

User's Guide

TPS548B22 SWIFT™ Step-Down Converter Evaluation Module User's Guide



ABSTRACT

This user's guide describes the characteristics, operation, and use of the TPS548B22 Evaluation Module (EVM). The user's guide includes test information, descriptions, and results. A complete schematic diagram, printed-circuit board layouts, and bill of materials are also included in this document. Throughout this user's guide, the abbreviations EVM, TPS548B22EVM, and the term evaluation module are synonymous with the TPS548B22EVM-847, unless otherwise noted.

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1 Introduction

The PWR847EVM evaluation module uses the TPS548B22 device. The TPS548B22 is a highly integrated synchronous buck converter that is designed for up to 25-A current output.

1.1 Before You Begin

The following warnings and cautions are noted for the safety of anyone using or working close to the TPS548B22EVM-847. Observe all safety precautions.

**Warning**

The TPS548B22EVM-847 circuit module may become hot during operation due to dissipation of heat. Avoid contact with the board. Follow all applicable safety procedures applicable to your 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. This may result in exposed voltages, hot surfaces or sharp edges. Do not reach under the board during operation.

CAUTION

The circuit module may be damaged by over temperature. To avoid damage, monitor the temperature during evaluation and provide cooling, as needed, for your system environment.

CAUTION

Some power supplies can be damaged by application of external voltages. If using more than 1 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. Also be aware that the computer is referenced to the Battery- potential of the EVM.

2 Description

The PWR847EVM is designed as a single output DC-DC converter that demonstrates the TPS548B22 in a typical low-voltage application while providing a number of test points to evaluate the performance. It uses a nominal 12-V input bus to produce a regulated 1-V output at up to 25-A load current.

2.1 Typical End-User Applications

- Enterprise storage, SSD, NAS
- Wireless and wired communication infrastructure
- Industrial PCs, automation, ATE, PLC, video surveillance
- Enterprise server, switches, routers
- ASIC, SoC, FPGA, DSP core and I/O rails

2.2 EVM Features

- Regulated 1-V output up to 25-A, steady-state output current
- Convenient test points for probing critical waveforms

3 EVM Electrical Performance Specifications

Table 3-1. PWR-847EVM Electrical Performance Specifications

Parameter	Test Conditions	Min	Typ	Max	Units
Input Characteristics					
Voltage range	V _{IN} tied to V _{DD}	5	12	14	V
Maximum input current	V _{IN} = 12 V, I _O = 25 A			12	A
No load input current	V _{IN} = 12 V, I _O = 0 A		60		mA
Output Characteristics					
V _{OUT} Output voltage	Output current = 10 A	1			V
I _{OUT} Output load current	I _{OUT(min)} to I _{OUT(max)}	0	25		A
Output voltage regulation	Line regulation: input voltage = 5 V to 14 V	0.5%			
	Load regulation: output current = 0 A to I _{OUT(max)}	0.5%			
V _{OUT} Output voltage ripple	V _{IN} = 12 V, I _{OUT} = 25 A	10			mV _{PP}
V _{OUT} Output overcurrent		32			A
Systems Characteristics					
Switching frequency	F _{SW}	650			kHz
V _{OUT} Peak efficiency	V _{IN} = 12 V, I _O = 12 A, F _{SW} = 650 kHz	90%			
Operating temperature	T _{oper}	0	85		°C

4 Schematic

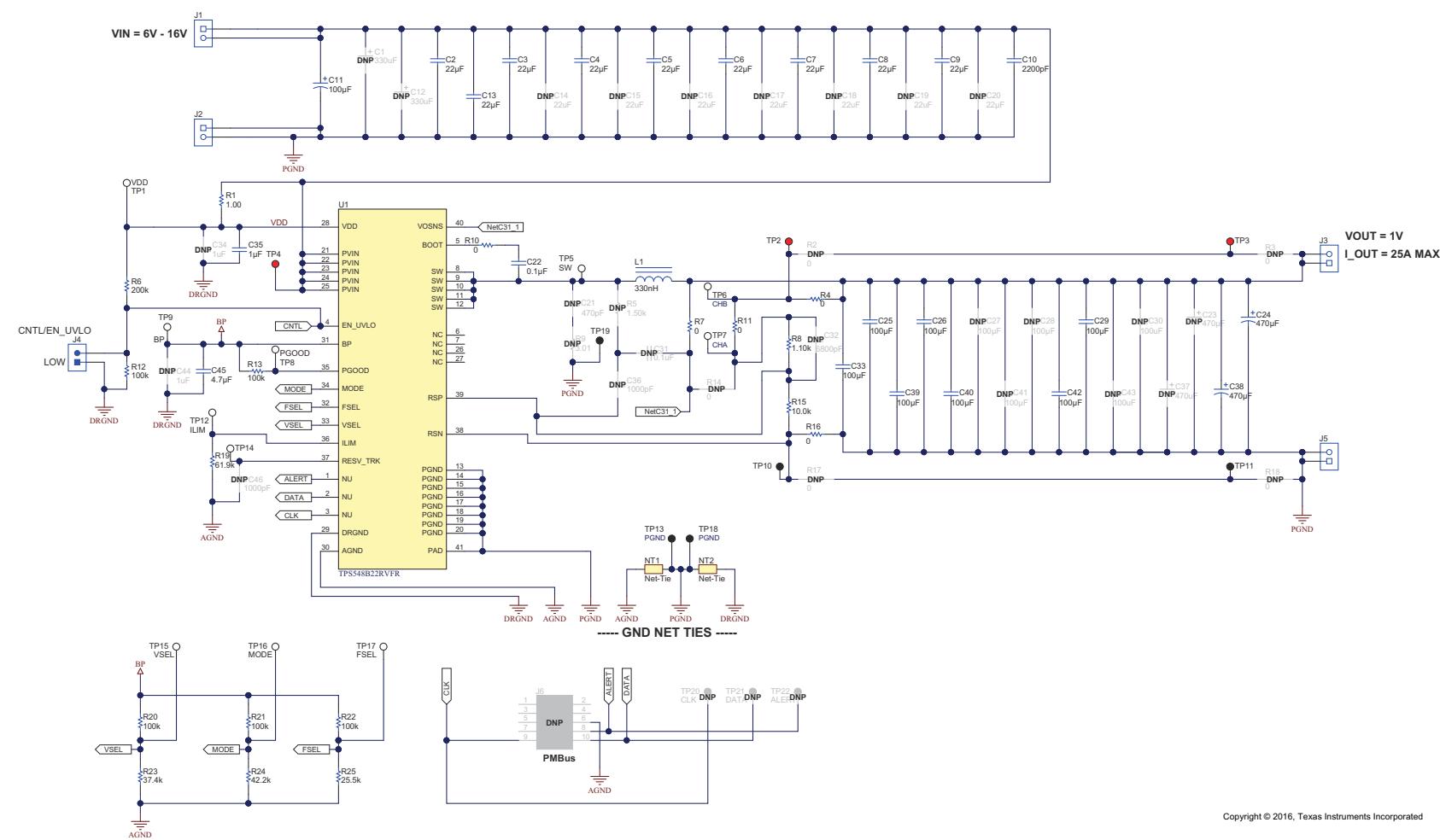


Figure 4-1. PWR-847EVM Schematic

5 Test Equipment

Voltage Source: The input voltage source V_{IN} must be a 0-V to 18-V variable DC source capable of supplying at least 12 A_{DC}. Also, the output impedance of the external voltage source must be much less than 100 kΩ.

Multimeters: It is recommended to use two separate multimeters [Figure 6-1](#). One meter is used to measure V_{IN} and one to measure V_{OUT} .

Output Load: A variable electronic load is recommended for testing [Figure 6-1](#). It must be capable of 25 A at voltages as low as 0.6 V.

Oscilloscope: An oscilloscope is recommended for measuring output noise and ripple. Output ripple must be measured using a tip-and-barrel method or better as shown in [Figure 6-2](#). The scope must be adjusted to 20-MHz bandwidth, AC coupling at 50 mV/division, and must be set to 1-μs/division.

Fan: During prolonged operation at high loads, it may be necessary to provide forced air cooling with a small fan aimed at the EVM. Temperature of the devices on the EVM must be maintained below 105°C.

Recommended Wire Gauge: The voltage drop in the load wires must be kept as low as possible in order to keep the working voltage at the load within its operating range. Use the AWG 14 wire (2 wires parallel for V_{OUT} positive and 2 wires parallel for the V_{OUT} negative) of no more than 1.98 feet between the EVM and the load. This recommended wire gauge and length should achieve a voltage drop of no more than 0.2 V at the maximum 25-A load.

6 PWR-847EVM

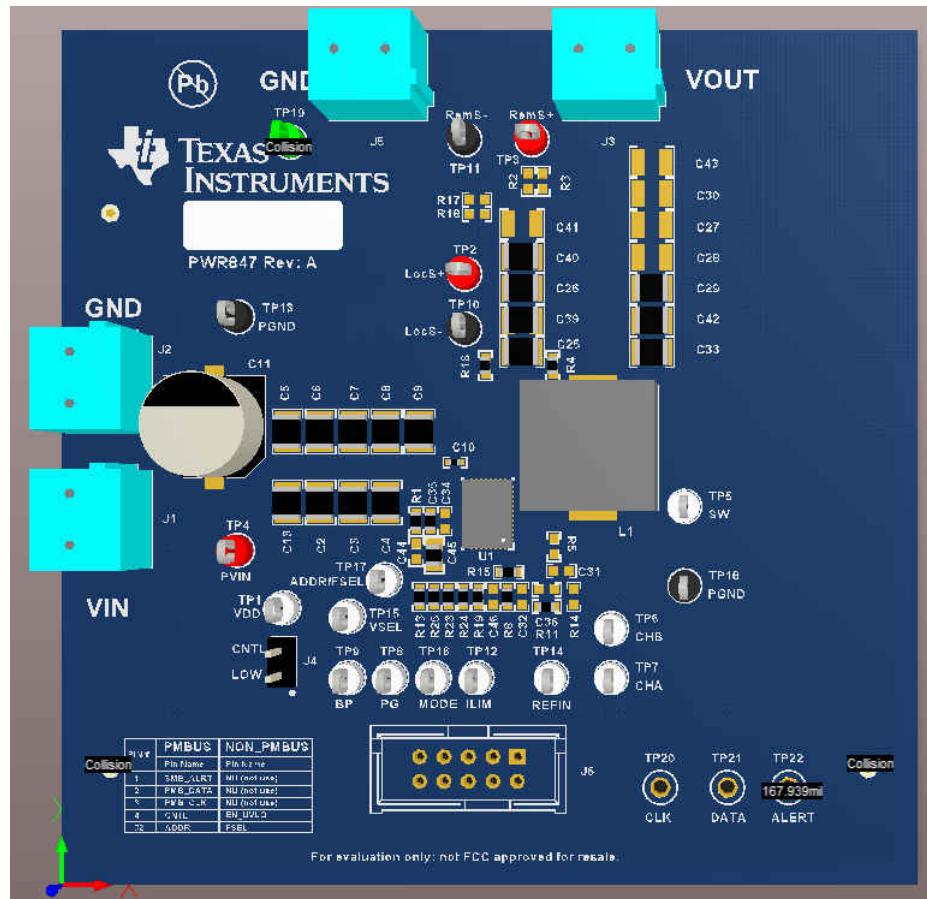


Figure 6-1. PWR-847EVM Overview

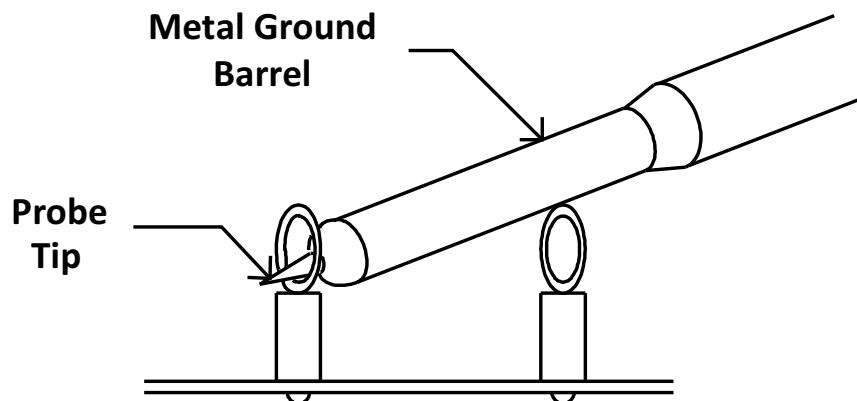


Figure 6-2. Tip and Barrel Measurement

7 List of Test Points, Jumpers, and Switch

Table 7-1. Test Point Functions

Item	Type	Name	Description
TP5	T-H loop	SW	Power supply Switch node
TP7	T-H loop	CH-A	Measure loop stability
TP6	T-H loop	CH-B	Measure loop stability
TP2	T-H loop	LocS+	Sense VOUT + locally across C5. Use for efficiency and ripple measurements
TP10	T-H loop	LocS-	Sense VOUT- locally across C5. Use for efficiency and ripple measurements
TP3	T-H loop	RemS+	Remote sense +
TP11	T-H loop	RemS-	Remote sense -
TP4	T-H loop	PVIN	Sense VIN + across C10
TP13	T-H loop	PGND	Sense VIN – across C10
TP1	T-H loop	VDD	Supplies the internal circuitry
TP17	T-H loop	FSEL	Monitor the FSEL external resistor divider ratio during initial power up.
TP15	T-H loop	VSEL	Monitor the VSEL external resistor divider ratio during initial power up.
TP9	T-H loop	BP	LDO output
TP8	T-H loop	PG	Power good
TP16	T-H loop	MODE	Monitor the MODE external resistor divider ratio during initial power up.
TP12	T-H loop	ILIM	Program over-current limit.
TP14	T-H loop	RESV_TRK	Do not connect.
TP19	T-H loop	PGND	Common GND
TP18	T-H loop	PGND	Common GND
TP20	T-H loop	CLK	Not used
TP21	T-H loop	DATA	Not used
TP22	T-H loop	ALERT	Not used
JP4	2-pin jumper	CNTL	Shunts control pin to GND

8 Test Procedure

8.1 Line and Load Regulation Measurement Procedure

1. Connect VOUT to J3 and VOUT_GND to J5 [Figure 6-1](#).
2. Ensure that the electronic load is set to draw 0 A_{DC}.
3. Ensure the jumper provided on the EVM shorts on J4 before V_{IN} is applied
4. Connect VIN to J1 and VIN_GND to J2 [Figure 6-1](#).
5. Increase V_{IN} from 0 V to 12 V using the digital multimeter to measure input voltage.
6. Remove the jumper on J4 to enable the controller.
7. Use the other digital multimeter or the oscilloscope to measure output voltage V_{OUT} at TP2 and TP10.

Table 8-1. List of Test Points for Line and Load Measurements

Test Point	Node Name	Description
TP2	LocS+	Sense VOUT + locally across C5. Use for efficiency and ripple measurements
TP10	LocS-	Sense VOUT - locally across C5. Use for efficiency and ripple measurements
TP4	PVIN	Sense VIN + across C10
TP13	PGND	Sense VIN - across C10

8. Vary the load from 0 A_{DC} to maximum rated output 25 A_{DC}. V_{OUT} must remain in regulation as defined in [Table 3-1](#).
9. Vary V_{IN} from 5 V to 14 V. V_{OUT} must remain in regulation as defined in [Table 3-1](#).
10. Decrease the load to 0 A.
11. Put the jumper back on J4 to disable the converter.
12. Decrease V_{IN} to 0 V or turn off the supply.

8.2 Efficiency

To measure the efficiency of the power train on the EVM, it is important to measure the voltages at the correct location. This is necessary because otherwise the measurements will include losses in efficiency that are not related to the power train itself. 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, and they must not be included in efficiency measurements.

Table 8-2. List of Test Points for Efficiency Measurements

Test Point	Node Name	Description
TP2	LocS+	Sense VOUT + locally across C25. Use for efficiency and ripple measurements
TP10	LocS-	Sense VOUT - locally across C25. Use for efficiency and ripple measurements
TP4	PVIN	Sense VIN + across C10
TP13	PGND	Sense VIN - across C10

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. Using these measurement points result in efficiency measurements that do not include losses due to the connectors and PCB traces.

8.3 Equipment Shutdown

1. Reduce the load current to 0 A.
2. Reduce input voltage to 0 V.
3. Shut down the external fan if in use.
4. Shut down equipment.

9 Performance Data and Typical Characteristic Curves

Figure 9-1 through Figure 9-10 present typical performance curves for the PWR-847EVM.

9.1 Efficiency

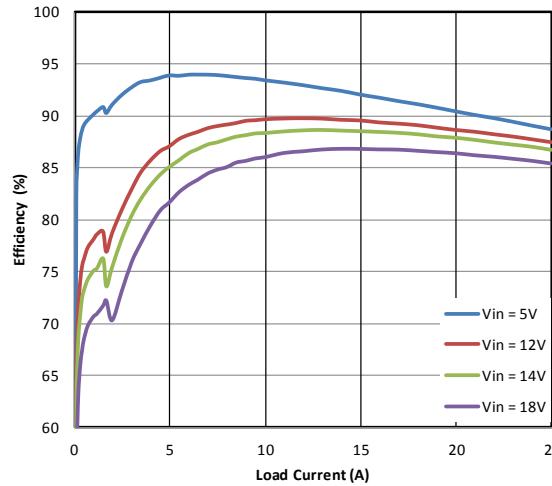


Figure 9-1. Efficiency of 1-V Output vs Load

9.2 Power Loss

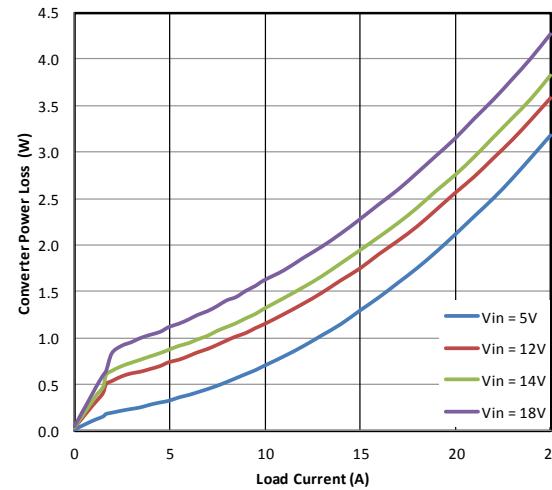


Figure 9-2. Power Loss of 1-V Output vs Load

9.3 Load Regulation

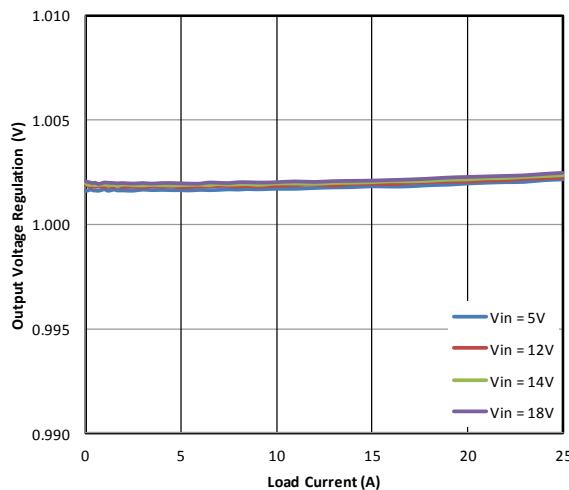


Figure 9-3. Load Regulation of 1-V Output

9.4 Transient Response



Figure 9-4. Transient Response of 1-V Output at 12 V_{IN}, Transient is 0.5 A to 15.5 A, the Step is 15 A at 40 A/µs

9.5 Output Ripple

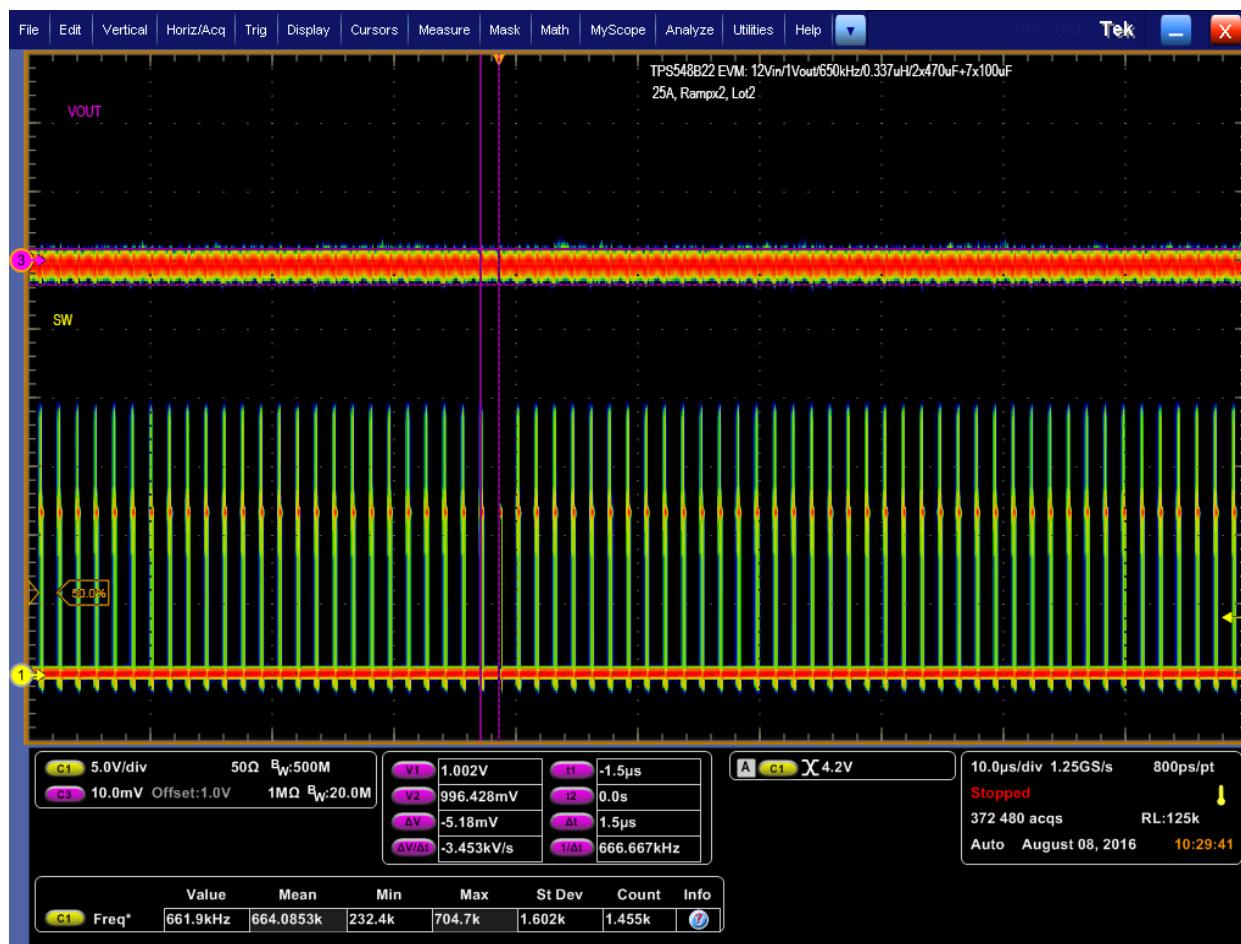


Figure 9-5. Output Ripple and SW Node of 1-V Output at 12 V_{IN}, 25-A Output

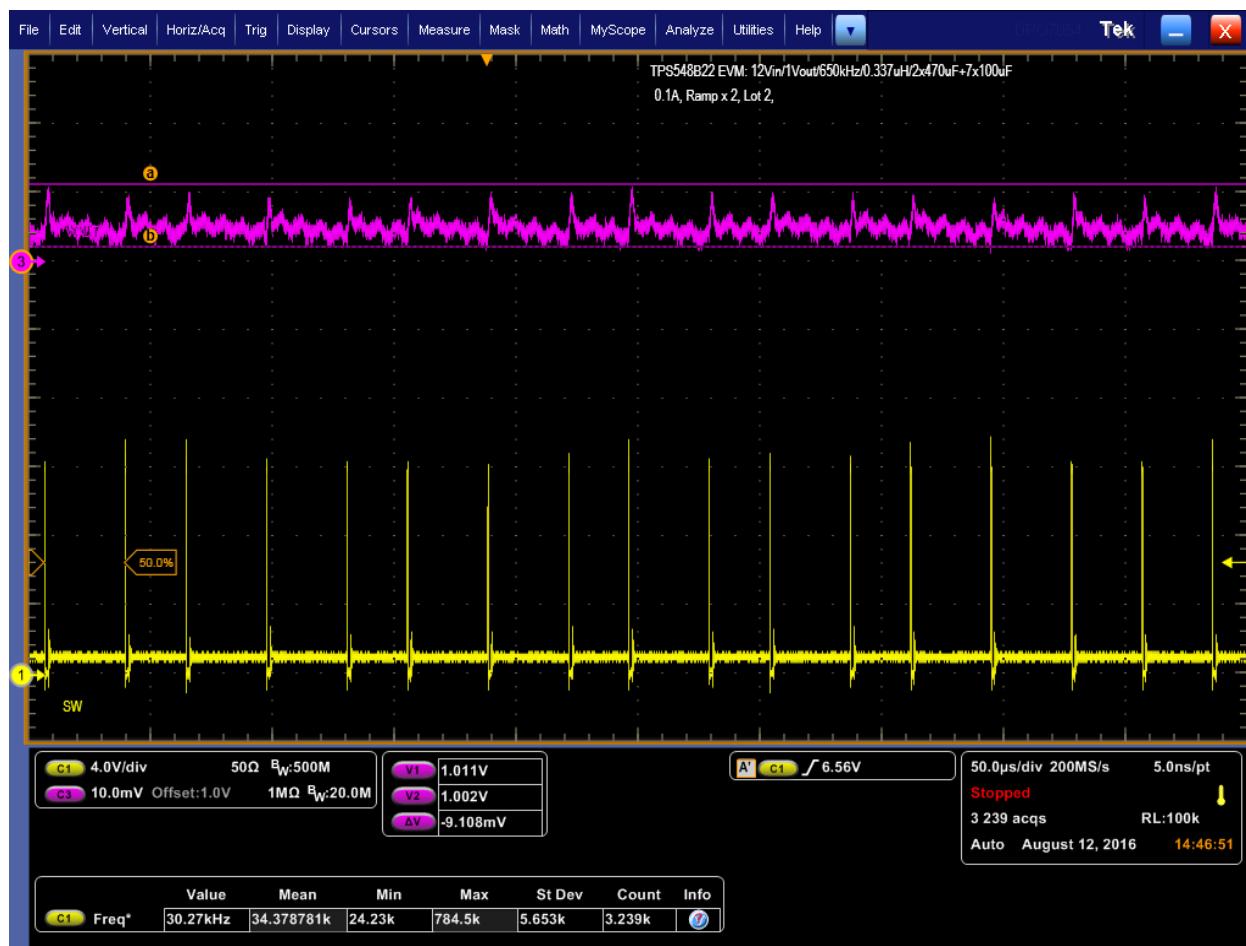


Figure 9-6. Output Ripple and SW Node of 1-V Output at 12 V_{IN}, 0-A Output

9.6 Control On

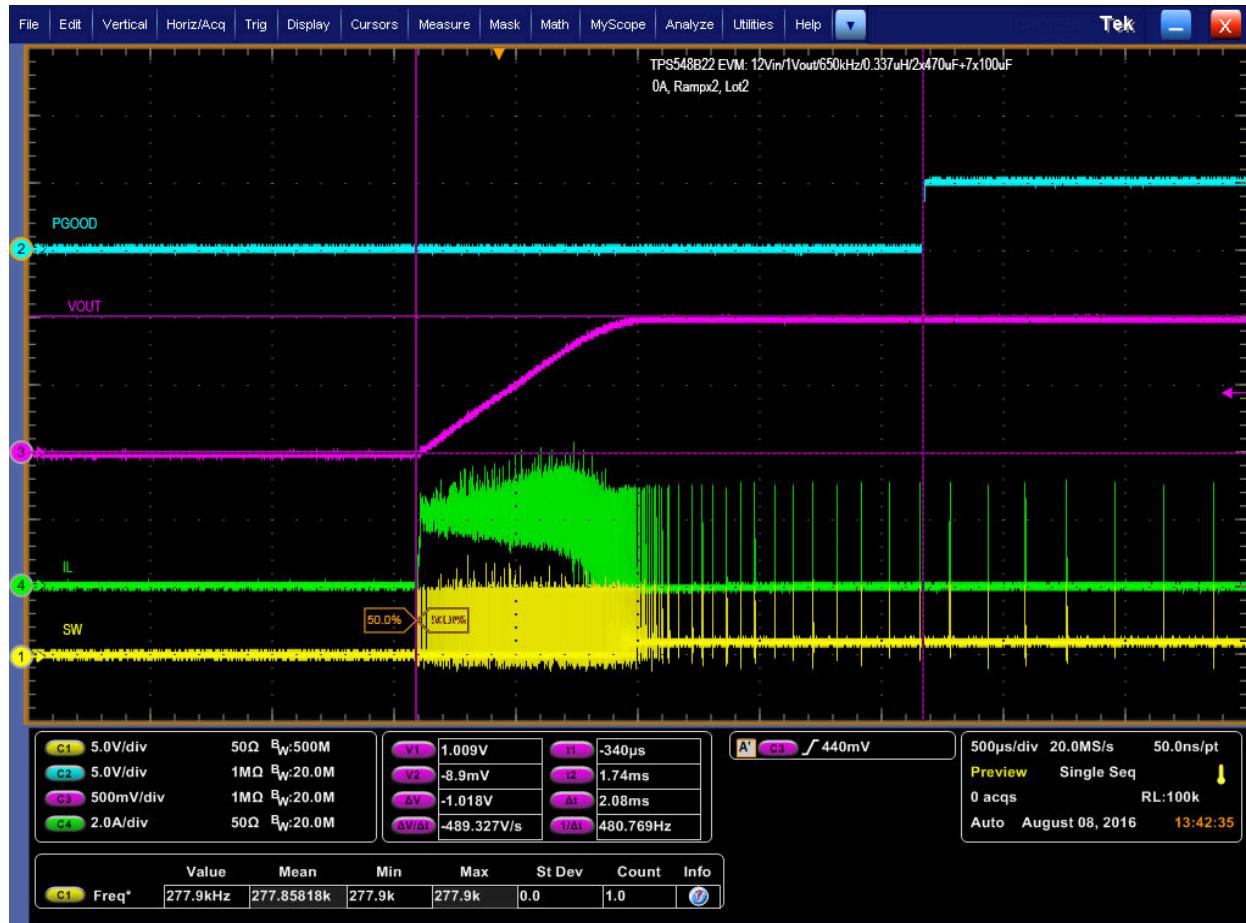


Figure 9-7. Start up from Control, 1-V Output at 12 V_{IN}, 0-A Output

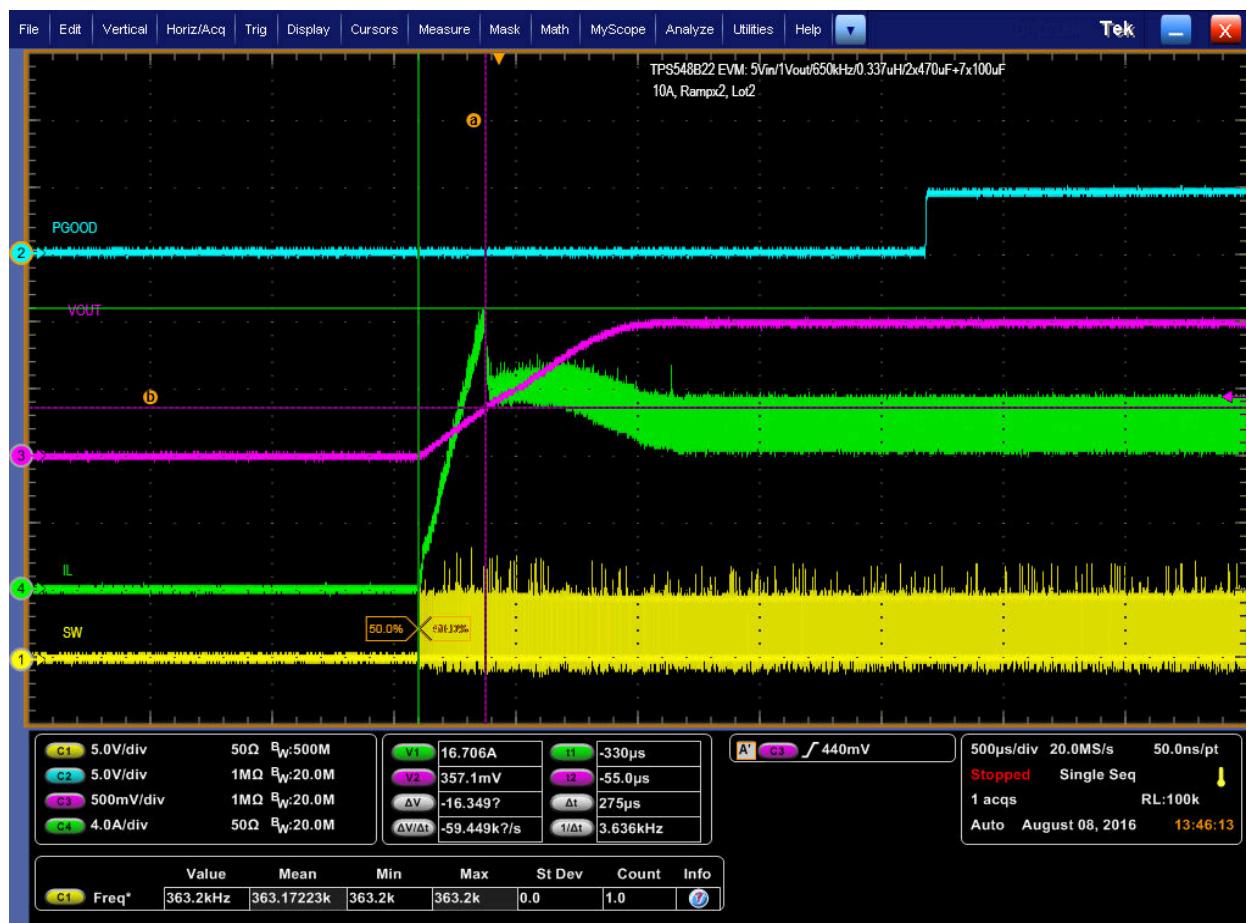


Figure 9-8. 0.5-V Pre-bias start up from Control, 1-V Output at 12 V_{IN}, 10-A Output

9.7 Control On and Off

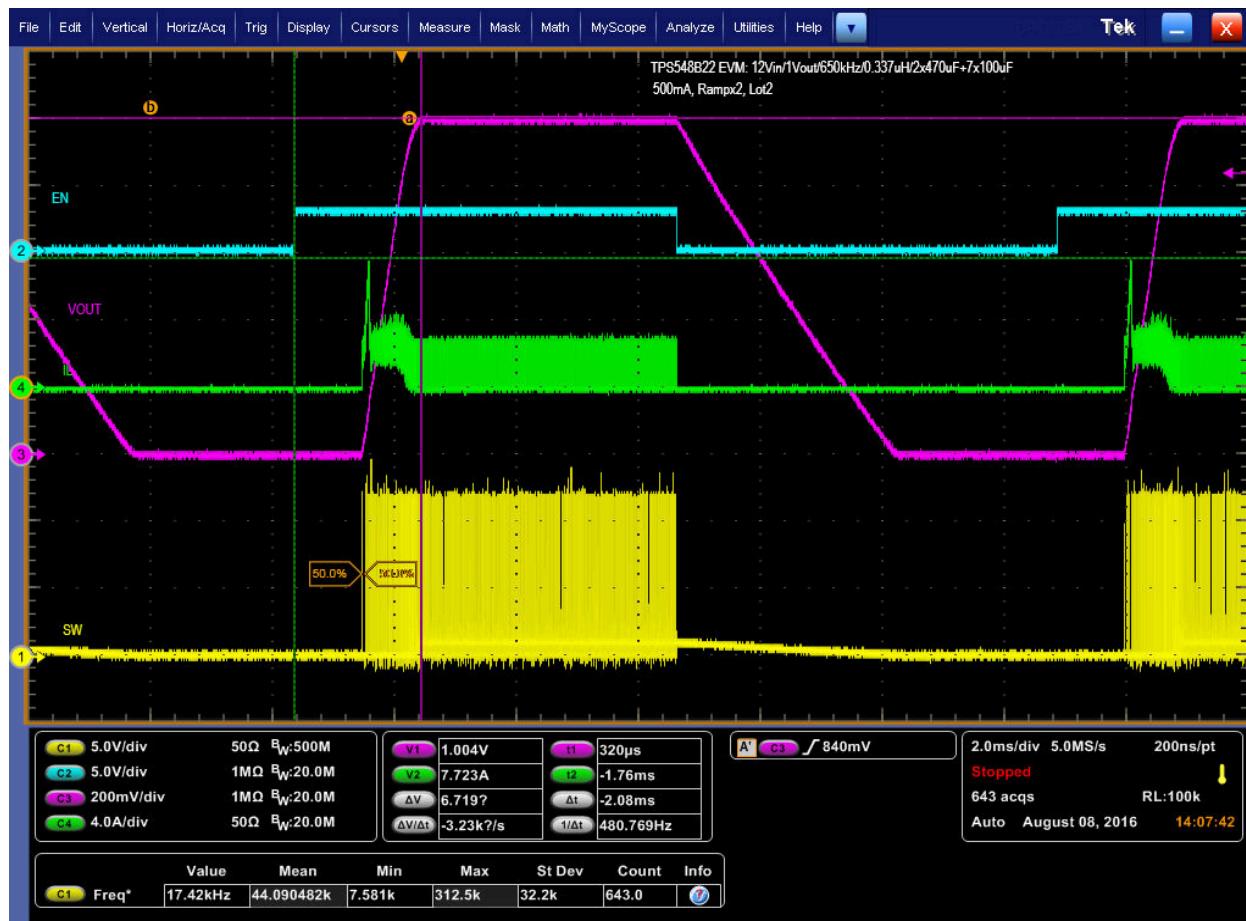


Figure 9-9. Output Voltage Start-up and Shutdown, 1-V Output at 1 2V_{IN}, 0.5-A Output

9.8 Thermal Image

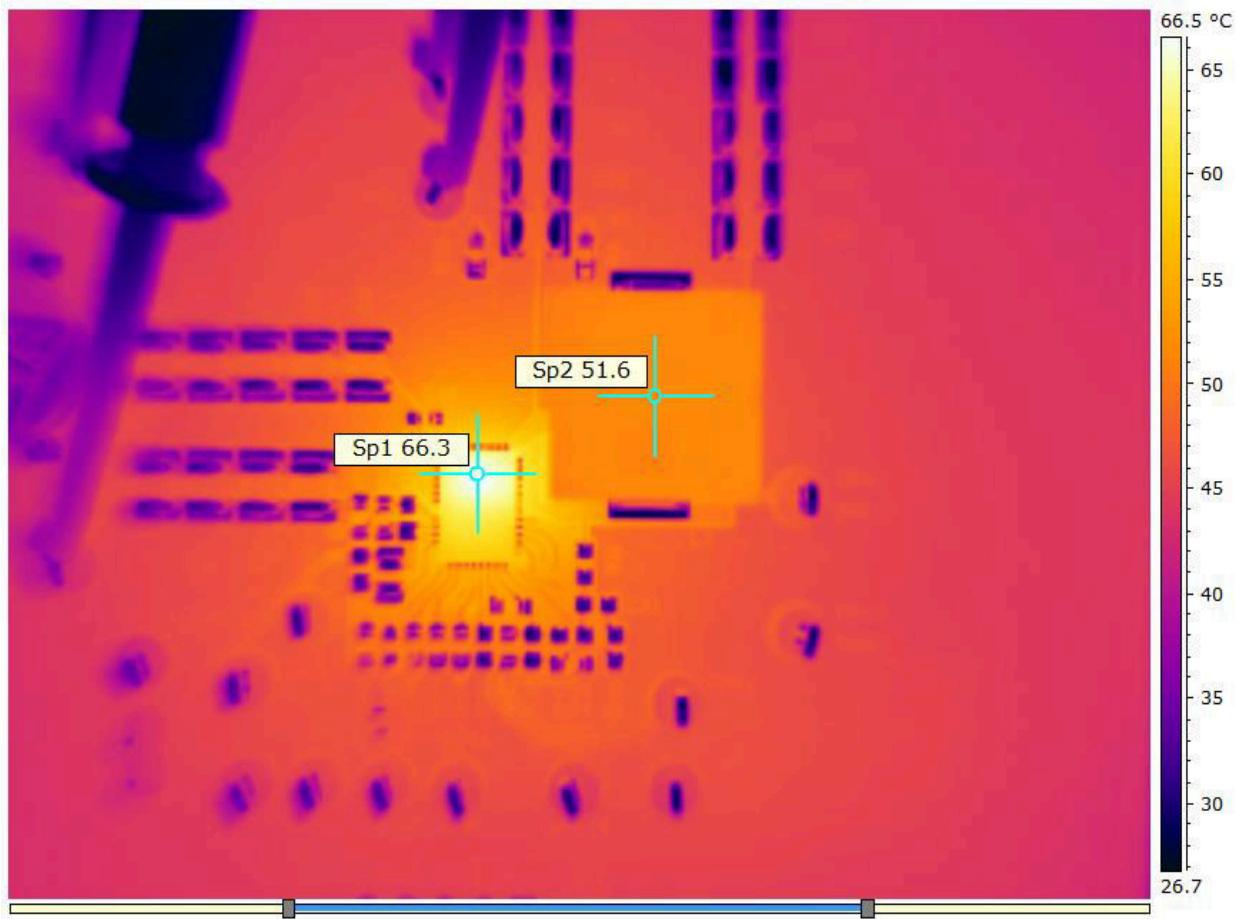


Figure 9-10. Thermal Image at 1-V Output at 12 V_{IN}, 25-A Output, at 25°C Ambient

10 EVM Assembly Drawing and PCB Layout

Figure 10-1 through Figure 10-8 show the design of the PWR-847EVM printed-circuit board (PCB). The PWR-847EVM has a 2-oz. copper finish for all layers.

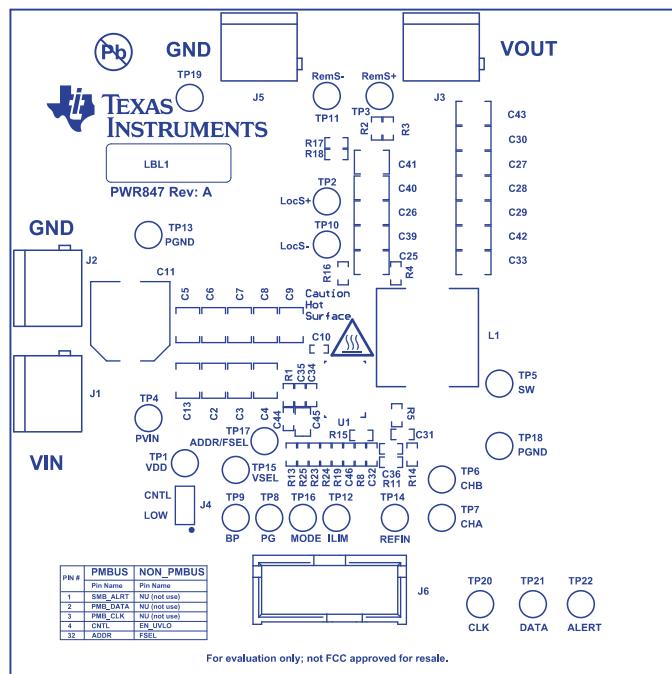


Figure 10-1. PWR-847EVM Top Layer Assembly Drawing (Top View)

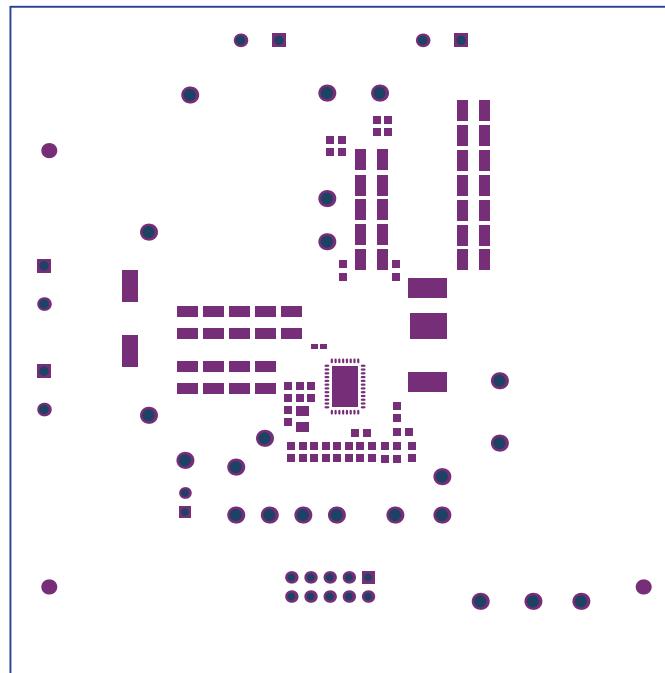


Figure 10-2. PWR-847EVM Top Solder Mask (Top View)

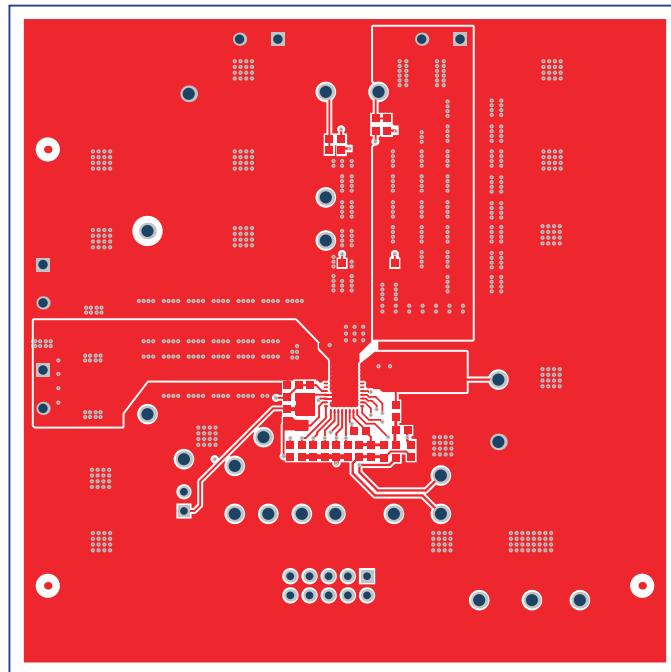


Figure 10-3. PWR-847EVM Top Layer (Top View)

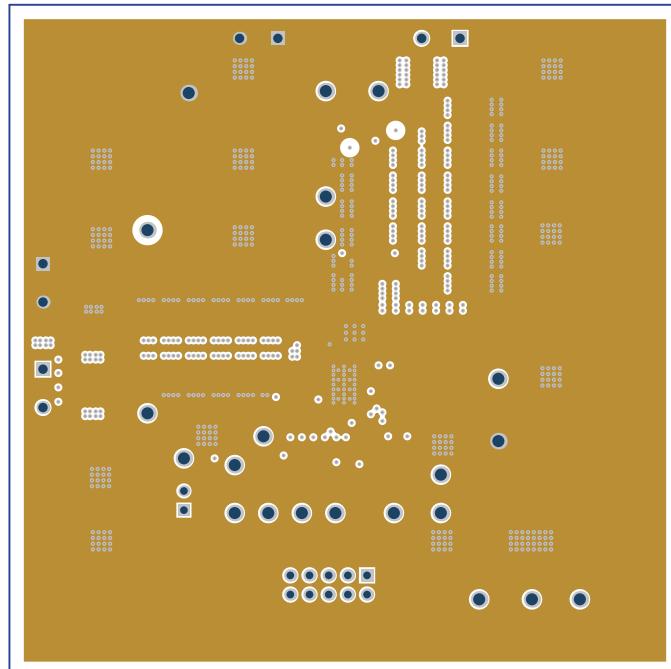


Figure 10-4. PWR-847EVM Inner Layer 1 (Top View)

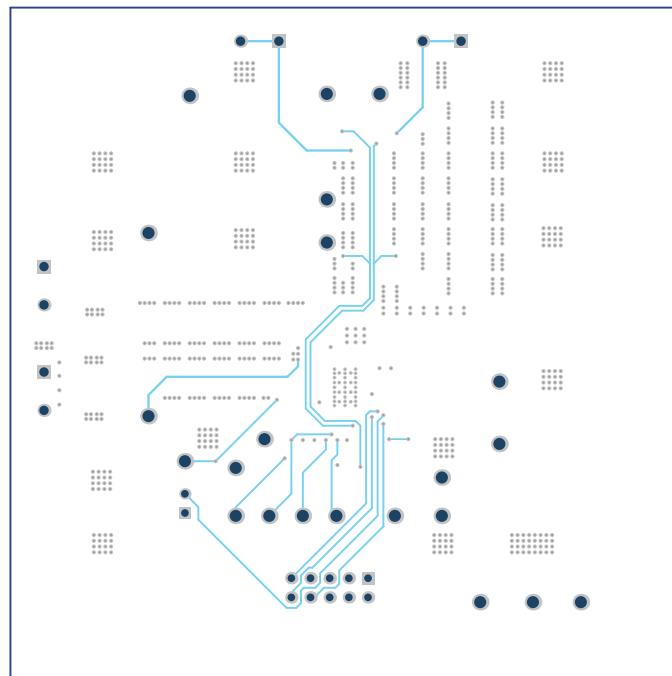


Figure 10-5. PWR-847EVM Inner Layer 2 (Top View)

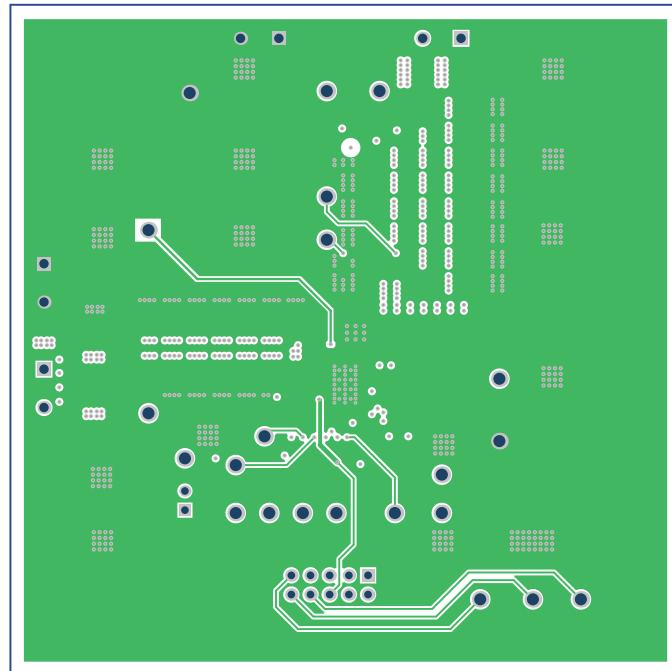


Figure 10-6. PWR-847EVM Inner Layer 3 (Top View)

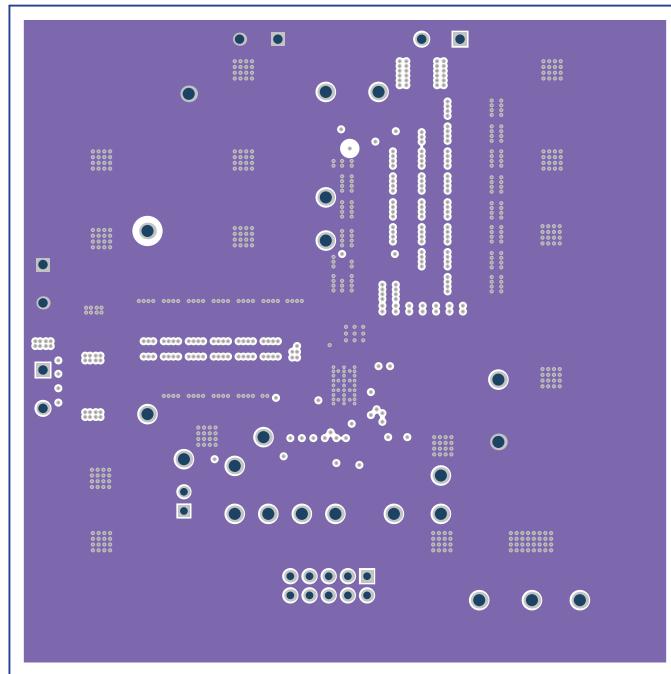


Figure 10-7. PWR-847EVM Inner Layer 4 (Top View)

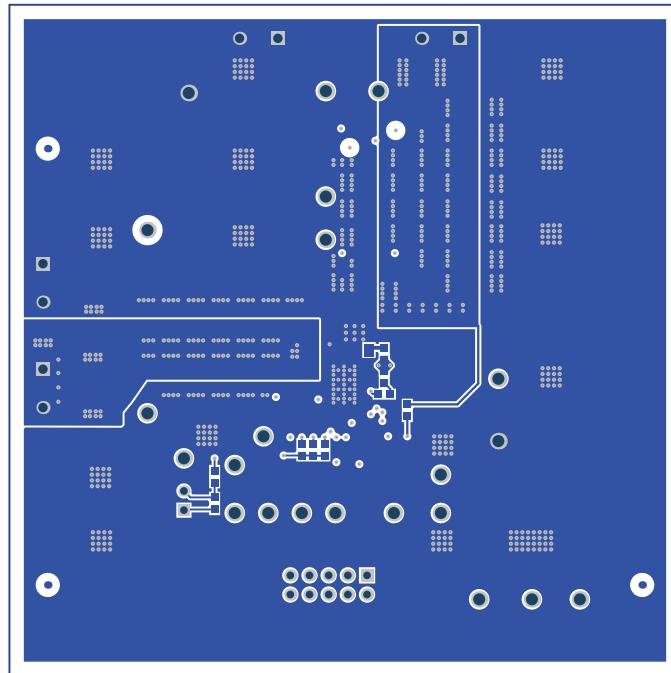


Figure 10-8. PWR-847EVM Bottom Layer (Top View)

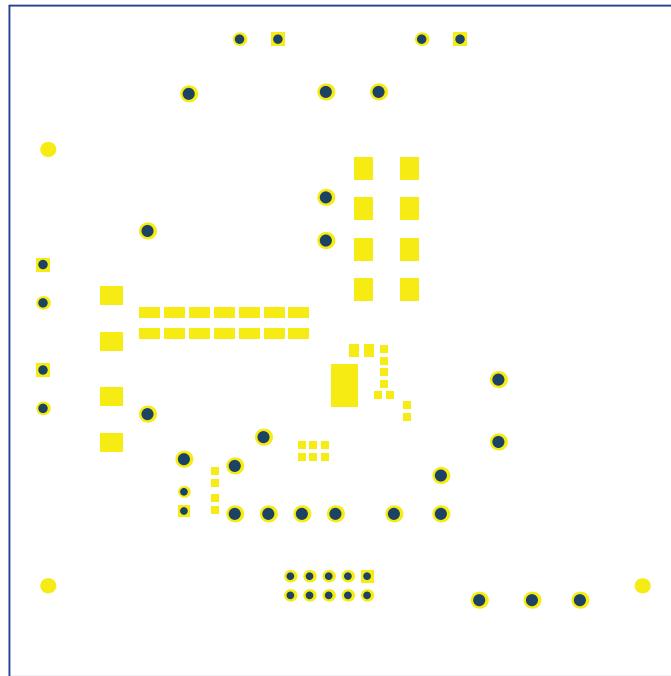


Figure 10-9. PWR-847EVM Bottom Solder Mask (Top View)

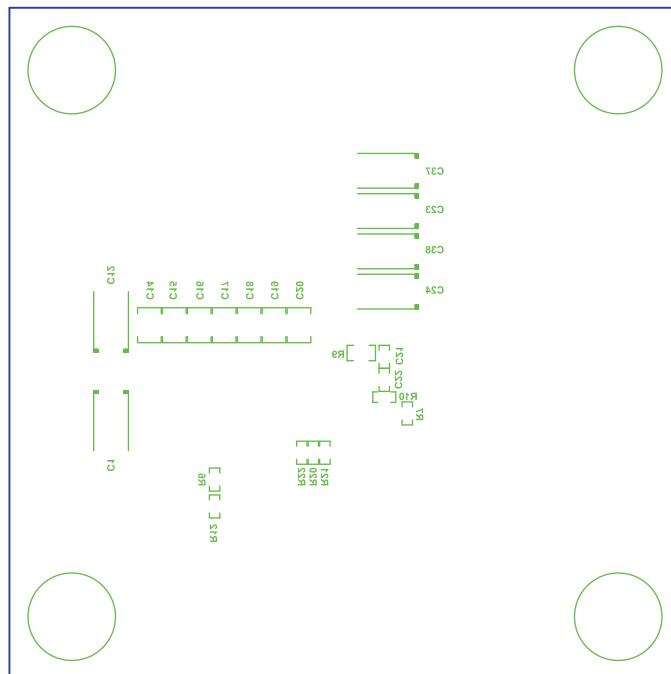


Figure 10-10. PWR-847EVM Bottom Overlay Layer (Top View)

11 List of Materials

The EVM components list, according to the schematic, is shown in [Table 11-1](#).

Table 11-1. PWR847 List of Materials

Item#	Designator	Qty	Value	Part Number	Manufacturer	Description	Package Reference
2	C2, C3, C4, C5, C6, C7, C8, C9, C13	9	22uF	GRM32ER71E226KE15L	MuRata	CAP, CERM, 22 μ F, 25 V, +/- 10%, X7R, 1210	1210
3	C10	1	2200pF	GRM155R61E222KA01D	MuRata	CAP, CERM, 2200 pF, 25 V, +/- 10%, X5R, 0402	0402
4	C11	1	100uF	EEE-FC1V101P	Panasonic	CAP, AL, 100uF, 35V, +/-20%, 0.15 ohm, SMD	SMT Radial G
5	C22	1	0.1uF	GRM188R71H104KA93D	MuRata	CAP, CERM, 0.1 μ F, 50 V, +/- 10%, X7R, 0603	0603
6	C24, C38	2	470uF	2R5TPF470M6L	Panasonic	CAP, Tantalum Polymer, 470 μ F, 2.5 V, +/- 20%, 0.006 ohm, 7.3x2.8x4.3mm SMD	7.3x2.8x4.3mm
7	C25, C26, C29, C33, C39, C40, C42	7	100uF	GRM32ER60J107ME20L	MuRata	CAP, CERM, 100 μ F, 6.3 V, +/- 20%, X5R, 1210	1210
8	C35	1	1uF	C0603C105K4PACTU	Kemet	CAP, CERM, 1 μ F, 16 V, +/- 10%, X5R, 0603	0603
9	C45	1	4.7uF	GRM21BR71C475KA73L	MuRata	CAP, CERM, 4.7 μ F, 16 V, +/- 10%, X7R, 0805	0805
10	H9, H10, H11, H12	4		SJ-5303 (CLEAR)	3M	Bumpon, Hemisphere, 0.44 X 0.20, Clear	Transparent Bumpon
11	J1, J2, J3, J5	4		ED120/2DS	On-Shore Technology	TERMINAL BLOCK 5.08MM VERT 2POS, TH	TERM_BLK, 2pos, 5.08mm
12	J4	1		PEC02SAAN	Sullins Connector Solutions	Header, 100mil, 2x1, Tin, TH	Header, 2 PIN, 100mil, Tin
13	L1	1	330nH	744309033	Wurth Elektronik	Inductor, Shielded Drum Core, Ferrite, 330 nH, 50 A, 0.000165 ohm, SMD	12.5x13mm
14	LBL1	1		THT-14-423-10	Brady	Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650" W x 0.200" H
15	R1	1	1.00	RC0603FR-071RL	Yageo America	RES, 1.00, 1%, 0.1 W, 0603	0603
16	R4, R7, R10, R11, R16	5	0	CRCW06030000Z0EA	Vishay-Dale	RES, 0, 5%, 0.1 W, 0603	0603
17	R6	1	200k	CRCW0603200KFKEA	Vishay-Dale	RES, 200 k, 1%, 0.1 W, 0603	0603
18	R8	1	1.10k	CRCW06031K10FKEA	Vishay-Dale	RES, 1.10 k, 1%, 0.1 W, 0603	0603
19	R12, R13, R20, R21, R22	5	100k	CRCW0603100KFKEA	Vishay-Dale	RES, 100 k, 1%, 0.1 W, 0603	0603
20	R15	1	10.0k	CRCW060310K0FKEA	Vishay-Dale	RES, 10.0k ohm, 1%, 0.1W, 0603	0603
21	R19	1	61.9k	CRCW060361K9FKEA	Vishay-Dale	RES, 61.9 k, 1%, 0.1 W, 0603	0603
22	R23	1	37.4k	CRCW060337K4FKEA	Vishay-Dale	RES, 37.4 k, 1%, 0.1 W, 0603	0603
23	R24	1	42.2k	CRCW060342K2FKEA	Vishay-Dale	RES, 42.2 k, 1%, 0.1 W, 0603	0603
24	R25	1	25.5k	CRCW060325K5FKEA	Vishay-Dale	RES, 25.5 k, 1%, 0.1 W, 0603	0603
25	TP1, TP5, TP6, TP7, TP8, TP9, TP12, TP14, TP15, TP16, TP17	11	White	5012	Keystone	Test Point, Multipurpose, White, TH	White Multipurpose Testpoint
26	TP2, TP3, TP4	3	Red	5010	Keystone	Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint
27	TP10, TP11, TP13, TP18, TP19	5	Black	5011	Keystone	Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint
28	U1	1		TPS548B22RVFR	Texas Instruments	1.5-V to 16-V VIN, 4.5-V to 22-V VDD, 25-A SWIFT Synchronous Step-Down Converter with Full Differential Sense, RVF0040A (LQFN-CLIP-40)	RVF0040A
29	C1, C12	0	330uF	6TP330ML	Sanyo	CAP, TA, 330 μ F, 6.3 V, +/- 20%, 0.025 ohm, SMD	7.3x2.8x4.3mm
30	C14, C15, C16, C17, C18, C19, C20	0	22uF	GRM32ER71E226KE15L	MuRata	CAP, CERM, 22 μ F, 25 V, +/- 10%, X7R, 1210	1210
31	C21	0	470pF	GRM188R71H471KA01D	MuRata	CAP, CERM, 470 pF, 50 V, +/- 10%, X7R, 0603	0603

Table 11-1. PWR847 List of Materials (continued)

Item#	Designator	Qty	Value	Part Number	Manufacturer	Description	Package Reference
32	C23, C37	0	470uF	2R5TPF470M6L	Panasonic	CAP, Tantalum Polymer, 470 μ F, 2.5 V, +/- 20%, 0.006 ohm, 7.3x2.8x4.3mm SMD	7.3x2.8x4.3mm
33	C27, C28, C30, C41, C43	0	100uF	GRM32ER60J107ME20L	MuRata	CAP, CERM, 100 μ F, 6.3 V, +/- 20%, X5R, 1210	1210
34	C31	0	0.1uF	GRM188R71H104KA93D	MuRata	CAP, CERM, 0.1 μ F, 50 V, +/- 10%, X7R, 0603	0603
35	C32	0	6800pF	GRM188R71H682KA01D	MuRata	CAP, CERM, 6800 pF, 50 V, +/- 10%, X7R, 0603	0603
36	C34, C44	0	1uF	C0603C105K4PACTU	Kemet	CAP, CERM, 1 μ F, 16 V, +/- 10%, X5R, 0603	0603
37	C36	0	1000pF	GRM188R71E102KA01D	MuRata	CAP, CERM, 1000 pF, 25 V, +/- 10%, X7R, 0603	0603
38	C46	0	1000pF	C0603C102J5GACTU	Kemet	CAP, CERM, 1000 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603
39	FID1, FID2, FID3, FID4, FID5, FID6	0		N/A	N/A	Fiducial mark. There is nothing to buy or mount.	Fiducial
40	J6	0		5103308-1	TE Connectivity	Header (shrouded), 100mil, 5x2, Gold, TH	5x2 Shrouded header
41	R2, R3, R14, R17, R18	0	0	CRCW06030000Z0EA	Vishay-Dale	RES, 0, 5%, 0.1 W, 0603	0603
42	R5	0	1.50k	RC0603FR-071K5L	Yageo America	RES, 1.50 k, 1%, 0.1 W, 0603	0603
43	R9	0	3.01	CRCW08053R01FKEA	Vishay-Dale	RES, 3.01 ohm, 1%, 0.125W, 0805	0805
44	TP20, TP21, TP22	0	White	5012	Keystone	Test Point, Multipurpose, White, TH	White Multipurpose Testpoint

12 Revision History

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

Changes from Revision * (November 2016) to Revision A (August 2021)	Page
• Updated user's guide title.....	3
• Updated the numbering format for tables, figures, and cross-references throughout the document.	3

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 isotope 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。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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

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

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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3.4 European Union

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

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

4 *EVM Use Restrictions and Warnings:*

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

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

4.3 *Safety-Related Warnings and Restrictions:*

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

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

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

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

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