*EVM User's Guide: LM5169PEVM*

# *LM5169PEVM Evaluation Module*

## Description

The LM5169PEVM is a 115V DC/DC buck regulator that employs synchronous rectification to achieve high conversion efficiency in a small footprint. The EVM operates over a wide input voltage range of 20V to 115V to provide a regulated 12V output at up to 0.650A with a 500kHz switching frequency. The output voltage has better than 1.5% set-point accuracy and is adjustable using an external resistor divider. The module design uses the LM5169PNGUR synchronous buck converter with wide input voltage range, wide duty-cycle range, integrated high-side and low-side power MOSFETs, advanced over-current protection, and precision enable. The LM5169PNGUR is rated to operate over a junction temperature range of –40°C to +125°C.

## Get Started

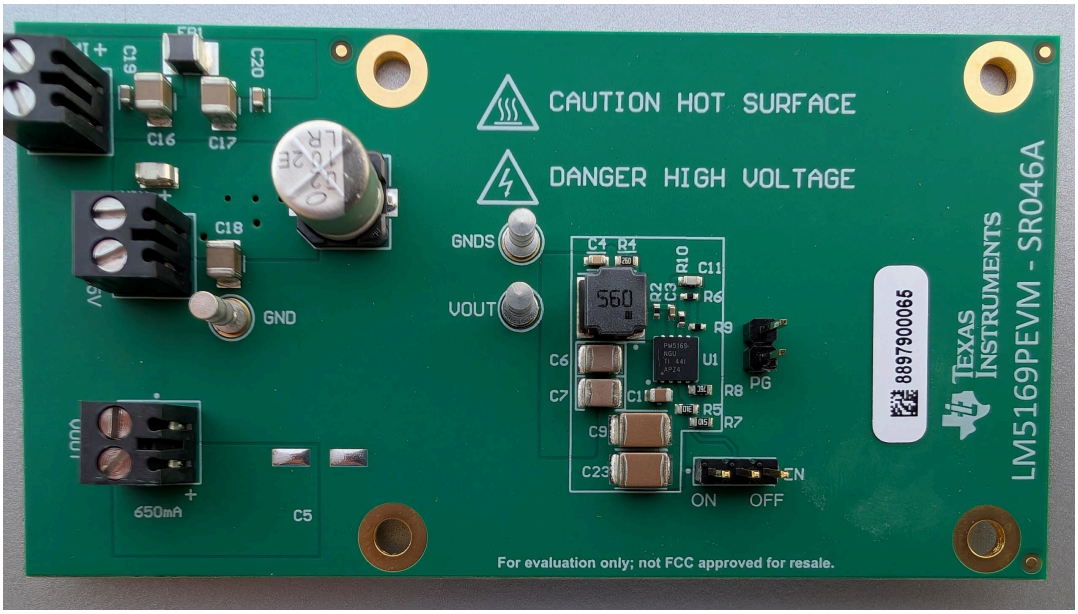
1. Order the LM5169PEVM.
2. Carefully review this user's guide.
3. Set up the EVM as detailed in this user's guide.
4. Test and measure performance.

## Features

- Wide input voltage range from 20V to 115V
- Fixed 3ms soft start
- COT mode control architecture
- Peak and valley current-limit protection
- PFM mode for light load efficiency
- WSON package for small solution size

## Applications

- Communications - brick power module
- Industrial battery pack (≥10 S)
- Battery pack - e-bike, e-scooter, LEV
- Factory automation - PLC
- Motor drives - BLDC
- Grid infrastructure - solar




**LM5169PEVM**

# 1 Evaluation Module Overview

## 1.1 Introduction

The LM5169PEVM is configured to deliver a regulated 12V output, 0.65A at 500kHz switching frequency. The LM5169 uses a COT control architecture, with input voltage feed-forward to provide a constant frequency regulator with tightly regulated output voltage. This type of control requires adequate voltage ripple at the FB input to achieve stable regulation. The LM5169PEVM is set up with type III ripple injection to minimize the output voltage ripple while making sure of a stable regulator. The LM5169PEVM also provides the option to use type I or type II ripple injection. See the *LM516x, 0.65A/0.3A, 120V Absolute Maximum, Step-Down Converter With Fly-Buck™ Converter Capability* data sheet for more information. Figure 2-1 and Figure 4-1 show an overall view of the LM5169PEVM and the schematic, respectively. While the board is optimized for the LM5169PNGUR, there are component pads which can make the board compatible with the LM5017 to evaluate design changes when replacing the device with the LM5169.

## 1.2 Kit Contents

Table 1-1 lists the contents of the EVM kit. Contact the TI Product Information Center at (972) 644-5580 if any component is missing.

**Table 1-1. EVM Contents**

| Item | Quantity |
|---|---|
| LM5169PEVM | 1 |

## 1.3 Specification

A simplified schematic for the LM5169PEVM is shown in Figure 1-1, and the EVM specifications are listed in Table 2-1.

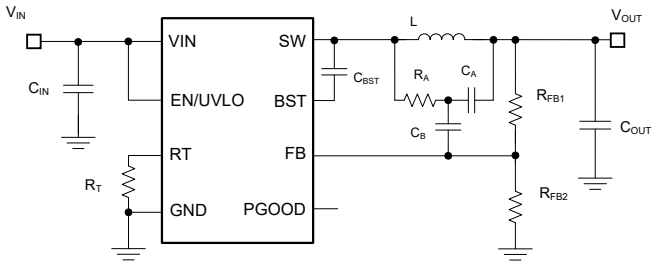



**Figure 1-1. LM5169P Simplified Buck Schematic**

## 1.4 Device Information

**Table 1-2. EVM Configuration**

| EVM | CONVERTER IC | PACKAGE |
|---|---|---|
| LM5169PEVM | LM5169PNGUR | 8-pin NGU package with PowerPAD™ (4.0mm × 4.0mm) |

## 1.5 General TI High Voltage Evaluation User Safety Guidelines


Always follow TI's set-up and application instructions, including use of all interface components within the recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and the safety of those working around you. Contact TI's Product Information Center http://support.ti.com for further information.

**Save all warnings and instructions for future reference.**

**Failure to follow warnings and instructions can result in personal injury, property damage, or death due to electrical shock and/or burn hazards.**

The term TI HV EVM refers to an electronic device typically provided as an open-framed, unenclosed printed-circuit board assembly. This is intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise, and knowledge of electrical safety risks in development and application of high-voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments. If you are not suitably qualified, you should immediately stop from further use of the HV EVM.

- **Work Area Safety:**
  - Maintain a clean and orderly work area.
  - A qualified observer or observers must be present any time circuits are energized.
  - Effective barriers and signage must be present in the area where the TI HV EVM and the interface electronics are energized, indicating operation of accessible high voltages can be present, for the purpose of protecting inadvertent access.
  - All interface circuits, power supplies, evaluation modules, instruments, meters, scopes, and other related apparatus used in a development environment exceeding $50V_{RMS}$/75 VDC must be electrically located within a protected Emergency Power Off (EPO) protected power strip.
  - Use a stable and non-conductive work surface.
  - Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.
- **Electrical Safety:**

  As a precautionary measure, this is always a good engineering practice to assume that the entire EVM can have fully accessible and active high voltages.

  - De-energize the TI HV EVM and all the inputs, outputs, and electrical loads before performing any electrical or other diagnostic measurements. Confirm that TI HV EVM power has been safely de-energized.
  - With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment hook-ups, and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
  - When EVM readiness is complete, energize the EVM as intended.

**WARNING**

**WARNING: While the EVM is energized, never touch the EVM or the electrical circuits as the EVM or the electrical circuits can be at high voltages capable of causing electrical shock hazard.**

- **Personal Safety:**
  - Wear personal protective equipment, for example, latex gloves, safety glasses with side shields, or both, or protect EVM in an adequate lucent plastic box with interlocks from accidental touch.
- **Limitation for Safe Use:**
  - EVMs are not to be used as all or part of a production unit.

### Safety and Precautions

The EVM is designed for professionals who have received the appropriate technical training, and is designed to operate from an AC power supply or a high-voltage DC supply. Please read this user's guide and the safety-related documents that come with the EVM package before operating this EVM.

**CAUTION**

Do not leave the EVM powered when unattended.

**WARNING**

Hot surface! Contact can cause burns. Do not touch!

**WARNING**

High Voltage! Electric shock is possible when connecting board to live wire. Board must be handled with care by a professional.
For safety, use of isolated test equipment with overvoltage and overcurrent protection is highly recommended.

# 2 Hardware

## 2.1 Quick Start Procedure

1. Connect the input voltage supply to the VIN connector (+ and –).
2. Connect the load to the VOUT connector (+ and –).
3. Set the input supply voltage to an appropriate level between 20V to 115V.
4. Turn on the power supply. The EVM powers up and provides $V_{OUT}$ = 12V.

See Figure 2-1 for the location of the connectors.

**CAUTION**

Hot surface. Contact can cause burns. Do not touch.

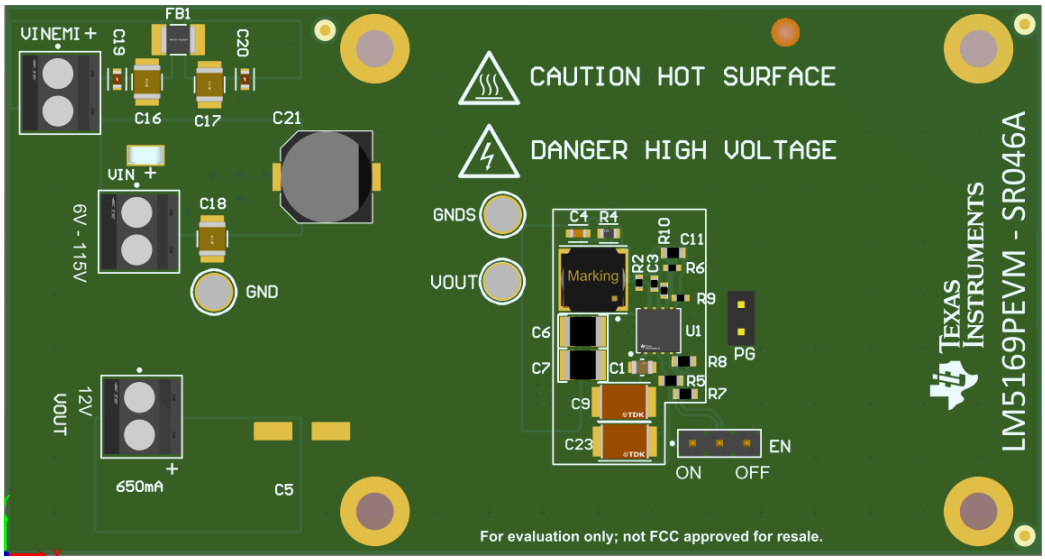



**Figure 2-1. LM5169PEVM (Top View)**

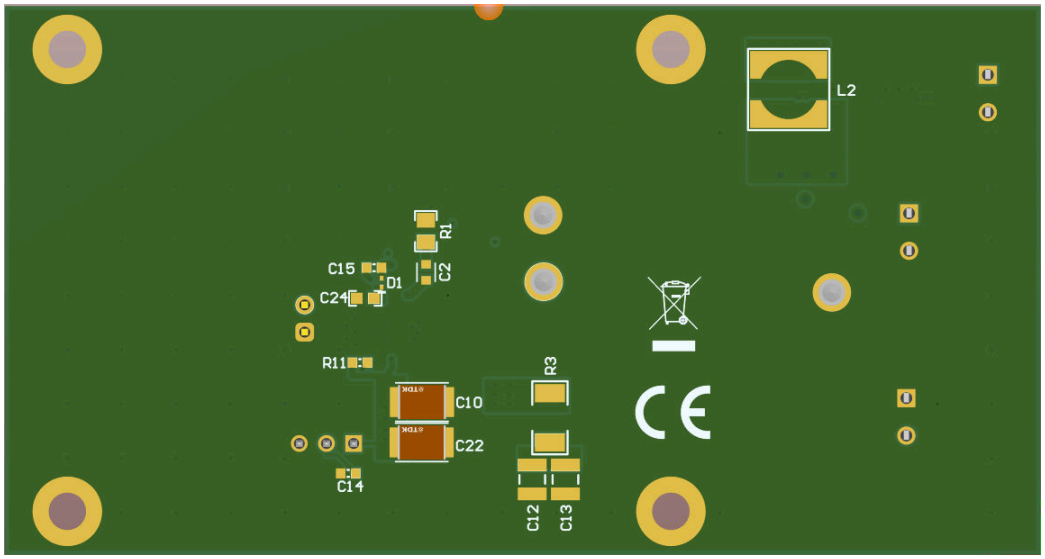



**Figure 2-2. LM5169PEVM (Bottom View)**

## 2.2 Detailed Description

This section describes the connectors and the test points on the EVM and how to properly connect, set up, and use the LM5169PEVM. See Figure 2-3 for location of connectors and jumpers.

**VOUT** Output voltage of the converter

VOUT screw terminal connector. Apply load to this connector (+ and –). The VOUT test point is used to monitor output voltage.

**GND** Ground of the converter

GND and GNDS test points. Used as ground test points for the EVM.

**VIN** Input voltage to the converter

VIN screw terminal connector. Apply input voltage to this connector (+ and –). The VIN test point is used to monitor input voltage.

**VINEMI** Input voltage to input filter of the converter

If there is desire to use the built-in EMI filter on the EVM, then connect the input supply to the VINEMI screw terminal connector (+ and –).

**Input Filter** EMI mitigation

An input EMI filter is provided on the EVM. Note L2 is not populated and must be installed for the EMI filter to operate. Also, note that the maximum input voltage to the filter is $100V_{DC}$.

**EN/UVLO Jumper** Set EN, UVLO pin options

Use this jumper to enable, disable the EVM. The resistors connected to this pin set the input UVLO thresholds. Input UVLO thresholds are set to approximately 6V and 5.6V. These levels can be changed by changing the values of R5 and R7. For external control of the device, these resistors must be removed and the control signal applied to the center pin of the header. Note that for accurate shutdown current measurement, these resistors must also be removed and the EN input (center pin) grounded.

1. Jumper open (default setup): Device starts up and shuts down with UVLO.
2. Center pin connected to *ON*: Device starts up and shuts down without UVLO.
3. Center pin connected to *OFF*: Device is off.

**PGOOD** The PGOOD header used as a test point to monitor the power-good indicator. This flag indicates whether the output voltage has reached the regulation level. PGOOD is an open-drain output that is tied to $V_{OUT}$ through a 100kΩ, resistor $R_{10}$.

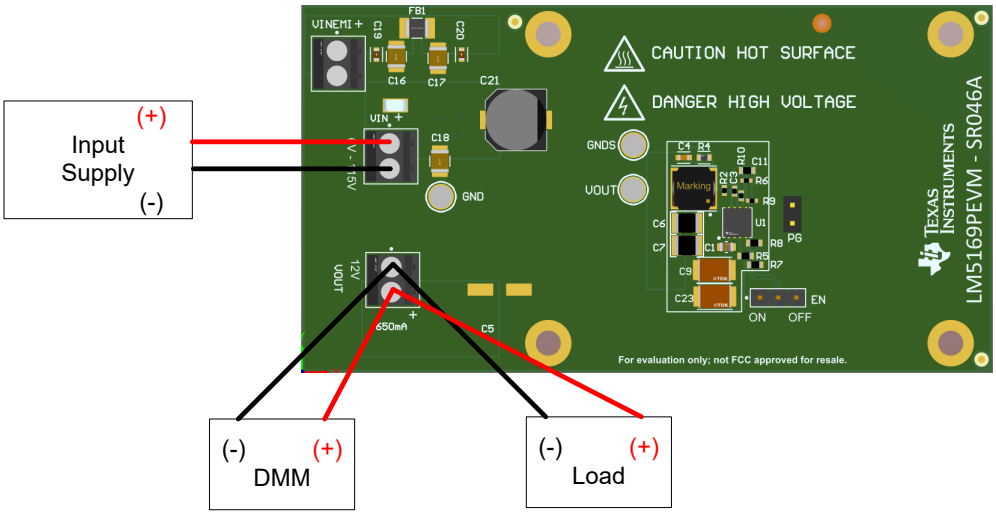



**Figure 2-3. LM5169PEVM Test Setup**

### 2.2.1 Compatibility With the LM5017

The LM5169PEVM has component pads available to make the device compatible with the LM5017 for evaluation compared to the LM5169. Configuring the EVM for the LM5017 requires the following changes:

- Remove the LM5169 PG resistor, R10
- Remove the LM5169 RT resistor, R8
- Populate the LM5017 RON resistor, R11
- Populate the LM5017 VCC capacitor, C24
- Populate the LM5017 VCC diode, D1

While the EVM is compatible with the LM5017 using the above changes, the PCB design is optimized for the LM5169. Refer to the LM5017 data sheet for the relevant external component selection criteria.

## 2.3 EVM Characteristics

Unless otherwise specified, the following conditions apply: $T_A$ = 25ºC, $V_{IN}$ = 24V.

**Table 2-1. LM5169PEVM Electrical Performance Characteristics**

| PARAMETER | TEST CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **INPUT CHARACTERISTICS** | | | | | | |
| Input voltage range, $V_{VIN}$ | EVM input voltage operating range | | 20 | 48 | 115 | V |
| Input voltage turn-on, $V_{IN(ON)}$ | Adjusted by EN/UVLO resistors | | | 6.0 | | V |
| Input voltage turn-off, $V_{IN(OFF)}$ | | | | 5.6 | | V |
| Input voltage hysteresis, $V_{IN(HYS)}$ | | | | 0.4 | | V |
| Input current, no load, $I_{IN(NL)}$ | $I_{OUT}$ = 0A, no EN divider | $V_{IN}$ = 24V | | 25 | | µA |
| Input current, disabled, $I_{IN(OFF)}$ | $V_{EN/UVLO}$ = 0V, no EN divider | $V_{IN}$ = 24V | | 3 | | µA |
| **OUTPUT CHARACTERISTICS** | | | | | | |
| Output voltage, $V_{OUT}$ | $V_{IN}$ = 24V, $I_{OUT}$ = 0A | | | 12.13 | | V |
| | $V_{IN}$ = 24V, $I_{OUT}$ = 0.65A | | | 12.26 | | V |
| Output voltage regulation, $\Delta V_{OUT}$ | Load regulation, $V_{IN}$ = 24V | $I_{OUT}$ = 0A to 0.05A | | 80 | | mV |
| Output voltage regulation, $\Delta V_{OUT}$ | Load regulation, $V_{IN}$ = 24V | $I_{OUT}$ = 0.05A to 0.65A | | 90 | | |
| Output voltage regulation, $\Delta V_{OUT}$ | Line regulation, $I_{OUT}$ = 0A | $V_{IN}$ = 24V to 115V | | 2 | | |
| Output voltage regulation, $\Delta V_{OUT}$ | Line regulation, $I_{OUT}$ = 0.65A | $V_{IN}$ = 24V to 115V | | 97 | | |
| Maximum output current | $V_{IN}$ = 24V | | | 0.74 | | A |
| Soft-start time, $t_{SS}$ | | | | 3.5 | | ms |
| **SYSTEM CHARACTERISTICS** | | | | | | |
| Switching frequency | $V_{IN}$ = 24V, $I_{OUT1}$ = 0.65A | | | 543 | | kHz |
| Half-load efficiency | $I_{OUT}$ = 0.3A | $V_{IN}$ = 24V | | 92% | | |
| Full load efficiency | $I_{OUT}$ = 0.65A | $V_{IN}$ = 24V | | 89% | | |
| | | $V_{IN}$ = 60V | | 86% | | |

# 3 Implementation Results

## 3.1 Performance Curves

Unless otherwise specified the following condition apply: $T_A$ = 25ºC, $V_{IN}$ = 24V.

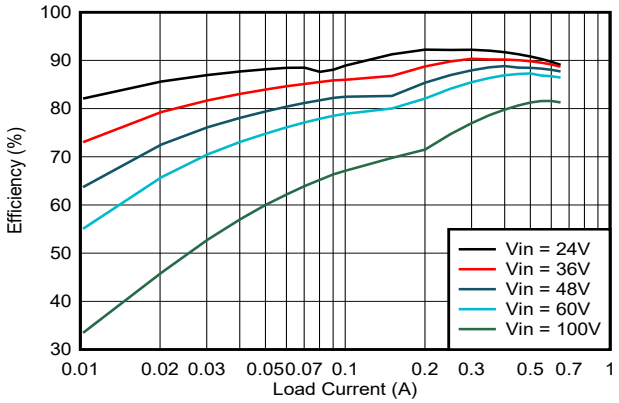



**Figure 3-1. Efficiency**

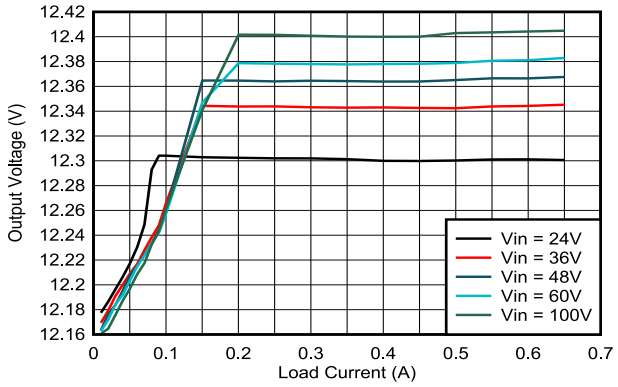
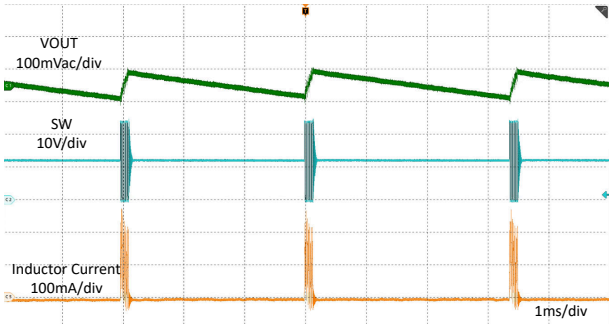
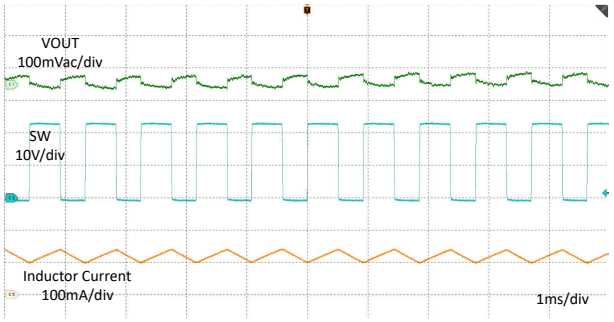



**Figure 3-2. Output Voltage Regulation**



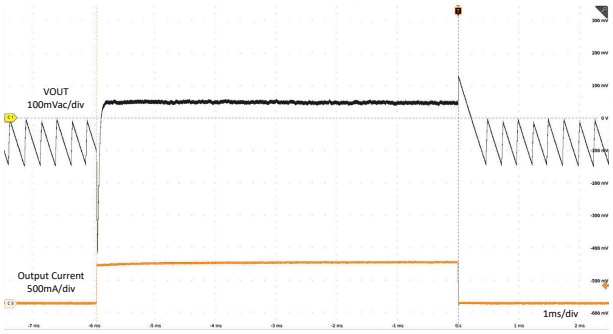

$I_{OUT}$ = 5mA

**Figure 3-3. Typical Switching Waveform**



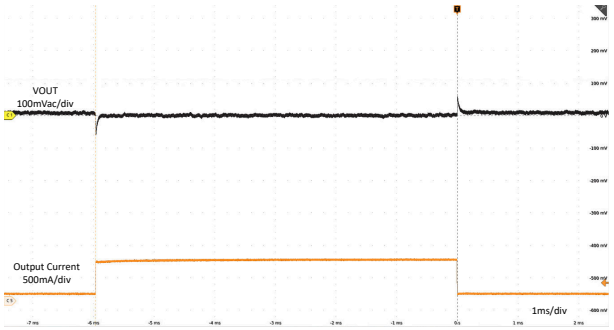

$I_{OUT}$ = 600mA

**Figure 3-4. Typical Switching Waveform**




$V_{IN}$ = 24V $I_{OUT}$ = 10mA to 650mA

**Figure 3-5. Load Transient**




$V_{IN}$ = 24V $I_{OUT}$ = 100mA to 650mA

**Figure 3-6. Load Transient**

# 4 Hardware Design Files

## 4.1 Schematic

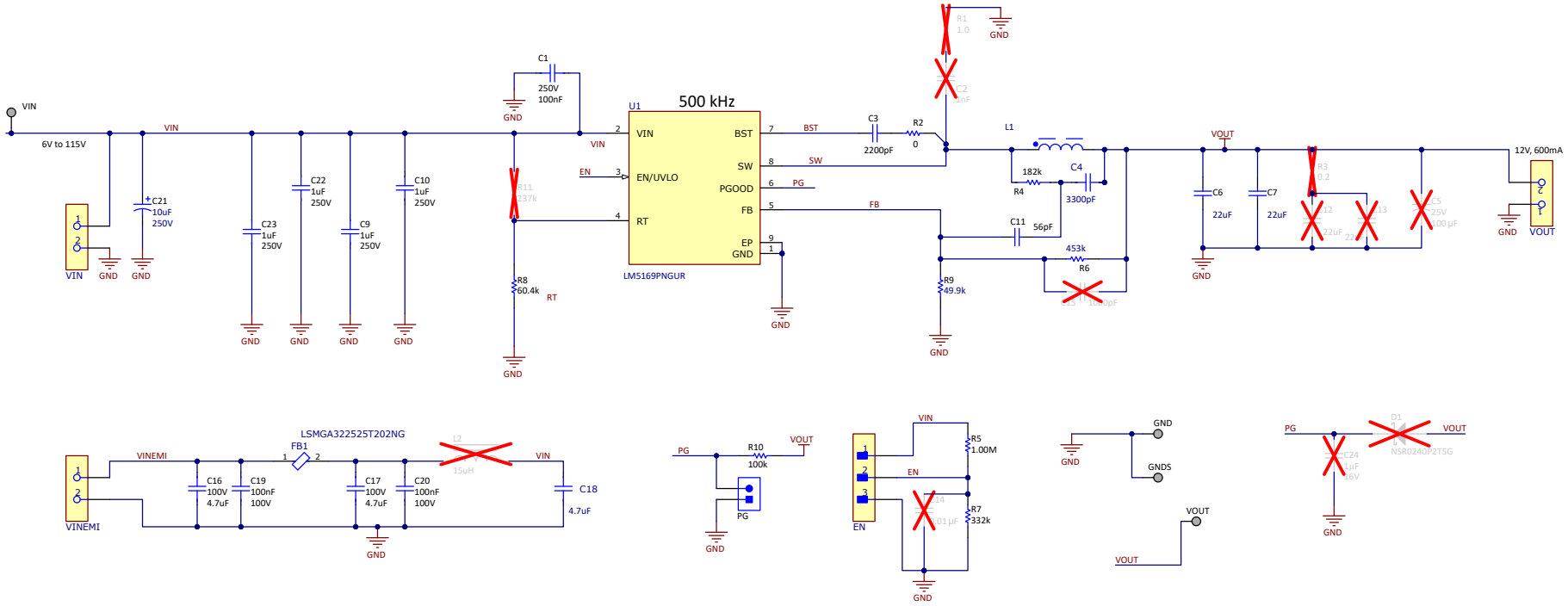



**Figure 4-1. LM5169PEVM Schematic**

## 4.2 PCB Layout

Figure 4-2 through Figure 4-5 show the board layout for the LM5169PEVM.

The 8-pin NGU PowerPAD integrated circuit package offers an exposed thermal pad, which must be soldered to the copper landing on the PCB for best thermal performance. The PCB consists of a 4-layer design. There are 2-oz copper planes on the top and bottom and 1-oz copper mid-layer planes to dissipate heat with an array of thermal vias under the thermal pad to connect to all four layers.

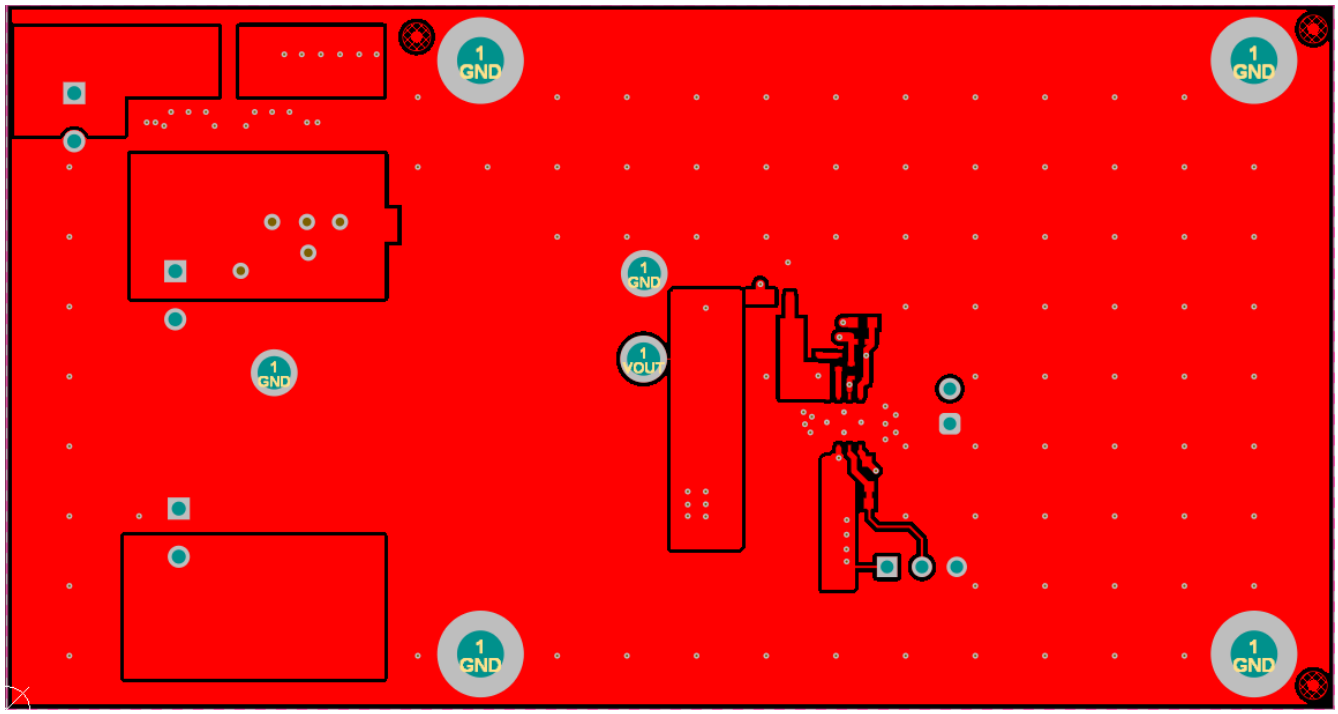



**Figure 4-2. Top Layer**

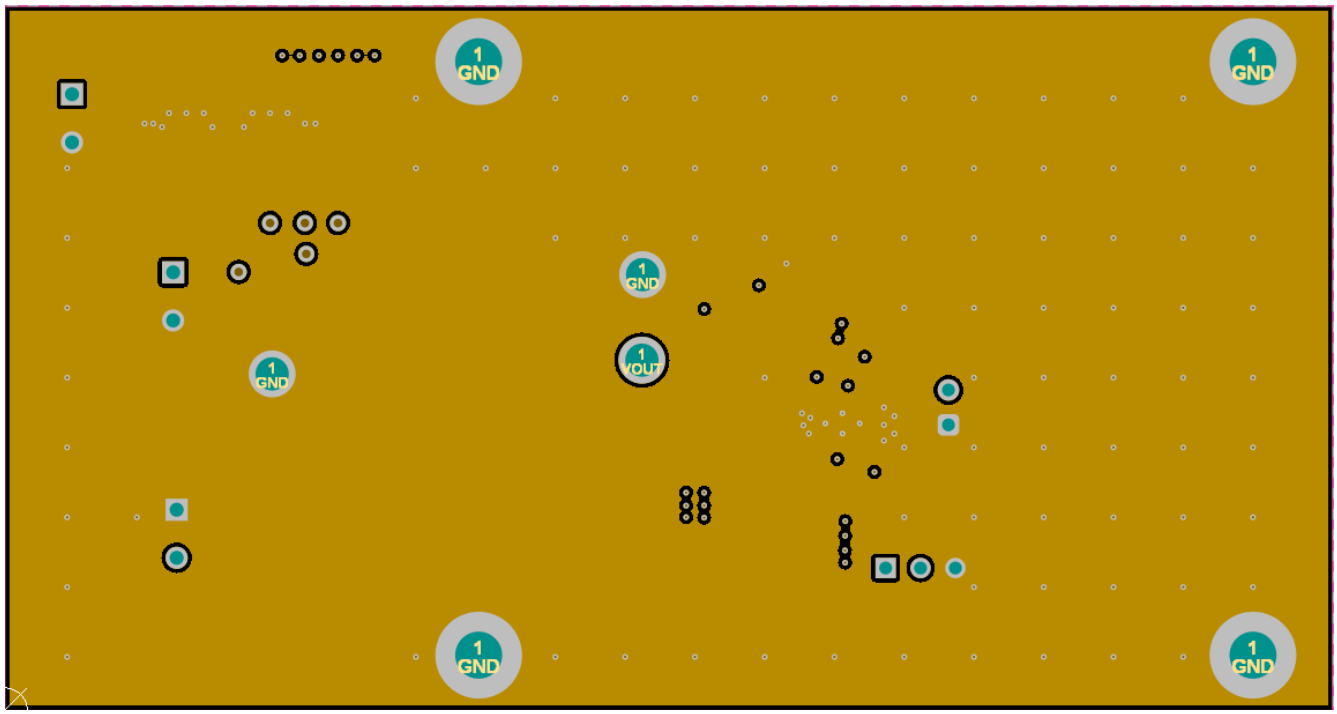



**Figure 4-3. Mid-Layer 1 Ground Plane**

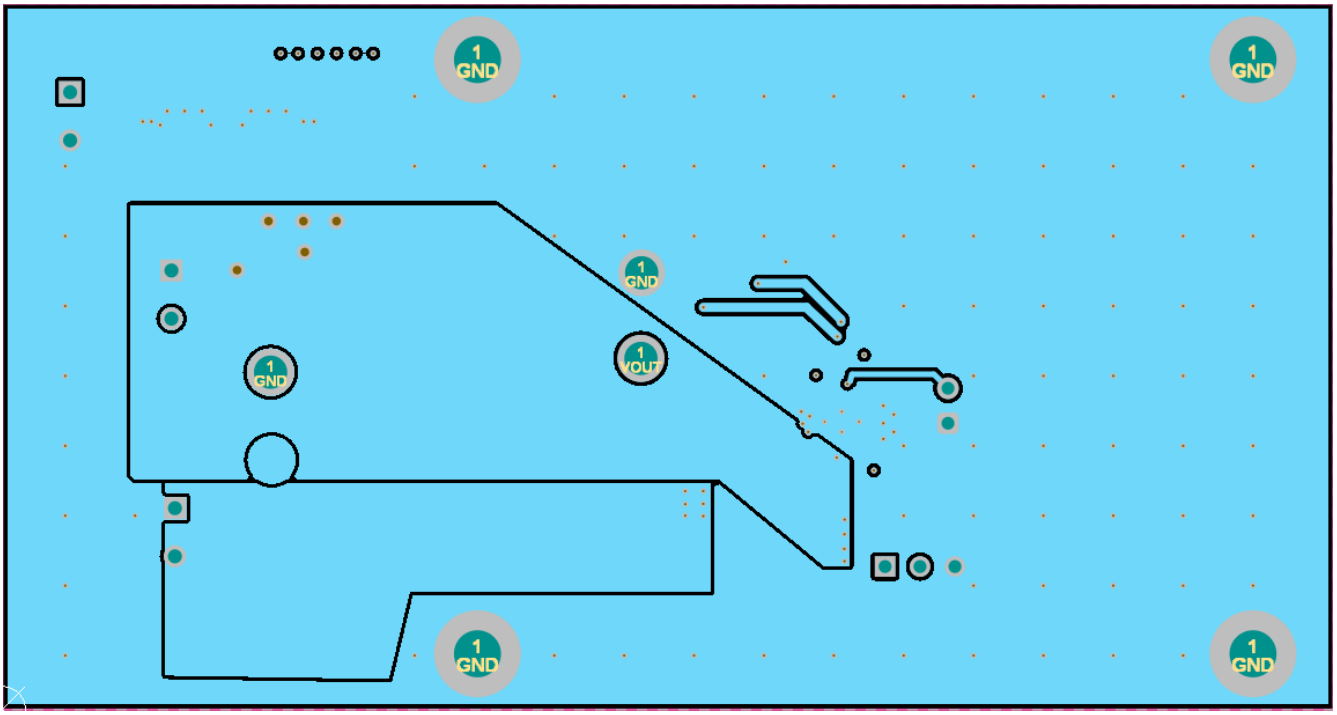



**Figure 4-4. Mid-Layer 2 Routing**

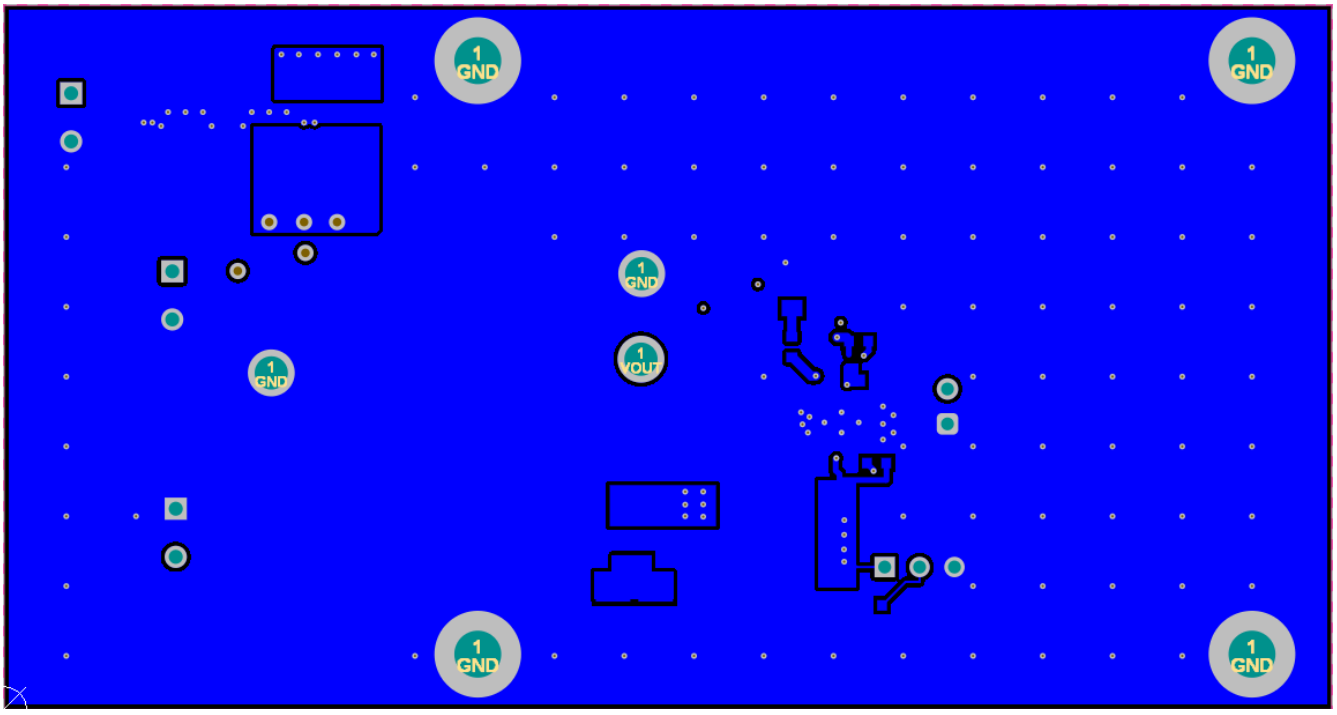



**Figure 4-5. Bottom Layer**

## 4.3 Bill of Materials

**Table 4-1. LM5169PEVM Bill of Materials**

| DESIGNATOR | QUANTITY | DESCRIPTION | PART NUMBER | MANUFACTURER |
|---|---|---|---|---|
| C1 | 1 | 0.1µF ±10% 250V Ceramic Capacitor X7T 0805 (2012 Metric) | C2012X7T2E104K125AE | TDK Corporation |
| C3 | 1 | CAP, CERM, 2200pF, 50V, +/- 10%, X7R, AEC-Q200 Grade 1, 0402 | GCM155R71H222KA37D | MuRata |
| C4 | 1 | 3300pF ±5% 100V Ceramic Capacitor X7R 0603 (1608 Metric) | 06031C332J4Z2A | AVX Corporation |
| C6, C7 | 2 | CAP, CERM, 22uF, 25V, +/- 10%, X5R, 1210 | CL32A226KAJNNNE | Samsung Electro-Mechanics |
| C9, C10, C22, C23 | 4 | Cap Ceramic 1uF 250V X7T 10% Pad SMD 1812 +125°C Automotive T/R | CGA8P3X7T2E105K250KE | TDK |
| C11 | 1 | CAP, CERM, 56pF, 50V, +/- 5%, C0G/NP0, 0603 | C0603C560J5GACTU | Kemet |
| C16, C17, C18 | 3 | 4.7µF ±10% 100V Ceramic Capacitor X7R 1210 (3225 Metric) | CNC6P1X7R2A475K250AE | TDK |
| C19, C20 | 2 | Cap Ceramic 100nF 100V X7R ±10% Pad SMD 0603 +125°C T/R | CL10B104KC8NNNC | Samsung |
| C21 | 1 | CAP, AL, 10uF, 250V, +/- 20%, SMD | ULR2E100MNL1GS | Nichicon |
| FB1 | 1 | 2 kOhms at 100MHz 1 Power Line Ferrite Bead 1210 (3225 Metric) 1.2A 130mOhm | LSMGA322525T202NG | Taiyo Yuden |
| J2, J3, J7 | 3 | | 1776112-2 | TE Connectivity |
| J4 | 1 | | 68001-203HLF | Amphenol ICC |
| J6 | 1 | Header, 100mil, 2x1, Gold, TH | TSW-102-07-G-S | Samtec |
| L1 | 1 | WE-LQS SMT Power Inductor, size 6045, 56uH, 1.3A, 0.22Ohm | 74404064560 | Wurth Elektronik |
| R2 | 1 | RES, 0, 5%, 0.063 W, AEC-Q200 Grade 0, 0402 | CRCW04020000Z0ED | Vishay-Dale |
| R4 | 1 | RES Thick Film SMD 182kΩ 1% 1/10W 0603 100ppm/°C | RMCF0603FT182K | Stackpole |
| R5 | 1 | RES, 1.00M, 1%, 0.1W, 0603 | RC0603FR-071ML | Yageo |
| R6 | 1 | RES, 453 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402 | CRCW0402453KFKED | Vishay-Dale |
| R7 | 1 | RES, 332 k, 1%, 0.1 W, 0603 | RC0603FR-07332KL | Yageo |
| R8 | 1 | RES, 60.4 k, 1%, 0.1 W, 0603 | RC0603FR-0760K4L | Yageo |
| R9 | 1 | RES, 49.9 k, 1%, 0.1 W, AEC-Q200 Grade 0, 0402 | ERJ-2RKF4992X | Panasonic |
| R10 | 1 | RES, 100 k, 1%, 0.1 W, 0402 | ERJ-2RKF1003X | Panasonic |
| TP1 | 1 | Test Lead clips and hooks, SMT | S1751-46 | Harwin |
| TP2, TP3, TP4 | 3 | Terminal, Turret, TH, Triple | 1598-2 | Keystone |
| U1 | 1 | 0.65A, 120V absolute maximum, Step-Down Converter with Fly-Buck Converter Capability | LM5169PNGUR | Texas Instruments |
| C2 | 0 | Multilayer Ceramic Capacitors Cap Ceramic 0.001uF 250V X7R 10% Pad SMD 0603 125° | CC0603KRX7RYBB102 | YAGEO |
| C5 | 0 | CAP, AL, 100µF, 25V, +/- 20%, SMD | UWT1E101MCL1GS | Nichicon |
| C12, C13 | 0 | CAP, CERM, 22uF, 25V, +/- 10%, X7R, AEC-Q200 Grade 1, 1210 | TMK325B7226KMHT | Taiyo Yuden |
| C14 | 0 | CAP, CERM, 0.01µF, 100V,+/- 10%, X8R, AEC-Q200 Grade 0, 0603 | CGA3E2X8R2A103K080AD | TDK |
| C15 | 0 | CAP, CERM, 1000pF, 50V, +/- 5%, X7R, AEC-Q200 Grade 1, 0603 | C0603C102J5RACAUTO | Kemet |
| C24 | 0 | CAP, CERM, 1µF, 16V,+/- 10%, X7R, AEC-Q200 Grade 1, 0603 | GCM188R71C105KA64J | MuRata |

**Table 4-1. LM5169PEVM Bill of Materials (continued)**

| DESIGNATOR | QUANTITY | DESCRIPTION | PART NUMBER | MANUFACTURER |
|---|---|---|---|---|
| D1 | 0 | Diode, Schottky, 40V, 0.2A, SOD-923 | NSR0240P2T5G | ON Semiconductor |
| L2 | 0 | Inductor, Shielded Drum Core, Ferrite, 15uH, 1.8A, 0.05 ohm, AEC-Q200 Grade 1, SMD | MSS7341T-153MLB | Coilcraft |
| R1 | 0 | RES, 1.0, 5%, 0.4 W, AEC-Q200 Grade 0, 0805 | ESR10EZPJ1R0 | Rohm |
| R3 | 0 | RES, 0.2, 1%, 1 W, 2010 | CSRN2010FKR200 | Stackpole Electronics Inc |
| R11 | 0 | RES, 60.4 k, 1%, 0.1 W, 0603 | RC0603FR-0760K4L | Yageo |

# 5 Additional Information

## 5.1 Trademarks

PowerPAD™ is a trademark of Texas Instruments.
All trademarks are the property of their respective owners.

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1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

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2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms 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 a nonconforming EVM if (a) the nonconformity was 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, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, 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.

**WARNING**

**Evaluation Kits 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 shall operate the Evaluation Kit within TI’s recommended guidelines and any applicable legal or environmental requirements as well as reasonable and customary safeguards. Failure to set up and/or operate the Evaluation Kit within TI’s recommended guidelines may result in personal injury or death or property damage. Proper set up entails following TI’s instructions for electrical ratings of interface circuits such as input, output and electrical loads.**

NOTE:

EXPOSURE TO ELECTROSTATIC DISCHARGE (ESD) MAY CAUSE DEGREDATION OR FAILURE OF THE EVALUATION KIT; TI RECOMMENDS STORAGE OF THE EVALUATION KIT IN A PROTECTIVE ESD BAG.

3 *Regulatory Notices:*

3.1 *United States*

3.1.1 *Notice applicable to EVMs not FCC-Approved:*

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

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

**CAUTION**

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

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

**FCC Interference Statement for Class A EVM devices**

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

**FCC Interference Statement for Class B EVM devices**

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

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

3.2 *Canada*

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

**Concerning EVMs Including Radio Transmitters:**

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

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

**Concernant les EVMs avec appareils radio:**

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

**Concerning EVMs Including Detachable Antennas:**

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

**Concernant les EVMs avec antennes détachables**

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

3.3 *Japan*

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

https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-delivered-in-japan.html

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

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

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

【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。 技術適合証明を受けていないもの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取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿 6 丁目 2 4 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。https://www.ti.com/ja-jp/legal/notice-for-evaluation-kits-for-power-line-communication.html

3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

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

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

4.3 *Safety-Related Warnings and Restrictions:*

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

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

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

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 MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS 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 EPIDEMIC FAILURE WARRANTY OR 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 SHALL BE CONSTRUED AS GRANTING OR CONFERRING 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, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

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. 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 OR THE USE OF THE EVMS , 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 TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

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.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

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