EVM User's Guide: TPS1689EVM

TPS1689 Evaluation Module for eFuse

Description

The TPS1689EVM is used to evaluate the performance of the TPS1689 eFuse device. The TPS1689EVM comes with 1 TPS16890 eFuse and 1 TPS16851 connected in parallel to evaluate a 54V (typical) and 40A (steady state) design. This evaluation module incorporates 1 TPS16890 device in parallel with 1 TPS16851, which supports a 2kW input power path protection design at an input voltage of 48V. The TPS1689EVM enables the evaluation of TPS1689 eFuse by communicating with the TPS1689EVM-GUI using the USB-TO-GPIO2 USB interface adapter evaluation module.

Features

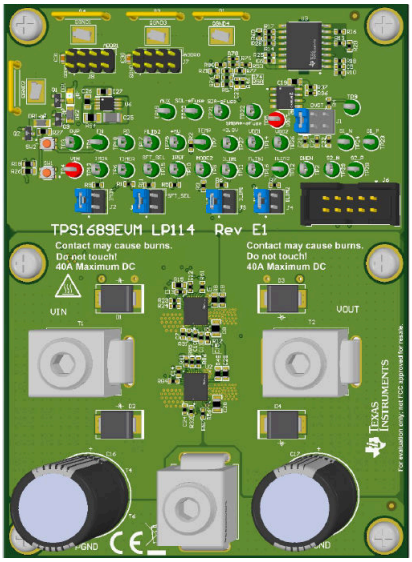
TPS1689EVM comes with one TPS16890 eFuse and one TPS16851 eFuse connected in parallel to evaluate a 54V (typical) and 40A (steady-state) design. General TPS1689EVM eFuse evaluation board features include:

- 40V to 54V (typical) operation
- 25A and 44A 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 (32h) register
- Adjustable output voltage slew rate control both in hardware and firmware
- Adjustable transient current blanking timer in firmware through OC_TIMER (14h) register
- Adjustable 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
- Options to engage the power cycle and the quick output discharge (QOD) using EN/UVLO pin
- PMBus interface with the TPS1689EVM-GUI using the USB-TO-GPIO2 USB interface adapter evaluation module
- Option to interface an external EEPROM with TPS1689 for indefinite configuration of the eFuse and Blackbox fault recording

Applications

This EVM can be used on the following applications:

- Input hotswap and hotplug
- Server and high performance computing
- Network interface cards
- Graphics and hardware accelerator cards
- Data center switches and routers
- Fan trays
- Switches and routers



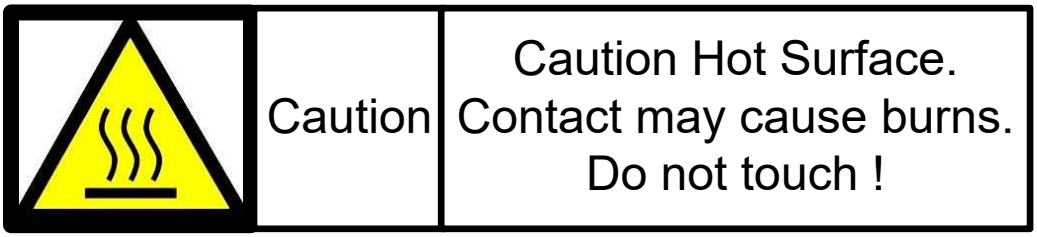
1 Evaluation Module Overview

1.1 Introduction

The TPS1689EVM eFuse evaluation board allows reference circuit evaluation of Texas Instruments (TI) TPS1689 eFuse. The TPS1689 device is a 9-V to 80-V, 20-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 TPS1685 eFuses for higher current designs by actively synchronizing the device states and sharing the loads during start-up and steady-state. The TPS1689 eFuse has an integrated FET with ultra-low ON resistance of 3.65-mΩ, adjustable and robust overcurrent and short-circuits protections, fast overvoltage protection , adjustable output slew rate control for inrush current protection, and overtemperature protection to verify FET safe operating area (SOA). The TPS1689 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.

Note

TPS1689EVM-GUI provides access to the TPS1689 evaluation module GUI.



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 Kit Contents

Item	Description	Quantity
TPS1689EVM	Evaluation module for TPS1689 eFuse	1

1.3 Specification

Table 1-1. TPS1689EVM Design Specifications

Parameter	Value
Input voltage range (V_{IN})	40V to 60V
Maximum RMS load current ($I_{OUT(max)}$)	40A
Over-current protection threshold (I_{TRIP})	44A
Are all the loads off until the PG is asserted?	No

Table 1-1. TPS1689EVM Design Specifications (continued)

Parameter	Value
Maximum ambient temperature	70°C
Transient overload blanking timer	2.1ms
Output voltage slew rate	0.5V/ms
Need to survive a *hot-short* on output condition?	Yes
Need to survive a *power up into short* condition?	Yes
Can a board be hot-plugged in or power cycled?	Yes
Load current monitoring needed?	Yes
Fault response	Latch-off
Maximum output capacitance (C_{LOAD})	2mF

1.4 Device Information

The TPS1689EVM enables the evaluation of TPS1689 eFuse. PMBus features can be accessed by communicating with the TPS1689EVM-GUI using the USB-TO-GPIO2 USB interface adapter evaluation module. This EVM has one TPS16890 eFuse (primary device) and one TPS16851 eFuse (secondary device) connected in parallel to evaluate the performance of a 40A 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 5-1 and EVM test setup in Figure 3-1. TVS diodes D1 and D2 protect the input from transient overvoltages. Schottky diodes D3 and D4 protect the output by clamping the negative voltage excursion at the OUT pins of TPS1689 and TPS1685 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 and FLTb2) indicators are provided by LED DG1, DR1, and DR2, respectively.

Table 1-2. TPS1689EVM eFuse Evaluation Board Options and Settings

Parameters	Options and Settings
V_{IN} UVLO Threshold	40V
V_{IN} OVLO Threshold	60V in hardware and configurable through PMBus in the range of 16V to 80V with a default value of 60.1V (0xb1 in VIN_OV_FLT (55h) register)
Overcurrent Blanking Timer Duration (t_{TIMER})	Set at 2.1ms (0x14h in OC_TIMER (E6h) register) by default and configurable through PMBus in the range of 0ms to 27.3ms
Output Voltage Slew Rate (dv/dt)	Selectable in hardware. 1V/ms, 0.5V/ms, and 0.1V/ms and configurable through PMBus in the range of 25 % 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. 25A and 44A with V_{IREF} of 1V
Active Current Sharing Threshold for TPS1689 eFuse (U1)	Selectable in hardware. 25A and 22A of active current sharing threshold with V_{IREF} of 1V
Inrush Current Limit and Active Current Sharing Threshold for TPS1685 eFuse (U2)	Selectable in hardware. 25A and 22A of active current sharing threshold with V_{IREF} of 1V
Reference Voltage for Overcurrent Protection and Active Current Sharing (V_{IREF})	Configurable through PMBus in the range of 0.3V to 1.2V with a default value of 1V (0x32h in VIREF (E0h) register)
PMBus Address of TPS1689 eFuse	0x40h (7 bit format) with both ADDR0 and ADDR1 pins OPEN

2 Hardware

2.1 General Configurations

2.1.1 Physical Access

Table 2-1 lists the TPS1689EVM eFuse Evaluation Board input and output connectors functionality. Table 2-2 and Table 2-3 describe the availability of test points and the functionality of the jumpers. Table 2-4 summarizes the way to configure the device address. Table 2-5 presents the function of the signal LED.

Table 2-1. 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 2-2. Test Points Description

Test Points	Label	Description
TP1	EN	Active high enable input.
TP2	SWEN	Open-drain signal to indicate and control power switch ON and OFF status.
TP3	OVP	Overvoltage protection pin.
TP4	VIN	Input voltage.
TP5	VOUT	Output voltage.
TP6	TIMER	Overcurrent blanking timer.
TP7	TEMP	Maximum device die temperature monitor analog voltage output for TPS1689 and TPS1685 in parallel.
TP8	MODE2	MODE selection: Secondary Device.
TP9	DVDT	Start-up output slew rate control.
TP10	IREF	Reference voltage for overcurrent and amp; short-circuit protections, and active current-sharing blocks.
TP11	ILIM1	Individual eFuse current monitor and active current sharing threshold under steady-state: primary device.
TP12	ILIM2	Individual eFuse current monitor and active current sharing threshold under steady-state: secondary device.
TP13	IMON	Load current monitor and overcurrent threshold and fast-trip threshold during steady-state.
TP14	VDD1	Controller input power: primary device.
TP15	SFT_SEL	Scalable fast trip threshold selector during steady state.
TP16	FLTb1	Open-drain active low fault indication: primary device.
TP17	FLTb2	Open-drain active low fault indication: secondary device.
TP18	PG	Open-drain active high power good indication.
TP19	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.
TP20	SCL-eFuse	PMBus clock line of eFuse.
TP21	SDA-eFuse	PMBus data line of eFuse.
TP22	SMBA#-eFuse	SMBus™ alert output.
TP23	S1_P	Kelvin sensing points to measure primary eFuse ON resistance.
TP24	S1_N	Kelvin sensing points to measure primary eFuse ON resistance.
TP25	VDD Pullup	5V pullup power supply generated using a LDO from VIN.
TP26	VDD2	Controller input power: secondary device.
TP27	+3P3V	3.3V pullup power supply generated using a LDO from VIN.
TP28	S2_P	Kelvin sensing points to measure secondary eFuse ON resistance.
TP29	S2_N	Kelvin sensing points to measure secondary eFuse ON resistance.

Table 2-2. Test Points Description (continued)

Test Points	Label	Description
QGND1, QGND2, QGND3, and QGND4	QGND	Device ground.
G1, G2, G3, and G4	QGND	Device ground.

Table 2-3. Jumper Descriptions and Default Positions

Jumper	Label	Description	Default Jumper Position
J1	DVDT	1-2 Position sets the output slew rate to 1V/ms	3-4
		3-4 Position sets the output slew rate to 0.5V/ms	
		5-6 Position sets the output slew rate to 0.1V/ms	
J2	IMON	1-2 Position sets the circuit breaker threshold to 25A with V_{IREF} of 1V	3-4
		3-4 Position sets the circuit breaker threshold to 44A with V_{IREF} of 1V	
J3	ILIM1	1-2 Position sets the active current sharing threshold to 25A with V_{IREF} of 1V: Primary Device	3-4
		3-4 Position sets the active current sharing threshold to 22A with V_{IREF} of 1V: Primary Device	
J4	ILIM2	1-2 Position sets the active current sharing threshold to 25A with V_{IREF} of 1V: Primary Device	3-4
		3-4 Position sets the active current sharing threshold to 22A with V_{IREF} of 1V: Primary Device	
J5	SFT_SEL	1-2 Position sets the scalable fast-trip threshold at 2.5 times over-current threshold when U2 is used in primary mode	3-4
		3-4 Position sets the scalable fast-trip threshold at 2 times over-current threshold when U2 is used in primary mode	

Table 2-4. Configuring Device Address

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

Table 2-5. 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

2.1.2 Test Equipment and Setup

2.1.2.1 Power supplies

One adjustable power supply with 0V to 80V output and 0A to 100A output current limit.

2.1.2.2 Meters

Two (2) digital multimeters (DMM).

2.1.2.3 Oscilloscope

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

2.1.2.4 USB-to-GPIO Interface Adapter

A communication adapter is required between the TPS1689EVM and the host computer to use TPS1689EVM-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.

Note

TPS1689EVM kit does not include this USB-TO-GPIO2 adapter.

Note

The TPS1689EVM-GUI does not communicate with USB-TO-GPIO USB Interface Adapter EVM.

2.1.2.5 Loads

One resistive load or equivalent which can tolerate up to 100A DC load at 80V.

3 Implementation Results

3.1 Test Setup and Procedures

In this user's guide, the test procedure is described for TPS1689 eFuse. Make sure the evaluation board has default jumper settings as shown in Table 3-1.

Table 3-1. Default Jumper Setting for TPS1689EVM eFuse Evaluation Board

J1	J2	J3	J4	J5	J7	J8
3-4	3-4	3-4	3-4	3-4	OPEN	OPEN

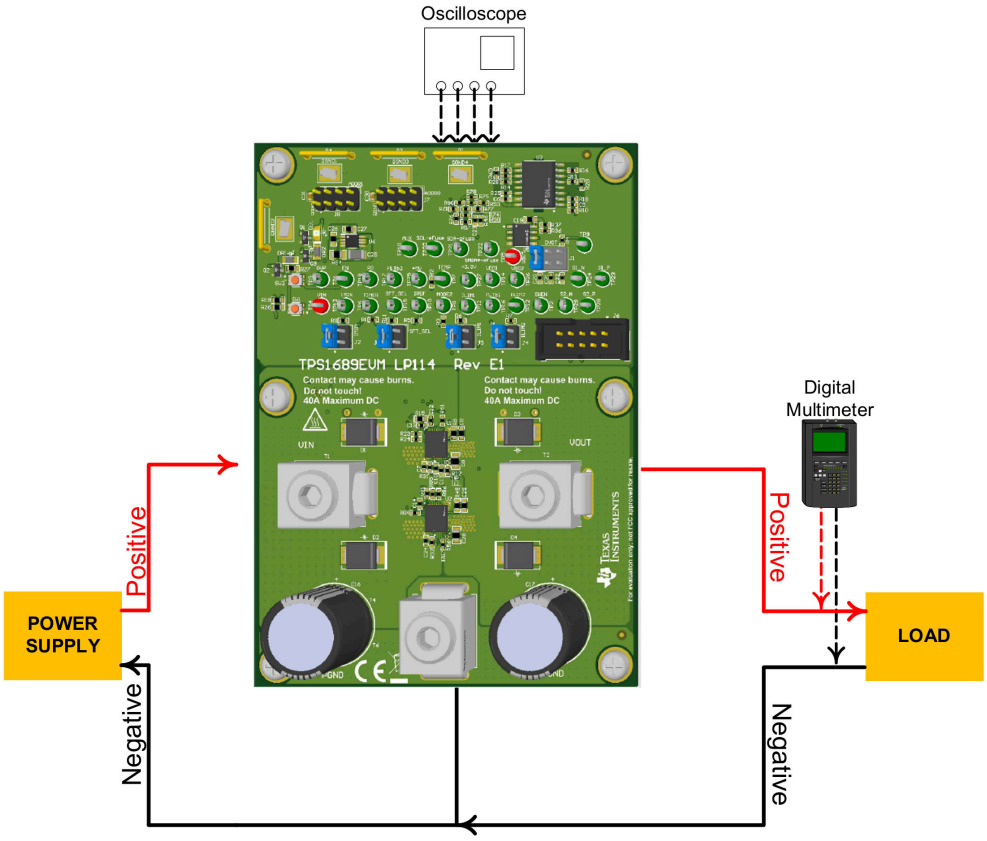


Figure 3-1. TPS1689EVM Setup With Test Equipment

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 3-1.
- Turn the power supply on and set the power supply output (VIN) to 54V, 100A, and keep the power supply output disabled.
- Enable the power supply output so that the EVM gets the input power supply.

3.1.1 Hot Plug

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

1. Configure the jumper J1 position to the desired start-up slew rate as detailed in Jumper Descriptions and Default Positions.
2. Connect a capacitive load of 1mF between VOUT (Connector T2) and PGND (Connector T3).
3. Connect the negative terminal of the power supply to connector T3.
4. Set the input supply voltage VIN to 54V and current limit to 5A. Enable the power supply.
5. Hot plug the positive terminal of the power supply at connector T1.
6. Observe the waveforms at VOUT (TP5) and input current using an oscilloscope to measure the slew rate and rise time of the VOUT with a given input voltage of 54V.

The examples of the hot plug event captured on the TPS1689EVM are shown in Figure 3-2.

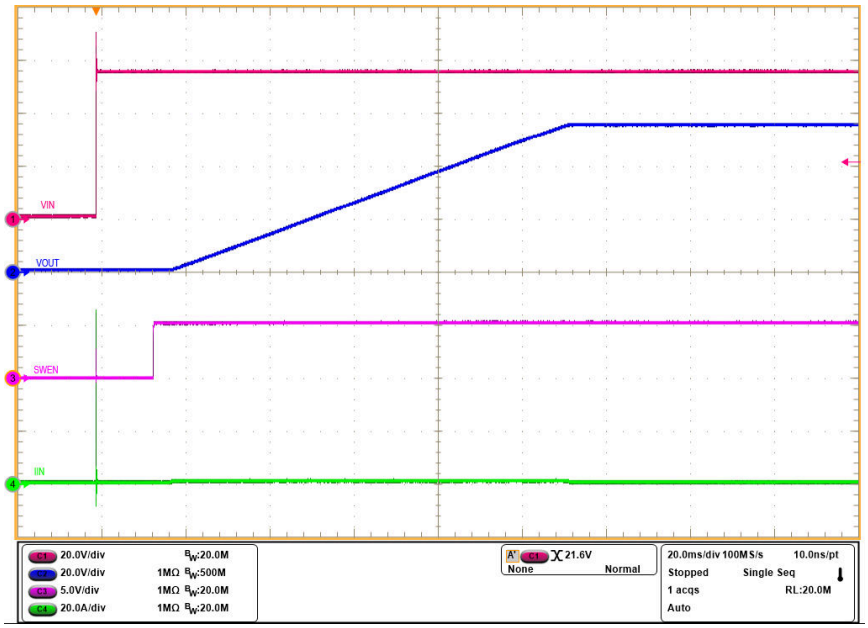


Figure 3-2. TPS1689EVM Hot Plug Profile (V_{IN} Stepped Up from 0V to 54V, C_{OUT} = 1mF, and C_{DVDT} = 100nF)

3.1.2 Start-up With Enable

Use the following instructions to power up with ENABLE:

1. Configure the jumper J1 position to the desired slew rate as described in Jumper Descriptions and Default Positions.
2. Set the input supply voltage VIN to 54V and current limit to 5A.
3. Connect a capacitive load of 1mF between VOUT (connector T2) and PGND (connector T3).
4. Connect the input supply between VIN (connector T1) and PGND (connector T3).
5. Turn on the power supply by keeping the device disabled using the switch SW1.
6. Enable the eFuses by releasing the switch SW1.
7. Observe the waveform at VOUT (TP5) and input current using an oscilloscope to measure the slew rate and rise time of the VOUT with a given input voltage of 54V.

The start-up profile of TPS1689EVM with ENABLE using two devices in parallel is shown in Figure 3-3.

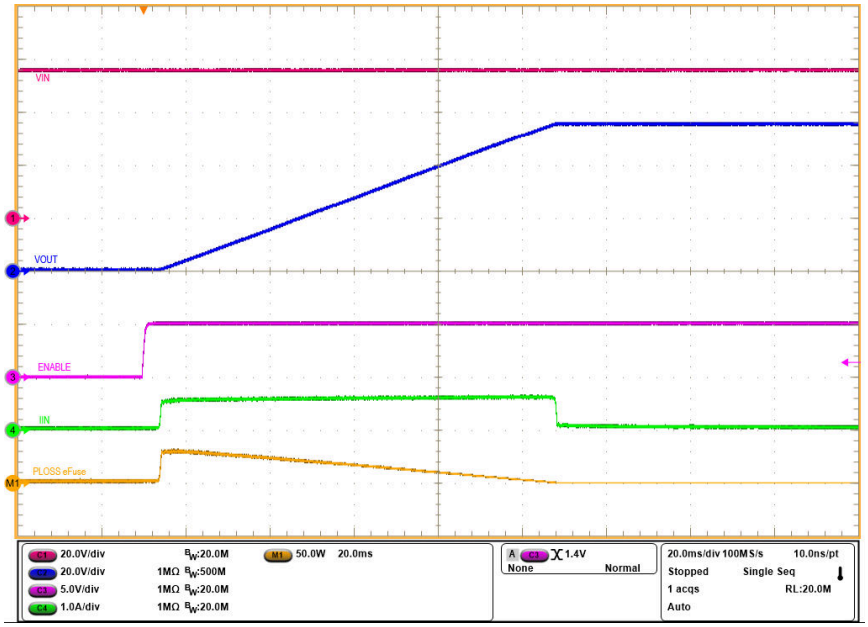


Figure 3-3. TPS1689EVM Start-up Profile With ENABLE (V_{IN} = 54V, EN Stepped Up From 0V to 5V, C_{OUT} = 1mF, and C_{DVDT} = 82nF)

3.1.3 Power Up Into Short

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

1. Set the input supply voltage VIN to 54V and current limit to 5A. Keep the power supply OFF. Connect the supply between VIN (connector T1) and PGND (connector T3).
2. Short the output of the EVM to ground. For example, VOUT (connector T2) to PGND (connector T3) through a cable.
3. Keep the eFuses disabled by pressing the switch SW1.
4. Turn ON the power supply.
5. Enable the TPS1689 eFuse by releasing the switch SW1.

The test waveforms of power up into output short on the TPS1689EVM with two devices in parallel are shown in Figure 3-4.

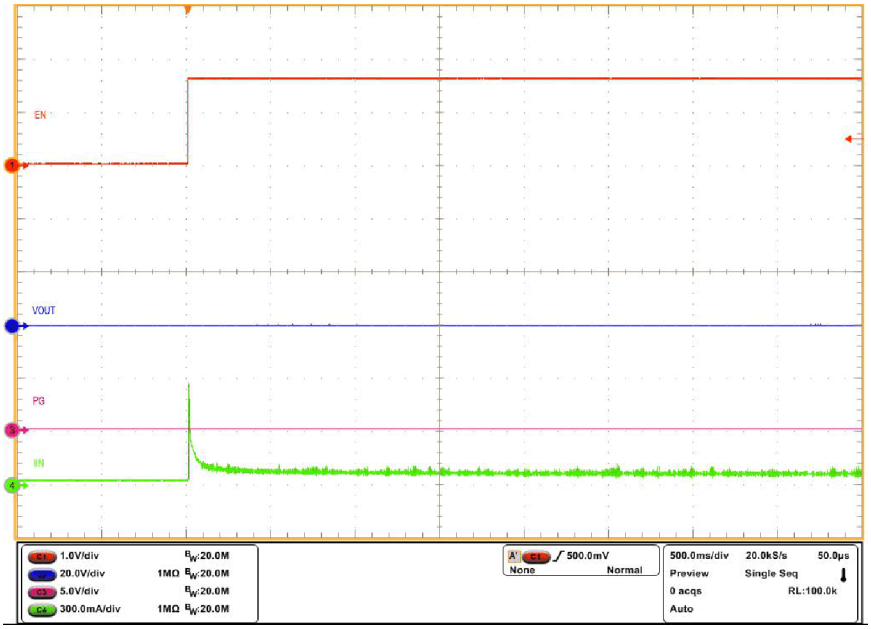


Figure 3-4. Power Up Into Output Short Response of TPS1689EVM (V_{IN} = 54V, EN Stepped Up From 0V to 5V, and OUT Shorted to PGND)

3.1.4 Undervoltage Lockout

Use the following instructions to perform the overvoltage protection test:

1. Set the input supply voltage VIN to 54V and current limit to 5A. Apply the supply between VIN (Connector T1) and PGND (Connector T3) and enable the power supply.
2. Apply a load of 50Ω between VOUT (connector T2) and PGND (connector T3).
3. Decrease the input supply VIN from 54V to 38V and increase to 54V again, and observe the waveforms using an oscilloscope.

The undervoltage lockout response of TPS1689 eFuse on TPS1689EVM is shown in Figure 3-5.

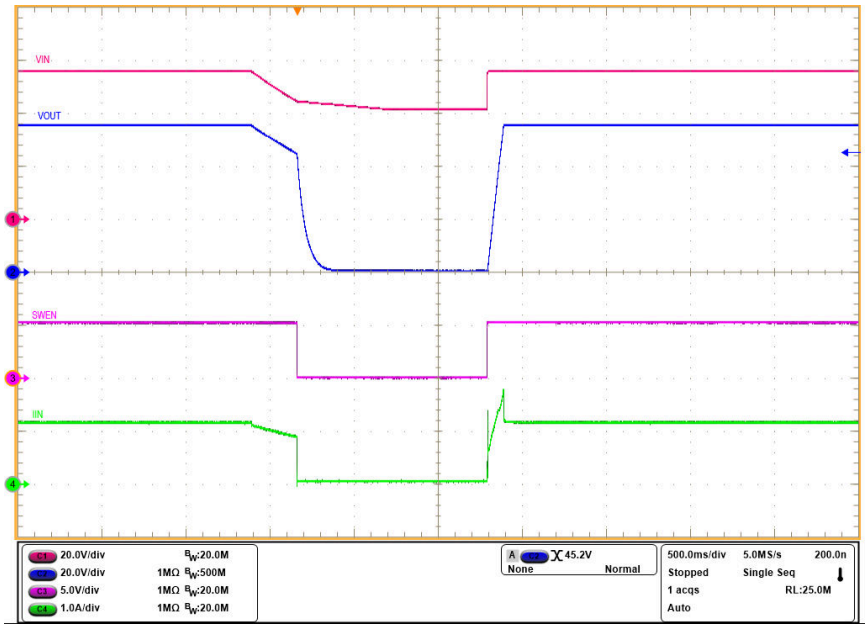


Figure 3-5. Undervoltage Lockout Response of TPS1689 eFuse (V_{IN} Ramped Down From 54V to 38V and Ramped Up to 54V, $V_{IN(UVP)}$ = 40V, C_{OUT} = 1mF, and R_{LOAD} = 50Ω)

3.1.5 Overvoltage Lockout

Use the following instructions to perform the overvoltage protection test:

1. Set the input supply voltage VIN to 54V and current limit to 5A. Apply the supply between VIN (connector T1) and PGND (connector T3) and enable the power supply.
2. Apply a load of 50Ω between VOUT (connector T2) and PGND (connector T3).
3. Increase the input supply VIN from 54V to 62V and decrease to 54V again, and observe the waveforms using an oscilloscope.

The overvoltage lockout response of TPS1689 eFuse on TPS1689EVM is shown in Figure 3-6.

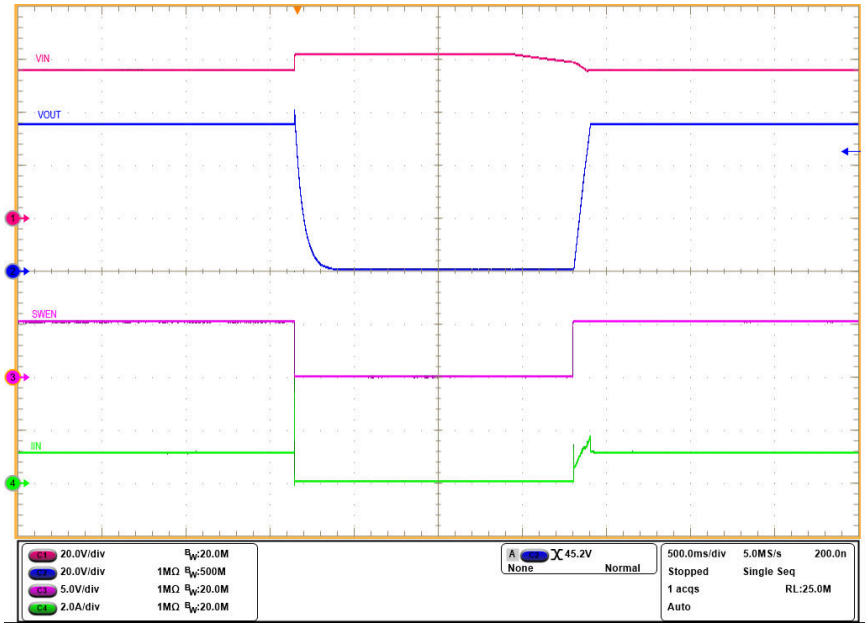


Figure 3-6. Overvoltage Lockout Response of TPS1689 eFuse (V_{IN} Ramped Up From 54V to 62V and Ramped Down to 54V, $V_{IN(OVP)}$ = 60V, C_{OUT} = 1mF, and R_{LOAD} = 50Ω)

3.1.6 Overcurrent Event

Use the following instructions to perform the persistent over-current test on TPS1689 eFuse:

1. The overcurrent blanking timer duration (tTIMER) is 2.18ms 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 0ms to 27.8ms.
2. The reference voltage for overcurrent protection and active current sharing is at 1V 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 0.3V to 1.2V.
3. Configure the Jumper J2 in a good position to set the required circuit breaker threshold (I_{OCP}) as per Table 2-3.
4. Configure the Jumper J5 in a good position to set the required scalable fast-trip threshold (I_{SFT}) as per Table 2-3.
5. Set the input supply voltage VIN to 54V and the current limit of 100A.
6. Connect the power supply between VIN (connector T1) and PGND (connector T3) and enable the power supply.
7. Now apply an overload in the range of I_{OCP} and I_{SFT} between VOUT (connector T2) and PGND (connector T3) for a time duration more than t_{TIMER}.
8. Observe the waveforms using an oscilloscope.

The circuit breaker response of TPS1689 eFuse on TPS1689EVM evaluation board with two devices in parallel is shown in Figure 3-7.

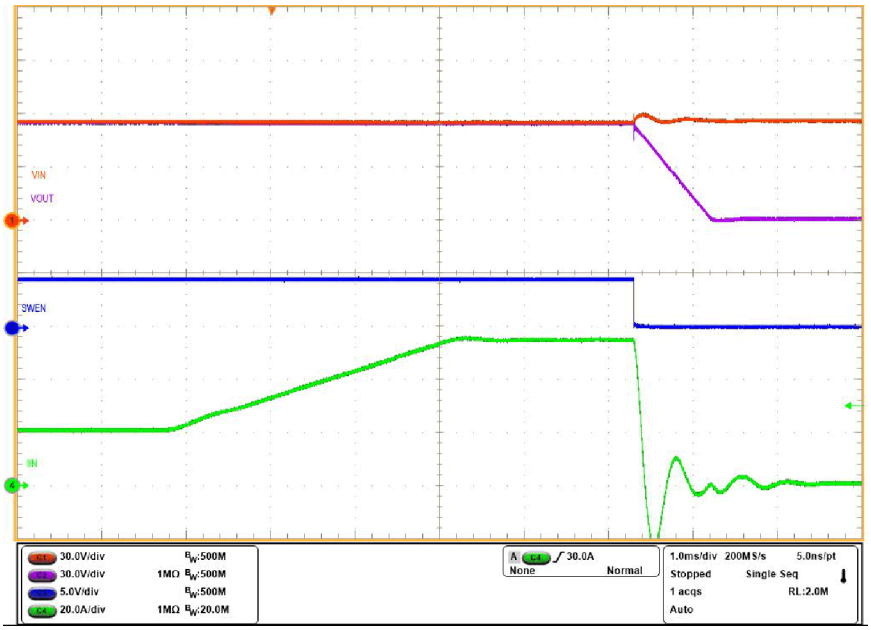


Figure 3-7. Persistent Overload Performance of TPS1689 eFuse

3.1.7 Output Hot Short

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

1. Set the input supply voltage VIN to 54V and connect the power supply between VIN (connector T1) and PGND (Connector T3).
2. Configure the Jumper J5 in a good position to set the required scalable fast-trip threshold (I_{SFT}) as per Table 2-3.
3. Turn ON the power supply to power up the EVM.
4. Short the output of the device for example, VOUT (connector T2) to PGND (connector T3) through a short cable.
5. Observe the waveforms using an oscilloscope.

The test waveforms of output hot short on the TPS1689EVM are shown in Figure 3-9 and Figure 3-9.

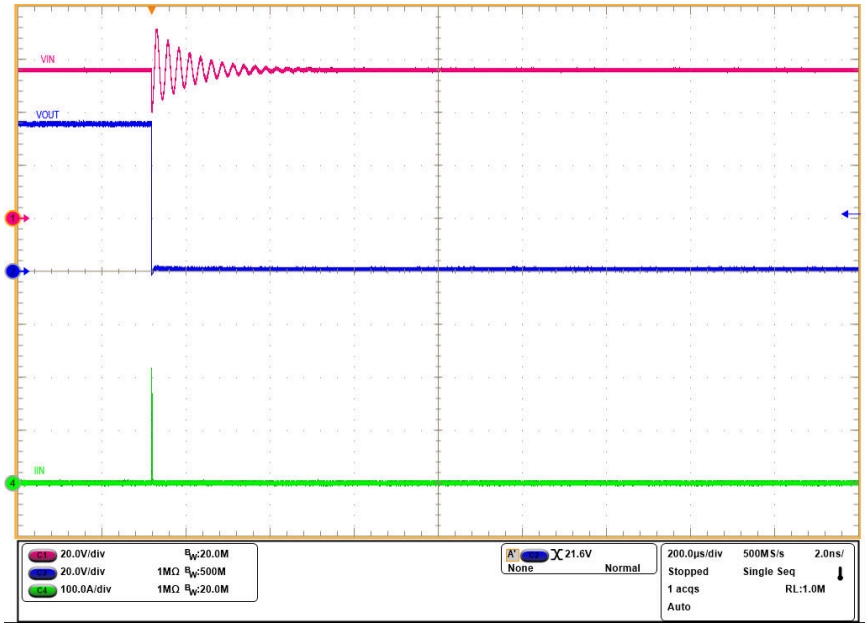


Figure 3-8. Output Hot Short Response (Zoomed Out) in TPS1689EVM (V_{IN} = 54V, R_{IMON} = 1.24kΩ, R_{IREF} = 40.2kΩ, R_{SFT} = 150kΩ, and C_{OUT} = 1mF)

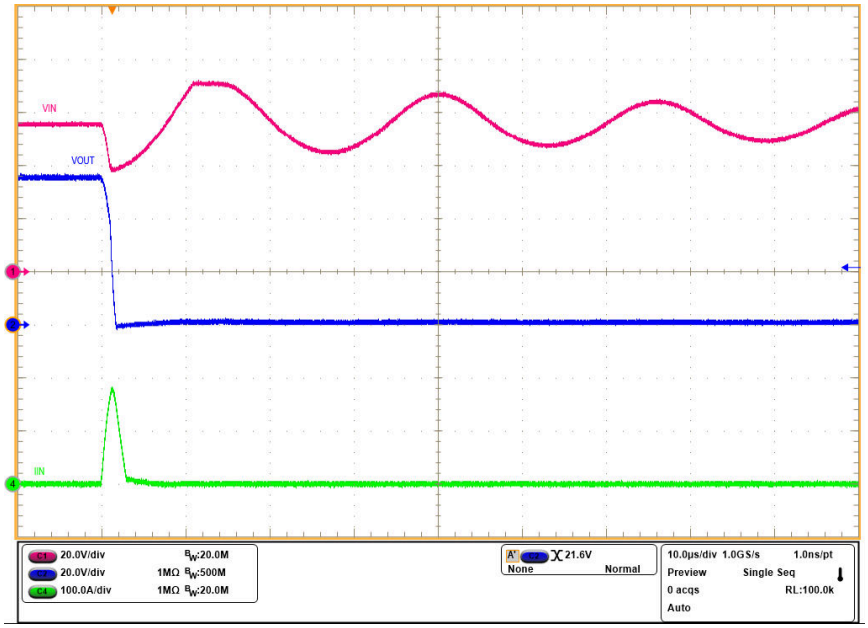


Figure 3-9. Output Hot Short Response (Zoomed In) in TPS1689EVM (V_{IN} = 54V, R_{IMON} = 1.24kΩ, R_{IREF} = 40.2kΩ, R_{SFT} = 150kΩ, and C_{OUT} = 1mF)

Note

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.

To obtain repeatable and similar short-circuit testing results is very 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 short microscopically bounces and arcs. Make sure 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.

3.1.8 Thermal Performance of TPS1689EVM

Use the following instructions to evaluate the thermal performance of TPS1685EVM:

1. Set the input supply voltage VIN to 54V and current limit of 50A.
2. Connect the power supply between VIN (connector T1) and PGND (connector T3) and enable the power supply.
3. Now apply a load of 40A (DC) between VOUT (connector T2) and PGND (connector T3) for half an hour or more to reach the thermal equilibrium point.
4. Capture the thermal image of the EVM or monitor the voltage at TEMP (TP7) pin using a digital multimeter. Voltage at the TEMP (V_{TEMP}) pin reports the maximum die temperature between two eFuses, which can be obtained using Equation 1.

$$T_J(°C) = \left[25 + \left\{\frac{V_{TEMP}(mV) - 680}{2.65\ (mV/°C)}\right\}\right] \quad (1)$$

The thermal performance of TPS1689EVM is shown in Figure 3-10.

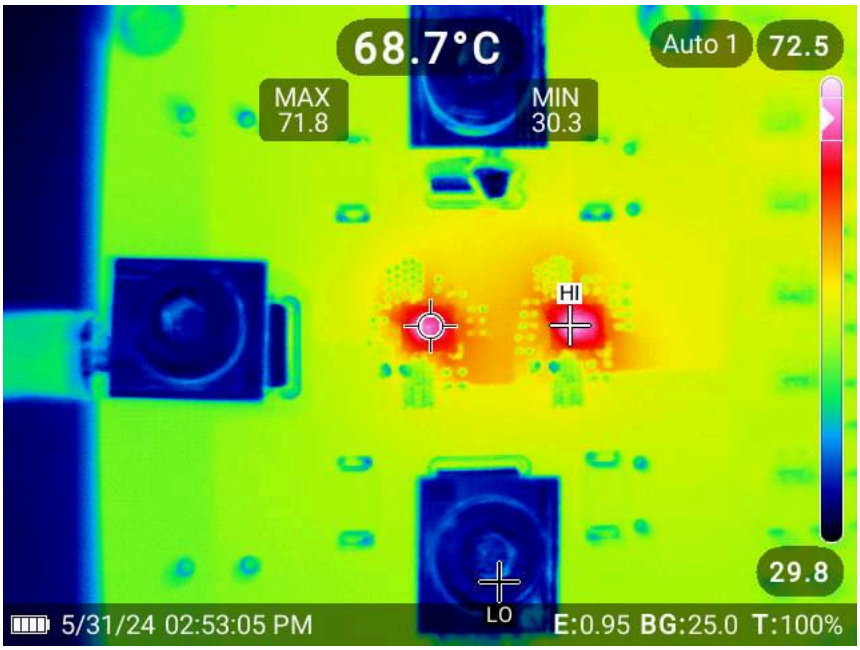


Figure 3-10. Thermal Performance of TPS1689EVM (V_{IN} = 54V, I_{OUT} = 40A, T_A = 30°C, and No External Air Flow)

4 Using the TPS1689EVM-GUI

4.1 Access the TPS1689EVM-GUI

After accessing the TPS1689EVM-GUI for the first time in a web browser (preferably Google Chrome™ browser), the following pop-up appears as shown in Figure 4-1. Make sure to complete *Step 1* and *Step 2* and then click on the *FINISH* icon.

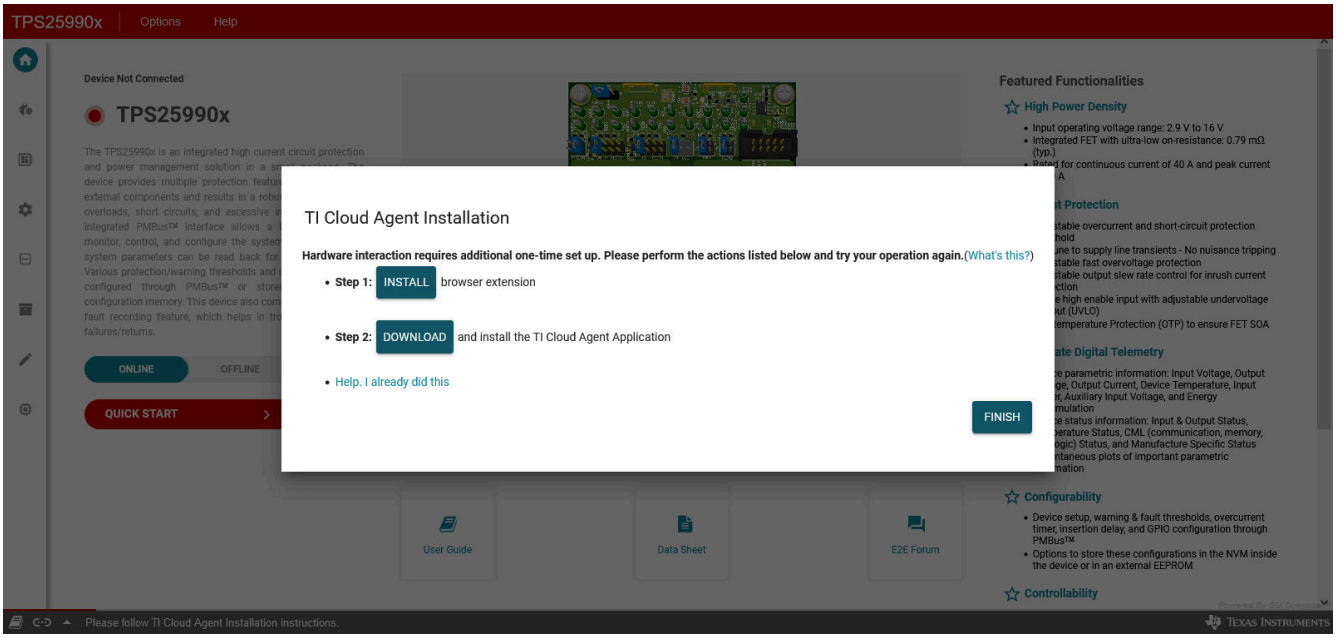


Figure 4-1. Prerequisite to Establish Communication Between the EVM and GUI

4.2 Introduction to the TPS1689EVM-GUI

On the introductory page of the GUI, shown in Figure 4-2, users are introduced to the TPS1689 eFuse functionalities and features. Furthermore, the page provides links to the TPS1689 eFuse data sheet, the TPS1689EVM user's guide, and the TI E2E™ forum where users can post their questions.

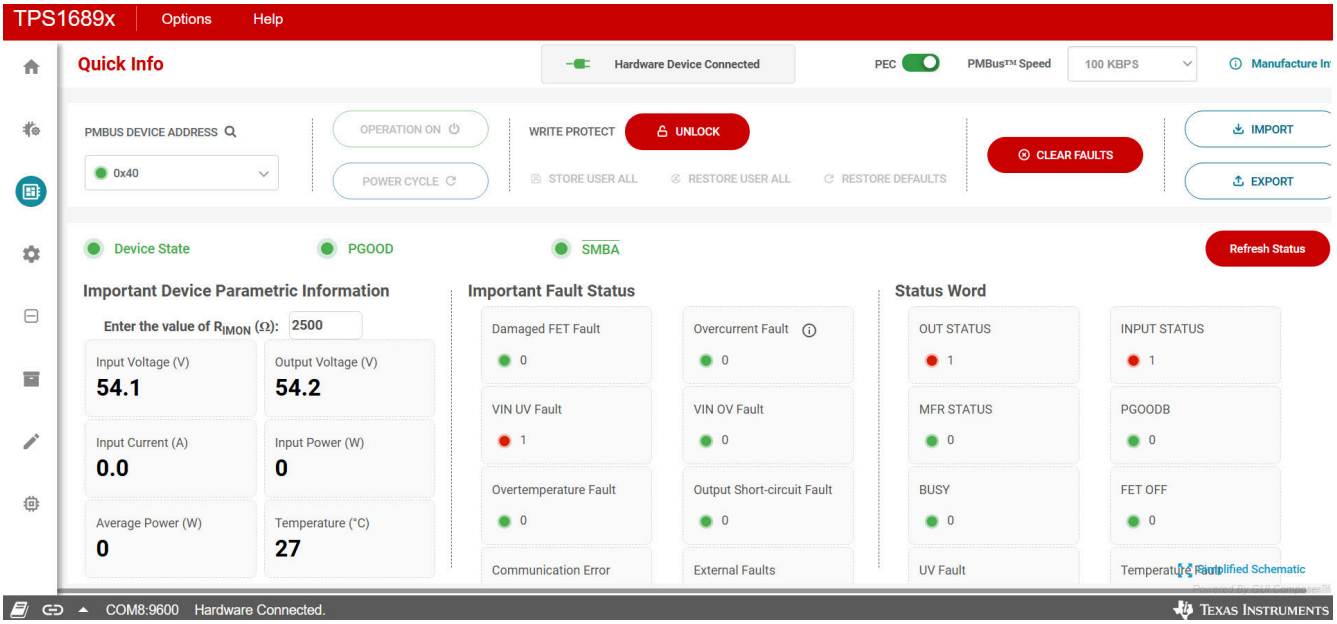


Figure 4-2. TPS1689EVM-GUI: Introduction

4.3 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 4-3.

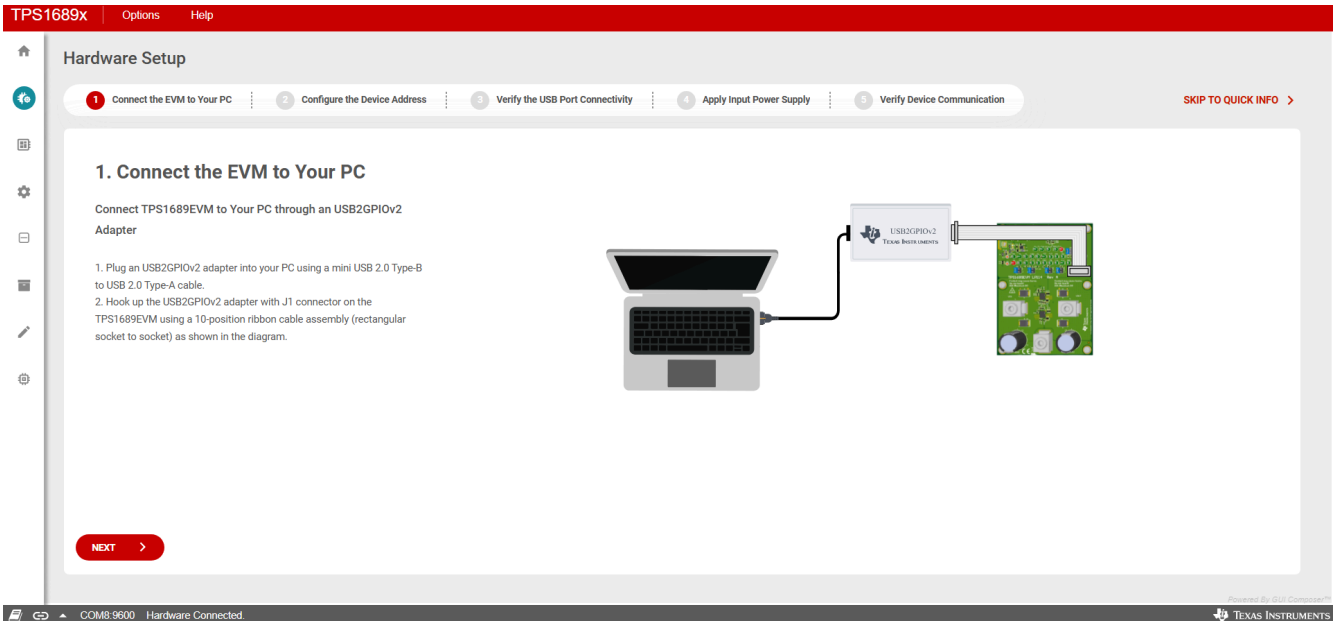


Figure 4-3. Hardware Setup: Establishing the Communication Between the EVM and GUI

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 4-4, after completing all the previous four steps as outlined.

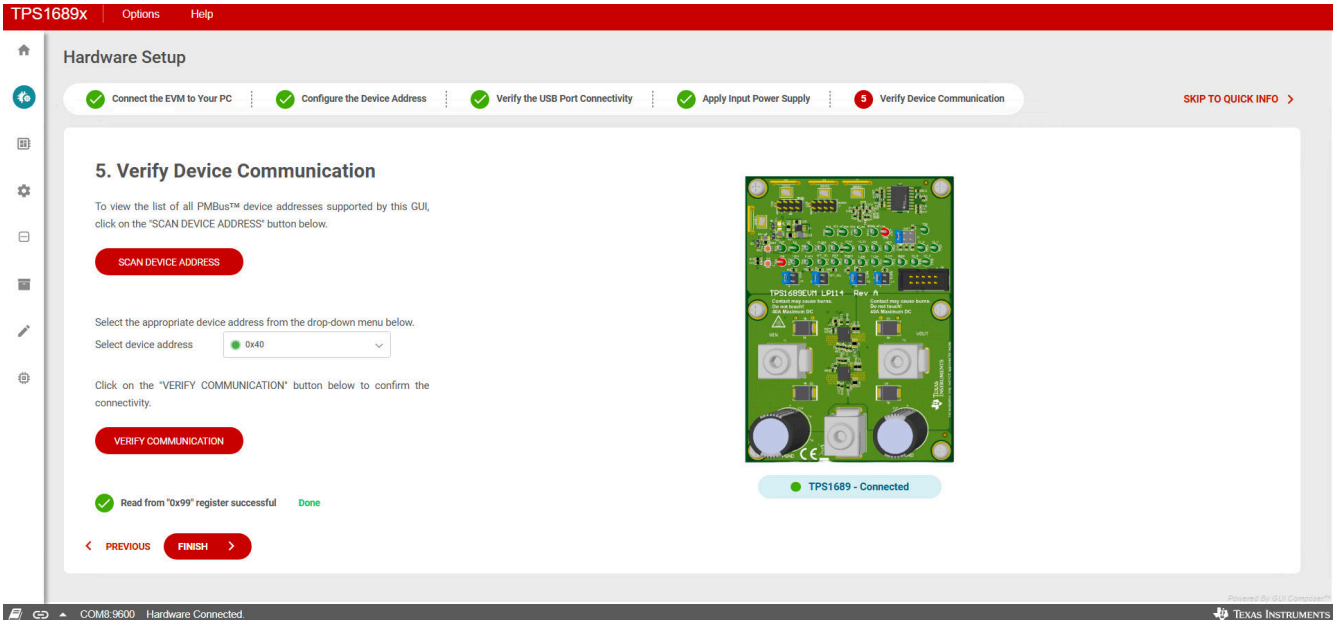


Figure 4-4. TPS1689EVM-GUI: Verify Device Connectivity

4.4 Quick Info

As presented in Figure 4-5, users reach to the *Quick Info* page after clicking on the *FINISH* icon upon verifying the device communication, depicted in Figure 4-4. As shown in Figure 4-5, 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 TPS1689 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
- 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

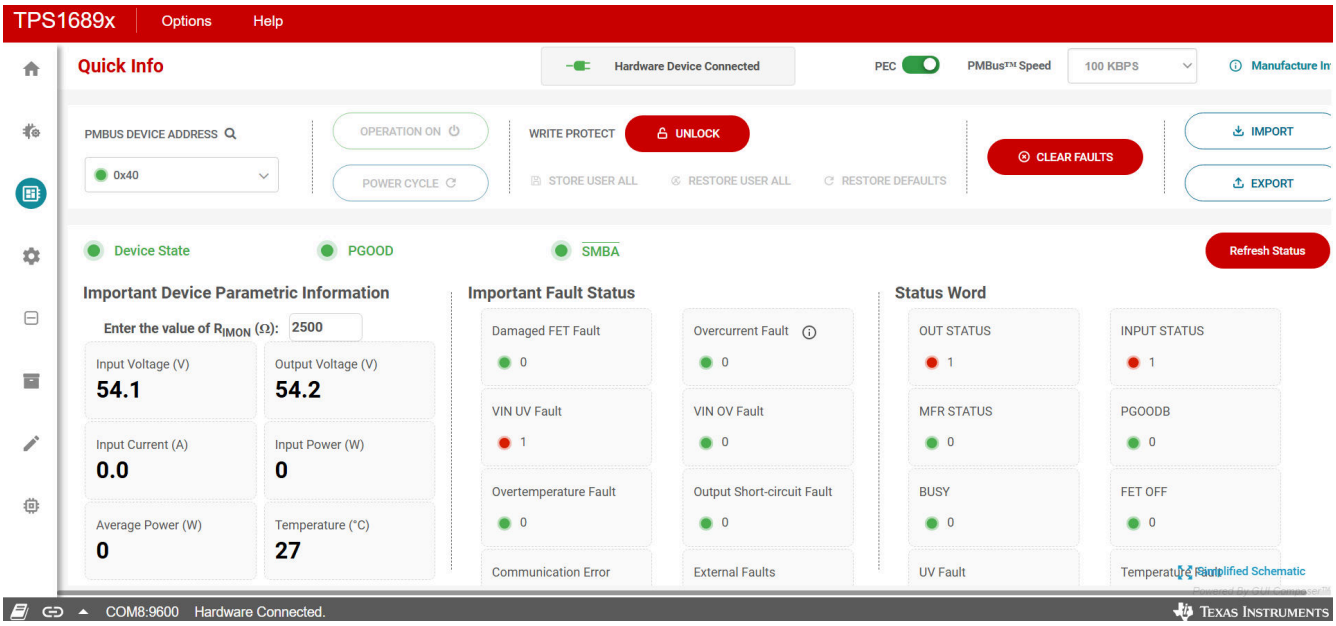


Figure 4-5. TPS1689EVM-GUI: Quick Info

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 4-5) so that it matches the resistance placed at the IMON pin on the EVM.

4.5 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 4-6.

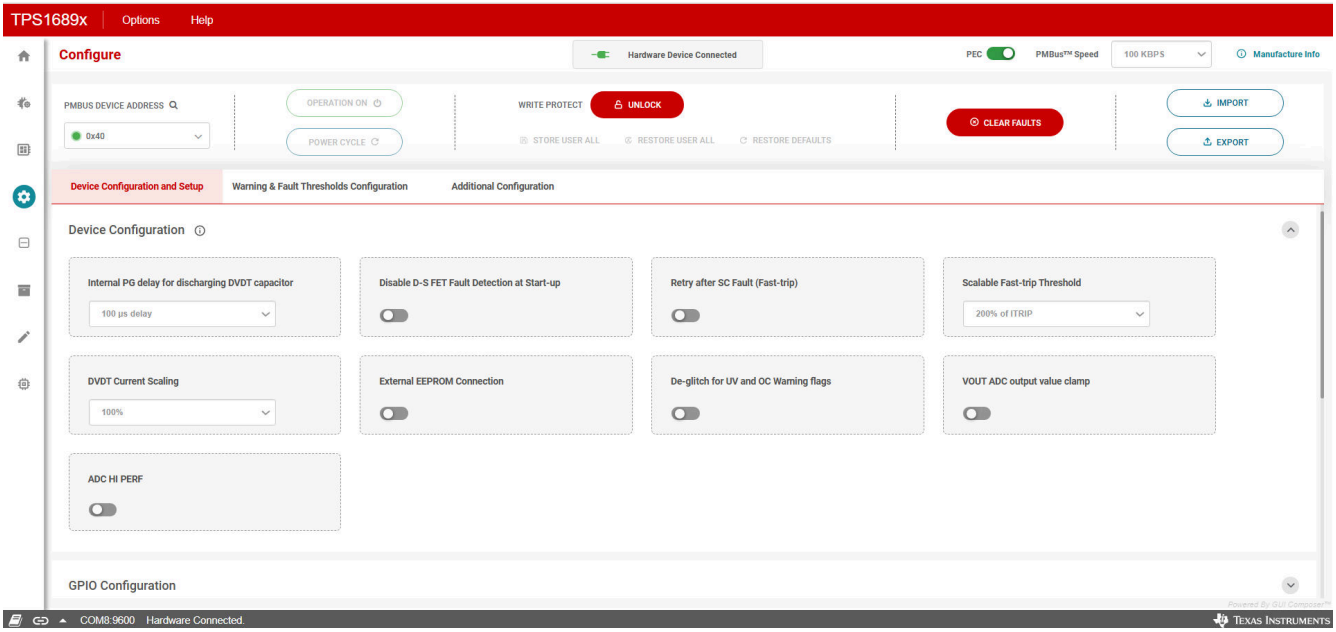


Figure 4-6. TPS1689EVM-GUI: Device Configuration

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

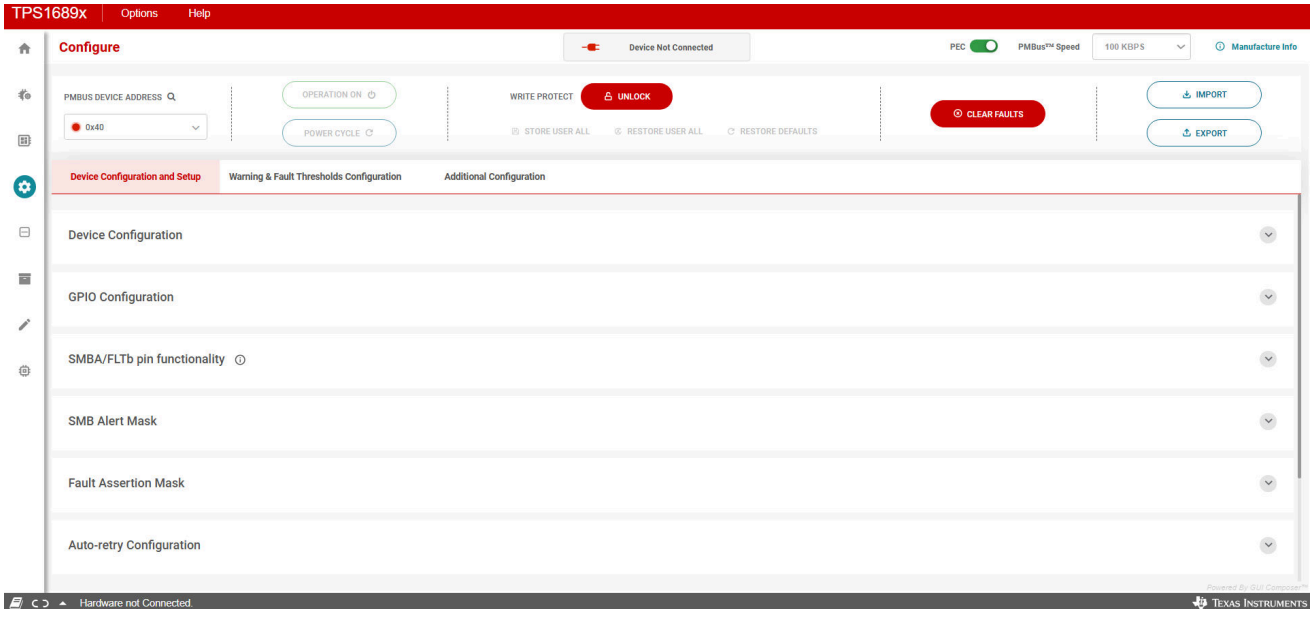


Figure 4-7. TPS1689EVM-GUI: Device Configuration: Device Configuration and Setup

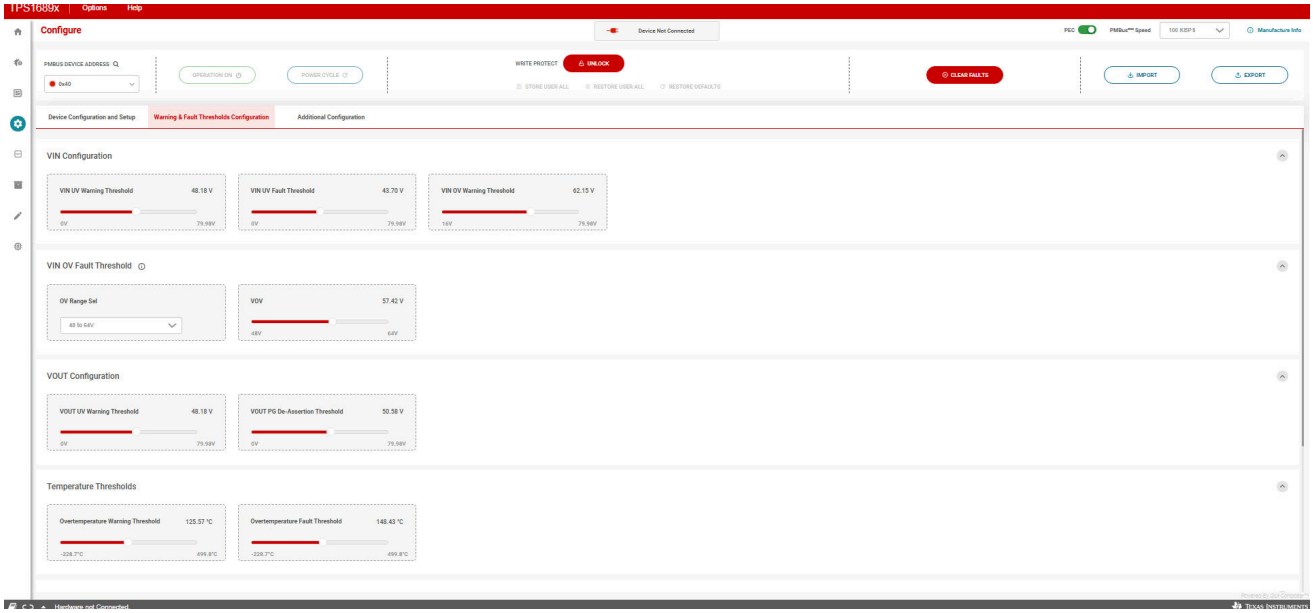


Figure 4-8. TPS1689EVM-GUI: Device Configuration: Warning & Fault Thresholds Configuration

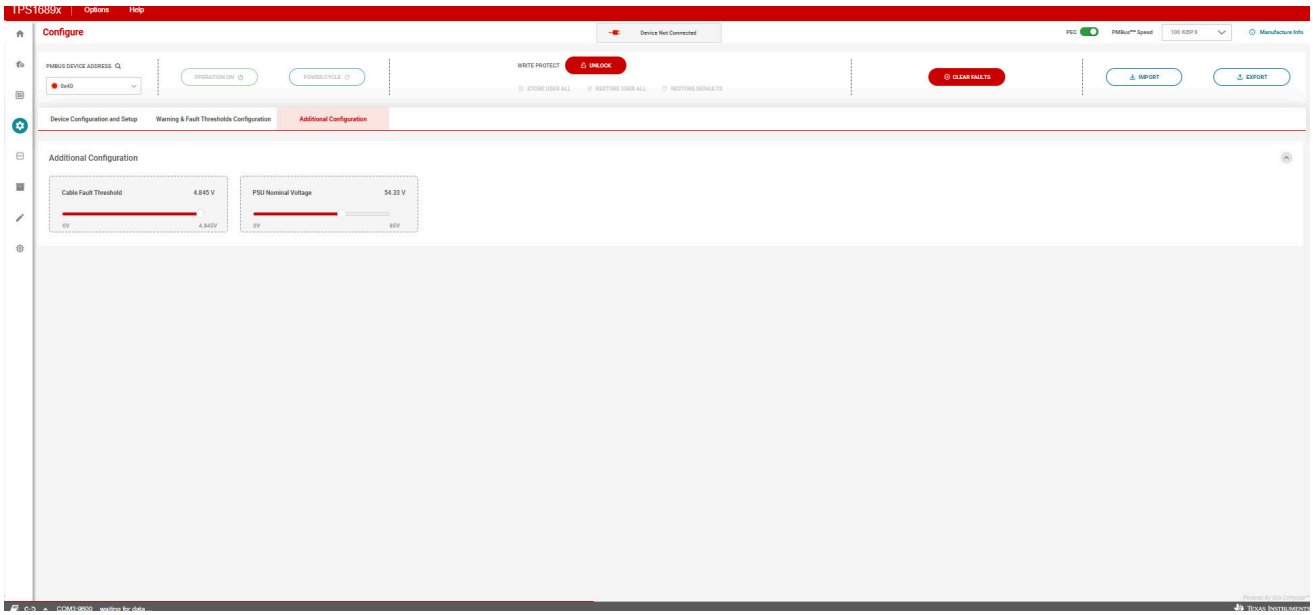


Figure 4-9. TPS1689EVM-GUI: Device Configuration: Additional Configuration

4.6 Telemetry

The *Telemetry* page as shown in Figure 4-10 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.

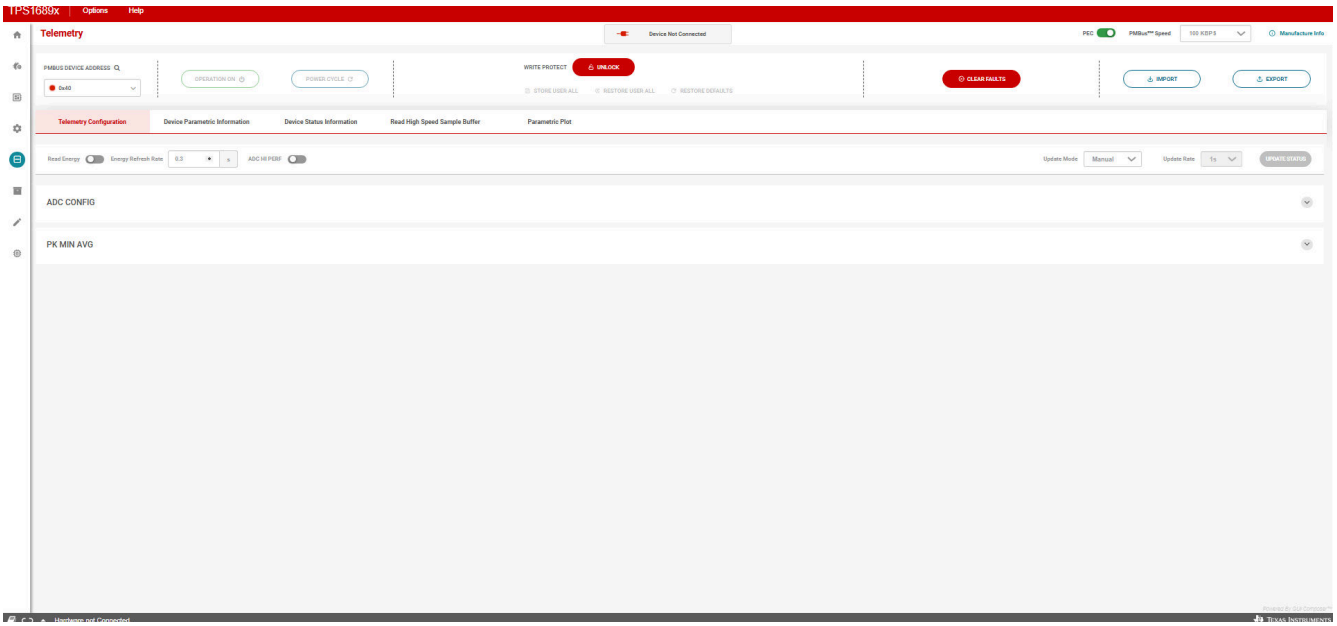


Figure 4-10. TPS1689EVM-GUI: Device Telemetry

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*.

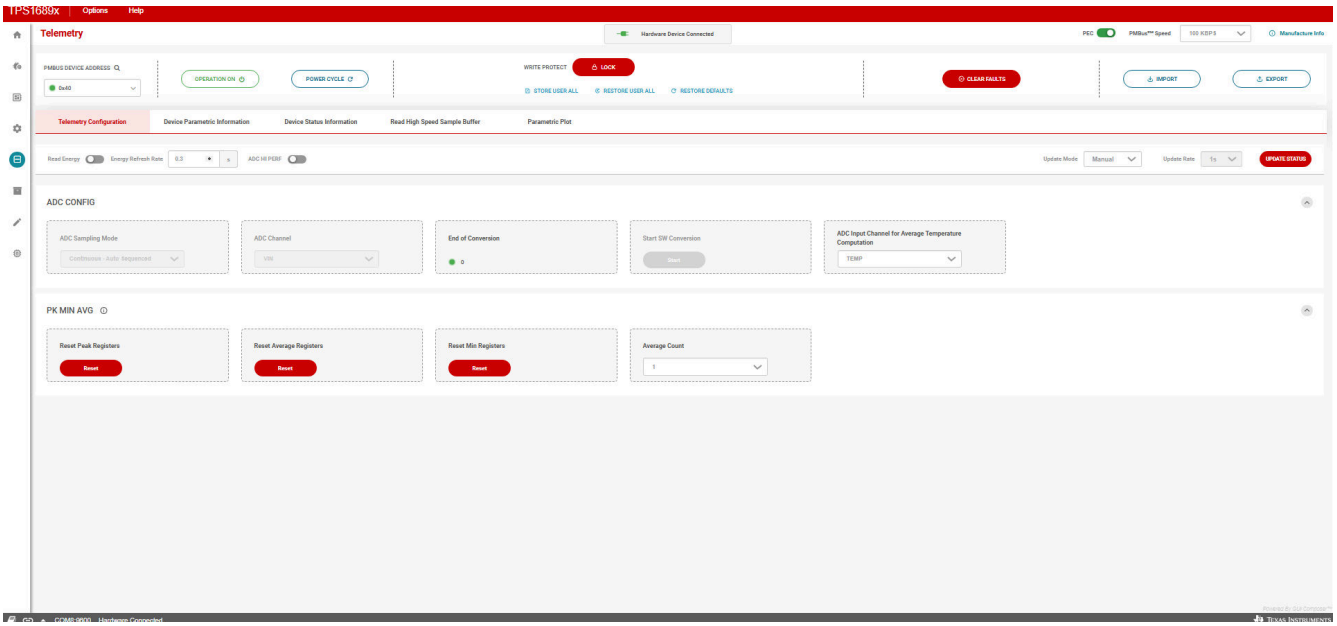


Figure 4-11. Telemetry Configuration

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.

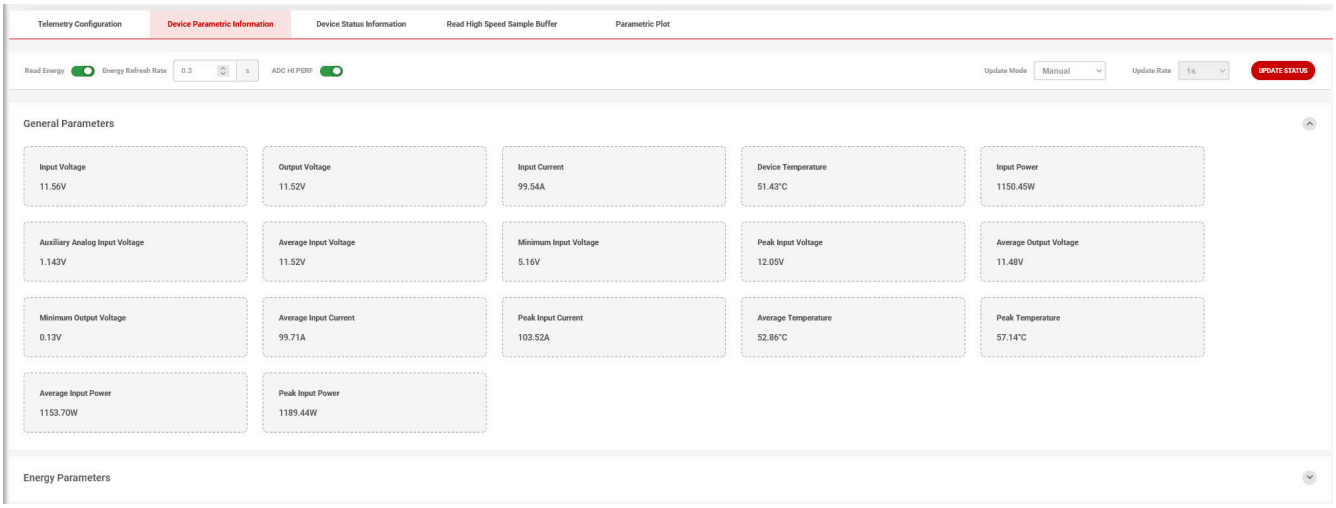


Figure 4-12. Device Parametric Information: General Parameters

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 4-13. 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 4-13. *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 11µs 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.

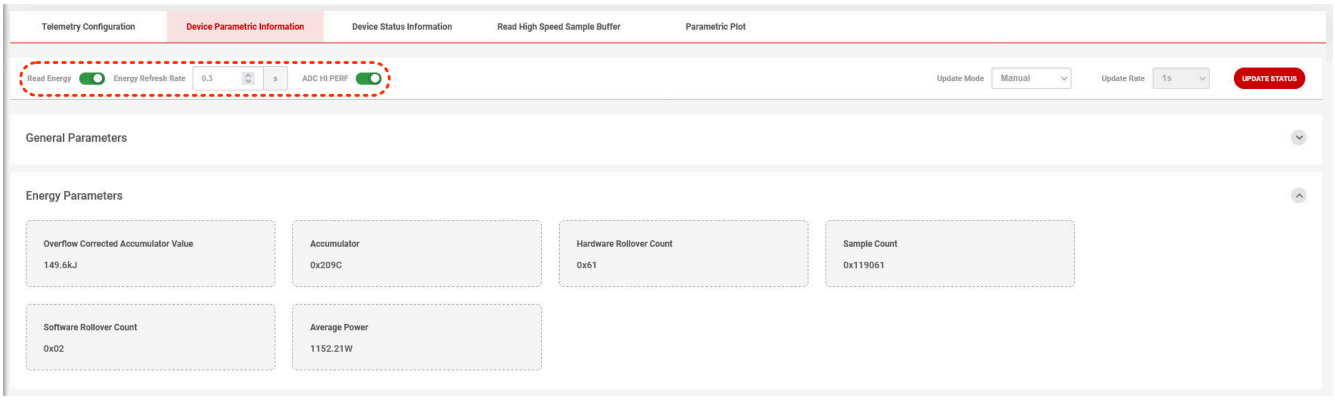


Figure 4-13. Device Parametric Information: Energy Parameters

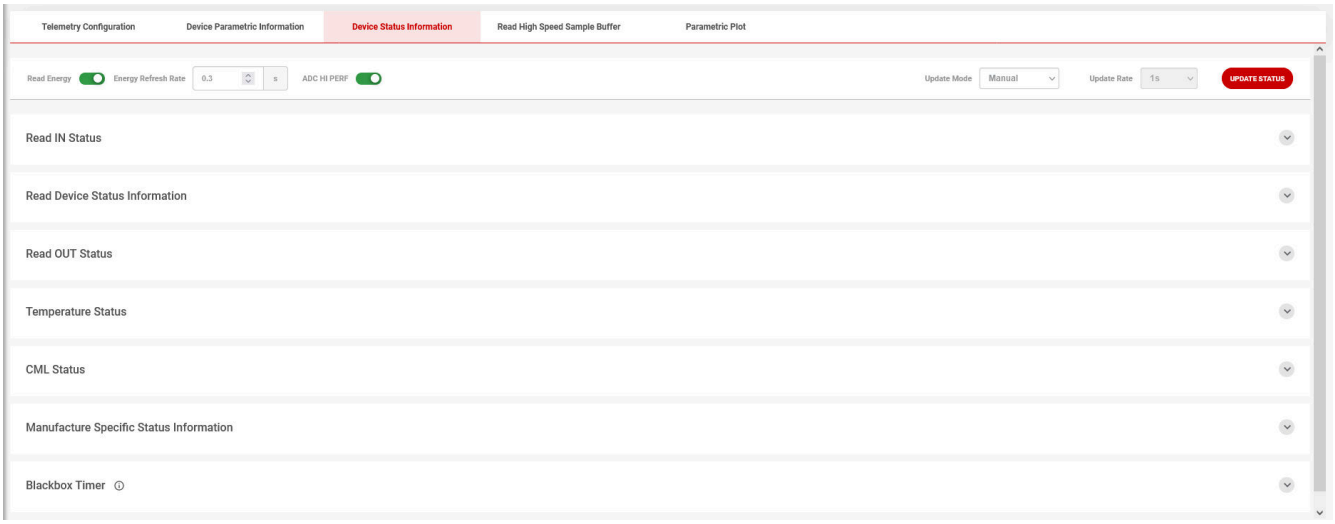


Figure 4-14. Device Status Information

Device parametric and status information can be updated manually or automatically as selected in the *Update Mode* drop-down menu shown in Figure 4-15. 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 4-15. 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.

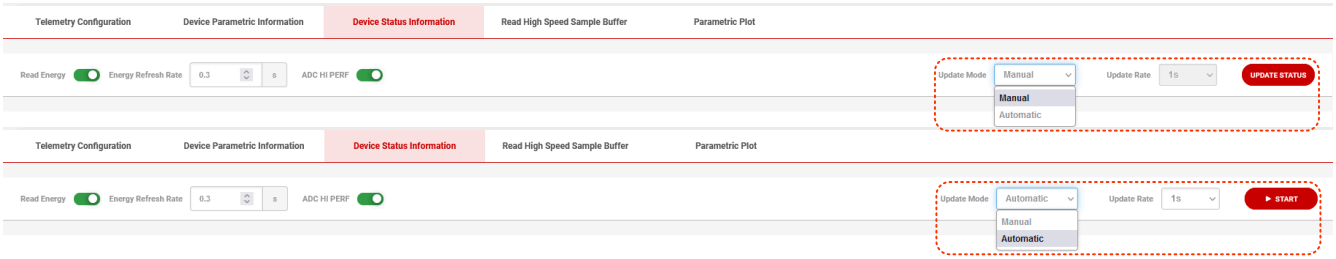


Figure 4-15. Device Telemetry Update

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 4-15. 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.

Figure 4-16 represents the plots of input voltage using the data retrieved by sending the READ_SAMPLE_BUF (D8h) block read command.

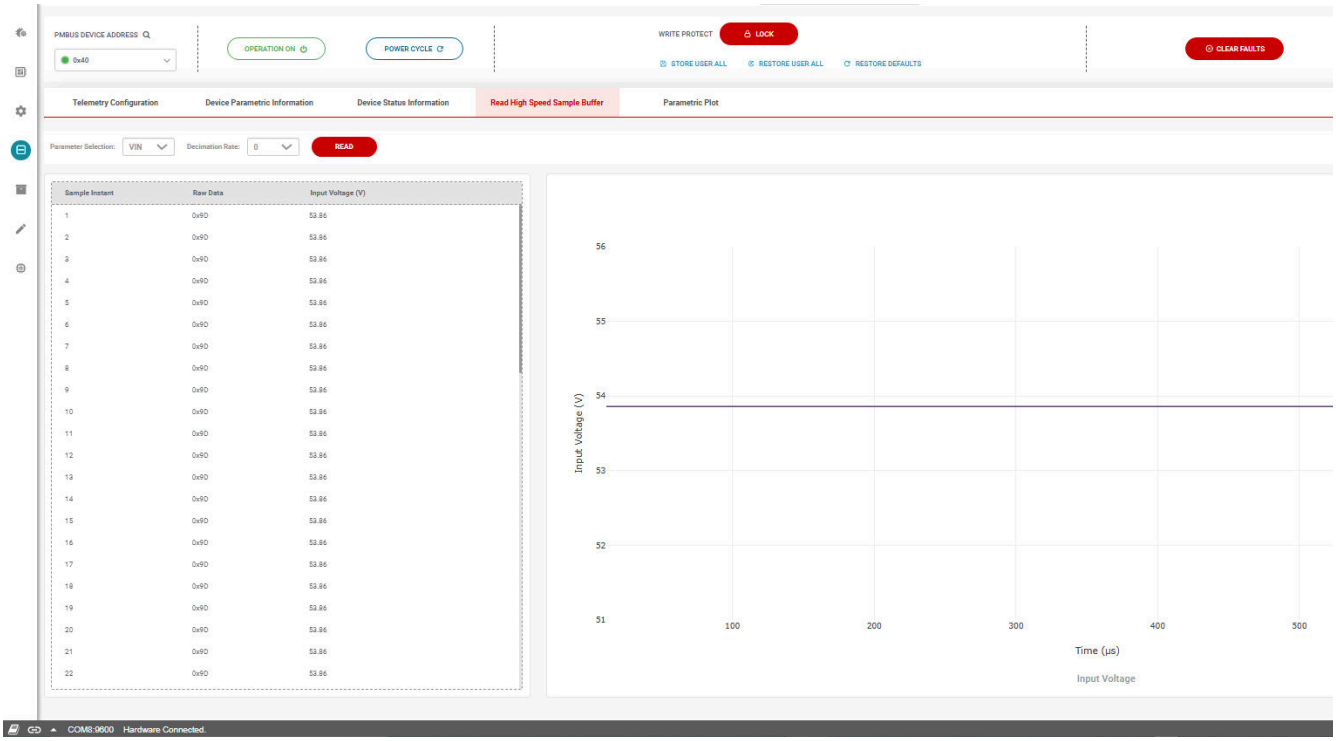


Figure 4-16. Read High Speed Sample Buffer, Input Voltage

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 4-17. Users must select the update rate from the drop-down menu called *Update Rate* as presented in Figure 4-17. 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.

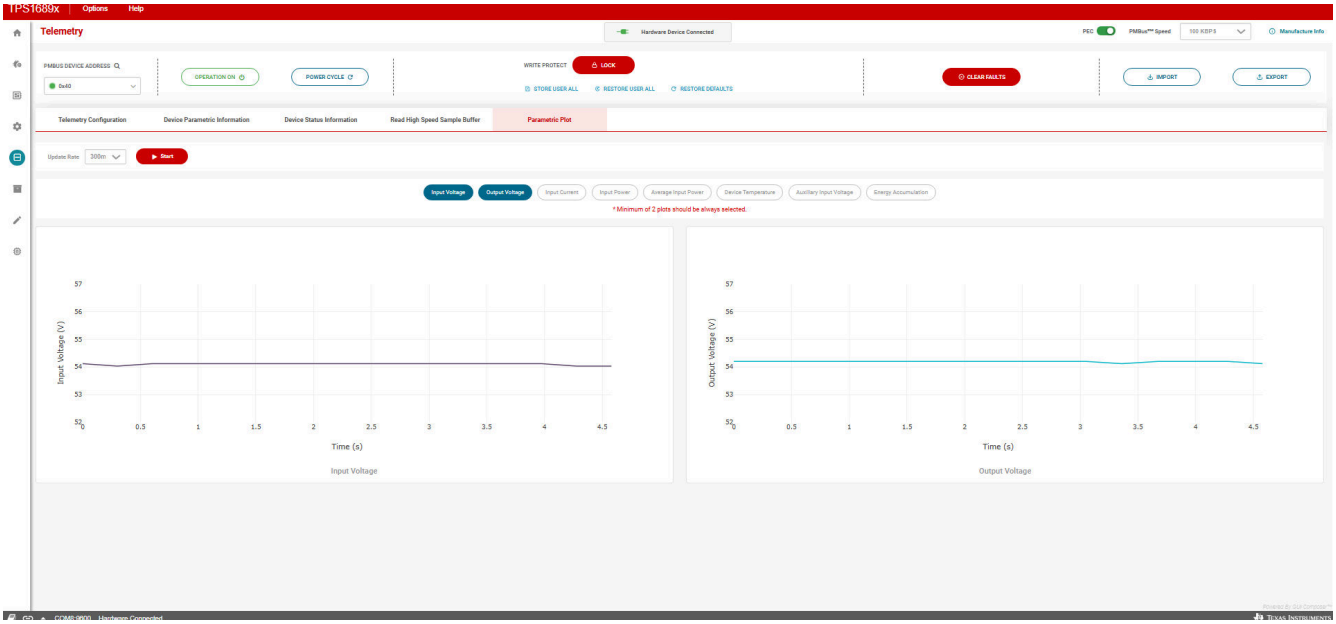


Figure 4-17. Parametric Plot

4.7 Register Map Page

The *Register Map* page as shown in Figure 4-18 enables users to access all the registers supported by TPS1689 eFuse at a glance. Additionally, read and write operations can also be performed here on each register as applicable.

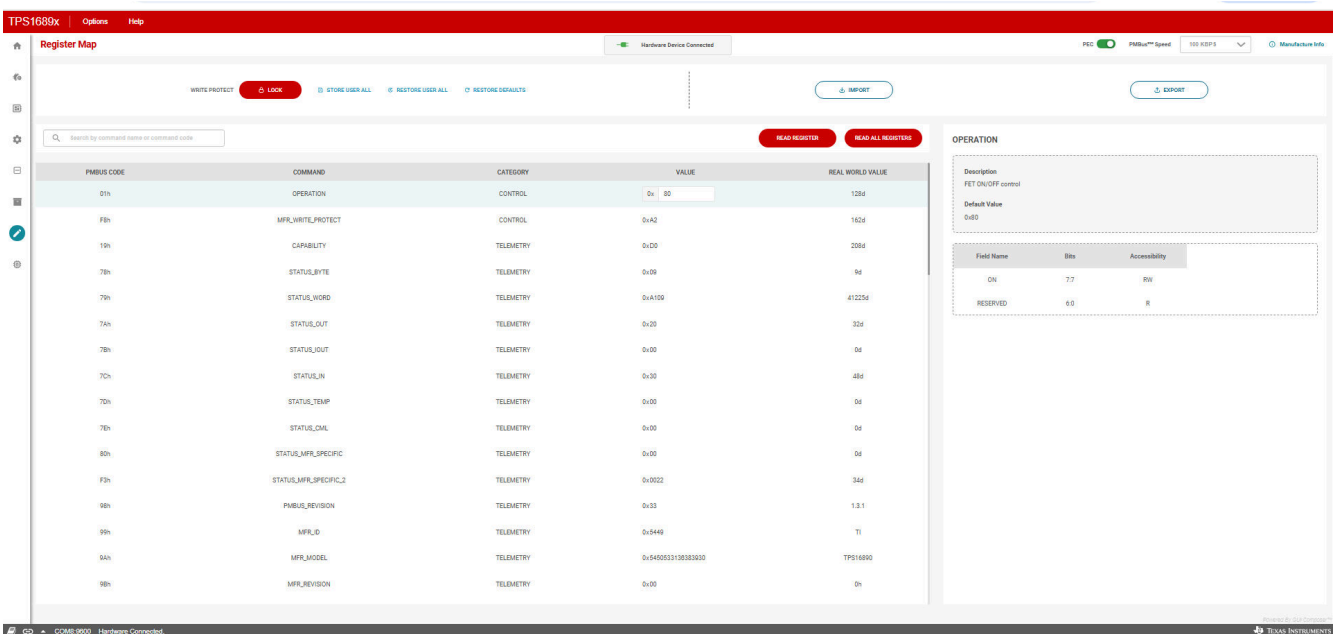


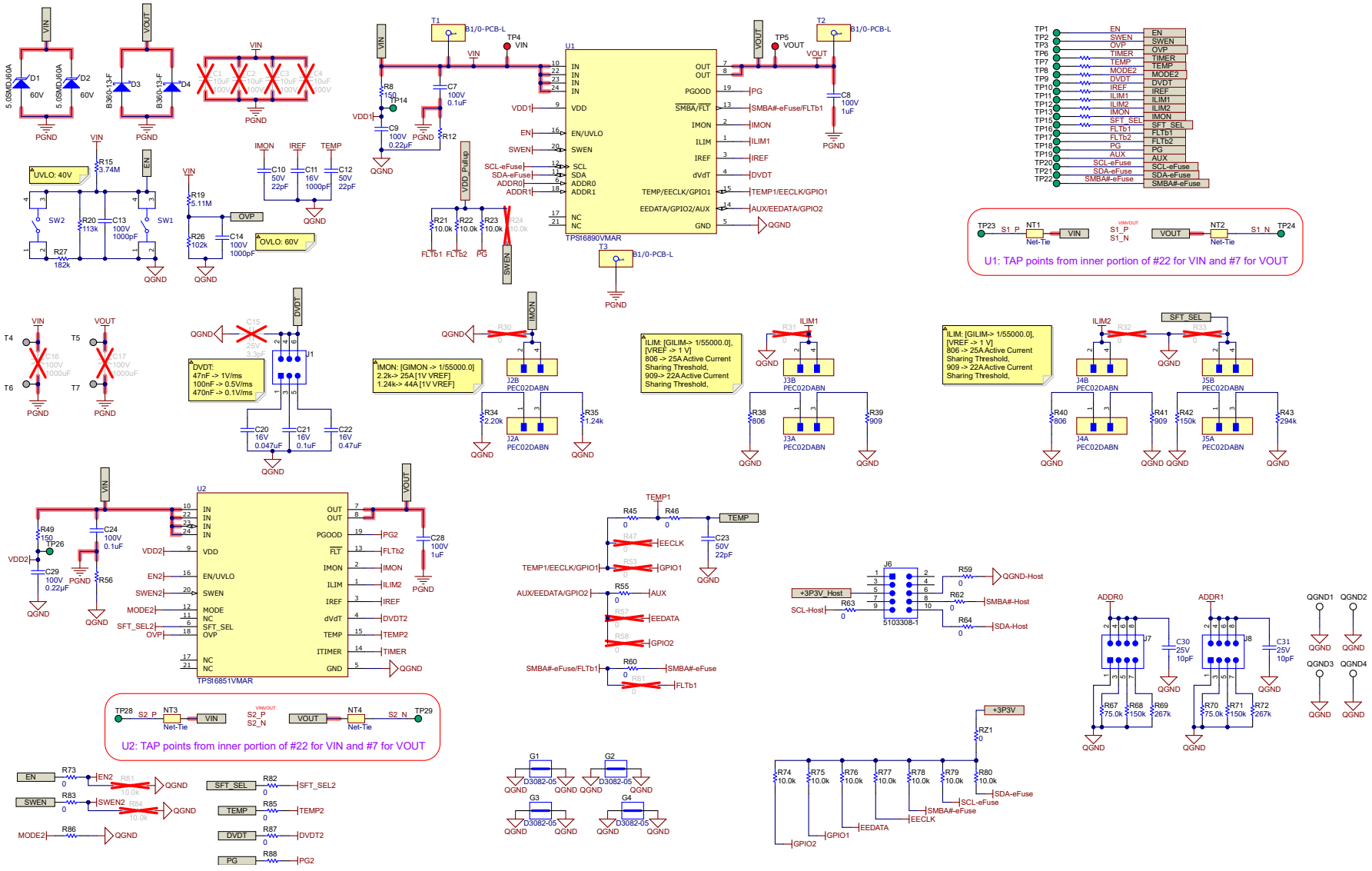
Figure 4-18. TPS1689EVM-GUI: Register Map

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.

5 Hardware Design Files

5.1 Schematic

Figure 5-1 illustrates the EVM schematic.



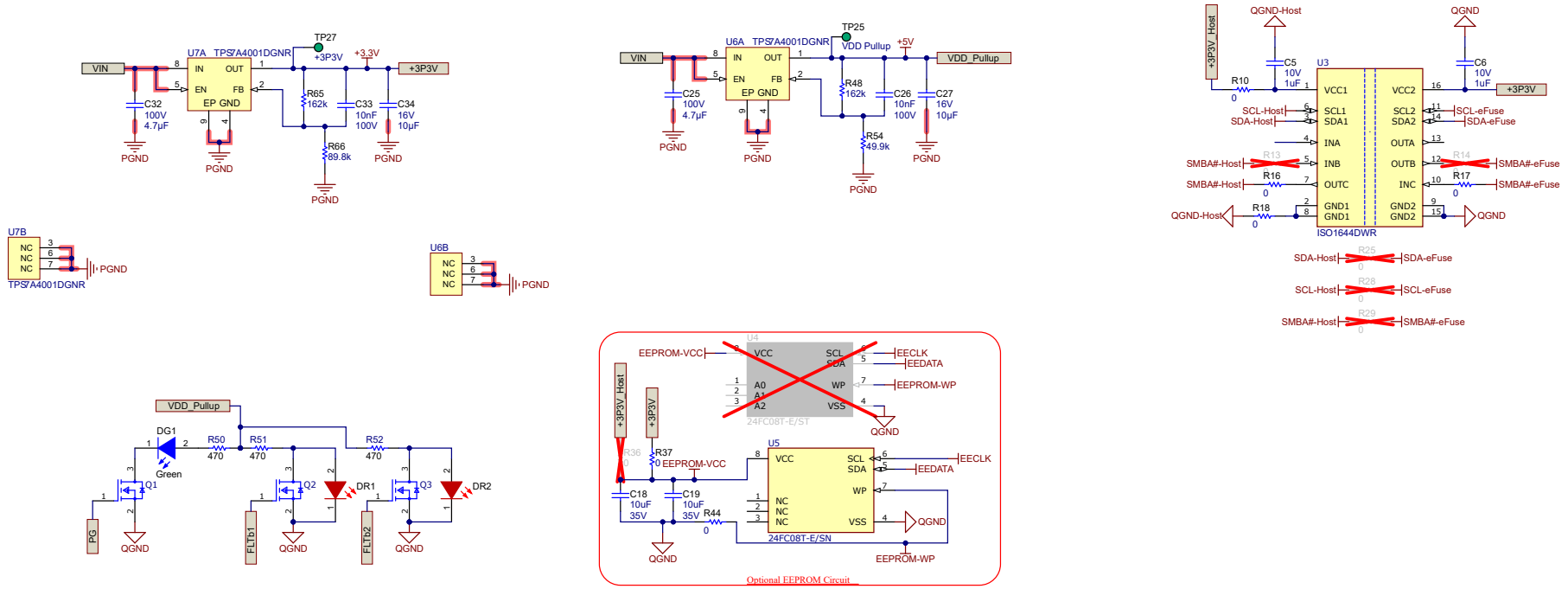


Figure 5-1. TPS1689EVM eFuse Evaluation Board Schematic

Note

- To evaluate the performance of TPS1689 at lower currents (<20A), R83, R85, R73, R88, R87 and R82resistors need to be depopulated, and R81 and R84 resistors must be populated to disable the secondary eFuse (TPS1685).
- The ground connections for the various components around the TPS1689 and TPS1685 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.

5.2 PCB Drawings

Figure 5-2 and Figure 5-3 show the component placements of the EVM. A pictorial representation of the TPS1689EVM PCB layers can be found in Figure 5-4 and Figure 5-5.

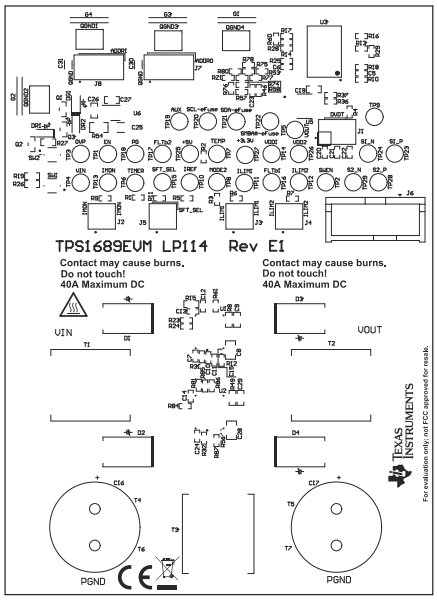


Figure 5-2. TPS1689EVM Board: Top Assembly

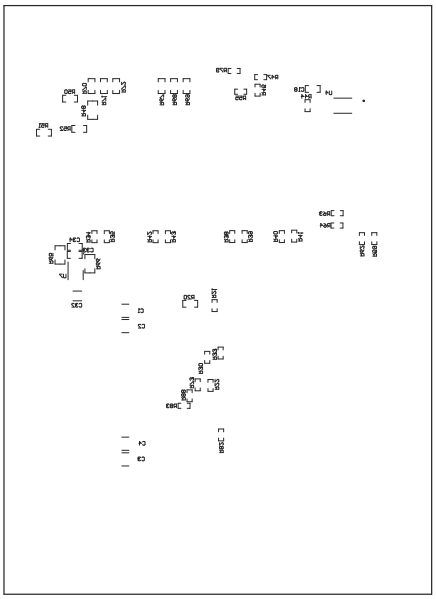


Figure 5-3. TPS1689EVM Board: Bottom Assembly

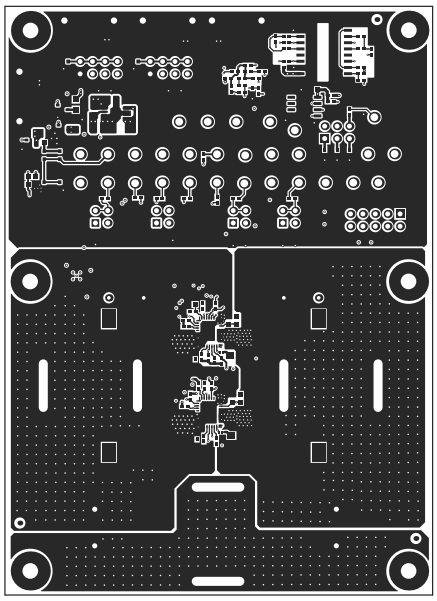


Figure 5-4. TPS1689EVM Board: Top Layer

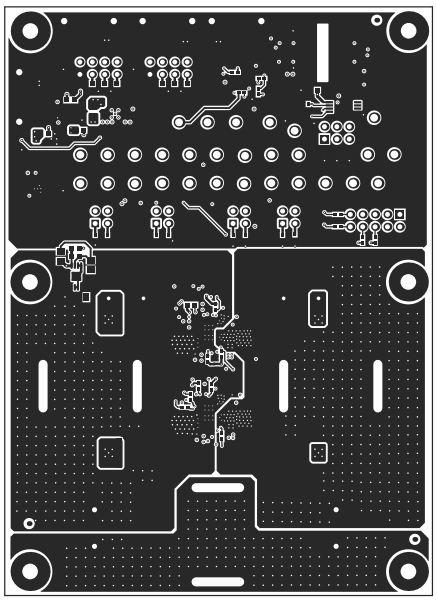


Figure 5-5. TPS1689EVM Board: Bottom Layer

Note

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

5.3 Bill Of Materials (BOM)

Table 5-1. TPS1689EVM Bill of Materials

Item #	Designator	Quantity	Value	PartNumber	Manufacturer	Description	PackageReference
1	!PCB1	1		LP114	Any	Printed Circuit Board	
2	C5, C6	2	1uF	GRM155R61A105KE15D	MuRata	CAP, CERM, 1 uF, 10 V, +/- 10%, X5R, 0402	402
3	C7, C24	2	0.1uF	GRM155R62A104KE14D	MuRata	CAP, CERM, 0.1 uF, 100 V, +/- 10%, X5R, 0402	402
4	C8, C28	2	1uF	C2012X7S2A105K125AB	TDK	CAP, CERM, 1 uF, 100 V, +/- 10%, X7S, 0805	805
5	C9, C29	2	0.22uF	HMK107C7224KAHTE	Taiyo Yuden	CAP, CERM, 0.22 µF, 100 V,+/- 10%, X7S, AEC-Q200 Grade 1, 0603	603
6	C10, C12, C23	3	22pF	GRM1555C1H220FA01D	MuRata	CAP, CERM, 22 pF, 50 V, +/- 1%, C0G/NP0, 0402	402
7	C11	1	1000pF	GRM155R61C102KA01D	MuRata	CAP, CERM, 1000 pF, 16 V, +/- 10%, X5R, 0402	402
8	C13, C14	2	1000pF	GRM155R72A102KA01D	MuRata	CAP, CERM, 1000 pF, 100 V, +/- 10%, X7R, 0402	402
9	C18, C19	2	10uF	GRM188R6YA106MA73D	Murata	CAP, CERM, 10 uF, 35 V, +/- 20%, X5R, 0603	603
10	C20	1	0.047uF	GRM155R61C473KA01D	MuRata	CAP, CERM, 0.047 uF, 16 V, +/- 10%, X5R, 0402	402
11	C21	1	0.1uF	GRM155R71C104KA88D	MuRata	CAP, CERM, 0.1 uF, 16 V, +/- 10%, X7R, 0402	402
12	C22	1	0.47uF	GRM155R61C474KE01	MuRata	CAP, CERM, 0.47 uF, 16 V, +/- 10%, X5R, 0402	402
13	C25, C32	2	4.7uF	12061Z475MAT2A	AVX	CAP, CERM, 4.7 µF, 100 V,+/- 20%, X7S, 1206	1206
14	C26, C33	2	0.01uF	GRM188R72A103KA01D	MuRata	CAP, CERM, 0.01 uF, 100 V, +/- 10%, X7R, 0603	603
15	C27, C34	2	10uF	GRM188R61C106KAALD	MuRata	CAP, CERM, 10 µF, 16 V,+/- 10%, X5R, 0603	603
16	C30, C31	2	10pF	06033A100JAT2A	AVX	10pF ±5% 25V Ceramic Capacitor C0G, NP0 0603 (1608 Metric)	603

Table 5-1. TPS1689EVM Bill of Materials (continued)

Item #	Designator	Quantity	Value	PartNumber	Manufacturer	Description	PackageReference
17	D1, D2	2	60V	5.0SMDJ60A	Littelfuse	Diode, TVS, Uni, 60 V, 96.8 Vc, SMC	SMC
18	D3, D4	2	60V	B360-13-F	Diodes Inc.	Diode, Schottky, 60 V, 3 A, SMC	SMC
19	DG1	1	Green	LG R971-KN-1	OSRAM	LED, Green, SMD	2x1.25mm
20	DR1, DR2	2	Red	LS R976-NR-1	OSRAM	LED, Red, SMD	2.1x1.35mm
21	FID1, FID2, FID3, FID4, FID5, FID6	6		N/A	N/A	Fiducial mark. There is nothing to buy or mount.	N/A
22	G1, G2, G3, G4	4		D3082-05	Harwin	1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Shorting Plug, 10.16mm spacing, TH
23	H1, H3, H4, H5, H9, H10	6		NY PMS 440 0025 PH	B&F Fastener Supply	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw
24	H2, H6, H7, H8, H11, H12	6		1902C	Keystone	Standoff, Hex, 0.5"L #4-40 Nylon	Standoff
25	J1	1		PEC03DAAN	Sullins Connector Solutions	Header, 100mil, 3x2, Tin, TH	3x2 Header
26	J2, J3, J4, J5	4		PEC02DABN	Sullins Connector Solutions		HDR4
27	J6	1		5103308-1	TE Connectivity	Header (shrouded), 100mil, 5x2, Gold, TH	5x2 Shrouded header
28	J7, J8	2		PRPC004DAAN-RC	Sullins Connector Solutions	Header, 2.54mm, 4x2, Gold, TH	Header, 2.54mm, 4x2, TH
29	Q1, Q2, Q3	3		SI2306BDS-T1-GE3	Vishay Siliconix	N-Channel 30 V 3.16A (Ta) 750mW (Ta) Surface Mount SOT-23-3 (TO-236)	SOT23-3
30	QGND1, QGND2, QGND3, QGND4	4		5016	Keystone	Test Point, Compact, SMT	Testpoint_Keystone_Compact
31	R1, R2, R3, R4, R5, R6, R7, R9, R11	9	1.00k	ERA-2APB102X	Panasonic	RES, 1.00 k, 0.1%, 0.063 W, AEC-Q200 Grade 0, 0402	402
32	R8, R49	2	150	CRCW0603150RJNEA	Vishay-Dale	RES, 150, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	603
33	R10, R16, R17, R18, R37, R44, R45, R46, R55, R59, R60, R62, R63, R64, R73, R82, R83, R85, R86, R87, R88, RZ1	22	0	CRCW04020000Z0ED	Vishay-Dale	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	402

Table 5-1. TPS1689EVM Bill of Materials (continued)

Item #	Designator	Quantity	Value	PartNumber	Manufacturer	Description	PackageReference
34	R12, R56	2		RC0201JR-070RL	Yageo	RES SMD 0 OHM JUMPER 1/20W 0201	0201 (0603 Metric)
35	R15	1	3.74Meg	CRCW06033M74FKEA	Vishay-Dale	RES, 3.74 M, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	603
36	R19	1	5.11Meg	CRCW06035M11FKEA	Vishay-Dale	RES, 5.11 M, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	603
37	R20	1	113k	RC0603FR-07113KL	Yageo	RES, 113 k, 1%, 0.1 W, 0603	603
38	R21, R22, R23, R74, R75, R76, R77, R78, R79, R80	10	10.0k	RC0402FR-0710KL	Yageo America	RES, 10.0 k, 1%, 0.063 W, 0402	402
39	R26	1	102k	CRCW0603102KFKEA	Vishay-Dale	RES, 102 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	603
40	R27	1	182k	CRCW0603182KFKEA	Vishay-Dale	RES, 182 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	603
41	R34	1	2.20k	ERA2AEB222X	Panasonic	RES, 2.20 k, 0.1%, 0.0625 W, AEC-Q200 Grade 0, 0402	402
42	R35	1	1.24k	ERA2AEB1241X	Panasonic	RES, 1.24 k, 0.1%, 0.063 W, AEC-Q200 Grade 0, 0402	402
43	R38, R40	2	806	CRCW0402806RFKED	Vishay-Dale	RES, 806, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	402
44	R39, R41	2	909	CRCW0402909RFKED	Vishay-Dale	RES, 909, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	402
45	R42	1	150k	ERJ-2RKF1503X	Panasonic	RES, 150 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0402	402
46	R43	1	294k	ERJ-2RKF2943X	Panasonic	RES, 294 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0402	402
47	R48, R65	2	162k	RT0805BRD07162KL	Yageo America	RES, 162 k, 0.1%, 0.125 W, 0805	805
48	R50, R51, R52	3	470	RC0603JR-07470RL	Yageo	RES, 470, 5%, 0.1 W, 0603	603
49	R54	1	49.9k	RT0805BRD0749K9L	Yageo America	RES, 49.9 k, 0.1%, 0.125 W, 0805	805
50	R66	1	89.8k	RT0805BRD0789K8L	Yageo America	RES, 89.8 k, 0.1%, 0.125 W, 0805	805
51	R67, R70	2	75.0k	RT0603BRD0775KL	Yageo America	RES, 75.0 k, 0.1%, 0.1 W, 0603	603
52	R68, R71	2	150k	RT0603BRD07150KL	Yageo America	RES, 150 k, 0.1%, 0.1 W, 0603	603
53	R69, R72	2	267k	RT0603BRD07267KL	Yageo America	RES, 267 k, 0.1%, 0.1 W, 0603	603

Table 5-1. TPS1689EVM Bill of Materials (continued)

Item #	Designator	Quantity	Value	PartNumber	Manufacturer	Description	PackageReference
54	SH1, SH2, SH3, SH4, SH5, SH6, SH7, SH8, SH9, SH10, SH11, SH12	12		60900213621	Wurth Elektronik	Shunt, 2.54mm, Gold, Blue	Shunt, 2.54mm, Blue
55	SW1, SW2	2		PTS830GM140SMTRLFS	C&K Components	Tactile Switch SPST-NO Top Actuated Surface Mount	SMT_3MM05_2MM6
56	T1, T2, T3	3		B1/0-PCB-L	INTERNATIONAL HYDRAULICS	1/0 AWG High AMP PCB Wire Lugs 1/0-8 AWG	WIRE_LUG_150A_1-0AWG
57	T4, T5, T6, T7	4		0300-2-15-01-47-01-10-0	Mill-Max	Connector, Receptacle, Pin, TH	PCB Pin
58	TP1, TP2, TP3, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP17, TP18, TP19, TP20, TP21, TP22, TP23, TP24, TP25, TP26, TP27, TP28, TP29	27		5126	Keystone	Test Point, Multipurpose, Green, TH	Green Multipurpose Testpoint
59	TP4, TP5	2		5010	Keystone	Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint
60	U1	1		TPS16890VMAR	Texas Instruments	TPS16890VMAR	LQFN-CLIP23
61	U2	1		TPS16851VMAR	Texas Instruments	9 - 80 V , 4.3 mΩ, 20 A Stackable eFuse with Accurate & Fast Current Monitor	LQFN-CLIP23
62	U3	1		ISO1644DWR	Texas Instruments	Hot-swappable bidirectional I2C isolator with GPIO and enhanced EMC	SOICW16
63	U5	1		24FC08T-E/SN	Microchip	EEPROM Memory IC 8Kb (1K x 8) I²C 1 MHz 450 µs 8-SOIC	SOIC8
64	U6, U7	2		TPS7A4001DGNR	Texas Instruments	Single Output LDO, 50 mA, Adjustable 1.175 to 90 V Output, 7 to 100 V Input, 8-pin MSOP (DGN), -40 to 125 degC, Green (RoHS & no Sb/Br)	DGN0008B
65	C1, C2, C3, C4	0		GRM32EC72A106KE05L	Murata	10µF ±10% 100V Ceramic Capacitor X7S 1210 (3225 Metric)	1210
66	C15	0	3.3pF	GRM1555C1E3R3CA01D	MuRata	CAP, CERM, 3.3 pF, 25 V, +/- 5%, C0G/NP0, 0402	402

Table 5-1. TPS1689EVM Bill of Materials (continued)

Item #	Designator	Quantity	Value	PartNumber	Manufacturer	Description	PackageReference
67	C16, C17	0	1000uF	ECA-2AM102	Panasonic	CAP, AL, 1000 uF, 100 V, +/- 20%, TH	D18xL35.5mm
68	R13, R14, R25, R28, R29, R30, R31, R32, R33, R36, R47, R53, R57, R58, R61	0	0	CRCW04020000Z0ED	Vishay-Dale	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	402
69	R24	0	10.0k	RC0402FR-0710KL	Yageo America	RES, 10.0 k, 1%, 0.063 W, 0402	402
70	R81, R84	0	10.0k	ERJPA2F1002X	Panasonic	RES, 10.0 k, 1%, 0.2 W, AEC-Q200 Grade 0, 0402	402
71	U4	0		24FC08T-E/ST	Microchip	8KB I2C EEPROM, 1MHZ 1.7-5.5V, 8-TSSOP 8 TSSOP 4.4MM T/r Rohs Compliant: Yes	TSSOP8

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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.

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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

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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.

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8. *Limitations on Damages and Liability:*

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

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

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

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