User's Guide
SLUUBI9–November 2016

# TPS548B22EVM-847, 25-A Single Synchronous Step-Down Converter

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.


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# 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 1. PWR-847EVM Electrical Performance Specifications**

| Parameter | | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **Input Characteristics** | | | | | | |
| | Voltage range | $V_{IN}$ tied to VDD | 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 | ºC |



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# 4 Schematic

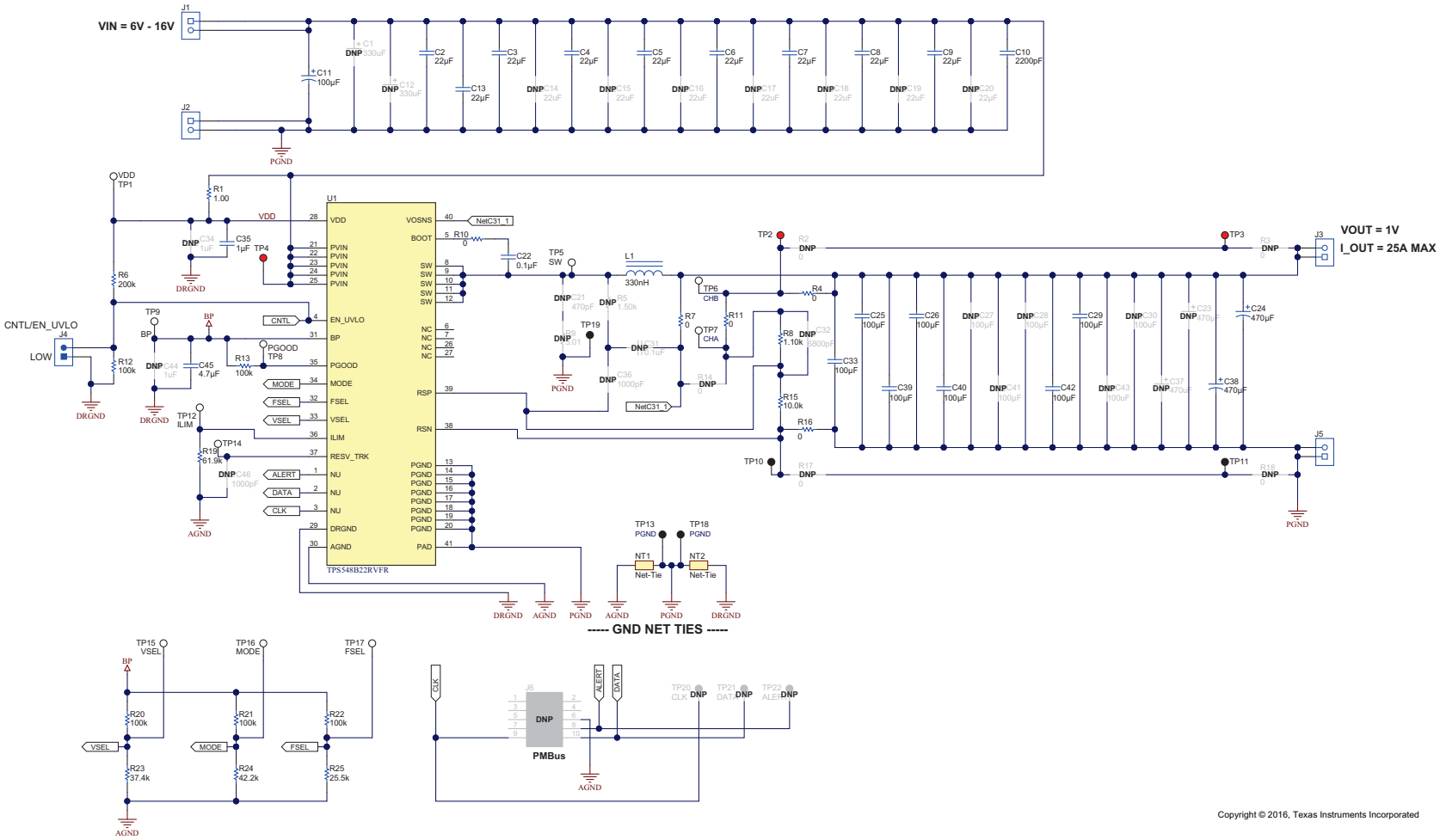



**Figure 1. PWR-847EVM Schematic**



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## 5 Test Equipment

**Voltage Source:** The input voltage source VIN 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 2. 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 2. 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 3.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 VOUT positive and 2 wires parallel for the VOUT 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.


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## 6 PWR-847EVM

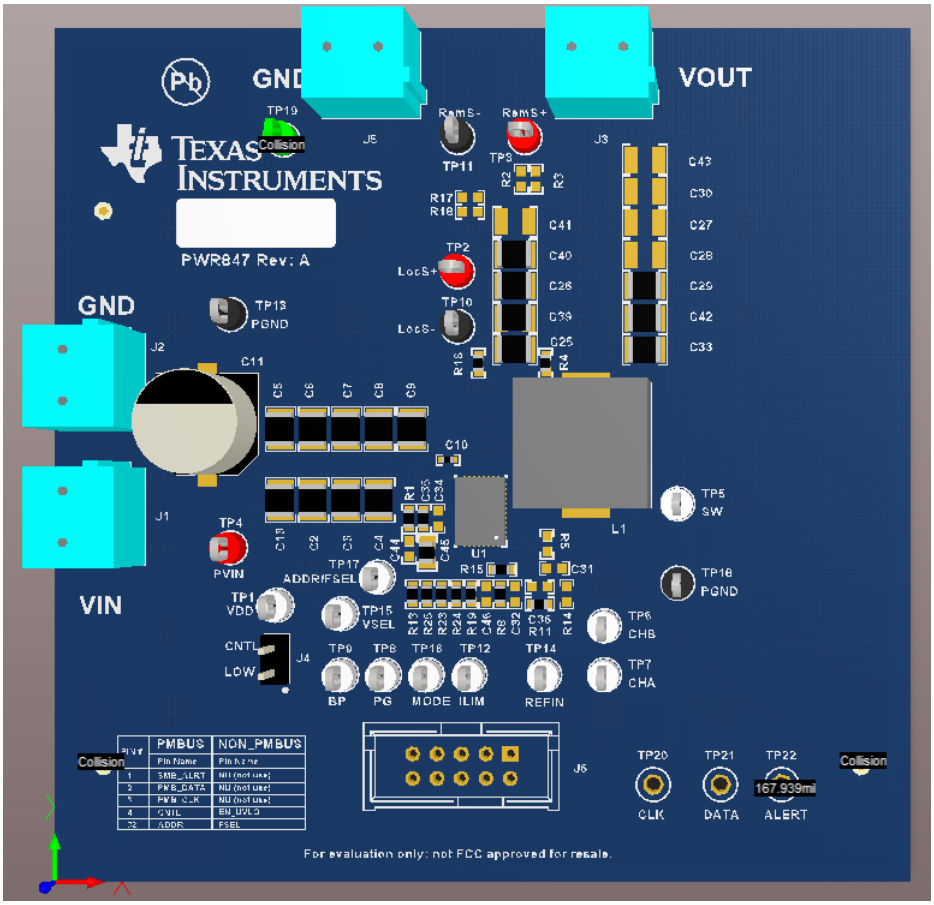



**Figure 2. PWR-847EVM Overview**

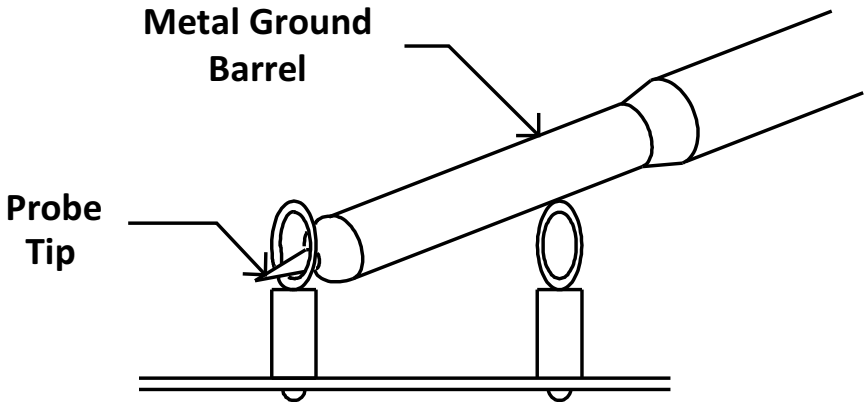



**Figure 3. Tip and Barrel Measurement**


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# 7 List of Test Points, Jumpers, and Switch

**Table 2. 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 |


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# 8 Test Procedure

## 8.1 Line and Load Regulation Measurement Procedure

1. Connect VOUT to J3 and VOUT_GND to J5 Figure 2.
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 2.
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 3. 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 1.
9. Vary $V_{IN}$ from 5 V to 14 V. $V_{OUT}$ must remain in regulation as defined in Table 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 4. 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.


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### 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 4 through Figure 13 present typical performance curves for the PWR-847EVM.

### 9.1 Efficiency

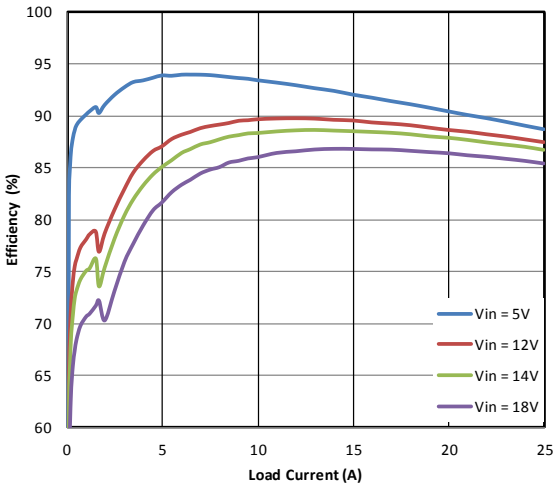



**Figure 4. Efficiency of 1-V Output vs Load**

### 9.2 Power Loss

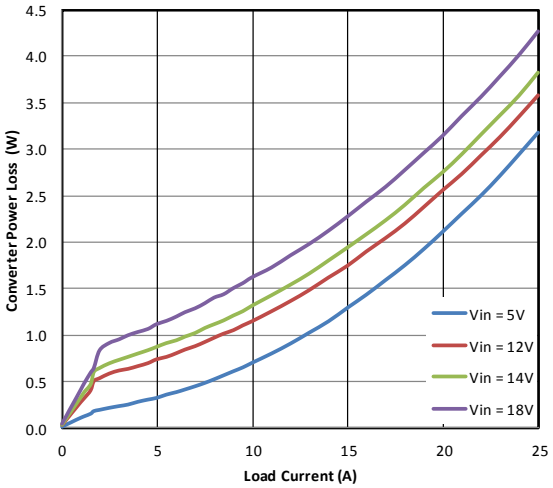



**Figure 5. Power Loss of 1-V Output vs Load**



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## 9.3 Load Regulation

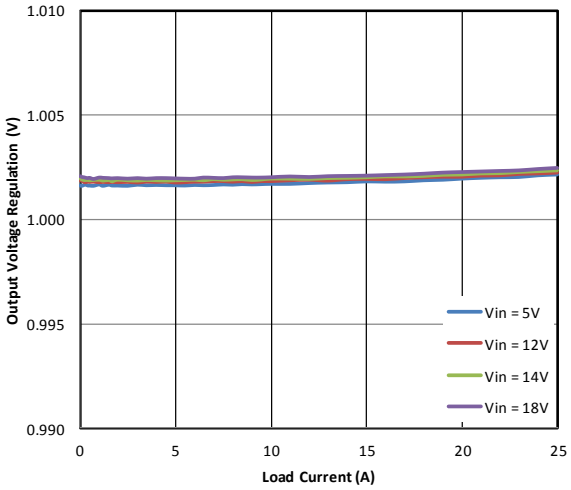



**Figure 6. Load Regulation of 1-V Output**

## 9.4 Transient Response




**Figure 7. 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**


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## 9.5 Output Ripple

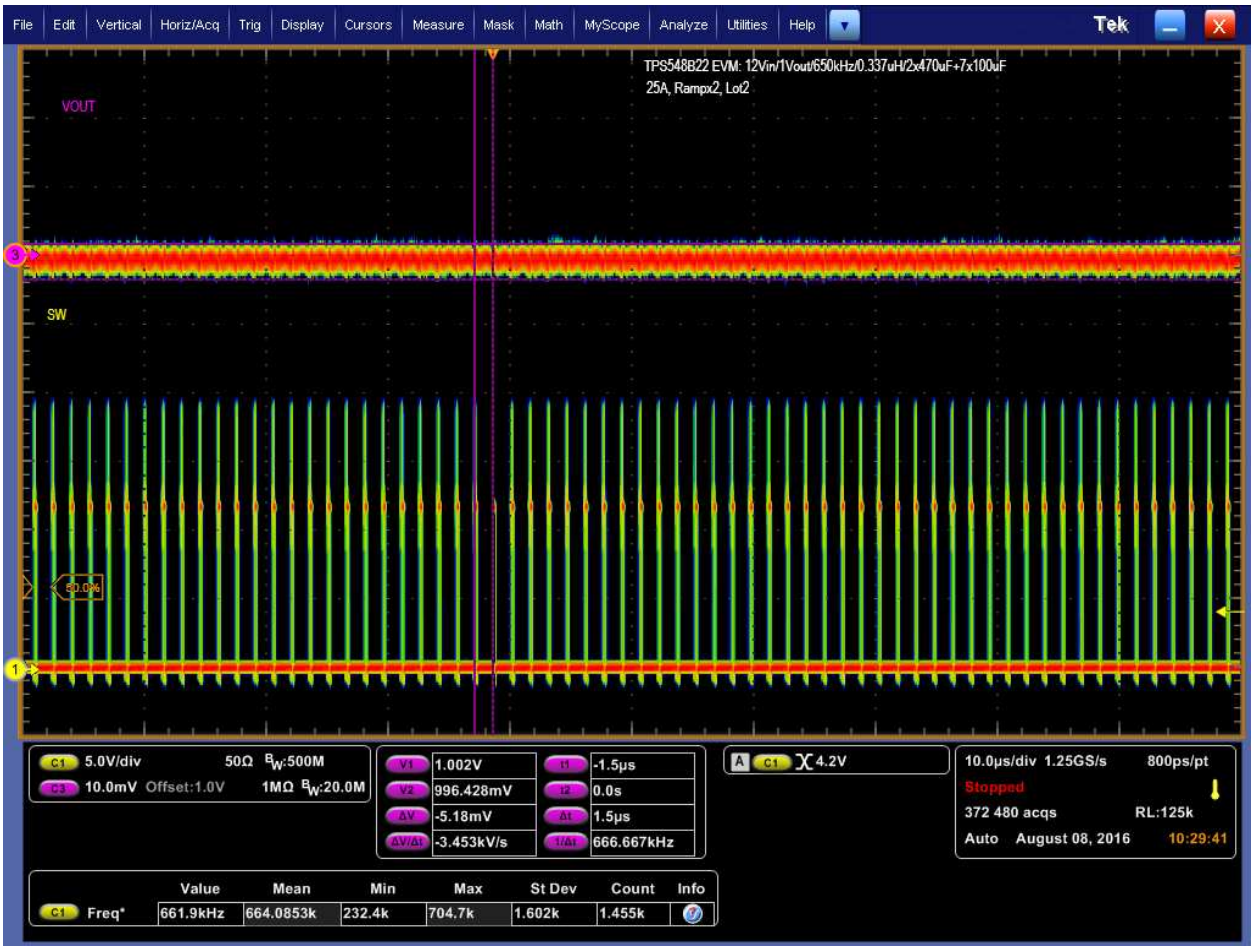



**Figure 8. Output Ripple and SW Node of 1-V Output at 12 $V_{IN}$, 25-A Output**



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


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## 9.6 Control On




**Figure 10. Start up from Control, 1-V Output at 12 $V_{IN}$, 0-A Output**



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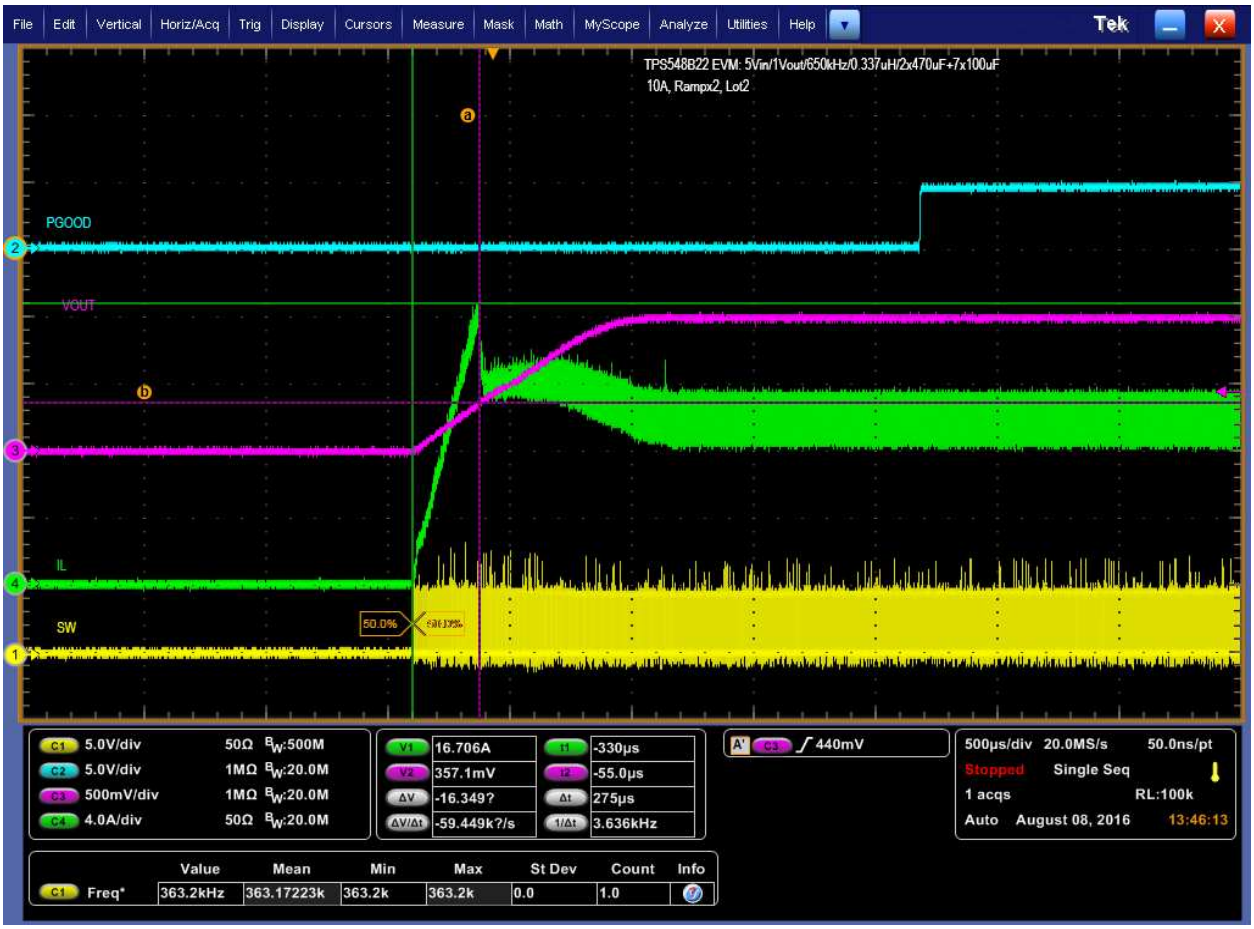



**Figure 11. 0.5-V Pre-bias start up from Control, 1-V Output at 12 $V_{IN}$, 10-A Output**


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## 9.7 Control On and Off

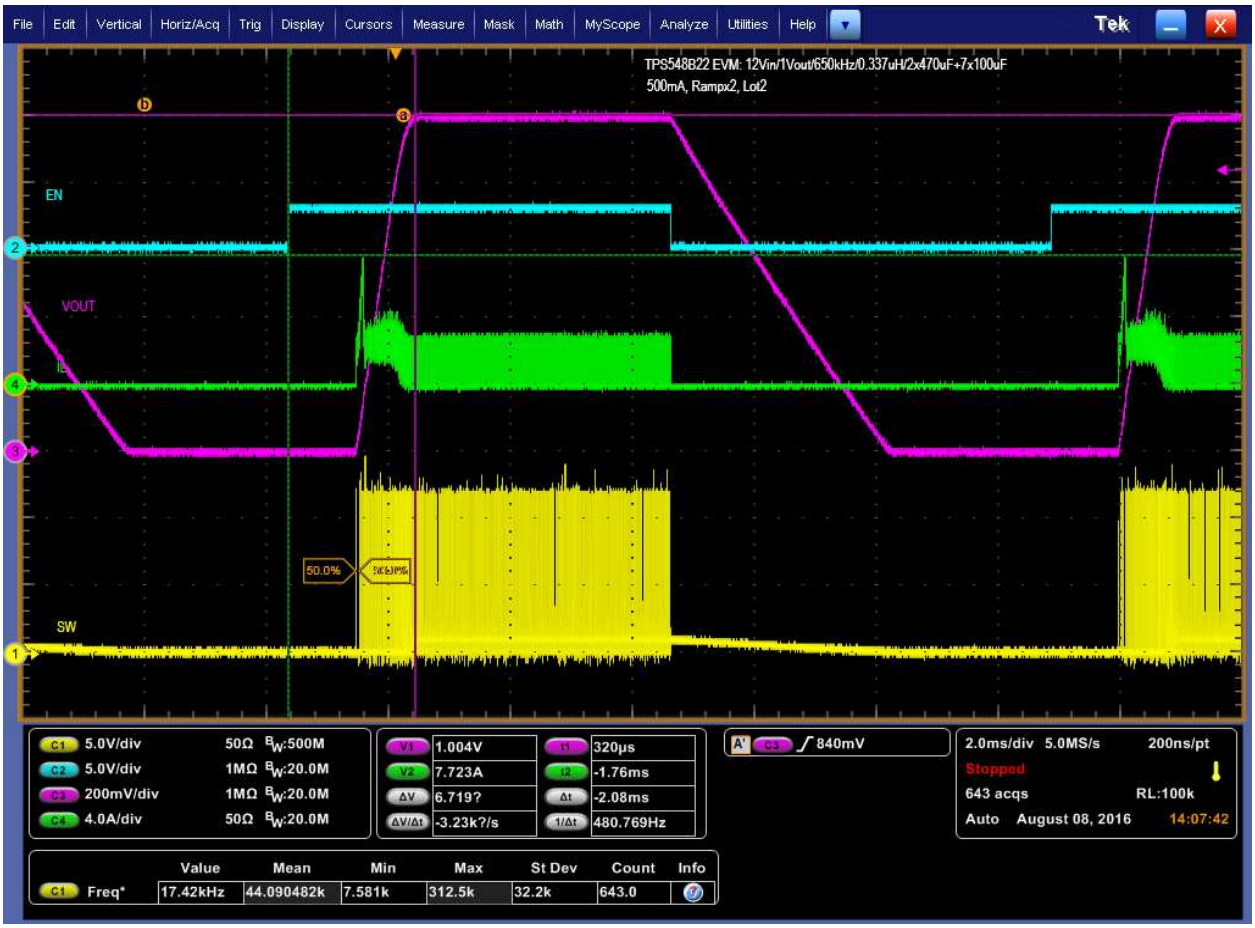



**Figure 12. Output Voltage Start-up and Shutdown, 1-V Output at 1 $2V_{IN}$, 0.5-A Output**



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## 9.8 Thermal Image

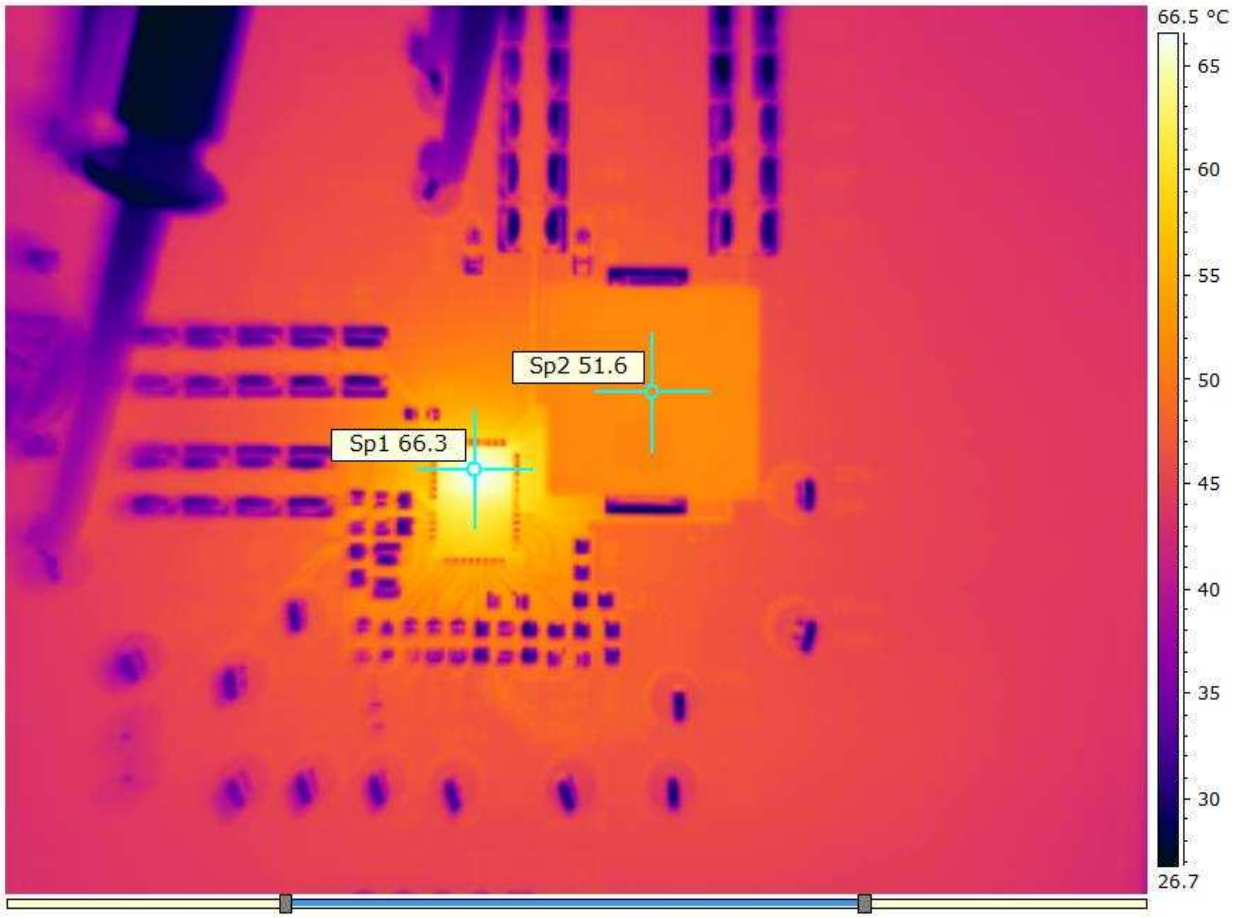



**Figure 13. Thermal Image at 1-V Output at 12 $V_{IN}$, 25-A Output, at 25°C Ambient**


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## 10 EVM Assembly Drawing and PCB Layout

Figure 14 through Figure 21 show the design of the PWR-847EVM printed-circuit board (PCB). The PWR-847EVM has a 2-oz. copper finish for all layers.

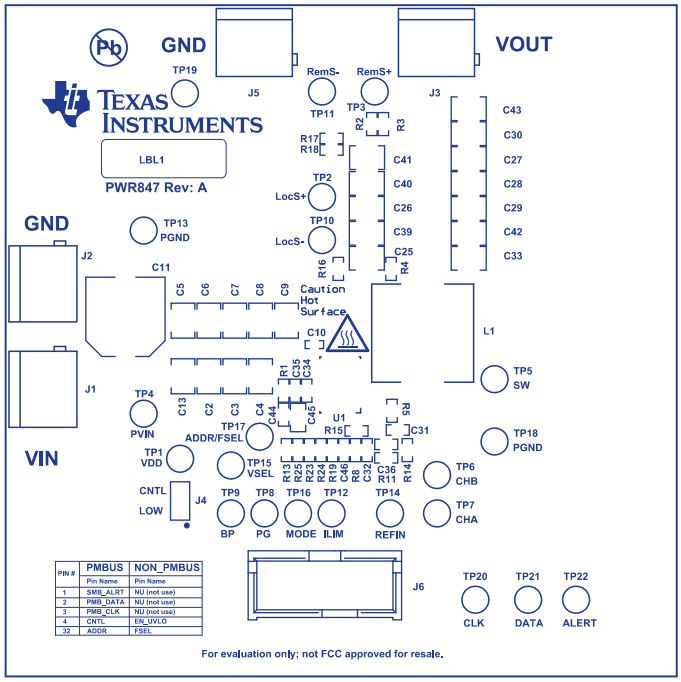



**Figure 14. PWR-847EVM Top Layer Assembly Drawing (Top View)**

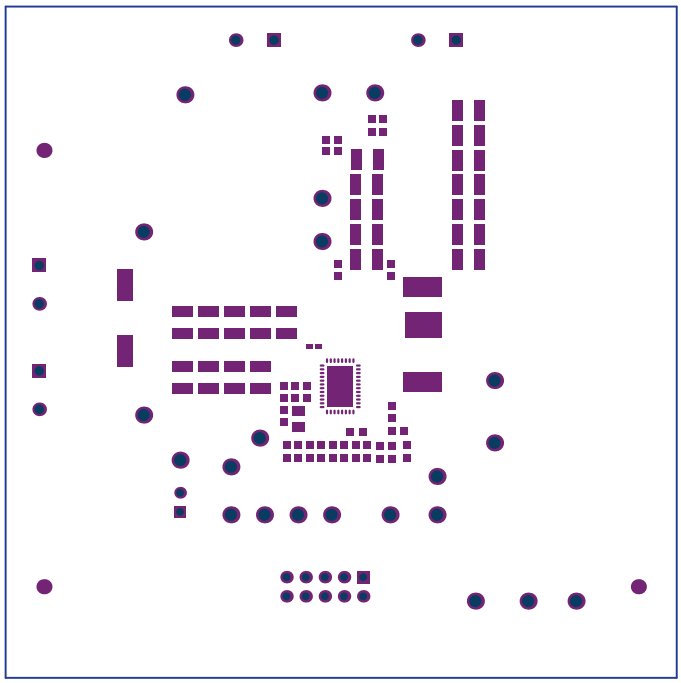


**Figure 15. PWR-847EVM Top Solder Mask (Top View)**



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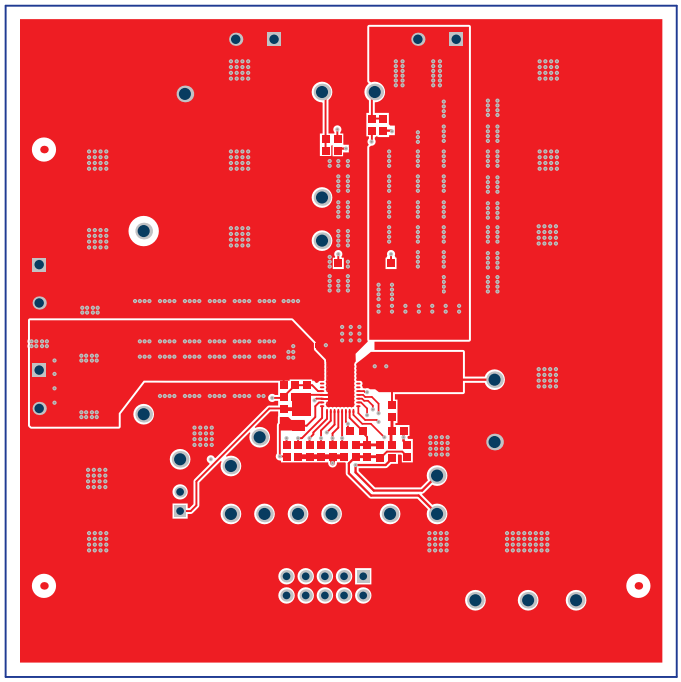


**Figure 16. PWR-847EVM Top Layer (Top View)**

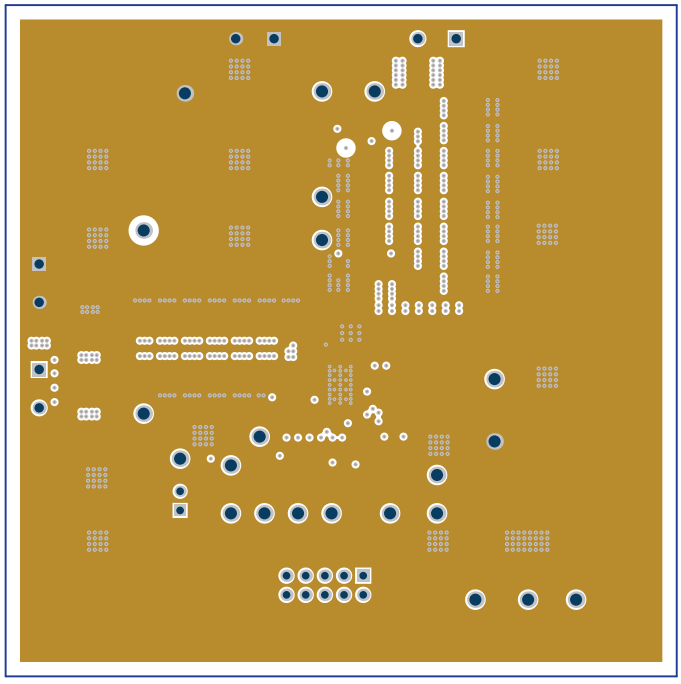


**Figure 17. PWR-847EVM Inner Layer 1 (Top View)**


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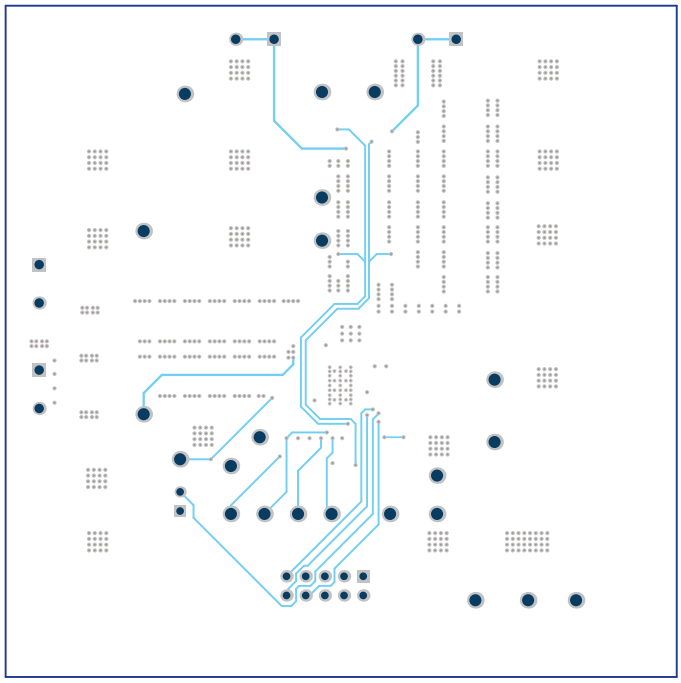


**Figure 18. PWR-847EVM Inner Layer 2 (Top View)**

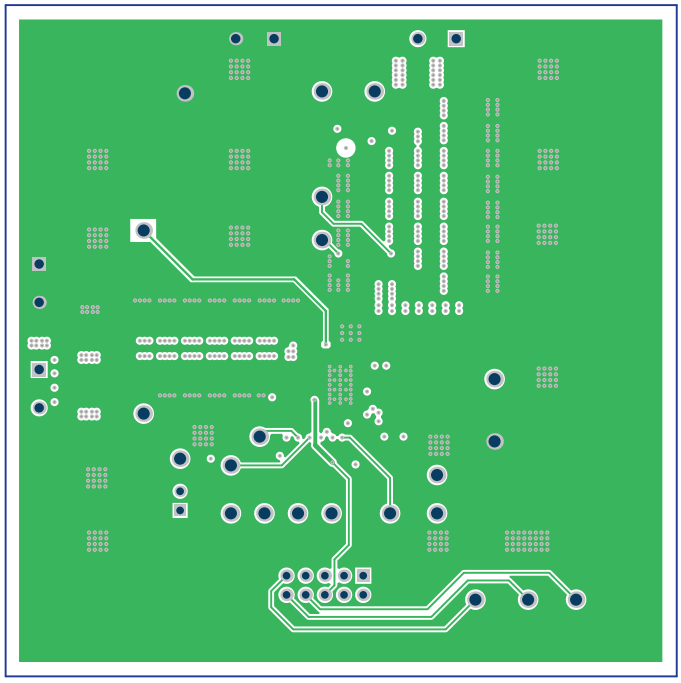


**Figure 19. PWR-847EVM Inner Layer 3 (Top View)**



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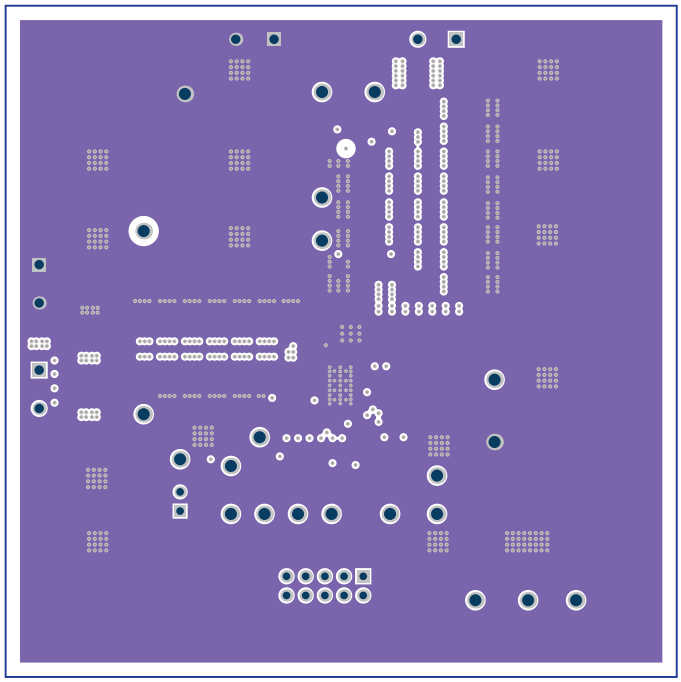


**Figure 20. PWR-847EVM Inner Layer 4 (Top View)**

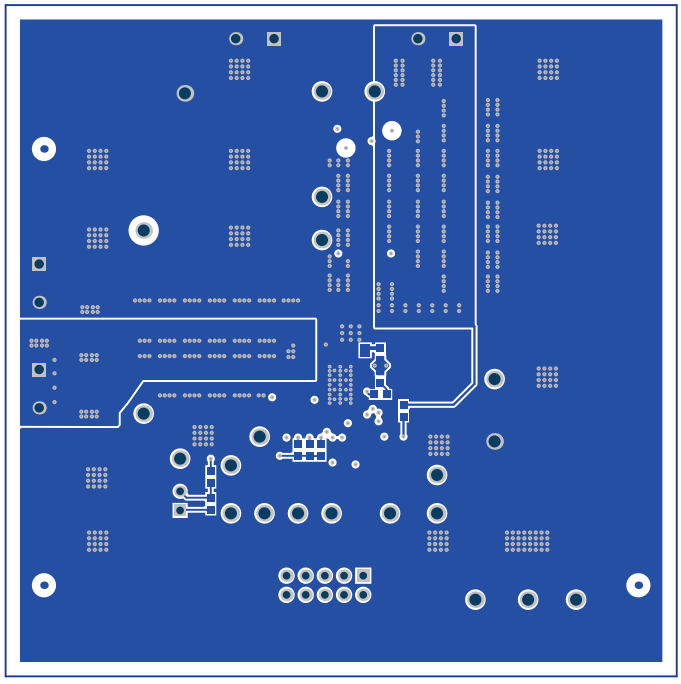


**Figure 21. PWR-847EVM Bottom Layer (Top View)**


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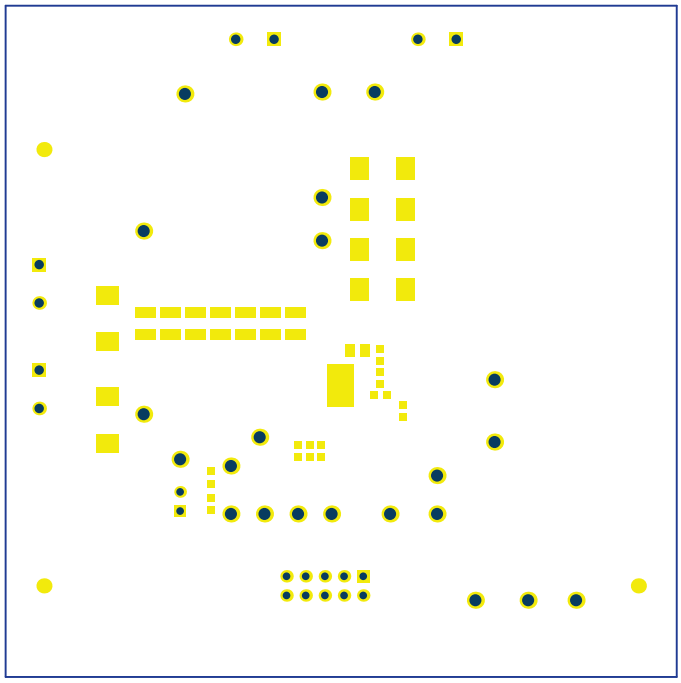


**Figure 22. PWR-847EVM Bottom Solder Mask (Top View)**

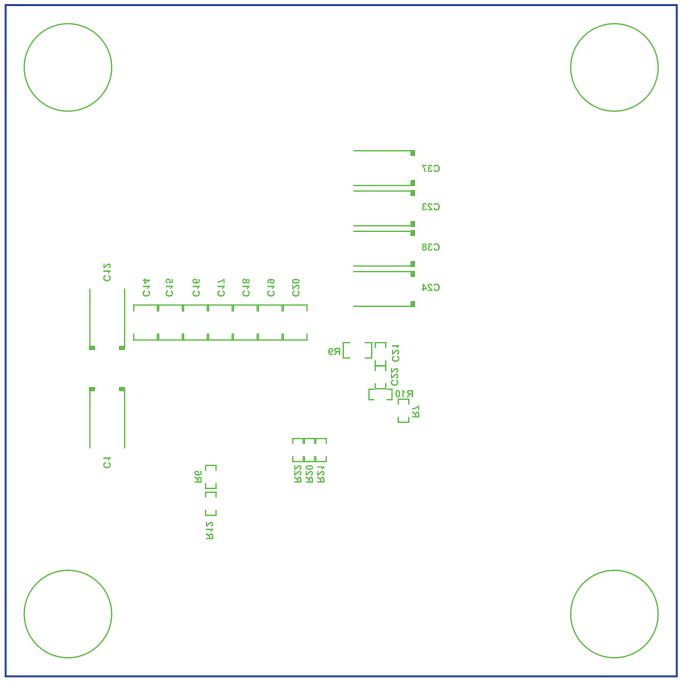


**Figure 23. PWR-847EVM Bottom Overlay Layer (Top View)**



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## 11 List of Materials

The EVM components list, according to the schematic, is shown in Table 5.

**Table 5. 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 µF, 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 µF, 50 V, +/- 10%, X7R, 0603 | 0603 |
| 6 | C24, C38 | 2 | 470uF | 2R5TPF470M6L | Panasonic | CAP, Tantalum Polymer, 470 µF, 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 µF, 6.3 V, +/- 20%, X5R, 1210 | 1210 |
| 8 | C35 | 1 | 1uF | C0603C105K4PACTU | Kemet | CAP, CERM, 1 µF, 16 V, +/- 10%, X5R, 0603 | 0603 |
| 9 | C45 | 1 | 4.7uF | GRM21BR71C475KA73L | MuRata | CAP, CERM, 4.7 µF, 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"H x 0.200"W |
| 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 | 6TPE330ML | Sanyo | CAP, TA, 330 µF, 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 µF, 25 V, +/- 10%, X7R, 1210 | 1210 |



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**Table 5. PWR847 List of Materials (continued)**

| Item# | Designator | Qty | Value | Part Number | Manufacturer | Description | Package Reference |
|---|---|---|---|---|---|---|---|
| 31 | C21 | 0 | 470pF | GRM188R71H471KA01D | MuRata | CAP, CERM, 470 pF, 50 V, +/- 10%, X7R, 0603 | 0603 |
| 32 | C23, C37 | 0 | 470uF | 2R5TPF470M6L | Panasonic | CAP, Tantalum Polymer, 470 µF, 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 µF, 6.3 V, +/- 20%, X5R, 1210 | 1210 |
| 34 | C31 | 0 | 0.1uF | GRM188R71H104KA93D | MuRata | CAP, CERM, 0.1 µF, 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 µF, 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 |



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

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      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.*

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- *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*

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**Concernant les EVMs avec appareils radio:**

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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

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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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