THE DATASHEET OF

TPS92410EVM-002

Switch Controlled Direct Drive Switch for Offline LED Drivers

The TPS92411EVM-001 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.

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1 Description

The TPS92411EVM-001 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 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 95 mA for approximately 12-W total power and 3 LED voltage stacks of 20 V, 40 V, and 80 V. The TPS92411 helps provide high efficacy, good power factor, low THD, and flicker free dimming.

1.1 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 data sheet (SLUSBQ6).

1.2 Features

1.2.1 Connector Description

This section describes the connectors and test points on the EVM and how to properly connect, setup, and use the TPS92411EVM-001.

1.2.1.1 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.

2 Warnings and Cautions

Observe the following precaution when using the TPS92411EVM-001.

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.

3 Electrical Performance Specifications

Table 1. TPS92411EVM-001 Electrical Performance Specifications

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
INPUT CHARACTERISTICS					
Voltage range		90	120	135	VAC
Maximum input current			95	105	mA
OUTPUT CHARACTERISTICS					
Output voltage, VOUT	Upper LED stack		80		V
	Middle LED stack		40		
	Lower LED stack		20		
Flicker Index			0.09		
Output current ripple percent			36%		
Output current ripple	Each stack		65		mApp
Overvoltage protection level	Each individual TPS92411P		100		V
SYSTEMS CHARACTERISTICS					
Efficiency	Input voltage = 120 Vac, No triac dimmer		83%		
Power Factor	Input voltage = 120 Vac, No triac dimmer		0.97		
THD	Input voltage = 120 Vac, No triac dimmer		14.9%		

4 Schematic

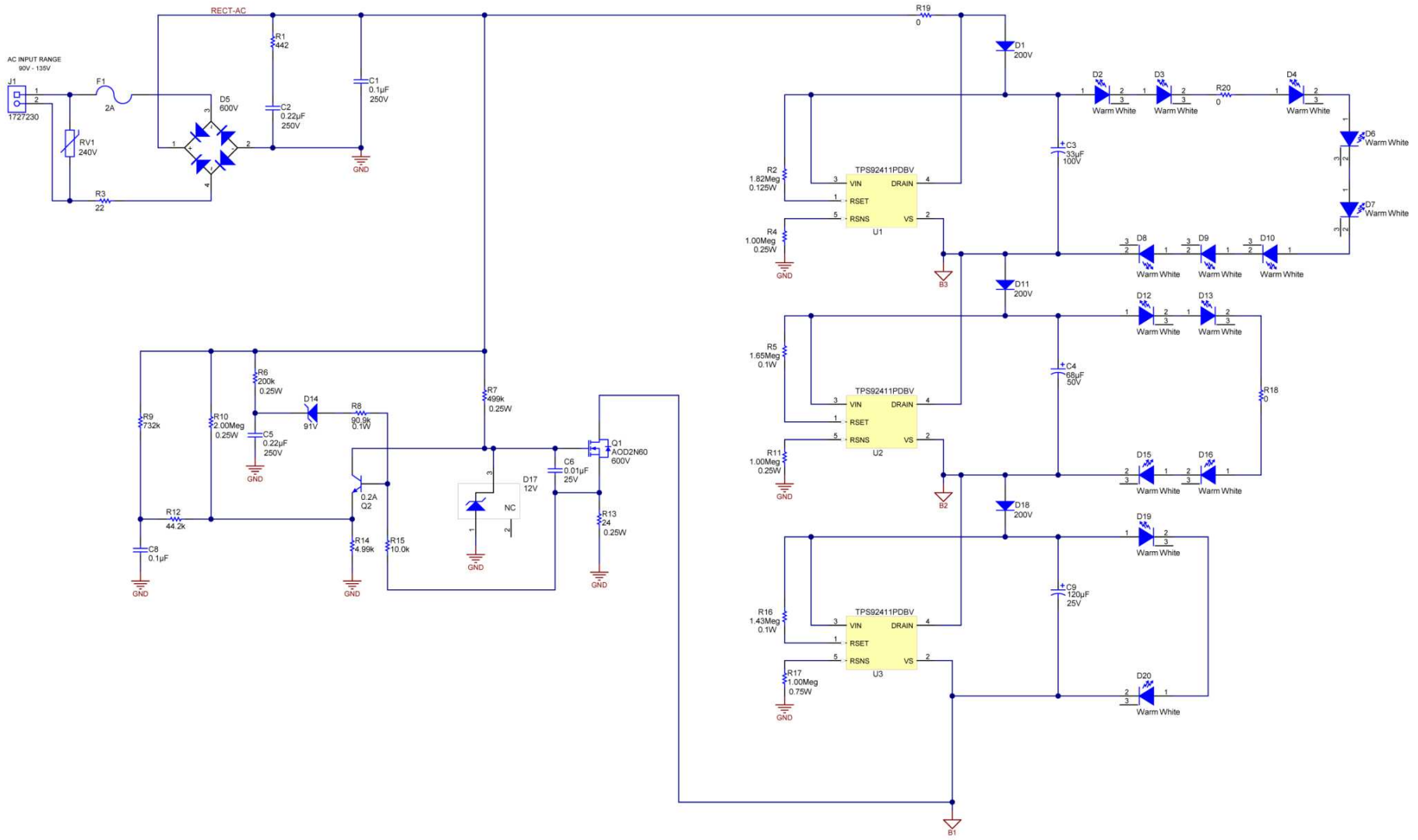

Figure 1. TPS92411EVM-001 Schematic

5 Performance Data and Typical Characteristic Curves

Figure 2 through Figure 12 present typical performance curves for TPS92411EVM-001.

5.1 Power Factor

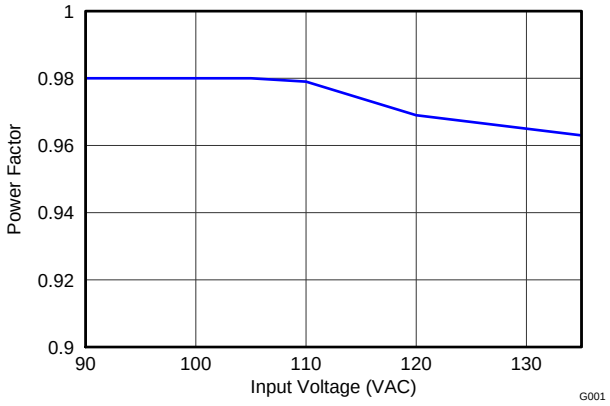

Figure 2. Power Factor Versus Input Voltage

5.2 Line Regulation

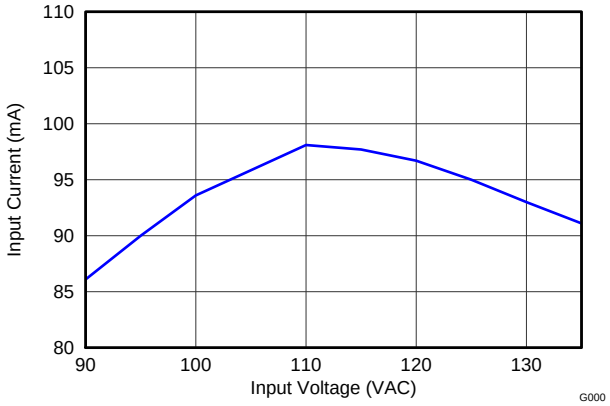

Figure 3. Input (Linear Regulator) Current Versus Input Voltage

5.3 Input Voltage and Input Current

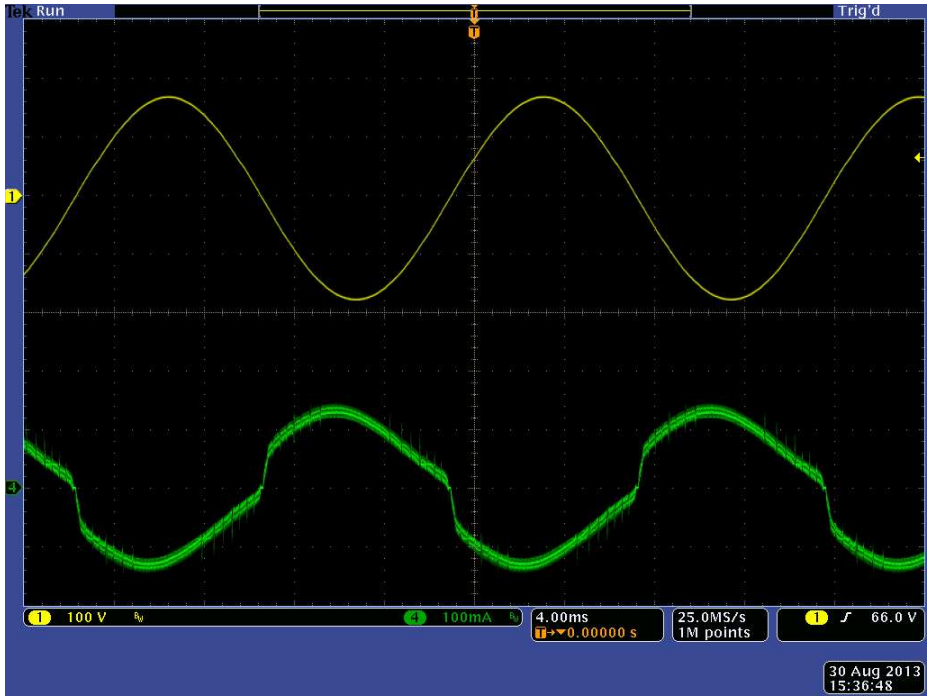

Figure 4. Input Voltage (Top) and Input Current (Bottom)

5.4 Linear Regulator Drain Voltage and Input Current

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

5.5 Triac Dimming Waveforms

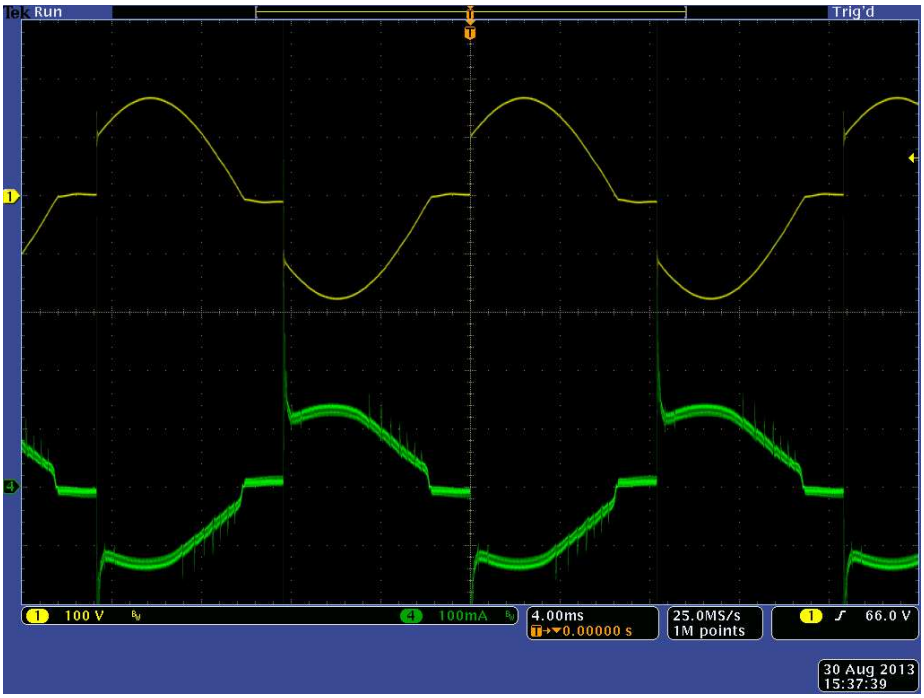

Figure 6. Forward Phase Triac Dimming: Input Voltage (Top) and Input Current (Bottom)

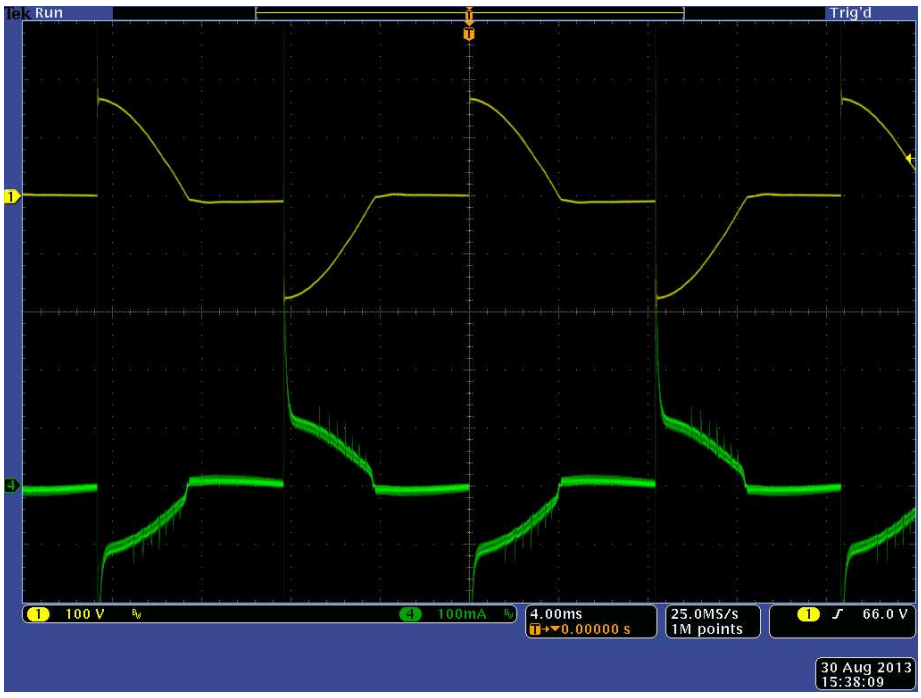

Figure 7. Forward Phase Triac Dimming: Input Voltage (Top) and Input Current (Bottom)

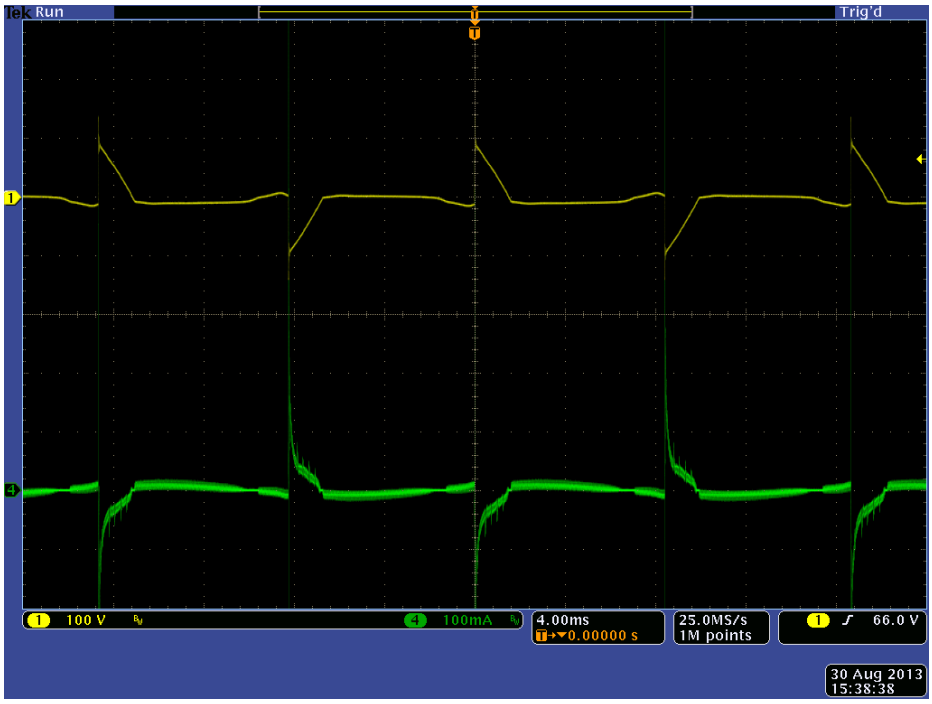

Figure 8. Forward Phase Triac Dimming: Input Voltage (Top) and Input Current (Bottom)

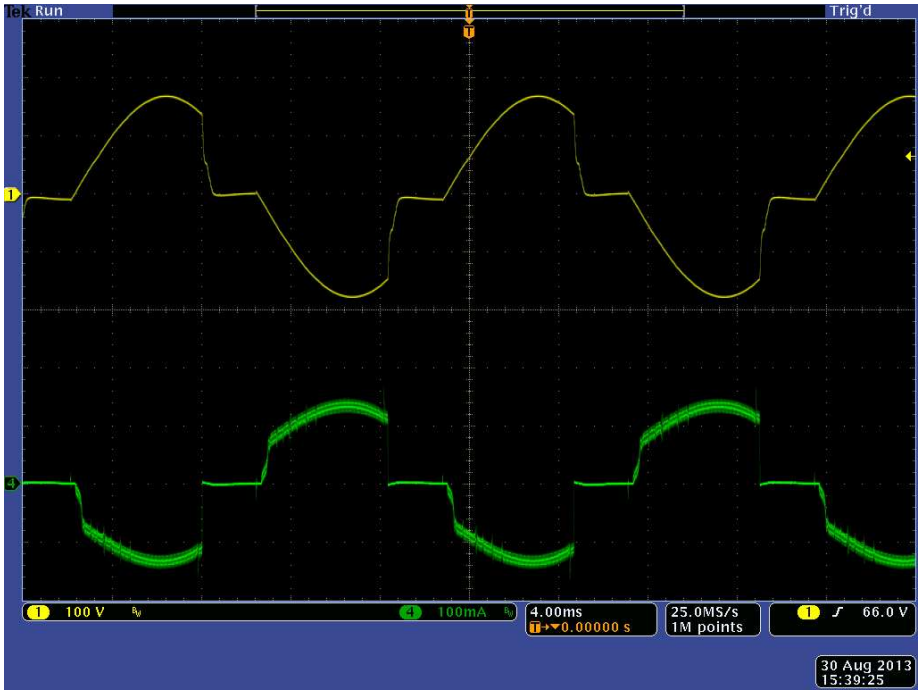

Figure 9. Reverse Phase Triac Dimming: Input Voltage (Top) and Input Current (Bottom)

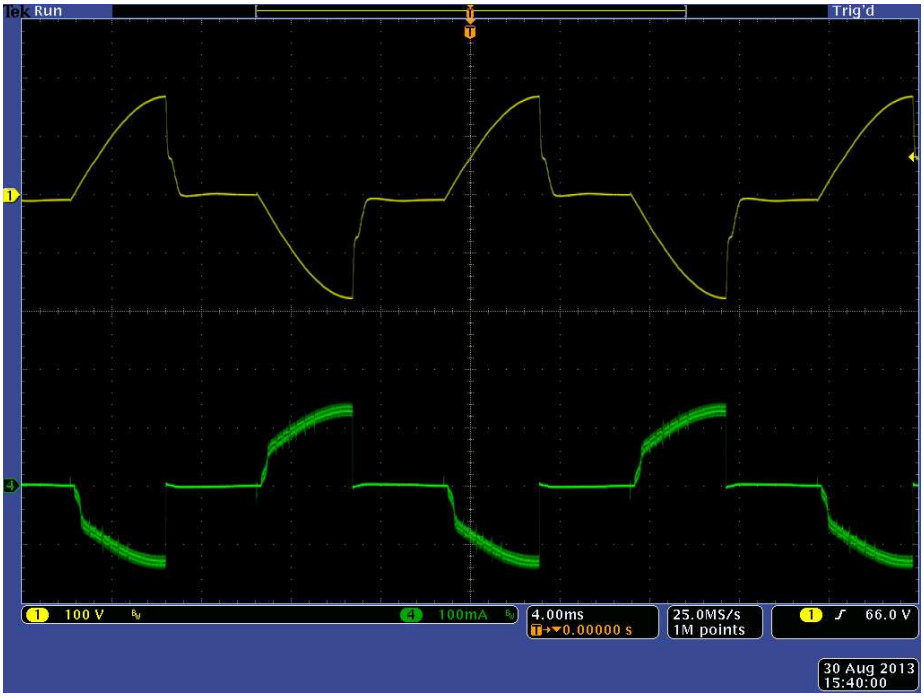

Figure 10. Reverse Phase Triac Dimming: Input Voltage (Top) and Input Current (Bottom)

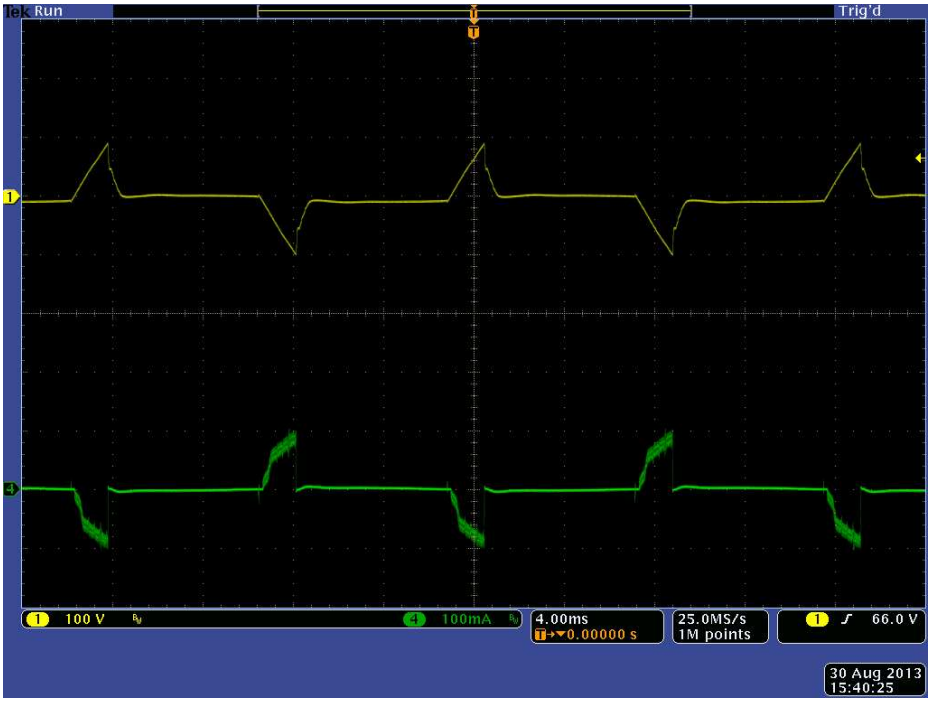

Figure 11. Reverse Phase Triac Dimming: Input Voltage (Top) and Input Current (Bottom)

5.6 EMI Performance

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

- P_{IN} = 12 W
- V_{IN} = 120 Vac
- "QP" = quasi-peak limit line
- "A" = average limit line
- Blue trace = peak scan
- Black trace = average scan

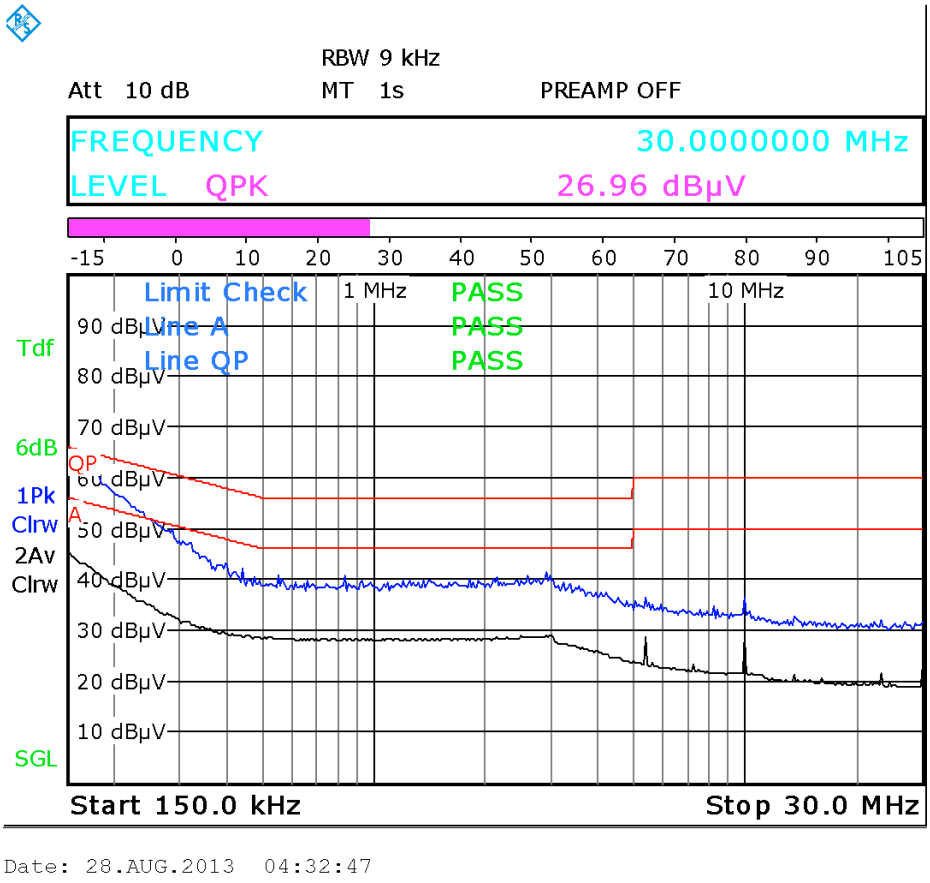

Figure 12. Conducted EMI Performance

6 TPS92411EVM-001 PCB layout

Figure 13 shows the design of the TPS92411EVM-001 metal clad printed-circuit board

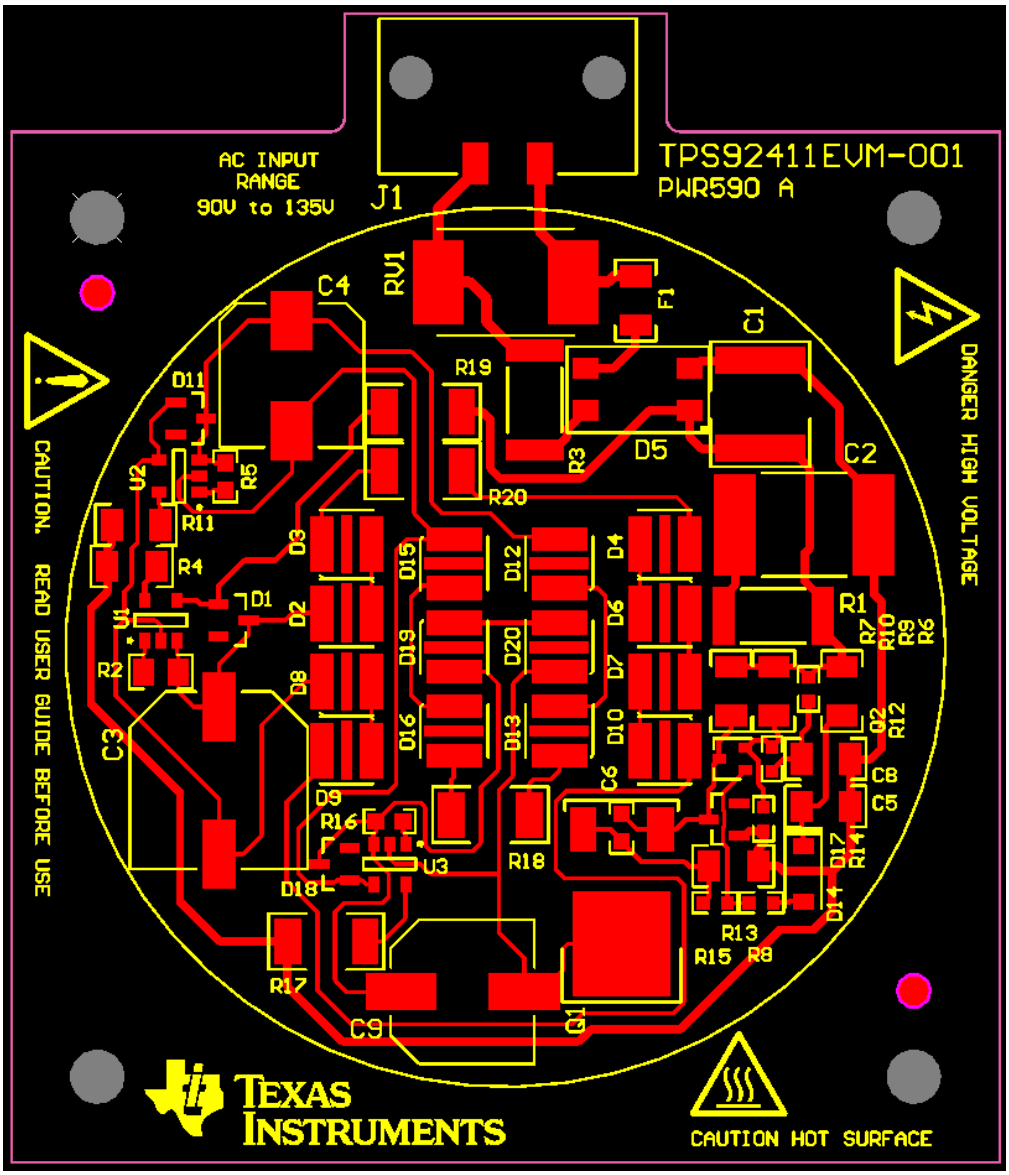

Figure 13. Top Layer and Top Overlay (Top view)

7 Bill of Materials

The bill of materials table for TPS92411EVM-001 contains the components list according to the schematic shown in Figure 1.

Table 2. TPS92411EVM-001 Components List

REF DES	QTY	Value	Description	Size	Part Number	MFR
C1	1	0.1µF	CAP, CERM, 0.1uF, 250VDC, 2220	2220 (5750 Metric)	LDEID3100KA0N00	Kemet
C2	1	0.22µF	CAP, Film, 0.22uF, 250VDC, 2824	2824	CB052G0224JBC	AVX
C3	1	33uF	CAP, AL, 33uF, 100V, ±20%, 0.7 ohm, SMD	SMT Radial G	EEE-FK2A330P	Panasonic
C4	1	68uF	CAP, AL, 68uF, 50V, ±20%, 0.34 ohm, SMD	8x10	UUD1H680MNL1GS	Nichicon
C5	1	0.22µF	CAP, CERM, 0.22uF, 250V, X7T, 10%, 1206	1206	CGA5L3X7T2E224K160AE	TDK
C6	1	0.01uF	CAP, CERM, 0.01uF, 25V, ±5%, C0G/NP0, 0603	0603	C1608C0G1E103J	TDK
C8	1	0.1uF	CAP, CERM, 0.1uF, 100V, ±5%, X7R, 1206	1206	12061C104JAT2A	AVX
C9	1	120µF	CAP, Alum, 120uF, 25V, ±20%, SMD	Radial, Can - SMD	PCV1E121MCL6GS	Nichicon
D1, D11, D18	3	200V	Diode, P-N, 200V, 200A, SOT-23	SOT-23	BAS21-TP	Micro Commercial Components
D2–D10, D12, D13, D15, D16, D19, D20	14	XLamp ML-E	LED, SMT, Neutral White, XLamp ML-E	2-SMD, Gull Wing Tabs	MLESWT-A1-0000-0002E7	Cree Inc
D5	1		Diode, Switching-Bridge, 600V, 0.8A, MiniDIP	MiniDIP	HD06-T	Diodes Inc.
D14	1		Diode, Zener, 91V, 500mW, SOD-123	SOD-123	MMSZ5270BT1G	ON Semiconductor
D17	1	12V	Diode, Zener, 12V, 225mW, SOT-23	SOT-23	MMBZ5242BLT1G	ON Semiconductor
F1	1		Fuse, 2A, 125V, 1206	1206	C1Q 2	Bel Fuse Inc
H3	1		HEATSINK DC/DC HALF BRICK VERT		518-95AB	Wakefield Thermal Solutions
J1	1		Header, Term Blk, 2Pos, 3.81mm, SMD	Header, 2mm, 2x1	1727230	Phoenix Contact
Q1	1		MOSFET, N-CH, 600V, 2A, DPAK	TO-252-3, DPak (2 Leads + Tab), SC-63	AOD2N60	Alpha & Omega Semiconductor Inc
Q2	1	Value	Transistor, NPN, 40V, 200mW, SOT-323	SC-70, SOT-323	MMST3904-7-F	Diodes Inc
R1	1	442	RES, 442 ohm, 1%, 1W, 2512	2512 (6432 Metric)	CRCW2512442RFKEG	Vishay Dale
R2	1	1.82Meg	RES, 1.82Meg ohm, 1%, 0.125W, 0805	0805	CRCW08051M82FKEA	Vishay-Dale
R3	1	22	RES, 22 ohm, 5%, 1.5W, 2512	2512 (6432 Metric)	CRCW251222R0JNEGHP	Vishay Dale
R4, R11	2	1.00Meg	RES, 1.00Meg ohm, 1%, 0.25W, 1206	1206	CRCW12061M00FKEA	Vishay-Dale
R5	1	1.65Meg	RES, 1.65Meg ohm, 1%, 0.1W, 0603	0603	CRCW06031M65FKEA	Vishay-Dale
R6	1	200k	RES, 200k ohm, 1%, 0.25W, 1206	1206	CRCW1206200KFKEA	Vishay-Dale
R7	1	499k	RES, 499k ohm, 1%, 0.25W, 1206	1206	CRCW1206499KFKEA	Vishay-Dale
R8	1	90.9k	RES, 90.9k ohm, 1%, 0.1W, 0603	0603	CRCW060390K9FKEA	Vishay-Dale
R9	1	732k	RES, 732k ohm, 1%, 0.1W, 0603	0603	CRCW0603732KFKEA	Vishay-Dale
R10	1	2.00Meg	RES, 2.00Meg ohm, 1%, 0.25W, 1206	1206	CRCW12062M00FKEA	Vishay-Dale
R12	1	44.2k	RES, 44.2k ohm, 1%, 0.1W, 0603	0603	CRCW060344K2FKEA	Vishay-Dale
R13	1	24	RES, 24 ohm, 5%, 0.25W, 1206	1206	CRCW120624R0JNEA	Vishay-Dale
R14	1	4.99k	RES, 4.99k ohm, 1%, 0.1W, 0603	0603	CRCW06034K99FKEA	Vishay-Dale
R15	1	10.0k	RES, 10.0k ohm, 1%, 0.1W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale
R16	1	1.43Meg	RES, 1.43Meg ohm, 1%, 0.1W, 0603	0603	CRCW06031M43FKEA	Vishay-Dale
R17	1	1M	RES, 1M ohm, 1%, 0.75W, 2010	2010 (5025 Metric)	CRCW20101M00FKEF	Vishay Dale
R18, R19, R20	3	0	RES, 0 ohm, 0.75W, 2010	2010 (5025 Metric)	CRCW20100000Z0EF	Vishay Dale
RV1	1		Varistor, 150VAC, 200VDC, 9J, 3225	3225 (8063 Metric)	PV150K3225T	Stackpole Electronics Inc
U1, U2, U3	3		IC, TPS92411 with OVP	SOT23-5	TPS92411PDBV	Texas Instrumenmts

Revision History

Changes from Original (October 2013) to A Revision	Page
• Added section 2, Warnings and Cautions.	2

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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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)
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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.
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.

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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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