TPS92512EVM-001 High-Current Buck Regulator With Analog and PWM Dimming for High Brightness LEDs

1 Introduction

The TPS92512EVM-001 evaluation module (EVM) helps designers evaluate the operation and performance of the TPS92512HV buck switching regulator designed for high-current LED-drive applications. The TPS92512HV device is designed to control the drive of high-brightness light emitting diodes and features a wide input voltage range (4.5 V to 60 V), PWM dimming capability, analog dimming capability, adjustable/syncable switching frequency, and input undervoltage protection.

2 Warnings

Observe the following precautions when using the TPS92512EVM-001.

**WARNING**

DO NOT STARE DIRECTLY INTO THE LED LIGHT SOURCE. Intense light sources have a high-secondary blinding effect. A temporary reduction in visual acuity and afterimages can occur, leading to irritation, annoyance, visual impairment, and even accidents—depending on the situation. Always consider the use of light filtering and darkening protective eyewear and be fully aware of surrounding laboratory-type set-ups when viewing intense light sources to minimize or eliminate such risks in order to avoid accidents related to temporary blindness.

**WARNING**

Do not stare at the operating LED (Risk Group1 [RG1]). See IEC32471-1 ed1.0:2009-08 for risk group definitions.

3 Description

The TPS92512EVM-001 provides a high-brightness LED driver based on the TPS92512HV buck regulator. It is designed to operate with an input voltage in the range of 12 V to 48 V. The EVM is set up for a default output current of 1.5 A for an LED stack between approximately 5 V and 25 V. The TPS92512 device helps provide high efficiency, good line regulation, low output ripple, and a wide dimming range.

3.1 Typical Applications

This converter design describes an application of the TPS92512HV device as an LED driver with the specifications described in Table 1. For applications with a different input voltage range or different output voltage range refer to the TPS92512 data sheet.
3.2 Features

3.2.1 Connector Description

This section describes the connectors and test points on the EVM and how to properly connect, setup, and use the TPS92512EVM-001.

3.2.1.1 J1, LED+, LED-

The screw-down connector, J1, and the test posts marked LED+ and LED- are for connecting the LED load to the board. The leads to the LED load should be twisted and kept as short as possible to minimize voltage drop, inductance, and EMI transmission. This design is for approximately 2 to 7 white LEDs.

3.2.1.2 J2, VIN, GND

The screw-down connector, J2, and the test posts marked VIN and GND are for connecting the EVM to the DC input voltage supply. The input supply ground should be connected to J2 or the GND test post directly next to J2. One other GND test point is provided on the board that can also be used for all purposes but input power.

3.2.1.3 UVLO

The test point UVLO connects directly to the UVLO pin of the TPS92512 device. The voltage range is 0 V to 4.5 V if driven externally. The UVLO resistor divider should be used for the UVLO function, but the UVLO voltage can be monitored with this test point. Pulling UVLO to GND will also serve to disable the part and put it into low power shutdown mode.

3.2.1.4 PDIM

The PDIM test point connects directly to the PDIM pin of the TPS92512 device. Leave open for normal operation. If PWM dimming is used, apply a square wave with a low level of GND and a high level of between 2 V and 4.5 V. The dimming frequency range is 100 Hz to 1 kHz.

3.2.1.5 SYNC

The SYNC test point is AC coupled to the RT/CLK pin of the TPS92512 device through a 4.02-kΩ resistor in series with a 470-pF capacitor. Apply a square wave with a low level of GND and a high level of 3.3 V to synchronize the switching frequency to the applied frequency. The frequency range of SYNC is 200 kHz to 2 MHz.

3.2.1.6 IADJ

The IADJ test point connects directly to the IADJ pin of the TPS92512 device. The default is pulled high through a 10M resistor to VIN resulting in an ISENSE voltage of 300mV. The range on the IADJ pin is 180 mV to 1.8 V and the corresponding ISENSE voltage is $V_{IADJ} / 6$.

3.2.1.7 PH

A large via, labelled PH, is included and sized specifically to receive the probe tip of a standard 10x probe. Use this via to monitor the switching waveform at the PH pin of the device.
4  Electrical Performance Specifications

Table 1. TPS92512EVM-001 Electrical Performance Specifications

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>INPUT CHARACTERISTICS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage range</td>
<td></td>
<td>12</td>
<td>48</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Maximum input current</td>
<td></td>
<td>1.5</td>
<td>1.5</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Input UVLO setting</td>
<td></td>
<td>11.5</td>
<td>11.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>OUTPUT CHARACTERISTICS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output voltage, VOUT</td>
<td>LED+ to LED-</td>
<td>5</td>
<td>25</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Output current</td>
<td></td>
<td>1.425</td>
<td>1.5</td>
<td>1.575</td>
<td>A</td>
</tr>
<tr>
<td>Output current ripple</td>
<td></td>
<td>20</td>
<td></td>
<td></td>
<td>mApp</td>
</tr>
<tr>
<td>Analog dimming range</td>
<td>IADJ = 180 mV to 1.8 V</td>
<td>10:1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PWM dimming range</td>
<td>250-Hz PWM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SYSTEMS CHARACTERISTICS</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Efficiency</td>
<td>Input voltage = 24 V, 4 LEDs</td>
<td>93%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switching frequency</td>
<td></td>
<td>570</td>
<td></td>
<td></td>
<td>kHz</td>
</tr>
</tbody>
</table>

5  Schematic

Figure 1. TPS92512EVM-001 Schematic
6 Performance Data and Typical Characteristic Curves

Figure 2 through Figure 8 show the typical performance curves for the TPS92512EVM-001. Unless otherwise noted, \( V_{\text{IN}} = 24 \) V and 3 LED output.

6.1 Efficiency

![Efficiency vs Input Voltage](image)

Top = 7 LEDs       Middle = 4 LEDs       Bottom = 2 LEDs

Figure 2. Efficiency vs Input Voltage

6.2 Line Regulation

![Output Current vs Input Voltage](image)

Figure 3. Output Current vs Input Voltage
6.3 **PWM Dimming**

![Graph showing LED Current vs PWM Duty Cycle (250Hz)](image)

**Figure 4. Output Current vs PWM Duty Cycle (250Hz)**

6.4 **Analog Dimming**

![Graph showing LED Current vs IADJ Voltage](image)

**Figure 5. Output Current vs IADJ Voltage**
6.5 PWM Dimming Waveforms

Figure 6. 1% Duty Cycle, 250-Hz PWM Dimming

Figure 7. 50% Duty Cycle, 250-Hz PWM Dimming
Figure 8. 99% Duty Cycle, 250-Hz PWM Dimming

Top = PDIM

Bottom = LED Current
Figure 9 and Figure 10 show the design of the TPS92512EVM-001 printed circuit board.

Figure 9. Top Layer and Top Overlay (Top View)

Figure 10. Bottom Layer and Bottom Overlay (Bottom View)
Table 2 lists the TPS92512EVM-001 components list according to the schematic shown in Figure 1.

<table>
<thead>
<tr>
<th>REFERENCE DESIGNATOR</th>
<th>QTY</th>
<th>VALUE</th>
<th>DESCRIPTION</th>
<th>SIZE</th>
<th>PART NUMBER</th>
<th>MFR</th>
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</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>0.1 µF</td>
<td>CAP, CERM, 0.1 µF, 25 V, ±10%, X5R</td>
<td>0603</td>
<td>885012206071</td>
<td>Wurth</td>
</tr>
<tr>
<td>C2, C4, C9</td>
<td>3</td>
<td>4.7 µF</td>
<td>CAP, CERM, 4.7 µF, 100 V, ±10%, X7S</td>
<td>1210</td>
<td>C3225X7S2A475K200AB</td>
<td>TDK</td>
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<tr>
<td>C3, C6</td>
<td>2</td>
<td>0.01 µF</td>
<td>CAP, CERM, 0.01 µF, 100 V, ±10%, X7R</td>
<td>0603</td>
<td>06031C103KAT2A</td>
<td>AVX</td>
</tr>
<tr>
<td>C5</td>
<td>1</td>
<td>4.7 µF</td>
<td>CAP, CERM, 4.7 µF, 25 V, ±10%, X7R</td>
<td>1206</td>
<td>885012208068</td>
<td>Wurth</td>
</tr>
<tr>
<td>C7</td>
<td>1</td>
<td>0.1 µF</td>
<td>CAP, CERM, 0.1 µF, 50 V, ±10%, X7R</td>
<td>0603</td>
<td>885012206095</td>
<td>Wurth</td>
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<tr>
<td>C8</td>
<td>1</td>
<td>470 pF</td>
<td>CAP, CERM, 470 pF, 50 V, ±10%, X7R</td>
<td>0603</td>
<td>885012206081</td>
<td>Wurth</td>
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<tr>
<td>D1</td>
<td>1</td>
<td>800 mV at 500 mA</td>
<td>DIODE SCHOTTKY 80 V 0.5 A</td>
<td>SOD-123</td>
<td>MBR0580-TP</td>
<td>Micro Commercial Co</td>
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<tr>
<td>D2</td>
<td>1</td>
<td>850 mV at 2 A</td>
<td>DIODE SCHOTTKY 80 V 2 A</td>
<td>DO-214AC, SMA</td>
<td>CDBA280-G</td>
<td>Comchip Technology</td>
</tr>
<tr>
<td>L1</td>
<td>1</td>
<td>33 µH</td>
<td>Inductor, Shielded Drum Core, Ferrite, 33 µH</td>
<td>1246</td>
<td>744771133</td>
<td>Wurth</td>
</tr>
<tr>
<td>J1, J2</td>
<td>2</td>
<td></td>
<td>Connector, rising clamp, 2 pins, 5mm pitch</td>
<td></td>
<td>691123710002</td>
<td>Wurth</td>
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<tr>
<td>R1, R4</td>
<td>1</td>
<td>1 kΩ</td>
<td>RES, 1 kΩ, 1%, 0.1W</td>
<td>0603</td>
<td>CRCW06031K00FKEA</td>
<td>Vishay-Dale</td>
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<tr>
<td>R2</td>
<td>1</td>
<td>10 MΩ</td>
<td>RES, 10 MΩ, 1%, 0.1 W</td>
<td>0603</td>
<td>CRCW060310M0FKEA</td>
<td>Vishay-Dale</td>
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<tr>
<td>R3</td>
<td>1</td>
<td>174 kΩ</td>
<td>RES, 174 kΩ, 1%, 0.1 W</td>
<td>0603</td>
<td>CRCW0603174KFKEA</td>
<td>Vishay-Dale</td>
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<tr>
<td>R5</td>
<td>1</td>
<td>191 kΩ</td>
<td>RES, 191 kΩ, 1%, 0.1 W</td>
<td>0603</td>
<td>CRCW0603191KFKEA</td>
<td>Vishay-Dale</td>
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<tr>
<td>R6</td>
<td>1</td>
<td>4.02 kΩ</td>
<td>RES, 4.02 kΩ, 1%, 0.1W</td>
<td>0603</td>
<td>CRCW06034K02FKEA</td>
<td>Vishay-Dale</td>
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<tr>
<td>R7</td>
<td>1</td>
<td>20.5 kΩ</td>
<td>RES, 20.5 kΩ, 1%, 0.1 W</td>
<td>0603</td>
<td>CRCW060320K5FKEA</td>
<td>Vishay-Dale</td>
</tr>
<tr>
<td>R8</td>
<td>1</td>
<td>0.2</td>
<td>RES, 0.2, 1%, 1 W</td>
<td>2010</td>
<td>CSRN2010FKR200</td>
<td>Stackpole Electronics Inc</td>
</tr>
<tr>
<td>U1</td>
<td>1</td>
<td></td>
<td>TPS92512 2.5A Buck Current Regulator for High-Brightness LEDs with Integrated Analog Current Adjust</td>
<td>DGQ0010D</td>
<td>TPS92512HV</td>
<td>Texas Instruments</td>
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## Revision History

### Changes from Original (February 2015) to A Revision

<table>
<thead>
<tr>
<th>Change Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Changed the PART NUMBER and MFR of C1, C5, C7, C8, and L1 in Table 2</td>
<td>9</td>
</tr>
<tr>
<td>• Added J1, J2 to Table 2</td>
<td>9</td>
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</table>

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

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

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3. 技術基準適合証明を取得後ご使用いただく。

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日本テキサス・インストゥルメンツ株式会社
東京都新宿区西新宿6丁目24番1号
西新宿三井ビル

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.

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