User's Guide
SLUUBZ4–February 2019

TPS562231EVM 2-A, Synchronous step-down converter evaluation module

This user's guide contains information for the TPS562231 as well as support documentation for the TPS562231EVM evaluation module. Included are the performance specifications, schematic, and the bill of materials of the TPS562231EVM.

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1 Introduction

The TPS562231 is a single, adaptive on-time, D-CAP3™ mode, synchronous buck converter requiring a very low external component count. The proprietary D-CAP3 mode control supports low ESR output capacitors such as specialty polymer capacitors and multi-layer ceramic capacitors without complex external compensation circuits. The fast transient response of D-CAP3 mode control can reduce the output capacitance required to meet a specific level of performance. The switching frequency is internally set at a nominal 850 kHz and enters Advanced Eco-mode in light load conditions. The high-side and low-side switching MOSFETs are incorporated inside the TPS562231 package along with the gate-drive circuitry. The low drain-to-source on resistance of the MOSFETs allows the TPS562231 to achieve high efficiencies and helps keep the junction temperature low at high output currents. The TPS562231 dc/dc synchronous converter is designed to provide up to a 2-A output from an input voltage source of 4.5 V to 17 V. The output voltage range is from 0.6 V to 7 V. Rated input voltage and output current ranges for the evaluation module are given in Table 1.

The TPS562231EVM evaluation module (EVM) is a single, synchronous buck converter providing 3.3 V at 2 A from 4.5-V to 17-V input. This user's guide describes the TPS562231EVM performance.

Table 1. Input Voltage and Output Current Summary

EVM	INPUT VOLTAGE RANGE	OUTPUT CURRENT RANGE
TPS562231EVM	V_{IN} = 4.5 V to 17 V	0 A to 2 A

2 Performance Characteristics Summary

A summary of the TPS562231EVM 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 noted. The ambient temperature is 25°C for all measurement, unless otherwise noted.

Table 2. TPS562231EVM Performance Characteristics Summary

SPECIFICATIONS		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input voltage range (V_{IN})			4.5	12	17	V
CH1	Output voltage			3.3		V
	Operating frequency	V_{IN} = 12 V, I_O = 2 A		850		kHz
	Output current range		0		2	A
	Over current limit	V_{IN} = 12 V, L_O = 3.3 µH		2.8		A
	Output ripple voltage	V_{IN} = 12 V, I_O = 2 A		15		mV_{PP}

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3 Modifications

These evaluation modules are designed to provide access to the features of the TPS562231. Some modifications can be made to this module.

3.1 Output Voltage Setpoint

To change the output voltage of the EVMs, it is necessary to change the value of resistor R5. Changing the value of R5 can change the output voltage above 0.6 V. The value of R5 for a specific output voltage can be calculated using Equation 1.

$$R_5 = \frac{R_6 \times (V_{OUT} - 0.6\,V)}{0.6\,V} \quad (1)$$

Table 3 lists the R5 values for some common output voltages. Note that the values given in Table 3 are standard values and not the exact value calculated using Table 3.

Table 3. Output Voltages

OUTPUT VOLTAGE (V)	R5 (kΩ)	R6 (kΩ)	L1 (µH)			C5 + C6 +C7 (µF)
			Min	Typ	Max	
1.0	6.65	10.0	1	1.5	4.7	20 - 68
1.05	7.5	10.0	1	1.5	4.7	20 - 68
1.2	10	10.0	1	1.5	4.7	20 - 68
1.5	15	10.0	1.5	2.2	4.7	20 - 68
1.8	20	10.0	1.5	2.2	4.7	20 - 68
2.5	31.6	10.0	2.2	3.3	4.7	20 - 68
3.3	45.3	10.0	2.2	3.3	4.7	20 - 68
5.0	73.2	10.0	3.3	4.7	4.7	20 - 68
6.5	98.3	10.0	3.3	4.7	4.7	20 - 68

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4 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS562231EVM. The section also includes test results typical for the evaluation modules and efficiency, output load regulation, output line regulation, load transient response, output voltage ripple, input voltage ripple, start-up, and switching frequency.

4.1 Input/Output Connections

The TPS562231EVM is provided with input/output connectors and test points as shown in Table 4. A power supply capable of supplying 2 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 2 A. Wire lengths must be minimized to reduce losses in the wires. Test point TP3 provides a place to monitor the V_{IN} input voltages with TP4 providing a convenient ground reference. TP9 is used to monitor the output voltage with TP5 as the ground reference.

Table 4. Connection and Test Points

REFERENCE DESIGNATOR	FUNCTION
J1	V_{IN} (see Table 1 for V_{IN} range)
J2	V_{OUT}, 3.3 V at 2-A maximum
JP1	EN control. Shunt EN to GND to disable
TP1	V_{IN} positive power point
TP2,TP11	GND power point
TP3	V_{IN} positive monitor point
TP4,TP5,TP12,TP13	GND monitor test point
TP6	EN test point
TP7	Switch node test point
TP8	Test point for loop response measurements
TP9	V_{OUT} positive monitor point
TP10	V_{OUT} positive power point

4.2 Start-Up Procedure

1. Ensure that the jumper at JP1 (Enable control) pins 1 and 2 are covered to shunt EN to GND, disabling the output.
2. Apply appropriate V_{IN} voltage to VI (J1-2) and GND (J1-1).
3. Move the jumper at JP1 (Enable control) pins 1 and 2 (EN and GND) to enable the output.

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4.3 Efficiency

Figure 1 shows the efficiency for the TPS562231EVM at an ambient temperature of 25°C.

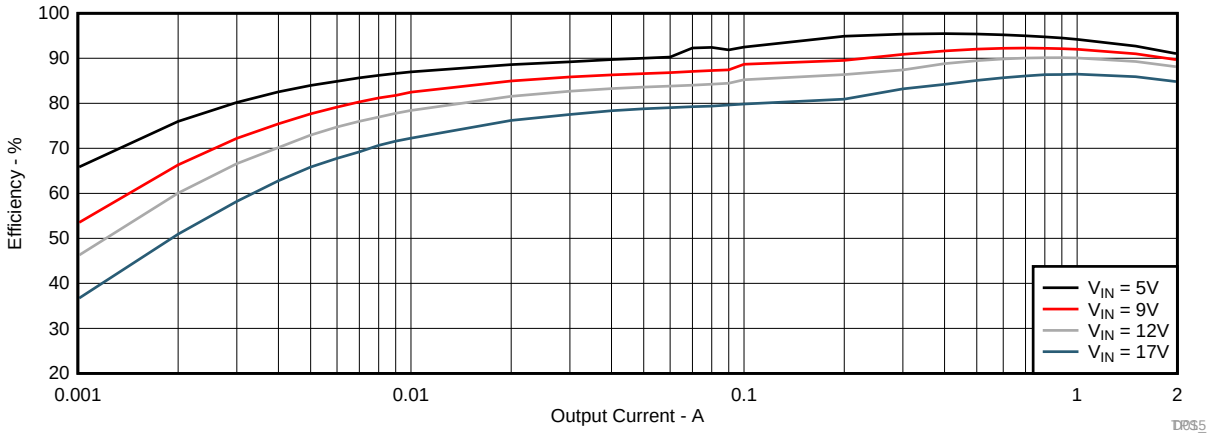

Figure 1. TPS562231EVM Efficiency

4.4 Load Transient Response

The TPS562231EVM response to load transient is shown in Figure 2. The voltage, current and time scale are indicated in the figures.

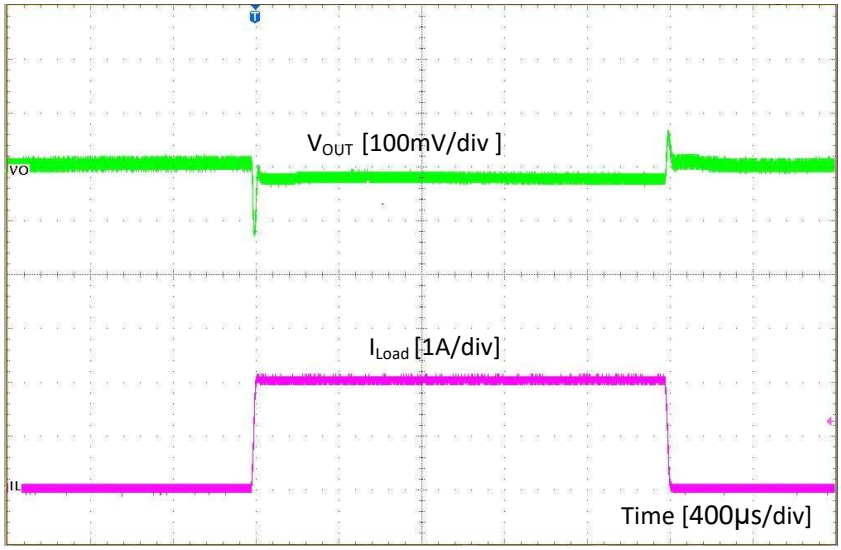

Figure 2. TPS562231EVM Load Transient Response

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4.5 Output Voltage Ripple

The TPS562231EVM output voltage ripple is shown in Figure 3, Figure 4, and Figure 5. The output currents are as indicated.

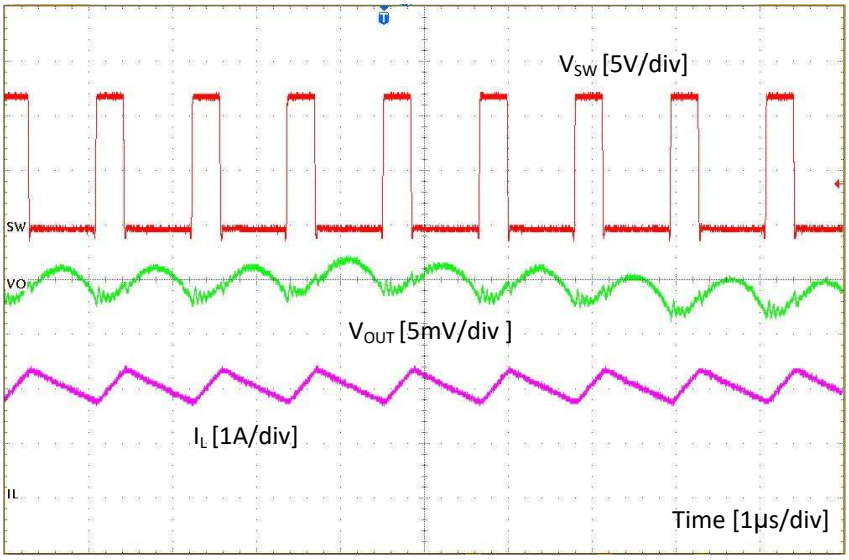

Figure 3. TPS562231EVM Output Voltage Ripple in CCM

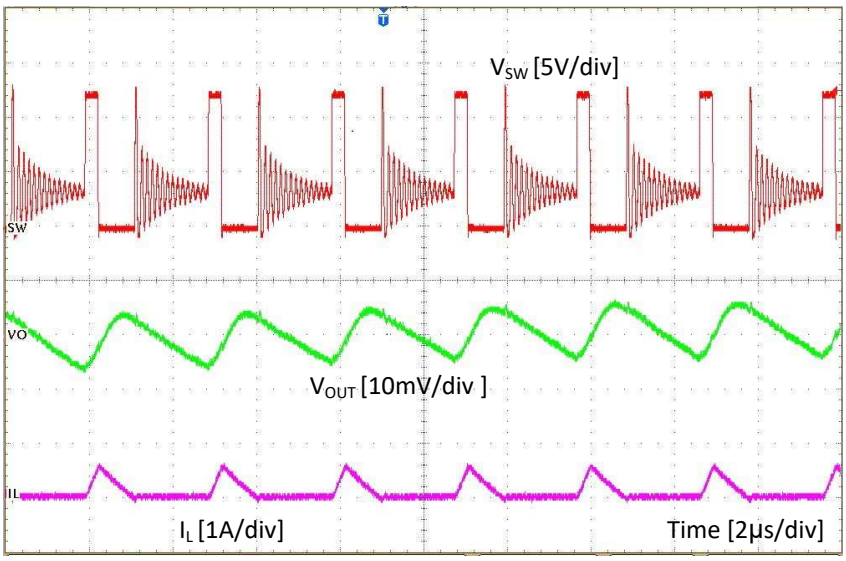

Figure 4. TPS562231EVM Output Voltage Ripple in DCM

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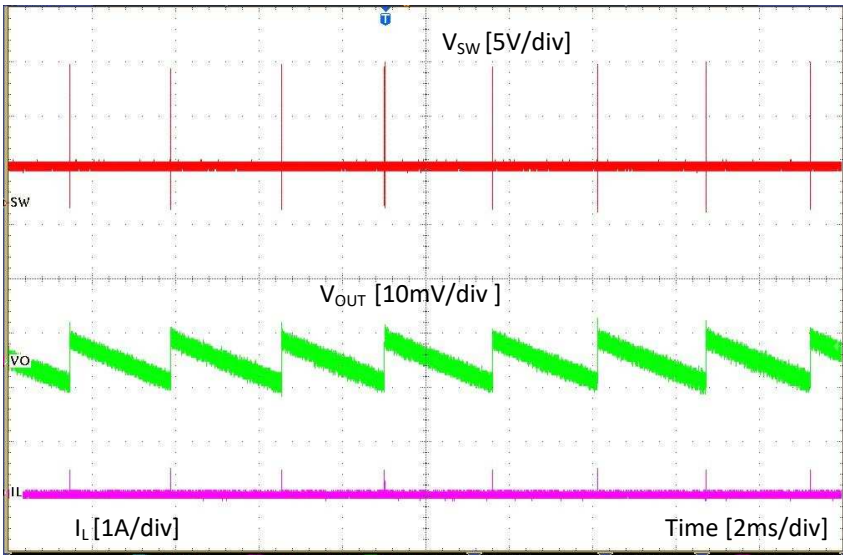

Figure 5. TPS562231EVM Output Voltage Ripple on No-load

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5 Board Layout

This section provides a description of the TPS562231EVM, board layout, and layer illustrations.

5.1 Layout

The board layout for the TPS562231EVM is shown in Figure 6, Figure 7 and Figure 8. The top layer contains the main power traces for VIN, VOUT, and ground. Also on the top layer are connections for the pins of the TPS562231 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, and C3 are located as close to the IC as possible. The input and output connectors, test points, and all of the components are located on the top side. 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 the switching node copper fill, signal ground copper fill and the feed back trace from the point of regulation to the top of the resistor divider network.

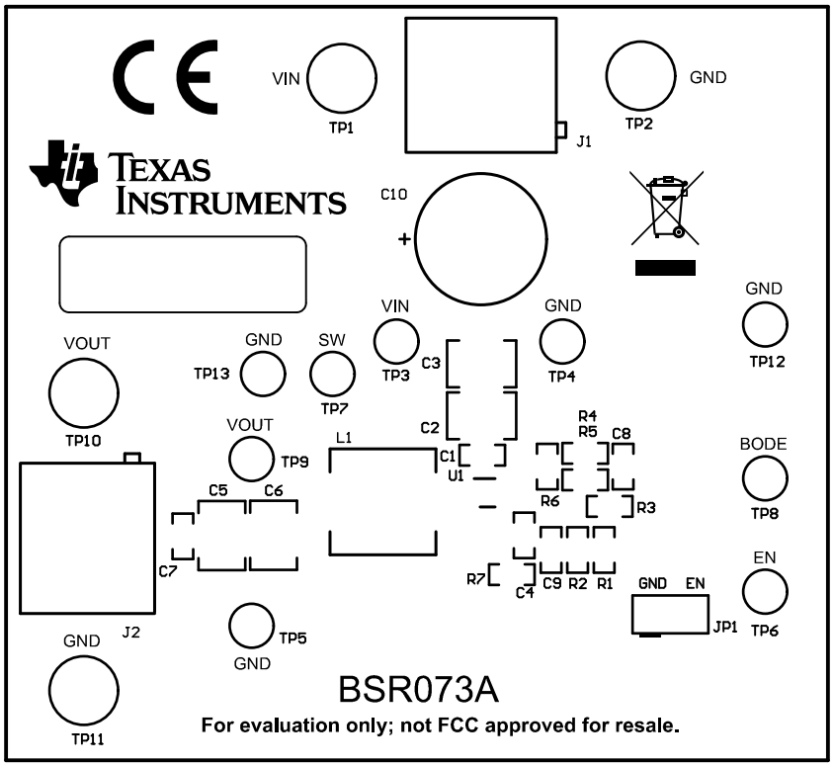

Figure 6. Top Assembly

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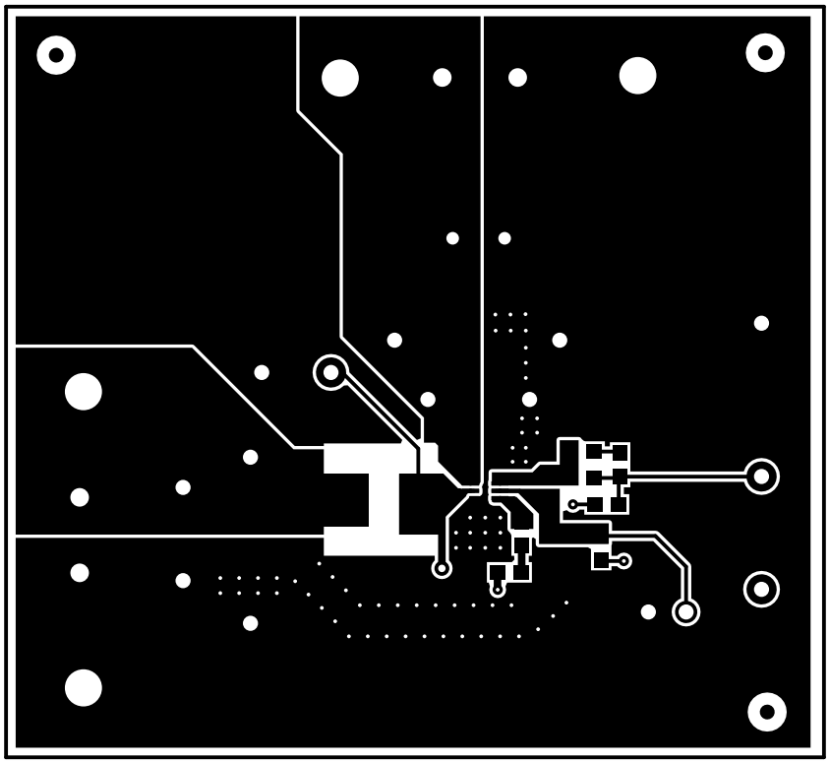

Figure 7. Top Layer

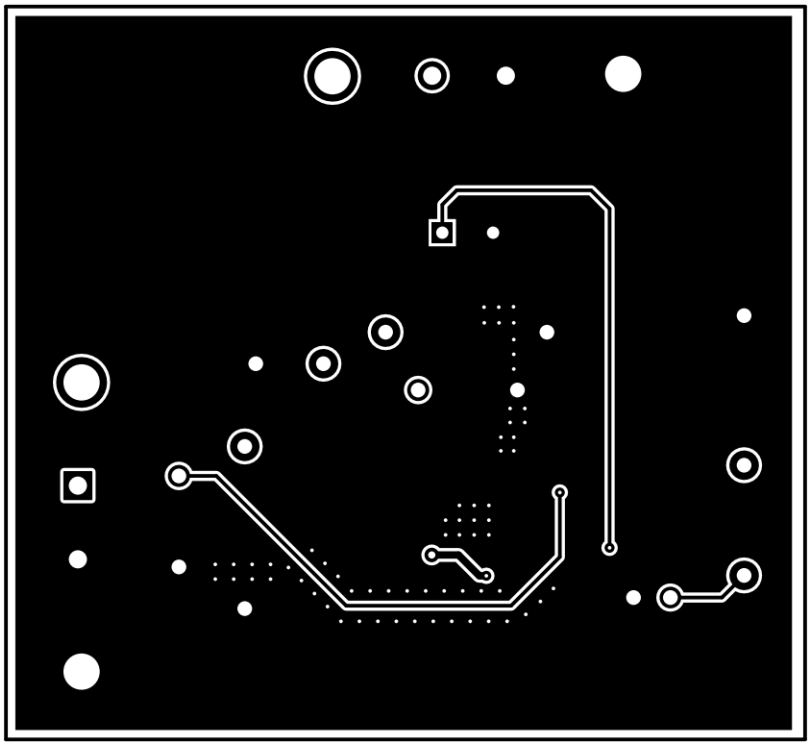

Figure 8. Bottom Layer

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6 Schematic, Bill of Materials, and Reference

6.1 Schematic

Figure 9 is the schematic for the TPS562231EVM.

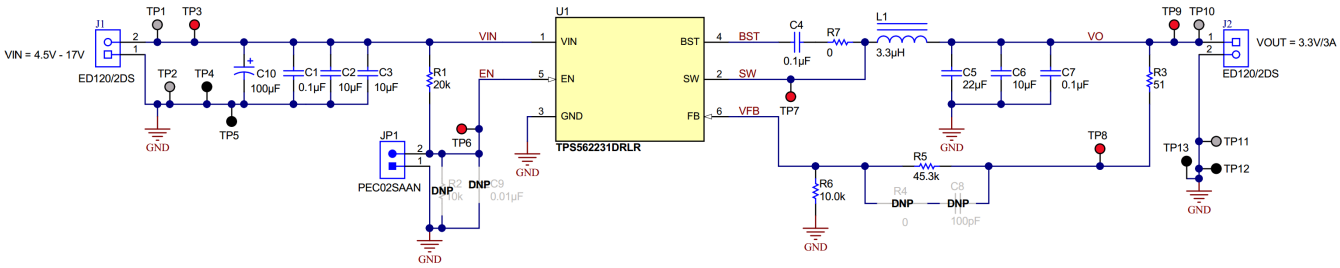

Figure 9. TPS562231EVM Schematic Diagram

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6.2 List of Materials

Table 5. List of Materials

Designator	Quantity	Value	Description	Package Reference	PartNumber	Manufacturer
!PCB	1		Printed Circuit Board		BSR073	Any
C1, C4, C7	3	0.1uF	CAP, CERM, 0.1 µF, 25 V, +/- 10%, X7R, 0603	0603	GRM188R71E104KA01D	MuRata
C2, C3	2	10uF	CAP, CERM, 10 µF, 25 V, +/- 10%, X7R, 1210	1210	GRM32DR71E106KA12L	MuRata
C5	1	22uF	CAP, CERM, 22 µF, 10 V, +/- 10%, X7R, 1210	1210	GRM32ER71A226ME20L	MuRata
C6	1	10uF	CAP, CERM, 10 µF, 10 V, +/- 10%, X7R, 1210	1210	GRM32DR71A106KA01L	MuRata
C10	1	100uF	CAP, AL, 100 µF, 25 V, +/- 20%, 0.13 ohm, TH	Cap D8.0x11.5mm	UBT1E101MPD1TD	Nichicon
J1, J2	2		Terminal Block, 5.08 mm, 2x1, Brass, TH	2x1 5.08 mm Terminal Block	ED120/2DS	On-Shore Technology
JP1	1		Header, 100mil, 2x1, Tin, TH	Header, 2 PIN, 100mil, Tin	PEC02SAAN	Sullins Connector Solutions
L1	1	3.3uH	Inductor, Shielded Drum Core, Powdered Iron, 3.3 µH, 6 A, 0.019 ohm, SMD	7.30x4.80x6.60 mm	74437349033	Wurth Elektronik
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650"H x 0.200"W	THT-14-423-10	Brady
R1	1	20k	RES, 20 k, 5%, 0.1 W, 0603	0603	CRCW060320K0JNEA	Vishay-Dale
R3	1	51	RES, 51, 5%, 0.1 W, 0603	0603	CRCW060351R0JNEA	Vishay-Dale
R5	1	45.3k	RES, 45.3 k, 1%, 0.1 W, 0603	0603	CRCW060345K3FKEA	Vishay-Dale
R6	1	10.0k	RES, 10.0k ohm, 1%, 0.1W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale
R7	1	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
SH-J1	1	1x2	Shunt, 100mil, Gold plated, Black	Shunt	SNT-100-BK-G	Samtec
TP1, TP2, TP10, TP11	4		Terminal, Turret, TH, Double	Keystone1502-2	1502-2	Keystone
TP3, TP6, TP7, TP8, TP9	5		Test Point, Miniature, Red, TH	Red Miniature Testpoint	5000	Keystone
TP4, TP5, TP12, TP13	4		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone
U1	1		4.5V to 17 V Input, 2-A Pulse Skip Mode Synchronous Step-Down Voltage Regulator, DRL0006A (SOT-5X3-6)	DRL0006A	TPS562231DRLR	Texas Instruments
C8	0	100pF	CAP, CERM, 100 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	GRM1885C1H101JA01D	MuRata
C9	0	0.01uF	CAP, CERM, 0.01 µF, 50 V, +/- 10%, X7R, 0603	0603	GRM188R71H103KA01D	MuRata
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A

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Table 5. List of Materials (continued)

R2	0	10k	RES, 10 k, 5%, 0.1 W, 0603	0603	CRCW060310K0JNEA	Vishay-Dale
R4	0	0	RES, 0 ohm, 5%, 0.1W, 0603	0603	ERJ-3GEY0R00V	Panasonic

6.3 Reference

1. *TPS56223x 4.5 V to 17 V Input, 2-A Synchronous Step-Down Voltage Regulator in SOT563* data sheet (SLUSDA4)

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NOTE:

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3.1 *United States*

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

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

CAUTION

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

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

FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 *Canada*

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

Concerning EVMs Including Radio Transmitters:

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

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

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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3.3.3 *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.

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