# bq51013EVM-725 Evaluation Module

The bqTESLA™ wireless power evaluation kit from Texas Instruments is a high-performance, easy-to-use development kit for the design of wireless power solutions. Consisting of a single-channel transmitter and 5-V power supply receiver and associated magnetics, the kit enables designers to speed the development of their end-applications.

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bqTESLA is a trademark of Texas Instruments.

# 1 Applications

The bq51013EVM-725 evaluation module (EVM) demonstrates the receiver portion of the bqTESLA™ wireless power system. This receiver EVM is a complete receiver-side solution that produces 5 V out at up to 1 A when coupled with the bqTESLA™ transmitter. The bq51013EVM-725 device shown on this EVM along with external components that support the device for a complete solution.

- The bqTESLA™ receiver can be used in any number of low-power battery portable devices as a power source for charging. With contact-free charging capability, no connections to the device are needed.
- Output voltage of 5 V up to 1 A
- External adapter switchover and control circuit
- Low-profile, external pick-up coil
- Frame is configured to provide correct receiver to transmitter spacing.
- Room above coil for testing with battery, key for tuning

# 2 bq51013EVM-725 Electrical Performance Specifications

Table 1 provides a summary of the bq51013EVM-725 performance specifications. All specifications are given for an ambient temperature of 25°C.

**Table 1. bq51013EVM-725 Electrical Performance Specifications**

| Parameter | | Notes and Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **INPUT CHARACTERISTICS** | | | | | | |
| $V_{IN}$ | Input Voltage | Typical V-rectified voltage at TP12 | 4 | 5.5 | 8 | V |
| $V_{ADAPTER}$ | Adapter Input Voltage | | 4 | | 20 | V |
| OVP | Input Overvoltage Protection | Voltage at V-rectified | | 15 | | V |
| **OUTPUT CHARACTERISTICS** | | | | | | |
| $V_{OUT}$ | V J3 to J4 | | | 5 | | V |
| $I_{OUT}$ | I J3 | | | 1 | | A |
| **SYSTEMS CHARACTERISTICS** | | | | | | |
| $F_S$ | Switching Frequency | | 110 | | 205 | kHz |
| Eff | Efficiency | Output current 500 mA | | 74 | | % |

# 3 Modifications

See the data sheet (SLVSAT9) when changing components. To aid in such customization of the EVM, the board was designed with devices having 0603 or larger footprints. A real implementation likely occupies less total board space.

Note that changing components can improve or degrade EVM performance.

# 4 Connector and Test Point Descriptions

## *4.1 Input/Output Connections*

The connections points are described in the following paragraphs.

### 4.1.1 J1 – AD External Adapter Input, J2-GND

Power can be provided to simulate an external adapter applied to the receiver. When this is done, an End Power Transfer signal is sent to the transmitter which enters a low power state. External adapter voltage must be a minimum of 4 V but not exceed 20V.

#### 4.1.2 J3 – Output Voltage, J4-GND

Output voltage is 5 V with a possible current of up to 1 A.

#### 4.1.3 J6 – Programming Connector

This connector is unpopulated and is only useful at factory level.

### *4.2 Jumpers/Switches*

The control jumpers are described in the following paragraphs.

#### 4.2.1 JP1 – EN1 Enable 1

One of two Enable signals that controls the Adapter and Wireless power transfer. Low on EN1 enables the wireless power transfer; High disables the wireless power transfer. The Default Shorting jumper setting is Low.

#### 4.2.2 JP2 – EN2 Enable 2

One of two Enable signals that controls the Adapter and Wireless power transfer. Low on EN2 enables the adapter power transfer; High disables the adapter power transfer. Default Shorting jumper setting is Low.

#### 4.2.3 JP3 – TS Enable or Disable

This jumper enables the TS adjustment feature using R3. The Disable position sets voltage at the TS pin to a safe value. The Default Shorting jumper setting is disabled

### *4.3 Test Point Descriptions*

The test points are described in the following paragraphs.

#### 4.3.1 TP1 – AD_EN

This push-pull driver for the external PFET connects the Adapter and the Output from the bq51013.

#### 4.3.2 TP2 – AC Input 2

This is the test point for measuring ac voltage applied to the EVM from the receiver coil.

#### 4.3.3 TP3 – Com2 Communication 2 Drive

Communication driver signal, open-drain output connected to communication capacitor.

#### 4.3.4 TP4 – AC Input 1

This is the test point for measuring ac voltage applied to the EVM from the receiver coil.

#### 4.3.5 TP5 – CLMP 1

Overvoltage clamp driver signal, open-drain output is connected to OVP capacitor.

#### 4.3.6 TP6 – CLMP 2

Overvoltage clamp drive signal, open-drain output is connected to OVP capacitor.

#### 4.3.7 TP7 – OUT Output Voltage

This test point is the output voltage from the bq51013 or the Adapter input.

### 4.3.8 TP8 – Boot-1 Boot Capacitor

This bootstrap capacitor 1 drive connects to the integrated circuit (IC).

### 4.3.9 TP9 – Boot-2 Boot Capacitor

This bootstrap capacitor 2 drive connects to the IC.

### 4.3.10 TP10 – CHG Charge

This output signal indicates that the output current is being delivered to OUT, the open-drain output.

### 4.3.11 TP11 – AC1 IC input

This is the ac input to the IC from series capacitors.

### 4.3.12 TP12 – Rectified Voltage

The input ac voltage is rectified into unregulated dc voltage; additional capacitance is used to filter the voltage before the regulator.

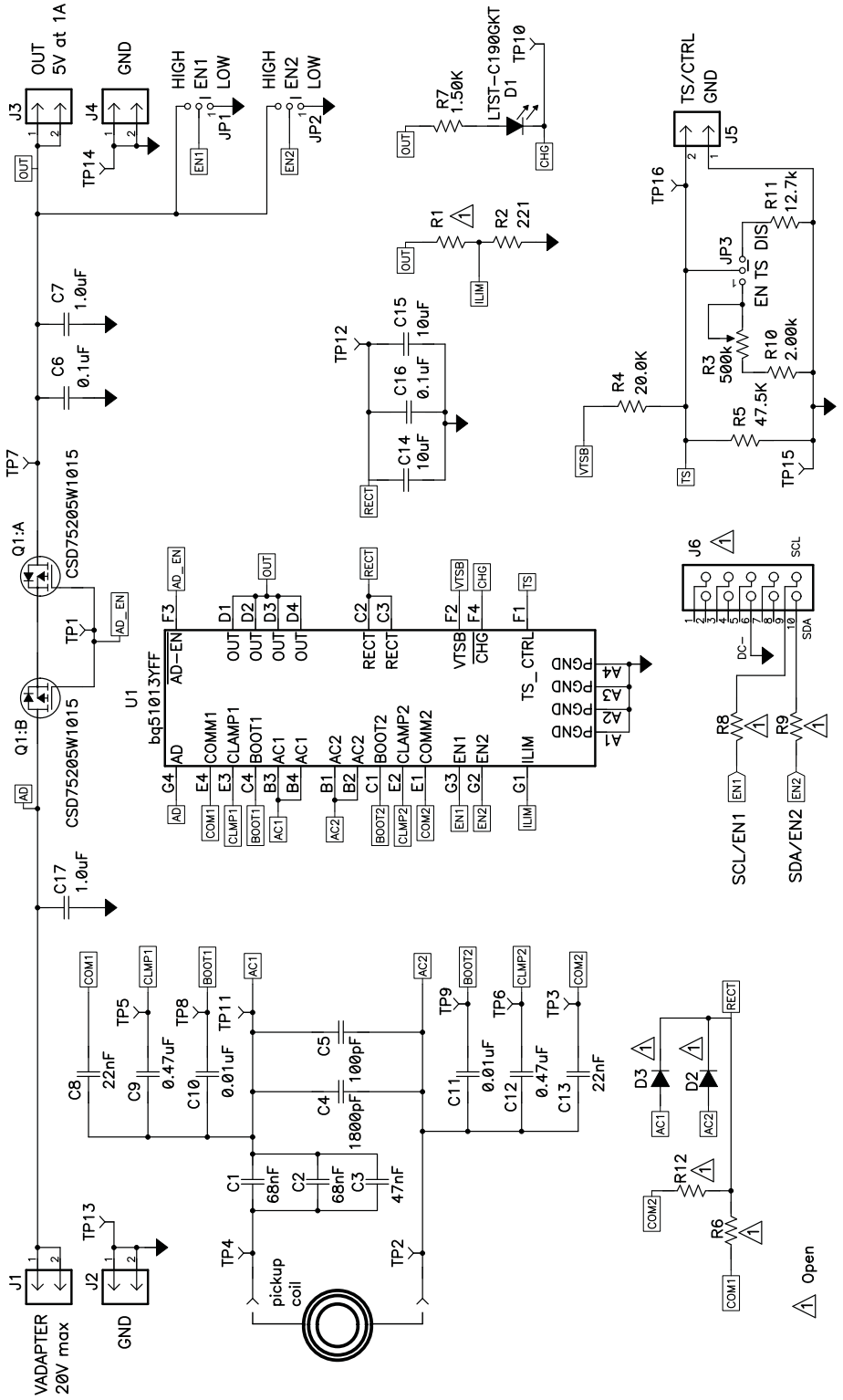
### 4.3.13 TP13, TP14, TP15 – GND

These are the ground test points.

### 4.3.14 TP16 – TS Temp Sensor

This is the connection point for external thermistor; see the data sheet for additional information.

# 5 Schematic and Bill of Materials




NOTE: For Reference Only, See Table 2 for Specific Values

**Figure 1. HPA725EVM Schematic**

## Table 2. Bill of Materials

| Qty | RefDes | Value | Description | Size | Part Number | MFR |
|---|---|---|---|---|---|---|
| 2 | C1, C2 | 68 nF | Capacitor, Ceramic, 50V, X7R, 10% | 0603 | Std | Std |
| 1 | C3 | 47 nF | Capacitor, Ceramic, 50V, X7R, 10% | 0603 | Std | Std |
| 1 | C4 | 1800 pF | Capacitor, Ceramic, 50V, X7R, 10% | 0603 | Std | Std |
| 1 | C5 | 100 pF | Capacitor, Ceramic, 50V, C0G, 5% | 0603 | Std | Std |
| 2 | C6, C16 | 0.1 µF | Capacitor, Ceramic, 50V, X7R, 10% | 0603 | Std | Std |
| 2 | C7, C17 | 1.0 µF | Capacitor, Ceramic, 50V, X5R, 10% | 0805 | Std | Std |
| 2 | C8, C13 | 22 nF | Capacitor, Ceramic, 50V, X7R, 10% | 0603 | Std | Std |
| 2 | C9, C12 | 0.47 µF | Capacitor, Ceramic, 25V, X5R, 10% | 0603 | Std | Std |
| 2 | C10, C11 | 0.01 µF | Capacitor, Ceramic, 50V, X7R, 10% | 0603 | Std | Std |
| 2 | C14, C15 | 10 µF | Capacitor, Ceramic, 25V, X5R, 10% | 1206 | Std | Std |
| 1 | D1 | LTST-C190GKT | Diode, LED, Green, 2.1-V, 20-mA, 6-mcd | 0603 | LTST-C190GKT | Lite On |
| 0 | D2, D3 | Open | Diode, Schottky, 2A, 20V | POWERLITE123 | SMD22PL-TP | Micro Commercial Components |
| 1 | Q1 | CSD75205W1015 | MOSFET, Dual PChan, -20V, 1.2A, 190 mΩ | CSP 1x1.5mm | CSD75205W1015 | TI |
| 0 | R1, R8, R9 | Open | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R2 | 221 | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R3 | 500k | Potentiometer, 1/4 in. Cermet, 12-Turn, Top-Adjust | 0.25x0.17 | 3266W-1-504LF | Bourns |
| 1 | R4 | 20.0K | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R5 | 47.5K | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 0 | R6, R12 | Open | Resistor, Metal Film, 1/4 watt, ± 1% | 1206 | CRCW120624R0FKEA | Vishay |
| 1 | R7 | 1.50K | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R10 | 2.00k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | R11 | 12.7k | Resistor, Chip, 1/16W, 1% | 0603 | Std | Std |
| 1 | U1 | bq51013YFF | IC, Wireless Secondary-Side Power Controller and Battery Charge | DSBGA | bq51013YFF | TI |
| 1 | | | Case Modified Polycase LP-11B with 4 screws | | J-6838A | Polycase |
| 1 | | | Receiver Coil | | IWAS-4832FF-50 or WR-483250-15M2-G or 760308201 | Vishay or TDK or Wurth |

# 6 Test Setup

## 6.1 Equipment

### 6.1.1 bqTESLA™ Transmitter

Power for the bq51013EVM-725 receiver EVM is supplied through a bqTESLA™ transmitter or WPC-certified transmitter. The input ac voltage is applied to the receiver through the coil located in the receiver bottom.

### 6.1.2 Voltage Source

Input power supply to the bqTESLA™ transmitter is typically 19 Vdc ±200 mV at 500 mA maximum, but consult transmitter specification. To simulate an external adapter, an additional 5 V at the 1-A power supply is used.

### 6.1.3 Meters

Output voltage can be monitored at TP7 with a voltmeter. Input current into the load must be monitored with an appropriate ammeter. Transmitter input current and voltage can be monitored also but the meter must use averaging function for reducing error due to communications packets.

### 6.1.4 Loads

A single load is required for 5 V with a maximum current of 1 A. The load can be resistive or electronic.

### 6.1.5 Oscilloscope

A multichannel oscilloscope with appropriate probes is used to observe the RECT voltage at TP12 and other signals.

### 6.1.6 Recommended Wire Gauge

For proper operation, 22 AWG wire is recommended when connecting the bq51013EVM-725EVM to loads.

## 6.2 Equipment Setup

- With the power supply off, connect supply to the bqTESLA™ transmitter.
- Place the bqTESLA™ receiver on the transmitter.
- Connect load to J3 with return to J4, monitor current through load with ammeter, and monitor current to load at TP7.
- Typical output voltage is 5 V, and the output current range is 0 mA to 1 A.

### 6.2.1 Equipment Setup Diagram

The diagram of Figure 2 shows the equipment test setup.

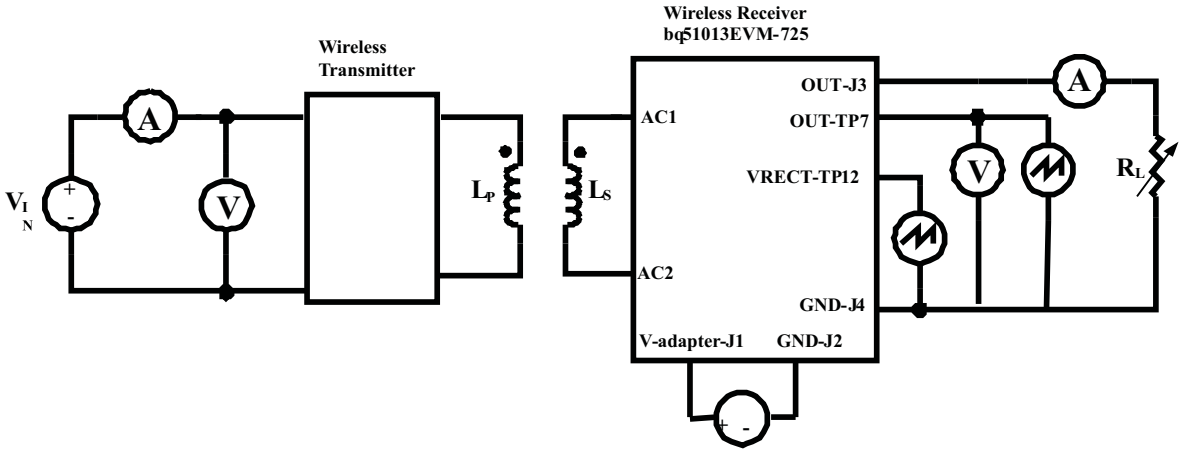



**Figure 2. Equipment Setup**

### 6.2.2 EVM Setup Procedures

This section guides the user through a few general test procedures to exercise the functionality of the presented hardware. A few key notes:

- To probe the output voltage of the receiver, connect the probe to TP7.
- To probe the rectifier voltage, connect the probe to TP12.
- The V-adapter supply which simulates an external adapter is connected to J1.
- All voltmeters must be Kelvin connected (at the pin) to the point of interest.
- The output load is recommended to be a variable power resistor or electronic load.

## 6.3 Load Step

The procedure for load step is as follows:

- Set up the test bench as described in Section 6.2.
- Power TX with 19 V.
- Provide a load step from no load (high impedance) to 10 Ω or 500 mA (if using a current source load).
- Monitor load current, rectifier voltage, and output voltage as shown in the following illustrations.

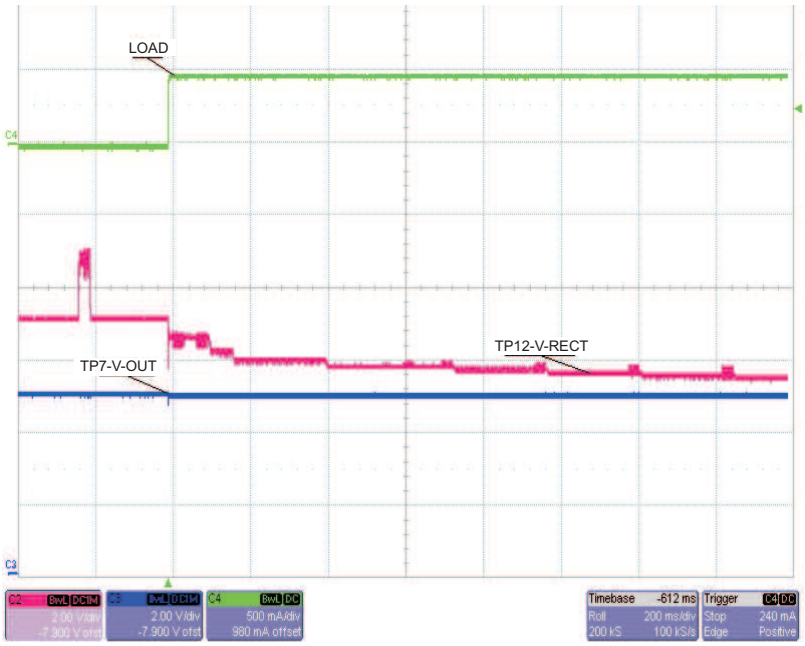



**Figure 3. Load Step**

## 6.4 Load Dump

The procedure for load dump is as follows:

- Set up the test bench as described in Section 6.2.
- Power TX with 19 V.
- Provide a load dump from 10 Ω or 500 mA (if using a current source load) to no load (high impedance).
- Monitor load current, rectifier voltage, and output voltage as shown in the following illustration.

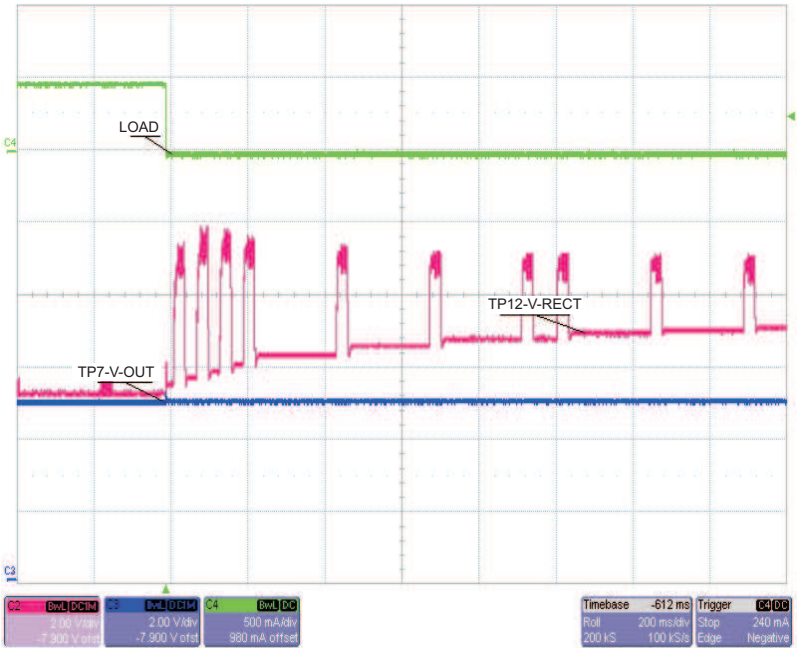



**Figure 4. Load Dump**

## 6.5 V-Adapter Input

The procedure for external adapter (wired adapter) testing is as follows:

- Set up the test bench as described in Section 6.2.
- Power TX with 19 V.
- Load output (the following was loaded with a X-Ω resistor).
- Apply a 6-V V-adapter input voltage.
- Monitor load current, rectifier voltage, output voltage, and V-adapter voltage as shown in the following illustration.

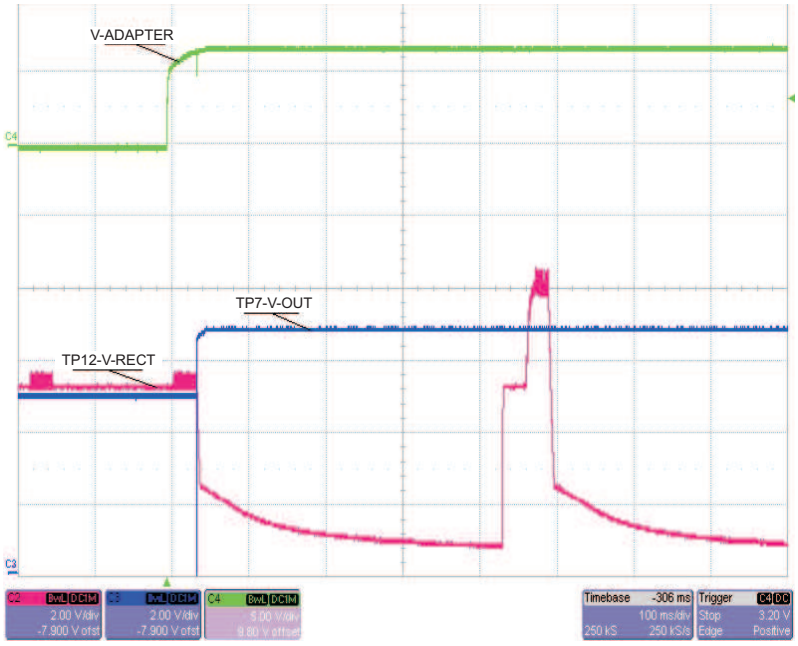



**Figure 5. V-Adapter Input**

## 6.6 Start-Up

The procedure demonstrates start-up:

- Set up the test bench as described in Section 6.2.
- Power TX with 19 V.
- Trigger scope sweep on TP2 AC IN.

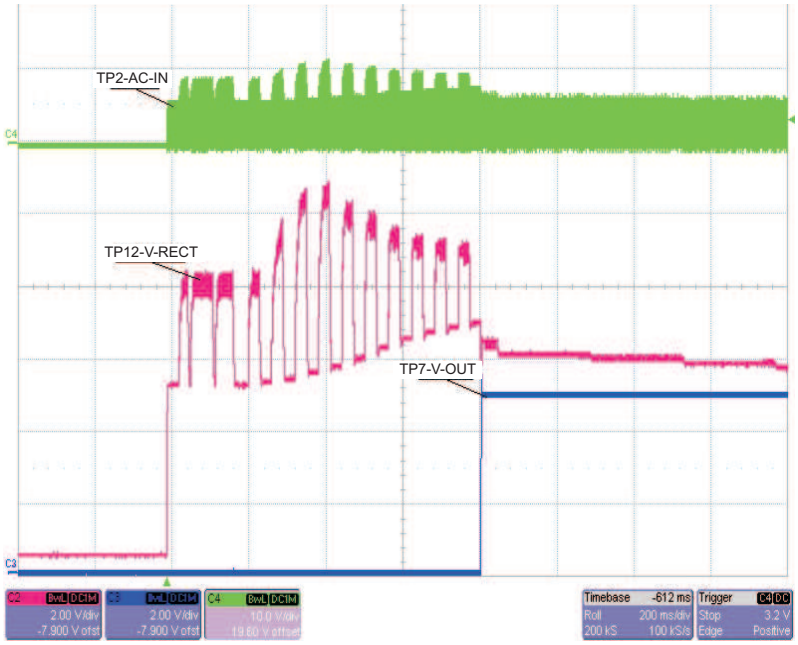



**Figure 6. Start-Up**

## 6.7 Disable Shutdown

The jumper JP2 (EN2) sends an End Power Transfer to Transmitter, Shutdown:

- With unit operating normally, move jumper JP2 from Low to High position.
- LED D1 turn OFF; output voltage drops to 0 V.
- Return jumper to Low position, RX restarts.

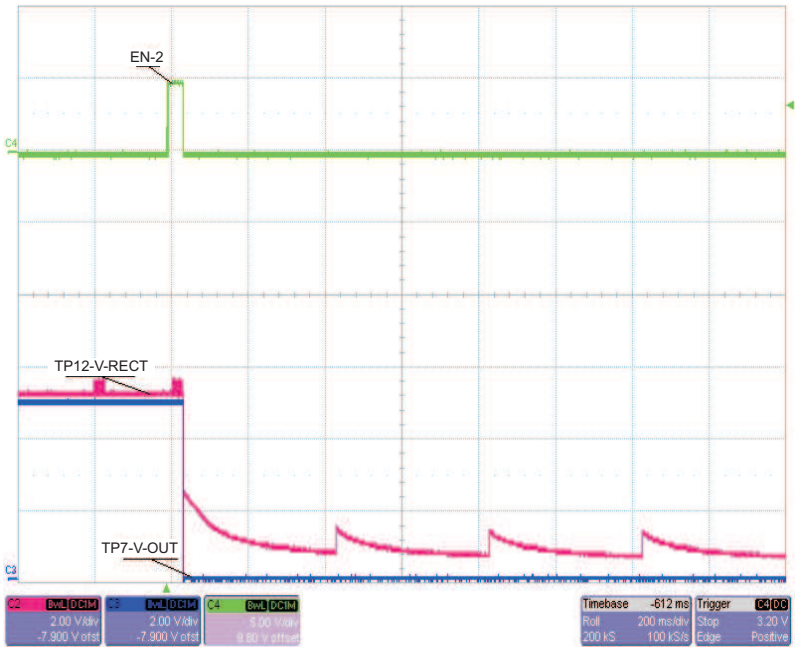



**Figure 7. Equipment Shutdown Wireless Disable**

## 6.8 System Efficiency

The efficiency is measured from input of TX EVM, HPA688 to output of RX EVM, HPA725 with 19-V input. Due to the communication packet that occurs at an approximate 250-ms rate, averaging of input current and voltage is required for good accuracy.

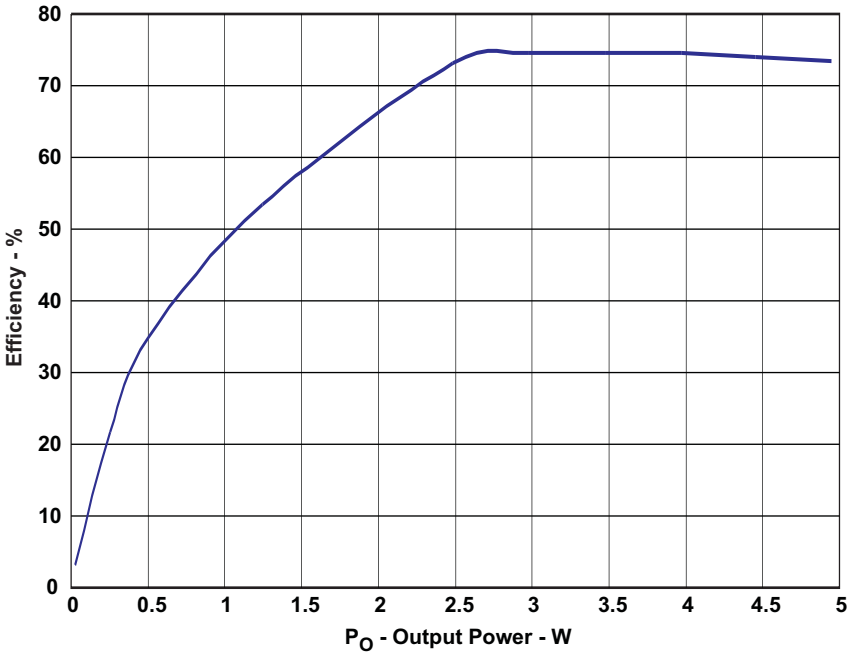



**Figure 8. bq51013EVM-725 Efficiency vs Output Power**

## 7 bq51013EVM-725 Assembly Drawings and Layout

The following figures (Figure 9 through Figure 12) show the design of the bq51013EVM-725 printed-circuit board (PCB). The EVM has been designed using a 2-layer, 2-oz, copper-clad PCB, 2.1-in. × 2.1-in. area to provide the user easy viewing, probing, and evaluating of the bq51013 IC in a practical double-sided application. Moving components to both sides of the PCB or using additional internal layers can offer additional size reduction for space-constrained systems.

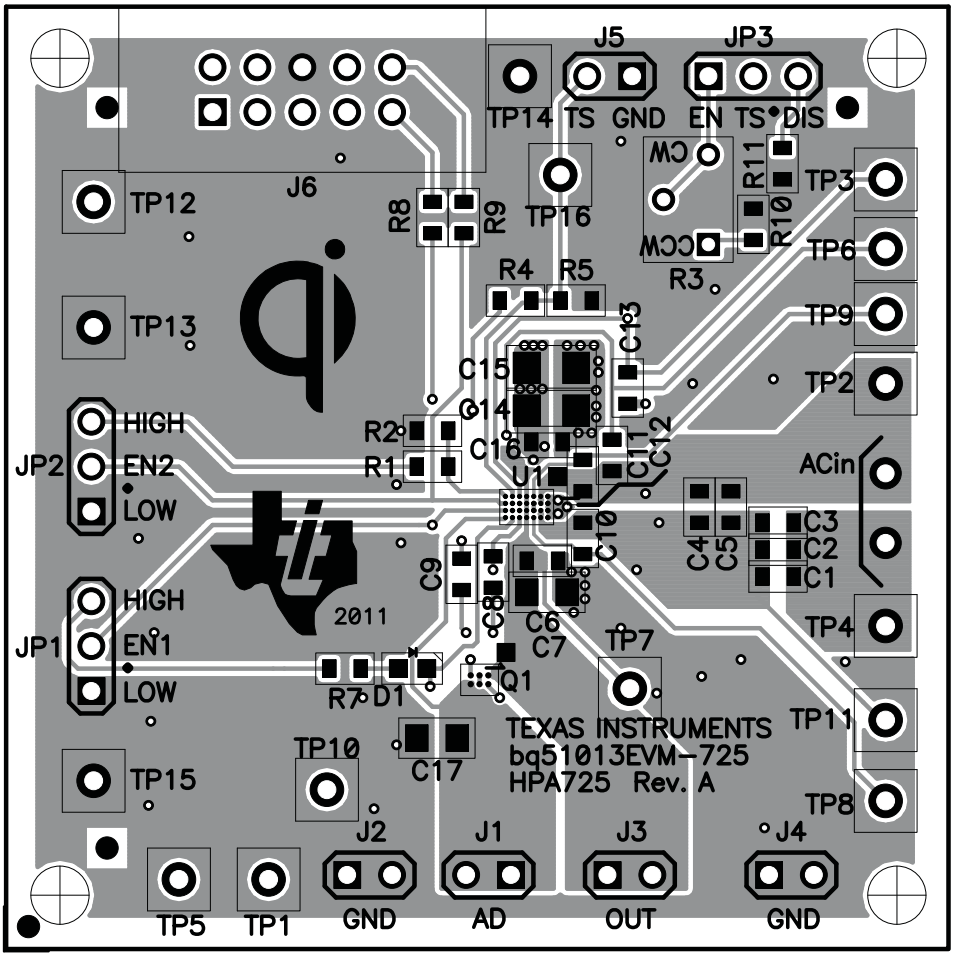



**Figure 9. Top Assembly**

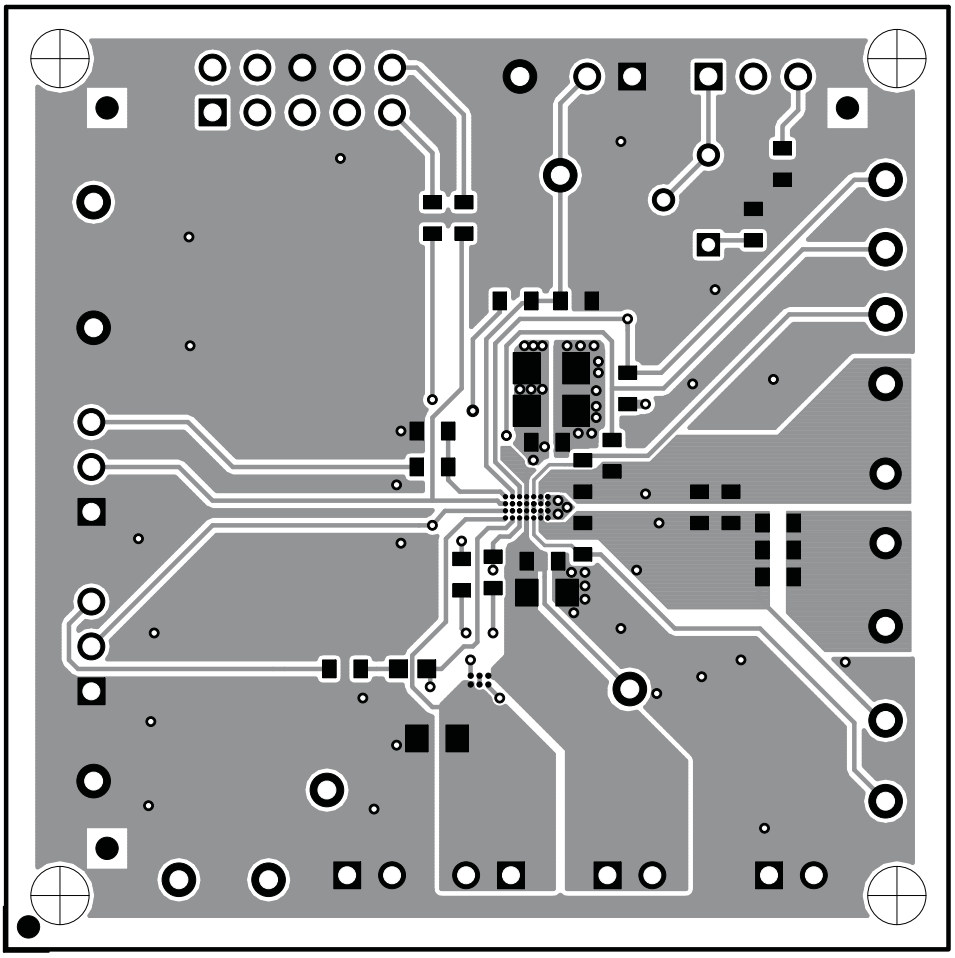


**Figure 10. Top Copper Layer**

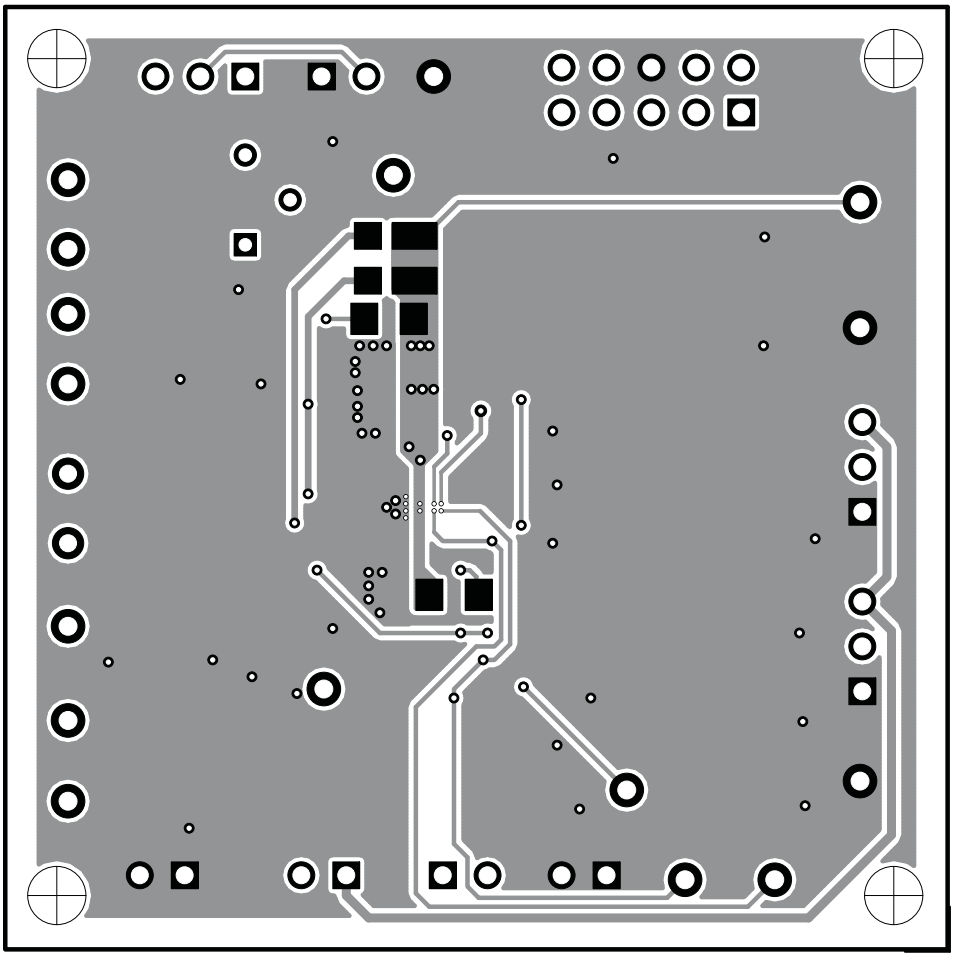


**Figure 11. Bottom Copper Layer**

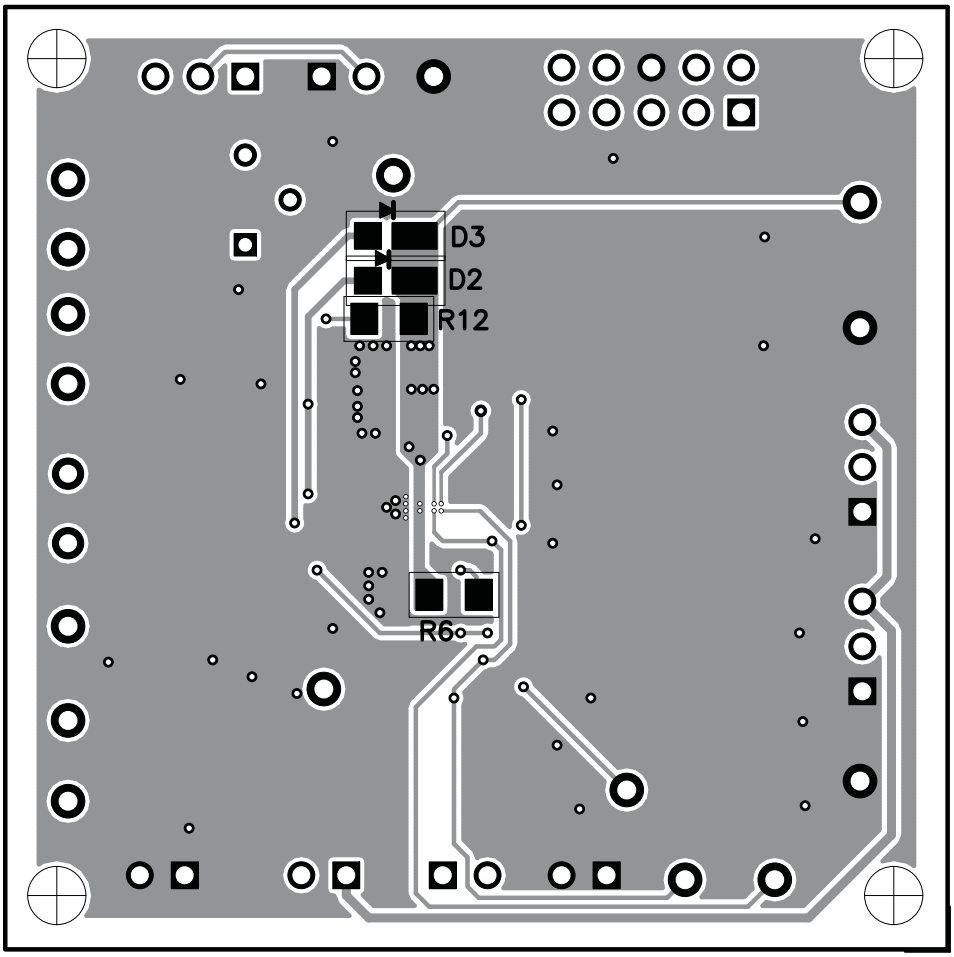



**Figure 12. Bottom Assembly**

## 8 Reference

For additional information about the bq51013EVM-725 Qi Compliant Integrated Wireless Power Receive kit from Texas Instruments, visit the product folder on the TI Web site at www.ti.com/tool/bq51013evm-725.

## EVALUATION BOARD/KIT/MODULE (EVM) ADDITIONAL TERMS

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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 are 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.

**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.

## 【Important Notice for Users of this Product in Japan】

**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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## EVALUATION BOARD/KIT/MODULE (EVM)
## WARNINGS, RESTRICTIONS AND DISCLAIMERS

**For Feasibility Evaluation Only, in Laboratory/Development Environments.** Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

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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