# TPS65321EVM (HVL125A) User Guide

The Texas Instruments TPS65321EVM evaluation module (EVM) helps designers evaluate the operation and performance of the TPS65321-Q1, a switch-mode DC-DC step-down converter with an integrated low-dropout voltage regulator (LDO). This user guide describes how to setup and configure the EVM for operation. The document includes the board layout, schematic, and bill of materials for the EVM.

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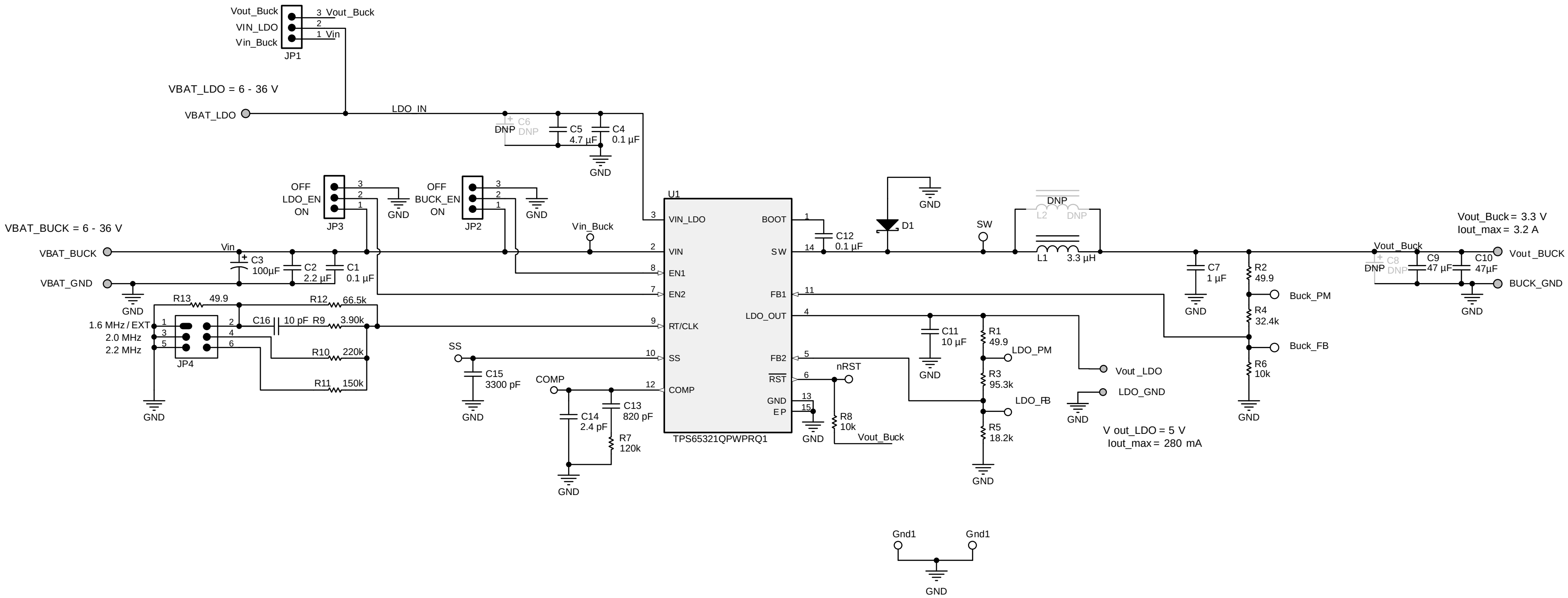
## 1 Introduction

The HVL125A is a fully assembled PCB design for evaluation of TPS65321-Q1, a device containing a DC-DC step-down converter and a low-dropout voltage regulator.

## 2 Schematic, Bill of Materials, and Layout

This section provides a detailed description of the schematic, bill of materials (BOM), and layout.

## 2.1 Schematic




C6, C8 and L2 are not fitted on the board.

**Figure 1. TPS65321-Q1 Schematic**

## 2.2 Bill of Materials

**Table 1. BOM**

| Designator | Quantity | Value | Description | Package Reference |
|---|---|---|---|---|
| !PCB | 1 | | Printed Circuit Board | |
| C1, C4, C12 | 3 | 0.1 µF | Capacitor, ceramic, 0.1 µF, 100 V, ±10%, X7R, 0805 | 0805 |
| C2 | 1 | 2.2 µF | Capacitor, ceramic, 2.2 µF, 100 V, ±10%, X7R, 1210 | 1210 |
| C3 | 1 | 100 µF | Capacitor, aluminum, 100 µF, 63 V, ±20%, 0.35 Ω, SMD | SMT Radial G |
| C5 | 1 | 4.7 µF | Capacitor, ceramic, 4.7 µF, 100 V, ±20%, X7R, 2220 | 2220 |
| C7 | 1 | 1 µF | Capacitor, ceramic, 1 µF, 50 V, ±10%, X7R, 0805 | 0805 |
| C9, C10 | 2 | 47 µF | Capacitor, ceramic, 47 µF, 25 V, ±20%, X7S, 6x5x5mm | 6x5x5mm |
| C11 | 1 | 10 µF | Capacitor, ceramic, 10 µF, 16 V, ±10%, X5R, 0805 | 0805 |
| C13 | 1 | 820 pF | Capacitor, ceramic, 820 pF, 50 V, ±5%, C0G/NP0, 0603 | 0603 |
| C14 | 1 | 2.4 pF | Capacitor, ceramic, 2.4 pF, 50 V, ±5%, C0G/NP0, 0402 | 0402 |
| C15 | 1 | 3300 pF | Capacitor, ceramic, 3300 pF, 100 V, ±5%, X7R, 0603 | 0603 |
| C16 | 1 | 10 pF | Capacitor, ceramic, 10 pF, 50 V, ±5%, C0G/NP0, 0603 | 0603 |
| D1 | 1 | 40 V | Diode, Schottky, 40 V, 4 A, SMC | SMC |
| H1, H2, H3, H4 | 4 | | Bumpon, Hemisphere, 0.44 X 0.20, Clear | Transparent Bumpon |
| JP1, JP2, JP3 | 3 | 1x3 | Header, 100mil, 3x1, Gold, TH | PBC03SAAN |
| JP4 | 1 | | Header, 100mil, 3x2, Gold, TH | Sullins 100mil, 2x3, 230 mil above insulator |
| L1 | 1 | 3.3 µH | Inductor, Shielded, Composite, 3.3 µH, 5.5 A, 0.026 Ω, SMD | 4.0x3.1x4.0mm |
| R1, R2, R13 | 3 | 49.9 Ω | Resistor, 49.9 Ω, 1%, 0.1 W, 0603 | 0603 |
| R3 | 1 | 95.3 kΩ | Resistor, 95.3 kΩ, 1%, 0.1 W, 0603 | 0603 |
| R4 | 1 | 32.4 kΩ | Resistor, 32.4 kΩ, 1%, 0.1 W, 0603 | 0603 |
| R5 | 1 | 18.2 kΩ | Resistor, 18.2 kΩ, 1%, 0.1 W, 0603 | 0603 |
| R6, R8 | 2 | 10 kΩ | Resistor, 10 kΩ, 5%, 0.1 W, 0603 | 0603 |
| R7 | 1 | 120 kΩ | Resistor, 120 kΩ, 1%, 0.1 W, 0603 | 0603 |
| R9 | 1 | 3.9 kΩ | Resistor, 3.90 kΩ, 1%, 0.1 W, 0603 | 0603 |
| R10 | 1 | 220 kΩ | Resistor, 220 kΩ, 1%, 0.1 W, 0603 | 0603 |
| R11 | 1 | 150 kΩ | Resistor, 150 kΩ, 1%, 0.1 W, 0603 | 0603 |
| R12 | 1 | 66.5 kΩ | Resistor, 66.5 kΩ, 1%, 0.1 W, 0603 | 0603 |
| SH-JP1, SH-JP2, SH-JP3, SH-JP4 | 4 | 1x2 | Shunt, 100mil, Gold plated, Black | Shunt |
| TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11 | 11 | SMT | Test Point, Miniature, SMT | Testpoint_Keystone_Miniature |
| TP12, TP13, TP14, TP15, TP16, TP17, TP18 | 7 | | PCB Pin, Swage Mount, TH | PCB Pin(2505-2) |
| U1 | 1 | | 36-V Step-Down Converter with Eco-mode™ and LDO Regulator, PWP0014E | PWP0014E |
| C6 | 0 | 100 µF | Capacitor, aluminum, 100 µF, 63 V, ± 20%, 0.35 Ω, SMD | SMT Radial G |
| C8 | 0 | 47 µF | Capacitor, aluminum, 47 µF, 80 V, ±20%, 0.7 Ω, SMD | SMT Radial G |
| FID1, FID2, FID3, FID4, FID5, FID6 | 0 | | Fiducial mark. There is nothing to buy or mount. | Fiducial |
| L2 | 0 | 10µH | Inductor, Shielded, Ferrite, 10 µH, 5.8 A, 0.019 Ω, SMD | 12.5x12.5mm |

### 2.3 Layout and Component Placement

Figure 2 and Figure 3 top and bottom overviews of the printed circuit board (PCB) to show the component placement of the EVM. Two additional solder pads are added to Vout_Buck, between C9 and C10. These pads allow the user to change the output capacitor configuration from the original setup with two ceramic, capacitors (C9 and C10), to an electrolytic capacitor. These pads also allow an additional electrolytic capacitor to be mounted on the C8-footprint.

The LDO input is decoupled with 4.7-µF and 0.1-µF capacitor, but provides and additional footprint for an electrolytic capacitor.

The default switching frequency for the EVM-configuration is 2 MHz and therefore a smaller inductor (3.3 µH, 4 mm × 4 mm) value was selected and mounted on the smaller footprint L1. In case a lower switching frequency is desired, the EVM provides a larger (12 mm × 12 mm) footprint to assemble a larger value (such as L2 as listed in Table 1).

Figure 4 and Figure 5 show the top and bottom layout of the EVM. Although the TPS65321-Q1 device is a highly efficient converter, a good connection between the heat sink and ground plane is important. Therefore, ensuring that the thermal pad has a good connection to the copper landing is important. To improve the thermal performance of the board, the thermal pad in this case is connected to ground with multiple vias to the bottom ground plane. For better noise immunity, the LDO-GND is connected to the PWR_GND only at the PowerPad™.

**NOTE:** The feedback trace from Vout_Buck to the feedback of the device is shielded with a ground plane which minimizes noise on the feedback node.

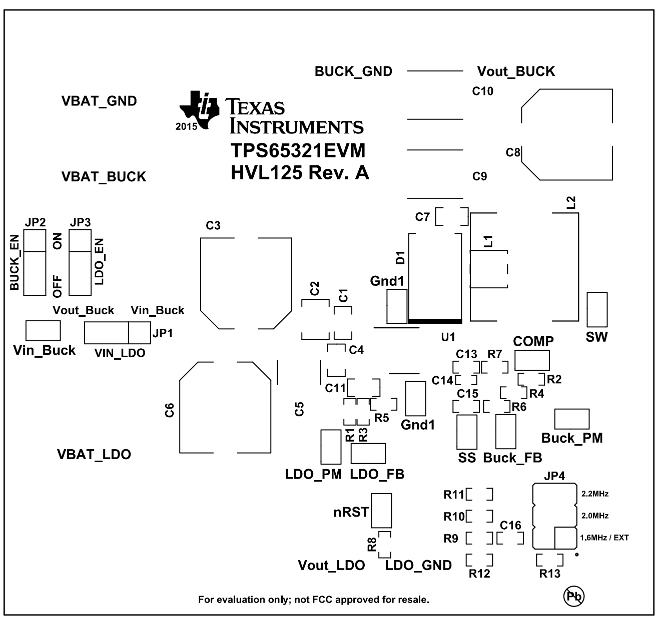



Figure 2. Component Placement—Top Overview

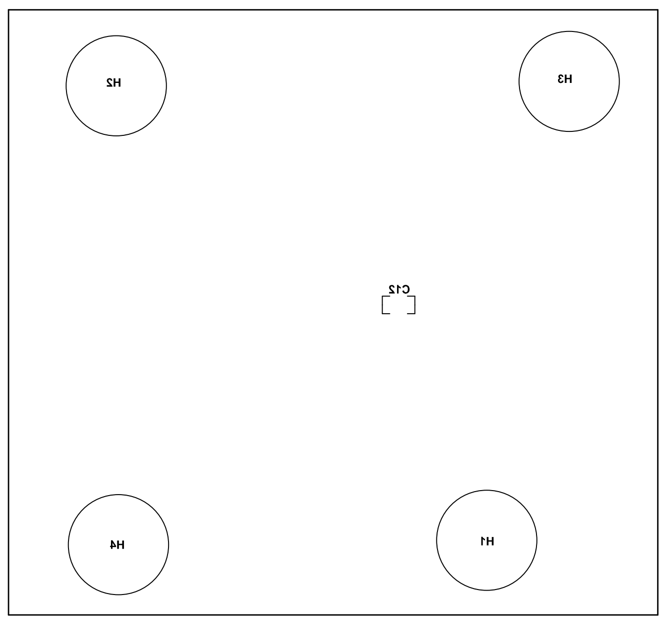


Figure 3. Component Placement—Bottom Overview

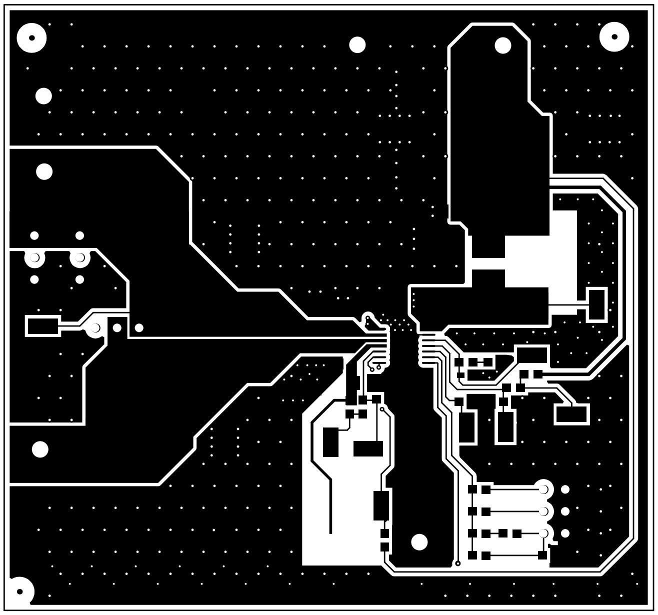


Figure 4. Layout—Top

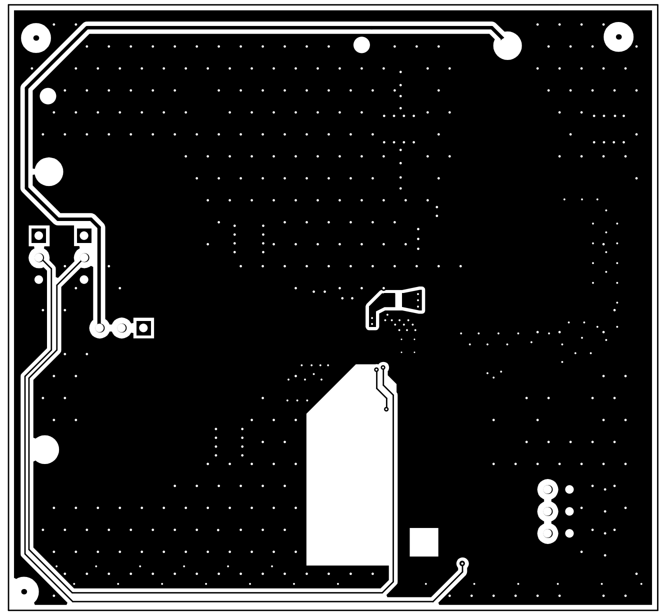


Figure 5. Layout—Bottom

## 3 Setup and Operation

This section describes how to setup and configure the EVM for basic operation. A detailed description of connectors, jumpers, and test points are provided in addition to the typical operation setup of the EVM. An example of operation is also included.

### 3.1 Input and Output Connectors

The EVM has four pairs of connectors (turrets): two inputs (VBAT_GND is shared) and two outputs. Table 2 lists the connectors in addition to a function description which includes the electrical specifications.

**Table 2. Terminal Descriptions**

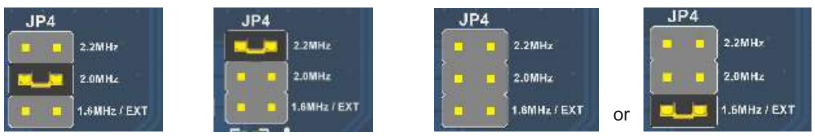
| Terminal | Direction | Description |
|---|---|---|
| VBAT_BUCK and VBAT_ GND | Input | This terminal is the supply voltage for the buck converter of the device, the device and the design is capable of operate with a input voltage between 3.6 to 36 V. |
| VBAT_LDO (and VBAT_GND) | Input | This terminal is the supply voltage for the LDO of the device, the device and the design can operate with an input voltage between 3 to 36 V. Note that the LDO input can be supplied from Vin_Buck or Vout_Buck by setting the Vin_LDO jumper. In the current configuration, Vout of the buck is lower than the desired output voltage of the LDO, so the LDO supply needs to be Vin_Buck. |
| Vout_Buck and BUCK_GND | Output | Buck is the output voltage of the buck regulator and are designed to deliver 3.3 V and capable to deliver a maximum output current of 3.2 A. |
| Vout_LDO and LDO_GND | Output | LDO is the output voltage of the LDO and are able to deliver 0.28 A. In this designed is the output voltage set to 5 V. |

## 3.2 Jumper Setting and Configuration

### 3.2.1 RT/CLK

RT/CLK is the jumper used to select the switching frequency for the switch-mode regulator. If no jumper is used, the switching frequency defaults to 1.6 MHz. The jumper enables additional pulldown resistors to set the frequency to approximately 2 MHz (default) or 2.2 MHz. The 1.6MHz/EXT header also supports the application of an external clock.

**NOTE:** If a significantly lower switching frequency is selected, additional modifications, such as a larger inductor-value or compensation for a lower bandwidth, may be required.




2 MHZ (default) 2.2 MHz 16 MHz

**Figure 6. Switching Frequency Jumper Settings**

### 3.2.2 BUCK_EN and LDO_EN

BUCK_EN and LDO_EN are the jumpers used to enable or disable the buck converter and the LDO. Setting either jumper to ON enables the respective rail. Setting the jumper to OFF or leaving it floating disables the respective rail.

**NOTE:** Manual installation of the jumper may cause ringing, potentially asserting nRST low.

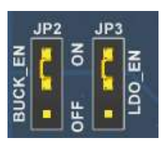



**Figure 7. Enable and Disable Jumper Configurations**

### 3.2.3 VIN_LDO

VIN_LDO is used to select the input voltage source for the LDO. The input can be selected between Vin_Buck or Vout_Buck. The default configuration configures the LDO-output voltage (5 V) to be higher than the Buck-output voltage (3.3 V). Vout-Buck is generally insufficient to supply the LDO. Consequently, VIN_LDO it should be set to Vin_Buck as shown in Figure 8. Alternatively, an external voltage can be applied to the VBAT_LDO input (in this case, remove the JP1 jumper).

**NOTE:** For proper operation, VBAT_BUCK must be supplied when the LDO is used (Buck can be disabled).


**Figure 8. Supply-Selection for LDO**

### 3.3 Test Point Description

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

**Vin_Buck —** This test point measures the voltage on the VIN pin of the device.

**SW —** This test point probes the switching of the buck converter.

**Buck_PM —** This test point allows for easy access for gain and phase analysis of the buck regulator.

**Buck_FB —** This test point measures the feedback of the buck.

**LDO_PM —** This test point allows for easy access for gain and phase analysis of the LDO.

**LDO_FB —** This test point measures the feedback of the LDO.

**COMP —** This test point is the compensation network for the feedback of the buck regulator.

**SS —** This test point measures the voltage drop over the soft start capacitor of the buck regulator.

**nRST —** This test point measures when the Buck is in regulation.

**Gnd1 (2x) —** These test-points provide additional GND connections close the device.

Output voltages can be measured at the turrets provided for each output.

### 3.4 Basic Operation

The input voltage range for the converter is 3.6 V to 36 V. Because the LDO is configured for 5-V output on this EVM, supply a sufficiently high voltage to the supply-pins.

For proper operation of the HVL125, configure BUCK_EN, LDO_EN, and RT/CLK properly using the following jumpers and configurations:

- BUCK_EN — ON
- LDO_EN — ON
- JP4 — 2 MHz
- VIN_LDO – Vin_Buck

In the default configuration, the output voltage of the Buck is lower than the desired LDO-output voltage, consequently the LDO should be supplied from VBAT by setting the VIN_LDO jumper to Vin_Buck. With this configuration, both regulators turn on when power is applied. Disable the regulators using the enable jumpers.

To change the switching frequency, power down the device before moving the jumper. If an external clock is used, it should be applied to the bottom-left pin of JP4, GND, to the bottom-right pin of JP4. If the external clock is missing, the buck can default to a frequency set by the RT-jumpers. If the buck is close to the previously used external frequency (essentially if approximately 2-MHz-clock is applied), keep jumper in the center installed. If approximately 2.2 MHz is used, keep the jumper on top installed. In case a frequency of about 1.6 MHz is used, the switching frequency will default to the 1.6-MHz setpoint without a jumper installed.

**NOTE:** The external components were selected for a high switching frequency (2.2 MHz). Lower frequencies will demand component changes, specifically a larger inductor and adapted compensation.

**Table 3. Configured Output Voltages and Maximum Currents**

| Regulator | Output Voltage | Maximum Output Current |
|---|---|---|
| Buck | 3.3 V | 3.2 A |
| LDO | 5 V | 280 mA |

**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, TI recommends replacing these with capacitors having higher voltage ratings.

Low switching frequencies, high load transients, or limiting the allowed deviation of VOUT may require larger capacitance values. If needed, use the footprints of the unassembled electrolytic capacitor, C8, and the added soldering pads between C9 and C10. Low-ESR capacitors also further reduce the coupled noise from the buck to the LDO.

On the EVM, a soft-start capacitor (C15) of 3.3 nF is installed which sets the time to approximately 700 µs. For other soft-start-times, the capacitor may be replaced.

## Revision History

**Changes from Original (September 2015) to A Revision** **Page**

- Changed value of R5 to 18.2k in schematic and BOM ........ 2

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

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      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**

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- *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*

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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

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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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4.1 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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