TPS54620EVM-374 6-A, SWIFT™ Regulator Evaluation Module

This user's guide contains background information for the TPS54620 as well as support documentation for the TPS54620EVM-374 evaluation module (HPA374). Also included are the performance specifications, the schematic, and the bill of materials for the TPS54620EVM-374.

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1 Introduction

1.1 Background

The TPS54620 dc/dc converter is designed to provide up to a 6 A output. The TPS54620 implements a split input power rails with separate input voltage inputs for the power stage and control circuitry. The power stage input (PVIN) is rated for 1.6 V to 17 V while the control input (VIN) is rated for 4.5 to 17 V. The TPS54620EVM-374 provides both inputs but is designed and tested using the PVIN connected to VIN. Rated input voltage and output current range for the evaluation module are given in Table 1. This evaluation module is designed to demonstrate the small printed-circuit-board areas that may be achieved when designing with the TPS54620 regulator. The switching frequency is externally set at a nominal 480 kHz. The high-side and low-side MOSFETs are incorporated inside the TPS54620 package along with the gate drive circuitry. The low drain-to-source on resistance of the MOSFET allows the TPS54620 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 TPS54620 provides adjustable slow start, tracking and undervoltage lockout inputs. The absolute maximum input voltage is 20 V for the TPS54620EVM-374.

Table 1. Input Voltage and Output Current Summary

EVM	INPUT VOLTAGE RANGE	OUTPUT CURRENT RANGE
TPS54620EVM-374	VIN = 8 V to 17 V (VIN start voltage = 6.521 V)	0 A to 6 A

1.2 Performance Specification Summary

A summary of the TPS54620EVM-374 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 TPS54620EVM-374 is designed and tested for V_{IN} = 8 V to 17 V with the VIN and PVIN pins connect together with the J3 jumper. The ambient temperature is 25°C for all measurements, unless otherwise noted.

Table 2. TPS54620EVM-374 Performance Specification Summary

SPECIFICATION	TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{IN} voltage range (PVIN = VIN)			8	12	17	V
V_{IN} start voltage				6.521		V
V_{IN} stop voltage				6.065		V
Output voltage set point				3.3		V
Output current range	V_{IN} = 8 V to 17 V		0		6	A
Line regulation	I_O = 3 A, V_{IN} = 8 V to 17 V			±0.02%		
Load regulation	V_{IN} = 12 V, I_O = 0 A to 6 A			±0.012%		
Load transient response	I_O = 1.5 A to 4.5 A	Voltage change		–100		mV
		Recovery time		60		µs
	I_O = 4.5 A to 1.5 A	Voltage change		100		mV
		Recovery time		120		µs
Loop bandwidth	V_{IN} = 12 V, I_O = 6 A			43		kHz
Phase margin	V_{IN} = 12 V , I_O = 6 A			52		°
Input ripple voltage	I_O = 6 A			520		mVPP
Output ripple voltage	I_O = 6 A			20		mVPP
Output rise time				4		ms
Operating frequency				480		kHz
Maximum efficiency	TPS54620EVM-374 , V_{IN} = 8 V, I_O = 2 A			95%		

1.3 Modifications

These evaluation modules are designed to provide access to the features of the TPS54620. Some modifications can be made to this module.

1.3.1 Output Voltage Set Point

The output voltage is set by the resistor divider network of R8 and R9. R9 is fixed at 10 kΩ. To change the output voltage of the EVM, it is necessary to change the value of resistor R8. Changing the value of R8 can change the output voltage above 0.8 V. The value of R8 for a specific output voltage can be calculated using Equation 1.

$$R8 = \frac{10\,k\Omega\,(V_{OUT} - 0.8\,V)}{0.8\,V} \quad (1)$$

Table 3 lists the R8 values for some common output voltages. Note that V_{IN} must be in a range so that the minimum on-time is greater than 120 ns, and the maximum duty cycle is less than 95%. The values given in Table 3 are standard values, not the exact value calculated using Equation 1.

Table 3. Output Voltages Available

Output Voltage (V)	R8 Value (kΩ)
1.8	12.4
2.5	21.5
3.3	31.6
5	52.3

1.3.2 Slow Start Time

The slow start time can be adjusted by changing the value of C7. Use Equation 2 to calculate the required value of C7 for a desired slow start time

$$C7(nF) = \frac{Tss(ms) \times Iss(\mu A)}{Vref(V)} \quad (2)$$

The EVM is set for a slow start time of 4 msec using C7 = 0.01 µF.

1.3.3 Track In

The TPS54620 can track an external voltage during start up. The J5 connector is provided to allow connection to that external voltage. Ratio-metric or simultaneous tracking can be implemented using resistor divider R5 and R6. See the TPS54620 data sheet (SLVS949) for details.

1.3.4 Adjustable UVLO

The under voltage lock out (UVLO) ca be adjusted externally using R1 and R2. The EVM is st for a start voltage of 6.521 V and a stop voltage of 6.065 V using R1 = 35.7 kΩ and R2 = 8.06 kΩ. Use Equation 3 and Equation 4 to calculate required resistor values for different start and stop voltages.

$$R1 = \frac{V_{START}\left(\frac{V_{ENFALLING}}{V_{ENRISING}}\right) - V_{STOP}}{I_p\left(1 - \frac{V_{ENFALLING}}{V_{ENRISING}}\right) + I_h} \quad (3)$$

$$R2 = \frac{R1 \times V_{ENFALLING}}{V_{STOP} - V_{ENFALLING} + R1(I_p + I_h)} \quad (4)$$

1.3.5 Input Voltage Rails

The EVM is designed to accommodate different input voltage levels for the power stage and control logic. During normal operation, the PVIN and VIN inputs are connected together using a jumper across J3. The single input voltage is supplied at J1. If desired, these to input voltage rails may be separated by removing the jumper across J3. Two input voltages must then be provided at both J1 and J2.

2 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS54620EVM-374 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 TPS54620EVM-374 is provided with input/output connectors and test points as shown in Table 4. A power supply capable of supplying 4 A must be connected to J1 through a pair of 20 AWG wires. The jumper across J3 must be in place. See Section 1.3.5 for split input voltage rail operation. The load must be connected to J7 through a pair of 20 AWG wires. The maximum load current capability must be 6 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 TP2 providing a convenient ground reference. TP8 is used to monitor the output voltage with TP9 as the ground reference.

Table 4. EVM Connectors and Test Points

Reference Designator	Function
J1	PVIN input voltage connector. (see Table 1 for V_{IN} range).
J2	VIN input voltage connector. Not normally used.
J3	PVIN to VIN jumper. Normally closed to tie VIN to PVIN for common rail voltage operation.
J24	2-pin header for enable. Connect EN to ground to disable, open to enable.
J5	2-pin header for tracking voltage input and ground.
J6	2-pin header for tracking output and ground.
J7	V_{OUT}, 3.3 V at 6 A maximum.
TP1	PVIN test point at PVIN connector.
TP2	GND test point at PVIN connector.
TP3	VIN test point at VIN connector.
TP4	GND test point at VIN connector.
TP5	PH test point.
TP6	Slow start / track in test point.
TP7	Test point between voltage divider network and output. Used for loop response measurements.
TP8	Output voltage test point at VOUT connector
TP9	GND test point at VOUT connector
TP10	PWRGD test point.

2.2 Efficiency

The efficiency of this EVM peaks at a load current of about 2 A and then decreases as the load current increases towards full load. Figure 1 shows the efficiency for the TPS54620EVM-374 at an ambient temperature of 25°C.

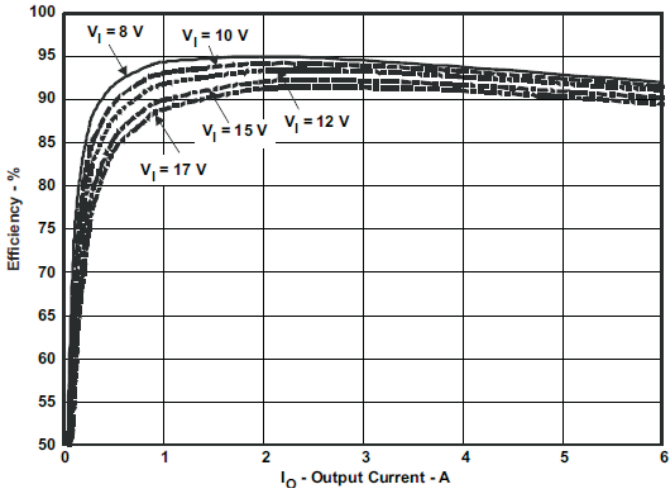

Figure 1. TPS54620EVM-374 Efficiency

Figure 2 shows the efficiency for the TPS54620EVM-374 at lower output currents below 0.10 A at an ambient temperature of 25°C.

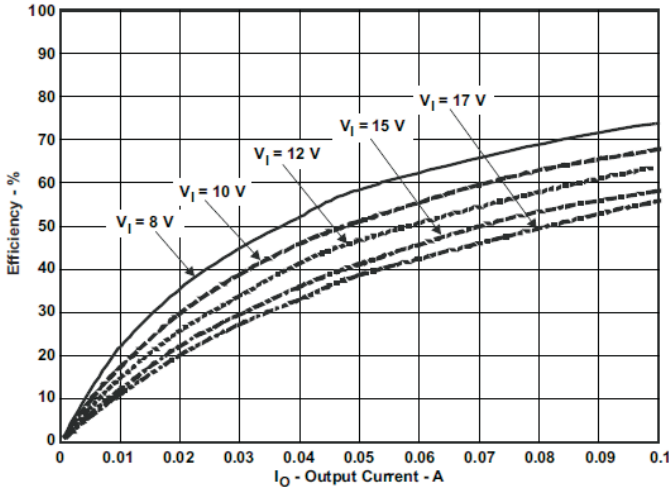

Figure 2. TPS54620EVM-374 Low Current Efficiency

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

2.3 Output Voltage Load Regulation

Figure 3 shows the load regulation for the TPS54620EVM-374.

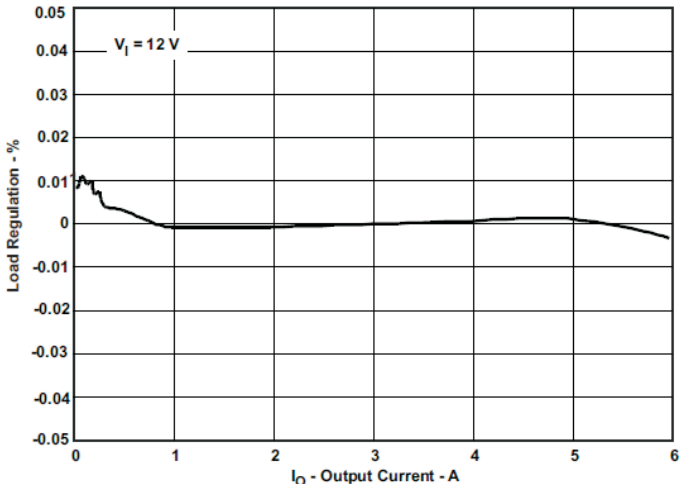

Figure 3. TPS54620EVM-374 Load Regulation

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

2.4 Output Voltage Line Regulation

Figure 4 shows the line regulation for the TPS54620EVM-374.

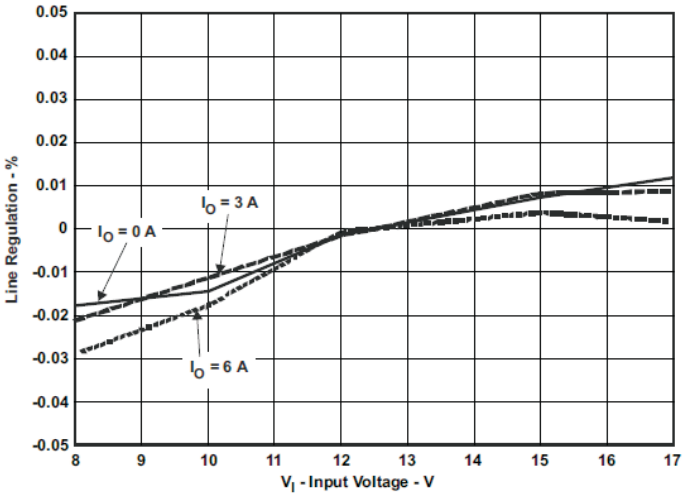

Figure 4. TPS54620EVM-374 Line Regulation

2.5 Load Transients

Figure 5 shows the TPS54620EVM-374 response to load transients. The current step is from 25% to 75% of maximum rated load at 12 V input. Total peak-to-peak voltage variation is as shown, including ripple and noise on the output.

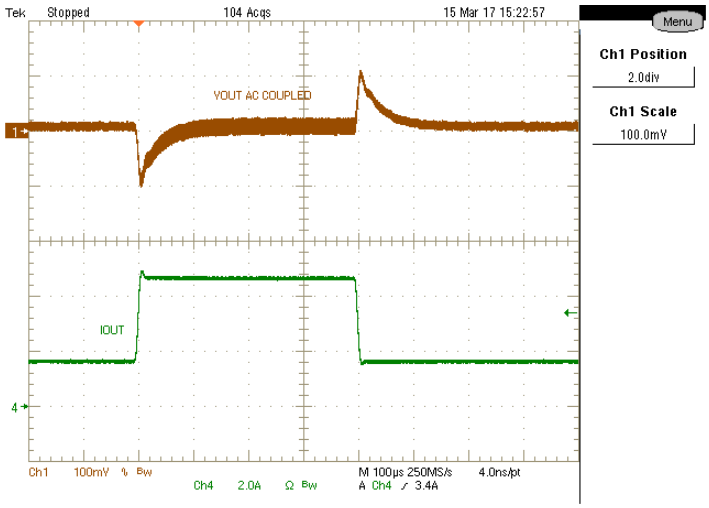

Figure 5. TPS54620EVM-374 Transient Response

2.6 Loop Characteristics

Figure 6 shows the TPS54620EVM-374 loop-response characteristics. Gain and phase plots are shown for V_{IN} voltage of 12 V. Load current for the measurement is 6 A.

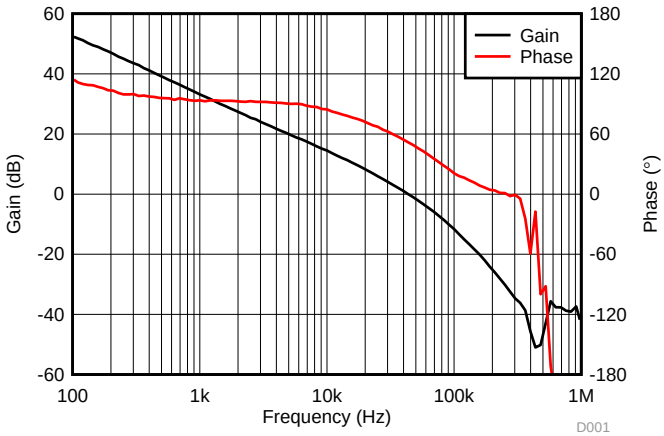

Figure 6. TPS54620EVM-374 Loop Response

2.7 Output Voltage Ripple

Figure 7 shows the TPS54620EVM-374 output voltage ripple. The output current is the rated full load of 6 A and V_{IN} = 12 V. The ripple voltage is measured directly across the output capacitors.

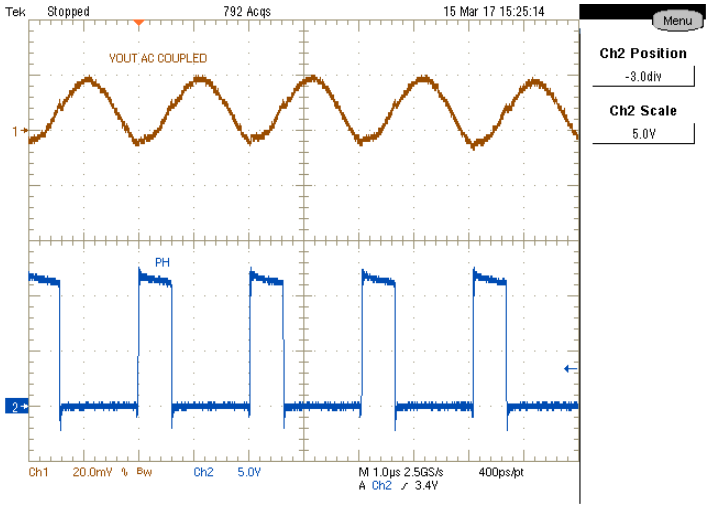

Figure 7. TPS54620EVM-374 Output Ripple

2.8 Input Voltage Ripple

Figure 8 shows the TPS54620EVM-374 input voltage. The output current is the rated full load of 4 A and V_{IN} = 12 V. The ripple voltage is measured directly across the input capacitors.

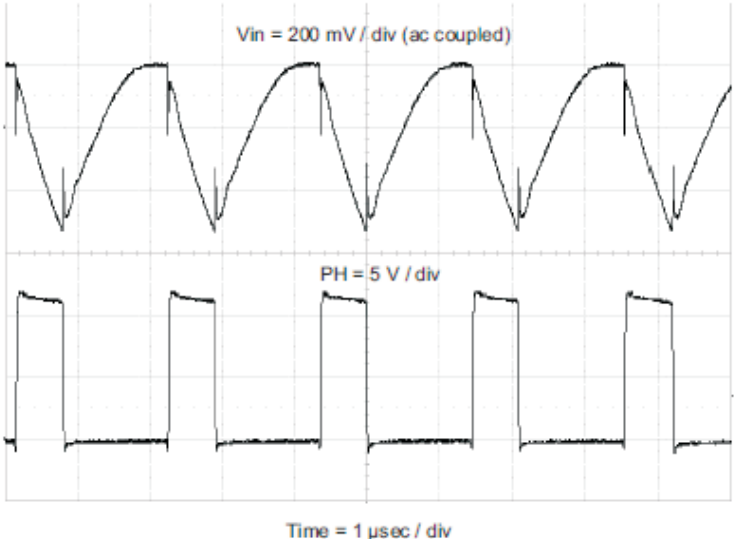

Figure 8. TPS54620EVM-374 Input Ripple

2.9 Powering Up

Figure 9 and Figure 10 show the start-up waveforms for the TPS54620EVM-374 . In Figure 9, the output voltage ramps up as soon as the input voltage reaches the UVLO threshold as set by the R1 and R2 resistor divider network. In Figure 10, the input voltage is initially applied and the output is inhibited by using a jumper at J2 to tie EN to GND. When the jumper is removed, EN is released. When the EN voltage reaches the enable-threshold voltage, the start-up sequence begins and the output voltage ramps up to the externally set value of 3.3 V. The input voltage for these plots is 12 V and the load is 1Ω.

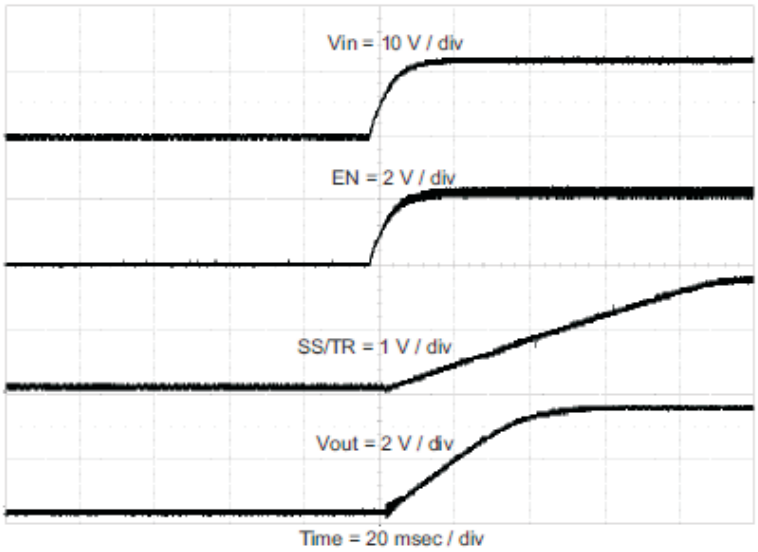

Figure 9. TPS54620EVM-374 Start-Up Relative to V_{IN}

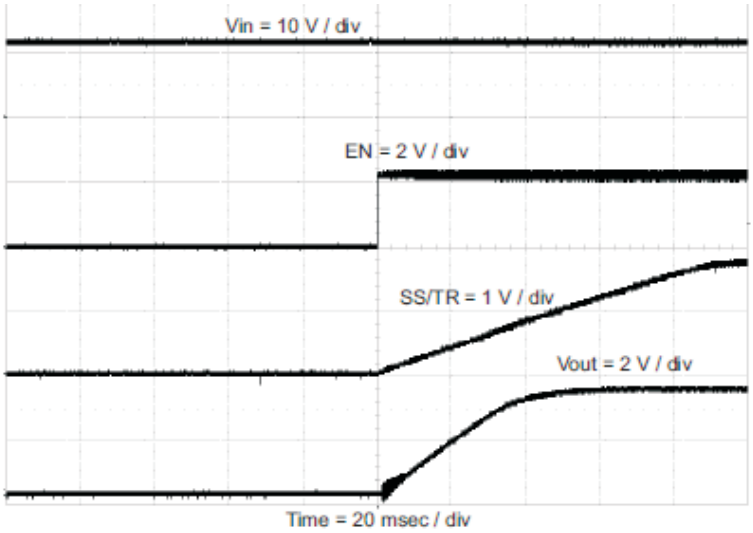

Figure 10. TPS54620EVM-374 Start-up Relative to Enable

2.10 Thermal Characteristics

This section shows a thermal image of the TPS54620EVM-374 running at 12 V input and 6 A load. there is no air flow and the ambient temperature is 25°C. The peak temperature of the IC (70°C) is well below the maximum recommended operating condition listed in the data sheet of 150°C.

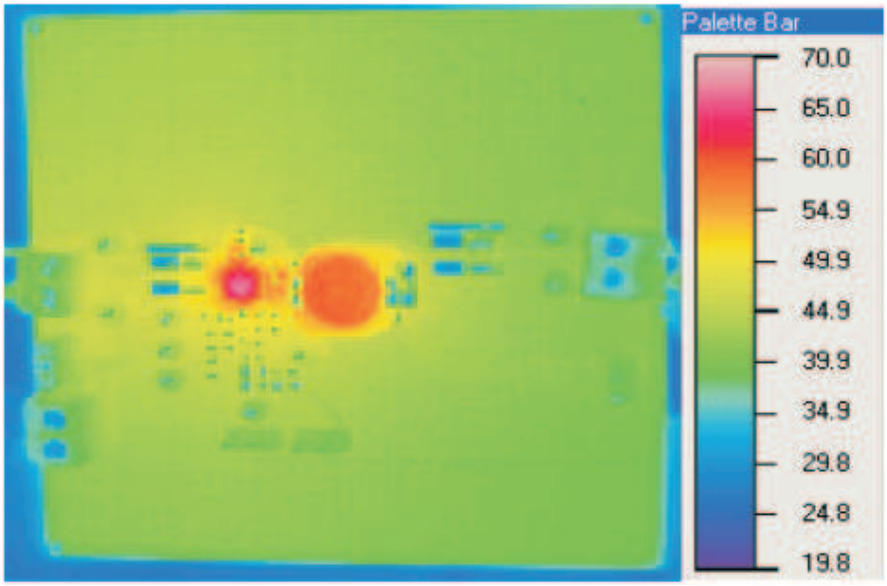

Figure 11. TPS54620EVM-374 Thermal Image

3 Board Layout

This section provides a description of the TPS54620EVM-374 , board layout, and layer illustrations.

3.1 Layout

The board layout for the TPS54620EVM-374 is shown in Figure 12 through Figure 16. The topside layer of the EVM is laid out in a manner typical of a user application. The top, bottom and internal layers are 2-oz. copper.

The top layer contains the main power traces for PVIN, VIN, V_{OUT}, and VPHASE. Also on the top layer are connections for the remaining pins of the TPS54620 and a large area filled with ground. The bottom and internal ground layers contains ground planes only. The top side ground traces are connected to the bottom and internal ground planes with multiple vias placed around the board including two vias directly under the TPS54620 device to provide a thermal path from the top-side ground plane to the bottom-side ground plane.

The input decoupling capacitors (C2, and C3) and bootstrap capacitor (C5) are all located as close to the IC as possible. In addition, the voltage set-point resistor divider components are also kept close to the IC. The voltage divider network ties to the output voltage at the point of regulation, the copper V_{OUT} trace at the J7 output connector. For the TPS54620, an additional input bulk capacitor may be required, depending on the EVM connection to the input supply. Critical analog circuits such as the voltage setpoint divider, frequency set resistor, slow start capacitor and compensation components are terminated to ground using a wide ground trace separate from the power ground pour.

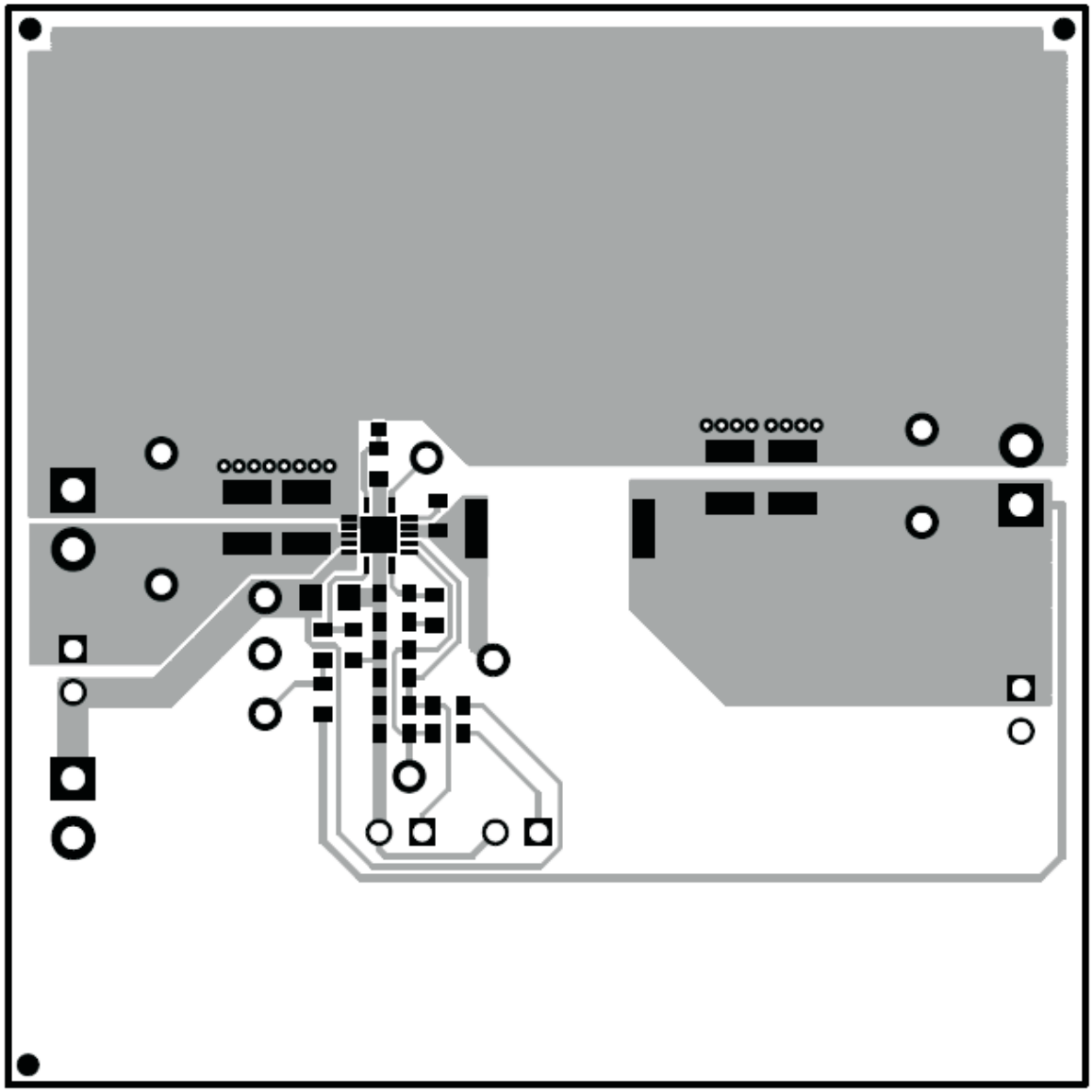

Figure 12. TPS54620EVM-374 Top-Side Layout

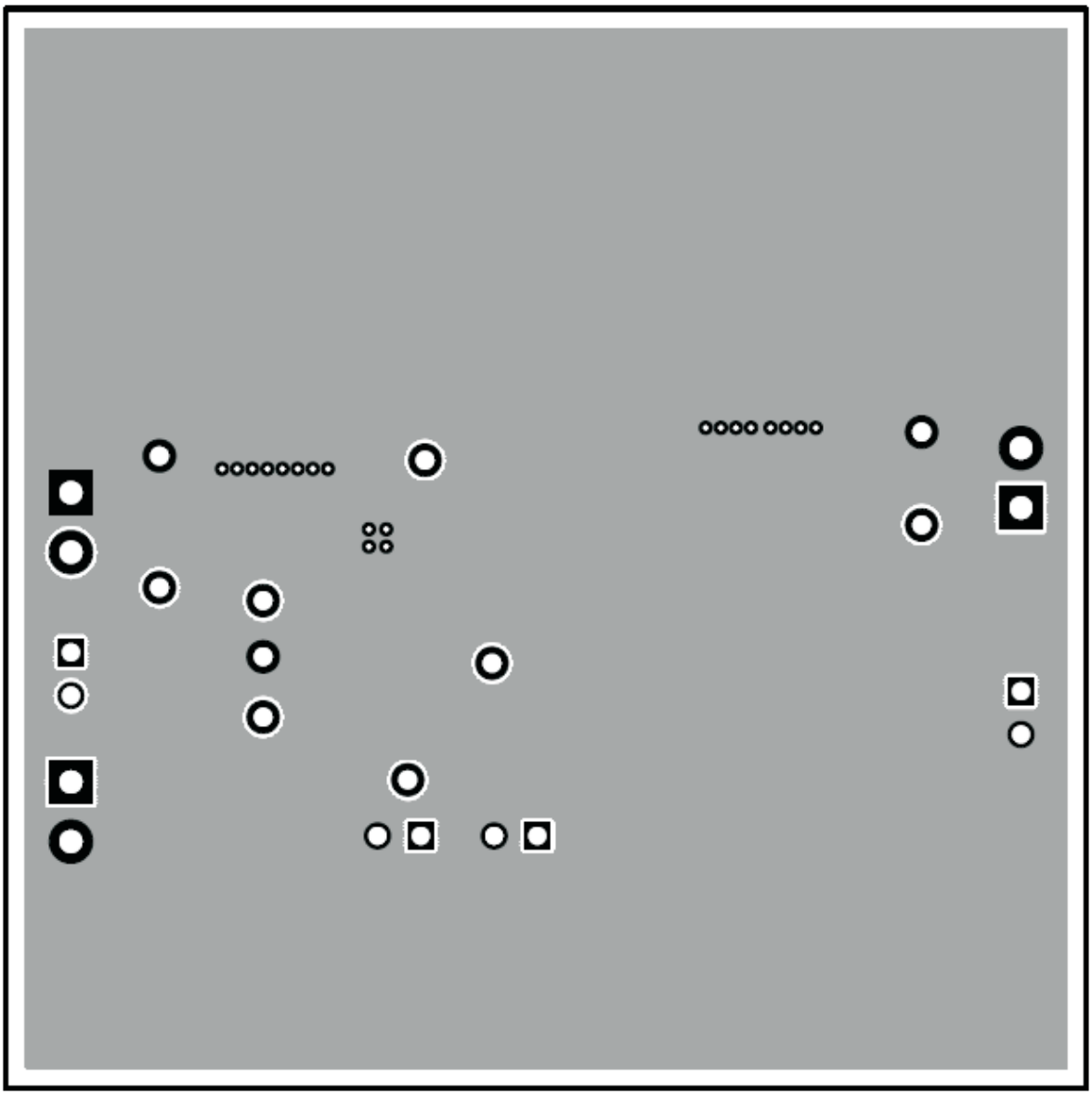

Figure 13. TPS54620EVM-374 Layout 2

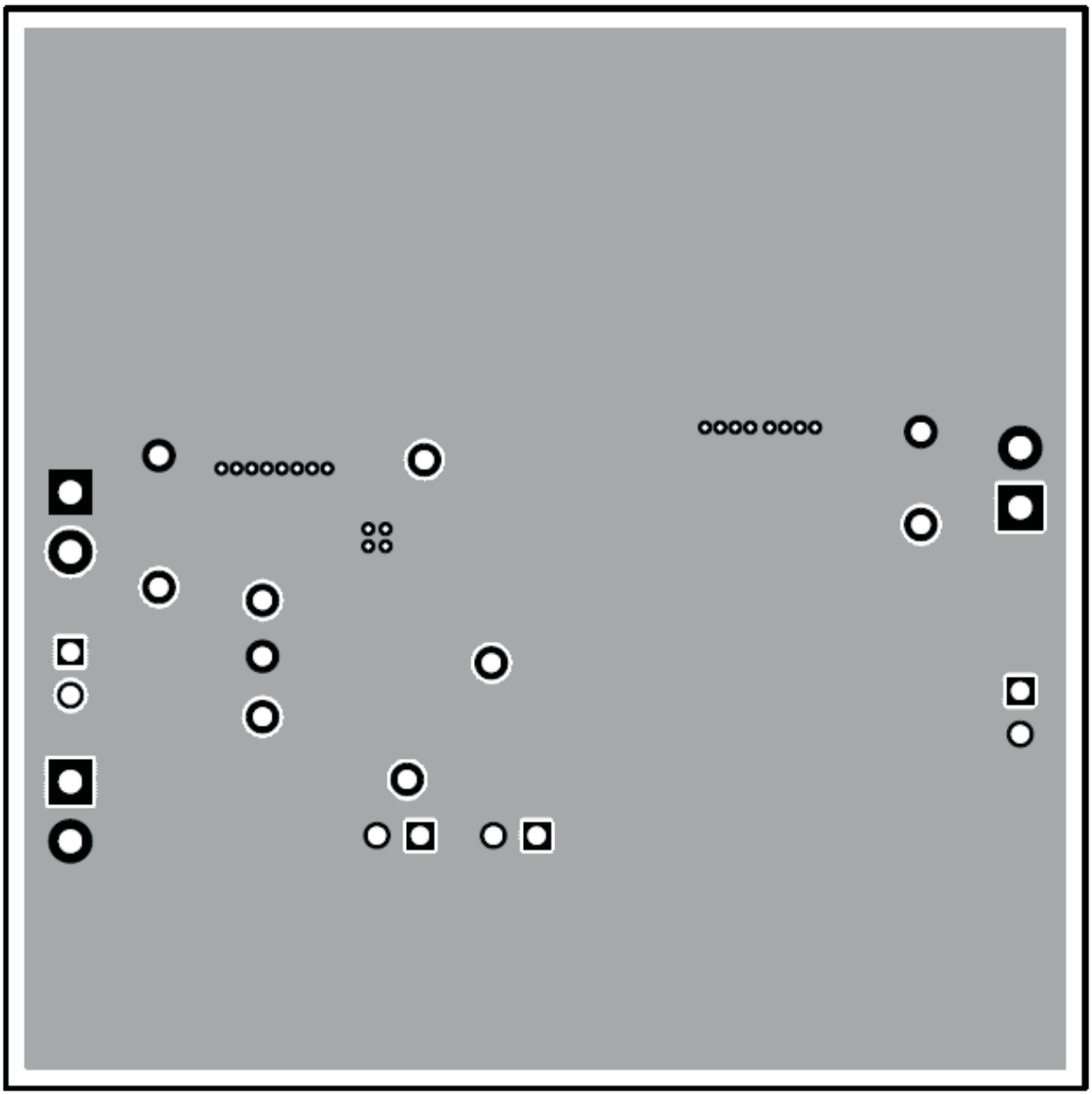

Figure 14. TPS54620EVM-374 Layout 3

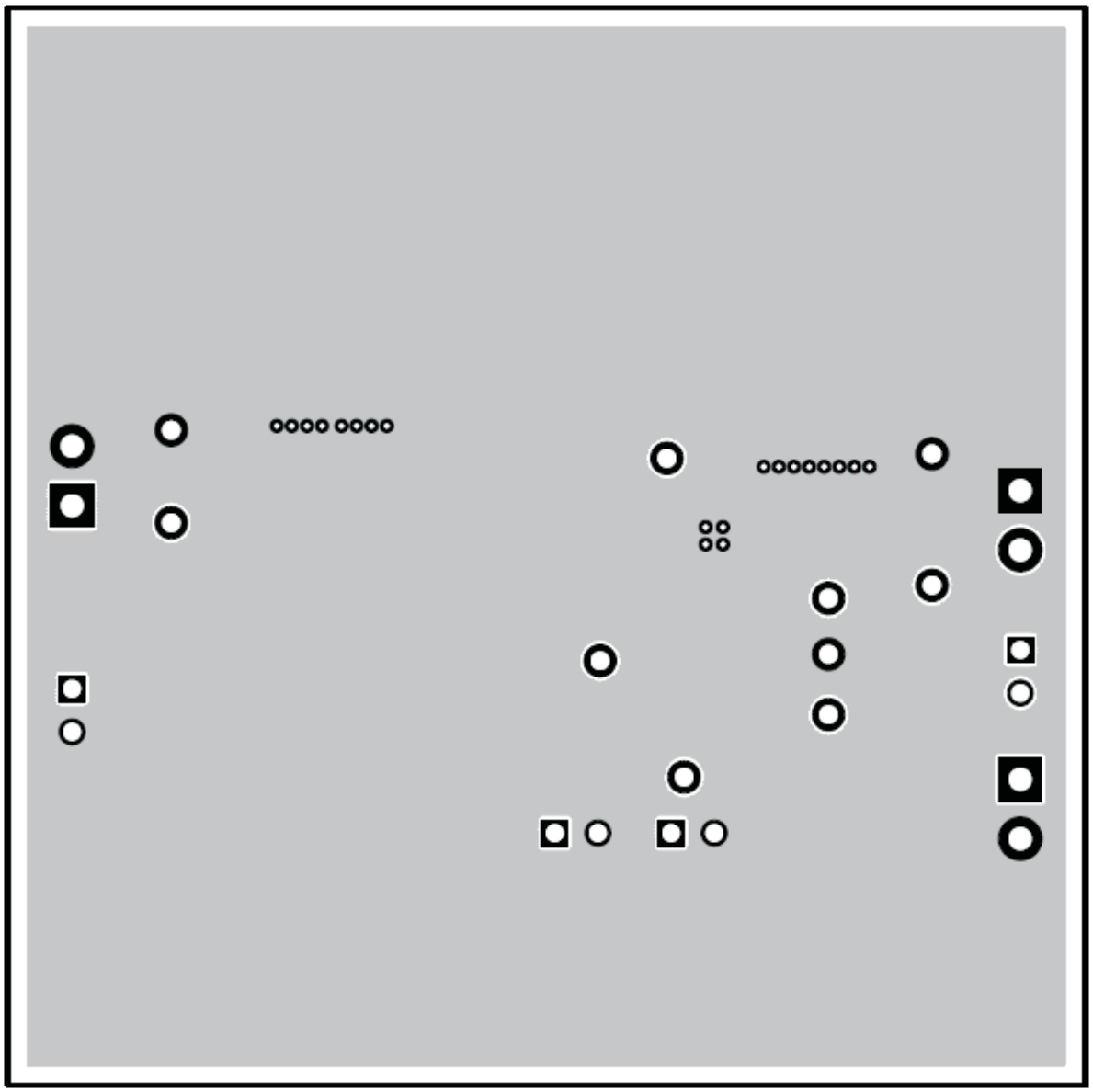

Figure 15. TPS54620EVM-374 Bottom-Side layout

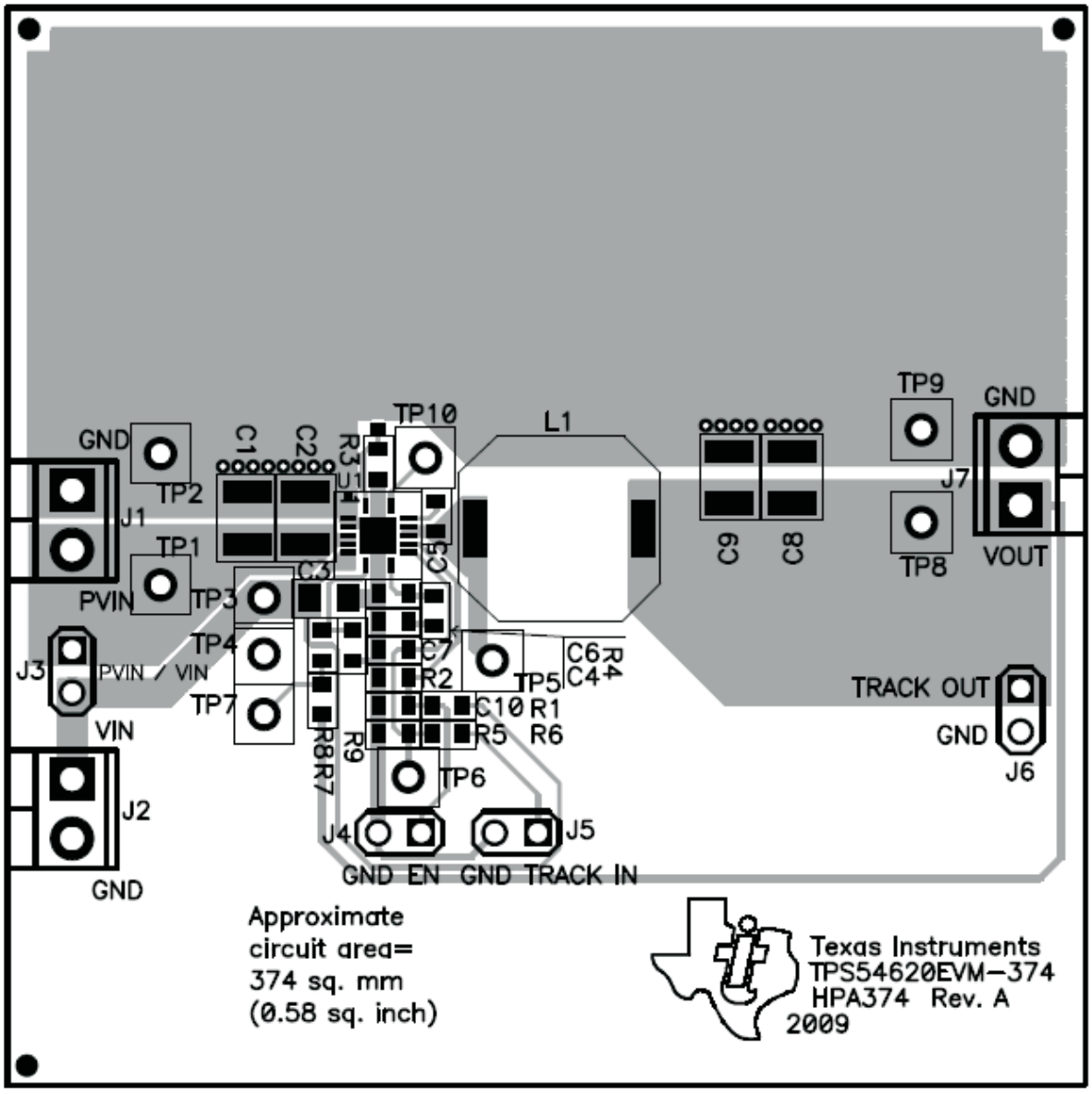

Figure 16. TPS54620EVM-374 Top-Side Assembly

3.2 Estimated Circuit Area

The estimated printed circuit board area for the components used in this design is 0.58 in^2 (374 mm^2). This area does not include test point or connectors.

4 Schematic and Bill of Materials

This section presents the TPS54620EVM-374 schematic and bill of materials.

4.1 Schematic

Figure 17 is the schematic for the TPS54620EVM-374.

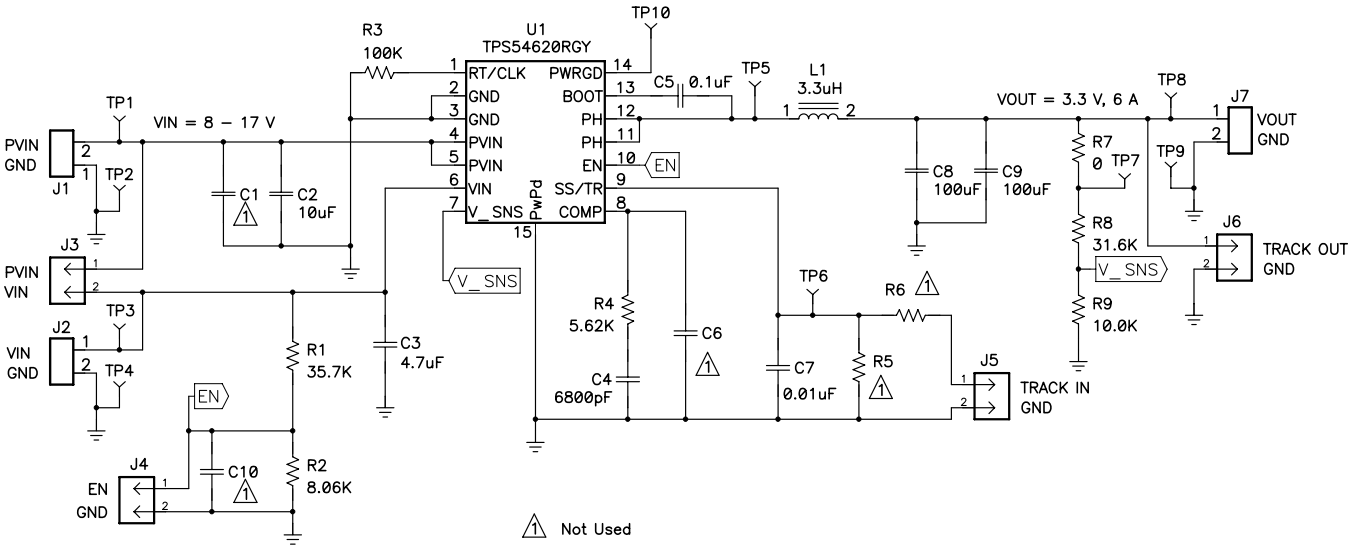

Figure 17. TPS54620EVM-374 Schematic

4.2 Bill of Materials

Table 5 presents the bill of materials for the TPS54620EVM-374 .

Table 5. TPS54620EVM-374 Bill of Materials

Count	RefDes	Value	Description	Size	Part Number	MFR
0	C1	Open	Capacitor, Ceramic, 25V, X5R, 20%	1210	Std	Std
1	C2	10µF	Capacitor, Ceramic, 25V, X5R, 20%	1210	Std	Std
1	C3	4.7µF	Capacitor, Ceramic, 25V, X5R, 10%	0805	Std	Std
1	C4	6800pF	Capacitor, Ceramic, 50V, X7R, 10%	0603	Std	Std
1	C5	0.1µF	Capacitor, Ceramic, 50V, X7R, 10%	0603	Std	Std
0	C6, C10	Open	Capacitor, Ceramic	0603	Std	Std
1	C7	0.01µF	Capacitor, Ceramic, 25V, X7R, 10%	0603	Std	Std
2	C8, C9	100µF	Capacitor, Ceramic, 6.3V, X5R, 20%	1210	Std	Std
3	J1, J2, J7	ED555/2DS	Terminal Block, 2-pin, 6-A, 3.5mm	0.27 x 0.25 inch	ED555/2DS	OST
4	J3, J4, J5, J6	PEC02SAAN	Header, Male 2-pin, 100mil spacing	0.100 inch x 2	PEC02SAAN	Sullins
1	L1	3.3µH	Inductor, SMT, 7.2A, 10.4milliohm	0.402 sq inch	MSS1048-332NL_	Coilcraft
1	R1	35.7K	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R2	8.06K	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R3	100K	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R4	5.62K	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	R5, R6	Open	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R7	0	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R8	31.6K	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R9	10.0K	Resistor, Chip, 1/16W, 1%	0603	Std	Std
6	TP1, TP3, TP5, TP6, TP7, TP8	5000	Test Point, Red, Thru Hole Color Keyed	0.100 x 0.100 inch	5000	Keystone
4	TP2, TP4, TP9, TP10	5001	Test Point, Black, Thru Hole Color Keyed	0.100 x 0.100 inch	5001	Keystone
1	U1	TPS54620RGY	IC, 4.5V-17V Synchronous Step Down Converter with Integrated MOSFETs	3.5mm x 3.5mm QFN14	TPS54620RGY	TI
2	—		Shunt, 100-mil, Black	0.100	929950-00	3M
1	—		PCB, 2.5” x 2.5” x 0.062”		HPA374	Any

Notes

1. These assemblies are ESD sensitive, ESD precautions shall be observed.
2. These assemblies must be clean and free from flux and all contaminants. Use of no clean flux is not acceptable.
3. These assemblies must comply with workmanship standards IPC-A-610 Class 2.
4. Ref designators marked with an asterisk (‘**’) cannot be substituted. All other components can be substituted with equivalent MFG's components.

5 Trademarks

All trademarks are the property of their respective owners.

Revision History

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

Changes from Original (May 2009) to A Revision **Page**

- Changed the Load transient response TYP values in Table 2 2
- Changed the Loop bandwidth TYP value From: 45 To 43 kHz in Table 2 2
- Changed the Phase margin TYP value From: 46 To 52° in Table 2 2
- Changed the Output ripple voltage TYP value From: 18 To 20 mVPP in Table 2 2
- Replaced Figure 5 7
- Replaced Figure 6 7
- Replaced Figure 7 8
- Replaced Figure 17 16
- Changed values of C8, C9, R4, C4, and the Description of U1 in Table 5 17

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   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

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。
3. 技術基準適合証明を取得後ご使用いただく。

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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東京都新宿区西新宿６丁目２４番１号

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

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3.4 *European Union*

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

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

4 *EVM Use Restrictions and Warnings:*

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

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

4.3 *Safety-Related Warnings and Restrictions:*

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

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

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

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

6. *Disclaimers:*

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

   6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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