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.

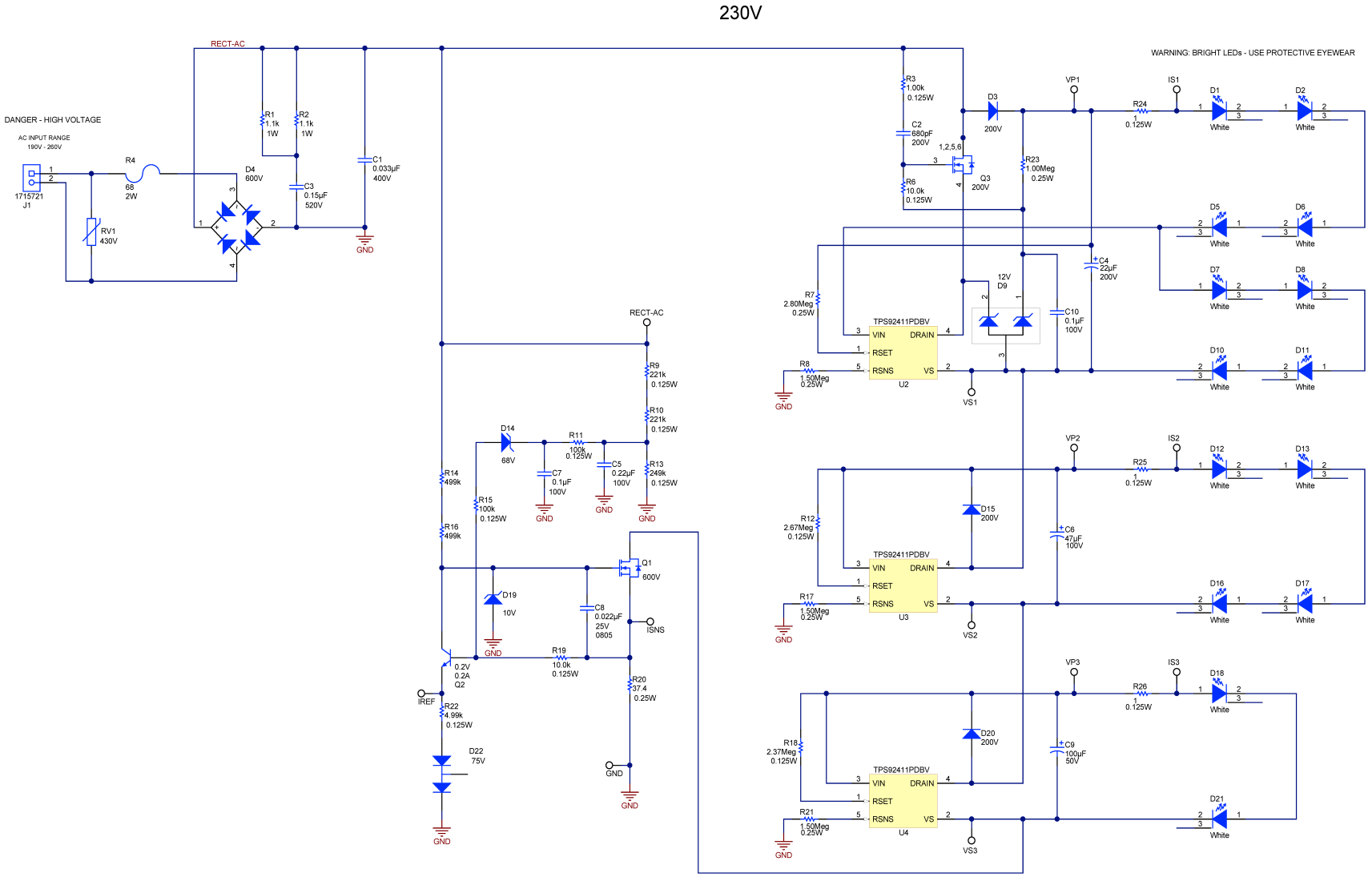

Figure 1. TPS92411EVM-002 Schematic

6 Performance Data and Typical Characteristic Curves

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

6.1 Power Factor

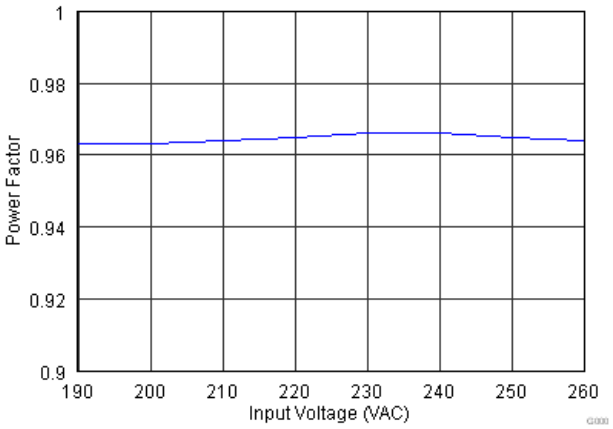

Figure 2. Power Factor Versus Input Voltage

6.2 Line Regulation

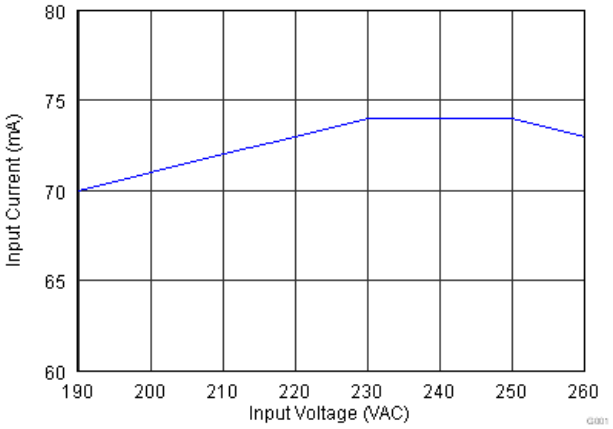

Figure 3. Input (Linear Regulator) Current Versus Input Voltage

6.3 Input Voltage and Input Current

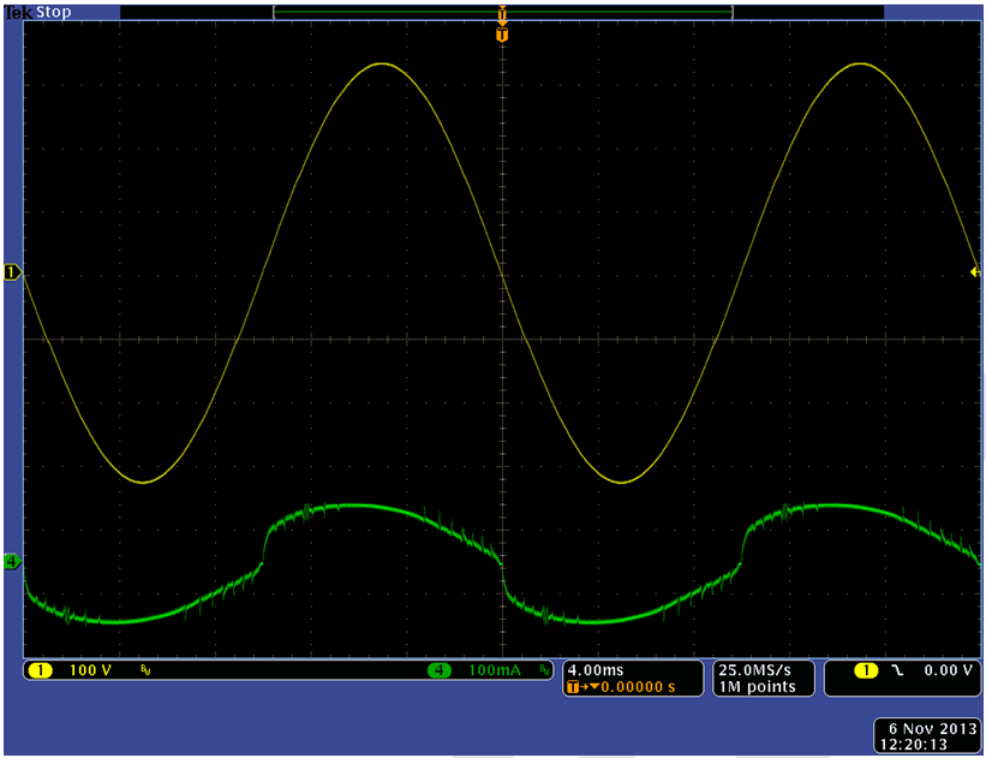

Figure 4. Input Voltage (Top) and Input Current (Bottom)

6.4 Linear Regulator Drain Voltage and Input Current

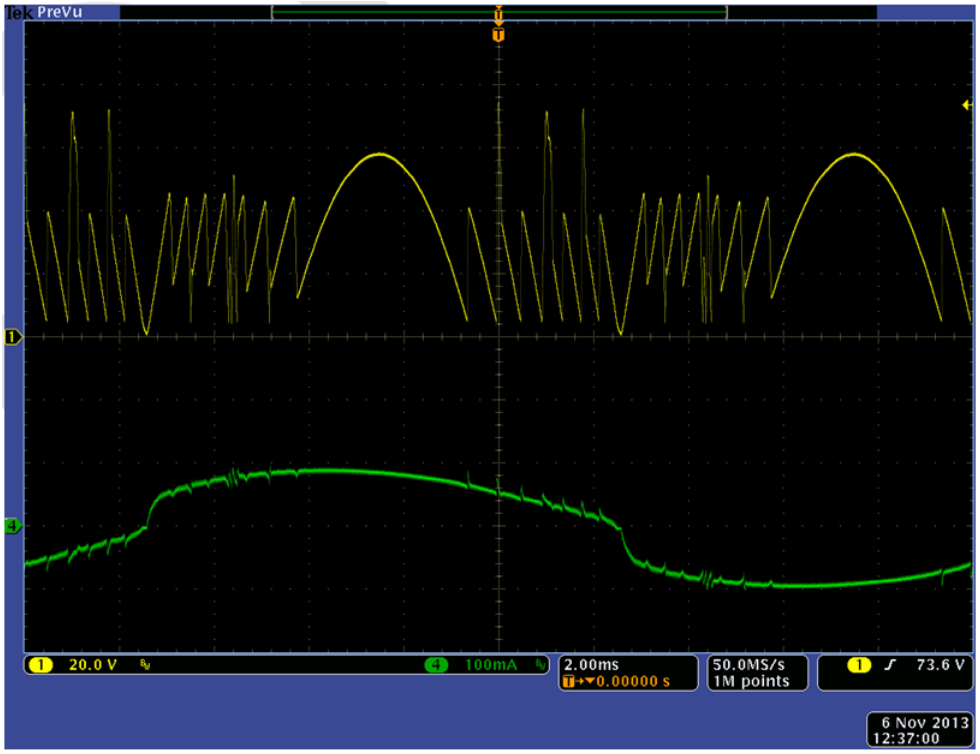

Figure 5. Drain Voltage (Top) and Input Current (Bottom)

6.5 Triac Dimming Waveforms

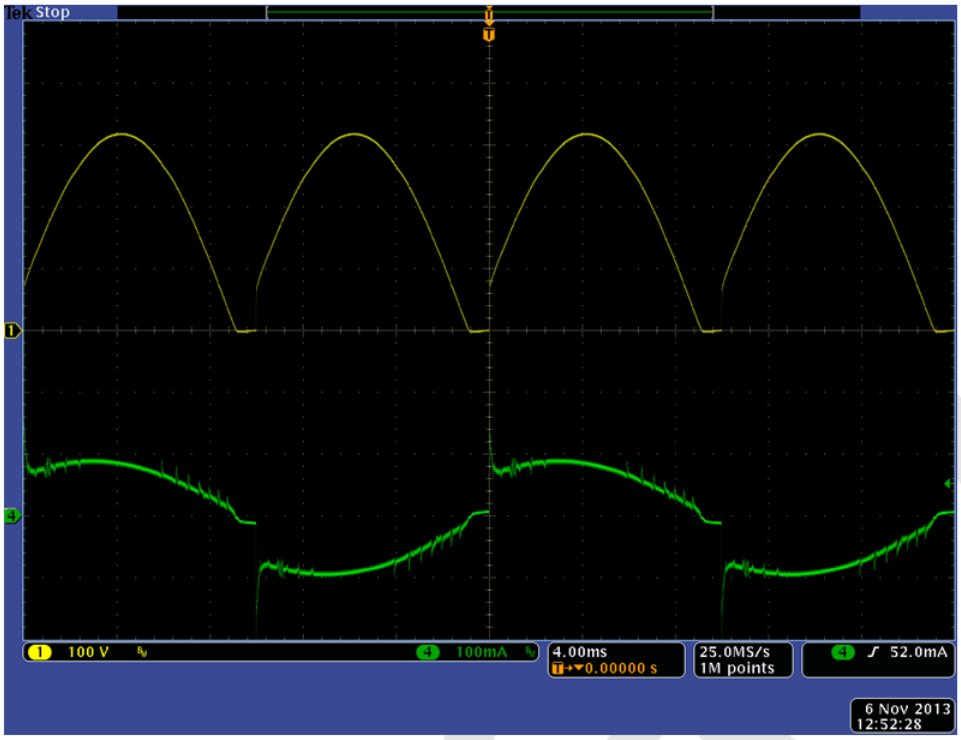

Figure 6. Forward Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom)

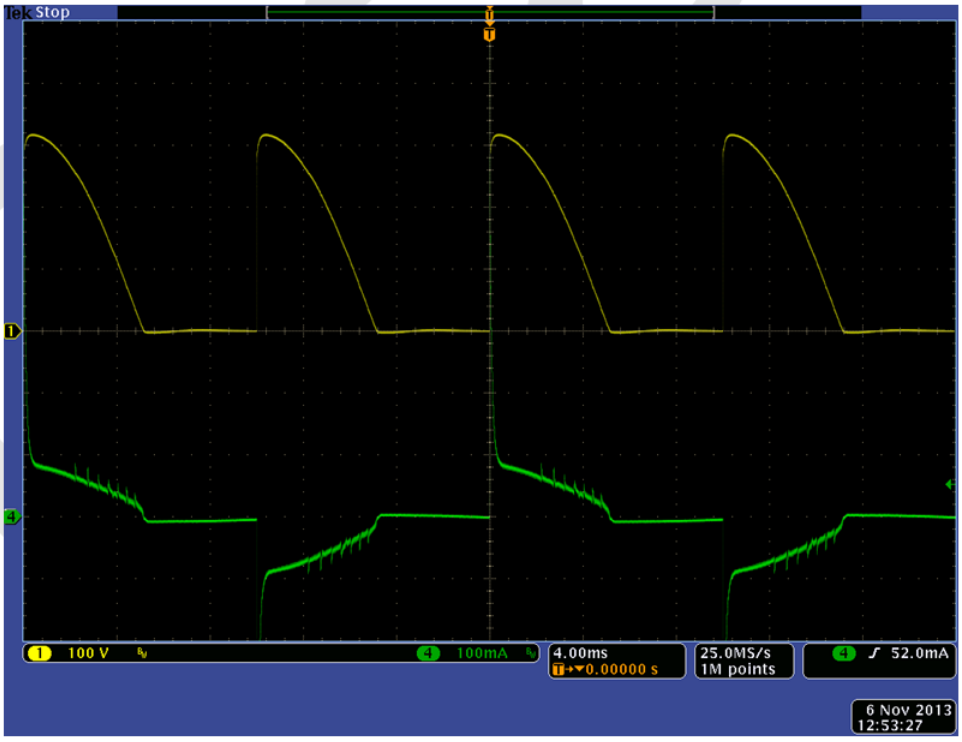

Figure 7. Forward Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom)

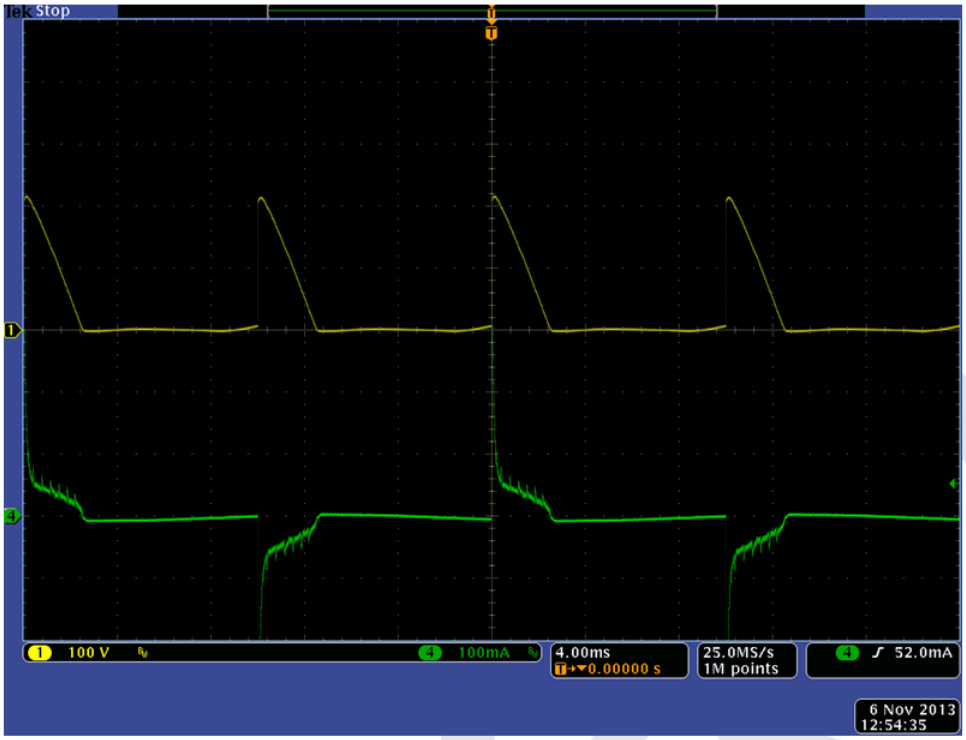

Figure 8. Forward Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom)

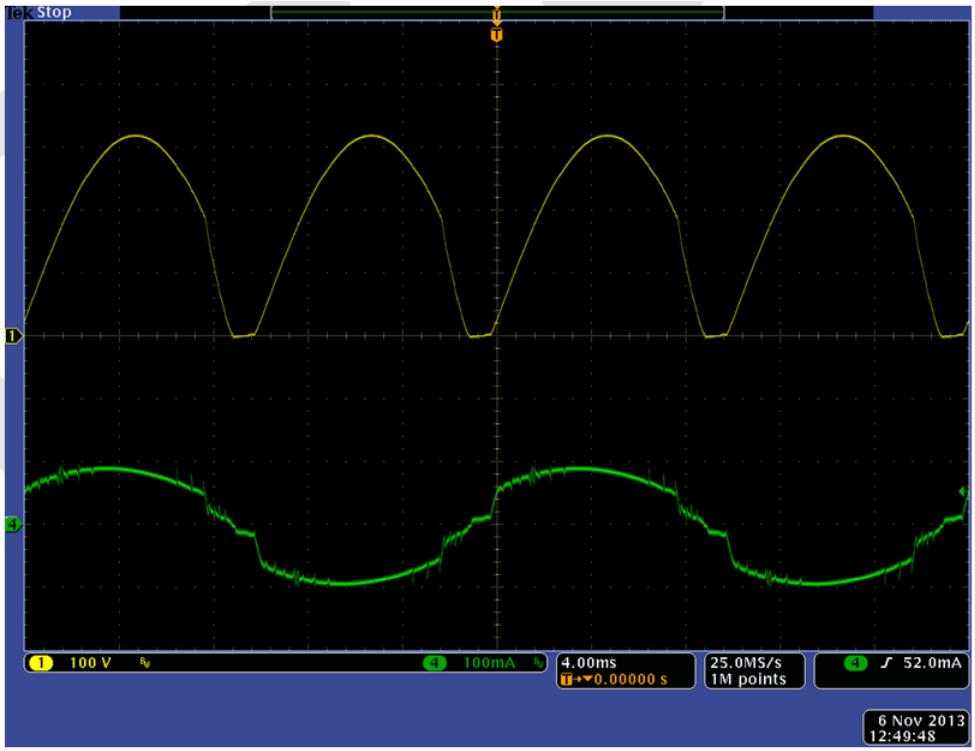

Figure 9. Reverse Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom)

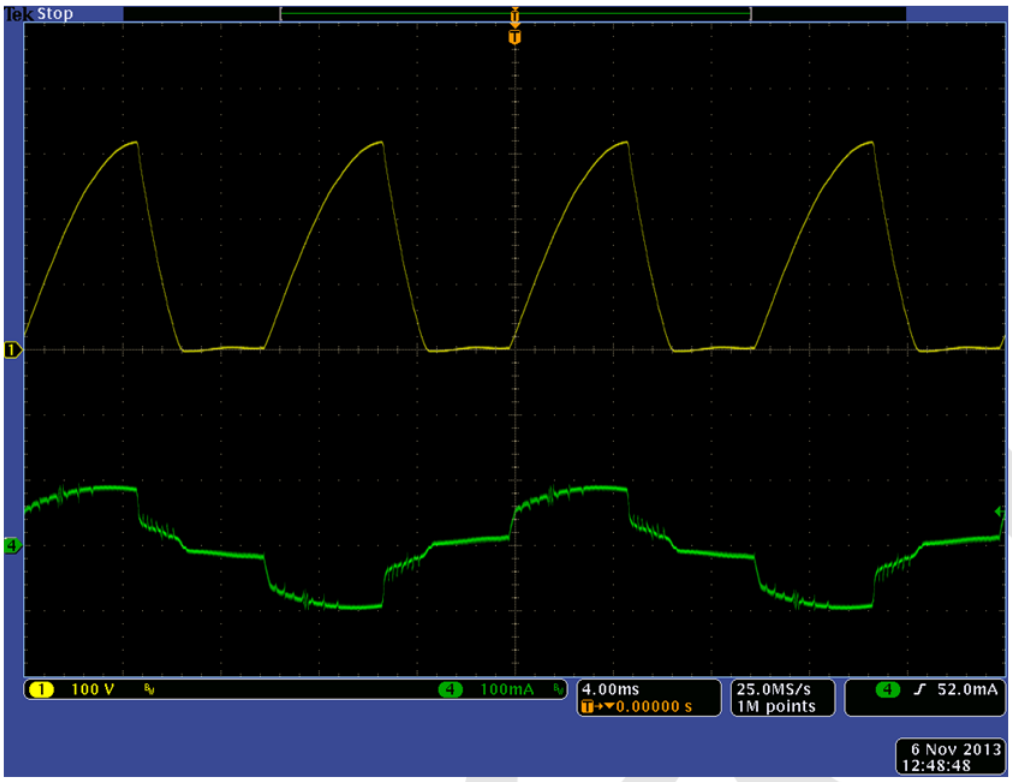

Figure 10. Reverse Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom)

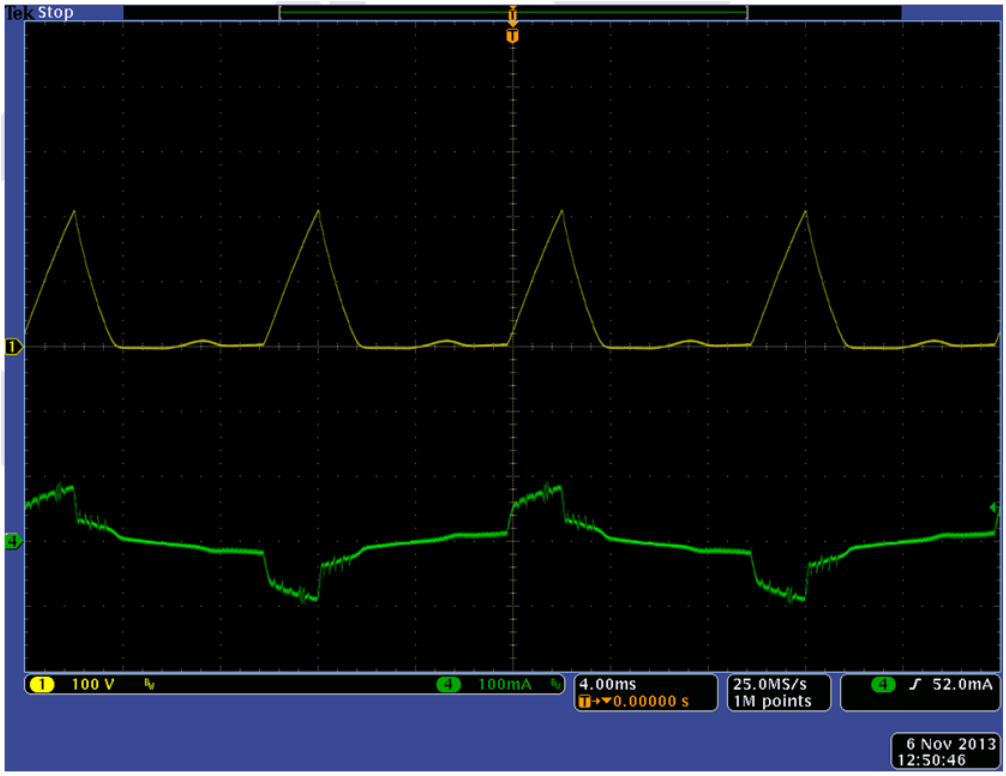

Figure 11. Reverse Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom)

6.6 EMI Performance

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

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

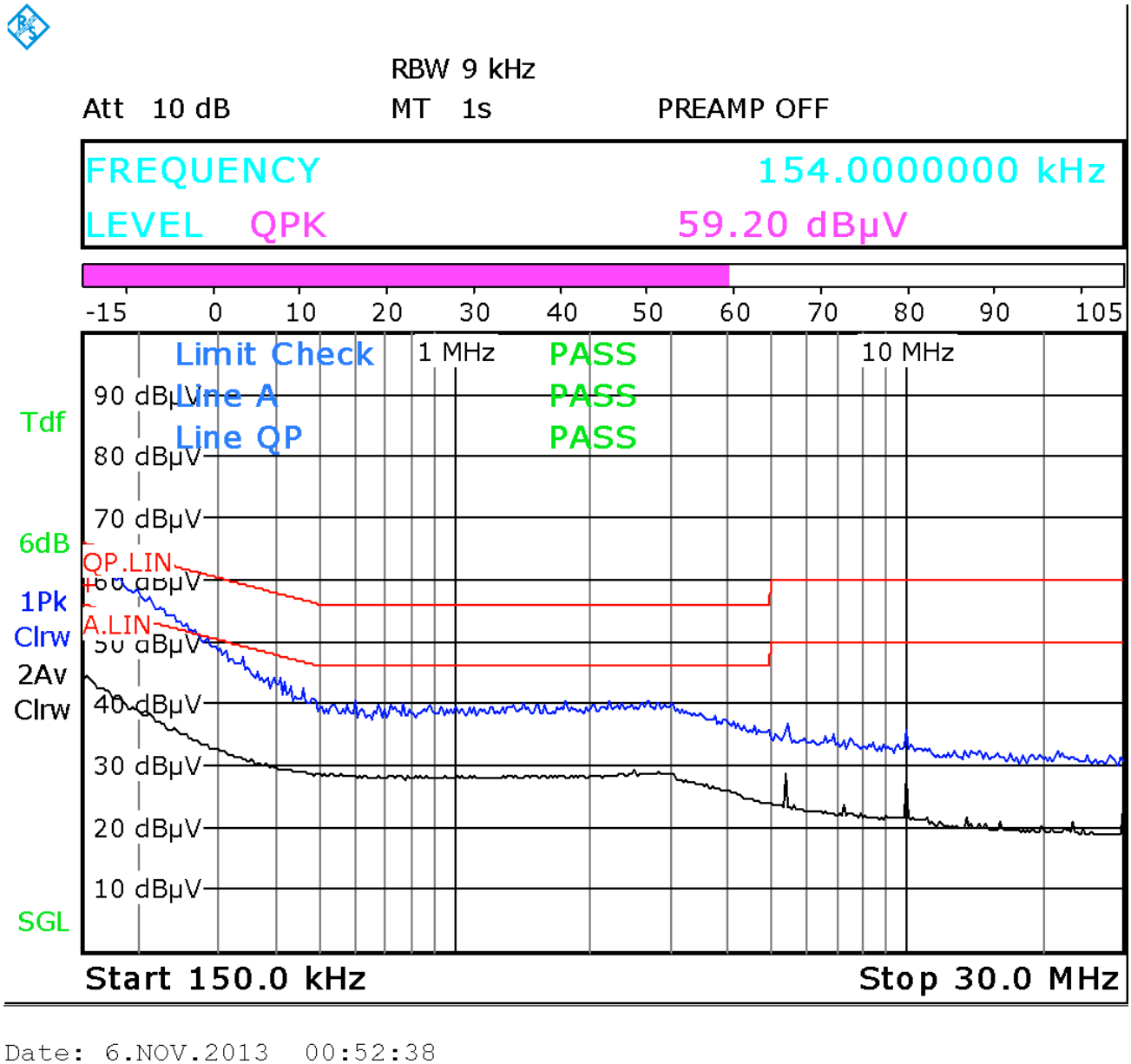

Figure 12. Conducted EMI Performance

7 TPS92411EVM-002 PCB Layout

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

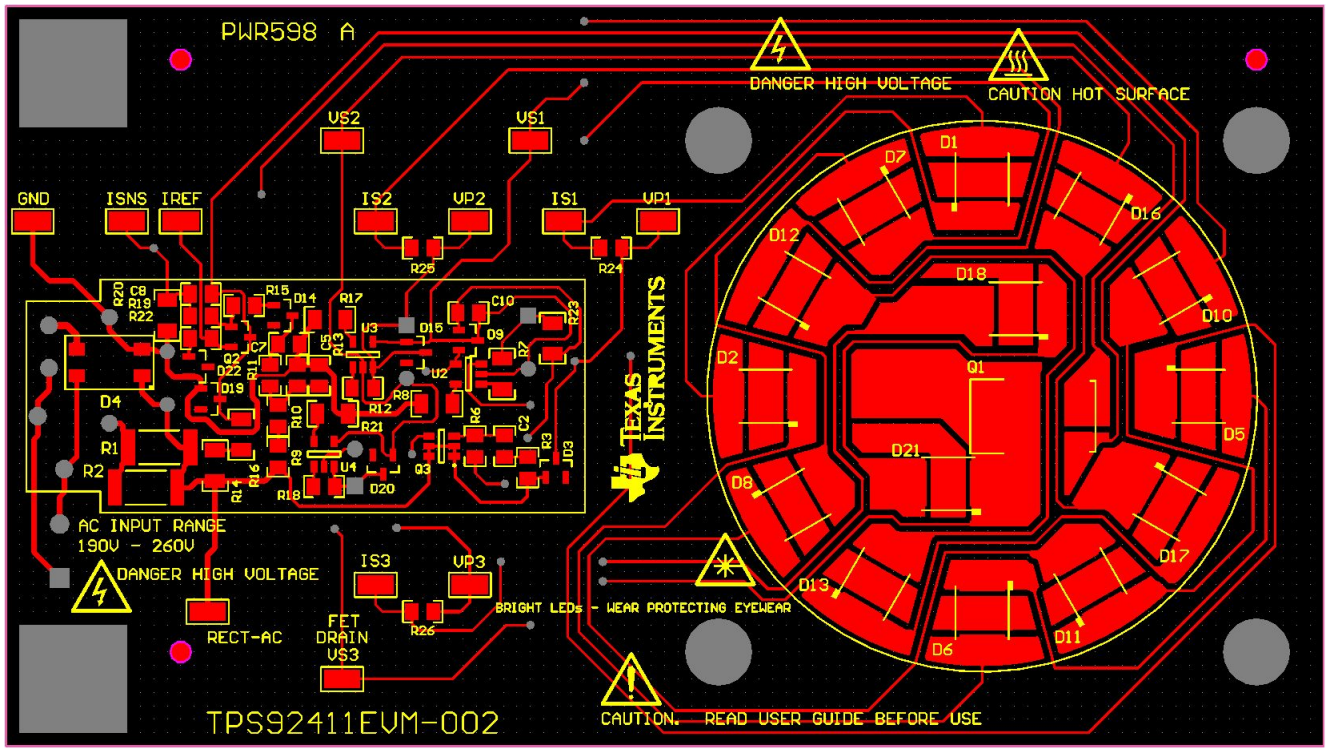

Figure 13. Top Layer and Top Overlay (Top View)

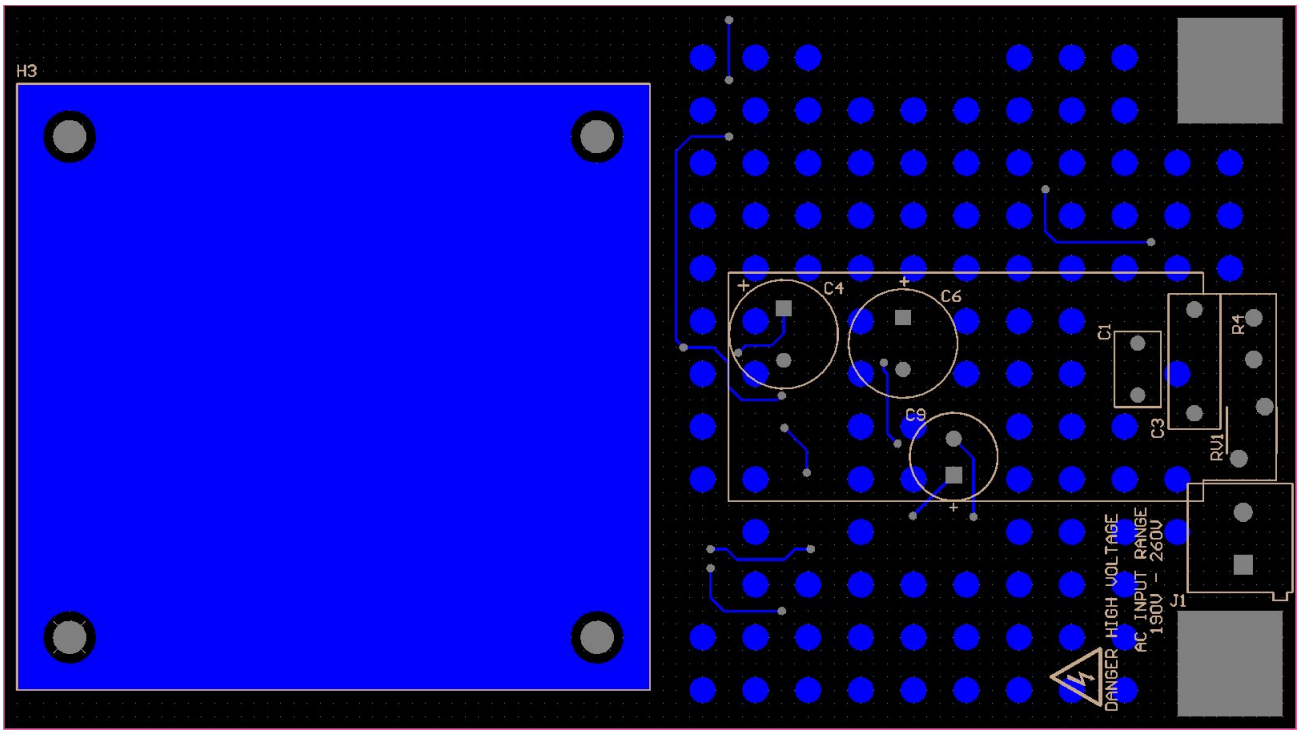

Figure 14. Bottom Layer and Bottom Overlay (Bottom View)

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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Texas Instruments (TI) provides the enclosed Evaluation Board/Kit/Module (EVM) under the following conditions:

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods.

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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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 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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(address) 24-1, Nishi-Shinjuku 6 chome, Shinjuku-ku, Tokyo, Japan

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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.
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