TPS544E27EVM 4V to 18V, 40A Step-Down Converter Evaluation Module

TEXAS INSTRUMENTS

Description

The TPS544E27EVM is an evaluation module for the TPS544E27 DC/DC synchronous buck converter with a digital PMBus® and a series voltage identification (SVID) interface to accommodate Intel® processors. The evaluation module accepts an 8V to 16V input and can deliver an output current up to 40A. The converter uses D-CAP+™ control scheme for fast transient response, using less output capacitance to save board space.

Get Started

1. Order the TPS544E27EVM on ti.com.
2. Download the Fusion GUI software on FUSION_DIGITAL_POWER_DESIGNER.

Features

- Evaluate TPS544E27 device using the provided test points on the EVM
- Evaluate TPS544E27 device configuration and monitoring using Fusion GUI

Applications

- Sever and cloud-computing POLs
- Hardware accelerator
- Network interface card
- Broadband, networking and optical
- Wireless infrastructure
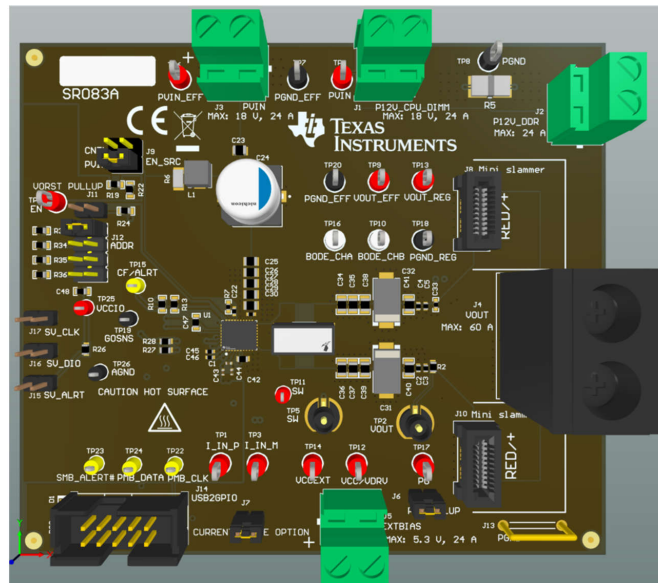
EVM User Interface

1 Evaluation Module Overview

1.1 Introduction

The TPS544E27EVM is a configurable, single output, buck converter module. The TPS544E27EVM uses a nominal 12V bus to produce a regulated 1V output up to 40A of load current. This user's guide describes the characteristics, operation and using of TPS544E27EVM. In addition, the user's guide includes test information and results. A complete schematic diagram, printed circuit board layouts and bill of materials are included in this document.

1.1.1 Before You Begin

The following warnings and cautions are noted for the safety of anyone using or working close to the TPS544E27EVM. Observe all safety precautions.

⚠️	**Warning:**	The TPS544E27EVM board can become hot during operation due to dissipation of heat. Avoid contact with board. Follow all applicable safety procedure applicable to your laboratory.

WARNING

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

CAUTION

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

CAUTION

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

CAUTION

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

1.2 Kit Contents

• TPS544E27EVM Circuit Board
• EVM Disclaimer Read Me

1.3 Specifications

Table 1-1 provides a summary of the TPS544E27EVM performance characteristics. The characteristics are given for an input voltage of V_{IN} = 12V and output voltage of 1V. The ambient temperature is room temperature (20°C to 25°C) for all measurements, unless otherwise specified.

Table 1-1. TPS544E27EVM Electrical Performance Specifications

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input voltage range		8	12	16	V
Full load input current	PVIN = 12V, internal VCC/VDRV, I_O = 40A, FCCM, f_{SW} = 800kHz		3.86		A
No load input current	PVIN = 12V, internal VCC/VDRV, I_O = 0A, DCM, f_{SW} = 800kHz		9.67		mA
VCC/VDRV input current	External 5V bias, f_{SW} = 800kHz, PVIN = 12V, I_O = 40A, FCCM		38.6		mA
Output voltage			1		V
Output current range		0		40	A
Output ripple voltage	f_{SW} = 800kHz, I_O = 40A		6		mVPP
Output load regulation	f_{SW} = 800kHz, I_O = 0A-40A, FCCM		0.11		%
Output voltage undershoot	f_{SW} = 800kHz, I_O = 0A – 20A, 2A/us slew rate, FCCM		24.1		mV
Output voltage overshoot	f_{SW} = 800kHz, I_O = 0A – 20A, 2A/us slew rate, FCCM		29.2		mV
Output rise time	Set by (61h) TON_RISE		0.5		ms
Output current limit	Set by (46h) IOUT_OC_FAULT_LIMIT		50		A
Switching frequency (f_{SW})	Set by (33h) FREQUENCY_SWITCH	600	800	1200	kHz
Efficiency	V_{IN} = 12V, external 5V Bias, f_{SW} = 800kHz, I_O = 40A		87.5		%
Loop bandwidth	V_{IN} = 12V, Internal LDO, f_{SW} = 800kHz, I_O = 40A		105.8		kHz
Phase margin	V_{IN} = 12V, Internal LDO, f_{SW} = 800kHz, I_O = 40A		54.8		Deg
IC case temperature	V_{IN} = 12V, external 5V bias, f_{SW} = 800kHz, I_O = 40A, 10 minute dwell time		91		°C

1.4 Device Information

The TPS544E27 is 4V to 18V input, 40A buck converter with SVID and PMBus. TPS544E27EVM uses the TPS544E27 device in a buck design. TPS544E27 is designed from a nominal 12V bus to produce a regulated 1V output up to 40A of load current. The TPS544E27EVM provides a number of test points to evaluate the performance of device.

2 Hardware

2.1 Test Equipment

2.1.1 Voltage Source

The input voltage source V_{IN} must be a 0V to 20V variable DC source capable of supplying a minimum of $10A_{DC}$ to support 40A load with 12V input. Connect input VIN and GND to J3. If the output voltage of the EVM is increased, the power supply can need to be capable of supplying more current.

2.1.2 Oscilloscope

TI recommends an oscilloscope for measuring switching node and output ripple. The switching node can be measured using test point TP5 (coaxial connector) or TP11. The output ripple can be measured using TP2 (coaxial connector)

2.1.3 Multimeters

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

2.1.4 Output Load

TI recommends a variable electronic load for the test setup. To test the full load current this EVM supports, the load must be capable of sinking at least 40A.

2.1.5 Fan

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

2.1.6 USB-to-GPIO Interface Adapter:

A communications adapter is required between the EVM and the host computer. This EVM is designed to use TI's USB-to-GPIO or USB-to-GPIO2 adapter. Purchase this adapter here.

2.1.7 Recommended Wire Gauge

- Input PVIN (12V input) at J3: the recommended wire size is AWG #12, with the total length of wire less than 2 feet (1 foot input, 1 foot return).
- Output VOUT (1V output) at J4: the minimum recommended wire size is AWG #10, with the total length of wire less than 1 feet (1/2 foot output, 1/2 foot return). A thicker wire gauge can be required to minimize the voltage drop the wires.

2.2 List of Test Points, Jumpers, and Connectors

lists the test point functions.

Table 2-1. Test Point Functions

Test Point	Name	Description
TP1	I_IN_P	Positive side of input current sensing point
TP2	VOUT	Monitor output ripple
TP3	I_IN_M	Negative side of input current sensing point
TP4	PVIN	Positive side of input voltage
TP5	SW	Monitor switching node frequency
TP6	PVIN_EFF	Positive side of input voltage sensing point to measure efficiency
TP7	PGND_EFF	PGND of input voltage sensing point to measure efficiency
TP8	PGND	PGND of input voltage
TP9	VOUT_EFF	Positive side of output voltage sensing point to measure efficiency
TP10	BODE_CHB	Measurement point of the receiving end from the frequency response analyzer
TP11	SW	Monitor switching node frequency
TP12	VCC/VDRV	Monitor the voltage on VCC/VDRV pin
TP13	VOUT_REG	Output voltage positive sense point
TP14	VCCEXT	Monitor the voltage on External Bias
TP15	CF/ALRT	Monitor catastrophic fault voltage if CAT_FAULT# is selected
TP16	BODE_CHA	Inject signal from the frequency response analyzer
TP17	PG	Monitor power-good signal
TP18	PGND_REG	Output voltage PGND sense point
TP19	GOSNS	Remote sense reference for PGND
TP20	PGND_EFF	PGND of output voltage sensing point to measure efficiency
TP21	EN	Monitor EN pin signal
TP22	PMB_CLK	Monitor PMBus CLK signal
TP23	PMB_ALERT#	Monitor PMBus ALERT# signal
TP24	PMB_DATA	Monitor PMBus DATA signal
TP25	VCCIO	Monitor external 1V pullup voltage for SVID
TP26	AGND	Monitor external 1V pullup AGND for SVID

lists the EVM jumper functions

Table 2-2. Jumper Functions

Jumper	Name	Description
J6	PG_PULLUP	Shunt short to pull up PG to VCC/VDRV
J7	CURRENT SENSE OPTION	Shunt short to connect I_IN_P and I_IN_M to PVIN
J9	EN_SRC	Shunt short pin3 and pin4 to EN from PVIN
J12	ADDR	Shunt short pin1 and pin2 to set PMBus address 0x7Bh
All others Jumper		No shunt short

lists the EVM connector functions.

Table 2-3. Connector Functions

Connector	Name	Description
J1	P12_CPU_DIMM	The option to connect to P12V_CPU_DIMM for DIMM input current measurement
J2	P12V_DDR	The option to connect to P12V_DDR for DIMM input current measurement
J3	PVIN	VIN screw terminal to connect input voltage
J4	VOUT	VIN screw terminal to connect output to load
J5	EXTBIAS	Override internal LDO with external 5V bias to improve efficiency
J6	PG PULLUP	PGOOD pullup, 2 pin header to pull up PGood to VCC/VDRV
J7	CUIRRENT SENSE OPTION	Input current sense option. Shunt short to disable input current sense feature
J8	Mini Slammer	Connector block to interface with Mini Slammer
J9	EN_SRC	2-pin header for enable. Add shunt to connect EN to PVIN and enable the device. Remove shunt to disable device
J10	Mini Slammer	Connector block to interface with Mini Slammer
J11	VORST PULLUP	VORST pullup. 2-pin header to pullup VORST to VCC/VDRV
J12	ADDR	Pin header block to select default PMBus address
J13	PGND	Power ground test point
J14	USB2GPIO	PMBus interface connector to connect the USB to GPIO interface adapter to the EVM
J15	SV_ALRT	2-pin header for SVID ALERT# line
J16	SV_DIO	2-pin header for SVID bi-directional data line
J17	SV_CLK	2-pin header for SVID CLK line

2.3 Efficiency Measurement Test Points

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

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

Table 2-4 shows the measurement points for input voltage and output voltage. PVIN and VOUT are measured to calculate the efficiency. Using these measurement points results in efficiency measurements that excluded losses due to the wires and connectors.

Table 2-4. Test Points for Efficiency Measurements

Test Point	Node Name	Description	Comment
TP6	PVIN_EFF	Input voltage measurement point for PVIN+	The pair of test points are connected to the PVIN/PGND pins of U1. The voltage drop between input terminal to the device pins is not included for efficiency measurement.
TP7	PGND_EFF	Input voltage measurement point for PVIN– (PGND)	
TP9	VOUT_EFF	Output voltage measurement point for VOUT+	The pair of test points are connected near the output terminals. The voltage drop from the output point of the inductor to the output terminals is not included for efficiency measurement.
TP20	PGND_EFF	Output voltage measurement point for VOUT– (GND)	

2.4 Control Loop Gain and Phase Measurement

The TPS544E27EVM includes a R11 10Ω series resistor in the feedback loop for V_{OUT}. The resistor is accessible at the test points TP16 (BODE_CHA) and TP10 (VOUT/BODE_CHB) for loop response analysis. These test points must be used during loop response measurements as the perturbation injecting points for the loop . See the description in Table 2-5.

Table 2-5. List of Test Points for Loop Response Measurements

Test Point	Node Name	Description	Comment
TP16	BODE_CHA	Input to feedback divider of V_{OUT}	The amplitude of the perturbation at this node must be limited to less than 30mV.
TP10	BODE_CHB	Resulting output of V_{OUT}	Bode can be measured by a network analyzer with a CHB/CHA configuration.

Measure the loop response with the following procedure:

1. Set up the EVM as described in Section 2.
2. For V_{OUT}, connect the isolation transformer of the network analyzer from TP16 to TP10.
3. Connect the input signal measurement probe to TP16. Connect the output signal measurement probe to TP10.
4. Connect the ground leads of both probe channels to TP13 (PGND).
5. On the network analyzer, measure the Bode as TP16/TP10 (In/Out).

2.5 External 5V Bias to Enhance Efficiency

An external bias ranging 4.75V to 5.3V can be connected to the VCC/VDRV pin. This connection enhances the efficiency of the converter because the VCC/VRDV power supply current now runs from this external bias instead of the internal LDO.

The following are considerations when using an external bias on the VCC/VDRV pin:

• Connect the external bias to VCC/VDRV pin.
• When the external bias is applied on the VCC/VDRV pin earlier than PVIN rail, the internal LDO is always forced off and the internal analog circuits have a stable power supply rail at the power enable.
• (Not recommended) When the external bias is applied on the VCC/VRDV pin late (for example, after PVIN rail ramp-up), any power-up and power-down sequencing can be applied as long as there is excess current pulled out of the VCC/VDRV pin. Understand that an external discharge path on the VCC/VDRV pin, which

can pull a current higher than the current limit of the internal LDO, can potentially turn off VCC/VDRV LDO, thereby shutting off the converter output.

- A good power-up sequence is: the external bias is applied first, then the 12V bus is applied on PVIN, and then EN signal goes high.

2.6 Input Current Measurement

TPS544E27EVM default setting is that input current measurement feature is not used with IN_IN_P and I_IN_M shorted together then shorts to PVIN through J7 shunt on. To test I_IN_P and I_IN_M feature, remove the shunt from J7, connect pin2 of J2 (P12V_DDR) to pin2 of J3 (PVIN) with a short 10-AWG wires or better. Apply PVIN + to pin2 of J1 (PVIN) and PGND to pin1 of J1. Thus the input current can be measured.

3 Software

The TPS544E27 leaves the factory pre-configured. The factory default settings for the parameters can be found in the data sheet. If configuring the EVM setting to other than the factory defaults, use the software PMBus Fusion GUI. Verify the input voltage is applied to the EVM prior to launching the software so that the TPS544E27 can response to the GUI and the GUI can recognize the device. The default configuration for the EVM to stop converting is set by EN resistor divider to a nominal input voltage of 4.6V, therefore, avoiding any converter activity during configuration is necessary. Apply an input voltage less than 4.6V. TI recommends an input voltage of 3.3V.

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

• Configure or update default parameters
• Turn on or off the device output
• Monitor real-time data, such as input voltage, output voltage, output current, die temperature
• Warnings and faults are continuously monitored and displayed by GUI

After clicking *Write to Hardware* to make changes to one or more configurable parameters, the changes can be committed to nonvolatile memory by clicking *Store to NVM*.

3.1 Opening the PMBus® Fusion GUI

Open the *PMBus GUI* shortcut on the desktop directly as shown in the following figure.
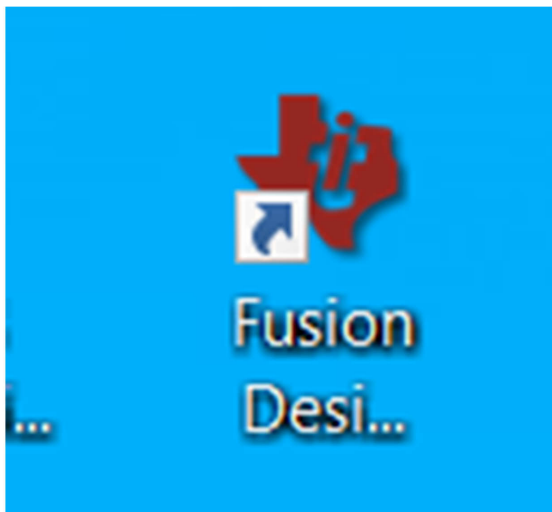
Figure 3-1. PMBus® GUI

After opening the PMBus GUI , the specific PMBus address of TPS544E27 system view is shown in Figure 3-2. By default, the position of the shunt on the EVM jumper sets the TPS544E27 address to 0x7Bh. Click on *Click to configure device.*
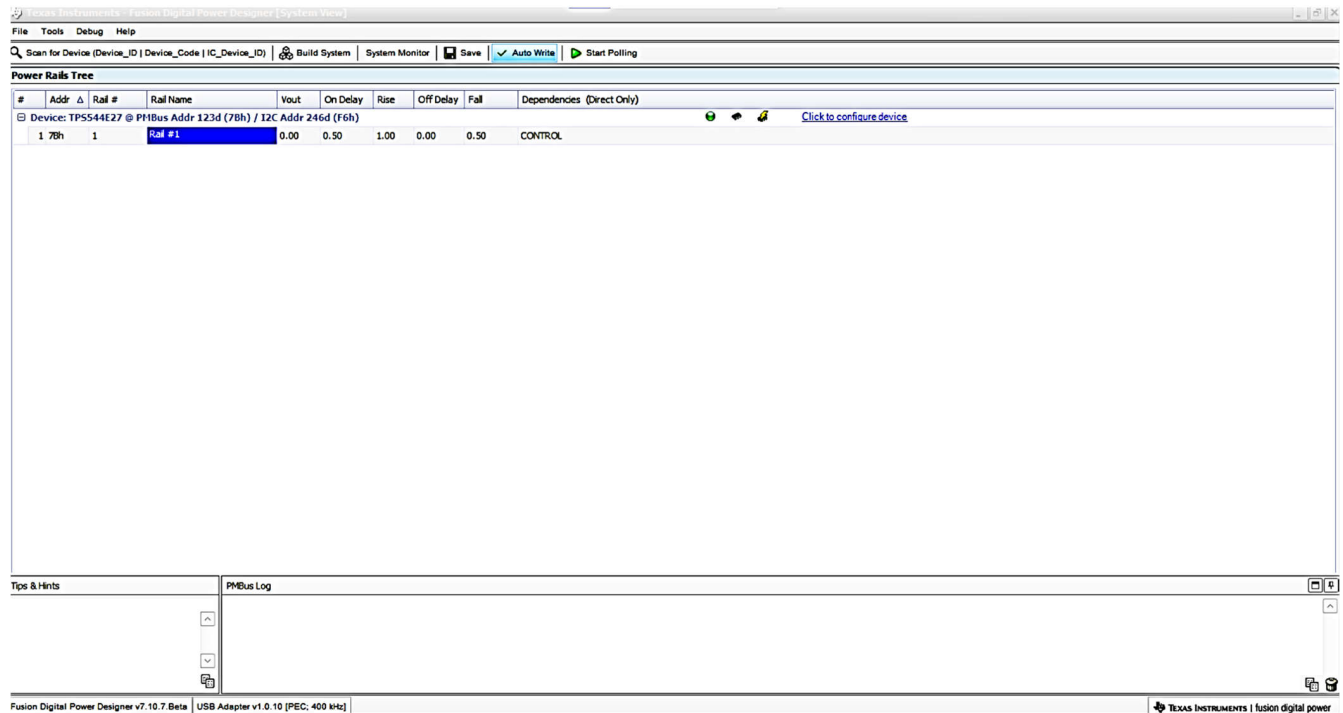
Figure 3-2. PMBus® GUI System View

3.2 Monitor Page

When the Monitor screen in the following figure is selected, the screen displays real-time data of parameters that are measured by device. The screen provides access to:

- Graphs of Vout, Iout, Vin, Pout and Die temperature
- Start and stop polling, which turns ON or OFF the real-time display data
- Quick access to On, Off Config
- Control pin activation and OPERATION command
- Margin control
- Clear Fault: selecting *Clear Faults* clears any prior fault flags
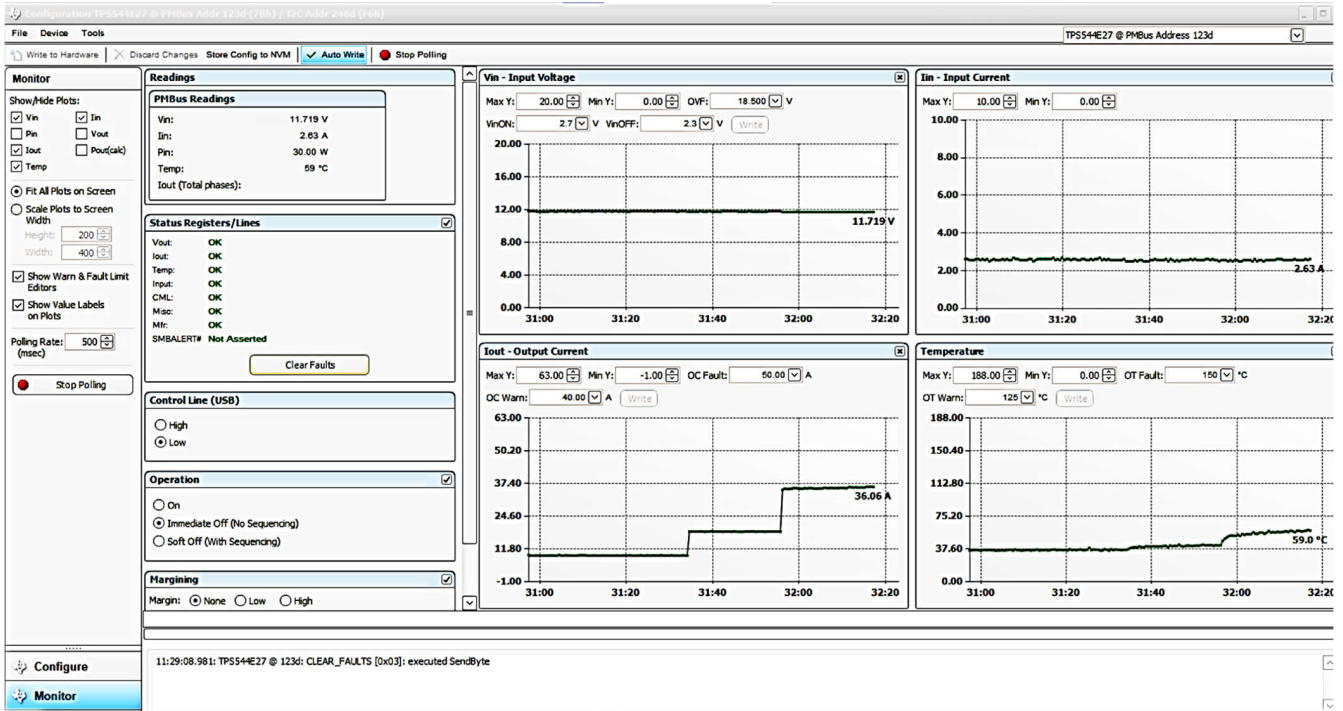
Figure 3-3. Monitor Screen

3.3 Status Page

Selecting the status screen from the lower left corner, shown in the following figure, shows the status of the device.
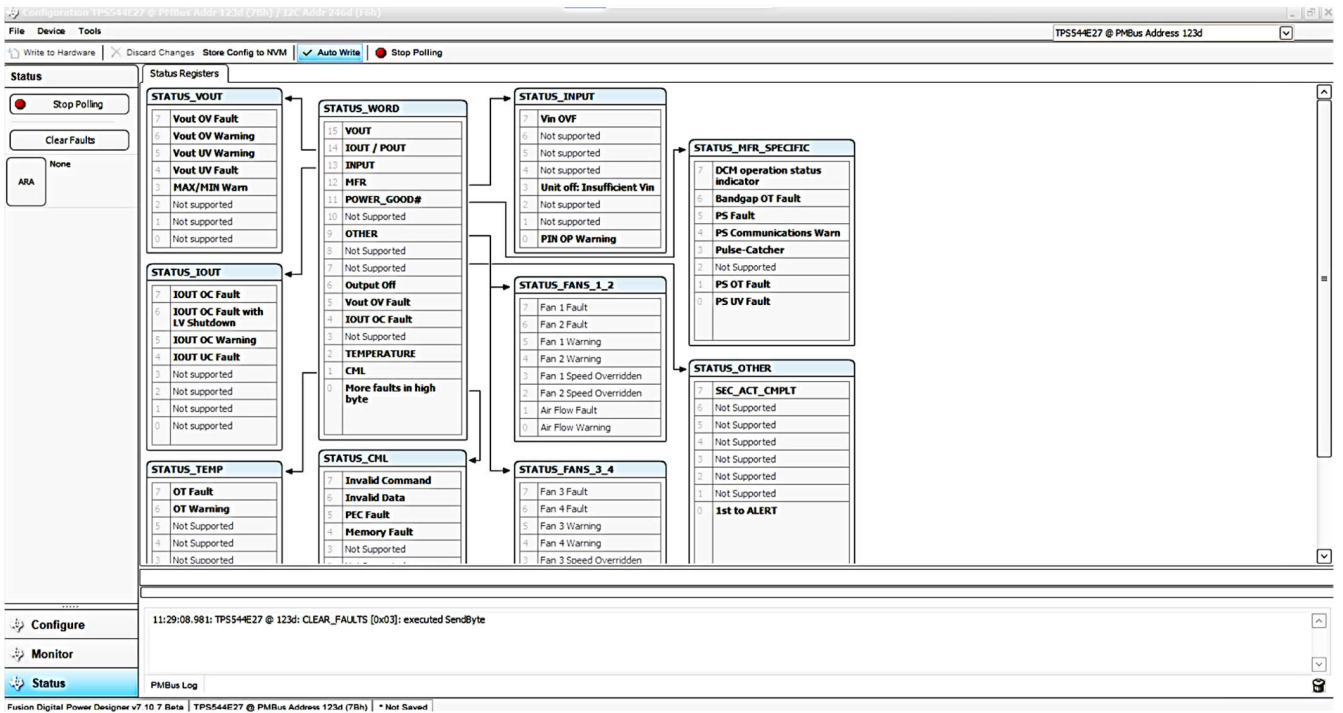
Figure 3-4. Status Screen

4 Implementation Results

4.1 Performance Data and Typical Characteristics Curves

Figure 4-1 through Figure 4-28 present typical performance curves for TPS544E27EVM. The input voltage is 12V, output voltage is 1V, unless otherwise noted.
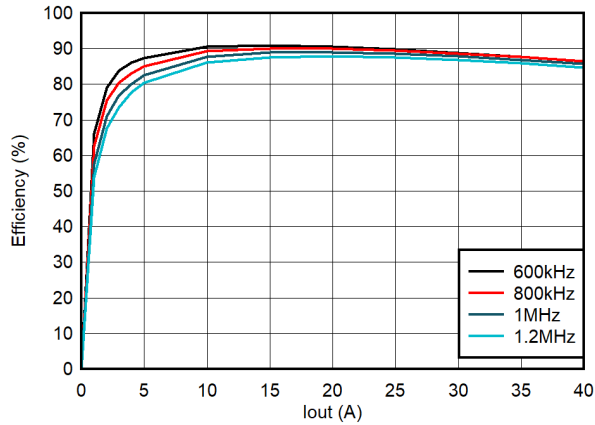
Figure 4-1. Efficiency, FCCM, Internal LDO
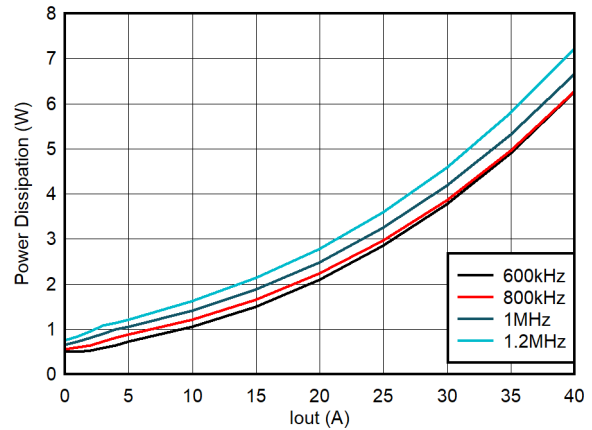
Figure 4-2. Power Dissipation, FCCM, Internal LDO
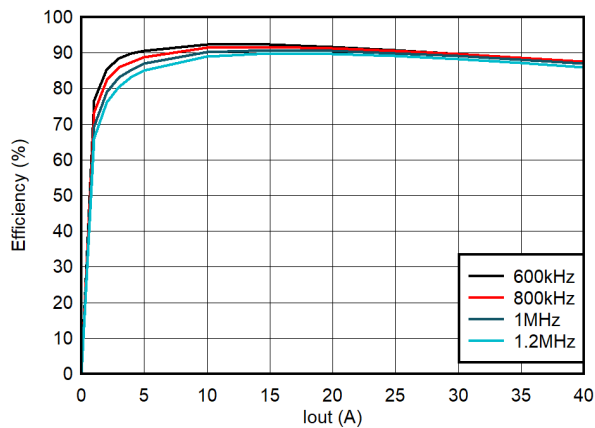
Figure 4-3. Efficiency, FCCM, External 5V Bias
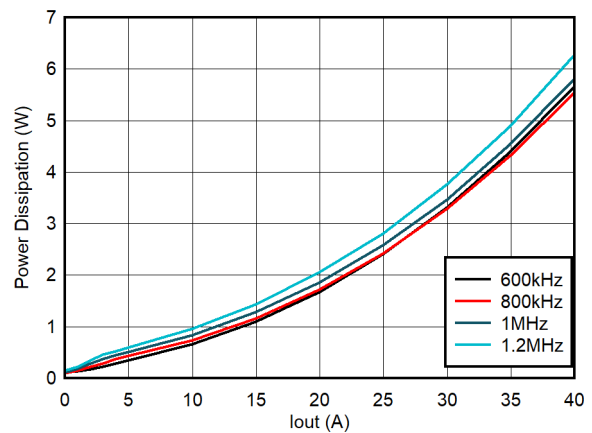
Figure 4-4. Power Dissipation, FCCM, External 5V Bias
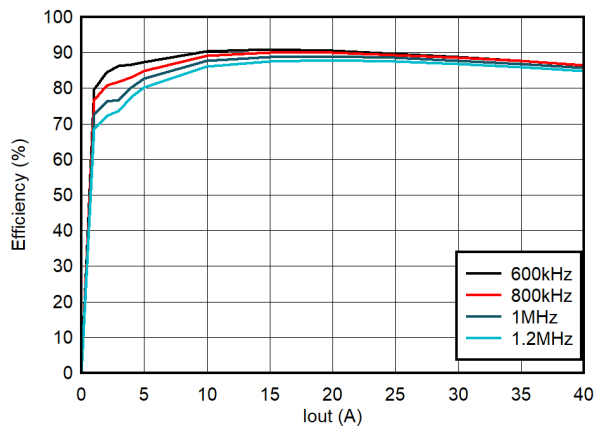
Figure 4-5. Efficiency, DCM. Internal LDO
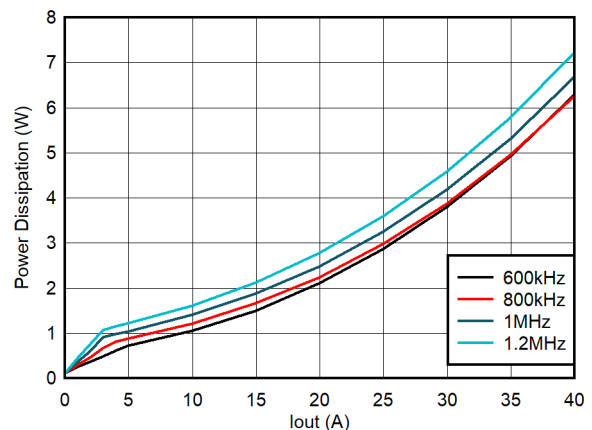
Figure 4-6. Power Dissipation, DCM, Internal LDO
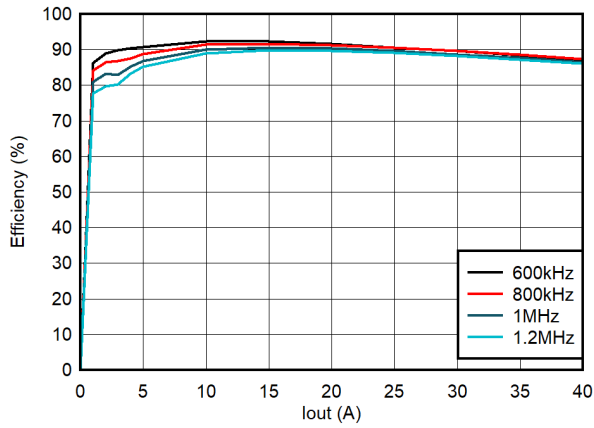
Figure 4-7. Efficiency, DCM, External 5V Bias
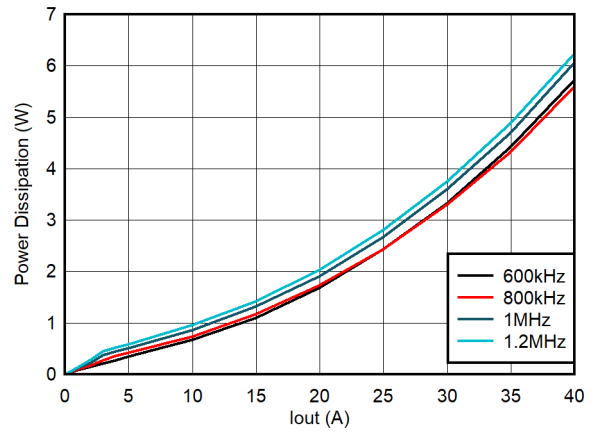
Figure 4-8. Power Dissipation, DCM, External 5V Bias
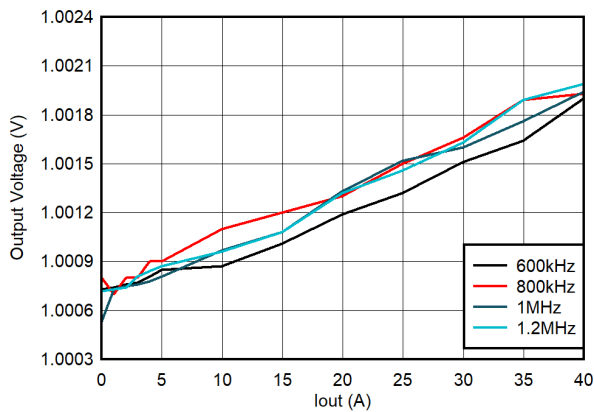
Figure 4-9. Load Regulation, FCCM, Internal LDO
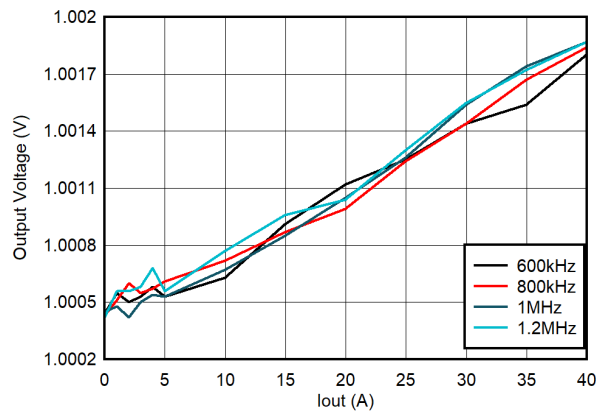
Figure 4-10. Load Regulation, FCCM, External 5V Bias
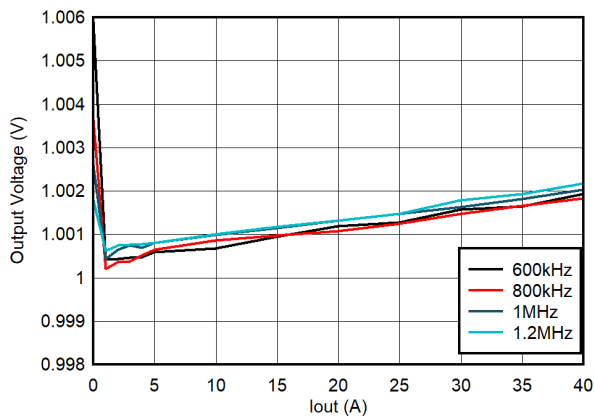
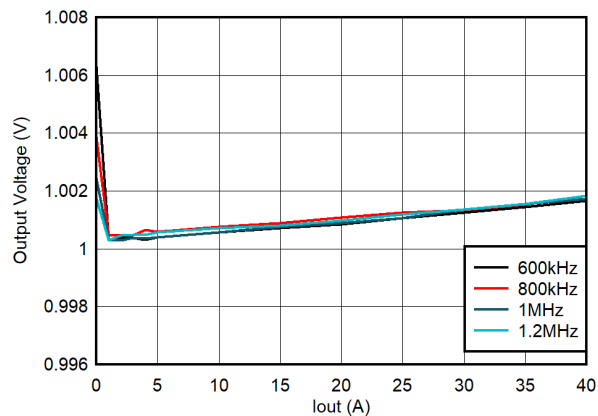**Figure 4-11. Load Regulation, DCM, Internal VCC LDO**

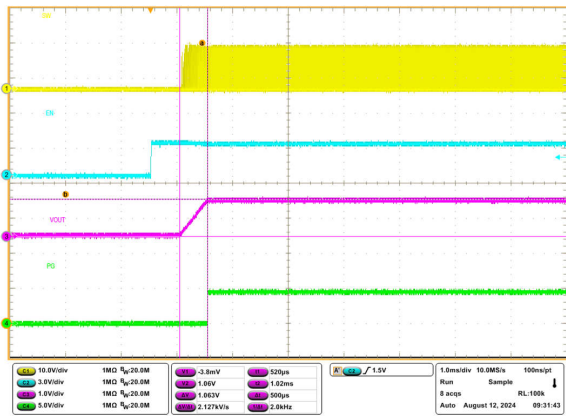**Figure 4-12. Load Regulation, DCM, External 5V Bias**

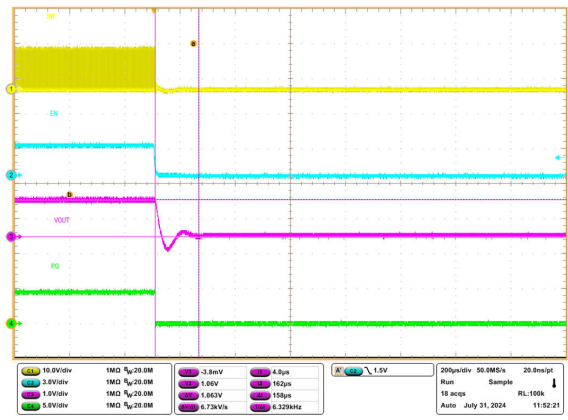**Figure 4-13. ENABLE Start-Up, 800kHz, 40A Load**

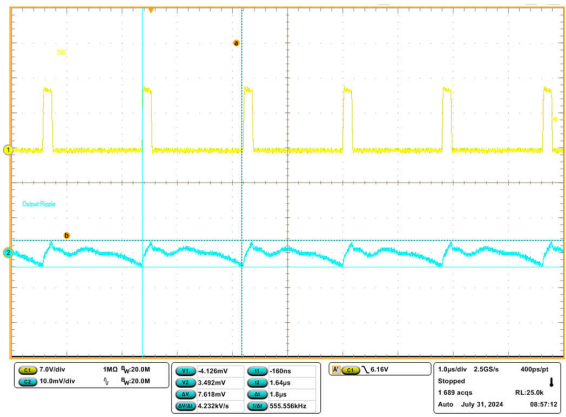**Figure 4-14. ENABLE Shutdown, 800kHz, 40A load**

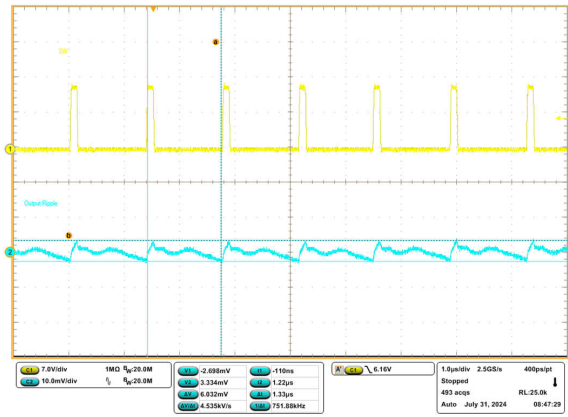**Figure 4-15. Output Voltage Ripple, 600kHz FCCM, 40A Load**

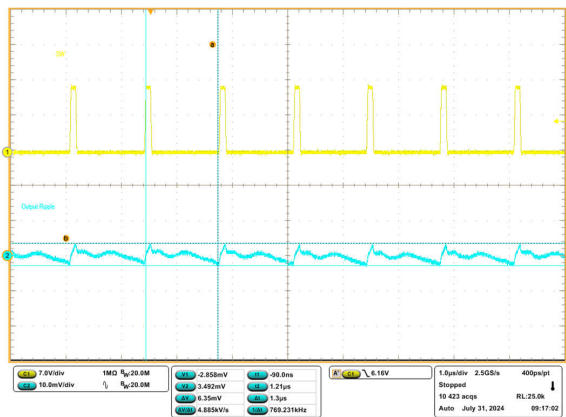**Figure 4-16. Output Voltage Ripple, 800kHz FCCM, 40A Load**

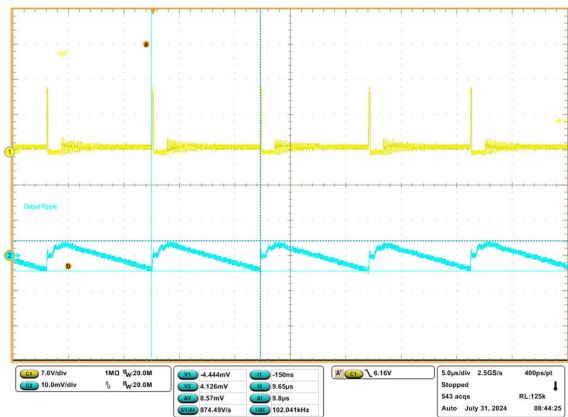**Figure 4-17. Output Voltage Ripple, FCCM, 800kHz, 0.5A Load**

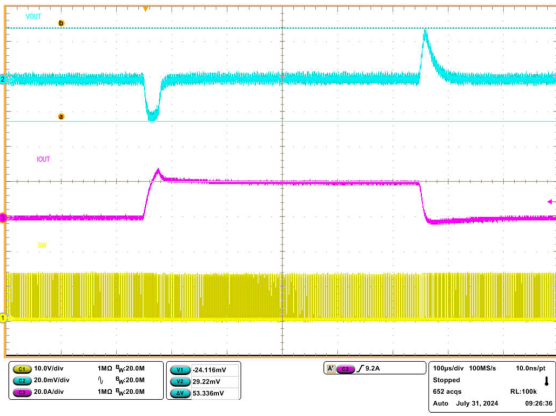**Figure 4-18. Output Voltage Ripple, DCM, 800kHz, 0.5A Load**

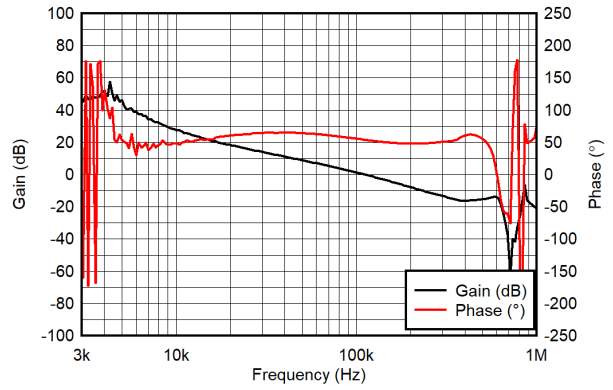**Figure 4-19. Load Transient, FCCM, 0A to 20A Load Step, 2A/us**

Figure 4-20. Bode Plot, FCCM, 800kHz, 40A Load

Figure 4-21. Thermal Characteristics, 600kHz FCCM, Internal LDO, 40A Load, No Airflow, Soak 10 Minutes

Figure 4-22. Thermal Characteristics, 600kHz FCCM, External 5V Bias, 40A Load, No Airflow, Soak 10 Minutes
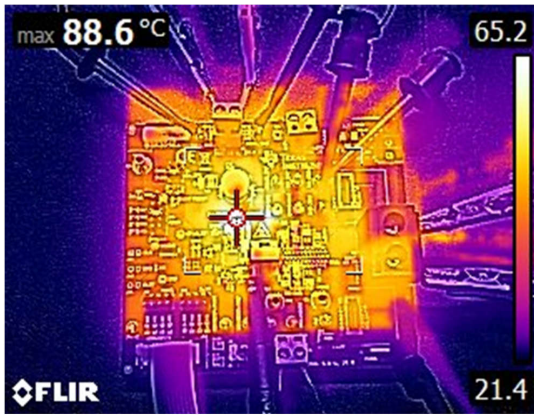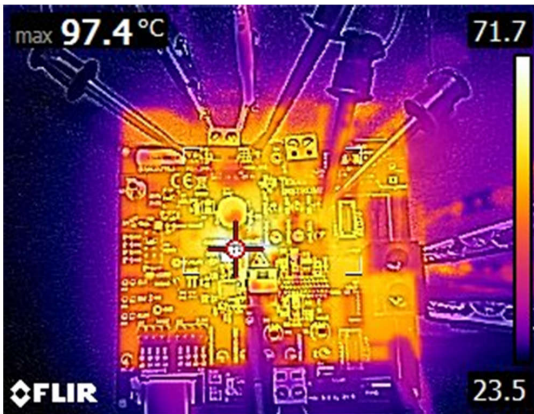

Figure 4-23. Thermal Characteristics, 800kHz FCCM, Internal LDO, 40A Load, No Airflow, Soak 10 Minutes

Figure 4-24. Thermal Characteristics, 800kHz FCCM, External 5V Bias, 40A Load, no Airflow, Soak 10 Minutes
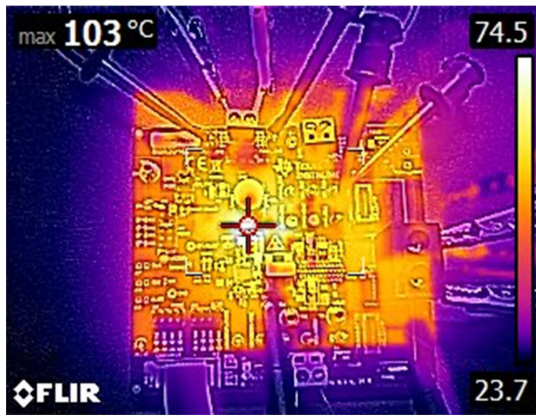
Figure 4-25. Thermal Characteristics, 1MHz FCCM, Internal LDO, 40A Load, No Airflow, Soak 10 Minutes
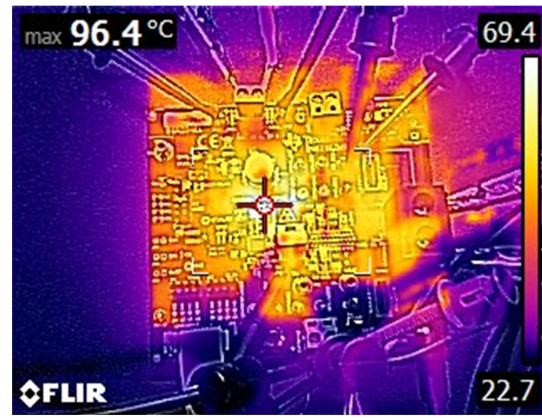
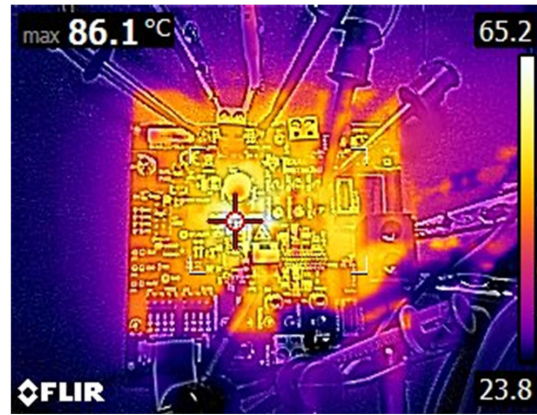**Figure 4-26. Thermal Characteristics, 1MHz FCCM, External 5V Bias, 40A Load, No Airflow, Soak 10 Minutes**
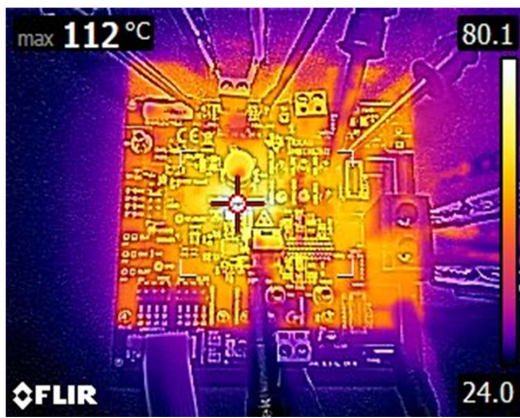
Figure 4-27. Thermal Characteristics, 1.2MHz, FCCM, Internal LDO, 40A Load, No Airflow, Soak 10 Minutes
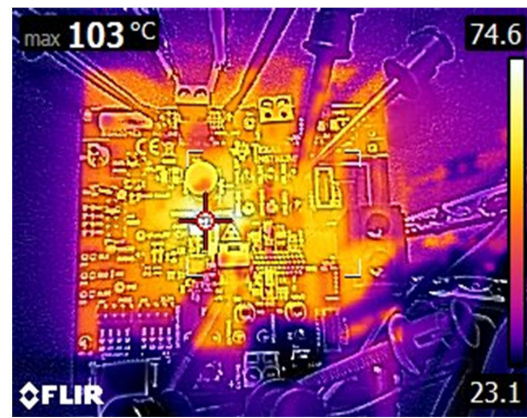
Figure 4-28. Thermal Characteristics, 1.2MHz, FCCM, External 5V Bias, 40A Load, No Airflow, Soak 10 Minutes
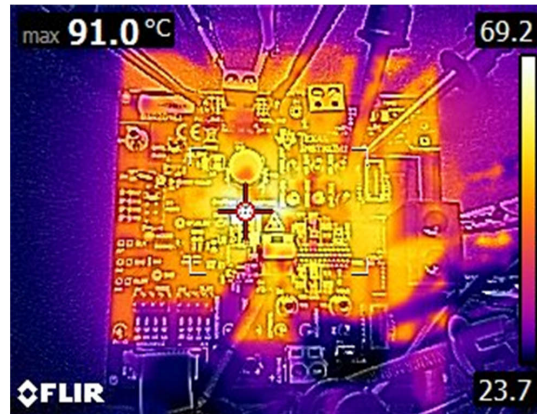
5 Hardware Design Files

5.1 Schematic
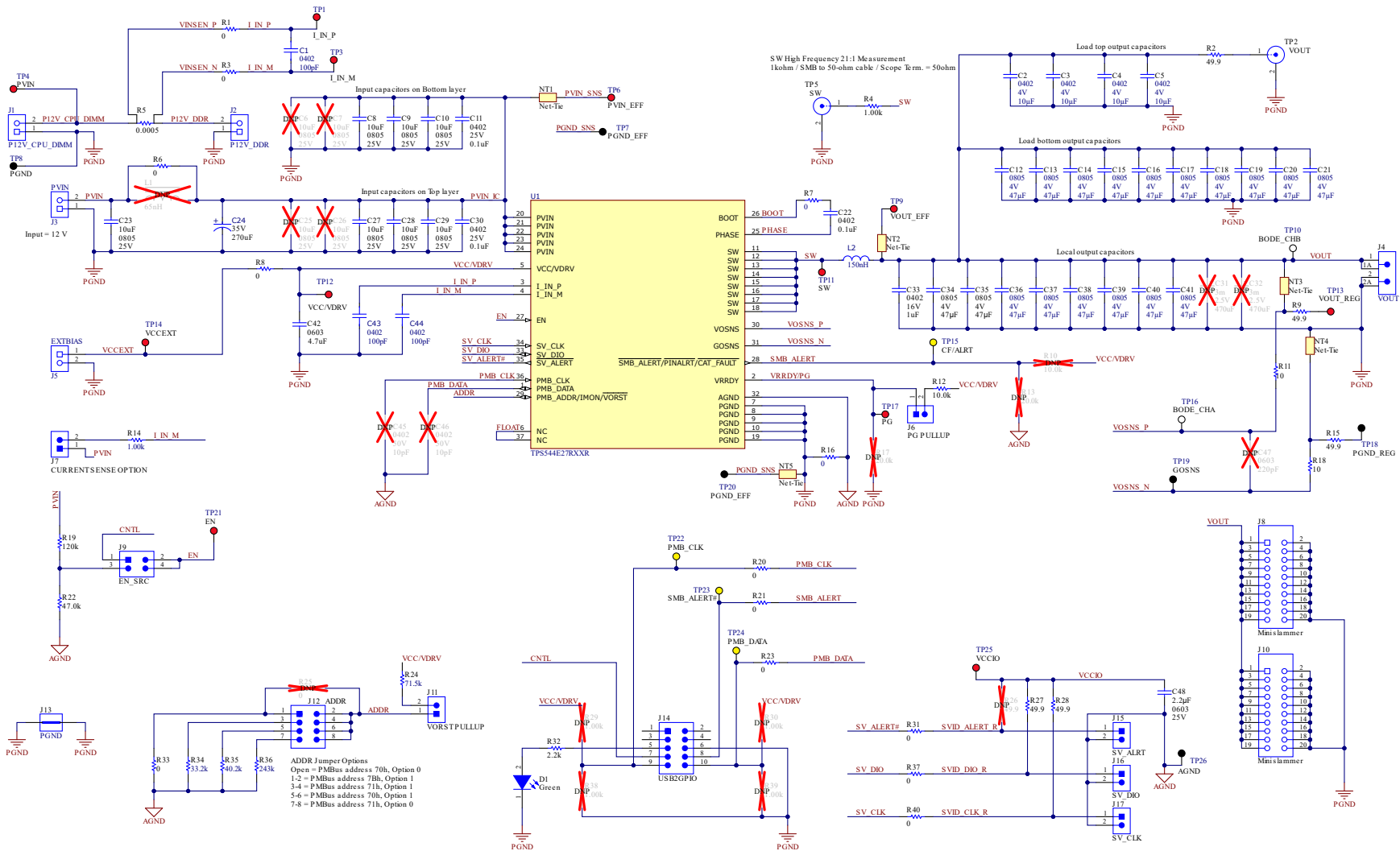
Figure 5-1. TPS544E27EVM Schematic

5.2 PCB Layout

Figure 5-2. TPS544E27EVM Top Composite View

Figure 5-3. TPS544E27EVM Bottom Composite View

Figure 5-4. TPS544E27EVM Top Layer

Figure 5-5. TPS544E27EVM Layer 2

Figure 5-6. TPS544E27EVM Layer 3

Figure 5-7. TPS544E27EVM Layer 4
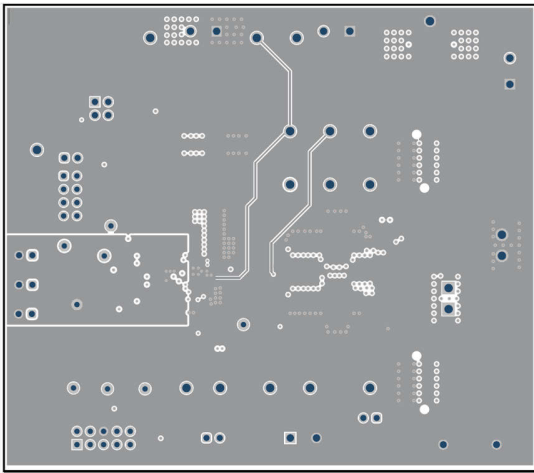
Figure 5-8. TPS544E27EVM Layer 5
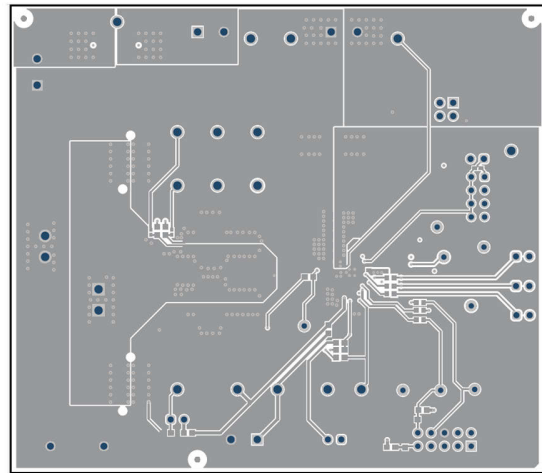
Figure 5-9. TPS544E27EVM Bottom Layer

5.3 Bill of Materials

Table 5-1. Bill of Materials

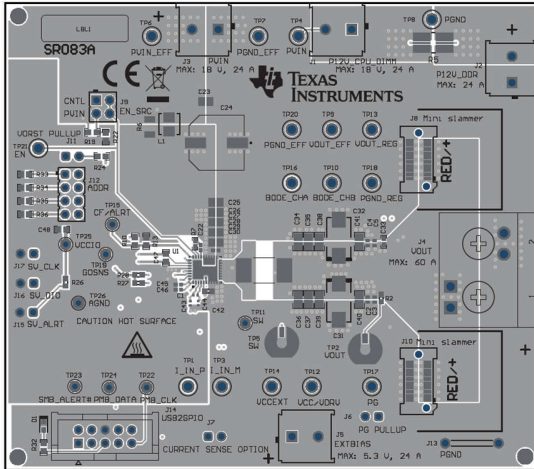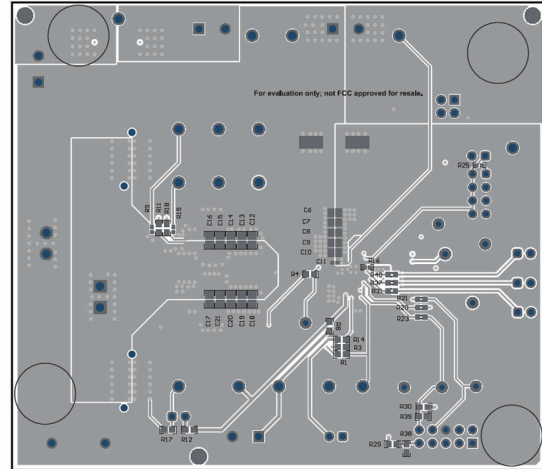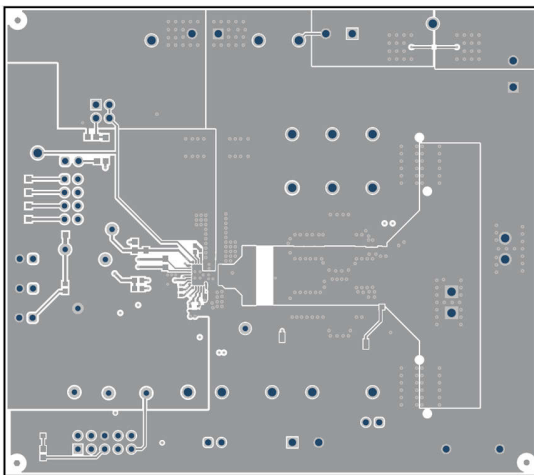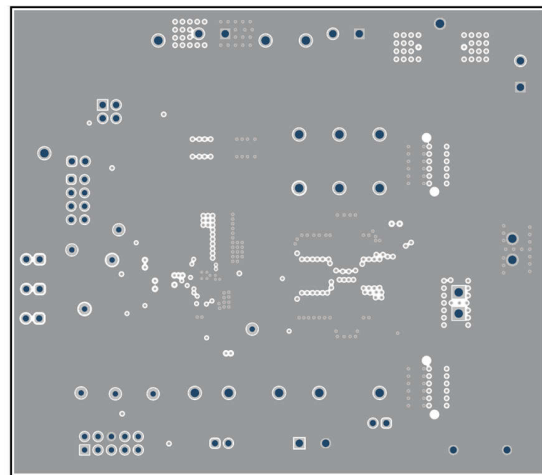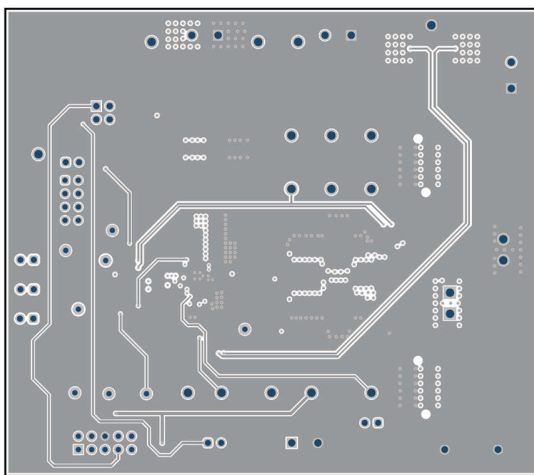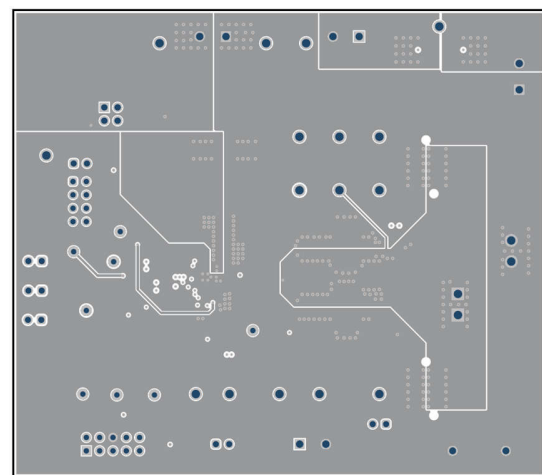| Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		SR083-001	Any
C1, C43,C44	3	100pF	CAP, CERM, 100pF,100V, +/- 5%, C0G, 0402	0402	GRT1555C2A101JA02D	MuRata
C2, C3, C4, C5	4	10µF	CAP, CERM,10µF, 4V, +/- 20%, X5R, 0402	0402	GRM155R60G106ME44J	MuRata
C8, C9, C10, C23, C27, C28, C29	7	10µF	CAP, CERM, 10µF, 25V, +/- 10%, X7R, 0805	0805	GRM21BZ71E106KE15L	Murata
C11, C22, C30	3	0.1µF	CAP, CERM, 0.1µF, 25V,+/- 10%, X7R, 0402	0402	GRM155R71E104KE14D	MuRata
C24	1	270µF	270µF 35V Polymer ALUM Electrolytic Capacitor, CR Series 4000h 10.3x10.3x9.9mm	SMT_ECAP_10MM3_10MM3	PCR1V271MCL1GS	Nichicon
C12, C13, C14, C15, C16, C17, C18, C19, C20, C21, C34, C35, C36, C37, C38, C39, C40, C41	18	47µF	CAP, CERM, 47µF, 4V,+/- 20%, X6S, 0805	0805	GRM21BC80G476ME15L	MuRata
C33	1	1µF	CAP, CERM, 1µF, 16V,+/- 10%, X6S, 0402	0402	C1005X6S1C105K050BC	TDK
C42	1	4.7µF	CAP, CERM, 4.7µF, 10V,+/- 10%, X7S, 0603	0603	C1608X7S1A475K080AC	TDK
C48	1	2.2µF	CAP, CERM, 2.2µF, 25V,+/- 10%, X7S, 0603	0603	GRM188C71E225KE11D	Murata
D1	1		LED, Green, SMD	LED_0603	150060GS75000	Wurth Elektronik
H1, H2, H3, H4	4		Bumpon, Hemisphere, 0.44X 0.20, Clear	Transparent Bumpon	SJ-5303 (CLEAR)	3M
J1, J2, J3, J5	4		Therminal Block, 5mm, 2-pole, Tin, TH	TH, 2-Leads, Body 10x10mm, Pitch 5mm	282856-2	TE Connectivity
J4	1		Terminal Block, 60A, 10.16mm Pitch, 2-Pos, TH	21.8x30x19mm	399100102	Molex
J6, J7, J11, J15, J16, J17	6		Header, 2.54mm, 2x1, Gold, TH	Header, 2.54mm, 2x1, TH	61300211121	Wurth Elektronik
J9	1		Header, 2.54mm, 2x2, Gold, TH	Header, 2.54mm, 2x2, TH	PBC02DAAN	Sullins Connector Solutions
J8, J10	2		Card Edge Socket, 0.8mm, 10x2, SMT	Card Edge Socket, 0.8mm, 10x2, SMT	HSEC8-110-01-S-DV-A	Samtec
J12	1		Header, 2.54mm, 4x2, Gold, TH	Header, 2.54mm, 4x2, TH	TSW-104-08-L-D	Samtec
J13	1		1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Shorting Plug, 10.16mm spacing, TH	D3082-05	Harwin

Table 5-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
J14	1		Header (shrouded), 100mil, 5x2, Gold, TH	5x2 Shrouded header	5103308-1	TE Connectivity
L2	1	150nH	SMD Power Inductor 150nH 20% 85A, 0.23mohm DCR	SMT_IND_10MM2_4MM8	AFA41405B-150L	ITG Electronics
R1, R3, R8, R20, R21, R23, R31, R33, R37, R40	10	0	RES, 0, 5%, 0.1W, 0603	0603	RC0603JR-070RL	Yageo
R2, R27, R28	3	49.9	RES, 49.9, 1%, 0.1W, 0603	0603	RC0603FR-0749R9L	Yageo
R4, R14	2	1.00k	RES, 1.00 k, 1%, 0.1W, 0603	0603	RC0603FR-071KL	Yageo
R6	1	0	RES, 0, 1%, 0.5W, 1206	1206	5108	Keystone
R7, R16	2	0	RES, 0, 5%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R9, R15	2	49.9	RES, 49.9, 1%, 0.1W, AEC-Q200 Grade 0, 0402	0402	ERJ-2RKF49R9X	Panasonic
R11, R18	2	10	RES, 10, 5%, 0.1W, AEC-Q200 Grade 0, 0603	0603	CRCW060310R0JNEA	Vishay-Dale
R12	1	10k	RES, 10.0k, 1%, 0.1W, 0603	0603	ERJ-3EKF1002V	Panasonic
R19	1	120k	RES, 120k, 1%, 0.1W, 0603	0603	RC0603FR-07120KL	Yageo
R22	1	47.0k	RES, 47.0k, 1%, 0.1W, 0603	0603	RC0603FR-0747KL	Yageo
R5	1	0.0005	RES, 0.0005, 1%, 3W, AEC-Q200 Grade 0, 2512	2512	WSLP2512L5000FEA	Vishay-Dale
R24	1	71.5k	RES, 71.5k, 1%, 0.1W, 0603	0603	RC0603FR-0771K5L	Yageo
R32	1	2.2k	RES, 2.2k, 5%, 0.1W, 0603	0603	RC0603JR-072K2L	Yageo
R34	1	33.2k	RES, 33.2k, 1%, 0.1W, 0603	0603	RC0603FR-0733K2L	Yageo
R35	1	40.2k	RES, 40.2k, 1%, 0.1W, 0603	0603	RC0603FR-0740K2L	Yageo
R36	1	243k	RES, 243k, 1%, 0.1 W, 0603	0603	RC0603FR-07243KL	Yageo
TP1, TP3, TP4, TP6, TP9, TP12, TP13, TP14, TP17, TP21	10		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone Electronics
TP2, TP5	2		Connector, Receptacle, 50 ohm, TH	SMB Connector	SMBR004D00	JAE Electronics
TP7, TP8, TP18, TP20	4		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone Electronics
TP11, TP25	2		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone Electronics
TP10, TP16	2		Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone Electronics
TP15, TP22, TP23, TP24	4		Test Point, Miniature, Yellow, TH	Yellow Miniature Testpoint0603	5004	Keystone Electronics
TP19, TP26	2		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone Electronics

Table 5-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
U1	1		4V to 18V Input, 40A Buck Converter with SVID and PMBus, WQFN-FCRLF37	WQFN-FCRLF37	TPS544E27RXXR	Texas Instruments

6 Additional Information

6.1 Trademarks

D-CAP+™ is a trademark of Texas Instruments.

PMBus® is a registered trademark of System Management Interface Forum, Inc.

Intel® is a registered trademark of Intel.

All trademarks are the property of their respective owners.

STANDARD TERMS FOR EVALUATION MODULES

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

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

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

2. *Limited Warranty and Related Remedies/Disclaimers*:

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

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

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

WARNING

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

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

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

3   *Regulatory Notices:*

3.1   *United States*

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

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

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

CAUTION

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

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

FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2   *Canada*

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 *Japan*

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

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

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

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

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,

2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or

3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けて

いないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの

措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。

2. 実験局の免許を取得後ご使用いただく。

3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。
        上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・イ

ンスツルメンツ株式会社

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.

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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.

IMPORTANT NOTICE AND DISCLAIMER