Using the LM3447-PAR-230VEVM

User's Guide

Literature Number: SLUUA02
AUGUST 2012

WARNING

Always follow the TI set-up and application instructions, including use of all interface components within their recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and the safety of those working around you. Contact the TI Product Information Center http://support/ti./com for further information.

Save all warnings and instructions for future reference.

Failure to follow warnings and instructions may result in personal injury, property damage, or death due to electrical shock and/or burn hazards.

The term TI HV EVM refers to an electronic device typically provided as an open framed, unenclosed printed circuit board assembly. It is intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise, and knowledge of electrical safety risks in development and application of high-voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments. If you are not suitably qualified, you should immediately stop from further use of the HV EVM.

1. **Work Area Safety:**
   (a) Keep work area clean and orderly.
   (b) Qualified observer(s) must be present anytime circuits are energized.
   (c) Effective barriers and signage must be present in the area where the TI HV EVM and its interface electronics are energized, indicating operation of accessible high voltages may be present, for the purpose of protecting inadvertent access.
   (d) All interface circuits, power supplies, evaluation modules, instruments, meters, scopes and other related apparatus used in a development environment exceeding 50 V_{RMS}/75 VDC must be electrically located within a protected Emergency Power Off (EPO) protected power strip.
   (e) Use a stable and non-conductive work surface.
   (f) Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.
2. **Electrical Safety:**
   (a) De-energize the TI HV EVM and all its inputs, outputs, and electrical loads before performing any electrical or other diagnostic measurements. Revalidate that TI HV EVM power has been safely de-energized.
   (b) With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment hook-ups and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
   (c) Once EVM readiness is complete, energize the EVM as intended.

   WARNING: while the EVM is energized, never touch the EVM or its electrical circuits as they could be at high voltages Capacitorable of causing electrical shock hazard.
3. **Personal Safety:**
   (a) Wear personal protective equipment (for example. latex gloves and/or safety glasses with side shields) or protect EVM in an adequate lucent plastic box with interlocks from accidental touch.
4. **Limitation for Safe Use:**
   (a) Do not use EVMs as all or part of a production unit.

LM3447-PAR-230VEVM is a Phase-Dimmable, Primary-Side Regulated LED Driver

1 Introduction

The LM3447-PAR-230VEVM is a 16-W, 230-V_{AC} isolated dimmable LED driver with form-factors intended for BR and PAR applications.

2 Description

The LM3447-PAR-230VEVM is a primary-side power regulated PFC controller used for commercial and residential phase-cut dimmer compatible LED lamp drivers. The LM3447-PAR-230VEVM uses fixed frequency valley switching operation resulting in discontinuous current operation.

2.1 Typical Applications

- BR Bulb Form Factor
- PAR Bulb Form Factor

2.2 Features

- Primary-Side Control
- Power Factor Correction
- Leading and Trailing Edge Compatible
- 50:1 Dimming Range
- Valley Switching with Fixed Frequency Discontinuous Operation
- Thermal Foldback
- Efficient Triac Hold Current Operation
- LED Short and Open Circuit Protection

3 Electrical Performance Specifications

Table 1. LM3447-PAR-230VEVM Electrical Performance Specifications

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input Characteristics					
Voltage range		180	230	265	V
Output Characteristics					
Output voltage, V_{OUT}	9 to 11 LED's	30	32	34	V
Output load current, I_{OUT}			500		mA
Output over voltage			38		V
Systems Characteristics					
Switching frequency			69		kHz
Full-load efficiency	V_{IN} = 230 V_{AC}		85%		
Power factor, PF			0.96		

4 Schematic

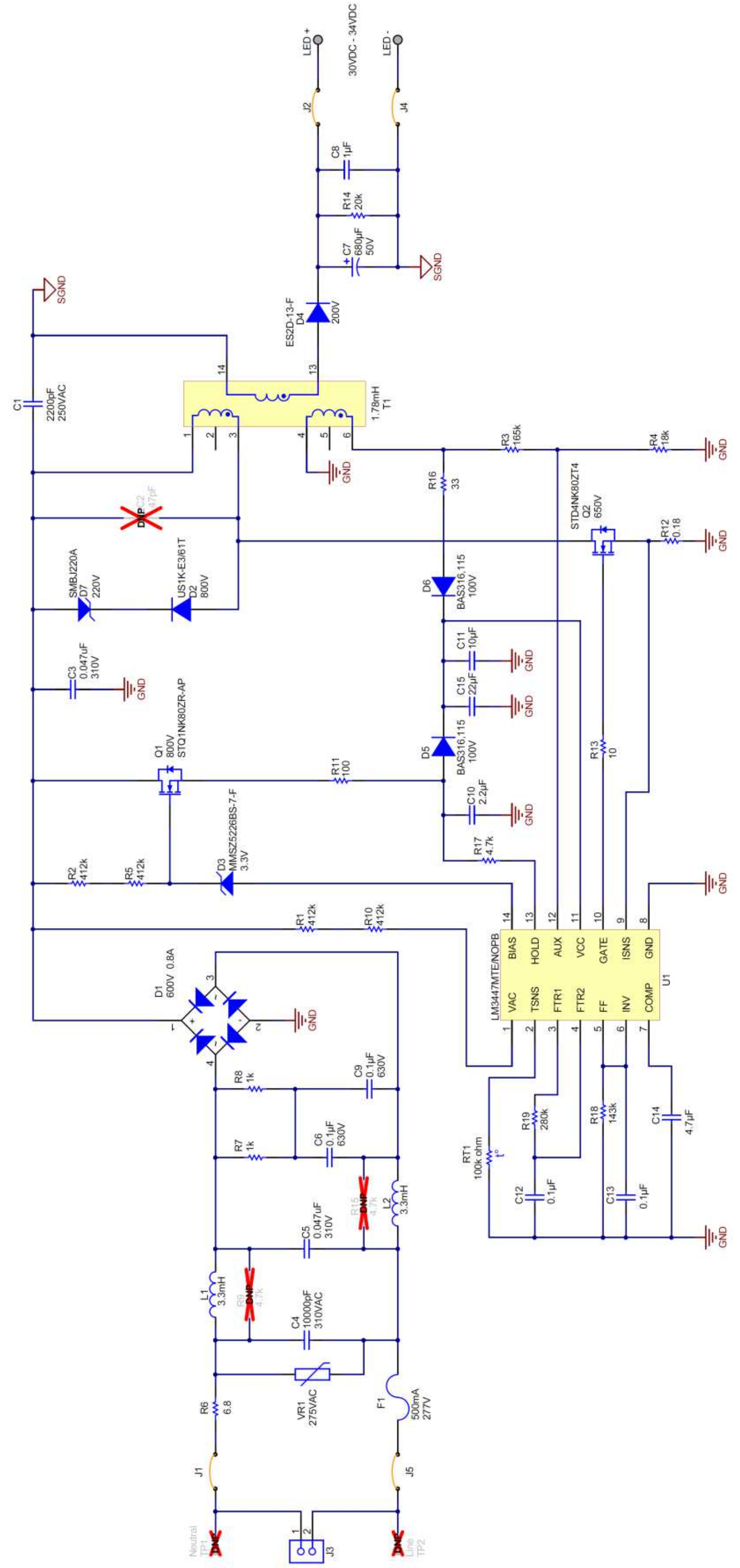


Figure 1. LM3447-PAR-230VEVM Schematic

5 Test Setup

5.1 Test Equipment

Voltage Source: 180 V_{RMS} to 270 V_{RMS} isolated AC source Agilent 6812B

Multimeters: Agilent 34410A

Power Meter: WT210 Digital Power Meter (Voltech)

Output Load: 10 LEDs in series (VF = 3.2 V at 350 mA per LED)

Oscilloscope: DPO4054 (TEKTRONIX)

Operating Temperature: 25°C

Recommended Wire Gauge: 18 AWG not more than two feet long

5.2 Recommended Test Setup

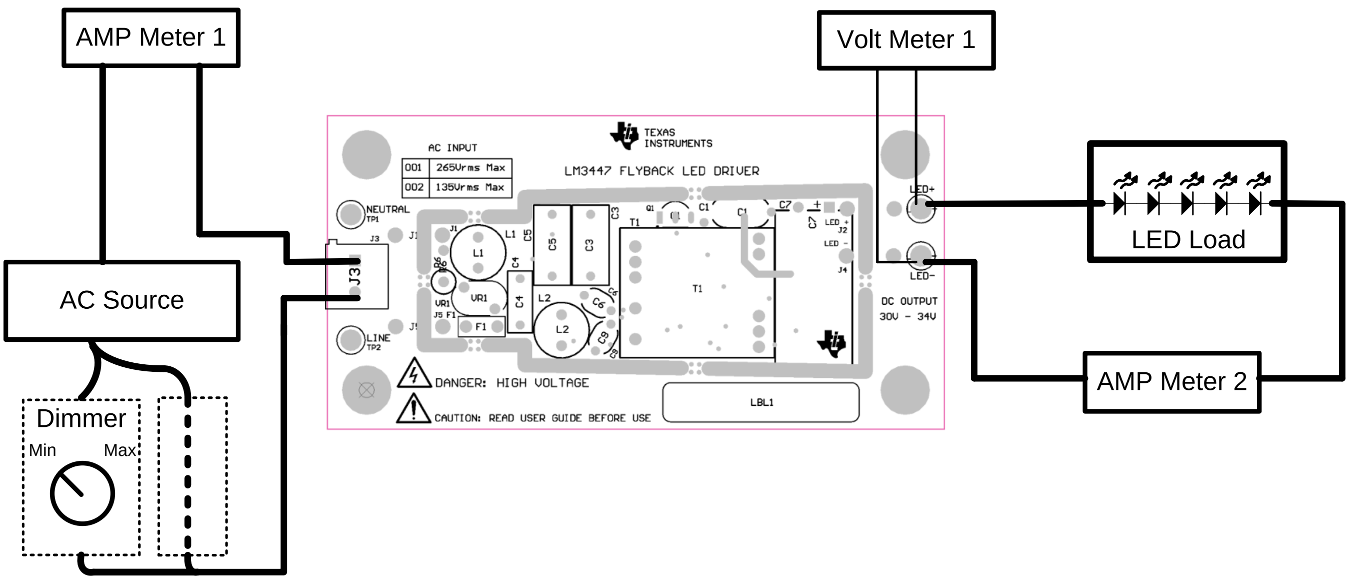


Figure 2. LM3447-PAR-230VEVM Recommended Test Set Up

5.3 List of Test Points

Table 2. Test Points Functions

TEST POINTS	NAME	DESCRIPTION
J3-1	Line	230 V_{AC} neutral connection
J3-2	Neutral	230 V_{AC} line voltage
	LED+	LED anode connection
	LED-	LED cathode connection

6 Test Procedure

6.1 Line/Load Regulation and Efficiency Measurement Procedure

1. Connect EVM per Figure 2. An external LED load must be used to start up the EVM.
2. Prior to turning on the AC source, set the voltage to 180 V_{RMS}.
3. Turn on the AC source.
4. Record the output voltage from Voltmeter 2 and output current reading from Ammeter 2 and input current from Ammeter 1.
5. Increase output voltage by 5 V_{RMS}.
6. Repeat steps 4 and 5 until 265 V_{AC} is reached.
7. Refer to Section 6.2 for shutdown procedure.

6.2 Equipment Shutdown

1. Turn off equipment.
2. Make sure Capacitoracitors are discharged.

6.3 EVM Phase Angle Decode vs LED Current

1. Connect EVM per Figure 2. An external LED load must be used to start up the EVM.
2. Prior to turning on the AC source, set the voltage to 230 VRMS.
3. Connect scope probe to EVM per Figure 2 to bridge rectifier output.
4. Turn on the AC source.
5. Record the output voltage from Voltmeter 2 and output current reading from Ammeter 2 and input current from Ammeter 1.
6. Set dimmer to maximum setting and note the LED current.
7. Varry the dimmer from maximum to minimum setting and evaluate the dimming performance.
8. Refer to Section 6.2 for shutdown procedure.

NOTE: The scope must be isolated.

7 EVM Assembly Drawing and PCB Layout

The following figures (Figure 3 through Figure 6) show the design of the LM3447-PAR-230VEVM printed circuit board.

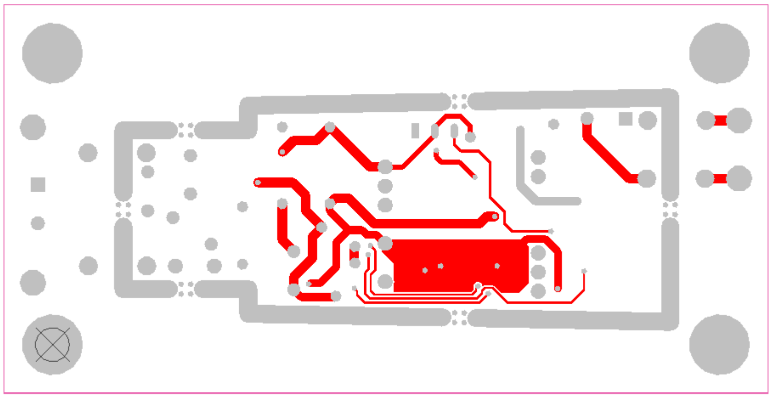


Figure 3. LM3447-PAR-230VEVM Top Layer Copper (top view)

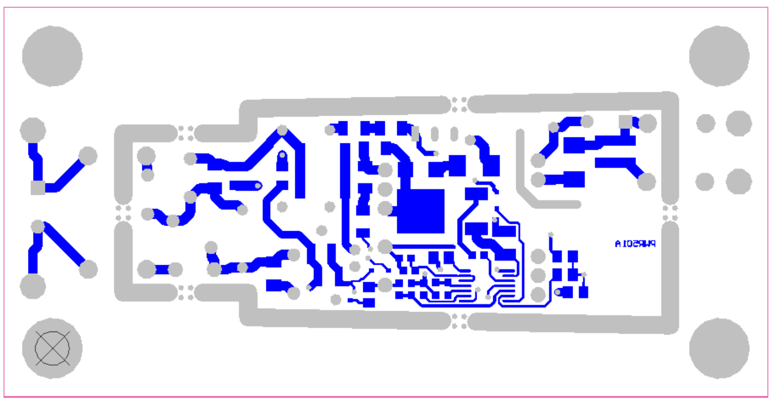


Figure 4. LM3447-PAR-230VEVM Bottom Layer Copper (bottom view)

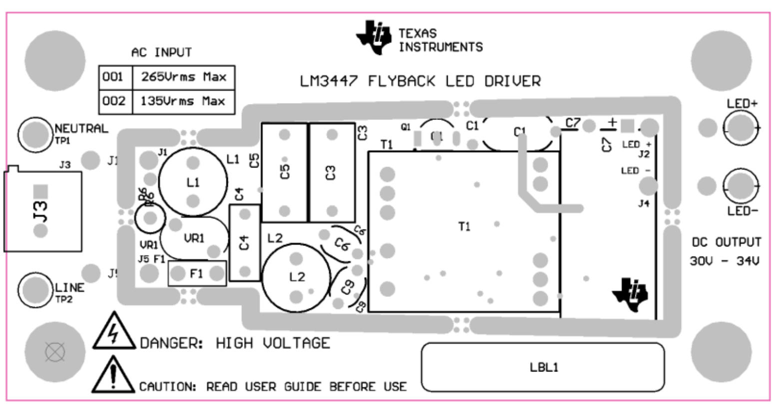


Figure 5. LM3447-PAR-230VEVM Top Assembly Drawing (top view)

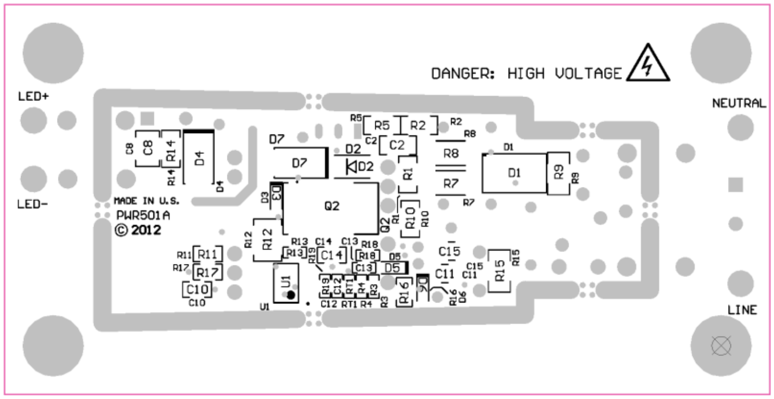


Figure 6. LM3447-PAR-230VEVM Bottom Assembly Drawing (bottom view)

8 Performance Data and Typical Characteristic Curves

Figure 7 through Figure 30 present typical performance curves for LM3447-PAR-230VEVM.

8.1 Efficiency

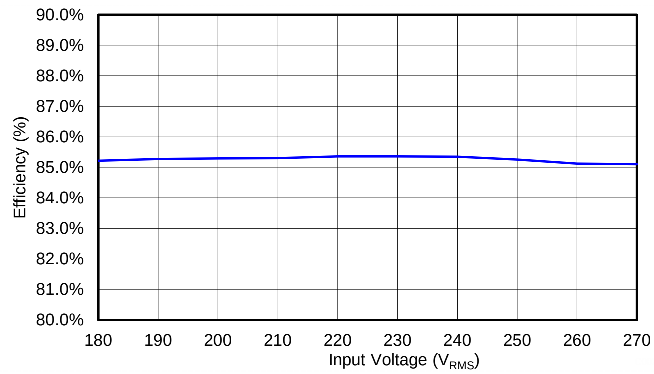


Figure 7. LM3447-PAR-230VEVM Efficiency

8.2 Power Factor

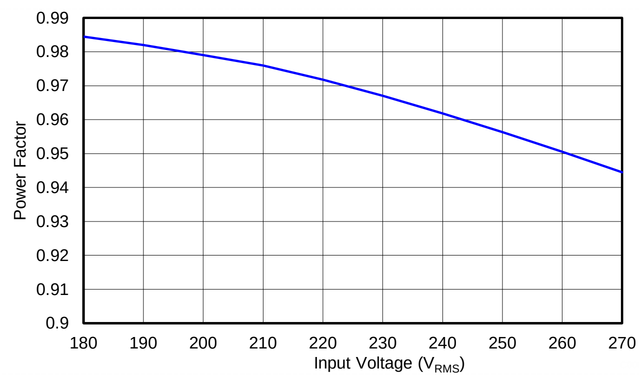


Figure 8. LM3447-PAR-230VEVM Power Factor vs Line Voltage

8.3 Line Regulation

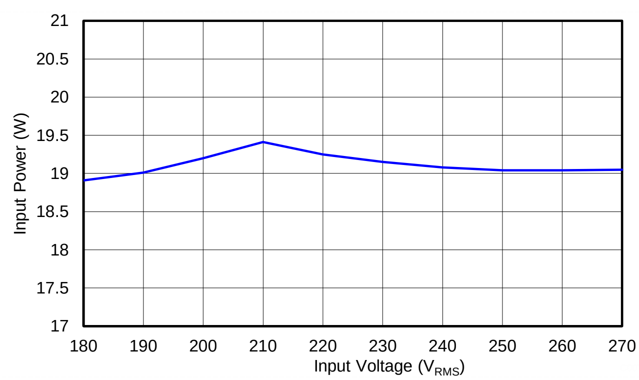


Figure 9. LM3447-PAR-230VEVM Input Power Regulation

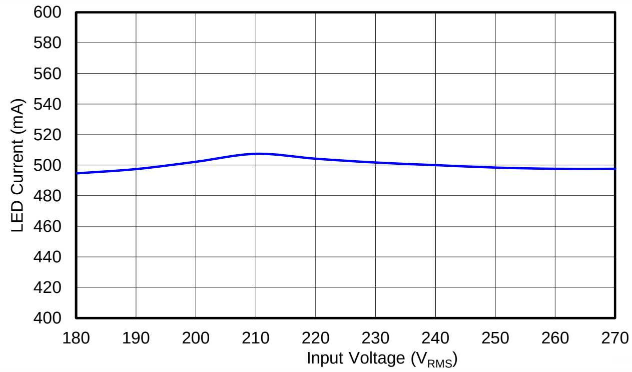


Figure 10. LM3447-PAR-230VEVM LED Current Regulation

8.4 Input Current THD

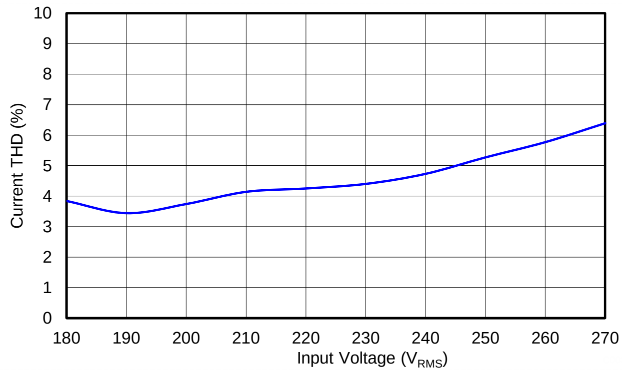


Figure 11. LM3447-PAR-230VEVM- Current THD % vs Line Voltage

8.5 Output Ripple

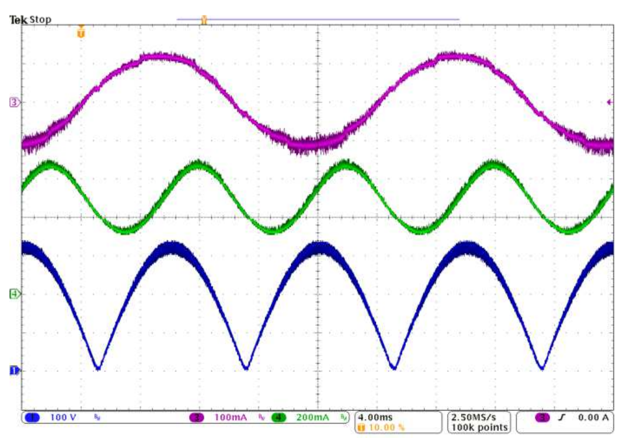


Figure 12. Output Ripple
(Ch1 - rectified line voltage (100V/div); Ch3 - line current (100mA/div); Ch4- LED current (100 mA/div))

8.6 Switch Node Voltage Valley Switching

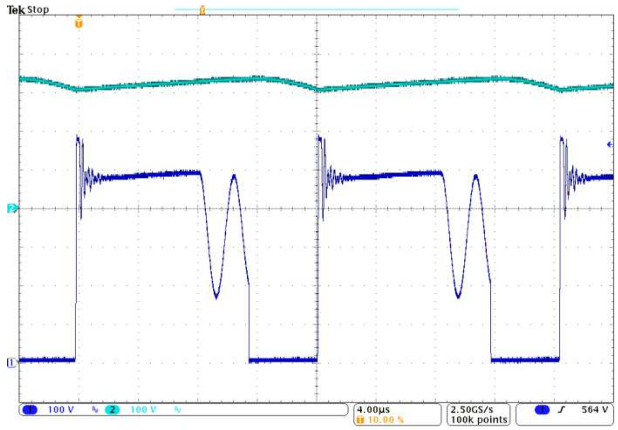


Figure 13. Switch Node Waveform
(Ch1 - switch node (100V/div); Ch2 - rectified line voltage (100V/div))

8.7 Current Sense Waveform

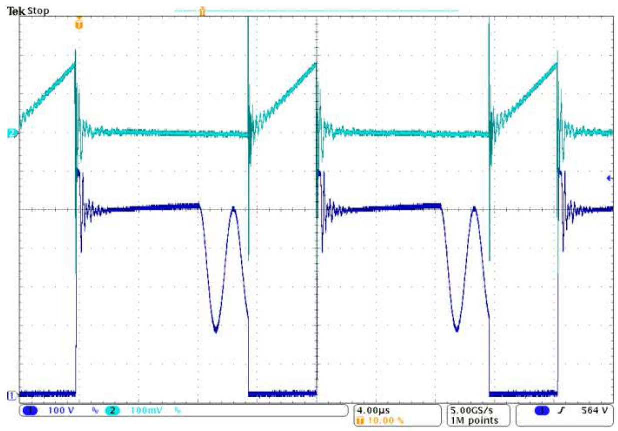


Figure 14. Current Sense Waveform
(Ch1 - switch node voltage (100V/div); Ch2 - R11 current sense (100mV/div))

8.8 LED Open Circuit Protection

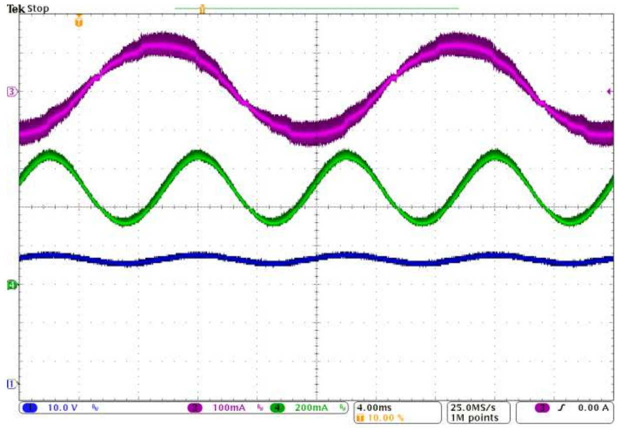


Figure 15. Pre-Open Circuit Waveforms
(Ch1 - LED voltage (10V/div); Ch3 - line current (100mA/div); Ch4 - LED current(200mA/div))

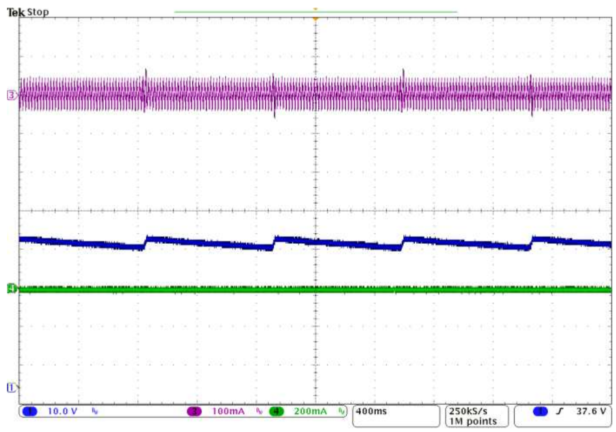


Figure 16. Open Circuit Steady State Waveforms
(Ch1 - LED voltage (10V/div); Ch3 - line current (100mA/div); Ch4 - LED current(200mA/div))

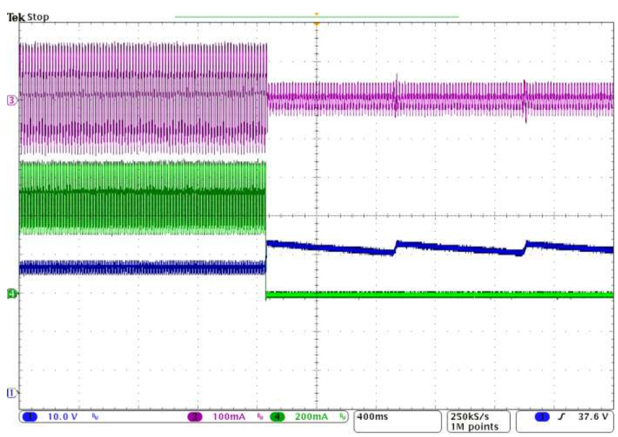


Figure 17. Open Circuit Transient Waveforms
(Ch1 - LED voltage (10V/div); Ch3 - line current (100mA/div); Ch4 - LED current(200mA/div))

8.9 LED Short Circuit Protection

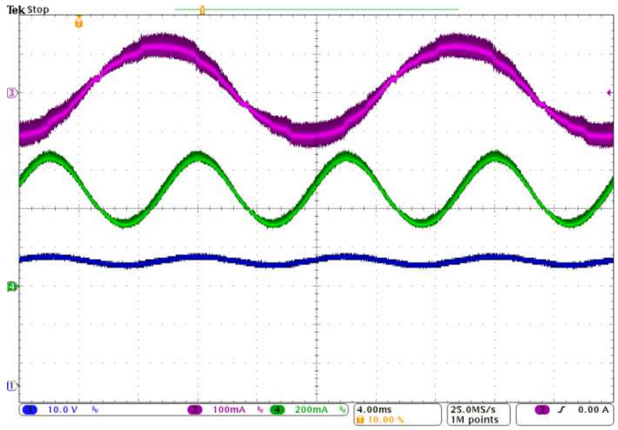


Figure 18. Pre-Short Circuit Waveforms
(Ch1 - LED voltage (10V/div); Ch3 - line current (100mA/div); Ch4 - LED current(200mA/div))

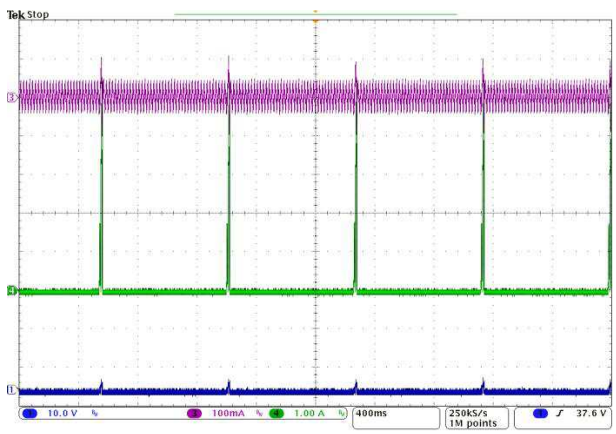


Figure 19. Short Circuit Steady State Waveforms
(Ch1 - LED voltage (10V/div); Ch3 - line current (100mA/div); Ch4 - LED current(200mA/div))

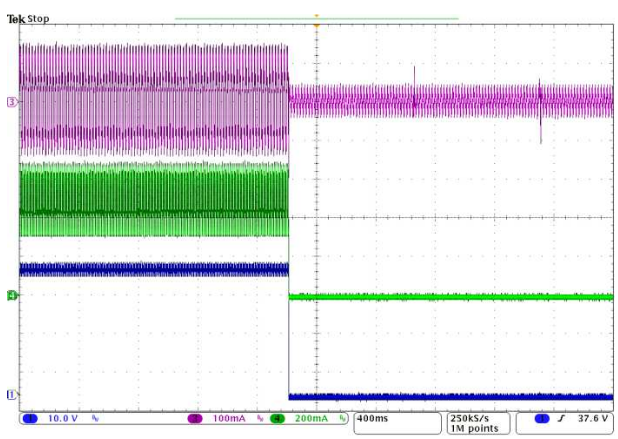


Figure 20. Short Circuit Transient Waveforms
(Ch1 - LED voltage (10V/div); Ch3 - line current (100mA/div); Ch4 - LED current(200mA/div))

8.10 Dimming Characteristics with Reverse Phase Dimmer

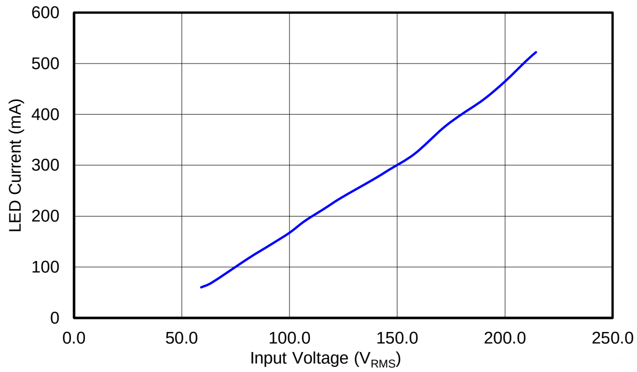


Figure 21. LED Current vs Conduction Angle

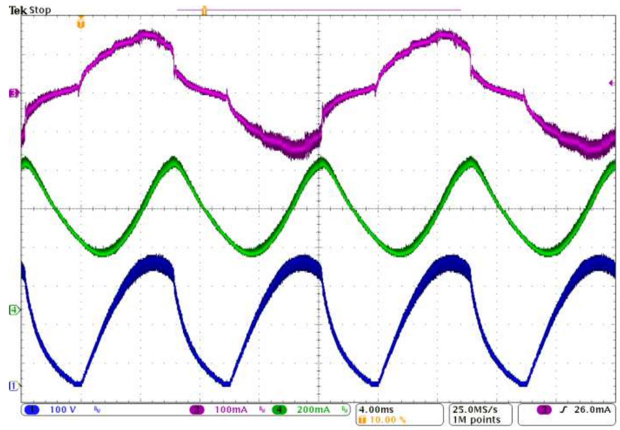


Figure 22. Dimmer at maximum brightness setting
(Ch1 - rectified line voltage (100V/div); Ch3 - line current (100mA/div); Ch4- LED current (100 mA/div))

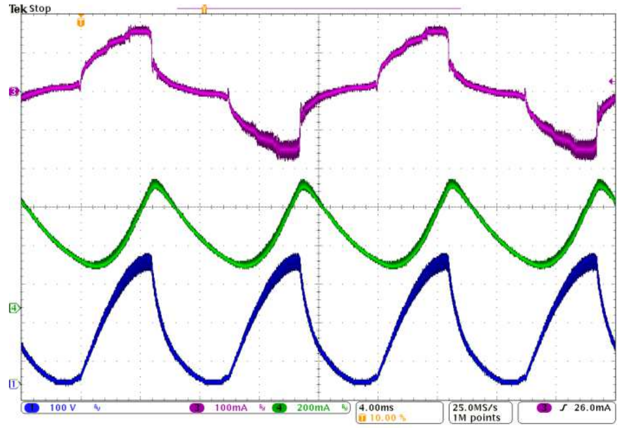


Figure 23. Dimmer at half brightness setting
(Ch1 - rectified line voltage (100V/div); Ch3 - line current (100mA/div); Ch4- LED current (100 mA/div))

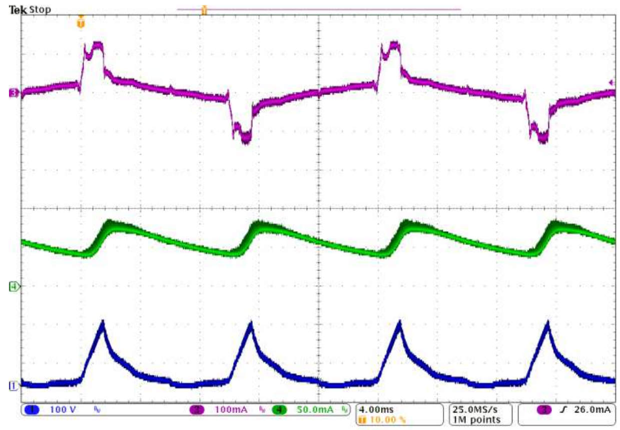


Figure 24. Dimmer at minimum brightness setting
(Ch1 - rectified line voltage (100V/div); Ch3 - line current (100mA/div); Ch4- LED current (100 mA/div))

8.11 Dimming Characteristics with Forward Phase Dimmer

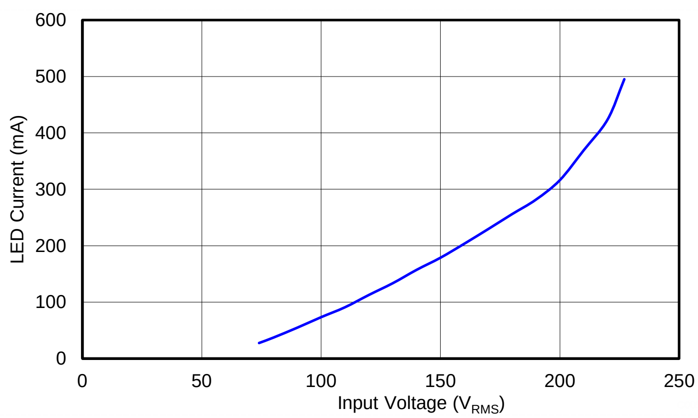


Figure 25. LED Current vs Input Voltage

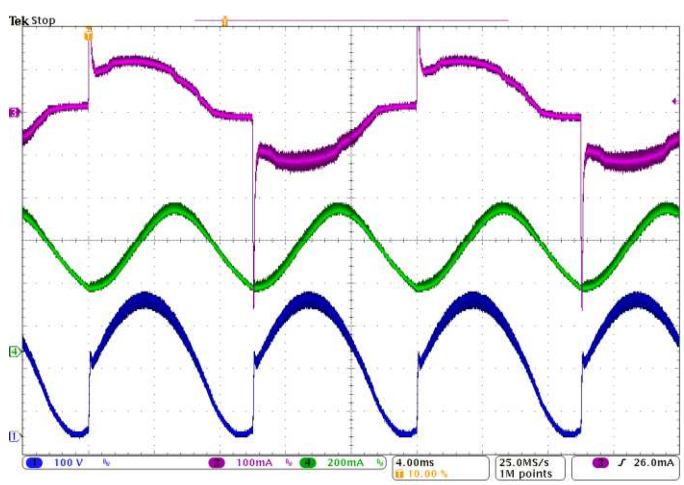


Figure 26. Dimmer at maximum brightness setting
(Ch1 - rectified line voltage (100V/div); Ch3 - line current (100mA/div); Ch4- LED current (100 mA/div))

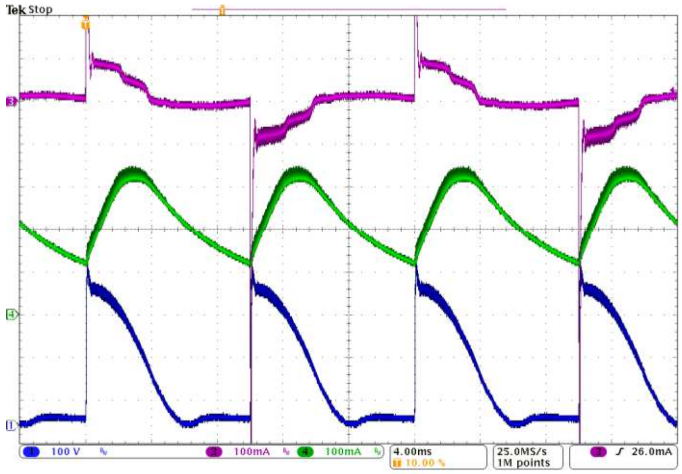


Figure 27. Dimmer at half brightness setting
(Ch1 - rectified line voltage (100V/div); Ch3 - line current (100mA/div); Ch4- LED current (100 mA/div))

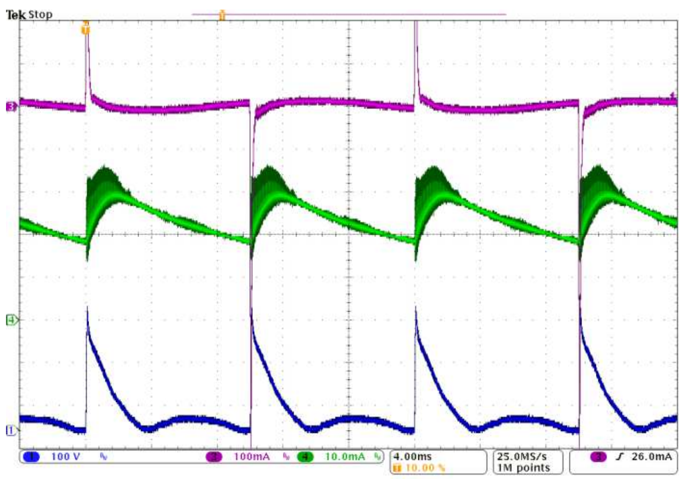


Figure 28. Dimmer at minimum brightness setting
(Ch1 - rectified line voltage (100V/div); Ch3 - line current (100mA/div); Ch4- LED current (100 mA/div))

8.12 EMI Plot

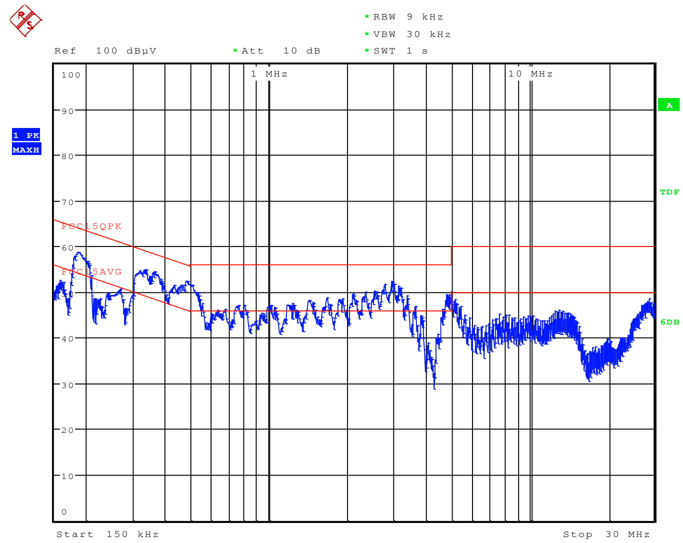


Figure 29. Peak EMI Scan

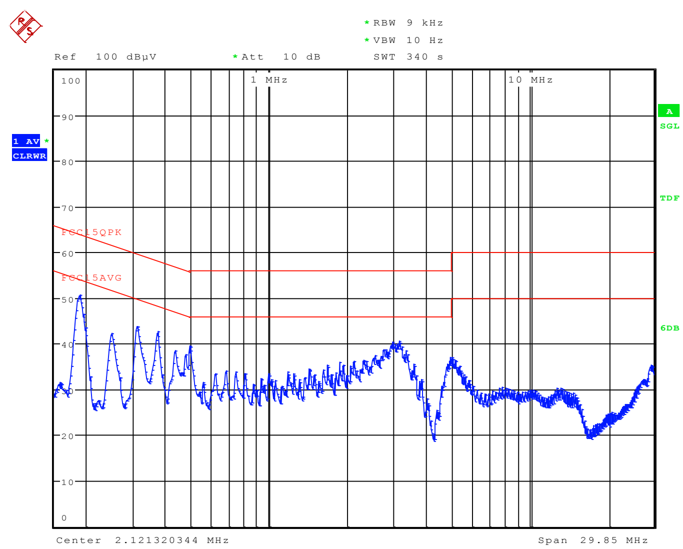


Figure 30. Average EMI Scan

8.13 Thermal Performance

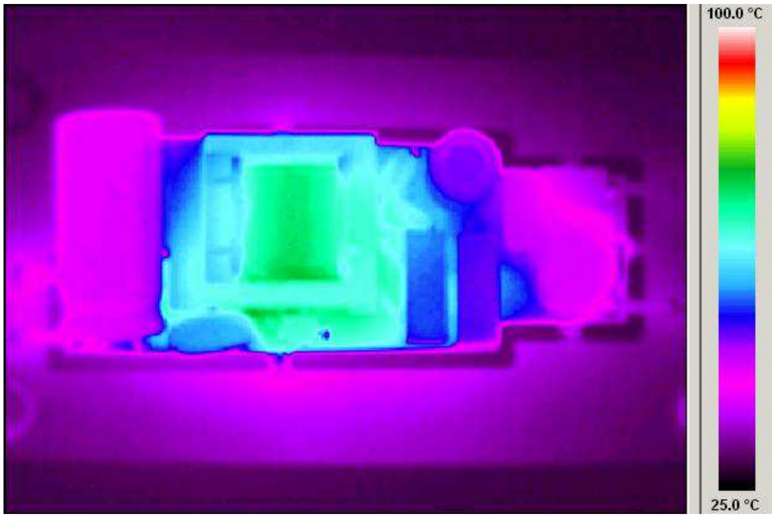


Figure 31. LM3447-PAR-230VEVM Thermal Image (top view)

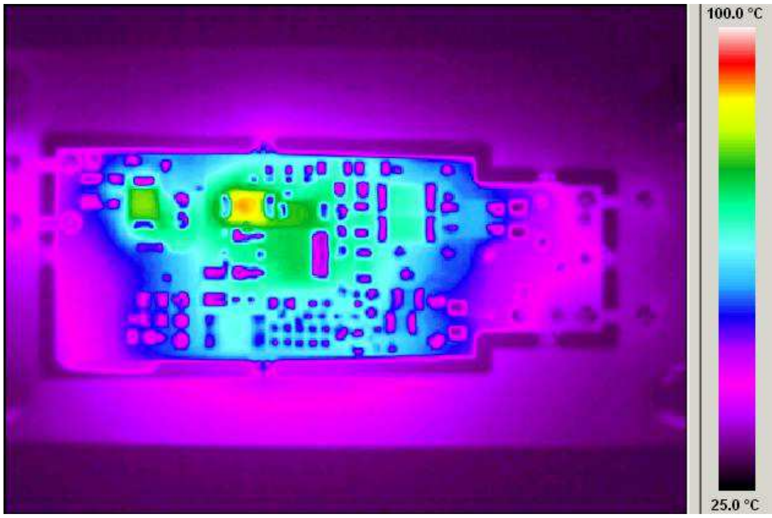
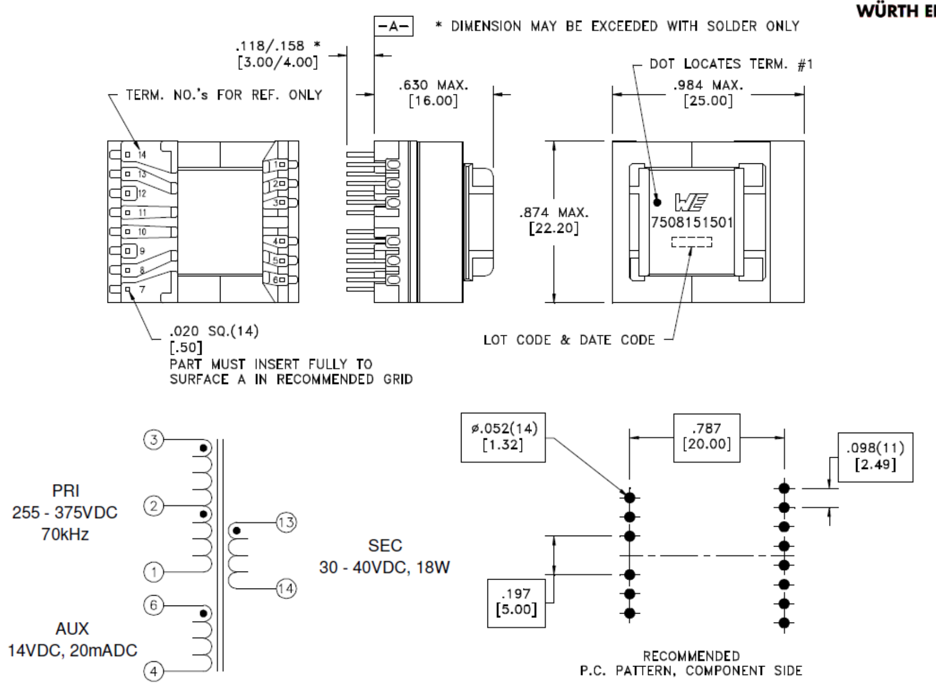


Figure 32. LM3447-PAR-230VEVM Thermal Image (bottom view)

9 Transformer Specification

CUSTOMER TERMINAL	RoHS	LEAD(Pb)–FREE
Sn96%, Ag4%	Yes	Yes

WÜRTH ELEKTRONIK



ELECTRICAL SPECIFICATIONS @ 25℃ unless otherwise noted:

D.C. RESISTANCE (@20℃): 3-1 , 3.80 Ohms ±10%.
6-4 , 0.385 Ohms ±10%.
13-14 , 0.120 Ohms ±10%.

DIELECTRIC RATING: 4500VAC, 1 minute tested by applying 4500VAC for 1 second between pins 3-13(tie 1+6).

INDUCTANCE: 1.78mH ±10%, 70kHz, 100mVAC, 0mADC, 3-1, Ls.

LEAKAGE INDUCTANCE: 45µH max., 100kHz, 100mVAC, 3-1(tie 4+6, 13+14), Ls.

TURNS RATIO: (3-1):(6-4), (11.54):(1.00), ±2%.
(3-1):(13-14), (5.17):(1.00), ±2%.
(3-2):(2-1), (1):(1.00), ±2%.

OPERATING TEMPERATURE RANGE: -40℃ to +125℃ including temp rise.

Designed to comply with the following requirements as defined by IEC61558-2-16:
- Reinforced insulation for a primary circuit at a working voltage of 400VDC.

Wire insulation & RoHS status not affected by wire color. Wire insulation color may vary depending on availability.

WE-Midcom, Inc.	Unless otherwise specified, tolerances are as follows: Angles: ±1° Fractions: ±1/64 Decimals:±.005(.127mm)	WE-Midcom, Inc.	
Watertown, SD USA Toll Free: 800-643-2661 Fax: 605-886-4486	Drawing Title Transformer	Drawing Number 7508151501	Rev. 01
This drawing is dual dimensioned. Dimensions is brackets are in millimeters	Revisions: See Sheet 1	Scale ----	Spec Sheet 1 of 1
	Engineer:EJK		06/05/2012

Figure 33. Transformer Specification

10 List of Materials

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

Table 3. LM3447-PAR-230VEVM List of Materials

QTY	REF DES	DESCRIPTION	MANUFACTURER	PARTNUMBER
1	U1	Phase-dimmable, primary-side power regulated, PFC flyback controller for LED Lighting	Texas Instruments	LM3447MTE/NOPB
1	C1	Capacitor, Ceramic, 2200 pF, 250 V, 20%, Radial	TDK Corporation	CD12-E2GA222MYNS
2	C3, C5	Capacitor, Film, 0.047 µF, 310 VAC, 20%, Radial	EPCOS	B32921C3473M
1	C4	Capacitor, Film, 0.01 µF, 630 VDC, 20%, Radial	Vishay BC Components	BFC233820103
2	C6, C9	Capacitor, Ceramic, 0.1 µF, 630 V, ±10%, X7R, Radial	TDK Corporation	FK22X7R2J104K
1	C7	AP, Aluminum, 680 µF, 50 V, ±20%, Radial	Vishay BC Components	MAL214651681E3
1	C8	Capacitor, Ceramic, 1 µF, 100 V, ±10%, X7R, 1210	MuRata	GRM32CR72A105KA35L
1	C10	Capacitor, Ceramic, 2.2 µF, 16 V, ±10%, X7R, 0805	MuRata	GRM21BR71C225KA12L
1	C11	Capacitor, Ceramic, 10uF, 35 V, ±10%, X7R, 1210	MuRata	GRM32ER7YA106KA12L
2	C12, C13	Capacitor, Ceramic, 0.1 µF, 16 V, ±10%, X7R, 0603	MuRata	GRM188R71C104KA01D
1	C14	Capacitor, Ceramic, 4.7 µF, 16 V, X7R, 10%, 0805	Murata Electronics North America	GRM21BR71C475KA73L
1	C15	Capacitor, Ceramic, 22 µF, 25 V, ±10%, X7R, 1210	MuRata	GRM32ER71E226KE15L
1	D1	Diode, Switching-Bridge, 600 V, 0.8 A, MiniDIP	Diodes Inc	HD06-T
1	D2	Diode, GPP Ultrafast, 800 V, 1 A, SMA	Vishay General Semiconductor	US1K-E3/61T
1	D3	Diode, Zener, 3.3V, 200 mW, SOD-323	Diodes Inc.	MMSZ5226BS-7-F
1	D4	Diode, Superfast, 200 V, 2 A, SMB	Diodes Inc	ES2D-13-F
2	D5, D6	Diode, Ultrafast, 100 V, 0.25 A, SOD-323	NXP Semiconductor	BAS316,115
1	D7	Diode, TVS, Uni, 220 V, 600 W, 5%, SMB	Littelfuse Inc	SMBJ220A
1	F1	Fuse, Slow, 500 mA, 250 VAC, Radial	Bel Fuse Inc	RST 500
2	L1, L2	Inductor, 3300 µH, 290 mA, 9.1 Ω (max), Radial	Bourns Inc.	RLB9012-332KL
1	Q1	MOSFET, N-channel, 800 V, 0.3 A, TO-92	STMicroelectronics	STQ1NK80ZR-AP
1	Q2	MOSFET, N-channel, 800 V, 3 A, DPAK	STMicroelectronics	STD4NK80ZT4
4	R1, R2, R5, R10	RES, 412 kΩ, 1%, 0.25W, 1206	Vishay-Dale	CRCW1206412KFKEA
1	R3	RES, 165 kΩ, 1%, 0.1W, 0603	Vishay-Dale	CRCW0603165KFKEA
1	R4	RES, 18 kΩ, 5%, 0.1W, 0603	Vishay-Dale	CRCW060318K0JNEA
1	R6	Res, Fusible, 6.8 Ω, x10%, 2W, Axial	WELWYN	EMC2-6R8K
2	R7, R8	RES, 1 kΩ, 5%, 1W, 2512	Vishay Dale	CRCW25121K00JNEGH P
1	R11	RES, 100 Ω, 1%, 0.125W, 0805	Vishay-Dale	CRCW0805100RFKEA
1	R12	RES, 0.18 Ω, 1%, 0.5W, 1210	Rohm	MCR25JZHFLR180
1	R13	RES, 10 Ω, 5%, 0.1W, 0603	Vishay-Dale	CRCW060310R0JNEA
1	R14	RES, 20 kΩ, 5%, 0.25W, 1206	Vishay-Dale	CRCW120620K0JNEA
1	R16	RES, 33 Ω, 5%, 0.125W, 0805	Vishay-Dale	CRCW080533R0JNEA
1	R17	RES, 4.7 kΩ, 5%, 0.125W, 0805	Vishay-Dale	CRCW08054K70JNEA
1	R18	RES, 143 kΩ, 1%, 0.1W, 0603	Vishay-Dale	CRCW0603143KFKEA
1	R19	RES, 280 kΩ, 1%, 0.1W, 0603	Vishay-Dale	CRCW0603280KFKEA
1	RT1	Thermistor NTC, 100 kΩ, 5%, 0603	MuRata	NCP18WF104J03RB
1	T1	Xfmr, EE20/10/6	Wurth/Midcom	7508151501 Rev 01
1	VR1	Varistor, 275VAC, 369VDC, 23J, 7 mm dia., Radial	Littelfuse Inc	V275LA4P

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During normal operation, some circuit components may have case temperatures greater than 90°C. The EVM is designed to operate properly with certain components above 90°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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