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

<table>
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<tr>
<th>CONVERTER</th>
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<th>PACKAGE</th>
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<tr>
<td>U1</td>
<td>TPS65320CQPWPRQ1</td>
<td>HTSSOP-14</td>
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</table>
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

<table>
<thead>
<tr>
<th>TERMINAL</th>
<th>DIRECTION</th>
<th>DESCRIPTION</th>
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<tr>
<td>VBAT</td>
<td>Input</td>
<td>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.</td>
</tr>
<tr>
<td>Vout_BUCK</td>
<td>Output</td>
<td>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.</td>
</tr>
<tr>
<td>Vout_LDO</td>
<td>Output</td>
<td>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.</td>
</tr>
</tbody>
</table>

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](image-url)
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 the following settings in Table 3.

<table>
<thead>
<tr>
<th>REGULATOR</th>
<th>OUTPUT VOLTAGE</th>
<th>MAXIMUM OUTPUT CURRENT</th>
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</thead>
<tbody>
<tr>
<td>BUCK</td>
<td>5 V</td>
<td>3.2 A</td>
</tr>
<tr>
<td>LDO</td>
<td>3.3 V</td>
<td>0.28 A</td>
</tr>
</tbody>
</table>

**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.

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)
## Bill of Materials

<table>
<thead>
<tr>
<th>DESIGNATOR</th>
<th>QUANTITY</th>
<th>VALUE</th>
<th>DESCRIPTION</th>
<th>PACKAGE REFERENCE</th>
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<td>CAP, CERM, 0.1 µF, 100 V, ±10%, X7R, 0805</td>
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<td>C0805C104K1RACTU</td>
<td>Kemet</td>
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(1) Unless otherwise noted in the Alternate Part Number and/or Alternate Manufacturer columns, all parts may be substituted with equivalents.
### Designators and Components

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### Revision History

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<tr>
<th>DATE</th>
<th>REVISION</th>
<th>NOTES</th>
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<tbody>
<tr>
<td>April 2016</td>
<td>*</td>
<td>Initial Release</td>
</tr>
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</table>
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 Industry 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/labs/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、次のとところをご覧ください。
http://www.tij.co.jp/labs/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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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

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

4 EVM Use Restrictions and Warnings:

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

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

4.3 Safety-Related Warnings and Restrictions:

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

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

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

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

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

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

7. **User's Indemnity Obligations and Representations:** User will defend, indemnify and hold TI, its licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "claims") arising out of or in connection with any handling or use of the EVM that is not in accordance with these terms and conditions. This obligation shall apply whether claims arise under statute, regulation, or the law of tort, contract or any other legal theory, and even if the EVM fails to perform as described or expected.

8. **Limitations on Damages and Liability:**

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

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

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