

TPS62080, TPS62080A, 1.2-A, High-Efficiency, Step-Down Converter in 2 x 2-mm SON Package

This user's guide describes the TPS62080 evaluation module (EVM), how to perform a stand-alone evaluation or interface with a host or system. The converter is designed to deliver up to 1200 mA of continuous current to the output. The converter can be switched into snooze mode by pulling the mode pin high. Snooze mode is typically used in system standby mode, results in better efficiency at light loads (longer run time) at the expense of higher output ripple and reduced dynamic performance, which is often a good tradeoff in this dormant system mode.

This EVM can support evaluation of either the TPS62080 or TPS62080A IC. The EVM is delivered with the TPS62080 IC and the only difference between the two ICs is the discharge resistor that is internally connected between the SW pin and the ground when the IC is disabled. The TPS62080 connects a 1k and the TPS62080A connects a 50 Ω . To test with the 50 Ω discharge resistor, the IC can be replaced with TPS62080A. When using TPS62080A, [Figure 9](#) will have a faster discharge on V_{OUT} .

1 Introduction

The TPS6208x focuses on high-efficiency, step-down conversion over a wide output current range. At medium-to-heavy loads, the converter operates in PWM mode and automatically enters PFM or Power Save mode operation at light-load currents to maintain high efficiency over the entire load current range. To maintain high efficiency at low load or no load currents, a Snooze mode with an ultralow quiescent current (5 μ A) is implemented, which maintains the output voltage. This function increases the run-time of battery- driven applications and keeps the standby current at its lowest level to meet green energy standards targeting for a low standby current. To address the requirements of powering supply rails, the internal compensation circuit allows a large selection of external output capacitor values ranging from 10 μ F up to 100 μ F. The TPS6208x operates at a nominal frequency of 3 MHz. With its DCS-Control™ architecture, excellent load transient performance, and output voltage regulation, accuracy is achieved. The robust architecture and safety features allow perfect system integration. The device is available in 2 x 2-mm package with thermal PAD.

2 Considerations With Evaluating the TPS62080

This integrated circuit (IC) has three modes of operation, the PWM/PFM mode is selected with the mode pin low and is in PWM mode when the load current is greater than half the ripple current (in continuous conduction mode). At light loads, when the inductor current is discontinuous, the IC automatically goes into PFM mode and delivers fewer pulses, trying to keep a tight regulation with low ripple.

Pulling the mode pin high puts the IC in snooze mode, which uses far less power to operate at the expense of higher ripple voltage and reduced transient performance.

3 Test Summary

The TPS62080EVM-641 board requires an adjustable dc power supply with up to a 6-V output and \geq 600 mA for powering the input to the EVM and a resistive output load between 825 Ω and 5 Ω . Choose the proper power rating for the load resistor, $P=V^2/R$. Use at least 2x the calculated power dissipation. The test setup connections and jumper settings selections are configured for a stand-alone evaluation, but can be changed to interface with external hardware such as a system load and microcontroller.

3.1 Equipment

- Adjustable dc power supply between 2.7 V and 6 V with adjustable current limit set to ~550 mA
- Load: System load or resistive load 5 Ω , 3 W; 100 Ω , 0.25 W; and 825 Ω , 0.25 W
- Three Fluke 75 digital multimeters (DMM); (equivalent or better)
- Oscilloscope, model TDS222 (equivalent or better)

3.2 Equipment and EVM Setup

Table 1 shows the setup input/output connections and configuration of the TPS62080 evaluation module. The silk screen labels are shown in parentheses.

Table 1. Setup I/O Connections and Configuration for TPS62080EVM Evaluation

| Jack/Component (Silk Screen) | Connect or Adjustment to: |
|------------------------------|---|
| J1-1/2 (Vin) | P/S positive lead, preset to 4 Vdc; 550-mA current limit. |
| J2-1 (+ SNS); Input | Positive lead of DMM #1 |
| J2-2 (- SNS); Input | Negative lead of DMM #1 |
| J3-1/2 (GND) | P/S negative lead. |
| J5-1/2 (Vout) | Positive lead to system load or load resistance |
| J6-1 (+ SNS); Output | Positive lead of DMM #2 |
| J6-2 (- SNS); Output | Negative lead of DMM #2 |
| J7-1/2 (GND) | Negative lead to system load or load resistance |
| J4-1 (PG) | Positive lead of DMM #3 |
| J4-2 (GND) | Negative lead of DMM #3 |
| JP1-1/2 (SNOOZE) | Do not apply shunt until procedures calls for change. |
| JP1-2/3 (PWM/PFM) | Apply shunt to PWM/PFM for converter operation |
| JP2-1/2 (ON) | Apply shunt to ON for converter operation |
| JP1-2/3 (OFF) | Do not apply shunt until procedures calls for change. |

Connect the meters, scope probes, output load, shunt, and input power supply as listed in Table 1 ; set the oscilloscope to 200 ns/div, positive trigger, dc-coupled on CH2, CH1; ac-coupled and 20 mV/div on CH3; and ac-coupled and 10 mV/div. Users may want to replace resistive load with system load or decade load box to vary load (1-k Ω to 5- Ω load).

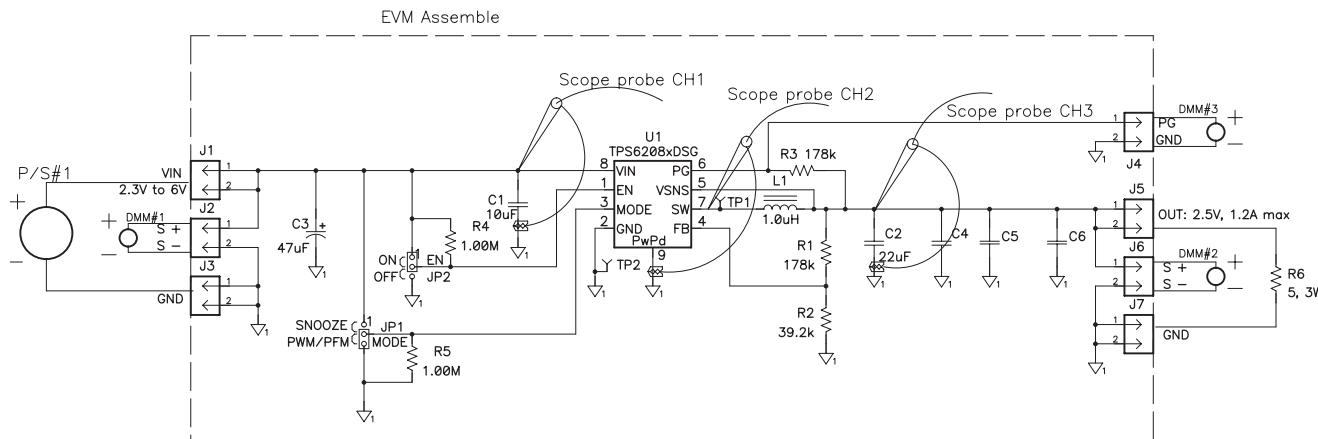


Figure 1. EVM Schematic and Evaluation Setup

3.3 Test Procedure

1. Ensure that the EVM is set up according to [Table 1](#) and [Figure 1](#), and that the power supply is preset to 4 Vdc at ~550-mA current limit.
2. Turn on input supply, and verify that the input voltage is ~4 Vdc (DMM#1) and the output voltage is at ~2.5 Vdc (DMM#2).
3. Look at CH2 and CH3, and verify that the duty cycle is near 67% and the output ripple is less than 10-mV ripple; see [Figure 2](#) for typical waveforms. Note that the output inductance used on the test board used to take the photographs is a 2.2- μ H inductor and the one on the factory EVM is a 1- μ H inductor; therefore, the output ripple is approximately twice the amplitude shown. These waveforms were taken with high-frequency probes (meaning that the ground lead was very short (~1 cm)). This greatly reduces the high-frequency spikes that the ground loop on the probe picks up.
4. Change the load to from 5 Ω to 100 Ω , 0.25 W. Observe the change in the switching waveforms. As the load is reduced, the inductor current becomes discontinuous, and the control automatically switches to PFM mode. Users may need to change the time scale on the oscilloscope to 1 μ s/div for light loads (see [Figure 3](#)). Set the load back to approximately 5 Ω .
5. Vary input voltage between 2.5 V and 5 V, and observe the change in duty cycle and ripple waveforms.
6. Set the load to 100 Ω (25 mA), set CH3 to 50 mV/div, and move shunt from JMP1-PWM/PFM to JP1-SNOOZE. Observe that the IC is in low-power mode where the IC shuts down for short periods and then wakes up to restore regulation. Note how the ripple is much larger at the expense of better efficiency at light loads (see [Figure 4](#)).
7. Reduce load to 825 Ω (~3 mA), and set CH2 to 5 V/div (see [Figure 5](#)).
8. Set shunt on JP1 to JP1-PWM/PFM. Disconnect positive lead of input supply, and change output load to 5 Ω . Set CH1 to 2 Vdc/div, CH3 to 1 Vdc/div, and time to 50 μ s/div. Set trigger to CH1, trigger level to 2 V, and arm single-sequence trigger. Hot-plug input supply. See [Figure 6](#) for a typical power up. [Figure 7](#) shows the timing of the PG pin applying the input hot plug.
9. Set the single-sequence trigger for negative slope and time for 100 μ s/div; arm scope and unplug power supply. See [Figure 8](#) for an example of power down by removing input supply.
10. Remove the enable shunt, JP2, and connect CH1 to JP2-2 (EN) and plug in the input supply. Arm the oscilloscope, and short between JP2-2 and JP2-1 (OFF). The captured waveform shows output power down by pulling EN low ([Figure 9](#)).
11. Set Scope to positive trigger, arm scope and remove short between JP2-1/2. The captured waveform shows output power up by pulling EN high ([Figure 10](#))
12. With an understanding of the basic functions of the EVM, users may want to connect the EVM into their system using short, twisted wires to minimize impedance.

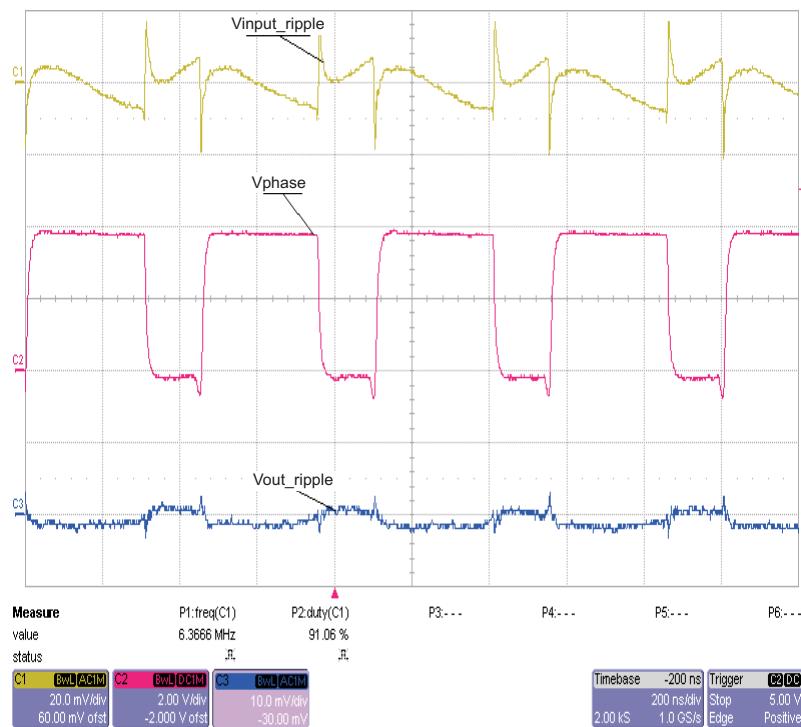


Figure 2. PWM Mode. Vin = 4 V, Vout = 2.5 V, Iout = 0.5 A. CCM Operation, Therefore PWM Mode CH1 = Input Ripple; CH2 = Phase; CH3 = Output Ripple

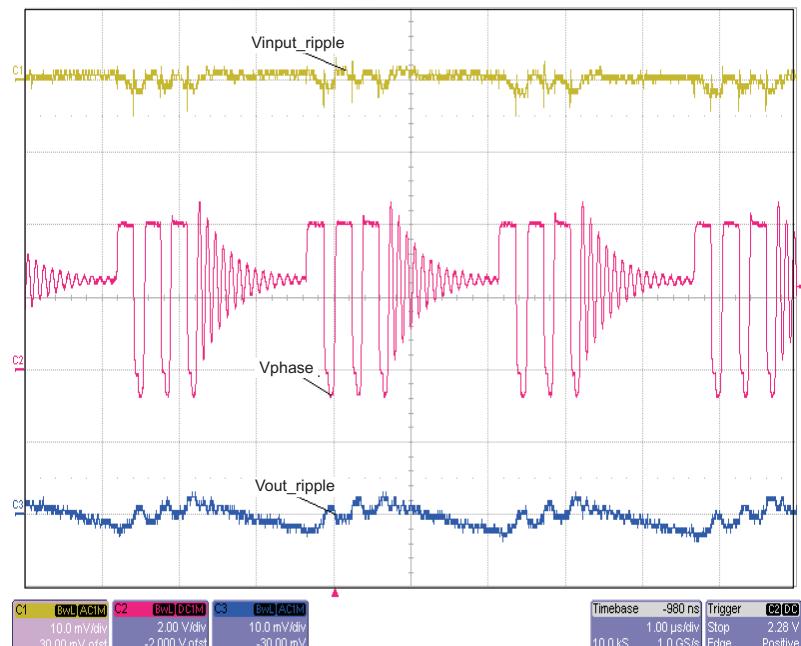


Figure 3. PFM Mode. Vin = 4 V, Vout = 2.5 V, Iout = 25 mA. DCM Operation, Therefore PFM Mode CH1 = Input Ripple; CH2 = Phase; CH3 = Output Ripple

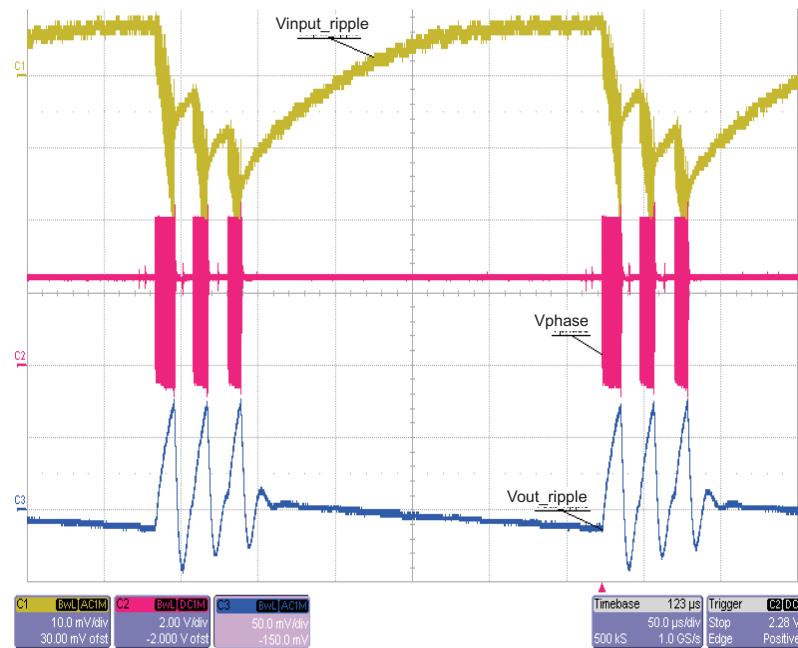


Figure 4. SNOOZE Mode. Vin = 4 V, Vout = 2.5 V, Iout = 25 mA. CH1 = Input Ripple; CH2 = Phase; CH3 = Output Ripple

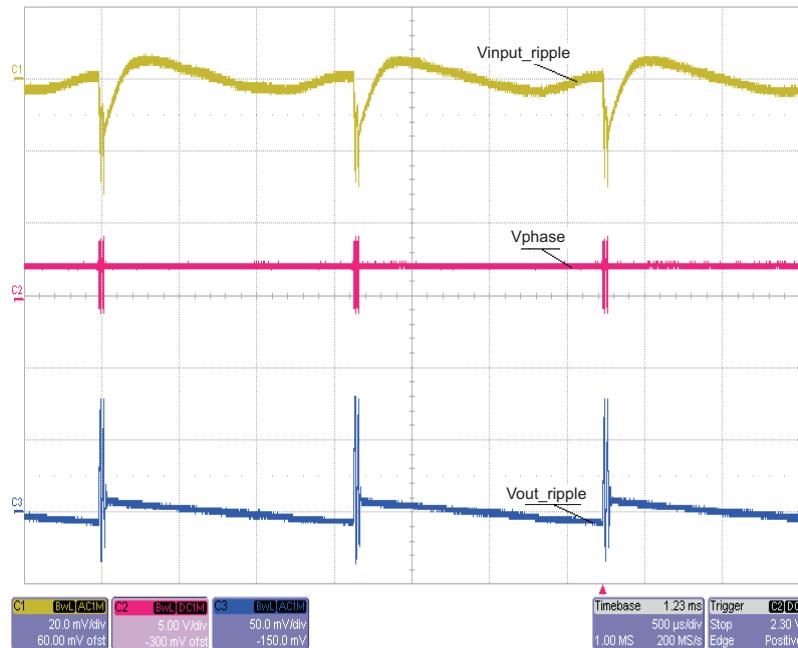


Figure 5. SNOOZE Mode. Vin = 4 V, Vout = 2.5 V, Iout = 3 mA; CH1 = Input Ripple; CH2 = Phase; CH3 = Output Ripple

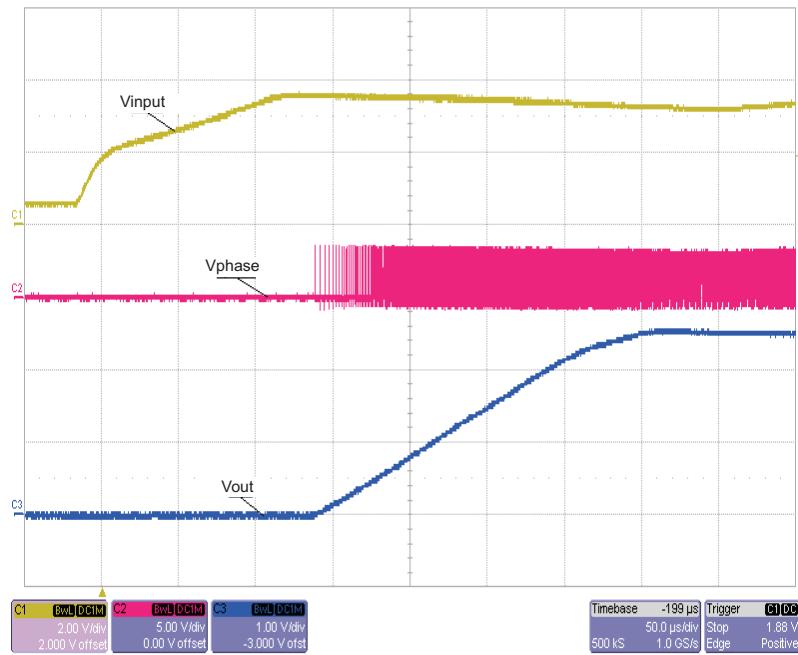


Figure 6. Start-up in PWM/PFM Mode. Vin = 4 V, Vout = 2.5 V, Iout = 0.5 A; CH1 = Input Voltage; CH2 = Phase; CH3 = Output Voltage

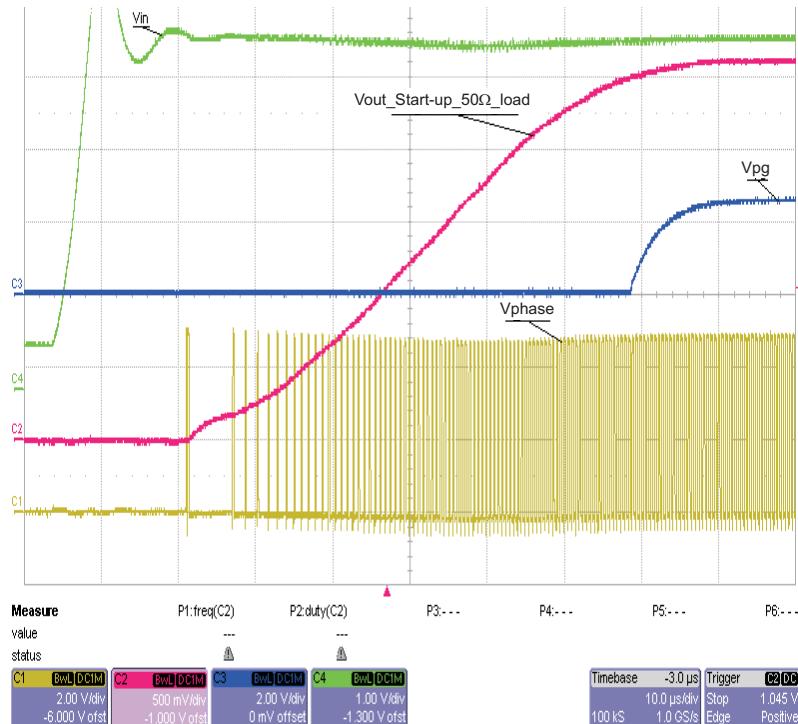


Figure 7. Start-up in PWM/PFM Mode. Vin = 5 V, Vout = 2.5 V, Iout = 0.5 A; CH4 = Input Voltage; CH1 = Phase; CH2 = Output Voltage; CH3 = PG

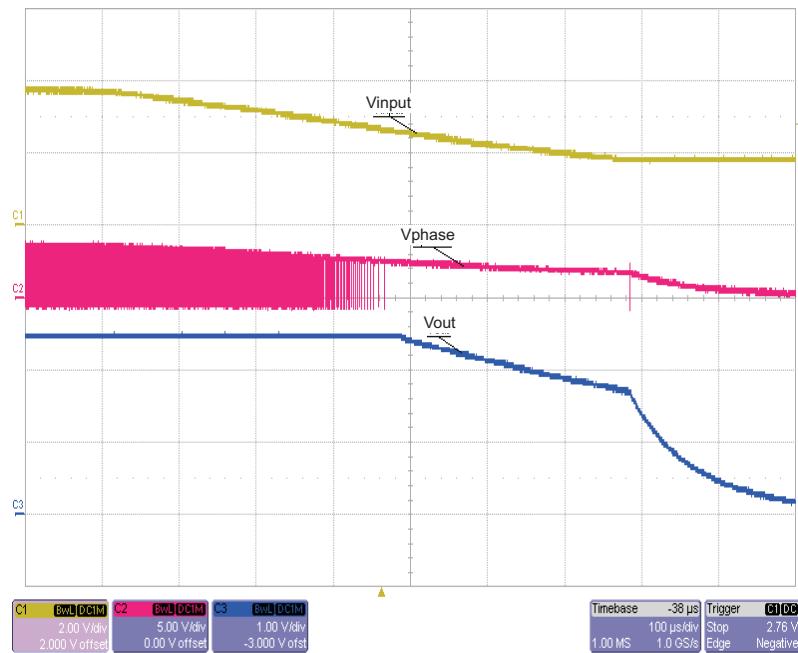


Figure 8. Power Down in PWM/PFM Mode, $V_{in} = 4$ V, $V_{out} = 2.5$ V, $I_{out} = 0.5$ A; CH1 = Input Voltage; CH2 = Phase; CH3 = Output Voltage

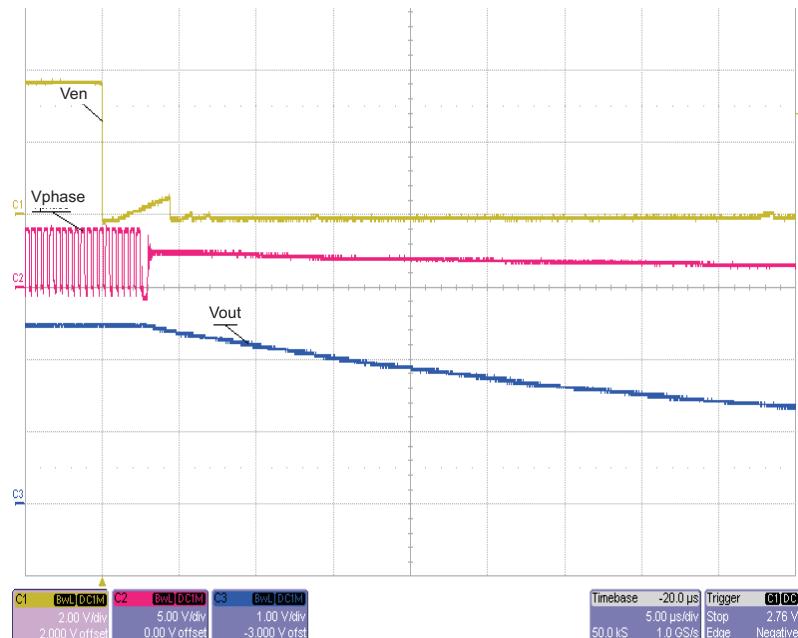


Figure 9. Shutdown Output With EN Pin. $V_{in} = 4$ V, $V_{out} = 2.5$ V, $I_{out} = 0.5$ A; CH1 = Input Voltage; CH2 = Phase; CH3 = Output Voltage

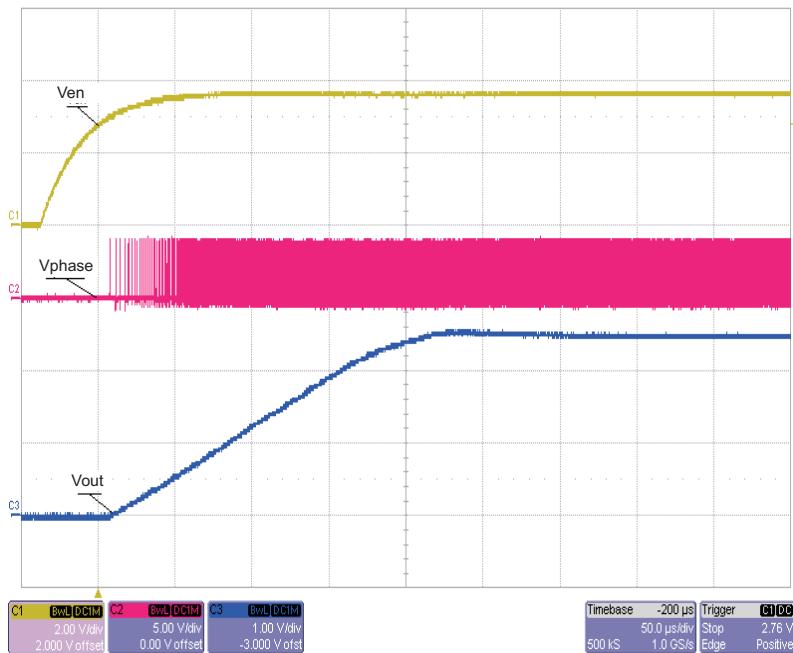


Figure 10. Power-up Output With EN pin. Vin = 4 V, Vout = 2.5 V, Iout = 0.5 A; CH1 = Input Voltage; CH2 = Phase; CH3 = Output Voltage

4 Schematic, Physical Layout and Bill of Materials

4.1 Schematic

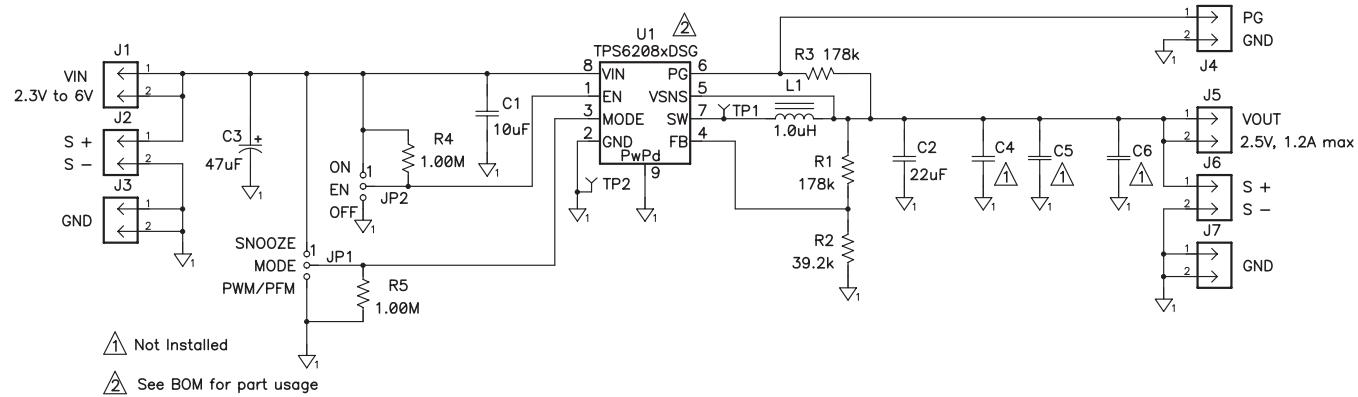


Figure 11. Schematic

4.2 Physical Layouts

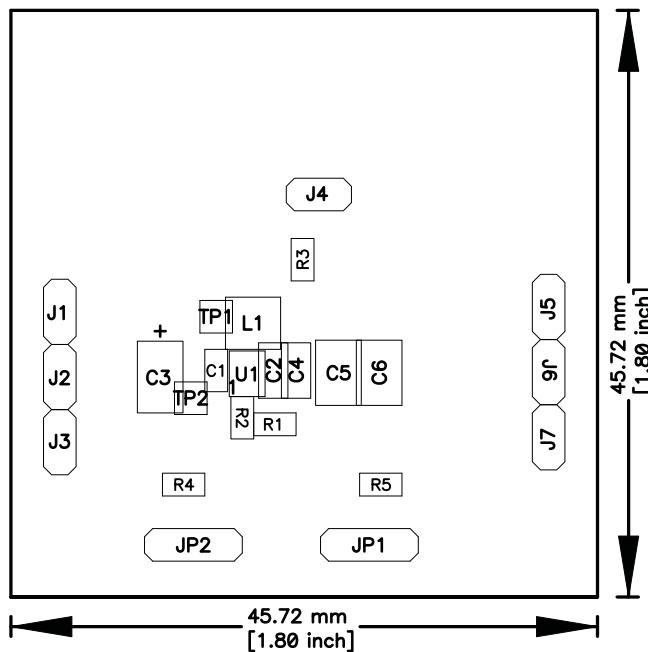


Figure 12. Assembly Layer

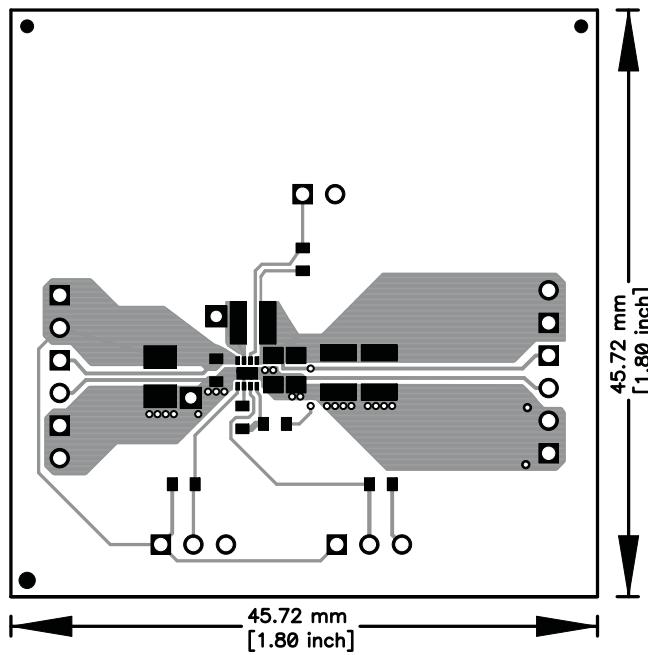


Figure 13. Top Layer

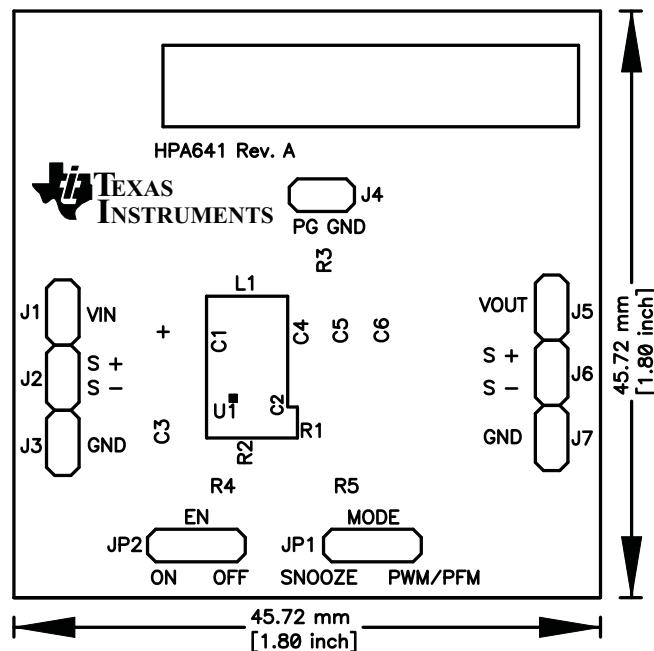


Figure 14. Bottom Layer

4.3 Bill of Materials

Table 2. Bill of Materials

| Count | RefDes | Value | Description | Size | Part Number | MFR |
|-------|----------------------------|-------------|---|--------------------|--------------------|-----------|
| -001 | | | | | | |
| 1 | C1 | 10 μ F | Capacitor, Ceramic, 6.3V, X5R, 20% | 0603 | Std | Std |
| 1 | C2 | 22 μ F | Capacitor, Ceramic, 6.3V, X5R, 20% | 0805 | GRM21BR60J226ME39L | Murata |
| 1 | C3 | 47 μ F | Capacitor, Tantalum, 8V, 35m Ω , 20% | 3528(B) | T520B476M008ATE035 | Kemet |
| 0 | C4 | Open | Capacitor, Ceramic, | 0805 | Std | Std |
| 0 | C5, C6 | Open | Capacitor, Ceramic, | 1210 | Std | Std |
| 7 | J1, J2, J3, J4, J5, J6, J7 | PEC02SAAN | Header, Male 2-pin, 100mil spacing | 0.100 inch x 2 | PEC02SAAN | Sullins |
| 2 | JP1, JP2 | PEC03SAAN | Header, 3 pin, 100mil spacing | 0.100 x 3 | PEC03SAAN | Sullins |
| 1 | L1 | 1.0uH | Inductor, Power, 2.2A, \pm 20% | 0.120 x 0.120 inch | XFL3012-102MEB | Coilcraft |
| 2 | R1, R3 | 178k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R2 | 39.2k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 2 | R4, R5 | 1.00M | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | U1 | TPS62080DSG | IC, 1.2A Sync. Step Down Converter with Snooze Mode | SON-8 | TPS62080DSG | TI |
| 2 | — | | Shunt, 100-mil, Black | 0.1 | 929950-00 | 3M |
| 1 | — | | Label (SeeNote 6) | 1.25 x 0.25 inch | THT-13-457-10 | Brady |
| 1 | — | | PCB, 1.8 in x 1.8 in x 0.031 in | | HPA641 | Any |

Notes:

1. These assemblies are ESD sensitive, ESD precautions shall be observed.
2. These assemblies must be clean and free from flux and all contaminants. Use of no clean flux is not acceptable.
3. These assemblies must comply with workmanship standards IPC-A-610 Class 2.
4. Ref designators marked with an asterisk (**) cannot be substituted. All other components can be substituted with equivalent MFG's components.
5. Place shunt on JP1-2/3 (PWM/PFM) and JP2-1/2 (ON)
6. Install label after final wash. Text shall be 8 pt font. Text shall be per Table 1.

Table 1

| Assembly Number | Text |
|-----------------|-----------------|
| HPA641-001 | TPS62080EVM-641 |

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As noted in the EVM User's Guide and/or EVM itself, this EVM and/or accompanying hardware may or may not be subject to the Federal Communications Commission (FCC) and Industry Canada (IC) rules.

For EVMs **not** subject to the above rules, this evaluation board/kit/module is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this is strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

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

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.

REGULATORY COMPLIANCE INFORMATION (continued)

FCC Interference Statement for Class B EVM devices

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.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

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

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-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.

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.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

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.

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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This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product 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 this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure 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.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please 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 result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's 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, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to 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 use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

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STANDARD TERMS FOR EVALUATION MODULES

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.
 - 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 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 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 DEGRADATION 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 isotope 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/lsts/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.

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2. 実験局の免許を取得後ご使用いただく。
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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsts/ti_ja/general/eStore/notice_02.page
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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/LICENSENSORS 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, INDEMNITY 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.

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