# LM5175 Wide VIN 4-Switch Buck-Boost Converter High Power Evaluation Module

# User's Guide

Literature Number: SNVU465
February 2015

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This user's guide describes the characteristics, operation, and use of the LM5175 high power evaluation module (EVM). The LM5175EVM-HP is a fully assembled and tested circuit for evaluating the performance of the LM5175 42 V wide VIN Synchronous 4-Switch Buck-Boost Controller. This user's guide contains the electrical specification, quick setup procedure, performance curves, application schematic, and bill of materials (BOM).

# 1 Introduction

The LM5175 is a synchronous 4-switch buck-boost controller capable of regulating the output voltage at, below, or above the input voltage. The wide input voltage of 3.5 V to 42 V supports a variety of applications. The output voltage is adjustable from 0.8 V to 55 V.

The LM5175EVM-HP high power EVM is fully assembled and tested platform for evaluating the operation and performance of the LM5175 buck-boost controller. The LM5175EVM-HP has an input voltage range from 6 V to 36 V, the output voltage is set as 12 V using an external feedback resistor divider.

## *1.1 Features*

- Wide input voltage range from 6 V to 36 V
- 12 V nominal output voltage
- Up to 10 A output current capability (120W output power)
- 260kHz switching frequency
- Constant Output Voltage and Constant Output Current Options
- Optional frequency dithering
- Optional parallel FET sites provide flexibility to further extend output power capability

## *1.2 Applications*

- Industrial PCs
- Point of Sale Terminals
- Automotive Start-Stop Systems
- Battery Backup Systems

# 2 Connector, Test Point and Selection Switch Descriptions

## 2.1 Connector and Test Point Descriptions

This EVM includes I/O connectors and test points as shown in Table 1. The power supply must be connected to input connectors, J1 and J2. The load must be connected to output connectors, J3 and J4.

**Table 1. Connectors and Test Points**

| Reference Designator | Description |
|---|---|
| J1 | Input voltage positive connection |
| J2 | Input voltage return connection |
| J3 | Output voltage connection |
| J4 | Output voltage return connection |
| TP1 (VIN) | Input voltage positive test point |
| TP2 (GND) | Input voltage return test point |
| TP3 (VOUT) | Output voltage positive test point |
| TP4 (GND) | Output voltage return test point |
| TP5 (PGOOD) | Power Good output |
| TP6 (BIAS) | BIAS voltage test point |
| TP7(SYNC) | SYNC input |

## 2.2 Selection Switch Descriptions

### 2.2.1 S1 Mode

This switch provides selection of different operation modes detailed as following:

- Switch in position 1 (Mode pin tied to GND), Hiccup mode disabled and DCM.
- Switch in position 2 (Mode pin tied to 93.1kΩ resistor), Hiccup mode enabled and CCM.
- Switch in position 3 (Mode pin tied to VCC), Hiccup disabled and CCM.

**Note 1:** If Hiccup enabled and DCM combination is desired, change R19 to 49.9 kΩ and put switch in position 2.

### 2.2.2 S2 ENABLE

This switch enables/disables LM5175 on the EVM, or it can be used to set adjustable VIN UVLO.

- Switch in position 1 (EN pin tied GND), LM5175 disabled.
- Switch in position 2 (EN pin tied to resistor divider network consist of R13 and R18), EN pin along the resistor divider network to set LM5175 UVLO threshold.
- Switch in position 3 (EN pin tied VCC), LM5175 enabled.

### 2.2.3 S3 DITHER

This switch enables/disables frequency dithering feature on the EVM.

- Switch in position 1 (EN pin tied GND), frequency dithering feature disabled.
- Switch in position 2 (EN pin tied to C27), frequency dithering feature enabled.
- No connection in position 3, do not apply switch to this position.

# 3 Test Setup and Procedure

## 3.1 Test Setup

Figure 1 shows a typical test setup to evaluate the LM5175EVM-HP

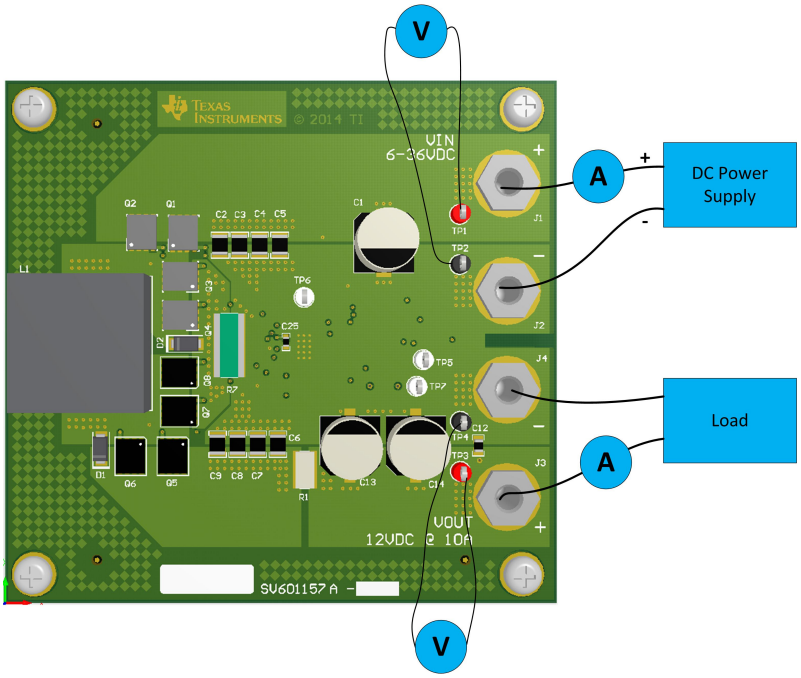


**Figure 1. Typical EVM Connection Diagram**

### 3.2 Test Procedure

**Step 1:** Set the power supply current limit to 1 A. Turn off the power supply. Connect the positive output of the power supply to J1 and the negative output to J2.

**Step 2:** Connect the load to J3 for the positive connection and J4 for the negative connection.

**Step 3:** Set the power supply voltage to 9V and the load to 0.1 A. The electronic load voltage should be in regulation with a nominal 12 V output.

**Step 4:** Slowly increase the load while monitoring the output voltage between TP3 and TP4. It should remain in regulation with a nominal 12 V output as the load is increased up to 10 A.

**Step 5:** Slowly sweep the input voltage from 6 V to 36 V. The output voltage should remain in regulation with a nominal 12 V output.

**Step 6:** Turn off the load, and decrease the input voltage down to 0 V to shut down the buck-boost converter, and then turn on the load to discharge the output capacitors.

## 4 Test Data and Performance Curve

### 4.1 Efficiency

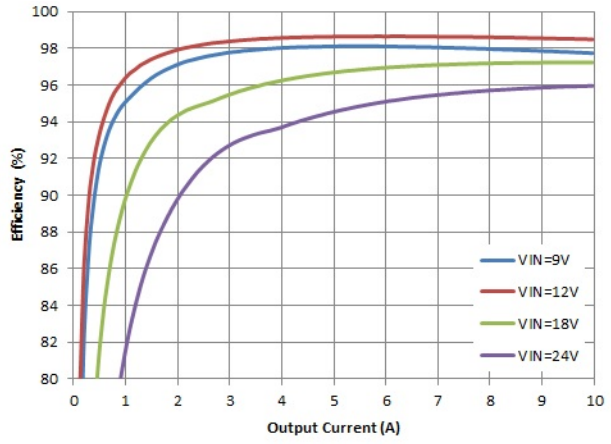


**Figure 2. Efficiency vs. Output Current**

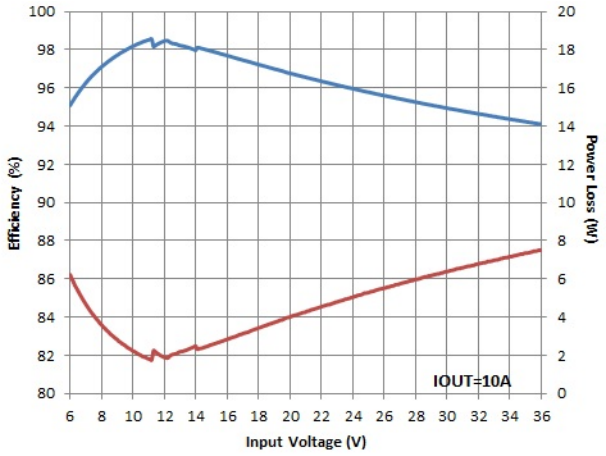


**Figure 3. Efficiency and Power Loss vs. Input Voltage**

## 4.2 Typical Operation Waveforms

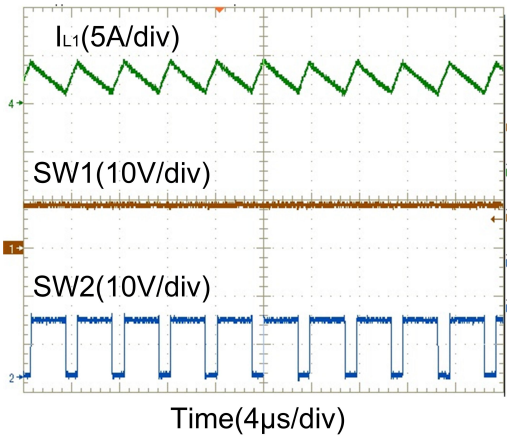


**Figure 4. Typical Operation Waveforms (VIN=9 V, IOUT=2 A)**

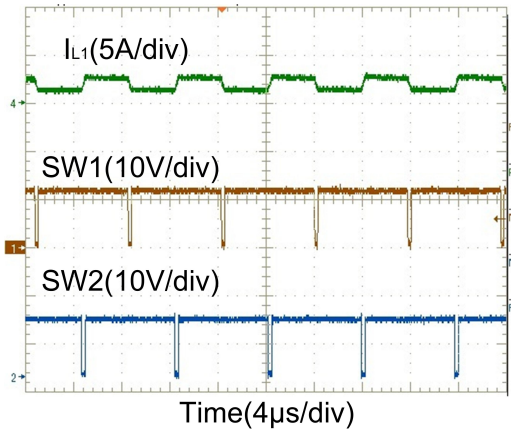


**Figure 5. Typical Operation Waveforms (VIN=12 V, IOUT=2 A)**

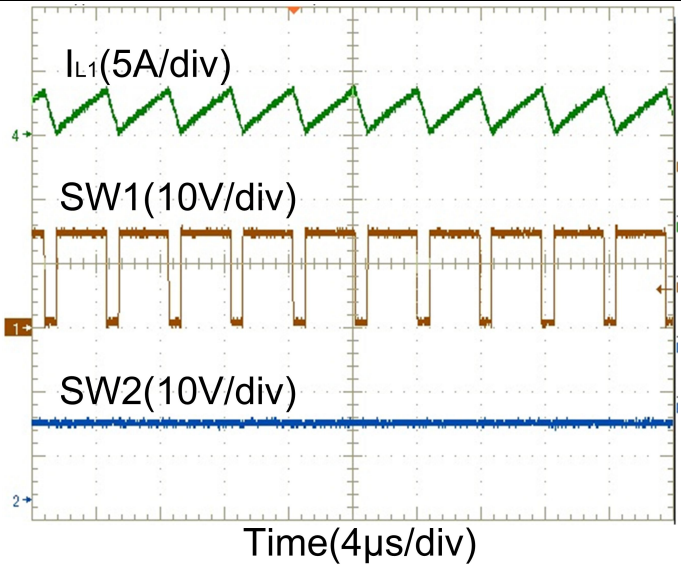


**Figure 6. Typical Operation Waveforms (VIN=15 V, IOUT=2 A)**

### 4.3 Soft Start

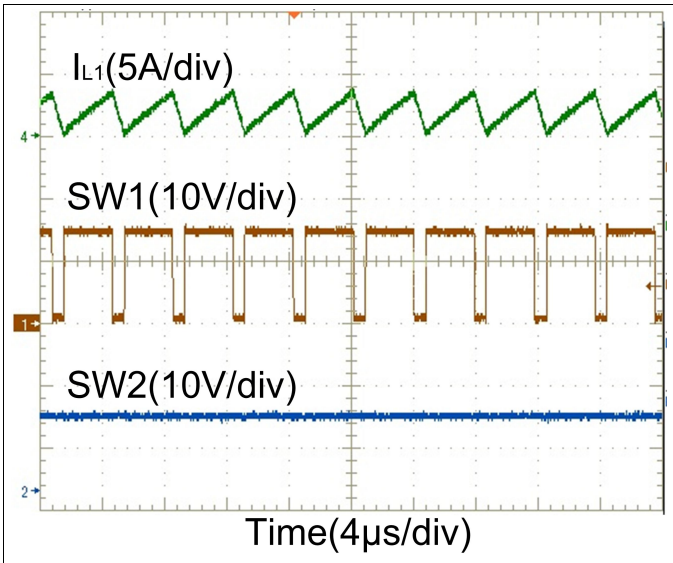


**Figure 7. Turn-on Waveforms (VIN=24 V, IOUT=0 A)**

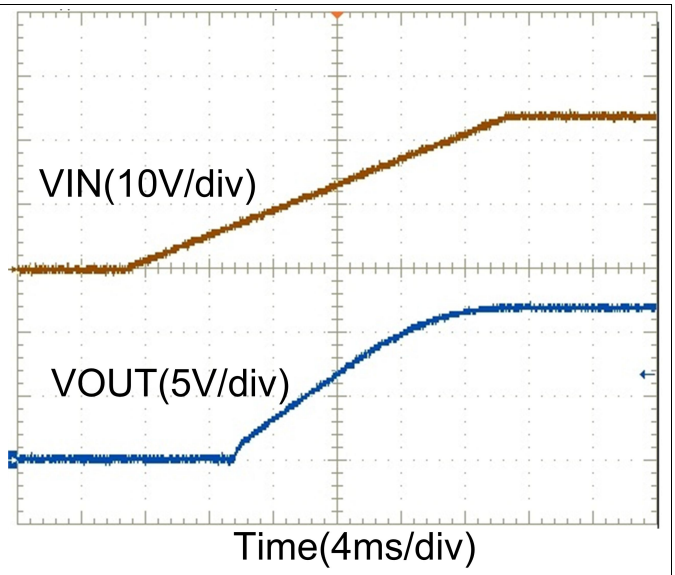


**Figure 8. Turn-on Waveforms (VIN=24 V, IOUT=10 A)**

# 5 LM5175EVM-HP Schematic

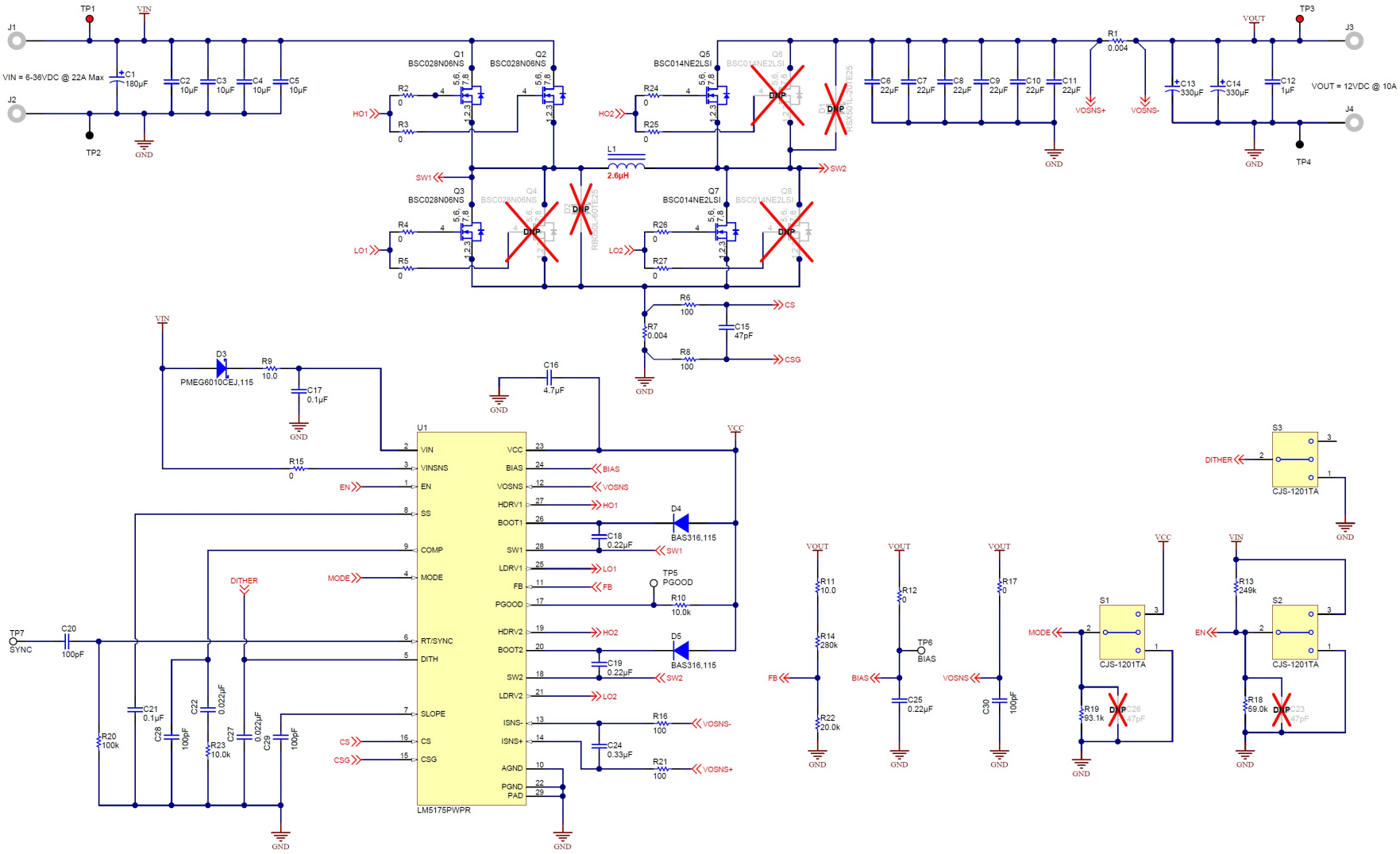


**Figure 9. 4-Switch Buck-Boost Converter Schematic**

## 6 Assembly Drawings and Layout

Figure 12 through Figure 17 show the design of the LM5175EVM-HP PCB.

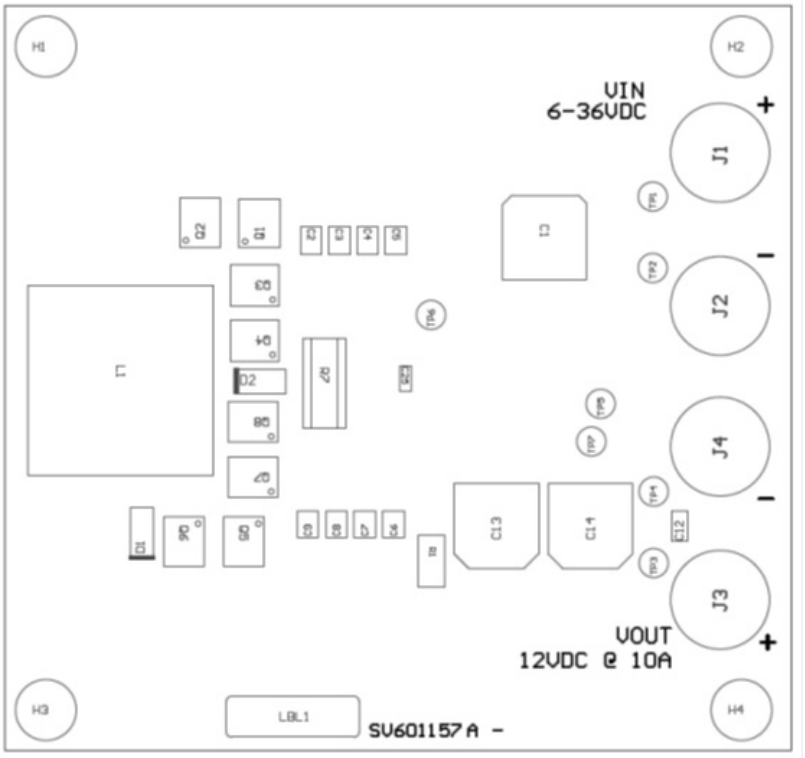


**Figure 10. Top Assembly**

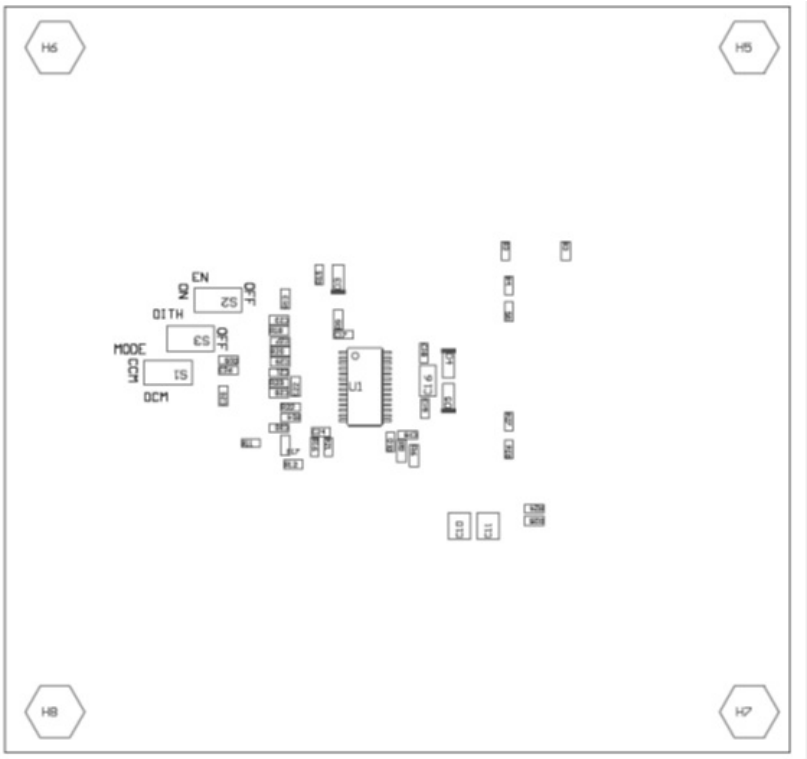


**Figure 11. Assembly Bottom**

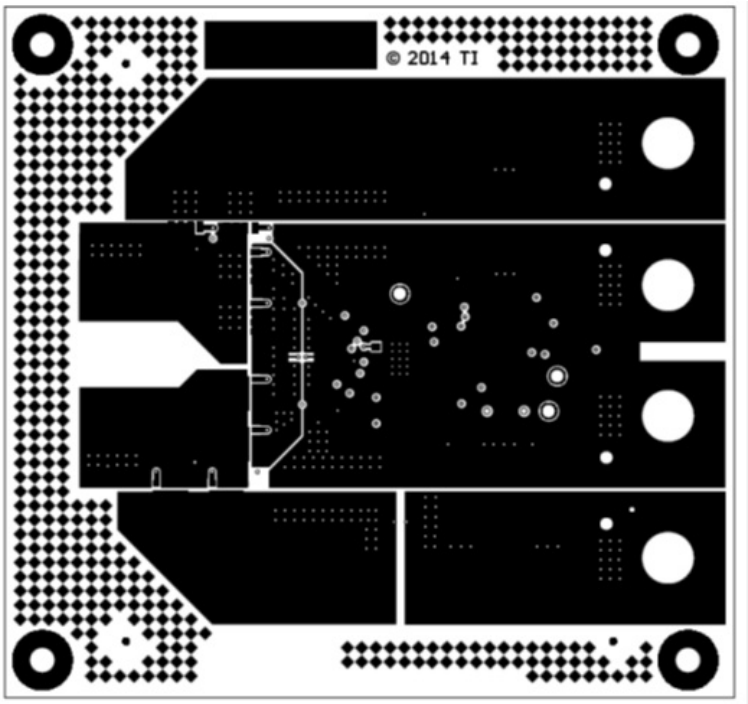


**Figure 12. Top Layer**

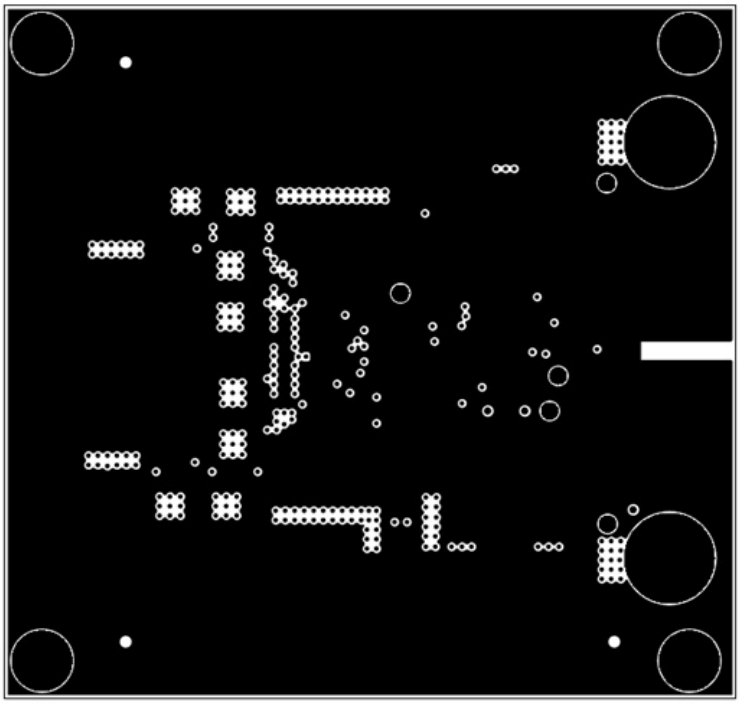

**Figure 13. Mid-Layer 1**

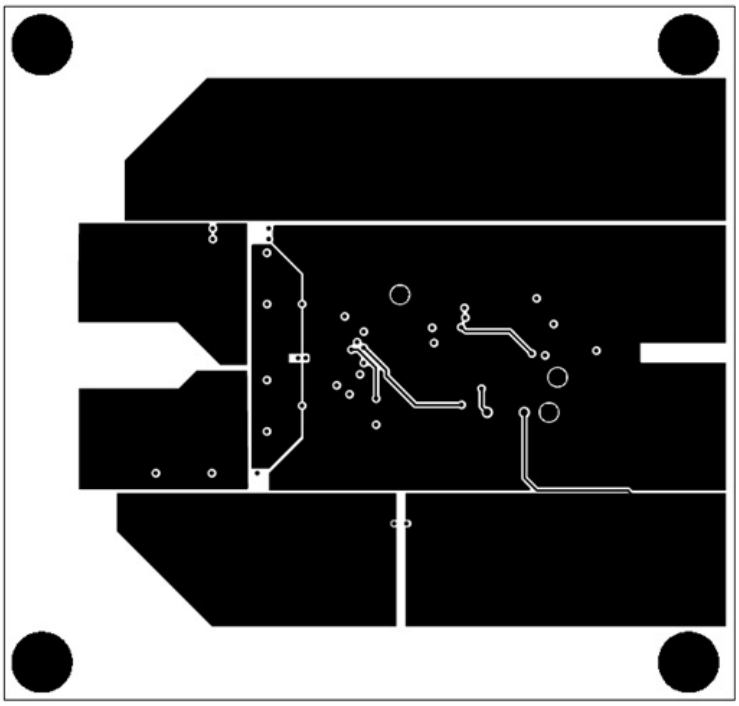

**Figure 14. Mid-Layer 2**

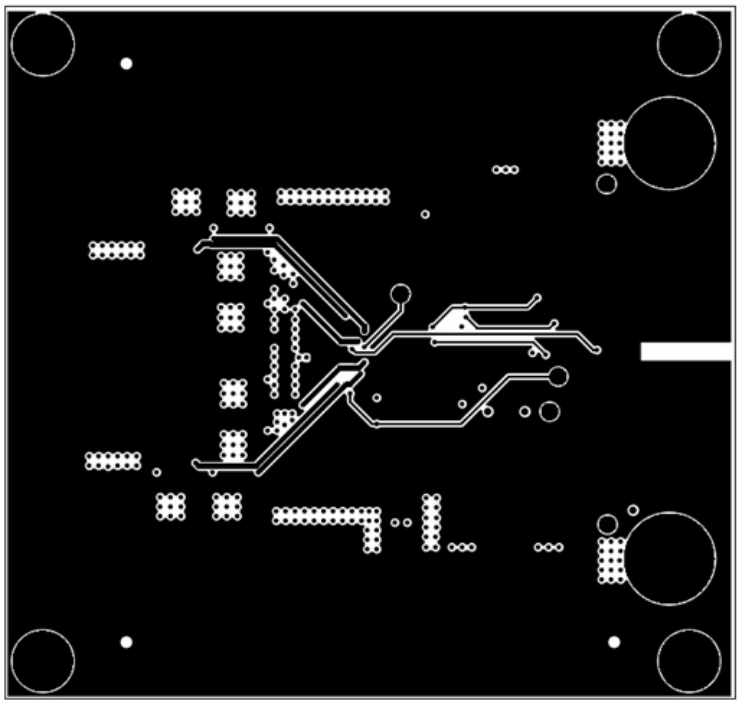

**Figure 15. Mid-Layer 3**

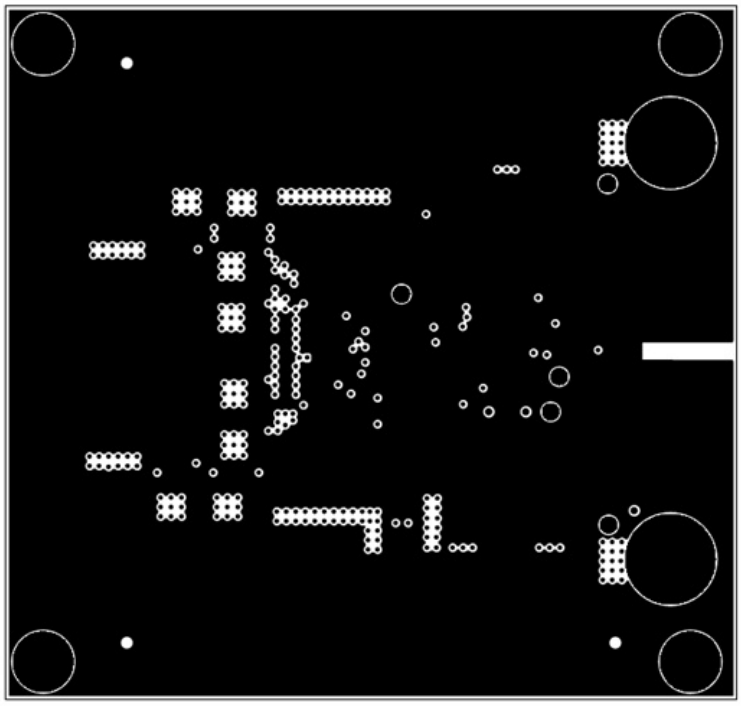

**Figure 16. Mid-Layer 4**

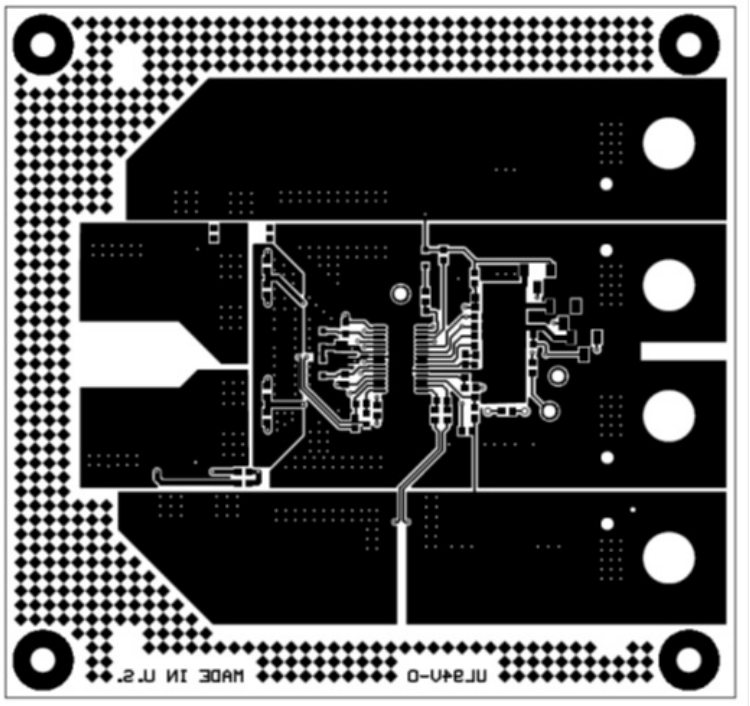

**Figure 17. Bottom Layer**

# 7 LM5175EVM-HP Bill of Materials

**Table 2. LM5175EVM-HP Bill of Materials**

| Ref Des | Quantity | Description | Part Number | Manufacturer |
|---|---|---|---|---|
| PCB | 1 | Printed Circuit Board | SV601157 | Any |
| C1 | 1 | CAP, AL, 180 µF, 50 V, +/- 20%, 0.019 ohm, SMD | PCR1H181MCL1GS | Nichicon |
| C2, C3, C4, C5 | 4 | CAP, CERM, 10 µF, 50 V, +/- 10%, X7R, 1210 | GRM32ER71H106KA12L | MuRata |
| C6, C7, C8, C9, C10, C11 | 6 | CAP, CERM, 22 µF, 16 V, +/- 20%, X7R, 1210 | GRM32ER71C226ME18L | MuRata |
| C12 | 1 | CAP, CERM, 1 µF, 25 V, +/- 10%, X7R, 0805 | GRM219R71E105KA88D | MuRata |
| C13, C14 | 2 | CAP, OS-CON, 330 µF, 16 V, +/- 20%, 0.016 ohm, 10x10.3 SMD | 16SVP330M | Sanyo |
| C15 | 1 | CAP, CERM, 47pF, 50V, +/-5%, C0G/NP0, 0603 | Std | Std |
| C16 | 1 | CAP, CERM, 4.7 µF, 16 V, +/- 10%, X7R, 0805 | Std | Std |
| C17, C21 | 2 | CAP, CERM, 0.1µF, 100V, +/-10%, X7R, 0603 | Std | Std |
| C18, C19, C25 | 3 | CAP, CERM, 0.22 µF, 25 V, +/- 10%, X7R, 0603 | Std | Std |
| C20, C28, C29, C30 | 4 | CAP, CERM, 100pF, 100V, +/-5%, C0G/NP0, 0603 | Std | Std |
| C22, C27 | 2 | CAP, CERM, 0.022µF, 50V, +/-10%, X7R, 0603 | Std | Std |
| C24 | 1 | CAP, CERM, 0.33 µF, 16 V, +/- 10%, X7R, 0603 | Std | Std |
| D3 | 1 | DIODE SCHOTTKY 60V 1A SOD323F | PMEG6010CEJ,115 | NXP Semiconductors |
| D4, D5 | 2 | Diode, Ultrafast, 100V, 0.25A, SOD-323 | BAS316,115 | NXP Semiconductors |
| H1, H2, H3, H4 | 4 | Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead | NY PMS 440 0025 PH | B&F Fastner Supply |
| H5, H6, H7, H8 | 4 | Standoff, Hex, 0.5"L #4-40 Nylon | 1902C | Keystone |
| J1, J2, J3, J4 | 4 | Standard Banana Jack, Uninsulated, 15A | 108-0740-001 | Emerson Network Power |
| L1 | 1 | Inductor, Shielded Drum Core, WE-Superflux200, 2.6 µH, 31.5 A, 0.0016 ohm, SMD | 7443556260 | Wurth Elektronik eiSos |
| Q1, Q2, Q3 | 3 | MOSFET, N-CH, 60 V, 100 A, TDSON-8 | BSC028N06NS | Infineon Technologies |
| Q5, Q7 | 2 | MOSFET, N-CH, 25 V, 100 A, TDSON-8 | BSC014NELSI | Infineon Technologies |
| R1 | 1 | RES 0.004 OHM 3W 1% 2512 WIDE | KRL6432E-M-R004-F-T1 | Susumu |
| R2, R3, R4, R5, R12, R15, R17, R24, R25, R26, R27 | 11 | RES, 0 ohm, 5%, 0.1W, 0603 | Std | Std |
| R6, R8, R16, R21 | 4 | RES, 100 ohm, 1%, 0.1W, 0603 | Std | Std |
| R7 | 1 | RES, 0.004, 1%, 6 W, 4320_WIDE | KRL11050-C-R004-F-T1 | Susumu Co Ltd |
| R9, R11 | 2 | RES, 10.0 ohm, 1%, 0.1W, 0603 | Std | Std |
| R10, R23 | 2 | RES, 10.0k ohm, 1%, 0.1W, 0603 | Std | Std |
| R13 | 1 | RES, 249k ohm, 1%, 0.1W, 0603 | Std | Std |
| R14 | 1 | RES, 280k ohm, 1%, 0.1W, 0603 | Std | Std |
| R18 | 1 | RES, 59.0k ohm, 1%, 0.1W, 0603 | Std | Std |

**Table 2. LM5175EVM-HP Bill of Materials (continued)**

| Ref Des | Quantity | Description | Part Number | Manufacturer |
|---|---|---|---|---|
| R19 | 1 | RES, 93.1 k, 1%, 0.1 W, 0603 | Std | Std |
| R20 | 1 | RES, 100 k, 1%, 0.1 W, 0603 | Std | Std |
| R22 | 1 | RES, 20.0k ohm, 1%, 0.1W, 0603 | Std | Std |
| S1, S2, S3 | 3 | Slide SW, SPDT 0.1A 50VDC | CJS-1201TA | Copal Electronics |
| TP1, TP3 | 2 | Test Point, Compact, Red, TH | 5005 | Keystone |
| TP2, TP4 | 2 | Test Point, Compact, Black, TH | 5006 | Keystone |
| TP5 | 1 | Test Point, Compact, White, TH | 5007 | Keystone |
| TP6, TP7 | 2 | Test Point, Compact, White, TH | 5007 | Keystone |
| U1 | 1 | 42V Wide VIN 4-Switch Synchronous Buck-Boost Controller, TSSOP-28 | LM5175PWP | Texas Instruments |
| C23, C26 | 0 | CAP, CERM, 47pF, 50V, +/-5%, C0G/NP0, 0603 | Std | Std |
| D1 | 0 | DIODE SCHOTTKY 20V 5A PMDS | RSX501L-20TE25 | Rohm Semiconductor |
| D2 | 0 | DIODE SCHOTTKY 60V 3A PMDS | RB050L-60TE25 | Rohm Semiconductor |
| Q4 | 0 | MOSFET, N-CH, 60 V, 100 A, TDSON-8 | BSC028N06NS | Infineon Technologies |
| Q6, Q8 | 0 | MOSFET, N-CH, 25 V, 100 A, TDSON-8 | BSC014NELSI | Infineon Technologies |

# STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms and conditions that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms and conditions do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for any defects that are caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 *Regulatory Notices:*

   3.1 *United States*

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

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

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

      **CAUTION**

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

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

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

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

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

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

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

3.2 *Canada*

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

**Concerning EVMs Including Radio Transmitters:**

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

**Concernant les EVMs avec appareils radio:**

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

**Concerning EVMs Including Detachable Antennas:**

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

**Concernant les EVMs avec antennes détachables**

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

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/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。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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

If User uses EVMs in 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】

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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

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