

# TPS65320C-Q1-EVM User Guide

The TPS65320C-EVM is a fully assembled PCB design for evaluation of TPS65320C-Q1, a switch mode DC-to-DC step-down converter with an integrated low-dropout voltage regulator (LDO).

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## 1 Introduction

The Texas Instruments TPS65320C-EVM evaluation module (EVM) helps designers evaluate the operation and performance of the TPS65320C-Q1, a switch-mode DC-to-DC step-down converter with an integrated low-dropout voltage regulator (LDO). This document describes how to setup and configure the EVM for operation. The document also provides the board layout, schematic, and bill of materials for the EVM. See [Table 1](#) and [Figure 1](#).

**Table 1. Device and Package Configurations**

CONVERTER	IC	PACKAGE
U1	TPS65320CQPWRQ1	HTSSOP-14

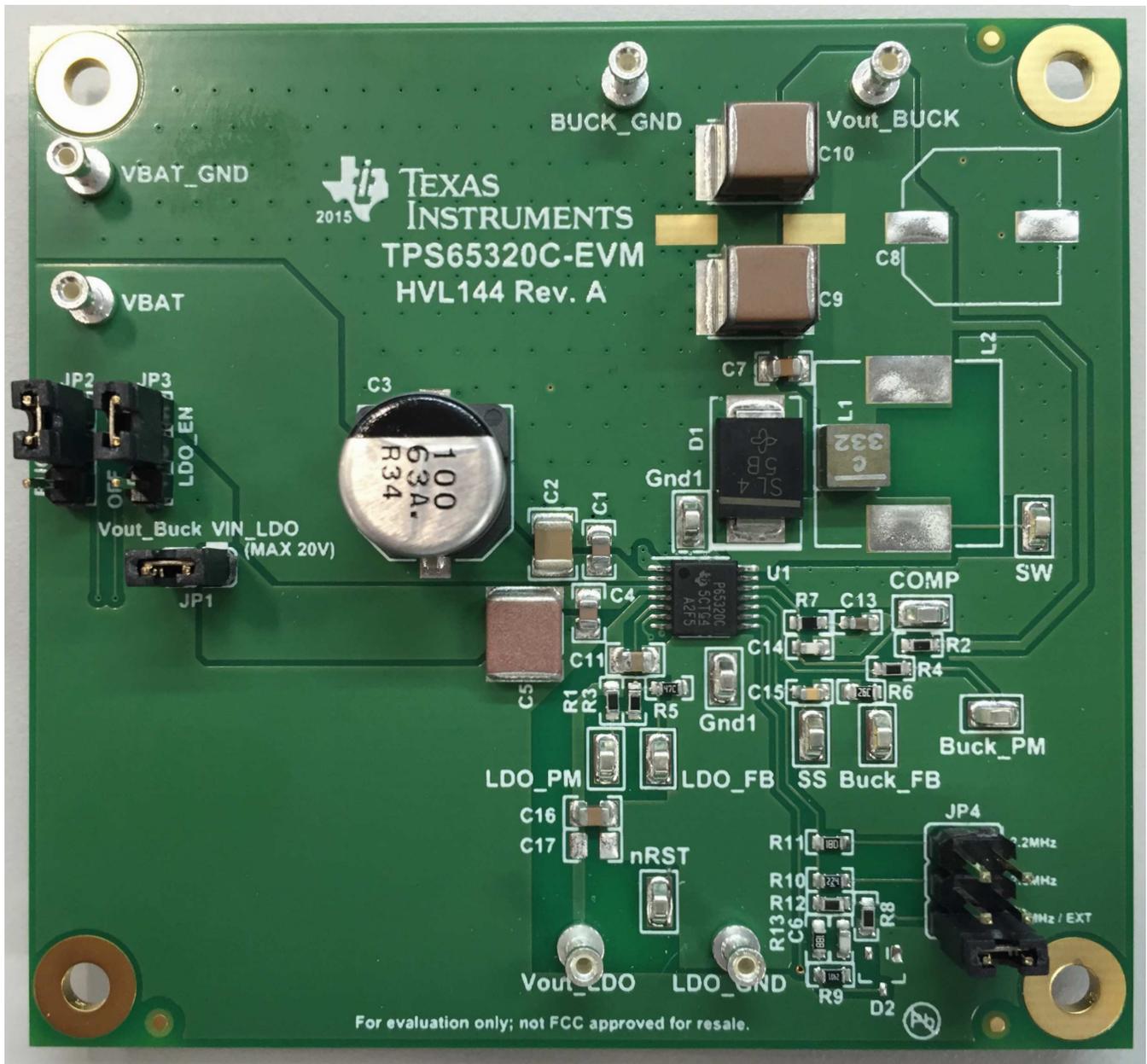


Figure 1. EVM Board

## 2 Setup and Operation

This section describes the jumpers and connectors on the EVM as well and how to properly connect, set up and use the TPS65320C-EVM.

### 2.1 Input and Output Connectors

The EVM terminal descriptions are in [Table 2](#).

**Table 2. Terminal Descriptions**

TERMINAL	DIRECTION	DESCRIPTION
VBAT	Input	This terminal is the power input terminal for the device. Adjacent to this terminal is the VBAT_GND reference ground. Use these terminals to attach the EVM to a cable harness.
Vout_BUCK	Output	This terminal is the output terminal for the TPS65320C-Q1 switch-mode regulator. Adjacent to this terminal is the BUCK_GND reference ground, which is closely coupled with the VBAT_GND.
Vout_LDO	Output	This terminal is the output terminal for the TPS65320C-Q1 switch-mode regulator. Adjacent to this terminal is the BUCK_GND reference ground, which is closely coupled with the VBAT_GND.

### 2.2 Jumper Settings

#### 2.2.1 JP4

JP4 is the jumper for selecting the operating switching frequency for the switch-mode regulator. The jumper will enable the pull-down resistor to set the frequency to approximately 1.6 MHz, 2.0 MHz, or 2.2 MHz, see [Figure 2](#). To apply an external clock, use the bottom pin for the GND connection. In case no jumper is set, the part defaults to 1.6 MHz.



**Figure 2. RT Jumper Settings**

### 2.2.2 BUCK\_EN and LDO\_EN

BUCK\_EN (JP2) and LDO\_EN (JP3) are the jumpers (Figure 3) for enabling the switch-mode converter, respectively the LDO. The rail will be enabled when the respective jumper is high, and disabled when low.

**NOTE:** Manual installation may cause ringing, potentially asserting nRST low. A power-cycle is required if this happens. Please use a signal generator to drive the Enable-pins to avoid this.

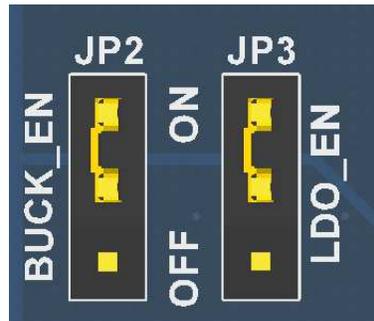


Figure 3. Enable Jumper Settings

### 2.2.3 JP1 (VIN\_LDO)

VIN\_LDO (JP1) selects the input supply for the LDO, see Figure 4. If the jumper is installed, the LDO is supplied from the Buck output, as long as the Buck is enabled. If the Buck should be disabled, the Auto-source function of the TPS65320C-Q1 will automatically use VIN as LDO-supply. Alternatively, another source could be used to supply the VIN\_LDO-pin. This source must not exceed a maximum 20 V and also must be smaller or equal to VIN. For proper LDO-usage, do not leave VIN\_LDO unsupplied.



Figure 4. VIN\_LDO Jumper

## 2.3 Test Points

The following list includes all test points with a short description:

- **Gnd1** — This test point is Ground
- **BUCK\_PM** — This test point allows easy access for Gain-Phase-Analysis for BUCK
- **BUCK\_FB** — This test point is for feedback-divider input for BUCK
- **SW** — This is the Buck phase pin
- **SS** — This is the soft-start and tracking pin
- **COMP** — This is for compensation of Buck
- **LDO\_PM** — This test point allows easy access for gain-phase-analysis for LDO
- **LDO\_FB** — This test point is for the feedback-divider input for LDO
- **nRST** — This is the reset output for LDO

## 2.4 Operation

The input voltage range for the converter is 4 V to 40 V. Since the Buck configuration is for a 5 V output, a higher voltage (approximately 6 V minimum) needs to be applied for normal performance. Also, the part has an initial start-up-voltage of 6 V minimum, so even if the board is modified for lower-output voltages, at first power-on, a supply-voltage of a minimum of 6 V needs to be applied once, before it can be lowered.

For proper operation of the TPS65320C-Q1-EVM, properly configure BUCK\_EN, LDO\_EN, VIN\_LDO, and J6 using the jumper terminals as follows.

- BUCK\_EN – enabled (left)
- LDO\_EN – enabled (left)
- JP4 - 2.0 MHz (R10)
- VIN\_LDO - installed

In this configuration, both regulators will turn on when power is applied. Disable regulators by moving the enable jumpers to the right. If the BUCK is disabled, the LDO is supplied from VIN, consider the power-dissipation at high VIN, VIN\_LDO will be at GND-level in this condition. To change the switching frequency, power-down the device before moving the jumper. To apply an external clock, install jumpers to set the frequency to the set-point closest to the external clock. In case of a loss of the external clock, the part falls back to the frequency created by the jumpers.

Configure the regulator using to the following settings in [Table 3](#).

**Table 3. Regulator Configuration**

REGULATOR	OUTPUT VOLTAGE	MAXIMUM OUTPUT CURRENT
BUCK	5 V	3.2 A
LDO	3.3 V	0.28 A

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**NOTE:** The output capacitors of the BUCK regulator are 25-V types, supporting up to 18 V of Vout. In case of higher output voltage, the recommendation is to replace those with capacitors providing higher-voltage ratings.

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At low-switching frequencies, high load-transients and limited allowed deviation of Vout, larger capacitance-values may be required. If needed, use the footprints of the unassembled electrolytic capacitors C9 and C10. Low-ESR-capacitors will also further reduce the coupled noise from the buck to the LDO.

On the EVM, a soft-start capacitor (C6) of 3.3 nF is installed, setting the time to approximately 1 ms. For other soft-start times, the capacitor may be replaced.

## 3 Board Layout

[Figure 5](#), [Figure 6](#), and [Figure 7](#) show the board layout for the TPS65320C-Q1-EVM. The EVM offers resistors and jumpers to program the switching frequency. Jumpers are also provided to enable the individual regulators.

The TPS65320C-Q1 converter offers high efficiency, but does dissipate power. The PowerPAD™ package offers an exposed thermal pad to enhance thermal performance. This must be soldered to the copper landing on the PCB, which is preferably connected to the GND-plane with multiple thermal vias for optimal performance.

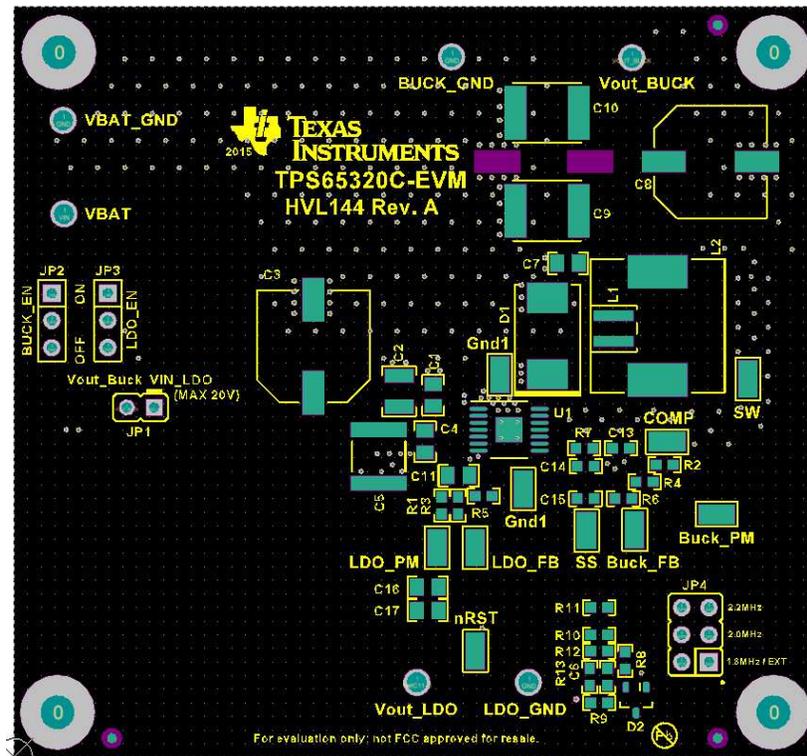


Figure 5. Top Assembly Layer

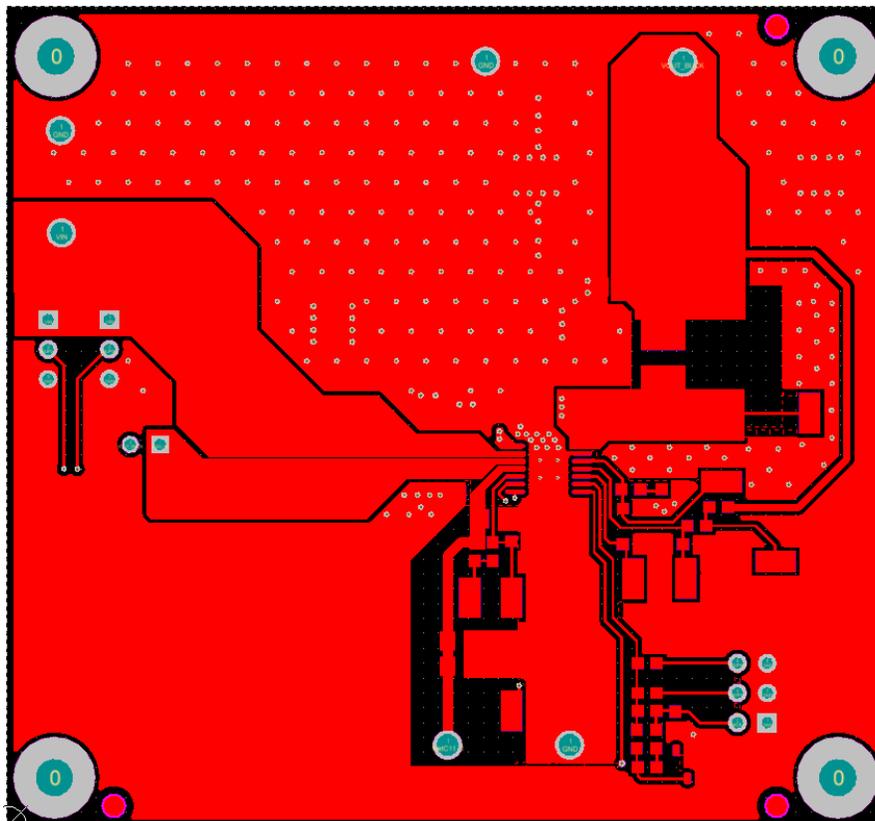


Figure 6. Top Layer Routing

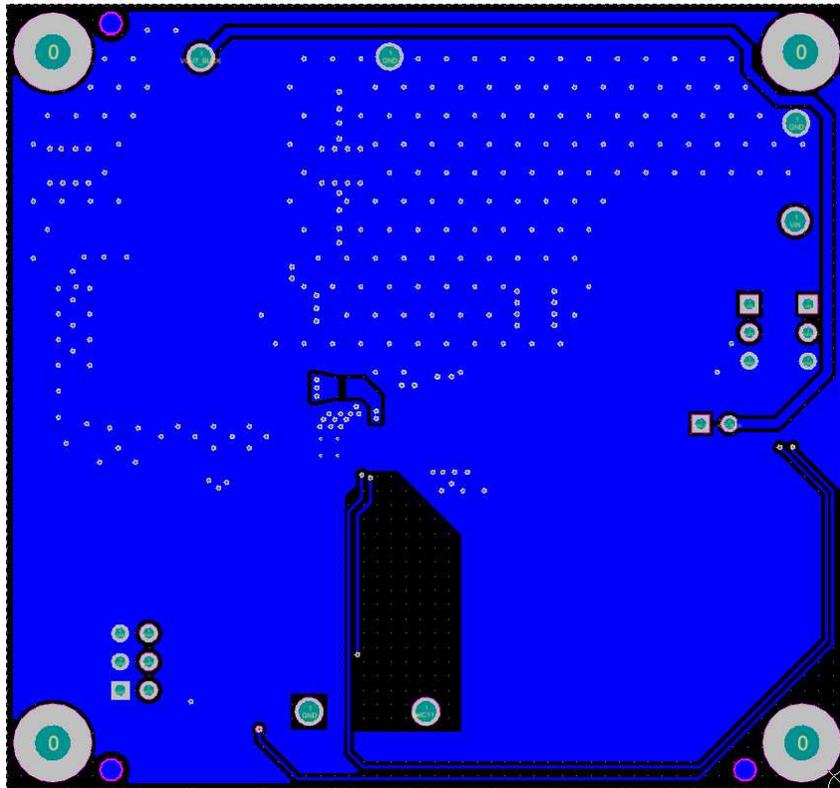


Figure 7. Bottom Layer Routing (Flipped)

4 Schematic

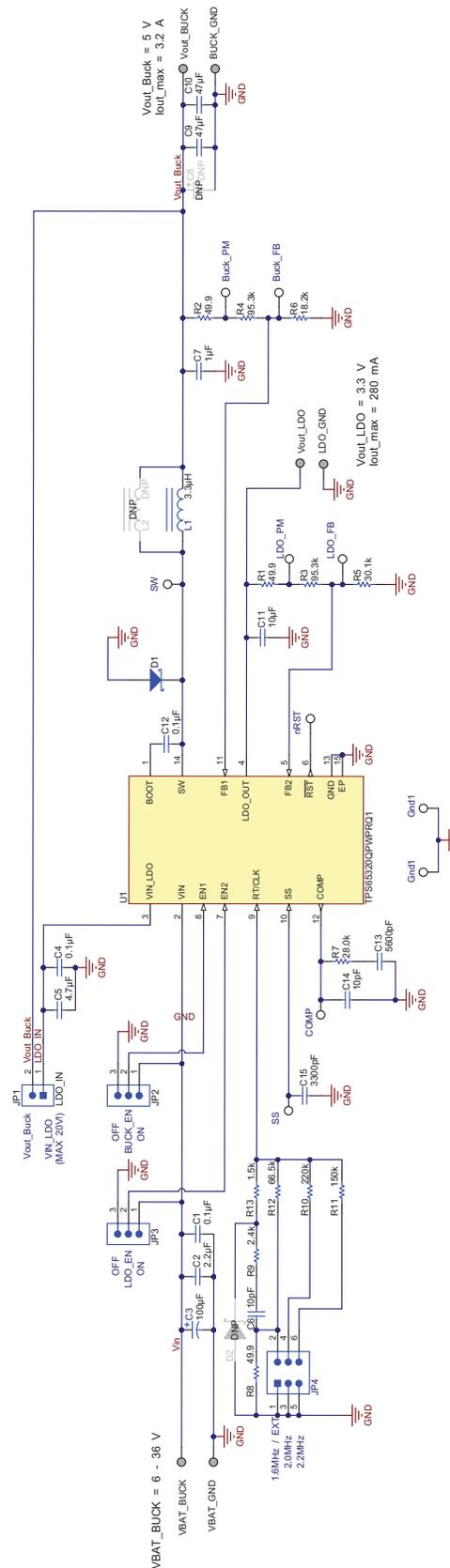


Figure 8. TPS65320C-Q1-EVM Schematic

## 5 Bill of Materials

DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE REFERENCE	PART NUMBER	MANUFACTURER	ALTERNATE PART NUMBER <sup>(1)</sup>	ALTERNATE MANUFACTURER
!PCB	1		Printed Circuit Board		HVL144	Any	–	–
C1, C4, C12	3	0.1uF	CAP, CERM, 0.1 $\mu$ F, 100 V, $\pm$ 10%, X7R, 0805	0805	C0805C104K1RACTU	Kemet		
C2	1	2.2uF	CAP, CERM, 2.2 $\mu$ F, 100 V, $\pm$ 10%, X7R, 1210	1210	C1210C225K1RACTU	Kemet		
C3	1	100uF	CAP, AL, 100 $\mu$ F, 63 V, $\pm$ 20%, 0.35 ohm, SMD	SMT Radial G	EEE-FK1J101P	Panasonic	N/A	N/A
C5	1	4.7uF	CAP, CERM, 4.7 $\mu$ F, 100 V, $\pm$ 20%, X7R, 2220	2220	C5750X7R2A475M	TDK		
C6	1	10pF	CAP, CERM, 10 pF, 50 V, $\pm$ 5%, C0G/NP0, 0603	0603	C0603C100J5GACTU	Kemet		
C7	1	1uF	CAP, CERM, 1 $\mu$ F, 50 V, $\pm$ 10%, X7R, 0805	0805	GRM21BR71H105KA12L	MuRata		
C9, C10	2	47uF	CAP, CERM, 47 $\mu$ F, 25 V, $\pm$ 20%, X7S, 6x5x5mm	6x5x5mm	CKG57NX7S1E476M500JH	TDK	N/A	N/A
C11	1	10uF	CAP, CERM, 10 $\mu$ F, 16 V, $\pm$ 10%, X7S, AEC-Q200 Grade 1, 0805	0805	GCM21BC71C106KE36L	MuRata		
C13	1	5600pF	CAP, CERM, 5600 pF, 100 V, $\pm$ 5%, X7R, 0603	0603	06031C562JAT2A	AVX		
C14	1	10pF	CAP, CERM, 10 pF, 50 V, $\pm$ 5%, C0G/NP0, 0603	0603	06035A100JAT2A	AVX		
C15	1	3300pF	CAP, CERM, 3300 pF, 100 V, $\pm$ 5%, X7R, 0603	0603	06031C332JAT2A	AVX		
D1	1	40V	Diode, Schottky, 40 V, 4 A, SMC	SMC	SL44-E3/57T	Vishay-Semiconductor	N/A	N/A
H1, H2, H3, H4	4		Bumpon, Hemisphere, 0.44 X 0.20, Clear	Transparent Bumpon	SJ-5303 (CLEAR)	3M		
JP1	1		Header, 2.54 mm, 2x1, Gold, TH	Header, 2.54 mm, 2x1, TH	GBC02SAAN	Sullins Connector Solutions		
JP2, JP3	2	1x3	Header, 100mil, 3x1, Gold, TH	PBC03SAAN	PBC03SAAN	Sullins Connector Solutions		
JP4	1		Header, 100mil, 3x2, Gold, TH	Sullins 100mil, 2x3, 230 mil above insulator	PBC03DAAN	Sullins Connector Solutions		
L1	1	3.3uH	Inductor, Shielded, Composite, 3.3 $\mu$ H, 5.5 A, 0.026 ohm, SMD	4.0x3.1x4.0mm	XAL4030-332MEB	Coilcraft	N/A	N/A
R1, R2, R8	3	49.9	RES, 49.9, 1%, 0.1 W, 0603	0603	CRCW060349R9FKEA	Vishay-Dale		
R3, R4	2	95.3k	RES, 95.3 k, 1%, 0.1 W, 0603	0603	CRCW060395K3FKEA	Vishay-Dale		

<sup>(1)</sup> Unless otherwise noted in the Alternate Part Number and/or Alternate Manufacturer columns, all parts may be substituted with equivalents.

**Revision History**
[www.ti.com](http://www.ti.com)

DESIGNATOR	QUANTITY	VALUE	DESCRIPTION	PACKAGE REFERENCE	PART NUMBER	MANUFACTURER	ALTERNATE PART NUMBER <sup>(1)</sup>	ALTERNATE MANUFACTURER
R5	1	30.1k	RES, 30.1 k, 1%, 0.1 W, 0603	0603	CRCW060330K1FKEA	Vishay-Dale		
R6	1	18.2k	RES, 18.2 k, 1%, 0.1 W, 0603	0603	CRCW060318K2FKEA	Vishay-Dale		
R7	1	28.0k	RES, 28.0 k, 1%, 0.1 W, 0603	0603	CRCW060328K0FKEA	Vishay-Dale		
R9	1	2.4k	RES, 2.4 k, 5%, 0.1 W, 0603	0603	CRCW06032K40JNEA	Vishay-Dale		
R10	1	220k	RES, 220 k, 1%, 0.1 W, 0603	0603	RC0603FR-07220KL	Yageo America		
R11	1	150k	RES, 150 k, 1%, 0.1 W, 0603	0603	CRCW0603150KFKEA	Vishay-Dale		
R12	1	66.5k	RES, 66.5 k, 1%, 0.1 W, 0603	0603	CRCW060366K5FKEA	Vishay-Dale		
R13	1	1.5k	RES, 1.5 k, 5%, 0.1 W, 0603	0603	CRCW06031K50JNEA	Vishay-Dale		
SH-JP1, SH-JP2, SH-JP3, SH-JP4	4	1x2	Shunt, 100mil, Gold plated, Black	Shunt	969102-0000-DA	3M	SNT-100-BK-G	Samtec
TP1, TP12, TP13, TP14, TP15, TP16	6		PCB Pin, Swage Mount, TH	PCB Pin(2505-2)	2505-2-00-44-00-00-07-0	Mill-Max		
TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11	10	SMT	Test Point, Miniature, SMT	Testpoint_Keystone_Miniature	5015	Keystone		
U1	1		40-V Step-Down Converter With Eco-mode and LDO Regulator, PWP0014E	PWP0014E	TPS65320QPWRQ1	Texas Instruments		
C8	0	47uF	CAP, AL, 47 µF, 80 V, ±20%, 0.7 ohm, SMD	SMT Radial G	EEE-FK1K470P	Panasonic		
D2	0	40V	Diode, Schottky, 40 V, 0.2 A, SOT-23	SOT-23	BAS40-7-F	Diodes Inc.		
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A		
L2	0	10uH	Inductor, Shielded, Ferrite, 10 µH, 5.8 A, 0.019 ohm, SMD	12.5x12.5mm	B82477P4103M000	TDK		

**6 Revision History**

DATE	REVISION	NOTES
April 2016	*	Initial Release

## STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an "EVM" or "EVMs") to the User ("User") in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.
  - 1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM ("Software") shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms and conditions that accompany such Software
  - 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.
2. *Limited Warranty and Related Remedies/Disclaimers:*
  - 2.1 These terms and conditions do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.
  - 2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for any defects that are caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.
  - 2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, 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:*

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

#### Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). 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/lstds/ti\\_ja/general/eStore/notice\\_01.page](http://www.tij.co.jp/lstds/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/lstds/ti\\_ja/general/eStore/notice\\_01.page](http://www.tij.co.jp/lstds/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 by Radio Law of Japan to follow the instructions below with respect to EVMs:

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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#### 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:*

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