Using the TPS92210EVM-647

User's Guide

Texas Instruments

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Natural PFC LED Lighting Driver Controller

1 Introduction

The TPS92210EVM-647 evaluation module is a constant current TRIAC dimmable LED driver. It can drive 6 to 10 LEDs at 350 mA and is rated for an AC input of 85 V_{RMS} to 144 V_{RMS}.

2 Description

The TPS92219EVM-647 uses the TPS92210 in a Discontinuous Conduction Mode (DCM) flyback topology. The controller uses cascode configuration which allows for faster start-up times as well as eliminates the need for an external sense resistor for primary-side current sense. Additionally, the controller employs a maximum on-time modulation scheme that allows it to be used in a Power Factor Correction (PFC) circuit. This results in a compact LED driver design that achieves greater than 0.99 Power Factor (PF) driven by a single controller.

The TPS92210EVM-647 is also compatible with a wide variety of TRIAC dimmers. Secondary-side feedback responds to the conduction time of the sinusoidal wave, as governed by the TRIAC, and appropriately lowers the LED current to dim the LEDs. The secondary side also includes an adaptive supplemental load that sinks current when LED current becomes too low, therefore ensuring conduction of the TRIAC during very low dimming.

2.1 Typical Applications

- Commercial/Household LED Lighting

2.2 Features

- Single Stage Power Factor Correction (PF greater than 0.99)
- TRIAC Dimming to Zero LED Current
- Test Points for Output Voltage/Current
- Cascoded Configuration for Fully Integrated Current Control (with no external sense resistor)

3 Electrical Performance Specifications

Table 1. TPS92210EVM-647 Electrical Performance Specifications

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input Characteristics					
Voltage range		85		144	VAC
Maximum input current			142		mA
Output Characteristics					
Output voltage, VOUT		19		32	V
Output load current, IOUT		330	350	370	mA
Output current ripple	At VIN = 120 VAC		108		mA_{PP}
Output over voltage			36		V
Systems Characteristics					
Switching frequency			~115		kHz
Peak efficiency			84.9%		
Full load efficiency	At VIN = 120 VAC		84%		
Power Factor, PF			> 0.99		

4 Schematic

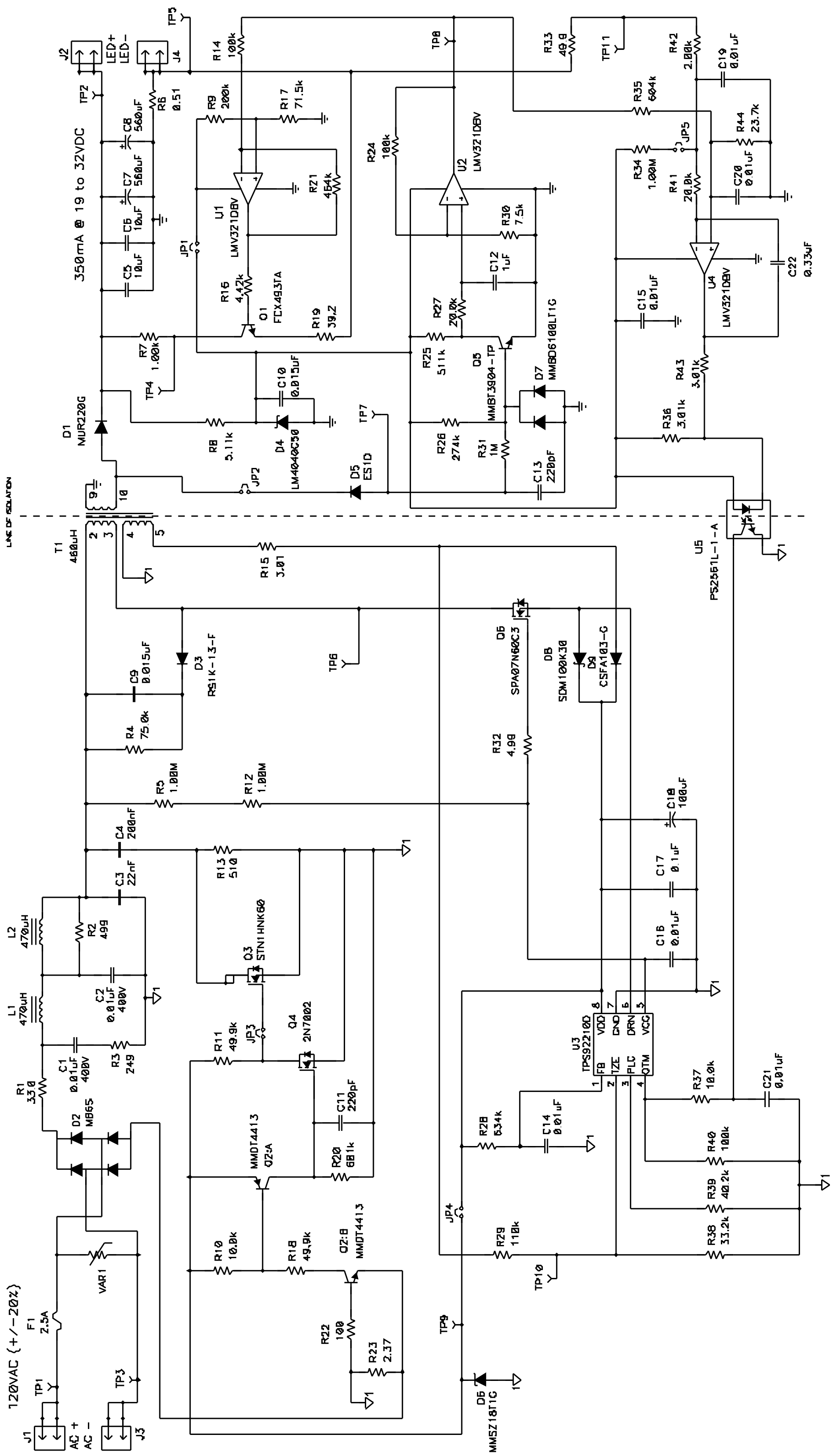

Figure 1. Schematic

5 Test Setup

5.1 Test Equipment

- **Voltage Source:** 150 V_{RMS} AC source capable of at least 12 W
- **Multimeters:** 4 voltmeters
- **Network Analyzer:** To measure loop response (phase/magnitude measurements)
- **Output Load:** 9 LEDs in series (Vf = 3.5 V at 350 mA per LED) or 80-Ω, 12-W resistor
- **Oscilloscope:** 4 channel 100 MHz, high voltage probe rated for at least 600 V
- **Recommended Wire Gauge:** 18 AWG

5.2 Recommended Test Setup

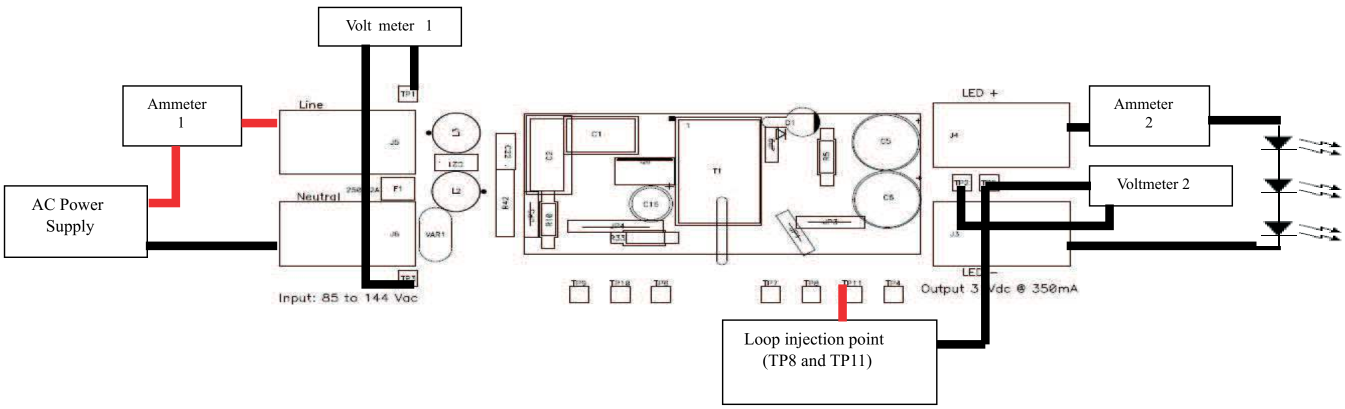

Figure 2. Recommended Test Setup

5.3 List of Test Points

Table 2. Test Point Functions

TEST POINTS	NAME	DESCRIPTION
TP1	Input AC +	AC line input
TP2	LED +	LED output
TP3	Input AC -	AC line input
TP4	Dummy load	Dummy load test point
TP5	LED -	LED return point
TP6	Switch node	Flyback switch node
TP7	N/A	Recreated primary side sinusoidal voltage
TP8	TRIAC conduction angle	Scaled TRIAC conduction angle
TP9	VDD	VDD of TPS92210
TP10	TZE	Transformer zero energy detection
TP11	Loop response	Loop injection point for phase/gain measurement

6 Test Procedure

CAUTION

High voltages exist on this EVM. Please handle with care. Do not touch EVM when powered.

An external load MUST be used to power up this EVM. No load on the output will trigger the over-voltage protection and shut down the EVM.

6.1 Line Regulation and Efficiency Measurement Procedure

1. Connect EVM per Figure 2 above. An external LED load must be used to start up the EVM. (A frequency analyzer is not required for this procedure).
2. Set AC source to 85 V_{RMS}.
3. Turn on AC source.
4. Record output voltage reading from Voltmeter 2 and output current reading from Ammeter 2 and input voltage reading from Voltmeter 1 and Ammeter 1.
5. Increase output voltage by 5 V_{RMS}.
6. Repeat steps 4 and 5 until you reach 144 V_{RMS}.
7. Turn off the AC source.

6.2 TRIAC Dimmer Measurement Procedure

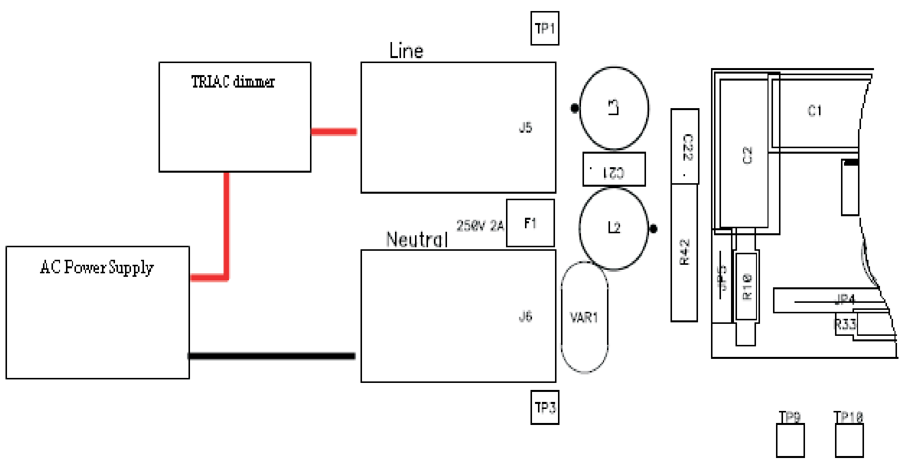

Figure 3. TRIAC Dimmer Test Setup

1. Set up the EVM per Figure 2.
2. Add TRIAC dimmer to the input per Figure 3.
3. Set AC source to 120 V_{RMS}.
4. Set TRIAC to maximum output.
5. Measure output current.
6. Slowly slide TRIAC dimmer to minimum output.
7. Observe output current reduces.

6.3 Equipment Shutdown

1. Turn off the AC source.

7 Performance Data and Typical Characteristic Curves

Figure 4 through Figure 15 present typical performance curves for TPS92210EVM-647.

7.1 Efficiency

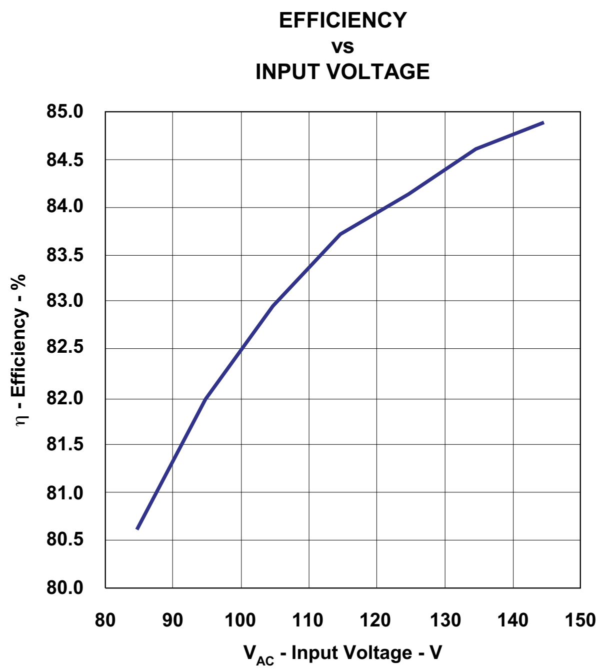

Figure 4. Efficiency

7.2 Line Regulation

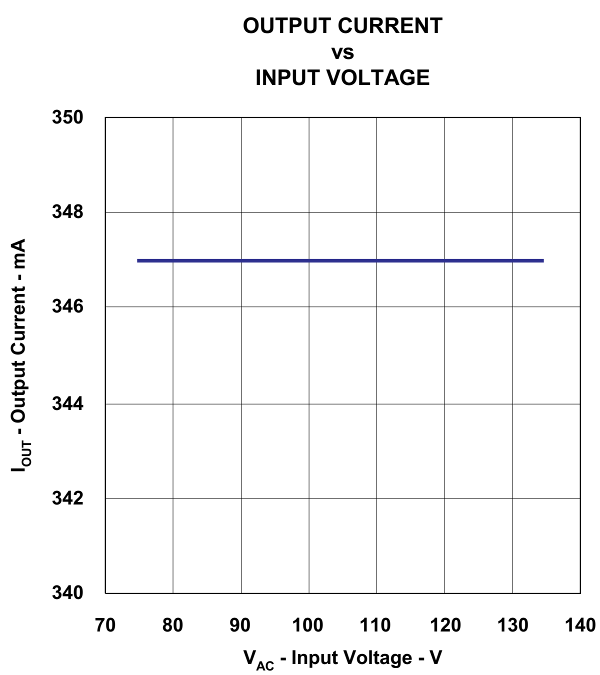

Figure 5. Line Regulation

7.3 Power Factor

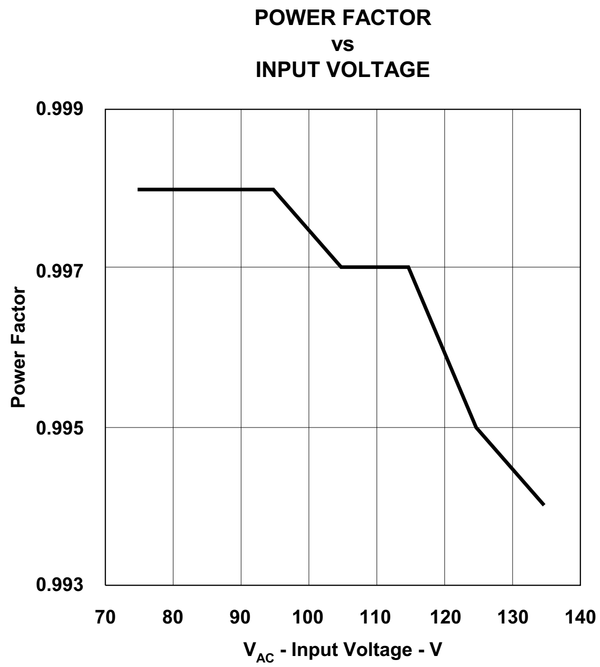

Figure 6. Power Factor Performance

7.4 Load Regulation

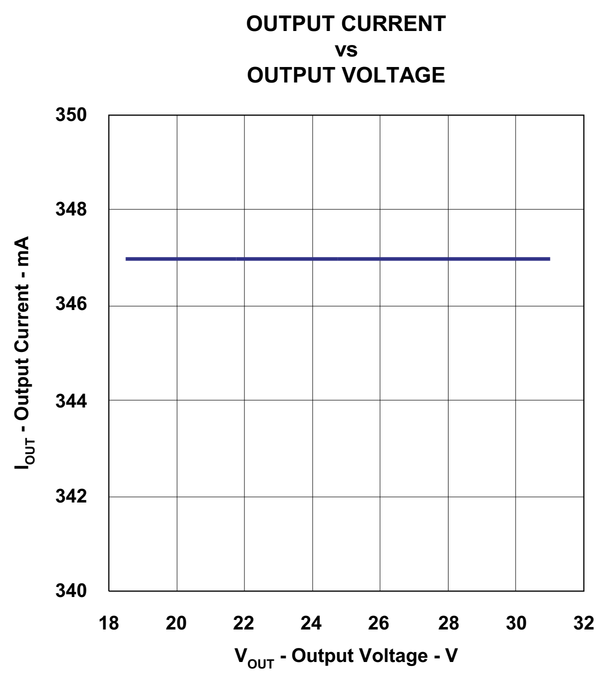

Figure 7. Load Regulation

7.5 Bode Plot

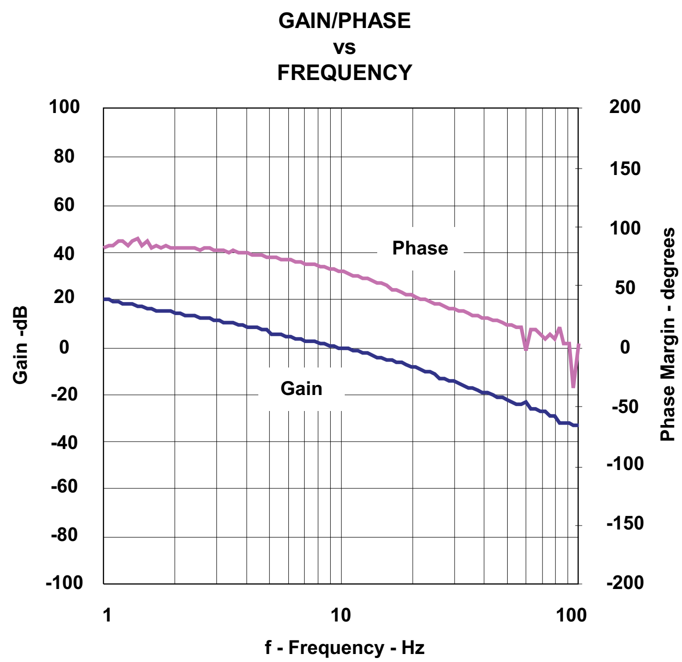

Figure 8. Loop Response Gain and Phase (crossover: 10 Hz, 63 degrees phase margin)

7.6 TRIAC Dimmer Performance

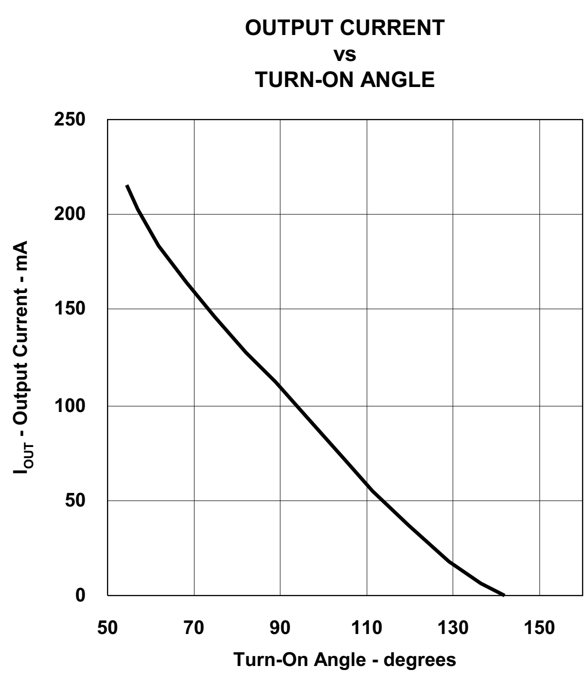

Figure 9. TRIAC Dimmer Performance

7.7 Output Ripple

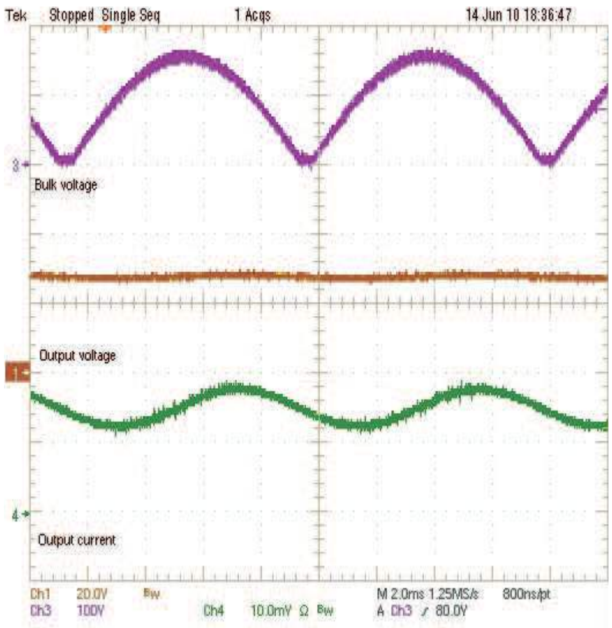

Figure 10. Output Ripple (CH4 – 200 mA/10 mV)

7.8 Switch Node Voltage

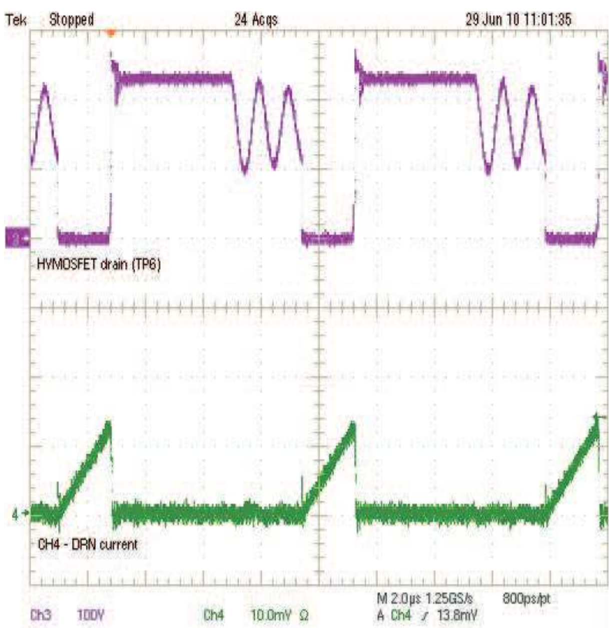

Figure 11. Switching-Node Waveform (CH4 – 500 mA/10 mV)

7.9 Turn-On Waveform

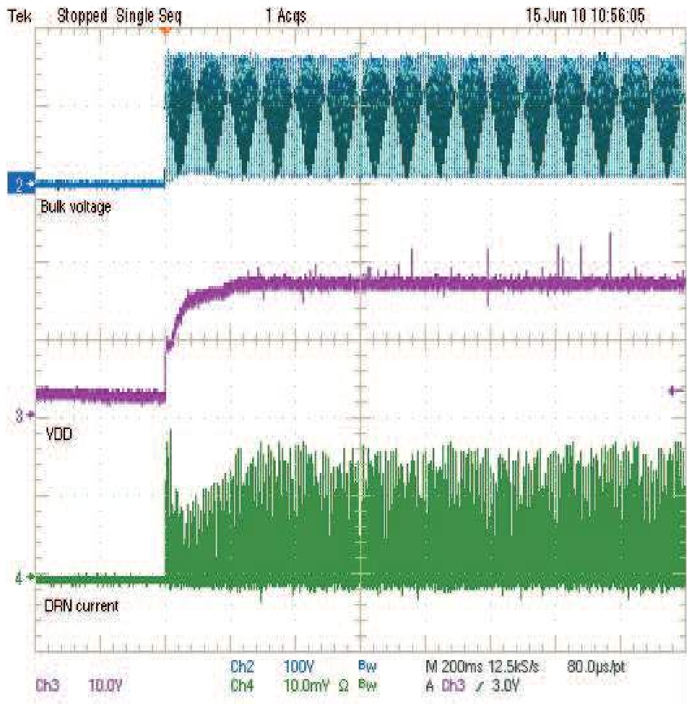

Figure 12. Turn-On Waveform (CH4 – 500 mA/10 mV)

7.10 Turn-Off Waveform

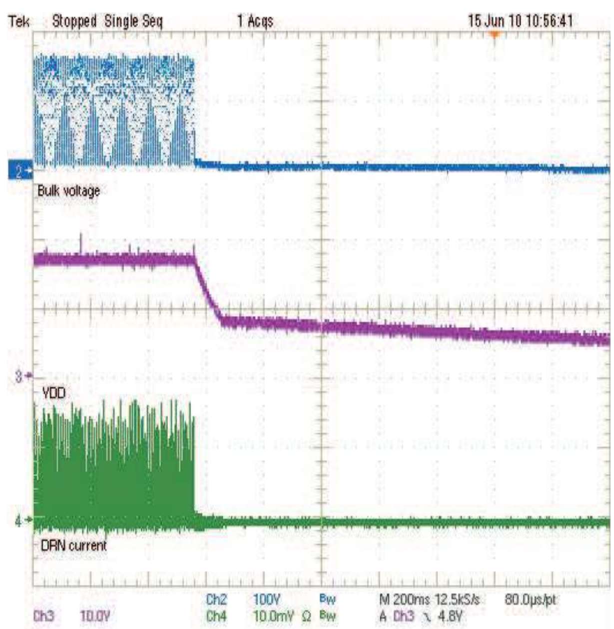

Figure 13. Turn-Off Waveform (CH4 – 500 mA/10 mV)

7.11 TRIAC Dimming Waveform

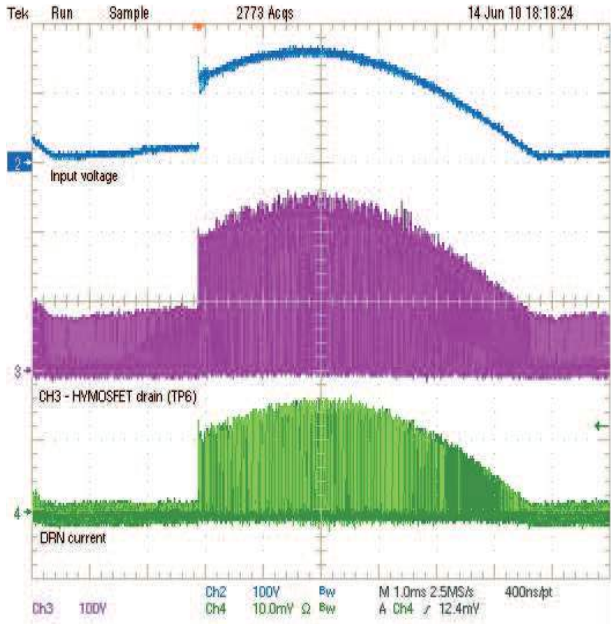

Figure 14. TRIAC triggering at 100% (CH4 – 500 mA/10 mV)

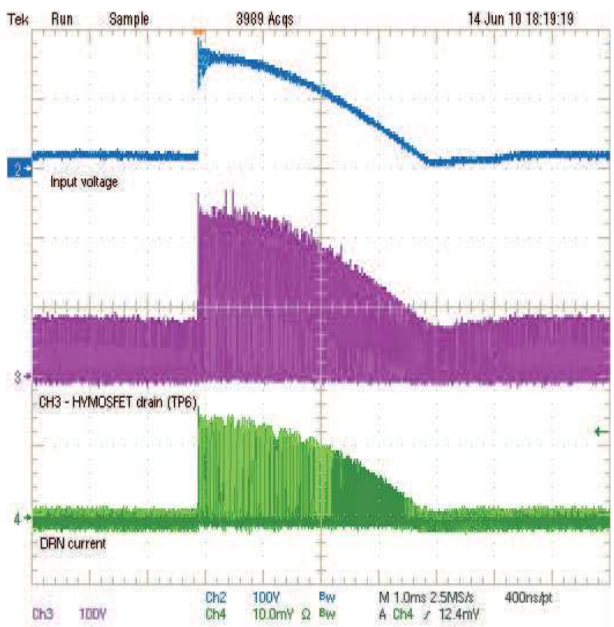

Figure 15. TRIAC Triggering at 50% (CH4 – 500 mA/10 mV)

8 EVM Assembly Drawing and PCB Layout

The following figures (Figure 16 through Figure 19) show the design of the TPS92210EVM-647 printed circuit board.

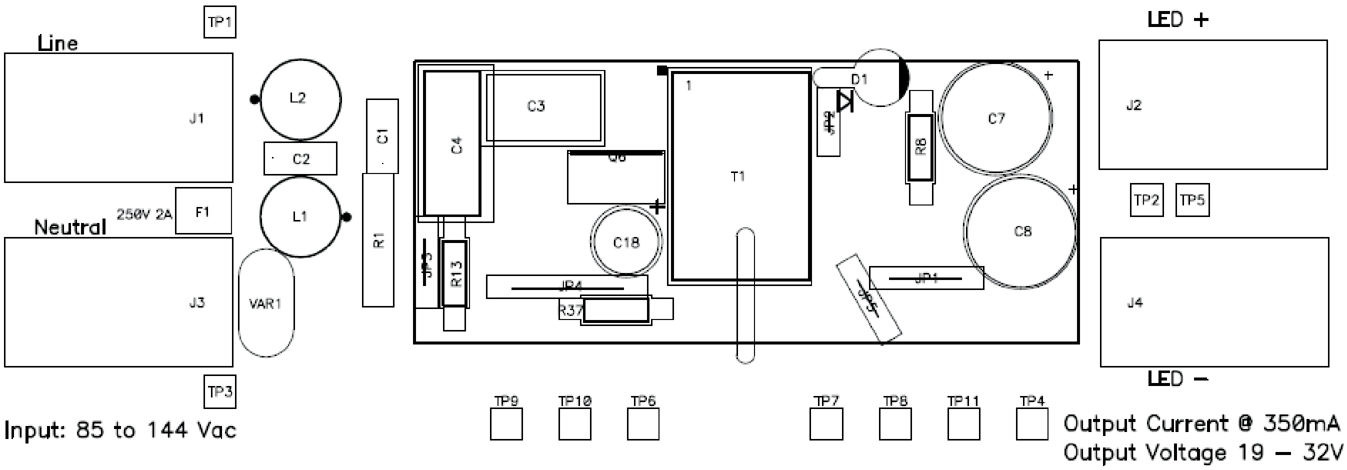

Figure 16. Top Layer Assembly Drawing (top view)

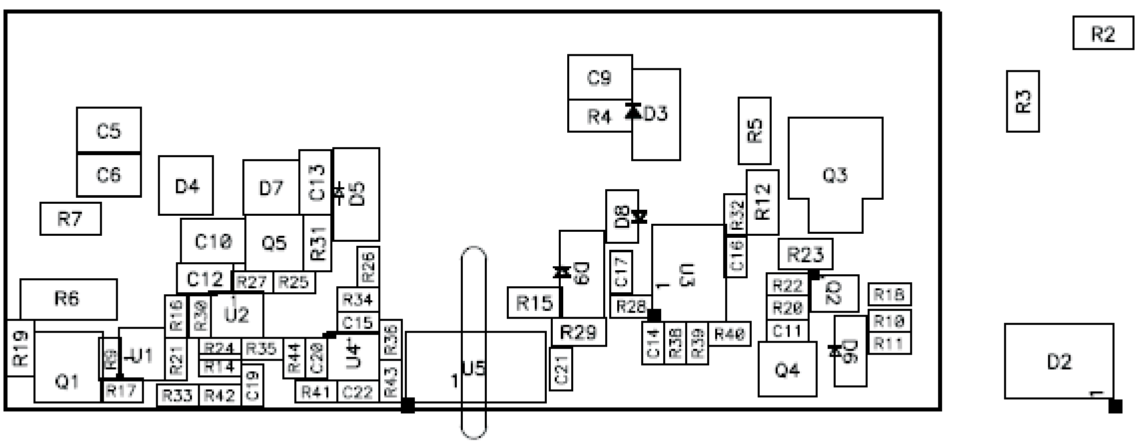

Figure 17. Bottom Assembly Drawing (bottom view)

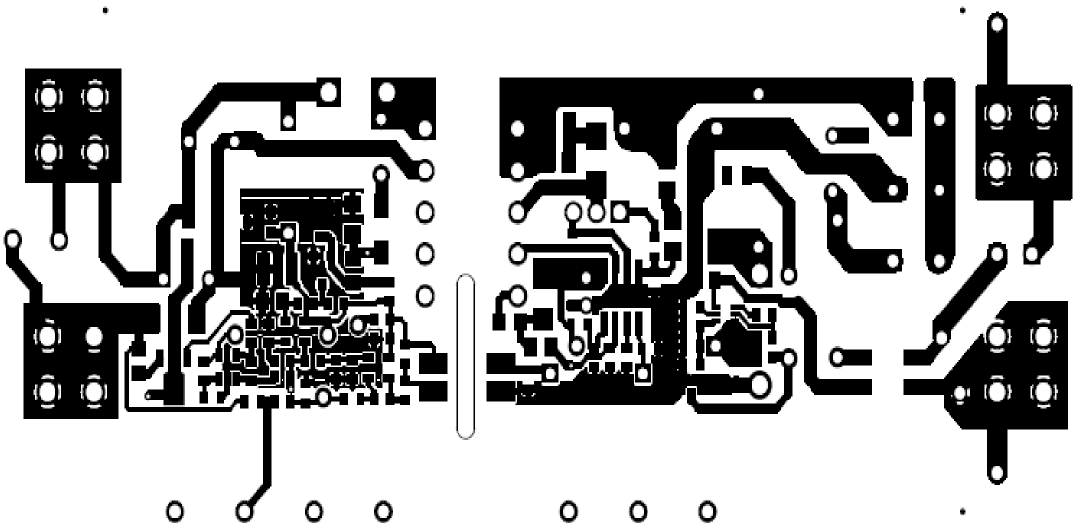

Figure 18. Bottom Copper (bottom view)

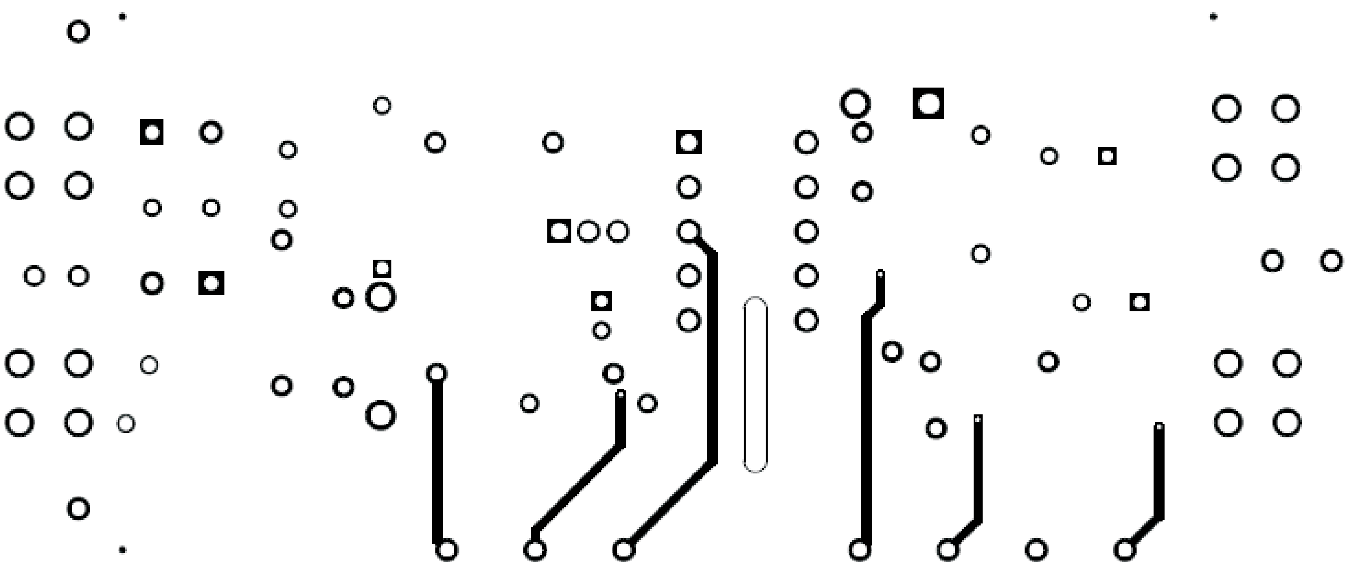

Figure 19. Internal Layer 1 (top view)

9 List of Materials

Table 3. TPS92210EVM-647 List of Materials

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
2	C1, C2	Capacitor, metal polyester, 0.01 µF, 400 V, 125°C, ±5%, 3.0 mm x 7.2 mm	B32529C6103J	Epcos
1	C3	Capacitor, polyester film, 22 nF, 630 V, ±10%, 0.260 inch x 0.470 inch	ECQ-E6223KZ	Panasonic
1	C4	Capacitor, polypropylene film, 200 nF, 630 V, ±10%, 0.256 inch x 0.650 inch	ECW-F6Z204JL	Panasonic
2	C5, C6	Capacitor, ceramic, 10 µF, 50 V, X7R, ±10%, 1210	Std	Std
2	C7, C8	Capacitor, alumninum electrolytic, 560 µF, 50 V, ±20%, 12.5 mm x 25 mm	UPW1H561MHD	Rubycon/Nichicon
2	C9, C10	Capacitor, ceramic, 0.015 µF, 100 V, C0G, ±5%, 1210	Std	Std
1	C11	Capacitor, ceramic, 220 pF, 50 V, X7R, ±10%, 0603	Std	Std
1	C12	Capacitor, ceramic, 1.0 µF, 10 V, X7R, ±10%, 0805	Std	Std
1	C13	Capacitor, ceramic, 220 pF, 100 V, 125°C, ±5%, 1206	12061A221JAT2A	AVX
6	C14, C15, C16, C19, C20, C21	Capacitor, ceramic, 0.01 µF, 50 V, X7R, ±10%, 0603	Std	Std
1	C17	Capacitor, ceramic, 0.1 µF, 25 V, X7R, ±10%, 0603	Std	Std
1	C18	Capacitor, aluminum, 100 µF, 25 V, ±20%, 0.200 inch	EEU-FC1E101S	Panasonic
1	C22	Capacitor, Ceramic, 0.33 µF, 16 V, X7R, ±10%, 0603	Std	Std
1	D1	Diode, utrafast, power rectifier, 2 A, 200 V, DO-201AD	MUR220G	On Semiconductor
1	D2	Diode, bridge rectifier, 0.5 A, 600 V, SO-4	MB6S	Fairchild
1	D3	Diode, ultra fast rectifier, 1 A, 800 V, SMA	RS1K-13-F	Diodes, Inc.
1	D4	Diode, shunt voltage reference, SOT-23	LM4040C50	Texas Instruments
1	D5	Diode, super fast rectifier, 1 A, 200 V, 0.220 inch x 0.115 inch	ES1D	Diodes, Inc.
1	D6	Diode, Zener, 18V, 500 mW, SOD-123	MMSZ18T1G	On Semiconductor
1	D7	Diode, switching, dual, 200 mA, 70 V, SOT-23	MMBD6100LT1G	On Semiconductor
1	D8	Diode, Schottky, 1 A, 30 V, SOD-323	SDM100K30	Diodes, Inc
1	D9	Diode, ultra fast, 1 A, 200 V, SMA	CSFA103-G	On Semiconductor
1	F1	Fuse, axial, fast acting, 2.5 A, 250 V, 0.160 inch x 0.400 inch	026302.5WRT1-L	Littelfuse
2	L1, L2	Inductor, radial, 470 µH, 310 mA, ±10%, 70°C, 0.315 inch Dia.	22R474C	Murata
1	Q1	Bipolar, NPN, 100 V, 1 A, SOT-89	FCX493TA	Zetex
1	Q2	Bipolar, complementary, NPN/PNP 60/40 V, 600 mA, SOT-363	MMDT4413-7-F	Diodes, Inc.
1	Q3	MOSFET, N-channel, 600 V, 0.4 A, 8.5 Ω, SOT-223	STN1HNK60	STMicroelectronics
1	Q4	MOSFET, N-channel, 60 V, 115 mA, SOT-23	2N7002	Std
1	Q5	Bipolar, NPN, 40 V, 200 mA, 350 mW, SOT-23	MMBT3904-TP	Micro Commercial Co
1	Q6	MOSFET, N-channel, 650 V, 7.3 A, 0.6 W, TO-220	SPA07N60C3	Infineon
1	R1	Resistor, metal oxide, 33 Ω, 1 W, ±5%, 2.8 mm x 9.00 mm	ERG-1SJ330	Panasonic
1	R2	Resistor, chip, 499 Ω, 1/4 W, ±1%, 1206	Std	Std
1	R3	Resistor, chip, 249 Ω, 1/4 W, ±1%, 1206	Std	Std
1	R4	Resistor, chip, 75.0 kΩ, 1/4 W, ±1%, 1206	Std	Std
2	R5, R12	Resistor, chip, 1.00 MΩ, 1/4 W, ±1%, 1206	Std	Std
1	R6	Resistor, chip, 0.51 Ω, 1/2 W, ±1%, 2010	Std	Std
1	R7	Resistor, chip, 1.00 kΩ, 1/4 W, ±5%, 1206	Std	Std
1	R8	Resistor, metal film, 5.11 kΩ, 1/2 W, ±1%	Std	Std
1	R9	Resistor, chip, 200 kΩ, 1/10 W, ±1%, 0603	Std	Std

Table 3. TPS92210EVM-647 List of Materials (continued)

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
1	R10	Resistor, chip, 10.0 kΩ, 1/10 W, ±1%, 0603	Std	Std
2	R11, R18	Resistor, chip, 49.9 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R13	Resistor, carbon film, 510 Ω, 1/2 W, ±5%, RN55	Std	Std
3	R14, R24, R40	Resistor, chip, 100 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R15	Resistor, chip, 3.01 Ω, 1/8 W, ±1%, 0805	Std	Std
1	R16	Resistor, chip, 4.42 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R17	Resistor, chip, 71.5 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R19	Resistor, chip, 39.2 Ω, 1/8 W, ±1%, 0805	Std	Std
1	R20	Resistor, chip, 681 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R21	Resistor, chip, 464 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R22	Resistor, chip, 100 Ω, 1/10 W, ±1%, 0603	Std	Std
1	R23	Resistor, chip, 2.37 Ω, 1/8 W, ±1%, 0805	Std	Std
1	R25	Resistor, chip, 511 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R26	Resistor, chip, 274 kΩ, 1/10 W, ±1%, 0603	Std	Std
2	R27, R41	Resistor, chip, 20.0 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R28	Resistor, chip, 634 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R29	Resistor, chip, 110 kΩ, 1/8 W, ±1%, 0805	Std	Std
1	R30	Resistor, chip, 7.5 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R31	Resistor, chip, 1 MΩ, 1/8 W, ±1%, 0805	Std	Std
1	R32	Resistor, chip, 4.99 Ω, 1/10 W, ±1%, 0603	Std	Std
1	R33	Resistor, chip, 49.9 Ω, 1/10 W, ±1%, 0603	Std	Std
1	R34	Resistor, chip, 1.00 MΩ, 1/10 W, ±1%, 0603	Std	Std
1	R35	Resistor, chip, 604 kΩ, 1/10 W, ±1%, 0603	Std	Std
2	R36, R43	Resistor, chip, 3.01 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R37	Resistor, carbon film, 10.0 kΩ, 1/2 W, ±5%, RN55	Std	Std
1	R38	Resistor, chip, 33.2 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R39	Resistor, chip, 40.2 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R42	Resistor, chip, 2.00 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	R44	Resistor, chip, 23.7 kΩ, 1/10 W, ±1%, 0603	Std	Std
1	T1	Transformer, flyback, 460 µH, ±10%, 14.40 mm x 22.30 mm	G104039LF	GCi
3	U1, U2, U4	Op-Amp Low Voltage Rail-to-Rail Output, 130 µA typical, SOT-23-5	LMV321DBV	Texas Instruments
1	U3	PFC LED Lighting Driver Controller, SO-8	TPS92210D	Texas Instruments
1	U5	Optocoupler, High Isolation Voltage, SOP4 Gull-wing	PS2561L-1-A	NEC
1	VAR1	Varistor, disk, 275 VAC, 8.5 mm diameter	S10K275E2	EPCOS

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EVM Warnings and Restrictions

It is important to operate this EVM within the input voltage range of 85 V to 144 V and the output voltage range of 19 V to 32 V .

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. 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 50° C. The EVM is designed to operate properly with certain components above 50° C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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