EVM User's Guide: TPS544C27

TPS544C27EVM 4V to 18V, 35A Step-Down Converter Evaluation Module

Description

The TPS544C27EVM is an evaluation module for the TPS544C27 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 35A. The converter uses D-CAP+™ control scheme for fast transient response, using less output capacitance to save board space.

Get Started

1. Order the TPS544C27EVM on ti.com
2. Download the Fusion GUI software on FUSION_DIGITAL_POWER_DESIGNER

Features

- Evaluate TPS544C27 device using the provided test points on the EVM
- Evaluate TPS544C27 device configuration and monitoring using Fusion GUI

Applications

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

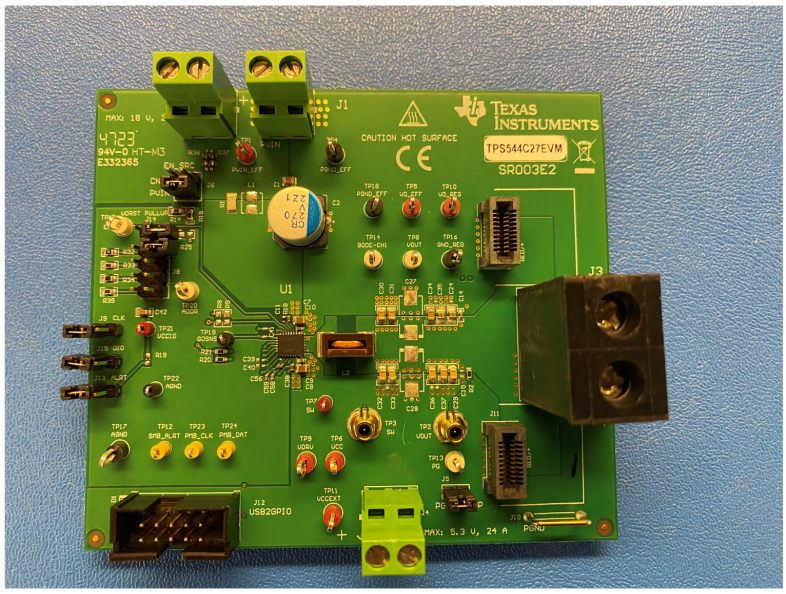

Figure 1-1. EVM User Interface

1 Evaluation Module Overview

1.1 Introduction

The TPS544C27EVM is a configurable single output buck converter module. The TPS544C27EVM uses a nominal 12V bus to produce a regulated 1V output up to 35A of load current. This user's guide describes the characteristics, operation and using of TPS544C27EVM. 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 TPS544C27EVM. Observe all safety precautions.

	**Caution:**	The TPS544C27EVM board may 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 Electrical Performance Specifications

Table 1-1 provides a summary of the TPS544C27EVM 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. TPS544C27EVM 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 = 35A, FCCM, f_{SW}=800kHz		3.46		A
No load input current	PVIN = 12V, internal VCC/VDRV, I_O = 0A, DCM, f_{SW}=800kHz		9.5		mA
VCC/VDRV input current	External 5V bias, f_{SW} = 800kHz, PVIN = 12V, I_O = 35A, FCCM		38		mA
Output voltage			1		V
Output current range		0		35	A
Output ripple voltage	f_{SW} = 800kHz, I_O = 35A		6		mVPP
Output load requaltion	f_{SW} = 800kHz, I_O = 0A-35A, FCCM		0.15		%
Output voltage undershoot	f_{SW} = 800kHz, I_O = 0A-15A, 1A/us slew rate, FCCM		13.3		mV
Output voltage overshoot	f_{SW} = 800kHz, I_O = 0A-15A, 1A/us slew rate, FCCM		11.7		mV
Output rise time	Set by (61h) TON_RISE		1		ms
Output current limit	Set by (46h) IOUT_OC_FAULT_LIMIT		40		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 = 35A		86.1		%
Loop bandwidth	V_{IN} = 12V, Internal LDO, f_{SW} = 800kHz, I_O = 35A		109.5		kHz
Phase margin	V_{IN} = 12V, Internal LDO, f_{SW} = 800kHz, I_O = 35A		53.9		Deg
IC case temperature	V_{IN} = 12V, external 5V bias, f_{SW} = 800kHz, I_O = 35A, 10-minute dwell time		88		°C

1.3 Device Information

The TPS544C27 is 4V to 18V input, 35A buck converter with SVID and PMBus®. TPS544C27EVM uses the TPS544C27 device in a buck design. TPS544C27 is designed from a nominal 12V bus to produce a regulated 1V output up to 35A of load current. The TPS544C27EVM 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 35A load with 12V input. Connect input VIN and GND to J1. 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

An oscilloscope is recommended for measuring switching node and output ripple. The switching node can be measured using test point TP3 (coaxial connector) or TP7. 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 35A.

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 their rated temperature.

2.1.6 USB-to-GPIO Interface Adapter:

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

2.1.7 Recommended Wire Gauge

- Input PVIN(12V input) at J1– The recommended wire size is AWG #12, with the total length of wire less than 2 feet (1 foot input, 1 foot return).
- Output J3(1V output) – The minimum recommended wire size is AWG #10, with the total length of wire less than 2 feet (1 foot output, 1 foot return). A thicker wire gauge can be required to minimize the voltage drop the wires.

2.2 List of Test Points, Jumpers, and Connectors

Table 2-1 lists the test point functions.

Table 2-1. Test Point Functions

Test Point	Name	Description
TP1	PVIN_EFF	Positive side of input voltage sensing point to measure efficiency
TP2	VOUT	Monitor output ripple
TP3	SW	Monitor switching node frequency
TP4	PGND_EFF	PGND of input voltage sensing point to measure efficiency
TP5	VOUT_EFF	Positive side of output voltage sensing point to measure efficiency
TP6	VCC	Monitor the voltage on VCC pin
TP7	SW	Monitor switching node frequency
TP8	VOUT/ BODE_CHB	Measurement point of the receiving end from the frequency response analyzer
TP9	VDRV	Monitor the voltage on VDRV pin
TP10	VOUT_REG	Monitor the output voltage
TP11	VCCEXT	Monitor the voltage on EXTBIAS
TP12	PMB_ALERT	Monitor PMBus ALERT signal
TP13	PG	Monitor the power good signal
TP14	BODE_CHA	Inject signal from the frequency response analyzer
TP15	EN	Monitor EN pin signal
TP16	PGND_REG	Output voltage PGND sense point
TP17	AGND	Analog ground test point
TP18	PGND_EFF	PGND of output voltage sensing point to measure efficiency
TP19	GOSNS	Remote sense reference for PGND
TP20	ADDR	Monitor PMBus address voltage
TP21	VCCIO	Monitor external 1V pullup voltage for SVID
TP22	AGND	Monitor external 1V pull up AGND for SVID
TP23	PMB_CLK	Monitor PMBus CLK signal
TP24	PMB_DAT	Monitor PMBus DAT signal

Table 2-2 lists the EVM jumper functions

Table 2-2. Jumper Functions

Jumper	Name	Description
J5	PG_PULLUP	Shunt short to pull up PG to VCC
J6	EN_SRC	Shunt short pin3 and pin4 to EN from PVIN
J16	ININ Option	Shunt short to connect I_IN_P/I_IN_M to PVIN
All others Jumper		No shunt short

Table 2-3 lists the EVM connector functions.

Table 2-3. Connector Functions

Connector	Name	Description
J1	PVIN	VIN screw terminal to connect input voltage
J2	IIN	Screw terminal to connect to input connector J1 for the input current measurement
J3	VOUT	VOUT screw terminal to connect load to output
J4	EXTBIAS	Override internal LDO with external 5V bias for improving efficiency
J5	PG PULLUP	PGOOD pullup. 2-pin header to pull up PGOOD to VCC

Table 2-3. Connector Functions (continued)

Connector	Name	Description
J6	EN_SRC	2-pin header for enable. Add shunt to connect EN to PVIN and enable device. Remove shunt to disable device.
J7	Mini-Slammer	Connector block to interface with Mini Slammer
J8	ADDR	Pin header block to select default PMBus address
J9	SV_CLK	2-pin header for SVID CLK line
J10	PGND	Power ground test point.
J11	Mini-Slammer	Connector block to interface with Mini Slammer
J12	USB2GPIO	PMBus interface connector to connect the USB to GPIO interface adapter to the EVM
J13	SV_ALERT	2-pin header for SVID ALERT line
J14	VORST PULLUP	VORST pullup. 2-pin header to pull up VORST to VCC
J15	SV_DIO	2-pin header for SVID bi-directional data line
J16	IIN Option	2-pin header for input current measurement option

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 itself. 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
TP1	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.
TP4	PGND_EFF	Input voltage measurement point for PVIN– (PGND)	
TP5	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.
TP18	PGND_EFF	Output voltage measurement point for VOUT– (GND)	

2.4 Control Loop Gain and Phase Measurement

The TPS544C27EVM includes a R7 10Ω series resistor in the feedback loop for V_{OUT}. The resistor is accessible at the test points TP14 (BODE_CHA) and TP8 (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
TP14	BODE_CHA	Input to feedback divider of V_{OUT}	The amplitude of the perturbation at this node must be limited to less than 30mV
TP8	VOUT_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 TP14 to TP8.
3. Connect the input signal measurement probe to TP14. Connect the output signal measurement probe to TP8.
4. Connect the ground leads of both probe channels to TP16 (PGND_REG).
5. On the network analyzer, measure the Bode as TP14/TP8 (In/Out).

2.5 External 5V bias to enhance efficiency

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

Considerations when using an external bias on the VCC and VDRV pin are shown below

- 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 be always forced off and the internal analog circuits have a stable power supply rail at their 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 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

TPS544C27EVM 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 J16 shunt on. To test I_IN_P and I_IN_M feature, remove the shunt from J16, connect pin1 of J2 (IIN) to pin2 of J1 (PVIN) with a short 10-AWG wires or better. Apply PVIN + to pin2 of J2 (IIN) and PGND to pin1 of J1. Thus the input current can be measured.

3 Software

The TPS544C27 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 TPS544C27 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 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 Figure 3-1.

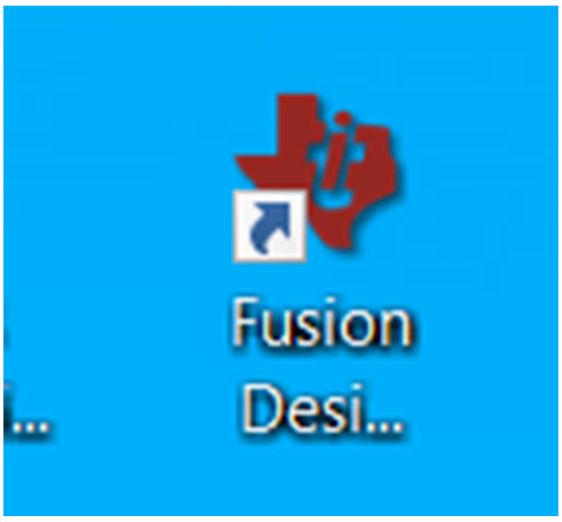

Figure 3-1. PMBus GUI

After opening the PMBus GUI , the specific PMBus address of TPS544C27 system view is shown in Figure 3-2. By default, the position of the shunt on the EVM jumper sets the TPS544C27 address to 0x70h. Click on "Click to configure device"

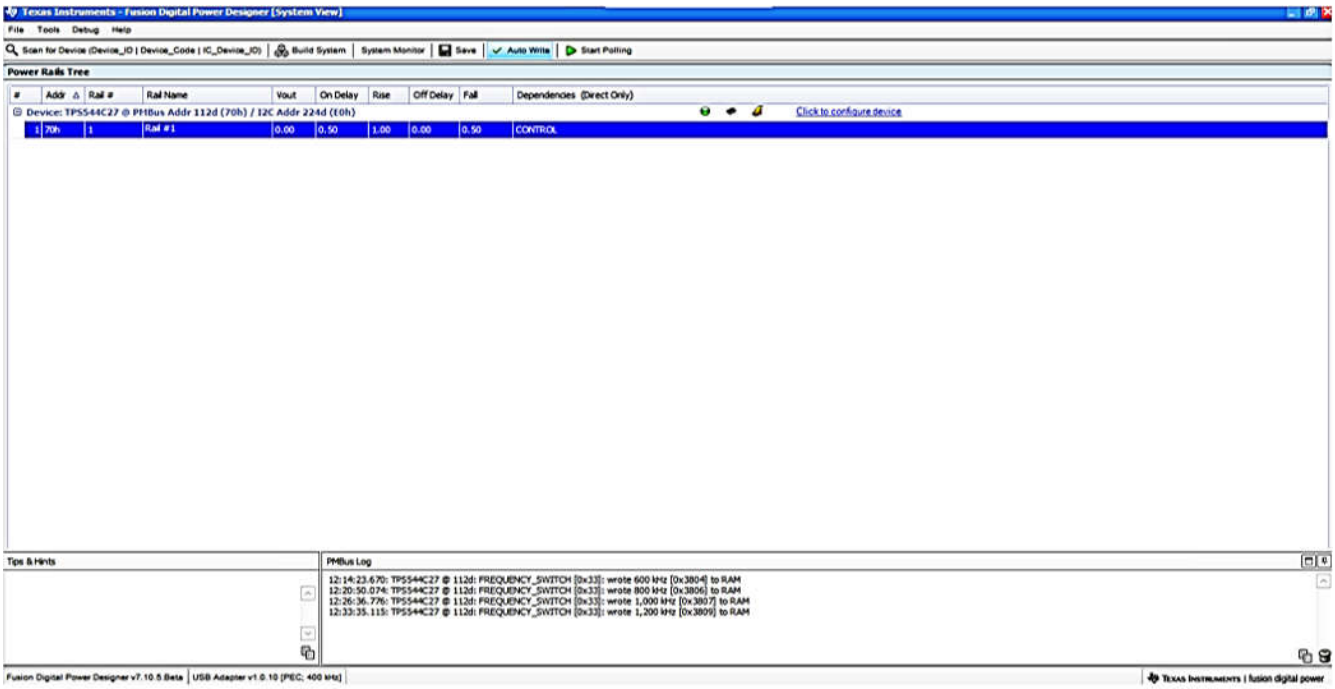

Figure 3-2. PMBus GUI System View

3.2 Monitor Page

When the Monitor screen Figure 3-3 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

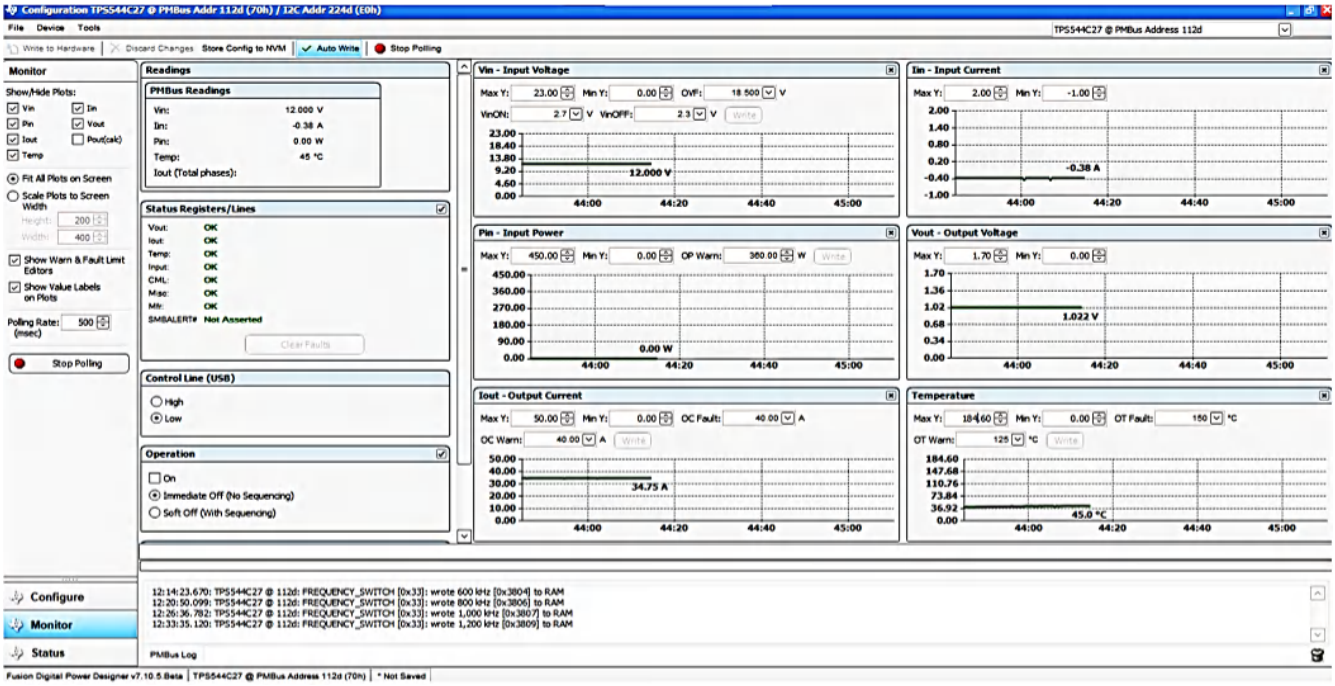

Figure 3-3. Monitor Screen

3.3 Status Page

Selecting Status screen from lower left corner Figure 3-4 shows the status of the device.

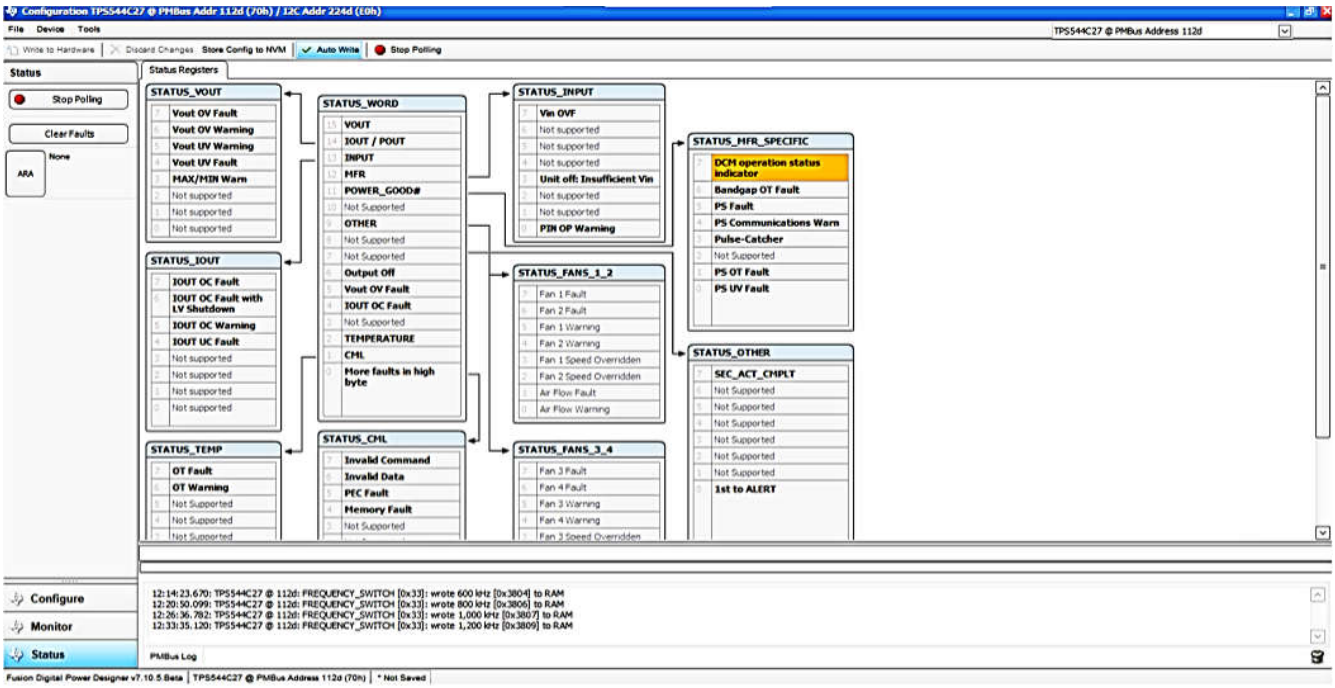

Figure 3-4. Status screen

4 Performance Data and Typical Characteristics Curves

Figure 4-1 through Figure 4-28 present typical performance curves for TPS544C27EVM. The input voltage is 12V, output voltage is 1V, unless otherwise noted.

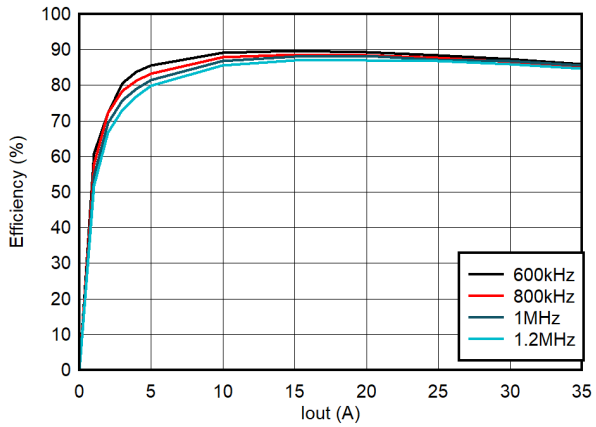

Figure 4-1. Efficiency, FCCM, Internal LDO

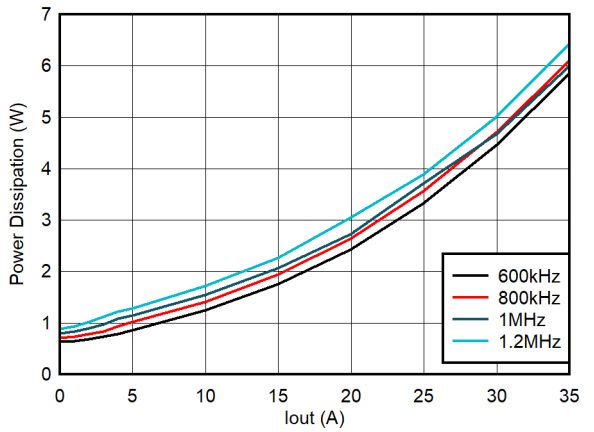

Figure 4-2. Power Dissipation, FCCM, Internal LDO

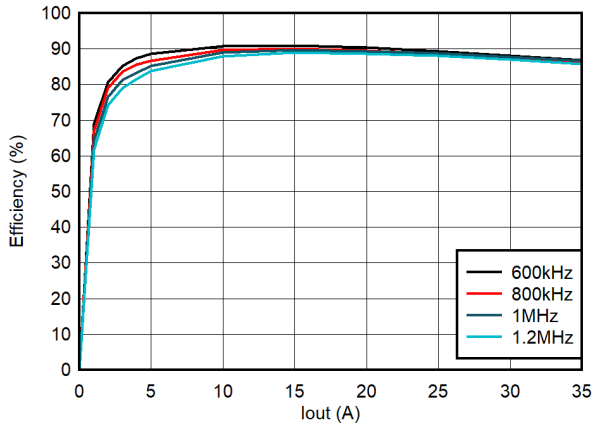

Figure 4-3. Efficiency, FCCM, External 5V Bias

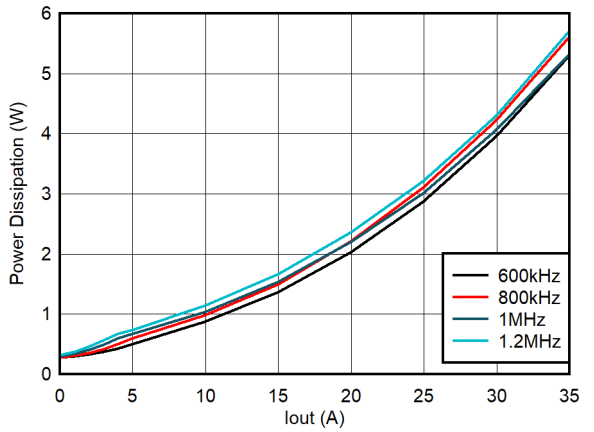

Figure 4-4. Power Dissipation, FCCM, External 5V Bias

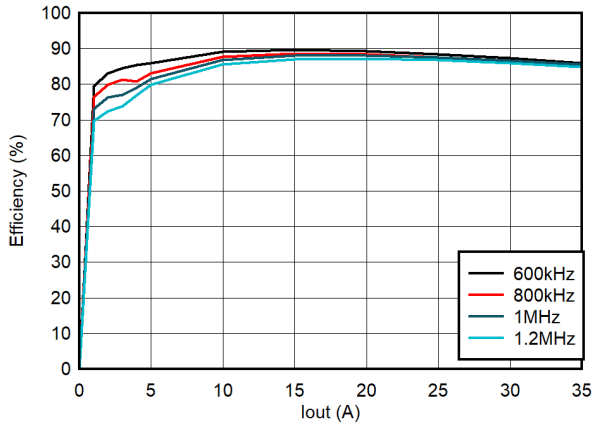

Figure 4-5. Efficiency, DCM. Internal LDO

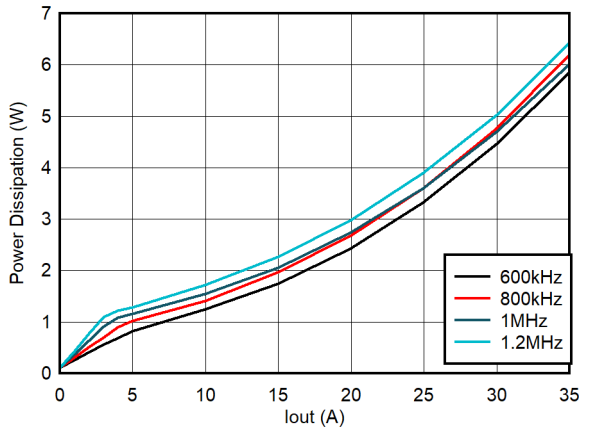

Figure 4-6. Power Dissipation, DCM, Internal LDO

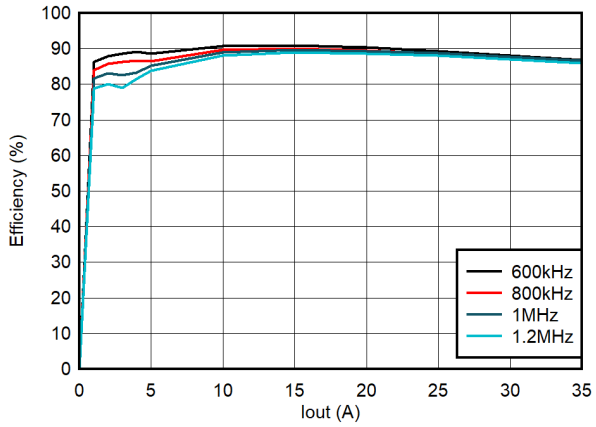

Figure 4-7. Efficiency, DCM, External 5V Bias

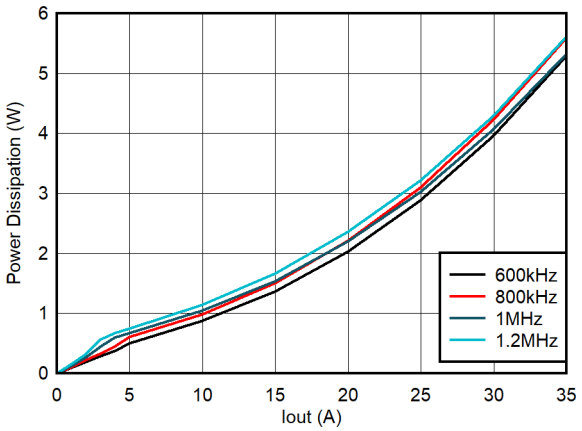

Figure 4-8. Power Dissipation, DCM, External 5V Bias

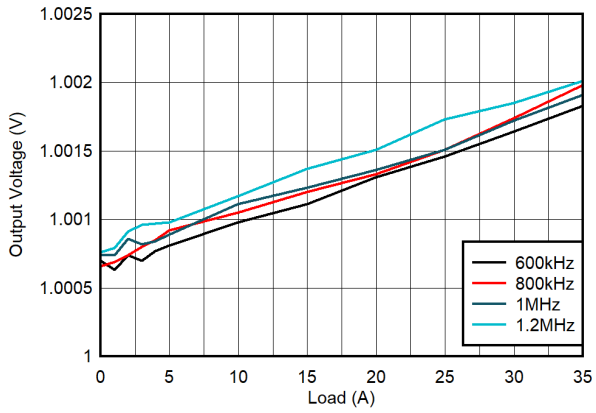

Figure 4-9. Load Regulation, FCCM, Internal LDO

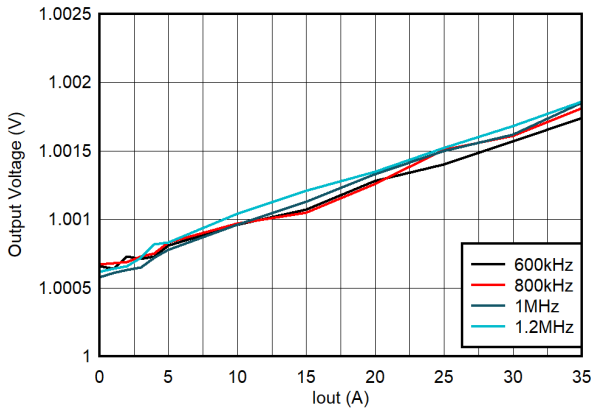

Figure 4-10. Load Regulation, FCCM, External 5V Bias

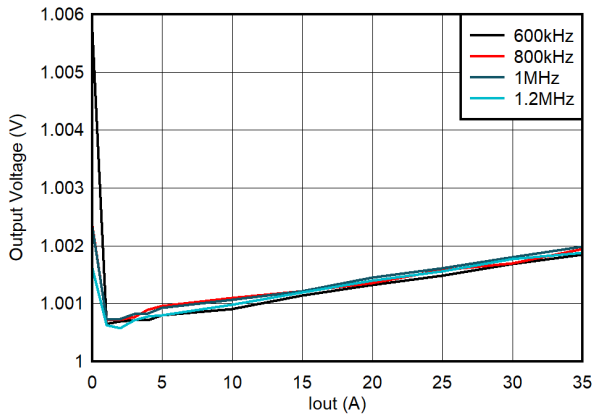

Figure 4-11. Load Regulation, DCM, Internal VCC LDO

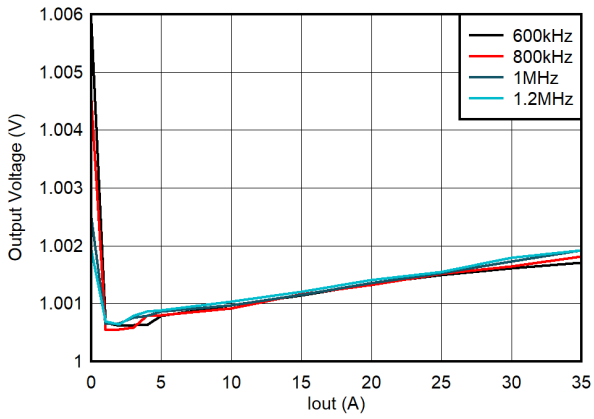

Figure 4-12. Load Regulation, DCM, External 5V Bias

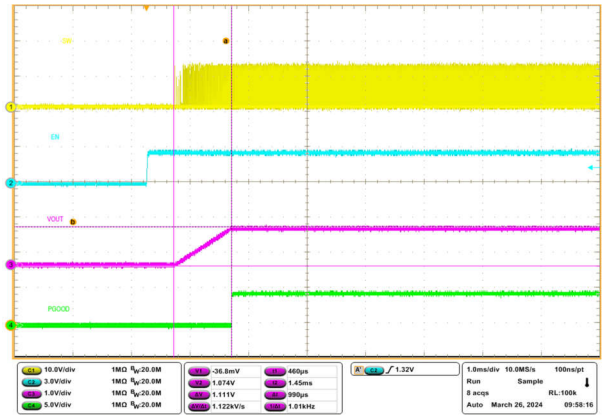

Figure 4-13. ENABLE Start-Up, 800kHz, 20A Load

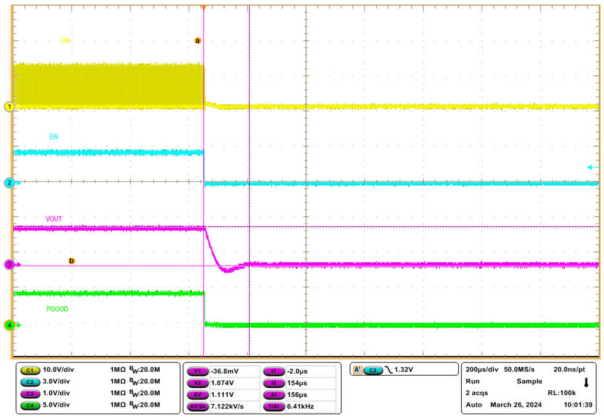

Figure 4-14. ENABLE Shutdown, 800kHz, 20A load

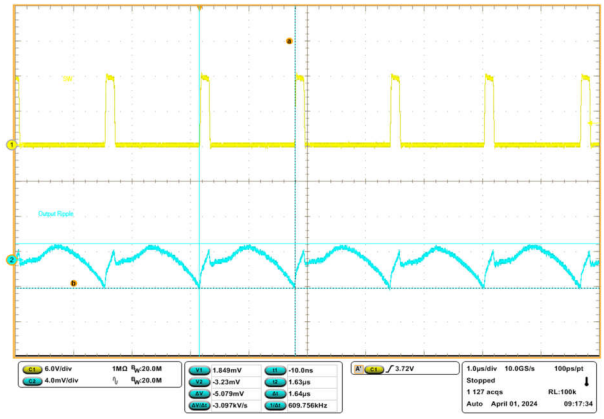

Figure 4-15. Output Voltage Ripple, 600kHz FCCM, 35A Load

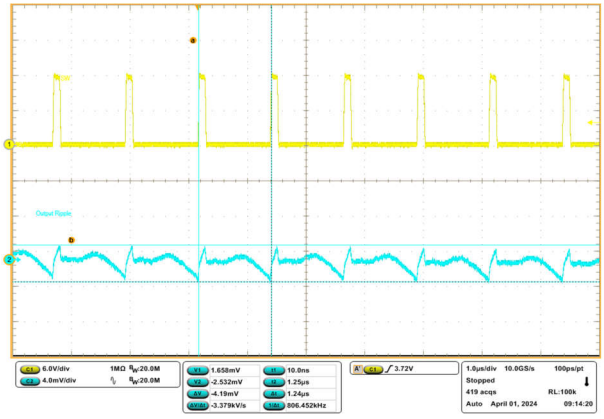

Figure 4-16. Output Voltage Ripple, 800kHz FCCM, 35A Load

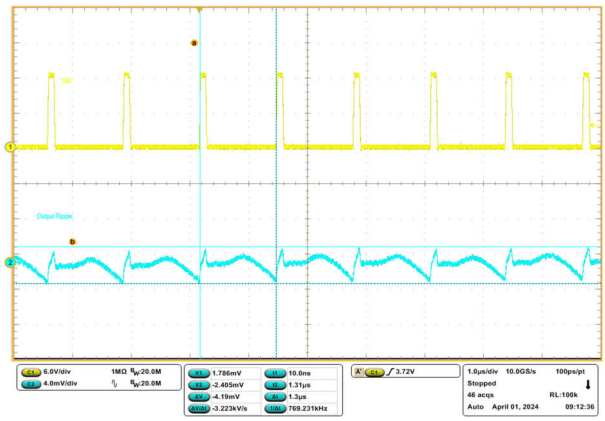

Figure 4-17. Output Voltage Ripple, FCCM, 800kHz, 0.5A Load

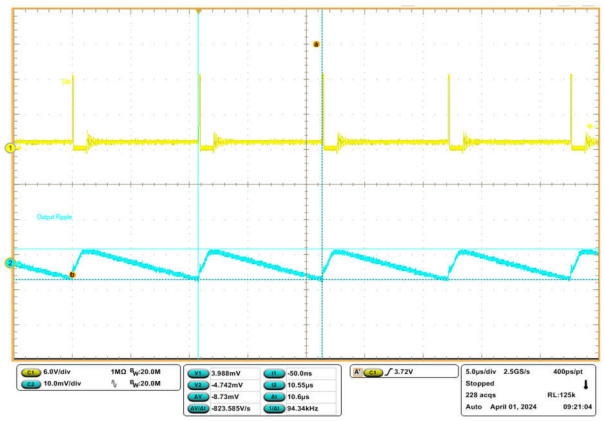

Figure 4-18. Output Voltage Ripple, DCM, 800kHz, 0.5A Load

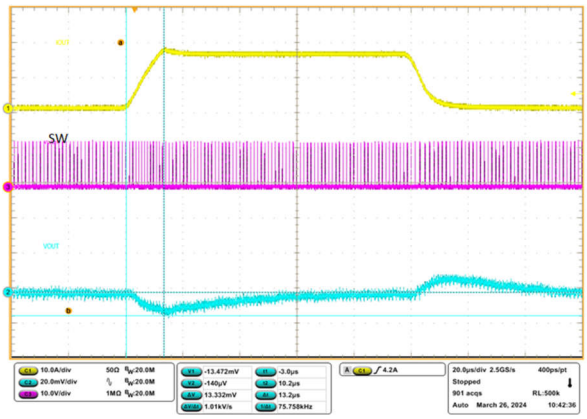

Figure 4-19. Load Transient, FCCM, 0A to 15A Load Step, 1A/us

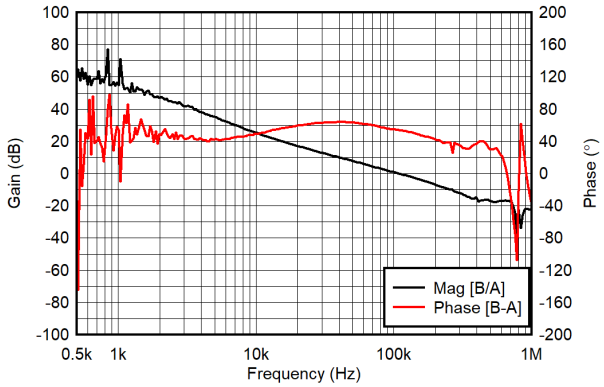

Figure 4-20. Bode Plot, FCCM, 800kHz, 35A Load

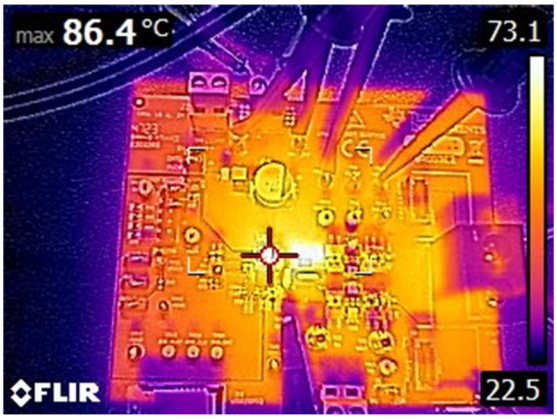

Figure 4-21. Thermal Characteristics, 600kHz FCCM, Internal LDO, 35A Load, no airflow, soak 10 minutes

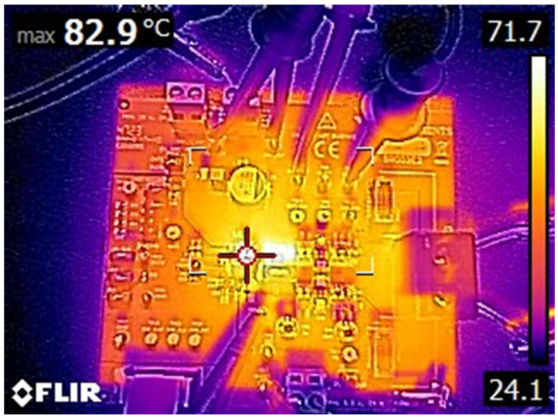

Figure 4-22. Thermal Characteristics, 600kHz FCCM, External 5V Bias, 35A Load, no airflow, soak 10 minutes

Figure 4-23. Thermal Characteristics, 800kHz FCCM, Internal LDO, 35A Load, no airflow, soak 10 minutes

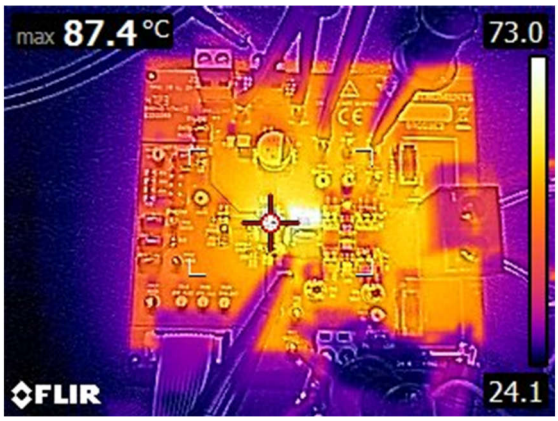

Figure 4-24. Thermal Characteristics, 800kHz FCCM, External 5V Bias, 35A Load, no airflow, soak 10 minutes

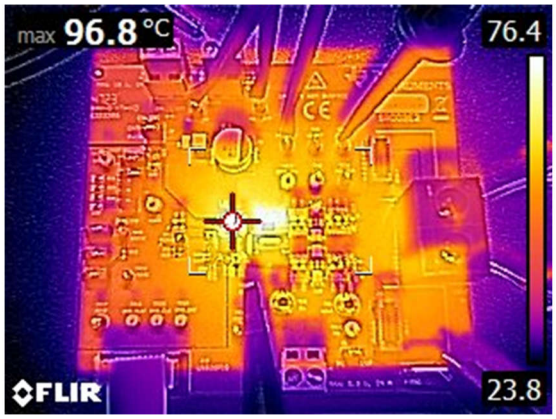

Figure 4-25. Thermal Characteristics, 1MHz FCCM, Internal LDO, 35A Load, no airflow, soak 10 minutes

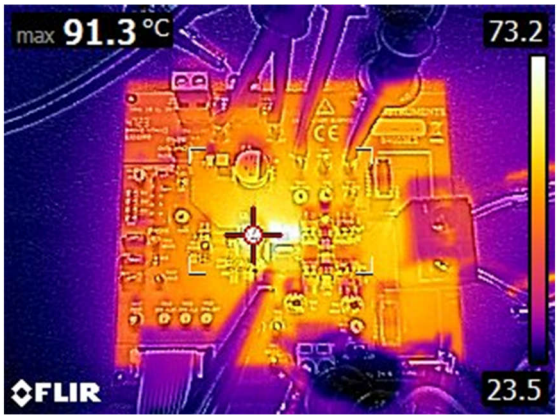

Figure 4-26. Thermal Characteristics, 1MHz FCCM, External 5V Bias, 35A Load, no airflow, soak 10 minutes

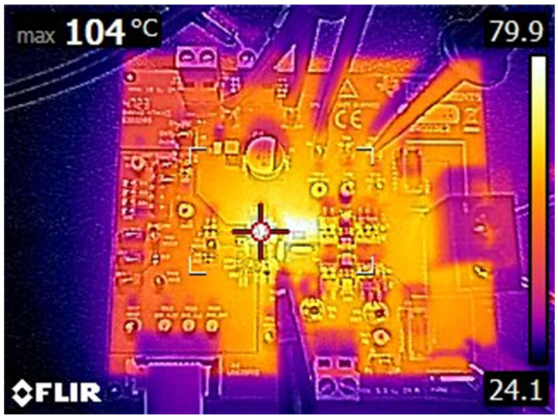

Figure 4-27. Thermal Characteristics, 1.2MHz, FCCM, Internal LDO, 35A Load, no airflow, soak 10 minutes

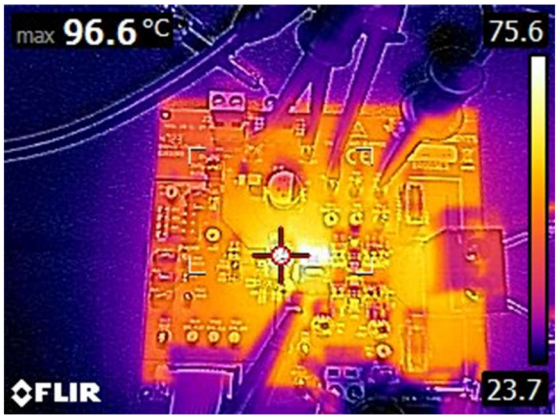

Figure 4-28. Thermal Characteristics, 1.2MHz, FCCM, External 5V Bias, 35A Load, no airflow, soak 10 minutes

5 Hardware Design Files

5.1 Schematics

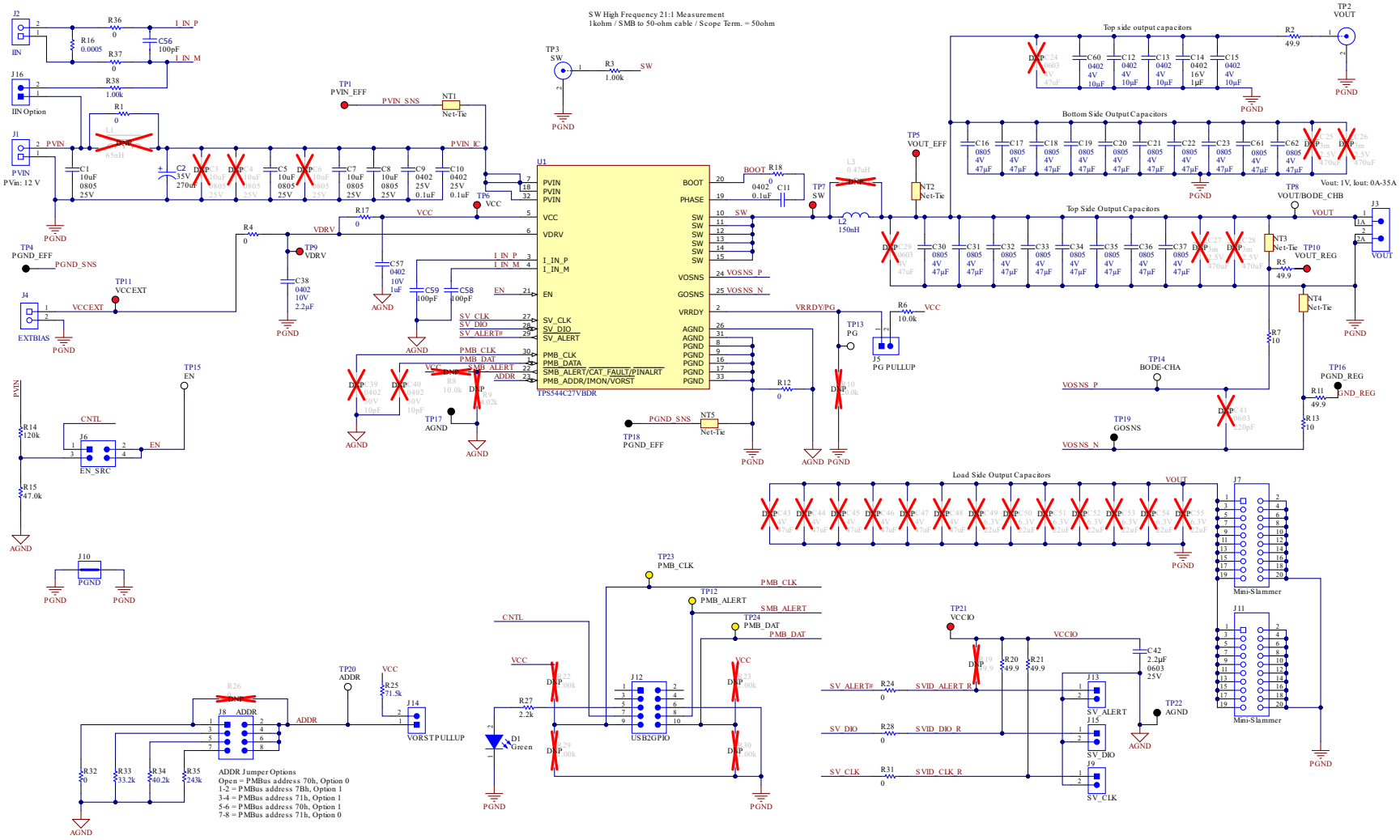

Figure 5-1. TPS544C27EVM Schematic

5.2 PCB Layout

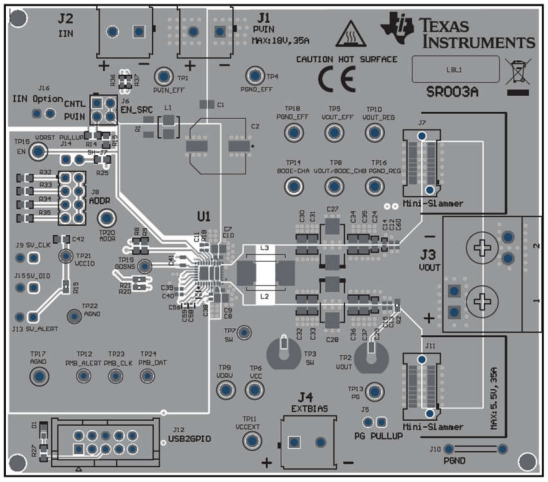

Figure 5-2. TPS544C27EVM Top Composite View

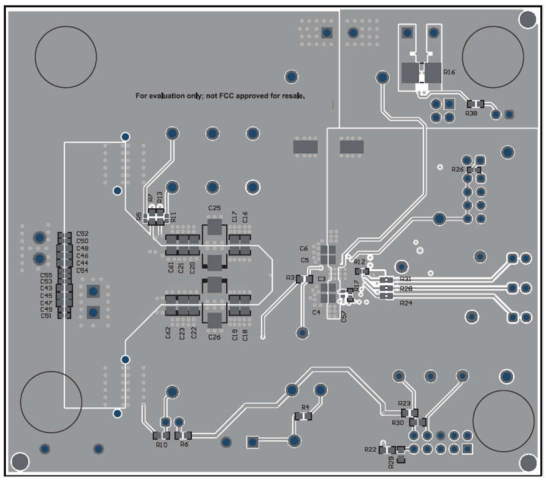

Figure 5-3. TPS544C27EVM Bottom Composite View

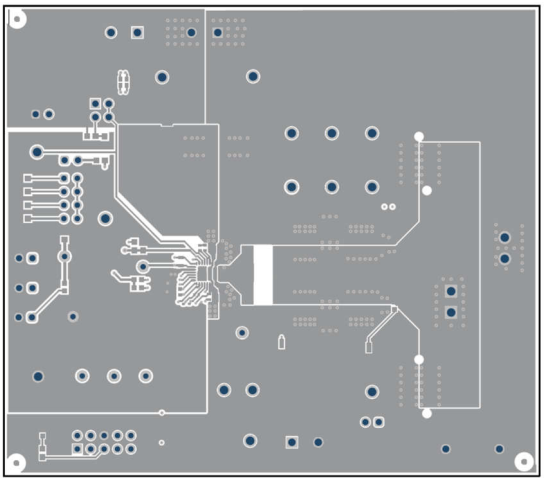

Figure 5-4. TPS544C27EVM Top Layer

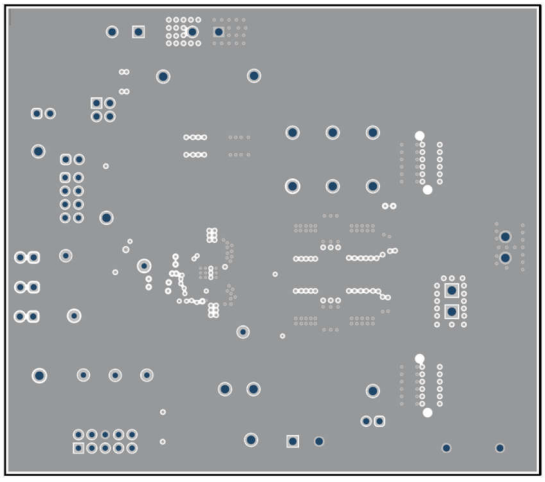

Figure 5-5. TPS544C27EVM Layer 2

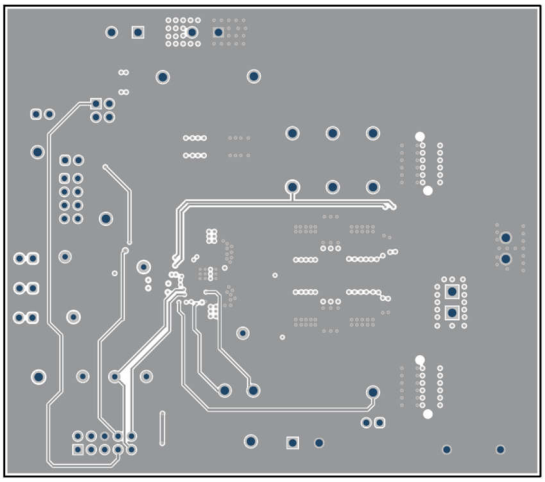

Figure 5-6. TPS544C27EVM Layer 3

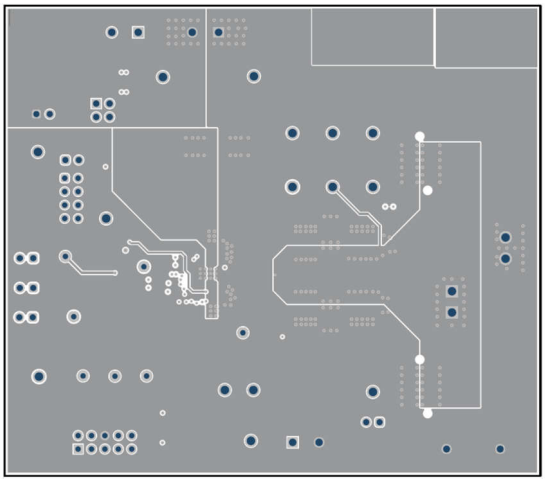

Figure 5-7. TPS544C27EVM Layer 4

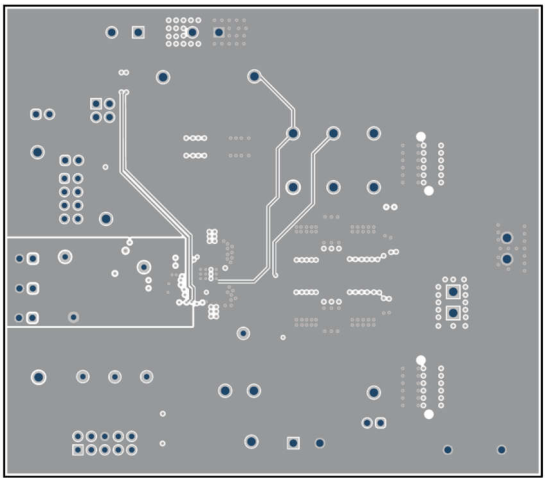

Figure 5-8. TPS544C27EVM Layer 5

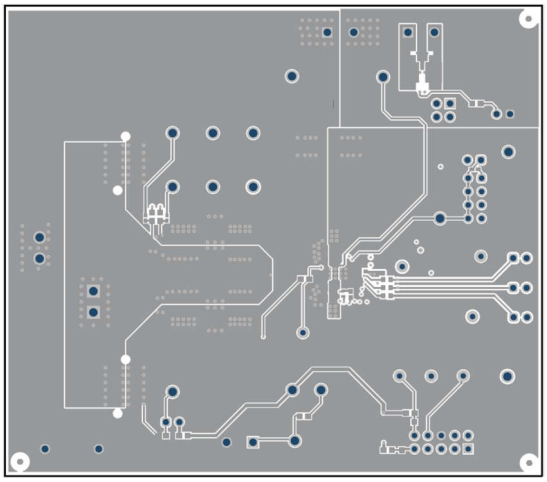

Figure 5-9. TPS544C27EVM Bottom Layer

5.3 BOM

Table 5-1. Bill of Materials

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		SR003-001	Any
C1, C5, C7, C8	4	10µF	CAP, CERM, 10µF, 25V, +/- 10%, X7R, 0805	0805	GRM21BZ71E106KE15L	MuRata
C9, C10, C11	3	0.1µF	CAP, CERM, 0.1µF, 25V, +/- 10%, X7R, 0402	0402	GRM155R71E104KE14D	MuRata
C12, C13, C15, C60	4	10µF	CAP, CERM, 10µF, VAC/4VDC,+/- 20%, X5R, 0402	0402	GRM155R60G106ME44J	Murata
C14	1	1µF	CAP, CERM, 1µF, 16V,+/- 20%, X5R, 0402	0402	GRM155R61C105MA12D	MuRata
C2	1	270µF	270µF 35V Polymer ALUM Electrolytic Capacitor, CR Series 4000h 10.3x10.3x9.9mm	SMT_ECAP_10MM3_10MM3	PCR1V271MCL1GS	Nichicon
C16, C17, C18, C19, C20, C21, C22, C23, C30, C31, C32, C33, C34, C35, C36, C37, C61, C62	18	47µF	CAP, CERM, 47µF, 4V,+/- 20%, X6S, 0805	0805	GRM21BC80G476ME15L	MuRata
C38	1	2.2µF	CAP, CERM, 2.2µF, 10V,+/- 10%, X7S, AEC-Q200 Grade 1, 0402	0402	GRT155C71A225KE13	Murata
C42	1	2.2µF	CAP, CERM, 2.2µF, 25V,+/- 10%, X7S, 0603	0603	GRM188C71E225KE11D	Murata
C56, C58. C59	3	100pF	CAP 0402 100pF 5% C0G 100V 30ppm	0402	GRT1555C2A101JA02D	Murata
C57	1	1µF	CAP, CERM, 1µF, 10V, +/- 10%, X7S, AEC-Q200 Grade 1, 0402	0402	GCM155C71A105KE38D	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, J4	3		Therminal Block, 5mm, 2-pole, Tin, TH	TH, 2-Leads, Body 10x10mm, Pitch 5mm	282856-2	TE Connectivity
J3	1		Terminal Block, 60A, 10.16mm Pitch, 2-Pos, TH	21.8x30x19mm	399100102	Molex
J5, J9, J13, J14, J15, J16	6		Header, 2.54mm, 2x1, Gold, TH	Header, 2.54mm, 2x1, TH	61300211121	Wurth Elektronik
J6	1		Header, 2.54mm, 2x2, Gold, TH	Header, 2.54mm, 2x2, TH	PBC02DAAN	Sullins Connector Solutions
J7, J11	2		Card Edge Socket, 0.8mm, 10x2, SMT	Card Edge Socket, 0.8mm, 10x2, SMT	HSEC8-110-01-S-DV-A	Samtec
J8	1		Header, 2.54mm, 4x2, Gold, TH	Header, 2.54mm, 4x2, TH	TSW-104-08-L-D	Samtec

Table 5-1. Bill of Materials (continued)

Designator	Quantity	Value	Description	Package Reference	Part Number	Manufacturer
J10	1		1mm Uninsulated Shorting Plug, 10.16mm spacing, TH	Shorting Plug, 10.16mm spacing, TH	D3082-05	Harwin
J12	1		Header (shrouded), 100mil, 5x2, Gold, TH	5x2 Shrouded header	5103308-1	TE Connectivity
L2	1	150nH	SMD Power Inductor 150nH 20% 45A Isat at 25°C	SMT, 10.2mm x 4.6mm	VLBU1024660R15MF4	TDK
L2(allternative source)	0	150nH	SMD Power Inductor 150nH 20% 65A Isat at 25°C	SMT, 10.2mm x 4.8mm	AFA41405B-150L	ITG
R1	1	0	RES, 0, 1%, 0.5W, 1206	1206	5108	Keystone
R2, R20, R21	3	49.9	RES, 49.9, 1%, 0.1W, 0603	0603	RC0603FR-0749R9L	Yageo
R3, R38	2	1.00k	RES, 1.00 k, 1%, 0.1W, 0603	0603	RC0603FR-071KL	Yageo
R4, R24, R28, R31, R32	5	0	RES, 0, 5%, 0.1W, 0603	0603	RC0603JR-070RL	Yageo
R5, R11	2	49.9	RES, 49.9, 1%, 0.1W, AEC-Q200 Grade 0, 0402	0402	ERJ-2RKF49R9X	Panasonic
R6	1	10.0k	RES, 10.0k, 1%, 0.1W, 0603	0603	ERJ-3EKF1002V	Panasonic
R7, R13	2	10	RES, 10, 1%, 0.1W, 0603	0603	CRCW060310R0JNEA	Vishay-Dale
R12, R17, R18, R36, R37	5	0	RES, 0, 5%, 0.063W, AEC-Q200 Grade 0, 0402	0402	CRCW04020000Z0ED	Vishay-Dale
R14	1	120k	RES, 120k, 1%, 0.1W, 0603	0603	RC0603FR-07120KL	Yageo
R15	1	47.0k	RES, 47.0k, 1%, 0.1W, 0603	0603	RC0603FR-0747KL	Yageo
R16	1	0.0005	RES, 0.0005, 1%, 2W, 2512	2512	WSL2512L5000FEA18	Vishay-Dale
R25	1	71.5k	RES, 71.5k, 1%, 0.1W, 0603	0603	RC0603FR-0771K5L	Yageo
R27	1	2.2k	RES, 2.2k, 5%, 0.1W, 0603	0603	RC0603JR-072K2L	Yageo
R33	1	33.2k	RES, 33.2k, 1%, 0.1W, 0603	0603	RC0603FR-0733K2L	Yageo
R34	1	40.2k	RES, 40.2k, 1%, 0.1W, 0603	0603	RC0603FR-0740K2L	Yageo
R35	1	243k	RES, 243k, 1%, 0.1 W, 0603	0603	RC0603FR-07243KL	Yageo
TP1, TP5, TP6, TP9, TP10, TP11	6		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone Electronics
TP2, TP3	2		Connector, Receptacle, 50 ohm, TH	SMB Connector	SMBR004D00	JAE Electronics
TP4, TP16, TP17, TP18	4		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone Electronics
TP7, TP21	2		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone Electronics
TP8, TP13, TP14, TP15, TP20	5		Test Point, Multipurpose, White, TH	White Multipurpose Testpoint	5012	Keystone Electronics
TP12, TP23, TP24	3		Test Point, Miniature, Yellow, TH	Yellow Miniature Testpoint0603	5004	Keystone Electronics
TP19, TP22	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, 35A Buck Converter with SVID and PMBus, WQFN-FCRLF33	WQFN-FCRLF33	TPS544C27VBDR	Texas Instruments

6 Trademarks

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

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

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

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

3.4 *European Union*

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

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

4 *EVM Use Restrictions and Warnings:*

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

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

4.3 *Safety-Related Warnings and Restrictions:*

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

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

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

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