User's Guide

TPS566231P and TPS566238P Step-Down Converter Evaluation Module User's Guide

ABSTRACT

This user's guide contains information for the TPS566231P and TPS566238P as well as support documentation for the TPS566231PEVM and TPS566238PEVM. Included are the performance specifications, schematic, and the list of materials of the TPS566231PEVM.

Table of Contents

List of Figures

List of Tables

Trademarks

D-CAP3™ is a trademark of Texas Instruments.

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1 Introduction

The TPS566231P is a single, D-CAP3™ mode, synchronous buck converter that requires a very low external component count. The TPS566231P is a cost-effective, high-voltage input, synchronous buck converter with integrated FETs. One of the key features of the TPS566231P is its ULQ (Ultra Low Quiescent), which is extremely beneficial for long battery life in low-power operation. The TPS566231P operates with wider supply input voltage ranging from 3 V to 18 V. The device uses DCAP3 control mode to provide the following:

- Fast transient response
- Good line
- Load regulation
- No requirement for external compensation
- Support to low-ESR output capacitors

The TPS566231P is a high-efficiency converter, and provides complete protection (OVP, UVP, OCP, OTP), and with PGOOD indicator. The TPS566238P is in continuous current mode. Others are same with the TPS566231P. Table 1-1.

The TPS566231PEVM and TPS566238PEVM are single, synchronous buck converter evaluation modules that provide 1 V at 6 A from a 3-V to 18-V input. This user's guide describes the TPS566231PEVM performance.

Table 1-1. Input Voltage and Output Current Summary

EVM	INPUT VOLTAGE (V_{IN}) RANGE	OUTPUT CURRENT (I_{OUT}) RANGE
TPS566231PEVM	3 V to 18 V	0 A to 6 A

2 Performance Specification Summary

A summary of the TPS566231PEVM performance specifications is provided in Table 2-1. Specifications are given for an input voltage of 12 V and an output voltage of 1 V, unless otherwise noted. The ambient temperature is 25°C for all measurement, unless otherwise noted.

Table 2-1. TPS566231PEVM Performance Specifications Summary

Specifications		Test Conditions	MIN	TYP	MAX	Unit
V_{IN}	Input voltage		3	12	18	V
CH1	Output voltage			1		V
	Operating frequency	V_{IN} = 12 V, I_{OUT} =6 A		600		kHz
	Output current range		0		6	A
	Over current limit	V_{IN} = 12 V, L_{OUT} = 1 µH		7.4		A
	Output ripple voltage	V_{IN} = 12 V, I_{OUT} = 6 A		10		mV_{PP}

3 Output Voltage Setpoint

To change the output voltage of the EVM, it is necessary to change the value of resistor R4 (Rupper) and R5 (Rlower). The value of R4 and R5 for a specific output voltage can be calculated using Equation 1 and refer to Table 3-1 for some recommendation values.

$$V_{OUT} = 0.6 \times (1 + \frac{R_{UPPER}}{R_{LOWER}}) \quad (1)$$

Table 3-1. Recommended Component Values

V_{OUT} (V)	R_{LOWER} (kΩ)	R_{UPPER} (kΩ)	L_{OUT} (µH)			C_{OUT} (µF)		C_{FF} (PF)
			MIN	TYP	MAX	MIN	MAX	
0.6	10	0	0.68	1	4.7	44	220	-
1	30	20	0.68	1	4.7	44	220	-
1.8	20	40	1	1.5	4.7	44	220	0-50
3.3	20	90	1.5	2.2	4.7	44	220	10-100
5.0	30	220	1.5	2.2	4.7	44	220	10-100

4 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS566231PEVM. The section also includes test results typical for the evaluation modules, includes power on/off, voltage ripple.

4.1 Input/Output Connections

The TPS566231PEVM is provided with input/output connectors and test points as shown in Table 4-1. A power supply capable of supplying 6 A must be connected to J1 through a pair of 20-AWG wires. The load must be connected to J2 through a pair of 20-AWG wires. The maximum load current capability is 6 A. Wire lengths must be minimized to reduce losses in the wires. Test point TP2 provides a place to monitor the V_{IN} input voltages with TP7 providing a convenient ground reference. TP5 is used to monitor the output voltage with TP13 as the ground reference.

Table 4-1. Connection and Test Points

Reference Designator	Function
J1	V_{IN} (see Table 1-1 for V_{IN} range)
J2	V_{OUT}, 1V with DC 6-A maximum current
JP1	Two resistor dividers connected to V_{IN} to enable EN.
JP2	En Control, short pin1 and pin2 to make EN on, short pin2 and pin3 to make EN off.
TP1	V_{IN} positive monitor point
TP2	V_{IN} positive monitor point
TP3	Switch node test point
TP4	V_{OUT} positive monitor point
TP5	V_{OUT} positive monitor point
TP6	GND monitor test point
TP7	GND monitor test point
TP8	V_{CC} monitor test point
TP9	EN Test point
TP10	PGOOD monitor test point
TP11	GND monitor test point
TP12	Loop test point
TP13	GND monitor test point
TP14	GND monitor test point
TP15	GND monitor test point

4.2 Start-Up Procedure

1. Ensure that the jumper at JP2 (Enable control) pins 2 and 3 are covered to shunt EN to GND, disabling the output.
2. Apply appropriate input voltage to VIN (J1-1) or TP1 and GND (J1-2) or TP6. and be noted that the board can't support hot plug-in. The input lines should be connected between J1 and external power source first before turning on the external input power supply.
3. Move the jumper at JP2 (Enable control) from pins 2(EN) and 3(OFF), to pins 1(ON) and 2(EN) and make JP1 pin 1 and pin 2 are covered, then the output can be enabled.
4. Apply the loading to Vout (J2-1) or TP4 and GND (J2-2) or TP10.

4.3 Start-Up

The TPS566231PEVM start-up waveform relative to EN is shown in Figure 4-1.

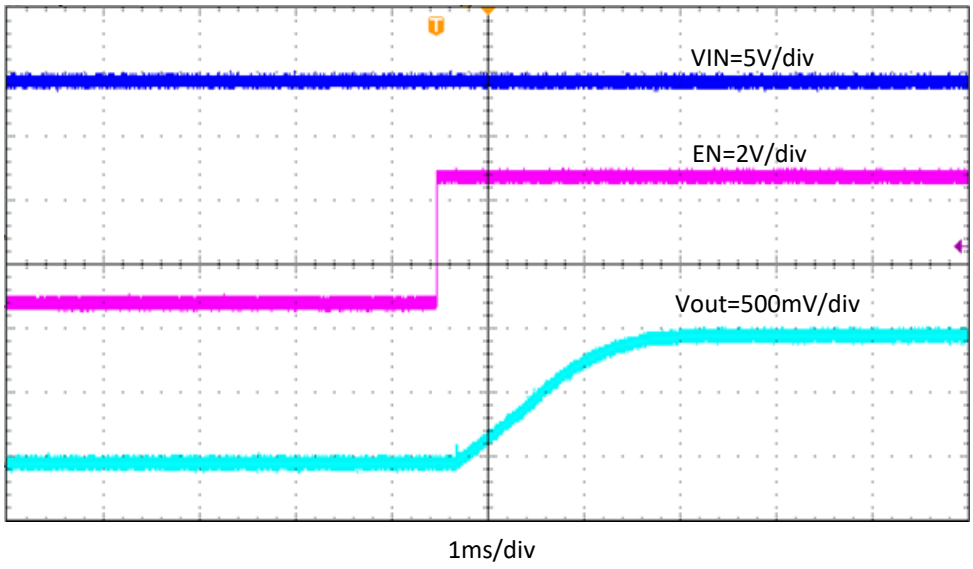

Figure 4-1. Start-Up Relative to EN, I_{OUT}= 3A

4.4 Shut-Down

The TPS566231PEVM shut-down waveform relative to EN is shown in Figure 4-2.

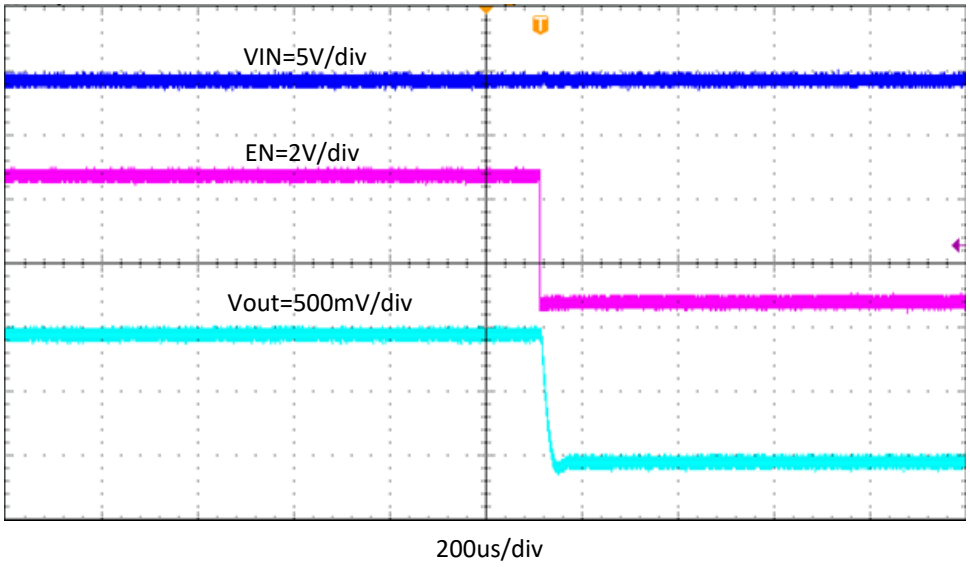

Figure 4-2. Shut-Down Relative to EN, I_{OUT}= 3A

4.5 Output Voltage Ripple

The TPS566231PEVM output voltage ripple is shown in Figure 4-3 and Figure 4-4. The output currents are as indicated.

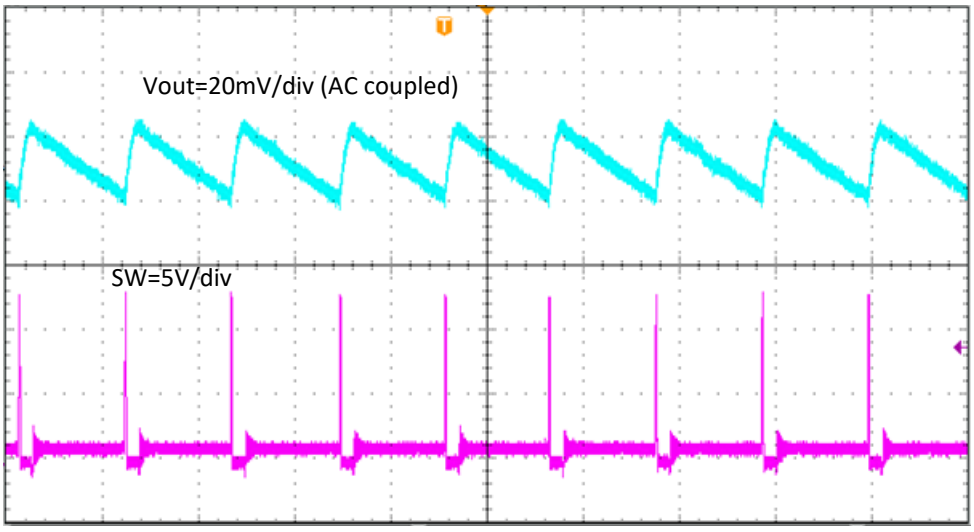

Figure 4-3. TPS566231P Output Voltage Ripple, I_{OUT} = 0.01A

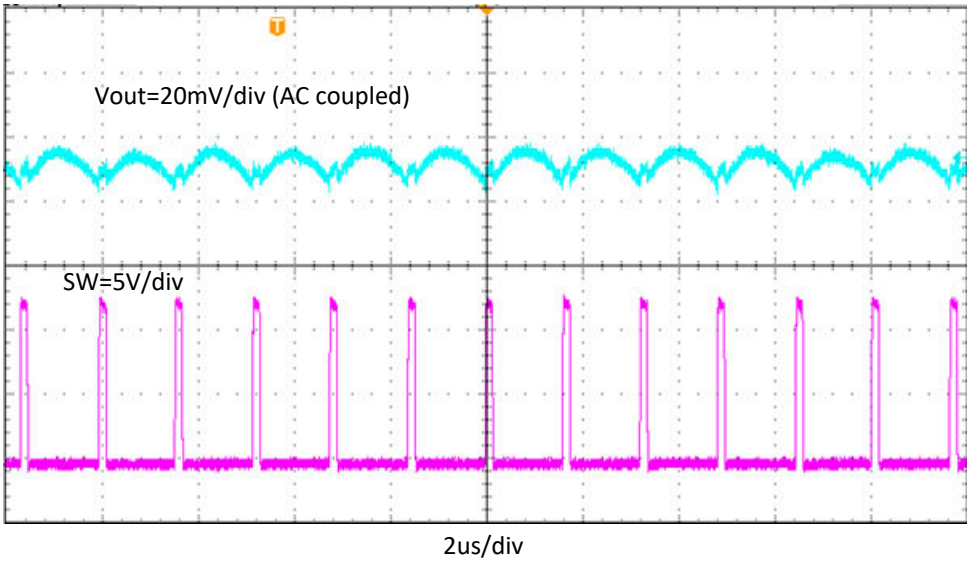

Figure 4-4. TPS566231P Output Voltage Ripple, I_{OUT} = 6A

5 Board Layout

This section provides a description of the TPS566231PEVM, board layout, and layer illustrations.

5.1 Layout

The board layout for the TPS566231PEVM is shown in Figure 5-1 and Figure 5-2 to Figure 5-5.

TPS566231PEVM is with four layers, The top layer contains the main power traces for VIN, VOUT and GND. Also on the top layer are connections for the pins of the TPS566231P and a large area filled with ground. Most of the signal traces are also located on the top side. The input decoupling capacitors, C1, C2, C3 and C4 are located as close to Vin pins and PGND pins of the IC as possible. The input and output connectors, test points and all of the components are located on the top side.

The bottom layer is a ground plane along with signal ground copper fill and the feed back trace from the point of regulation to the top of the resistor divider network.

Two inner layers are ground plane.

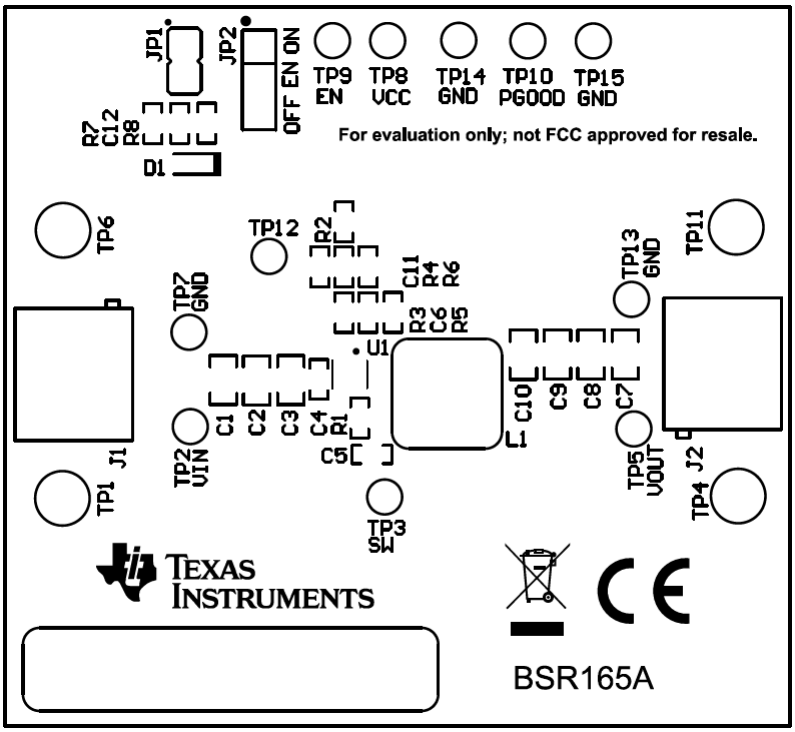

Figure 5-1. Top Assembly

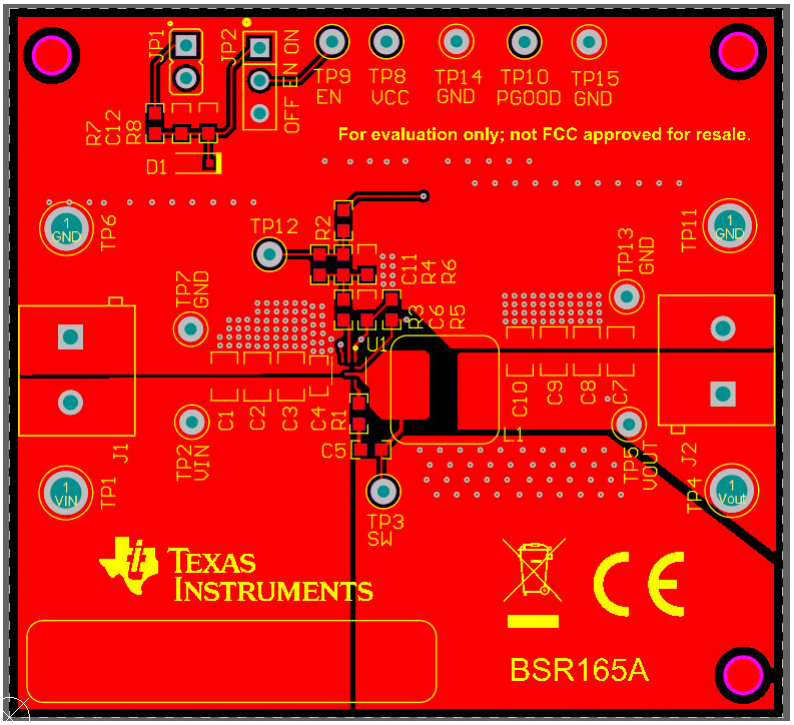

Figure 5-2. Top Layer

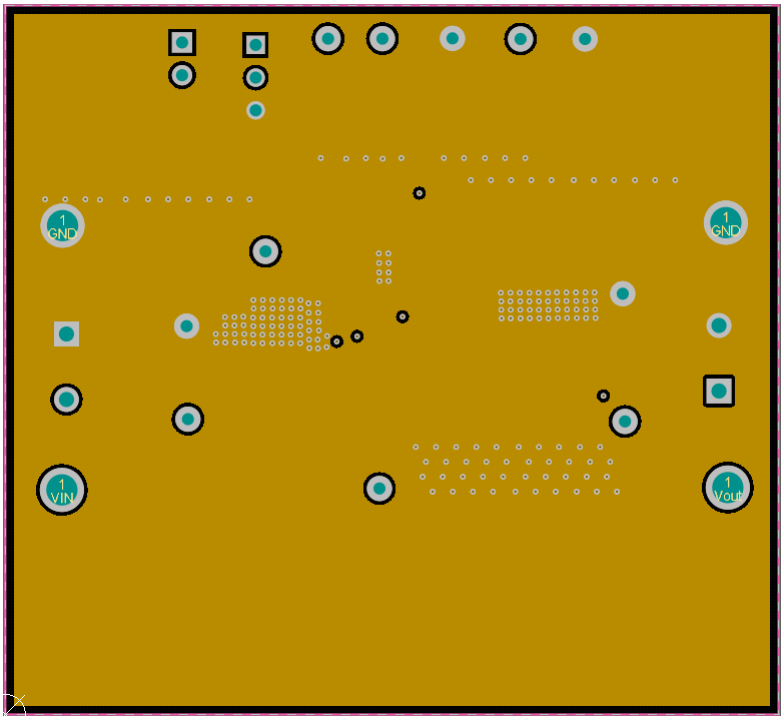

Figure 5-3. Inner1 Layer

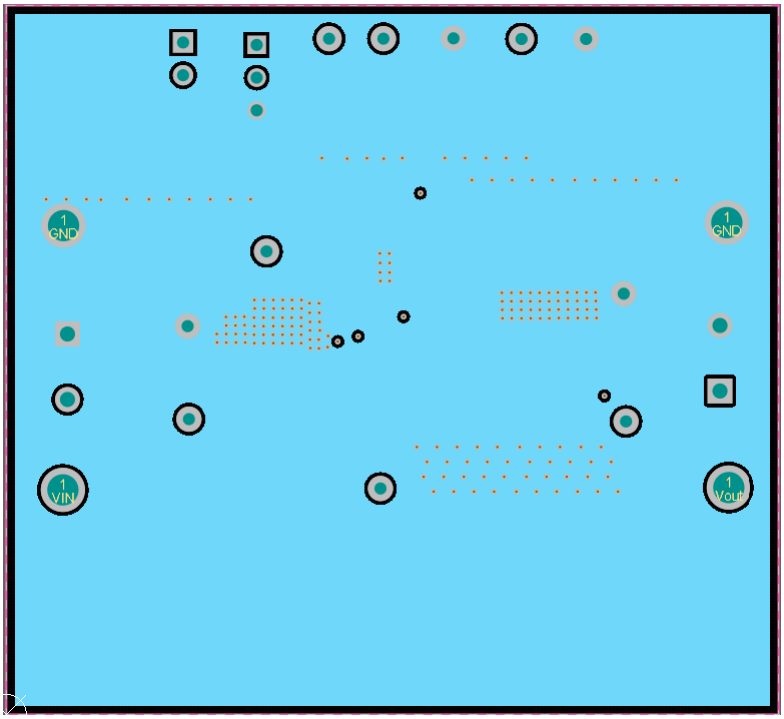

Figure 5-4. Inner2 Layer

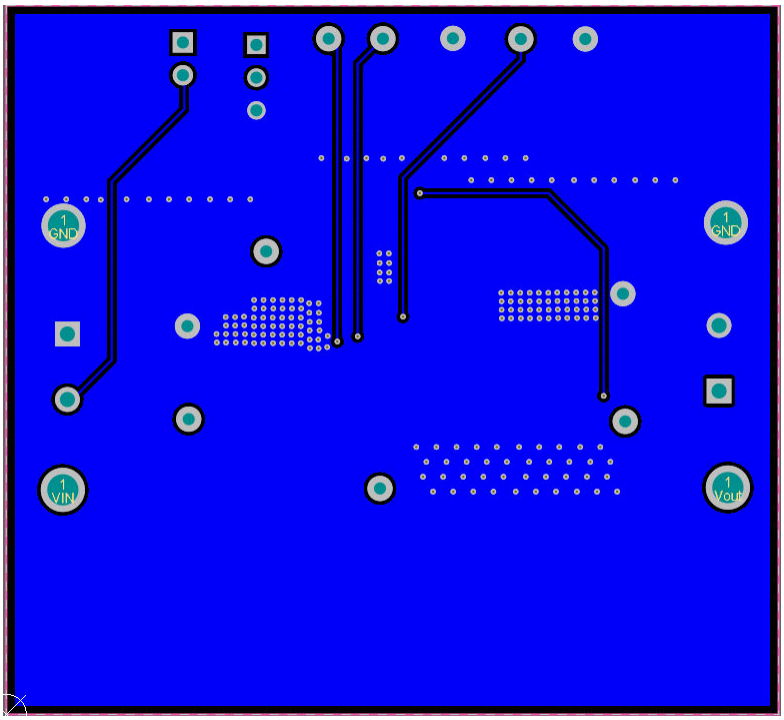

Figure 5-5. Bottom Layer

6 Board Profile, Schematic, List of Materials, and Reference

6.1 Board Profile

Figure 6-1 is the top view for the TPS566231PEVM.

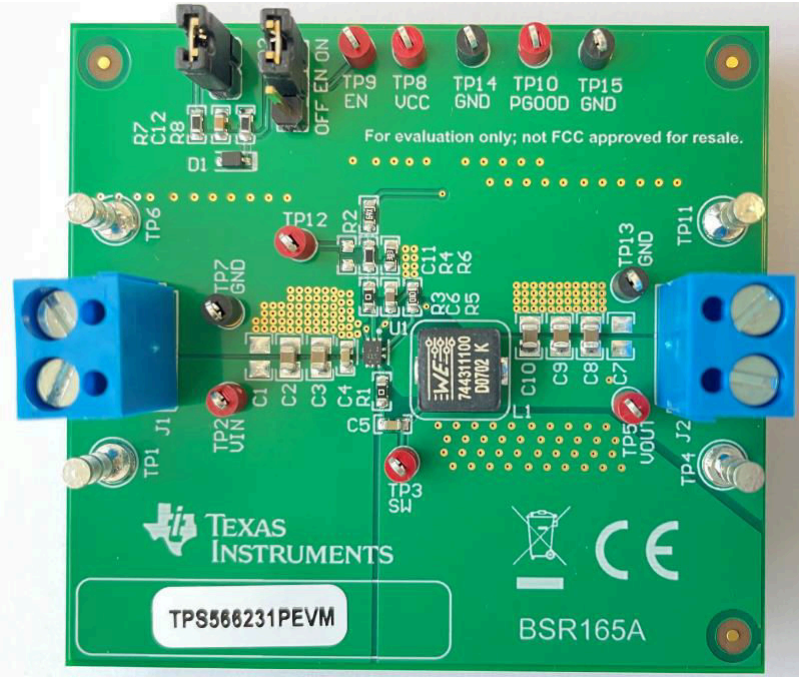

Figure 6-1. Top View of TPS566231PEVM

Figure 6-2 is the bottom view for the TPS566231PEVM.

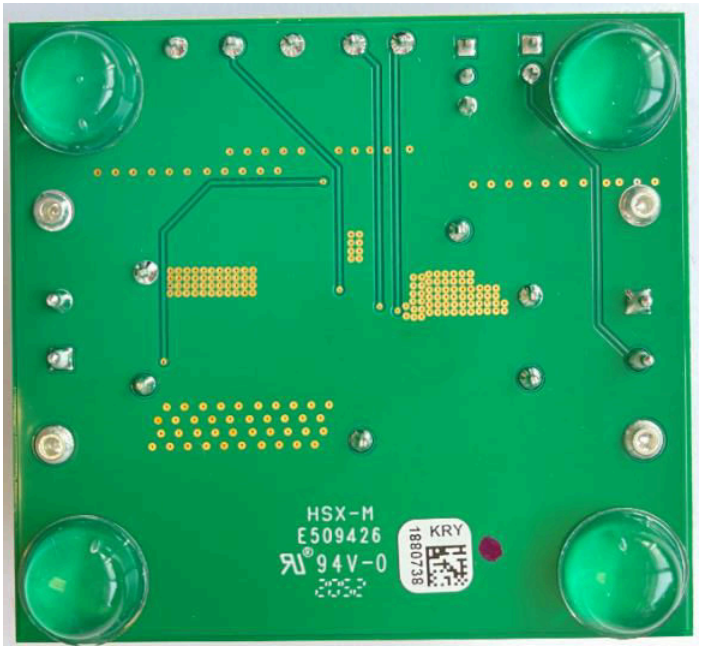

Figure 6-2. Bottom View of TPS566231PEVM

6.2 Schematic

Figure 6-3 is the schematic for the TPS566231PEVM.

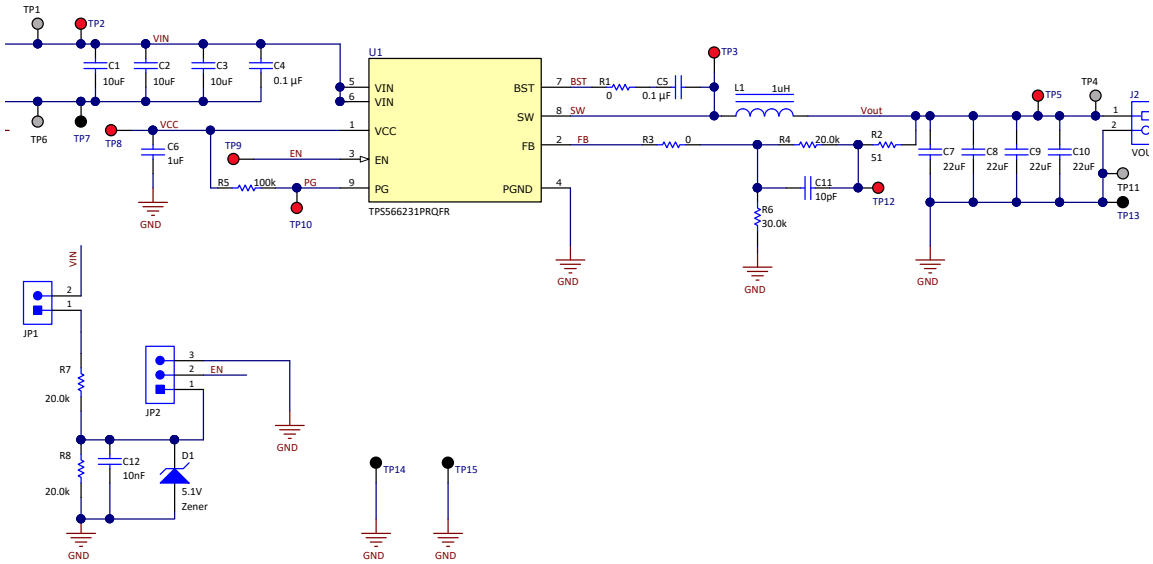

Figure 6-3. TPS566231PEVM Schematic Diagram

6.3 List of Materials

Table 6-1 displays the TPS566231PEVM list of materials.

Table 6-1. List of Materials(1)

Designator	Qty	Description	Part Number	Manufacturer
PCB1	1	Printed Circuit Board	BSR106	
C2, C3	2	Capacitor, ceramic, 10 uF, 25 V, +/- 20%, X5R, 0805	GRM21BR61E106MA73L	MuRata
C4, C5	2	Capacitor, ceramic, 0.1 µF, 25 V,+/- 10%, X5R, 0603	CL10A104KA8NNNC	Samsung Electro-Mechanics
C6	1	Capacitor, ceramic, 1 uF, 10 V, +/- 10%, X5R, 0603	C1608X5R1A105K080AC	TDK
C8, C9, C10	3	Capacitor, ceramic, 22 uF, 10 V, +/- 20%, X5R, 0805	GRM21BR61A226ME44L	MuRata
C12	1	Capacitor, ceramic, AP, CERM, 0.01 uF, 16 V, +/- 10%, X7R, 0603	C0603C103K4RACTU	Kemet
D1	1	Diode, Zener, 5.1 V, 200 mW, SOD-323	MMSZ5231BS-7-F	Diodes Inc.
H1, H2, H3, H4	4	Bumpon, Hemisphere, 0.44 X 0.20, Clear, Transparent	SJ-5303 (CLEAR)	3M
J1, J2	2	Terminal Block, 5.08 mm, 2x1, Brass, TH	ED120/2DS	On-Shore Technology
JP1	1	Header, 100mil, 2x1, Gold, TH, 230 mil above insulator	PBC02SAAN	Sullins Connector Solutions
JP2	1	Header, 100mil, 3x1, Tin, TH, 3 PIN	PEC03SAAN	Sullins Connector Solutions
L1	1	Inductor, Shielded Drum Core, WE-Superflux200, 1 uH, 15 A, 0.0046 ohm, SMD, 6.9x3.8x6.9mm	744311100	Wurth Elektronik
LBL1	1	Thermal Transfer Printable Labels, 1.250" W x 0.250" H - 10,000 per roll	THT-13-457-10	Brady
R1, R3	2	Resistor, 0, 5%, 0.1 W, 0603	RC0603JR-070RL	Yageo
R2	1	Resistor, 51, 5%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060351R0JNEA	Vishay-Dale
R4, R7, R8	3	Resistor, 20.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	CRCW060320K0FKEA	Vishay-Dale
R6	1	Resistor, 30.0 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0603	ERJ-3EKF3002V	Panasonic
R5	1	RES, 100 k, 5%, 0.1 W, 0603	CRCW0603100KJNEAC	Vishay-Dale
SH-JP1, SH-JP2	2	Shunt, 100mil, Gold plated, Black	SNT-100-BK-G or 969102-0000-DA	Samtec or 3M
TP1, TP4, TP6, TP11	4	Terminal, Turret, TH, Triple	1598-2	Keystone
TP2, TP3, TP5, TP8, TP9, TP10, TP12	7	Test Point, Miniature, Red, TH	5000	Keystone
TP7, TP13, TP14, TP15	4	Test Point, Miniature, Black, TH	5001	Keystone
U1	1	TPS566231PRQFR, RQF0009A (VQFN-HR-9)	TPS566231PRQFR	Texas Instruments
C1	0	Capacitor, ceramic, 10 uF, 25 V, +/- 20%, X5R, 0805	GRM21BR61E106MA73L	MuRata
C7	0	Capacitor, ceramic, 22 uF, 10 V, +/- 20%, X5R, 0805	GRM21BR61A226ME44L	MuRata
C11	0	Capacitor, ceramic, 10 pF, 10 V, +/- 10%, X7R, 0603	0603ZC100KAT2A	AVX
FID1, FID2, FID3	0	Fiducial mark. There is nothing to buy or mount.	N/A	N/A

(1) Unless otherwise noted in the *Alternate Part Number* or *Alternate Manufacturer* columns, all parts may be substituted with equivalents.

6.4 Reference

1. Texas Instruments, *TPS566231 3 V to 18 V Input, 6-A Synchronous Step-Down Voltage Regulator* data sheet.

7 Revision History

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

Changes from Revision * (March 2021) to Revision A (April 2021)	Page
• Updated user's guide title	3

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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.

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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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

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

3.4 *European Union*

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

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

4 *EVM Use Restrictions and Warnings:*

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

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

4.3 *Safety-Related Warnings and Restrictions:*

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

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

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

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

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