



**THE DATASHEET OF
TPS61161EVM-243**



TPS92411EVM-002 Offline LED Driver Evaluation Module

User's Guide



Literature Number: SLVUA08

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Switch Controlled Direct Drive Switch for Offline LED Drivers

1 Introduction

The TPS92411EVM-002 evaluation module (EVM) helps designers evaluate the operation and performance of the TPS92411P direct drive switch designed for use with a linear regulator in offline LED drive applications. The TPS92411P is designed to control the drive of high-brightness light emitting diodes (LEDs) and features a wide input voltage range (7.5 V to 100 V) and overvoltage protection.

2 Warnings and Cautions

Observe the following precautions when using the TPS92411EVM-002.

CAUTION



DO NOT STARE DIRECTLY INTO THE LED LIGHT SOURCE.

Intense light sources have a high secondary blinding effect. A temporary reduction in visual acuity and afterimages can occur, leading to irritation, annoyance, visual impairment, and even accidents – depending on the situation. Always consider the use of light filtering and darkening protective eyewear and be fully aware of surrounding laboratory type set-ups when viewing intense light sources to minimize or eliminate such risks in order to avoid accidents related to temporary blindness.

WARNING



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

3 Description

The TPS92411EVM-002 provides a high-brightness LED driver based on the TPS92411P in conjunction with a discrete linear regulator. It is designed to operate with an input voltage in the range of 190 VAC to 260 VAC with a 230-VAC nominal input voltage. This input voltage range is typical for offline applications. The EVM is set up for a default input current of 70 mA for 16 W total power and 3 LED voltage stacks of 40 V, 80 V, and 160 V. The TPS92411 helps provide high LED utilization, good power factor, low THD, and flicker free dimming.

3.1 Typical Applications

This converter design describes an application of the TPS92411P as an LED driver controller with the specifications listed below. For applications with a different input voltage range or different output voltage range refer to the TPS92411 datasheet.

3.2 Connector Descriptions

This section describes the connectors and test points on the EVM and how to properly connect, setup, and use the TPS92411EVM-002.

3.2.1 J1

The screw down connector J1 is for the input voltage supply to the LED driver. The leads to the input supply should be twisted and kept as short as possible to minimize voltage drop, inductance, and EMI transmission. The input is not polarized. Line and neutral may be connected to either terminal.

3.2.2 VPx, VSx, ISx

The test points VP1, VS1, IS1, VP2, VS2, IS2, VP3, VS3, and IS3 are for testing the different LED stack voltages and currents. For example, connect a voltmeter from VP1 to IS1 across the 1- Ω resistor R24 to measure the current in the top (160 V) LED string (1 mV = 1 mA). Connect a voltmeter from VP1 to VS1 to measure the top stack voltage. The middle and lower stack currents and voltages can be measured in the same way using the test points labeled with 2 and 3, respectively.

4 Electrical Performance Specifications

Table 1 contains the electrical performance specifications for the EVM.

Table 1. TPS92411EVM-002 Electrical Performance Specifications

| Parameter | Test Conditions | MIN | TYP | MAX | Units |
|--------------------------------|--|-----|-------|-----|-------|
| Input Characteristics | | | | | |
| Voltage range | | 190 | 230 | 260 | VAC |
| Maximum input current | | 64 | 72 | 80 | mA |
| Output Characteristics | | | | | |
| Output voltage, VOUT | Upper LED stack | | 160 | | V |
| | Middle LED stack | | 80 | | |
| | Lower LED stack | | 40 | | |
| Flicker Index | | | 0.06 | | |
| Output current ripple percent | | | 23 | | % |
| Output current ripple | Each stack | | 30 | | mApp |
| Overvoltage protection level | Each individual TPS92411P | | 100 | | V |
| Systems Characteristics | | | | | |
| Efficiency | Input voltage = 230 VAC, No triac dimmer | | 77 | | % |
| Power Factor | Input voltage = 230 VAC, No triac dimmer | | 0.966 | | |
| THD | Input voltage = 230 VAC, No triac dimmer | | 16.6 | | % |

5 TPS92411EVM-002 Schematic

Figure 1 illustrates the TPS92411EVM-002 schematic.

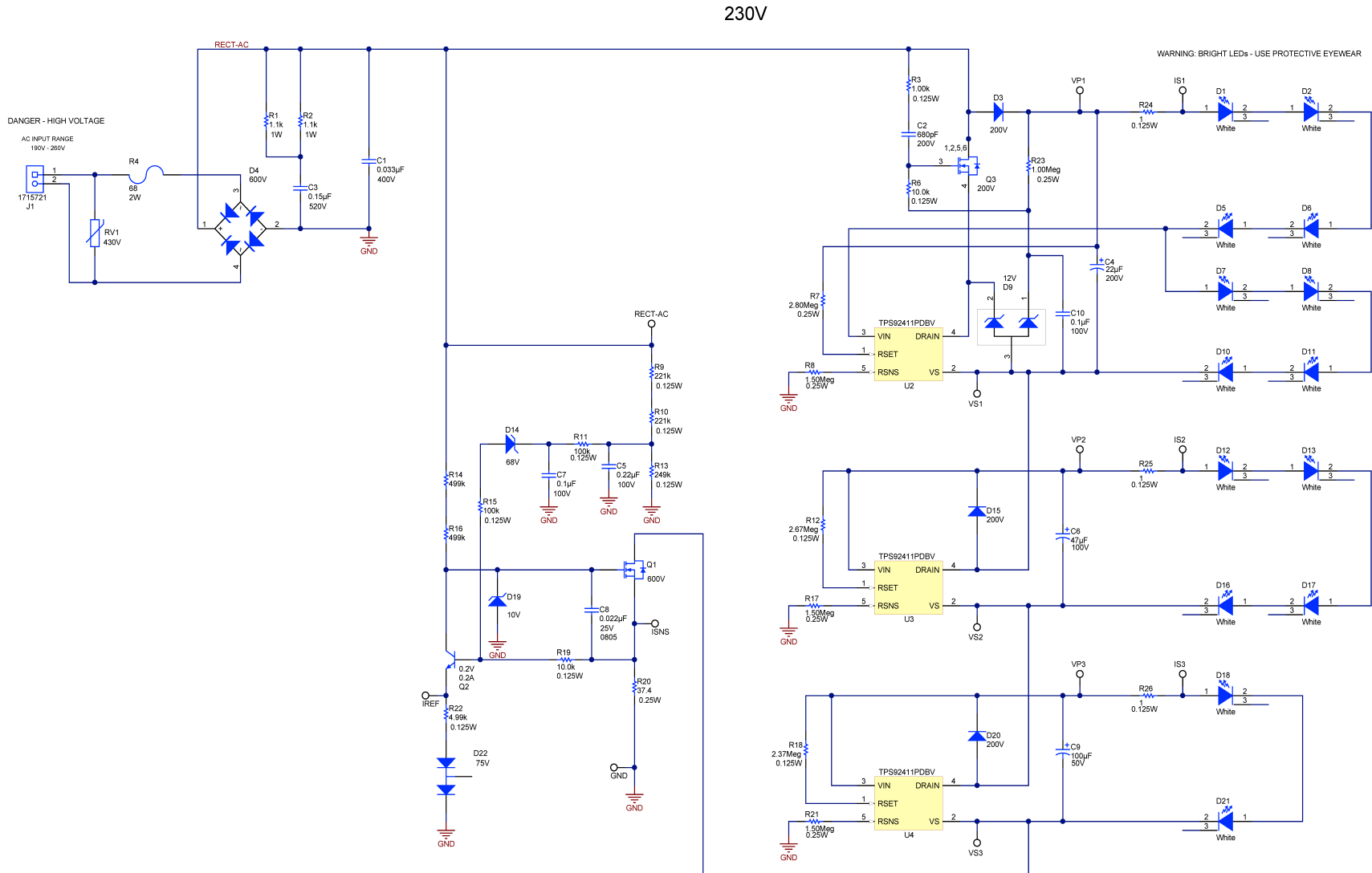


Figure 1. TPS92411EVM-002 Schematic

6 Performance Data and Typical Characteristic Curves

Figure 2 through Figure 11 present typical performance curves for TPS92411EVM-002.

6.1 Power Factor

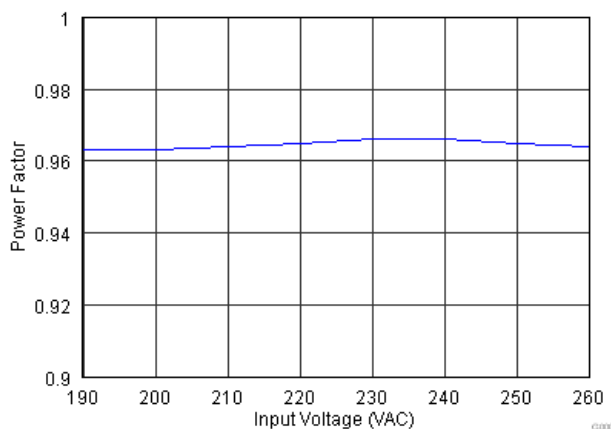


Figure 2. Power Factor Versus Input Voltage

6.2 Line Regulation

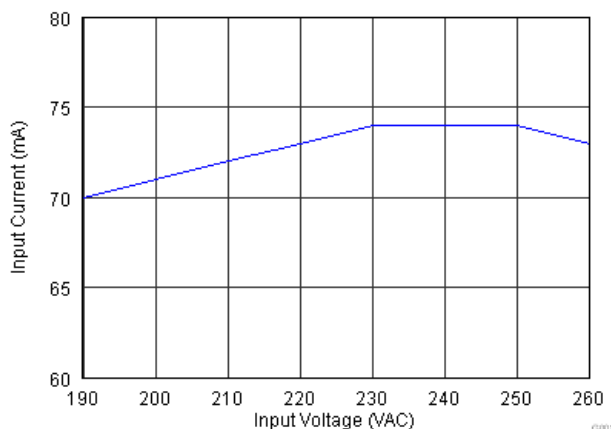


Figure 3. Input (Linear Regulator) Current Versus Input Voltage

6.3 Input Voltage and Input Current

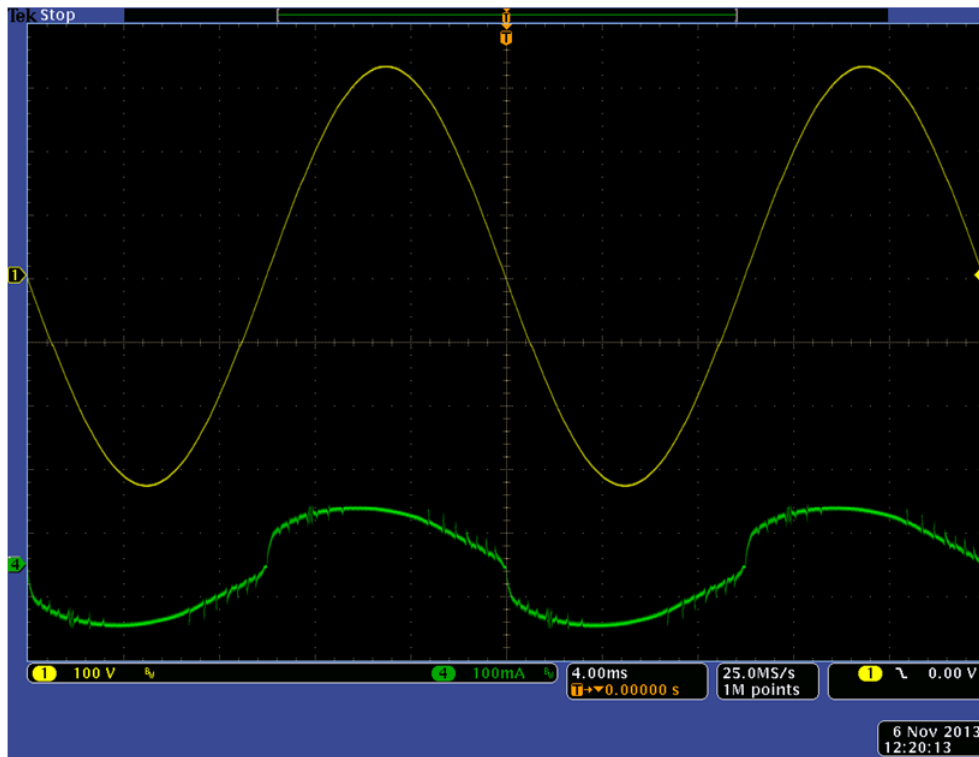


Figure 4. Input Voltage (Top) and Input Current (Bottom)

6.4 Linear Regulator Drain Voltage and Input Current

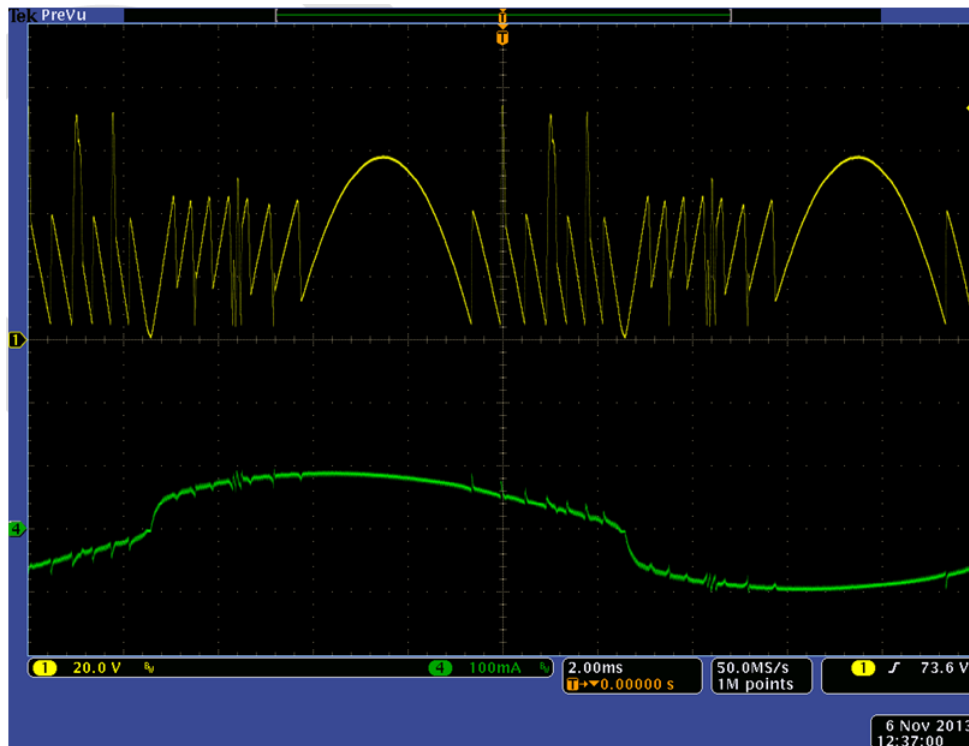


Figure 5. Drain Voltage (Top) and Input Current (Bottom)

6.5 Triac Dimming Waveforms

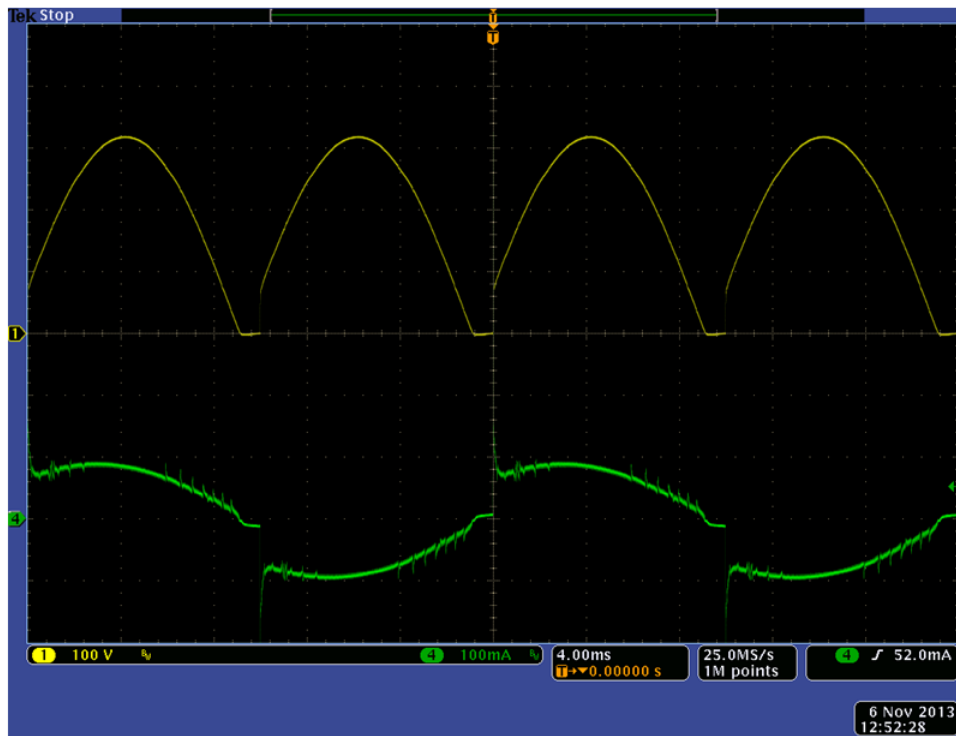


Figure 6. Forward Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom)

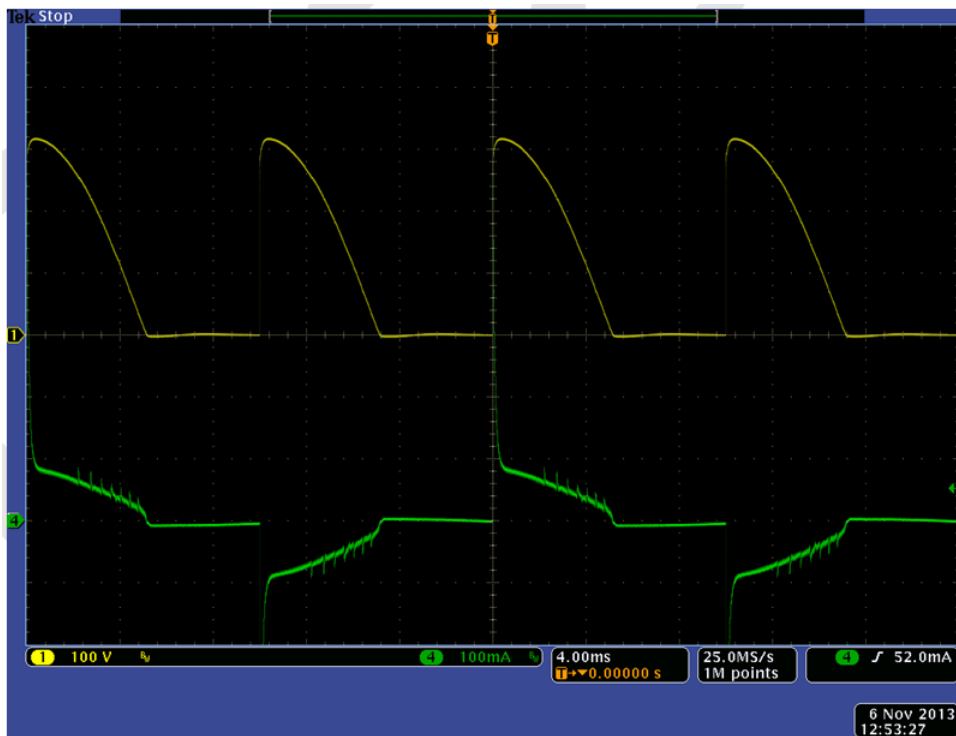


Figure 7. Forward Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom)

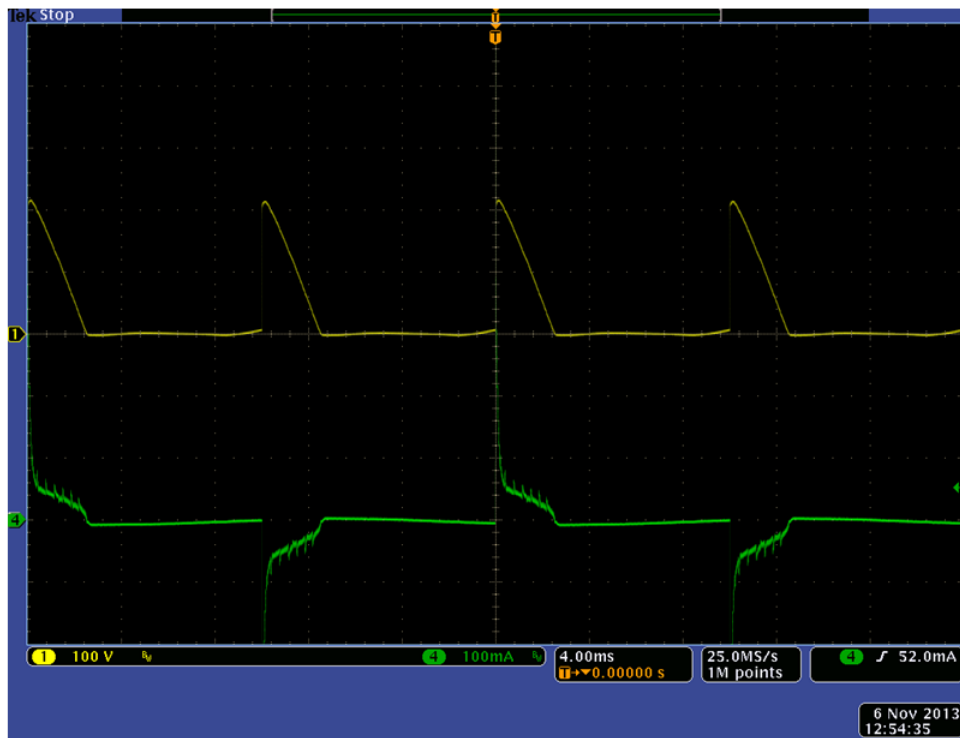


Figure 8. Forward Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom)

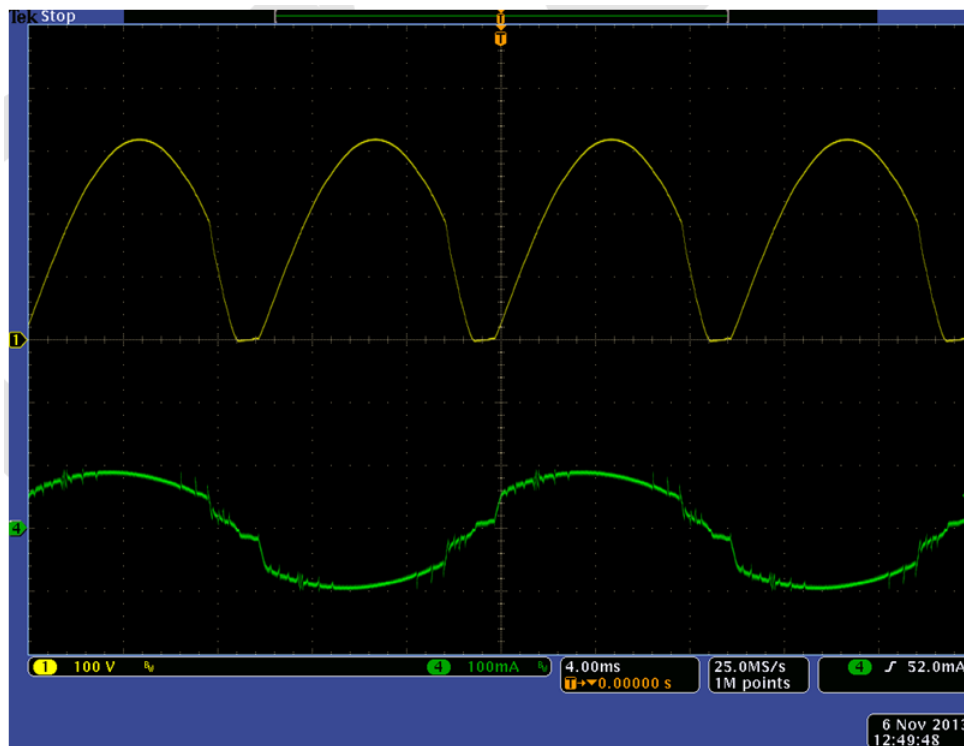


Figure 9. Reverse Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom)

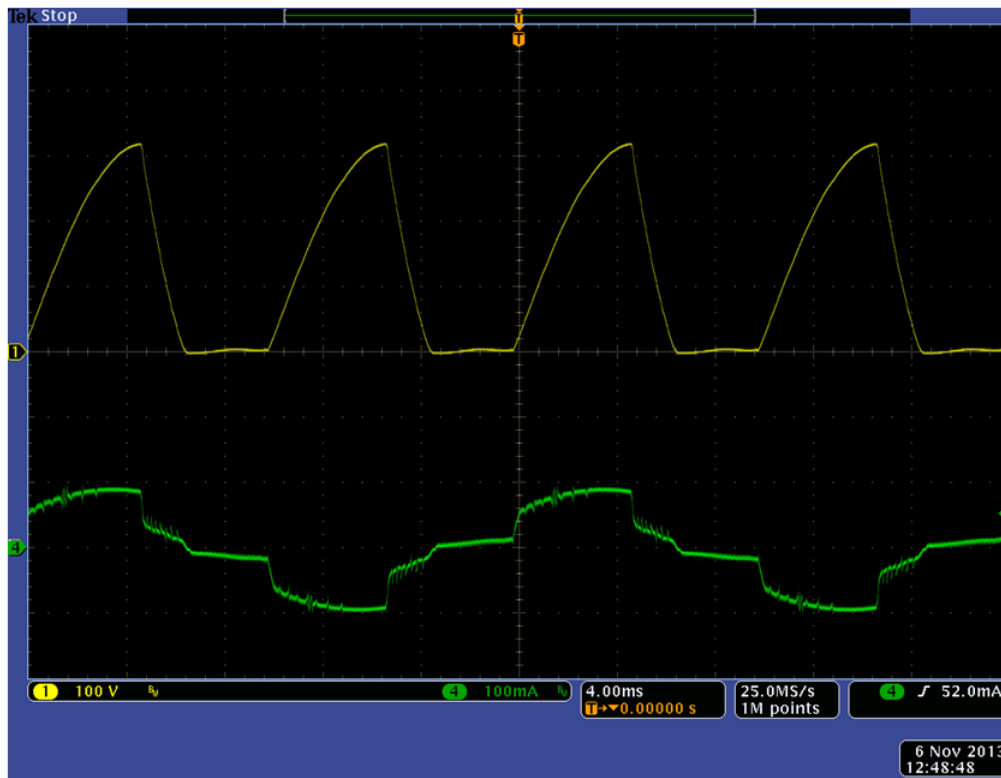


Figure 10. Reverse Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom)

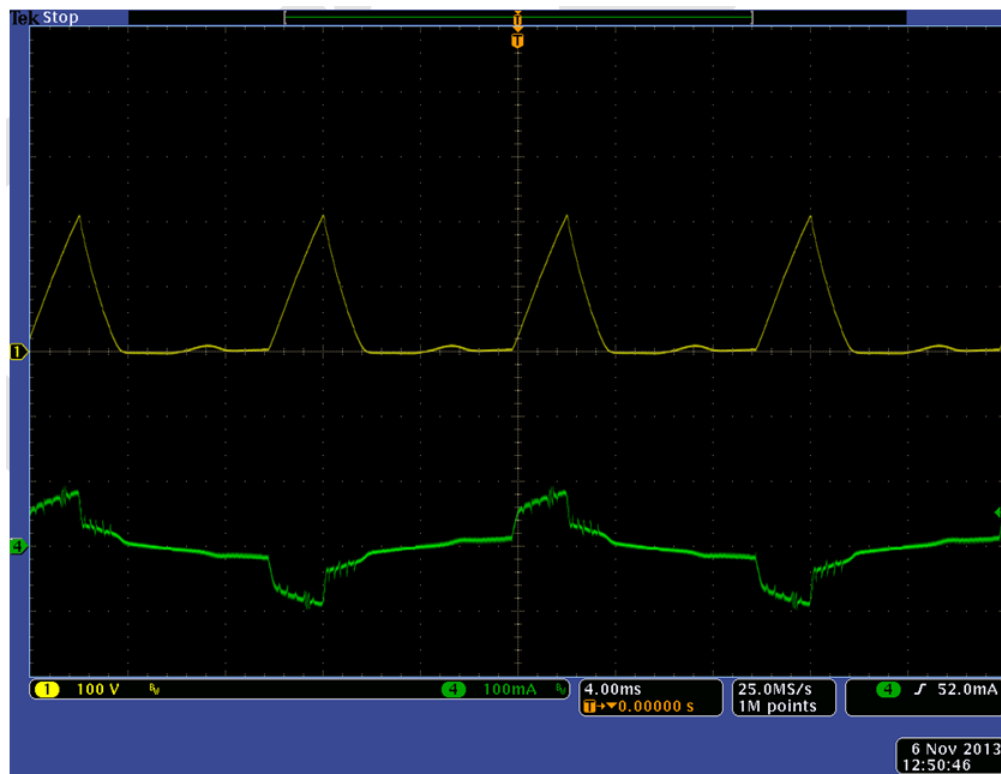
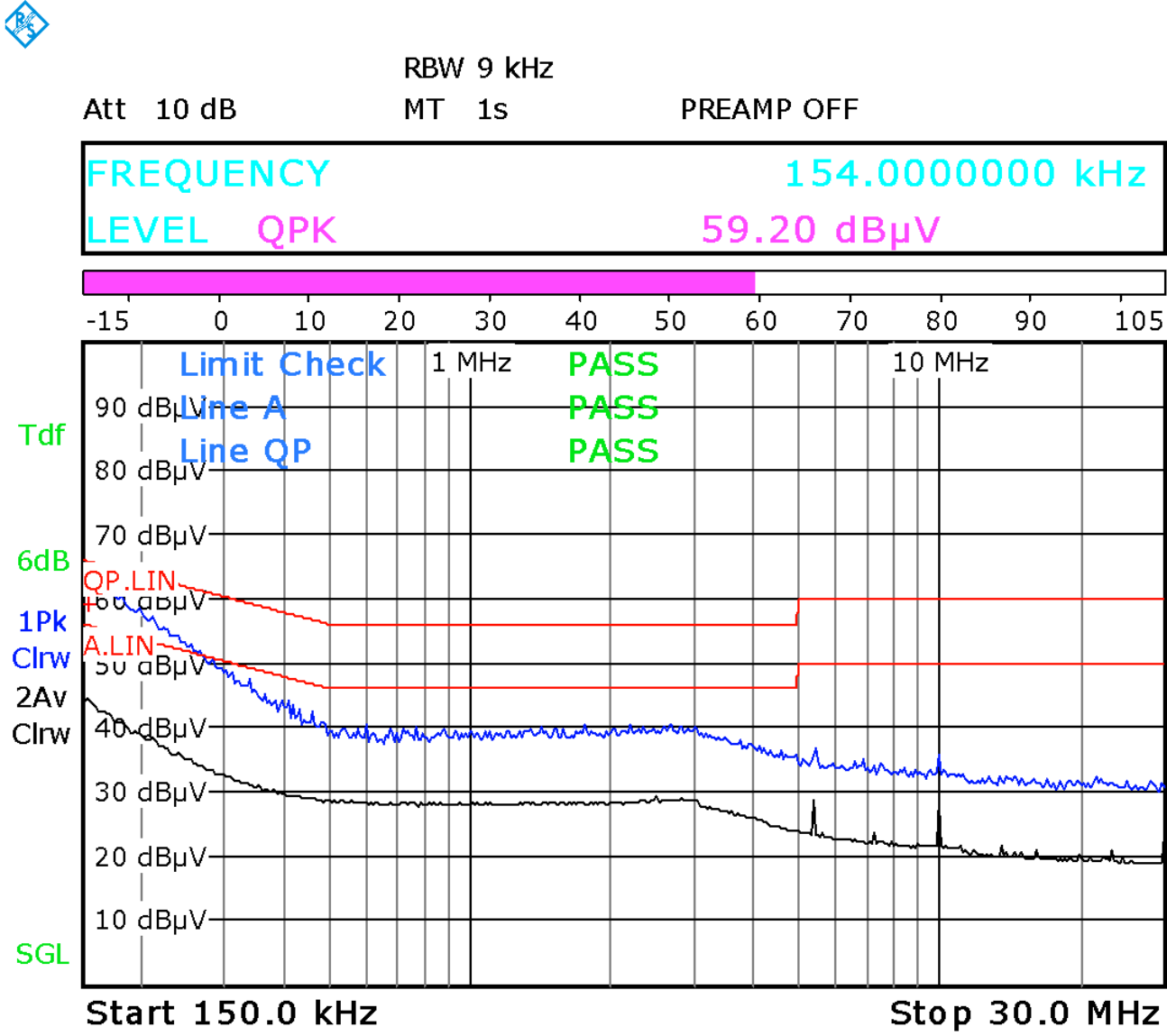


Figure 11. Reverse Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom)

6.6 EMI Performance

Figure 12 shows the conducted EMI performance of the EVM under the following conditions:

- $P_{IN} = 16\text{ W}$
- $V_{IN} = 230\text{ VAC}$
- QP = quasi-peak limit line
- A = average limit line
- Blue trace = peak scan
- Black trace = average scan



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Figure 12. Conducted EMI Performance

7 TPS92411EVM-002 PCB Layout

Figure 13 and Figure 14 show the design of the TPS92411EVM-002 printed circuit board.

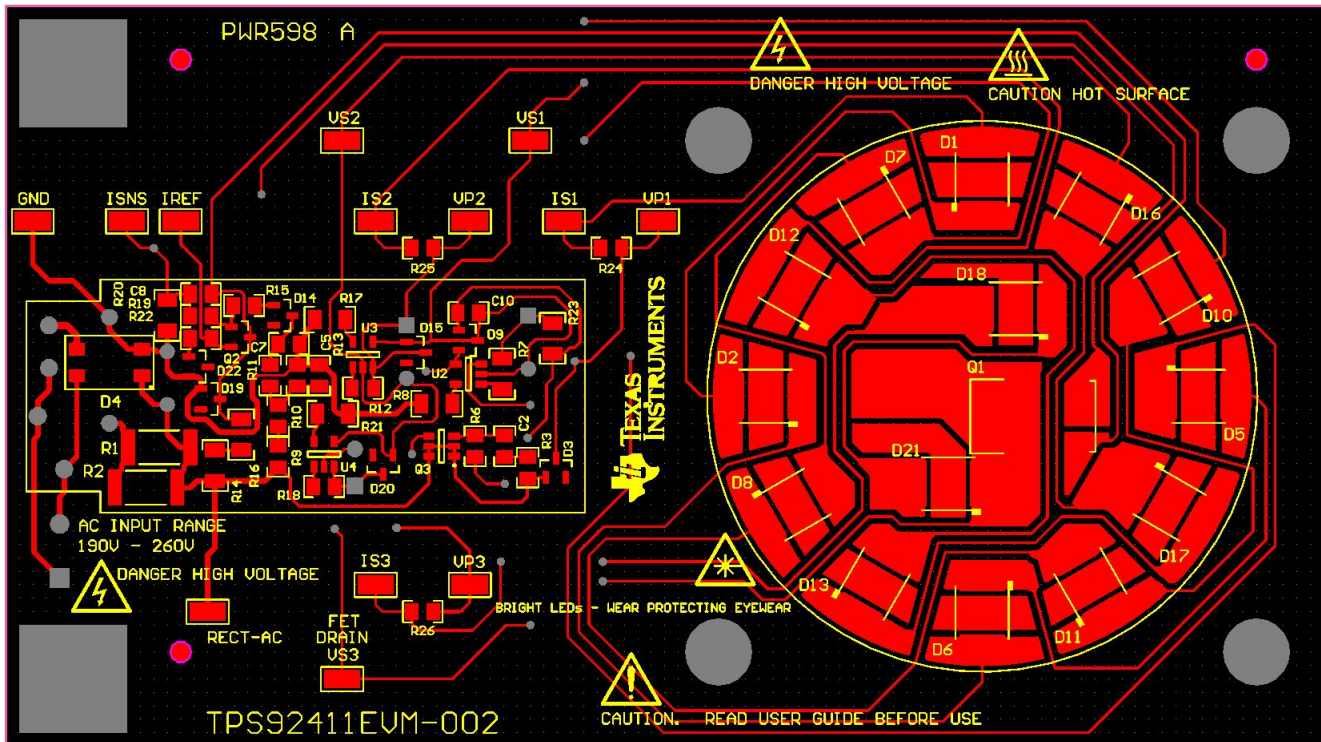


Figure 13. Top Layer and Top Overlay (Top View)

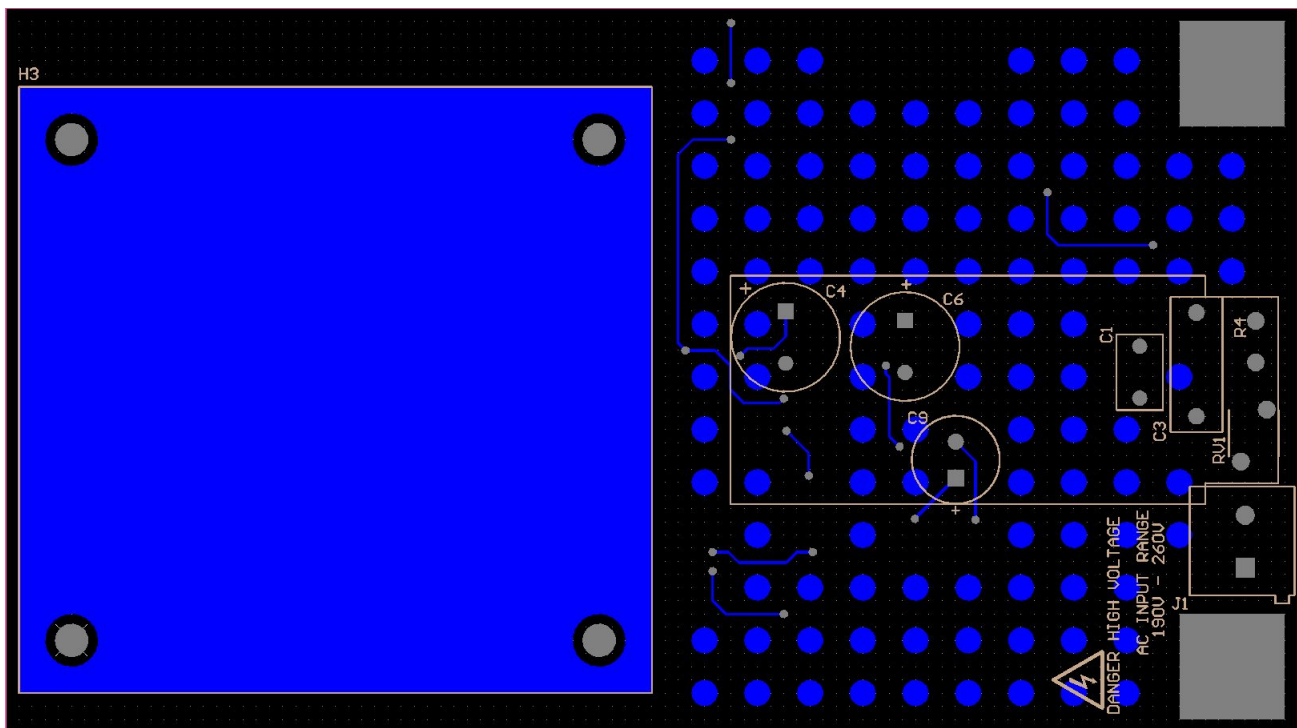


Figure 14. Bottom Layer and Bottom Overlay (Bottom View)

8 Bill of Materials

Table 2 contains the TPS92411EVM-002 components list according to the schematic shown in Figure 1.

Table 2. TPS92411EVM-002 Bill of Materials

| Reference Designator | QTY | Value | Description | Size | Part Number | MFR |
|--|-----|---------------|--|-----------------------|-----------------------|---------------------------------|
| C1 | 1 | 0.033µF | CAP, Film, 0.033µF, 400V, Radial | Radial | B32529C6333J289 | EPCOS Inc. |
| C2 | 1 | 680pF | CAP, CERM, 680pF, 200V, X7R, 10% | 0805 | CC0805KRX7RABB681 | Yageo |
| C3 | 1 | 0.15µF | CAP, Film, 0.15µF, 520V, Radial | Radial | B32671P5154K | EPCOS Inc. |
| C4 | 1 | 22µF | CAP, Alum, 22µF, 200V, +/-20%, Radial | Radial, Can | UPW2D220MPD | Nichicon |
| C5 | 1 | 0.22µF | CAP, CERM, 0.22µF, 100V, X7R, 10% | 0805 | CL21B224KCFSNWE | Samsung Electro-Mechanics |
| C6 | 1 | 47µF | CAP, Alum, 47µF, 100V, +/-20%, Radial | Radial, Can | UHE2A470MPD | Nichicon |
| C7, C10 | 2 | 0.1µF | CAP, CERM, 0.1µF, 250V, X7R, 10% | 0805 | CL21B104KCFSFNE | Samsung Electro-Mechanics |
| C8 | 1 | 0.022µF | CAP, CERM, 0.022µF, 25V, +/-5%, C0G/NP0 | 0805 | C2012C0G1E223J | TDK |
| C9 | 1 | 100µF | CAP, Alum, 100µF, 50V, +/-20%, Radial | Radial, Can | UHE1H101MPD | Nichicon |
| D1, D2, D5, D6, D7, D8, D10, D11, D12, D13, D16, D17, D18, D21 | 14 | XLamp MX-6S | LED, SMT, Warm White, XLamp MX-6S | 2-SMD, Gull Wing Tabs | MX6SWT-A1-0000-000AE8 | Cree Inc |
| D3, D15, D20 | 3 | 200V | Diode, Switching, 200V, 0.2A | SOT-23 | BAS21-7-F | Diodes Inc. |
| D4 | 1 | | Diode, Switching-Bridge, 600V, 0.8A, MiniDIP | MiniDIP | HD06-T | Diodes Inc. |
| D9 | 1 | | Diode, Zener, Dual, 12V | SOT-23 | | |
| D14 | 1 | 900mV @ 10mA | Diode, Zener, 68V, 225mW | SOT-23 | BZX84C68LT1G | ON Semiconductor |
| D19 | 1 | 900mV @ 10mA | Diode, Zener, 10V, 225mW | SOT-23 | BZX84C10LT1G | ON Semiconductor |
| D22 | 1 | 1.25V @ 150mA | Diode, 75V, 0.3A | SOT-23 | BAV99-7-F | Diodes Inc. |
| H3 | 1 | | HEATSINK DC/DC HALF BRICK VERT | | 518-95AB | Wakefield Thermal Solutions |
| J1 | 1 | | Header, Term Blk, 2Pos, 5.08mm, TH | 2POS Terminal Block | 1715721 | Phoenix Contact |
| Q1 | 1 | 600V | MOSFET, N-CH, 600V, 2 | TO-252-3, DPak | AOD2N60 | Alpha & Omega Semiconductor Inc |
| Q2 | 1 | 0.2V | Transistor, NPN, 40V, 0.2A | SOT-23 | MMBT3904-7-F | Diodes Inc |
| Q3 | 1 | | MOSFET, N-CH, 200V, 600mA | 6-TSOP | IRF5801TRPBF | International Rectifier |
| R1, R2 | 2 | 1.1k | RES, 1.1k ohm, 5%, 1W | 2512 (6432 Metric) | CRCW25121K10JNEG | Vishay-Dale |
| R3 | 1 | 1.00k | RES, 1.00k ohm, 1%, 0.125W | 0805 | CRCW08052M67FKEA | Vishay-Dale |
| R4 | 1 | 68 | RES, 68 ohm, 10%, 2W, Fusible, Axial | Axial | EMC2-68RKI | TT Electronics/Welwyn |
| R6, R19 | 2 | 10.0k | RES, 10.0k ohm, 1%, 0.125W | 0805 | CRCW080510K0FKEA | Vishay-Dale |
| R7 | 1 | 2.80Meg | RES, 2.80Meg ohm, 1%, 0.25W | 1206 | CRCW12062M80FKEA | Vishay-Dale |
| R8, R17, R21 | 3 | 1.5Meg | RES, 1.5Meg ohm, 1%, 0.25W | 1206 | RC1206FR-071M5L | Yageo America |
| R9, R10 | 2 | 221k | RES, 221k ohm, 1%, 0.125W | 0805 | CRCW0805221KFKEA | Vishay-Dale |
| R11, R15 | 2 | 100k | RES, 100k ohm, 1%, 0.125W | 0805 | CRCW0805100KFKEA | Vishay-Dale |
| R12 | 1 | 2.67Meg | RES, 2.67Meg ohm, 1%, 0.125W | 0805 | CRCW08052M67FKEA | Vishay-Dale |
| R13 | 1 | 249k | RES, 249k ohm, 1%, 0.125W | 0805 | CRCW0805249KFKEA | Vishay-Dale |
| R14, R16 | 2 | 499k | RES, 499k ohm, 1%, 0.25W | 1206 | CRCW1206499KFKEA | Vishay-Dale |
| R18 | 1 | 2.37Meg | RES, 2.37Meg ohm, 1%, 0.125W | 0805 | CRCW08052N37FKEA | Vishay-Dale |
| R20 | 1 | 37.4 | RES, 37.4 ohm, 1%, 0.25W | 1206 | CRCW120637R4FKEA | Vishay-Dale |
| R22 | 1 | 4.99k | RES, 4.99k ohm, 1%, 0.125W | 0805 | CRCW08054K99FKEA | Vishay-Dale |
| R23 | 1 | 1.00Meg | RES, 1.00Meg ohm, 1%, 0.25W | 1206 | CRCW12061M00FKEA | Vishay-Dale |

Table 2. TPS92411EVM-002 Bill of Materials (continued)

| Reference Designator | QTY | Value | Description | Size | Part Number | MFR |
|----------------------|-----|-------|---|----------|----------------|----------------------------|
| R24, R25, R26 | 3 | 1 | RES, 1 ohm, 1%, 0.125W | 0805 | RMCF0805FT1R00 | Stackpole Electronics Inc. |
| RV1 | 1 | | Varistor, 430V, 28J, 7MM, Radial | Disc 7mm | MOV-07D431K | Bourns Inc. |
| U2, U3, U4 | 4 | | Switch Controlled Direct Drive Switch for Offline LED Drivers, DBV0005A | SOT23-5 | TPS92411PDBV | Texas Instruments |

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Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING LIMITED WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

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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 EVMs for RF Products 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. Since the EVM is not a completed product, it may not meet all applicable regulatory and safety compliance standards (such as UL, CSA, VDE, CE, RoHS and WEEE) which may normally be associated with similar items. You assume full responsibility to determine and/or assure compliance with any such standards and related certifications as may be applicable. 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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