

TPS92410EVM-001 Offline LED Driver Evaluation Module

User's Guide



Literature Number: SLVUA49

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Switch Controlled Direct Drive Linear Controller for Offline LED Drivers

1 Introduction

The TPS92410EVM-001 evaluation module (EVM) helps designers evaluate the operation and performance of the TPS92410 direct drive linear controller designed for use with the TPS92411 in offline LED-drive applications. The TPS92410 is designed to control the drive of high-brightness light emitting diodes (LEDs) and features a wide input voltage range (9.5 V to 400 V), thermal foldback, analog dimming capability, and linear FET overvoltage protection.

2 Warnings and Cautions

Observe the following precautions when using the TPS92410EVM-001.

WARNING



High Voltage

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 IEC62471-1 ed1.0:2009-08 for risk group definitions.

3 Description

The TPS92410EVM-001 provides a high-brightness LED driver based on the TPS92410 in conjunction with the TPS92411 direct drive switch. It is designed to operate with an input voltage in the range of 90 VAC to 135 VAC with a 120 VAC nominal input voltage. This input voltage range is typical for offline applications. The EVM is set up for a default input current of 58 mA for 6.8 W total power and 3 LED voltage stacks of 20 V, 40 V, and 80 V. The TPS92410 helps provide high efficacy, good power factor, low THD, and flicker-free triac and phase dimming, due to its dimmer detect function that switches the input current mode to a DC level.

3.1 Typical Applications

This converter design describes an application of the TPS92410 as an LED driver controller with the specifications listed in [Section 4](#). For applications with a different input voltage range or different output voltage range, refer to the TPS92410 datasheet ([SLUSBW9](#)) and TPS92411 datasheet ([SLUSBQ6](#)).

3.2 Connector Descriptions

This section describes the connectors and test points on the EVM and how to properly connect, setup, and use the TPS92410EVM-001.

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, R1, to measure the current in the top (80 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.

3.2.3 ADIM

The test point ADIM connects directly to the ADIM pin of the TPS92410. The voltage range is 0 V to 3 V. Applying a voltage between 1.5 V and 3 V allows the internal reference to take over, resulting in a 1.5-V reference at the CS pin. Applying a voltage below 1.5 V results in the applied voltage being the reference at the CS pin down to 50 mV. Below 50 mV, the linear regulator is disabled and the GDL pin is pulled to ground.

4 Electrical Performance Specifications

Table 1 contains the electrical performance specifications for the EVM.

Table 1. TPS92410EVM-001 Electrical Performance Specifications

Parameter	Test Conditions	MIN	TYP	MAX	Units
Input Characteristics					
Voltage range		90	120	135	VAC
Maximum input current			58		mA
Output Characteristics					
Output voltage, V_{OUT}	Upper LED stack		80		V
	Middle LED stack		40		
	Lower LED stack		20		
Flicker Index			0.03		
Output current ripple percent			12		%
Output current ripple	Each stack		23		mApp
Overvoltage protection level	Each individual TPS92410		100		V
Linear FET overvoltage protection level			51		V
Systems Characteristics					
Efficiency	Input voltage = 120 VAC, No triac dimmer		79.5		%
Power factor	Input voltage = 120 VAC, No triac dimmer		0.99		
THD	Input voltage = 120 VAC, No triac dimmer		7.5		%

5 TPS92410EVM-001 Schematic

Figure 1 illustrates the TPS92410EVM-001 schematic.

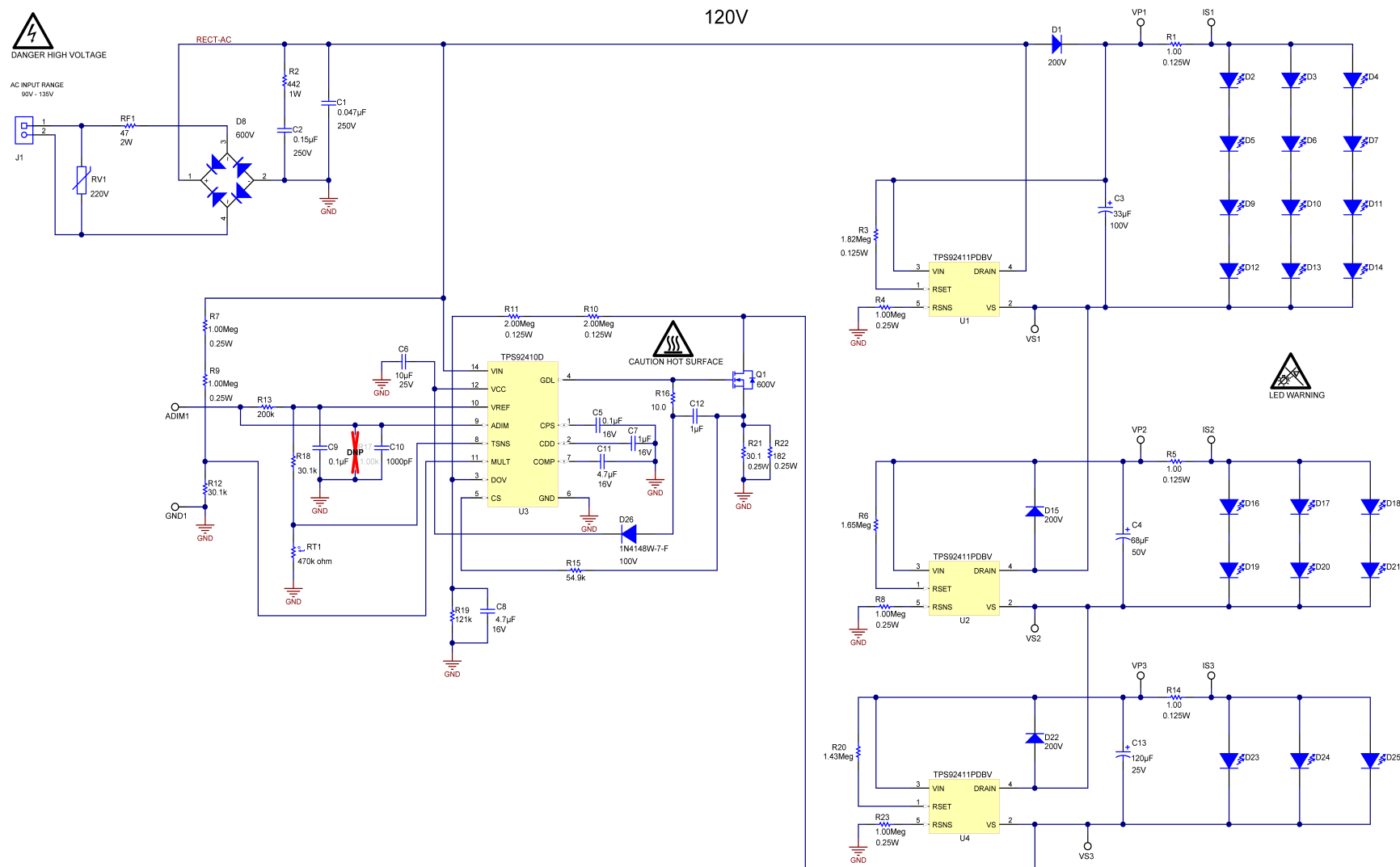


Figure 1. TPS92410EVM-001 Schematic

6 Performance Data and Typical Characteristic Curves

Figure 2 through Figure 13 present typical performance curves for the TPS92410EVM-001.

6.1 Power Factor

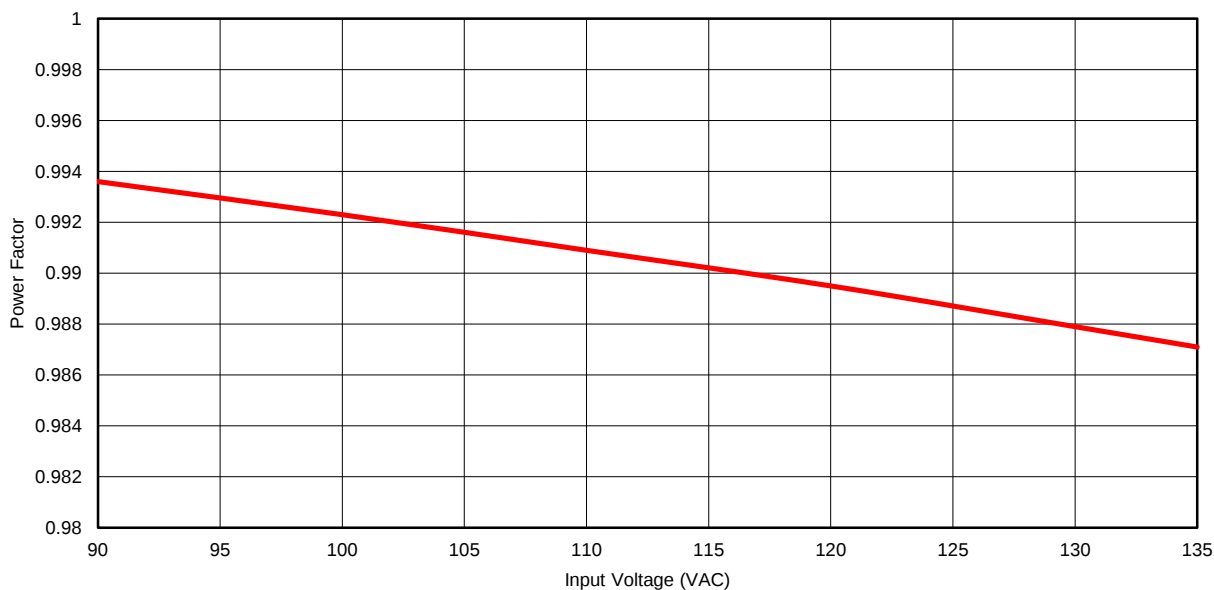


Figure 2. Power Factor Versus Input Voltage

6.2 Line Regulation

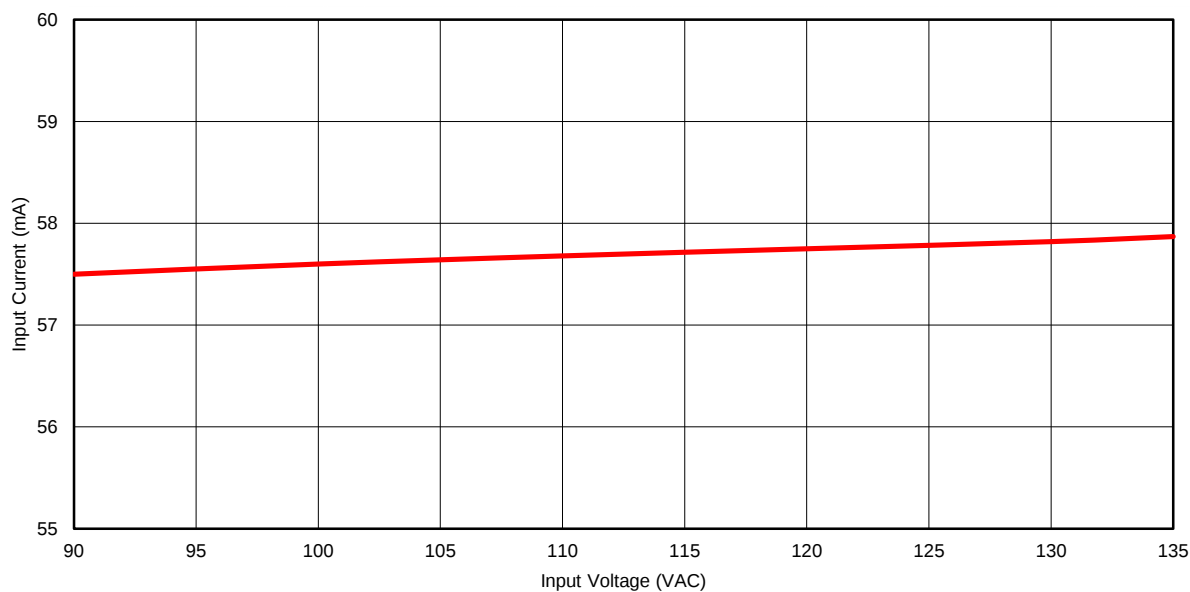


Figure 3. Input (Linear Regulator) Current Versus Input Voltage

6.3 Input Voltage and Input Current

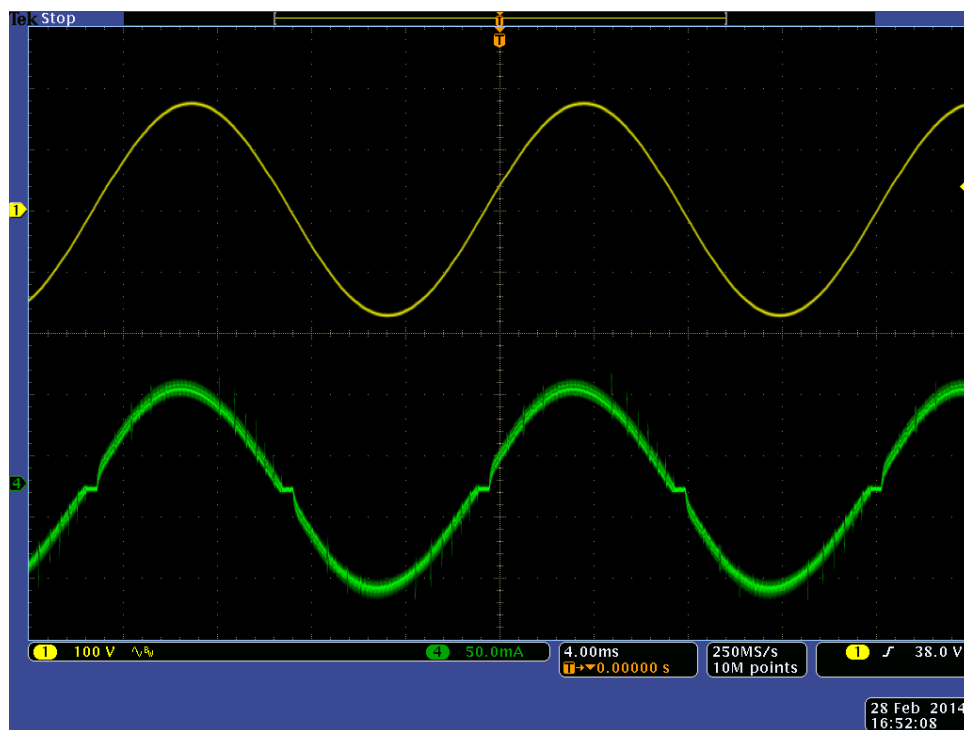


Figure 4. Input Voltage (Top) and Input Current (Bottom)

6.4 Linear Regulator Drain Voltage and Input Current

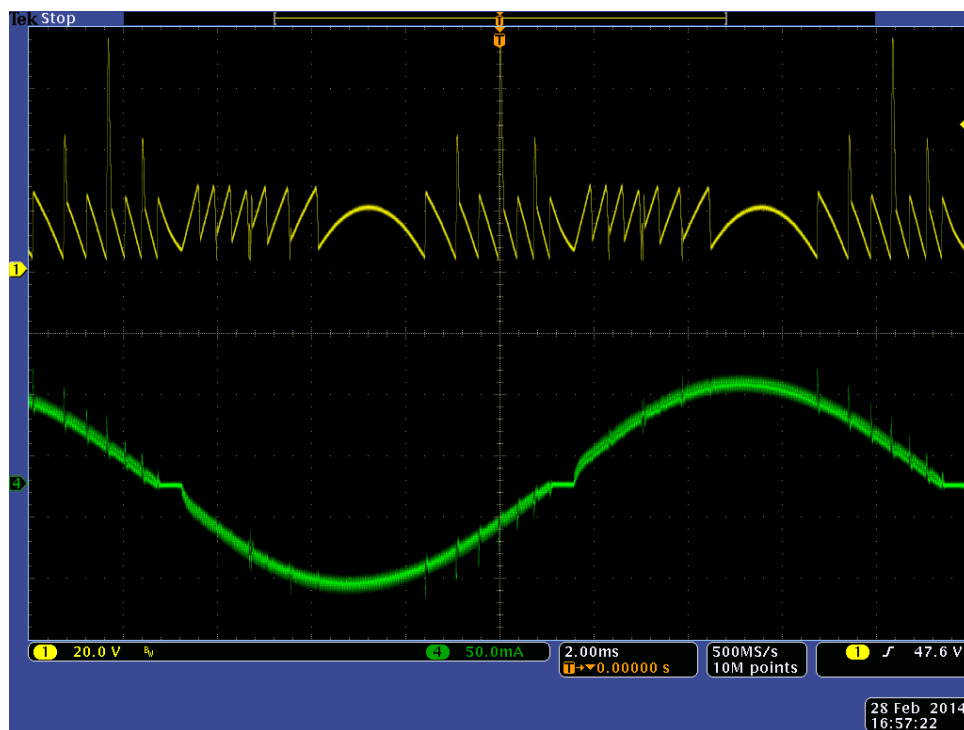


Figure 5. Drain Voltage (Top) and Input Current (Bottom)

6.5 Output Current

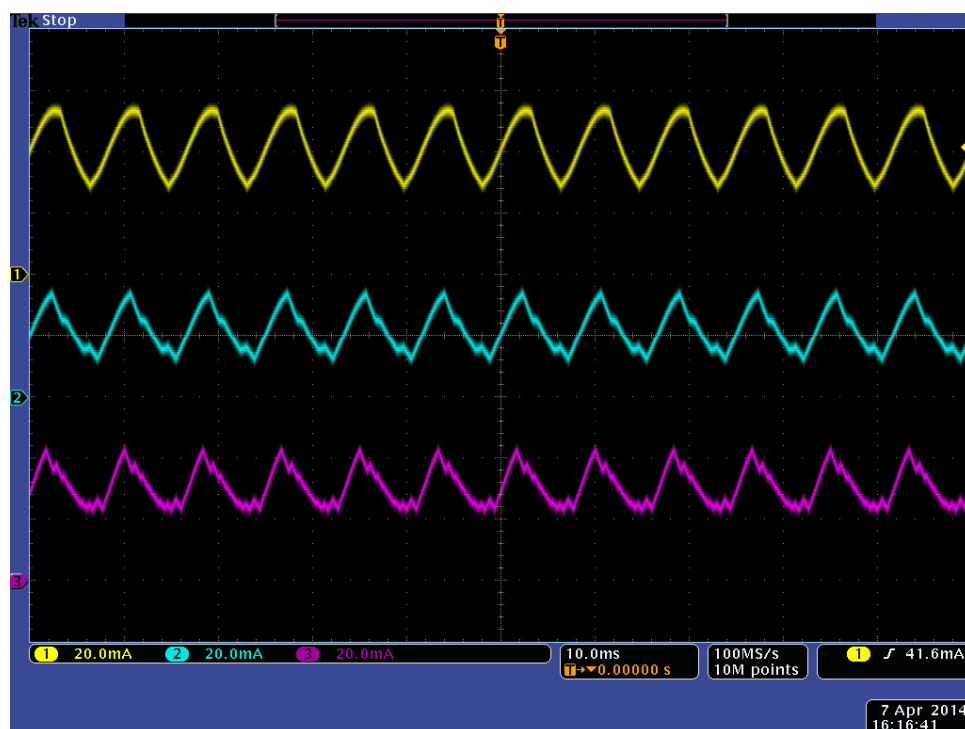


Figure 6. 80-V Stack (Top), 40-V Stack (Middle), and 20-V Stack (Bottom)

6.6 Drain Overvoltage (DOV) Event (80-V Stack Shorted then Released)

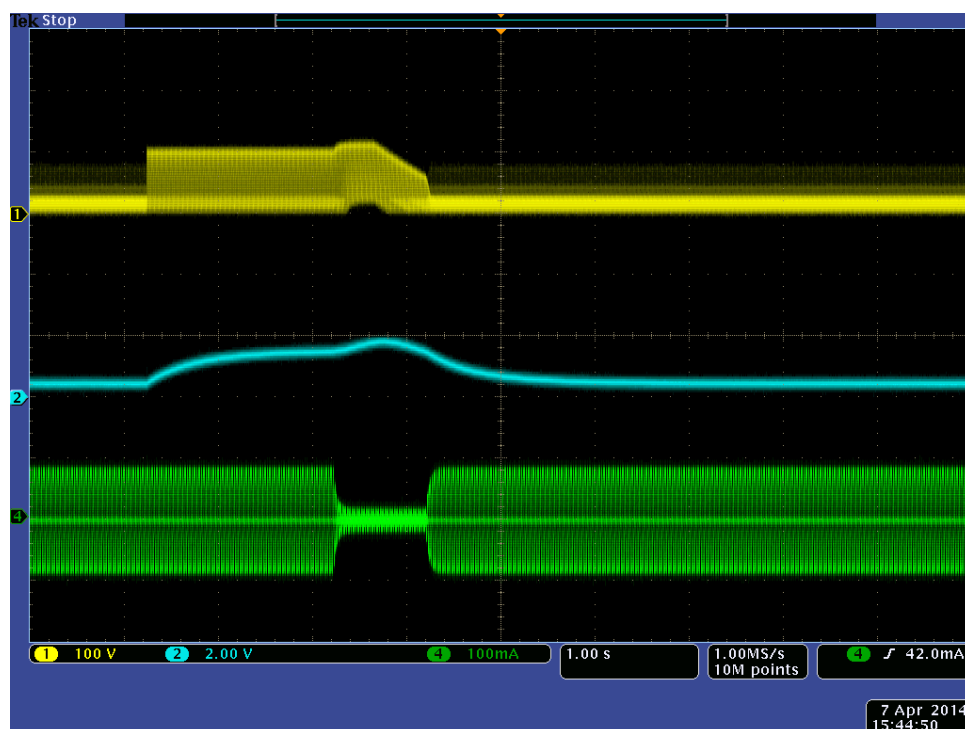


Figure 7. Drain Voltage (Top), DOV Pin Voltage (Middle), and Input Current (Bottom)

6.7 Triac Dimming Waveforms

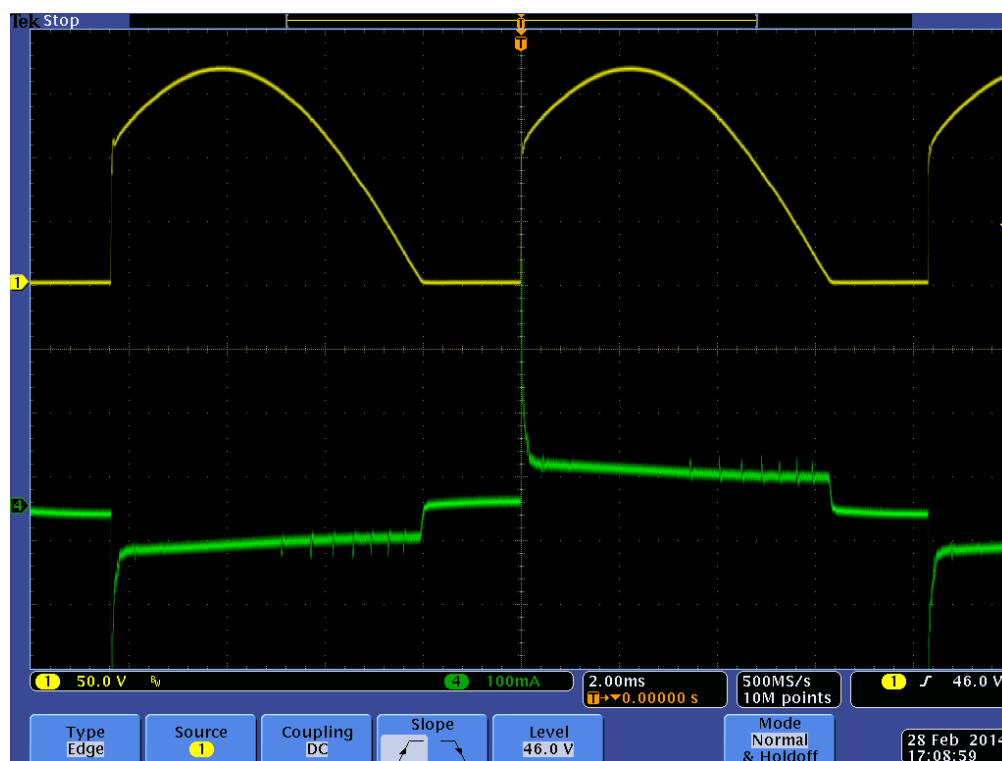


Figure 8. Forward Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom) – Full

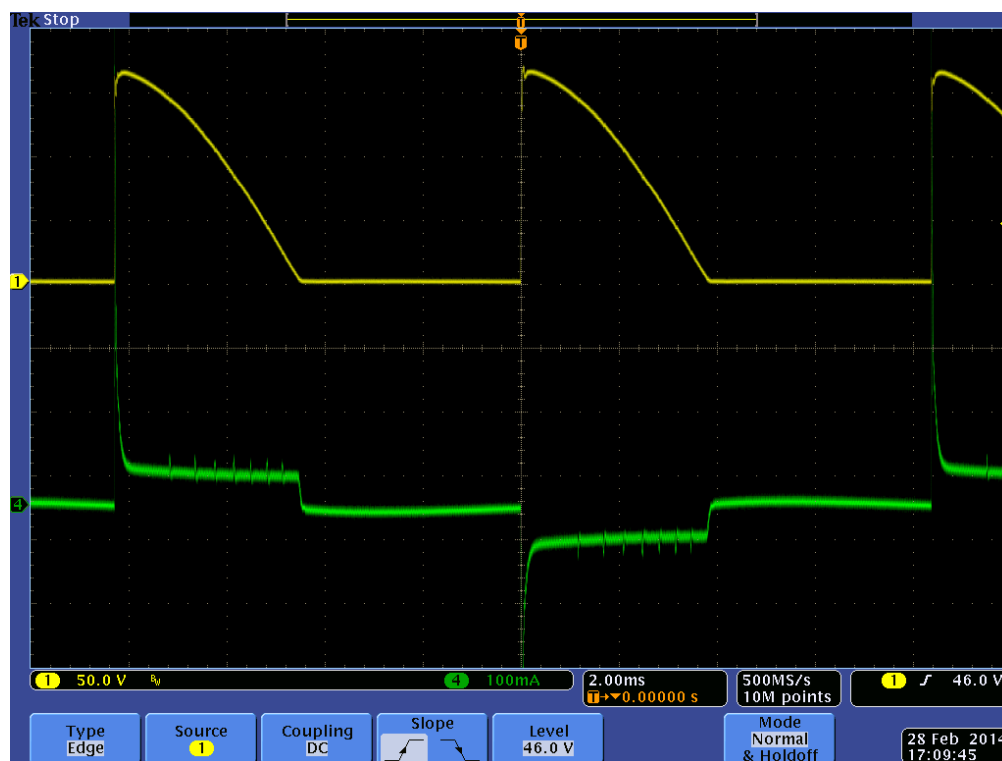


Figure 9. Forward Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom) – Half

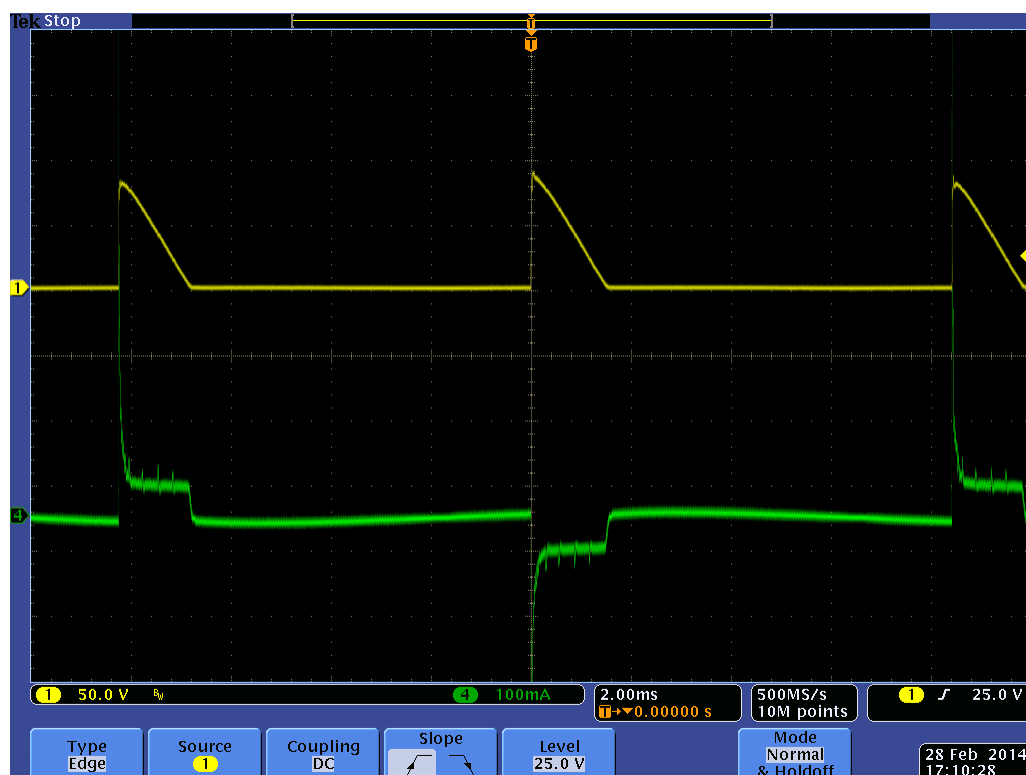


Figure 10. Forward Phase Triac Dimming: Rectified Input Voltage (Top) and Input Current (Bottom) – Low

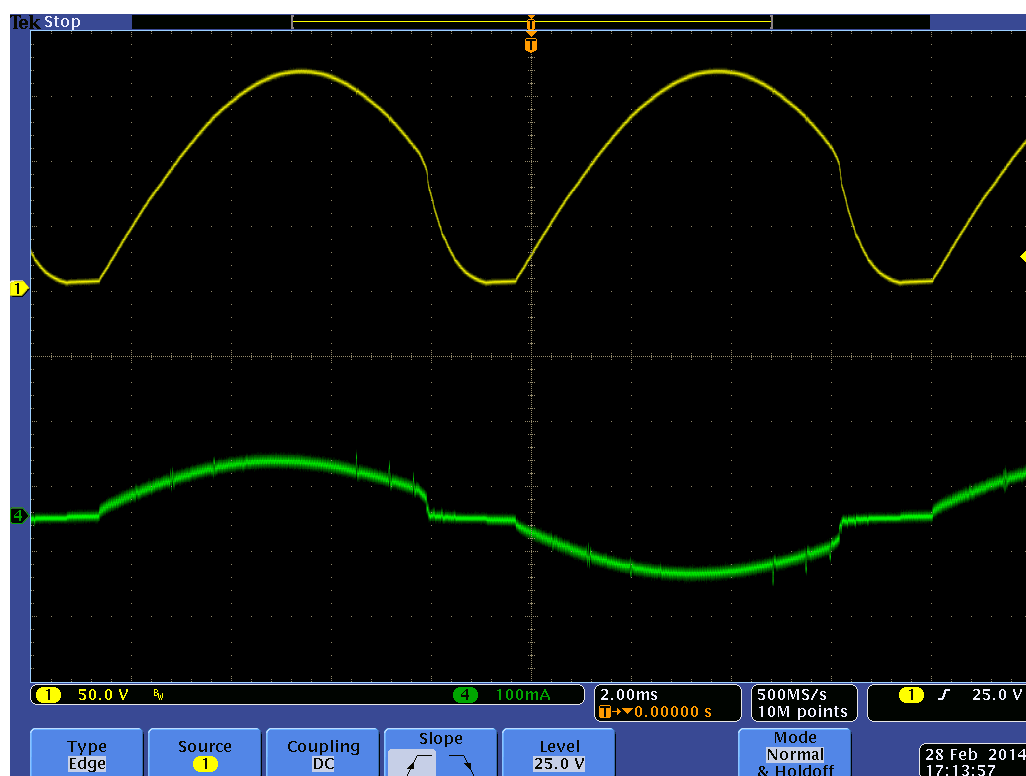


Figure 11. Reverse Phase Dimming: Rectified Input Voltage (Top) and Input Current (Bottom) – Full

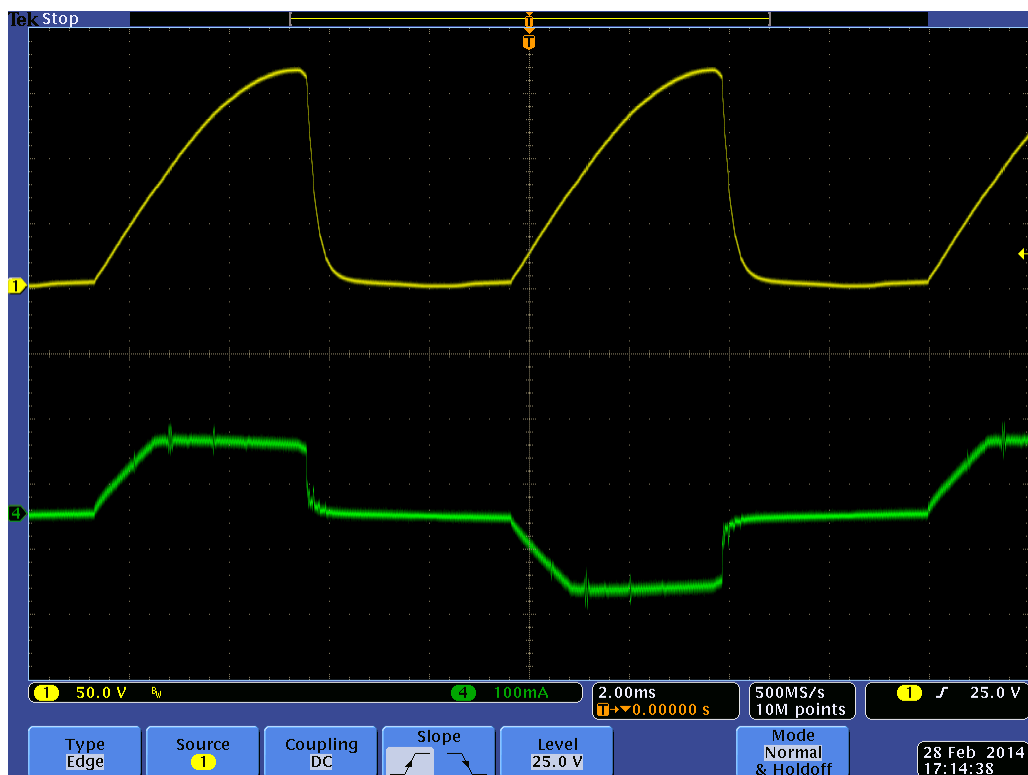


Figure 12. Reverse Phase Dimming: Rectified Input Voltage (Top) and Input Current (Bottom) – Half

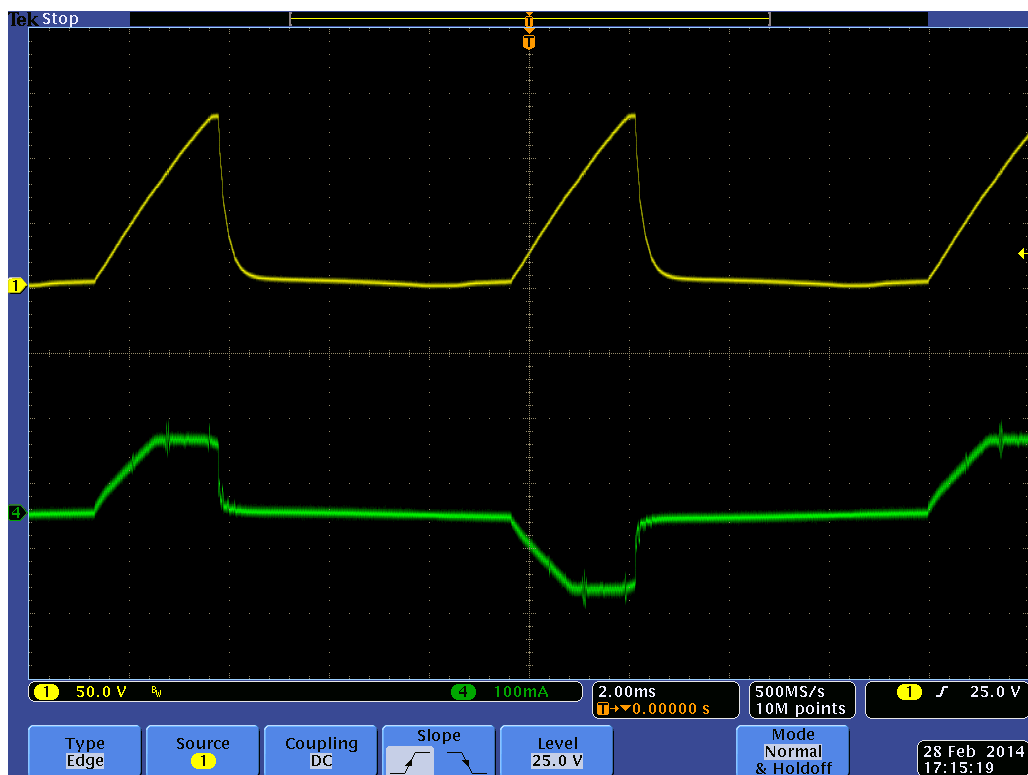


Figure 13. Reverse Phase Dimming: Rectified Input Voltage (Top) and Input Current (Bottom) – Low

6.8 EMI Performance

Figure 14 shows the conducted EMI performance of the EVM under the following conditions:

- $P_{IN} = 6.8 \text{ W}$
- $V_{IN} = 120 \text{ VAC}$
- QP = quasi-peak limit line
- A = average limit line
- Blue trace = peak scan
- Black trace = average scan

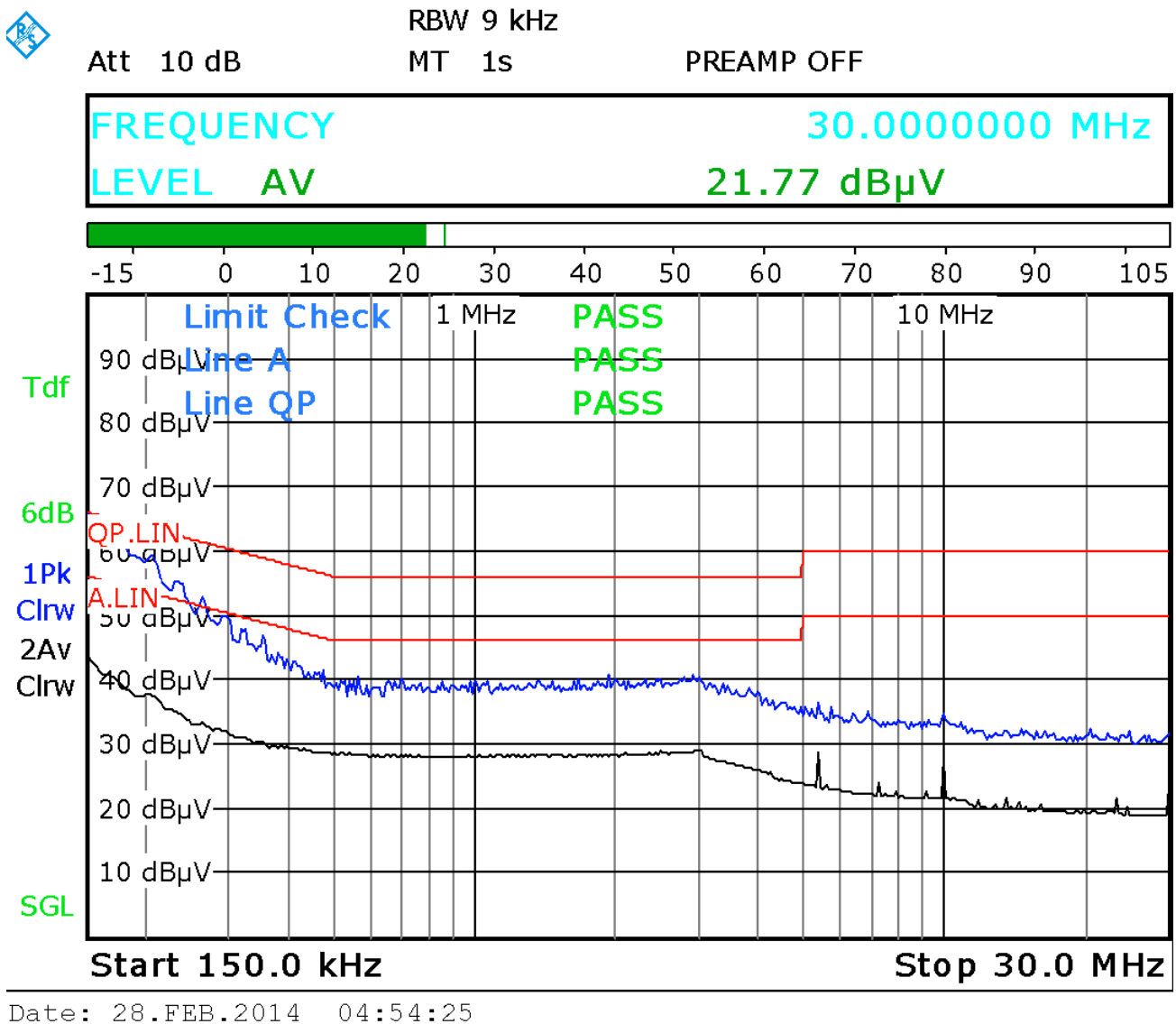


Figure 14. Conducted EMI Performance

7 TPS92410EVM-001 PCB Layout

Figure 15 and Figure 16 show the design of the TPS92410EVM-001 printed circuit board.

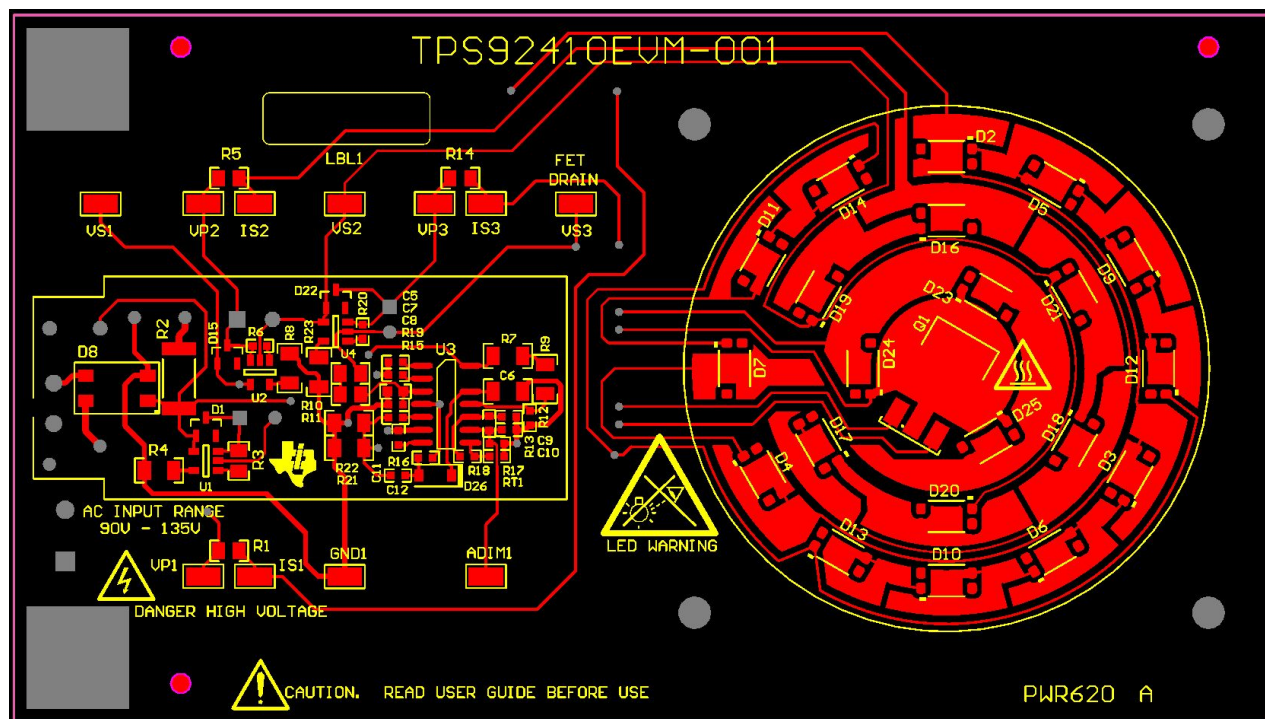


Figure 15. Top Layer and Top Overlay (Top View)

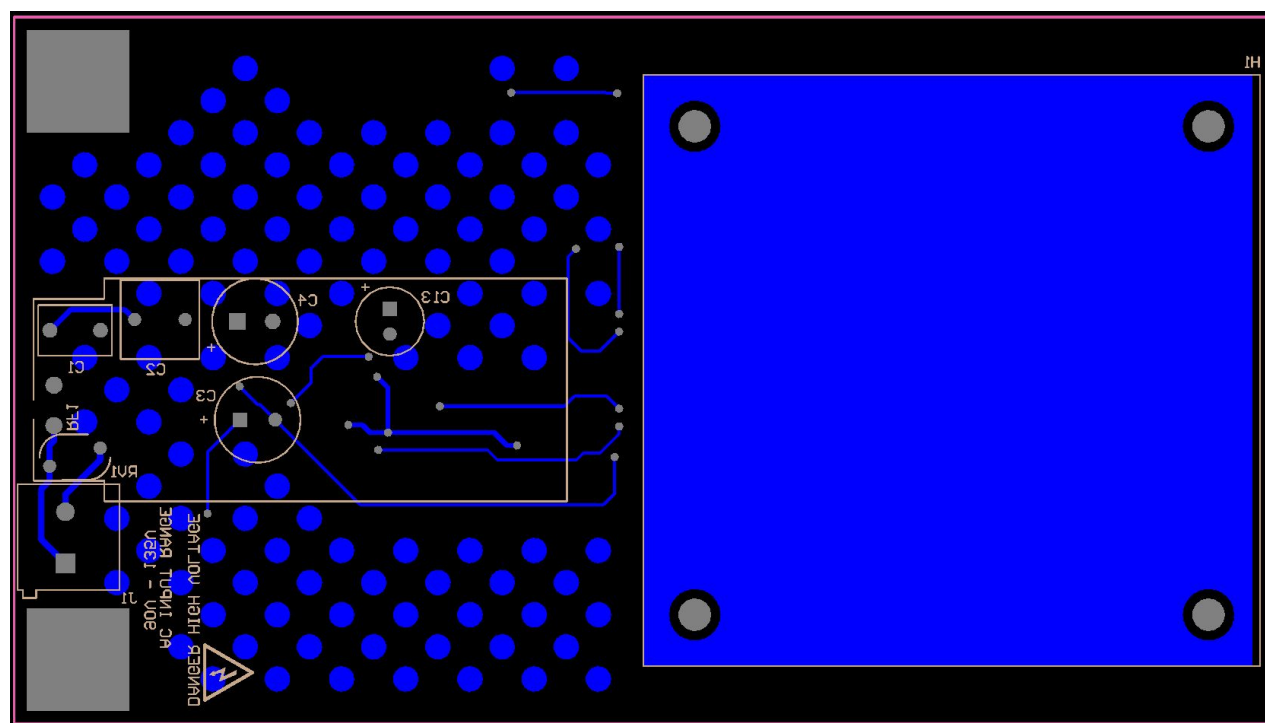


Figure 16. Bottom Layer and Bottom Overlay (Bottom View)

8 Bill of Materials

Table 2 contains the TPS92410EVM-001 components list according to the schematic shown in Figure 1.

Table 2. TPS92410EVM-001 Bill of Materials

Reference Designator	QTY	Value	Description	Size	Part Number	MFR
C1	1	0.047μF	CAP, Film, 0.047μF, 250VDC	Radial	B32529C3473K189	EPCOS Inc
C2	1	0.15μF	CAP, Film, 0.15μF, 250VDC	Radial	B32529C3154J	EPCOS Inc
C3	1	33μF	CAP, AL, 33μF, 100V, +/-20%, 0.45 ohm	8x15mm	UPW2A330MPD6	Nichicon
C4	1	68μF	CAP, AL, 68μF, 50V, +/-20%, 0.234 ohm	8x11.5mm	EEU-FC1H680	Panasonic
C5, C9	2	0.1μF	CAP, CERM, 0.1μF, 16V, +/-5%, X7R	0603	C0603C104J4RACTU	Kemet
C6	1	10μF	CAP, CERM, 10μF, 25V, +/-10%, X7R	1206	GRM31CR71E106KA12L	MuRata
C7, C12	2	1μF	CAP, CERM, 1μF, 16V, +/-10%, X7R	0603	C1608X7R1C105K	TDK
C8, C11	2	4.7μF	CAP, CERM, 4.7μF, 16V, +/-10%, X5R	0603	GRM188R61C475KAAJ	MuRata
C10	1	1000pF	CAP, CERM, 1000pF, 50V, +/-10%, X7R	0603	GRM188R71H102KA01D	MuRata
C13	1	120μF	CAP, AL, 120μF, 25V, +/-20%, 0.23 ohm	6.3x15mm	UPW1E121MED	Nichicon
D1, D15, D22	3	200V	Diode, Switching, 200V, 0.2A	SOT-23	BAS21-7-F	Diodes Inc.
D2, D3, D4, D5, D6, D7, D9, D10, D11, D12, D13, D14, D16, D17, D18, D19, D20, D21, D23, D24, D25	21	Cool White	LED, Cool White, SMD	3x.75x5.2mm	SAW8KG0B-Y1Z4-CA	Seoul Semiconductor
D8	1		Diode, Switching-Bridge, 600V, 0.8A	MiniDIP	HD06-T	Diodes Inc.
D26	1	100V	Diode, Ultrafast, 100V, 0.15A	SOD-123	1N4148W-7-F	Diodes Inc.
J1	1	2x1	Conn Term Block, 2POS, 5.08mm	2POS Terminal Block	1715721	Phoenix Contact
Q1	1	600V	MOSFET, N-CH, 600V, 2A	DPAK	AOD2N60	AOS
R1, R5, R14	3	1.00Ω	RES, 1.00 ohm, 1%, 0.125W	0805	RMCF0805FT1R00	Stackpole Electronics Inc
R2	1	442 Ω	RES, 442 ohm, 1%, 1W	2512	CRCW2512442RFKEG	Vishay-Dale
R3	1	1.82MΩ	RES, 1.82Meg ohm, 1%, 0.125W	0805	CRCW08051M82FKEA	Vishay-Dale
R4, R7, R8, R9, R23	5	1.00MΩ	RES, 1.00Meg ohm, 1%, 0.25W	1206	CRCW12061M00FKEA	Vishay-Dale
R6	1	1.65MΩ	RES, 1.65Meg ohm, 1%, 0.1W	0603	CRCW06031M65FKEA	Vishay-Dale
R10, R11	2	2.00MΩ	RES, 2.00Meg ohm, 1%, 0.125W	0805	CRCW08052M00FKEA	Vishay-Dale
R12, R18	2	30.1kΩ	RES, 30.1k ohm, 1%, 0.1W	0603	CRCW060330K1FKEA	Vishay-Dale
R13	1	200kΩ	RES, 200k ohm, 1%, 0.1W	0603	CRCW0603200KFKEA	Vishay-Dale
R15	1	54.9kΩ	RES, 54.9k ohm, 1%, 0.1W	0603	CRCW060354K9FKEA	Vishay-Dale
R16	1	10.0Ω	RES, 10.0 ohm, 1%, 0.1W	0603	CRCW060310R0FKEA	Vishay-Dale
R19	1	121kΩ	RES, 121k ohm, 1%, 0.1W	0603	CRCW0603121KFKEA	Vishay-Dale
R20	1	1.43MΩ	RES, 1.43Meg ohm, 1%, 0.1W	0603	CRCW06031M43FKEA	Vishay-Dale
R21	1	30.1Ω	RES, 30.1 ohm, 1%, 0.25W	1206	CRCW120630R1FKEA	Vishay-Dale
R22	1	182Ω	RES, 182 ohm, 1%, 0.25W	1206	CRCW1206182RFKEA	Vishay-Dale
RF1	1	47Ω	RES, 47 ohm, 10%, 2W	Axial	EMC2-47RKI	TT Electronics/Welwyn
RT1	1	470kΩ	Thermistor NTC, 470k ohm, 5%	0603	NCP18WM474J03RB	MuRata

Table 2. TPS92410EVM-001 Bill of Materials (continued)

Reference Designator	QTY	Value	Description	Size	Part Number	MFR
RV1	1	220V	Varistor, 220V, 600A	Disc 10x7mm	ERZ-V05D221	Panasonic
U1, U2, U4	3		Switch Controlled Direct Drive Switch for Offline LED Drivers	SOT23-5	TPS92411PDBV	Texas Instruments
U3	1		Switch Controlled Direct Drive Linear Controller for Offline LED Drivers	SOIC-13	TPS92410D	Texas Instruments
R17	0	DNP				

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.

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- 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.

- 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 isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

3.3 Japan

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/llds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/llds/ti_ja/general/eStore/notice_01.page

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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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lstds/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.

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