TPSM846C24, 35-A Power Module, Evaluation Module

This user's guide contains information for the TPSM846C24EVM-006 evaluation module (BSR006). Also included are the performance specifications, schematic, bill of materials (BOM), and layout of the EVM.

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Trademarks

All trademarks are the property of their respective owners.

1 Description

The TPSM846C24 device is a highly integrated, synchronous buck power module that combines a 35-A DC/DC converter with power MOSFETs, a shielded inductor, some input and output capacitors, and passives into a low profile package. The input voltage range is from 4.5 V to 15 V. The output voltage range is from 0.5 V to 2 V.

This evaluation module is designed to demonstrate the ease-of-use and small printed-circuit-board area that may be achieved when designing with the TPSM846C24 power module. Monitoring test points are provided to allow measurement of efficiency, power dissipation, input ripple, output ripple, line and load regulation, and transient response. Additionally, control test points are provided for use of the power good, enable control, and synchronization features of the device. The EVM uses a recommended PCB layout that maximizes thermal performance and minimizes output ripple and noise.

2 Getting Started

Figure 1 highlights the user interface items associated with the EVM. The polarized input power terminal block (TB1) is used for connection to the host input supply. TB2 allows 2 terminals for VOUT and TB3 allows 2 terminals for PGND for connection to the load. These terminal blocks can except up to 10-AWG wire.

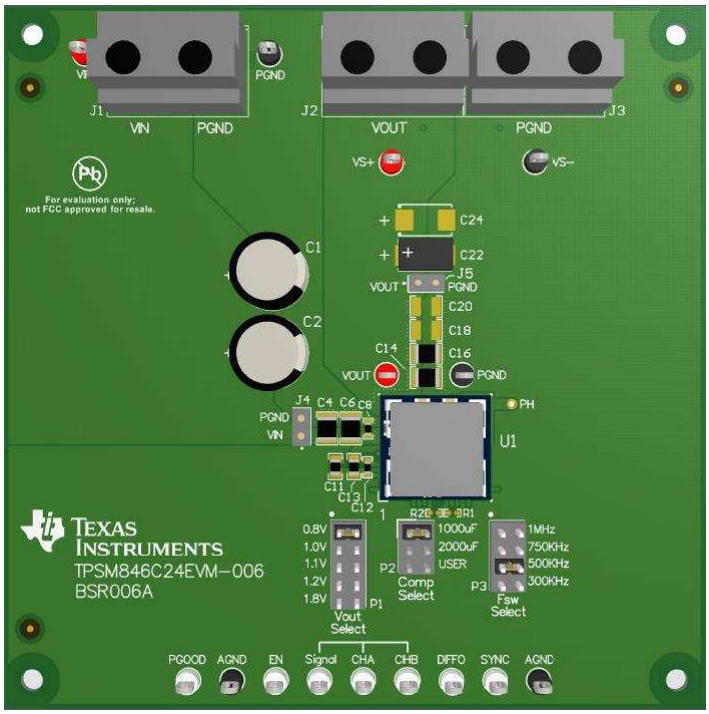

Figure 1. EVM User Interface

The VIN monitor (VIN and PGND) test points and VOUT monitor (VS+ and VS–) test points located near the input terminal block and the output terminal blocks are intended to be used as voltage monitoring points where voltmeters can be connected to measure the input and output voltages. Do **not** use these VIN and VOUT monitoring test points as the input supply or output load connection points. The PCB traces connecting to these test points are not designed to support high currents.

The VIN scope (J1) and VOUT scope (J2) test points can be used to monitor VIN and VOUT waveforms with an oscilloscope. These test points are intended for use with un-hooded scope probes outfitted with a low-inductance ground lead (ground spring) mounted to the scope probe barrel. The two sockets of each test point are on 0.1 inch centers. Insert the scope probe tip into the socket labeled VIN or VOUT, and insert the scope ground lead into the hole of the socket labeled PGND.

The test points located along the bottom of the EVM are made available to test the features of the device. Any external connections made to these test points should be referenced to one of the AGND test points. Refer to *Test Point Descriptions* for more information on the individual control test points.

The *Vout Select* jumper (P1) is used to set the output voltage. Select one of the five output voltages using a jumper. If a different voltage is required than the five selected using the jumper, leave the P1 jumper open and populate the correct resistor in position R2 on the EVM.

The *Comp Select* jumper (P2) sets the proper frequency compensation for the total amount of output capacitance present on the V_{OUT} bus. The EVM is shipped with approximately 1000 µF of output capacitance loaded on the board. Locations are provided on the board to add additional output capacitance (C18–C21, C24, C25). The default *Comp Select* jumper is loaded in the 1000 µF position which is the correct setting for output capacitance from 1000 µF to 1500 µF. The jumper position labeled 2000 µF selects compensation components for 1500 µF to 3000 µF of output capacitance. The jumper position labeled *USER* selects compensation components for 3000 µF to 5000 µF of output capacitance. See *TPSM846C24 4.5-V to 15-V Input, 0.5-V to 2.0-V Output, 35-A Power Module* for more information on selecting compensation components.

The *Fsw Select* jumper (P3) is used to set the switching frequency. Select from 300 kHz, 500 kHz, 750 kHz, and 1 MHz. The default jumper loading is the 500 kHz position.

3 Test Point Descriptions

Wire-loop test points and scope probe test points are provided as convenient connection points for digital voltmeters (DVM) or oscilloscope probes to aid in the evaluation of the device. Table 1 provides a description of each test point:

Table 1. Test Points

Test Point	Description
VIN	Input voltage monitor. Connect DVM across this point and PGND for measuring efficiency.
VS+	Supply path output voltage monitor. Connect DVM positive lead to this point for line and load regulation.
VS–	Return path output voltage monitor. Connect DVM negative lead to this point for measuring line and load regulation.
VOUT	Output voltage monitor. Connect DVM to this point and PGND for measuring efficiency.
PGND	Input and output voltage monitor grounds. Reference the VIN and VOUT DVMs to these ground points.
VIN MON (J1)	Input voltage scope monitor. Connect an oscilloscope to this set of points to measure input ripple voltage.
VOUT MON (J2)	Output voltage scope monitor. Connect an oscilloscope to this set of points to measure output ripple voltage and transient response.
AGND	Analog ground point. Use any of the AGND test points as the ground reference for the control signals.
ALERT	PMBus ALERT line, used to monitor the ALERT signal.
CLK	PMBus CLK line, used to monitor the CLK signal.
DATA	PMBus DATA line, used to monitor the DATA signal.
PGOOD	Monitors the power good signal of the device. This is an open-drain signal that has an onboard 10-kΩ pullup resistor to 3.3 V.
CNTL	Control pin, pull to GND to stop power conversion. Float or pull to 3.3 V to enable power conversion. An internal 10-kΩ pullup resistor to 3.3 V is present on the EVM.
Signal	Signal injection point for Bode plot analyzer. Inject from Signal to CHB.
CHA	Input signal monitoring point for Bode plot analyzer.
CHB	Output signal monitoring point for Bode plot analyzer.
DIFFO	Output of remote sense differential amplifier.
SYNC	Connects to the SYNC pin of the device. An external clock signal can be applied to this point to synchronize the device to an appropriate frequency.
PH	Switch node of the TPSM846C24 device. Use an un-hooded scope probe to monitor this point.

NOTE: Refer to *TPSM846C24 4.5-V to 15-V Input, 0.5-V to 2.0-V Output, 35-A Power Module* for absolute maximum ratings associated with features in Table 1.

4 Operation Notes

To operate the EVM, apply a valid input voltage from 4.5 V to 15 V. The power supply providing the input voltage must be rated for sufficient input current. The undervoltage lock out (UVLO) can be programmed using the PMBus commands.

The output voltage range is from 0.5 V to 2.0 V. The EVM can be evaluated at 5 popular output voltage settings by selecting a jumper (P1).

The TPSM846C24 is a 35-A device. When connecting the EVM to the external load, use wiring capable of safely handling 35 A of output current.

The Power Good (PGOOD) indicator of the EVM will assert high when the output voltage is within ±5% of the programmed output voltage value. A 10-kΩ pullup resistor (R11) is populated between the PGOOD pin and the BP3 pin.

The TPSM846C24 EVM is set-up to operate at 500 kHz, but the switching frequency can be adjusted using the P3 jumper. If an exact switching frequency is required, the device can be synchronized to an external clock over the frequency range of 300 kHz to 1 MHz. Refer to *TPSM846C24 4.5-V to 15-V Input, 0.5-V to 2.0-V Output, 35-A Power Module* for further information on synchronization.

The TPSM846C24EVM-006 includes both input and output capacitors. The EVM includes footprints for adding additional input and output capacitors to the EVM. Adding additional capacitance will improve transient response. The actual capacitance required will depend on the input and output voltage conditions of the particular application, along with the desired transient response. Refer to the product data sheet for further information on input and output capacitance and transient response.

The EVM uses remote sense connections to regulate the output voltage at the output terminals of the EVM. The remote sense connections are made through 0-Ω resistors, R16 and R18. If remote sense is required at a different point, R16 and R18 can be replaced with 10-Ω resistors and VS+ and VS– test points can be extended to the new sense point.

5 Performance Data

Figure 2 through Figure 4 provide the EVM performance data using the following conditions:

V_{IN} = 12 V, F_{sw} = 500 kHz, C_{OUT} = 4 × 47-µF ceramic plus 2 × 470-µF polymer

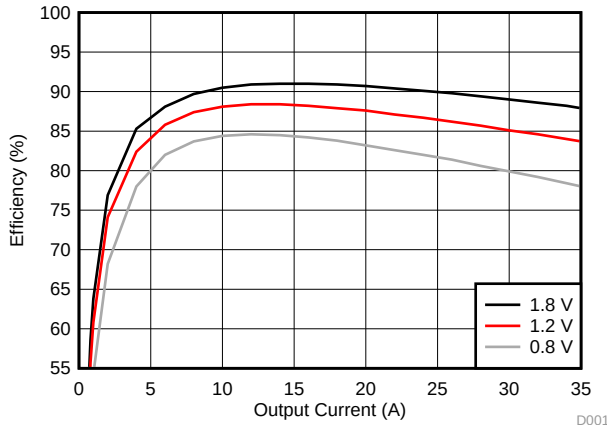

Figure 2. Efficiency

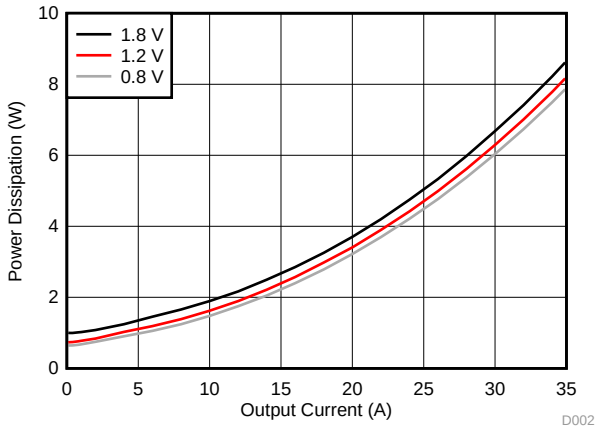

Figure 3. Power Dissipation

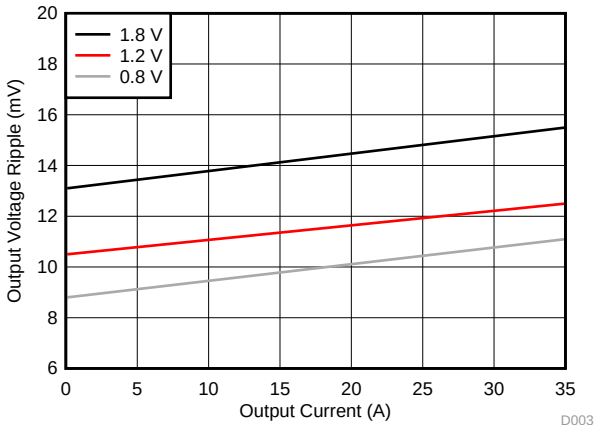

Figure 4. Output Voltage Ripple

6 Schematic

Figure 5 illustrates the TPSM846C24EVM schematic.

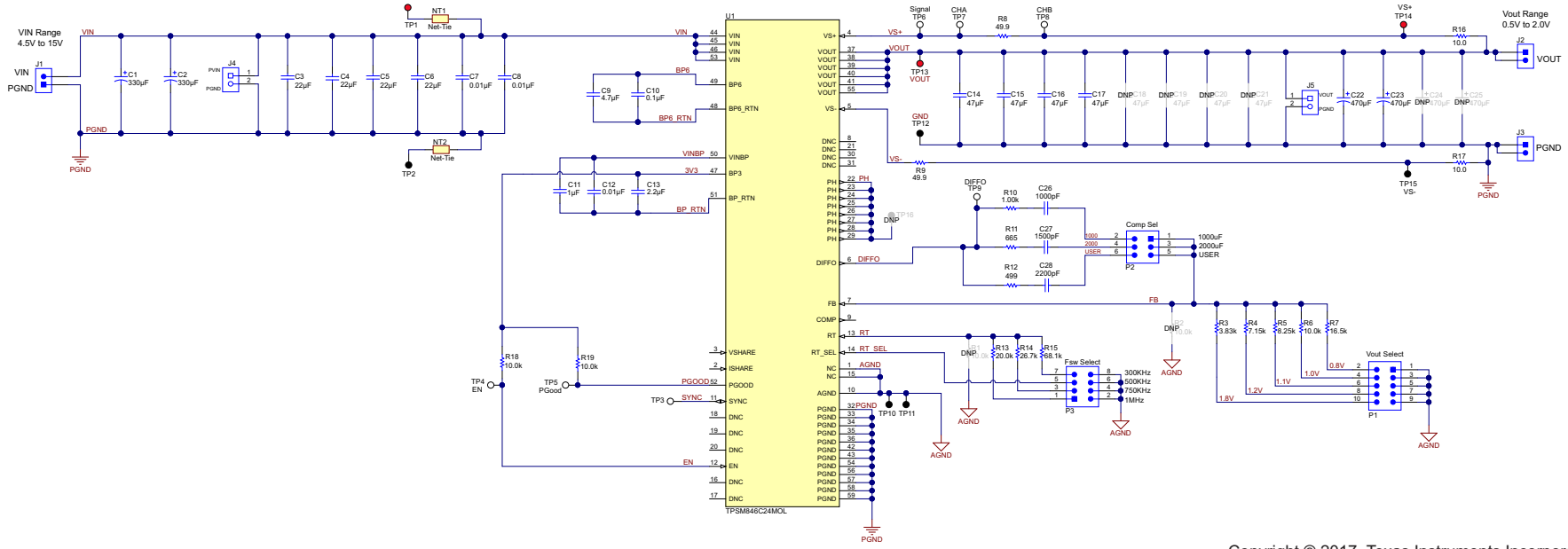

Figure 5. TPSM846C24EVM Schematic

7 Bill of Material

Table 2 lists the EVM BOM.

Table 2. TPSM846C24EVM Bill of Material

Designator	QTY	Description	Part Number	Manufacturer
PCB	1	Printed Circuit Board	74-01196	Any
U1	1	TPSM846C24	TPSM846C24MOL	Texas Instruments
C1, C2	2	CAP, AL, 330 µF, 25 V, ±20%, 0.053 ohm, TH	25ZL330MEFC10X12.5	Rubycon
C3, C4, C5, C6	4	CAP, CERM, 22 µF, 25 V, ±10%, X5R, 1210	GRM32ER61E226KE15L	Murata
C7, C8, C12	3	CAP, CERM, 0.01 µF, 50 V, ±10%, X7R, 0603	GRM188R71H103KA01D	Murata
C9	1	CAP, CERM, 4.7 µF, 16 V, ±10%, X5R, 0805	GRM21BR61C475KA88L	Murata
C10	1	CAP, CERM, 0.1 µF, 16 V, ±10%, X7R, 0603	GRM188R71C104KA01D	Murata
C11	1	CAP, CERM, 1 µF, 25 V, ±10%, X7R, 0805	GRM21BR71E105KA99L	Murata
C13	1	CAP, CERM, 2.2 µF, 16 V, ±10%, X7R, 0805	GRM21BR71C225KA12L	Murata
C14, C15, C16, C17	4	CAP, CERM, 47 µF, 6.3 V, ±20%, X5R, 1210	GRM32ER60J476ME20L	Murata
C22, C23	2	CAP, Tantalum Polymer, 470 µF, 6.3 V, ±20%, 0.01 ohm, 7343-40 SMD	6TPF470MAH	Panasonic
C26	1	CAP, CERM, 1000 pF, 16 V, ±10%, X7R, 0402	GRM155R71C102KA01D	Murata
C27	1	CAP, CERM, 1500 pF, 50 V, ±10%, X7R, 0402	GRM155R71H152KA01D	Murata
C28	1	CAP, CERM, 2200 pF, 50 V, ±10%, X7R, 0402	GRM155R71H222KA01D	Murata
J1, J2, J3	3	Terminal Block, 30A, 9.52mm (.375) Pitch, 2-Pos, TH	OSTT7022150	On-Shore Technology
J4, J5	2	Socket Strip, 2x1, 100mil, Black, Tin, TH	310-43-102-41-001000	Mill-Max
P1	1	Header, 100mil, 5x2, Tin, TH	PEC05DAAN	Sullins Connector Solutions
P2	1	Header, 100mil, 3x2, Tin, TH	PEC03DAAN	Sullins Connector Solutions
P3	1	Header, 100mil, 4x2, Tin, TH	PEC04DAAN	Sullins Connector Solutions
R3	1	RES, 3.83 k, 1%, 0.063 W, 0402	CRCW04023K83FKED	Vishay-Dale
R4	1	RES, 7.15 k, 1%, 0.063 W, 0402	CRCW04027K15FKED	Vishay-Dale
R5	1	RES, 8.25 k, 1%, 0.063 W, 0402	CRCW04028K25FKED	Vishay-Dale
R6, R18, R19	3	RES, 10.0 k, 1%, 0.063 W, 0402	CRCW040210K0FKED	Vishay-Dale
R7	1	RES, 16.5 k, 1%, 0.063 W, 0402	CRCW040216K5FKED	Vishay-Dale
R8, R9	2	RES, 49.9, 1%, 0.1 W, 0603	CRCW060349R9FKEA	Vishay-Dale
R10	1	RES, 1.00 k, 1%, 0.063 W, 0402	CRCW04021K00FKED	Vishay-Dale
R11	1	RES, 665, 1%, 0.063 W, 0402	CRCW0402665RFKED	Vishay-Dale
R12	1	RES, 499, 1%, 0.063 W, 0402	CRCW0402499RFKED	Vishay-Dale
R13	1	RES, 20.0 k, 1%, 0.063 W, 0402	CRCW040220K0FKED	Vishay-Dale
R14	1	RES, 26.7 k, 1%, 0.063 W, 0402	CRCW040226K7FKED	Vishay-Dale
R15	1	RES, 68.1 k, 1%, 0.063 W, 0402	CRCW040268K1FKED	Vishay-Dale
R16, R17	2	RES, 10.0, 5%, 0.1 W, 0603	CRCW060310R0FKEA	Vishay-Dale
TP1, TP13, TP14	3	Test Point, Multipurpose, Red, TH	5010	Keystone
TP2, TP10, TP11, TP12, TP15	5	Test Point, Multipurpose, Black, TH	5011	Keystone
TP3, TP4, TP5, TP6, TP7, TP8, TP9	7	Test Point, Multipurpose, White, TH	5012	Keystone
C18, C19, C20, C21	0	CAP, CERM, 1210	1210	Murata
C24, C25	0	CAP, Tantalum Polymer, 7343-40 SMD	7343-40	Panasonic
R1, R2	0	RES, 0402	0603	Vishay-Dale

8 PCB Layout

Figure 6 through Figure 13 display the EVM PCB layout images.

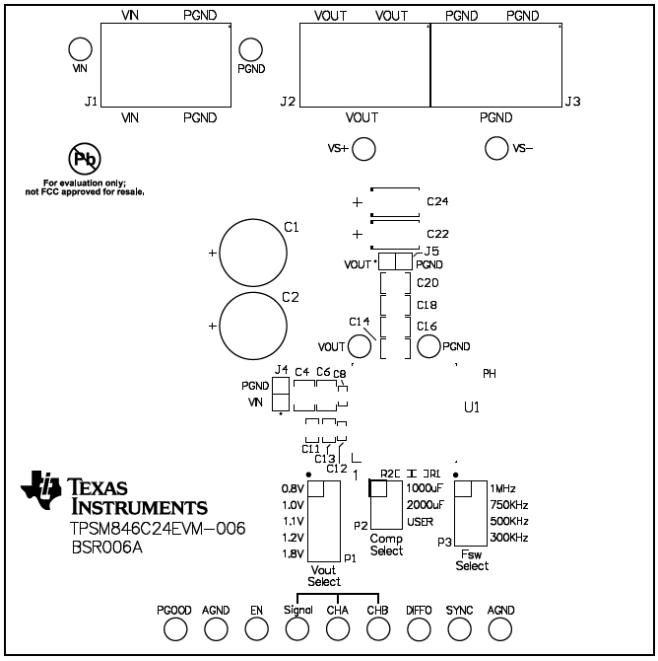

Figure 6. Top Components (Top View)

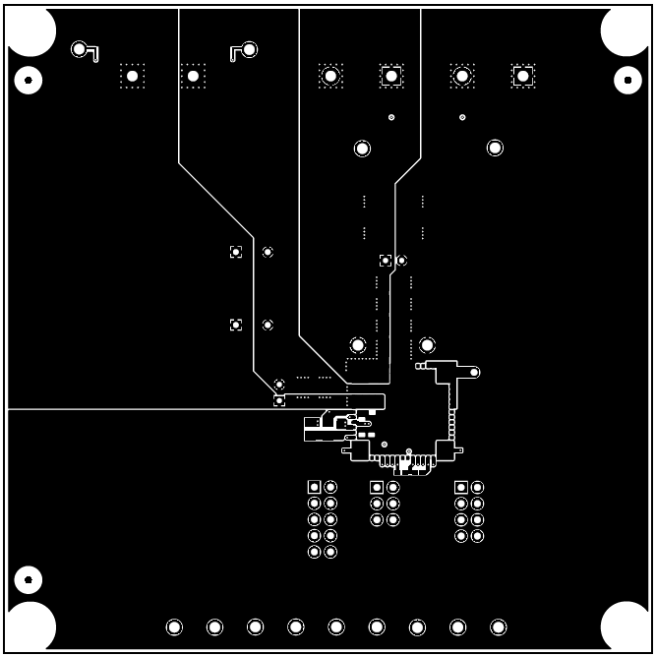

Figure 7. Topside Copper (Top View)

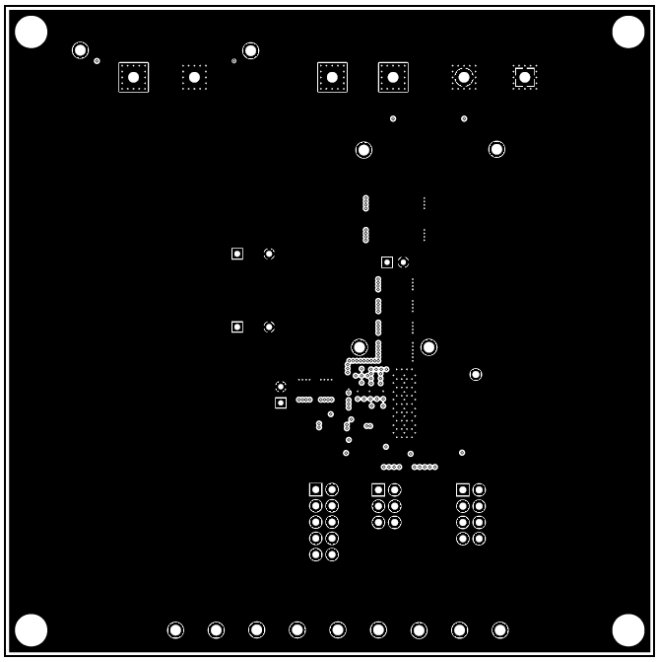

Figure 8. Layer 2 Copper (Top View)

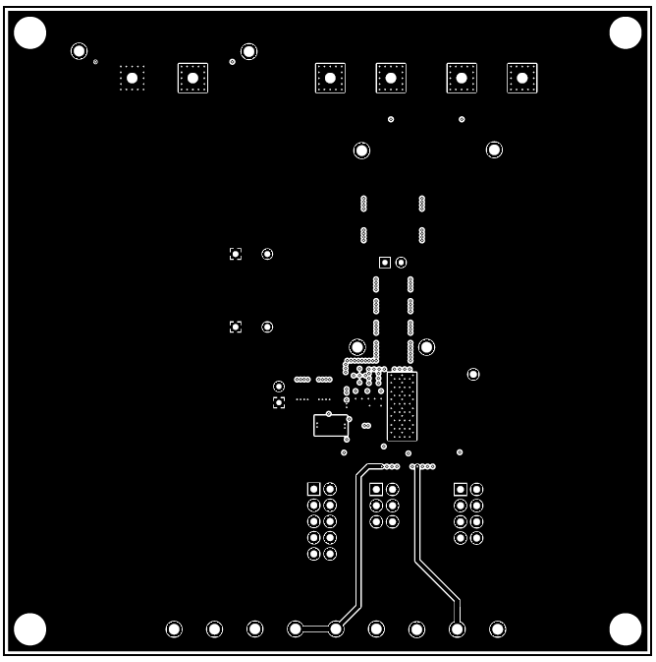

Figure 9. Layer 3 Copper (Top View)

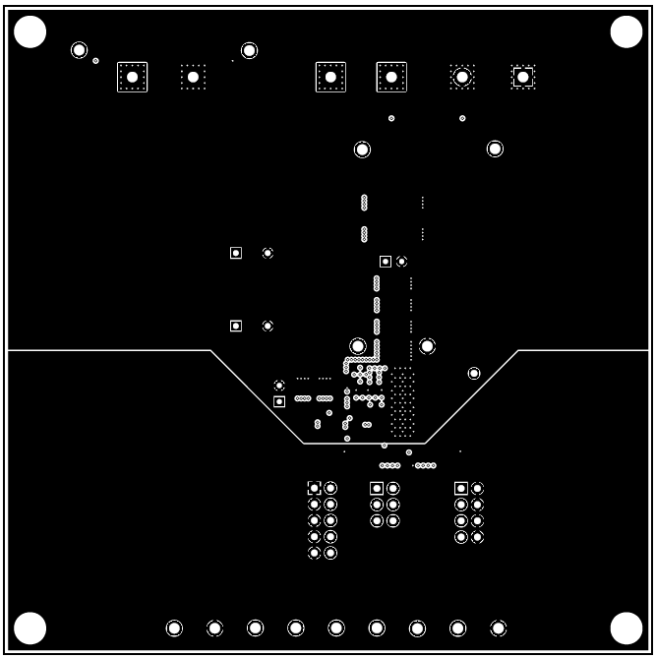

Figure 10. Layer 4 Copper (Top View)

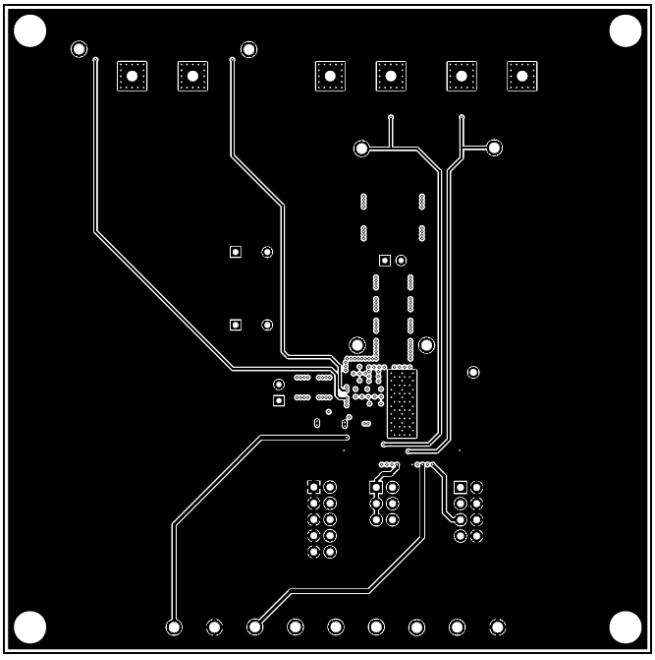

Figure 11. Layer 5 Copper (Top View)

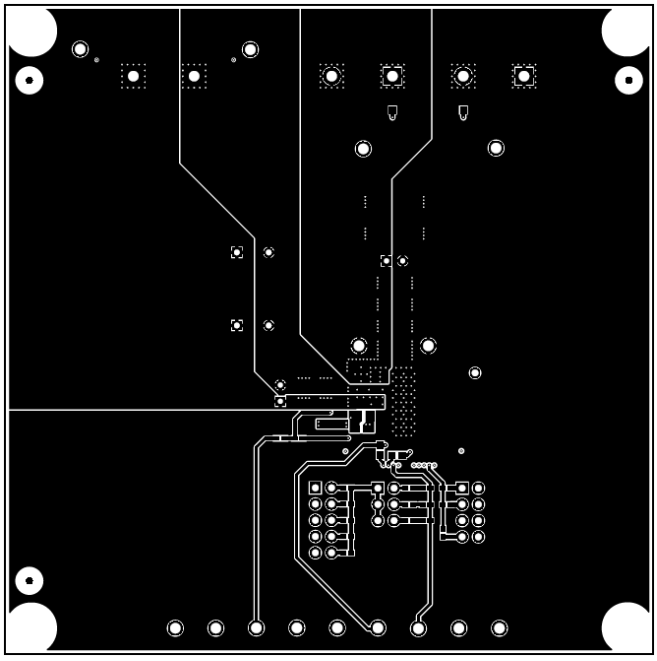

Figure 12. Bottom-Side Copper (Top View)

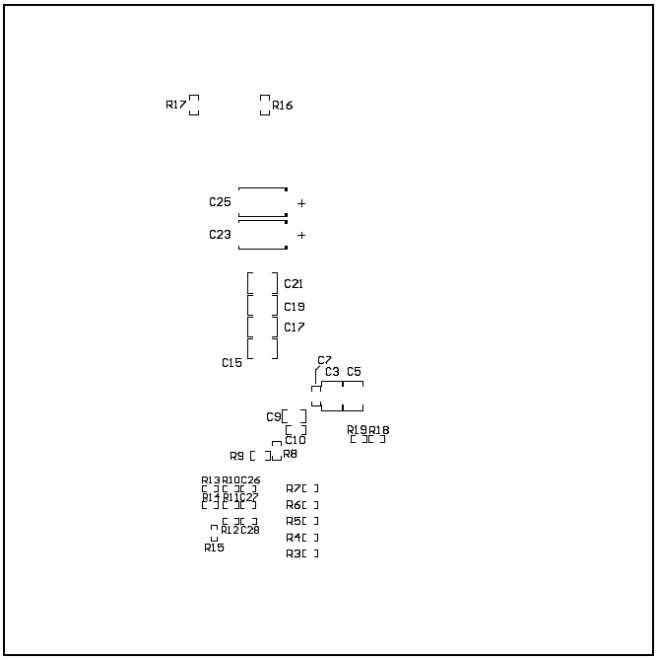

Figure 13. Bottom Components (Bottom View)

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3 *Regulatory Notices:*

   3.1 *United States*

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

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

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

      CAUTION

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

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

      FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 *Canada*

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 *Japan*

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

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西新宿三井ビル

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

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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.

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