS is a system level simulator that facilitates the modeling and simulation of complete systems with optimized device models for maximum speed and accuracy. PLECS is not a SPICE-based circuit simulator, where the focus is on low-level behavior of circuit components .
- Power transistors are treated as simple switches that can be easily configured to demonstrate losses associated with conduction and switching transitions.
- The PLECS models, referred to as "thermal models", are composed of lookup tables for conduction and switching losses, along with a thermal chain in the form of a Cauer or Foster equivalent network.
- During simulation, PLECS interpolates and/or extrapolates using the loss tables to get the bias point conduction and switching losses for the circuit operation.

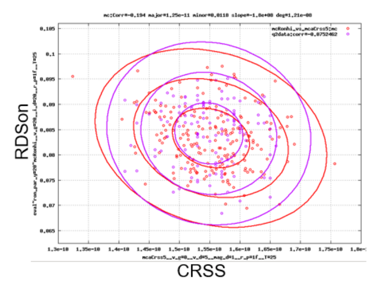
www.onsemi.com/elite-power-simulator

Elite Power Simulator Features

Broad Range Of Circuit Topologies

Covering DC-DC, AC-DC, and DC-AC applications, including 32 circuit topologies in industrial (DC fast charging, UPS, ESS, solar inverters), automotive (OBC, traction), and non-traction spaces

Corner Simulation Capability



onsemi's PLECS models go beyond nominal data from datasheets to include based on physical correlations in t**industry first corner simulation** he manufacturing environment.

Custom PLECS Model

Interface with onsemi's **industry first Self-Service PLECS Model Generator** (SSPMG) to simulate with models tailored to your application.

Soft Switching Simulation

onsemi provides **industry first PLECS models valid for soft switching** applications such as DC-DC LLC and CLLC Resonant, Dual Active Bridge, and Phase Shifted Full Bridge.

Loss Plotting

Explore device conduction loss, switching energy loss, and thermal impedance in a multifunctional 3D data visualization utility.

Flexible Design & Fast Simulations

Flexible to capture adjustments to various attributes such as, **gate drive impedance**, **cooling designs**, and **load profiling**.

www.onsemi.com/elite-power-simulator

onsemi’s State-of-the-Art PLECS Models

- Typical industry PLECS models are composed of measurement-based loss tables that are consistent with datasheets provided by the manufacturer.

  There are four major problems with this approach:

  1. The switching energy loss data is dependent on the parasitics of the measurements set ups and circuits.
  2. The conduction and switching energy loss data is limited and thus is often not dense enough to ensure accurate interpolation and minimal extrapolation by PLECS.
  3. The loss data is based on nominal semiconductor process conditions only.
  4. The switching energy loss data comes from datasheet double pulse generated loss data. This means the PLECS models are only valid for hard switching topology simulation. The models are highly inaccurate if used in soft switching topology simulation.

- onsemi’s Self-Service PLECS Model Generator (SSPMG) provides solutions to all four problems.
- Ultimate power is delivered to the user to build PLECS models tailored for the user’s application. Unleash the power here: www.onsemi.com/self-plecs-generator

Mixing onsemi SPICE expertise and PLECS power

SPICE engine to generate PLECS models

With **onsemi** Physical & Scalable SPICE Models

onsemi power products in your own environment

Parasitic capacitors, leakage inductors ...

Self-Service PLECS Model Generator

Generate

PLECS

High fidelity system level PLECS models with parasitic effects for your own use

?

Upload your PLECS model

Application/System simulation with onsemi power products

Elite Power Simulator

Powered by PLECS

Simulate

Intuitive and easy to use flow

Rapidly report temperature, losses and much more for your system/application

PLECS engine to generate results

onsemi

Corner PLECS Models

- Conventional PLECS models based on measurements are only valid for the typical or nominal process case in manufacturing. onsemi has developed accurate corner PLECS models based on real manufacturing distribution.
- Physics dictates that worst case conduction and switching losses do not happen simultaneously for example.
- Depending on the application, the influence of conduction and switching energy losses on the overall system performance will vary. The onsemi corner PLECS models provide the user the flexibility to investigate the entire correlated space.
- Corner models currently available for EliteSiC and T10M 40V products. More T10 and FS7 IGBT corner models are coming soon.
- Accurate corner and statistical modeling covered in detail in
  - SiC MOSFET Corner and Statistical SPICE Model Generation – Proceeding of International Symposium on Power Semiconductor Devices and ICs (ISPSD), pp. 154-147, September 2020

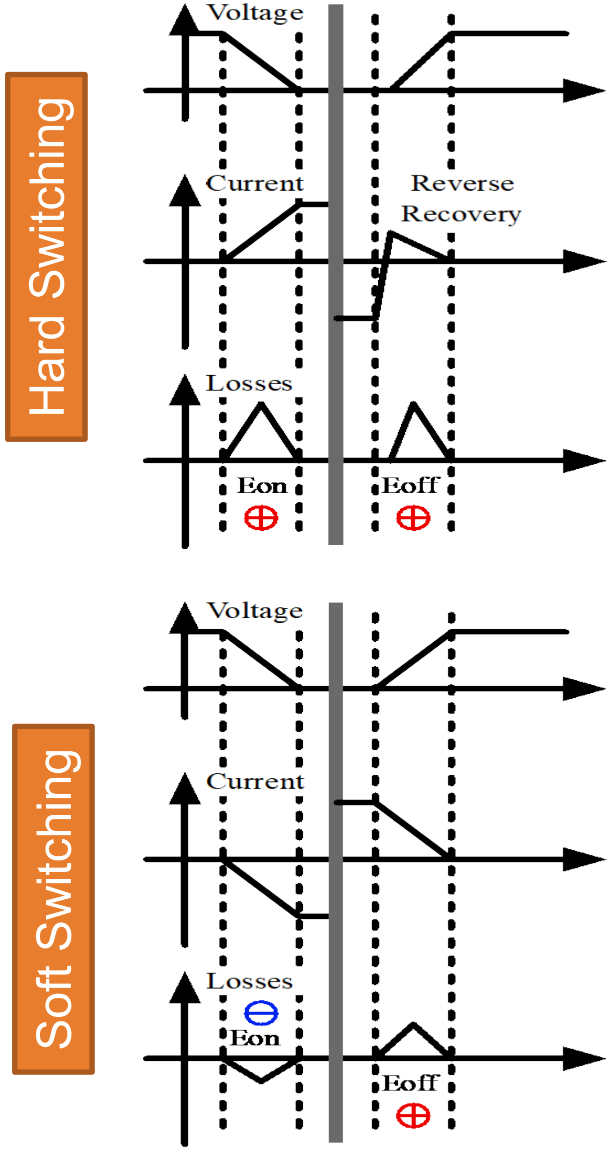
Process Condition	R_{DSon}, V_{th}, BV	Capacitance, Device RG	Conduction Loss	Switching Energy Loss
Nominal	Nominal	Nominal	Nominal	Nominal
Best Case Conduction Loss, Worst Case Switching Loss	Low	High	Low	High
Worst Case Conduction Loss, Best Case Switching Loss	High	Low	High	Low

Full Switching Energy Losses

Full Switching Simulation*

onsemi provides **industry first** Full Switching PLECS models **valid for hard, soft, and partial soft switching** including Synchronous Rectifier Operations. Example Full Switching topologies include DC-DC LLC and CLLC Resonant, Dual Active Bridge, and Phase Shifted Full Bridge.

*The Double Pulse Test is **NOT** representative of Soft Switching. Using double pulse switching energy losses in the simulation of a Soft Switching Topology is highly inaccurate.

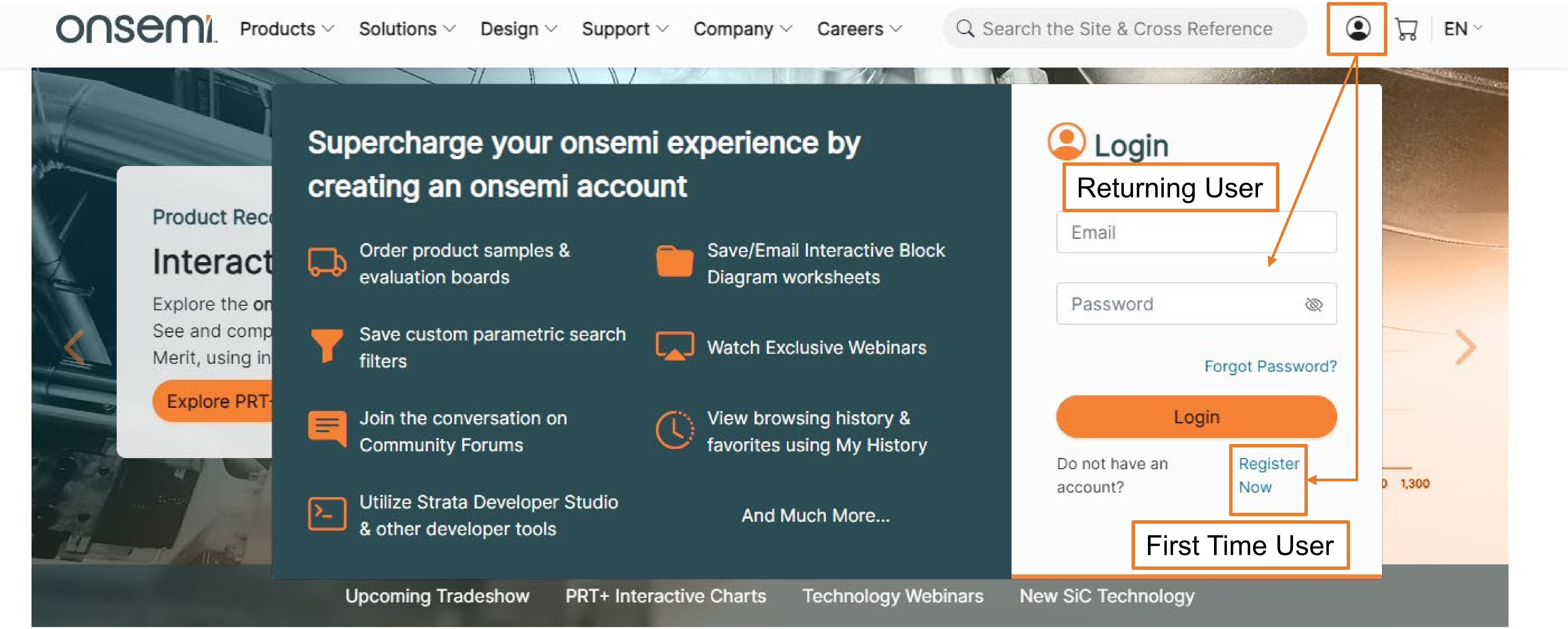


Outline of User Guide

Access Elite Power Simulator with MYON Account

MyON is required to use the Elite Power Simulator

MYON Login

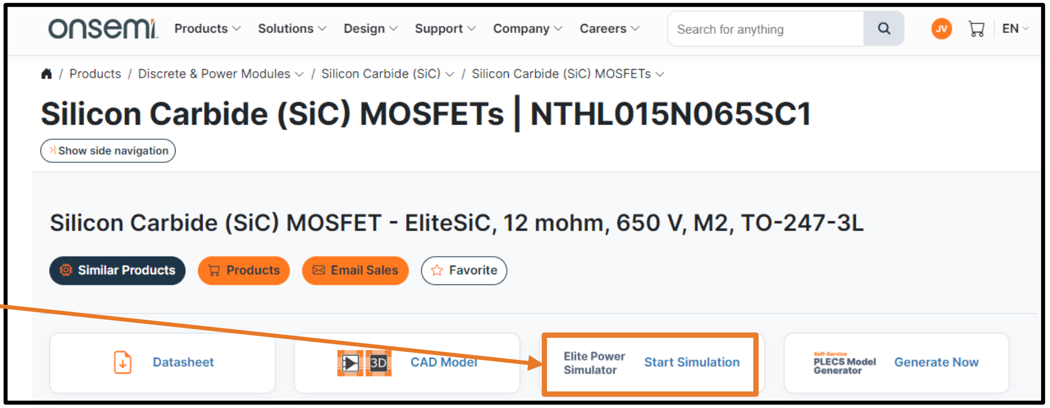


onsemi

Access Through Direct Link or Product Page

In addition to direct access to the Elite Power Simulator
www.onsemi.com/elite-power-simulator

Access is available on each EliteSiC, FS7 IGB, and T10 Si MOSFET Product Page.



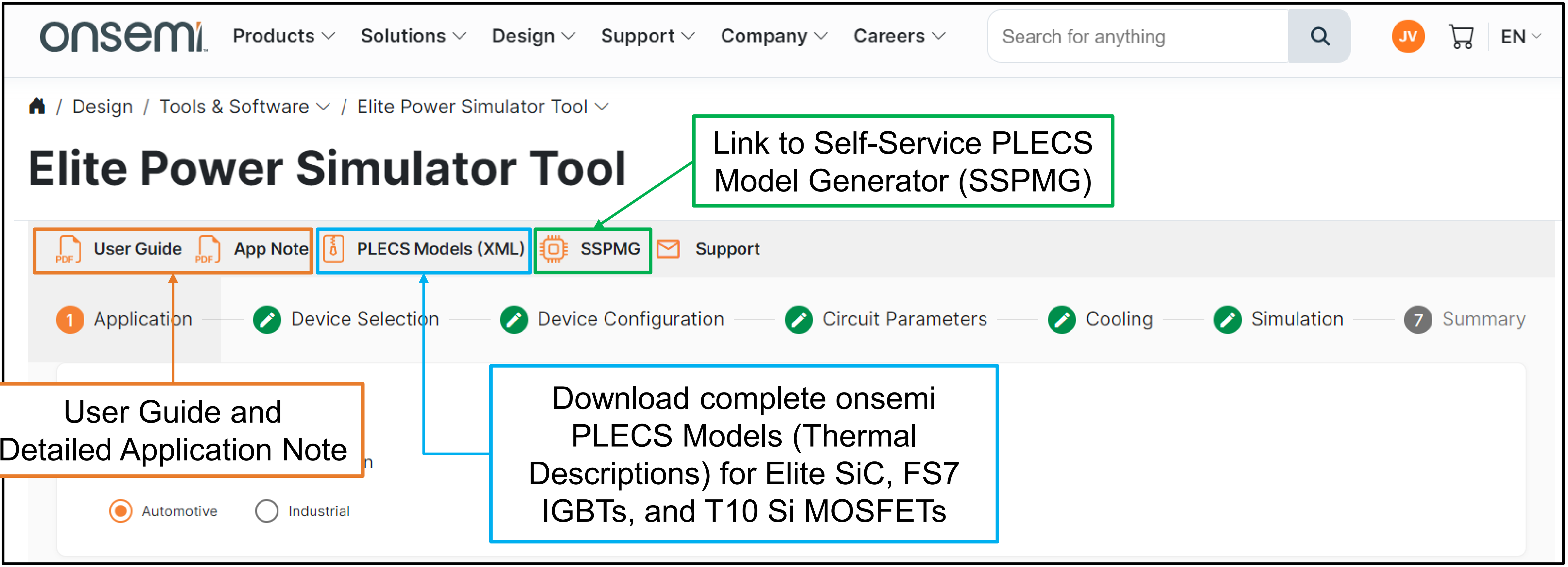
Learn more about EliteSiC, FS7 IGBTs, and T10 Si MOSFETs at
[EliteSiC]
[Field Stop 7 (FS7) IGBTs]
[T10 Si MOSFETs]

Outline of User Guide

1	Introduction to the Elite Power Simulator: What is it and What are the benefits
2	Simulator Access
3	Step by Step Tool Flow

Getting Started

Go to landing page
www.onsemi.com/elite-power-simulator
and select Simulate Now



Link to Self-Service PLECS Model Generator (SSPMG)

User Guide and Detailed Application Note

Download complete onsemi PLECS Models (Thermal Descriptions) for Elite SiC, FS7 IGBTs, and T10 Si MOSFETs

Step 1: Select Application and Topology

1 Application — 2 Device Selection — 3 Device Configuration — 4 Circuit Parameters — 5 Cooling — 6 Simulation — 7 Summary

Target application

Start by selecting target application

- (●) Automotive
- ( ) Industrial

Application choice filters the available topologies

Automotive converter topologies

AC/DC

- ( ) Active Front End (1 phase, 2 level)
- (●) Active Front End (3 phase, 2 level)
- ( ) Active Front End (3 phase, 2 level) (Traction)
- ( ) Asymmetrical Bridgeless PFC Converter
- ( ) Boost PFC Converter (diode bridge) (1/2 phases)
- ( ) Classic Bridgeless PFC Converter
- ( ) Totempole Bridgeless PFC Converter (1/2/3 phases)
- ( ) Vienna Rectifier (3 phase, 1 switch per leg)
- ( ) Vienna Rectifier (3 phase, 2 switches per leg)

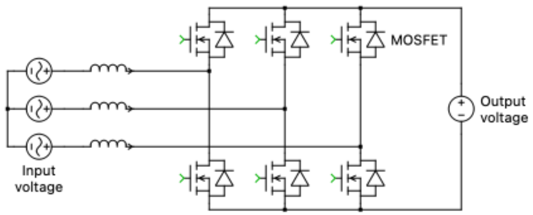
Topologies grouped by converter class

DC/DC

DC/AC

Active Front End (3 phase, 2 level)

Basic circuit schematic displayed



Next Step

Elite Power Simulator Topologies & Applications

All major topologies are available :

Automotive converter topologies

AC/DC
- Active Front End (1 phase, 2 level)
- Active Front End (3 phase, 2 level)
- Active Front End (3 phase, 2 level) (Traction)
- Asymmetrical Bridgeless PFC Converter
- Boost PFC Converter (diode bridge) (1/2 phases)
- Classic Bridgeless PFC Converter
- Totempole Bridgeless PFC Converter (1/2/3 phases)
- Vienna Rectifier (3 phase, 1 switch per leg)
- Vienna Rectifier (3 phase, 2 switches per leg)

DC/DC

DC/AC

Automotive converter topologies

AC/DC

DC/DC
- Synchronous Boost Converter
- Synchronous Buck Converter
- Synchronous Boost Converter (3 level)
- Synchronous Buck Converter (3 level)
- Flyback Converter (1 switch)
- Flyback Converter (2 switch)
- Half-bridge LLC Resonant Converter
- Full-bridge LLC Resonant Converter
- Dual Active Bridge Converter
- CLLC Resonant Converter (charging mode)
- CLLC Resonant Converter (discharging mode)
- Phase Shift Full Bridge Converter

DC/AC

Automotive converter topologies

AC/DC

DC/DC

DC/AC
- Traction Inverter (3 phase)

Industrial converter topologies

AC/DC
- Active Front End (1 phase, 2 level)
- Active Front End (3 phase, 2 level)
- Asymmetrical Bridgeless PFC Converter
- Boost PFC Converter (diode bridge) (1/2 phases)
- Classic Bridgeless PFC Converter
- Totempole Bridgeless PFC Converter (1/2/3 phases)
- Vienna Rectifier (3 phase, 1 switch per leg)
- Vienna Rectifier (3 phase, 2 switches per leg)

DC/DC

DC/AC

Industrial converter topologies

AC/DC

DC/DC
- Boost Converter
- Boost Converter (3 level, symmetric)
- Buck-Boost Converter (inverting, 2 switch)
- Synchronous Boost Converter
- Synchronous Buck Converter
- Synchronous Boost Converter (3 level)
- Synchronous Buck Converter (3 level)
- Synchronous Buck-Boost Converter (inverting, 2 switch)
- Flying Capacitor Boost Converter (3 level)
- Hybrid Switched Capacitor Converter
- Resonant Switched Capacitor 4 to 1 Converter
- Resonant Switched Capacitor 8 to 1 Converter
- Flyback Converter (1 switch)
- Flyback Converter (2 switch)
- Forward Converter (2 switch)
- Active Clamp Forward Converter
- Half-bridge Converter (hard-switched)
- Full-bridge Converter (hard-switched)
- Half-bridge LLC Resonant Converter
- Full-bridge LLC Resonant Converter
- Dual Active Bridge Converter
- CLLC Resonant Converter (charging mode)
- CLLC Resonant Converter (discharging mode)
- Phase Shift Full Bridge Converter

DC/AC

Industrial converter topologies

AC/DC

DC/DC

DC/AC
- Full Bridge Inverter (1 phase, 2 level)
- Half Bridge Inverter (1 phase, 2 level)
- HERIC Inverter
- H5 Inverter
- H6.5 Inverter
- Inverter (3 phase, 2 level, grid load)
- Inverter (3 phase, 2 level, motor load)
- NPC Inverter (1 phase, 3 level)
- NPC Inverter (3 phase, 3 level)
- T-Type Inverter (1 phase, 3 level)
- T-Type Inverter (3 phase, 3 level)
- ANPC Inverter (1 phase, 3 level)
- ANPC Inverter (3 phase, 3 level)
- Inverter (3 phase, 2 level, BLDC load)

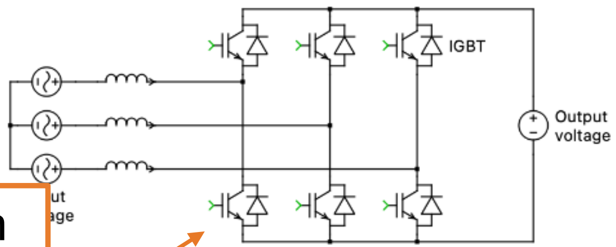
New Topologies available with T10

onsemi.com products available are:

- EliteSiC Discretes and Modules
- Field Stop 7 IGBTs
- T10 Medium Voltage Silicon MOSFETs

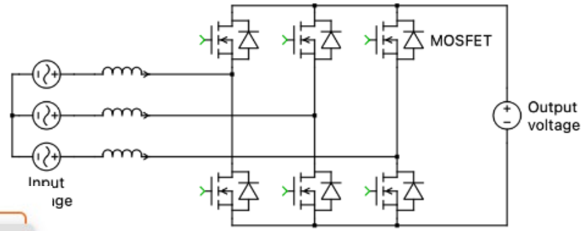
onsemi

Step 2: Select Device



Application — 2 Device Selection — 3 Device Configuration — 4 Circuit Parameters — 5 Cooling

Circuit image toggles based on MOSFET or IGBT choice



Voltage and power rating

Input voltage V_{in}

Value *

300 Vrms,l-l

Output voltage V_{out}

Value *

600 Vdc

Rated power P_{out}

Value *

4000 W

Inputs used to filter valid devices

Use SiC MOSFETs, SiC modules, or Si IGBTs?

Select option *

SiC MOSFETs (discretes)

Select option *

- SiC MOSFETs (discretes)
- SiC modules (half bridge/six pack)
- Si IGBTs

Choose Device Type (Varies Depending on Topology)

Select MOSFET

Please select device from the list to continue.

Select device to move onto next step

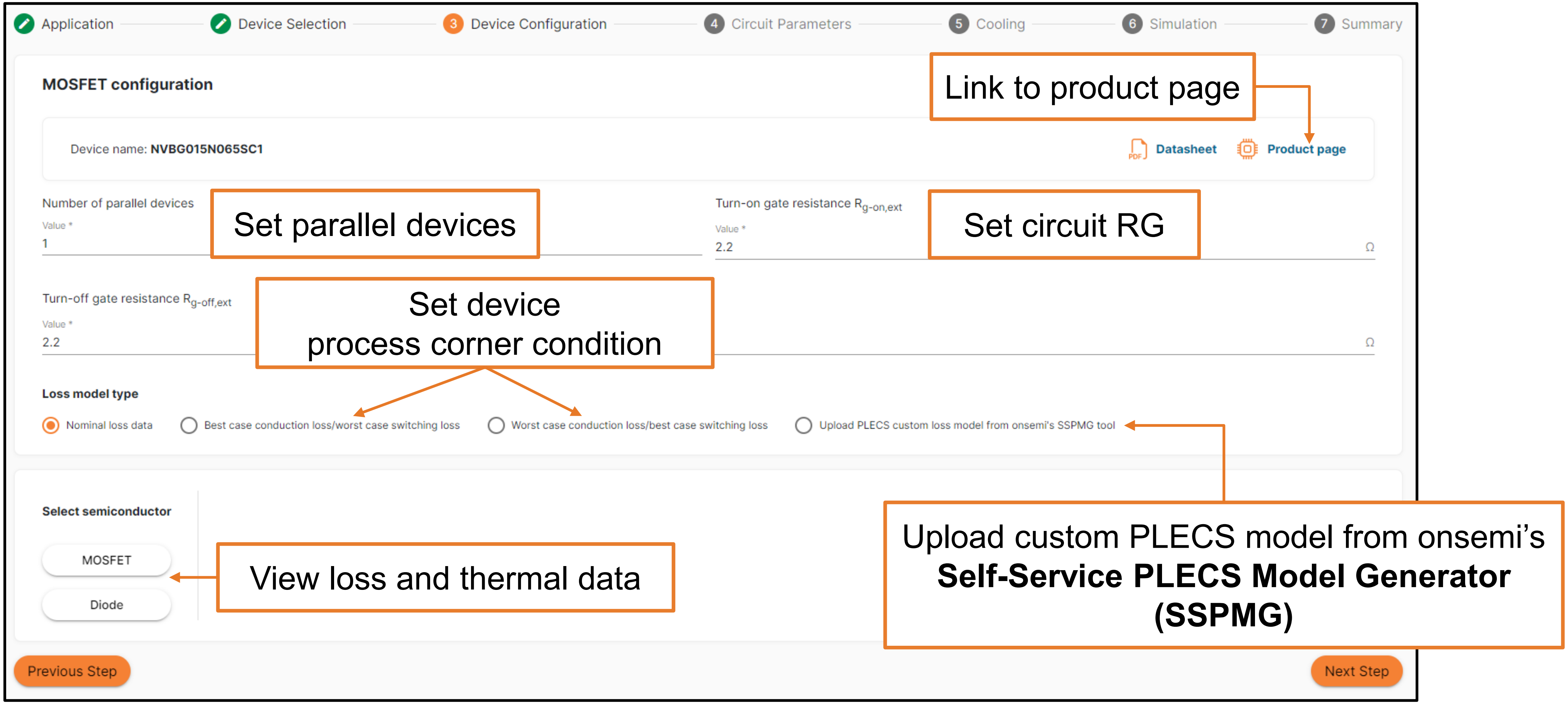
Show all

	Product name	Family	V_{MAX}	$R_{DS(on)}$	$I_{D(max)}$	Package	Data Sheet
○	NVBG015N065SC1	M2	650	12	145	D2PAK7	PDF
○	NVBG025N065SC1	M2	650	19	106	D2PAK7	PDF
○	NVBG045N065SC1	M2	650	31	62	D2PAK7	PDF
○	NVBG060N065SC1	M2	650	4			PDF
○	NVBG075N065SC1	M2	650	5			PDF

Direct datasheet download

onsemi

Step 3: Configure Device



View Device Loss Data

Toggle on/off temperatures in 3D plot

Select MOSFET, IGBT, or Body Diode

Interactive 3D plot

Toggle table data with temperature

View loss data

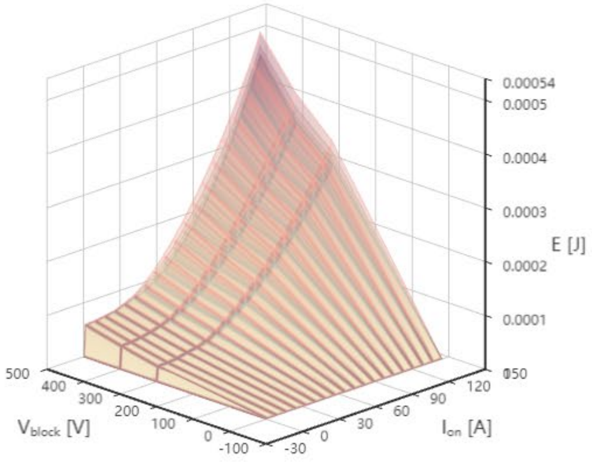
Select semiconductor

MOSFET

Diode

Turn-on loss | Turn-off loss | Conduction loss | Thermal chain

Temperature
Click to toggle
25 °C
75 °C
125 °C
175 °C



Zoom
Rotate
Pan

25 °C | 75 °C | 125 °C | 175 °C

Selected temperature plot is highlighted

[J]	-1 A	0 A	1 A	9 A	17 A	25 A	33 A	41 A	49 A	57 A	65 A	73 A	81 A	89 A	97 A	105 A	113 A
-1 V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0 V	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
300 V	0.0000	0.0000	0.000026689	0.000027558	0.000029493	0.000034086	0.000036367	0.000040567	0.000049200	0.000060209	0.000073136	0.000088014	0.00010502	0.00012252	0.00014345	0.00016481	0.00018639
400 V	0.0000	0.0000	0.000041049	0.000041945	0.000044487	0.000048131	0.000053271	0.000057382	0.000064618	0.000075513	0.000089415	0.00010605	0.00012464	0.00014549	0.00016797	0.00019314	0.00021880
500 V	0.0000	0.0000	0.000057611	0.000058410	0.000061098	0.000064109	0.000070784	0.000077459	0.000084134	0.000095186	0.00010962	0.00012810	0.00015032	0.00017278	0.00020004	0.00023209	0.00026606

View Device Thermal Data

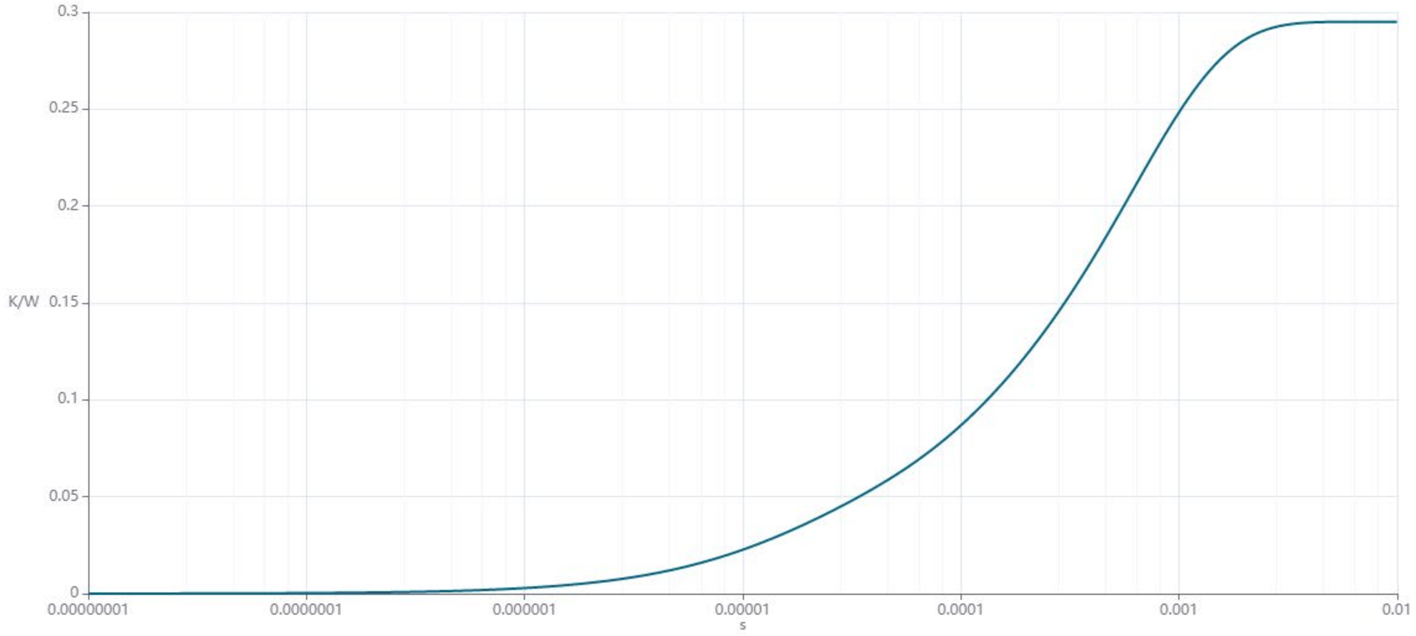
Select semiconductor

MOSFET

Diode

Turn-on loss | Turn-off loss | Conduction loss | Thermal chain

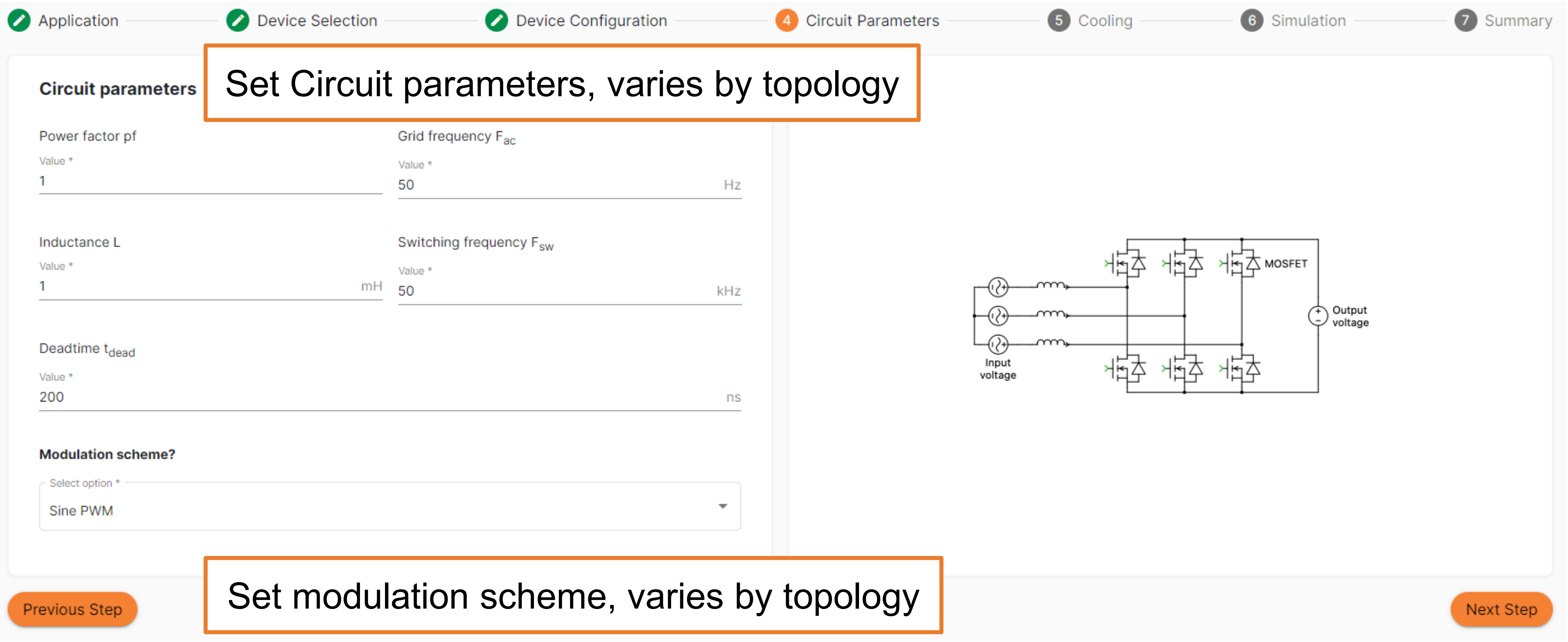
Impedance diagram Zth



	1	2	3	4
R	0.012841 K/W	0.014814 K/W	0.034181 K/W	0.23327 K/W
C	0.00086733 J/K	0.0010006 J/K	0.0023087 J/K	0.002669 J/K

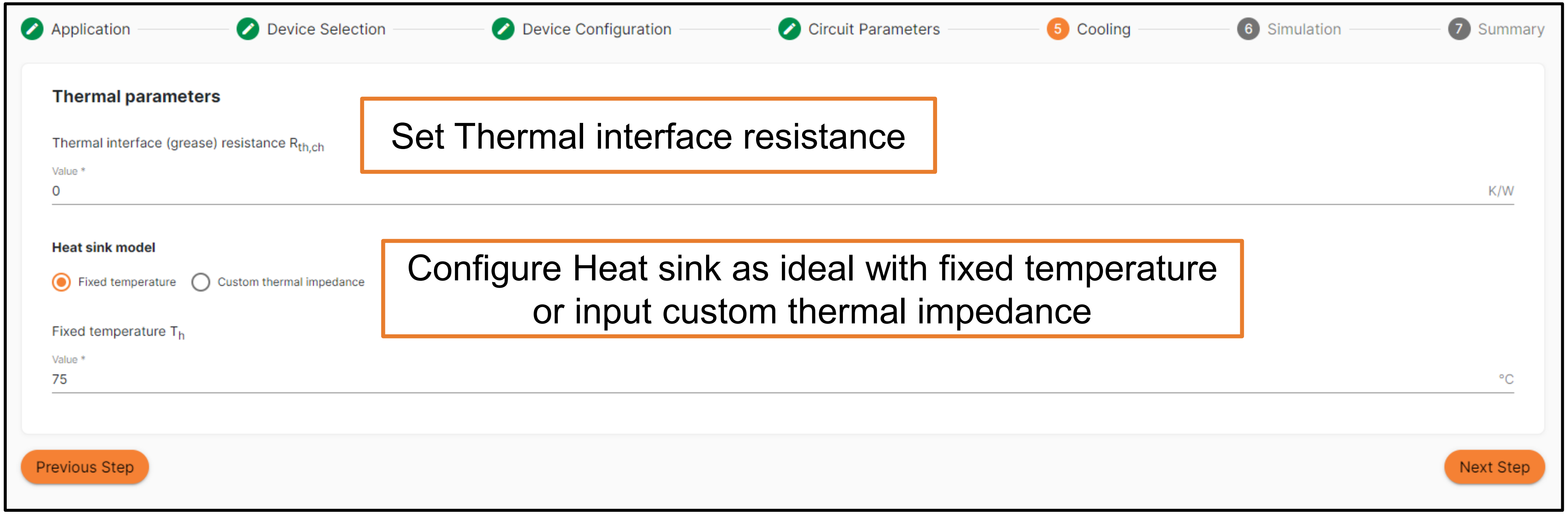
View thermal chain

Step 4: Configure Circuit Parameters

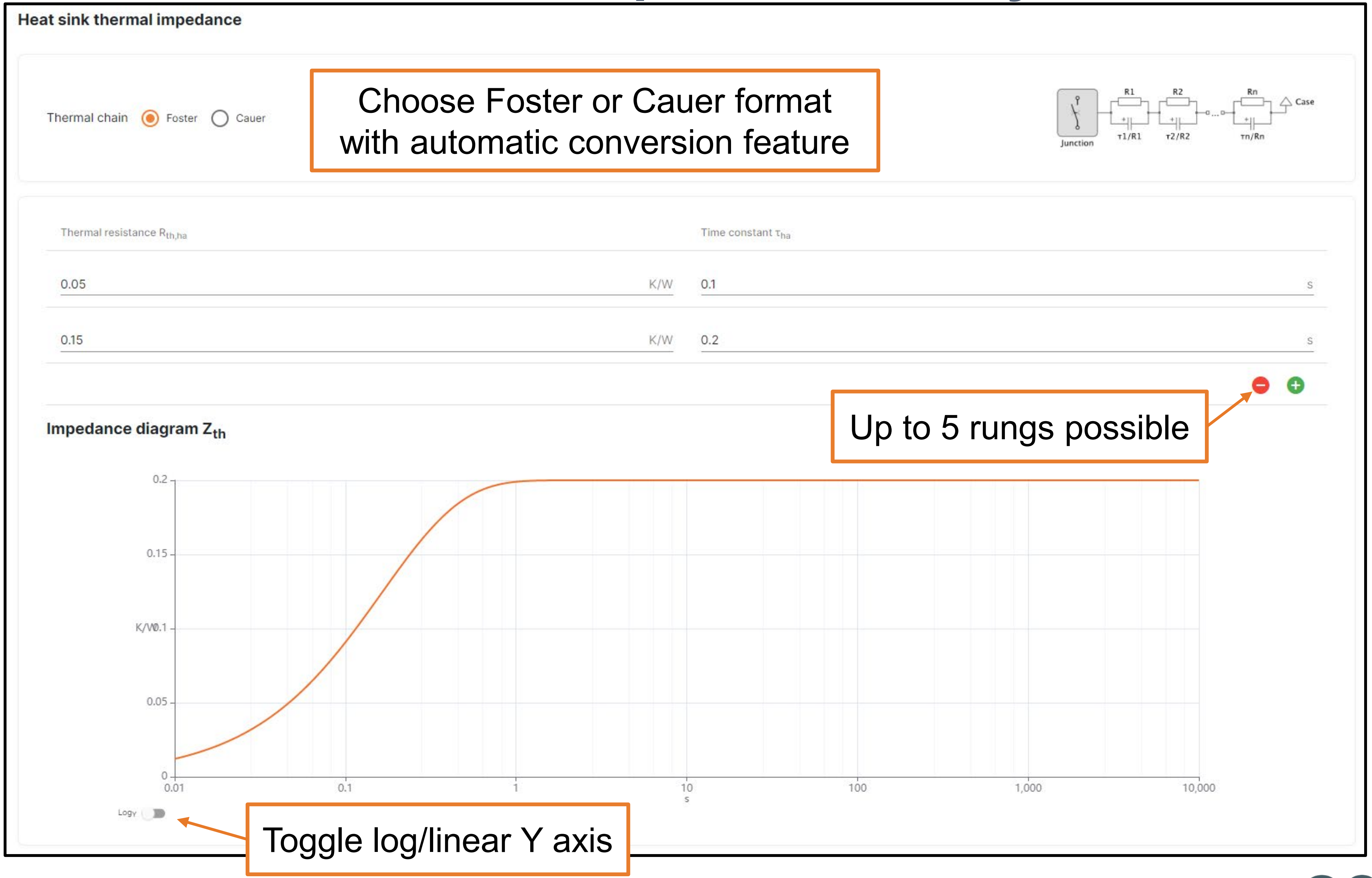


onsemi

Step 5: Configure Cooling



Custom Heat Sink Thermal Impedance Utility

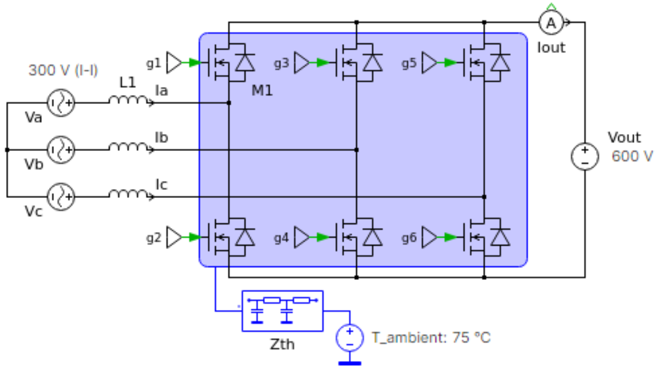


Step 6a: Run Simulation

Application — Device Selection — Device Configuration — Circuit Parameters

Detailed temperature, loss, and efficiency reported

Circuit



Simulation Control

Simulate | Hold Result

Launch Simulation

Less details

Simulation completed

System Overview

Input Voltage	Output Voltage	Power Rating	Power Factor	Grid Frequency	Switching Frequency
300.0 V_l-l,rms	600.0 Vdc	4.000 kW	1.0	50.0 Hz	50.0 kHz

Temperatures

MOSFET	NVBG015N065SC1
Module	
IGBT	
Number of Parallel	1
Switch Max Tj	85.2 °C
Heatsink Max Temp.	82.2 °C
Ambient Temp.	75.0 °C

Pivot table, export csv

Losses Overview

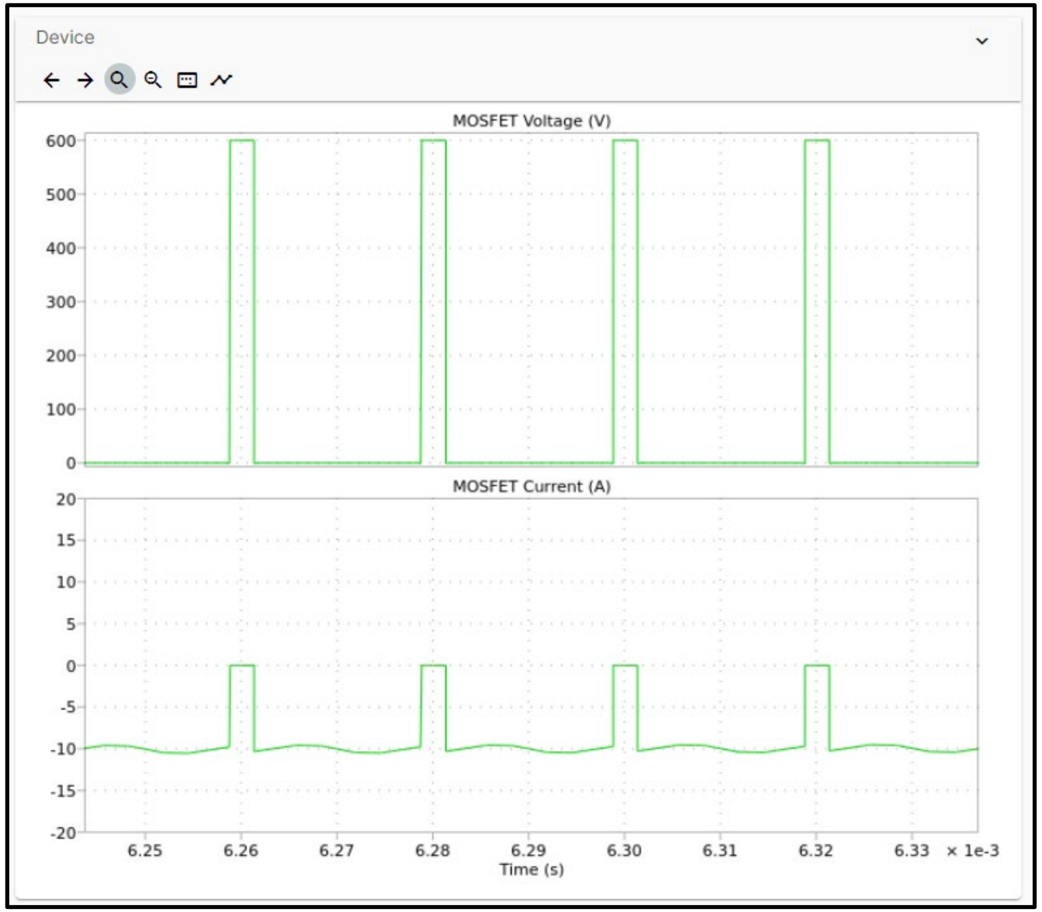
Switching Losses	32.98 W
Conduction Losses	3.20 W
Combined Losses	36.18 W
Efficiency	99.10 %

Losses Breakdown

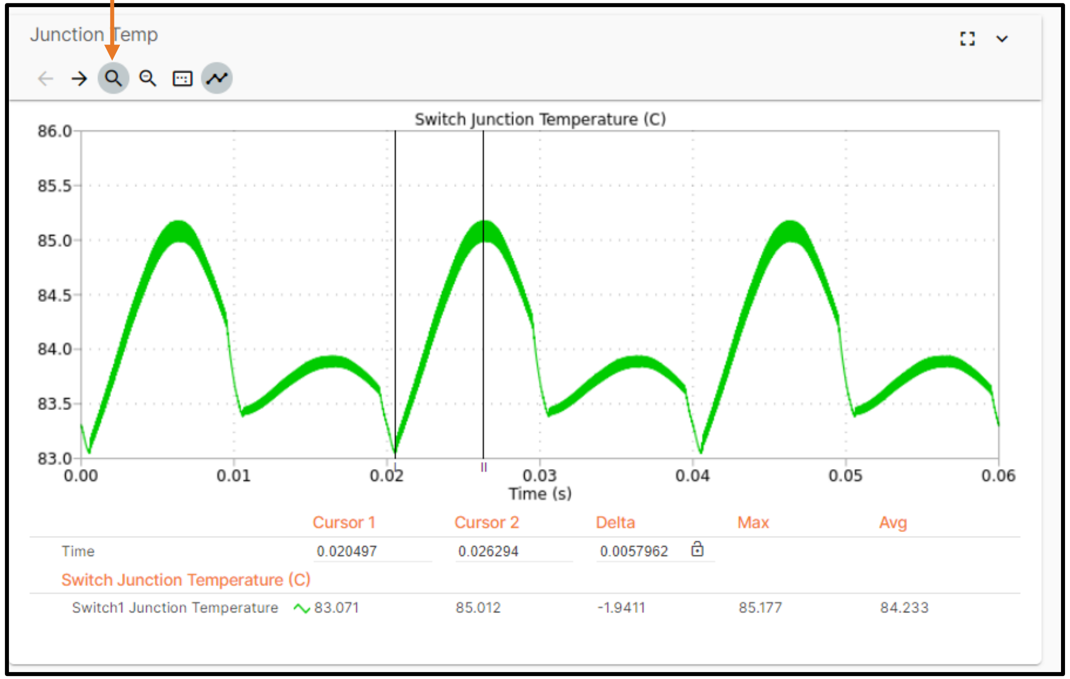
Turn-on Losses	11.09 W
Turn-off Losses	2.71 W
Recovery Losses	19.17 W
Forward Conduction	0.32 W
Reverse Conduction	1.68 W
(Body) Diode Conduction (Deadtime)	1.21 W

Step 6b: View Plots

Application — Device Selection — Device Configuration — Circuit Parameters — Cooling — 6 Simulation — 7 Summary



Zooming and cursor features



onsemi

Step 6c: Compare Multiple Simulation Cases

Compare
- Device Selection
- Device Configuration
  - ✓ Corner process loss data
  - ✓ SSPMG Model
- Circuit Parameters
- Cooling

Simulation

Simulation Control

Simulate | Hold Result

Less details

Go back to steps 2, 3, 4, or 5 to make changes

2 Device Selection

MOSFET: NVBG025N065SC1 Change

Simulation

Simulate

Compare Results

Temperatures

MOSFET	NVBG025N065SC1 NVBG015N065SC1
Module	
IGBT	
Number of Parallel	1 1
Switch Max Tj	83.0 °C 85.2 °C
Heatsink Max Temp.	80.5 °C 82.2 °C
Ambient Temp.	75.0 °C 75.0 °C

onsemi

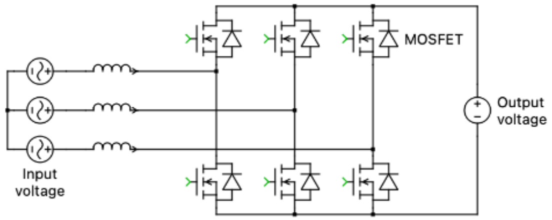
Step 7: Review Summary Table

Application — Device Selection — Device Configuration — Circuit Parameters — Cooling — Simulation — 7 Summary

Summary for Active Front End (3 phase, 2 level) topology (automotive)

CSV Download

Print CSV Download



You can highlight rows by clicking on them

Highlight rows to be print or downloaded to CSV

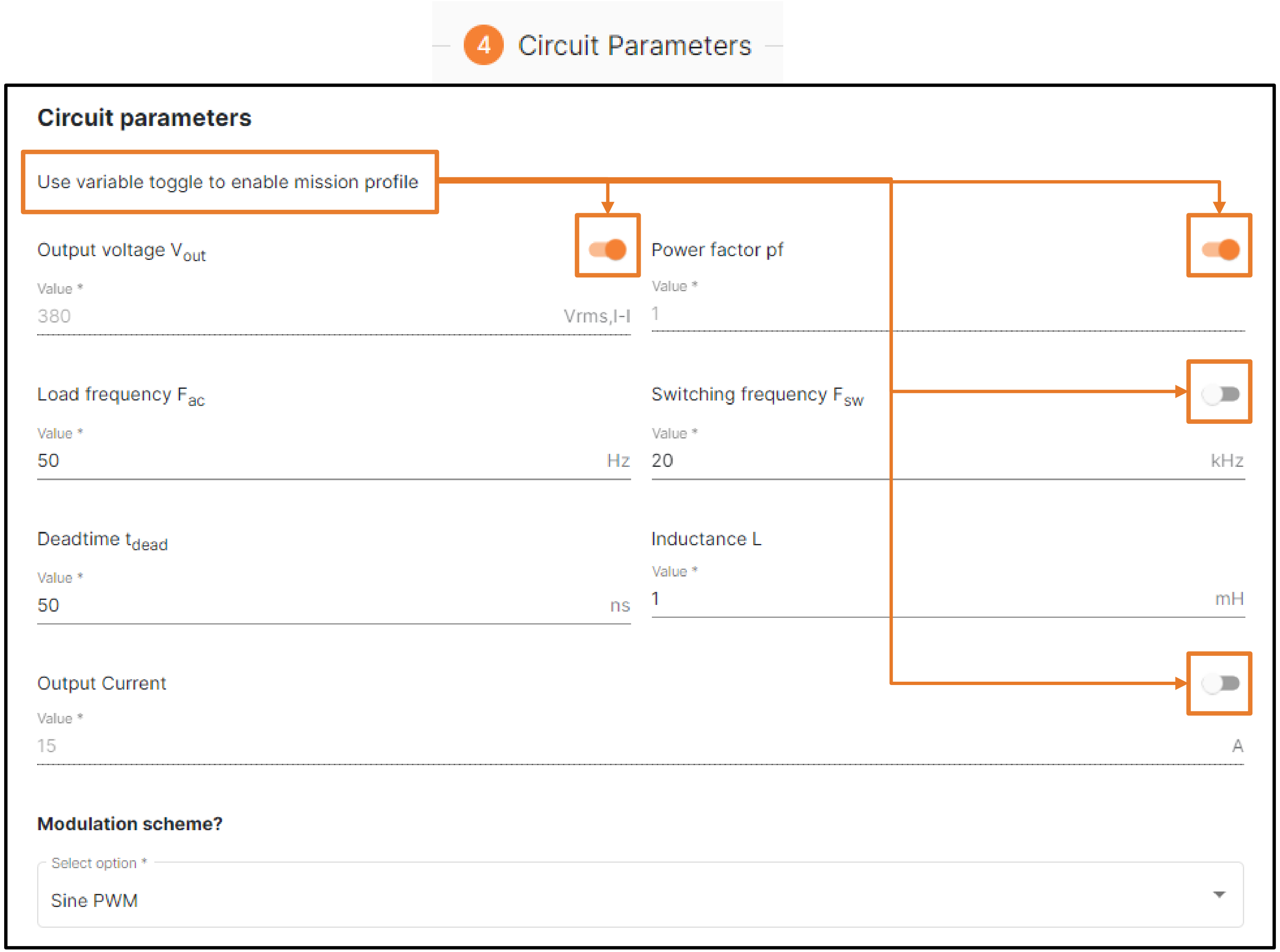
Parameter	Sine PWM, NVBG015N065SC1, Nominal loss data
Selected part	NVBG015N065SC1
Input voltage V_{in}	300 Vrms,l-l
Output voltage V_{out}	600 Vdc
Rated power P_{out}	4000 W
Use SiC MOSFETs, SiC modules, or Si IGBTs?	SiC MOSFETs (discretes)
Number of parallel devices	1
Turn-on gate resistance $R_{g\text{-}on,ext}$	2.2 Ω
Turn-off gate resistance $R_{g\text{-}off,ext}$	2.2 Ω
Loss model type	Nominal loss data
Power factor pf	1
Grid frequency F_{ac}	50 Hz
Inductance L	1 mH
Switching frequency F_{sw}	50 kHz
Deadtime t_{dead}	200 ns
Modulation scheme?	Sine PWM

onsemi

Load Profile Simulation

- Load profile simulation enables power and thermal estimations at multiple, user-defined operating points
- Simple intuitive flow

Topologies with Load Profiling
NPC inverter (1 phase, 3 level)
NPC inverter (3 phase, 3 level)
T-Type inverter (1 phase, 3 level)
T-Type inverter (3 phase, 3 level)
ANPC inverter (1 phase, 3 level)
ANPC inverter (3 phase, 3 level)
Inverter (3 phase, 2 level, grid load)
Inverter (3 phase, 2 level, motor load)
Traction Inverter (3 phase)



onsemi

Load Profile Setup

Set up time intervals

Set up parameter profiles

Linear ramping when stepped changes not enabled

Add or subtract time intervals

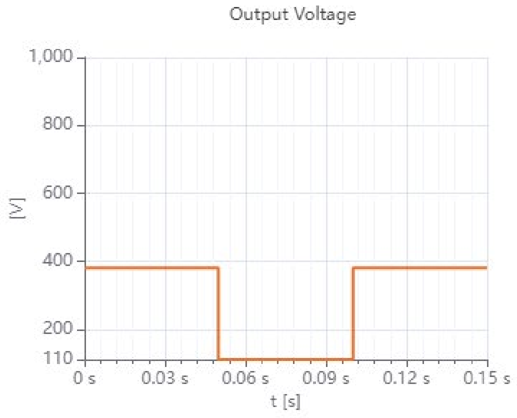
Real time plotting of load profile parameters for inspection before launching simulation

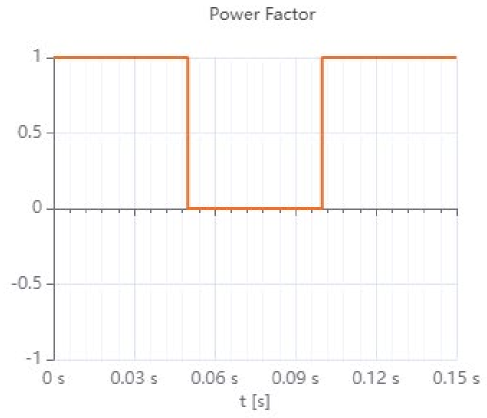
Mission Profile

Enable stepped changes

Time [s]	Output Voltage [V]	Power Factor
0 s	380 V	1
0.05 s	110 V	0
0.1 s	380 V	1
0.15 s	380 V	1

Diagrams





4 Circuit Parameters

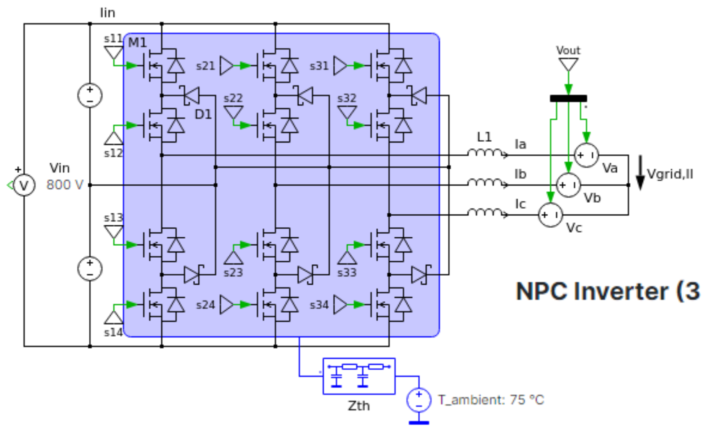
onsemi

Load Profile Simulation

6 Simulation

Mission Profile simulation button is enabled (orange) when any circuit parameter is enabled with a load profile

Circuit/MissionProfile



NPC Inverter (3 phase, 3 level)

Simulation Control

Simulate | Mission Profile | Hold Result

Less details

Simulation completed

System Overview

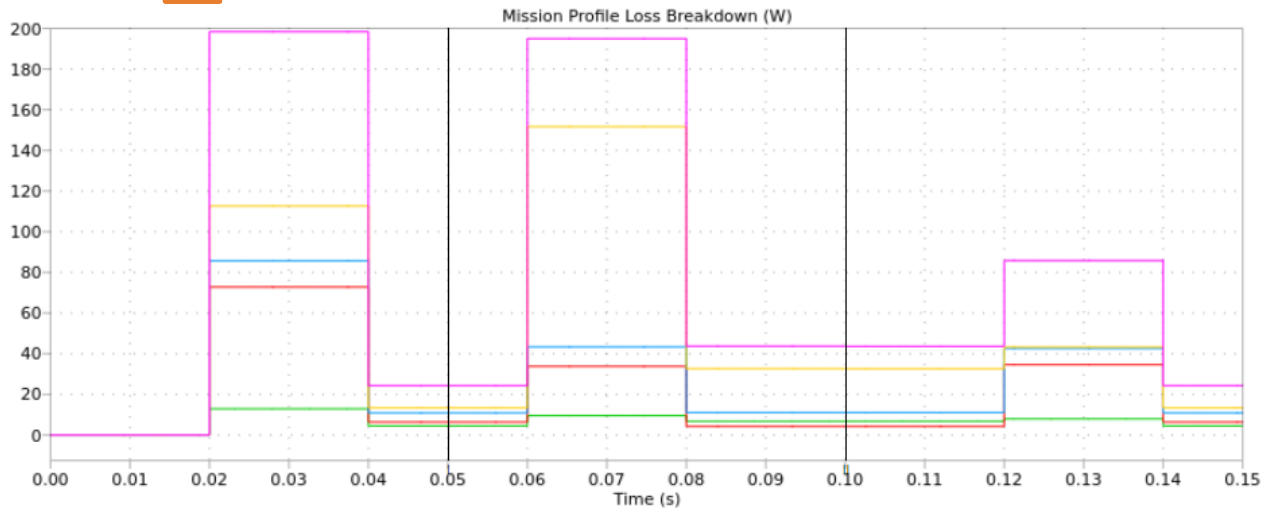
Input Voltage	Output Voltage	Power Rating	Power Factor	Load Frequency	Switching Frequency
800.0 V	380.0 V	20.00 kW	1.0	50.0 Hz	20.0 kHz

Temperatures

SiC MOSFET	MOSFET Max Tj	SiC Diode	Diode Max Tj	Heatsink Max Temp.	Ambient Temp.
NTBG015N065SC1	77.5 °C	FFSB2065B	89.6 °C	75.0 °C	75.0 °C

Example Load Profile Simulation Results

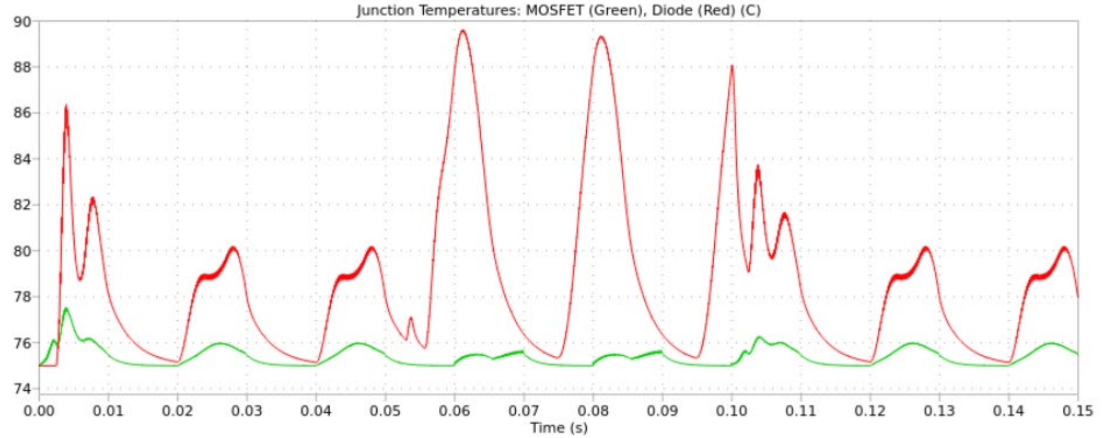
Losses Calculation/Mission Losses



	Cursor 1	Cursor 2	Delta	Max	Avg
Time	0.050000	0.10000	0.050000		
Mission Profile Loss Breakdown (W)					
MOSFET Switching Losses	4.4876	6.7870	-2.2994	9.5516	7.4330
MOSFET Conduction Losses	6.3765	4.2431	2.1334	33.763	16.481
MOSFET Total Losses	10.864	11.038	-0.17337	43.315	23.914
Diode Conduction Losses	13.416	32.608	-19.191	151.66	76.417
Total Overall Losses	24.281	43.645	-19.364	194.97	100.33

Losses can be tracked over the load profile by enabling the cursor

Junction Temp



Junction Temperature

Questions?

Have questions, comments, or need support with your Elite Power Simulator needs? We're here to help! Write us an email at **elitesim@onsemi.com**.

- Self-Service PLECS Model Generator:

  www.onsemi.com/self-plecs-generator

- Elite Power Simulator:

  www.onsemi.com/elite-power-simulator

onsemi

onsemi™

Intelligent Technology. Better Future.

Follow Us @onsemi

www.onsemi.com