

# ***TPSM846C24 70-A Parallel Operation Evaluation Module***

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This user's guide contains information for the TPSM846C24DEVM-007 evaluation module (BSR007). Also included are the performance specifications, schematic, bill of materials (BOM), and layout of the EVM.

### **Contents**

1	Description .....	2
2	Getting Started .....	2
3	Test Point Descriptions .....	3
4	Operation Notes.....	4
5	Performance Data .....	5
6	Schematic.....	6
7	Bill of Material .....	7
8	PCB Layout.....	8

### **List of Figures**

1	EVM User Interface.....	2
2	Efficiency.....	5
3	Power Dissipation.....	5
4	Output Voltage Ripple.....	5
5	TPSM846C24DEVM-007 Schematic.....	6
6	Top Components .....	8
7	Topside Copper .....	8
8	Layer 2 Copper .....	8
9	Layer 3 Copper .....	8
10	Layer 4 Copper .....	8
11	Layer 5 Copper .....	8
12	Bottom-Side Copper.....	9
13	Bottom Components (Bottom View).....	9

### **List of Tables**

1	Test Points.....	3
2	TPSM846C24DEVM-007 Bill of Material .....	7

### **Trademarks**

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## 1 Description

The TPSM846C24 device is a synchronous buck power module designed to provide up to 35-A of output current. The TPSM846C24 can be paralleled with two devices to achieve output current up to 70 A. The TPSM846C24 is a highly integrated, DC-DC 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 paralleling two TPSM846C24 power modules. 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 undervoltage lock out (UVLO) 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 and TB3 allow 4 terminals for VOUT and TB4 and TB5 allow 4 terminals for PGND for connection to the load. These terminal blocks can accept up to 12-AWG wire.

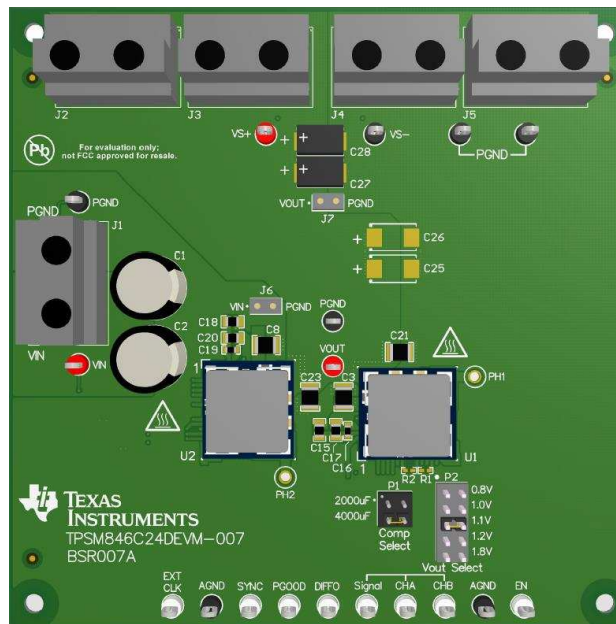


Figure 1. EVM User Interface

The VIN monitor (VIN and PGND) 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 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 directly below the device 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 located along the bottom of the EVM. Refer to [Test Point Descriptions](#) for more information on the individual control test points.

The *Vout Select* jumper (P4) is used to set the output voltage. The default loading is the 1.0 V position.

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 2000  $\mu\text{F}$  of output capacitance loaded on the board. Locations are provided on the board to add another 2000  $\mu\text{F}$  of output capacitance (C28–C31). The default jumper load is the 2000  $\mu\text{F}$  position.

When two TPSM846C24 devices are paralleled, the SYNC pins of the Master and the Slave must be supplied with a 50% duty cycle external clock signal at the desired switching frequency. A 500-kHz clock is present on the EVM which supplies the required 50% duty cycle signal. The *Master* device (U1) locks to the rising edge of the clock and the *Slave* device (U2) locks to the falling edge of the clock.

### 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 to this point for measuring efficiency.
VS+	Supply path output voltage monitor. Connect DVM positive lead to this point for line regulation and load regulation.
VS–	Return path output voltage monitor. Connect DVM negative lead to this point for measuring line regulation 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.
EN	EN pin. Pull to AGND to stop power conversion. Float or pull to 3.3 V to enable power conversion. An internal 10-k $\Omega$ pullup resistor to 3.3 V is present on the EVM.
EXT CLK	External clock input. This is the input to a D flip-flop. Apply an external clock at a frequency that is twice the required switching frequency. Remove R13 before applying the clock signal.
SYNC	SYNC monitor pin. This pin is the output of a D flip-flop which supplies a clock to both devices.
PGOOD	Monitors the power good signal of the device. This is an open-drain signal that has an onboard 10-k $\Omega$ pullup resistor to 3.3 V.
DIFFO	Output of remote sense differential amplifier.
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.
PH1	Switch node of the TPSM846C24 Master device (U1). Use an unshielded scope probe to monitor this point.
PH2	Switch node of the TPSM846C24 Slave device (U2). Use an unshielded 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 output voltage can be set over the range from 0.5 V to 2.0 V.

The Power Good (PGOOD) indicator of the EVM will assert high when the output voltage is within  $\pm 5\%$  of the programmed output voltage value. A 10-k $\Omega$  pullup resistor (R18) is populated between the PGOOD pin and the 3V3 pin.

The TPSM846C24DEVM-007 is set-up to operate at 500 kHz. A clock circuit is present on the bottom of the EVM. The clock circuit produces a 500 kHz, 50% duty cycle clock that feeds both devices. If another switching frequency is required, R20 must be removed from the clock circuit on the bottom of the EVM and an external clock must be connected to the EXT CLK test point. The external clock applied to EXT CLK test point must be 2  $\times$  the required frequency. 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 TPSM846C24DEVM-007 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.

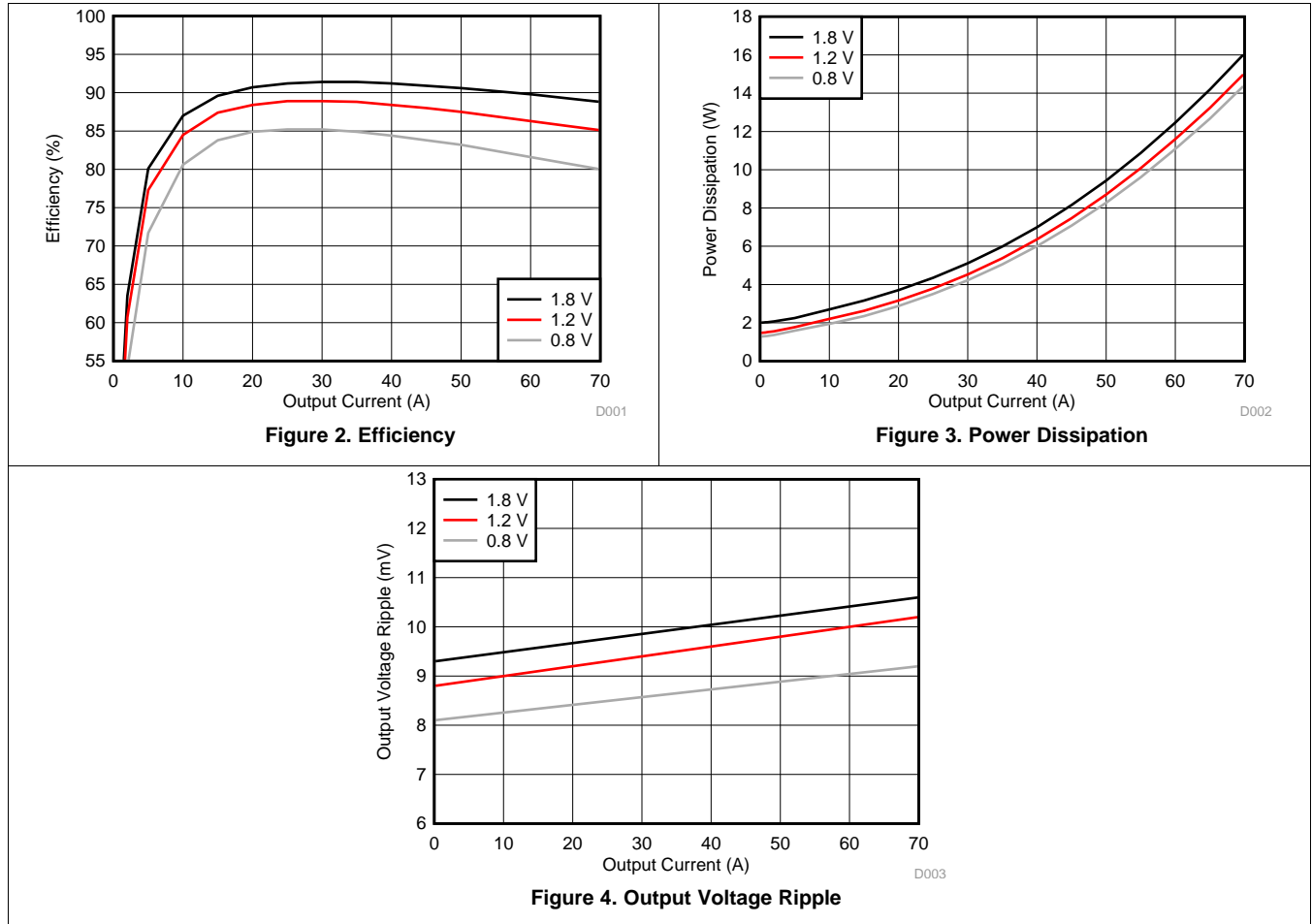
### CAUTION

Do **not** change jumper settings while the module is powered. Permanent damage may occur.

## 5 Performance Data

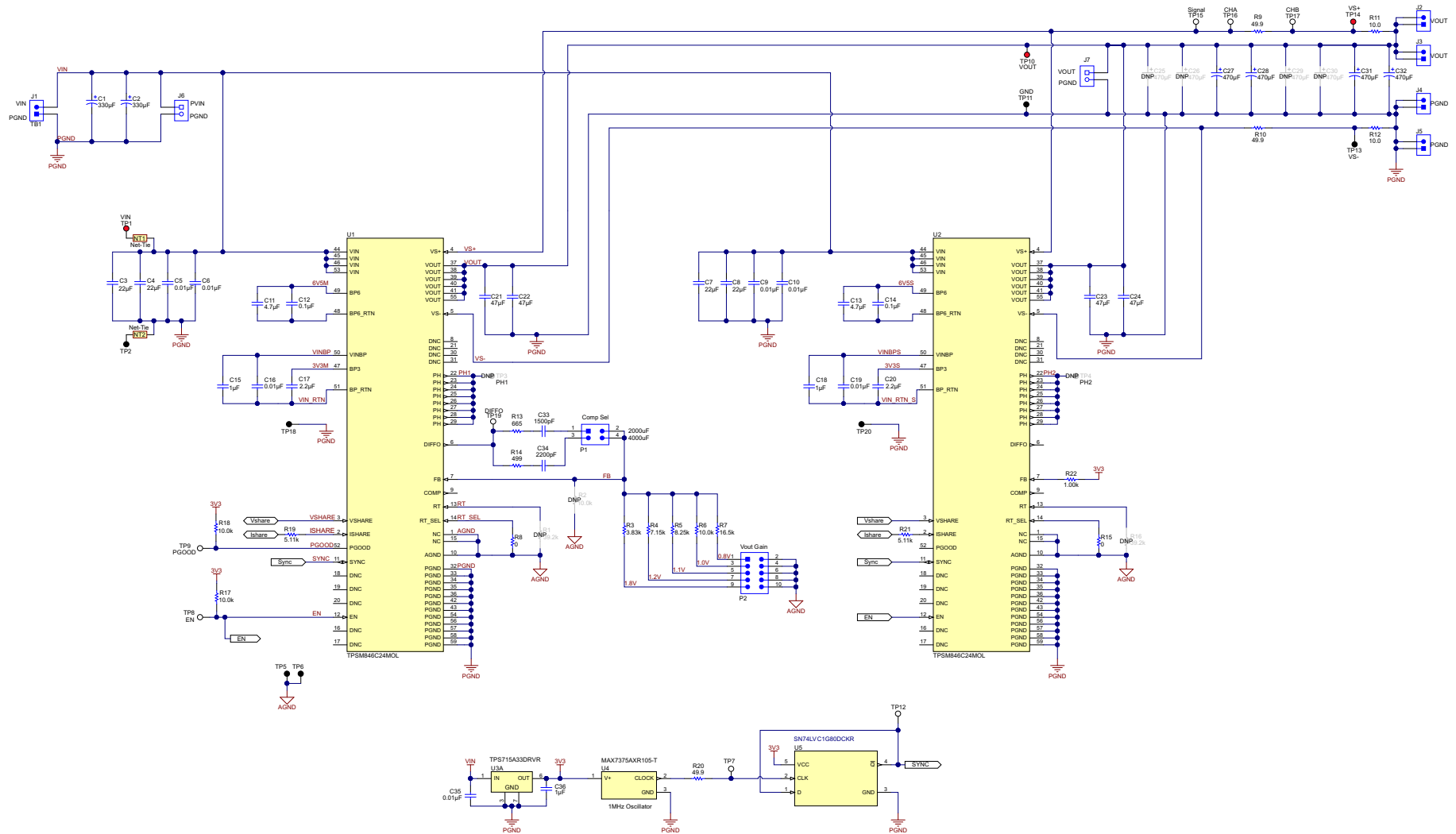
Figure 2 through Figure 4 provide the EVM performance data with the following conditions:

$V_{IN} = 12\text{ V}$ ,  $F_{sw} = 500\text{ kHz}$ ,  $C_{OUT} = 4 \times 47\text{-}\mu\text{F}$  ceramic plus  $4 \times 470\text{-}\mu\text{F}$  polymer



## 6 Schematic

Figure 5 illustrates the TPSM846C24DEVM-007 schematic.



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Figure 5. TPSM846C24DEVM-007 Schematic

## 7 Bill of Material

Table 2 lists the EVM BOM.

**Table 2. TPSM846C24DEVM-007 Bill of Material**

Designator	QTY	Description	Part Number	Manufacturer
PCB	1	Printed Circuit Board	-	Any
U1, U2	2	TPSM846C24	TPSM846C24MOL	Texas Instruments
C1, C2	2	CAP, AL, 330 $\mu$ F, 25 V, $\pm$ 20%, 0.053 ohm, TH	25ZL330MEFC10X12.5	Rubycon
C3, C4, C7, C8	4	CAP, CERM, 22 $\mu$ F, 25 V, $\pm$ 10%, X5R, 1210	GRM32ER61E226KE15L	Murata
C5, C6, C9, C10, C16, C19, C35	7	CAP, CERM, 0.01 $\mu$ F, 50 V, $\pm$ 10%, X7R, 0603	GRM188R71H103KA01D	Murata
C11, C13	2	CAP, CERM, 4.7 $\mu$ F, 16 V, $\pm$ 10%, X5R, 0805	GRM21BR61C475KA88L	Murata
C12, C14	2	CAP, CERM, 0.1 $\mu$ F, 16 V, $\pm$ 10%, X7R, 0603	GRM188R71C104KA01D	Murata
C15, C18	2	CAP, CERM, 1 $\mu$ F, 25 V, $\pm$ 10%, X7R, 0805	GRM21BR71E105KA99L	Murata
C17, C20	2	CAP, CERM, 2.2 $\mu$ F, 16 V, $\pm$ 10%, X7R, 0805	GRM21BR71C225KA12L	Murata
C21, C22, C23, C24	4	CAP, CERM, 47 $\mu$ F, 6.3 V, $\pm$ 20%, X5R, 1210	GRM32ER60J476ME20L	Murata
C27, C28, C31, C32	4	CAP, Tantalum Polymer, 470 $\mu$ F, 6.3 V, $\pm$ 20%, 0.01 ohm, 7343-40 SMD	6TPF470MAH	Panasonic
C33	1	CAP, CERM, 1000 pF, 16 V, $\pm$ 10%, X7R, 0402	GRM155R71C102KA01D	Murata
C34	1	CAP, CERM, 2200 pF, 50 V, $\pm$ 10%, X7R, 0402	GCM155R71H222KA37D	Murata
C36	1	CAP, CERM, 1 $\mu$ F, 16 V, $\pm$ 10%, X7R, 0603	GRM188R71C105KA12D	Murata
C25, C26, C29, C30	0	CAP, Tantalum Polymer, 470 $\mu$ F, 6.3 V, $\pm$ 20%, 0.01 ohm, 7343-40 SMD	6TPF470MAH	Panasonic
D1	1	LED, Green, SMD	150060GS75000	Würth Elektronik
J1, J2	2	Socket Strip, 2x1, 100mil, Black, Tin, TH	310-43-102-41-001000	Mill-Max
P1	1	Header, 2.54mm, 5x2, Gold, TH	AWHW-10G-0202-T	Assman WSW
P2, P4	2	Header, 100mil, 2x2, Tin, TH	PEC02DAAN	Sullins Connector Solutions
R1, R3	2	RES, 0, 5%, 0.063 W, 0402	CRCW0402000Z0ED	Vishay-Dale
R5, R6, R7	3	RES, 121 k, 1%, 0.063 W, 0402	CRCW0402121KFKED	Vishay-Dale
R8	1	RES, 51.1 k, 1%, 0.063 W, 0402	CRCW040251K1FKED	Vishay-Dale
R9, R10, R23	3	RES, 49.9, 1%, 0.1 W, 0603	CRCW060349R9FKEA	Vishay-Dale
R11, R12	2	RES, 10.0, 1%, 0.1 W, 0603	CRCW060310R0FKEA	Vishay-Dale
R13	1	RES, 665, 1%, 0.063 W, 0402	CRCW0402665RFKED	Vishay-Dale
R14	1	RES, 499, 1%, 0.063 W, 0402	CRCW0402499RFKED	Vishay-Dale
R15, R16, R18, R20	4	RES, 10.0 k, 1%, 0.063 W, 0402	CRCW040210K0FKED	Vishay-Dale
R17	1	RES, 4.99 k, 1%, 0.063 W, 0402	CRCW04024K99FKED	Vishay-Dale
R19, R21	2	RES, 5.11 k, 1%, 0.063 W, 0402	CRCW04025K11FKED	Vishay-Dale
R22	1	RES, 1.00 k, 1%, 0.063 W, 0402	CRCW04021K00FKED	Vishay-Dale
R2, R4	0	RES, 39.2 k, 1%, 0.063 W, 0402	CRCW040239K2FKED	Vishay-Dale
TB1, TB2, TB3, TB4, TB5	5	Terminal Block, 30A, 9.52mm (.375) Pitch, 2-Pos, TH	OSTT7022150	On-Shore Technology
TP1, TP5, TP6, TP7, TP8, TP9, TP10, TP12, TP15, TP16, TP17, TP19, R24	13	Test Point, Multipurpose, White, TH	5012	Keystone
TP2, TP11, TP13, TP18, TP20, TP21, TP22, TP23	8	Test Point, Multipurpose, Black, TH	5011	Keystone
TP14	1	Test Point, Multipurpose, Red, TH	5010	Keystone
TP3, TP4	0	Test Point, Multipurpose, White, TH	5012	Keystone
U3	1	Single Output LDO, 80 mA, Fixed 3.3 V Output, 2.5 to 24 V Input, 6-pin SON (DRV)	TPS715A33DRVR	Texas Instruments
U4	1	1MHz CMOS Silicon Oscillator, SOT-323	MAX7375AXR105-T	Maxim
U5	1	Single Positive-Edge-Triggered D-Type Flip-Flop, (SOT-5)	SN74LVC1G80DCKR	Texas Instruments

## 8 PCB Layout

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

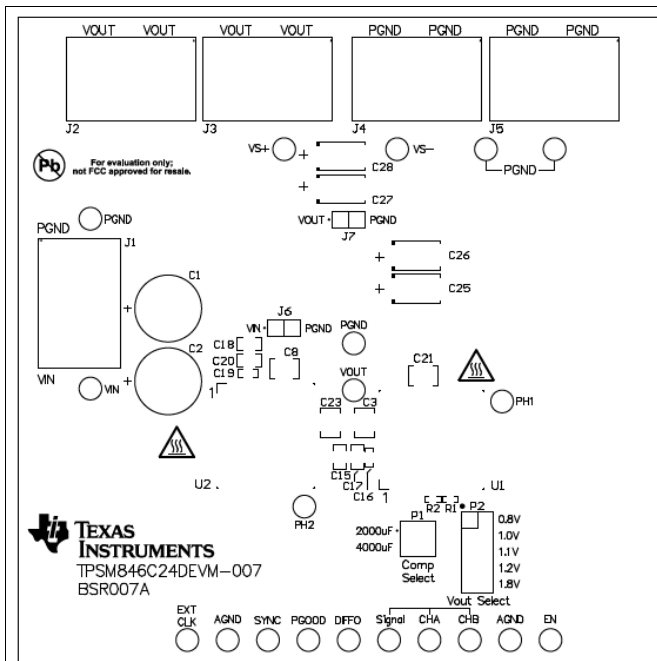


Figure 6. Top Components

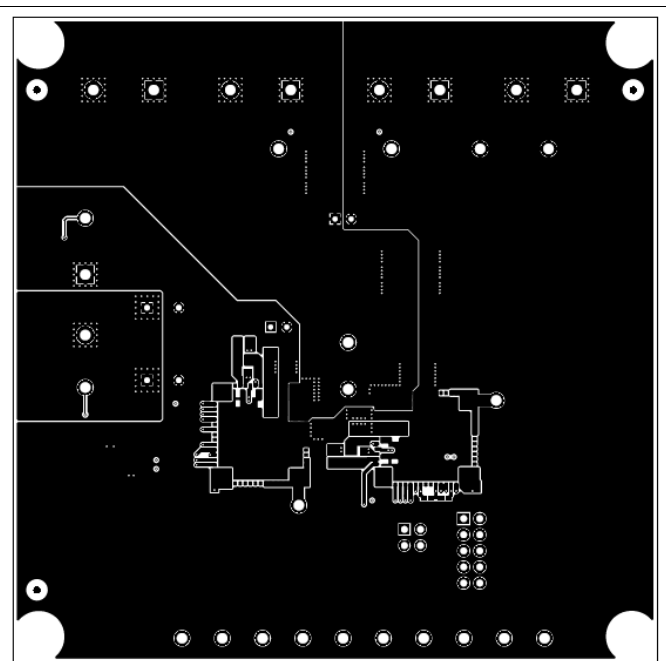


Figure 7. Topside Copper

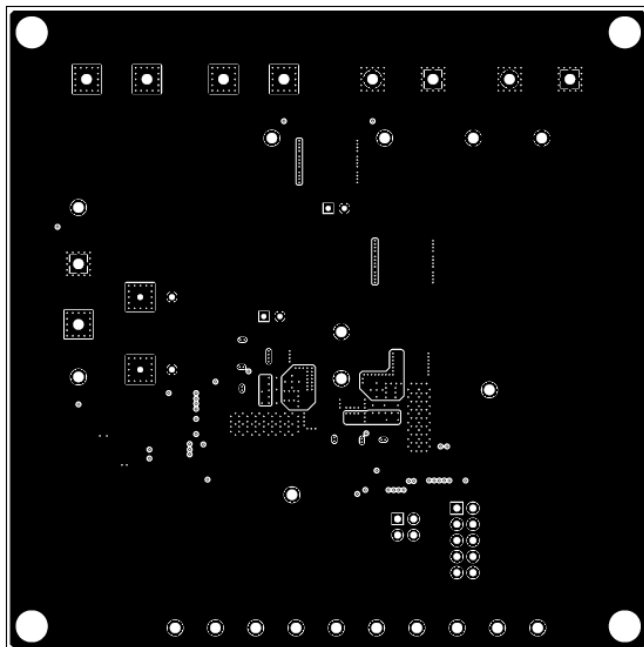


Figure 8. Layer 2 Copper

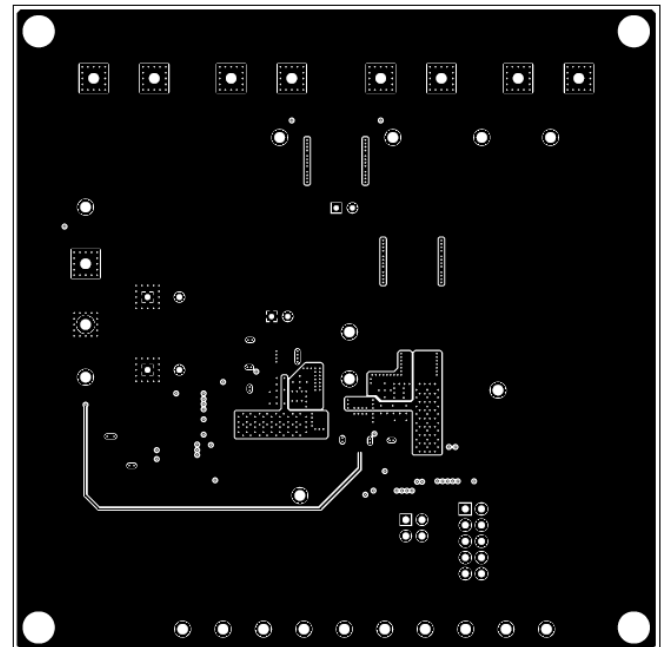


Figure 9. Layer 3 Copper



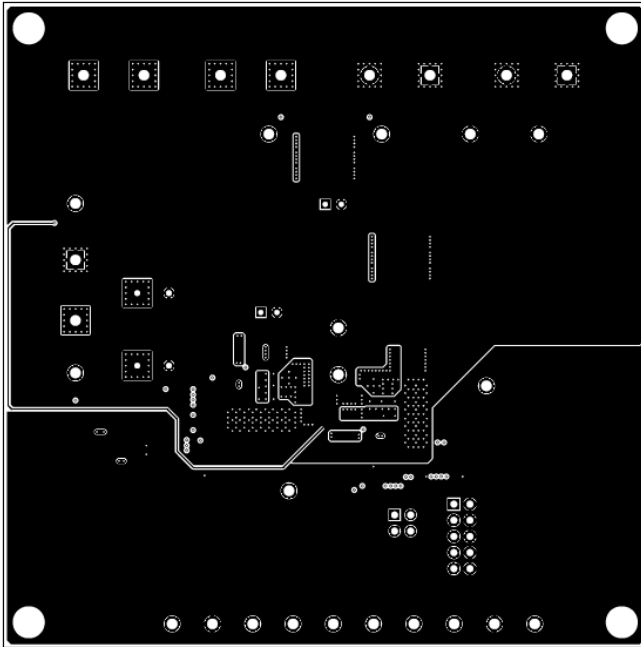


Figure 10. Layer 4 Copper

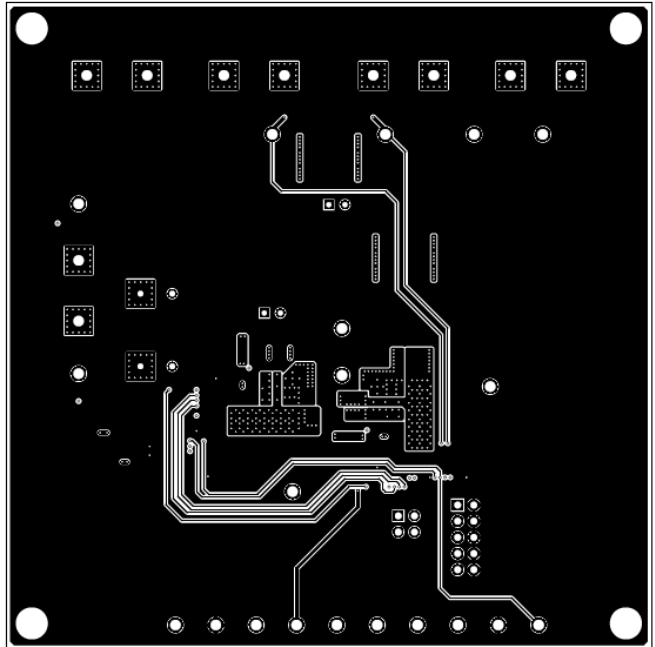


Figure 11. Layer 5 Copper

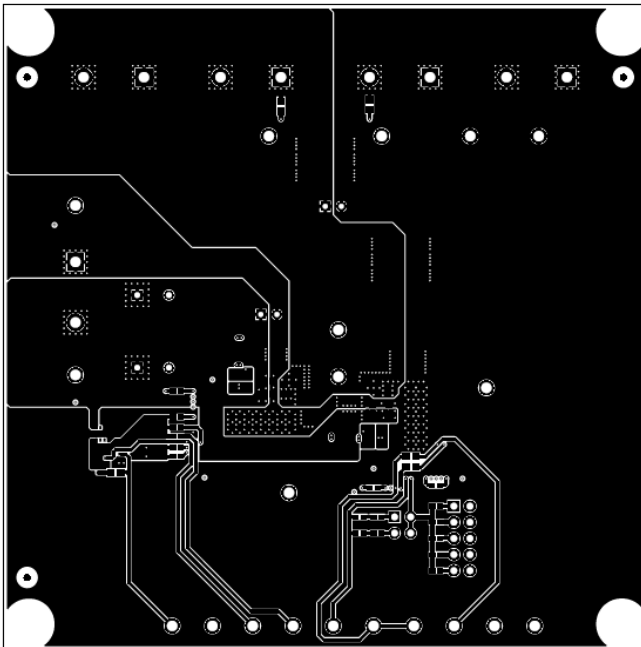


Figure 12. Bottom-Side Copper

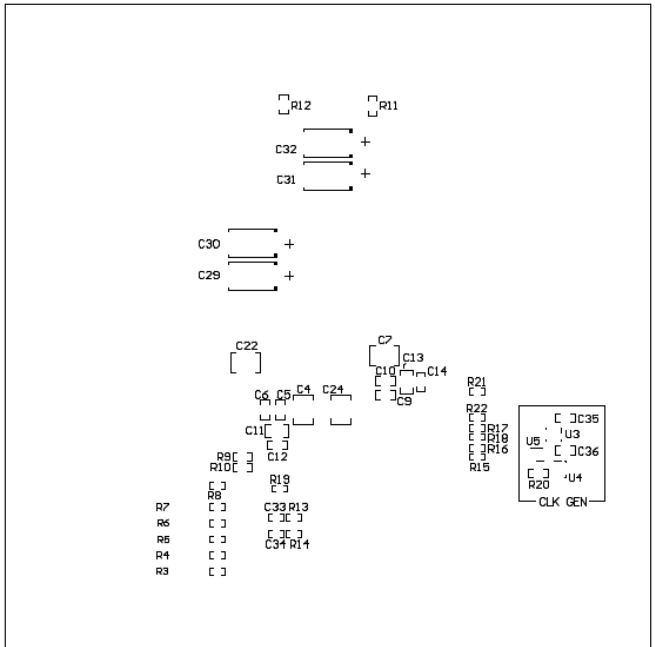


Figure 13. Bottom Components (Bottom View)

## Revision History

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

<b>Changes from Original (December 2017) to A Revision</b>	<b>Page</b>
• Corrected resistor references R18 and R20 .....	<b>4</b>

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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.*

## FCC Interference Statement for Class B EVM devices

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

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

### 3.2 Canada

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

#### Concerning EVMs Including Radio Transmitters:

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

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

#### Concernant les EVMs avec appareils radio:

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

#### Concerning EVMs Including Detachable Antennas:

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

#### Concernant les EVMs avec antennes détachables

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

### 3.3 Japan

3.3.1 *Notice for EVMs delivered in Japan:* Please see [http://www.tij.co.jp/lstds/ti\\_ja/general/eStore/notice\\_01.page](http://www.tij.co.jp/lstds/ti_ja/general/eStore/notice_01.page) 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。  
[http://www.tij.co.jp/lstds/ti\\_ja/general/eStore/notice\\_01.page](http://www.tij.co.jp/lstds/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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3.3.3 *Notice for EVMs for Power Line Communication:* Please see [http://www.tij.co.jp/lstds/ti\\_ja/general/eStore/notice\\_02.page](http://www.tij.co.jp/lstds/ti_ja/general/eStore/notice_02.page)  
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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.

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