EVM User's Guide: TPSM8S6C24SEVM-1PH

TPSM8S6C24 Power Module Evaluation Module

Description

The TPSM8S6C24SEVM-1PH is designed to provide a quick setup to evaluate TPSM8S6C24 device and gain familiarity with device down to PMBus® command and extended write protection.

The TPSM8S6C24 is a configurable single-output buck converter module. The TPSM8S6C24SEVM-1PH uses a nominal 12-V bus to produce a regulated 1.2-V output at up to 35 A of load current. The TPSM8S6C24SEVM-1PH demonstrates the single output capability.

Get Started

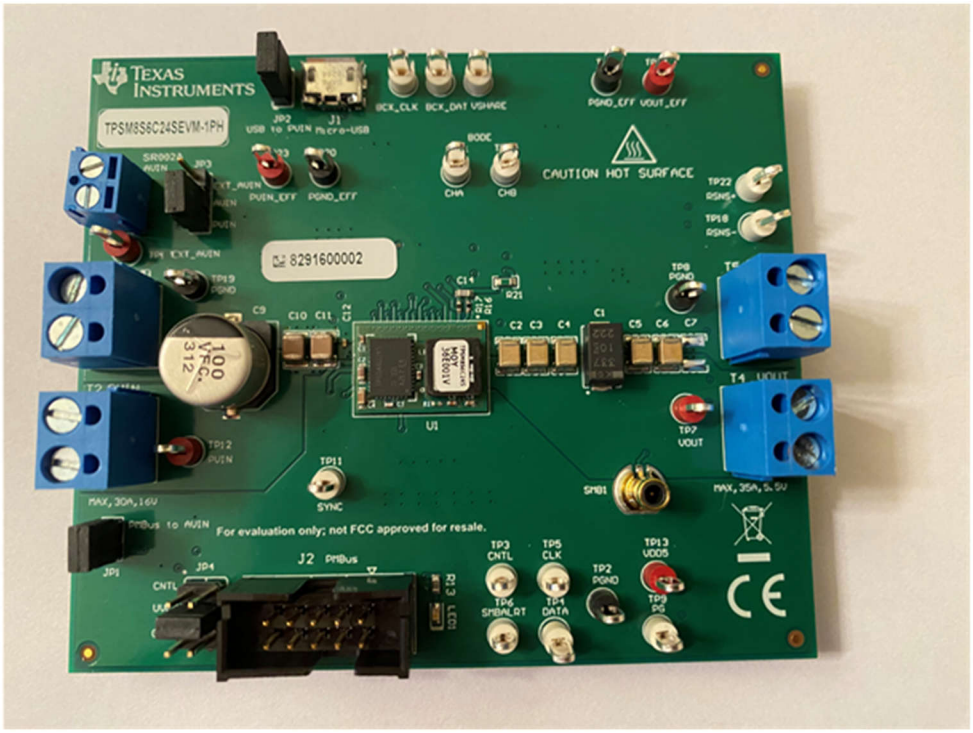
1. Order the TPSM8S6C24SEVM-1PH on ti.com
2. Visit TPSM8S6C24SEVM-1PH to launch or down load Fusion GUI software.

Features

- Evaluate TPSM8S6C24 device using the provided test points on the EVM
- Evaluate TPSM8S6C24 device configuration and monitoring using Fusion GUI

Applications

- Data center switches, rack servers
- Active antenna system, remote radio and baseband unit
- Automated test equipment, CT, PET and MRI
- ASIC, SoC, FPGA, DSP core and I/O voltage



TPSM8S6C24SEVM-1PH

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1 Evaluation Module Overview

1.1 Introduction

This user's guide describes the characteristics, operation, and use of the TPSM8S6C24SEVM-1PH evaluation module (EVM). In addition, the user's guide includes test information, descriptions, and results. A complete schematic diagram, printed circuit board layouts, and bill of materials are also included in this document.

1.1.1 Before You Begin

The following warnings and cautions are noted for the safety of anyone using or working close to the TPSM8S6C24SEVM-1PH. Observe all safety precautions.

Warning The TPSM8S6C24SEVM-1PH circuit module can become hot during operation due to dissipation of heat. Avoid contact with the board. Follow all applicable safety procedures applicable to the laboratory.

Caution Do not leave the EVM powered when unattended.

WARNING

The circuit module has signal traces, components, and component leads on the bottom of the board, which can result in exposed voltages, hot surfaces, or sharp edges. Do not reach under the board during operation.

CAUTION

The circuit module can be damaged by overtemperature. To avoid damage, monitor the temperature during evaluation and provide cooling, as needed, for the system environment.

CAUTION

Some power supplies can be damaged when applying external voltages. If using more than one power supply, check the equipment requirements and use blocking diodes or other isolation techniques, as needed, to prevent damage to the equipment.

CAUTION

The communication interface is not isolated on the EVM. Be sure no ground potential exists between the computer and the EVM. Be aware that the computer is referenced to the battery potential of the EVM.

1.2 Kit Contents

Table 1-1 lists the contains of the EVM kit. Contact the Texas Instruments Product Information Center nearest you if any components are missing. TI highly recommends that users check the TI website at https://www.ti.com to verify that the latest versions of the Fusion GUI software is being used

Table 1-1. Kit Contents

Item	Quantity
TPSM8S6C24SEVM-1PH	1

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1.3 Specifications

Table 1-2 lists the electrical performance specifications in room temperature (20°C to 25°C). Characteristics are given for an input voltage of V_{IN} = 12 V, unless otherwise specified.

Table 1-2. TPSM8S6C24SEVM-1PH Electrical Performance Specifications(1)

Parameter	Test Conditions	MIN	TYP	MAX	Unit
Input Characteristics					
Input voltage range, V_{IN}		5	12	16	V
Full load input current	I_{OUT} = 35 A		4.3		A
	V_{IN} = 5 V, I_{OUT} = 35 A		9.84		A
No load input current	V_{IN}=12 V, I_{OUT} = 0 A, switching enabled		76		mA
Enable switching threshold	Set by default resistor divider, JP4 pin3 and 4 shorted		3.92		V
Disable switching threshold	Set by default resistor divider, JP4 pin3 and 4 shorted		3.51		V
Output Characteristics					
Output voltage, V_{OUT}			1.2		V
Output load current, I_{OUT}		0		35	A
Output voltage regulation	Line regulation: V_{IN} = 5 V to 16 V		0.1%		
	Load regulation: I_{OUT} = 0 A to 35 A		0.1%		
Output voltage ripple	I_{OUT}=35A		10		mV
Output voltage undershoot	I_{OUT}=17.5A to 35 A step at 1 A/µs		28		mV
Output voltage overshoot	I_{OUT}=17.5A to 35 A setp at 1 A/µs		33		mV
VOUT output overcurrent fault threshold	Programmed by MSEL2		52		A
Systems Characteristics					
Switching frequency	Programmed by MSEL1		650		kHz
Full load efficiency, V_{OUT}	I_{OUT}=35A		84.7		%
Loop bandwidth	I_{OUT}=35A		63.5		kHz
Phase margin			68.6		°
Operating case temperature	I_{OUT} = 35 A, airflow = 200 LFM, 10-minute soak		96		°C
PMBus Interface and Pin-Strapping					
PMBus address	Programmed by NVM and ADRSEL		36		Decimal
Voltage reference	Default setting of VOUT_COMMAND programmed by VSEL		1.2		V
Soft-start time(TON_RISE)	Default setting iof TON_RISE programmed by MSEL2		3		ms

(1) The efficiency is measured using the test points listed in Table 4-1 to minimize the effect of DC drops caused by onboard copper traces.

1.4 Device Information

TPSM8S6C24 is 2.95-V to 16-V, single 35 A synchronous buck power module, up to 4x stackable, with PMBus and extended write protection. The TPSM8S6C24SEVM-1PH uses the TPSM8S6C24 device in a buck design. The device is designed from a nominal 12-V bus to produce a regulated 1.2-V output at up to 35-A of load current. The TPSM8S6C24SEVM-1PH provides a number of test points to evaluate the performance of the device.

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2 Hardware

2.1 Test Equipment

2.1.1 Voltage Source

The input voltage source V_{IN} must be a 0-V to 20-V variable DC source capable of supplying a minimum of 10 A_{DC} to support 35-A load with 5-V input. Connect input VIN and GND to T2 (PVIN) and T3 (PGND). If the output voltage of the EVM is increased, then the power supply needs to supply more current.

2.1.2 Oscilloscope

An oscilloscope is recommended for measuring output noise and ripple. Output ripple must be measured using a tip-and-barrel method. Figure 2-1 illustrates the tip and barrel measurement for output ripple waveform on TP7 and TP8.

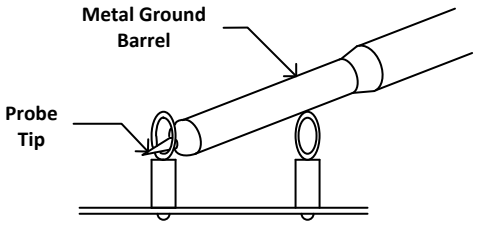

Figure 2-1. Tip and Barrel Measurement

2.1.3 Multimeters

TI recommends using two separate multimeters: one meter to measure V_{IN} and the other to measure V_{OUT}.

2.1.4 Output Load

A variable electronic load is recommended for the test setup. To test the full load current this EVM supports, the load must be capable of sinking at least 35 A.

2.1.5 Fan

During prolonged operation at high loads, to provide forced air cooling with a small fan aimed at the EVM is necessary. Maintain the surface temperature of the devices on the EVM below their rated temperature.

2.1.6 USB-to-GPIO Interface Adapter

A communications adapter is required between the EVM and the host computer. This EVM is designed to use TI's USB-to-GPIO adapter. Purchase this adapter at http://www.ti.com/tool/usb-to-gpio.

2.1.7 Recommended Wire Gauge

- Input connection to the VIN and PGND terminal blocks (T2 and T3) — The recommended wire size is AWG #12 with the total length of wire less than two feet (1-foot input, 1-foot return).
- Output load connection to the VOUT, and PGND terminal blocks (T4 and T5) — The minimum recommended wire size is AWG #10 with the total length of wire less than two feet (1-foot output, 1-foot return). A thicker wire gauge can be required to minimize the voltage drop in the wires.

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2.1.8 List of Test Points, Jumpers, and Connectors

Table 2-1 lists the test point functions.

Table 2-1. Test Point Functions

Test Point	Name	Description
TP1	EXT_AVIN	External AVIN test point
TP2, TP8, TP19	PGND	PGND test point
TP3	CNTL	CNTL signal on J2 header
TP4	DATA	DATA signal on J2 header
TP5	CLK	CLK signal on J2 header
TP6	SMBALRT	SMBALERT signal on J2 header
TP7	VOUT	VOUT + test point
TP9	PG	PGOOD signal of VOUT
TP10	VSHARE	VSHARE test point. Sensitive signal
TP11	SYNC	External clock input (SYNC IN) or output to synchronize other devices(SYNC OUT)
TP12	PVIN	VIN + test point
TP13	VDD5	VDD5 test point or external VDD5 input
TP14	BCX_CLK	Clock for back-channel communications between stacked devices
TP15	BCX_DAT	Data for back-channel communications between stacked devices
TP16	CHA	Channel A for VOUT small signal loop gain measurements (B/A setup)
TP17	CHB	Channel B for VOUT small signal loop gain measurements (B/A setup)
TP18	RSNS –	VOUT remote sense – voltage point
TP20	PGND_EFF	PGND reference for PVIN efficiency measurement
TP21	PGND_EFF	PGND reference for VOUT efficiency measurement
TP22	RSNS +	VOUT remote sense + voltage point
TP23	PVIN_EFF	PVIN measurement point for efficiency, reference to TP20
TP24	VOUT_EFF	VOUT measurement point for efficiency, reference to TP21

Table 2-2 lists the EVM jumpers.

Table 2-2. Jumpers

Jumper	Name	Description
JP1	PMBus to AVIN	Short to connect USB-to-GPIO 3.3V to AVIN, Remove Jumper if not use external AVin
JP2	USB to PVIN	Short to connect PVIN to micro USB connector, Remove Jumper if not use Micro UBS connection
JP3	AVIN	AVIN input source selection, Default: Jumper short on pin2 and pin3
JP4	EN	EN pin selections, Default: Jumper short on pin3 and pin4

Table 2-3 lists the options for the EN pin selections on JP4.

Table 2-3. JP4 Selections

Shunt Position	Selection
CNTL_INPUT	PMBus adapter control signal
UVLO	Resistor divider to PVIN
GND	EN short to ground

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Table 2-4 lists the options for the AVIN pin selections on JP3.

Table 2-4. JP3 Selections

Shunt Position	Selection
EXT	AVIN pin connected to external AVIN input through 10-Ω resistor. Use this selection when testing with a split rail input.
PVIN	AVIN pin connected to PVIN through 10-Ω resistor

Table 2-5 lists the EVM connector functions.

Table 2-5. Connector Functions

Connector	Name	Description
J1	Micro-USB Power	Micro USB connector to power EVM from a 5-V USB source
J2	PMBus	PMBus socket for TI FUSION adapter
T2	PVIN	VIN+ connector
T3	PGND	VIN– connector
T1	AVIN	External AVIN connector
T4	VOUT	VOUT+ connector
T5	PGND	VOUT– connector

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2.2 Test Setup

2.2.1 Test and Configuration Software

To change any of the default configuration parameters on the EVM through PMBus, obtain the *TI Fusion Digital Power Designer* software.

2.2.1.1 Description

The *TI Fusion Digital Power Designer* is the graphical user interface (GUI) used to configure and monitor the Texas Instruments TPSM8S6C24 power converter installed on this evaluation module. The application uses the PMBus protocol to communicate with the controller over serial bus by way of a TI USB adapter described in Section 2.1.6.

2.2.1.2 Features

Some of the tasks the user can perform with the GUI include:

- Turn on or off the power supply output, either through the hardware control line or the PMBus operation command.
- Monitor real-time data. Items such as input voltage, output voltage, output current, die temperature, and warnings and faults are continuously monitored and displayed by the GUI.
- Configure common operating characteristics such as the following:
  - V_{OUT} trim and margin
  - UVLO
  - Soft-start time
  - Warning and fault thresholds
  - Fault response
  - On and off modes

This software is available for download at http://www.ti.com/tool/fusion_digital_power_designer.

2.2.2 Evaluating Split Rail Input

The default configuration of the EVM is for single rail input. Split rail input enables operation with 3.3-V PVIN. For split rail operation, configure the jumpers on the EVM as follows:

1. Move the jumper JP3 to EXT_AVIN position (Jumper on pin1 and pin2) to disconnect the AVIN pin from the PVIN pins.
2. Apply the EXT_AVIN input to T1. 4-V or greater AVIN is required to bring the VDD5 voltage high enough to enable conversion.
3. If operation with 3.3-V PVIN is needed and the CNTL jumpers (JP4) is in UVLO position, the resistor divider at the EN needs to be changed. Alternately, move the CNTL jumpers to CNTL_INPUT position (Jumper on pin1 and pin2) and use the control signal to enable conversion or use the ON_OFF_CONFIG and OPERATION commands to enable conversion.

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3 Software

3.1 Using the Fusion GUI

3.1.1 Opening the Fusion GUI

The Fusion GUI includes *IC_DEVICE_ID* in scanning mode to find TPSM8S6C24. The EVM needs power to be recognized by the Fusion GUI. See Section 3.2 for the recommended procedure.

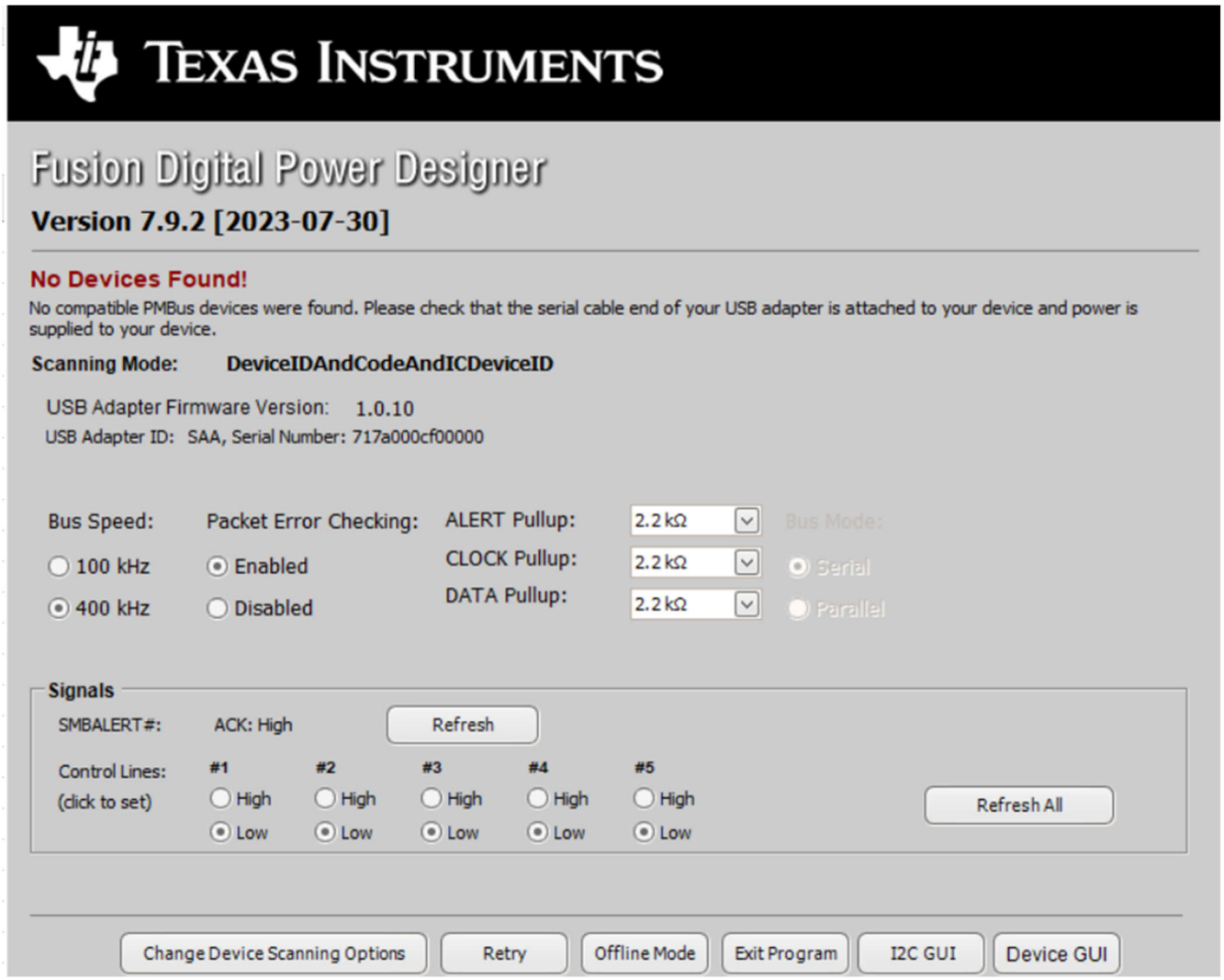

Figure 3-1. Select Device Scanning Mode

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3.1.2 General Settings

Figure 3-2 shows the *General Settings* that can be used to configure the following:

- V_{OUT} settings, power-good limits, and margin voltages
- OC fault, OC warn, and fault response
- OT fault, OT warn (die temperature), and fault response
- V_{IN} on and off UVLO
- On and off configurations
- Soft start (output rise time), other turn-on timing and turn-off timing
- Switching frequency
- Compensation

After clicking *Write to Hardware* to make changes to one or more configurable parameters, the changes can be committed to nonvolatile memory by clicking *Store Config to NVM*. This action prompts a pop-up, and if confirmed, the changes are committed to nonvolatile memory to store all the modifications in nonvolatile memory.

Both the loop controller device and the loop follower device are tied to same bus interface. In a two-phase stacking system, the loop controller device receives and responds to all PMBus communication and loop follower devices do not need to be connected to the PMBus. If the controller receives commands that require updates to the PMBus registers of the follower, the controller relays these commands to the followers. All commands on this tab are for PHASE = 0xFF.

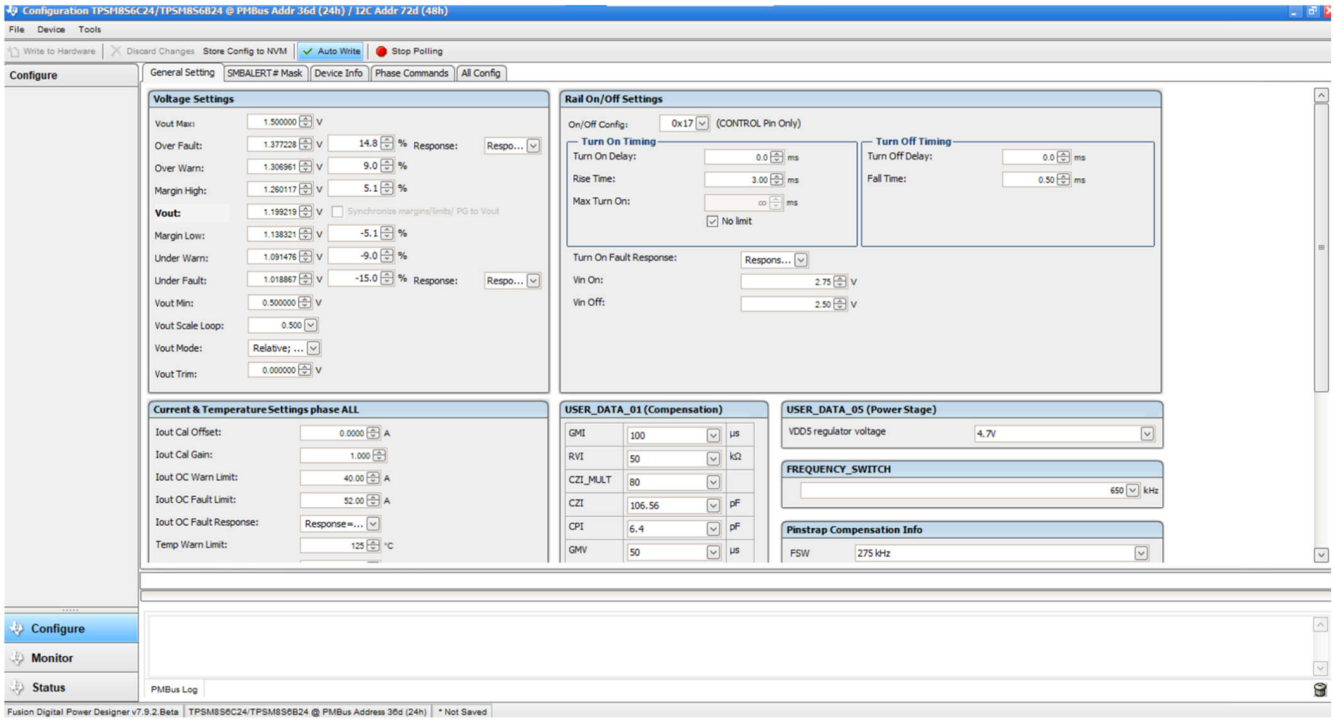

Figure 3-2. General Settings

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3.1.3 Changing ON_OFF_CONFIG

Changing the *On/Off Config* prompts a pop-up window with details of the options shown in Figure 3-3. This pop-up provides multiple options on what turns on and off power conversion. By default, the TPSM8S6C24 is configured to *CONTROL Pin Only*, which is the EN/UVLO pin.

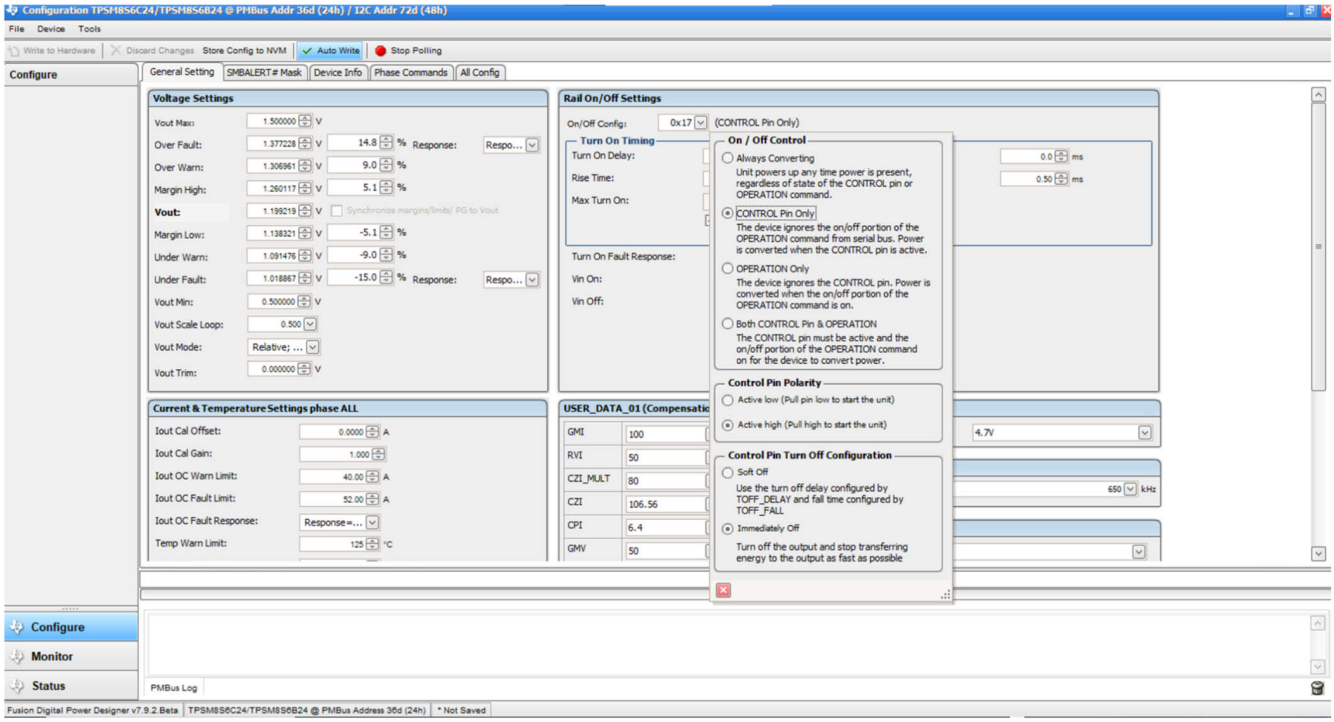

Figure 3-3. Configure – ON_OFF_CONFIG

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3.1.4 Pop-Up for Some Commands While Conversion is Enabled

Some commands cause a pop-up like the one shown in Figure 3-4 when trying to change them while conversion is enabled. The settings in the GUI that cause this pop-up include *FREQUENCY_SWITCH*, *USER_DATA_01 (Compensation)*, *Vout Mode*, and *Vout Scale Loop*. To change these settings to a new value, click on *Stop Power Conversion*, then *Close and continue*. The GUI automatically disables conversion, writes the new value, and enables conversion again.

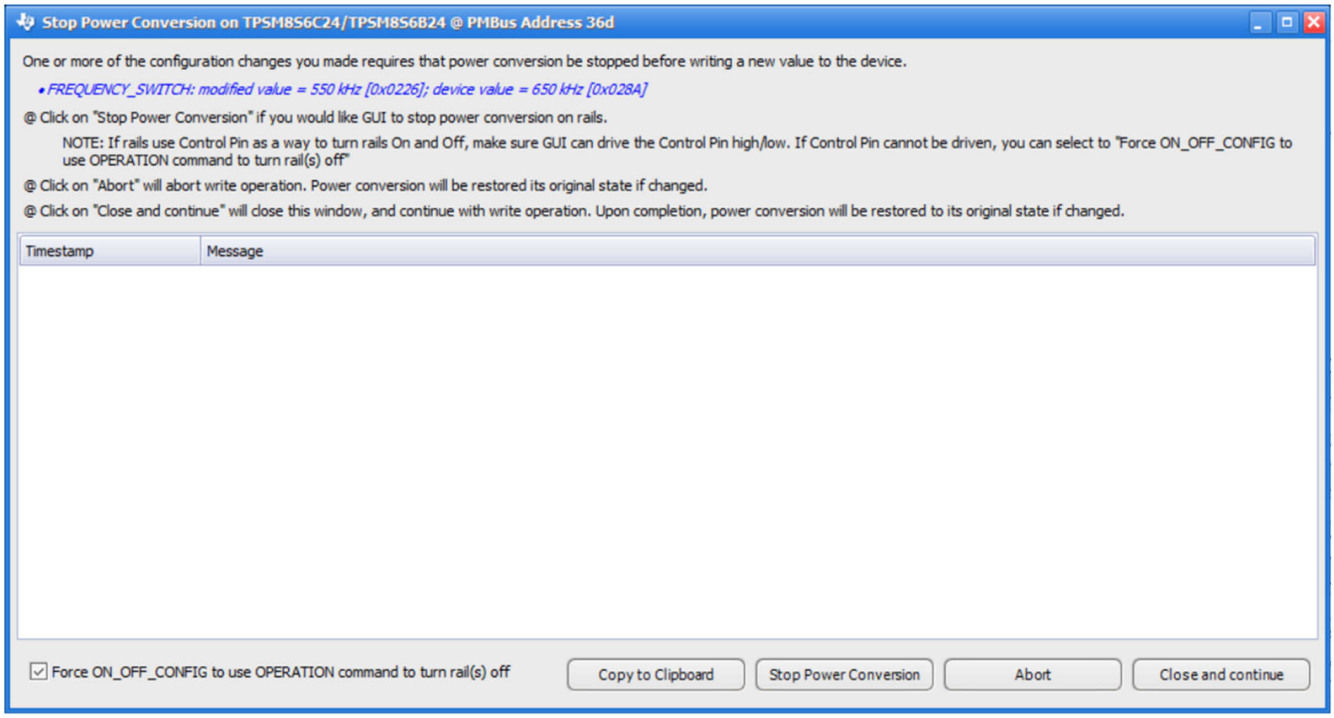

Figure 3-4. Pop-Up When Trying to Change FREQUENCY_SWITCH With Conversion Enabled

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3.1.5 SMBALERT# Mask

The sources of SMBALERT that can be masked are found and configured on the *SMBALERT# Mask* tab (see Figure 3-5).

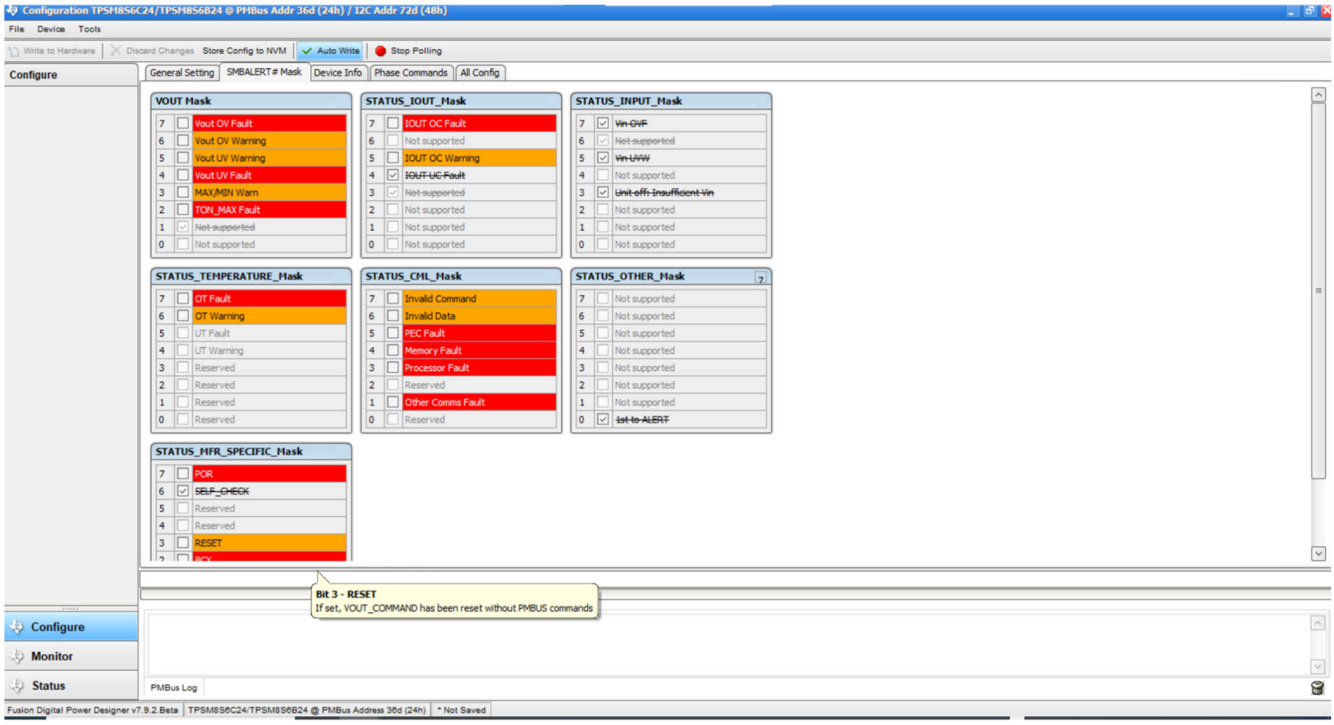

Figure 3-5. Configure – SMBALERT# Mask

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3.1.6 Device Info

The following are found on the *Device Info* tab (see Figure 3-6):

- Device information
- Write protection options
- Configuration of *Vout Scale Loop*, *Vout Transition Rate*, and *Iout Cal Offset*

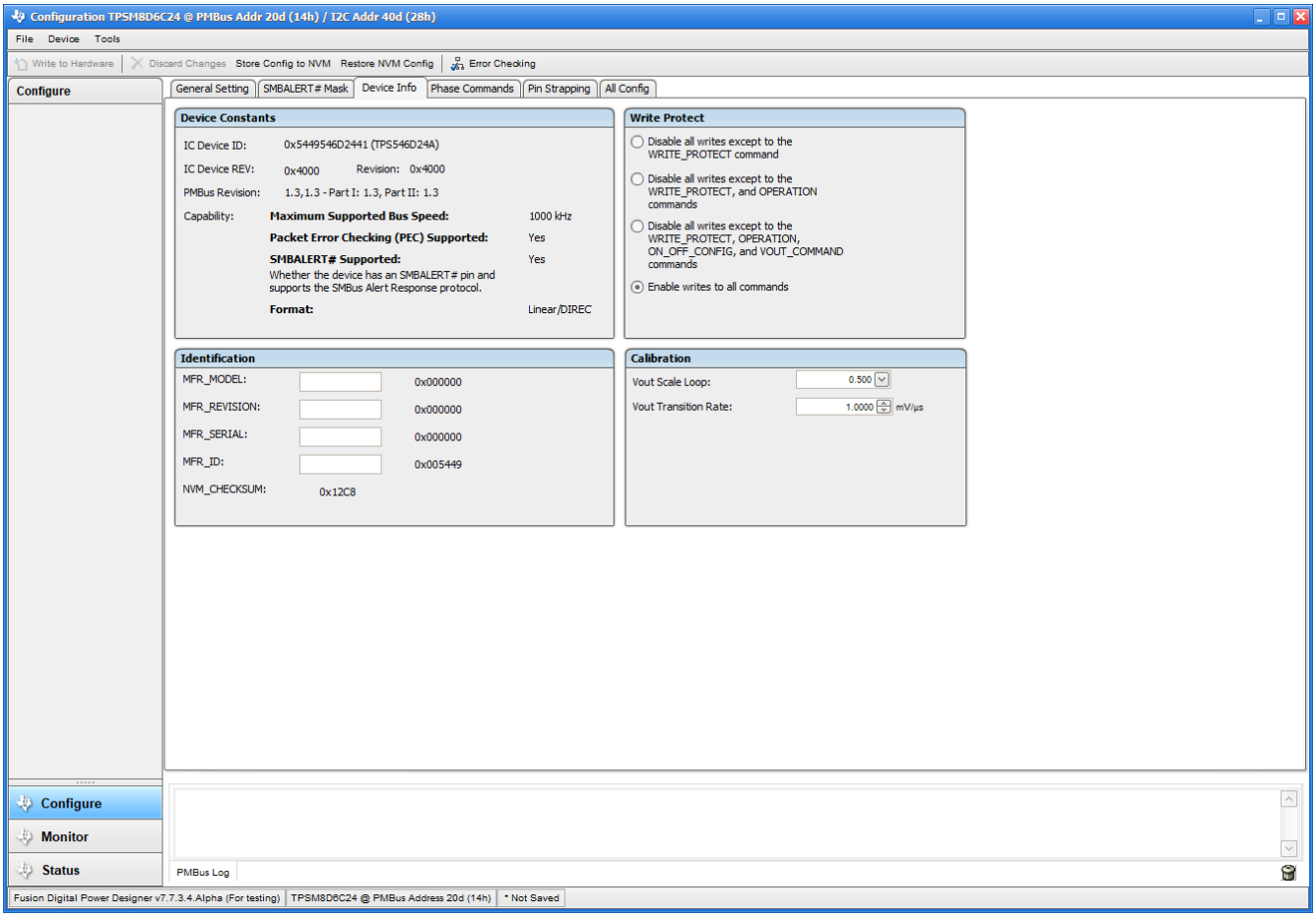

Figure 3-6. Configure – Device Info

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3.1.7 Phase Commands

Use the *Phase Command* tab (Figure 3-7) to calibrate the IOUT and temperature of each phase.

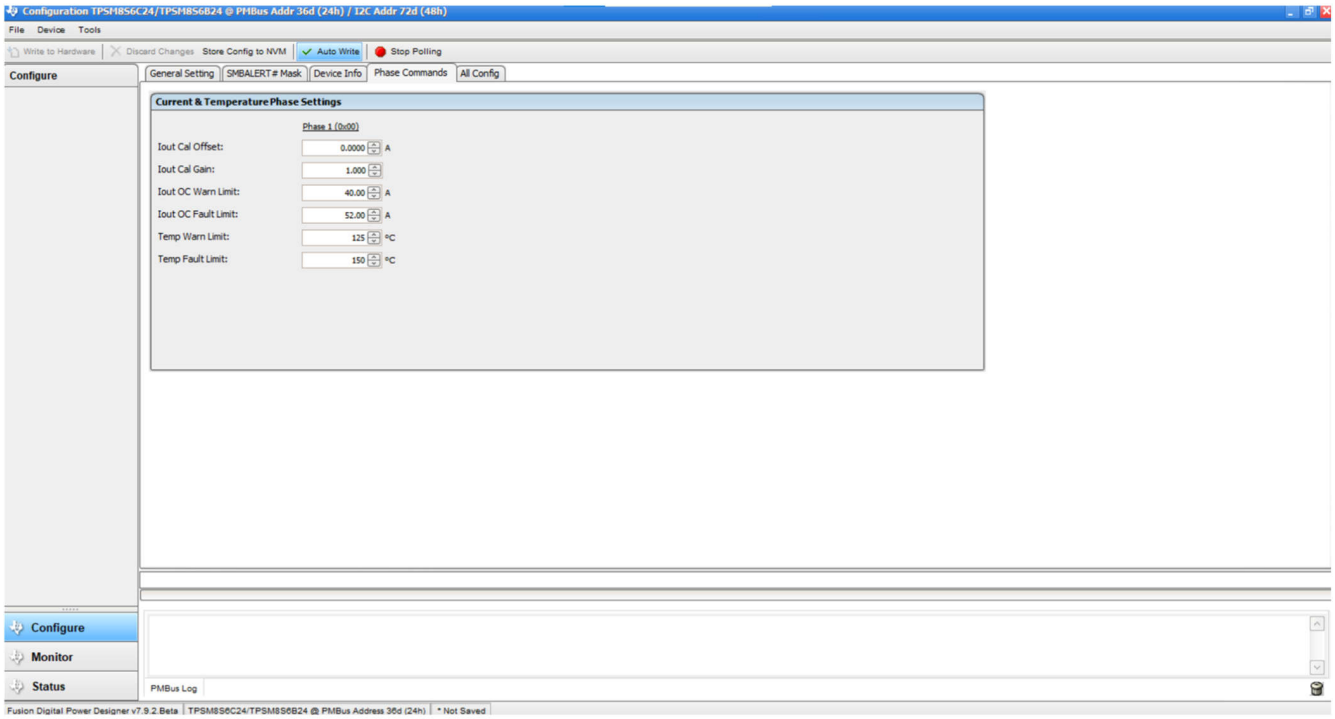

Figure 3-7. Phase Commands

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3.1.8 All Config

Use the *All Config* tab (Figure 3-8) to configure all of the configurable parameters, which also shows other details like Hex encoding.

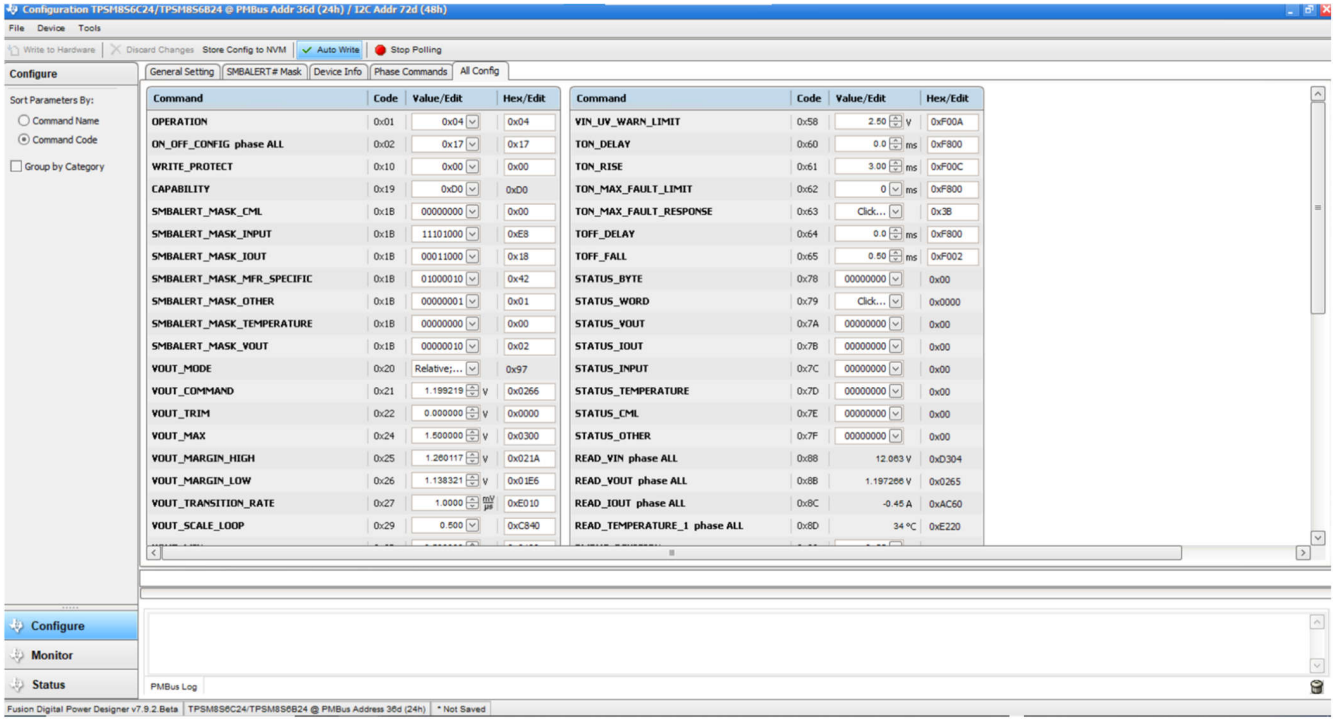

Figure 3-8. Configure – All Config

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3.1.9 Monitor

When the *Monitor* screen (Figure 3-9) is selected, the screen changes to display real-time data of the parameters that are measured by the device. This screen provides access to:

- Graphs of *Vout*, *Iout*, *Vin*, *Pout*, and *Temperature*
- *Start and Stop Polling*, which turns ON or OFF the real-time display of data
- Quick access to *On/Off Config*
- Control pin activation and *OPERATION* command
- Margin control
- Clear Fault: Selecting ***Clear Faults*** clears any prior fault flags.

With two devices stacked together, the *Iout* reading is the total load supported by both devices. *Iout* also shows the current in each phase.

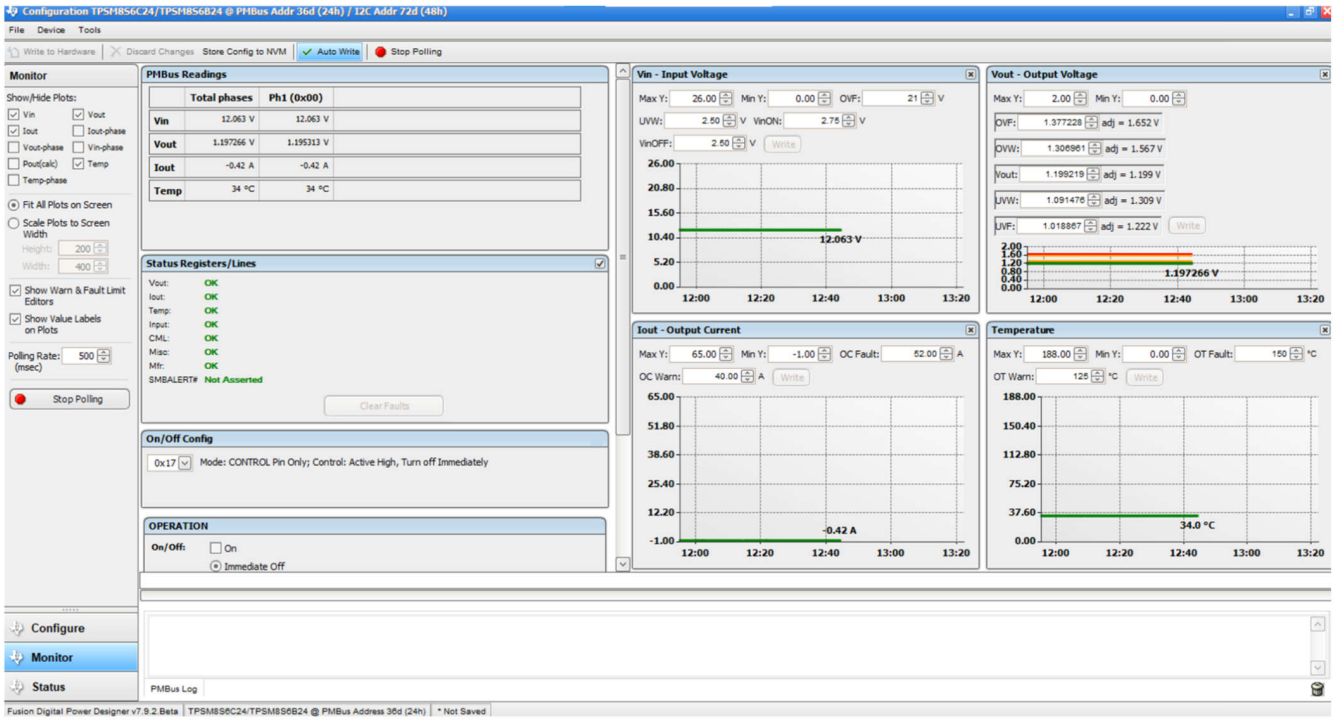

Figure 3-9. Monitor Screen

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3.1.10 Status

Selecting *Status* screen from lower left corner (Figure 3-10) shows the status of the device.

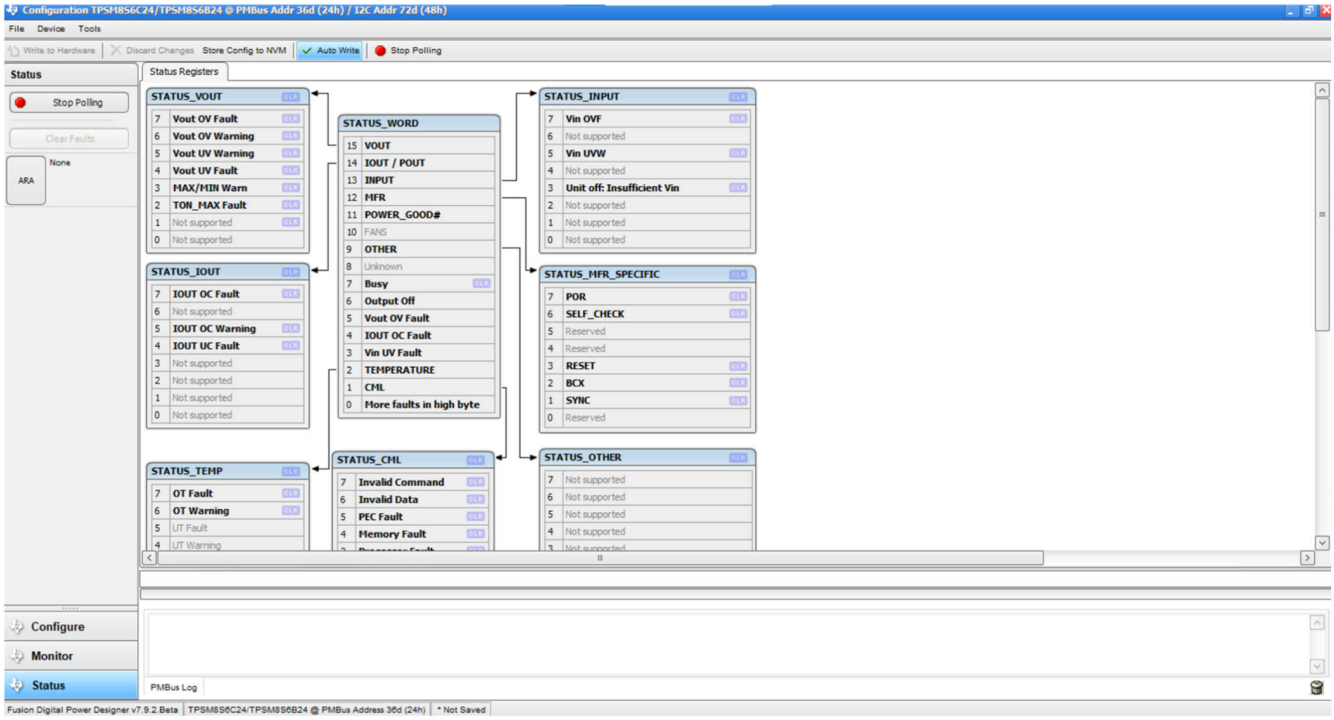

Figure 3-10. Status Screen

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3.2 EVM Configuration Using the Fusion GUI

The TPSM8S6C24 leaves the factory settings pre-configured. The factory default settings for the parameters can be found in the data sheet. If configuring the EVM to settings other than the factory defaults, then use the software described in Section 2.2.1. Make sure the input voltage is applied to the EVM prior to launching the software so that the TPSM8S6C24 can respond to the GUI and the GUI can recognize the device. The default configuration for the EVM to stop converting is set by the EN resistor divider to a nominal input voltage of 4.22 V. Therefore, if the user wants to avoid any converter activity during configuration, then apply an input voltage less than 4.22 V. TI recommends an input voltage of 3.3 V.

3.2.1 Configuration Procedure

1. Adjust the input supply to provide 3.3 V_{DC}. Current is limited to 1 A.
2. Apply the input voltage to the EVM. See Section 2.1 for connections and test setup.
3. Launch the Fusion GUI software. See the screen shots in Section 3.1 for more information.
4. Configure the EVM operating parameters as desired.

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4 Implementation Results

4.1 Performance Data and Typical Characteristic Curves

Figure 4-1 through Figure 4-10 present typical performance curves for the TPSM8S6C24SEVM-1PH. The input voltage is 12 V and the oscilloscope measurements use 20-MHz bandwidth limiting, unless otherwise noted.

4.1.1 Efficiency

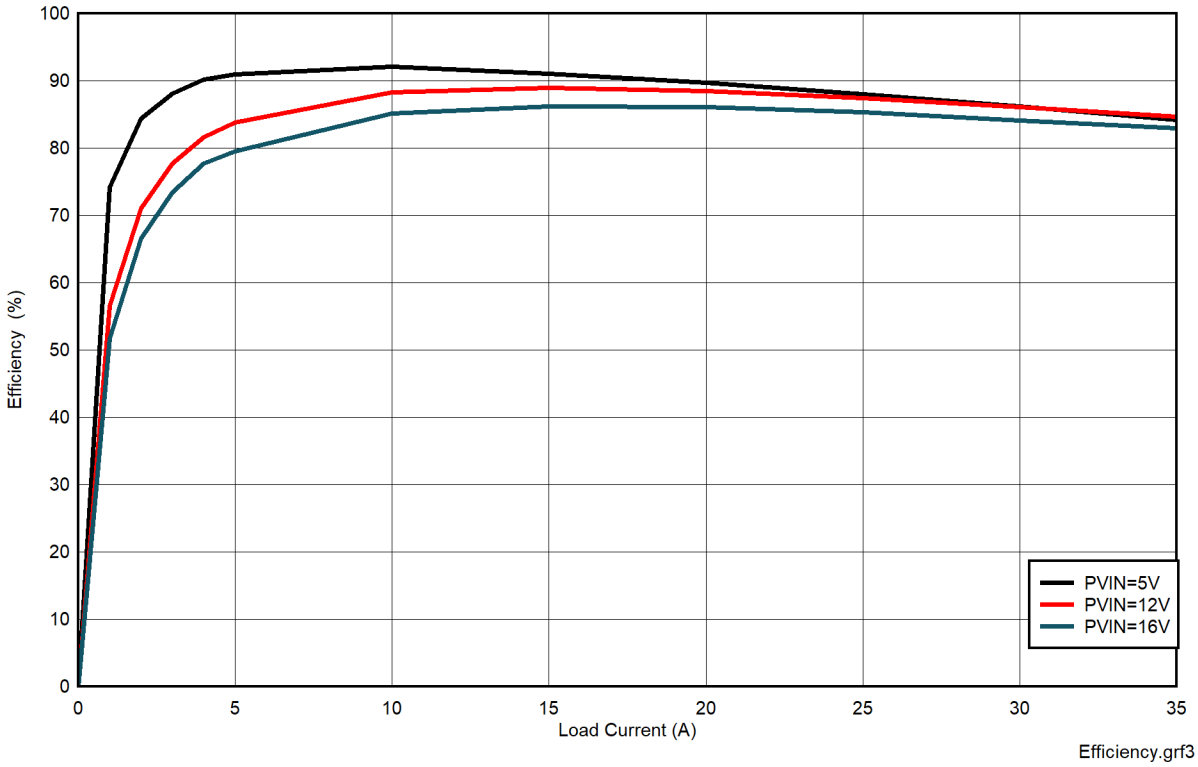

Figure 4-1. VOUT Efficiency

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4.1.2 Load Regulation

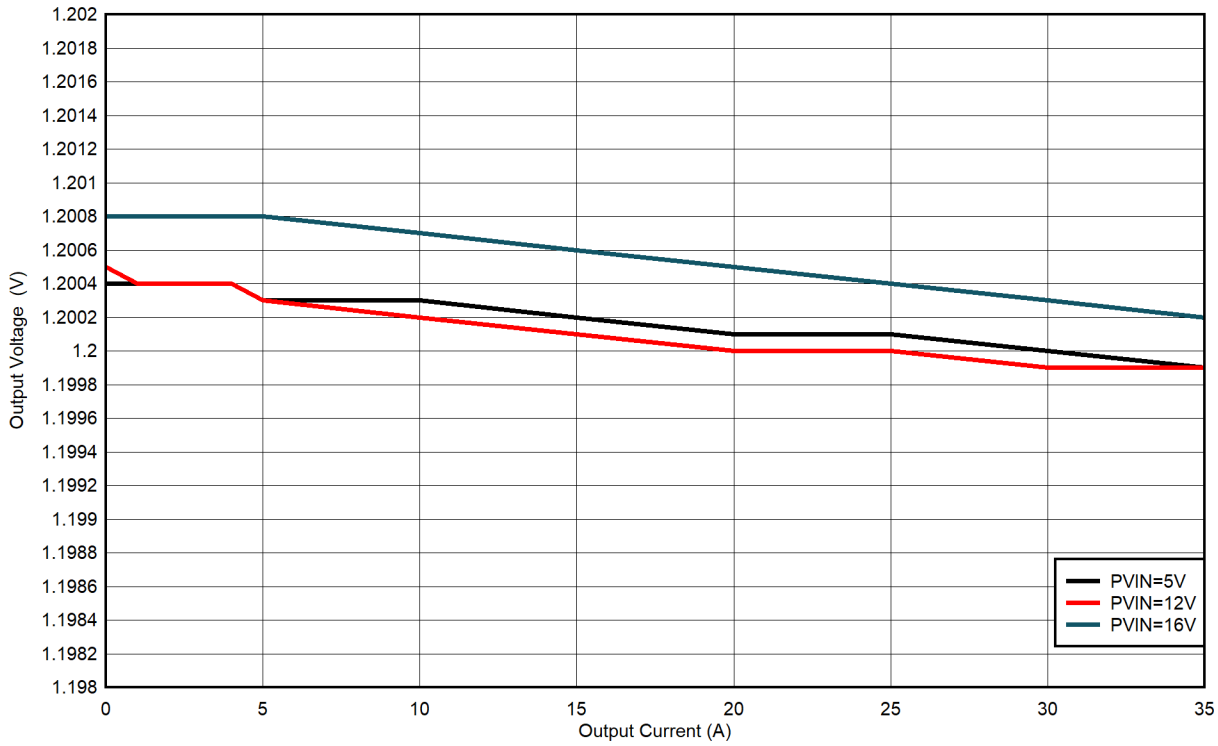

Figure 4-2. VOUT Load Regulation

4.1.3 Line Regulation

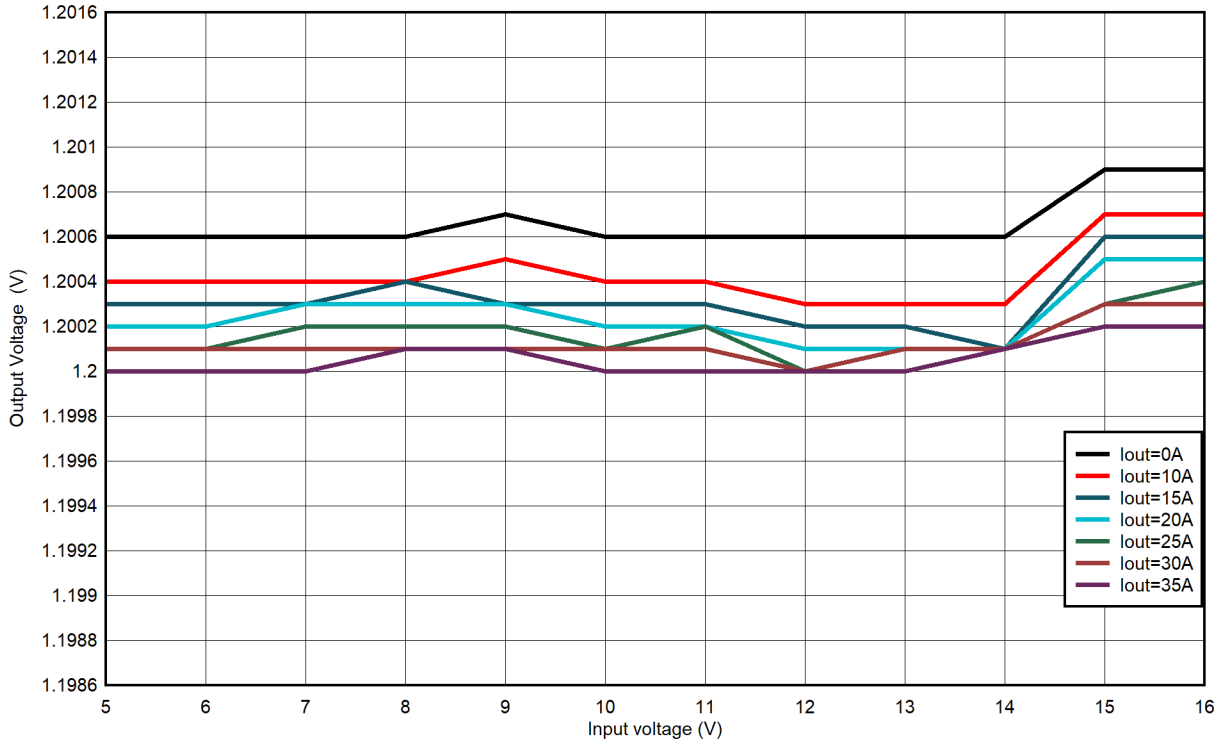

Figure 4-3. VOUT Line Regulation

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4.1.4 Transient Response

Figure 4-4 and show the transient response waveform with a 17.5-A to 35-A transient at 1 A/µs.

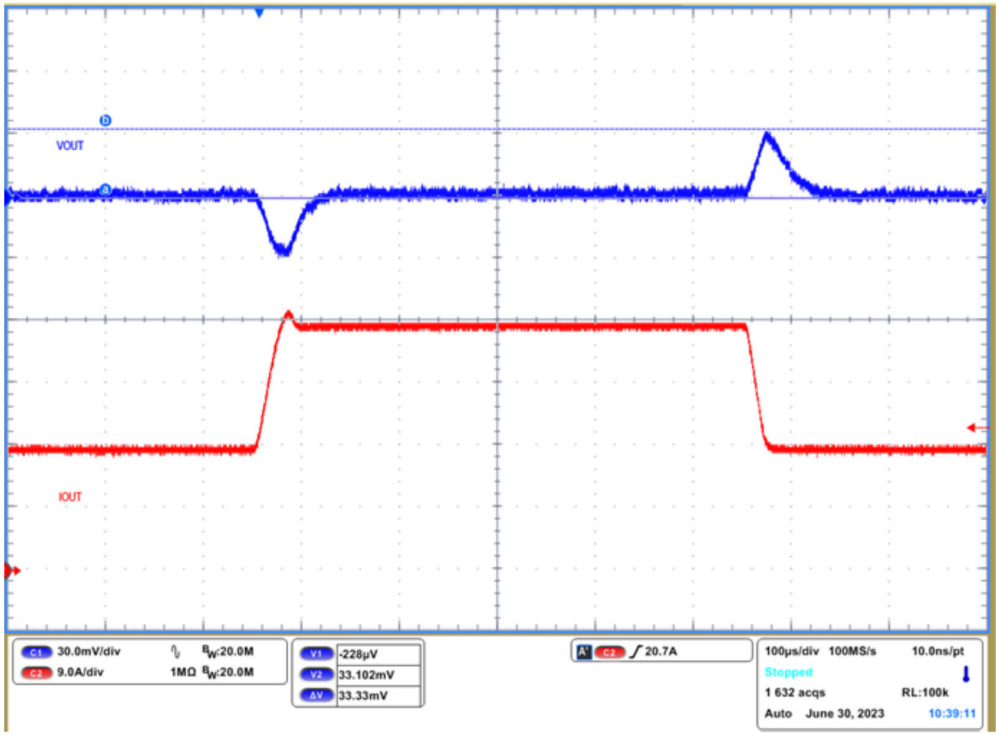

Figure 4-4. VOUT Transient Response

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4.1.5 Control Loop Bode Plot

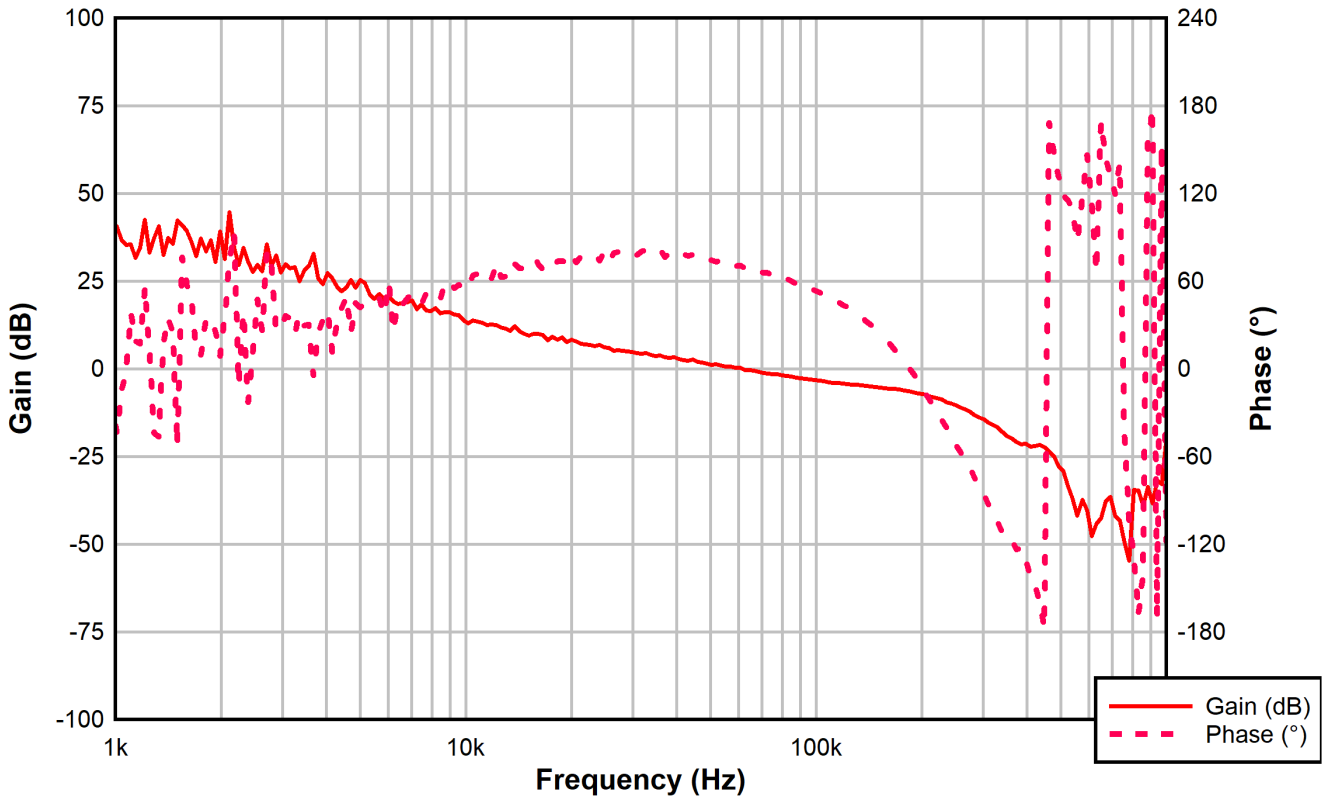

Figure 4-5. VOUT Bode Plot, 12Vin, 1.2-V, 35-A Load

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4.1.6 Output Ripple

Figure 4-6 and show the output ripple waveforms at 0-A and 25-A load.

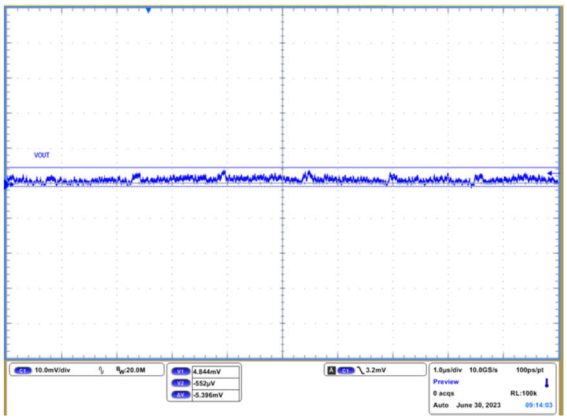

Figure 4-6. VOUT Output Ripple, No Load

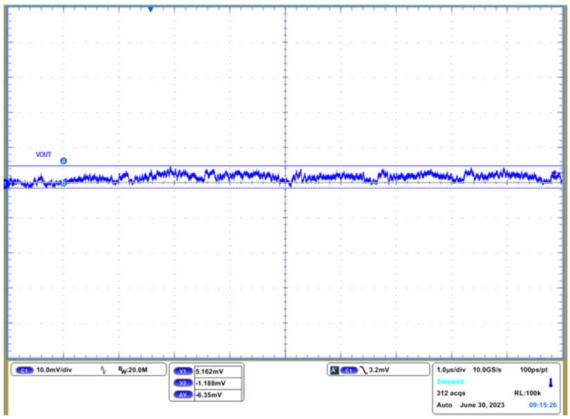

Figure 4-7. VOUT Output Ripple, 35-A Load

4.1.7 Control On

Figure 4-8 and illustrate the start-up from control on waveforms at 35-A outputs.

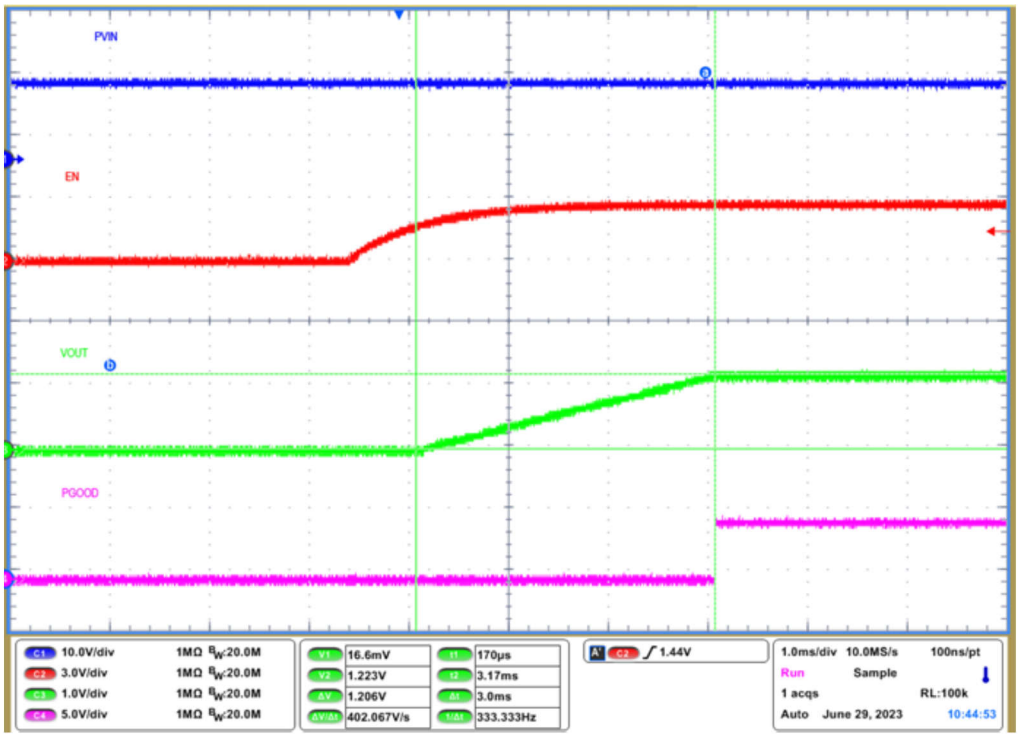

Figure 4-8. VOUT Start-Up From Enable, 35-A Load

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4.1.8 Control Off

Figure 4-9 and illustrate the control off waveforms at 35-A outputs.

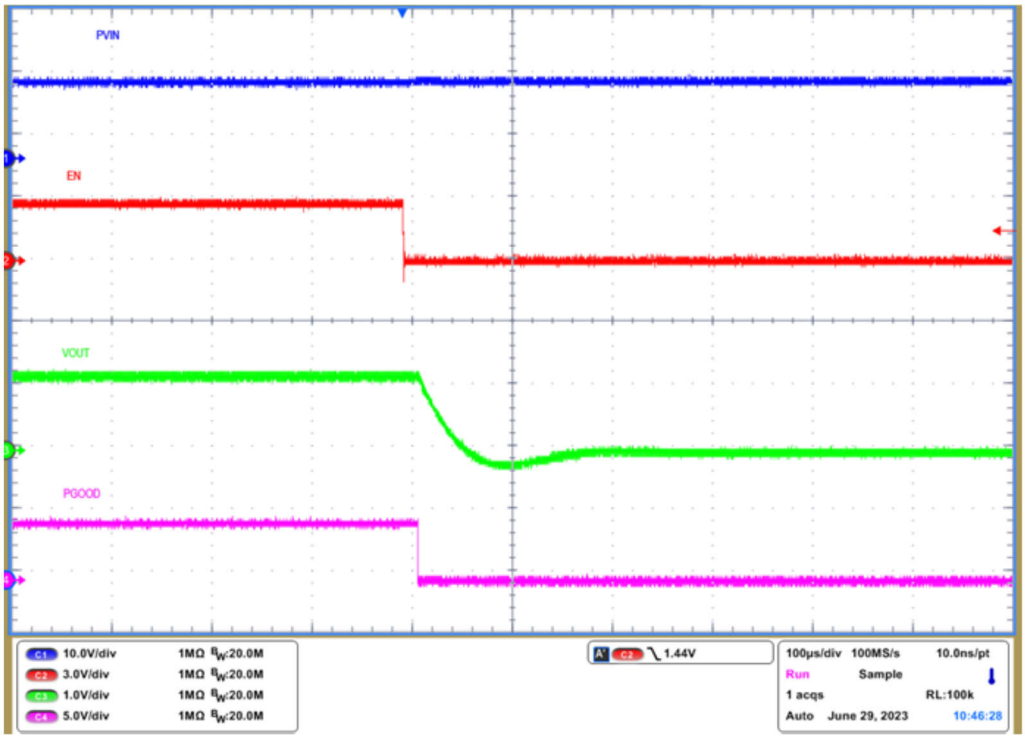
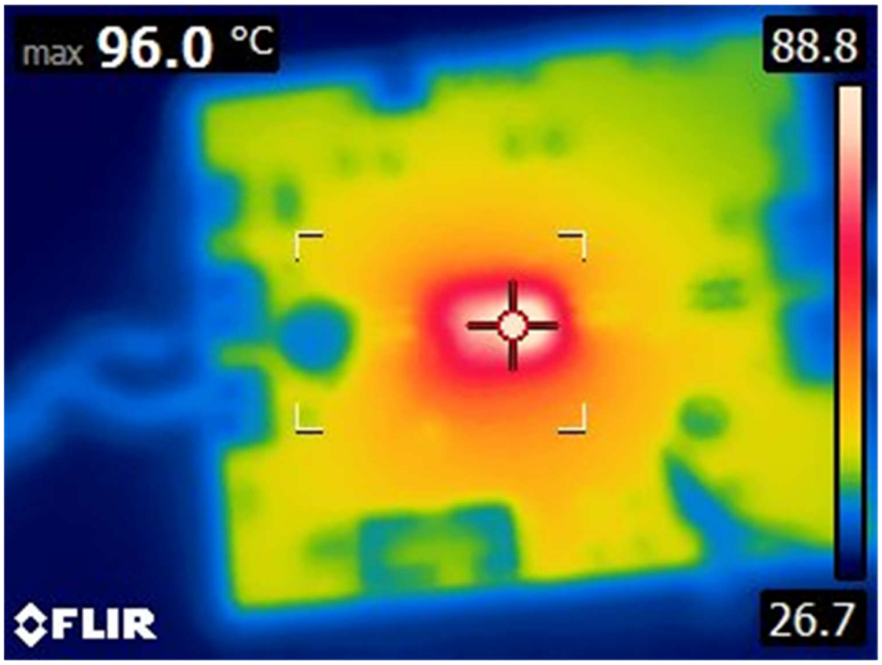


Figure 4-9. VOUT Shutdown From Enable, 35-A Load

4.1.9 Thermal Image

Figure 4-10 shows the TPSM8S6C24SEVM-1PH thermal image.



V_{IN} = 12 V, V_{OUT}=1.2 V, I_{OUT} = 35 A, Airflow = 200 LFM, 10-min soak

Figure 4-10. Thermal Image

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4.2 Test Procedure

4.2.1 Line and Load Regulation and Efficiency Measurement Procedure

1. Set up the EVM as described in Section 2.1 and Section 4.2.2.
2. Set the electronic load to draw 0 A_{DC}.
3. Increase V_{IN} from 0 V to 12 V using a voltage meter to measure input voltage.
4. Use the other voltage meter to measure output voltage, V_{OUT}.
5. Vary the load from 0 to 35 A_{DC}. V_{OUT} must remain in regulation as defined in Figure 4-2.
6. Vary V_{IN} from 5 V to 16 V. V_{OUT} must remain in regulation as defined in Figure 4-3.
7. Decrease the load to 0 A.
8. Decrease V_{IN} to 0 V.

4.2.2 Efficiency Measurement Test Points

To evaluate the efficiency of the power train (device and inductor), to measure the voltages at the correct location is important. Otherwise, the measurements include losses that are not related to the power train itself. Losses incurred by the voltage drop in the copper traces and in the input and output connectors are not related to the efficiency of the power train, which must not be included in efficiency measurements.

Input current can be measured at any point in the input wires. Output current can be measured anywhere in the output wires of the output being measured.

Table 4-1 shows the measurement points for input voltage and output voltage. VIN and VOUT are measured to calculate the efficiency. Using these measurement points results in efficiency measurements that excluded losses due to the wires and connectors.

Table 4-1. Test Points for Efficiency Measurements

Test Point	Node Name	Description	Comment
VOUT			
TP23	PVIN_EFF	Input voltage measurement point for VIN+	The pair of test points are connected to the PVIN/PGND pins of U1. The voltage drop between input terminal to the device pins is not included for efficiency measurement.
TP20	PGND_EFF	Input voltage measurement point for VIN– (GND)	
TP24	VOUT_EFF	Output voltage measurement point for VOUT+	The pair of test points are connected near the output terminals. The voltage drop from the output point of the inductor to the output terminals is not included for efficiency measurement.
TP21	PGND_EFF	Output voltage measurement point for VOUT– (GND)	

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4.2.3 Control Loop Gain and Phase Measurement Procedure

The TPSM8S6C24SEVM-1PH includes a 49.9-Ω series resistor in the feedback loop for V_{OUT}. The resistor is accessible at the test points TP16, TP17 for loop response analysis. Use these test points during loop response measurements as the perturbation injecting points for the loop. See the description in Table 4-2.

Table 4-2. List of Test Points for Loop Response Measurements

Test Point	Node Name	Description	Comment
VOUT_A			
TP16	CHA	Input to feedback divider of VOUT	The amplitude of the perturbation at this node must be limited to less than 30 mV.
TP17	CHB	Resulting output of VOUT	Bode can be measured by a network analyzer with a CH_B/CH_A configuration.

Measure the loop response with the following procedure:

1. Set up the EVM as described in Section 2.1.
2. For VOUT, connect the isolation transformer of the network analyzer from TP16 to TP17.
3. Connect the input signal measurement probe to TP16. Connect the output signal measurement probe to TP17.
4. Connect the ground leads of both probe channels to TP8.
5. On the network analyzer, measure the Bode as TP17/TP16 (Out/In).

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5 Hardware Design Files

5.1 Schematic

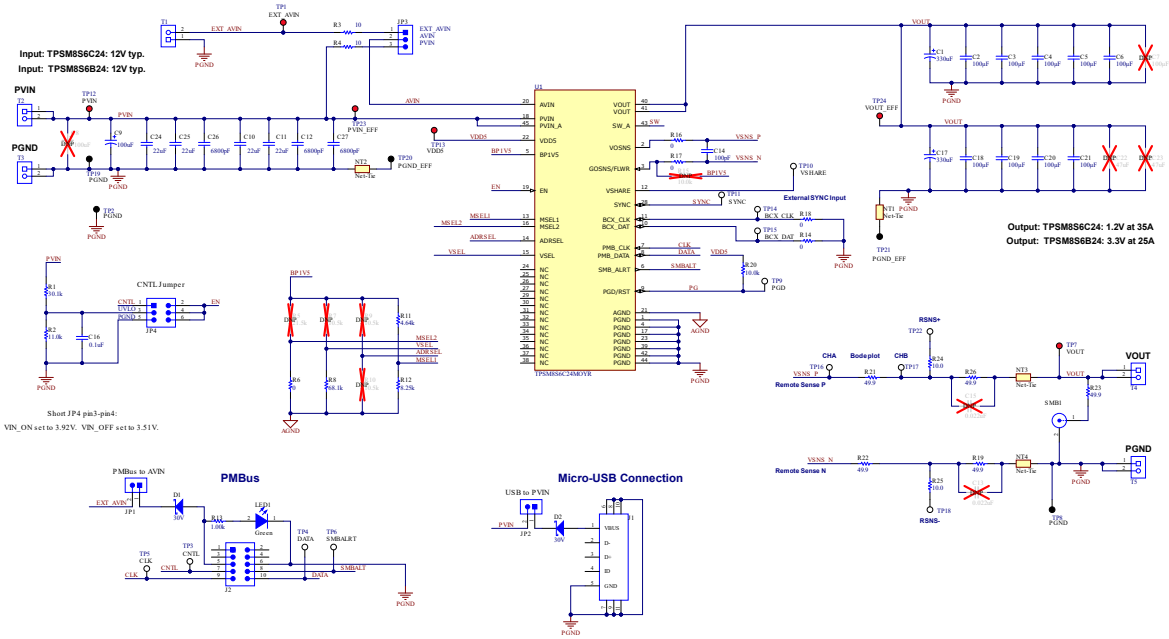

Figure 5-1. TPSM8S6C24SEVM-1PH Schematic

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5.2 EVM Assembly Drawing and PCB Layout

Figure 5-2 through Figure 5-9 show the design of the TPSM8S6C24SEVM-1PH printed circuit board.

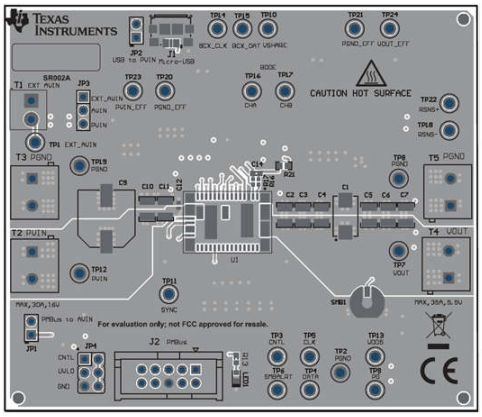

Figure 5-2. TPSM8S6C24SEVM-1PH Top Side Component View (Top View)

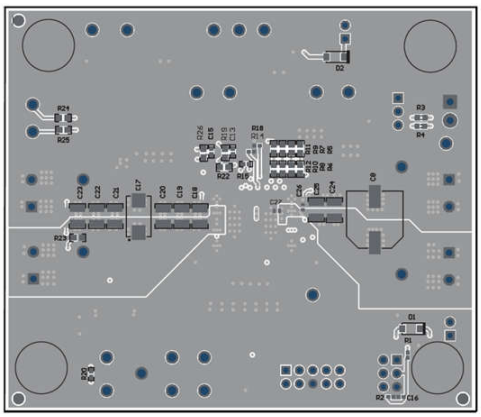

Figure 5-3. TPSM8S6C24SEVM-1PH Bottom Side Component View (Bottom View)

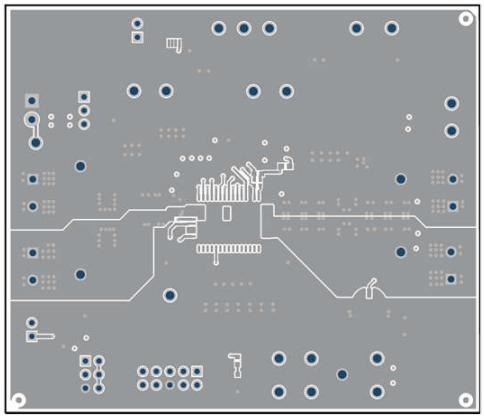

Figure 5-4. TPSM8S6C24SEVM-1PH Top Copper (Top View)

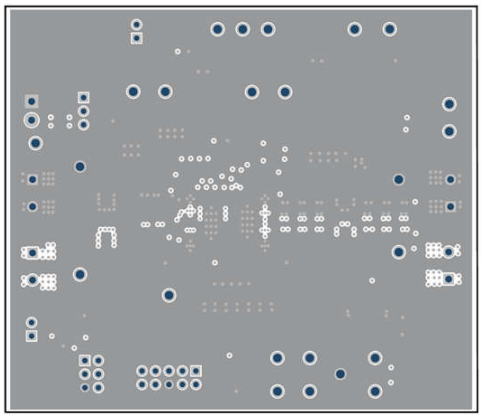

Figure 5-5. TPSM8S6C24SEVM-1PH Internal Layer 1 (Top View)

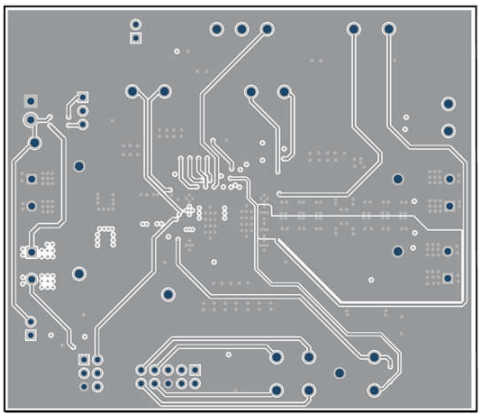

Figure 5-6. TPSM8S6C24SEVM-1PH Internal Layer 2 (Top View)

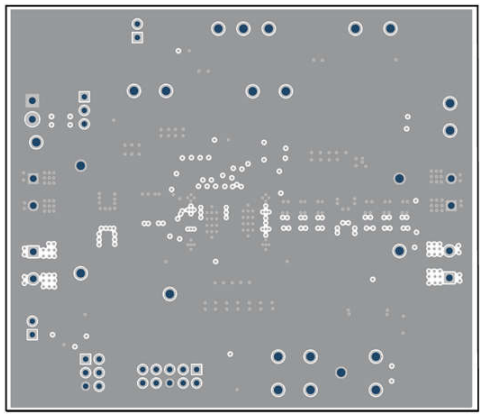

Figure 5-7. TPSM8S6C24SEVM-1PH Internal Layer 3 (Top View)

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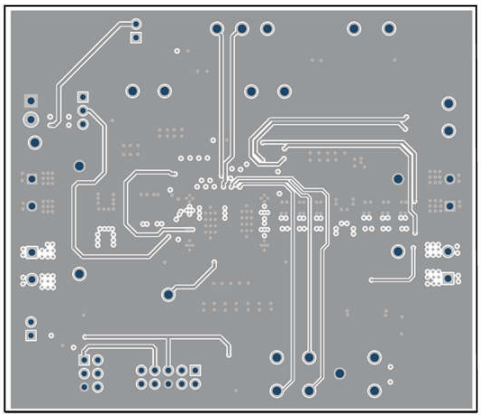

Figure 5-8. TPSM8S6C24SEVM-1PH Internal Layer 4 (Top View)

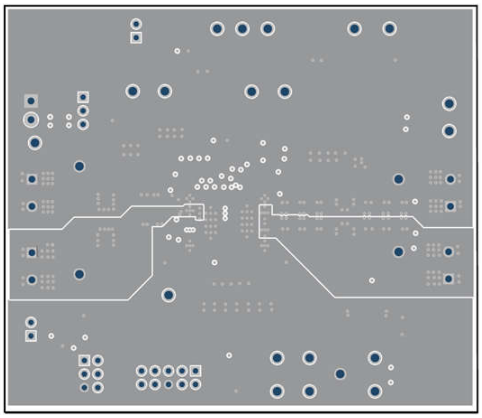

Figure 5-9. TPSM8S6C24SEVM-1PH Internal Layer 5 (Top View)

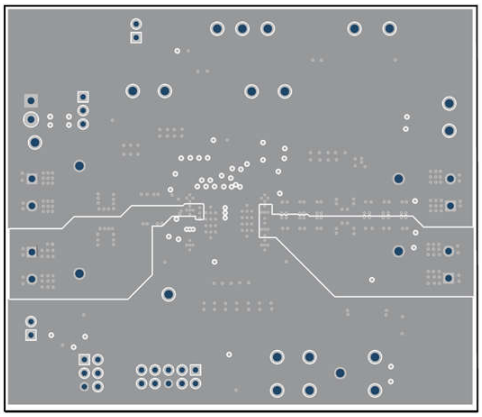

Figure 5-10. TPSM8S6C24SEVM-1PH Internal Layer 6 (Top View)

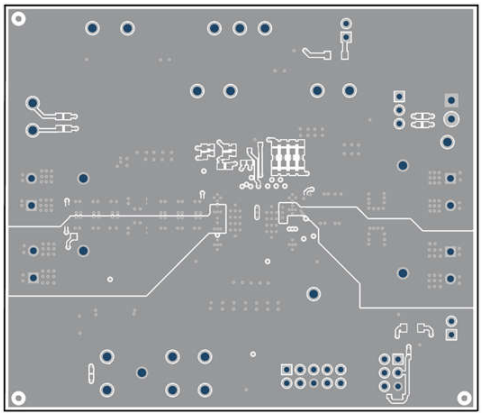

Figure 5-11. TPSM8S6C24SEVM-1PH Internal Bottom Layer (Top View)

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5.3 Bill of Materials

Table 5-1 lists the BOM for the TPSM8S6C24SEVM-1PH.

Table 5-1. TPSM8S6C24SEVM-1PH Bill of Materials

Designator	Quantity	Value	Description	Part Number	Manufacturer	Package Reference
!PCB1	1		Printed Circuit Board	SR002-001	Any	
C1,C17	2	330 µF	CAP, Tantalum Polymer, 330 µF, 10 V, ±20%, 6 mΩ, 7343-43 SMD	T530X337M010ATE006	Kemet	7343-43
C2, C3, C4, C5, C6, C18, C19, C20, C21	9	100 µF	CAP, CERM, 100 µF, 6.3 V, ±20%, X7S, 1210	GRM32EC70J107ME15L	MuRata	1210
C9	1	100 µF	CAP, AL, 100 µF, 35 V, ±20%, 0.15 Ω, SMD	EEE-FC1V101P	Panasonic	SMT Radial G
C10, C11, C24, C25	4	22 µF	CAP, CERM, 22 µF, 25 V, ±10%, X6S, 1210	GRM32EC81E226KE15L	MuRata	1210
C21, C26, C27	3	6800 pF	CAP, CERM, 6800 pF, 50 V, ±10%, X7R, 0402	GCM155R71H682KA55D	Murata	402
C16	1	0.1 µF	CAP, CERM, 0.1 µF, 50 V, ±10%, X7R, AEC-Q200, Grade 1, 0402	CGA2B3X7R1H104K050BB	TDK	0402
C14	1	100 pF	CAP, CERM, 100 pF, 50 V, ±5%, C0G/NP0, 0603	C1608C0G1H101J080AE	TDK	0603
D1, D2	2	30 V	Diode, Schottky, 30 V, 2 A, AEC-Q101, SOD-123FL	MBR230LSFT1G	ON Semiconductor	SOD-123FL
H1, H2, H3, H4	4		Bumpon, Hemisphere, 0.375 × 0.235, Black	SJ61A2	3M	Black Bumpon
J1	1		Connector, Receptacle, Micro-USB Type B, R/A, Bottom Mount SMT	1981568-1	TE Connectivity	MICRO USB CONN, R/A
J2	1		Header (shrouded), 100 mil, 5 × 2, Gold, TH	5103308-1	TE Connectivity	5 × 2 Shrouded header
JP1, JP2	2		Header, 100 mil, 2 × 1, Tin, TH	5-146278-2	TE Connectivity	Header, 2x1, 100mil, TH
JP3	1		Header, 100 mil, 3 × 1, Gold, TH	PBC03SAAN	Sullins Connector Solutions	PBC03SAAN
JP4	1		Header, 100mil, 3 × 2, Gold, TH	PBC03DAAN	Sullins Connector Solutions	Sullins 100mil, 2x3, 230 mil above insulator
LBL1	1		Thermal Transfer Printable Labels, 0.650" W × 0.200" H - 10,000 per roll	THT-14-423-10	Brady	PCB Label 0.650 × 0.200 inch
LED1	1	Green	LED, Green, SMD	150060GS75000	Wurth Elektronik	LED_0603
R3, R4	2	10	RES, 10, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060310R0JNEA	Vishay-Dale	0603
R1	1	30.1 k	RES, 30.1 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040230K1FKED	Vishay-Dale	0402

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Table 5-1. TPSM8S6C24SEVM-1PH Bill of Materials (continued)

Designator	Quantity	Value	Description	Part Number	Manufacturer	Package Reference
R2	1	11 k	RES, 11 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040211K0FKED	Vishay-Dale	0402
R6	1	0	RES, 0, 5%, 0.1 W, AEC-Q200 Greade 0, 0603	CRCW06030000Z0EA	Vishay-Dale	0603
R8	1	68.1k	RES, 68.1k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060368K1FKEA	Vishay-Dale	0603
R11	1	4.64 k	RES, 4.64 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06034K64FKEA	Vishay-Dale	0603
R12	1	8.25k	RES, 8.25k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06038K25FKEA	Vishay-Dale	0603
R13	1	1.00 k	RES, 1.00k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06031K00FKEA	Vishay-Dale	0603
R14, R16, R17, R18	4	0	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04020000Z0ED	Vishay-Dale	0402
R20	1	10.0 k	RES, 10.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040210K0FKED	Vishay-Dale	0402
R21, R22, R23, R26, R19	5	49.9	RES, 49.9, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060349R9FKEA	Vishay-Dale	0603
R24, R25	2	10	RES, 10, 1%, 0.25 W, AEC-Q200 Grade 0, 0603	CRCW060310R0FKEAHP	Vishay-Dale	0603
SH-JP3, SH-JP4,	2	1 × 2	Shunt, 100 mil, Gold plated, Black	SNT-100-BK-G	Samtec	Shunt
SMB1	1		Connector, Receptacle, 50 Ω, TH	SMBR004D00	JAE Electronics	SMB Connector
T1	1		Therminal Block, 3.5 mm, Pitch, 2x1, TH	ED555/2DS	On-Shore Technology	7.0x8.2x6.5mm
T2, T3, T4, T5	4		Terminal Block, 5.08 mm, 2 × 1, Brass, TH	ED120/2DS	On-Shore Technology	2 × 1, 5.08 mm Terminal Block
TP1, TPS7, TP12, TP13, TP23, TP24	6		Test Point, Multipurpose, Red, TH	5010	Keystone Electronics	Red Multipurpose Testpoint
TP2, TP8, TP19, TP20, TP21	5		Test Point, Multipurpose, Black, TH	5011	Keystone Electronics	Black Multipurpose Testpoint
TP3, TP4, TP5, TP6, TP9, TP10, TP11, TP14, TP15, TP16, TP17, TP18, TP22	13		Test Point, Multipurpose, White, TH	5012	Keystone Electronics	White Multipurpose Testpoint
U1	1		Catfish Plus Single phase Power Module	TPSM8S6C24MOYR	Texas Instruments	QFM45
C6, C7	0	100 µF	CAP, CERM, 100 µF, 6.3 V, ±20%, X7S, 1210	GRM32EC70J107ME15L	MuRata	1210
C8	0	100 µF	CAP, AL, 100 µF, 35 V, ±20%, 0.15 Ω, SMD	EEE-FC1V101P	Panasonic	SMT Radial G
C13, C15	0	0.022 µF	CAP, CERM, 0.022 µF, 50 V, ±10%, X7R, 0402	GRM155R71H223KA12D	Murata	0402

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Table 5-1. TPSM8S6C24SEVM-1PH Bill of Materials (continued)

Designator	Quantity	Value	Description	Part Number	Manufacturer	Package Reference
C17	0	330 µF	CAP, Tantalum Polymer, 330 µF, 10 V, ±20%, 6 mΩ, 7343-43 SMD	T530X337M010ATE006	Kemet	7343-43
C22, C23	0	47 µF	CAP, CERM, 47 µF, 10 V, ±10%, X7R, 1210	GRM32ER71A476KE15L	Murata	1210
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
R5	0	21.5 k	RES, 21.5 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060321K5FKEA	Vishay-Dale	0603
R7, R9, R10	0	10.5 k	RES, 10.5 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060310K5FKEA	Vishay-Dale	0603
R15	0	10.0 k	RES, 10.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040210K0FKED	Vishay-Dale	0402
SH-JP1, SH-JP2	0	1x2	Shunt, 100mil, Gold plated, Black	SNT-100-BK-G	Samtec	Shunt

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6 Additional Information

Trademarks

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All trademarks are the property of their respective owners.

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   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

WARNING

Evaluation Kits are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems.

User shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

3.1.1 *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿 6 丁目 2 4 番 1 号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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