# Using the TPS92210EVM-613

# User's Guide

Literature Number: SLUU436A
August 2010–Revised November 2010

# Natural PFC LED Lighting Driver Controller

## 1 Introduction

The TPS92210EVM-613 evaluation module is a constant current TRIAC dimmable LED driver. It can drive 9 to 10 LEDs at 350 mA and is rated for an AC input of 184 $V_{RMS}$ to 265 $V_{RMS}$.

## 2 Description

The TPS92210EVM-613 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 max 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 0.95 power factor (PF) driven by a single controller.

The TPS92210EVM-613 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 Achieves PF Greater than 0.95
- TRIAC Dimming to Zero LED Current
- Test Points for Output Voltage/Current
- Cascoded Configuration for Fully Integrated Current Control with No External Sense Resistor



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# 3 Electrical Performance Specifications

**Table 1. Electrical Performance Specifications**

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| **Input Characteristics** | | | | | |
| Voltage range | | 184 | | 265 | $V_{AC}$ |
| Maximum input current | | | 45 | | mA |
| **Output Characteristics** | | | | | |
| Output voltage, VOUT | | 19 | | 32 | V |
| Output load current, IOUT | | 330 | 350 | 370 | mA |
| Output current ripple | At VIN = 230 $V_{AC}$ | | 127 | | mApp |
| Output over voltage | | | 36 | | V |
| **Systems Characteristics** | | | | | |
| Switching frequency | | | ~115 | | kHz |
| Peak efficiency | | | 87.3% | | |
| Full load efficiency | VIN = 230 $V_{AC}$ | | 87% | | |
| Power Factor | | | > 0.95 | | |


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# 4 Schematic

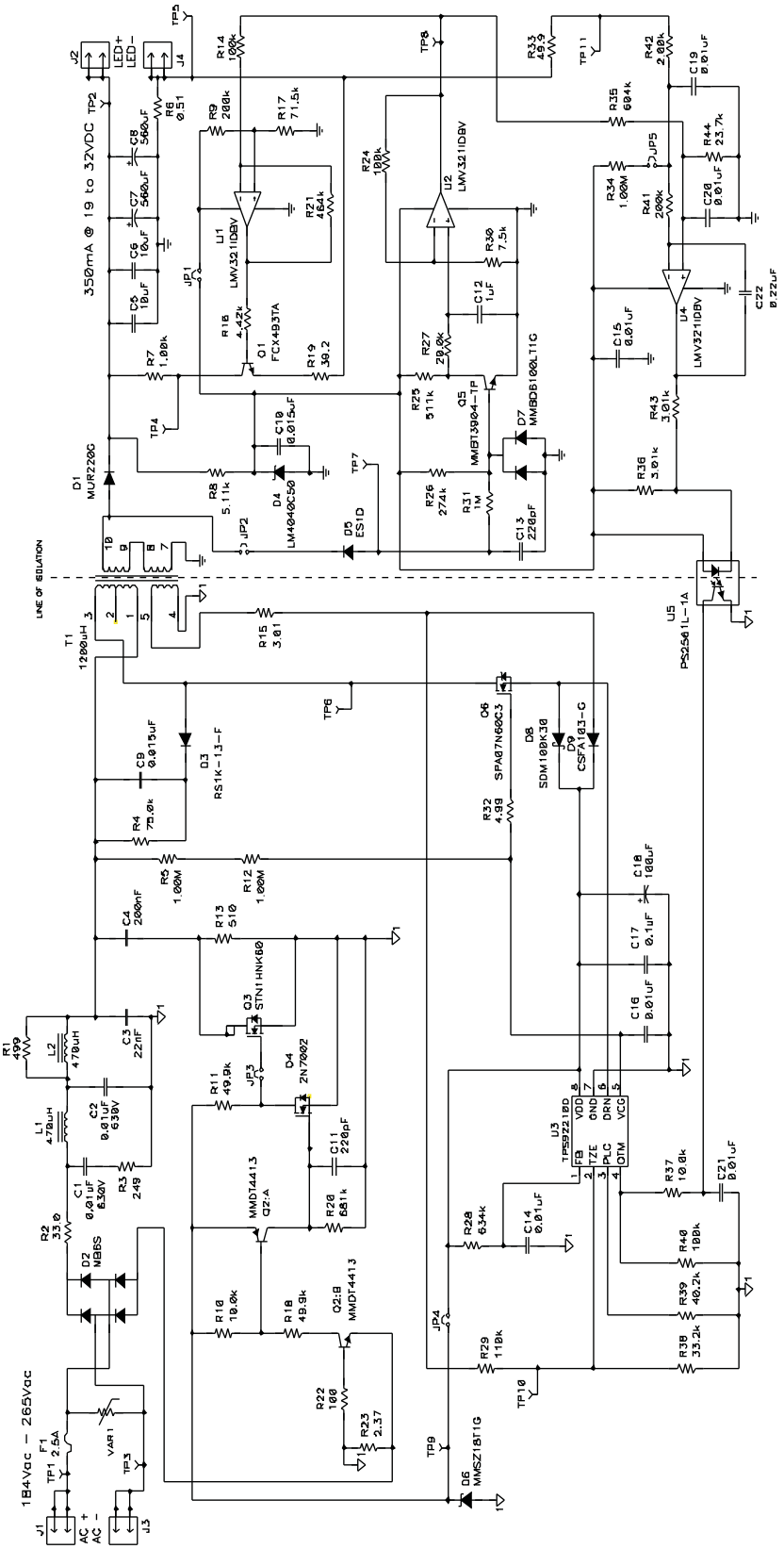



**Figure 1. Schematic**



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# 5 Test Setup

## 5.1 Test Equipment

**Voltage Source:** 265-$V_{RMS}$ 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

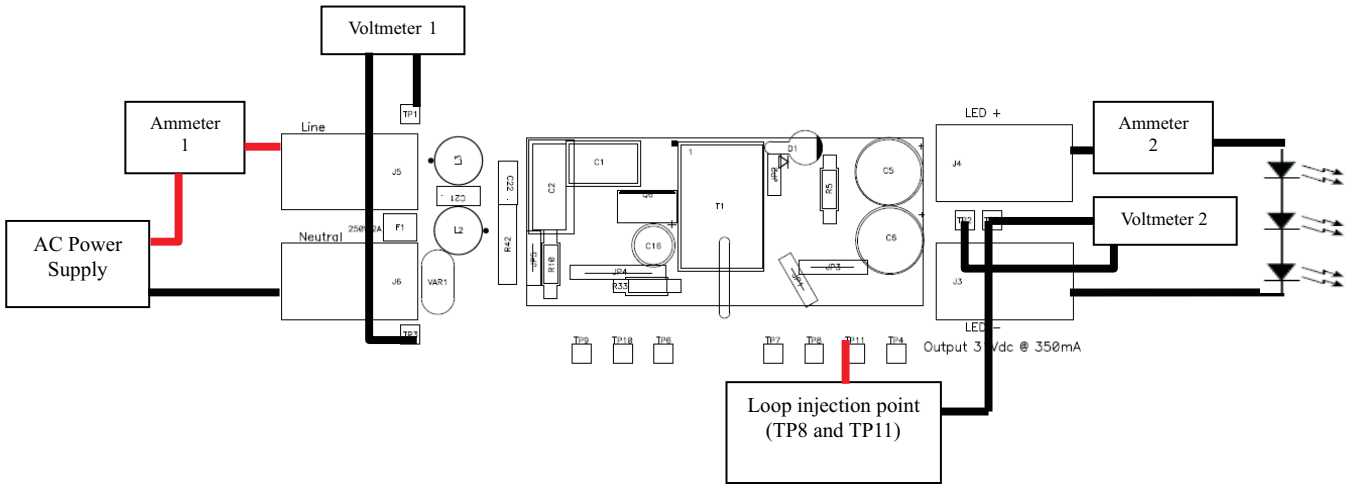



**Figure 2. Recommended Test Setup**

## 5.3 List of Test Points

**Table 2. Test Points 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 |



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# 6 Test Procedure

**CAUTION**

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.

**NOTE:** Frequency analyzer not required for this procedure.

2. Set AC source to 184 $V_{RMS}$.
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 265 $V_{RMS}$.
7. Turn off the AC source.

## 6.2 TRIAC Dimmer Measurement Procedure

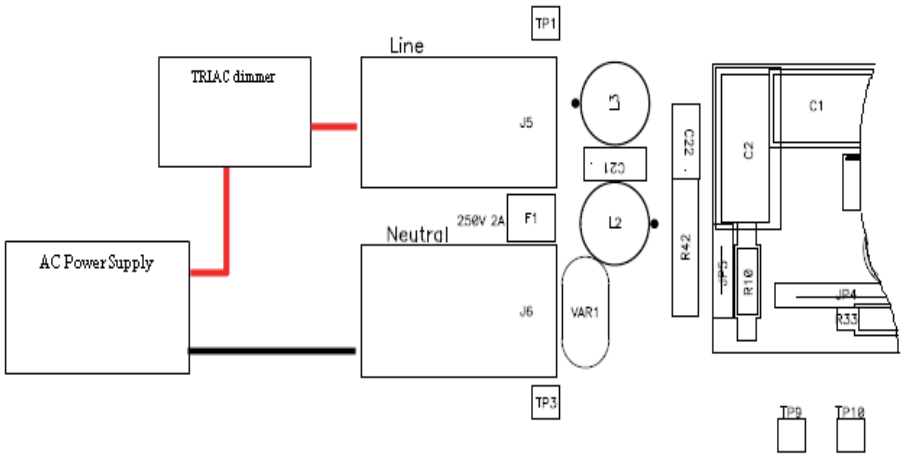



**Figure 3. TRIAC Dimmer Test Setup**

1. Set up the EVM per Figure 2.
2. Add TRIAC dimmer to the input per Figure 3.
3. Set AC source to 230 $V_{RMS}$ (or 220 $V_{RMS}$ depending on the TRIAC).
4. Set line frequency to 50 Hz.
5. Set TRIAC to maximum output.
6. Measure output current.
7. Slowly slide TRIAC dimmer to minimum output.
8. Observe output current reduces.

## 6.3 Equipment Shutdown

1. Turn off the AC source.



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# 7 Performance Data and Typical Characteristic Curves

Figure 4 through Figure 15 present typical performance curves for TPS92210EVM-613.

## 7.1 Efficiency

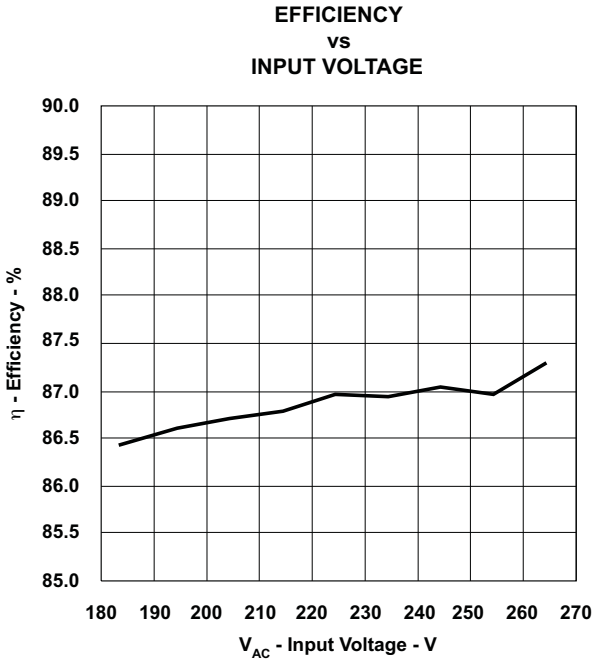



**Figure 4. Efficiency**

## 7.2 Line Regulation

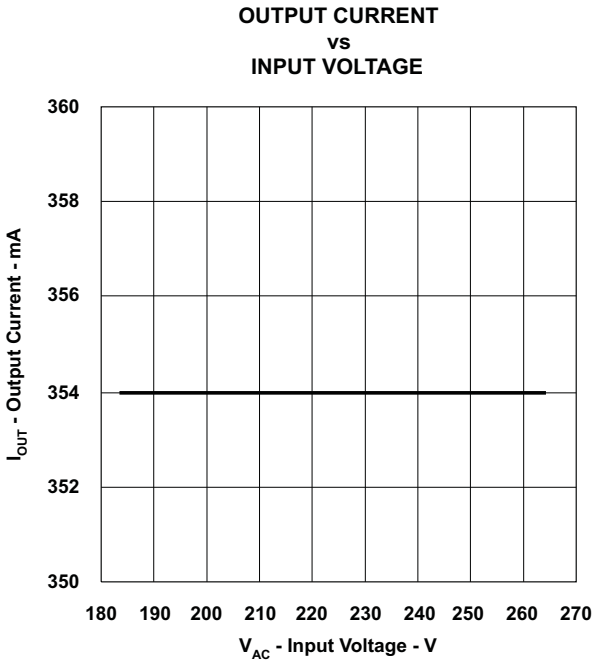



**Figure 5. Line Regulation**



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## 7.3 Power Factor

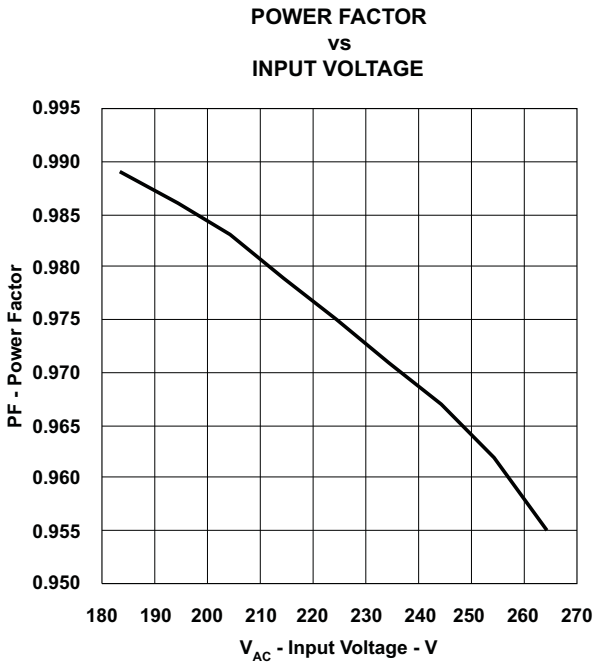



**Figure 6. Power Factor Performance**

## 7.4 Load Regulation

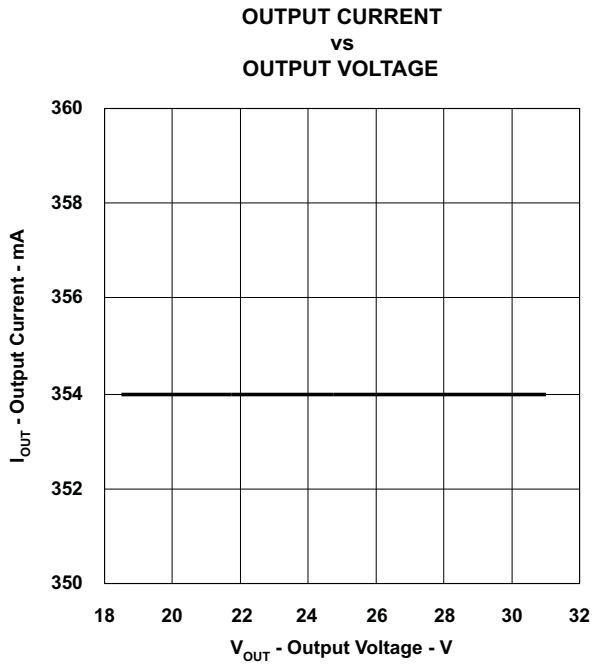



**Figure 7. Load Regulation**



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## 7.5 Bode Plot

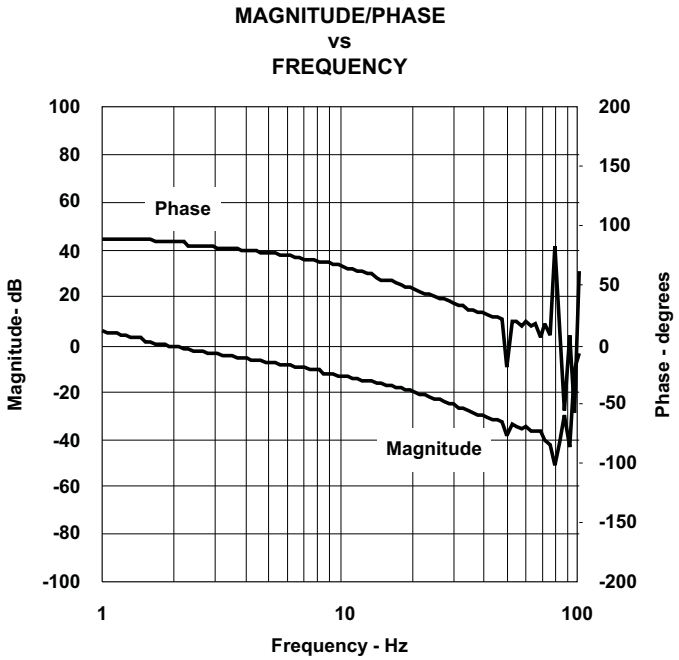



**Figure 8. Loop Response Gain and Phase (crossover: 1.8 Hz, 86 degrees phase margin)**

## 7.6 TRIAC Dimmer Performance

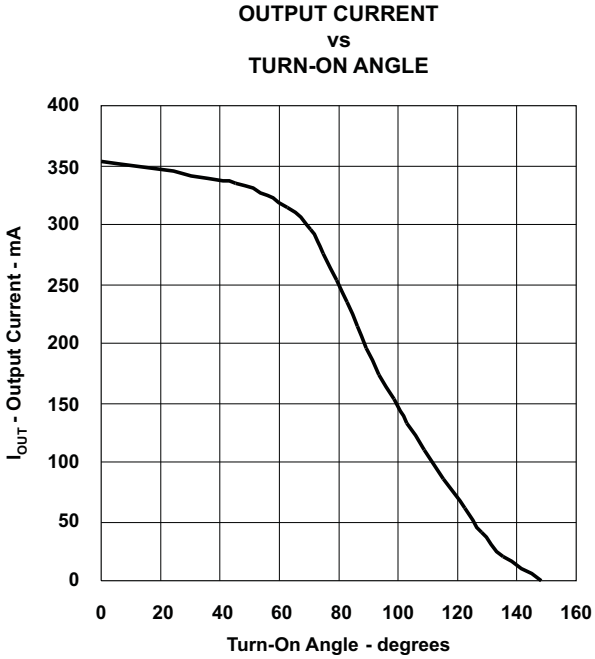



**Figure 9. TRIAC Dimmer Performance**


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## 7.7 Output Ripple

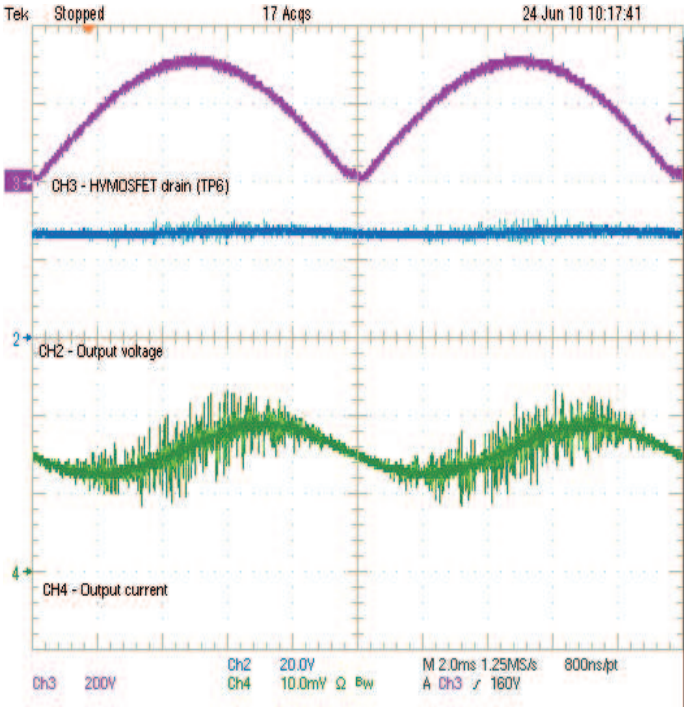



**Figure 10. Output Ripple (CH4 – 200 mA/10 mV)**

## 7.8 Switch-Node Voltage

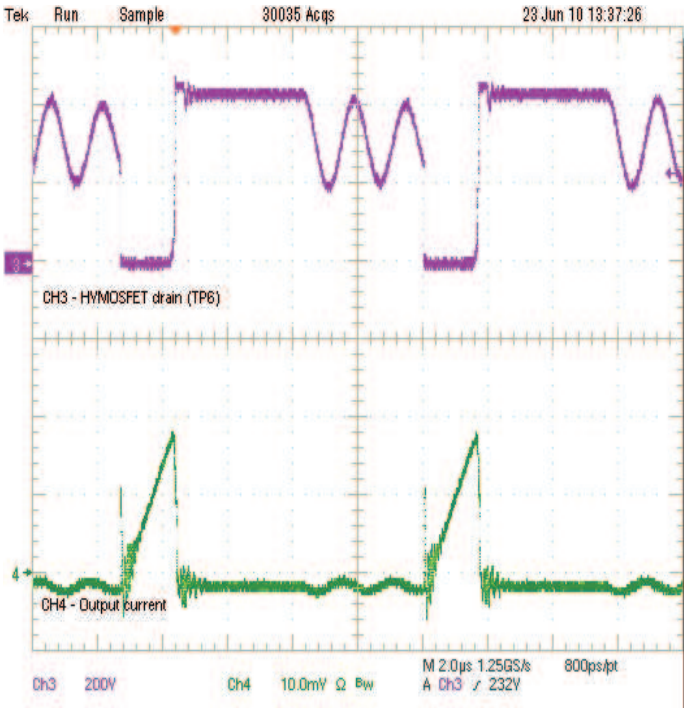



**Figure 11. Switching-Node Waveform (CH4 – 200 mA/10 mV)**



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## 7.9 Turn On Waveform

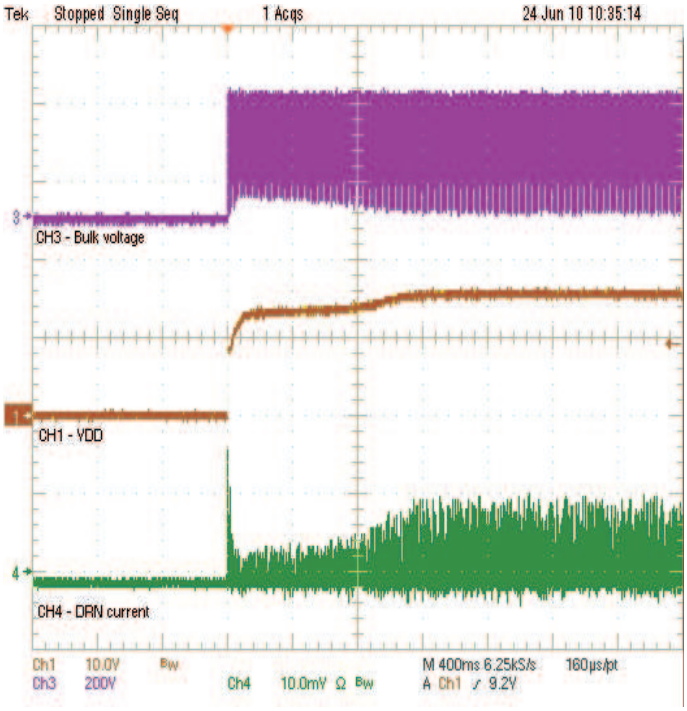



**Figure 12. Turn-On Waveform (CH4 – 500 mA/10 mV)**

## 7.10 Turn Off Waveform

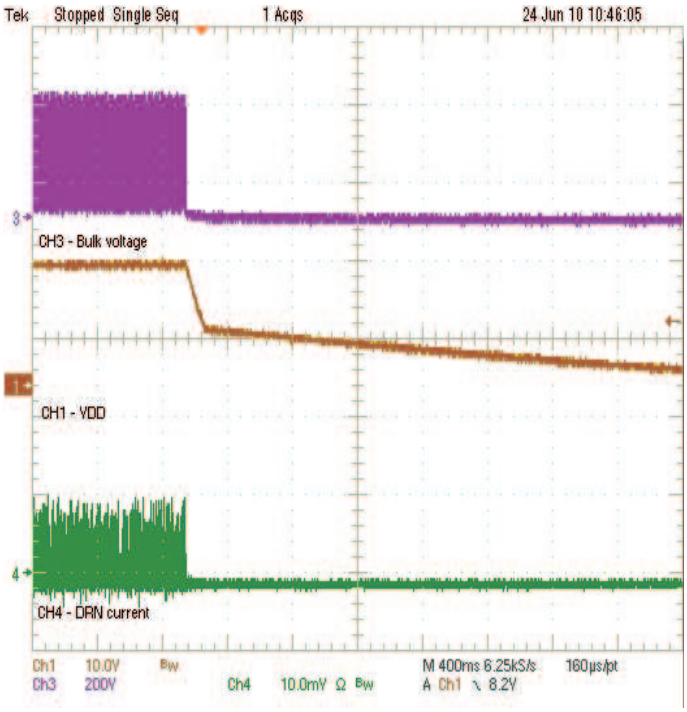



**Figure 13. Turn-Off Waveform (CH4 – 500 mA/10 mV)**


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## 7.11 TRIAC Dimming Waveform

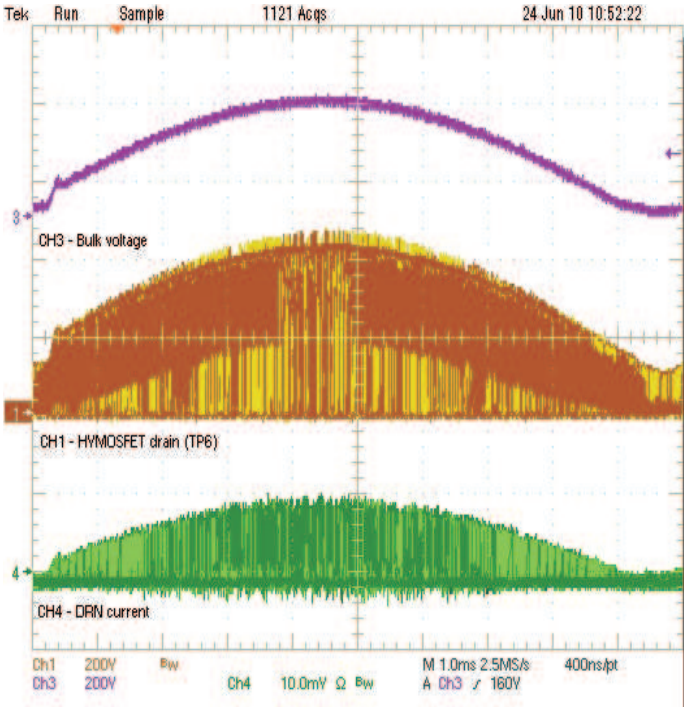



**Figure 14. TRIAC Triggering at 100% (CH4 – 500 mA/10 mV)**

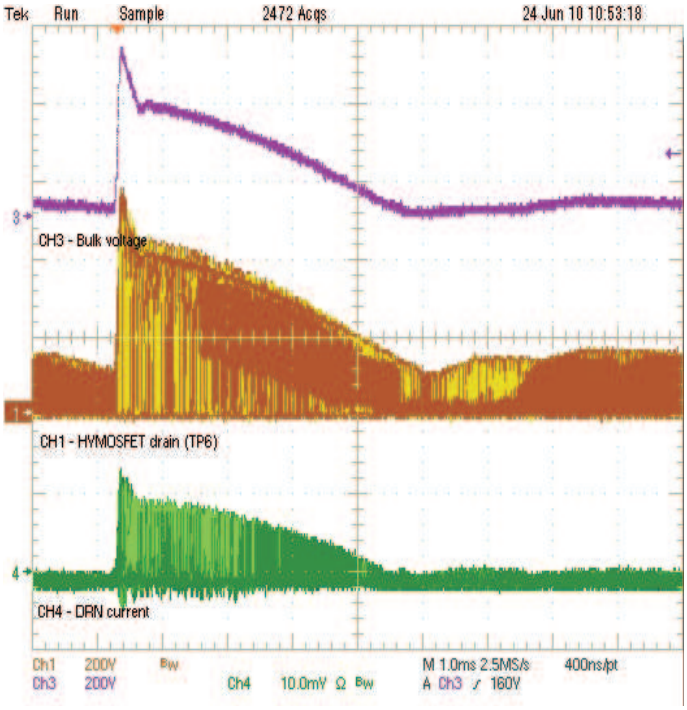



**Figure 15. TRIAC Triggering at 50% (CH4 – 500 mA/10 mV)**



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## 8 EVM Assembly Drawing and PCB layout

The following figures (Figure 16 through Figure 19) show the design of the TPS92210EVM-613 printed circuit board.

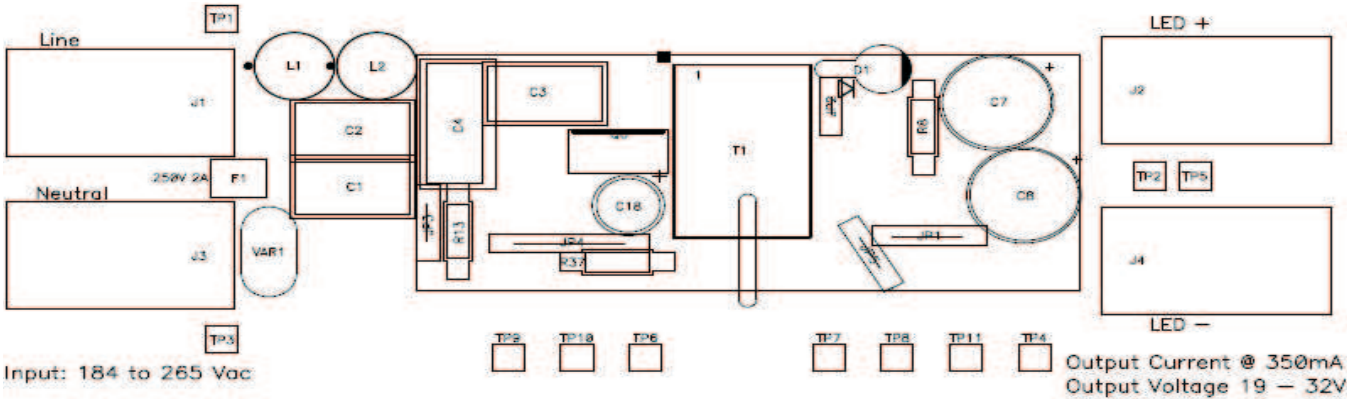



**Figure 16. Top Layer Assembly Drawing (top view)**

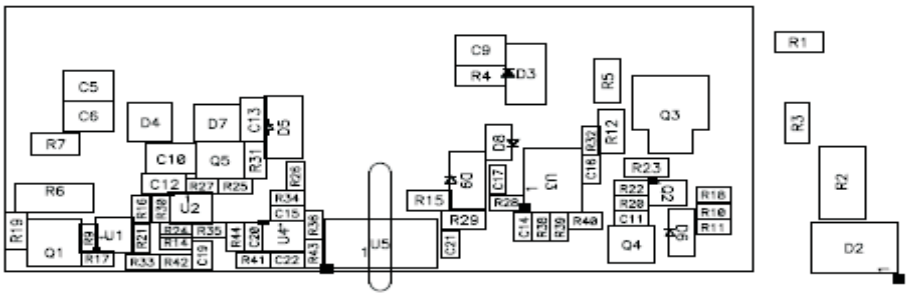


**Figure 17. Bottom Assembly Drawing (bottom view)**


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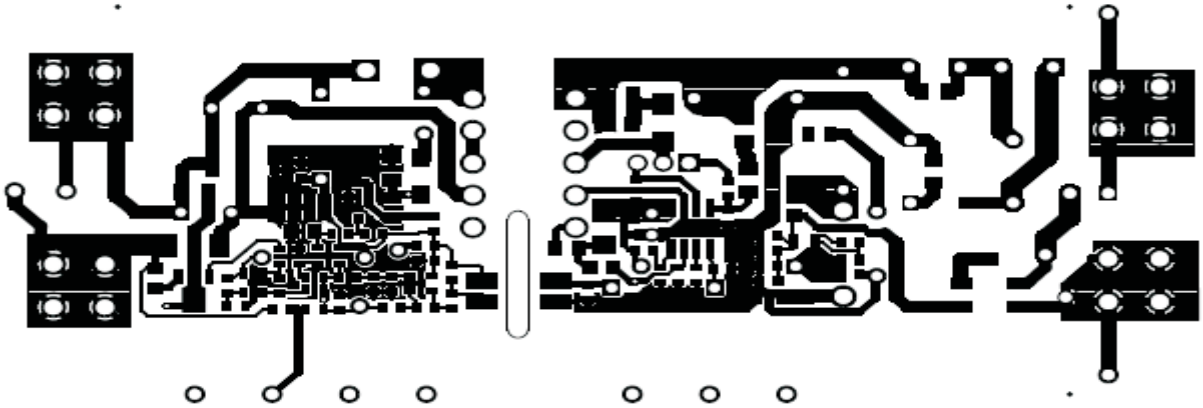


**Figure 18. Bottom Copper (bottom view)**

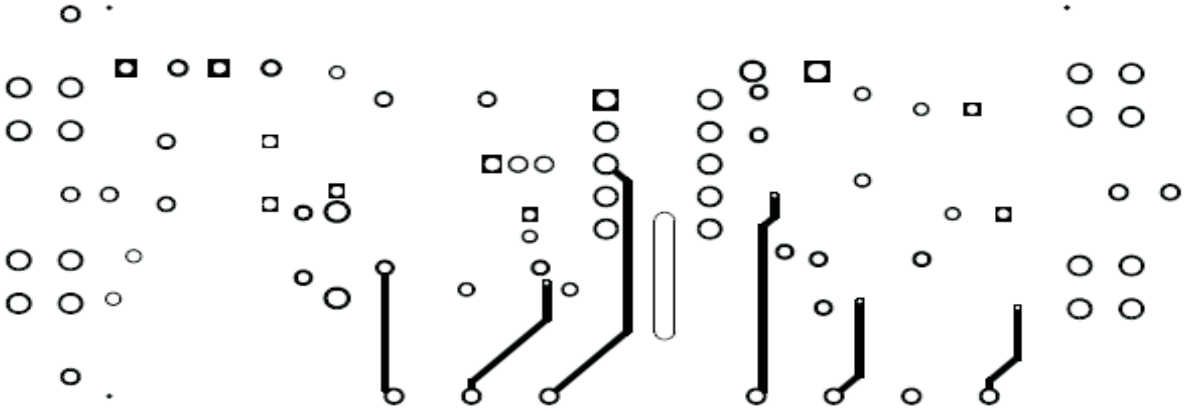


**Figure 19. Internal Layer 1 (top view)**



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## 9 List of Materials

The EVM components list according to the schematic shown in Figure 1

**Table 3. List of Materials**

| COUNT | REFDES | DESCRIPTION | PART NUMBER | MFR |
|---|---|---|---|---|
| 2 | C1, C2 | Capacitor, metal polyester, 0.01 µF, 630 V, 85°C, +/-10%, 12 mm x 4.5 mm | ECQ-E6103KF | Panasonic |
| 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-F6204JL | 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, ±5%, 1210 | GRM3291X2A222JZ01 | Murata |
| 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, 0.22 µF, 25 V, X7R, ±10%, 0603 | Std | Std |
| 1 | D1 | Diode, utrafast, power rectifier, 1 A, 100 V, DO-201AD | MUR220RLG | 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, 1A, 200V, 0.220 inch x 0.115 inch | ES1D | Diodes, Inc. |
| 1 | D6 | Diode, Zener, 18 V, 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, 250V, 0.160 x 0.400 inch | 026302.5WRT1-L | Littelfuse |
| 2 | L1, L2 | Inductor, radial, 470 µH, 310 mA, +/-10%, 70°C, 0.315 inch Diameter | 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 W, 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, chip, 499 Ω, 1/4 W, ±1%, 1206 | Std | Std |
| 1 | R2 | Resistor, metal oxide, 33 Ω, 1 W, ±5%, 2512 | ERG-1SJ330 | Panasonic |
| 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%, RN55 | Std | Std |


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**Table 3. List of Materials (continued)**

| COUNT | REFDES | DESCRIPTION | PART NUMBER | MFR |
|---|---|---|---|---|
| 2 | R9, R41 | Resistor, chip, 200 kΩ, 1/10 W, ±1%, 0603 | Std | Std |
| 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 |
| 1 | R27 | 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, 1.0 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, 1200 µH, ±10%, 0.567 inch x 0.876 inch | 750811145 | Wurth Midcom |
| 3 | U1, U2, U4 | Op-Amp Low Voltage Rail-to-Rail Output, 130 µA Typical, SOT-23-5 | LMV321IDBVR | 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, 220 V, 8.5 mm Dia. | ERZ-V07D221 | Panansonic |



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## EVM Warnings and Restrictions

It is important to operate this EVM within the input voltage range of 184 VAC to 265 VAC and the output voltage range of 19 VDC to 32 VDC .

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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