User's Guide
SNVU602–May 2019

TPS54240EVM-VSON Regulator Evaluation Module

This user's guide contains information for the TPS54240EVM-VSON evaluation module. Included are the performance specifications, the schematic, and the bill of materials for the TPS54240EVM-VSON.

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1 Introduction

This user's guide contains background information for the TPS54240 as well as support documentation for the TPS54240EVM-VSON evaluation module, which is for the VSON package. Also included are the performance specifications, the schematic, and the bill of materials for the TPS54240EVM-VSON.

1.1 Background

The TPS54240 DC/DC converter is designed to provide up to a 2.5-A output from an input voltage source of 3.5 V to 42 V. Rated input voltage and output current range for the evaluation module are given in Table 1. This evaluation module is designed for VSON package. The switching frequency is internally set at a nominal 500 kHz. The high-side MOSFET is incorporated inside the TPS54240 package along with the gate-drive circuitry. The low drain-to-source on-resistance of the MOSFET allows the TPS54240 to achieve high efficiencies and helps keep the junction temperature low at high output currents. The compensation components are external to the integrated circuit (IC), and an external divider allows for an adjustable output voltage. Additionally, the TPS54240 provides adjustable slow start and undervoltage lockout inputs. The absolute maximum input voltage is 42 V for the TPS54240EVM-VSON.

Table 1. Input Voltage and Output Current Summary

EVM	INPUT VOLTAGE RANGE	OUTPUT CURRENT RANGE
TPS54240EVM-VSON	V_{IN} = 7 V to 24 V	0 A to 2.5 A

Note that EN has an absolute maximum rating of 5 V input and a 1.25-V typical threshold voltage, the selection of R_1 and R_4 limits input voltage range between 7 V and 24 V.

1.2 Performance Specification Summary

A summary of the TPS54240EVM-VSON performance specifications is provided in Table 2. Specifications are given for an input voltage of V_{IN} = 12 V and an output voltage of 3.3 V, unless otherwise specified. The TPS54240EVM-VSON is designed and tested for V_{IN} = 7 V to 24 V. The ambient temperature is 25°C for all measurements, unless otherwise noted. The EVM may be modified by the user to operate from input voltages up to the 42 V operating limit of the TPS54240.

CAUTION

Risk of electric shock for voltages exceeding 50 VDC.

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Table 2. TPS54240EVM-VSON Performance Specification Summary

SPECIFICATION	TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{IN} voltage range			7	12	24	V
Output voltage set point				3.3		V
Output current range	V_{IN} = 10 V to 20 V		0		2.5	A
Load regulation	V_{IN} = 12 V, I_{OUT} = 0.001 A to 2.5 A			±0.06%		
Load transient response	I_{OUT} = 0.5 A to 2.5 A	Voltage change		–30		mV
		Recovery time		1		ms
	I_{OUT} = 2.5 A to 0.5 A	Voltage change		40		mV
		Recovery time		1		ms
Loop bandwidth	V_{IN} = 12 V, I_{OUT} = 2.5 A			36.9		kHz
Phase margin	V_{IN} = 12 V , I_{OUT} =2.5 A			64		°
Input ripple voltage	I_{OUT} = 2.5 A			320		mVpp
Output ripple voltage	I_{OUT}= 2.5 A			20		mVpp
Slow start time				3		ms
Operating frequency				500		kHz
Peak efficiency	TPS54240EVM-VSON, V_{IN} = 12 V, I_{OUT} = 0.7 A			87.7%		
CCM/DCM boundary	V_{IN} = 12 V			0.4		A
Eco-mode™ threshold	V_{IN} = 12 V			45		mA

2 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS54240EVM-VSON evaluation module. The section also includes test results typical for the evaluation module and covers efficiency, output voltage regulation, load transients, loop response, output ripple, input ripple, and start-up.

2.1 Input/Output Connections

The TPS54240EVM-VSON is provided with input/output connectors and test points as shown in Table 3. See Figure 1 for the location of the connectors. A power supply capable of supplying 2.5 A must be connected to J1 and J3 through a pair of 20 AWG wires. The load must be connected to J2 and J3 through a pair of 20 AWG wires. The maximum load current capability must be 2.5 A. Wire lengths must be minimized to reduce losses in the wires. Test-point TP1 provides a place to monitor the V_{IN} input voltages with TP3 providing a convenient ground reference. TP2 is used to monitor the output voltage with TP4 as the ground reference.

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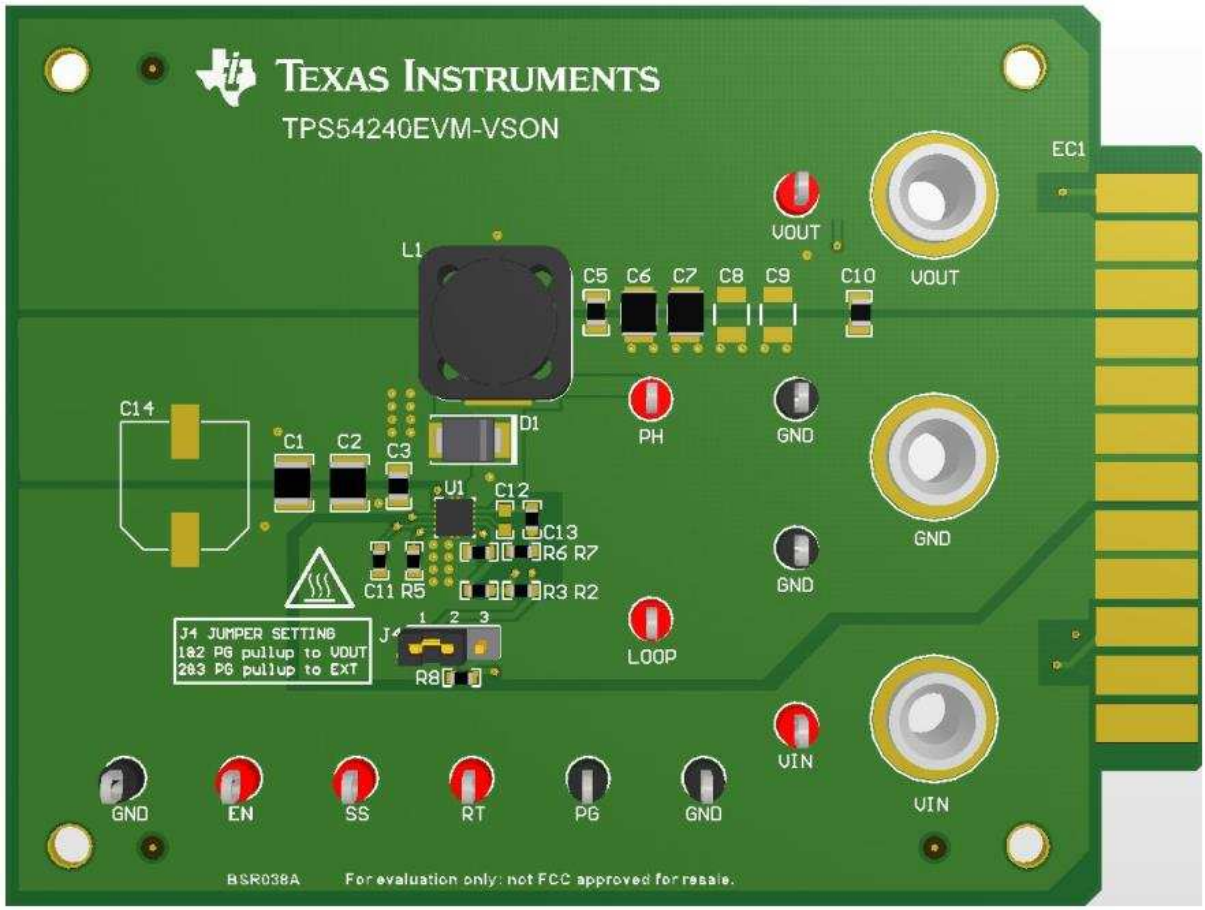


Figure 1. Top View of TPS54240EVM-VSON

Table 3. EVM Connectors and Test Points

REFERENCE DESIGNATOR	FUNCTION
J1	V_{IN} (see Table 1 for V_{IN} range)
J2	V_{OUT}, 3.3 V at 2.5 A maximum
J3	Input and output GND
TP1	V_{IN} test point at V_{IN} connector
TP2	Output voltage test point at OUT connector
TP5	Test point between voltage divider network and output. Used for loop response measurements.
TP6	EN test point. Connect EN to ground to disable, open to enable.
TP7	Slow start monitor test point
TP8	RT test point.
TP11	PWRGD test point
TP12	PH test point
TP3,TP4,TP9,TP10	GND test point

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2.2 Efficiency

The efficiency of this EVM peaks at a load current of about 0.7 A with V_{IN} = 12 V, 18 V, and 24 V. And then decreases as the load current increases towards full load. Figure 2 shows the efficiency for the TPS54240EVM-VSON at an ambient temperature of 25°C.

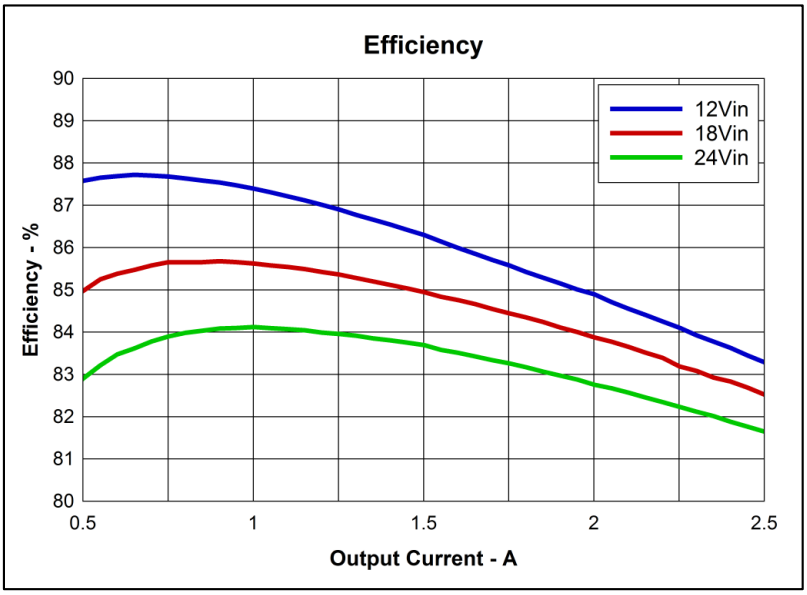


Figure 2. TPS54240EVM-VSON Efficiency

Figure 3 shows the efficiency for the TPS54240EVM-VSON at lower output currents between 0.001 A and 0.5 A at an ambient temperature of 25°C.

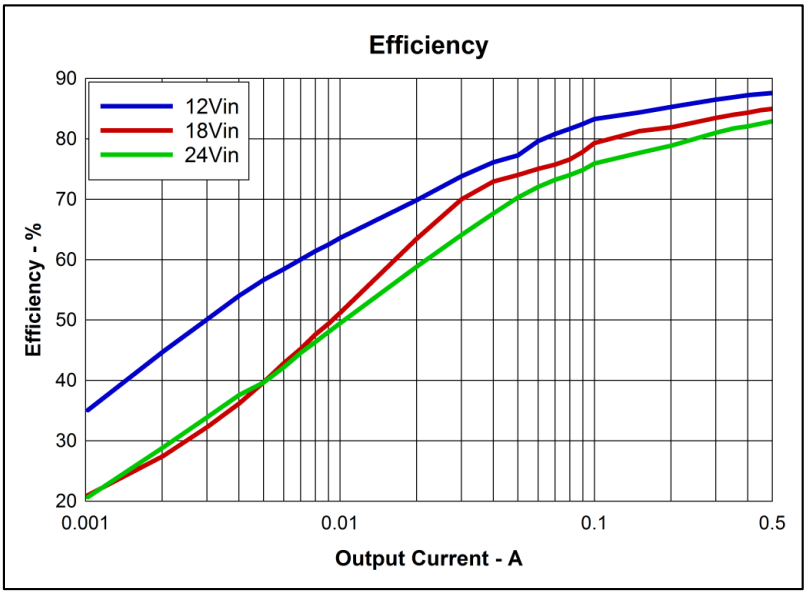


Figure 3. TPS54240EVM-VSON Low Current Efficiency

The efficiency may be lower at higher ambient temperatures, due to temperature variation in the drain-to-source resistance of the internal MOSFET.

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2.3 Output Voltage Load Regulation

The load regulation for the TPS54240EVM-VSON is shown in Figure 4.

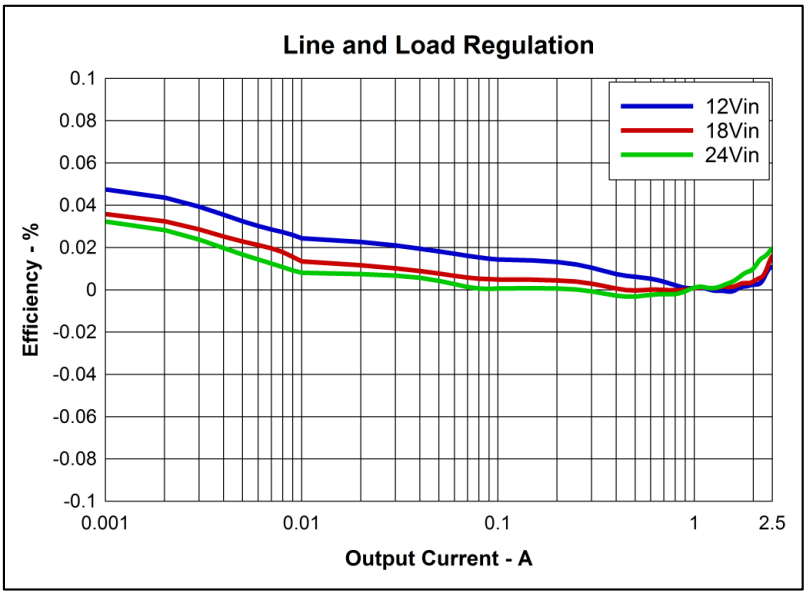


Figure 4. TPS54240EVM-VSON Load Regulation

Measurements are given for an ambient temperature of 25°C.

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2.4 Load Transients

The TPS54240EVM-VSON response to load transients is shown in Figure 5. The current step is from 0.5 A to 2.5 A . The input voltage is 12 V. Total peak-to-peak voltage variation is as shown, including ripple and noise on the output.

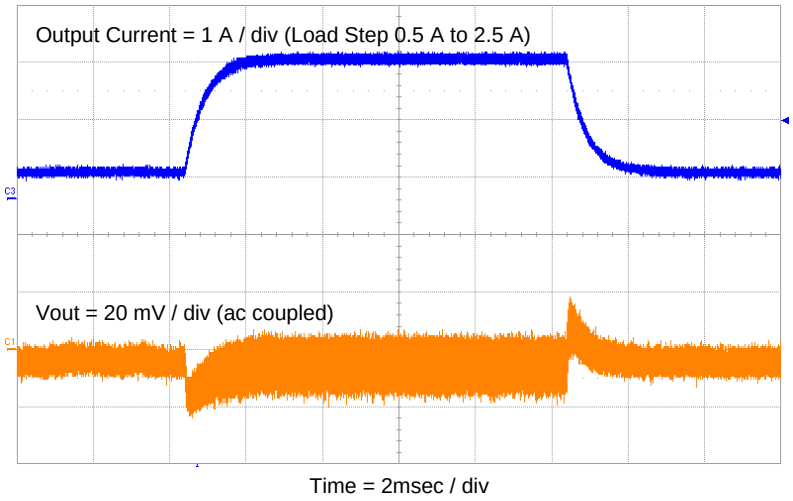


Figure 5. TPS54240EVM-VSON Transient Response

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2.5 Output Voltage Ripple

The output current is the rated full load of 2.5 A and V_{IN} = 12 V. The ripple voltage is measured directly across the output capacitors.

When the output current is greater than one half the peak-to-peak inductor current, the circuit is operating in continuous conduction mode (CCM).The TPS54240EVM-VSON output voltage ripple in CCM mode is shown in Figure 6. The ripple voltage is measured directly across the input capacitors.

When the output current is less than one half the peak to peak inductor current, the circuit is operating in discontinuous conduction mode (DCM). The circuit enters DCM when the nominal output current falls below 400 mA. The TPS54240EVM-VSON output voltage ripple in DCM mode is shown in Figure 7

At light load currents, the TPS54240 is designed to operate in the pulse-skipping Eco-mode™ operation. When the nominal output current falls below 45 mA. typical, the device enters the Eco-mode™ operation. The TPS54240EVM-VSON output voltage ripple in Eco-mode is shown in Figure 8.

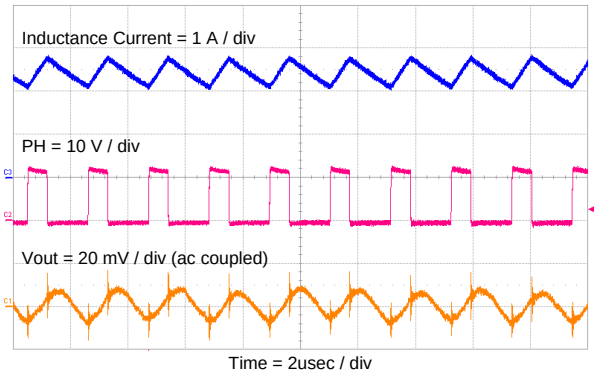


Figure 6. TPS54240EVM-VSON Output Voltage Ripple in CCM Mode at 2.5-A I_{LOAD}

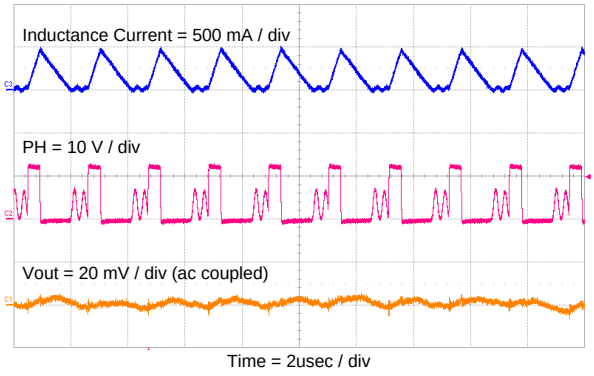


Figure 7. TPS54240EVM-VSON Output Voltage Ripple in DCM Mode at 200-mA I_{LOAD}

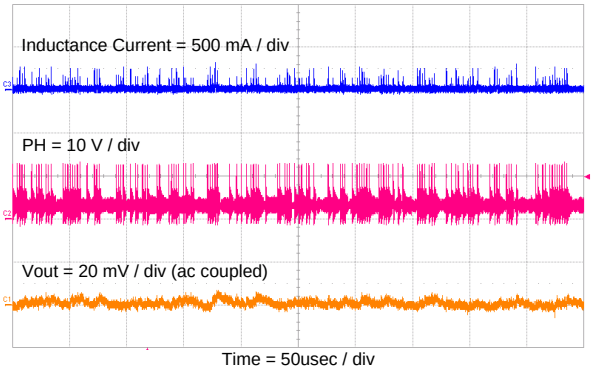


Figure 8. TPS54240EVM-VSON Output Voltage Ripple in Eco-mode™ at 20-mA I_{LOAD}

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2.6 Input Voltage Ripple

The TPS54240EVM-VSON input voltage ripple in CCM mode is shown in Figure 9. The output current is the rated full load of 2.5 A and V_{IN} = 12 V. The ripple voltage is measured directly across the input capacitors. The TPS54240EVM-VSON input voltage ripple in DCM mode is shown in Figure 10. The output current is 200 mA. The TPS54240EVM-VSON input voltage ripple in Eco-mode is shown in Figure 11. The output current is 20 mA.

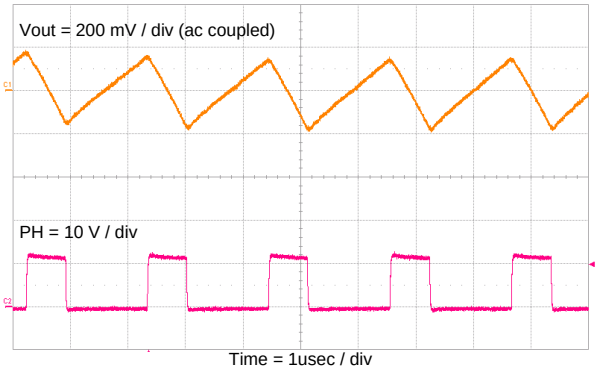


Figure 9. TPS54240EVM-VSON Input Voltage Ripple in CCM mode at 2.5-A I_{LOAD}

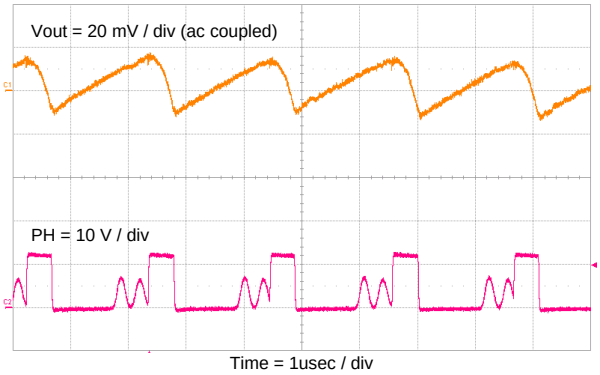


Figure 10. TPS54240EVM-VSON Input Voltage Ripple in DCM Mode at 200 mA I_{LOAD}

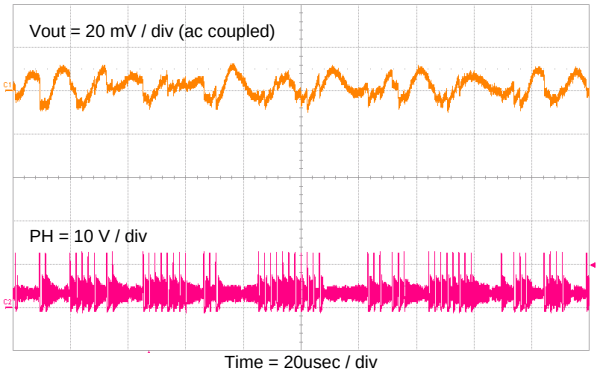


Figure 11. TPS54240EVM-VSON Input Voltage Ripple in Eco-mode™ at 20 mA I_{LOAD}

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2.7 Powering Up

The start-up waveforms are shown in Figure 12. Start-up is relative to V_{IN} rising. The input voltage is initially applied, and when the input reaches the undervoltage lockout threshold, the start-up sequence begins, and the output ramps up at the externally set rate toward the set value of 3.3 V.

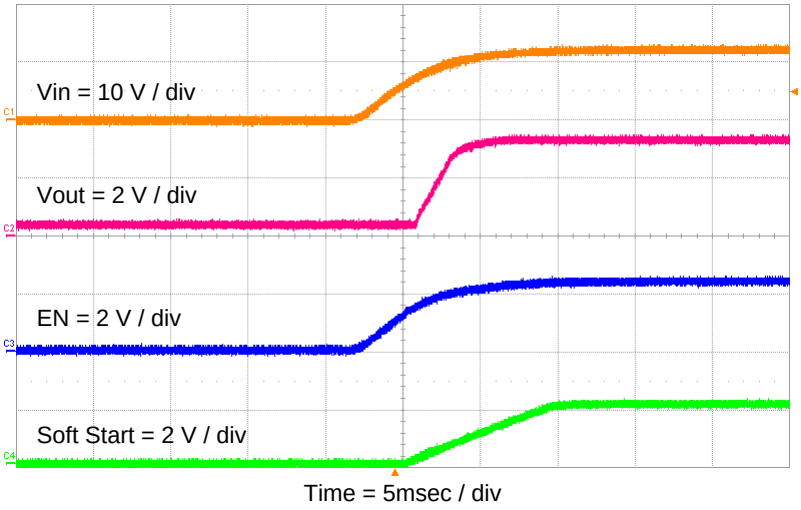


Figure 12. TPS54240EVM-VSON Start-Up

2.8 Power Good Output

The power-good (PWRGD) pin can be pull up by a 10-kΩ resistor to V_{OUT} or an external voltage source. When connected to V_{OUT}, the power good output waveforms are shown in Figure 13. When connected to an external 3.3 V, the power-good output waveforms are shown in Figure 14.

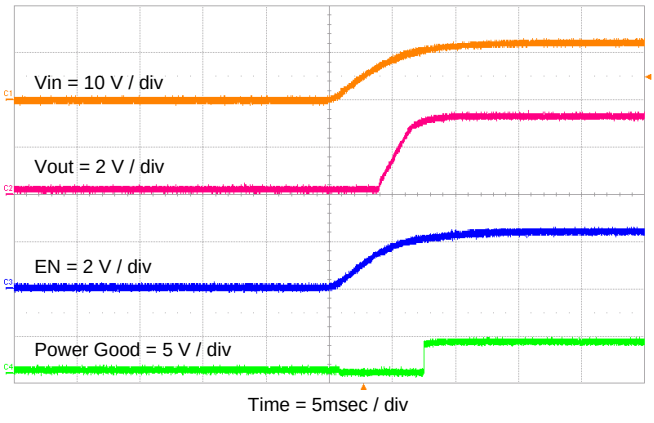


Figure 13. TPS54240EVM-VSON Power-Good Output (pulled up to V_{OUT})

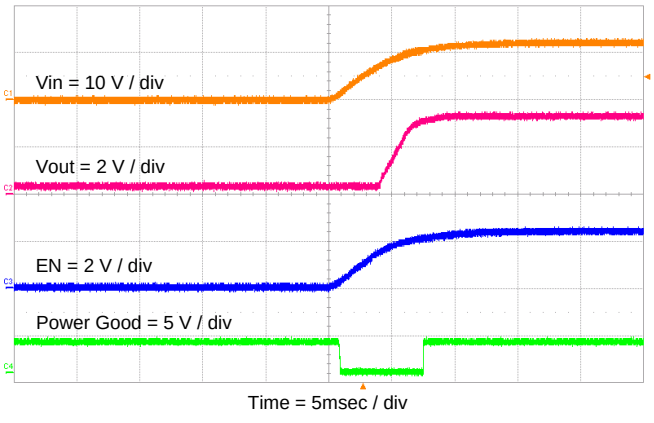


Figure 14. TPS54240EVM-VSON Power-Good Output (Pulled up to external 3.3 V)

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2.9 Loop Characteristics

The TPS54240EVM-VSON loop-response characteristics are shown in Figure 15 . Gain and phase plots are shown for V_{IN} voltage of 12V. Load current for the measurement is 2.5 A.

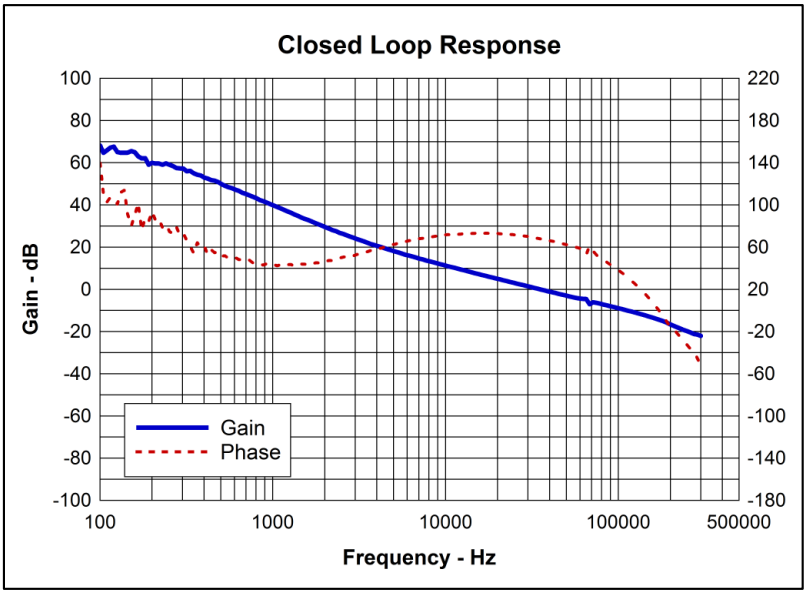


Figure 15. TPS54240EVM-VSON Loop Response

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3 Schematic and Bill of Materials

This section presents the TPS54240EVM-VSON schematic and bill of materials.

3.1 Schematic

Figure 16 is the schematic for the TPS54240EVM-VSON.

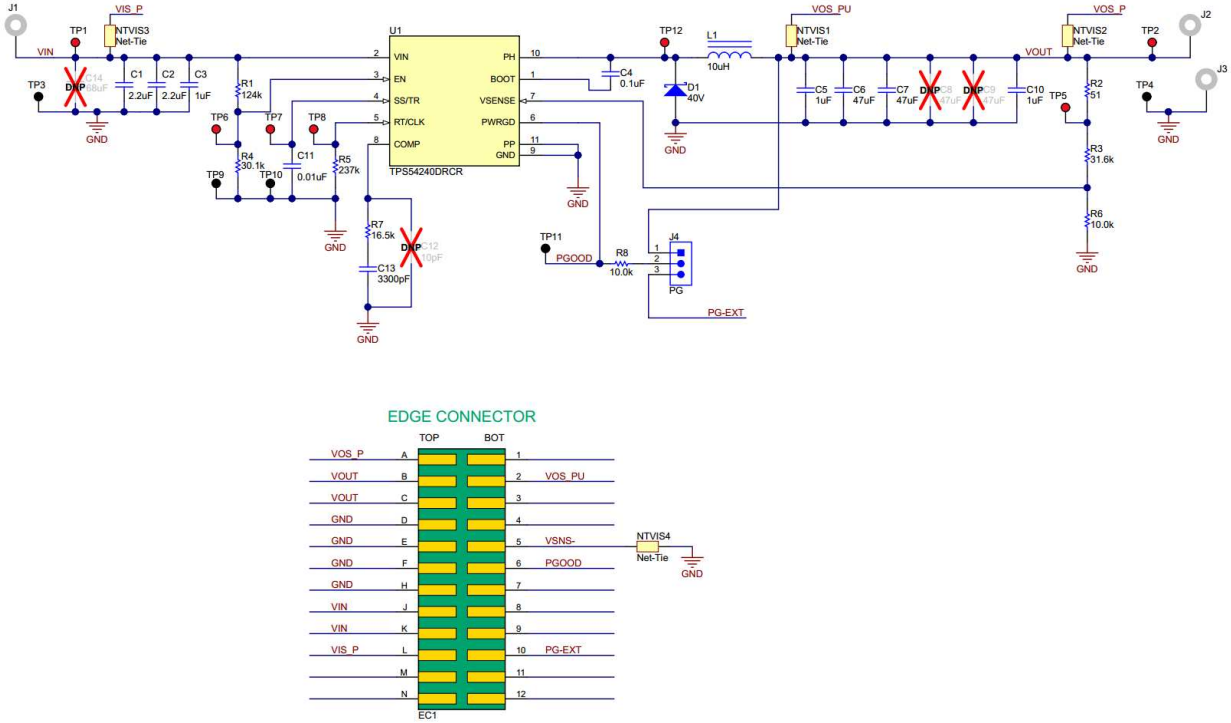


Figure 16. TPS54240EVM-VSON Schematic

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3.2 Bill of Materials

Table 4 presents the bill of materials for the TPS54240EVM-VSON.

Table 4. Bill of Materials

Qty	Designator	Value	Description	Package	PartNumber	Manufacturer
2	C1, C2	2.2uF	CAP, CERM, 2.2 uF, 100 V, +/- 10%, X5R,	1210	Std	Std
1	C11	0.01uF	CAP, CERM, 0.01 uF, 25 V, +/- 10%, X7R, 0603	0603	Std	Std
0	C12	10pF	CAP, CERM, 10 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	Std	Std
1	C13	3300pF	CAP, CERM, 3300 pF, 50 V, +/- 10%, X7R, 0603	0603	Std	Std
0	C14	68uF	CAP, AL, 68 uF, 63 V, +/- 20%, SMD	JA0	Std	Std
3	C3, C5, C10	1uF	CAP, CERM, 1 uF, 25 V, +/- 10%, X7R, 0805	0805	Std	Std
1	C4	0.1uF	CAP, CERM, 0.1 uF, 10 V, +/- 10%, X7R, 0603	0603	Std	Std
2	C6, C7	47uF	CAP, CERM, 47 uF, 10 V, +/- 20%, X5R, 1210	1210	Std	Std
0	C8, C9	47uF	CAP, CERM, 47 uF, 10 V, +/- 20%, X5R, 1210	1210	Std	Std
1	D1	40V	Diode, Schottky, 40 V, 3 A, SMB	SMB	B340B-13-F	Diodes Inc.
3	J1, J2, J3		Standard Banana Jack, Uninsulated, 8.9mm	Keystone575-8	575-8	Keystone
1	J4		Header, 100mil, 3x1, Gold, TH	Header, 100mil, 3x1, TH	HTSW-103-07-G-S	Samtec
1	L1	10uH	Inductor, Shielded Drum Core, Ferrite, 10 uH, 4.09 A, 0.021 ohm, SMD	SMD	74477110	Wurth Elektronik
1	R1	124k	RES, 124 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	Std	Std
1	R2	51	RES, 51, 0.1%, 0.1 W, 0603	0603	Std	Std
1	R3	31.6k	RES, 31.6 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	Std	Std
1	R4	30.1k	RES, 30.1 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	Std	Std
1	R5	237k	RES, 237 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	Std	Std
2	R6, R8	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	0603	Std	Std
1	R7	16.5k	RES, 16.5 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	0603	Std	Std
7	TP1, TP2, TP5, TP6, TP7, TP8, TP12		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	Keystone
5	TP3, TP4, TP9, TP10, TP11		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011	Keystone
1	U1		3.5V to 42V Input, 2.5A Step-Down Converter with Eco-Mode, DRC0010J (VSON-10)	DRC0010J	TPS54240DRCR	Texas Instruments

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4 Board Layout

This section provides a description of the TPS54240EVM-VSON, board layout, and layer illustrations.

4.1 Layout

The board layout for the TPS54240EVM-VSON is shown in Figure 17 through Figure 18. The EVM offers resistors, capacitors and test points to configure the output voltage, enable (EN) pin, set frequency, and external clock synchronization.

The VSON package offers an exposed thermal pad, which must be soldered to the copper landing on the PCB for optimal thermal performance. The PCB consists of a 4-layer design. There are 2-oz copper planes on the top and bottom and 1-oz copper mid-layer planes to dissipate heat with an array of thermal vias under the thermal pad to connect to all four layers.

Test points have been provided for ease of use to connect the power supply, required load and to monitor critical signals. The 12-pin edge connector can also be used to facilitate the use of a cable harness if one is required.

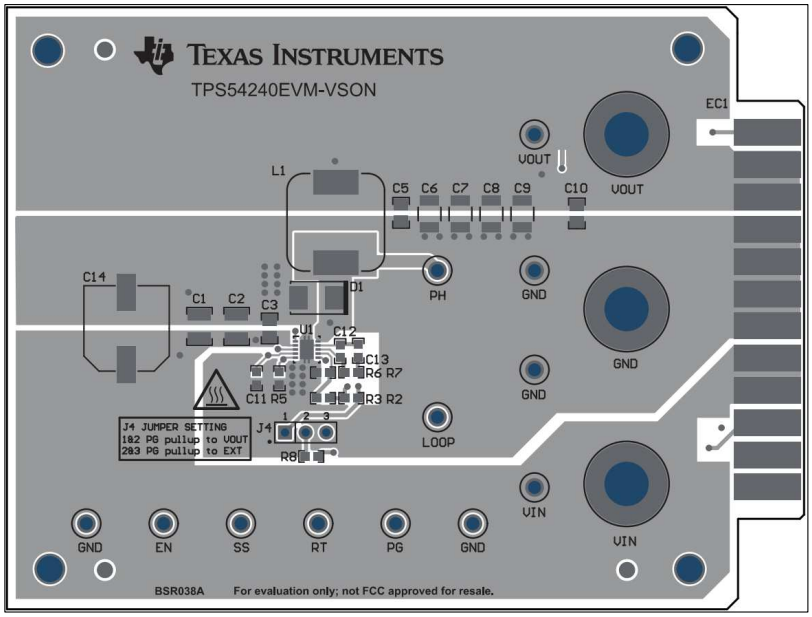


Figure 17. TPS54240EVM-VSON Top-Side Assembly

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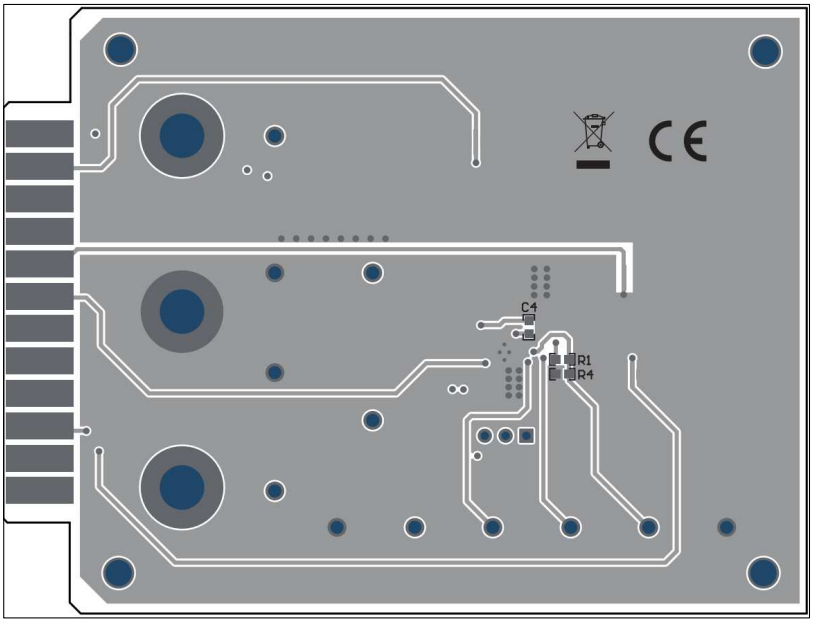


Figure 18. TPS54240EVM-VSON Bottom-Side Assembly

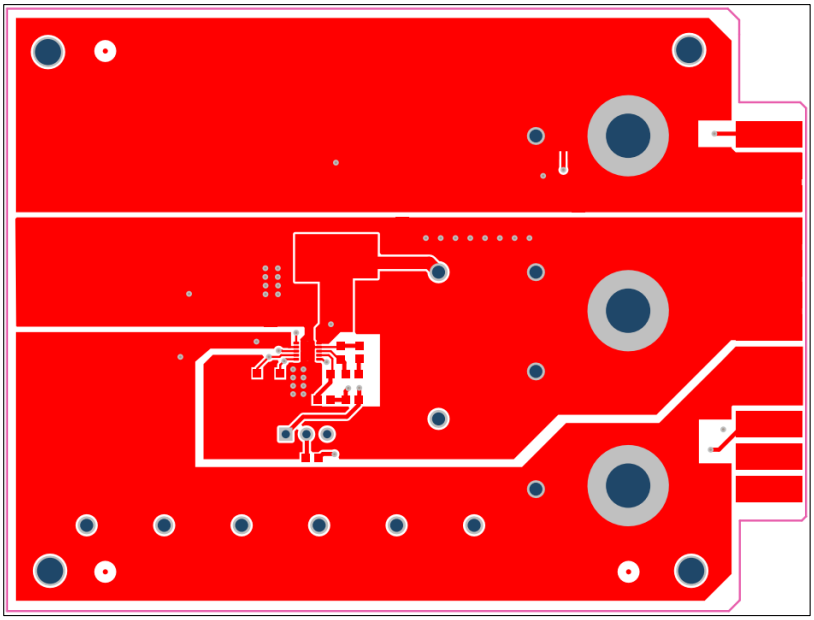


Figure 19. TPS54240EVM-VSON Top-Side Layout

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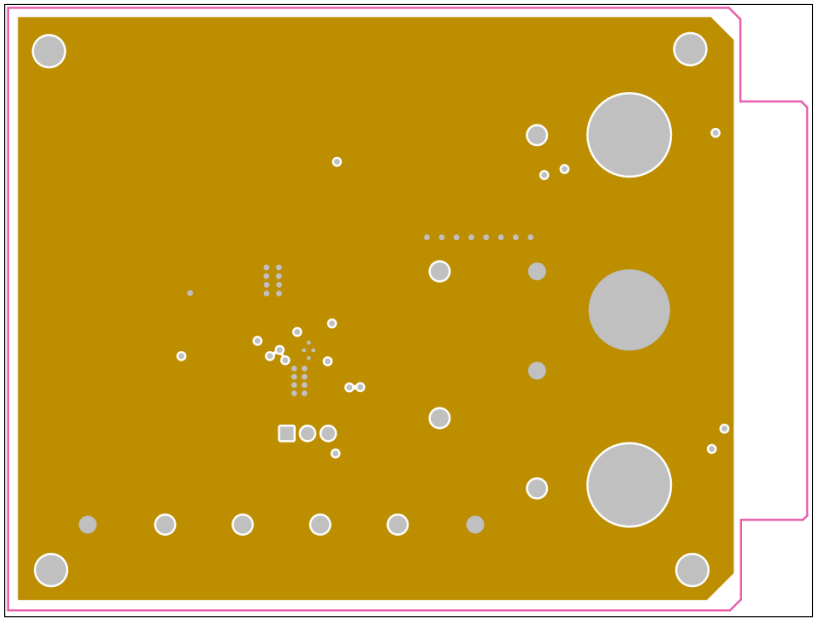


Figure 20. TPS54240EVM-VSON Mid-Layer 1 Layout

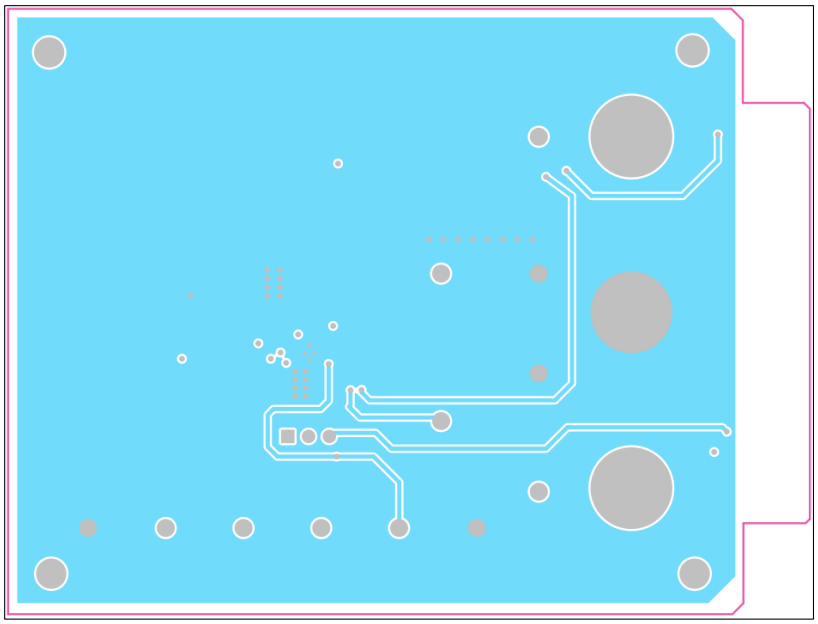


Figure 21. TPS54240EVM-VSON Mid-Layer 2 Layout

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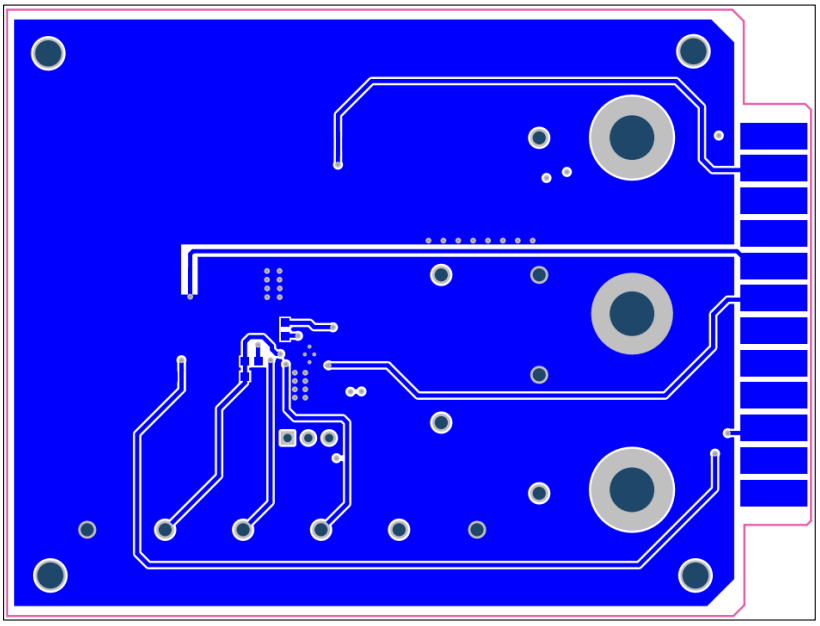


Figure 22. TPS54240EVM-VSON Bottom-Side Layout

4.2 Estimated Circuit Area

The estimated printed-circuit board area for the components used in this design is about 1.5 in^2. This area does not include test points or connectors.

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5 Modifications

These evaluation modules are designed to provide access to the features of the TPS54240. Some modifications can be made to this module.

5.1 Output Voltage Setpoint

The voltage divider of R_3 and R_6 is used to set the output voltage of the EVM. The 51-Ω resistor R_2 is provided as an aid to check the loop response of the circuit. To change the output voltage of the EVM, it is necessary to change the value of resistor R_3. Changing the value of R_3 can change the output voltage above 0.8 V or 90% V_{IN}. The value of R_3 for a specific output voltage can be calculated using Equation 1.

$$R_3 = 10\ k\Omega \times \frac{(V_{OUT} - 0.8\ V)}{0.8\ V} \quad (1)$$

Table 5 lists the R_3 values for some common output voltages. Note that V_{IN} must be in a range so that the minimum on-time is greater than 130 ns, and the maximum duty cycle is less than 90%. Higher duty cycles are possible, but may result in uneven switching behavior. The values given in Table 5 are standard values, not the exact value calculated using Equation 1.

Table 5. Output Voltages Available

OUTPUT VOLTAGE (V)	R_3 VALUE (kΩ)
1.8	12.4
2.5	21.5
3.3	31.6
5	52.3

Be aware that changing the output voltage can affect the loop response. It may be necessary to modify the compensation components. Also, changing output voltage may need to change L_{OUT} and C_{OUT} as well. Check C_{OUT} voltage rating if higher V_{OUT} is used. See the device data sheet for details.

5.2 Operating Frequency, Soft Start, and UVLO

The operating frequency, soft-start time, and UVLO voltage may also be adjusted. R_5 sets the operating frequency, C_{11} sets the soft-start time and the resistor divider of R_1 and R_2 sets the UVLO start and stop voltages. See the TPS54240 device data sheet for details on adjusting these parameters.

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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 DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

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

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

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

CAUTION

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

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

FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 *Canada*

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/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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3.4.1 *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.

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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.

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