EVM User's Guide: TPS546C25EVM-1PH

TPS546C25EVM-1PH 4V to 18V, 35A, Buck Converter with PMBus and Telemetry Evaluation Module

Description

The TPS546C25EVM-1PH is a single-phase buck design using the TPS546C25 device. The TPS546C25EVM-1PH is designed for a nominal 12V bus and produces a regulated 1.2V output at up to 35A of load current. The TPS546C25EVM-1PH is designed to demonstrate operation of the TPS546C25 in a single-phase, low-output voltage application, while providing a number of test points to evaluate the performance of the devices. See *Tip and Barrel Measurement* for more information on single-phase configuration.

Get Started

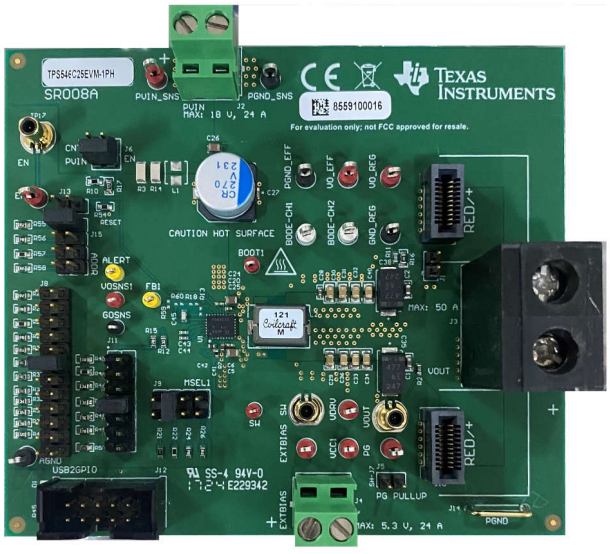
1. Order the TPS546C25EVM-1PH on ti.com.
2. Download the Fusion graphical user interface (GUI) software on FUSION_DIGITAL_POWER_DESIGNER.
3. Download the TPS546C25 data sheet.

Features

- Regulated 1.2V output up to $35A_{DC}$ steady-state output current
- The output voltage is marginable and trimmable using the PMBus interface
  - Programmable under-voltage lockout (UVLO), soft start, and enable through the PMBus interface
  - Programmable overcurrent warning and fault limits, and programmable response to faults through the PMBus interface
  - Programmable overvoltage and undervoltage warning, fault limits, and response to faults through the power management bus (PMBus) interface
  - Programmable turn-on and turn-off delays
- Convenient test points for probing critical waveforms

Applications

- Server and cloud-computing POLs
- Hardware accelerator
- Network interface card
- Remote radio unit
- Active antenna systems
- Data center switch



TPS546C25EVM-1PH (Top View)

1 Evaluation Module Overview

1.1 Introduction

The TPS546C25EVM-1PH evaluation module (EVM) is a single phase buck converter with a TPS546C25 device. The TPS546C25 device is a stackable synchronous buck with PMBus® interface that can operate from a nominal 2.7V to 18V supply with external bias. The device allows programming and monitoring through the PMBus interface.

The TPS546C25 device is configured as a single-phase buck converter in factory default.

1.2 Kit Contents

The kit includes the TPS546C25EVM-1PH.

1.3 Specification

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

Table 1-1. TPS546C25EVM-1PH Electrical Performance Specifications

Parameter	Test Conditions	MIN	TYP	MAX	Unit
Input Characteristics					
Input voltage range, V_{IN}		10.8	12	13.2	V
Output Characteristics					
Output voltage, V_{OUT}			1.2		V
Output load current, I_{OUT}		0		35	A
Output overcurrent fault threshold	Current limit setting of U1 programmed by MSEL1 J9 pins 3-4 shorted		100		%
Systems Characteristics					
Switching frequency	Programmed by MSEL2 J8 pins 7-8		800		kHz
PMBus Interface and Pin-Strapping					
U1 PMBus address	Programmed by PMB_ADDR J15 pins 1-2 shorted		11		h
U1 Voltage reference	Default setting by VSEL J11 pins 7-8 shorted		1.2		V
U1 Soft-start time (TON_RISE)	Default setting of TON_RISE programmed by MSEL1 J9 pins 3-4 shorted		2		ms

1.4 Device Information

The TPS546C25 device is a highly integrated buck with D-CAP4 control topology for fast transient response. The PMBus interface configures all programmable parameters and stores them in the non-volatile memory (NVM) as the new default values to minimize the external component count. Pinstrap options allow for configuration as primary or secondary, stack position and stack number, DCM (single phase only) or FCCM, overcurrent limit, fault response, internal or external feedback resistor, output voltage selection or range, switching frequency, and compensation.

The PMBus interface with a 1MHz clock support gives a convenient, standardized digital interface for configuration, as well as telemetry of key parameters including output voltage, output current, and internal die temperature. Response to fault conditions is set to restart, latch off, or ignore, depending on system requirements. Two, three, or four TPS546C25 devices can be interconnected to provide up to 140 A on a single output.

One device option is to overdrive the internal 5V LDO with an external 5V supply through the VDRV and VCC pins to improve efficiency, reduce power dissipation, and enable start-up with a lower input voltage. The TPS546C25 is a lead-free device and is Restriction of Hazardous Substances (RoHS) compliant without exemption.

2 Hardware

2.1 Test Setup

2.1.1 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.

2.1.1.1 Description

The *TI Fusion Digital Power Designer* is the graphical user interface (GUI) configures and monitors the Texas Instruments TPS546C25 power converter installed on this evaluation module. The TPS546C25 device is early sampling the GUI is available from the product line. Contact local support for a copy of the GUI. The application uses the PMBus protocol to communicate with the controller over serial bus by way of a TI USB adapter described in Section 2.1.2.6.

2.1.1.2 Features

Some of the tasks performed 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 V_{OUT} trim and margin, UVLO, soft-start time, warning and fault thresholds, fault response, and on and off modes.

2.1.2 Test Equipment

2.1.2.1 Voltage Source

The input voltage source V_{IN} must be a 0V to 18V variable DC source that can supply a minimum of 12ADC to support a 35A load with a 5V input. Connect input VIN and GND to J2. If the output voltage of the EVM is increased, the power supply must be able to supply more current.

2.1.2.2 Multimeters

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

2.1.2.3 Output Load

TI recommends a variable electronic load for the test setup. To test the full load current this EVM supports, the load must be able to sink at least 35A.

2.1.2.4 Oscilloscope

When using an oscilloscope to measure the switching node voltage or voltage ripple, measure using the *Tip-and-Barrel* method as Figure 2-1 shows for a better ripple measurement.

2.1.2.5 Fan

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

2.1.2.6 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 or USB-to-GPIO2 adapter. Purchase this adapter at http://www.ti.com/tool/usb-to-gpio2.

2.1.2.7 Recommended Wire Gauge

- Input VIN and GND to J2 (12V input) – The recommended wire size is AWG #12, with the total length of wire less than 2 feet (1 foot input, 1 foot return). Use test points labeled PVIN_SNS and PGND_SNS to for a sense connection to the input voltage source.
- Output J3 (1.2V output) – The minimum recommended wire size is AWG #10, with the total length of wire less than 2 feet (1 foot output, 1 foot return). To minimize the voltage, a thicker wire gauge is required to drop the wires.

2.1.3 Tip and Barrel Measurement

Figure 2-1 illustrates the tip and barrel measurement for switching node waveform on the TP8 with TP1.

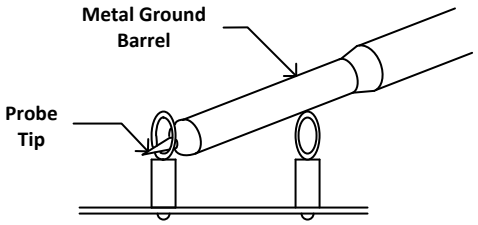


Figure 2-1. Tip and Barrel Measurement

2.1.4 List of Test Points, Jumpers, and Connectors

Table 2-1 lists the test point functions.

Table 2-1. Test Point Functions

Test Point	Type	Name	Description
BOOT1	T-H Loop	BOOT1	Test point connection to the BOOT pin
FB1	T-H Loop	FB1	Test point connection to the VSEL/FB pin
TP1	SMB	SW	SMB connection to the SW node
TP2	SMB	VOUT	SMB connection to the V_{out} node
TP3	T-H Loop	PVIN_SNS	Kelvin sense connection to the PVIN
TP4	T-H Loop	VO_EFF	Connection for measuring efficiency
TP5	T-H Loop	BODE-CH2	VOUT and BODE-CH2
TP6	T-H Loop	PGND_SNS	Kelvin sense connection to the PGND
TP7	T-H Loop	VDRV	Connection to the VDRV pin
TP8	T-H Loop	SW	Test point connection to the SW pin
TP9	T-H Loop	VO_REG	Connection for measuring regulation
TP10	T-H Loop	EXTBIAS	External Bias measurement point for the VDRV
TP11	T-H Loop	PG	Test point connection to the PGOOD pin
TP12	T-H Loop	EN	Test point connection to the EN pin
TP13	T-H Loop	BODE-CH1	BODE-CH1
TP14	T-H Loop	GND_REG	Connection for measuring regulation
TP15	T-H Loop	ALERT	Connection to the SMB_ALERT
TP16	T-H Loop	PGND_EFF	Kelvin connection to the GND for efficiency measurement
TP17	SMB	EN	SMB connection for EN signal on J6
TP18	T-H Loop	AGND	Connection to AGND pour and AGND pin
TP19	T-H Loop	GOSNS	Connection to the GOSNS pin
VCC1	T-H Loop	VCC1	Measurement point for the VCC
VOSNS1	T-H Loop	VOSNS1	Connection to the VOSNS1 pin

Table 2-2 lists the EVM jumpers.

Table 2-2. Jumpers

Jumper	Type	Name	Description
J5	Header, 2.54mm, 2x1, Gold, TH	PG_PULLUP	Connect RESET to pullup resistor default pins 1-2 shorted
J8	Header, 2.54mm, 12x2, Gold, TH	MSEL2	Jumper for setting MSEL2 default pins 5-6 shorted
J9	Header, 2.54mm, 4x2, Gold, TH	MSEL1	Jumper for setting MSEL1 default pins 3-4 shorted
J11	Header, 100mil, 7x2, Gold, TH	VSEL	Jumper for setting VSEL default pins 7-8 shorted
J13	Header, 2.54mm, 2x1, Gold, TH	RESET	Connect RESET to pullup resistor default pins 1-2 open
J15	Header, 2.54mm, 4x2, Gold, TH	ADDR	Jumper for setting ADDR default pins 1-2 shorted

Table 2-3 lists the options for the EN/UVLO pin selections on J6.

Table 2-3. J6 Selections

Shunt Position	Selection
Pin 1 to 2 shorted	PMBus adapter control signal
Pin 3 to 4 shorted	Resistor divider to PVIN default pins 3-4 shorted

Table 2-4 lists the EVM connector functions.

Table 2-4. Connector Functions

Connector	Type	Name	Description
J1	Header, 2.54mm, 2x1, Gold, TH	VOUT	Connect for differential probe with 100mil spacing
J2	Terminal Block, 5mm, 2-pole, Tin, TH	VIN	Connection for input voltage source. Maximum current rating = 24A
J3	Terminal Block, 60A, 10.16mm Pitch, 2-Pos, TH	VOUT	Connection for load, maximum current rating = 50A
J4	Terminal Block, 5mm, 2-pole, Tin, TH	EXTBIAS	Connection for external bias supply
J7	Card Edge Socket, 0.8mm, 10x2, SMT	VOUT	Connection for miniSlammer
J10	Card Edge Socket, 0.8mm, 10x2, SMT	VOUT	Connection for miniSlammer
J12	Header (shrouded), 100mil, 5x2, Gold, TH	USB2GPIO	Connection for USB2GPIO2
J14	1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	PGND	Ground connection

2.1.5 Configuring EVM to Overdrive VDRV

The EVM has a terminal connection J4 that is used to overdrive the VDRV. The output of the internal regulator is set for 4.5V by default. Using the external supply is useful to minimize the power dissipation in the TPS546C25 IC when operating at high switching frequency. Overdriving the VDRV moves the loss from the internal regulator of the TPS546C25 to the external supply. To use the external supply, follow the steps on the EVM as follows:

1. Connect external supply to J4 and set external supply to between 4.5V to 5.5V.
2. Power up the external supply to overdrive VDRV, then power up PVIN .

2.2 Best Practices

The following warnings and cautions are noted for the safety of anyone using or working close to the TPS546C25EVM-1PH. Observe all safety precautions.

	**Caution**	Hot surface. Contact can cause burns. Do not touch! TPS546C25EVM-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 your 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. This can result in exposed voltages, hot surfaces, and sharp edges. Do not reach under the board during operation.

WARNING

External Connections: All external connections to the hardware must stay within the recommended operating conditions and intended usage for all hardware/components connected in the system.

CAUTION

The circuit module can be damaged by over temperature. To avoid damage, monitor the temperature during evaluation and provide cooling.

CAUTION

Some power supplies can be damaged by application of external voltages. If using more than one power supply, check your equipment requirements and use blocking diodes or other isolation techniques, to prevent damage to the equipment.

CAUTION

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

3 Software

3.1 EVM Configuration Using the Fusion GUI

The TPS546C25 IC leaves the factory preconfigured. The factory default settings for the parameters are found in the data sheet. Use the software in *Test and Configuration Software* to configure the EVM to settings other than the factory defaults. Make sure to have the input voltage applied to the EVM before launching the software so that the TPS546C25 is responsive to the GUI and the GUI recognizes the device. The default configuration for the EVM to stop converting is set by the EN/UVLO resistor divider to a nominal input voltage of 4.75V; therefore if necessary to avoid any converter activity during configuration, an input voltage less than 4.75V must be applied. TI recommends an input voltage of 3.3V.

3.1.1 Configuration Procedure

1. Adjust the input supply to provide 3.3VDC with the current limited to 1A.
2. Apply the input voltage to the EVM. See Section 2.1.2 for connections and test setup.
3. Launch the Fusion GUI software. See the screen shots in Section 3.2 for more information.
4. Configure the EVM operating parameters as desired.

By default, the resistors on MSEL1 and MSEL2 configure U1 single phase converter.

3.2 Using the Fusion GUI

3.2.1 Opening the Fusion GUI

The Fusion GUI must include the *IC_DEVICE_ID* in the scanning mode to find the TPS546C25. The EVM needs power to be recognized by the Fusion GUI. See Section 3.1 for the recommended procedure. Figures in this section use screen shots showing other TPS546C25 family devices to illustrate the use of the FUSION GUI with the TPS546C25EVM-1PH when those functions are similar.

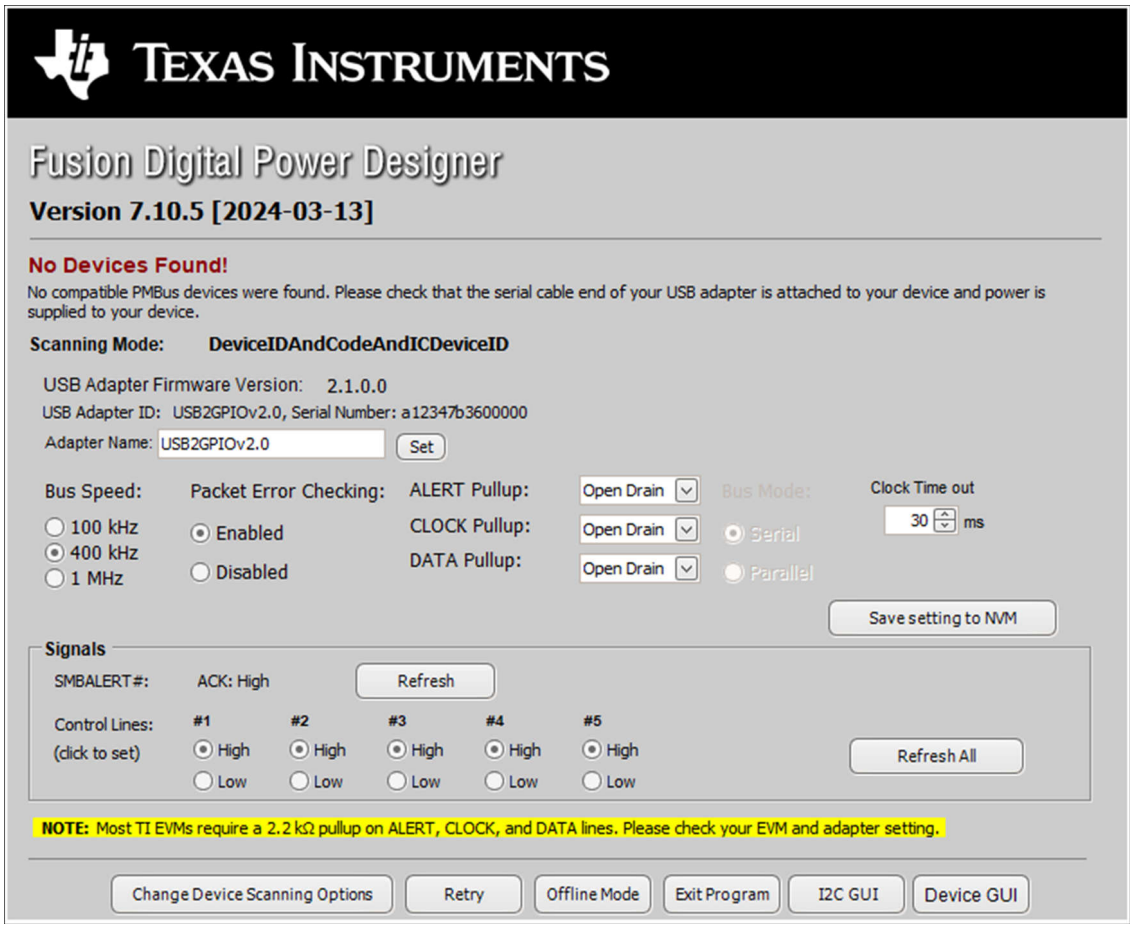


Figure 3-1. Select Device Scanning Mode

3.2.2 Changing ON_OFF_CONFIG

Changing the *On and Off Config* prompts a pop-up window with details of the options shown in Figure 3-2. This pop-up window shows multiple options of what turns on and off the power conversion. By default, the TPS546C25 is configured to *CONTROL Pin Only*. This pin functions as the EN/UVLO pin with resistors.

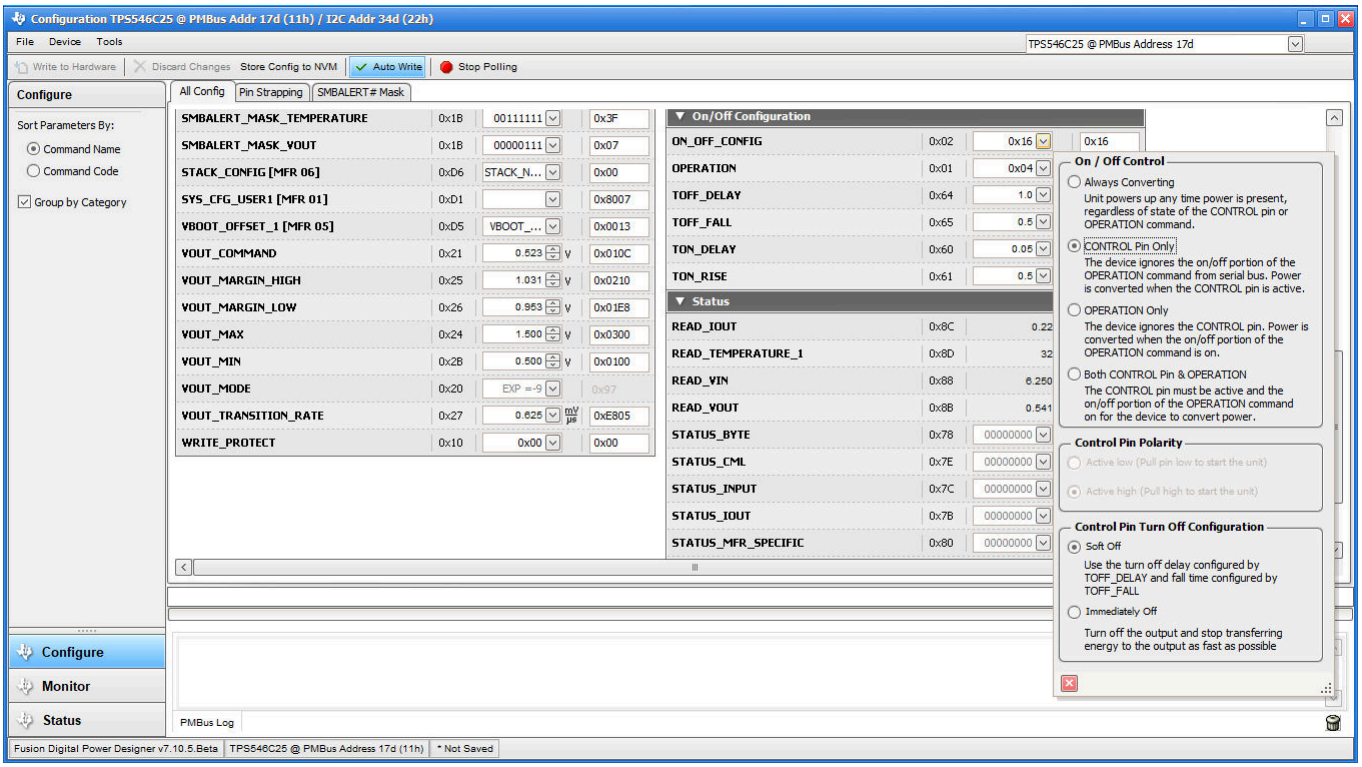


Figure 3-2. Configure – ON_OFF_CONFIG

3.2.3 SMBALERT# Mask

The sources of the SMBALERT are found and configured on the *SMBALERT # Mask* tab (Figure 3-3).

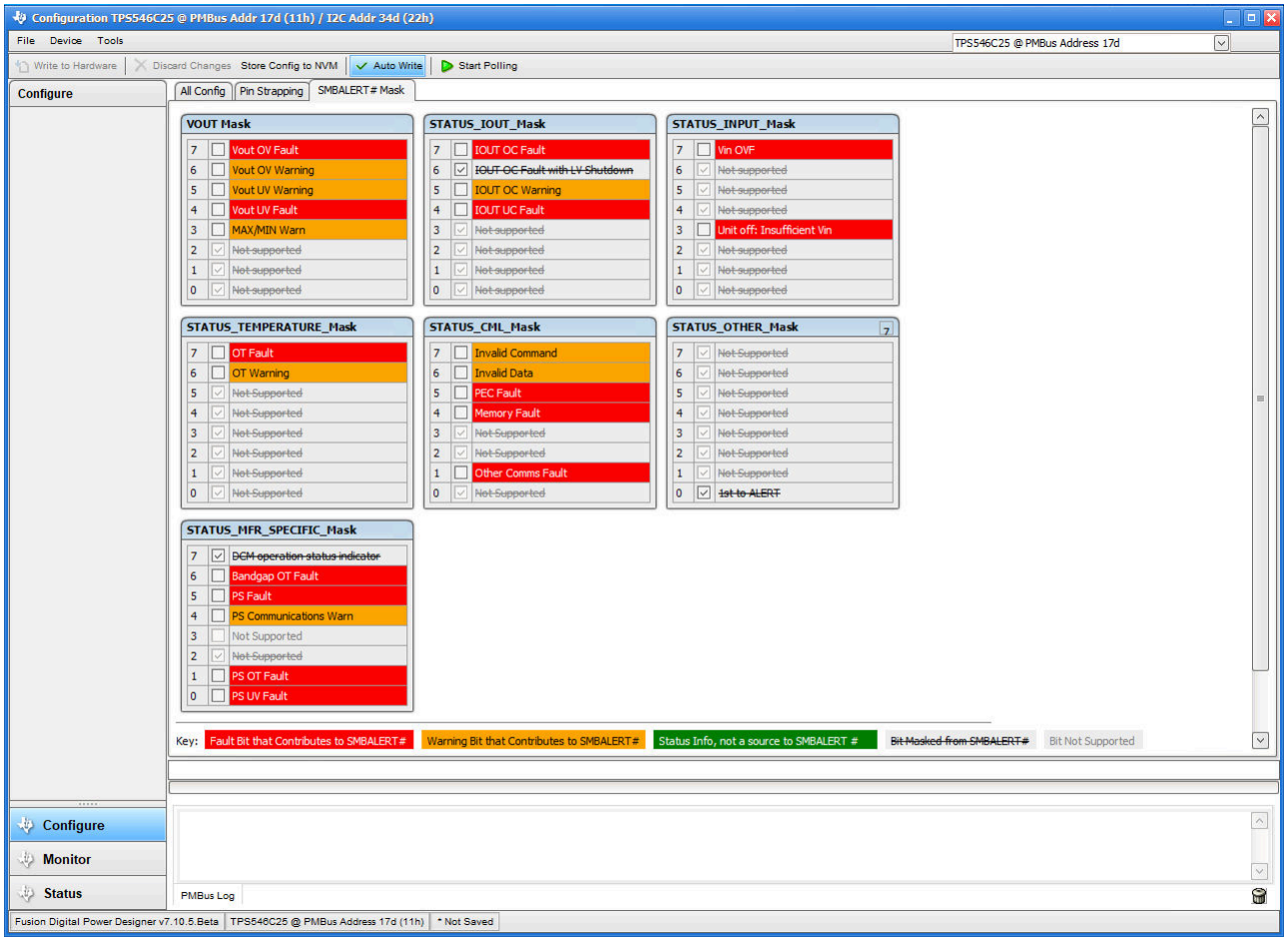


Figure 3-3. Configure – SMBALERT # Mask

3.2.4 All Config

To set up the configurable parameter, sse the *All Config* tab (Figure 3-4), which also shows other details like Hex encoding.

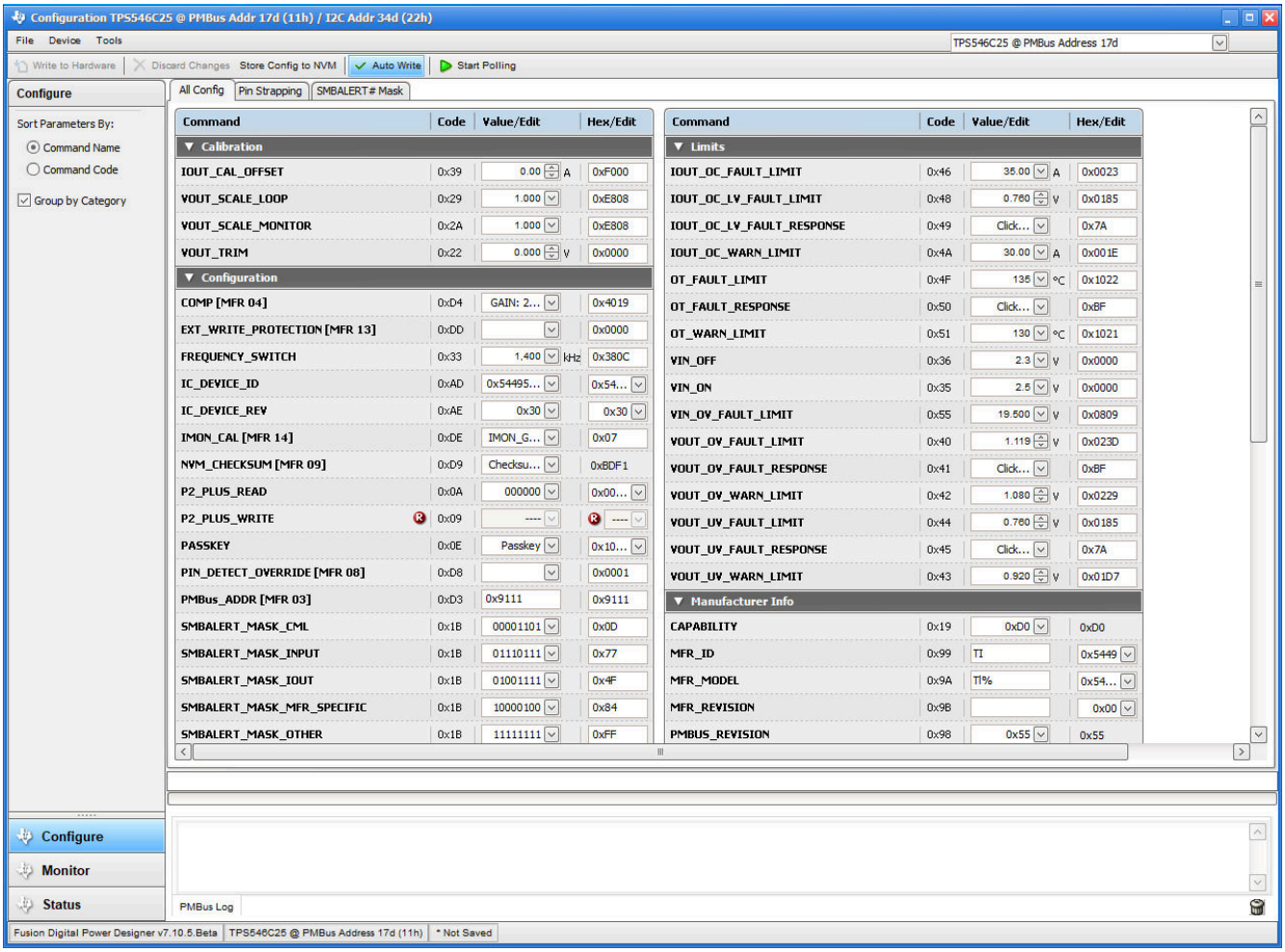


Figure 3-4. Configure – All Config

3.2.5 Pin Strapping

Use the *Pin Strapping* tab (Figure 3-5) to aid in selecting external pin strapping resistors used to program some of the PMBus commands at power-up.

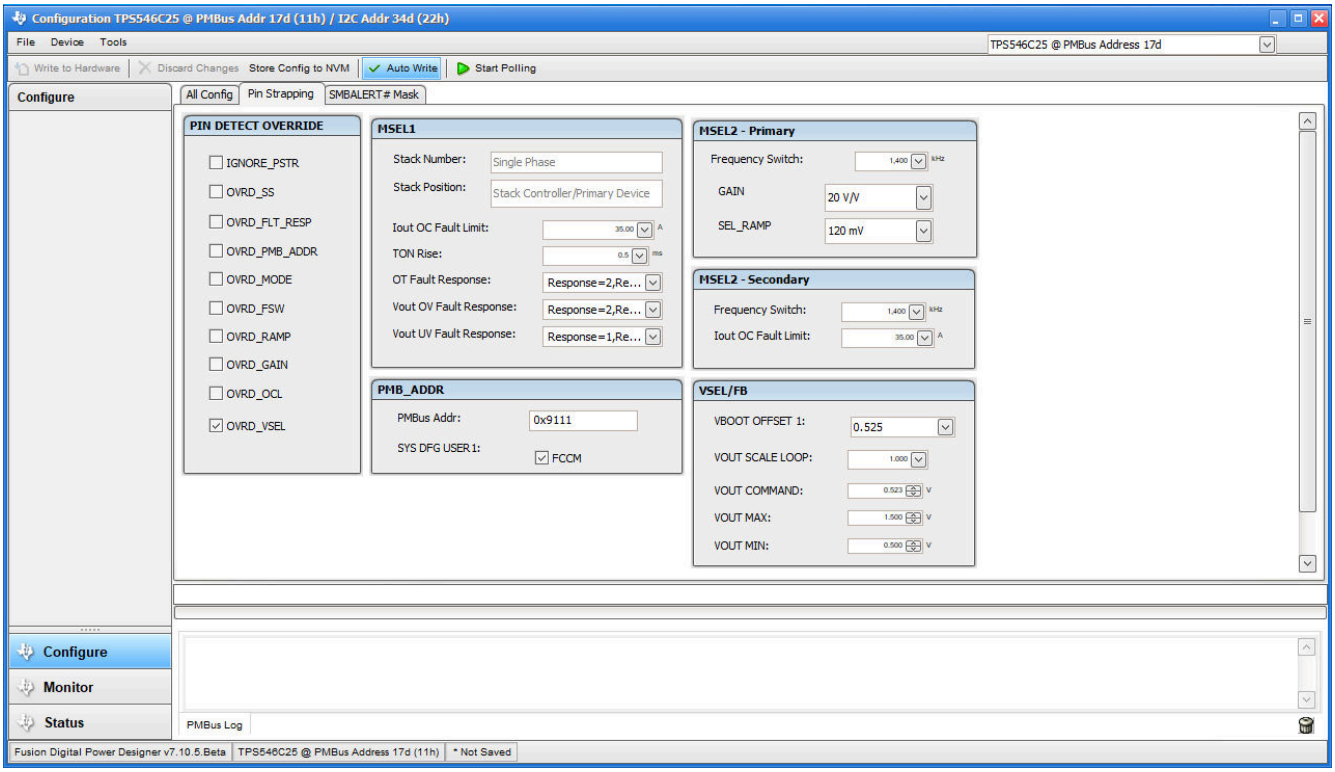


Figure 3-5. Configure – Pin Strapping

3.2.6 Monitor

When the *Monitor* screen (Figure 3-6) 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 V_{OUT}, I_{OUT}, V_{IN}, P_{OUT}, and *Temperature*
- *Start and Stop Polling* which turns ON or OFF the real-time display of data
- Quick access to *On and Off Config*
- Control pin activation and *OPERATION* command
- Margin control
- Clear Fault: Selecting ***Clear Faults*** clears any prior fault flags.

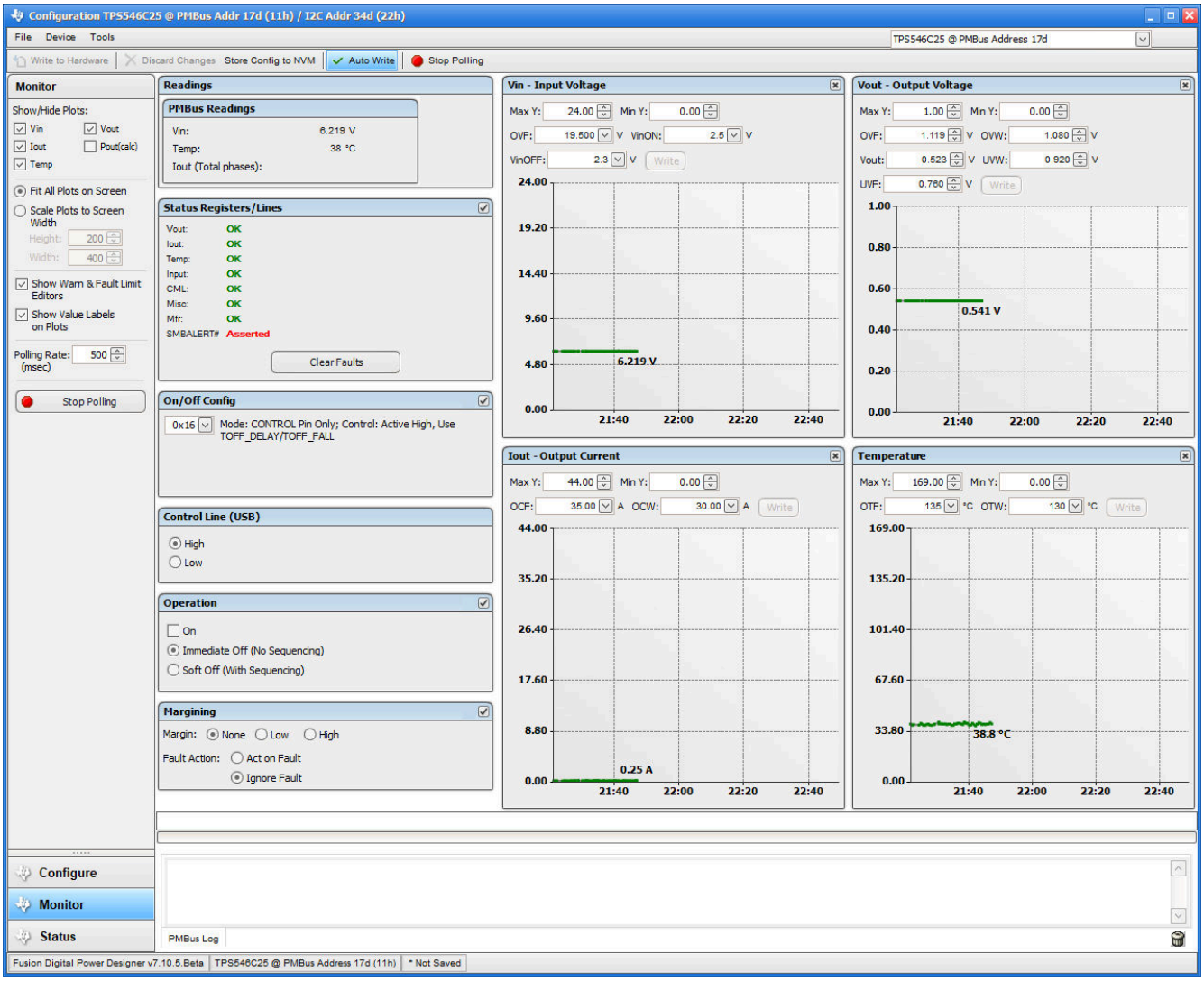


Figure 3-6. Monitor Screen

3.2.7 Status

Selecting the *Status* screen from the lower left corner (Figure 3-7) shows the status of the device.

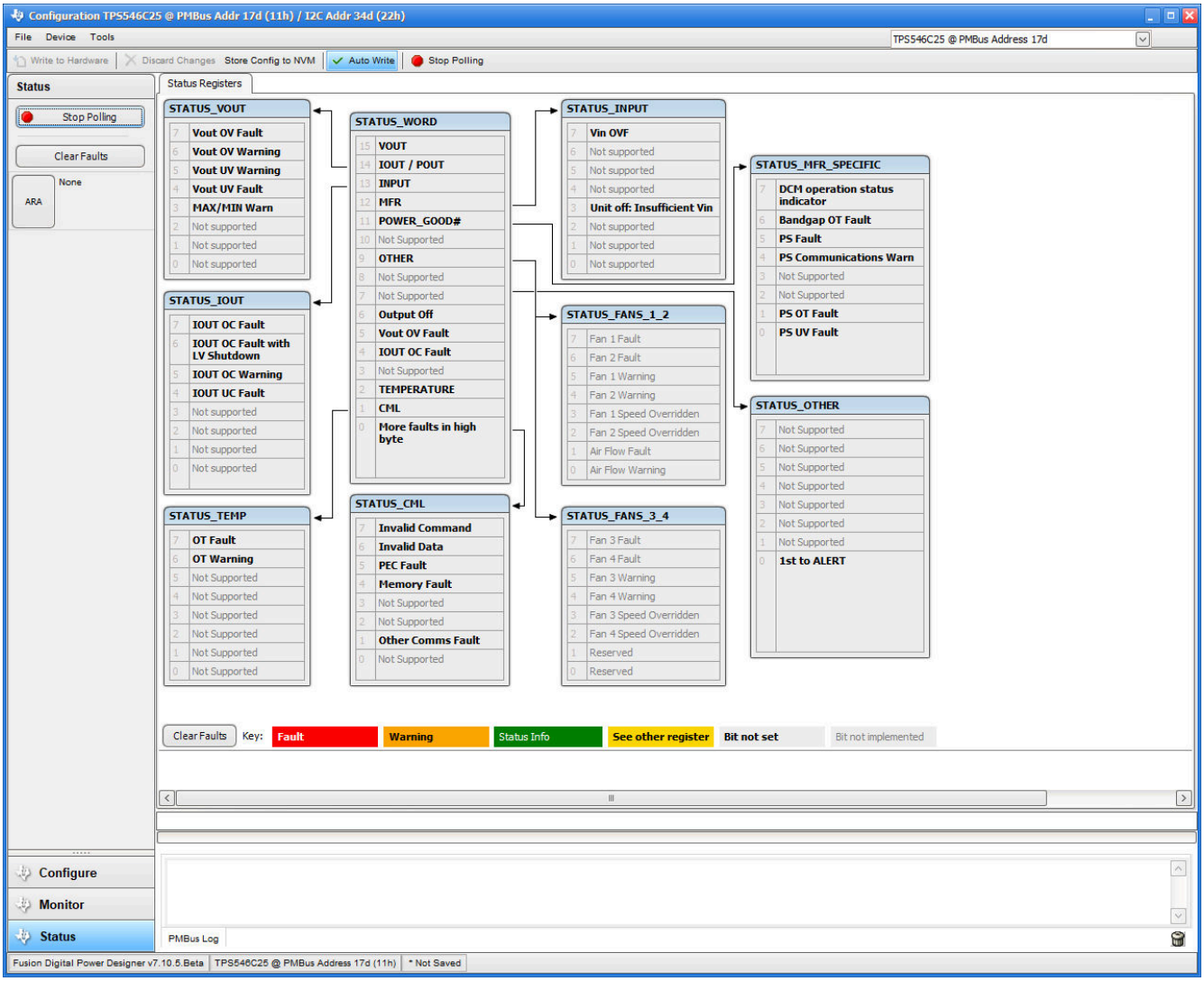


Figure 3-7. Status Screen

4 Implementation Results

4.1 Test Procedure

4.1.1 Line and Load Regulation and Efficiency Measurement Procedure

1. Set up the EVM according to Section 2.1.2 and Section 4.1.2.
2. Set the electronic load to draw $0A_{DC}$.
3. Increase the V_{IN} from 0V to 12V 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 $35A_{DC}$. V_{OUT} must remain in regulation as defined in Table 1-1.
6. Vary the V_{IN} from 5V to 18V. V_{OUT} must remain in regulation as defined in Table 1-1.
7. Decrease the load to 0A.
8. Decrease V_{IN} to 0V.

4.1.2 Efficiency Measurement Test Points

Measure the voltages at the correct location to evaluate the efficiency of the power train (device and inductor). This action is necessary because otherwise the efficiency measurements include losses that are not related to the power train. Losses incurred by the voltage drop in the copper traces and input and output connectors are not related to the efficiency of the power train, which must not be included in efficiency measurements.

Input current is measured a between the input suppply and EVM input in the input wires, and output current is measured in the output wires between the evm and load

Table 4-1 shows the measurement points for input and output voltage. VIN and VOUT are measured to calculate the dc-dc converter efficiency. Using the VIN and VOUT 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
TP3	PVIN_SNS	Input voltage measurement point for PVIN	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 included for efficiency measurement.
TP6	PGND_SNS	Input voltage measurement point for PGND	
TP9	VOUT_REG	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 included for efficiency measurement.
TP14	GND_REG	Output voltage measurement point for PGND	

For more accurate efficiency measurements of the power train, remove the voltage drop between the power train and the terminals from the measurement. Using the test points in Table 4-2 reduces these losses.

Table 4-2. Test Points for Better Efficiency Measurements

Test Point	Node Name	Description	Comment
TP3	PVIN_SNS	Input voltage measurement point for PVIN	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 included for efficiency measurement.
TP6	PGND_SNS	Input voltage measurement point for PGND	
TP4	VOUT_EFF	Output voltage measurement point for VOUT	This pair of test points are connected to VOUT and GND near the output inductor for U1 and U1 PGND .
TP16	GND_EFF	Output voltage measurement point for PGND	

4.1.3 Control Loop Gain and Phase Measurement Procedure

The TPS546C25EVM-1PH includes a 10Ω series resistor in the feedback loop for V_{OUT}. The resistor is accessible at test points TP13 and TP5 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 4-3 on how to connect test equipment.

Table 4-3. List of Test Points for Loop Response Measurements

Test Point	Node Name	Description	Comment
TP5	CH2	Input to feedback divider of V_{OUT}	Limit the amplitude of the perturbation at this node to less than TBDmV
TP13	CH1	Resulting output of V_{OUT}	Bode is measurable by a network analyzer with a CH2/CH1 configuration

Measure the loop response with the following procedure:

1. Set up the EVM as described in Section 2.1.2.
2. For V_{OUT}, connect the isolation transformer of the network analyzer from TP5 to TP13.
3. Connect the input signal measurement probe for CH1 to TP13. Connect the output signal measurement probe for CH2 to TP5.
4. Connect the ground leads of both probe channels to TP14.
5. On the network analyzer, measure the Bode as TP5/TP13 (CH2/CH1).

4.2 Performance Data and Typical Characteristic Curves

Figure 4-1 through Figure 4-8 present typical performance curves for the TPS546C25EVM-1PH. The input voltage is 12V and the oscilloscope measurements use 20MHz bandwidth limiting, unless otherwise noted.

4.2.1 Efficiency

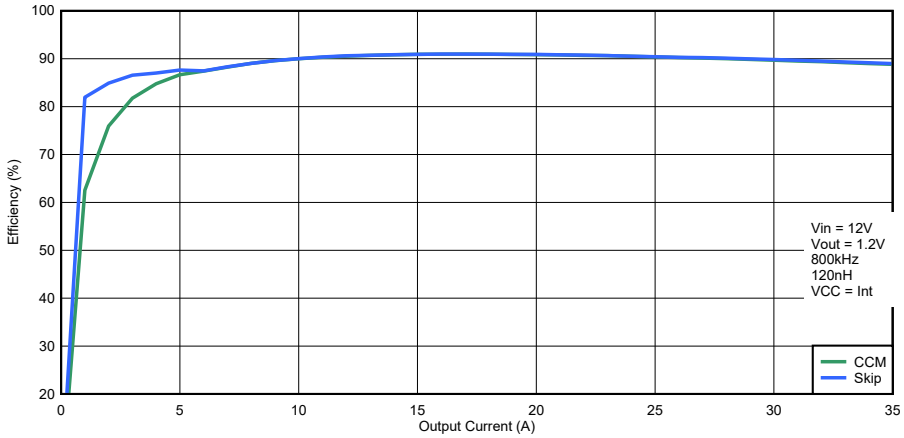


Figure 4-1. Efficiency, V_{OUT} Measured Using VO_EFF, PGND_EFF, PVIN_SNS and PGND_SNS Test Points

4.2.2 Transient Response

Figure 4-2 shows the transient response waveform with a 0A to 20A transient at 20A/µs

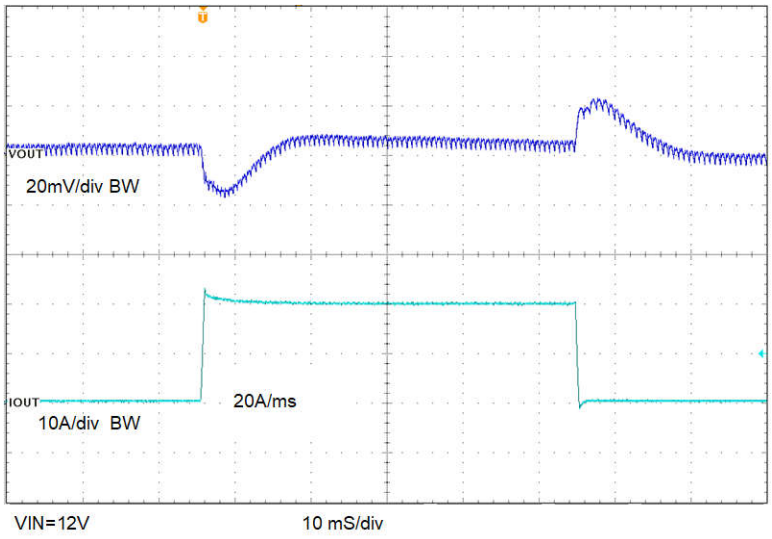


Figure 4-2. Transient Response

4.2.3 Control Loop Bode Plot

Figure 4-3 is the control loop bode plot.

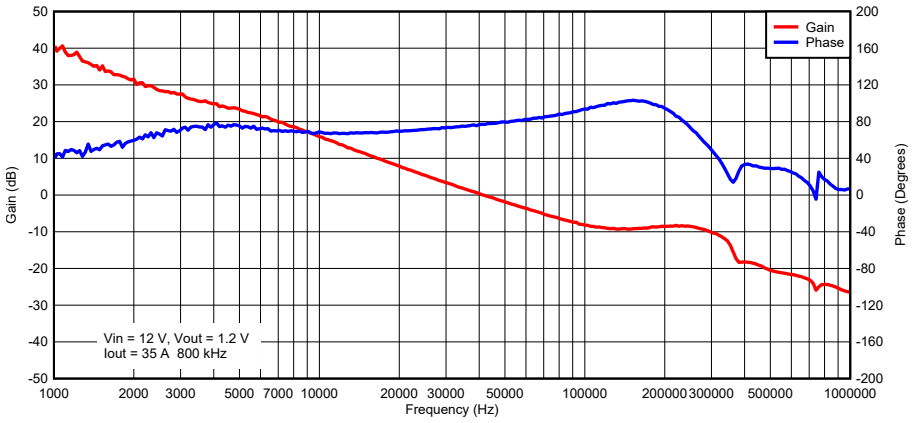


Figure 4-3. Bode Plot at 1.2V Output at 12V_{IN}, 35A Load

4.2.4 Output Ripple

Figure 4-4 and Figure 4-5 show the output ripple waveforms at 0A and 17.5 A load.

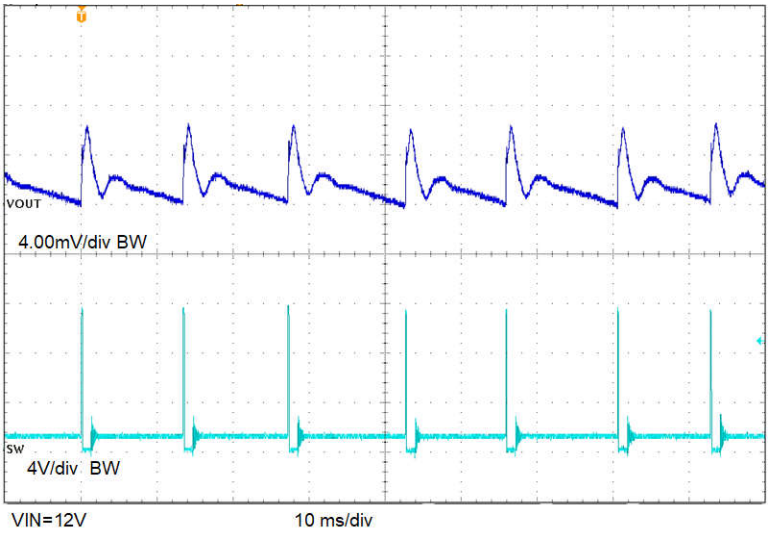


Figure 4-4. Output Ripple With 0A Load

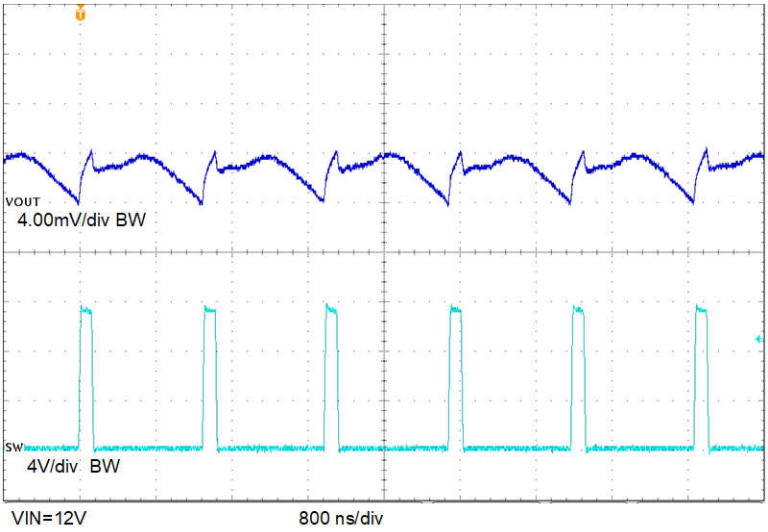


Figure 4-5. Output Ripple With 17.5 A Load

4.2.5 Control On

Figure 4-6 illustrate the start-up from control on waveform at 0A output.

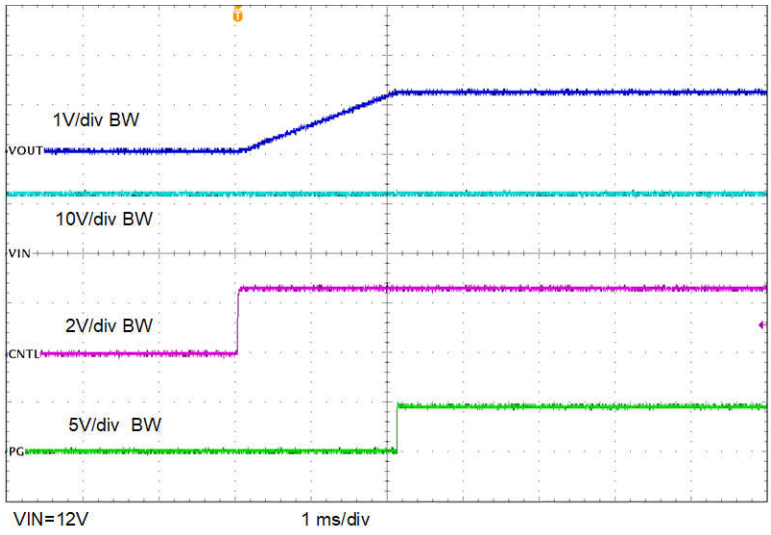


Figure 4-6. Start-Up From Control, 0A Load

4.2.6 Control Off

Figure 4-7 illustrate the control off waveforms at 0A.

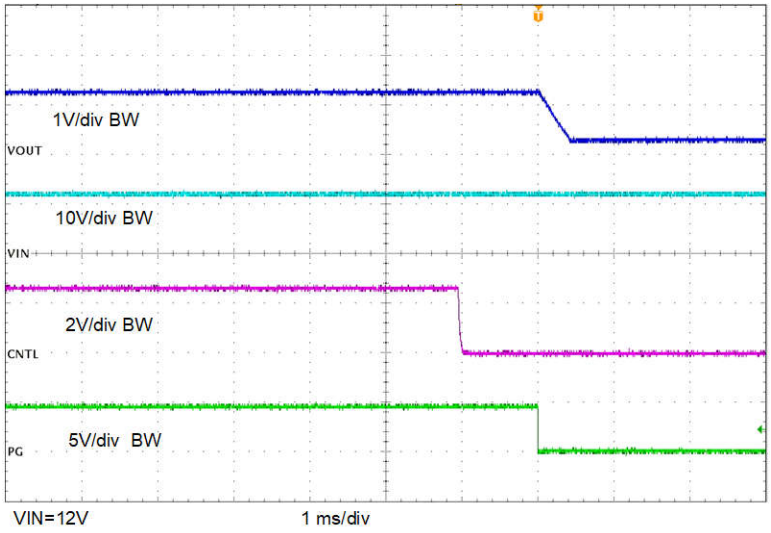


Figure 4-7. Shutdown From Control, 0A Load

4.2.7 Control On With Prebiased Output

Figure 4-8 illustrates the control on waveform with a prebiased output voltage.

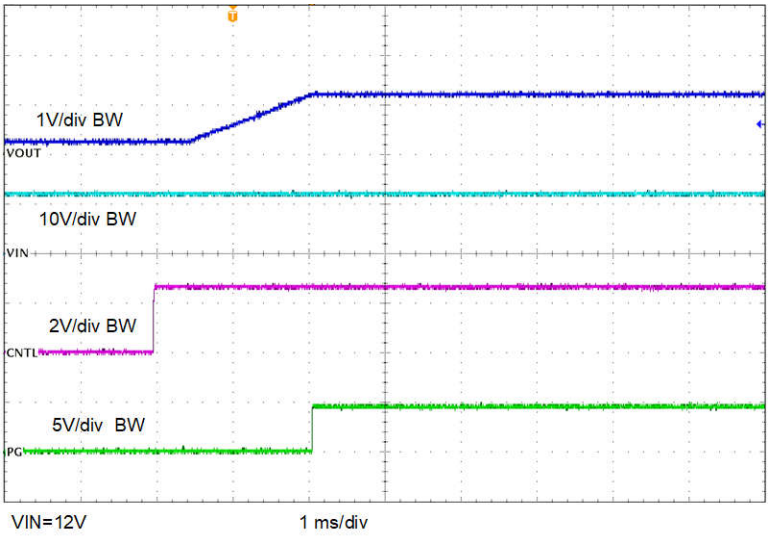
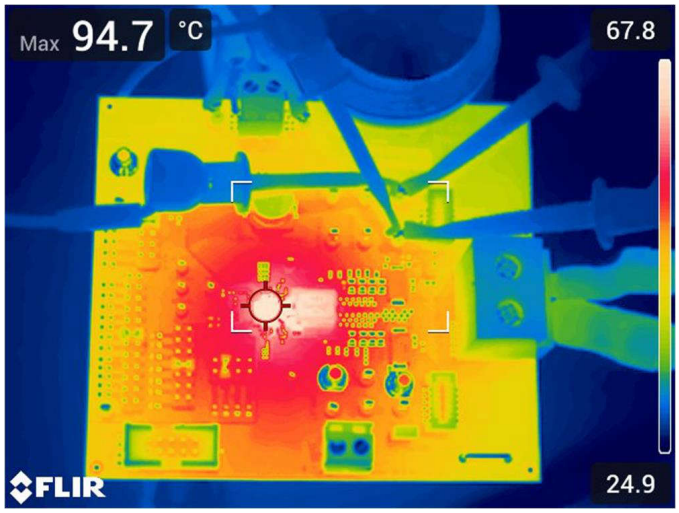


Figure 4-8. Start-Up From Control With Prebiased Output

4.2.8 Thermal Image

Figure 4-9 shows the TPS546C25EVM-1PH thermal image.



V_{IN} = 12V, V_{OUT} = 1.2V, I_{OUT} = 35A

Figure 4-9. Thermal Image

5 Hardware Design Files

5.1 Schematic

Figure 5-1 illustrates the TPS546C25EVM-1PH schematic.

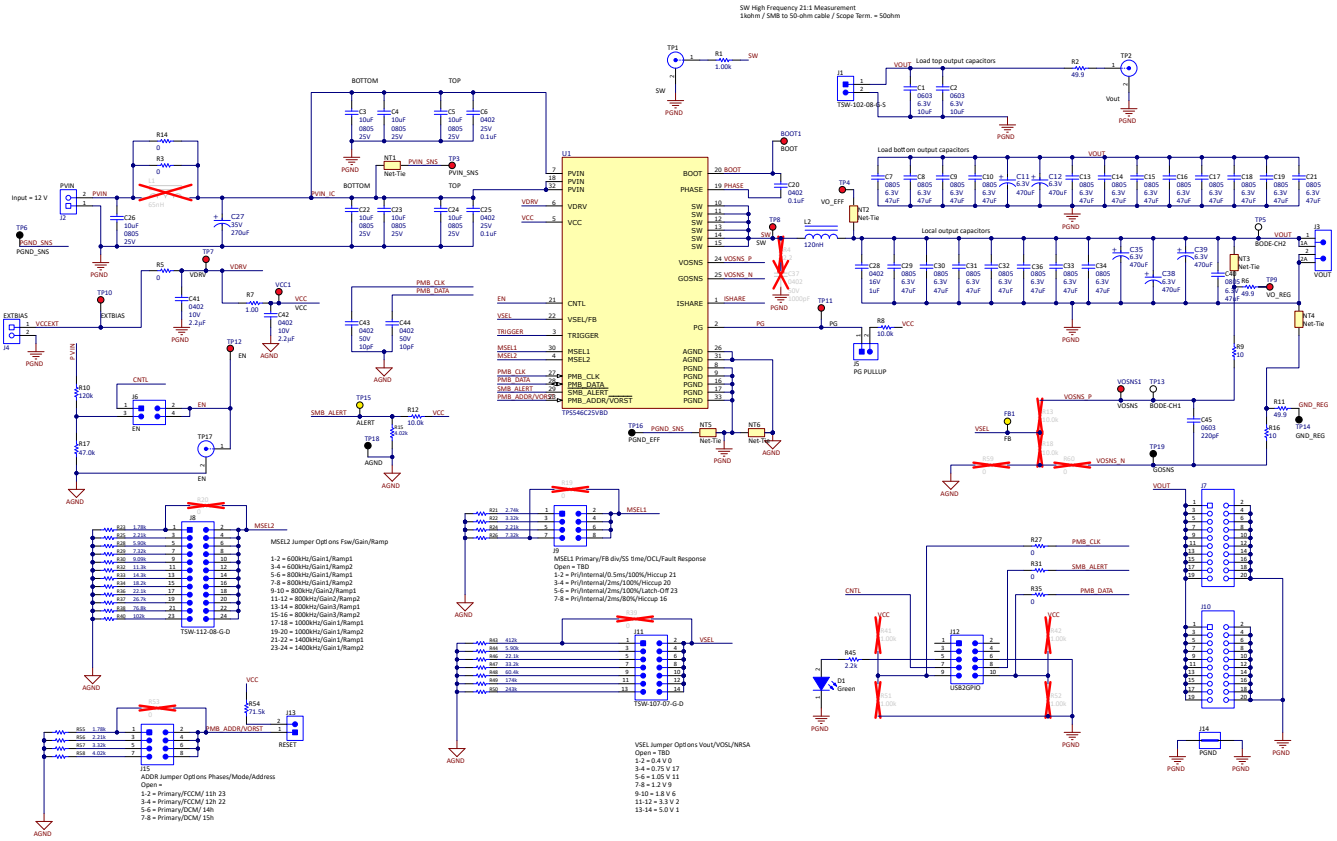


Figure 5-1. TPS546C25EVM-1PH Schematic

5.2 EVM Assembly Drawing and PCB Layout

Figure 5-2 through Figure 5-8 show the design of the TPS546C25EVM-1PH printed circuit board.

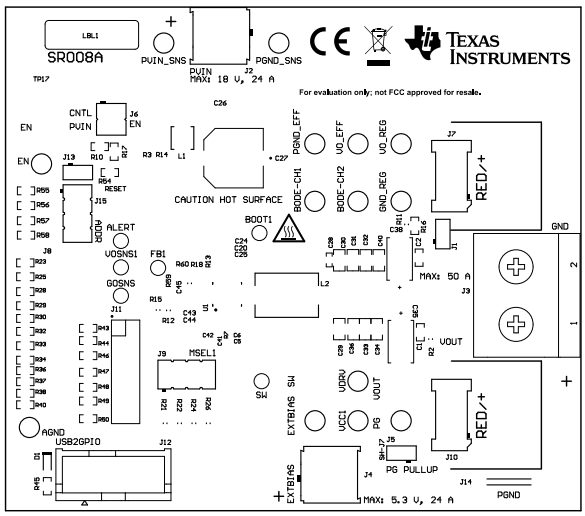


Figure 5-2. TPS546C25EVM-1PH Top Side Overlay View (Top View)

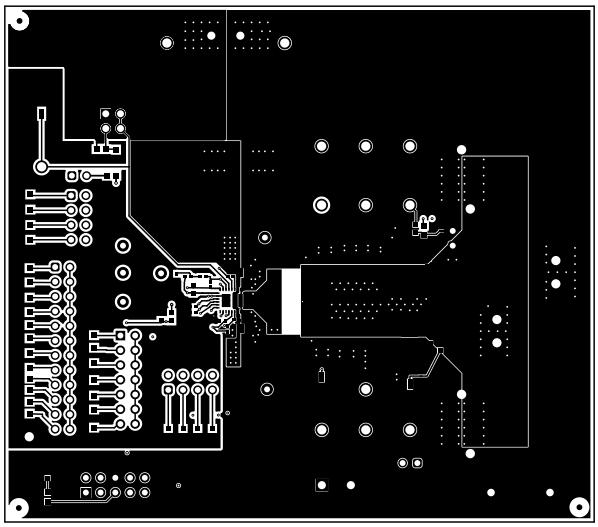


Figure 5-3. TPS546C25EVM-1PH Top Copper (Top View)

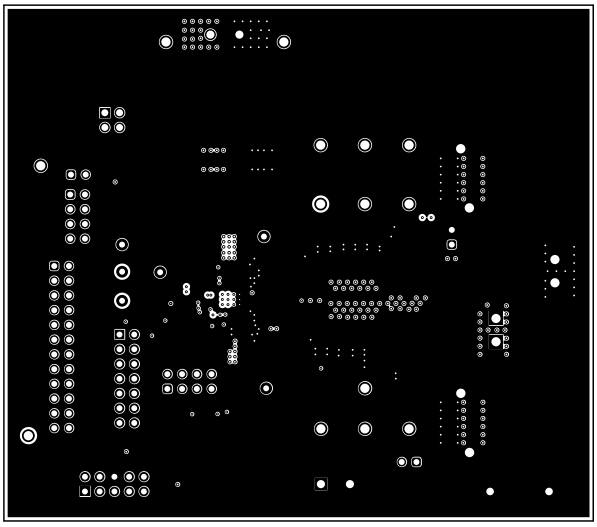


Figure 5-4. TPS546C25EVM-1PH Internal Layer 1 (Top View)

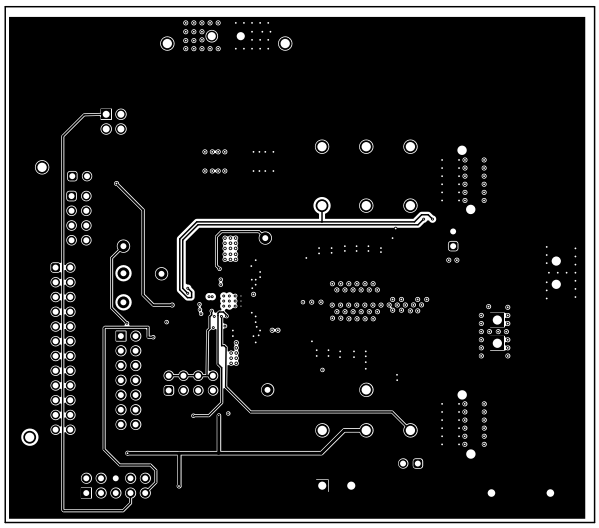


Figure 5-5. TPS546C25EVM-1PH Internal Layer 2 (Top View)

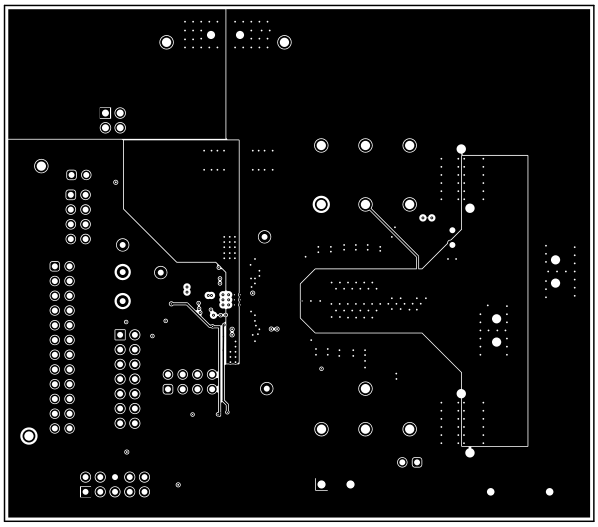


Figure 5-6. TPS546C25EVM-1PH Internal Layer 3 (Top View)

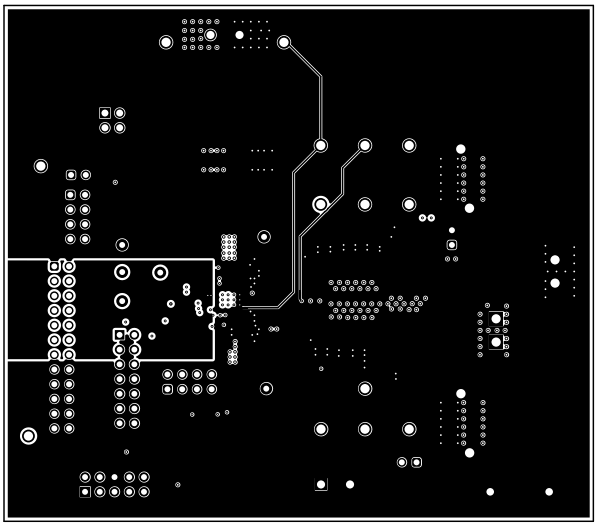


Figure 5-7. TPS546C25EVM-1PH Internal Layer 4 (Top View)

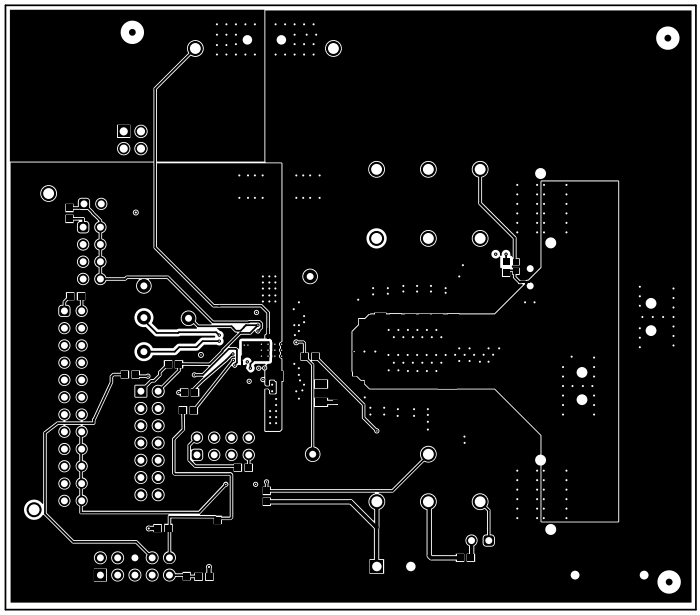


Figure 5-8. TPS546C25EVM-1PH Bottom Copper Layer (Top View)

5.3 Bill of Materials

Table 5-1 lists the bill of materials for the TPS546C25EVM-1PH.

Table 5-1. TPS546C25EVM-1PH Bill of Materials

Designator[1]	Quantity	Value	Description	Package	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		SR008	Any
BOOT1, TP8, VOSNS1	3		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone Electronics
C1, C2	2	10uF	CAP, CERM, 10uF, 6.3V, +/- 20%, X5R, 0603	603	GRM188R60J106ME47D	MuRata
C3, C4, C5, C22, C23, C24, C26	7	10uF	CAP, CERM, 10uF, 25V, +/- 10%, X7R, 0805	805	GRM21BZ71E106KE15L	MuRata
C6, C20, C25	3	0.1uF	CAP, CERM, 0.1uF, 25V, +/- 10%, X7R, 0402	402	GRM155R71E104KE14D	MuRata
C7, C8, C9, C10, C13, C14, C15, C16, C17, C18, C19, C21, C29, C30, C31, C32, C33, C34, C36, C40	20	47uF	CAP, CERM, 47uF, 6.3V, +/- 20%, X5R, AEC-Q200 Grade 3, 0805	805	GRT21BR60J476ME13L	MuRata
C11, C12, C35, C38, C39	5	390µF	390µF 2.5V Aluminum - Polymer Capacitors 2917 (7343 Metric) 9mOhm 3000 Hrs @ 125°C	2917	EEF-JX0E391RE	Panasonic
C27	1	270µF	270uF 35V Polymer ALUM Electrolytic Capacitor, CR Series 4000h 10.3x10.3x9.9mm	SMT_ECAP_10MM3_10MM3	PCR1V271MCL1GS	Nichicon
C28	1	1uF	CAP, CERM, 1uF, 16V, +/- 10%, X6S, 0402	402	C1005X6S1C105K050BC	TDK
C41, C42	2	2.2uF	CAP, CERM, 2.2µF, 10V,+/- 10%, X7S, AEC-Q200 Grade 1, 0402	402	GRT155C71A225KE13	MuRata
C43, C44	2	10pF	CAP, CERM, 10pF, 50V, +/- 5%, C0G/NP0, 0402	402	8.85012E+11	Wurth Elektronik
C45	1	220pF	CAP, CERM, 220pF, 50V, +/- 5%, C0G/NP0, 0603	603	C0603C221J5GACTU	Kemet
D1	1	Green	LED, Green, SMD	LED_0603	150060GS75000	Wurth Elektronik
FB1, TP15	2		Test Point, Miniature, Yellow, TH	Yellow Miniature Testpoint	5004	Keystone Electronics
FID1, FID2, FID3, FID4, FID5, FID6	6		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
H1, H2, H3, H4	4		Bumpon, Hemisphere, 0.44 × 0.20, Clear	Transparent Bumpon	SJ-5303 (CLEAR)	3M
J1, J5, J13	3		Header, 2.54mm, 2x1, Gold, TH	Header, 2.54mm, 2x1, TH	TSW-102-08-G-S	Samtec
J2, J4	2		Therminal Block, 5mm, 2-pole, Tin, TH	TH, 2-Leads, Body 10x10mm, Pitch 5mm	282856-2	TE Connectivity
J3	1		Terminal Block, 60A, 10.16mm Pitch, 2-Pos, TH	21.8x30x19 mm	399100102	Molex
J6	1		Header, 2.54mm, 2x2, Gold, TH	Header, 2.54mm, 2x2, TH	PBC02DAAN	Sullins Connector Solutions
J7, J10	2		Card Edge Socket, 0.8mm, 10x2, SMT	Card Edge Socket, 0.8mm, 10x2, SMT	HSEC8-110-01-S-DV-A	Samtec
J8	1		Header, 2.54mm, 12x2, Gold, TH	Header, 2.54mm, 12x2, TH	TSW-112-08-G-D	Samtec
J9, J15	2		Header, 2.54mm, 4x2, Gold, TH	Header, 2.54mm, 4x2, TH	TSW-104-08-L-D	Samtec
J11	1		Header, 100mil, 7x2, Gold, TH	7x2 Header	TSW-107-07-G-D	Samtec
J12	1		Header (shrouded), 100mil, 5x2, Gold, TH	5x2 Shrouded header	5103308-1	TE Connectivity
J14	1		1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Shorting Plug, 10.16mm spacing, TH	D3082-05	Harwin
L2	1	120nH	Inductor, Shielded, Ferrite, 120nH, 35.5A, 0.000228 ohm, SMD	10.8x7.2x7.5mm	SLC1175-121MEB	Coilcraft

Table 5-1. TPS546C25EVM-1PH Bill of Materials (continued)

Designator[1]	Quantity	Value	Description	Package	Part Number	Manufacturer
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650 x 0.200 inch	THT-14-423-10	Brady
R1, R41, R42, R51, R52	5	1.00k	RES, 1.00 k, 1%, 0.1 W, 0603	603	RC0603FR-071KL	Yageo
R2, R6, R11	3	49.9	RES, 49.9, 1%, 0.1 W, 0603	603	RC0603FR-0749R9L	Yageo
R3, R14	2	0	RES, 0, 1%, 0.5 W, 1206	1206	5108	Keystone
R5, R27, R31, R35	4	0	RES, 0, 5%, 0.1 W, 0603	603	RC0603JR-070RL	Yageo
R7	1	1	RES, 1.00, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	402	CRCW04021R00FKED	Vishay-Dale
R8, R12	2	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	603	RC0603FR-0710KL	Yageo
R9, R16	2	10	RES, 10, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	603	CRCW060310R0JNEA	Vishay-Dale
R10	1	120k	RES, 120 k, 1%, 0.1 W, 0603	603	RC0603FR-07120KL	Yageo
R15, R58	2	4.02k	RES, 4.02 k, 1%, 0.1 W, 0603	603	RC0603FR-074K02L	Yageo
R17	1	47.0k	RES, 47.0 k, 1%, 0.1 W, 0603	603	RC0603FR-0747KL	Yageo
R21	1	2.74k	RES, 2.74 k, 1%, 0.1 W, 0603	603	RC0603FR-072K74L	Yageo
R22, R57	2	3.32k	RES, 3.32 k, 1%, 0.1 W, 0603	603	RC0603FR-073K32L	Yageo
R23, R55	2	1.78k	RES, 1.78 k, 1%, 0.1 W, 0603	603	RC0603FR-071K78L	Yageo
R24, R25, R56	3	2.21k	RES, 2.21 k, 1%, 0.1 W, 0603	603	RC0603FR-072K21L	Yageo
R26, R29	2	7.32k	RES, 7.32 k, 1%, 0.1 W, 0603	603	RC0603FR-077K32L	Yageo
R28, R44	2	5.90k	RES, 5.90 k, 1%, 0.1 W, 0603	603	RC0603FR-075K9L	Yageo
R30	1	9.09k	RES, 9.09 k, 1%, 0.1 W, 0603	603	RC0603FR-079K09L	Yageo
R32	1	11.3k	RES, 11.3 k, 1%, 0.1 W, 0603	603	RC0603FR-0711K3L	Yageo
R33	1	14.3k	RES, 14.3 k, 1%, 0.1 W, 0603	603	RC0603FR-0714K3L	Yageo
R34	1	18.2k	RES, 18.2 k, 1%, 0.1 W, 0603	603	RC0603FR-0718K2L	Yageo
R36, R46	2	22.1k	RES, 22.1 k, 1%, 0.1 W, 0603	603	RC0603FR-0722K1L	Yageo
R37	1	26.7k	RES, 26.7 k, 1%, 0.1 W, 0603	603	RC0603FR-0726K7L	Yageo
R38	1	76.8k	RES, 76.8 k, 1%, 0.1 W, 0603	603	RC0603FR-0776K8L	Yageo
R40	1	102k	RES, 102 k, 1%, 0.1 W, 0603	603	RC0603FR-07102KL	Yageo
R43	1	412k	RES, 412 k, 1%, 0.1 W, 0603	603	RC0603FR-07412KL	Yageo
R45	1	2.2k	RES, 2.2 k, 5%, 0.1 W, 0603	603	RC0603JR-072K2L	Yageo
R47	1	33.2k	RES, 33.2 k, 1%, 0.1 W, 0603	603	RC0603FR-0733K2L	Yageo
R48	1	60.4k	RES, 60.4 k, 1%, 0.1 W, 0603	603	RC0603FR-0760K4L	Yageo
R49	1	174k	RES, 174 k, 1%, 0.1 W, 0603	603	RC0603FR-07174KL	Yageo
R50	1	243k	RES, 243 k, 1%, 0.1 W, 0603	603	RC0603FR-07243KL	Yageo
R54	1	71.5k	RES, 71.5 k, 1%, 0.1 W, 0603	603	RC0603FR-0771K5L	Yageo
SH-J1	1	1x2	Shunt, 100mil, Gold plated, Black	Shunt	SNT-100-BK-G	Samtec
TP1, TP2, TP17	3		Connector, Receptacle, 50 ohm, TH	SMB Connector	SMBR004D00	JAE Electronics
TP3, TP4, TP7, TP9, TP10, TP11, TP12, VCC1	8		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone Electronics

Table 5-1. TPS546C25EVM-1PH Bill of Materials (continued)

Designator[1]	Quantity	Value	Description	Package	Part Number	Manufacturer
TP5, TP13	2		Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone Electronics
TP6, TP14, TP16, TP18	4		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone Electronics
TP19	1		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone Electronics
U1	1		TPS546C25VBD	WQFN-FCRLF33	TPS546C25VBD	Texas Instruments
C37	0	1000pF	CAP, CERM, 1000pF, 50V, +/- 10%, X7R, 0402	402	8.85012E+11	Wurth Elektronik
L1	0	65nH	Inductor, Ferrite, 65nH, 19A, 0.00032 ohm, SMD	4.0x4.0x4.0mm	FP0404R1-R065-R	Coiltronics
R4	0	2.2	RES, 2.2, 5%, 0.5 W, 1206	1206	CRM1206-JW-2R2ELF	Bourns
R13, R18	0	10.0k	RES, 10.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	402	AC0402FR-0710KL	Yageo America
R19, R20, R39, R53	0	0	RES, 0, 5%, 0.1 W, 0603	603	RC0603JR-070RL	Yageo
R59, R60	0	0	RES, 0, 5%, 0.063 W, 0402	402	RC0402JR-070RL	Yageo America

(1) Unless otherwise noted, all parts can be substituted with equivalents.

6 Additional Information

6.1 Trademarks

PMBus® is a registered trademark of System Management Interface Forum.
All trademarks are the property of their respective owners.

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   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

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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:*

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