User's Guide

TPS25990 Evaluation Module for eFuse

ABSTRACT

This user's guide describes the evaluation module (EVM) for the TPS25990 eFuse. The TPS25990 device is a 2.9-V to 16-V and 50-A stackable eFuse with a PMBus® interface for accurate digital telemetry, control, configuration, and debugging. This device provides an accurate and fast load current monitor output, which helps in Intel PSYS™ and PROCHOT™ implementations. This eFuse supports parallel connection with multiple TPS25985 eFuses for higher current designs by actively synchronizing the device states and sharing the loads during start-up and steady-state.

The TPS25990 eFuse has an integrated FET with ultra-low ON resistance of 0.8-mΩ, adjustable and robust overcurrent and short-circuits protections, fast overvoltage protection (fixed 16.7-V threshold in hardware and adjustable through PMBus), adjustable output slew rate control for inrush current protection, and overtemperature protection to verify FET safe operating area (SOA). The TPS25990 eFuse also has an adjustable overcurrent transient blanking timer to support load transients, adjustable undervoltage protection, integrated FET health monitoring, and reporting, analog die temperature monitor output, dedicated fault and power good indication pins, and uncommitted general purpose fast comparator.

	Caution	Caution Hot Surface. Contact may cause burns. Do not touch !

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1 Introduction

The TPS25990EVM eFuse evaluation board allows reference circuit evaluation of Texas Instruments (TI) TPS25990 eFuse. The TPS25990 device is a 2.9-V to 16-V, 50-A stackable eFuse with a PMBus interface for accurate digital telemetry, control, configuration, and debugging. This device provides an accurate and fast load current monitor output, which helps in Intel PSYS and PROCHOT implementations. This eFuse supports parallel connection with multiple TPS25985 eFuses for higher current designs by actively synchronizing the device states and sharing the loads during start-up and steady-state. The TPS25990 eFuse has an integrated FET with ultra-low ON resistance of 0.8-mΩ, adjustable and robust overcurrent and short-circuits protections, fast overvoltage protection (fixed 16.7-V threshold in hardware and adjustable through PMBus), adjustable output slew rate control for inrush current protection, and overtemperature protection to verify FET safe operating area (SOA). The TPS25990 eFuse also has an adjustable overcurrent transient blanking timer to support load transients, adjustable undervoltage protection, integrated FET health monitoring, and reporting, analog die temperature monitor output, dedicated fault and power good indication pins, and uncommitted general purpose fast comparator.

Note

TPS25990EVM-GUI provides access to the TPS25990 evaluation module GUI.

1.1 EVM Features

TPS25990EVM comes with one TPS25990 eFuse and one TPS25985 eFuse connected in parallel to evaluate a 12-V (typical) and 110-A (steady-state) design. General TPS25990EVM eFuse evaluation board features include:

- 5-V to 16-V (typical) operation
- 9-A to 130-A programmable circuit breaker threshold using on-board jumpers
- Adjustable reference voltage (V_{IREF}) for overcurrent, short-circuit protection, and active current sharing blocks through VIREF (E0h) register
- Adjustable output voltage slew rate control both in hardware and firmware
- Adjustable transient current blanking timer in firmware through OC_TIMER (E6h) register
- Adjustable current limit during start-up and active current sharing threshold using on-board jumpers
- TVS diode for input and Schottky diode for output transient protections
- LED status for power good and fault indications
- On-board test points to use the general purpose comparator in implementing the PROCHOT functionality
- Options to engage the power cycle and the quick output discharge (QOD) using EN/UVLO pin
- Option to apply custom load transients using on-board MOSFETs, gate drive circuit, and load resistors
- PMBus interface with the TPS25990EVM-GUI using the USB-TO-GPIO2 USB interface adapter evaluation module
- Option to interface an external EEPROM with TPS25990 for indefinite configuration of the eFuse and Blackbox fault recording

CAUTION

Do not leave the EVM powered when unattended

WARNING

Signal traces, components, and component leads are located on the bottom of the circuit module. There can be exposed voltages, hot surfaces, or sharp edges as a result. When operating the board, do not reach under.

CAUTION

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

1.2 EVM Applications

This EVM can be used on the following applications:

- Input hot-swap and hot-plug
- Server motherboard and add-on cards
- Graphics and accelerator cards
- Switches and routers
- Fan trays

2 Description

The TPS25990EVM enables the evaluation of TPS25990 eFuse by communicating with the TPS25990EVM-GUI using the USB-TO-GPIO2 USB interface adapter evaluation module. This EVM has one TPS25990 eFuse (Primary device) and one TPS25985 eFuse (Secondary device) connected in parallel to evaluate the performance of a 110-A Hot Swap design.

The input power is applied across the connectors T1 and T3, while T2 and T3 provide the output connection for the EVM; refer to the schematic in Figure 3-1 and EVM test setup in Figure 5-1. TVS diodes D2 and D3 protect the input from transient overvoltages. Schottky diodes D1 and D5 protect the output by clamping the negative voltage excursion at the OUT pins of TPS25990 and TPS25985 eFuses within their minimum absolute ratings.

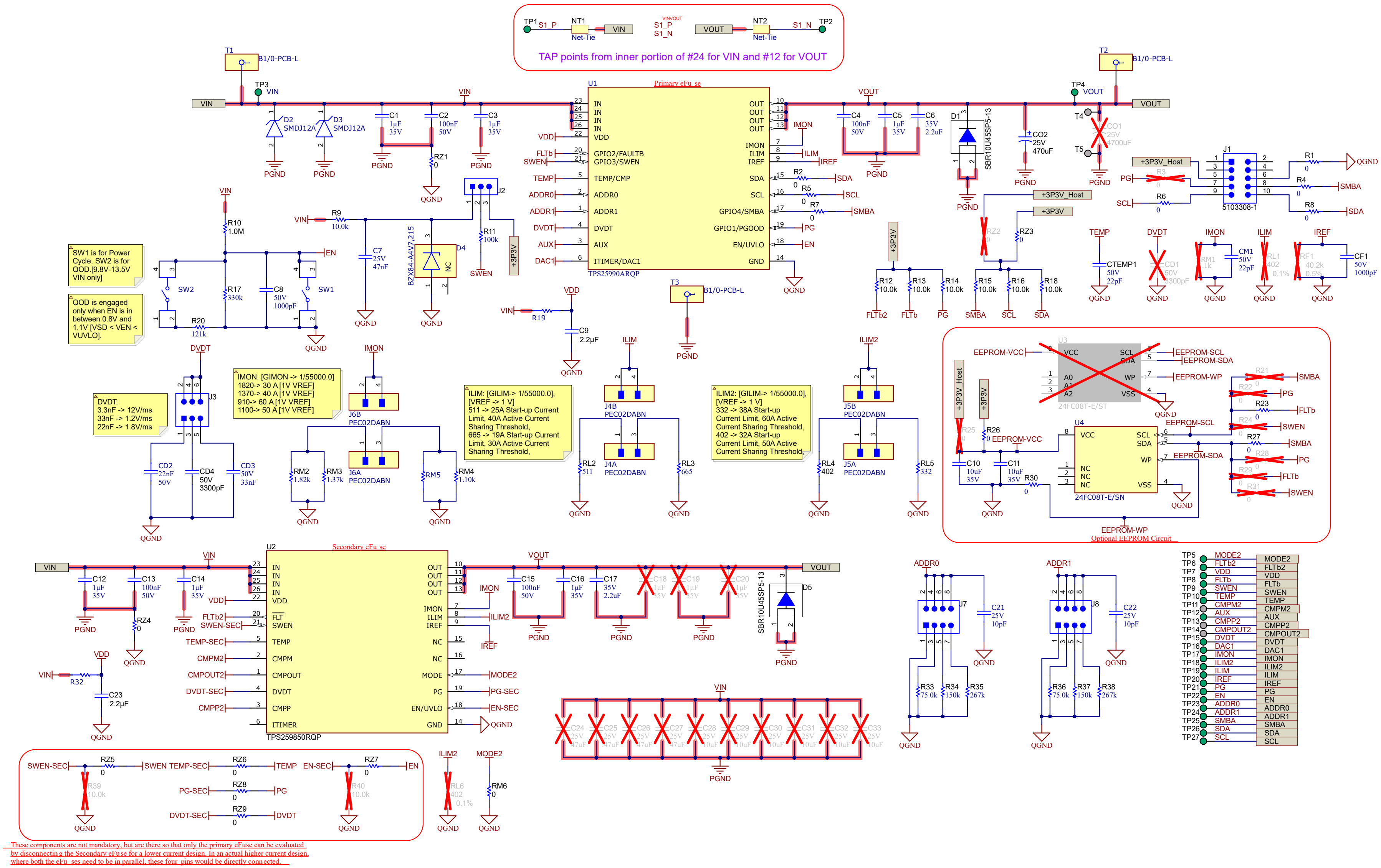
SW1 allows to do power cycle and SW2 enables the quick output discharge (QOD). Power Good (PG) and fault (FLTb & FLTb2) indicators are provided by LED DG1, DR1, and DR2 respectively. SW3 allows to apply a custom load transient using on-board MOSFETs, gate drive circuit, and load resistors.

Table 2-1. TPS25990EVM eFuse Evaluation Board Options and Settings

Parameters	Options and Settings
V_{IN} UVLO Threshold	5 V
V_{IN} OVLO Threshold	16.7 V in hardware and configurable through PMBus in the range of 3 V to 17.7 V with a default value of 16.7 V (0x0Eh in VIN_OV_FLT (55h) register)
Overcurrent Blanking Timer Duration (t_{TIMER})	Set at 2.18 ms (0x14h in OC_TIMER (E6h) register) by default and configurable through PMBus in the range of 0 ms to 27.8 ms with a step of 109 µs
Output Voltage Slew Rate (dv/dt)	Selectable in hardware - 1.2 V/ms, 1.8 V/ms, and 12 V/ms and configurable through PMBus in the range of 50 % to 150 % of nominal slew-rate (Set by hardware) with a default value of 100 % (10b in the 10:9 bits of DEVICE_CONFIG (E4h) register)
Circuit-breaker Threshold (I_{OCP})	Selectable in hardware - 110 A and 70 A with V_{IREF} of 1 V
Inrush Current Limit and Active Current Sharing Threshold for TPS25990 eFuse (U1)	Selectable in hardware - 25 A and 19 A of inrush current limit and 40 A and 30 A of active current sharing threshold with V_{IREF} of 1 V
Inrush Current Limit and Active Current Sharing Threshold for TPS25985 eFuse (U2)	Selectable in hardware - 38 A and 32 A of inrush current limit and 60 A and 50 A of active current sharing threshold with V_{IREF} of 1 V
Reference Voltage for Overcurrent Protection and Active Current Sharing (V_{IREF})	Configurable through PMBus in the range of 0.3 V to 1.2 V with a default value of 1 V (0x32h in VIREF (E0h) register)
PMBus Address of TPS25990 eFuse	0x46h (7 bit format) with both ADDR0 and ADDR1 pins are connected to GND

3 Schematic

Figure 3-1 illustrates the EVM schematic.



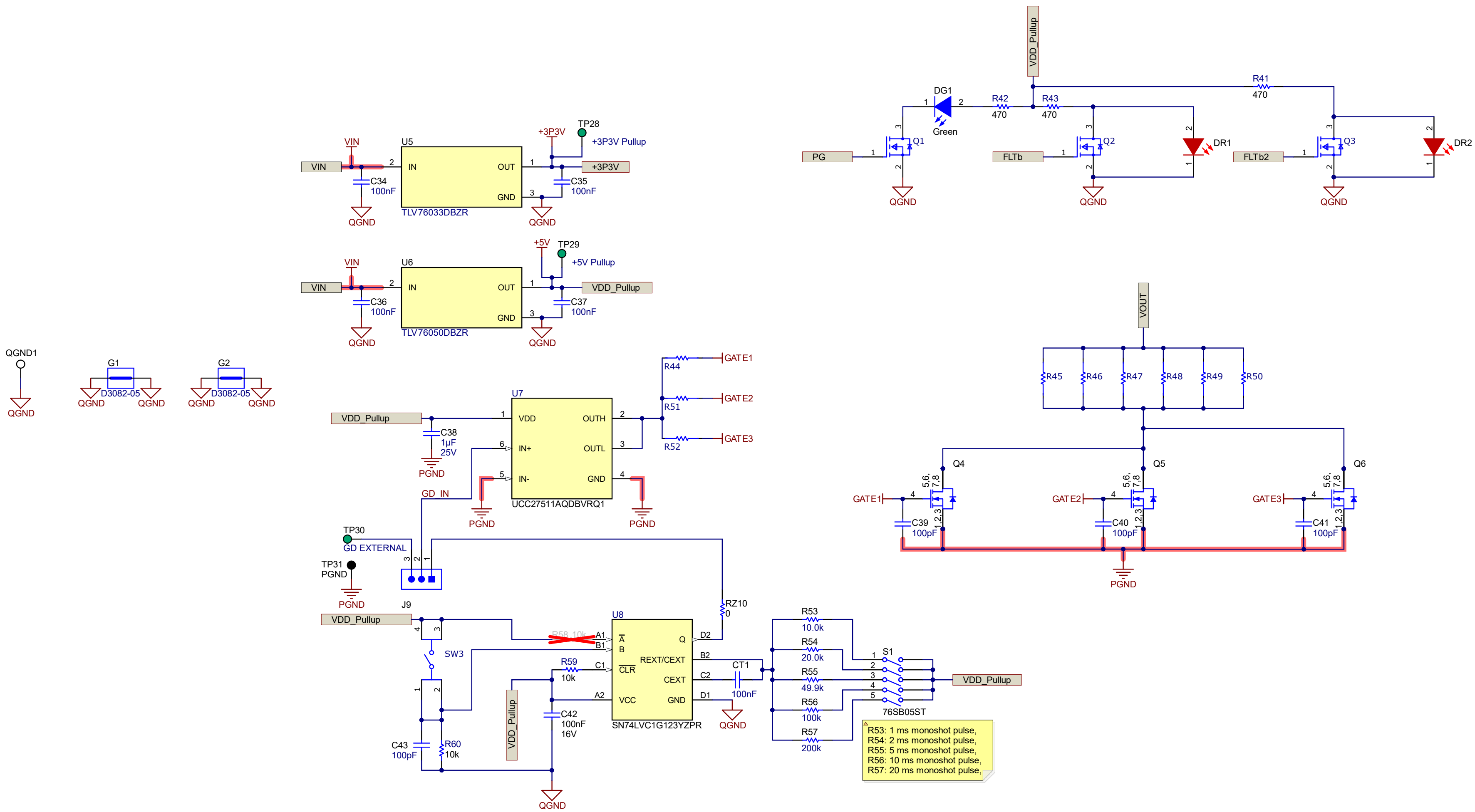


Figure 3-1. TPS25990EVM eFuse Evaluation Board Schematic

Note

- To evaluate the performance of TPS25990 at lower currents (< 50 A), RZ5, RZ6, RZ7, RZ8, & RZ9 resistors need to be depopulated, and R39 & R40 resistors must be populated to disable the secondary eFuse (TPS25985).
- The ground connections for the various components around the TPS25990 & TPS25985 must be wired directly to each other and the GND pins of respective eFuses. This must be followed by connecting them to the system ground at one point, as implemented using RZ1 and RZ4 resistors in the EVM schematic. Do not connect the various component grounds through the high current system ground line.

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4 General Configurations

4.1 Physical Access

Table 4-1 lists the TPS25990EVM eFuse Evaluation Board input and output connectors functionality. Table 4-2 and Table 4-3 describe the availability of test points and the functionality of the jumpers. Table 4-4 summarizes the way to configure the device address. Table 4-5 presents the function of the signal LED.

Table 4-1. Input and Output Connector Functionality

Connector	Label	Description
T1	VIN (+)	Positive terminal for the input power to the EVM
T2	VOUT (+)	Positive terminal for the output power from the EVM
T3	PGND (–)	Negative terminal for the EVM (common for both input and output)

Table 4-2. Test Points Description

Test Points	Label	Description
TP1	S1_P	Kelvin sensing points to measure • Combined on-resistance with both TPS25990 & TPS25985 eFuses enabled, • On-resistance of the primary device, TPS25990 (U1) when the secondary device, TPS25985 (U2) disabled.
TP2	S1_N	
TP3	VIN	Input Voltage
TP4	VOUT	Output Voltage
TP5	MODE2	MODE selection: Secondary Device
TP6	FLTb2	Open-drain active low fault indication: Secondary Device
TP7	VDD	Controller input power
TP8	FLTb	Open-drain active low fault indication: Primary Device
TP9	SWEN	Open-drain signal to indicate and control power switch ON and OFF status
TP10	TEMP	Maximum device die temperature monitor analog voltage output with TPS25990 and TPS25985 in parallel
TP11	CMPM2	General purpose comparator negative input: Secondary Device
TP12	AUX	Auxiliary ADC input channel used to monitor external analog signal through PMBus Also functions as analog input for fast comparator with internal programmable threshold
TP13	CMPP2	General purpose comparator positive input: Secondary Device
TP14	CMPOUT2	General purpose comparator open-drain output: Secondary Device
TP15	DVDT	Start-up output slew rate control
TP16	DAC1	Programmable DAC analog buffered current output
TP17	IMON	Load current monitor and overcurrent threshold and fast-trip threshold during steady-state
TP18	ILIM2	Current limit and fast-trip threshold during start-up: Secondary Device
TP19	ILIM	Current limit and fast-trip threshold during start-up: Primary Device
TP20	IREF	Reference voltage for overcurrent & short-circuit protections, and active current sharing blocks
TP21	PG	Open-drain active high power good indication
TP22	EN	Active high enable input
TP23	ADDR0	PMBus Address Configuration Pin
TP24	ADDR1	PMBus Address Configuration Pin
TP25	SMBA	SMBus™ alert output
TP26	SDA	PMBus data line
TP27	SCL	PMBus clock line
TP28	+3P3V Pullup	3.3 V pullup power supply generated using a LDO from VIN
TP29	+5V Pullup	5 V pullup power supply generated using a LDO from VIN
TP30	GD EXTERNAL	External gate signal for custom load transient
TP31	PGND	Supply ground
QGND1	QGND	Device ground

Table 4-2. Test Points Description (continued)

Test Points	Label	Description
G1	QGND	Device ground
G2	QGND	Device ground

Table 4-3. Jumper Descriptions and Default Positions

Jumper	Label	Description	Default Jumper Position
J2	SWEN	1-2 Position: The SWEN pullup supply is generated from VIN using a Zener diode	1-2
		3-4 Position: The SWEN pullup supply is generated from VIN using a LDO	
J3	DVDT	1-2 Position sets the output slew rate to 1.8 V/ms	5-6
		3-4 Position sets the output slew rate to 12 V/ms	
		5-6 Position sets the output slew rate to 1.2 V/ms	
J4	ILIM	1-2 Position sets the inrush current limit to 25 A and the active current sharing threshold to 40 A with V_{IREF} of 1 V: Primary Device	1-2
		3-4 Position sets the inrush current limit to 19 A and the active current sharing threshold to 30 A with V_{IREF} of 1 V: Primary Device	
J5	ILIM2	1-2 Position sets the inrush current limit to 32 A and the active current sharing threshold to 50 A with V_{IREF} of 1 V: Secondary Device	1-2
		3-4 Position sets the inrush current limit to 38 A and the active current sharing threshold to 60 A with V_{IREF} of 1 V: Secondary Device	
J6	IMON	1-2 Position sets the circuit breaker threshold to 70-A with V_{IREF} of 1-V: Both primary and secondary devices are connected in parallel	1-2
		3-4 Position sets the circuit breaker threshold to 110-A with V_{IREF} of 1-V: Both primary and secondary devices are connected in parallel	
J9	EXTERNAL GATE SIGNAL	1-2 Position provides the GATE signal to the MOSFETs (Q4 – Q6) from the on-board mono-shot timer	1-2
		2-3 Position provides the GATE signal to the MOSFETs (Q4 – Q6) from the external signal generator	

Table 4-4. Configuring Device Address

J7 (ADDR0)	J8 (ADDR1)	Address	Default Address Set in the EVM
OPEN	OPEN	0x40	0x46
	GND (1-2 Position)	0x41	
	75 kΩ to GND (3-4 Position)	0x42	
	150 kΩ to GND (5-6 Position)	0x43	
	267 kΩ to GND (7-8 Position)	0x44	
GND (1-2 Position)	OPEN	0x45	
	GND (1-2 Position)	0x46	
	75 kΩ to GND (3-4 Position)	0x47	
	150 kΩ to GND (5-6 Position)	0x48	
	267 kΩ to GND (7-8 Position)	0x49	
75 kΩ to GND (3-4 Position)	OPEN	0x4A	
	GND (1-2 Position)	0x4B	
	75 kΩ to GND (3-4 Position)	0x4C	
	150 kΩ to GND (5-6 Position)	0x4D	
	267 kΩ to GND (7-8 Position)	0x4E	
150 kΩ to GND (5-6 Position)	OPEN	0x50	
	GND (1-2 Position)	0x51	
	75 kΩ to GND (3-4 Position)	0x52	
	150 kΩ to GND (5-6 Position)	0x53	
	267 kΩ to GND (7-8 Position)	0x54	
267 kΩ to GND (7-8 Position)	OPEN	0x55	
	GND (1-2 Position)	0x56	
	75 kΩ to GND (3-4 Position)	0x57	
	150 kΩ to GND (5-6 Position)	0x58	
	267 kΩ to GND (7-8 Position)	0x59	

Table 4-5. LED Descriptions

LED	Description
DG1	When ON, indicates that PG is asserted
DR1	When ON, indicates that FLTb is asserted
DR2	When ON, indicates that FLTb2 is asserted

4.2 Test Equipment and Setup

4.2.1 Power supplies

One adjustable power supply with 0-V to 30-V output and 0-A to 200-A output current limit

4.2.2 Meters

Two (2) Digital Multi Meters (DMM)

4.2.3 Oscilloscope

A DPO2024 or equivalent, three 10x voltage probes, and a DC current probe of 150 A rated

4.2.4 USB-to-GPIO Interface Adapter

A communication adapter is required between the TPS25990EVM and the host computer to use TPS25990EVM-GUI. The GUI communicates with the Texas Instruments USB-TO-GPIO**2** USB interface adapter evaluation module only. This adapter can be purchased at USB-TO-GPIO2 Evaluation board | TI.com.

TPS25990EVM kit does not include this USB-TO-GPIO2 adapter.

Note

The TPS25990EVM-GUI does not communicate with USB-TO-GPIO USB Interface Adapter EVM.

4.2.5 Loads

One resistive load or equivalent which can tolerate up to 150-A DC load at 24-V

5 Test Setup and Procedures

In this user's guide, the test procedure is described for TPS25990 eFuse. Make sure the evaluation board has default jumper settings as shown in Table 5-1.

Table 5-1. Default Jumper Setting for TPS25990EVM eFuse Evaluation Board

J2	J3	J4	J5	J6	J7	J8	J9
1-2	5-6	1-2	1-2	1-2	1-2	1-2	1-2

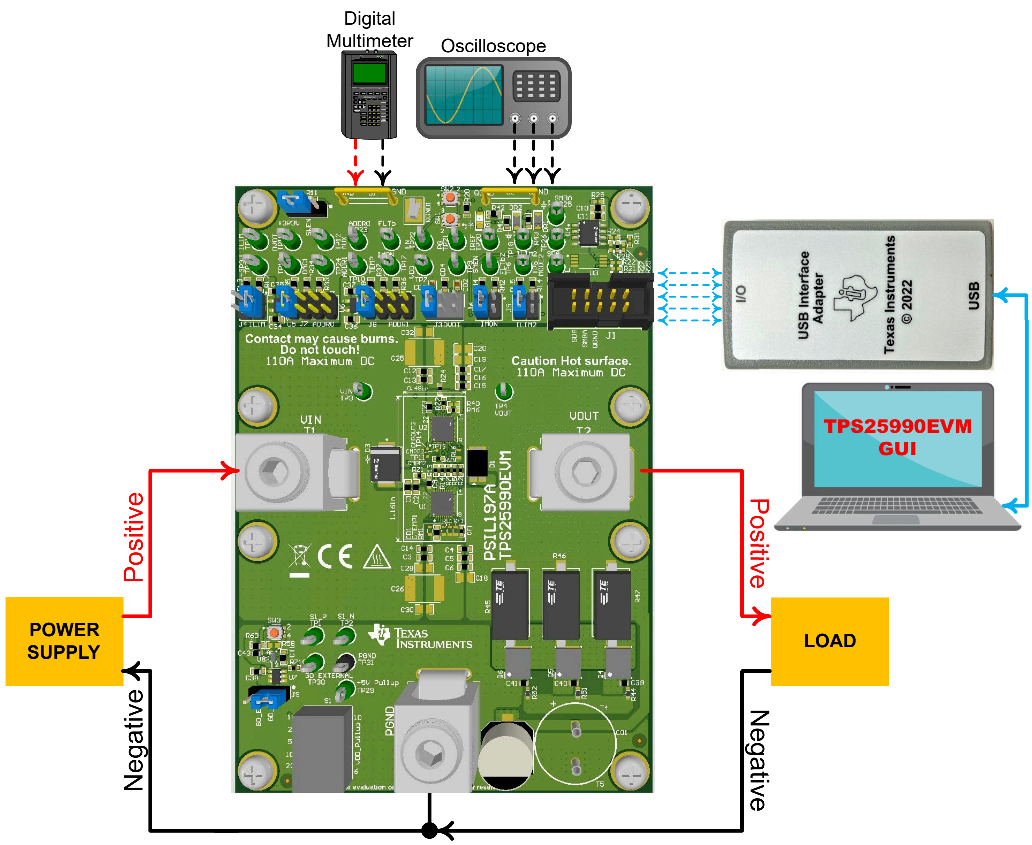

Figure 5-1. TPS25990EVM Setup with Test Equipment

Follow these instructions before starting any test and repeat again before moving to the next test:

- Set the power supply output (VIN) to zero volts.
- Turn off the power supply.
- Adjust the jumper positions on EVM to the default configuration as shown in Table 5-1.
- Turn the power supply on and set the power supply output (VIN) to 12 V, 200 A, and keep the power supply output disabled.
- Enable the power supply output so that the EVM gets the input power supply.

5.1 Hot Plug

Use the following instructions to measure the inrush current during hot plug event:

1. Configure the jumper J3 position to the desired slew rate mentioned in Table 4-3.
2. Configure the jumpers J4 and J5 positions to the desired current limits during start-up as mentioned in Table 4-3.
3. The reference voltage for overcurrent protection and active current sharing is at 1 V by default.
4. Connect a load of 0.4 Ω between VOUT (Connector T2) and PGND (Connector T3).
5. Connect the negative terminal of the power supply to connector T3.
6. Set the input supply voltage VIN to 12 V and current limit to 100 A. Enable the power supply.
7. Hot plug the positive terminal of the power supply at connector T1.
8. Observe the waveforms at VOUT (TP4) and input current using an oscilloscope to measure the slew rate and rise time of the VOUT with a given input voltage of 12 V.

Figure 5-2 shows the waveforms captured on the TPS25990EVM with one (1) TPS25990 eFuse and one (1) TPS25985 eFuse in parallel during the hot plug event.

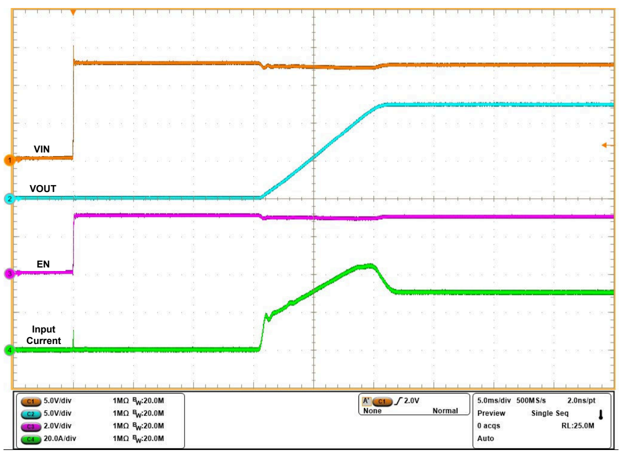

Figure 5-2. Hot Plug Profile with TPS25990 eFuse and TPS25985 eFuse in Parallel (V_{IN} Stepped Up from 0 V to 12 V, C_{OUT} = 15.47 mF, C_{DVDT} = 33 nF, $R_{ILIM(TPS25990)}$ = 523 Ω, $R_{ILIM(TPS25985)}$ = 402 Ω, V_{IREF} = 1 V, and R_{LOAD} = 0.4 Ω)

5.2 Start-up with Enable

Use the following instructions to power up the TPS25990EVM with ENABLE:

1. Configure the jumper J3 position to the desired slew rate mentioned in Table 4-3.
2. Configure the jumpers J4 and J5 positions to the desired current limits during start-up as mentioned in Table 4-3.
3. The reference voltage for overcurrent protection and active current sharing is at 1 V by default. The reference voltage is also programmed through PMBus using the VIREF (E0h) register if another reference voltage is needed in the range of 0.3 V to 1.2 V.
4. Set the input supply voltage VIN to 12 V and current limit to 100 A.
5. Connect a load of 0.4 Ω between VOUT (Connector T2) and PGND (Connector T3).
6. Connect the input supply between VIN (Connector T1) and PGND (Connector T3).
7. Turn on the power supply by keeping the device disabled using the switch SW1.
8. Enable the eFuses by releasing the switch SW1.
9. Observe the waveform at VOUT (TP4) and input current using an oscilloscope to measure the slew rate and rise time of the VOUT with a given input voltage of 12 V.

Figure 5-3 shows the start-up profile with ENABLE using one (1) TPS25990 eFuse and one (1) TPS25985 eFuse in parallel. Figure 5-4 presents the current sharing between two eFuses during start-up.

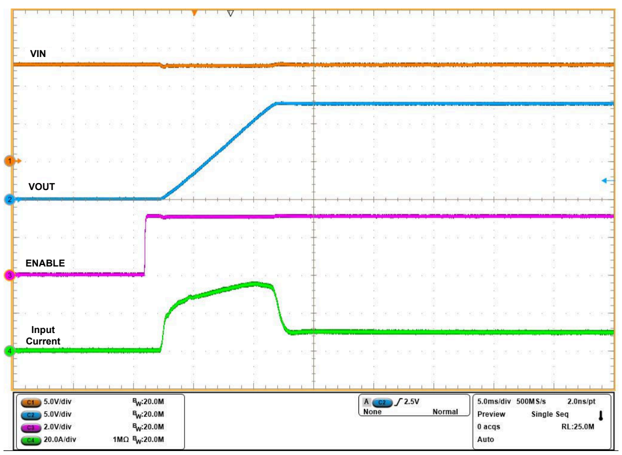

Figure 5-3. Start-up Profile with ENABLE (V_{IN} = 12 V, EN Stepped Up from 0 V to 3 V, C_{OUT} = 18.47 mF, R_{LOAD} = 1.2 Ω, $R_{ILIM(TPS25990)}$ = 523 Ω, $R_{ILIM(TPS25985)}$ = 402 Ω, V_{IREF} = 1 V, and C_{DVDT} = 33 nF)

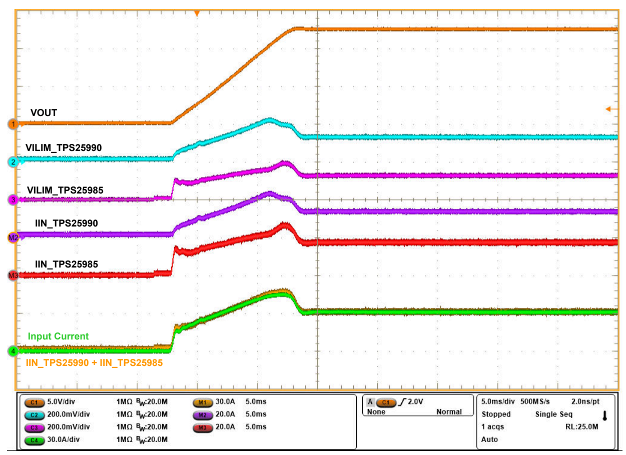

Figure 5-4. Start-up Profile with ENABLE: Current Sharing between TPS25990 and TPS25985 eFuses (V_{IN} = 12 V, EN Stepped Up from 0 V to 3 V, C_{OUT} = 15.47 mF, R_{LOAD} = 0.4 Ω, $R_{ILIM(TPS25990)}$ = 523 Ω, $R_{ILIM(TPS25985)}$ = 402 Ω, V_{IREF} = 1 V, and C_{DVDT} = 33 nF)

5.3 Current Limit Based Start-up Behavior

Use the following instructions to perform the start-up with current limit test:

1. Configure the jumper J3 position to the desired slew rate mentioned in Table 4-3.
2. Configure the jumpers J4 and J5 positions to the desired current limits during start-up as mentioned in Table 4-3.
3. The reference voltage for overcurrent protection and active current sharing is at 1 V by default. The reference voltage can also be programmed via PMBus using the VIREF (E0h) register if another reference voltage is needed in the range of 0.3 V to 1.2 V.
4. Set the input supply voltage VIN to 12 V and current limit to 100 A.
5. Connect a load of 0.45 Ω between VOUT (Connector T2) and PGND (Connector T3).
6. Connect the input supply between VIN (Connector T1) and PGND (Connector T3).
7. Turn on the power supply by keeping the device disabled using the switch SW1.
8. Enable the eFuse by releasing the switch SW1.
9. Observe the waveform at VOUT (TP4) and input current using an oscilloscope. The main intention of this test is to observe the output voltage and input current profiles and time required to complete the inrush with two different current limit set points during start-up having all other test conditions identical. The inrush current hits the current limit set point in one case, but does not in the next.

Figure 5-5 shows the current limit-based start-up behavior on the TPS25990EVM having one TPS25990 eFuse and one TPS25985 eFuse in parallel with $R_{ILIM(TPS25990)}$ of 665 Ω and $R_{LIM(TPS25985)}$ of 499 Ω.

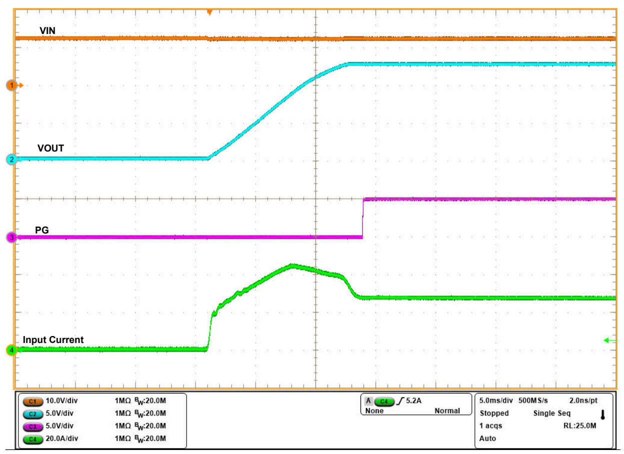

Figure 5-5. Start-up with Current Limit Response in TPS25990EVM (V_{IN} = 12 V, EN Stepped Up from 0 V to 3 V, $R_{ILIM(TPS25990)}$ = 665 Ω, $R_{LIMI(TPS25985)}$ = 499 Ω, V_{IREF} = 1 V, C_{OUT} = 18.47 mF, R_{LOAD} = 0.45 Ω, and C_{DVDT} = 33 nF)

5.4 Power Up into Short

Use the following instructions to perform the power up into short test:

1. Set the input supply voltage VIN to 12 V and current limit to 100 A. Keep the power supply OFF.
2. Short the output of the EVM. For example, VOUT (Connector T2) to PGND (Connector T3) through a short and thick cable to make sure the short-circuited path impedance is minimum as possible.
3. The reference voltage for overcurrent protection and active current sharing is at 1 V by default.
4. Configure the jumpers J4 and J5 positions to the desired current limits during start-up as mentioned in Table 4-3.
5. Keep the eFuses disabled by pushing the switch SW1.
6. Turn ON the power supply.
7. Enable the eFuses by releasing the switch SW1.

Figure 5-6 shows the test waveforms of power up into output short on the TPS25990EVM with one TPS25990 eFuse and one TPS25985 eFuse in parallel. Figure 5-7 presents the current sharing between two eFuses during start-up into short.

Note

During power-up into short, a thermal fold-back results in the current flowing through the device being less than the calculated value of the current limit during start-up.

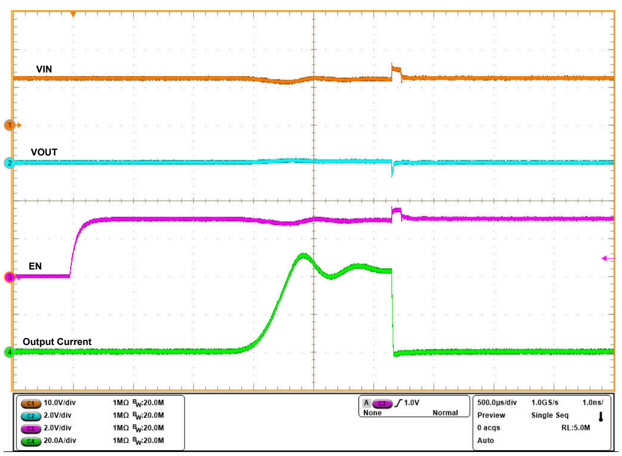

Figure 5-6. Power Up into Output Short Response in TPS25990EVM (V_{IN} = 12 V, EN Stepped Up from 0 V to 3 V, $R_{ILIM(TPS25990)}$ = 665 Ω, $R_{ILIM(TPS25985)}$ = 499 Ω, V_{IREF} = 1 V, and OUT Shorted to PGND)

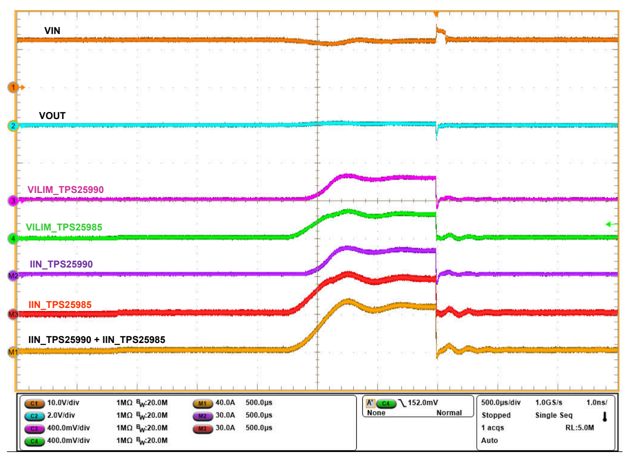

Figure 5-7. Power Up into Output Short Response in TPS25990EVM: Current Sharing between TPS25990 and TPS25985 eFuses (V_{IN} = 12 V, EN Stepped Up from 0 V to 3 V, $R_{ILIM(TPS25990)}$ = 665 Ω, $R_{LIMI(TPS25985)}$ = 499 Ω, V_{IREF} = 1 V, and OUT Shorted to PGND)

5.5 Overvoltage Lockout

Use the following instructions to perform the overvoltage protection test:

1. Set the input supply voltage VIN to 12 V and the current limit to 100 A. Connect the supply between VIN (Connector T1) and PGND (Connector T3) and enable the power supply.
2. Apply a load of 1.2 Ω between VOUT (Connector T2) and PGND (Connector T3).
3. Increase the input supply VIN from 12 V to 18 V and observe the waveforms using an oscilloscope.

Note

The input TVS diodes need to be removed during the overvoltage protection test. **Make sure to put them back after this experiment.**

Figure 5-8 shows overvoltage lockout response of TPS25990 eFuse on TPS25990EVM.

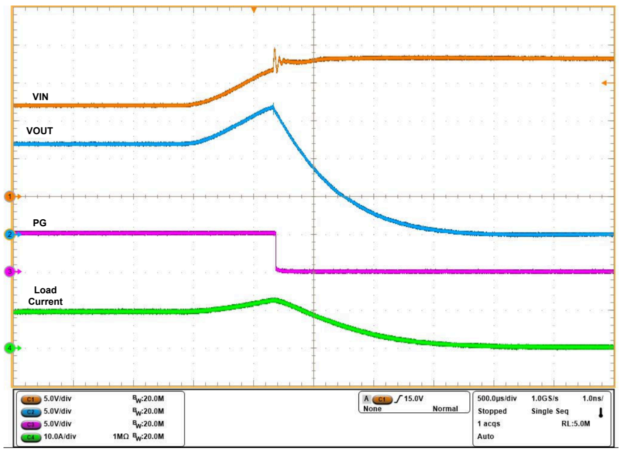

Figure 5-8. Overvoltage Lockout Response of TPS25990 eFuse (V_{IN} Ramped Up from 12 V to 18 V, C_{OUT} = 470 µF, and R_{LOAD} = 1.2 Ω)

5.6 Transient Overload Performance

Use the following instructions to observe the transient overload performance:

1. The overcurrent blanking timer duration (t_{TIMER}) is 2.18 ms by default. The overcurrent blanking timer duration can be programmed via PMBus using the OC_TIMER (E6h) register if another timer duration is needed in the range of 0 ms to 27.8 ms.
2. The reference voltage for overcurrent protection and active current sharing is at 1 V by default. The reference voltage can also be programmed via PMBus using the VIREF (E0h) register if another reference voltage is needed in the range of 0.3 V to 1.2 V.
3. Place jumper J6 in a good position to set required circuit breaker threshold (I_{OCP}) as per Table 4-3.
4. Set the input supply voltage VIN to 12 V and current limit of 200 A.
5. Connect the power supply between VIN (Connector T1) and PGND (Connector T3) and enable the power supply.
6. Now apply an overload in the range of $I_{OCP} < I_{LOAD} < 2 \times I_{OCP}$ between VOUT (Connector T2) and PGND (Connector T3) for a time duration less than t_{TIMER} decided by using the OC_TIMER (E6h) register through PMBus.
7. Observe the waveforms using an oscilloscope.

Figure 5-9 shows transient overload performance in TPS25990EVM with one TPS25990 eFuse and one TPS25985 eFuse in parallel. Figure 5-10 presents the current sharing between two eFuses during the transient overload.

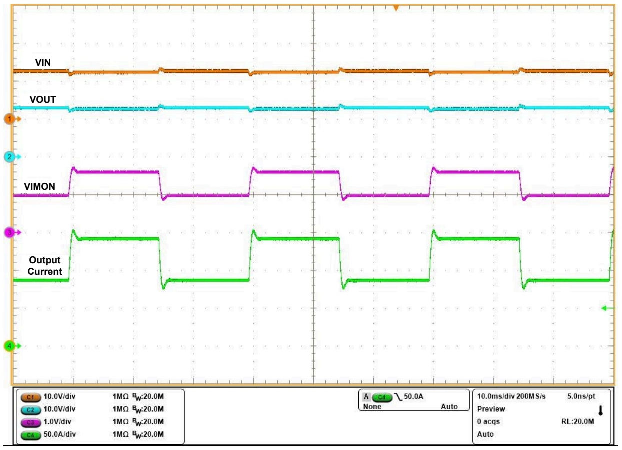

Figure 5-9. Transient Overload Performance in TPS25990EVM (V_{IN} = 12 V, t_{ITIMER} = 20 ms, C_{OUT} = 470 µF, R_{IMON} = 1.47 ‖ 1.1 kΩ, V_{IREF} = 1 V, I_{OUT} Ramped from 85 A to 140 A then 85 A within 15 ms)

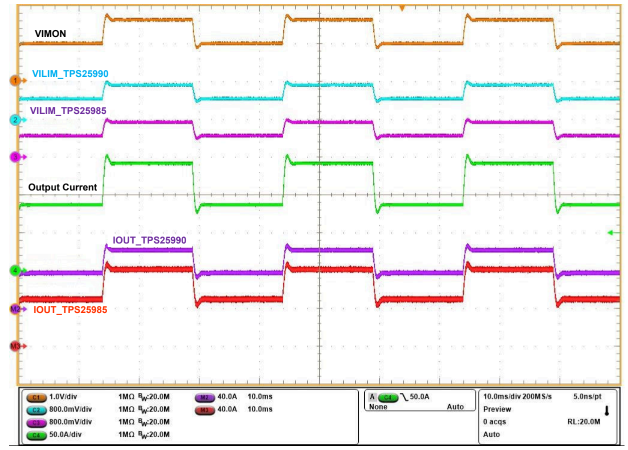

Figure 5-10. Transient Overload Performance in TPS25990EVM: Current Sharing between TPS25990 and TPS25985 eFuses (V_{IN} = 12 V, t_{ITIMER} = 20 ms, C_{OUT} = 470 µF, R_{IMON} = 1.47 ‖ 1.1 kΩ, V_{IREF} = 1 V, I_{OUT} Ramped from 85 A to 140 A then 85 A within 15 ms)

5.7 Overcurrent Event

Use the following instructions to perform the overcurrent test on TPS25990 eFuse:

1. The overcurrent blanking timer duration (t_{TIMER}) is 2.18 ms by default. The overcurrent blanking timer duration can be programmed via PMBus using the OC_TIMER (E6h) (E6h) register if another timer duration is needed in the range of 0 ms to 25.5 ms.
2. The reference voltage for overcurrent protection and active current sharing is at 1 V by default. The reference voltage can also be programmed via PMBus using the VIREF (E0h) register if another reference voltage is needed in the range of 0.3 V to 1.2 V.
3. Place jumper J6 in a good position to set required circuit breaker threshold (I_{OCP}) as per Table 4-3.
4. Set the input supply voltage VIN to 12 V and current limit to 200 A.
5. Connect the power supply between VIN (Connector T1) and PGND (Connector T3) and enable the power supply.
6. Now apply an overload in the range of $I_{OCP} < I_{LOAD} < 2 \times I_{OCP}$ between VOUT (Connector T2) and PGND (Connector T3) for a time duration more than t_{TIMER} decided by using the OC_TIMER (E6h) register through PMBus.
7. Observe the waveforms using an oscilloscope.

Figure 5-11 shows the circuit breaker response in TPS25990EVM with one TPS25990 eFuse and one TPS25985 eFuse in parallel. Figure 5-12 presents the current sharing between two eFuses during the circuit breaker event.

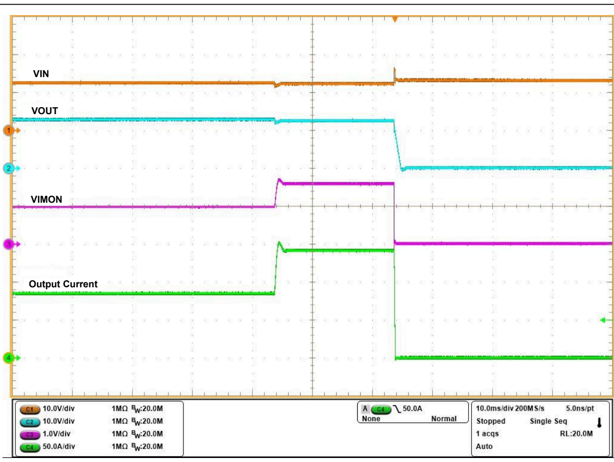

Figure 5-11. Overcurrent Performance in TPS25990EVM (V_{IN} = 12 V, t_{ITIMER} = 20 ms, C_{OUT} = 470 µF, R_{IMON} = 1.47 ‖ 1.1 kΩ, V_{IREF} = 1 V, I_{OUT} Ramped from 85 A to 140 A then 85 A within 30 ms)

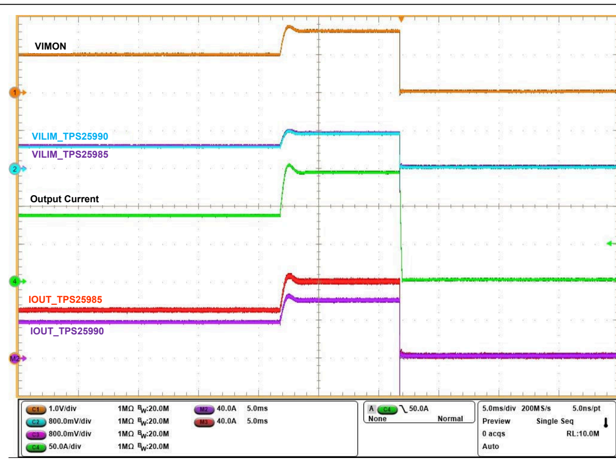

Figure 5-12. Overcurrent Performance in TPS25990EVM: Current Sharing between TPS25990 and TPS25985 eFuses (V_{IN} = 12 V, t_{ITIMER} = 10 ms, C_{OUT} = 470 µF, R_{IMON} = 1.47 ‖ 1.1 kΩ, V_{IREF} = 1 V, I_{OUT} Ramped from 85 A to 140 A then 85 A within 15 ms)

5.8 Provision to Apply Load Transient and Overcurrent Event Using an Onboard Switching Circuit

The TPS25990EVM provides an add-on circuit to facilitate load transients and persistent overcurrent events. The implementation consists of three low side MOSFETs (Q4, Q5, and Q6) and a mono-shot gate driver circuit (U7 and U8) as well as six onboard load resistors of 1 Ω each (R45 to R50) in parallel. Using a single pole single through (SPST) switch (S1), the mono-shot gate driver generates a gate signal lasting 1 ms, 2 ms, 5 ms, 10 ms, and 20 ms. By pressing the switch SW3, the low side MOSFETs are turned on for that specific duration, creating a load transient on the steady-state load above. Use the following instructions to apply a load transient or persistent overcurrent event using this onboard switching circuit:

1. The overcurrent blanking timer duration (t_{TIMER}) is 2.18 ms by default. The overcurrent blanking timer duration can be programmed via PMBus using the OC_TIMER (E6h) register if another timer duration is needed in the range of 0 ms to 27.8 ms.
2. The reference voltage for overcurrent protection and active current sharing is at 1 V by default. The reference voltage can also be programmed via PMBus using the VIREF (E0h) register if another reference voltage is needed in the range of 0.3 V to 1.2 V.
3. Configure the jumper J6 in a good position to set required circuit breaker threshold (I_{OCP}) as per Table 4-3.
4. Set the input supply voltage VIN to 12 V and current limit to 200 A.
5. Connect the power supply between VIN (Connector T1) and PGND (Connector T3) and enable the power supply.
6. Connect a steady-state load between VOUT (Connector T2) and PGND (Connector T3).
7. Use the single pole single through (SPST) switch (S1) to configure the transient load turn on duration. Press the switch SW3 to turn on the Q4, Q5, and Q6 MOSFETs, which creates a load transient of 72 A (typical) between VOUT and PGND with 12 V output.
8. Observe the waveforms of VOUT (TP4), MOSFET GATE (J9), and input current using an oscilloscope.

Another option is to apply a custom load transient using an external function generator, connected between TP30 and TP31, and the shunt of jumper J9 set to "2-3".

CAUTION

In that case, make sure to limit the transient load current magnitude to a safe level for reliable operation of the load resistors (R45 to R50) based on their maximum permissible peak pulse power vs pulse duration plot.

Figure 5-13 and Figure 5-14 show the test waveforms of transient overload and persistent overload events respectively using the onboard switching circuit.

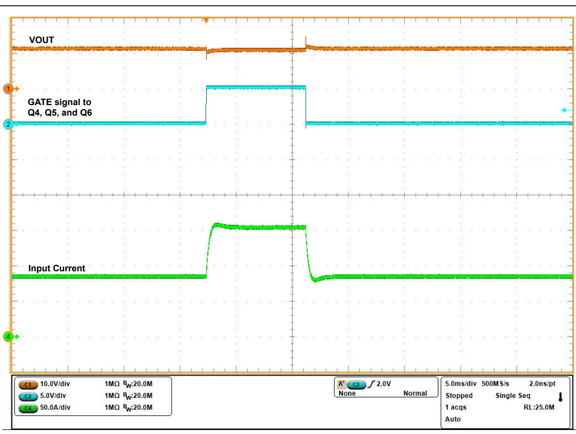

Figure 5-13. Transient Overload Performance in TPS25990EVM Using the Onboard Switching Circuit (V_{IN} = 12 V, t_{ITIMER} = 14 ms, C_{OUT} = 1470 µF, R_{IMON} = 1.47 ‖ 1.1 kΩ, V_{IREF} = 1 V, $I_{OUT(Steady\text{-}State)}$ = 85 A, and $I_{OUT(Transient)}$ = 65 A for 9 ms)

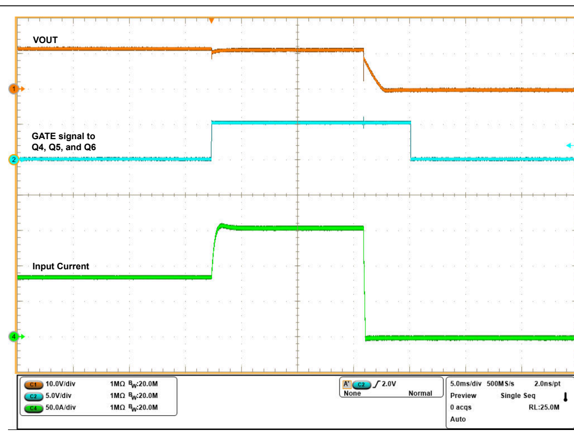

Figure 5-14. Persistent Overload Performance in TPS25990EVM Using the Onboard Switching Circuit (V_{IN} = 12 V, t_{ITIMER} = 14 ms, C_{OUT} = 1470 µF, R_{IMON} = 1.47 ‖ 1.1 kΩ, V_{IREF} = 1 V, $I_{OUT(Steady\text{-}State)}$ = 85 A, and $I_{OUT(Transient)}$ = 65 A for 18 ms)

5.9 Output Hot Short

Use the following instructions to perform the output hot short test:

1. Set the input supply voltage VIN to 12 V and connect the power supply between VIN (Connector T1) and PGND (Connector T3).
2. Turn ON the power supply.
3. Short the output of the device for example, VOUT (Connector T2) to PGND (Connector T3) through a shorter cable, which is just enough to insert a 150 A current probe.
4. Observe the waveforms using an oscilloscope.

Figure 5-15 shows the test waveforms of output hot short on the TPS25990EVM with one (1) TPS25990 eFuse and one (1) TPS25985 eFuse in parallel.

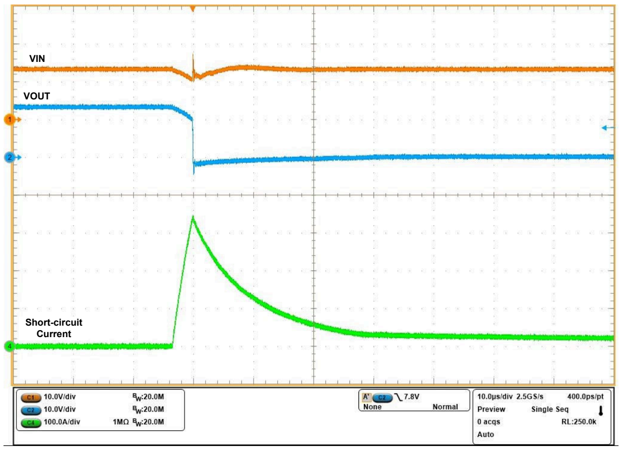

Figure 5-15. Output Hot Short Response in TPS25990EVM (V_{IN} = 12 V, R_{IMON} = 1.47 ‖ 1.1 kΩ, V_{IREF} = 1 V, and C_{OUT} = 10 µF)

Make sure there is sufficient input capacitor to eliminate voltage dips at the input. A combination of electrolytic and ceramic capacitors are preferred. With these capacitors, a large current can be provided for a short period of time during short-circuit.

Note that to obtain repeatable and similar short-circuit testing results is difficult. The following contributes to the variation in results:

- Source bypassing
- Input leads
- Board layout
- Component selection
- Output shorting method
- Relative location of the short
- Instrumentation

The actual short exhibits a certain degree of randomness because the actual short microscopically bounces and arcs. Verify that configuration and methods are used to obtain realistic results. Hence, do not expect to see waveforms exactly like the waveforms in this user's guide because every setup is different.

5.10 Quick Output Discharge (QOD)

Use the following instructions to observe the Quick Output Discharge (QOD) functionality:

1. Set the input supply voltage VIN to 12 V and current limit to 10 A. Turn ON the power supply.
2. Use the switch SW1 to connect the EN/UVLO pin to ground to do power cycling (QOD is disabled).
3. Use the switch SW2 to enable the QOD by making the voltage at EN/UVLO pin in the range of 0.8 V–1.1 V with the input voltage of 9.8 V–13.5 V (QOD is enabled).
4. Observe the waveforms of VIN (TP3), VOUT (TP4), PG (TP21), and EN (TP22) using an oscilloscope.

In Figure 5-16, the turn-off performance of the TPS25990 eFuse with QOD enabled is shown, whereas Figure 5-17 illustrates the turn-off performance with QOD disabled on the TPS25990EVM.

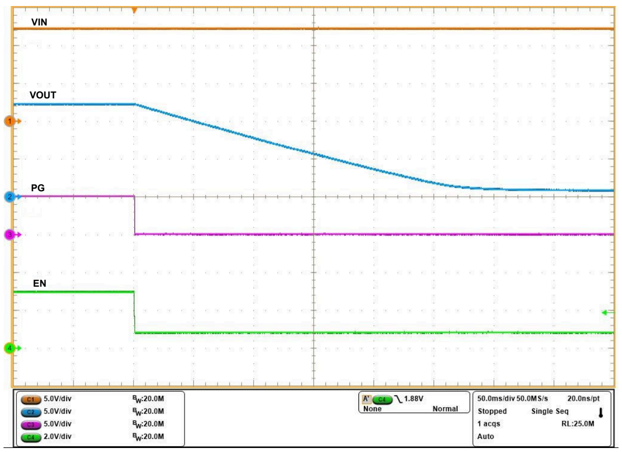

Figure 5-16. QOD Enabled on TPS25990 eFuse (V_{IN} = 12 V, C_{OUT} = 470 µF, and EN Pulled Low to 0.8 V)

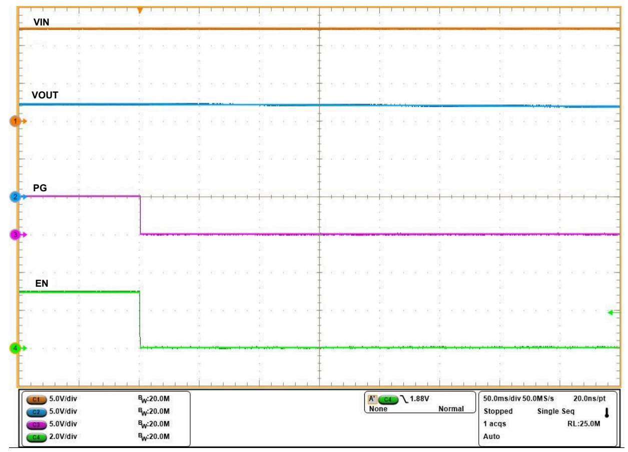

Figure 5-17. QOD Disabled on TPS25990 eFuse (V_{IN} = 12 V, C_{OUT} = 470 µF, and EN Pulled Low to 0 V)

5.11 Thermal Performance of TPS25990EVM

Use the following instructions to evaluate the thermal performance of TPS25990EVM:

1. The reference voltage for overcurrent protection and active current sharing is at 1 V by default. The reference voltage can also be programmed via PMBus using the VIREF (E0h) register if another reference voltage is needed in the range of 0.3 V to 1.2 V. VIREF is programmed to 1.13 V in this experiment.
2. Place jumper J6 in a good position to set required circuit breaker threshold (I_{OCP}) as per Table 4-3. The "3-4" position of the jumper J6 is selected in this experiment, which makes I_{OCP} as 124 A.
3. Set the input supply voltage VIN to 12 V and current limit of 130 A.
4. Connect the power supply between VIN (Connector T1) and PGND (Connector T3) and enable the power supply.
5. Now apply a load of 110 A (DC) between VOUT (Connector T2) and PGND (Connector T3) for half an hour or more to reach the thermal equilibrium point.
6. Capture the thermal image of the EVM or monitor the voltage at TEMP (TP10) pin using a digital multimeter. Voltage at the TEMP (V_{TEMP}) pin reports the maximum die temperature between TPS25990 and TPS25985, which can be obtained using Equation 1.

$$T_J(°C) = \left[25 + \left\{\frac{V_{TEMP}(mV) - 677.6}{2.72\ (mV/°C)}\right\}\right] \quad (1)$$

Figure 5-18 shows the thermal performance of TPS25990EVM with one (1) TPS25990 eFuse and one (1) TPS25985 eFuse in parallel.

Figure 5-18. Thermal Performance in TPS25990EVM (V_{IN} = 12 V, R_{IMON} = 0.91 ‖ 1.1 kΩ, V_{IREF} = 1.13 V, and I_{OUT} = 110 A)

6 Using the TPS25990EVM-GUI

6.1 Access the TPS25990EVM-GUI

After accessing the TPS25990EVM-GUI for the first time in a web browser (Preferably Google Chrome™ browser), the following pop-up appears as shown in Figure 6-1. Make sure to complete *Step 1* and *Step 2* and then click on the *FINISH* icon.

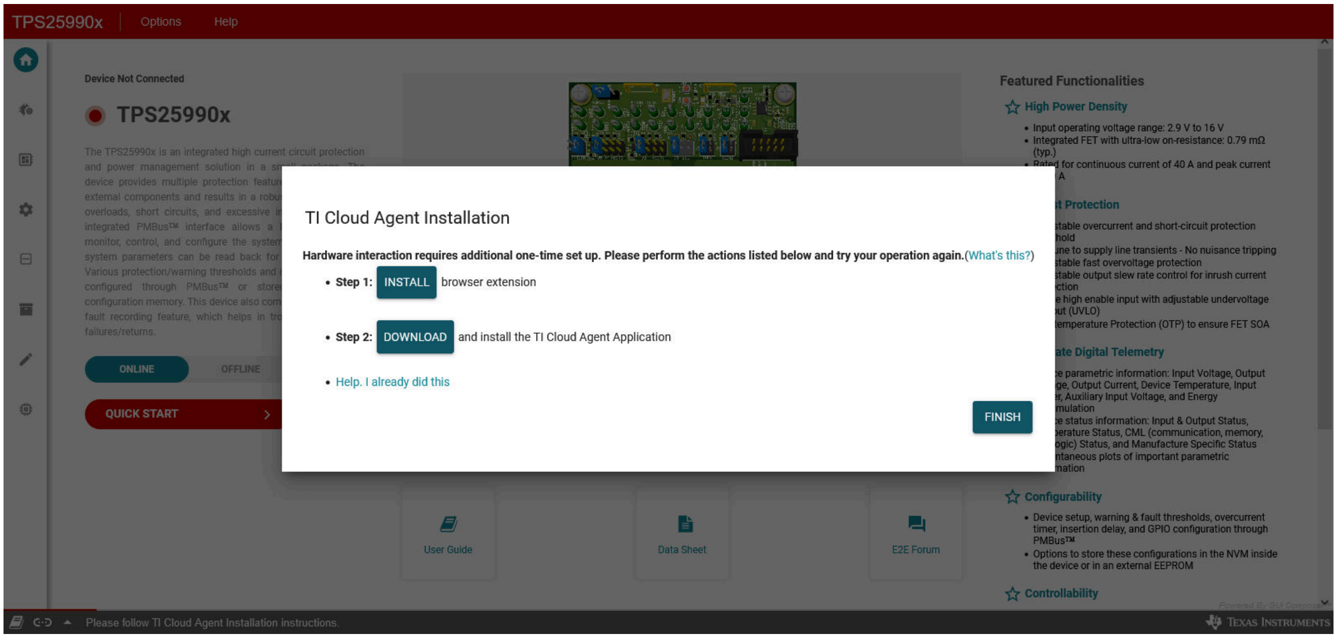

Figure 6-1. Prerequisite to Establish Communication Between the EVM and GUI

6.2 Introduction to the TPS25990EVM-GUI

On the introductory page of the GUI, shown in Figure 6-2, users are introduced to the TPS25990 eFuse functionalities and features. Furthermore, the page provides links to the TPS25990 eFuse data sheet, the TPS25990EVM user's guide, and the TI E2E™ forum where users can post their questions.

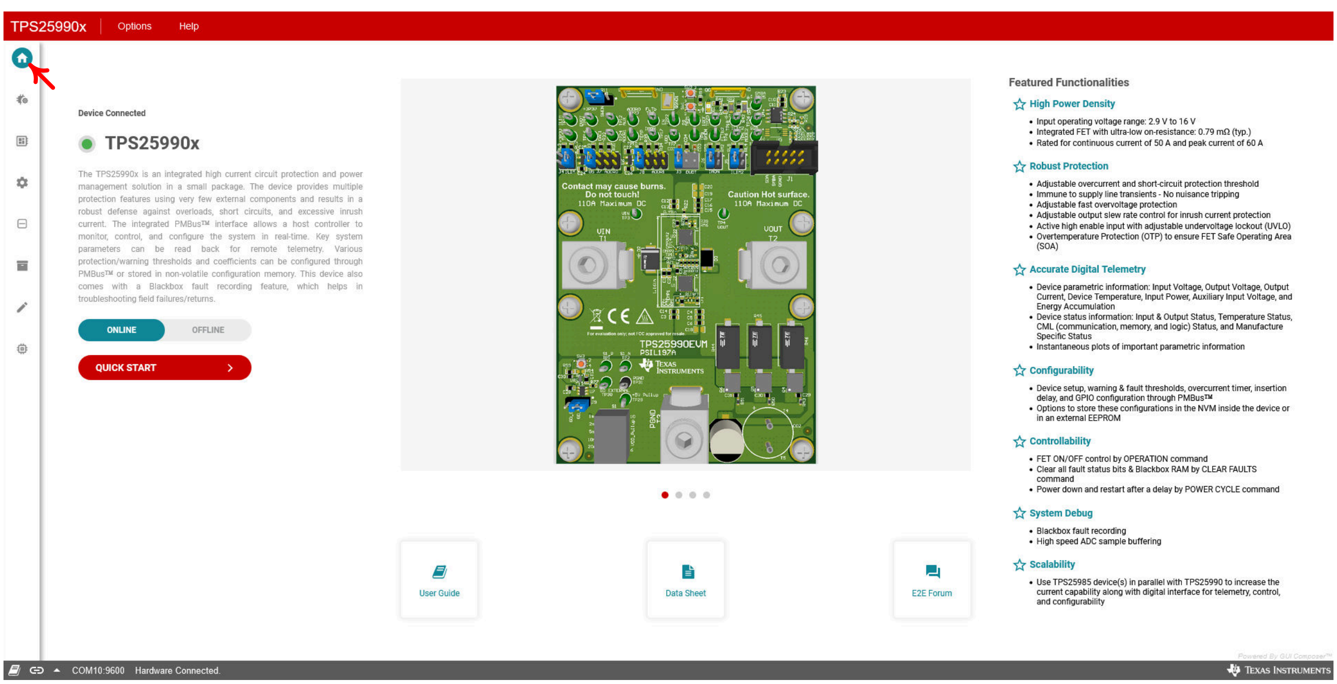

Figure 6-2. TPS25990EVM-GUI: Introduction

6.3 Establishing Communication Between the EVM and GUI

The steps to establish a connection between the GUI and EVM can be found on the *Hardware Setup* page in the GUI, as shown in Figure 6-3.

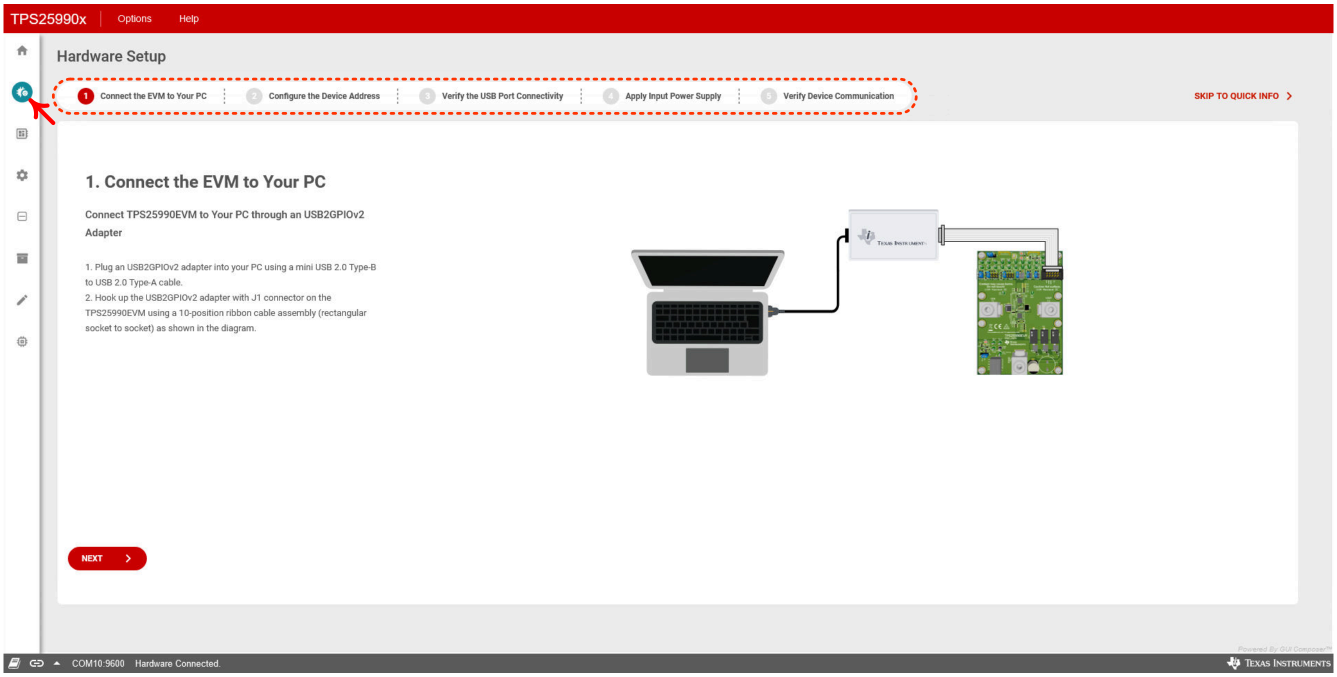

Figure 6-3. Hardware Setup: Establishing the Communication Between the EVM and GUI

Make sure to go through the all the steps carefully and verify the device communication at Step-5 on the *Hardware Setup* page as shown in Figure 6-4, after completing all the previous four steps as outlined.

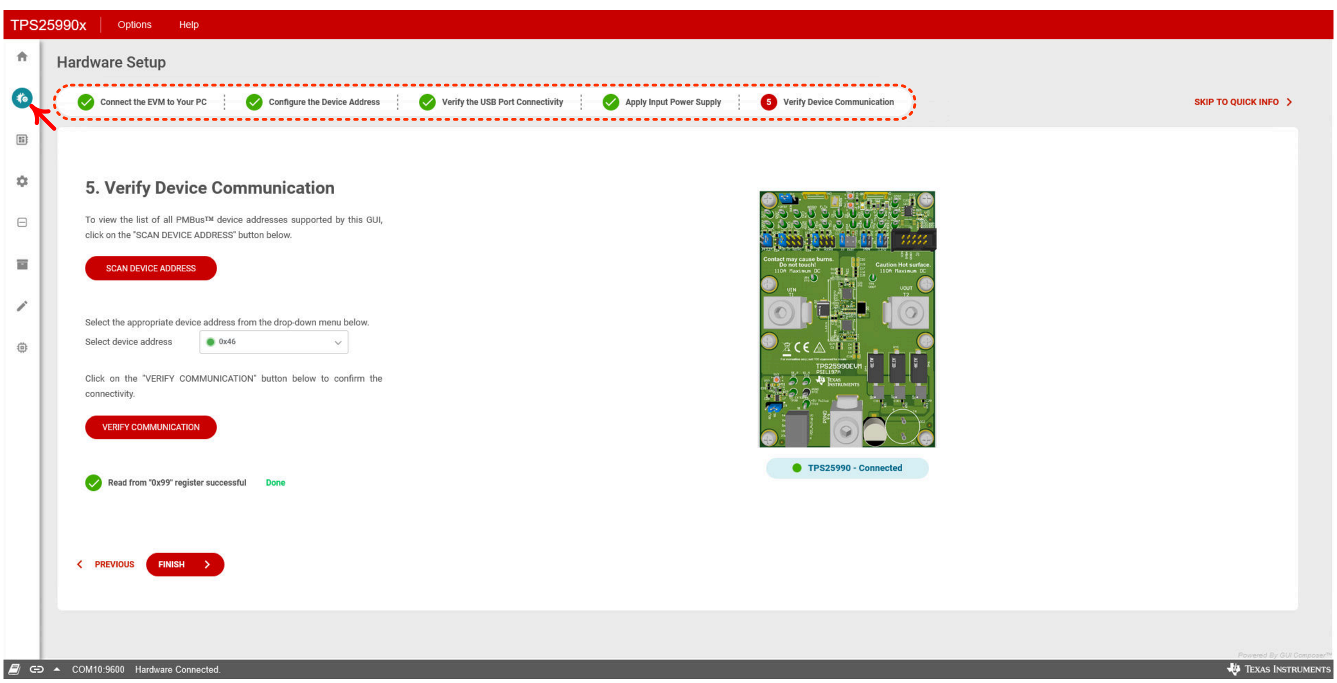

Figure 6-4. TPS25990EVM-GUI: Verify Device Connectivity

6.4 Quick Info

As presented in Figure 6-5, users reach to the *Quick Info* page after clicking on the *FINISH* icon upon verifying the device communication, depicted in Figure 6-4. As shown in Figure 6-5, this page can also be accessed by clicking on the *Quick Info* icon on the left side of the GUI. The *Quick Info* page provides the following features.

- PMBus addresses of all the devices, supported by this GUI
- All the important PMBus commands to control the TPS25990 eFuse, such as OPERATION (01h), POWER_CYCLE (D9h), MFR_WRITE_PROTECT (F8h), STORE_USER_ALL (15h), RESTORE_USER_ALL (16h), RESTORE_FACTORY_DEFAULTS (12h), and CLEAR_FAULTS (03h)
- Provision to import and export the user defined configuration file
- Option to enable or disable the Packet Error Checking (PEC) and to select the preferred PMBus speed
- Information about device state, PGOOD, $\overline{\text{SMBA}}$ (If the GPIO4 pin is configured as 'SMBA Output' in the GPIO_CONFIG_34 (E2h) register.), key device parameters & fault status, and STATUS_WORD (79h)
- Option to update (Clicking on the *Update Status* icon) the complete GUI as per the latest state in all the registers supported by the device

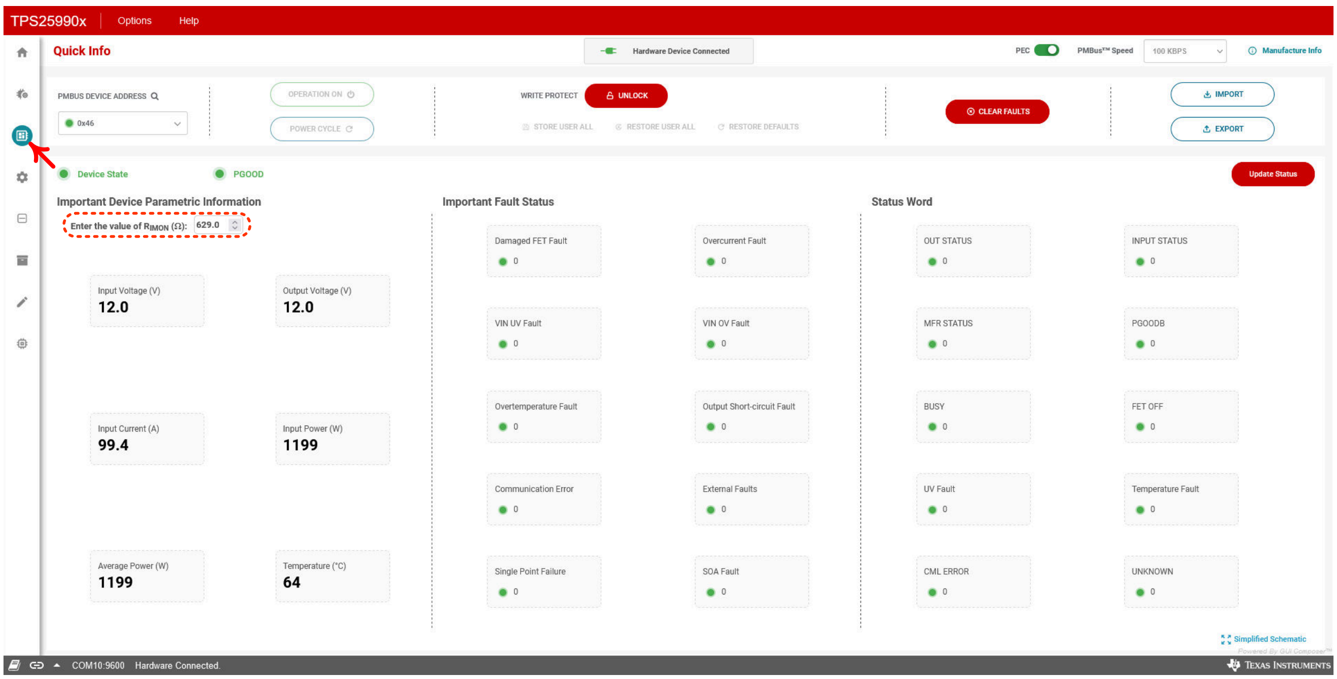

Figure 6-5. TPS25990EVM-GUI: Quick Info

Note

A correct value of input current (A) and input power (W) can only be obtained by updating R_{IMON} in the GUI (as pointed out by placing a RED circle in Figure 6-5) so that it matches the resistance placed at the IMON pin on the EVM.

6.5 Configuration

All the registers related to device configuration and setting up the different warning and fault thresholds are available under the *Configure* page as shown in Figure 6-6.

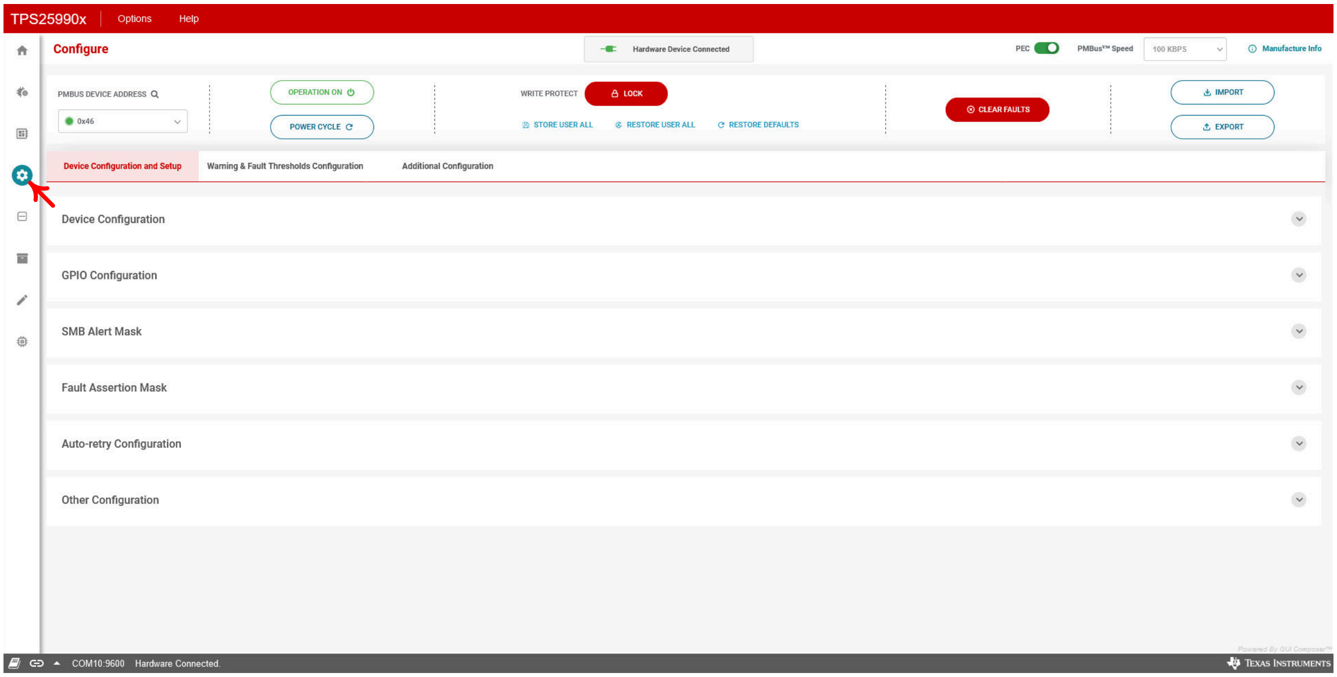

Figure 6-6. TPS25990EVM-GUI: Device Configuration

This portion of the GUI is divided into three tabs, *Device Configuration and Setup*, *Warning & Fault Thresholds Configuration*, and *Additional Configuration*.

Device Configuration and Setup tab includes the following registers in addition to the real world value of R_{IMON} resistance as shown in Figure 6-7:

- DEVICE_CONFIG (E4h)
- GPIO_CONFIG_12 (E1h)
- GPIO_CONFIG_34 (E2h)
- ALERT_MASK (DBh)
- FAULT_MASK (E3h)
- RETRY_CONFIG (E7h)
- INS_DLY (F9h)
- VIREF (E0h)

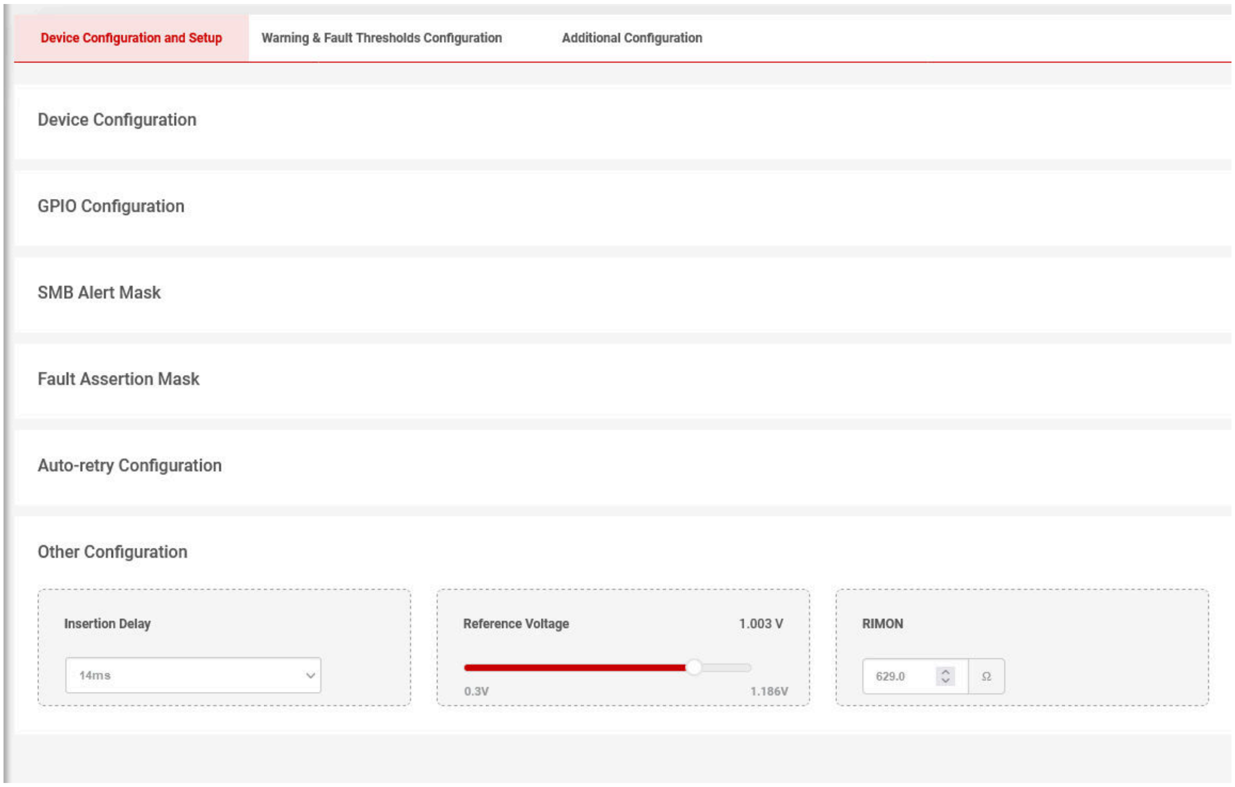

Figure 6-7. TPS25990EVM-GUI: Device Configuration: Device Configuration and Setup

Warning & Fault Thresholds Configuration tab includes the following registers as shown in Figure 6-8:

- VIN_UV_WARN (58h)
- VIN_UV_FLT (59h)
- VIN_OV_WARN (57h)
- VIN_OV_FLT (55h)
- VOUT_UV_WARN (43h)
- VOUT_PGTH (5Fh)
- OT_WARN (51h)
- OT_FLT (4Fh)
- PIN_OP_WARN (6Bh)
- IIN_OC_WARN (5Dh)
- OC_TIMER (E6h)

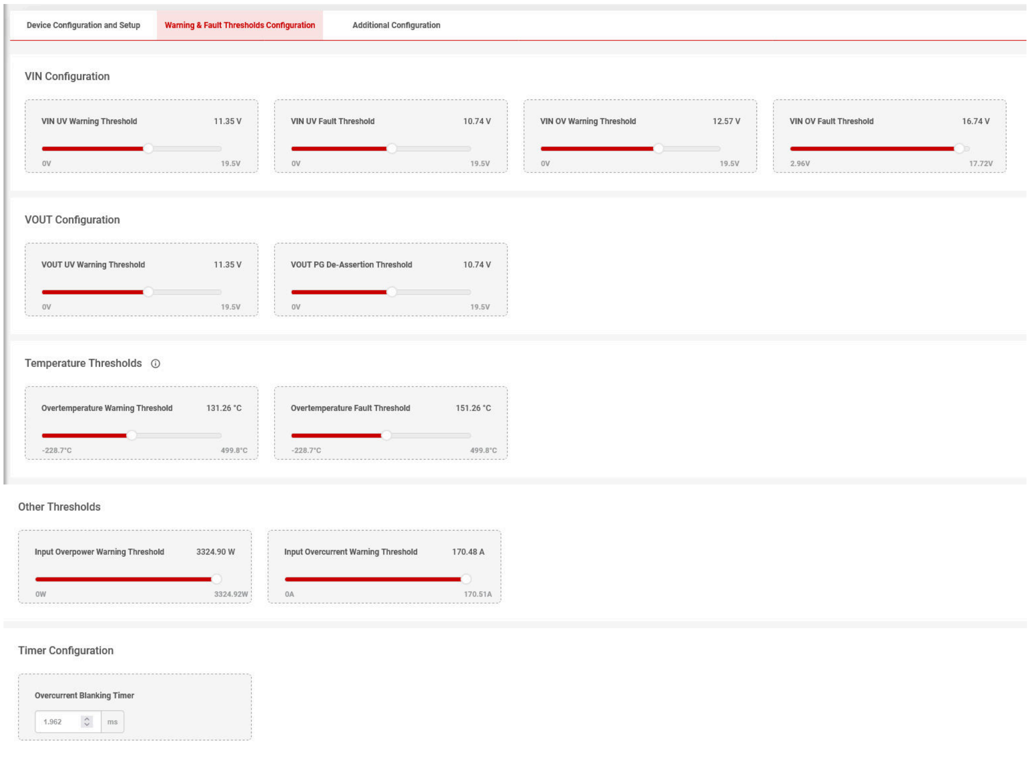

Figure 6-8. TPS25990EVM-GUI: Device Configuration: Warning & Fault Thresholds Configuration

Additional Configuration tab includes the following registers as shown in Figure 6-9:

- GPDAC1 (F0h)
- GPDAC2 (F1h)
- CABLE_DROP (EDh)
- PSU_VOLTAGE (ECh)
- VCMPxREF (EBh)

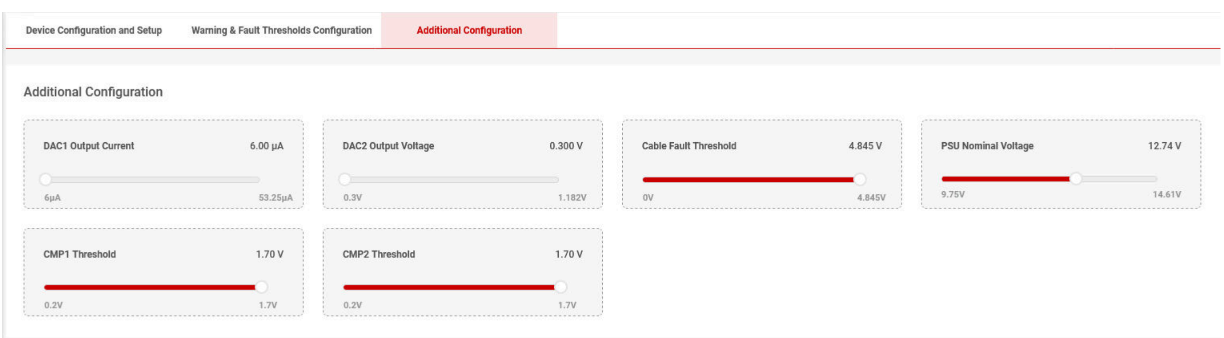

Figure 6-9. TPS25990EVM-GUI: Device Configuration: Additional Configuration

6.6 Telemetry

The *Telemetry* page as shown in Figure 6-10 guides the user through the device parametric data, status information, data read from the high speed sample buffer, and real time graphical plots of a few key device parameters.

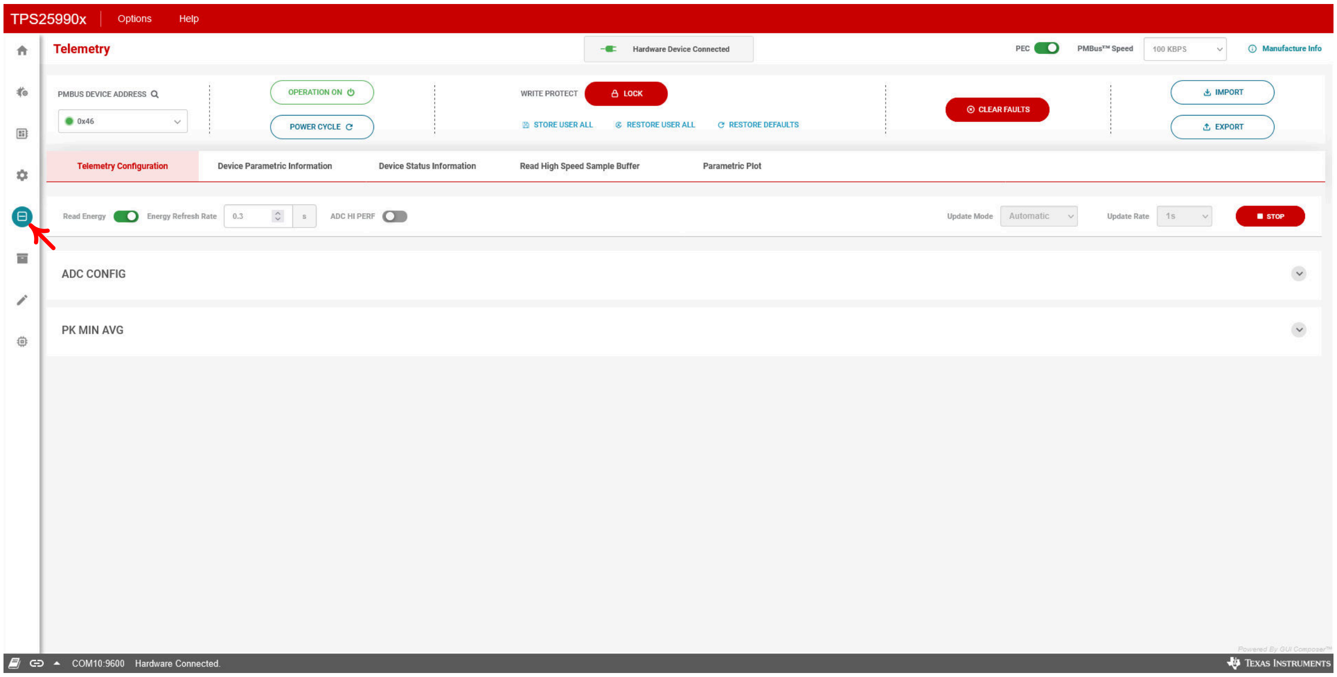

Figure 6-10. TPS25990EVM-GUI: Device Telemetry

This portion of the GUI is divided into five tabs, *Telemetry Configuration*, *Device Parametric Information*, *Device Status Information*, *Read High Speed Sample Buffer*, and *Parametric Plot*.

Telemetry Configuration tab includes the following registers as shown in Figure 6-11:

- ADC_CONFIG_1 (E8h)
- Bit[7] of ADC_CONFIG_2 (E9h)
- PK_MIN_AVG (EAh)

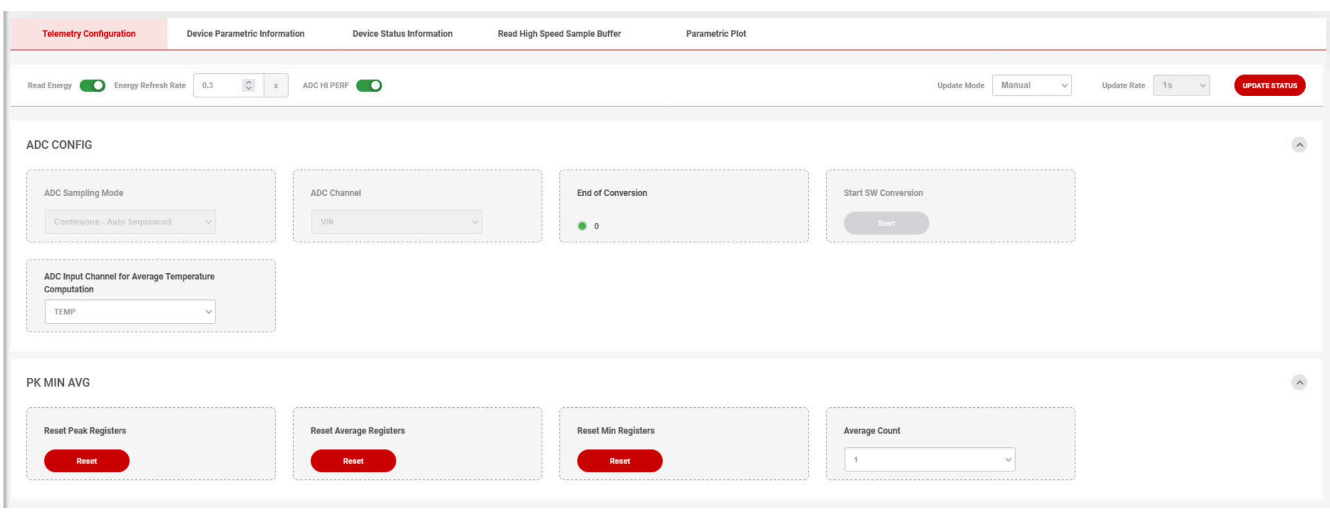

Figure 6-11. TPS25990EVM-GUI: Device Telemetry: Telemetry Configuration

Accessibility of the ADC_CONFIG_1 (E8h) register is disabled in the GUI. Changing the configuration of this register is not recommended under normal operation. This is because changing the configuration of this register prevents the ADC from sampling all the necessary signals needed for protection.

Device Parametric Information tab contains the following registers as shown in Figure 6-12 to represent real world values of all the parameters reported by the device:

- READ_VIN (88h)
- READ_VOUT (8Bh)
- READ_IIN (89h)
- READ_TEMPERATURE_1 (8Dh)
- READ_PIN (97h)
- READ_VAUX (D0h)
- READ_VIN_AVG (DCh)
- READ_VIN_MIN (D1h)
- READ_VIN_PEAK (D2h)
- READ_VOUT_AVG (DDh)
- READ_VOUT_MIN (DAh)
- READ_IIN_AVG (DEh)
- READ_IIN_PEAK (D4h)
- READ_TEMP_AVG or READ_VAUX_AVG (D6h)
- READ_TEMP_PEAK (D7h)
- READ_PIN_AVG (DFh)
- READ_PIN_PEAK (D5h)
- READ_EIN (86h)

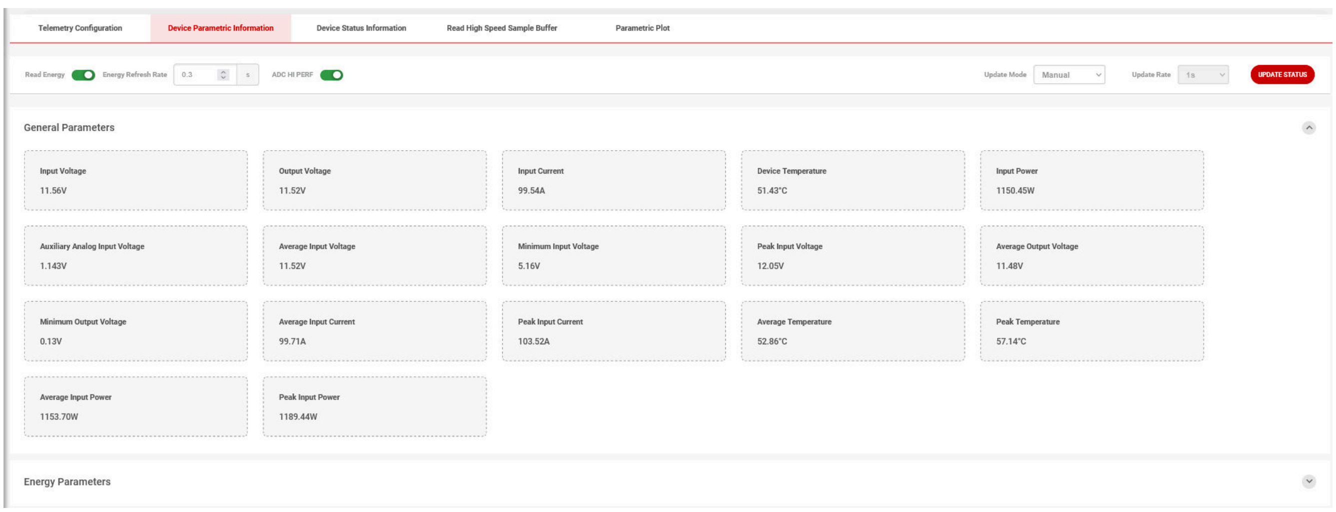

Figure 6-12. TPS25990EVM-GUI: Device Telemetry: Device Parametric Information: General Parameters

The GUI implements the algorithm described in the PMBus Specifications for computing the real-world value of accumulated energy and average power consumption by the system using READ_EIN (86h) register data as presented in Figure 6-13. To get the values of accumulated energy and average power consumption, the READ_EIN (86h) register must be read periodically with a periodicity specified in the *Energy Refresh Rate* field and by enabling the *Read Energy* toggle switch as indicated by the RED circle in Figure 6-13. *ADC HI PERF* toggle switch (Bit[3] of DEVICE_CONFIG (E4h) register) specifies the ADC internal operating modes, high speed or high performance. The effective ADC sampling period is 11 µs in high speed mode and 18 µs in high performance mode and comes with high speed mode by default. If changing the ADC internal modes is necessary, then changing the ADC internal modes must be done before the load is applied and after establishing communication with the GUI for the first time. Changing the ADC internal modes must not be changed under normal operation. This results in the wrong real world value for energy accumulation.

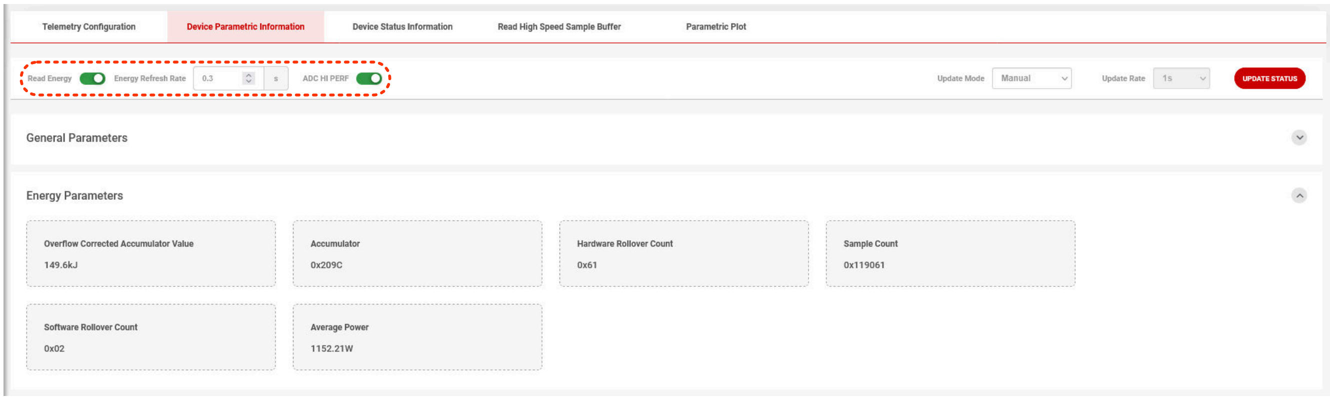

Figure 6-13. TPS25990EVM-GUI: Device Telemetry: Device Parametric Information: Energy Parameters

Device Status Information tab contains the following registers as shown in Figure 6-14 to represent the device status:

- STATUS_INPUT (7Ch)
- STATUS_WORD (79h)
- STATUS_OUT (7Ah)
- STATUS_TEMP (7Dh)
- STATUS_CML (7Eh)
- STATUS_MFR_SPECIFIC (80h)
- STATUS_MFR_SPECIFIC_2 (F3h)
- BB_TIMER (FAh)

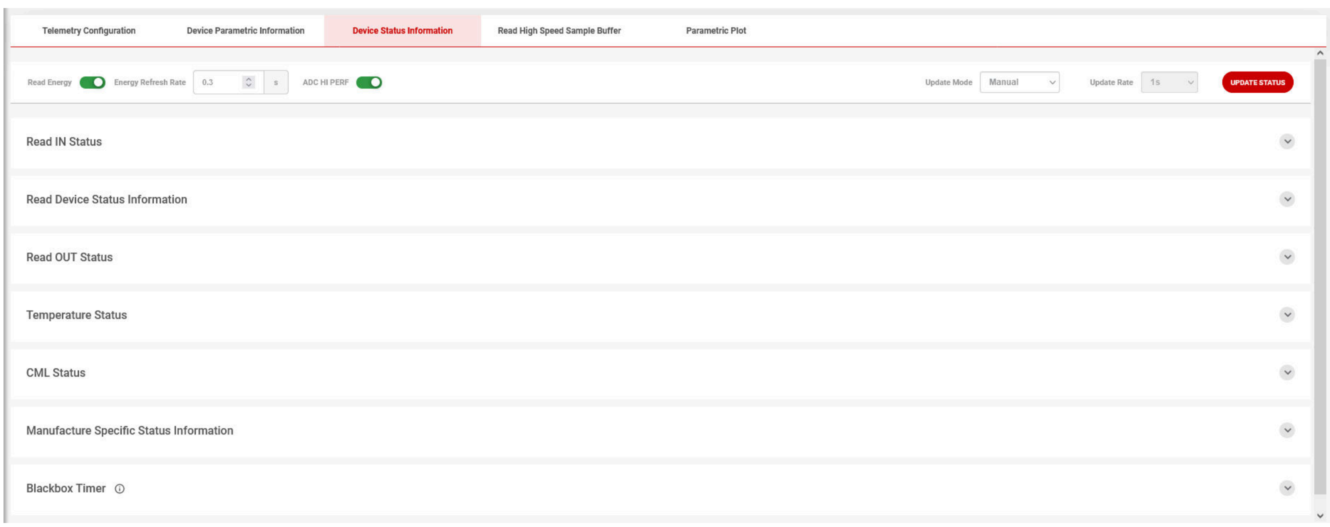

Figure 6-14. TPS25990EVM-GUI: Device Telemetry: Device Status Information

Device parametric and status information can be updated manually or automatically as selected in the *Update Mode* drop-down menu shown in Figure 6-15. In manual update mode, users need to click on the *UPDATE STATUS* icon to get the latest information. Upon clicking the *START* icon in automatic update mode, the GUI reads all telemetry registers except READ_EIN (86h) in a time interval specified in the *Update Rate* field, as shown by the RED circle in Figure 6-15. The GUI continues to read the registers as long as the user is in any one of the three tabs, *Telemetry Configuration*, *Device Parametric Information*, and *Device Status Information* under the *Telemetry* page. The GUI stops updating as the user navigates to other tabs.

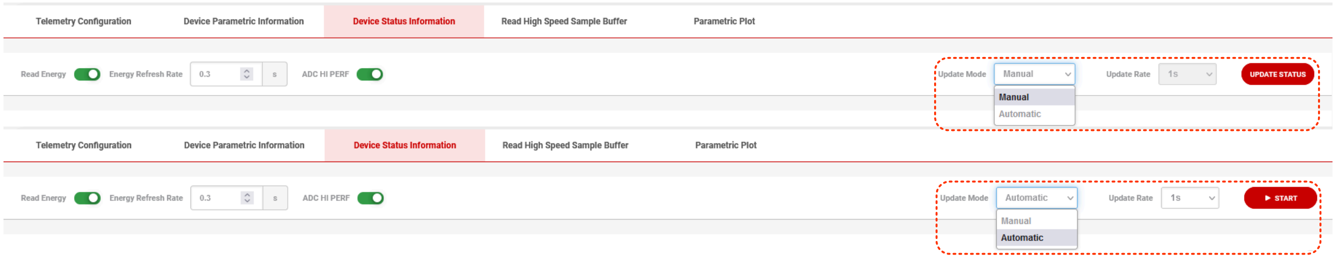

Figure 6-15. TPS25990EVM-GUI: Device Telemetry Update

Read High Speed Sample Buffer tab implements the READ_SAMPLE_BUF (D8h, Block Read) register. The ADC channel to sample for buffering and the decimation rate/sample skip count are configured through Bit[5:3] and Bit[2:0] respectively in the ADC_CONFIG_2 register. Parameter selection and decimation rate can be picked using the drop-down menus as shown by the RED circle in Figure 6-16. By selecting different decimation rates, users can choose between *fine time resolution & short aperture* and *coarse time resolution & wide aperture*. Click on the *READ* icon to plot the 64 samples retrieved from the READ_SAMPLE_BUF block read command as shown in Figure 6-16.

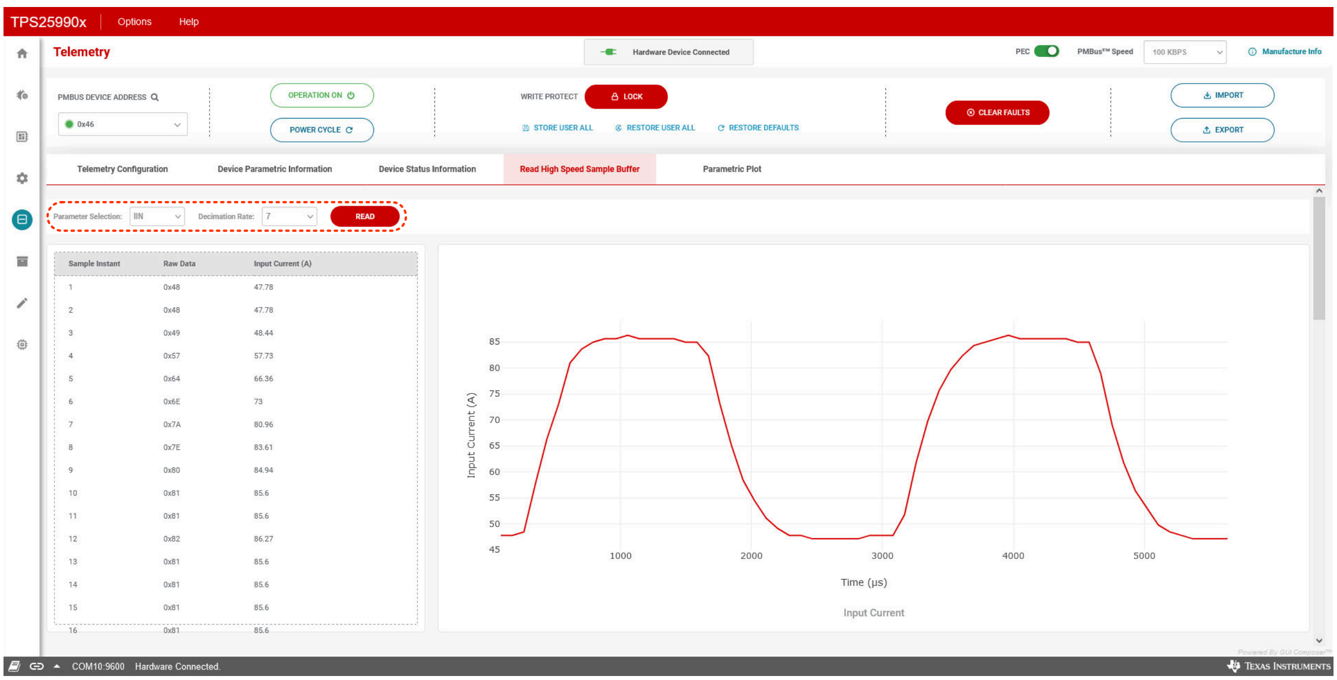

Figure 6-16. TPS25990EVM-GUI: Device Telemetry: Read High Speed Sample Buffer: Input Current

Figure 6-17 represents the plots of input and output voltages (during a load transient event) using the data retrieved by sending the READ_SAMPLE_BUF (D8h) block read command at two different times.

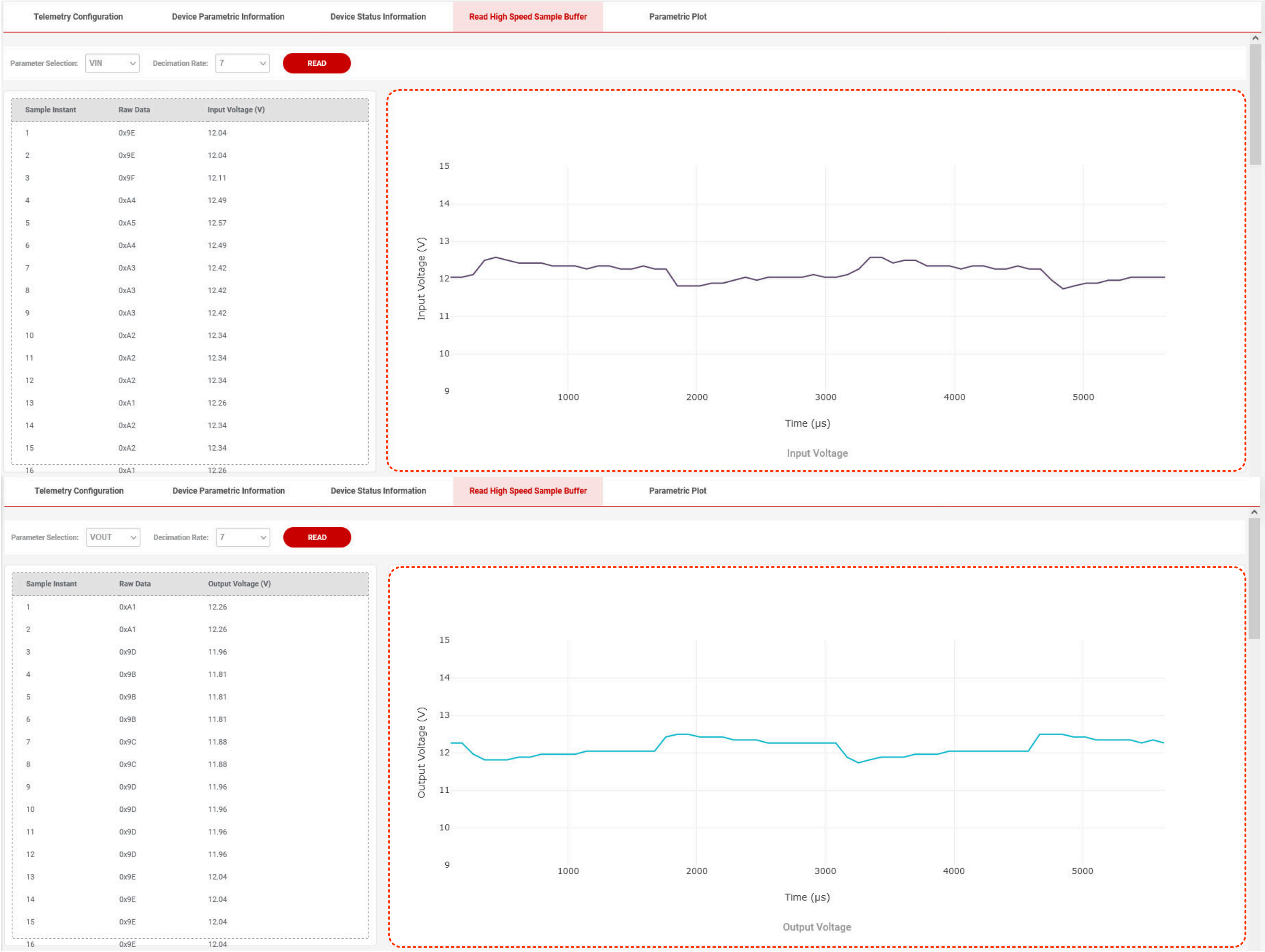

Figure 6-17. TPS25990EVM-GUI: Device Telemetry: Read High Speed Sample Buffer: Input and Output Voltages

Parametric Plot tab allows users to visualize some key device parameters, including input voltage, output voltage, input current, input power, average input power, device die temperature, auxiliary input voltage, and energy accumulation as shown in Figure 6-18. Users must select the update rate from the drop-down menu called *Update Rate* as presented by the RED circle in Figure 6-18. Then, users need to choose the parameters to plot. To begin plotting, two parameters must always be selected. Click on the *START* icon to initiate plotting. Plotting can be stopped by clicking on the *STOP* icon. Plotting stops as the user navigates to other tabs. Figure 6-19 shows a sample plot window with input power and energy accumulation.

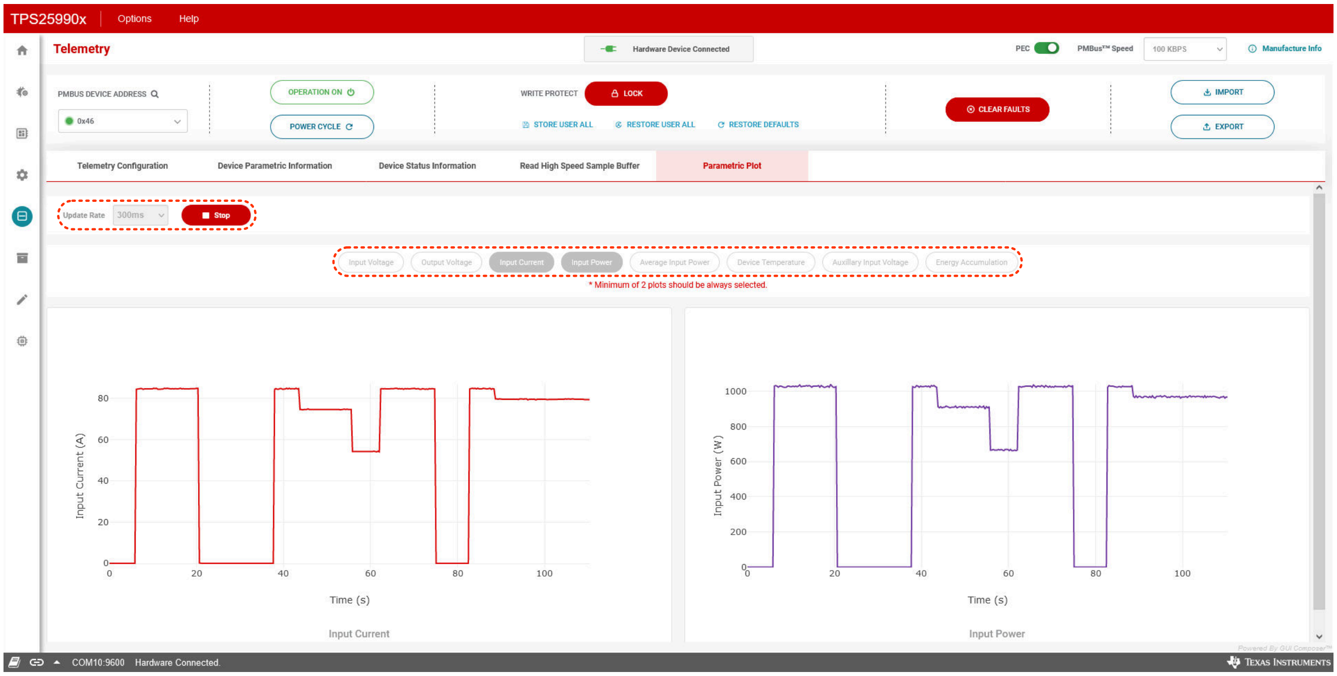

Figure 6-18. TPS25990EVM-GUI: Device Telemetry: Parametric Plot

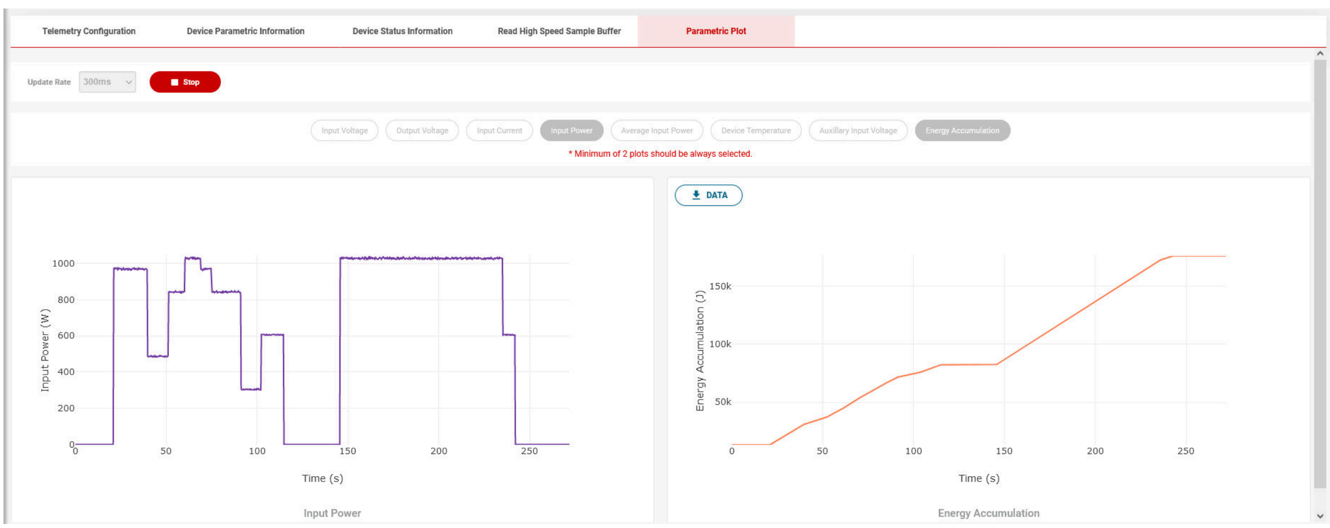

Figure 6-19. TPS25990EVM-GUI: Device Telemetry: Parametric Plot: Input Power and Energy Accumulation

6.7 Blackbox

The *Blackbox* page as shown in Figure 6-20 implements the Blackbox fault recording feature in TPS25990 eFuse. This feature greatly enhances the system designer's ability to debug power path related issues during design/development and field returns.

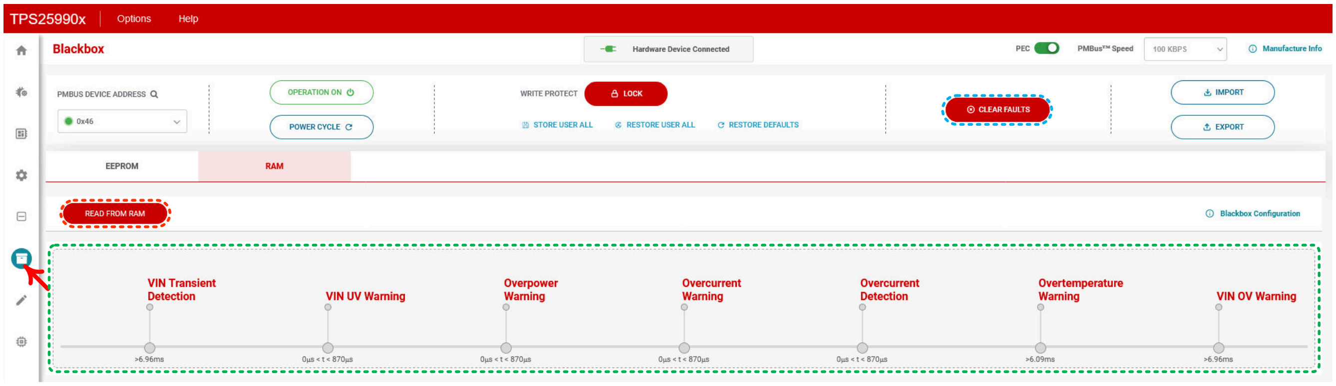

Figure 6-20. TPS25990EVM-GUI: Blackbox

After powering up the device, the Blackbox tick timer update rate must be configured in the BB_CONFIG (E5h) register. This is shown in the RED circle in Figure 6-21.

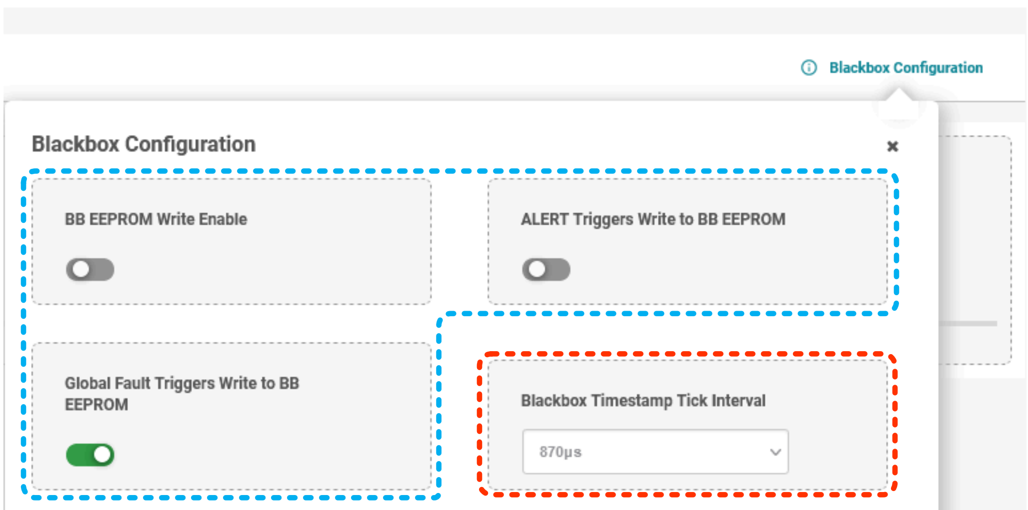

Figure 6-21. TPS25990EVM-GUI: Blackbox: Blackbox Configuration

To send the READ_BB_RAM (FDh) block read command for retrieving the contents of seven Blackbox RAM registers, starting from BB_RAM_0 to BB_RAM_6, click on the *READ FROM RAM* icon as outlined by the RED circle in Figure 6-20. Figure 6-20 shows the retrieved contents in the GREEN rectangular box.

Clicking on the *CLEAR FAULTS* icon as outlined by a BLUE circle in Figure 6-20 resets the Blackbox RAM registers to zero.

Once the device encounters a global fault or alert event (based on the ALERT_MASK (DBh) register), the Blackbox RAM contents, status registers, peak input voltage, peak input current, peak device temperature, and Blackbox timer values are written to an external EEPROM through the EECLK/EEDATA pins.

The EEPROM interface is a standard I2C controller and operates at 400 kHz clock speed. TI recommends using an I2C EEPROM with minimum 1 kbits of capacity and 16-byte page addressing. Examples of compatible EEPROM devices include 24LC04, 24AA04, etc.

The contents of the Blackbox RAM along with some status registers (STATUS_WORD (79h), STATUS_MFR_SPECIFIC (80h), and STATUS_INPUT (7Ch)) and certain parameters (VIN_PEAK, IIN_PEAK, and TEMPERATURE_PEAK) are stored into Page-0 of an external EEPROM when the following conditions are met. At the same time, Blackbox RAM contents and Blackbox tick timer values are locked.

1. An external EEPROM is successfully connected by setting the EXT_EEPROM bit high in the DEVICE_CONFIG (E4h) register as shown in Figure 6-22. In addition, this is done by configuring two of the four GPIOs as EECLK and EEDATA appropriately in the GPIO_CONFIG_12 (E1h) and GPIO_CONFIG_34 (E2h) registers. This is shown in Figure 6-23. Make sure those two selected GPIO pins are physically connected to the EEPROM clock and data pins respectively on the board.
2. Any one of the three BB EEPROM write trigger bits is set in the BB_CONFIG (E5h) register as outlined by BLUE circle in Figure 6-21.

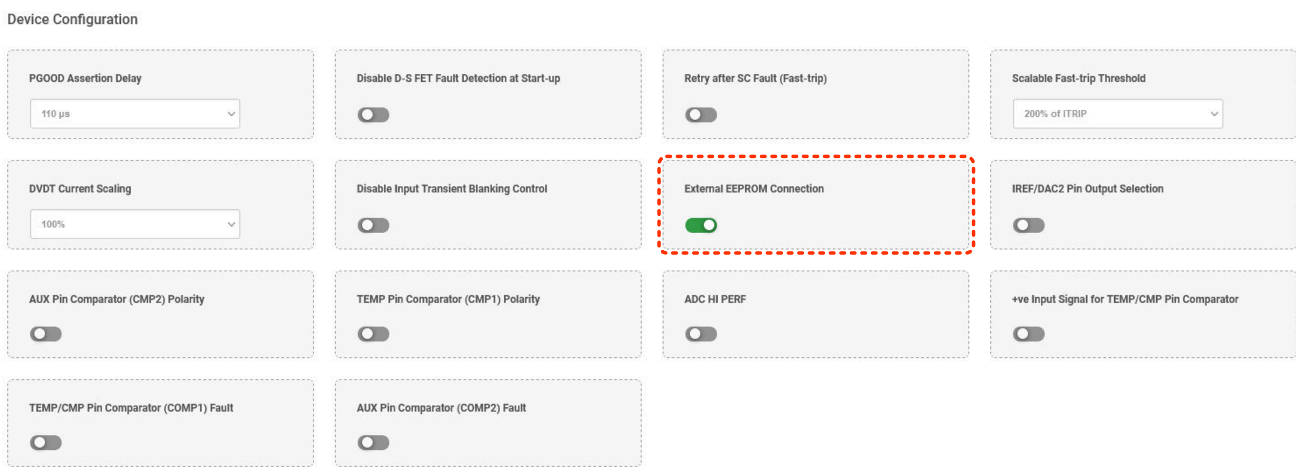

Figure 6-22. TPS25990EVM-GUI: Device Configuration: External EEPROM Connection

Figure 6-23. TPS25990EVM-GUI: GPIO Configuration: External EEPROM Connection

To access the Blackbox contents from that EEPROM, first click on the *FETCH EEPROM* icon and then click on the *READ EEPROM* icon as outlined by the RED and BLACK circles respectively in Figure 6-24. Figure 6-24 shows the retrieved contents in the GREEN GREEN rectangular box.

Clicking on the *ERASE BLACKBOX* icon while the WRITE PROTECT is unlocked as outlined by the BLUE circles in Figure 6-24 resets the EEPROM Blackbox contents to zero.

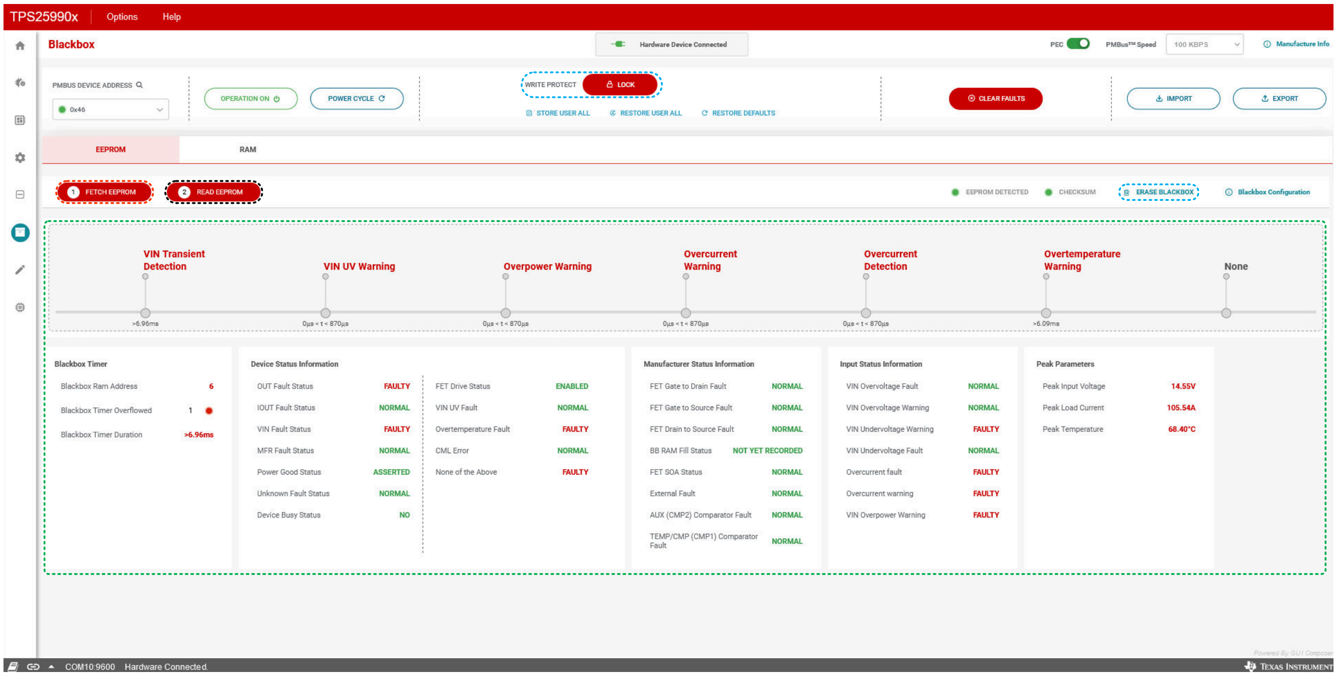

Figure 6-24. TPS25990EVM-GUI: Blackbox: READ BB EEPROM

6.8 Register Map Page

The *Register Map* page as shown in Figure 6-25 enables users to access all the registers supported by TPS25990 eFuse at a glance. Additionally, read and write operations can also be performed here on each register as applicable.

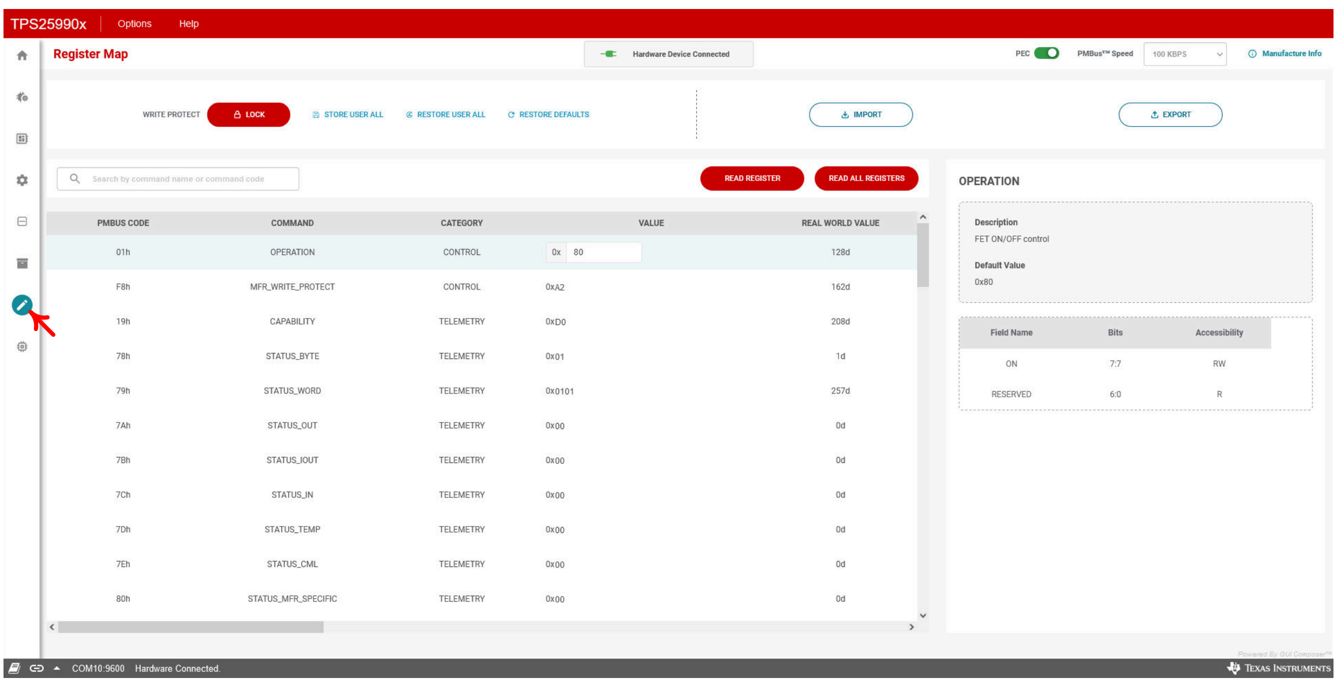

Figure 6-25. TPS25990EVM-GUI: Register Map

To write into a register if applicable, type the revised value in the field and press ENTER. To read a particular register, select the register and click on the *READ REGISTER* icon. Click on the *READ ALL REGISTERS* icon to read all the registers supported by the device at a time.

7 EVAL Board Assembly Drawings and Layout Guidelines

7.1 PCB Drawings

Figure 7-1 and Figure 7-2 show the component placements of the EVM. A pictorial representation of the TPS25990EVM PCB layers can be found in Figure 7-3 to Figure 7-10.

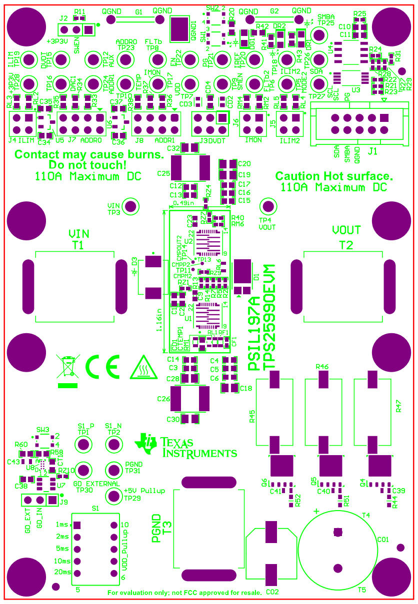

Figure 7-1. TPS25990EVM Board: Top Assembly

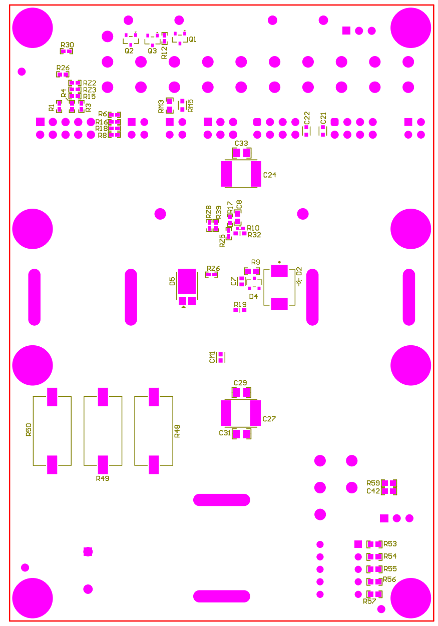

Figure 7-2. TPS25990EVM Board: Bottom Assembly

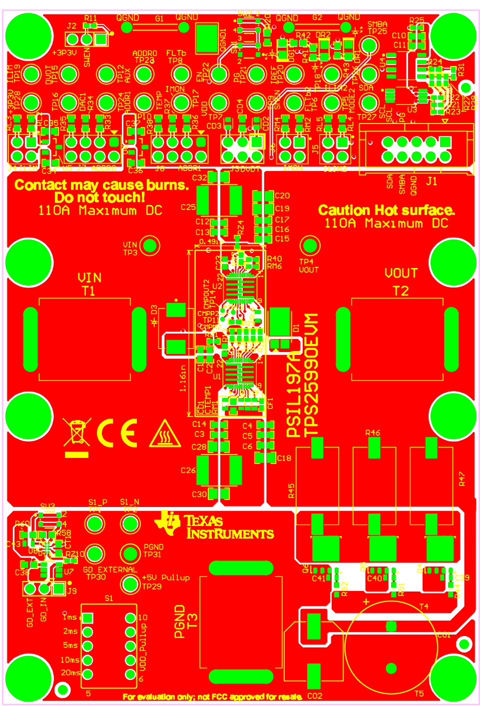

Figure 7-3. TPS25990EVM Board: Top Layer

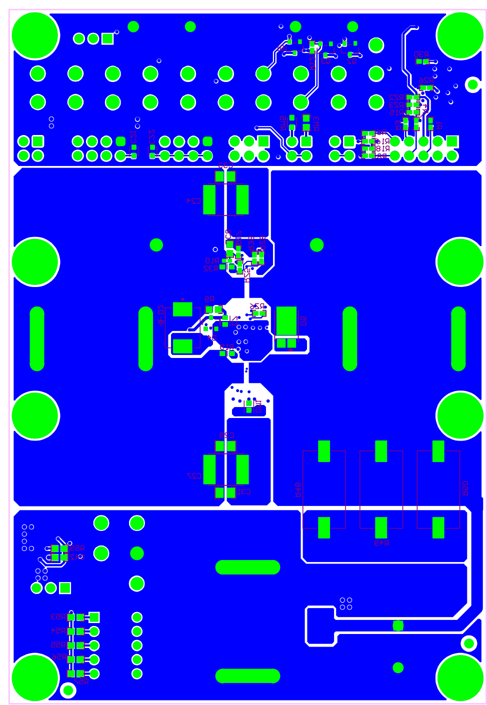

Figure 7-4. TPS25990EVM Board: Bottom Layer

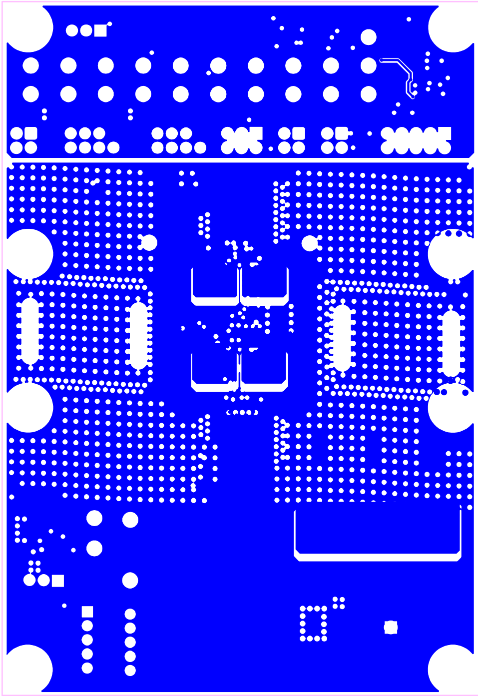

Figure 7-5. TPS25990EVM Board: Layer 2 (Power)

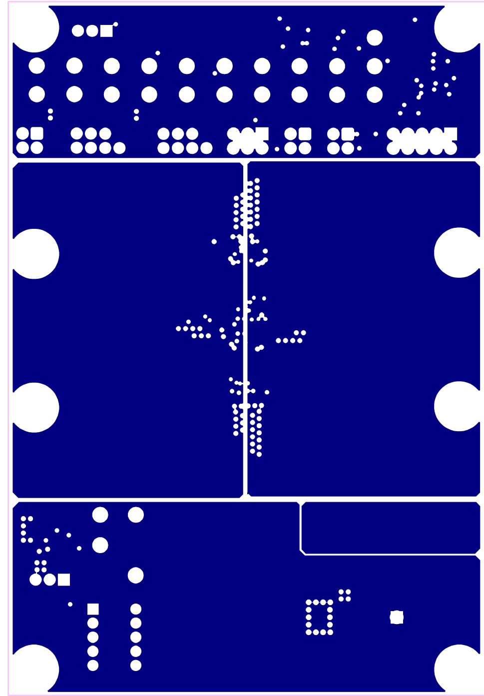

Figure 7-6. TPS25990EVM Board: Layer 3 (Power)

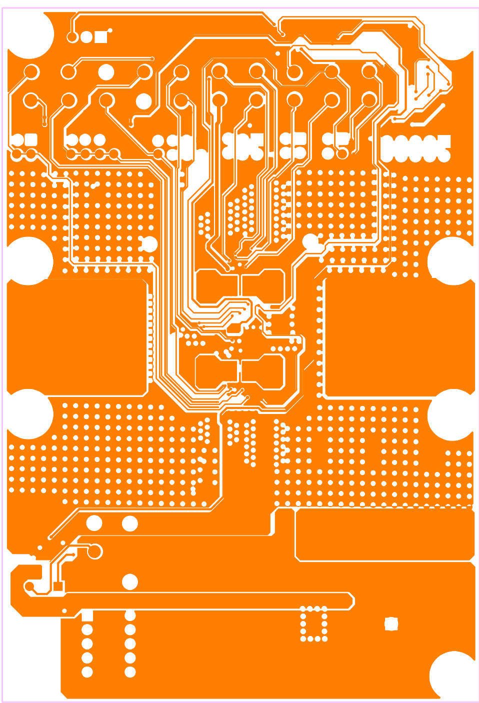

Figure 7-7. TPS25990EVM Board: Layer 4 (Signal)

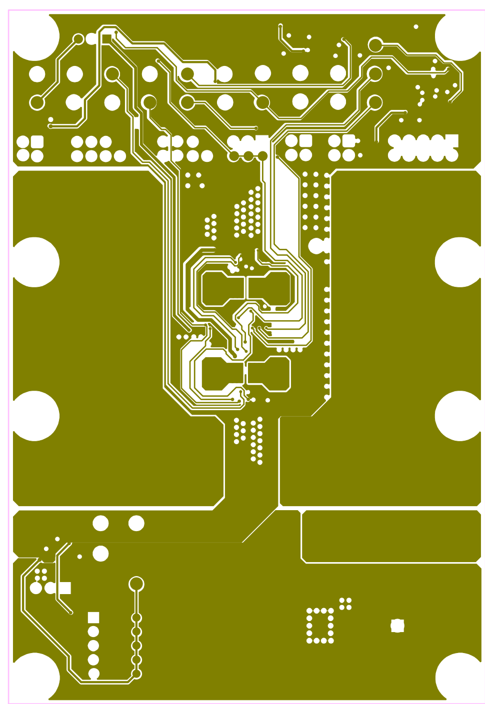

Figure 7-8. TPS25990EVM Board: Layer 5 (Signal)

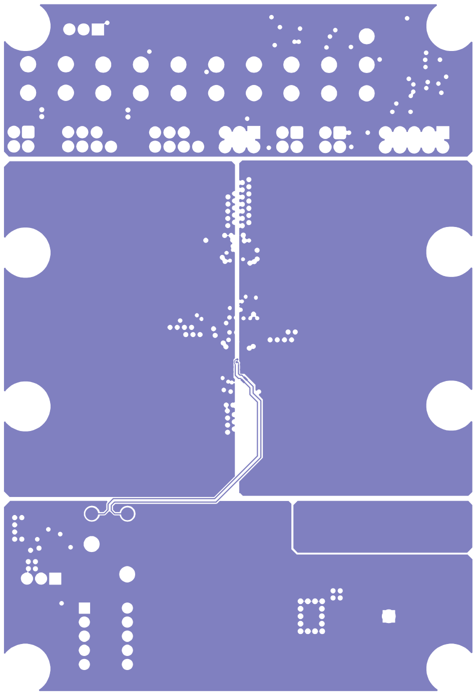

Figure 7-9. TPS25990EVM Board: Layer 6 (Power)

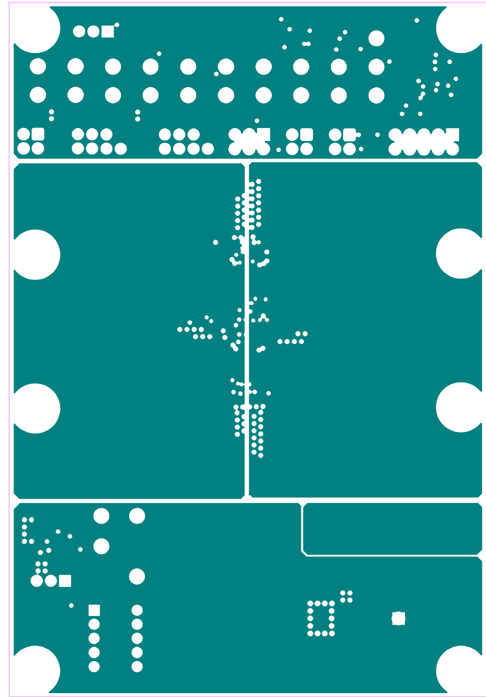

Figure 7-10. TPS25990EVM Board: Layer 7 (Power)

Note

Analog signal nets, such as IREF, IMON, and TEMP, need to be routed away as much as possible from power nets such as VIN, VOUT, and PGND.

8 Bill Of Materials (BOM)

Table 8-1 lists the EVM BOM.

Table 8-1. TPS25990EVM Bill of Materials

Designator	Qty	Value	Description	Footprint	Part Number	Manufacturer	Comments
!PCB1	1		Printed Circuit Board		PSIL197	Any	
C1, C3, C5, C12, C14, C16	6	1uF	CAP, CERM, 1 uF, 35 V, +/- 10%, X7R, 0603	0603	C1608X7R1V105K080AC	TDK	
C2, C4, C13, C15, CT1	5	0.1uF	CAP, CERM, 0.1 µF, 50 V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	C0603C104K5RACAUTO	Kemet	
C6, C17	2	2.2uF	CAP, CERM, 2.2 uF, 35 V, +/- 10%, X5R, 0603	0603	GRM188R6YA225KA12D	MuRata	
C7	1	47 nF	Cap Ceramic 0.047uF 25 V X7R 5% SMD 0603 125°C Paper T/R	FP-C0603C473J3RAC7867_0603-MFG	C0603C473J3RAC7867	KEMET	
C8	1	1000 pF	CAP, CERM, 1000 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	GRM1885C1H102JA01D	MuRata	
C9, C23	2	2.2uF	CAP, CERM, 2.2 µF, 25 V,+/- 10%, X7S, 0603	0603L	GRM188C71E225KE11D	MuRata	
C10, C11	2	10uF	CAP, CERM, 10 uF, 35 V, +/- 20%, X5R, 0603	0603	GRM188R6YA106MA73D	Murata	
C21, C22	2	10 pF	10 pF ±5% 25 V Ceramic Capacitor C0G, NP0 0603 (1608 Metric)	FP-06033A100JAT2A_0603-MFG	06033A100JAT2A	AVX	
C34, C35, C36, C37	4	0.1uF	CAP, CERM, 0.1 uF, 50 V, +/- 10%, X7R, 0603	0603	06035C104KAT2A	AVX	
C38	1	1uF	CAP, CERM, 1 uF, 25 V, +/- 10%, X7R, AEC-Q200 Grade 1, 0603	0603	GCM188R71E105KA64D	MuRata	

Table 8-1. TPS25990EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Footprint	Part Number	Manufacturer	Comments
C39, C40, C41, C43	4	100 pF	CAP, CERM, 100 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603S	885012006057	Wurth Elektronik	
C42	1	0.1uF	CAP, CERM, 0.1 µF, 16 V,+/- 10%, X7R, 0603	0603	CL10B104KO8WPNC	Samsung Electro-Mechanics	
CD2	1	22 nF	Cap Ceramic 22000 pF 50 V X7R 10% Pad SMD 0603 Soft Termination +125°C Automotive T/R	FP-GCJ188R71H223KA01D_0603-MFG	GCJ188R71H223KA01D	Murata	
CD3	1	33 nF	Cap Ceramic 33000 pF 50 V X7R 10% Pad SMD 0603 Soft Termination +125°C Automotive T/R	FP-GCJ188R71H333KA12D_0603-MFG	GCJ188R71H333KA12D	Murata	
CD4	1	3300 pF	CAP, CERM, 3300 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	GRM1885C1H332JA01D	MuRata	
CF1	1	1000 pF	CAP, CERM, 1000 pF, 50 V, +/- 5%, C0G/NP0, AEC-Q200 Grade 1, 0402	0402	CGA2B2C0G1H102J050BA	TDK	
CM1	1	22 pF	AgPd Termination Conductive Glue Mounting Chip Multilayer Ceramic Capacitors for Automotive 22 pF with 5% as tolerance, 50 V X8G 30 ppm/°C, 0603 Package	FP-GCG1885G1H220JA01D_0603-IPC_C	GCG1885G1H220JA01D	Murata	
CO2	1	470uF	CAP, AL, 470 uF, 25 V, +/- 20%, SMD	CAPSMT_62_JA0	EMVE250ADA471MJA0G	Chemi-Con	

Table 8-1. TPS25990EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Footprint	Part Number	Manufacturer	Comments
CTEMP1	1	22 pF	CAP, CERM, 22 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	06035A220JAT2A	AVX	
D1, D5	2	45 V	Diode, Super Barrier Rectifier, 45 V, 10 A, PowerDI5	POWERDI5	SBR10U45SP5-13	Diodes Inc.	
D2, D3	2		19.9V Clamp 150.8A Ipp Tvs Diode Surface Mount DO-214AB (SMCJ)	FP-SMDJ12A_DO214AB-MFG	SMDJ12A	Littelfuse Inc	
D4	1		Zener Diode 4.7 V 250 mW ±1% Surface Mount TO-236AB	FP-BZX84-A4V7,215_SOT23-3-MFG	BZX84-A4V7,215	Nexperia	
DG1	1	Green	LED, Green, SMD	LG_R971_Green	LG R971-KN-1	OSRAM	
DR1, DR2	2	Red	LED, Red, SMD	LS_R976_Red	LS R976-NR-1	OSRAM	
G1, G2	2		1 mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Harwin_D3082-05	D3082-05	Harwin	
H1, H2, H3, H4, H9, H10, H11, H12	8		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	NY PMS 440 0025 PH	NY PMS 440 0025 PH	B&F Fastener Supply	
H5, H6, H7, H8, H13, H14, H15, H16	8		Standoff, Hex, 0.5"L #4-40 Nylon	Keystone_1902C	1902C	Keystone	
J1	1		Header (shrouded), 100mil, 5x2, Gold, TH	CONN_5103308-1	5103308-1	TE Connectivity	
J2, J9	2		Header, 100mil, 3x1, Tin, TH	CONN_PEC03SAAN	PEC03SAAN	Sullins Connector Solutions	
J3	1		Header, 100mil, 3x2, Tin, TH	SULLINS_PEC03DAAN	PEC03DAAN	Sullins Connector Solutions	
J4, J5, J6	3			FP-PEC02DABN_HDR4-MFG	PEC02DABN	Sullins Connector Solutions	
J7, J8	2		Header, 2.54mm, 4x2, Gold, TH	Sullins_xxPC004DAAN-RC	PRPC004DAAN-RC	Sullins Connector Solutions	

Table 8-1. TPS25990EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Footprint	Part Number	Manufacturer	Comments
Q1, Q2, Q3	3		N-Channel 30 V 3.16A (Ta) 750mW (Ta) Surface Mount SOT-23-3 (TO-236)	FP-SI2306BDS-T1-GE3_SOT23-3-MFG	SI2306BDS-T1-GE3	Vishay Siliconix	
Q4, Q5, Q6	3	40 V	MOSFET, N-CH, 40 V, 42 A, DNK0008A (VSON-CLIP-8)	DNK0008A	CSD18510Q5B	Texas Instruments	
QGND1	1		Test Point, Compact, SMT	Testpoint_Keystone_Compact	5016	Keystone	
R1, R2, R4, R5, R6, R7, R8, R23, R26, R27, R30, RZ1, RZ3, RZ4, RZ5, RZ6, RZ7, RZ8, RZ9, RZ10	20	0	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0ED	Vishay-Dale	
R9	1	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0710KL	Yageo	
R10	1	1.0Meg	RES, 1.0 M, 5%, 0.063 W, 0402	0402L	CRCW04021M00JNED	Vishay-Dale	
R11	1	100k	RES, 100 k, 1%, 0.063 W, 0402	0402	CRCW0402100KFKED	Vishay-Dale	
R12, R13, R14, R15, R16, R18	6	10.0k	RES, 10.0 k, 1%, 0.063 W, 0402	0402	RC0402FR-0710KL	Yageo America	
R17	1	330k	RES, 330 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW0402330KFKED	Vishay-Dale	
R19, R32, R44, R51, R52	5	10	Res General Purpose Thick Film 0603 10 Ohm 5% 1/10W ±200ppm/°C Molded SMD Paper T/R	FP-RC0603JR-0710RL_0603-MFG	RC0603JR-0710RL	Yageo	
R20	1	121k	RES, 121 k, 1%, 0.1 W, 0603	0603	RC0603FR-07121KL	Yageo	
R33, R36	2	75.0k	RES, 75.0 k, 0.1%, 0.1 W, 0603	0603	RT0603BRD0775KL	Yageo America	
R34, R37	2	150k	RES, 150 k, 0.1%, 0.1 W, 0603	0603	RT0603BRD07150KL	Yageo America	

Table 8-1. TPS25990EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Footprint	Part Number	Manufacturer	Comments
R35, R38	2	267k	RES, 267 k, 0.1%, 0.1 W, 0603	0603	RT0603BRD07267KL	Yageo America	
R41, R42, R43	3	470	RES, 470, 5%, 0.1 W, 0603	0603	RC0603JR-07470RL	Yageo	
R45, R46, R47, R48, R49, R50	6	1	Res Wirewound 1 Ohm 5% 5W ±200ppm/°C Molded SMD T/R	FP-SMW51R0JT_5329-IPC_C	SMW51R0JT	TE Connectivity	
R53	1	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale	
R54	1	20.0k	RES, 20.0 k, 1%, 0.1 W, 0603	0603	CRCW060320K0FKEA	Vishay-Dale	
R55	1	49.9k	RES, 49.9 k, 1%, 0.1 W, 0603	0603	CRCW060349K9FKEA	Vishay-Dale	
R56	1	100k	RES, 100 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	CRCW0603100KFKEA	Vishay-Dale	
R57	1	200k	RES, 200 k, 1%, 0.1 W, 0603	0603	CRCW0603200KFKEA	Vishay-Dale	
R59, R60	2	10k	RES, 10 k, 5%, 0.1 W, 0603	0603	RC0603JR-0710KL	Yageo	
RL2	1	511	RES, 511, 0.1%, 0.1 W, 0603	0603	RT0603BRD07511RL	Yageo America	
RL3	1	402	RES, 402, 0.1%, 0.1 W, 0603	0603S	RT0603BRD07402RL	Yageo America	
RL4	1	402	RES, 402, 0.1%, 0.1 W, 0603	0603	RT0603BRD07402RL	Yageo America	
RL5	1	332	RES, 332, 0.1%, 0.1 W, 0603	0603	RT0603BRD07332RL	Yageo America	
RM2	1	1.10k	RES, 1.10 k, 0.1%, 0.1 W, 0603	0603	RT0603BRD071K1L	Yageo America	
RM3	1	1.37k	RES, 1.37 k, 0.1%, 0.1 W, 0603	0603	RT0603BRD071K37L	Yageo America	
RM4	1	1.10k	RES, 1.10 k, 0.1%, 0.1 W, 0603	0603	RT0603BRD071K1L	Yageo America	

Table 8-1. TPS25990EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Footprint	Part Number	Manufacturer	Comments
RM5	1	910	910 Ohms ±0.1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Thin Film	FP-RT0603BRC07910RL_0603-MFG	RT0603BRC07910RL	Yageo	
RM6	1	0	RES, 0, 5%, 0.063 W, 0402	0402	CRCW04020000Z0ED	Vishay-Dale	
S1	1		Switch, SPST 5Pos, Rocker, TH	SW_76SB05	76SB05ST	Grayhill	
SH1, SH2, SH3, SH4, SH5, SH6, SH7, SH8	8		Shunt, 2.54mm, Gold, Blue	Wurth_60900213621	60900213621	Wurth Elektronik	
SW1, SW2, SW3	3		Tactile Switch SPST-NO Top Actuated Surface Mount	FP-PTS830GM140SMTRLFS_SMT_3MM05_2MM6-MFG	PTS830GM140SMTRLFS	C&K Components	
T1, T2, T3	3		1/0 AWG High AMP PCB Wire Lugs 1/0-8 AWG	FP-B1-0-PCB-L_WIRE_LUG_150A_1-0AWG-MFG	B1/0-PCB-L	INTERNATIONAL HYDRAULICS	
T4, T5	2		Connector, Receptacle, Pin, TH	CONN_ 0300-2-15-01-47-01-10-0	0300-2-15-01-47-01-10-0	Mill-Max	
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP12, TP15, TP16, TP17, TP18, TP19, TP20, TP21, TP22, TP23, TP24, TP25, TP26, TP27, TP28, TP29, TP30	27		Test Point, Multipurpose, Green, TH	Keystone5126	5126	Keystone	
TP31	1		Test Point, Multipurpose, Black, TH	Keystone5011	5011	Keystone	
U1	1		TPS25990ARQP	RQP0026A-MFG	TPS25990ARQP	Texas Instruments	
U2	1		TPS259850RQP	RQP0026A-MFG	TPS259850RQP	Texas Instruments	
U4	1		EEPROM Memory IC 8Kb (1K x 8) I²C 1 MHz 450 µs 8-SOIC	FP-24FC08T-E_SN_SOIC8-MFG	24FC08T-E/SN	Microchip	

Table 8-1. TPS25990EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Footprint	Part Number	Manufacturer	Comments
U5	1		100-mA, 30-V, Fixed-Output, Linear-Voltage Regulator, DBZ0003A (SOT-23-3)	DBZ0003A_N	TLV76033DBZR	Texas Instruments	
U6	1		100-mA, 30-V, Fixed-Output, Linear-Voltage Regulator, DBZ0003A (SOT-23-3)	DBZ0003A_N	TLV76050DBZR	Texas Instruments	
U7	1		Single-Channel High-Speed Low-Side Gate Driver with 5 V Negative Input Voltage Handling Ability, DBV0006A (SOT-23-6)	DBV0006A_N	UCC27511AQDBVRQ1	Texas Instruments	
U8	1		Single Retriggerable Monostable Multivibrator with Schmitt-Trigger Inputs, YZP0008ADAD, LARGE T&R	YZP0008ADAD	SN74LVC1G123YZPR	Texas Instruments	
C18, C19, C20	0	1uF	CAP, CERM, 1 uF, 35 V, +/- 10%, X7R, 0805	0805_HV	GMK212B7105KG-T	Taiyo Yuden	DNL
C24, C25, C26, C27	0	47uF	CAP, CERM, 47 uF, 25 V, +/- 20%, X7S, 6x5x5mm	CKG57N	CKG57NX7S1E476M500JH	TDK	DNL
C28, C29, C30, C31, C32, C33	0	10uF	CAP, CERM, 10 uF, 25 V, +/- 10%, X5R, 0805	0805_HV	C2012X5R1E106K125AB	TDK	DNL
CD1	0	3300 pF	CAP, CERM, 3300 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603S	GRM1885C1H332JA01D	MuRata	DNL
CO1	0	4700uF	CAP, AL, 4700 uF, 25 V, +/- 20%, TH	KMQ_1600x2500	EKMQ250EIV472ML25S	Chemi-Con	DNL

Table 8-1. TPS25990EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Footprint	Part Number	Manufacturer	Comments
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	Fiducial6.4-20	N/A	N/A	DNL
R3, R21, R22, R24, R25, R28, R29, R31, RZ2	0	0	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0ED	Vishay-Dale	DNL
R39, R40	0	10.0k	RES, 10.0 k, 1%, 0.063 W, 0402	0402	RC0402FR-0710KL	Yageo America	DNL
R58	0	10k	RES, 10 k, 5%, 0.1 W, 0603	0603	RC0603JR-0710KL	Yageo	DNL
RF1	0	40.2k	RES, 40.2 k, 0.5%, 0.1 W, 0603	0603S	RT0603DRE0740K2L	Yageo America	DNL
RL1, RL6	0	402	RES, 402, 0.1%, 0.1 W, 0603	0603S	RT0603BRD07402RL	Yageo America	DNL
RM1	0	1.1k	1.1 kOhms ±0.1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Anti-Sulfur, Automotive AEC-Q200, Moisture Resistant Thin Film	FP-TNPW06031K10BYEN_0603-MFG	TNPW06031K10BYEN	Vishay	DNL
U3	0		8KB I2C EEPROM, 1 MHZ 1.7-5.5V, 8-TSSOP 8 TSSOP 4.4MM T/r Rohs Compliant: Yes	FP-24FC08T-E_ST_TSSOP8-MFG	24FC08T-E/ST	Microchip	DNL

9 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision * (September 2022) to Revision A (February 2023)	Page
• Changed the TPS25990EVM-GUI	4
• Added the increase of the EVM steady-state current rating from 88 A to 110 A	4
• Added minor modifications to the EVM schematic	6
• Changed the EVM thermal image	23
• Added more details about the TPS25990EVM-GUI	24
• Added minor modifications to the EVM layout	39
• Changed Bill of Materials	42

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

東京都新宿区西新宿６丁目２４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.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265