User's Guide
SLUU523–July 2011

Using the TPS92070EVM-648 Integrated Dimming LED Lighting Driver Converter for 230 VAC Input

The TPS92070EVM-648 evaluation module (EVM) is a low power isolated flyback converter that provides 5 on-board LEDs with 370 mA of drive current from a nominal 230 VAC input. This EVM is designed to demonstrate the TPS92070 in a typical application where LEDs can be used for general illumination applications that require dimming.

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1 Description

This evaluation module uses the TPS92070 High Efficiency Integrated Dimming LED Lighting Driver Controller (TI Literature Number SLUSAN1) in a low power offline flyback converter to provide 370 mA to the on-board LED load. The input accepts a nominal 50 Hz, 230 VAC input voltage. The TPS92070EVM-648 is designed to be used with a leading edge triac dimmer switch in series with the input voltage to control the lumen output of the LEDs. The integrated dimming interface circuit on the TPS92070 provides exponentially controlled light output based on the external dimmer position.

This user's guide provides the schematic, component list, assembly drawing, and test set up necessary to evaluate the TPS92070 in an AC input LED lighting application. To use an input voltage greater than 240 VAC, it is recommended the user change the fuse to one rated for at least 300 V at 1 A.

1.1 Typical Applications

The TPS92070 is suited for use in low power lighting applications such as:

- LED light bulb replacement
- LED luminaires
- LED down-lights
- LED wall washers

1.2 Features

The TPS92070EVM-648 features include:

- 180 VAC to 240 VAC input range
- LED current regulation of 370 mA, nominal
- 6 W output at 16.5 V
- Advanced integrated dimming interface
- Exponential dimming profile
- Programmable minimum LED Current
- Valley switching and DCM operation
- Leading edge dimmer detection
- Valley fill power factor correction
- Cycle by cycle current limit protection

2 Electrical Performance Specifications

Table 1. TPS92070EVM-648 Electrical Performance Specifications

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
INPUT CHARACTERISTICS						
V_{IN}	Voltage range		180	230	265	VAC
f_{LINE}	Input frequency			50		Hz
$I_{IN(MAX)}$	Input current	$V_{IN(TYP)}$, I_{LED} = full load[1]		50		mA
PF	Input power factor	$V_{IN(MAX)}$, I_{LED} = full load[1]		0.80		
OUTPUT CHARACTERISTICS						
V_{OUT}	Output voltage	$V_{IN(MIN)} \le V_{IN} \le V_{IN(MAX)}$, I_{LED} = full load[1]		16		V
I_{LED}	Output load current set point	$V_{IN(MIN)} \le V_{IN} \le V_{IN(MAX)}$, I_{LED} = full load[1]	352	370	388	mA
	Output current regulation	$V_{IN(MIN)} \le V_{IN} \le V_{IN(MAX)}$, I_{LED} = full load[1]		5%		
$I_{LED(min)}$	Minimum LED current	$V_{IN(MIN)} \le V_{IN} \le V_{IN(MAX)}$, I_{LED} = full load[1] With dimmer capable of 10% conduction angle		13		mA
	Output voltage ripple	$V_{IN(TYP)}$, I_{LED} = full load[1]		5		V_{PP}
SYSTEMS CHARACTERISTICS						
f_{SW}	Switching frequency		30		146	kHz
η	Full load efficiency	$V_{IN(TYP)}$, I_{LED} = full load[1]		83%		
T_A	Operating temperature			25		ºC

(1) Full load is 5 on-board LEDs in series.

CAUTION

High voltage levels are present on the evaluation module whenever it is energized. Proper precautions must be taken when working with the EVM. Serious injury can occur if proper safety precautions are not followed.

3 Schematic

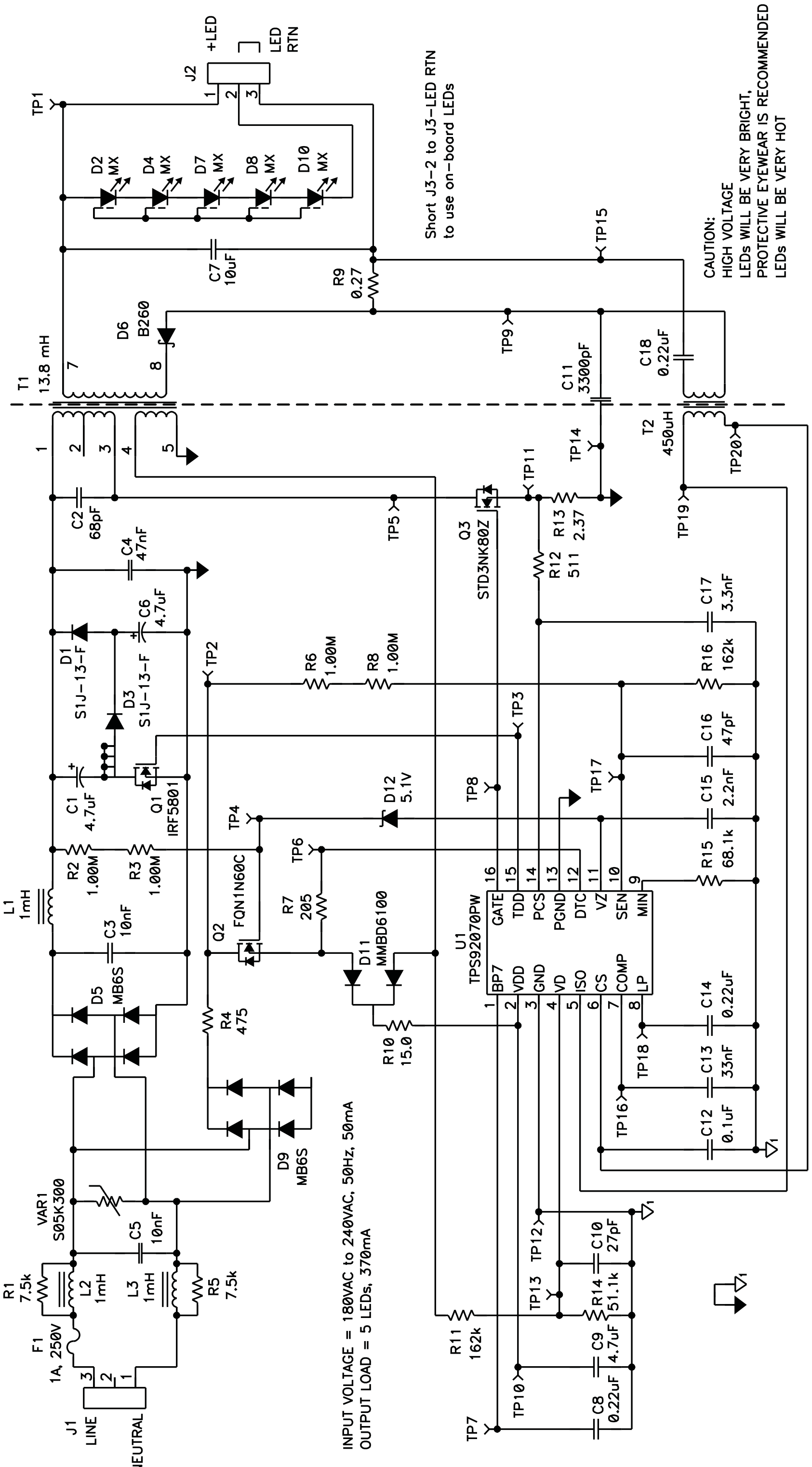


Figure 1. TPS92070EVM-648 Schematic

WARNING

High voltages that may cause injury exist on this evaluation module (EVM). Please ensure all safety procedures are followed when working on this EVM. Never leave a powered EVM unattended.

LEDs will be very bright! Shaded protective eyewear is recommended.

4 Test Setup

4.1 Test Equipment

Voltage Source: The input voltage source shall be an isolated variable AC source capable of supplying between 180 VAC and 265 VAC at no less than 10W and connected as shown in Figure 2. (example. Hewlett Packard 6813B AC Power Source)

Power meter: For accurate efficiency calculations, a power meter should be inserted between the AC source and the EVM. For highest accuracy, connect the voltage terminals of the power meter directly across the Line and Neutral terminals of the EVM. (example: Voltech PM100 Single Phase Power Analyzer)

Multimeters: Two digital multimeters are used to measure the LED voltage (DMM V_{LED}) and load current (DMM A_{LED}). (example: Fluke 45 Digital Multimeter)

Output Load: By connecting a jumper wire from J2 pin 2 to J2 pin 3 (LED RTN) the 5 Cree™ MX series white LEDs that are on the EVM may be used as the load. The EVM can also be used to drive the user's external LED load by connecting the jumper wire from J2 pin 1 (+LED) to the external 370mA, 3.2 V LEDs and return them to J2 pin 3 (LED RTN).

Oscilloscope: A 200 MHz digital oscilloscope with 4 isolated channels for differential mode measurements is recommended. Non-isolated probes may result in flickering. A high voltage probe and a current probe are also recommended. (examples: Tektronix TPS2024B Four Channel Digital Storage Oscilloscope, Tektronix P5205A High Voltage Differential Probe, Tektronix TCPA300 Amplifier AC/DC Current Probe)

Dimmer: A leading edge dimmer, rated for 230 VAC can be used for controlling to LED light output. (example: Busch 2250U)

Fan: Forced air cooling is not required.

Recommended Wire Gauge: A minimum of AWG 22 wire is recommended to connect the AC voltage source to the EVM at less than 3 feet long.

4.2 Recommended Test Setup

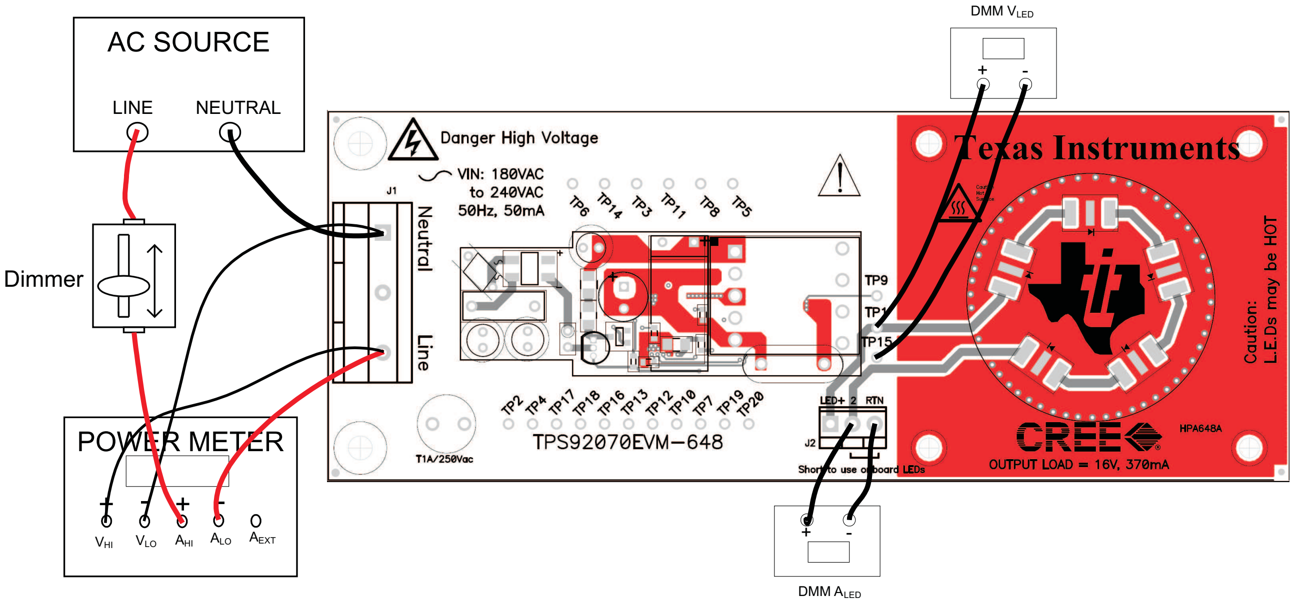


Figure 2. TPS92070EVM-648 Recommended Test Set Up

4.3 List of Test Points

Table 2. The Function of Each Test Point

Test Point	Name	Description
TP1	+LED	LED output voltage, reference to TP15
TP2	Q2 drain	Phase detection circuit, reference to TP12
TP3	TDD	TRIAC dimmer detect, reference to TP14
TP4	Q2 gate	Phase detection circuit, reference to TP12
TP5	Q3 drain	High voltage switch drain, reference to TP14
TP6	DTS	Dimmer trigger control input, reference to TP14
TP7	BP	Bypass for internal 7 V regulator, reference to TP12
TP8	GATE	Q3 gate drive, reference to TP14
TP9	SRTN	Secondary side return
TP10	VDD	Bias pin, reference to TP12
TP11	Q3 source	Primary current sense access, reference to TP14
TP12	GND	Ground, reference for TP2, TP4, TP7, TP10, TP13, TP16, TP17, TP18, TP19, TP20
TP13	VD	Valley detect, reference to TP12
TP14	PGND	Power ground, reference for TP3, TP5, TP6, TP8, TP11
TP15	LED RTN	Return for LED load, reference for TP1
TP16	COMP	Loop compensation, reference to TP12
TP17	SEN	Dimmer sense input, reference to TP12
TP18	LP	Pole for DTC low pass filter, reference to TP12
TP19	ISO	Inverting input to LED current sense comparator, reference to TP12
TP20	CS	Non-inverting input to LED current sense comparator, reference to TP12

5 Test Procedure

5.1 Line Regulation and Efficiency Measurement Procedure

1. With the dimmer removed from the test set up, set the AC voltage source to 180 VAC, 50 Hz.
2. The LEDs should be lit and the LED current should be within regulation per Table 1.
3. Adjust AC voltage up to 265 VAC.
4. LEDs should be lit and the current should remain within regulation per Table 1 with no flicker.
5. Efficiency data should be taken without the dimmer in circuit and input measurements taken from the power meter.
6. Turn off AC power. LEDs should turn off with no flashing or flicker.

5.2 Dimming

1. With dimmer in circuit, set the AC voltage source between 180 VAC and 265 VAC, 50 Hz.
2. Adjust the dimmer to control light output.

5.3 Equipment Shutdown

1. Turn off AC voltage source.

6 Performance Data and Typical Characteristic Curves

Figure 3 through Figure 17 present typical performance curves for the TPS92070EVM-648. Since actual performance data can be affected by measurement techniques and environmental variables, these curves are presented for reference and may differ from actual field measurements.

6.1 Efficiency

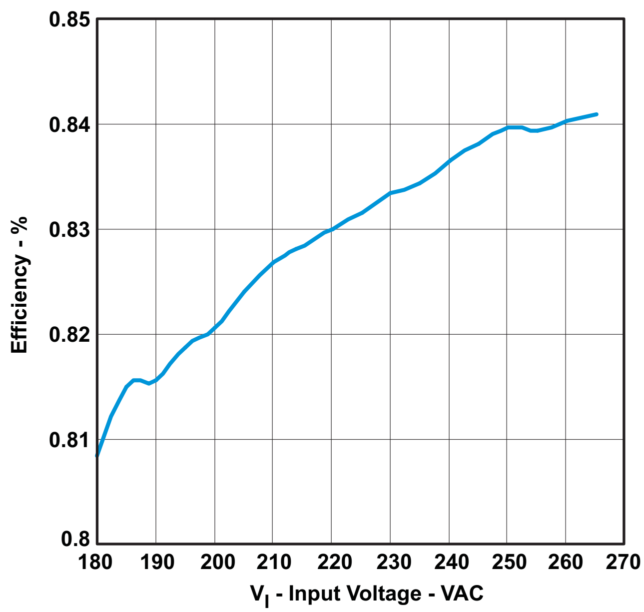


Figure 3. TPS92070EVM-648 Efficiency with Respect to Line Voltage, no Dimmer

6.2 LED Current Regulation

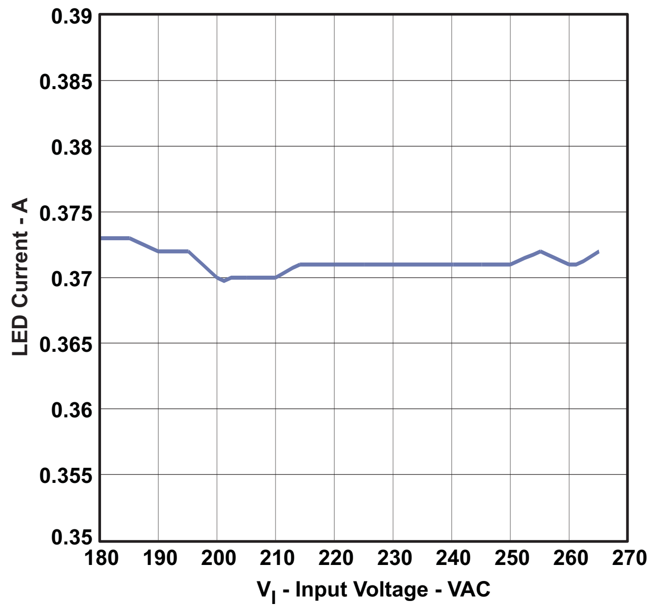


Figure 4. TPS92070EVM-648 LED Current Regulation with Respect to Line Voltage, no Dimmer

6.3 Power Factor

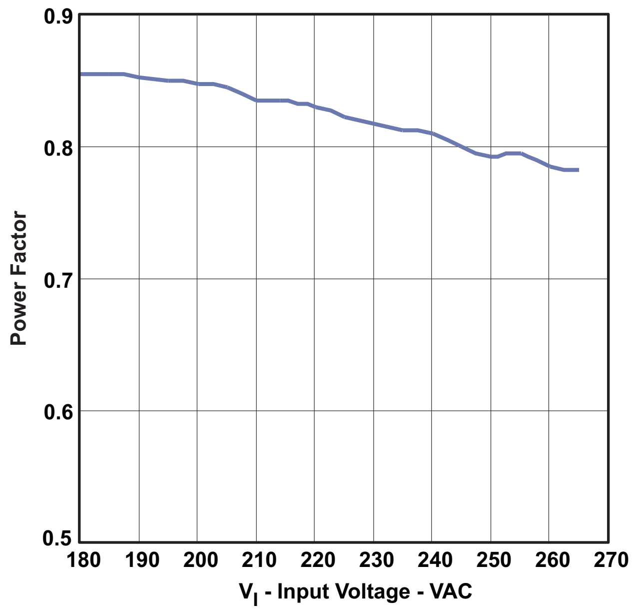


Figure 5. TPS92070EVM-648 Power Factor with Respect to Line Voltage, no Dimmer

6.4 Average Conduction

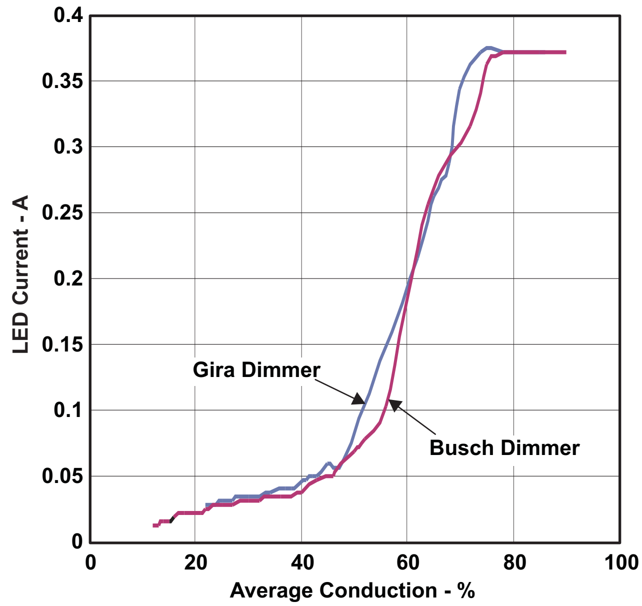


Figure 6. LED Current with Respect to Average Dimmer Conduction

6.5 Turn On

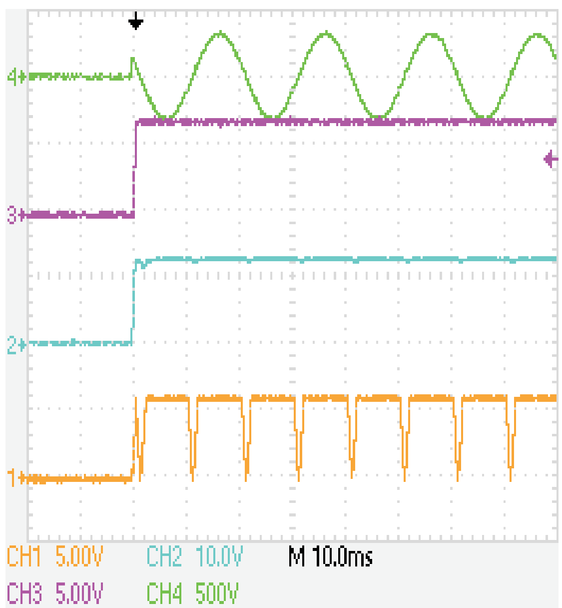


Figure 7. Turn on, Full Load, no Dimmer,
VIN = 230 VAC, CH1 = SEN, CH2 = VDD, CH3 = BP, CH4 = LINE

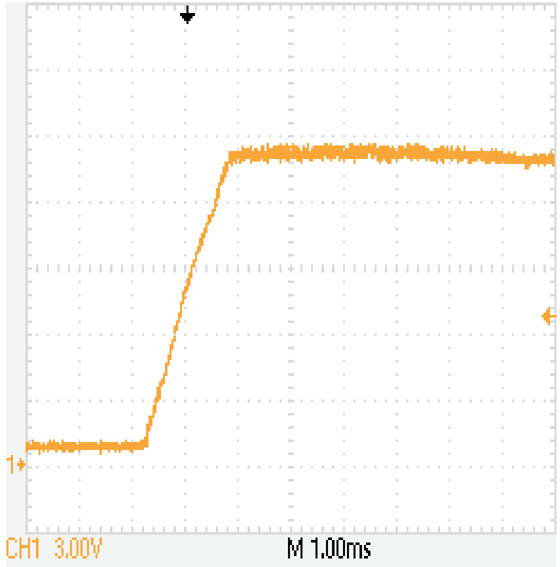


Figure 8. LED Turn on, Full Load, no Dimmer, VIN = 230 VAC

6.6 Output Voltage Ripple

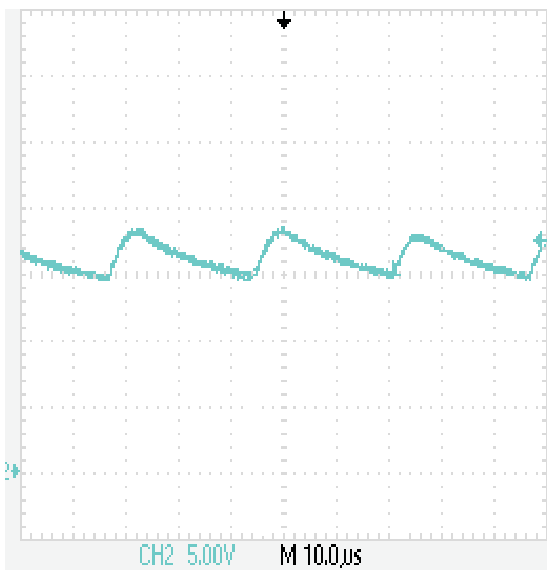


Figure 9. LED Output Voltage Ripple, Full Load, no Dimmer, VIN = 230 VAC

6.7 Output Current Ripple

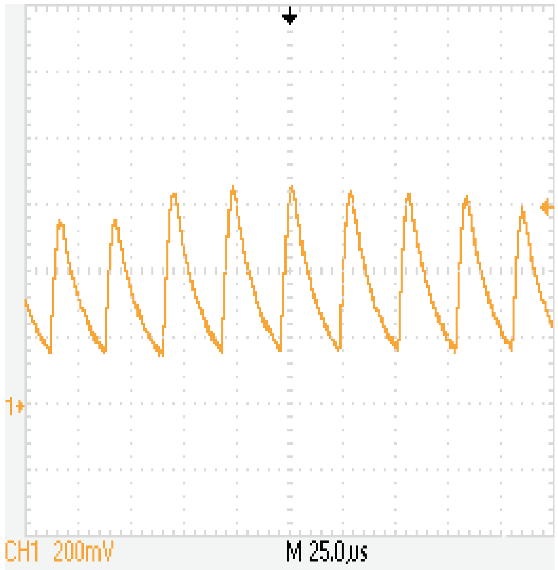
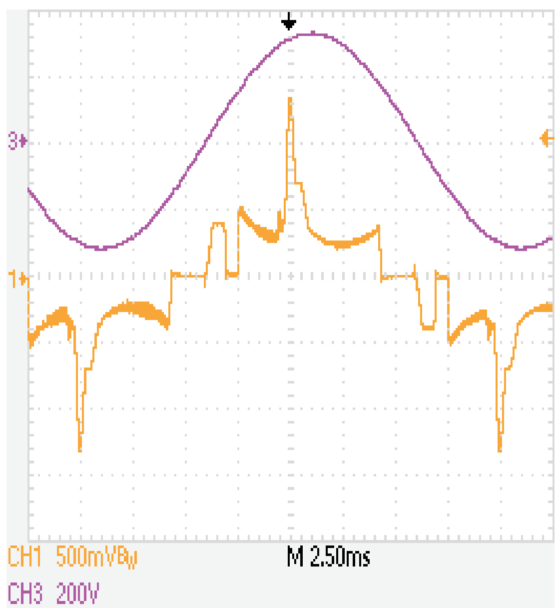


Figure 10. LED Output Current Ripple, Full Load, no Dimmer, VIN = 230 VAC, scale = 1 Amp per volt

6.8 AC Input



Notice the influence of the DTC circuit at the zero voltage crossings

Figure 11. Input AC Voltage and Current, Full Load, no Dimmer, CH1 = I_{IN}, CH3 = V_{IN}, scale = 1 Amp/V

6.9 Switching Waveform

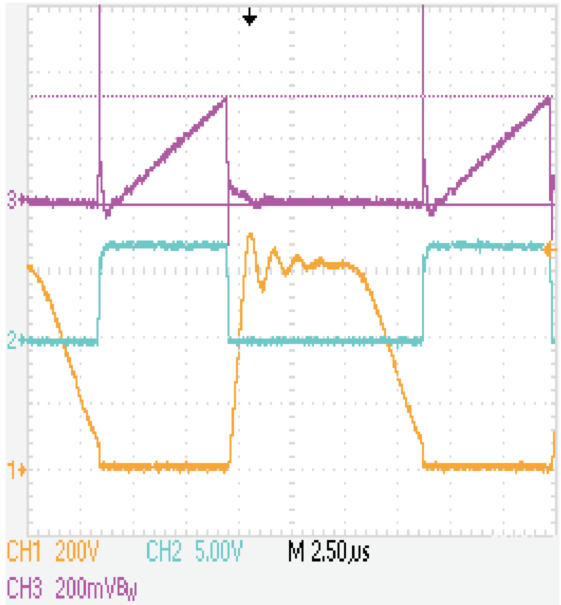


Figure 12. Switching Waveforms, Full Load, no Dimmer, VIN = 230 VAC, CH1 = Q3 drain, CH2 = GATE, CH3 = PCS, 328 mV

6.10 TDD, No Dimmer

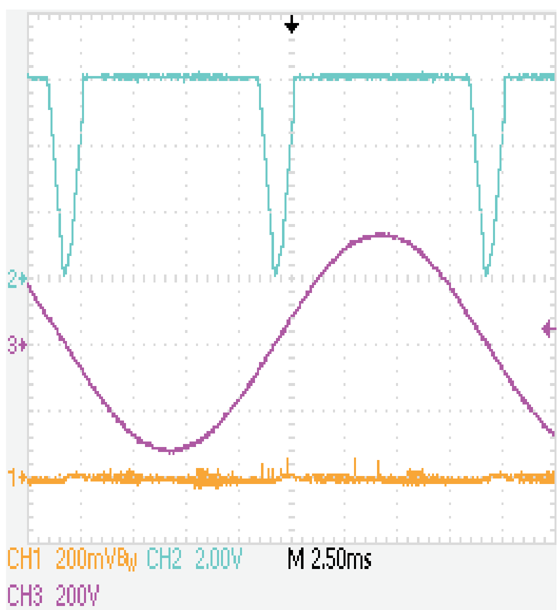


Figure 13. TDD Signal Low When There is no Dimmer Detected on the Input, Valley Fill PFC is Enabled, Full Load, VIN = 230 VAC, CH1 = TDD, CH2 = SEN, CH3 = VIN

6.11 TDD, With Dimmer

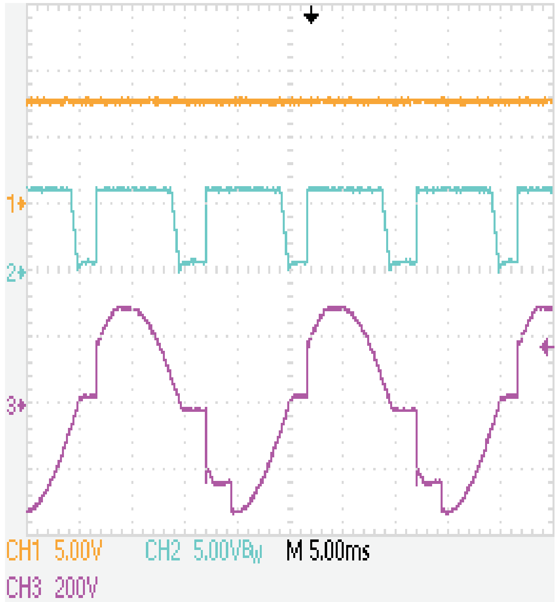


Figure 14. TDD Signal High When There is a Dimmer Detected on the Input, Valley Fill PFC is Disabled, Full Load, VIN = 230 VAC, CH1 = TDD, CH2 = SEN, CH3 = VIN

6.12 Valley Detect

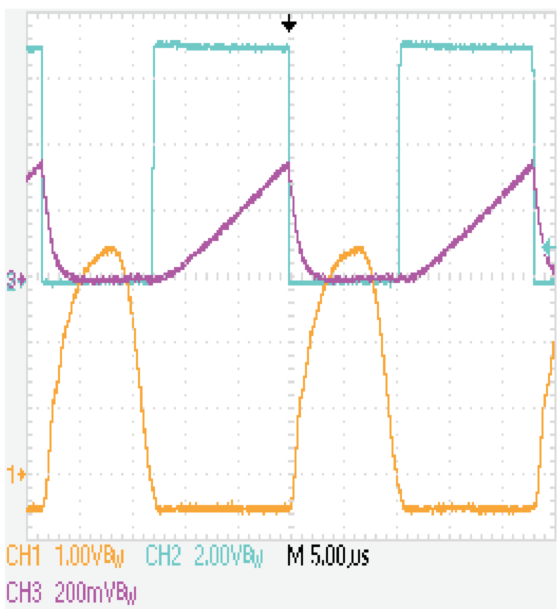


Figure 15. Valley Detect, Full Load, no Dimmer, VIN = 230 VAC, CH1 = VD, CH2 = GATE, CH3 = PCS

6.13 Turn Off

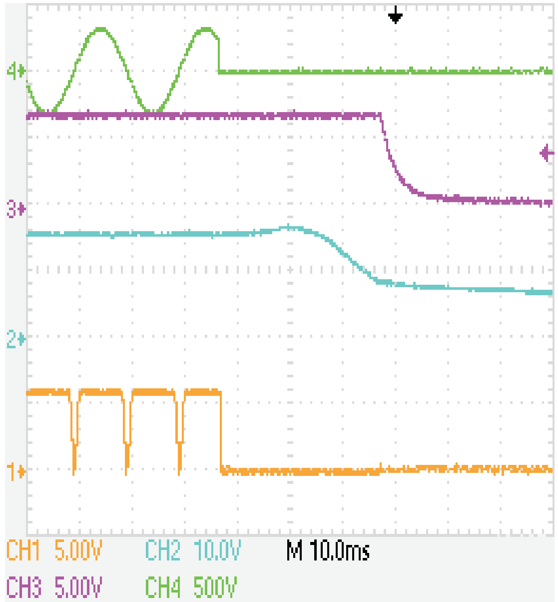


Figure 16. Turn off, Full Load, no Dimmer, VIN = 230 VAC, CH1 = SEN, CH2 = VDD, CH3 = BP, CH4 = LINE

6.14 Dimmer Detection

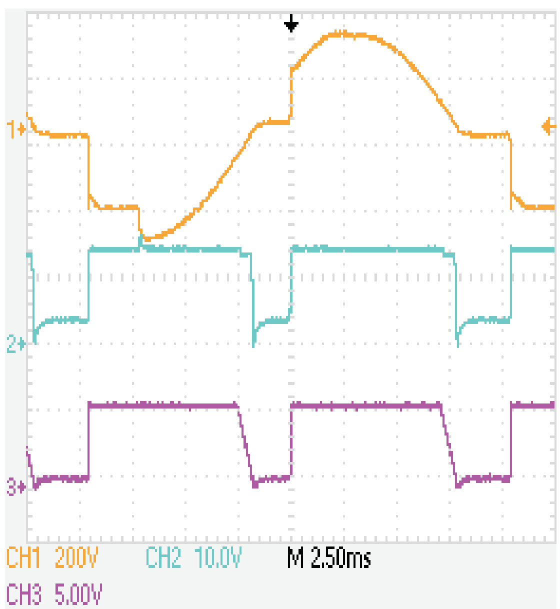


Figure 17. Dimmer Detection, DTC Sinks Current During AC Zero Crossing to Keep TRIAC Triggered. CH1 = VIN, CH2 = DTC, CH3 = SEN

7 EVM Assembly Drawing and PCB layout

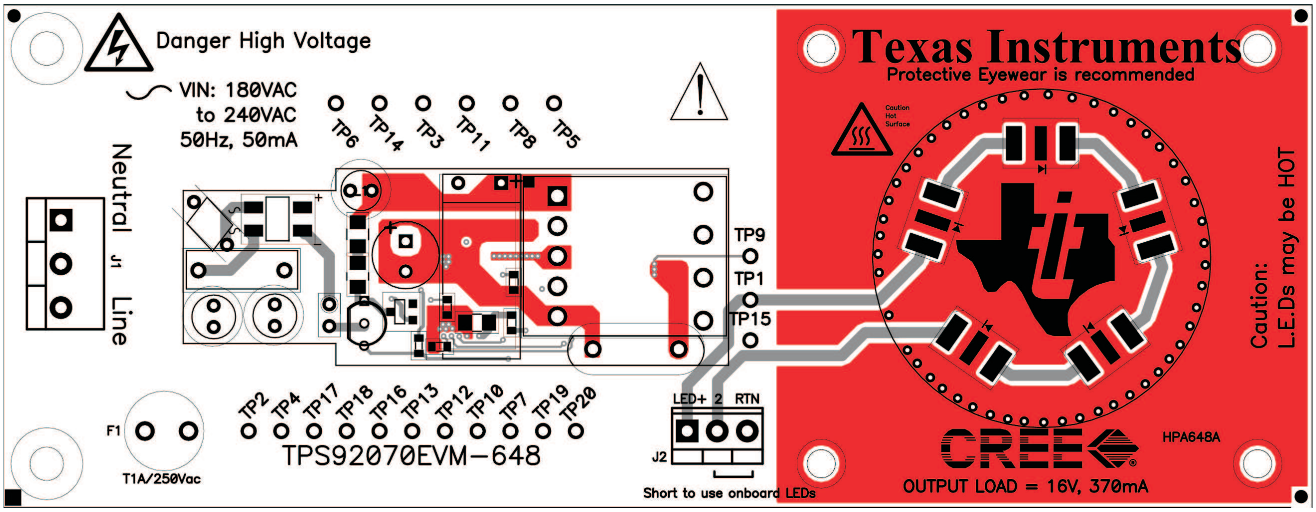


Figure 18. TPS92070EVM-648 Top View

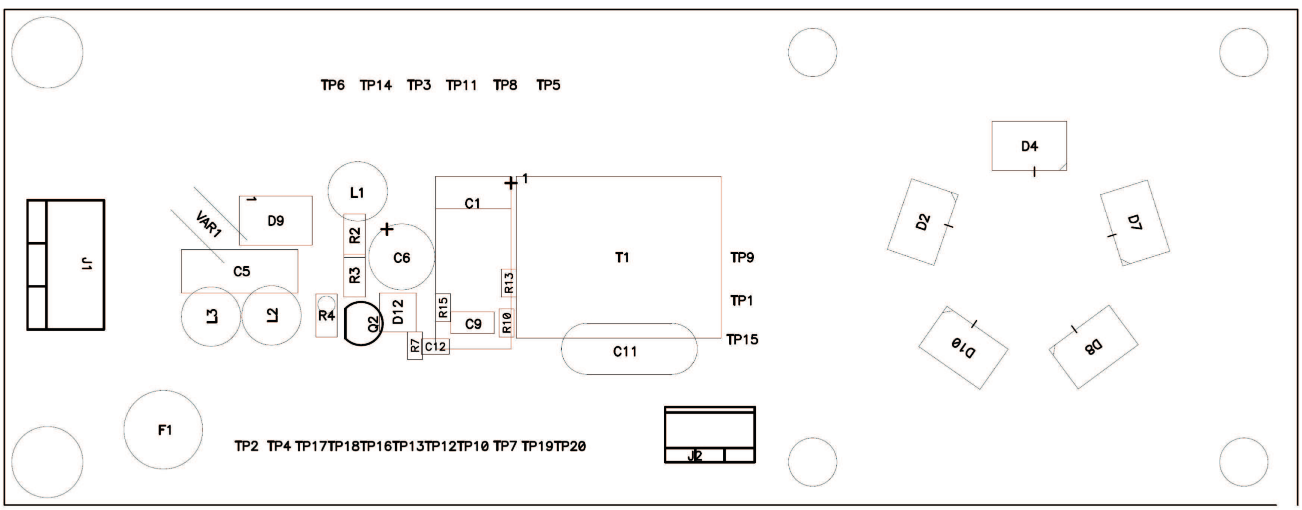


Figure 19. TPS92070EVM-648 Top Layer Assembly Drawing (Top View)

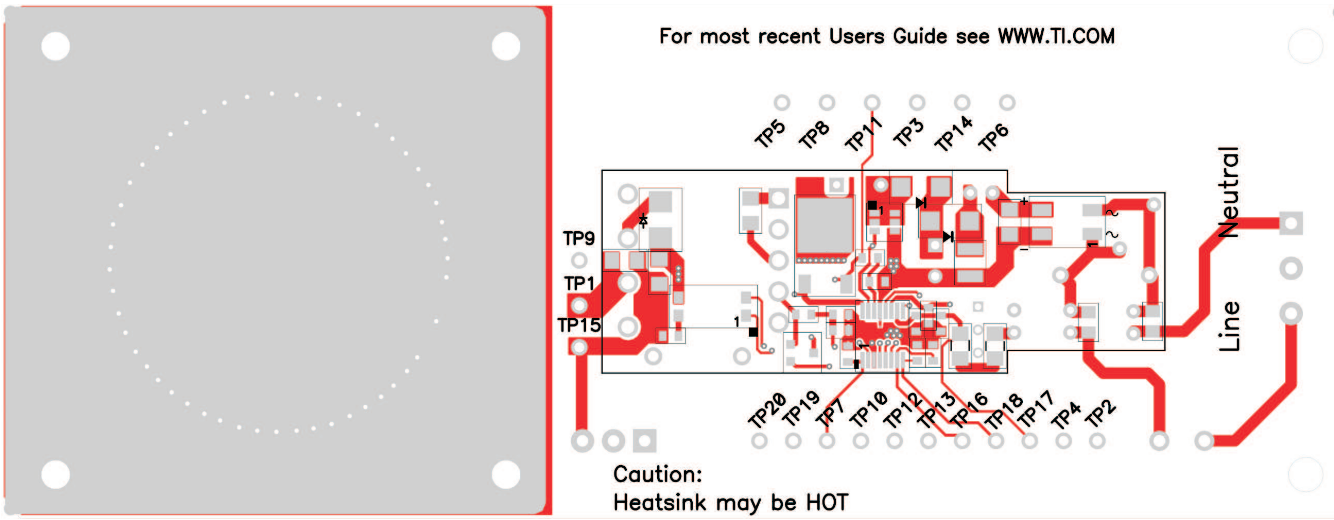


Figure 20. TPS92070EVM-648 Bottom View

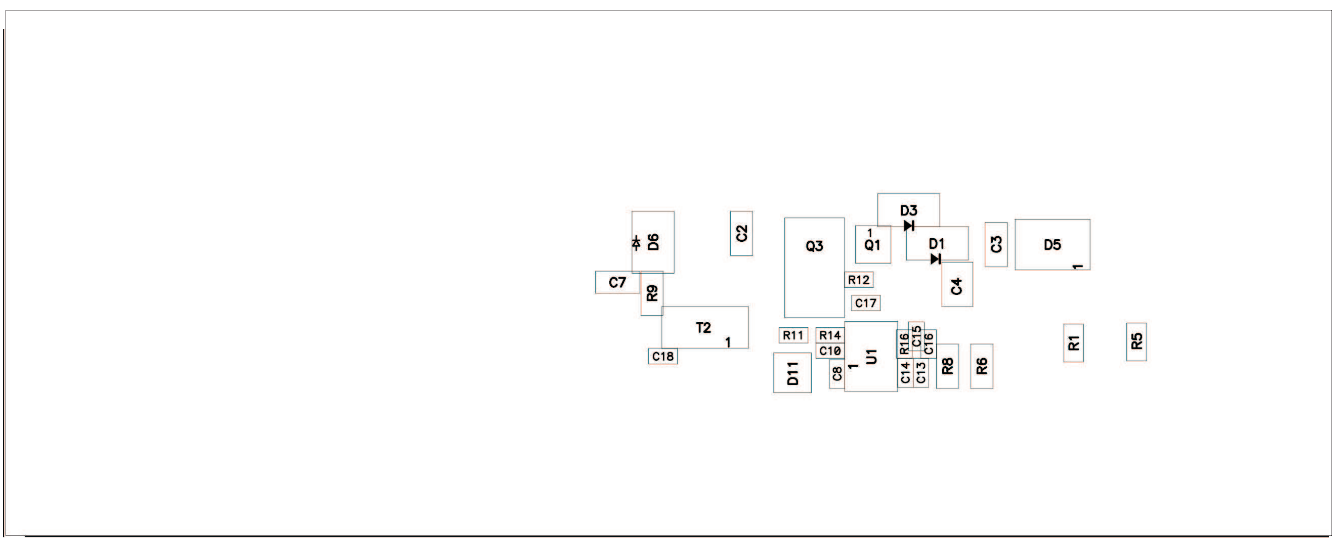


Figure 21. TPS92070EVM-648 Bottom Assembly Drawing (Bottom view)

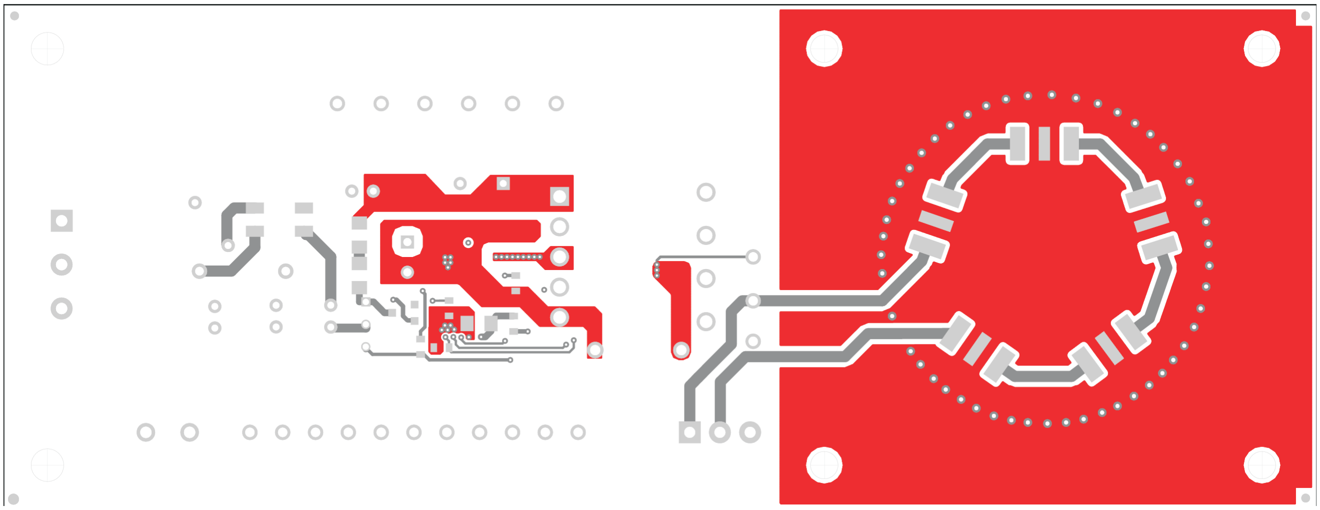


Figure 22. TPS92070EVM-648 Top Copper (Top View)

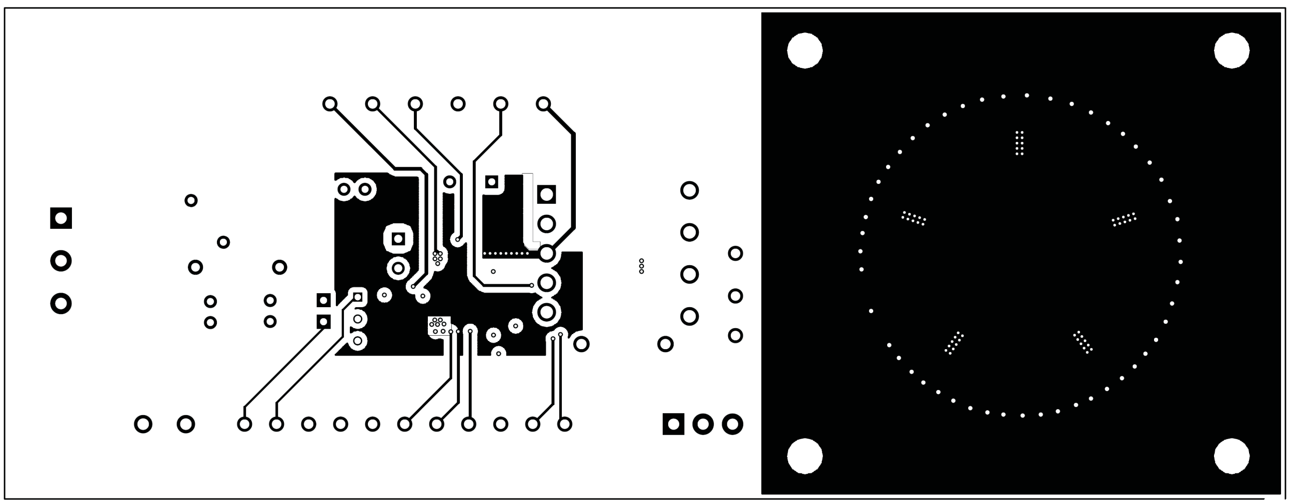


Figure 23. TPS92070EVM-648 Internal Layer 1 (Top View)

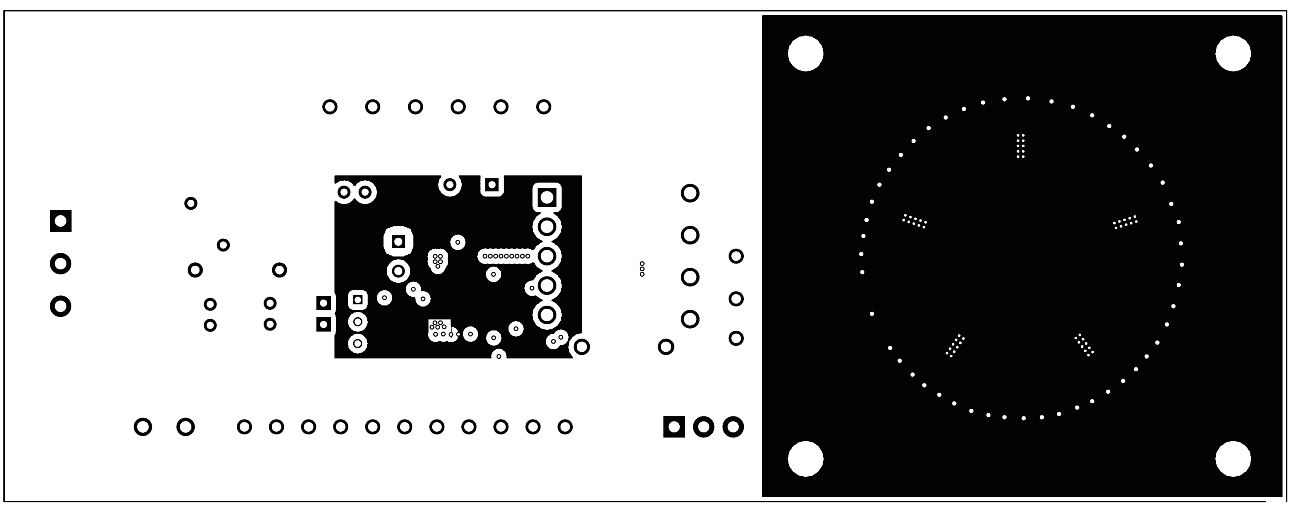


Figure 24. TPS92070EVM-648 Internal Layer 2 (Top View)

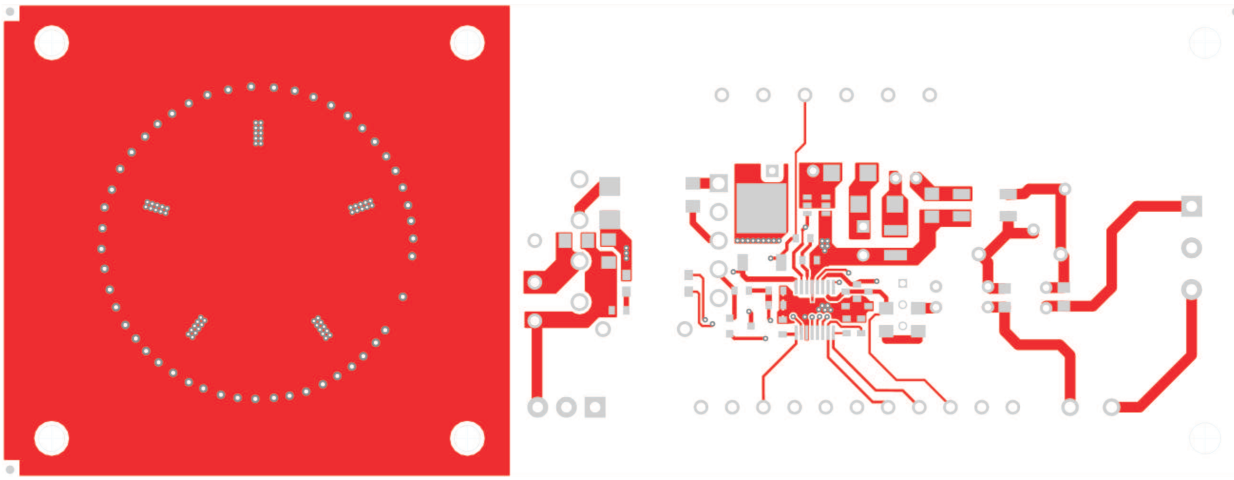


Figure 25. TPS92070EVM-648 Bottom Copper (Bottom View)

8 Bill of Materials

The bill of materials table list the components according to the schematic shown in Figure 1.

Table 3. Bill of Materials

Count	RefDes	Description	Part Number	Mfr
1	C1	Capacitor, Aluminum Electrolytic, 4.7 µF, 400V, –40 to 105°C, ±20%, 10.00 mm Dia	EKMG401ELL4R7MJ16S	United Chemi-Con
1	C2	Capacitor, Ceramic, 68 pF, 1000V, U2J, ±5%, 1206	GRM31A7U3A680JW31D	Murata Electronics
1	C3	Capacitor, Ceramic, 10 nF, 630V, X7R, ±10%, 1206	GRM31BR72J103KW01L	Murata Electronics
1	C4	Capacitor, Ceramic, 47 nF, 630V, X7R, ±10%, 1210	C3225X7R2J473K	TDK Corporation
1	C5	Capacitor, Metallized Polypropylene Film, 10 nF, 305VAC, X2, ±20%, 0.157 x 0.512 inch	B32921C3103M	Epcos Inc.
1	C6	Capacitor, Aluminum Electrolytic, 4.7 µF, 200V, -40 to +105°C, ±20%, 8.00 mm Dia	EKMG201ELL4R7MHB5D	United Chemi-Con
1	C7	Capacitor, Ceramic, 10 µF, 25V, X7R, ±10%, 1206	TMK316B7106KL-TD	Taiyo Yuden
3	C8, C14, C18	Capacitor, Ceramic, 0.22 µF, 16V, X7R, ±10%, 0603	Std	Std
1	C9	Capacitor, Ceramic, 4.7 µF, 25V, X7R, ±10%, 1206	GRM31CR71E475KA88L	Murata Electronics
1	C10	Capacitor, Ceramic, 27 pF, 50V, C0G, NP0, ±5%, 0603	Std	Std
1	C11	Capacitor, Ceramic Disc, 330 0pF, 500VAC, X1Y1, ±20%, 15 mm Dia	VY1332M59Y5UQ63V0	Vishay/BC Components
1	C12	Capacitor, Ceramic, 0.1 µF, 25 V, X7R, ±10%, 0603	Std	Std
1	C13	Capacitor, Ceramic, 33 nF, 25 V, X7R, ±10%, 0603	Std	Std
1	C15	Capacitor, Ceramic, 2.2 nF, 50 V, X7R, ±10%, 0603	Std	Std
1	C16	Capacitor, Ceramic, 47 pF, 50V, C0G, NP0, ±10%, 0603	Std	Std
1	C17	Capacitor, Ceramic, 3.3 nF, 50 V, X7R, ±10%, 0603	Std	Std
2	D1, D3	Diode, Rectifier, 1A, 60 0V, SMA	S1J-13-F	Diodes, Inc.
5	D2, D4, D7, D8, D10	LED, Xlamp, 1A Max, White, 5.0 x 6.0 mm	MX6AWT-A1-0000-000AE7 or MX3AWT-A1-0000-000BE7	Cree
2	D5, D9	Diode, Bridge Rectifier, 0.5A, 600V, SO-4	MB6S	Fairchild Semiconductor
1	D6	Diode, Schottky, 2A, 60V, SMB	B260-13-F	Diodes, Inc.
1	D11	Diode, Switching, Dual, 200mA, 70V, SOT-23	MMBD6100LT1G	On Semiconductor
1	D12	Diode, Zener, 5.1V, 250 mW, SOT-23	BZX84-C5V1,215	NXP Semiconductors
1	F1	Fuse, Slow Blow, 1A, 250V, 0.335 inch	38211000410	Littelfuse / Wickmann
3	L1, L2, L3	Inductor, Filter Choke, 1mH, ±10%, 6 mm Dia	7447462102V	Wurth Midcom
1	Q1	MOSFET, N-ch, 200V, 600mA, 2.2 Ohms, TSOP-6	IRF5801TRPBF	International Rectifier
1	Q2	MOSFET, N-ch, 600V, 0.3A, 11.5 Ohms, TO-92	FQN1N60CTA	Fairchild Semiconductor
1	Q3	MOSFET, N-ch, 800V, 2.5A, 4.5 Ohms, DPAK	STD3NK80ZT4	STMicroelectronics
2	R1, R5	Resistor, Chip, 7.5k, 1/10W, ±1%, 0805	Std	Std
4	R2, R3, R6, R8	Resistor, Thick Film, 1.00M, 1/4W, ±1%, 1206	Std	Std

Table 3. Bill of Materials (continued)

Count	RefDes	Description	Part Number	Mfr
1	R4	Resistor, Metal Film, 475, 1/4 W, ±1%, 0.250 inch x 0.093 inch Dia	RNF14FTD475R	Stackpole Electronics Inc.
1	R7	Resistor, Chip, 205, 1/10W, ±1%, 0603	Std	Std
1	R9	Resistor, Thick Film, 0.27, 1/2 Watt, ±1%, 1206	RCWE1206R270FKEA	Vishay/Dale
1	R10	Resistor, Chip, 15.0, 1/10W, ±1%, 0603	Std	Std
2	R11, R16	Resistor, Chip, 162k, 1/10W, ±1%, 0603	Std	Std
1	R12	Resistor, Chip, 511, 1/10W, ±1%, 0603	Std	Std
1	R13	Resistor, Chip, 2.37, 1/10W, ±1%, 0603	Std	Std
1	R14	Resistor, Chip, 51.1k, 1/10W, ±1%, 0603	Std	Std
1	R15	Resistor, Chip, 68.1k, 1/10W, ±1%, 0603	Std	Std
1	T1	Transformer, 13.8 mH, ±10%, 20.3 x 24.38 mm	7508110410	Wurth Midcom
1	T2	Transformer, 450 μH, 1:1, 0.173 x 0.360 inch	750082157	Wurth Midcom
1	U1	IC, Dimmable Quasi-Resonant LED Lighting Controller, TSSOP	TPS92070PW	Texas Instruments
1	VAR1	Varistor, Disk, 300VAC, 5mm Radial, D Size	S05K300	Epcos Inc.
1		Jumper Wire, U-Shape, 0.200 inch x 22 AWG	923345-02-C	3M

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FCC Warning

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EVM Warnings and Restrictions

It is important to operate this EVM within the input voltage range of 180 VAC to 240 VAC and the output voltage range of 15 V to 19 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 40°C. The EVM is designed to operate properly with certain components above 40°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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