User's Guide

TPS54331 Step-Down Converter Evaluation Module User's Guide

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1 Introduction

This user's guide contains background information for the TPS54331 as well as support documentation for the TPS54331EVM-232 evaluation module (HPA232). Also included are the performance specifications, the schematic, and the bill of materials for the TPS54331EVM-232.

1.1 Background

The TPS54331 dc/dc converter is designed to provide up to a 3-A output from an input voltage source of 3.5 V to 28 V. Rated input voltage and output current range for the evaluation module are given in Table 1-1. This evaluation module is designed to demonstrate the small printed-circuit-board areas that may be achieved when designing with the TPS54331 regulator. The switching frequency is internally set at a nominal 570 kHz. The high-side MOSFET is incorporated inside the TPS54331 package along with the gate drive circuitry. The low drain-to-source on resistance of the MOSFET allows the TPS54331 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 TPS54331 provides adjustable slow start and undervoltage lockout inputs. The absolute maximum input voltage is 30 V for the TPS54331EVM-232.

Table 1-1. Input Voltage and Output Current Summary

EVM	INPUT VOLTAGE RANGE	OUTPUT CURRENT RANGE
TPS54331EVM-232	VIN = 7 V to 28 V	0 A to 3 A

1.2 Performance Specification Summary

A summary of the TPS54331EVM-232 performance specifications is provided in Table 1-2. Specifications are given for an input voltage of VIN = 15 V and an output voltage of 3.3V, unless otherwise specified. The TPS54331EVM-232 is designed and tested for VIN = 10 V to 35 V. The ambient temperature is 25°C for all measurements, unless otherwise noted.

Table 1-2. TPS54331EVM-232 and Performance Specification Summary

SPECIFICATION	TEST CONDITIONS		MIN	TYP	MAX	UNIT
VIN voltage range			7	15	28	V
Output voltage set point				3.3		V
Output current range	V_{IN} = 7 V to 28 V		0		3	A
Line regulation	I_O = 1.5 A, VIN = 7 V – 28 V			±0.2%		
Load regulation	VIN = 14 V, I_O = 0 A to 3 A			±0.15%		
Load transient response	I_O = 0.75 A to 2.25 A	Voltage change		–100		mV
		Recovery time		160		µs
	I_O = 2.25 A to 0.75 A	Voltage change		100		mV
		Recovery time		160		µs
Loop bandwidth	VIN = 25 V, I_O = 1 A			25.0		kHz
Phase margin	VIN = 25 V , I_O = 1 A			58		°
Input ripple voltage	I_O = 3 A			200		mVpp
Output ripple voltage	I_O = 3 A			10		mVpp
Output rise time				3.5		ms
Operating frequency				570		kHz
Maximum efficiency	VIN = 10 V, V_O = 5 V, I_O = 0.75 A			91.6%		

1.3 Modifications

These evaluation modules are designed to provide access to the features of the TPS54331. Some modifications can be made to this module.

1.3.1 Output Voltage Set Point

To change the output voltage of the EVMs, it is necessary to change the value of resistor R6. Changing the value of R6 can change the output voltage above 0.8 V. The value of R6 for a specific output voltage can be calculated using Equation 1.

$$R2 = 10\ k\Omega \times \frac{1.221\ V}{V_O - 1.221\ V} \quad (1)$$

Table 1-3 lists the R6 values for some common output voltages. Note that VIN must be in a range so that the minimum on-time is greater than 150 ns, and the maximum duty cycle is less than 93%. The values given in Table 1-3 are standard values, not the exact value calculated using Table 1-3.

Table 1-3. Output Voltages Available

Output Voltage (V)	R_2 Value (kΩ)
1.8	8.25
2.5	4.75
3.3	3.24
5	1.96

2 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS54331EVM-232 and evaluation modules. The section also includes test results typical for the evaluation modules and covers efficiency, output voltage regulation, load transients, loop response, output ripple, input ripple, and start-up.

2.1 Input / Output Connections

The TPS54331EVM-232 is provided with input/output connectors and test points as shown in Table 2-1. A power supply capable of supplying 3 A must be connected to J1 through a pair of 20 AWG wires. The load must be connected to J4 through a pair of 20 AWG wires. The maximum load current capability must be 3 A. Wire lengths must be minimized to reduce losses in the wires. Test-point TP1 provides a place to monitor the VIN input voltages with TP2 providing a convenient ground reference. TP5 is used to monitor the output voltage with TP6 as the ground reference.

Table 2-1. EVM Connectors and Test Points

REFERENCE DESIGNATOR	FUNCTION
J1	VIN (see Table 1-1 for VIN range)
J2	2-pin header for enable. Connect EN to ground to disable, open to enable.
J3	2-pin header for slow start monitor and GND.
J4	VOUT, 3.3 V at 3-A maximum
TP1	VIN test point at VIN connector
TP2	GND test point at VIN
TP3	PH test point
TP4	Test point between voltage divider network and R3. Used for loop response measurements.
TP5	Output voltage test point at OUT connector
TP6	GND test point at OUT connector

2.2 Efficiency

The efficiency of this EVM peaks at a load current of about 0.6 A - 1 A and then decreases as the load current increases towards full load. Figure 2-1 shows the efficiency for the TPS54331EVM-232 at an ambient temperature of 25°C.

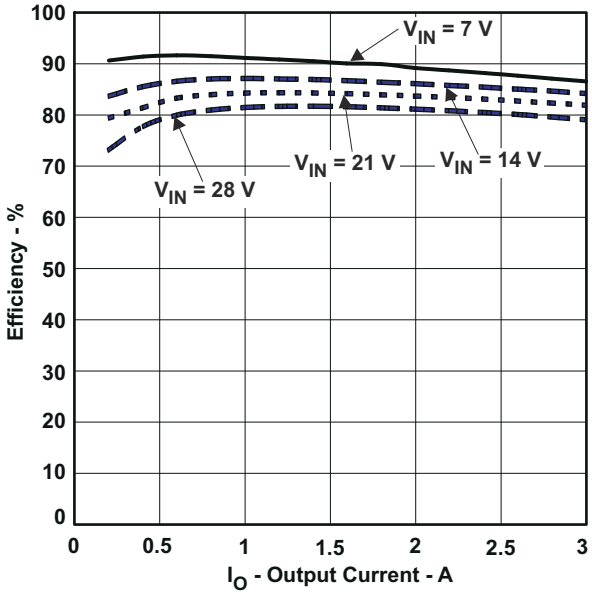

Figure 2-1. TPS54331 Efficiency

Figure 2-2 shows the efficiency for the TPS54331EVM-232 at lower output currents between 0.01 A and 0.20 A at an ambient temperature of 25°C.

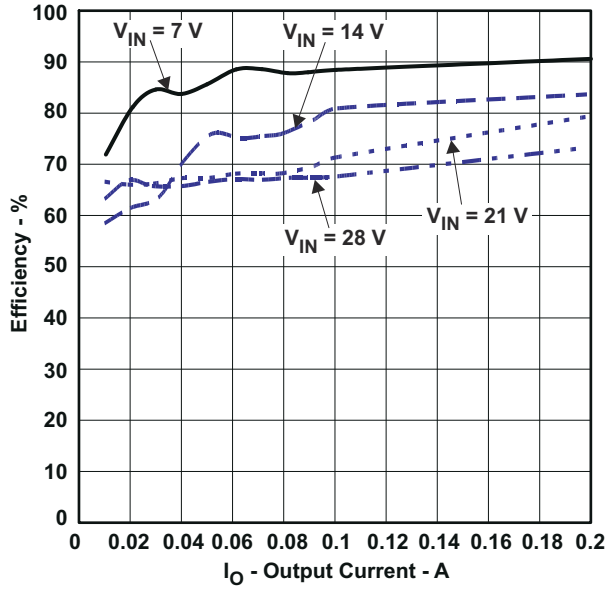

Figure 2-2. TPS54331 Low Current Efficiency

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

2.3 Output Voltage Load Regulation

The load regulation for the TPS54331EVM-232 is shown in Figure 2-3.

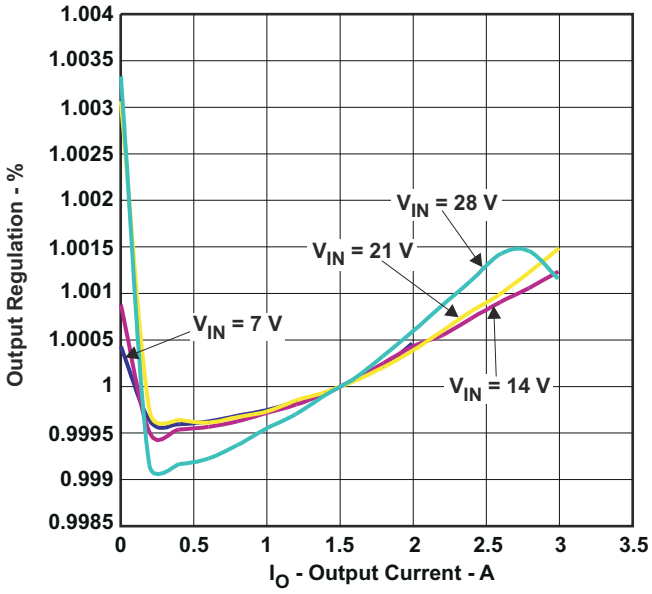

Figure 2-3. TPS54331 Load Regulation

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

2.4 Output Voltage Line Regulation

The line regulation for the TPS54331EVM-232 is shown in Figure 2-4.

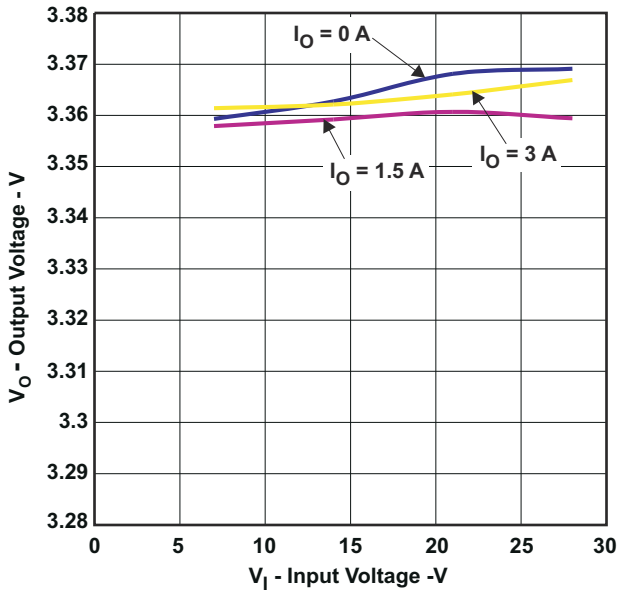

Figure 2-4. TPS54331 Line Regulation

2.5 Load Transients

The TPS54331EVM-232 response to load transients is shown in Figure 2-5. The current step is from 25% to 75% of maximum rated load. Total peak-to-peak voltage variation is as shown, including ripple and noise on the output.

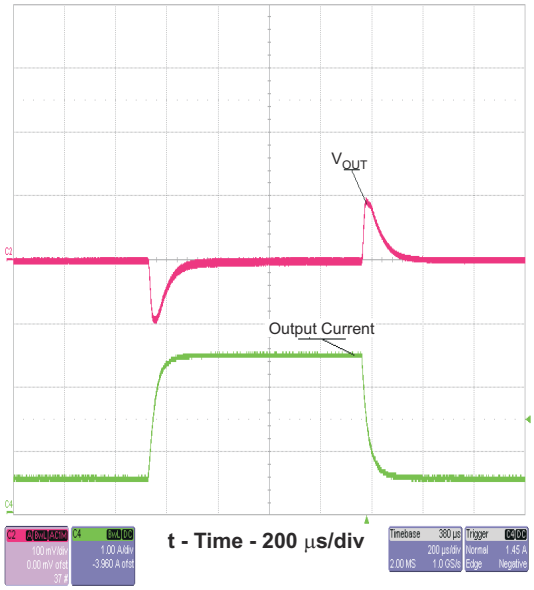

Figure 2-5. TPS54331 Transient Response

2.6 Loop Characteristics

The TPS54331EVM-232 loop-response characteristics are shown in Figure 2-6 . Gain and phase plots are shown for VIN voltage of 15 V. Load current for the measurement is 1.5 A.

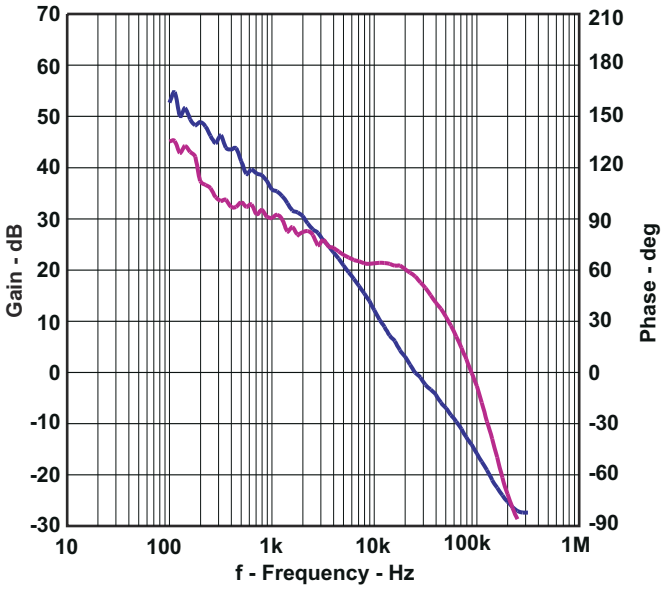

Figure 2-6. TPS54331 Loop Response

2.7 Output Voltage Ripple

The TPS54331EVM-232 output voltage ripple is shown in Figure 2-7 . The output current is the rated full load of 3 A. Voltage is measured directly across output capacitors.

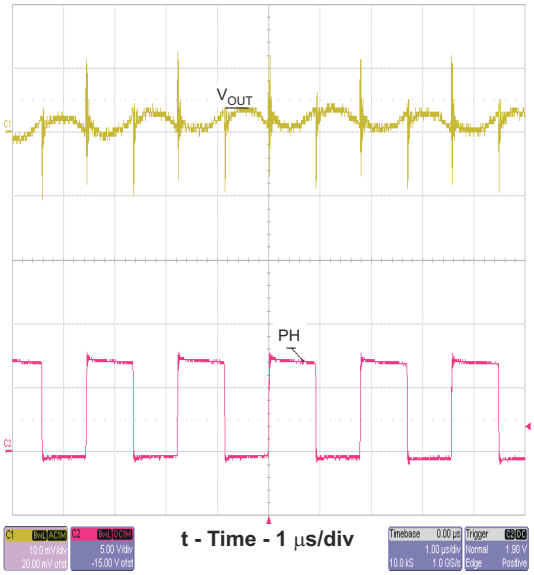

Figure 2-7. TPS54331 Output Ripple

2.8 Input Voltage Ripple

The TPS54331EVM-232 input voltage ripple is shown in Figure 2-8 . The output current for each device is at full rated load of 3 A.

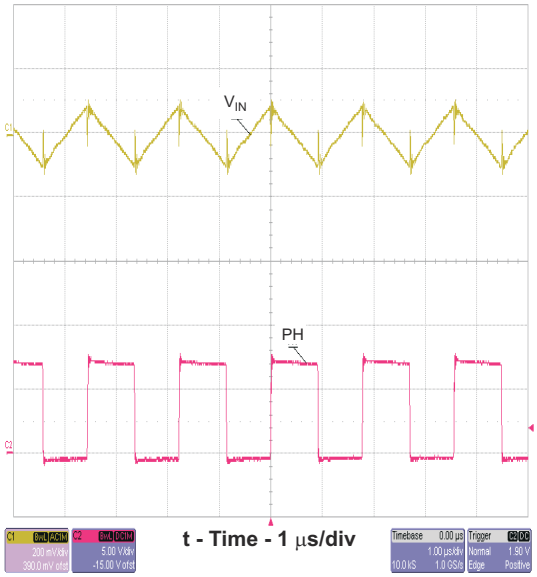

Figure 2-8. TPS54331 Input Ripple

2.9 Powering Up

The start-up waveform is shown in Figure 2-9 and Figure 2-10. In Figure 2-9, the top trace shows Vin, and the bottom trace shows Vout. InFigure 2-9 , the top trace shows EN (enable) whereas the bottom trace shows Vout. Initially, the input voltage is 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 of 1.25 V, the start-up sequence begins and the internal reference voltage begins to ramp up at the internally set rate toward 0.8 V and the output voltage ramps up to the externally set value of 3.3 V.

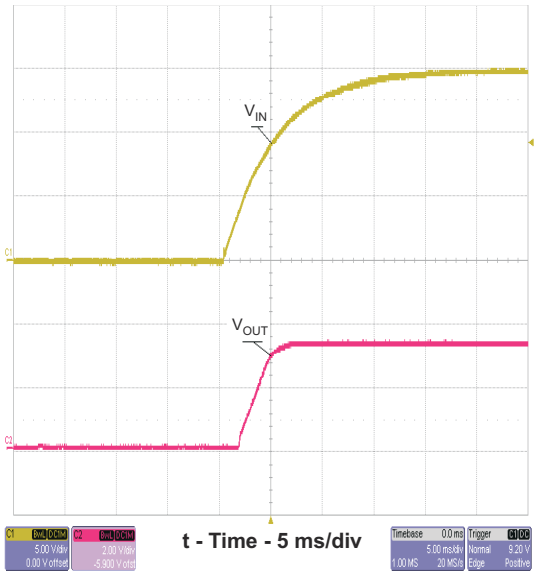

Figure 2-9. TPS54331 Start-Up Relative to Vin

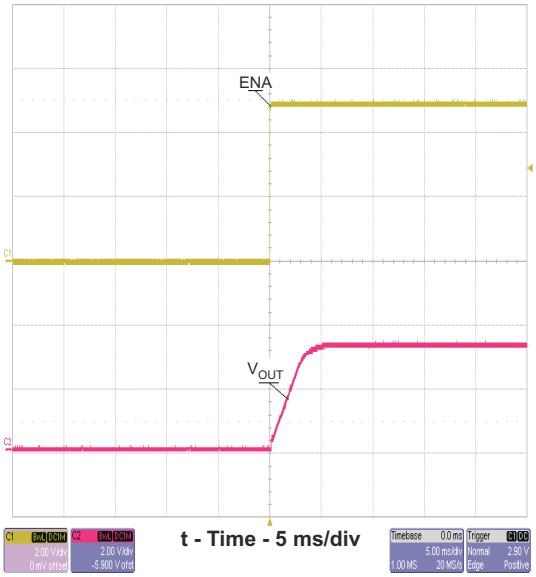

Figure 2-10. TPS5331 Start-up Relative to Enable

3 Board Layout

This section provides a description of the TPS54331EVM-232, board layout, and layer illustrations.

3.1 Layout

The board layout for the TPS54331EVM-232 and is shown in Figure 3-1 through Figure 3-3. The topside layer of the EVM is laid out in a manner typical of a user application. The top and bottom layers are 2-oz. copper.

The top layer contains the main power traces for VIN, OUT, and VPHASE. Also on the top layer are connections for the remaining pins of the TPS54331 and a large area filled with ground. The bottom layer contains ground and a signal route for the BOOT capacitor. The top and bottom and internal ground traces are connected with multiple vias placed around the board including four vias directly under the TPS54331 device to provide a thermal path from the top-side ground traces to the bottom-side ground plane.

The input decoupling capacitors (C1, C2, and C3) and bootstrap capacitor (C4) 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 Vout trace past the output capacitor C3. For the TPS54331, an additional input bulk capacitor may be required, depending on the EVM connection to the input supply.

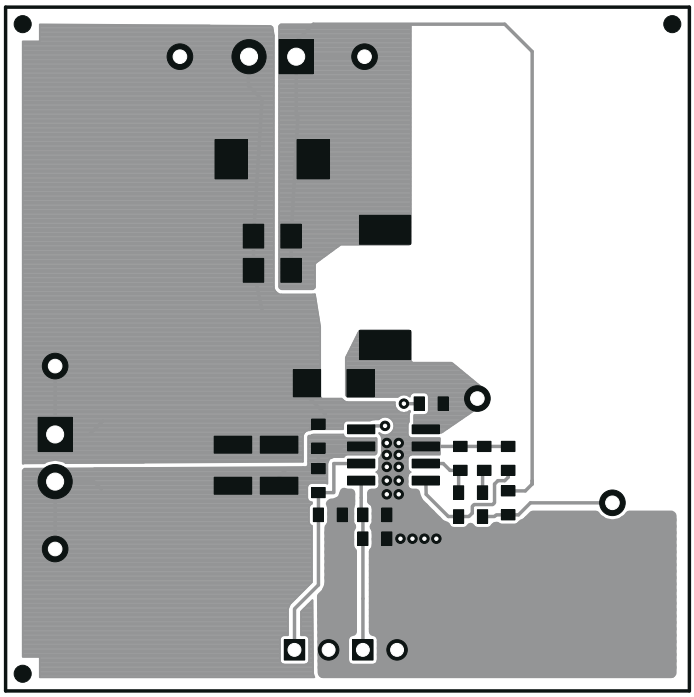

Figure 3-1. Top-Side Layout

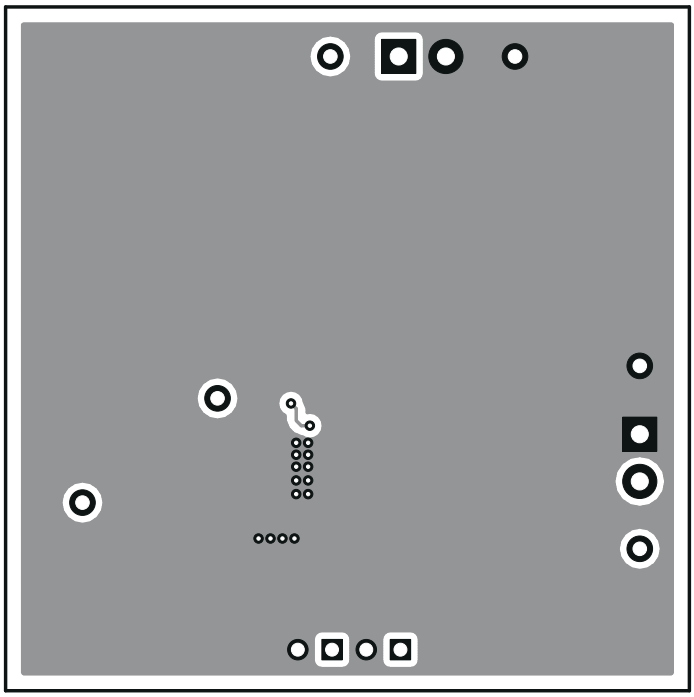

Figure 3-2. Bottom-Side Layout (Looking From Top Side)

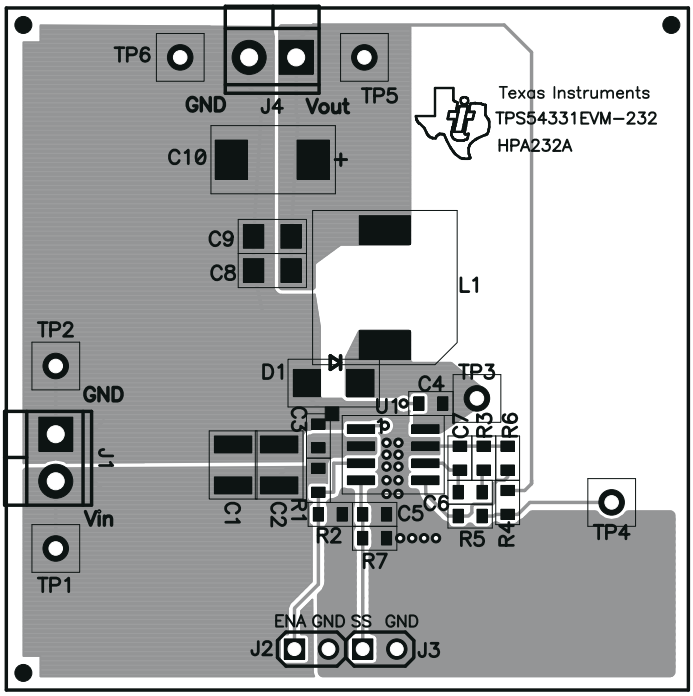

Figure 3-3. Top-Side Assembly

4 Schematic and Bill of Materials

This section presents the TPS54331EVM-232 schematic and bill of materials.

4.1 Schematic

Figure 4-1 is the schematic for the TPS54331EVM-232.

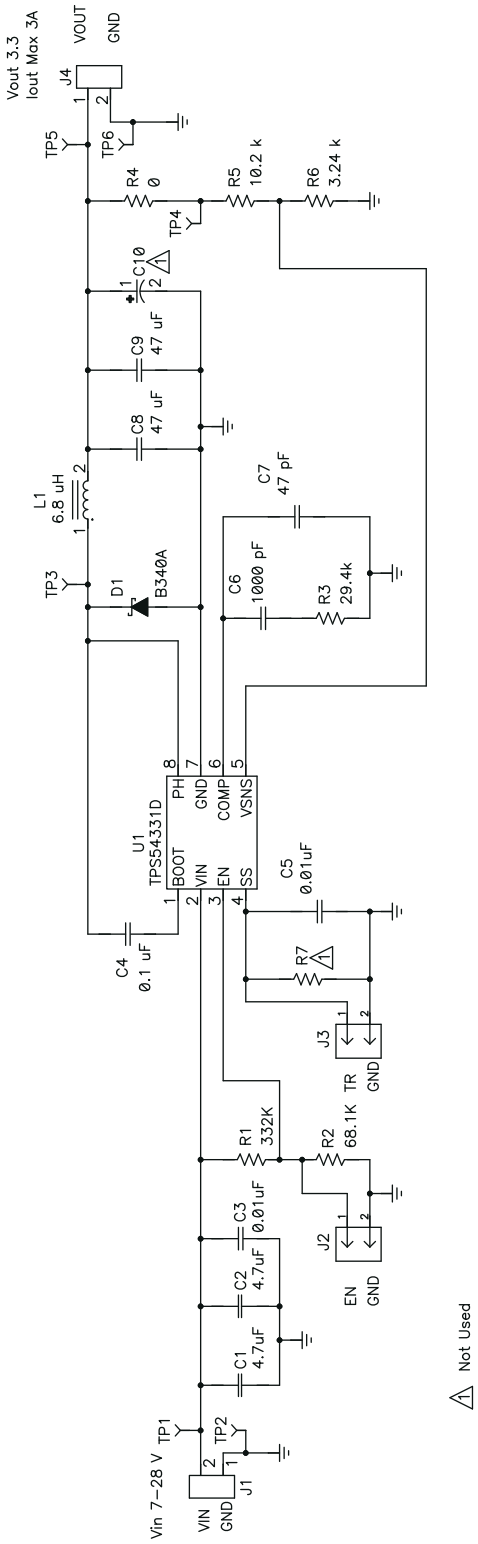

Figure 4-1. TPS54331EVM-232 Schematic

4.2 Bill of Materials

Table 4-1 presents the bill of materials for the TPS54331EVM-232..

Table 4-1. TPS54331EVM-232 Bill of Materials

COUNT	REFDES	VALUE	DESCRIPTION	SIZE	PART NUMBER	MFR
2	C1, C2	4.7 µF	Capacitor, Ceramic, 50 V, X7R, 20%	1210	Std	Std
0	C10			7343(D)	Std	Std
1	C3	0.01 µF	Capacitor, Ceramic, 50 V, X7R, 10%	0603	Std	Std
1	C4	0.1 µF	Capacitor, Ceramic, 1 6V, X7R, 10%	0603	Std	Std
1	C5	0.01 µF	Capacitor, Ceramic, 16 V, X7R, 10%	0603	Std	Std
1	C6	1000 pF	Capacitor, Ceramic, 16 V, X7R, 10%	0603	Std	Std
1	C7	47 pF	Capacitor, Ceramic, 16 V, X7R, 10%	0603	Std	Std
2	C8, C9	47 µF	Capacitor, Ceramic, 6.3, X5R, 20%	1206	C3216X5R0J476MT	TDK
1	D1	B340A	Diode, Schottky, 3 A, 40 V	SMA	B340A	Diodes Inc
2	J1, J4	ED1514	Terminal Block, 2-pin, 6-A, 3.5 mm	0.27 × 0.25 inch	ED1514	OST
2	J2, J3	PTC36SAAN	Header, 2-pin, 100-mil spacing, (36-pin strip)	0.100 × 2	PTC36SAAN	
1	L1	6.8 µH	Inductor, SMT, 3.84A, 35 mΩ	0.406 × 0.409	CDRH103RNP-6R8	Sumida
1	R1	332 k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R2	68.1 k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R3	29.4 k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R4	0	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R5	10.2 k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R6	3.24 k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	R7		Resistor, Chip, 1/16W, 1%	0603	Std	Std
3	TP1, TP3, TP5	5000	Test Point, Red, Thru Hole Color Keyed	0.100 × 0.100 inch	5000	Keystone
3	TP2, TP4, TP6	5001	Test Point, Black, Thru Hole Color Keyed	0.100 × 0.100 inch	5001	Keystone
1	U1	TPS5433xD	IC, DC-DC Converter, 28 V, 3 A	SO-8	TPS54331D	TI
1	—		PCB, HPA232	2.0" × 2.0" x 0.062"	HPA232	Any
2	—		Shunt, 100-mil, Black	0.100	929950-00	3M

5 Revision History

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

Changes from Revision * (July 2008) to Revision A (October 2021) **Page**

- Updated the numbering format for tables, figures, and cross-references throughout the document. 2
- Updated the user's guide title..... 2

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   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

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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.

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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2. 実験局の免許を取得後ご使用いただく。
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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.

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