

TPS544B28RBH Step-Down Converter Evaluation Module



Description

The TPS544B28RBHEVM is designed to provide a quick setup to evaluate the TPS544B28 in an RBH package and gain familiarity with the device. The TPS544B28RBHEVM is designed for a nominal 12V bus and to produce a regulated 1V output at up to 20A of load current. The TPS544B28RBHEVM is designed to demonstrate PMBus® functionality and different pin strap settings of the TPS544B28 with the help of different connectors and jumpers, while providing a number of test points and connectors to evaluate the performance of the device.

Get Started

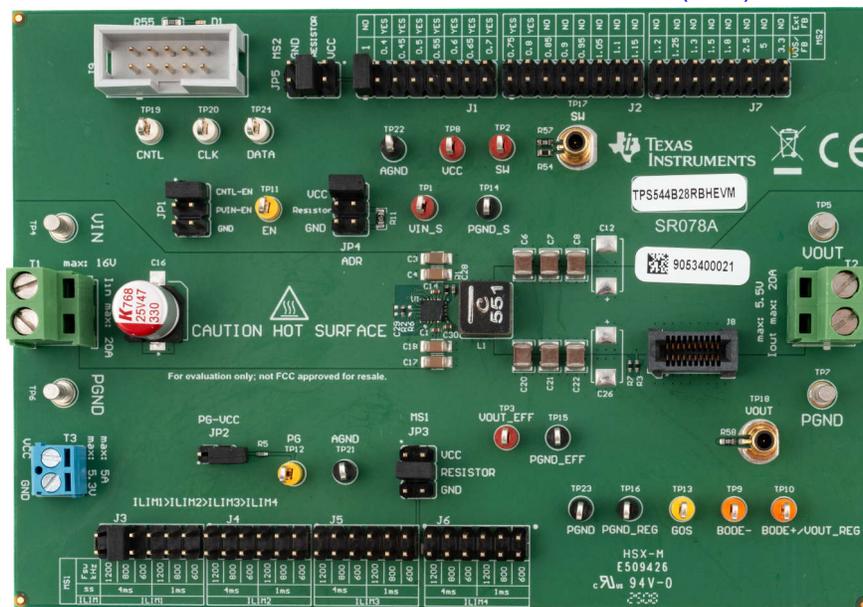
1. Order the TPS544B28RBHEVM on [ti.com](https://www.ti.com).
2. Download the Fusion GUI software on [FUSION_DIGITAL_POWER_DESIGNER](https://www.ti.com).
3. Download the TPS544B28 data sheet on [ti.com](https://www.ti.com).

Features

- Supports evaluation of the TPS544B28 in an RBH package
- Supports TPS544B28 device configuration and monitoring using PMBus and Fusion GUI
- Input voltage range: 4V to 16V, 12V nominal
- Output voltage range: 0.4V to 5.5V, 1V nominal
- Output current: 0A to 20A
- Programmable switching frequency, soft start, overcurrent limit, compensation, fault recovery, output voltage, PFM/FCCM
- Supports internal and external feedback configurations
- Convenient test points for probing critical waveforms
- Easy evaluation design includes PMBus connector and jumper selection at MS1, MS2 and ADR pins to evaluate different settings on TPS544B28

Applications

- [Rack server and blade server](#)
- [Data center switches](#)
- [Hardware accelerator and add-in cards](#)
- [Industrial PC](#)
- [Baseband unit \(BBU\)](#)



TPS544B28RBHEVM (Top View)

1 Evaluation Module Overview

1.1 Introduction

The TPS544B28RBHEVM evaluation module (EVM) is a buck converter built using the TPS544B28 in an RBH package. The EVM is designed to accommodate various settings through jumper options. The device allows programming and monitoring through the PMBus® interface, and therefore, the design is not optimized for any specific condition. The test data in this user's guide was all collected for 12V input voltage, 1V output voltage, and 800kHz switching frequency up to 20A output current, unless otherwise specified.

1.1.1 Before You Begin

The following warnings and cautions are noted for the safety of anyone using or working close to the TPS544B28RBHEVM. Observe all safety precautions.

WARNING

The TPS544B28RBHEVM circuit module can become hot during operation due to dissipation of heat. Avoid contact with the board. Follow all applicable safety procedures applicable to the laboratory.

CAUTION

Do not leave the EVM powered when unattended.

WARNING

The circuit module has signal traces, components, and component leads on the bottom of the board, which 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 provide 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 the equipment requirements and use blocking diodes or other isolation techniques, as needed, to prevent damage to the 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

[Table 1-1](#) lists the contains of the EVM kit. Contact the nearest Texas Instruments Product Information Center if any components are missing. TI highly recommends that users check the [TI website](#) to verify that the latest versions of the Fusion GUI software are used

Table 1-1. Kit Contents

Item	Quantity
TPS544B28RBHEVM	1

1.3 Specifications

The following table lists the electrical performance specifications in room temperature (20°C to 25°C). Characteristics are given for an input voltage of $V_{IN} = 12V$, $V_{OUT} = 1V$, $F_{SW} = 800kHz$, FCCM unless otherwise specified.

Table 1-2. TPS544B28RBHEVM Electrical Performance Specifications

Parameter ⁽¹⁾	Test Conditions	MIN	TYP	MAX	Unit
Input Characteristics					
Input voltage range, V_{IN}		8	12	16	V
Full load input current	$I_{OUT} = 20A$		1.98		A
	$V_{IN} = 8V$, $I_{OUT} = 20A$		2.95		A
No load input current	$I_{OUT} = 0A$, switching enabled		22.2		mA
Output Characteristics					
Output voltage, V_{OUT}			1		V
Output load current, I_{OUT}		0		20	A
Output voltage regulation	Line regulation: $V_{IN} = 8V$ to 16V, $I_{OUT} = 20A$		0.5		mV
	Load regulation: $I_{OUT} = 0A$ to 20A		0.65		mV
Output voltage ripple	$I_{OUT} = 20A$		4		mV
VOOUT output overcurrent fault threshold	Programmed by MS1/ PMBus		21		A
Systems Characteristics					
Switching frequency	Programmed by MS1/PMBus		800		kHz
Full load efficiency	$I_{OUT} = 20A$		84.3		%
Peak efficiency	$I_{OUT} = 7A$		90		%
Operating case temperature	$I_{OUT} = 20A$, 15-minute soak		79.5		°C
PMBus Interface and Pin Strapping					
PMBus address	Programmed by ADR JP4 pins 1 – 2 shorted		2E		Hex
Voltage reference	Programmed by MS2/PMBus		1		V
Soft-start time (TON_RISE)	Programmed by MS1/PMBus		4		ms

(1) The efficiency is measured using the test points listed in [Table 4-1](#) to minimize the effect of DC drops caused by on-board copper traces.

1.4 Device Information

The TPS544B28 is a small, high-efficiency, synchronous buck converter with an adaptive on-time D-CAP4 control mode. The control method provides low minimum on-time and fast load-transient response across the entire output voltage range without requiring an external compensation network. The TPS544B28 has differential remote sense, high-performance integrated MOSFETs. The device features accurate load and line regulation and PFM or FCCM operation. The PMBus interface with 1MHz clock support gives a convenient, standardized digital interface for device configuration as well as output voltage, output current, and die temperature telemetry. Pin strap options allow for the configuration of the device address, fault response, soft start, overcurrent limit, switching frequency, and output voltage selection. Internal NVM is also available to store a variety of the PMBus parameters.

2 Hardware

2.1 Test Equipment

2.1.1 Voltage Source

The input voltage source V_{IN} must be a 0V to 16V variable DC source capable of supplying full rated load across full rated output range on the output. A power supply capable of supplying greater than 10A must be connected to the VIN and PGND terminal block (T1). If the output voltage of the EVM is increased, then the power supply must supply more current.

2.1.2 Oscilloscope

When using oscilloscope to measure the switching node voltage or voltage ripple, measure using a tip-and-barrel method for better measurement. The following figure illustrates the tip and barrel measurement.

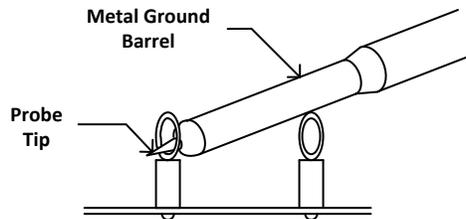


Figure 2-1. Tip and Barrel Measurement

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 20A.

2.1.5 Fan

During prolonged operation at high loads, to provide forced air cooling with a small fan aimed at the EVM is necessary. 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 adapter. Purchase this adapter at [USB-TO-GPIO2](#).

2.1.7 Recommended Wire Gauge

- Input connection to the VIN and PGND terminal blocks (T1) — the recommended wire size is AWG #12 with the total length of wire less than two feet (1-foot input, 1-foot return).
- Output load connection to the VOUT, and PGND terminal blocks (T2) — the minimum recommended wire size is AWG #10 with the total length of wire less than two feet (1-foot output, 1-foot return). A thicker wire gauge can be required to minimize the voltage drop in the wires.

2.1.8 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	VIN_S	VIN test point. Use this test point for efficiency measurements.
TP2	SW	SW node test point
TP3	VOUT_EFF	VOUT test point. Use this test point for efficiency.
TP4	VIN	VIN test point at input terminal (T1)
TP5	VOUT	VOUT test point at output terminal (T2)
TP6, TP7	PGND	PGND test points at input terminal (T1) and output terminal (T2)
TP8	VCC	VCC test point
TP9	BODE-	Use this test point for bode plot measurements.
TP10	BODE+/Vout_REG	VOUT test point. Use this test point for output regulation at remote sense and bode plot measurements.
TP11	EN	EN test point
TP12	PG	PG test point
TP13	GOS	GOS test point
TP14	PGND_S	PGND test point. Use this test point for efficiency measurements with VIN_S (TP1) test point.
TP15	PGND_EFF	PGND test point. Use this test point for efficiency measurements with VOUT_EFF (TP3) test point.
TP16	PGND_REG	PGND test point. Use this test point for output regulation at remote sense.
TP17	SW	SMB connector to measure SW node. When using this test point, set the scope for 50Ω termination. The combination of 50Ω termination and 450Ω series resistance creates a 10:1 attenuation.
TP18	VOUT	SMB connector to measure output voltage. When using this test point, set the scope for 1MΩ termination. When using 50Ω termination, a 2:1 divider is created.
TP19	CNTL	Test point connection to CNTL pin on J10 header
TP20	CLK	CLK test point
TP21/ TP22	AGND	AGND test point
TP23	PGND	PGND test point
TP24	DATA	DATA test point

Table 2-2 lists the EVM jumpers.

Table 2-2. Jumpers

Jumper	Name	Description
JP1	EN	EN pin selections, default: Jumper short on pin3 and pin4
JP2	PG-VCC pullup	Short to pull up PG pin to VCC pin through a 10kΩ resistor. Remove Jumper if not in use, default: Short.
JP3	MS1	MS1 selection header. Use shunt to select MS1 connect to VCC, GND, or resistor, default: Jumper short on pin3 and pin4 for resistor selection.
JP4	ADR	ADR selection header. Use shunt to select ADR connect to VCC, GND, or resistor, default: Jumper short on pin1 and pin2.
JP5	MS2	MS2 selection header. Use shunt to select MS2 connect to VCC, GND, or resistor, default: Jumper short on pin3 and pin4.

Table 2-3 lists the options for the EN pin selections on JP1.

Table 2-3. JP1 Selections

Shunt Position	Selection
CNTL-EN	PMBus adapter control signal
PVIN-EN	Resistor divider to PVIN
GND	EN short to ground

Table 2-4 lists the options for the MS1 pin selections on JP3.

Table 2-4. JP3 Selections

Shunt Position	Selection
VCC	MS1 pin connection to VCC
Resistor	MS1 pin selects resistor to GND options available through connectors J3, J4, J5, J6
GND	MS1 pin connection to GND

Table 2-5 lists the options for the ADR pin selections on JP4.

Table 2-5. JP4 Selections

Shunt Position	Selection
VCC	ADR pin connection to VCC
Resistor	ADR pin selects resistor to GND
GND	ADR pin connection to GND

Table 2-6 lists the options for the MS2 pin selections on JP5.

Table 2-6. JP5 Selections

Shunt Position	Selection
VCC	MS2 pin connection to VCC
Resistor	MS2 pin select resistor to GND options available through connectors J1, J2, J7
GND	MS2 pin connection to GND

Table 2-7 lists the EVM connector functions.

Table 2-7. Connector Functions

Connector	Name	Description
J1, J2	MS2 resistor to GND selection	MS2 resistor to GND connector, pin strap options
J3, J4, J5, J6	MS1 resistor to GND selection	MS1 resistor to GND connector, pin strap options
J7	MS2 resistor to GND selection	MS2 resistor to GND connector, pin strap options
J8	VOUT	Output current mini-slammer connector
J9	USB2GPIO	USB-to-GPIO connector for digital communication
T1	Input voltage source, VIN	Connection for input voltage source
T2	Output, VOUT	Connection for load
T3	External bias, VCC	Connection for external bias supply

2.2 Test Setup

2.2.1 Test and Configuration Software

To change any of the default configuration parameters on the EVM through PMBus, obtain the [TI Fusion Digital Power Designer](#) software.

2.2.1.1 Description

The *TI Fusion Digital Power Designer* is the graphical user interface (GUI) used to configure and monitor the Texas Instruments TPS544B28 power converter installed on this evaluation module. The application uses the PMBus protocol to communicate with the controller over serial bus by way of a TI USB adapter described in [Section 2.1.6](#).

2.2.1.2 Features

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

- Turn on or off the power supply output, either through the hardware control line or the PMBus operation command.
- Monitor real-time data. Items such as output voltage, output current, die temperature, and warnings and faults are continuously monitored and displayed by the GUI.
- Configure common operating characteristics such as V_{OUT} settings, soft-start time, fault response, on and off modes, PFM/FCCM, compensation, and switching frequency.

This software is available for download at [FUSION_DIGITAL_POWER_DESIGNER](#).

3 Software

3.1 EVM Configuration Using the Fusion GUI

The TPS544B28 leaves the factory settings preconfigured. The factory default settings for the parameters can be found in the data sheet. If configuring the EVM to settings other than the factory defaults, then use the software described in [Section 2.2.1](#). Make sure the input voltage is applied to the EVM prior to launching the software so that the TPS544B28 can respond to the GUI and the GUI can recognize the device. The default configuration for the EVM to start or stop converting is set by the EN.

3.1.1 Configuration Procedure

1. Adjust the input supply to provide $5V_{DC}$. Current is limited to 1A.
2. Connect the EN jumper JP1 pin 5 – pin 6 short to GND to disable the converter activity during configuration.
3. Apply the input voltage to the EVM. See [Section 2.1](#) for connections and test setup.
4. Launch the Fusion GUI software. See the screen shots in [Section 3.2](#) for more information.
5. Configure the EVM operating parameters as desired.

3.2 Using the Fusion GUI

3.2.1 Opening the Fusion GUI

The Fusion GUI includes `IC_DEVICE_ID` in scanning mode to find TPS544B28. The EVM needs power to be recognized by the Fusion GUI. See [Section 3.1](#) for the recommended procedure.

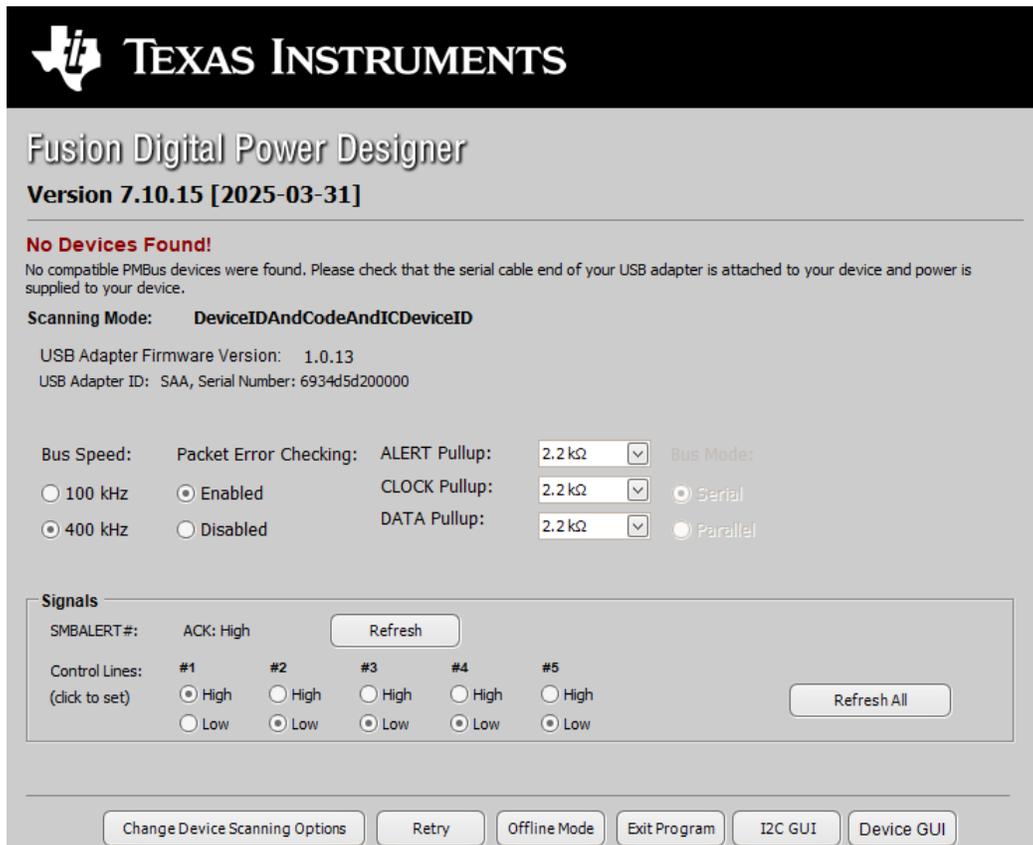


Figure 3-1. Select Device Scanning Mode

3.2.2 Changing ON_OFF_CONFIG

Changing the *On/Off Config* prompts a pop-up window with details of the options shown in Figure 3-2. This pop-up provides multiple options on what turns on and off power conversion. By default, the TPS544B28 is configured to *CONTROL Pin Only*, which is the EN pin.

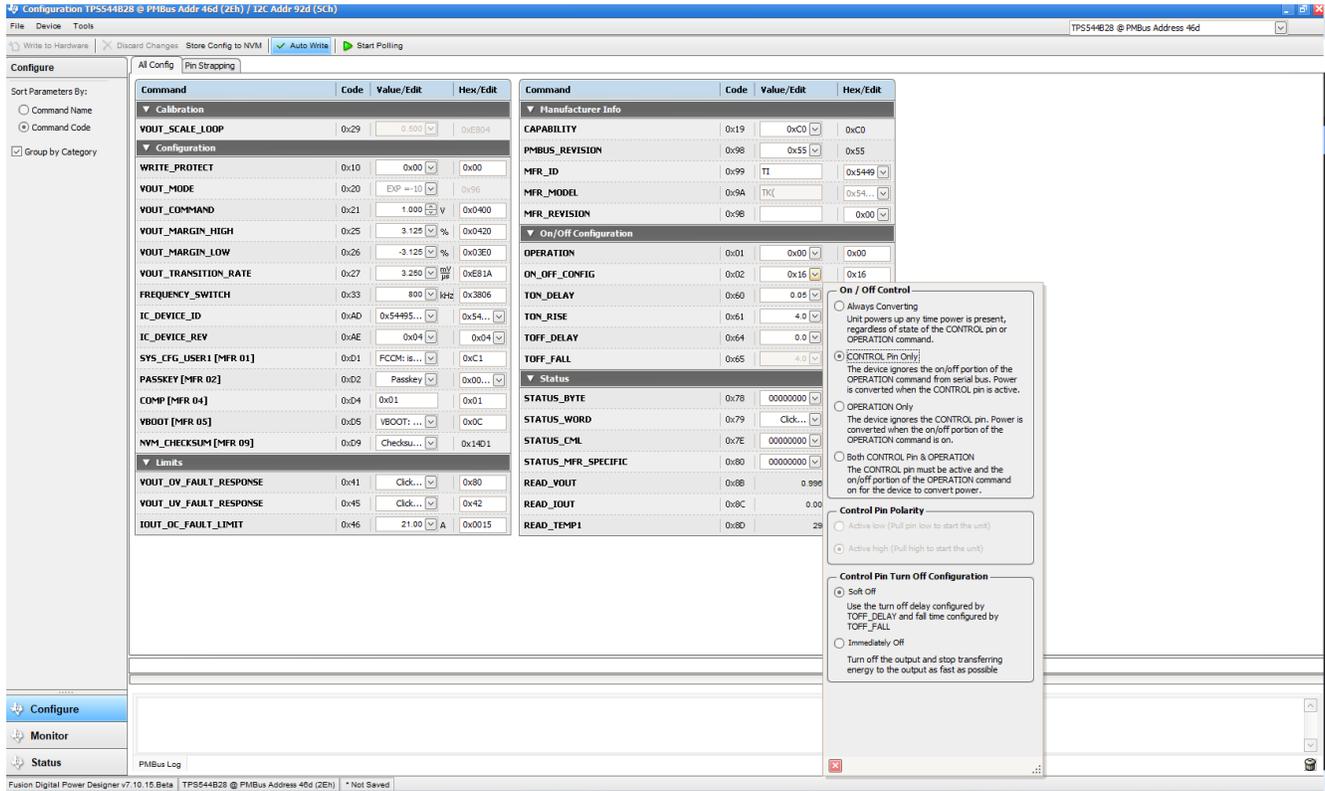


Figure 3-2. Configure – ON_OFF_CONFIG

3.2.3 Pin Strapping

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

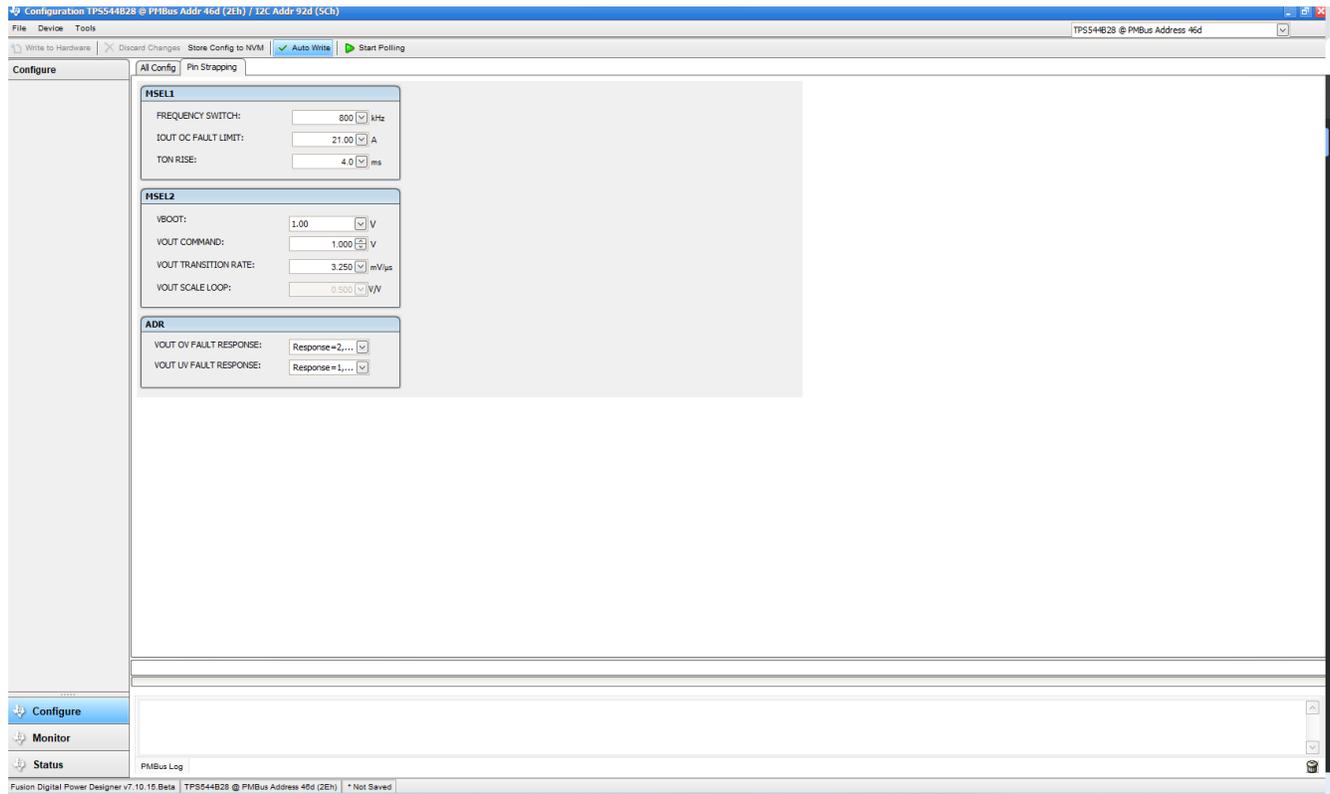


Figure 3-3. Configure - Pin Strapping

3.2.4 All Config

Use the *All Config* tab to configure all of the configurable parameters, which also shows other details like Hex encoding.

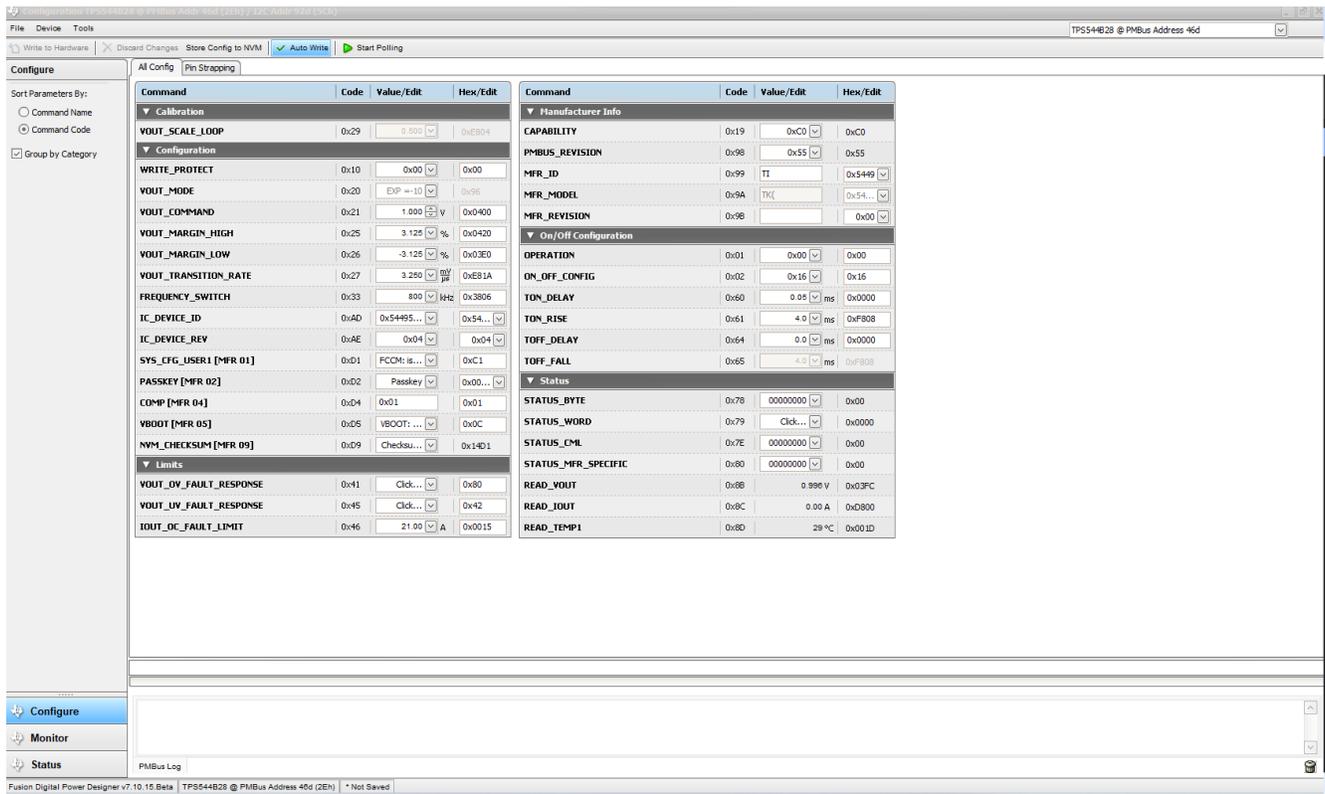


Figure 3-4. Configure – All Config

3.2.5 Monitor

When the *Monitor* screen is selected, the screen changes to display real-time data of the parameters that are measured by the device. This screen provides access to:

- Graphs of *Vout*, *Iout*, and *Temperature*
- *Start and Stop Polling*, which turns ON or OFF the real-time display of 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

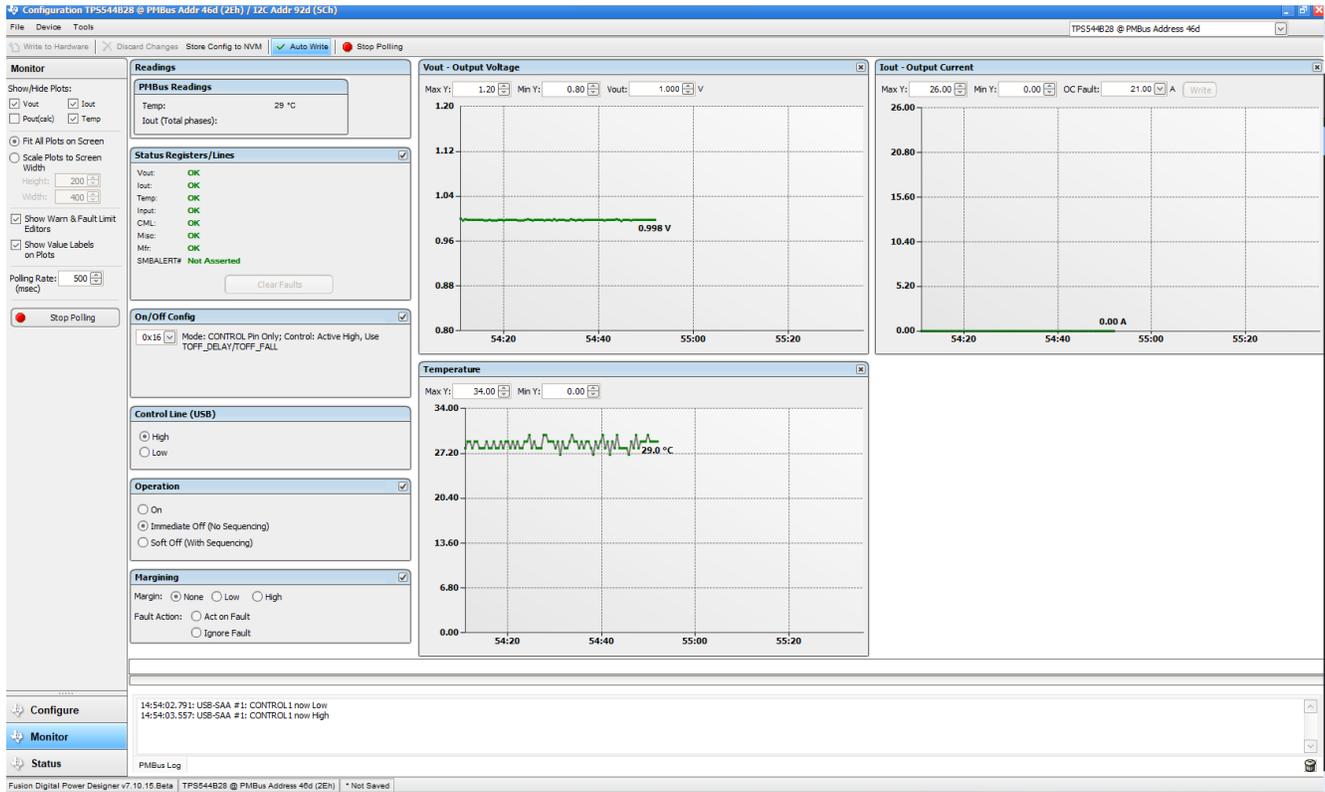


Figure 3-5. Monitor Screen

3.2.6 Status

Selecting *Status* screen from lower left corner shows the status of the device.

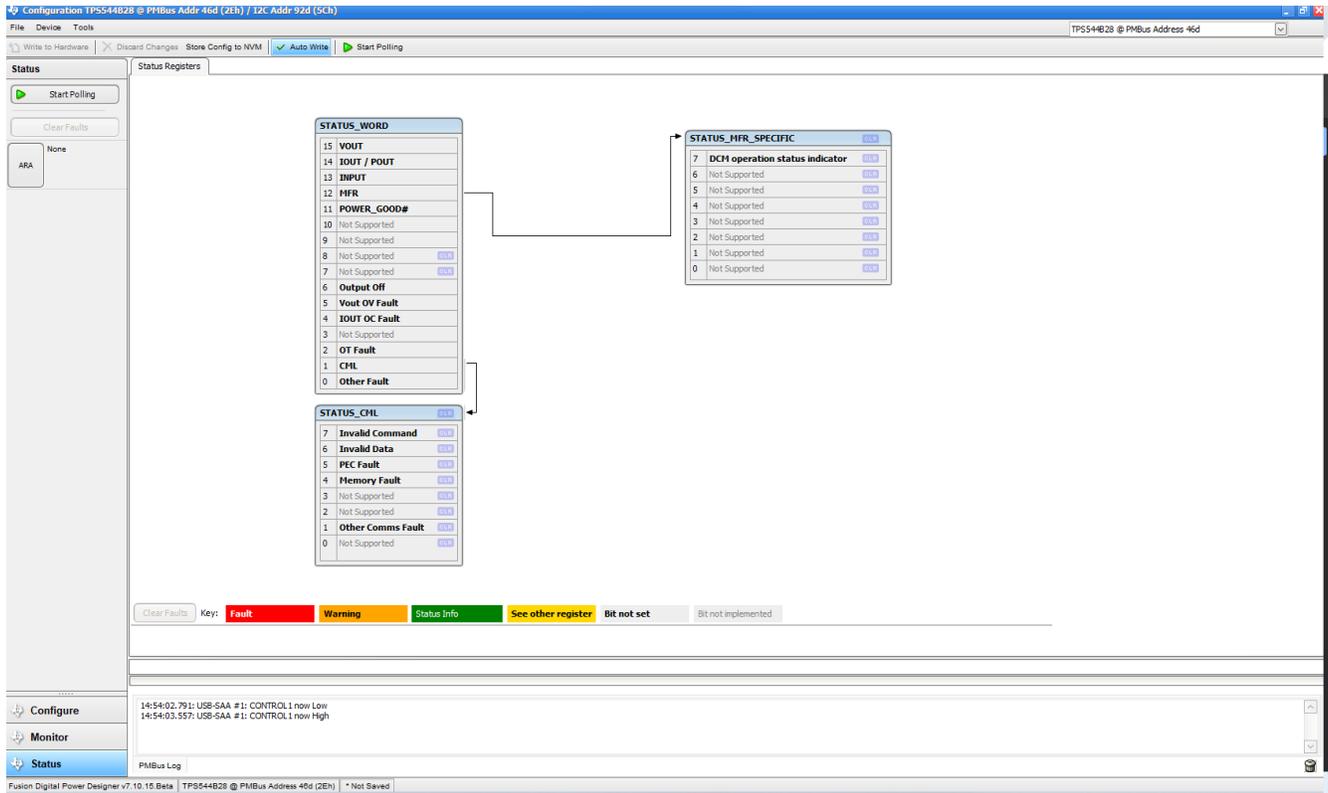


Figure 3-6. Status Screen

4 Implementation Results

4.1 Test Procedure

4.1.1 Line and Load Regulation and Efficiency Measurement Procedure

1. Set up the EVM as described in [Section 2.1](#) and [Section 4.1.2](#).
2. Set the electronic load to draw $0A_{DC}$.
3. Increase V_{IN} from 0V to 12V using a voltage meter to measure input voltage.
4. Use the other voltage meter to measure output voltage, V_{OUT} .
5. Vary the load from 0 to $20A_{DC}$. V_{OUT} must remain in regulation as defined in [Figure 4-2](#).
6. Vary V_{IN} from 4V to 16V. V_{OUT} must remain in regulation as defined in [Figure 4-3](#).
7. Decrease the load to 0A.
8. Decrease V_{IN} to 0V.

4.1.2 Efficiency Measurement Test Points

To evaluate the efficiency of the power train (device and inductor), measuring the voltages at the correct location is important. 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 and 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. Output current can be measured anywhere in the output wires of the output being measured.

The following table shows the measurement points for input voltage and output voltage. V_{IN} and V_{OUT} are measured to calculate the efficiency. Using these measurement points results in efficiency measurements that excluded losses due to the wires and connectors.

Table 4-1. Test Points for Efficiency Measurements

Test Point	Node Name	Description	Comment
TP1	PVIN_S	Input voltage measurement point for VIN	The pair of test points are connected to the VIN/PGND pins of U1. The voltage drop between input terminal to the device pins is not included for efficiency measurement.
TP14	PGND_S	Input voltage measurement point for PGND	
TP3	VOUT_EFF	Output voltage measurement point for VOUT	The pair of test points are connected near the output of the power train. The voltage drop from the output point of the inductor to the output terminals is not included for efficiency measurement.
TP15	PGND_EFF	Output voltage measurement point for PGND	

4.1.3 Control Loop Gain and Phase Measurement Procedure

The TPS544B28RBHEVM includes a 10Ω series resistor in the feedback loop for V_{OUT} . The resistor is accessible at the test points TP9, TP10 for loop response analysis. Use these test points during loop response measurements as the perturbation injecting points for the loop. See the description in [Table 4-2](#).

Table 4-2. List of Test Points for Loop Response Measurements

Test Point	Node Name	Comment
TP9	Bode-	Appropriate amplitude of the perturbation is injected across the test points. Bode can be measured by a network analyzer.
TP10	Bode+/Vout_REG	

4.2 Performance Data and Typical Characteristic Curves

[Figure 4-1](#) through [Figure 4-10](#) present typical performance curves for the TPS544B28 at 12Vin, 1V, 800kHz, FCCM and the oscilloscope measurements use 20MHz bandwidth limiting, unless otherwise noted.

4.2.1 Efficiency

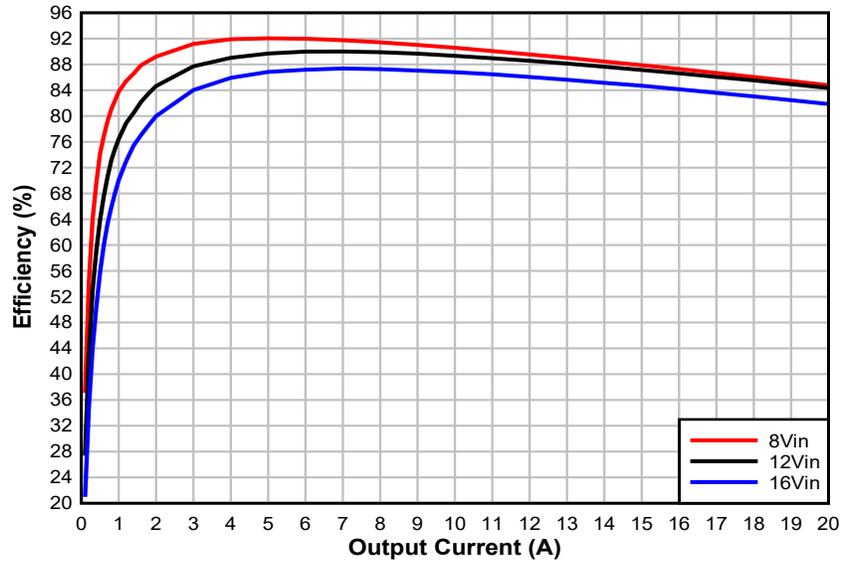


Figure 4-1. VOUT Efficiency

4.2.2 Load Regulation

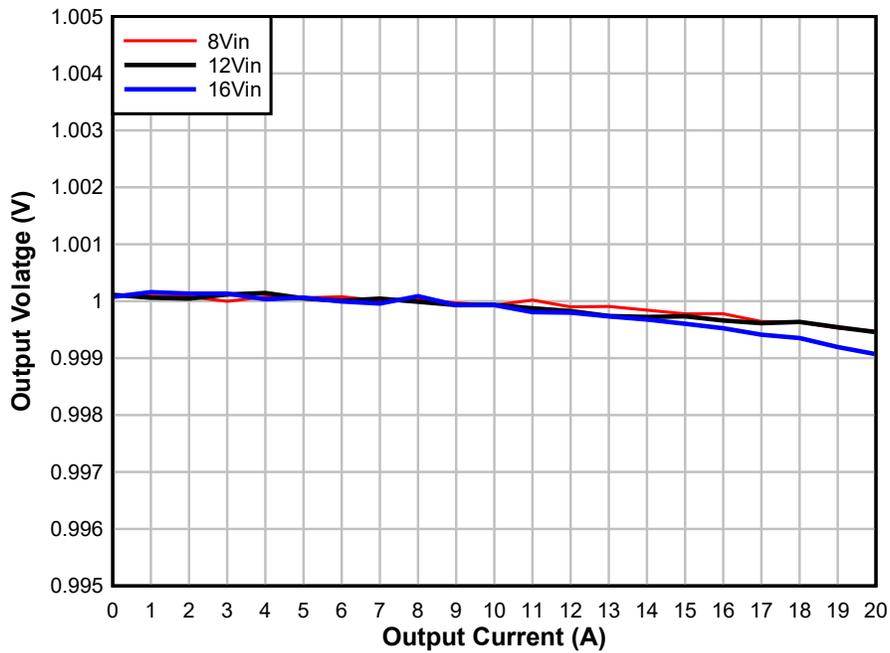


Figure 4-2. VOUT Load Regulation

4.2.3 Line Regulation

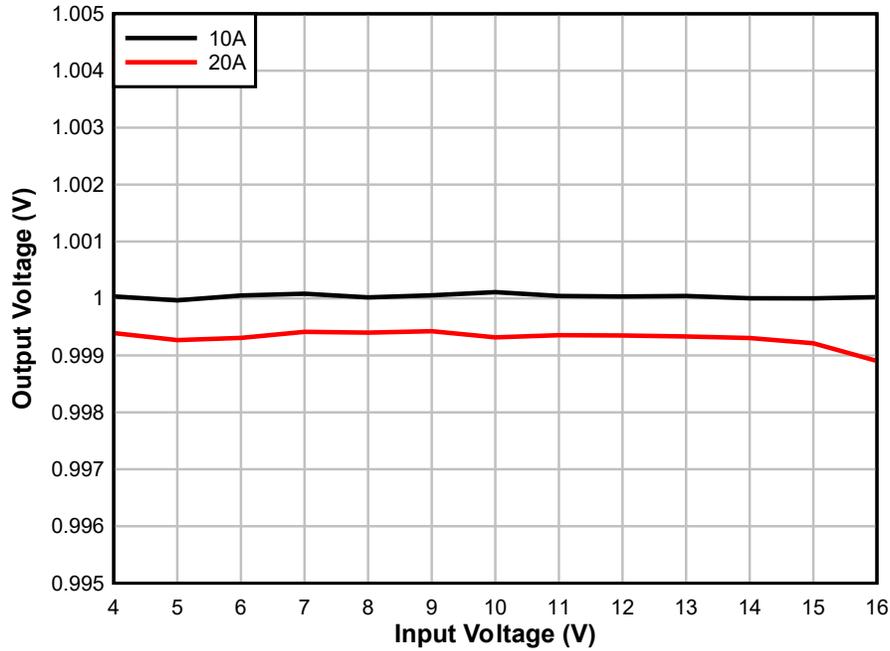


Figure 4-3. VOUT Line Regulation

4.2.4 Output Ripple

Figure 4-4 through Figure 4-7 show the output ripple waveforms at 10mA and 20A load.

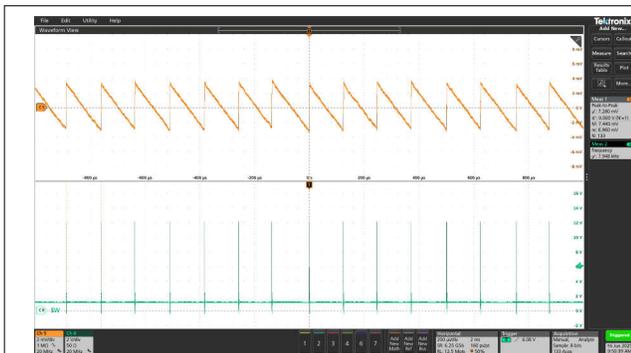


Figure 4-4. Output Ripple, 10mA load, PFM Mode

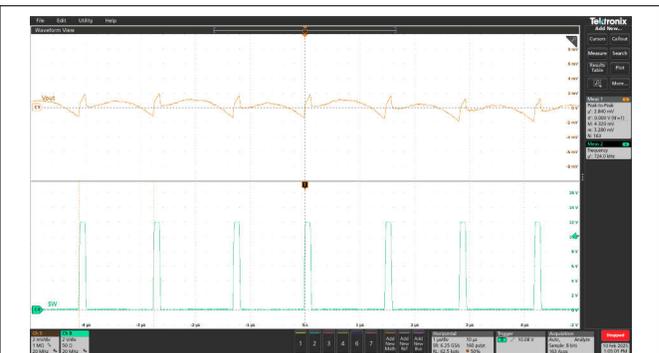


Figure 4-5. Output Ripple, 10mA Load, FCCM

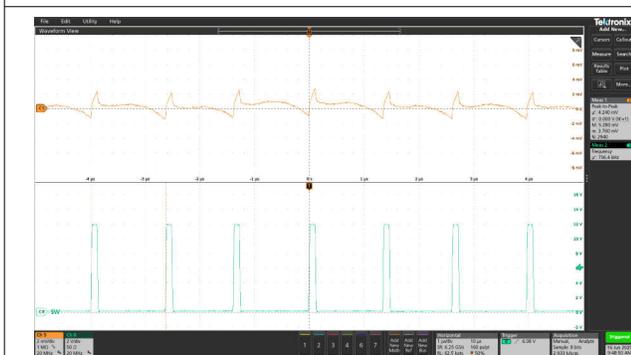


Figure 4-6. Output Ripple, 10A Load

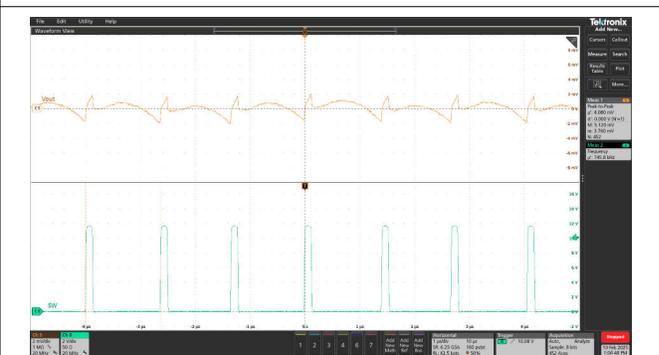


Figure 4-7. Output Ripple, 20A Load

4.2.5 Control On

The following figure illustrates the start-up from control on waveform at 0A output.

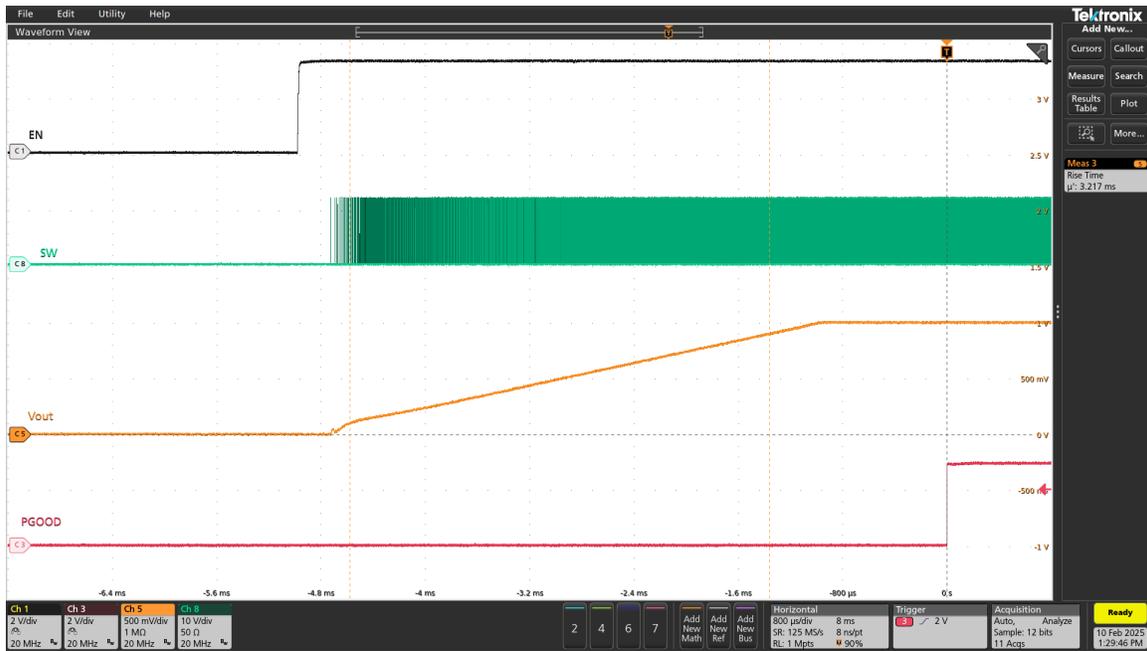


Figure 4-8. VOUT Start-Up From Enable

4.2.6 Control Off

The following figure illustrates the control off waveform at 0A output.

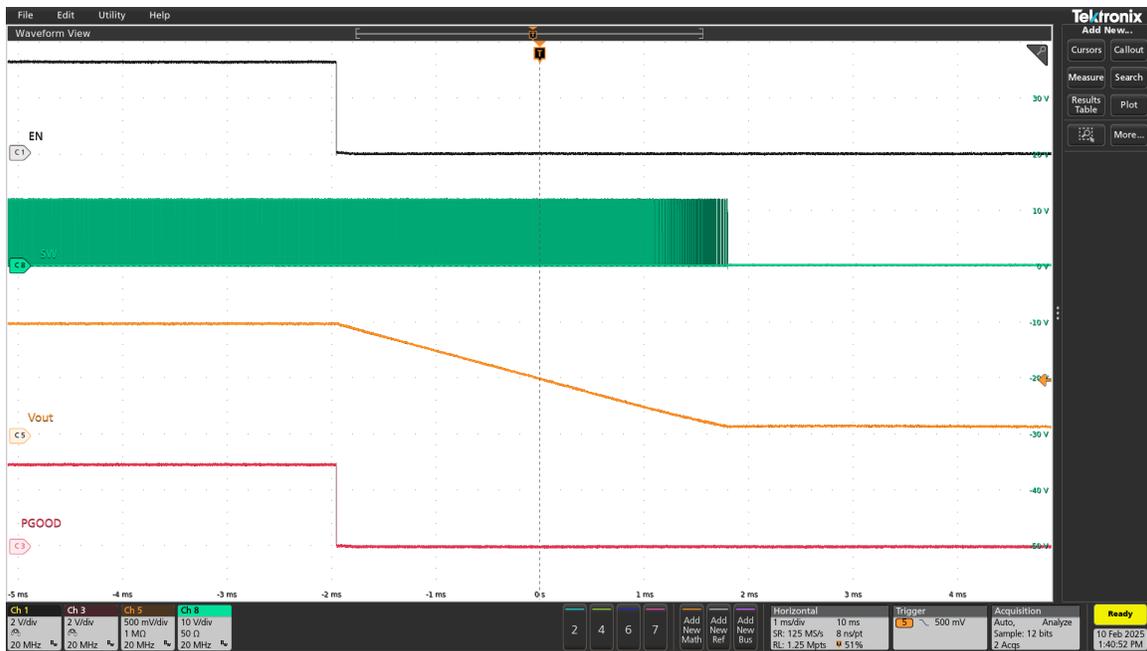


Figure 4-9. VOUT Shutdown From Enable

4.2.7 Thermal Image

Figure 4-10 shows the TPS544B28RBHEVM thermal image. $V_{IN} = 12V$, $V_{OUT} = 1V$, $F_{sw} = 800kHz$, $I_{OUT} = 20A$, 15-min soak.

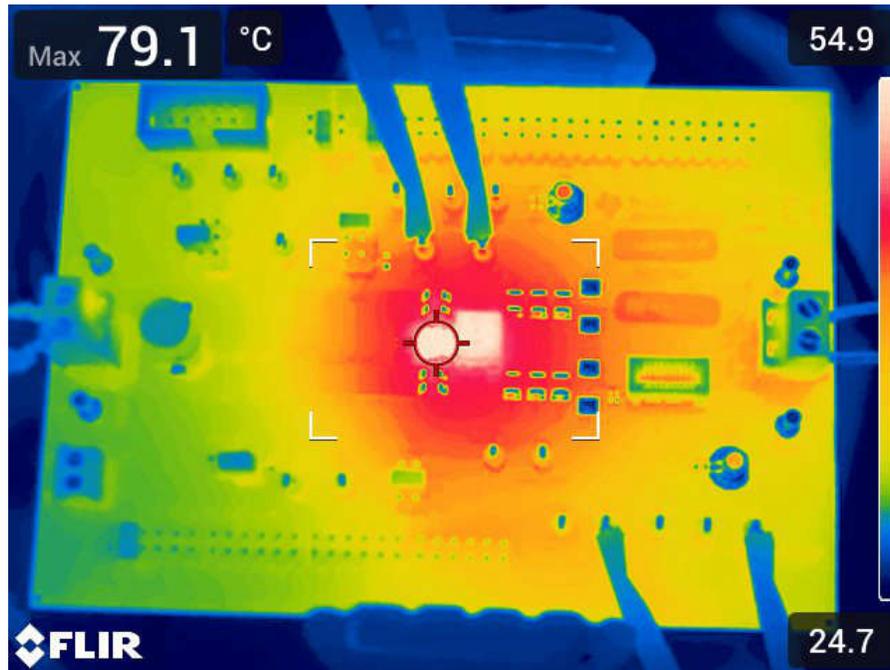


Figure 4-10. Thermal Image

5 Hardware Design Files

5.1 Schematic

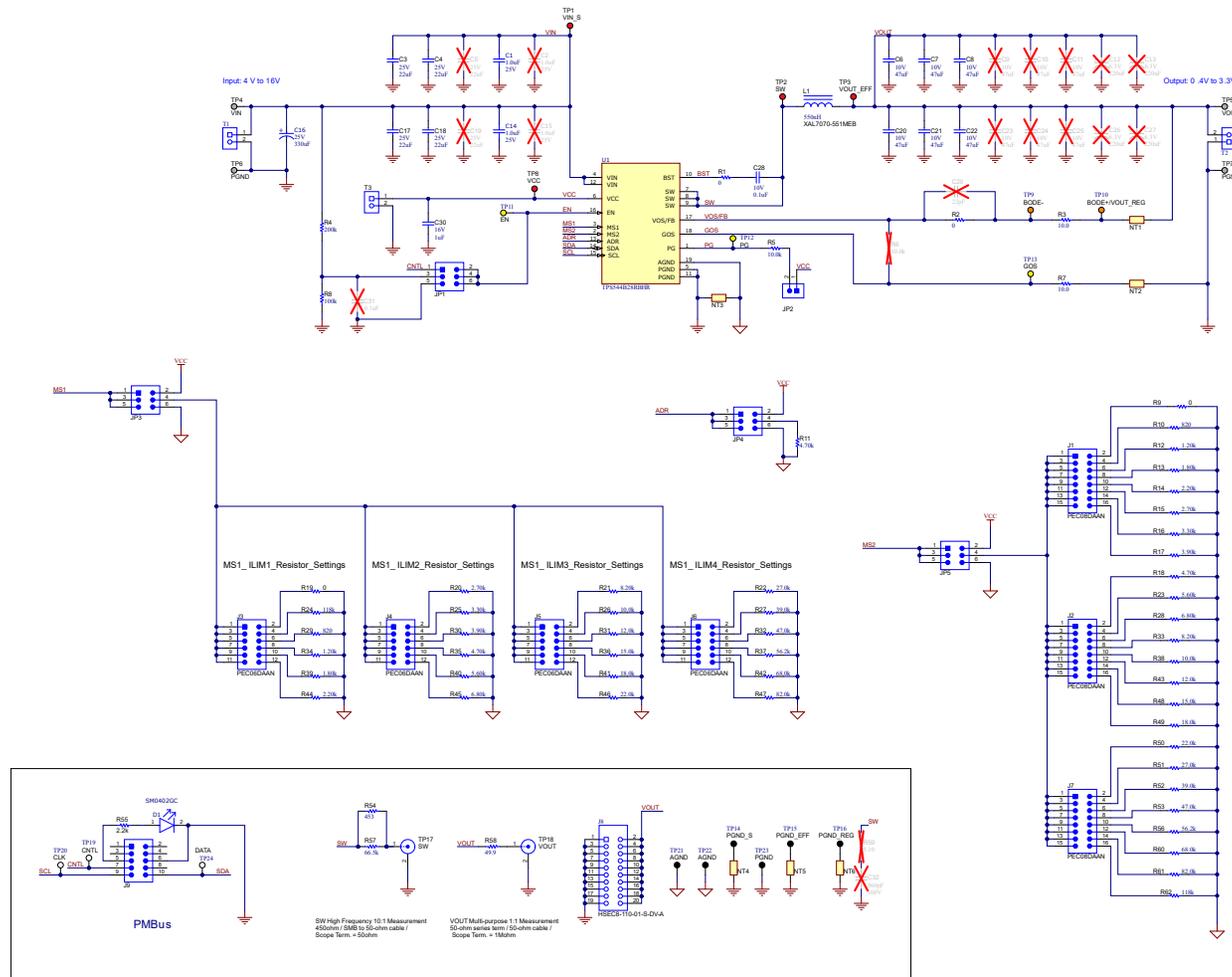


Figure 5-1. TPS544B28RBHEVM Schematic

5.2 EVM Assembly Drawing and PCB Layout

Figure 5-2 through Figure 5-9 show the design of the TPS544B28RBHEVM printed circuit board.

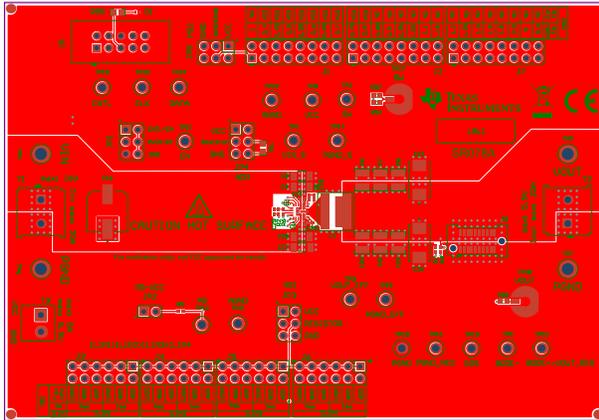


Figure 5-2. TPS544B28RBHEVM Top Side Component View (Top View)

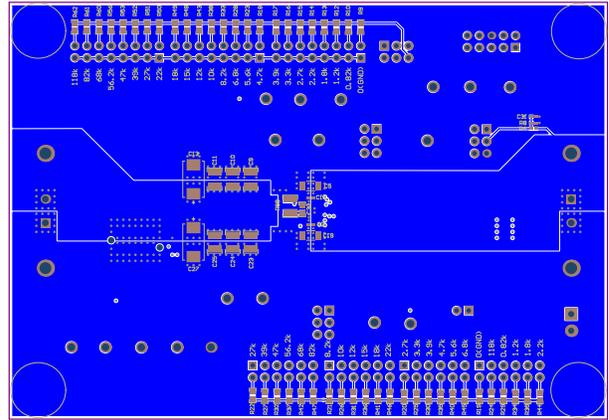


Figure 5-3. TPS544B28RBHEVM Bottom Side Component View (Bottom View)

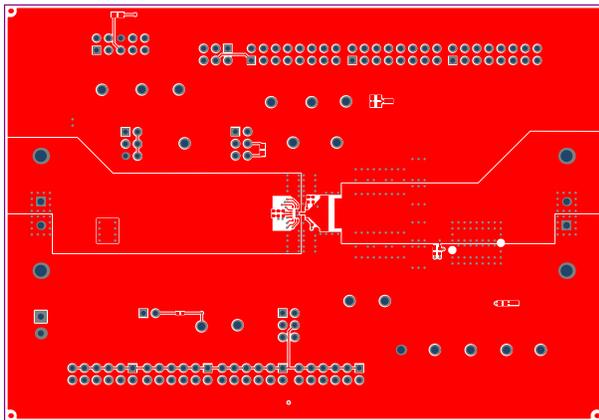


Figure 5-4. TPS544B28RBHEVM Top Copper (Top View)

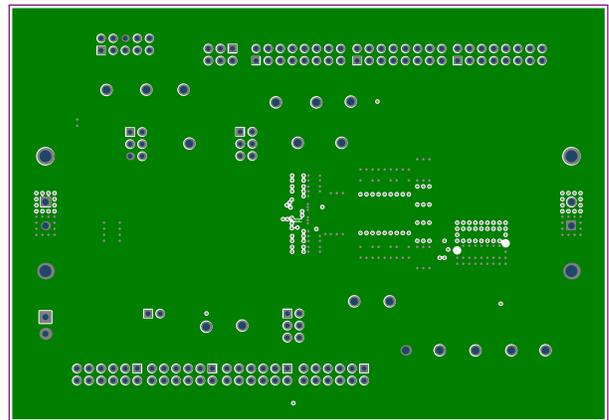


Figure 5-5. TPS544B28RBHEVM Internal Layer 1 (Top View)

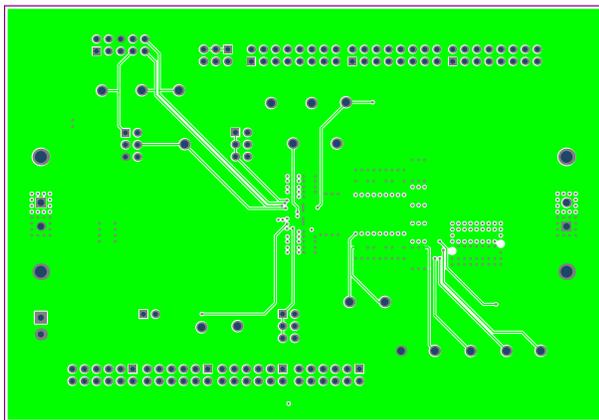


Figure 5-6. TPS544B28RBHEVM Internal Layer 2 (Top View)

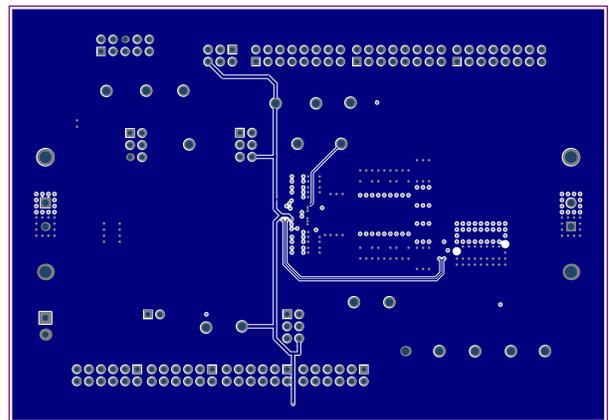


Figure 5-7. TPS544B28RBHEVM Internal Layer 3 (Top View)

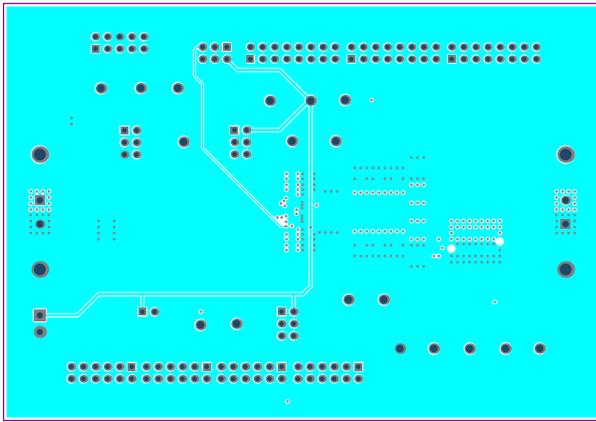


Figure 5-8. TPS544B28RBHEVM Internal Layer 4 (Top View)

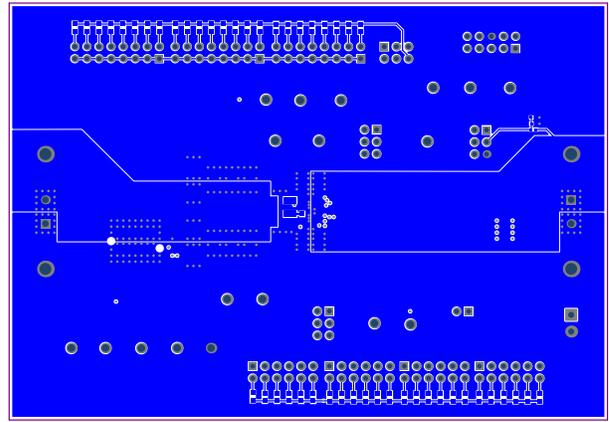


Figure 5-9. TPS544B28RBHEVM Bottom Copper (Bottom View)

5.3 Bill of Materials

The following table lists the BOM for the TPS544B28RBHEVM.

Table 5-1. TPS544B28RBHEVM Bill of Materials

Designator	Quantity	Value	Description	Part Number	Manufacturer	Package Reference
!PCB1	1		Printed Circuit Board	SR078	Any	
C1, C14	2	1 μ F	Chip Multilayer Ceramic Capacitors for General Purpose, 0402, 1.0uF, X6S, 22%, 10%, 25V	GRM155C81E105KE11D	Murata	0402
C3, C4, C17, C18	4	22uF	CAP, CERM, 22uF, 25V, +/- 20%, X6S, 1206_190	GRM31CC81E226ME11L	MuRata	1206_190
C6, C7, C8, C20, C21, C22	6	47uF	CAP, CERM, 47uF, 10V, +/- 20%, X7R, 1210	GRM32ER71A476ME15L	MuRata	1210
C16	1	330 μ F	Cap Aluminum Polymer 330uF 25V 20% Solder Cylindrical 19m Ohm 2325mA 2000 hr 125°C T/R	A768KS337M1ELAE019	KEMET	SMT_CAP_8MM3_8MM3
C28	1	0.1uF	CAP, CERM, 0.1uF, 10V, +/- 10%, X5R, 0402	C1005X5R1A104K050BA	TDK	0402
C30	1	1uF	CAP, CERM, 1uF, 16V, +/- 10%, X6S, 0402	C1005X6S1C105K050BC	TDK	0402
D1	1		LED GREEN CLEAR 0402 SMD	SM0402GC	Bivar	0402
H1, H2, H3, H4	4		Bumpon, Hemisphere, 0.44 X 0.20, Clear	SJ-5303 (CLEAR)	3M	Transparent Bumpon
J1, J2, J7	3		Header, 2.54mm, 8x2, Tin, Vertical, TH	PEC08DAAN	Sullins Connector Solutions	Header, 2.54mm, 8x2, TH
J3, J4, J5, J6	4		Header, 100mil, 6x2, Tin, TH	PEC06DAAN	Sullins Connector Solutions	Header, 6x2, 100mil, Tin
J8	1		Card Edge Socket, 0.8mm, 10x2, SMT	HSEC8-110-01-S-DV-A	Samtec	Card Edge Socket, 0.8mm, 10x2, SMT
J9	1		Header(Shrouded), 2.54mm, 5x2, Gold, TH	AWHW-10G-0202-T	Assman WSW	Header, 2.54mm, 5x2, TH
JP1, JP3, JP4, JP5	4		Header, 100mil, 3x2, Gold, TH	PBC03DAAN	Sullins Connector Solutions	Sullins 100mil, 2x3, 230 mil above insulator
JP2	1		Header, 100mil, 2x1, Gold, TH	PBC02SAAN	Sullins Connector Solutions	Sullins 100mil, 1x2, 230 mil above insulator
L1	1	550nH	Inductor, Shielded, Composite, 550nH, 29A, 0.00142ohm, SMD	XAL7070-551MEB	Coilcraft	7.2x7x7.5mm
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	THT-14-423-10	Brady	PCB Label 0.650 x 0.200 inch
R1, R2	2	0	RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW04020000Z0ED	Vishay-Dale	0402
R3, R7	2	10.0	RES, 10.0, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040210R0FKED	Vishay-Dale	0402
R4	1	200k	RES, 200 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW0402200KFKED	Vishay-Dale	0402
R5	1	10.0k	RES, 10.0 k, 1%, 0.2 W, AEC-Q200 Grade 0, 0402	ERJPA2F1002X	Panasonic	0402
R8	1	100k	RES, 100 k, 1%, 0.1 W, 0402	ERJ-2RKF1003X	Panasonic	0402
R9, R19	2	0	RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW06030000Z0EA	Vishay-Dale	0603
R10, R29	2	820	RES, 820, 1%, 0.1 W, 0603	RC0603FR-07820RL	Yageo	0603

Table 5-1. TPS544B28RBHEVM Bill of Materials (continued)

Designator	Quantity	Value	Description	Part Number	Manufacturer	Package Reference
R11, R18, R35	3	4.70k	RES, 4.70 k, 1%, 0.1 W, 0603	RC0603FR-074K7L	Yageo	0603
R12, R34	2	1.20k	RES, 1.20 k, 1%, 0.1 W, 0603	RC0603FR-071K2L	Yageo	0603
R13, R39	2	1.80k	RES, 1.80 k, 1%, 0.1 W, 0603	RC0603FR-071K8L	Yageo	0603
R14, R44	2	2.20k	RES, 2.20 k, 1%, 0.1 W, 0603	RC0603FR-072K2L	Yageo	0603
R15, R20	2	2.70k	RES, 2.70 k, 1%, 0.1 W, 0603	RC0603FR-072K7L	Yageo	0603
R16, R25	2	3.30k	RES, 3.30 k, 1%, 0.1 W, 0603	RC0603FR-073K3L	Yageo	0603
R17, R30	2	3.90k	RES, 3.90 k, 1%, 0.1 W, 0603	RC0603FR-073K9L	Yageo	0603
R21, R33	2	8.20k	RES, 8.20 k, 1%, 0.1 W, 0603	RC0603FR-078K2L	Yageo	0603
R22, R51	2	27.0k	RES, 27.0 k, 1%, 0.1 W, 0603	RC0603FR-0727KL	Yageo	0603
R23, R40	2	5.60k	RES, 5.60 k, 1%, 0.1 W, 0603	RC0603FR-075K6L	Yageo	0603
R24, R62	2	118k	RES, 118 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW0603118KFKEA	Vishay-Dale	0603
R26, R38	2	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	RC0603FR-0710KL	Yageo	0603
R27, R52	2	39.0k	RES, 39.0 k, 1%, 0.1 W, 0603	RC0603FR-0739KL	Yageo	0603
R28, R45	2	6.80k	RES, 6.80 k, 1%, 0.1 W, 0603	RC0603FR-076K8L	Yageo	0603
R31, R43	2	12.0k	RES, 12.0 k, 1%, 0.1 W, 0603	RC0603FR-0712KL	Yageo	0603
R32, R53	2	47.0k	RES, 47.0 k, 1%, 0.1 W, 0603	RC0603FR-0747KL	Yageo	0603
R36, R48	2	15.0k	RES, 15.0 k, 1%, 0.1 W, 0603	RC0603FR-0715KL	Yageo	0603
R37, R56	2	56.2k	RES, 56.2 k, 1%, 0.1 W, 0603	RC0603FR-0756K2L	Yageo	0603
R41, R49	2	18.0k	RES, 18.0 k, 1%, 0.1 W, 0603	RC0603FR-0718KL	Yageo	0603
R42, R60	2	68.0k	RES, 68.0 k, 1%, 0.1 W, 0603	RC0603FR-0768KL	Yageo	0603
R46, R50	2	22.0k	RES, 22.0 k, 1%, 0.1 W, 0603	RC0603FR-0722KL	Yageo	0603
R47, R61	2	82.0k	RES, 82.0 k, 1%, 0.1 W, 0603	RC0603FR-0782KL	Yageo	0603
R54	1	453	RES, 453, 1%, 0.1 W, 0603	RC0603FR-07453RL	Yageo	0603
R55	1	2.2k	RES, 2.2 k, 5%, 0.1 W, 0603	RC0603JR-072K2L	Yageo	0603
R57	1	66.5k	RES, 66.5 k, 1%, 0.1 W, 0603	RC0603FR-0766K5L	Yageo	0603
R58	1	49.9	RES, 49.9, 1%, 0.1 W, 0603	RC0603FR-0749R9L	Yageo	0603
SH-J1, SH-J2, SH-J3, SH-J4, SH-J5, SH-J6, SH-J7	7	1x2	Shunt, 100mil, Gold plated, Black	SNT-100-BK-G	Samtec	Shunt
T1, T2	2		Therminal Block, 5mm, 2-pole, Tin, TH	282856-2	TE Connectivity	TH, 2-Leads, Body 10x10mm, Pitch 5mm
T3	1		Terminal Block, 3.5mm Pitch, 2x1, TH	ED555/2DS	On-Shore Technology	7.0x8.2x6.5mm
TP1, TP2, TP3, TP8	4		Test Point, Multipurpose, Red, TH	5010	Keystone	Red Multipurpose Testpoint
TP4, TP5, TP6, TP7	4		Terminal, Turret, TH, Triple	1598-2	Keystone	Keystone1598-2

Table 5-1. TPS544B28RBHEVM Bill of Materials (continued)

Designator	Quantity	Value	Description	Part Number	Manufacturer	Package Reference
TP9, TP10	2		Test Point, Multipurpose, Orange, TH	5013	Keystone Electronics	Orange Multipurpose Testpoint
TP11, TP12, TP13	3		Test Point, Multipurpose, Yellow, TH	5014	Keystone Electronics	Yellow Multipurpose Testpoint
TP14, TP15, TP16, TP21, TP22, TP23	6		Test Point, Multipurpose, Black, TH	5011	Keystone Electronics	Black Multipurpose Testpoint
TP17, TP18	2		Connector, Receptacle, 50 ohm, TH	SMBR004D00	JAE Electronics	SMB Connector
TP19, TP20, TP24	3		Test Point, Multipurpose, White, TH	5012	Keystone Electronics	White Multipurpose Testpoint
U1	1		4V to 16V Input, 20A, Remote Sense, D-CAP4 Synchronous Buck Converter with PMBus	TPS544B28RBHR	Texas Instruments	WQFN-HR19
C2, C15	0	1 μ F	Chip Multilayer Ceramic Capacitors for General Purpose, 0402, 1.0uF, X6S, 22%, 10%, 25V	GRM155C81E105KE11D	Murata	0402
C5, C19	0	22uF	CAP, CERM, 22uF, 25V, +/- 20%, X6S, 1206_190	GRM31CC81E226ME11L	MuRata	1206_190
C9, C10, C11, C23, C24, C25	0	47uF	CAP, CERM, 47uF, 10V, +/- 20%, X7R, 1210	GRM32ER71A476ME15L	MuRata	1210
C12, C13, C26, C27	0	220 μ F	Molded Tantalum Polymer Capacitor 220uF 20% 6.3V life 1000Hours SMD 2917	6TCF220M5L	Panasonic	2917.0
C29	0	22pF	CAP, CERM, 22pF, 50V, +/- 5%, C0G/NP0, AEC-Q200 Grade 1, 0402	CGA2B2NP01H220J050BA	TDK	0402
C31	0	0.1uF	CAP, CERM, 0.1uF, 50V, +/- 10%, X7R, AEC-Q200 Grade 1, 0402	CGA2B3X7R1H104K050BB	TDK	0402
C32	0	560pF	CAP, CERM, 560pF, 100V, +/- 10%, X7R, 0603	GRM188R72A561KA01D	MuRata	0603
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
R6	0	10.0k	RES, 10.0 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	CRCW040210K0FKED	Vishay-Dale	0402
R59	0	5.10	RES, 5.10, 1%, 0.5 W, 1210	RC1210FR-075R1L	Yageo	1210

6 Additional Information

6.1 Trademarks

PMBus® is a registered trademark of System Management Interface Forum Inc.
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 DEGRADATION 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/lstds/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 2 4 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/lstds/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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