Design Example Report

Title	***8.8 W High Efficiency (>86%) High Power Factor (>0.91) TRIAC Dimmable Non-Isolated Buck LED Driver Using LYTSwitch™ -4 LYT4321E***
Specification	190 VAC – 265 VAC Input; 57 V_{TYP}, 155 mA Output
Application	PAR16 LED Driver
Author	Applications Engineering Department
Document Number	DER-370
Date	December 5, 2013
Revision	1.0

Summary and Features

- Efficiency >86% at 230 VAC
- TRIAC dimmable
  - Works with a wide selection of TRIAC dimmers
- Low-cost, low component count, small PCB
- Fast start-up time (<300 ms) – no perceptible delay
- Integrated protection and reliability features
  - Output short-circuit protected with auto-recovery
  - Auto-recovering thermal shutdown with large hysteresis
  - No damage during brown-out conditions
- PF >0.91 at 230 VAC
- A-THD <15% at 230 VAC
- Meets EN55015 conducted EMI

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Table of Contents

1 Introduction ... 4
2 Power Supply Specification ... 6
3 Schematic ... 7
4 Circuit Description ... 8
4.1 Input EMI Filtering ... 8
4.2 Power Circuit ... 8
4.3 Bias Supply and Output Feedback ... 9
4.4 TRIAC Phase Dimming Control Compatibility ... 9
5 PCB Layout ... 11
6 Bill of Materials ... 13
7 Inductor Specification ... 15
7.1 Electrical Diagram ... 15
7.2 Electrical Specifications ... 15
7.3 Materials ... 15
7.4 Inductor Build Diagram ... 16
7.5 Inductor Construction ... 16
8 Performance Data ... 17
8.1 Efficiency ... 17
8.2 Line and Load Regulation ... 18
8.3 Power Factor ... 19
8.4 A-THD ... 20
8.5 Harmonics ... 21
8.6 Test Data ... 22
8.6.1 Test Data, 60 V LED Load ... 22
8.6.2 Test Data, 57 V LED Load ... 22
8.6.3 Test Data, 54 V LED Load ... 22
8.6.4 Test Data, 51 V LED Load ... 23
9 Dimming Performance Data ... 24
9.1 Dimming Curve with Leading Edge Type Dimmer ... 24
9.2 Dimmer Compatibility List ... 25
10 Thermal Performance ... 27
10.1 Non-Dimming V_{LED} = 60 V LED Load ... 27
10.2 Dimming V_{LED} = 60 V LED Load ... 28
11 Non-Dimming Waveforms ... 29
11.1 Input Voltage and Input Current Waveforms ... 29
11.2 Output Current and Output Voltage at Normal Operation ... 29
11.3 Input Voltage and Output Current Waveform at Start-up ... 30
11.4 Drain Voltage and Current at Normal Operation ... 30
11.5 Start-up Drain Voltage and Current ... 32
11.6 Drain Current and Drain Voltage During Output Short Condition ... 33
11.7 Output Diode Current and Voltage Waveforms ... 34
11.8 Brown-out ... 35
12 Dimming Waveforms ... 36
12.1 Input Voltage and Input Current Waveforms ... 36

13 Conducted EMI 37
13.1 Test Set-up 37
14 Line Surge Test 39
15 Revision History 40

Important Note: Although this board is designed to satisfy safety isolation requirements, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.

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1 Introduction

The document describes a non-isolated, high power factor (PF), high efficiency, TRIAC dimmable LED driver designed to drive a nominal LED string voltage of 57 V at 155 mA from an input voltage range of 190 VAC to 265 VAC (50 Hz typical).

The topology used is a single-stage non-isolated buck that meets high power factor, constant current output and which provides dimming.

This document contains the LED driver specification, schematic, PCB information, bill of materials, transformer documentation and typical performance characteristics.

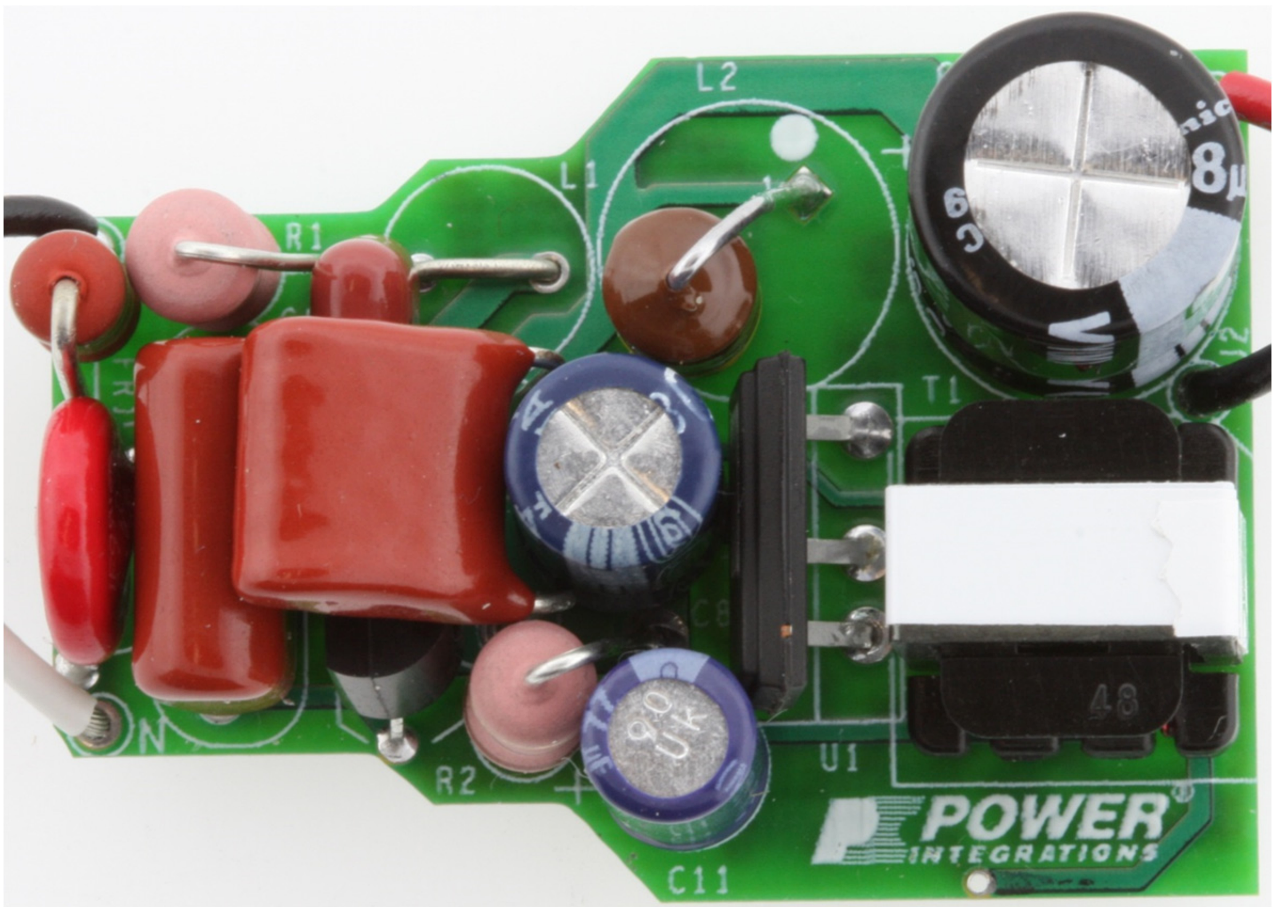

Figure 1 – Populated Circuit Board, Top View.

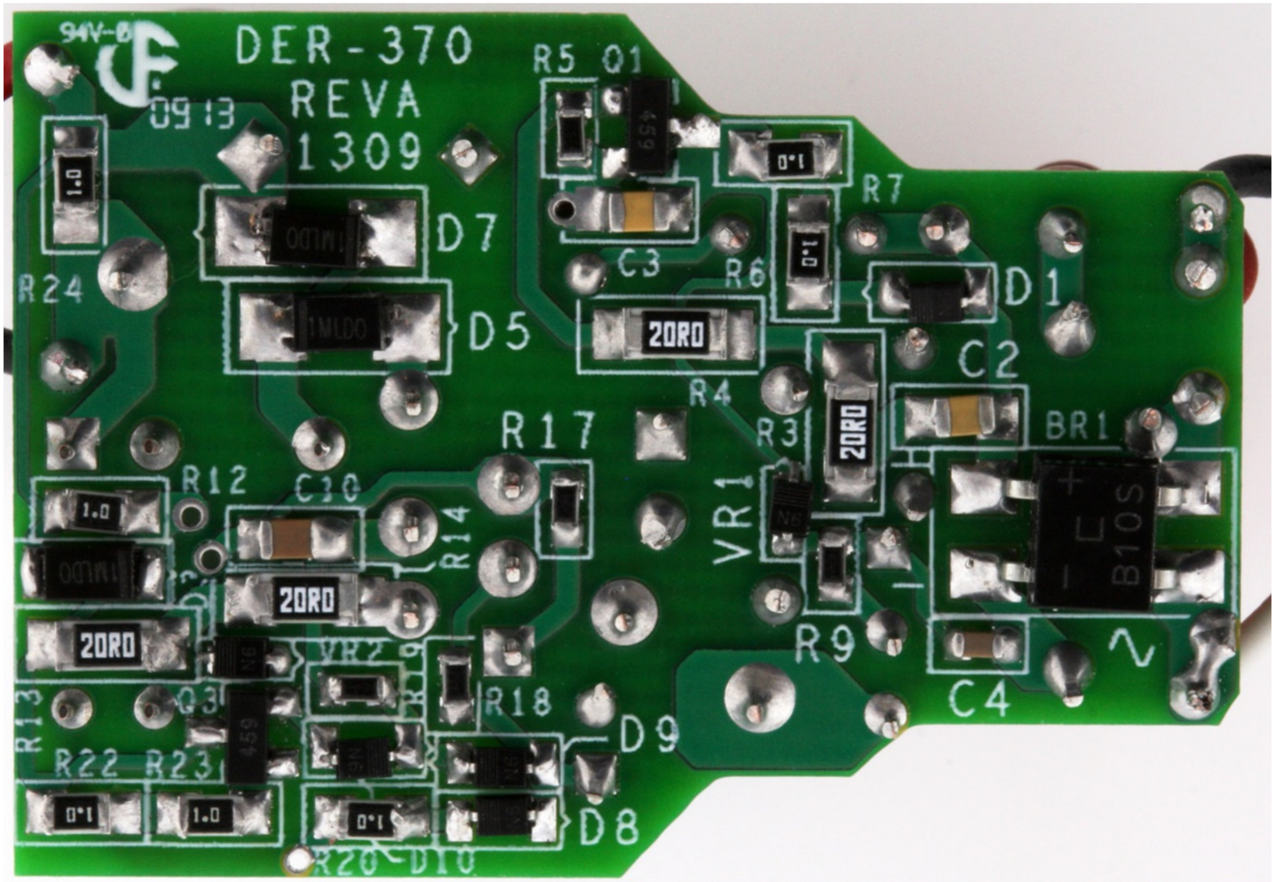

Figure 2 – Populated Circuit Board, Bottom View.

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2 Power Supply Specification

The table below represents the minimum acceptable performance of the design. Actual performance is listed in the results section.

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	190	230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}		50/60		Hz	
Output						
Output Voltage	V_{OUT}	51	57	60	V	
Output Current	I_{OUT}		155		mA	V_{OUT} = 54 V, V_{IN} = 230 VAC, 25 ^{0}C
Total Output Power						
Continuous Output Power	P_{OUT}		8.8		W	
Efficiency						
Full Load	η	88	89		%	Measured at P_{OUT} 25 ^{o}C
Environmental						
Conducted EMI		CISPR 15B / EN55015B				
Safety		Non-Isolated				
Ring Wave (100 kHz)						
Differential Mode (L1-L2)			2.5		kV	
Common mode (L1/L2-PE)						
Differential Surge			500		V	
Power Factor		0.91				Measured at $V_{OUT(TYP)}$, $I_{OUT(TYP)}$ and 230 VAC, 50 Hz
Harmonic Currents		EN 61000-3-2 Class C				
Ambient Temperature	T_{AMB}				^{o}C	

3 Schematic

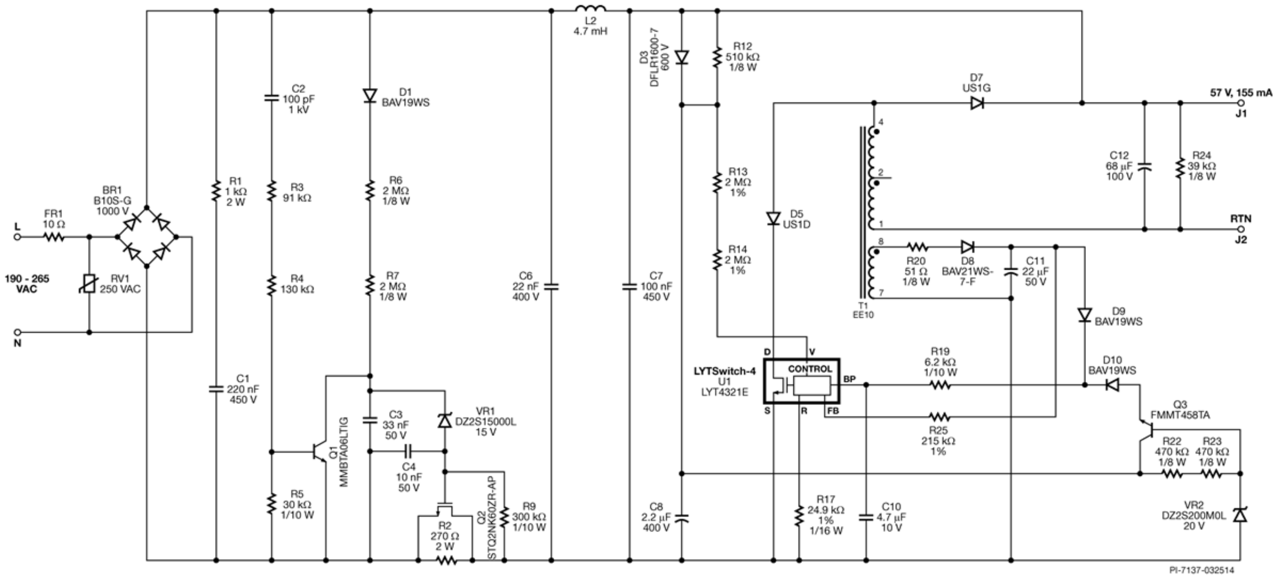

Figure 3 – Schematic.

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4 Circuit Description

The LYT4321E (U1) is a highly integrated primary-side controller designed for use in LED applications. It provides high power factor while regulating the output current across a range of input voltage (190 VAC to 265 VAC) in a single conversion stage. All of the control circuitry responsible for these functions plus the high-voltage power MOSFET is incorporated into the IC.

4.1 Input EMI Filtering

Fuse FR1 provides protection from component failure and provides extra damping during dimming. MOV RV1 provides a clamp to limit voltage during differential line surge events. Bridge rectifier BR1 rectifies the AC line voltage.

EMI filtering is provided by a π filter which consists of an inductor (L2) and capacitors C6 and C7.

4.2 Power Circuit

The topology chosen in this design is a low-side buck configured to provide high efficiency with small magnetics, low THD, high power factor, and constant current output for the input voltage range of 190 VAC to 265 VAC.

Inductor T1 is the main inductor of the buck converter. It consists of two windings - the primary and the bias winding. The primary winding is the main buck inductor. The bias winding is the supply for the IC and helps prevent flicker and shimmer during deep dimming. For TRIAC dimming, a bias supply of at least 25 V supply is required. This requirement ensures adequate voltage to supply the IC at the minimum LED string voltage and with a TRIAC dimmer operates at minimum conduction angle (<30 degrees).

Output diode D7 conducts every time U1 turns off, allowing stored energy in T1 to transfer to the load. Diode D5 is necessary to prevent reverse current from flowing back through U1 when the voltage across C7 (rectified input AC) falls below the output voltage.

To provide peak line voltage information to U1, the incoming rectified AC peak charges C8 via D3. This is then fed into the VOLTAGE MONITOR (V) pin of U1 as a current via R13 and R14. Resistor R12 is a discharge path for C8 to allow V pin to respond quickly when there is a line sag.

The line overvoltage shutdown function, sensed via the V pin, extends the rectified line voltage withstand (during surges and line swells) to the 725 BV_{DSS} rating of the internal power MOSFET. The fast acting line overvoltage detection of LYTSwitch in conjunction with D3 and C8 peak detector capacitor provides a clamp to limit the maximum voltage stress across the power MOSFET of the IC during line surge event. A value of 2.2 μF on C8 can withstand 500 V surges, while 4.7 μF can withstand 1 kV surge. An additional 270 VAC rated MOV (Metal Oxide Varistor) can be used for >1 kV differential line surge requirement.

Capacitor C10 provides local decoupling for the BYPASS (BP) pin of U1 which is the supply pin for the internal controller. During start-up, C10 is charged to ~6 V from an internal high-voltage current source connected to the DRAIN (D) pin of U1. The use of an external bias supply (via D9 and R19) is recommended to give the lowest device dissipation and provide sufficient supply to U1 during deep dimming condition. Capacitor C10 was chosen to be 4.7 μF since LYT4321E has only one power mode. A value of 24.9 kΩ resistor was used for the REFERENCE (R) pin (R17) and 4 MΩ (R13+R14) on the V pin to provide a linear relationship between input voltage and the output current.

Output capacitor C12 is the output filter capacitor. Pre-load resistor R24 causes the output to quickly discharge below the LED string voltage when the AC is removed and ensuring that the lamp is extinguished (rather than there being a slight glow for several seconds after AC is removed).

4.3 Bias Supply and Output Feedback

A bias winding on T1 is used to provide feedback and supply to the IC. The bias winding voltage is used to sense the output voltage indirectly, eliminating secondary-side feedback components. The voltage on the bias winding is proportional to the output voltage (set by the turn ratio between the bias and primary windings). The flyback voltage on the bias winding is rectified by D8 and filtered by C11 to smooth the voltage and R20 to reduce excess voltage coupled from the leakage inductance energy. The feedback current is then fed to the FEEDBACK (FB) pin thru resistor R25. Diode D9 and R19 link the BP pin to the bias winding. Diode D9 is necessary to isolate the voltage potential of the BP from inhibiting auto-restart function during start-up or in a short-circuit condition. Resistor R19 limits the current supplied to the BP pin from the bias winding. The internal engine within U1 combines the FB pin current, the V pin current, and internal drain current information to provide a constant output current whilst maintaining high input power factor.

4.4 TRIAC Phase Dimming Control Compatibility

The requirement to provide output dimming with low cost, TRIAC based, leading edge and trailing edge phase dimmers introduced a number of trade-offs with the design.

Due to the much lower power consumed by LED based lighting, the current drawn by the lamp is below the holding current of the TRIAC in many dimmers. This causes undesirable behavior such as limited dim range and/or flickering when the TRIAC fires inconsistently. The relatively large impedance presented to the line by the LED could cause significant ringing to occur due to the inrush current charging the input capacitance when the TRIAC turns on. This effect can cause shimmer as the ringing may cause the TRIAC current to fall to zero and turn off.

The damper, bleeder, and linear regulator circuit employed in the design overcome these issues with minimal impact on efficiency of the driver.

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The PI proprietary active damper consists of main components D1, R6, R7, VR1, R9, Q2, C4, Q1, Q2, R3, R4, R5 and R2. Where Q2 is fully on when there is no TRIAC connected, bypassing R2 which will keep the power dissipation low thereby making the system efficiency high. A TRIAC is detected through C2, R3 and R4 which will momentarily drive Q1 on, keeping C3 grounded and the gate of Q2 low allowing R2 to be in series with the TRIAC to act as damping element (current ringing) every time the TRIAC turns on.

The passive bleeder network comprises capacitor C1 and resistor R1. This network damps the input and aso provides the required latching and holding current for the TRIAC dimmer.

The linear regulator circuit R22, R23, VR2, Q3, and D10 were added to keep the supply of the IC (BP pin) constant - allowing it to operate normally at very low conduction angle or with very low input voltage and making the IC act as a load (vital for TRIACs with high leakage current). Most high power rated (>600 W) TRIAC dimmers have an LC input filter. If the TRIAC filter capacitance is large enough to provide sufficient energy to charge the input stage of the LED driver, the LED may turn on as the LED load is energized until the input is discharged. The cycle then repeats and causes flickering of the LED load even if the TRIAC is off.

The linear regulator is not activated when the bias voltage is higher than Vz_{VR2} $+Vt_{Q3}$ + Vf_{D10}. Voltage regulator VR2 is chosen such that the linear regulator will only work during deep dimming when the bias voltage is sufficiently low, this is to minimize Q3 power dissipation.

5 PCB Layout

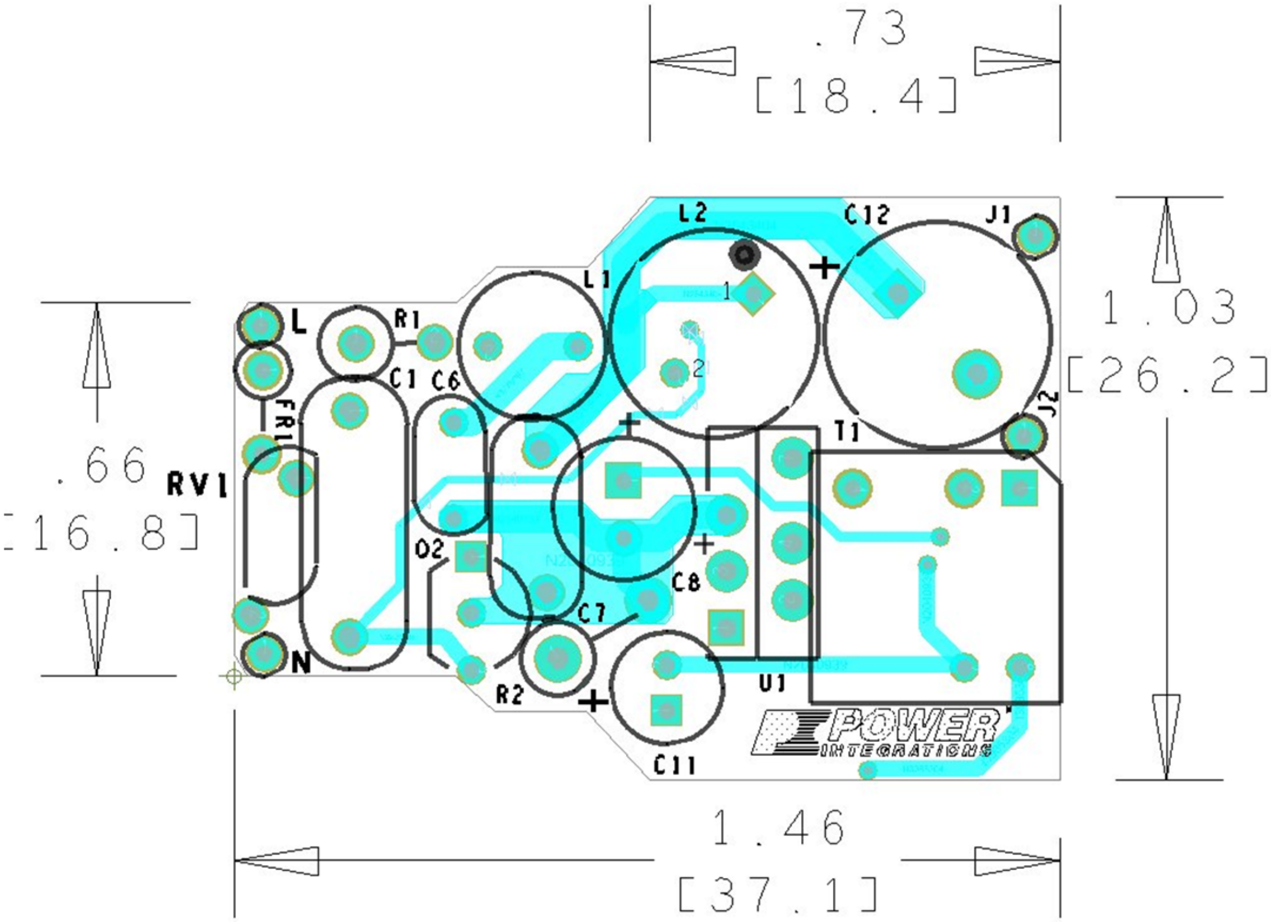

Figure 4 – Top Side.

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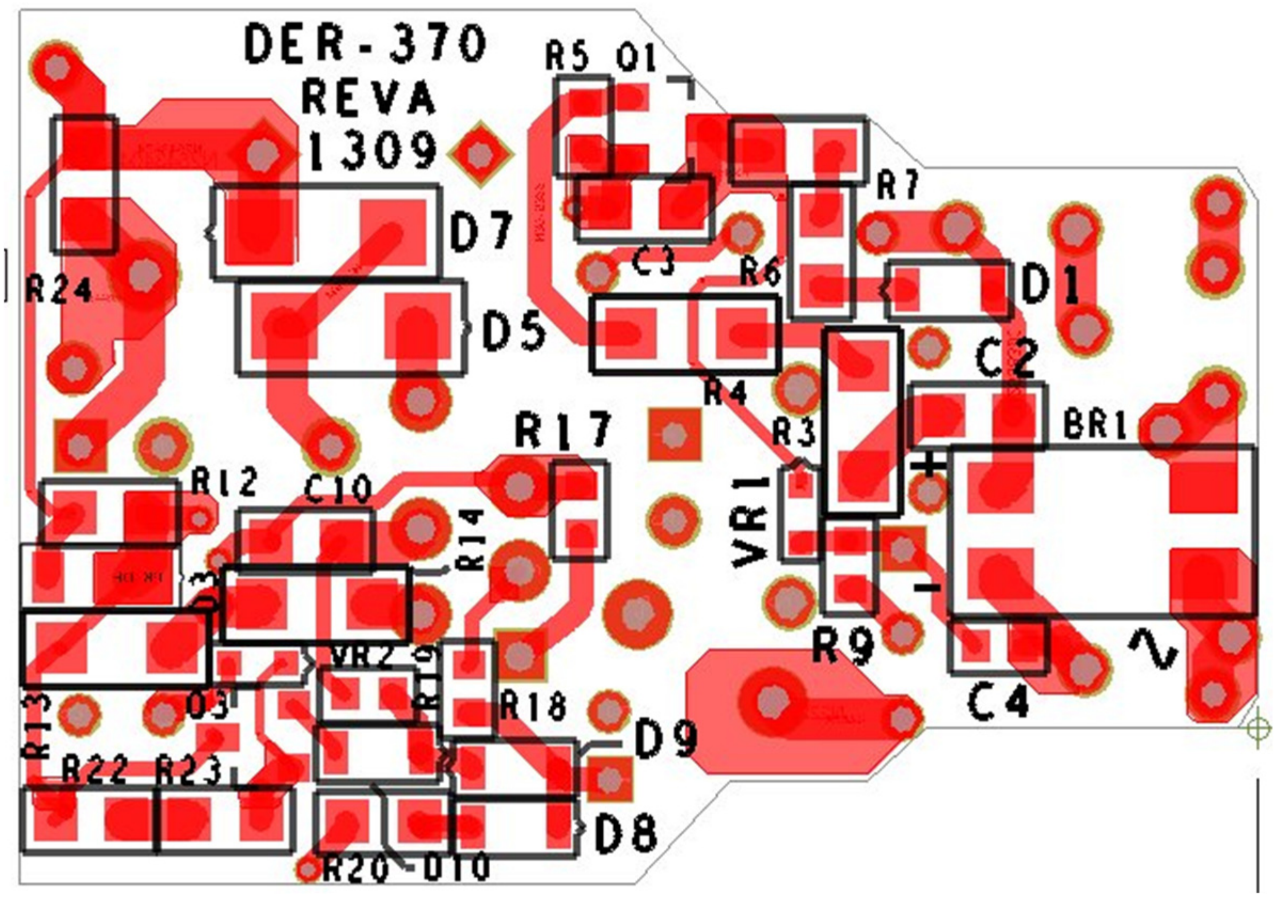

Figure 5 – Bottom Side.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip Technology
2	1	C1	220 nF, 450 V, Film	MEXXF32204JJ	Duratech
3	1	C2	100 pF, 1000 V, Ceramic, NPO, 0805	C0805C101MDGACTU	Kemet
4	1	C3	33 nF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB333	Yageo
5	1	C4	10 nF 50 V, Ceramic, X7R, 0603	C0603C103K5RACTU	Kemet
6	1	C6	22 nF, 400 V, Film	ECQ-E4223KF	Panasonic
7	1	C7	100 nF, 450 V, Film	MEXXD31004JJ1	Duratech
8	1	C8	2.2 μF, 400 V, Electrolytic, (6.3 x 11)	TAB2GM2R2E110	Ltec
9	1	C10	4.7 μF, 10 V, Ceramic, X7R, 0805	C0805C475K8PACTU	Kemet
10	1	C11	22 μF, 50 V, Electrolytic, (5 x 11)	UPW1H220MDD	Nichicon
11	1	C12	68 μF, 100 V, Electrolytic, (10 x 12.5)	UVY2A680MPD	Nichicon
12	1	D1	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diodes, Inc.
13	1	D3	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
14	1	D5	DIODE ULTRA FAST, SW, 200 V, 1 A, SMA	US1D-13-F	Diodes, Inc.
15	1	D7	DIODE ULTRA FAST, GPP, 400 V, 1 A SMA	US1G-13-F	Diodes, Inc.
16	1	D8	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
17	1	D9	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diodes, Inc.
18	1	D10	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diodes, Inc.
19	1	FR1	10 R, 5%, 2 W, Metal Film, Fusible	NFR0200001009JR500	Vishay
20	1	J1	PCB Terminal Hole, #30 AWG	N/A	N/A
21	1	J2	PCB Terminal Hole, #30 AWG	N/A	N/A
22	1	L	PCB Terminal Hole, #30 AWG	N/A	N/A
23	1	L1	Wire Jumper, Non-insulated,# 22 AWG, 0.2 in	298	Alpha
24	1	L2	4.7 mH, 90 mA, 20 Ω, RF Inductor	B82144A2475J	Epcos
25	1	N	PCB Terminal Hole, 30 AWG	N/A	N/A
26	1	Q1	NPN, Small Signal BJT, 80 V, 0.5 A, SOT-23	MMBTA06LT1G	On Semi
27	1	Q2	600 V, 0.4 A, 8 Ω, N-Channel, TO-92	STQ2NK60ZR-AP	ST Micro
28	1	Q3	NPN, HP, 400 V, 225 mA, SOT23-3	FMMT458TA	Diodes-Zetex
29	1	R1	1 kΩ, 5%, 2 W, Metal Film	FMP200JR-52-1K	Yageo
30	1	R2	270 Ω, 5%, 2 W, Metal Film	FMP200JR-52-270R	Yageo
31	1	R3	91 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ913V	Panasonic
32	1	R4	130 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ134V	Panasonic
33	1	R5	30 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ303V	Panasonic
34	1	R6	2 MΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ205V	Panasonic
35	1	R7	2 MΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ205V	Panasonic
36	1	R9	300 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ304V	Panasonic
37	1	R12	510 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ514V	Panasonic
38	1	R13	2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
39	1	R14	2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
40	1	R17	24.9 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2492V	Panasonic
41	1	R18	215 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2153V	Panasonic
42	1	R19	6.2 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ622V	Panasonic
43	1	R20	51 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ510V	Panasonic
44	1	R22	470 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ474V	Panasonic
45	1	R23	470 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ474V	Panasonic
46	1	R24	39 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ393V	Panasonic
47	1	RV1	250 V, 21 J, 7 mm, RADIAL LA	V250LA4P	Littlefuse

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48	1	T1	Transformer Bobbin, EE10, Vertical, 8 pins	SNX-R1727 TDK-118CPSFR	Santronics USA TDK
49	1	U1	LYTSwitch-4, eSIP-7C	LYT4321E	Power Integrations
50	1	VR1	15 V, 5%, 150 mW, SSMINI-2	DZ2S15000L	Panasonic-SSG
51	1	VR2	20 V, 5%, 150 mW, SSMINI-2	DZ2S200M0L	Panasonic

7 Inductor Specification

7.1 Electrical Diagram

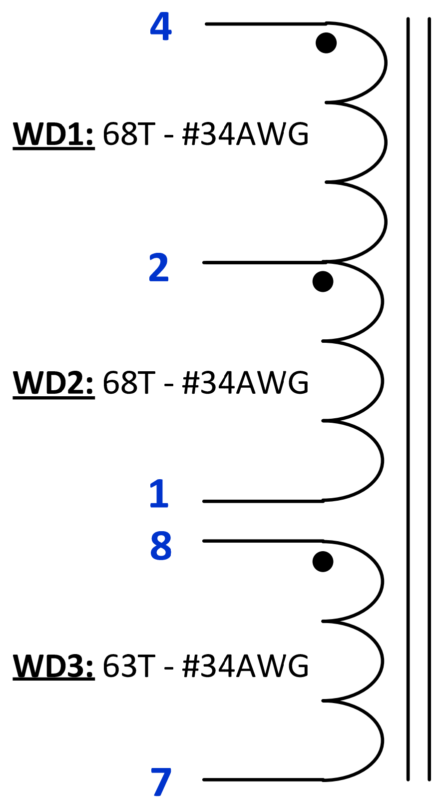

Figure 6 – Inductor Electrical Diagram.

7.2 Electrical Specifications

Primary Inductance	Pins 1-4, all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	1000 - 1100 μH
Resonant Frequency	Pins 1-4, all other windings open.	800 kHz (Min.)

7.3 Materials

Item	Description
[1]	Core: EE10, NC2H.
[2]	Bobbin: EE10-Vertical, 8 pins (4/4). P/N: TDK-118CPSFR; PI P/N: 25-00877-00.
[3]	Magnet wire: #34 AWG - Double coated.
[4]	Magnet wire: #34 AWG - Double coated.
[5]	Magnet wire: #34 AWG - Double coated.
[6]	Tape: 3M 1298 Polyester Film, 6 mm wide, 2.0 mils thick, or equivalent.
[7]	Varnish: Dolph BC-359 or equivalent.

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7.4 Inductor Build Diagram

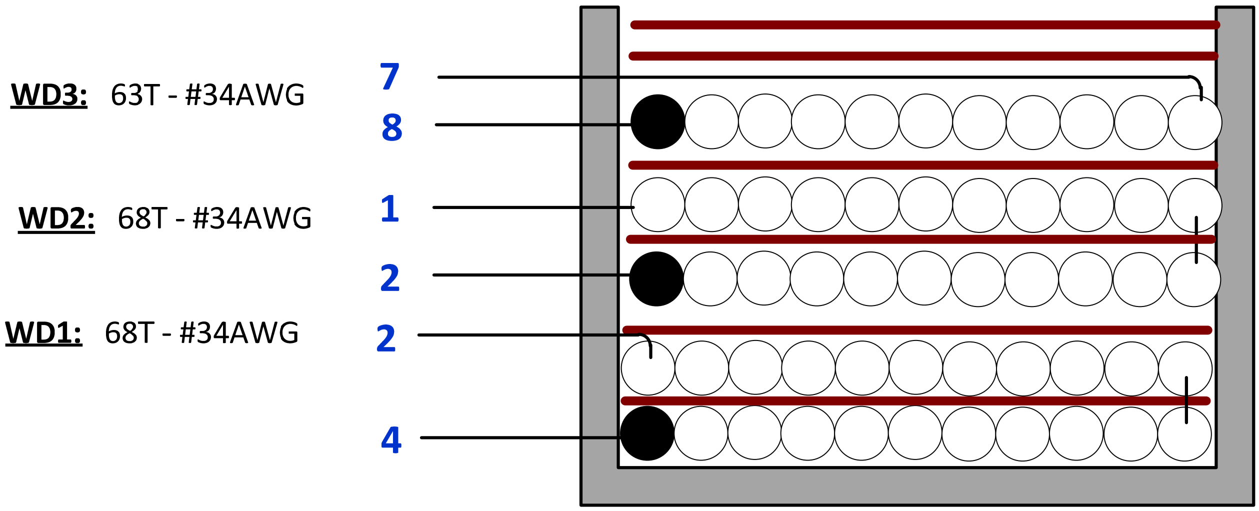

Figure 7 – Inductor Build Diagram.

7.5 Inductor Construction

Winding Preparation	Place the bobbin on the mandrel with the pin side is on the left side. Winding direction is clockwise direction.
WD1	Start at pin 4, wind 34 turns of wire item [3] from left to right, place 1 layer tape item [6], then continue wind another 34 turns from right to left, place 1 layer tape item [6], and end at pin 2.
Insulation	Place 1 layer of tape item [6].
WD2	Start at pin 2, wind 34 turns of wire item [3] from left to right, place 1 layer tape item [6], then continue wind another 34 turns from right to left, place 1 layer tape item [6], and end at pin 1.
Insulation	Place 1 layer of tape item [6].
WD3	Start at pin 8, wind 63 turns of wire item [5] from left to right in 1 layer. At the last turn bring the wire back to the left and end at pin 7.
Insulation	Place 2 layers of tape item [6].
Final Assembly	Grind, assemble, and secure core halves with tape. Varnish with item [7]. Cut pin 2.

8 Performance Data

All measurements performed at room temperature using an LED load. The following data was measured using 4 sets of loads representing a load range of 51 V to 60 V (output voltage). Refer to the table on Section 9.6 for test data.

8.1 Efficiency

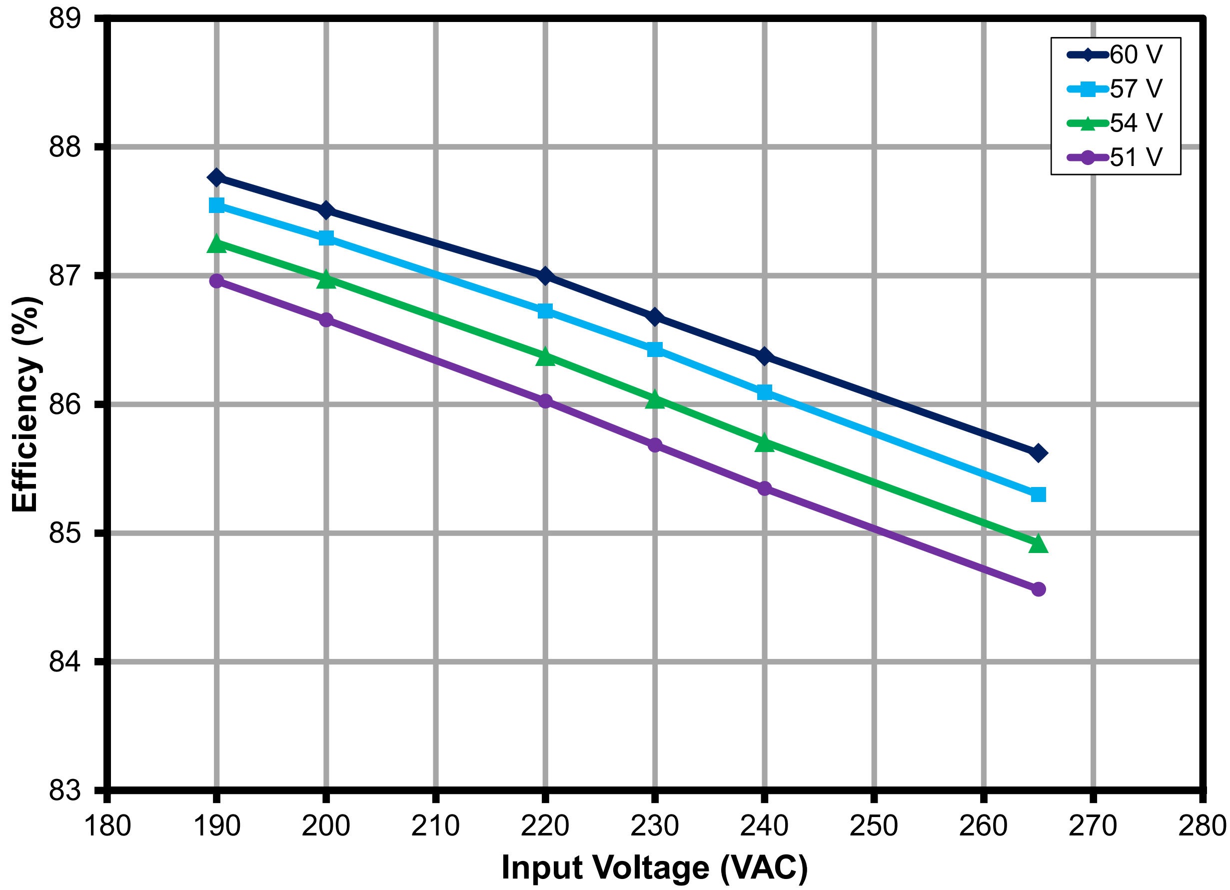

Figure 8 – Efficiency vs. Line and Load.

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8.2 Line and Load Regulation

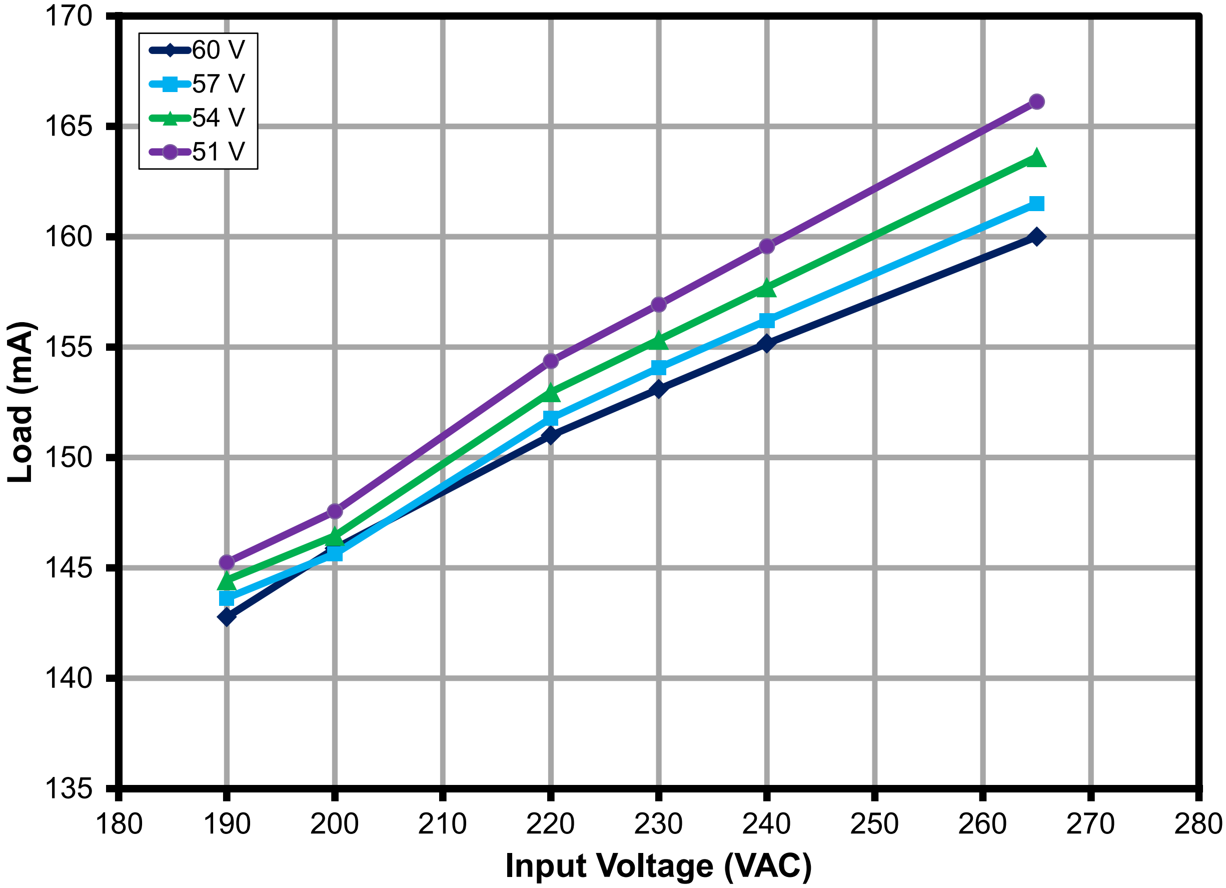

Figure 9 – Regulation vs. Line and Load.

8.3 Power Factor

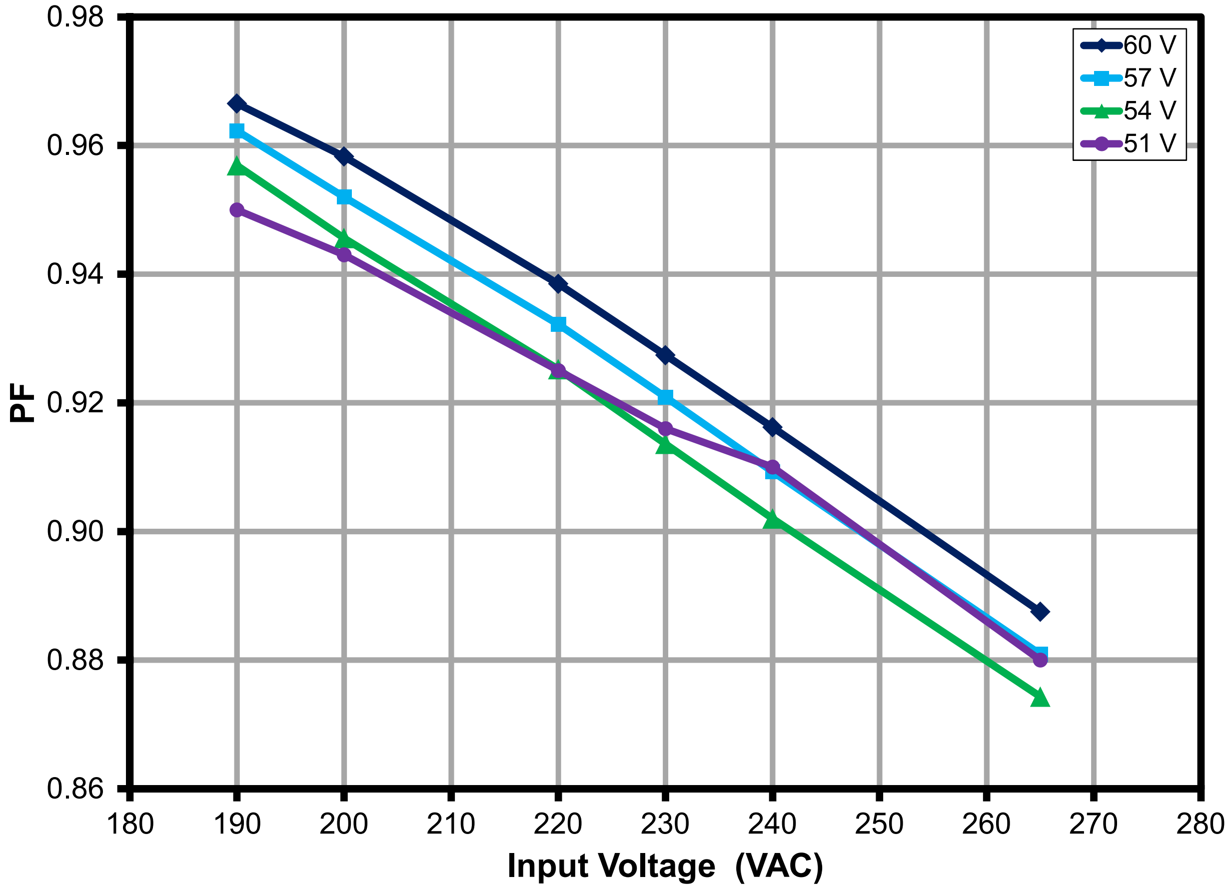

Figure 10 – Power Factor vs. Line and Load.

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8.4 A-THD

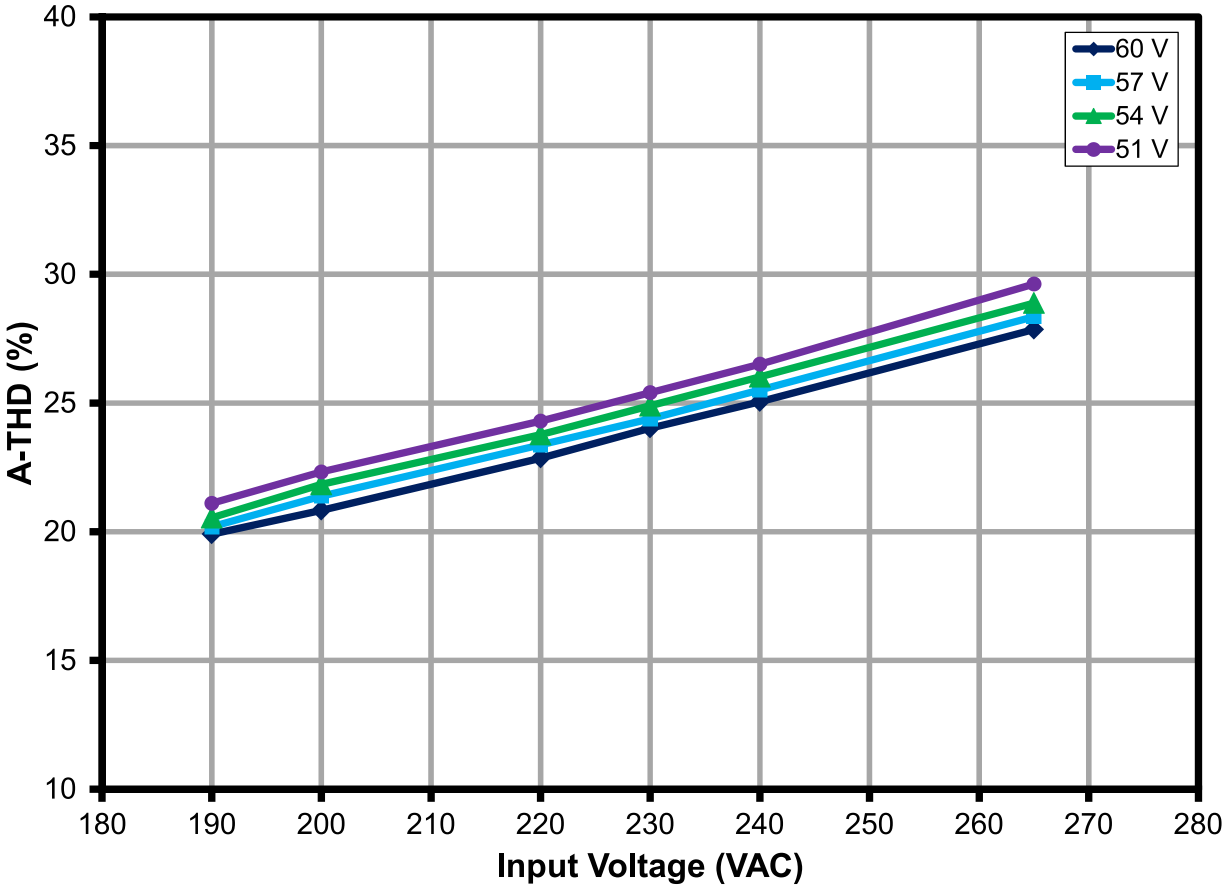

Figure 11 – A-THD vs. Line and Load.

8.5 Harmonics

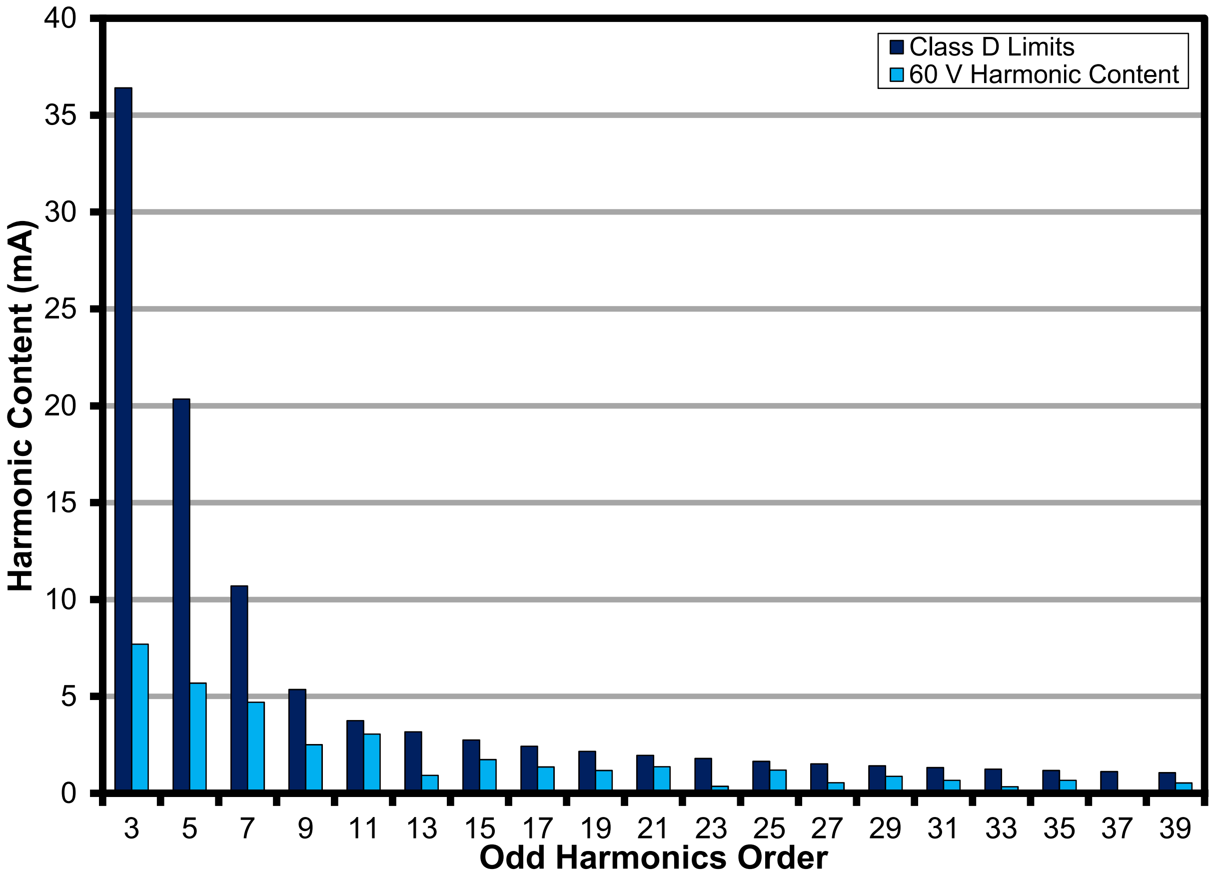

Figure 12 – 60 V LED Load Input Current Harmonics at 230 VAC, 50 Hz.

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8.6 Test Data

All measurements were taken with the board at open frame, 25 ºC ambient, and 50 Hz line frequency.

8.6.1 Test Data, 60 V LED Load

Input		Input Measurement					LED Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
190	50	189.89	54.78	9.846	0.967	19.906	59.8360	142.770	8.641	87.76
200	50	199.93	53.81	10.094	0.958	20.828	59.8670	145.880	8.833	87.51
220	50	219.89	52.09	10.520	0.939	22.853	59.9430	151.000	9.152	87.00
230	50	229.93	51.31	10.705	0.927	24.02	59.9540	153.090	9.279	86.68
240	50	239.97	50.64	10.890	0.916	25.047	59.9660	155.160	9.406	86.37
265	50	264.93	49.33	11.337	0.888	27.858	60.0400	160.000	9.707	85.62

8.6.2 Test Data, 57 V LED Load

Input		Input Measurement					LED Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
190	50	189.90	52.97	9.478	0.962	20.191	57.0910	143.630	8.298	87.55
200	50	199.93	51.72	9.638	0.952	21.379	57.1010	145.640	8.413	87.29
220	50	219.90	50.48	10.125	0.932	23.376	57.1960	151.770	8.781	86.73
230	50	229.93	49.79	10.314	0.921	24.388	57.2100	154.060	8.914	86.43
240	50	239.97	49.20	10.499	0.909	25.505	57.2220	156.210	9.039	86.09
265	50	264.93	48.08	10.966	0.881	28.353	57.3020	161.500	9.354	85.30

8.6.3 Test Data, 54 V LED Load

Input		Input Measurement					LED Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
190	50	189.90	50.96	9.067	0.957	20.548	54.1000	144.450	7.911	87.25
200	50	199.93	49.84	9.223	0.946	21.836	54.1230	146.450	8.022	86.98
220	50	219.90	48.82	9.718	0.925	23.776	54.2300	152.960	8.394	86.38
230	50	229.94	48.23	9.910	0.914	24.892	54.2550	155.330	8.527	86.04
240	50	239.97	47.74	10.104	0.902	26.017	54.2820	157.710	8.660	85.71
265	50	264.93	46.81	10.593	0.874	28.883	54.3790	163.610	8.996	84.92

8.6.4 Test Data, 51 V LED Load

Input		Input Measurement					LED Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
190	50	189.90	49.01	8.664	0.950	21.108	51.2240	145.240	7.534	86.96
200	50	199.93	48.08	8.836	0.943	22.32	51.2560	147.560	7.657	86.66
220	50	219.90	47.25	9.331	0.925	24.302	51.3660	154.360	8.027	86.03
230	50	229.94	46.76	9.528	0.916	25.401	51.4000	156.920	8.164	85.68
240	50	239.97	46.37	9.732	0.910	26.506	51.4330	159.560	8.306	85.35
265	50	264.94	45.56	10.242	0.880	29.626	51.5390	166.120	8.661	84.56

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9 Dimming Performance Data

TRIAC dimming results were taken with input voltage of 230 VAC, 50 Hz line frequency, room temperature, and nominal 60 V LED load.

9.1 Dimming Curve with Leading Edge Type Dimmer

Taken using programmable AC source providing leading edge chopped AC input.

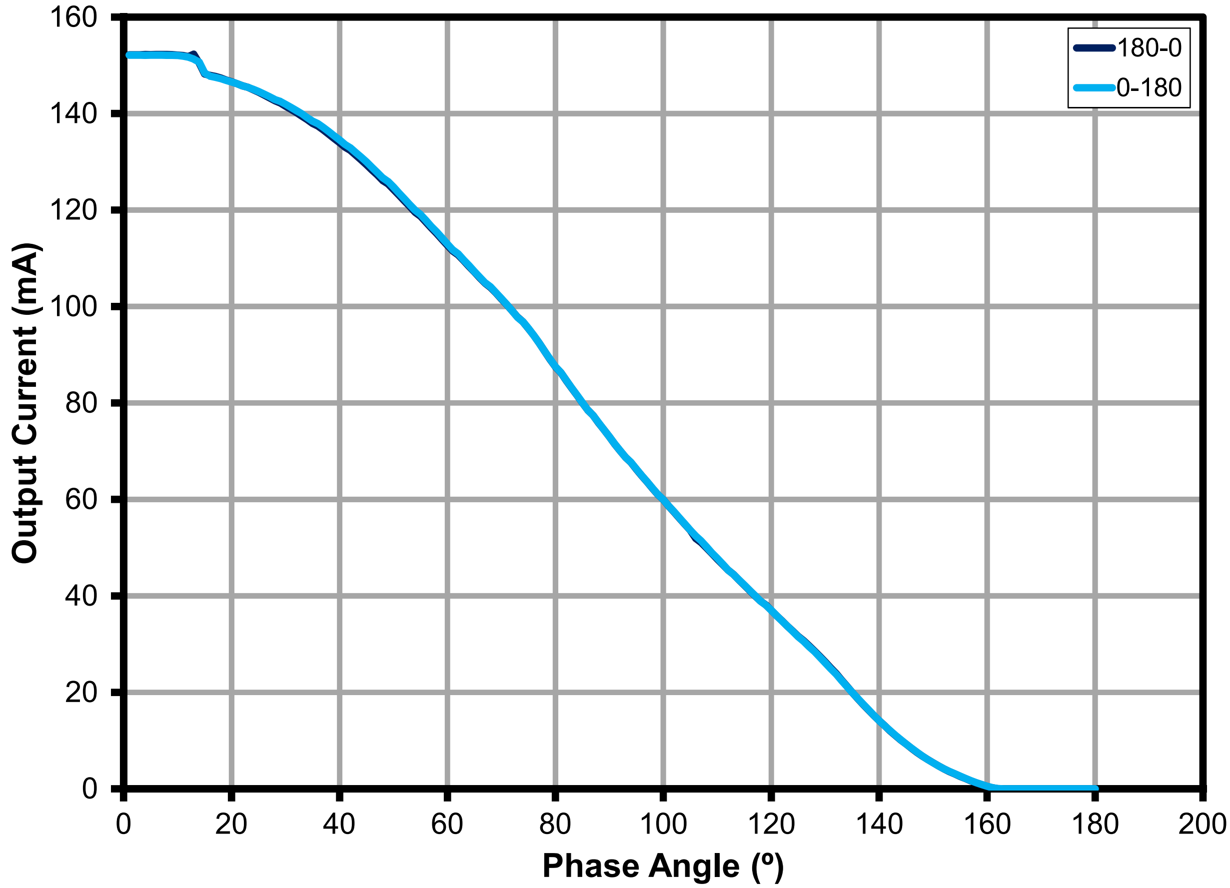

Figure 13 – Leading Edge Dimming Characteristics.

9.2 Dimmer Compatibility List

The unit was tested with the following high-line dimmers at 230 VAC, 50 Hz input and 60 V LED load and using Agilent 6812B AC source.

Chinese Dimmers	Type	Maximum Setting I_{OUT} (mA)	Minimum Setting I_{OUT} (mA)
TCL 630 W	L	145	1
SEN BO LANG 300W	L	147	3
EBA HUANG	L	147	3
SB ELECT 600 W	L	142	4
MYONGBO	L	148	4
KBE 650W	L	147	3
CLIPMEI	L	147	3
MANK 200 W	L	148	4

German Dimmers	Type	Maximum Setting I_{OUT} (mA)	Minimum Setting I_{OUT} (mA)
BUSCH 2250	L	140	6
MERTEN 572499	L	144	3
BERKER 2875 600 W	L	137	6

Italian Dimmers	Type	Maximum Setting I_{OUT} (mA)	Minimum Setting I_{OUT} (mA)
RELCO RM34DMA 160W	L	153	5
RELCO RM34DMA 500W	L	155	6
RELCO RTS34.43 RLI 300W	L	155	16
RELCO RT34DSL 500W	L	156	5
MATIX AM5702 500W	L	113	3

Korean Dimmers	Type	Maximum Setting I_{OUT} (mA)	Minimum Setting I_{OUT} (mA)
ANAM 500W	L	143	32
SHIN SUNG 500W	L	146	15
FANTASIA 500W	L	141	27
SHIN SUNG 700W		144	6

EU Dimmers	Type	Maximum Setting I_{OUT} (mA)	Minimum Setting I_{OUT} (mA)
BERKER 2830 10	L	138	8
JUNG 225 NV DE	L	140	13
JUNG 266 G DE	L	138	6
BUSCH 2200 UJ-212	L	136	9
BUSCH 2250 U	L	141	6
BUSCH 2247 U	L	137	11
GIRA 2262 00 / IO1	L	138	12
GIRA 0300 00 / IO1	L	136	11
GIRA 0302 00 / IO1	L	138	7
NIKO 310-013	L	141	5

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NIKO 310-014	L	142	11
NIKO 310-016	L	140	11

Trailing Edge Dimmers	**Type**	**Maximum Setting I_{OUT} (mA)**	**Minimum Setting I_{OUT} (mA)**
PEHA 433HAB	T	146	40
PEHA 433HAB oA	T	140	20

Figure 14 – Compatibility List.

10 Thermal Performance

Images captured after running for >60 minutes at room temperature (25 °C), open frame for the conditions described on the corresponding figures below.

NOTE: Potting the board or placing heat sink on U1 may be necessary when used in high ambient conditions.

10.1 Non-Dimming V_{LED} = 60 V LED Load

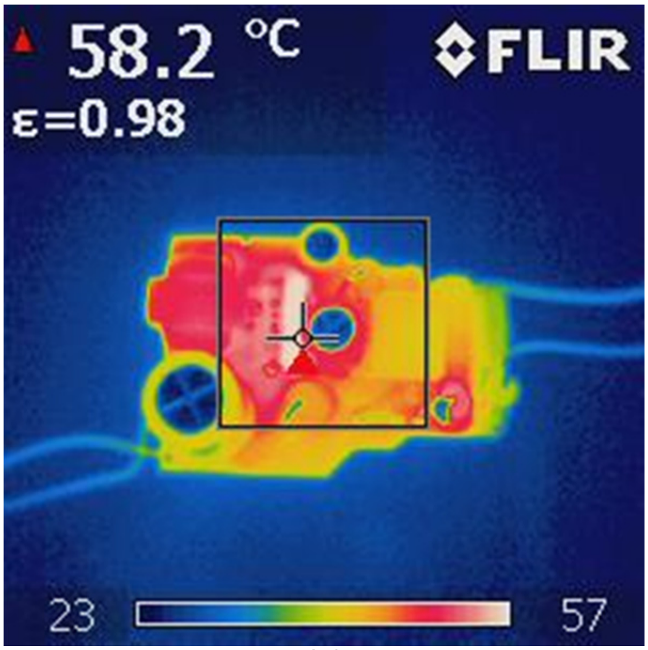

Figure 15 – V_{IN} = 190 VAC / 50 Hz.
U1-LYT4321E: 58.2 ºC

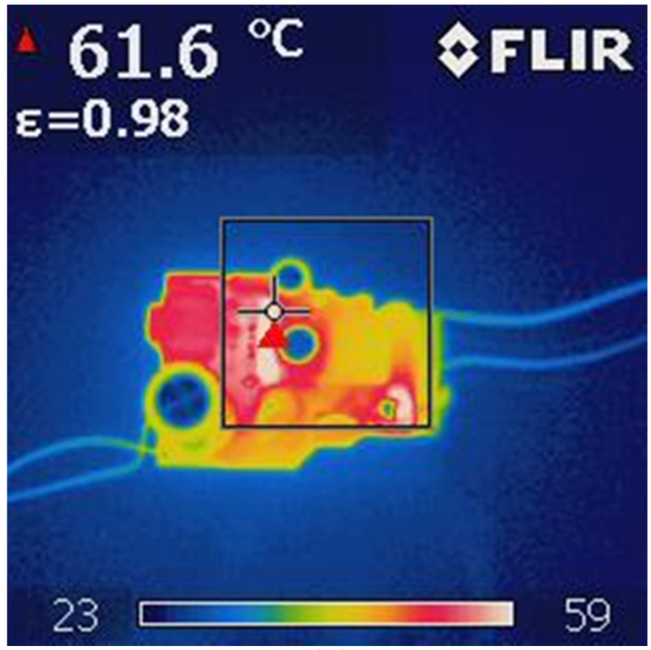

Figure 16 – V_{IN} = 230 VAC / 50 Hz.
U1-LYT4321E: 61.6 ºC.

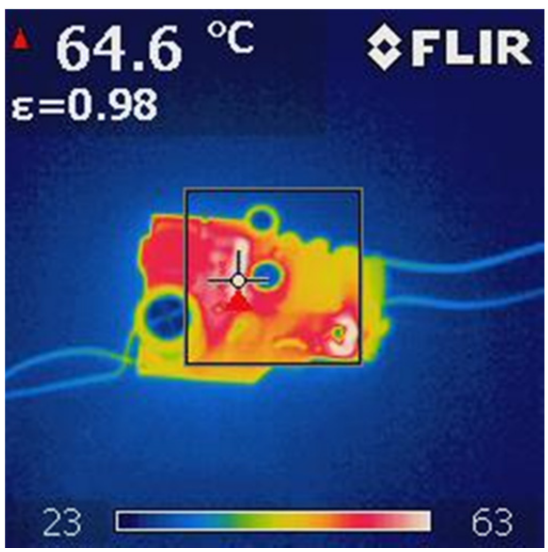

Figure 17 – V_{IN} = 265 VAC / 50 Hz.
U1-LYT4321E: 64.6 ºC.

10.2 Dimming V_{LED} = 60 V LED Load

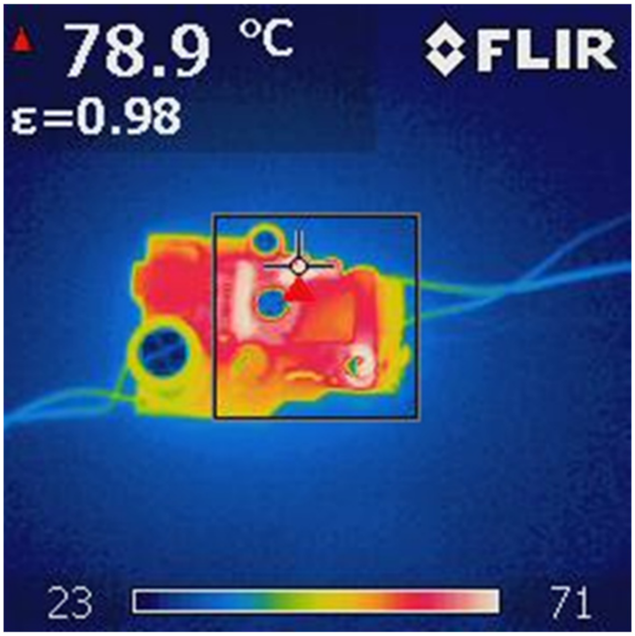

Figure 18 – V_{IN} = 190 VAC / 50 Hz; 90º Conduction Angle.
Damper Resistor R2: 78.9 ºC.

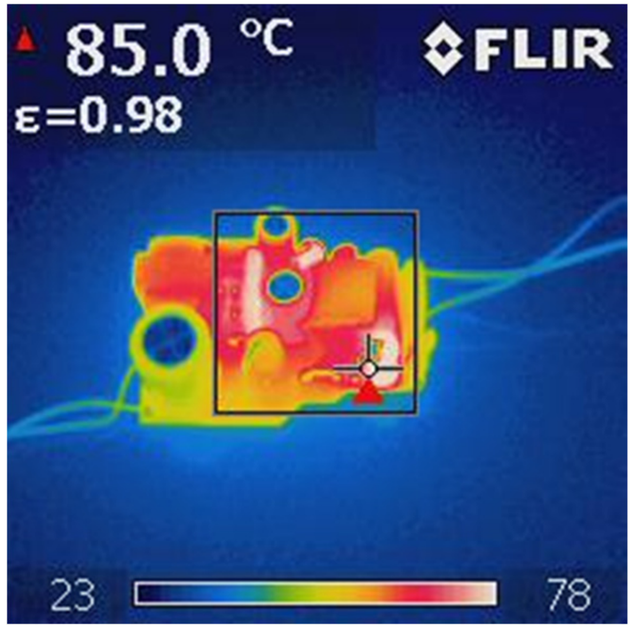

Figure 19 – V_{IN} = 230 VAC / 50 Hz; 90º Conduction Angle.
Bleeder Resistor R1: 78.9 ºC.

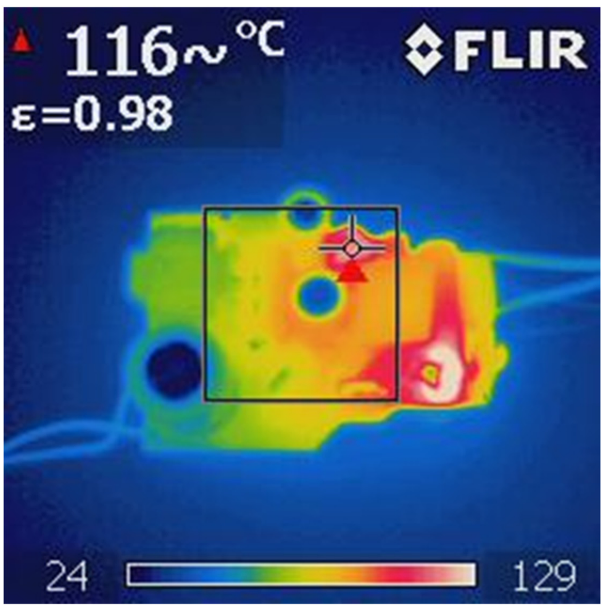

Figure 20 – VIN = 265 VAC / 50 Hz; 90º Conduction Angle.
Damper Resistor R2: 116 ºC.

11 Non-Dimming Waveforms

11.1 Input Voltage and Input Current Waveforms

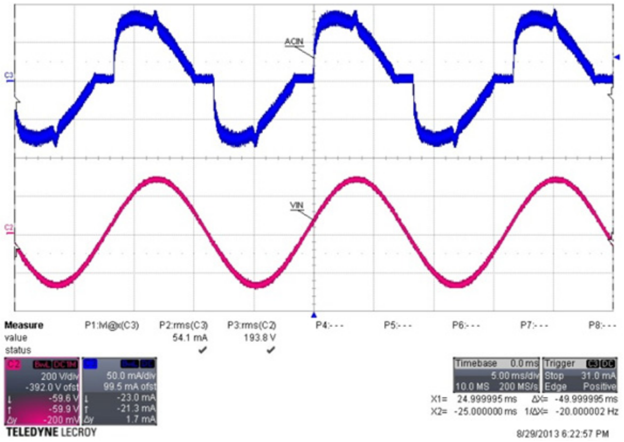

Figure 21 – 190 VAC, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V, 10 ms / div.

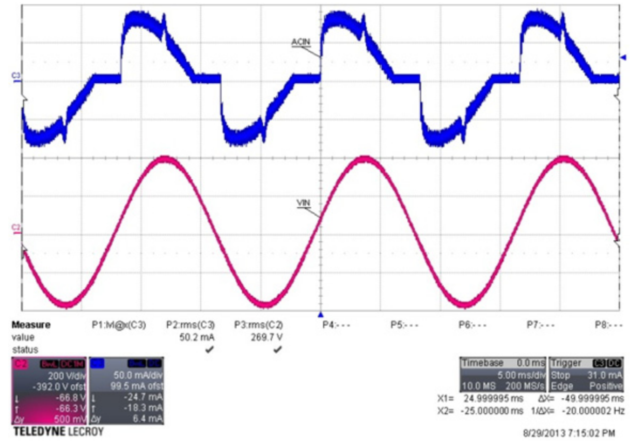

Figure 22 – 265 VAC, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V, 10 ms / div.

11.2 Output Current and Output Voltage at Normal Operation

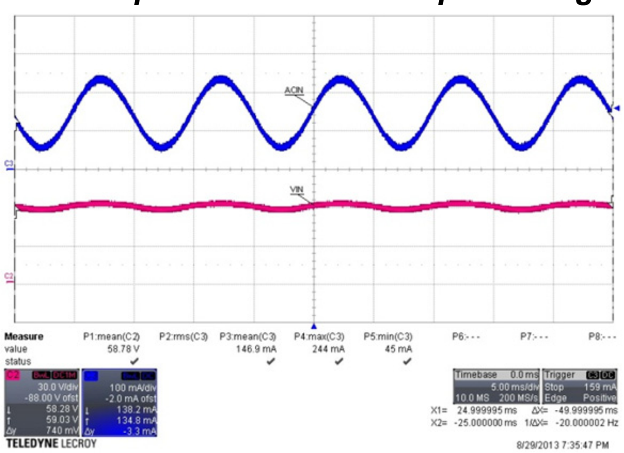

Figure 23 – 190 VAC, 50 Hz Full Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 30 V, 5 ms / div.

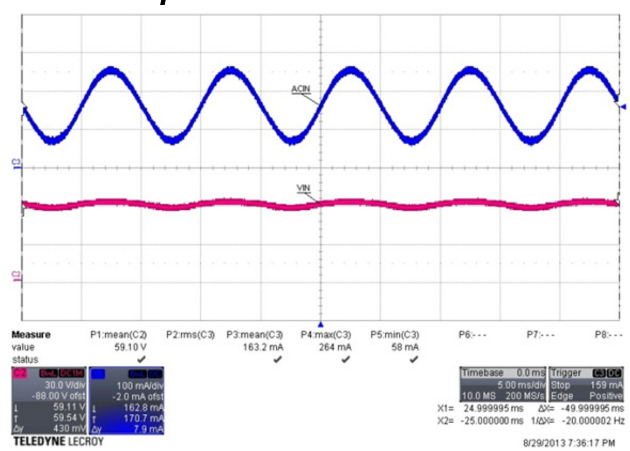

Figure 24 – 265 VAC, 50 Hz Full Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 30 V, 5 ms / div.

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11.3 Input Voltage and Output Current Waveform at Start-up

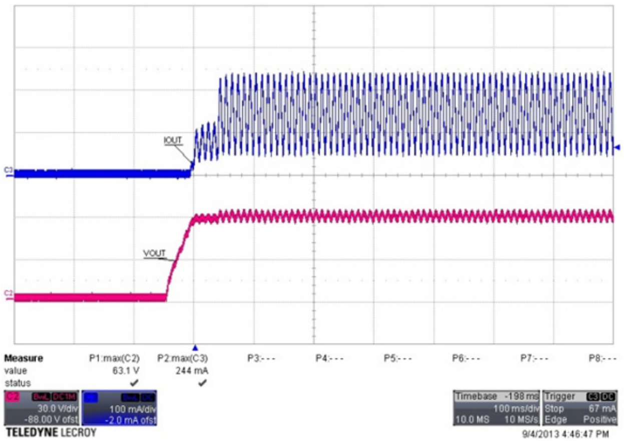

Figure 25 – 190 VAC, 50 Hz.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 30 V, 100 ms / div.

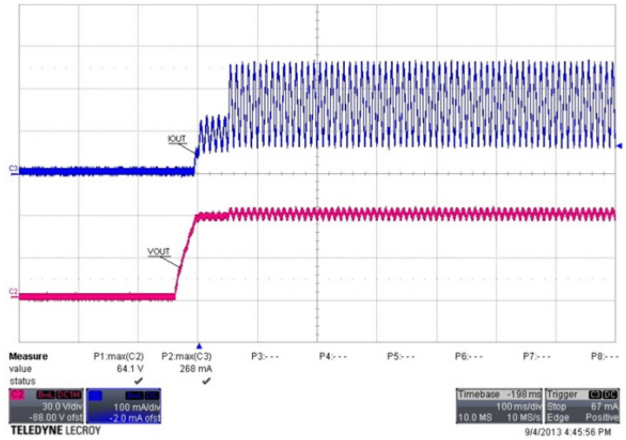

Figure 26 – 265 VAC, 50 Hz.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 30 V, 100 ms / div.

11.4 Drain Voltage and Current at Normal Operation

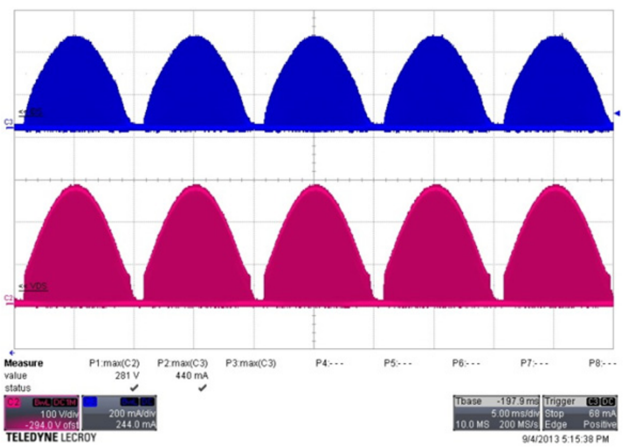

Figure 27 – 190 VAC, 50 Hz.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.

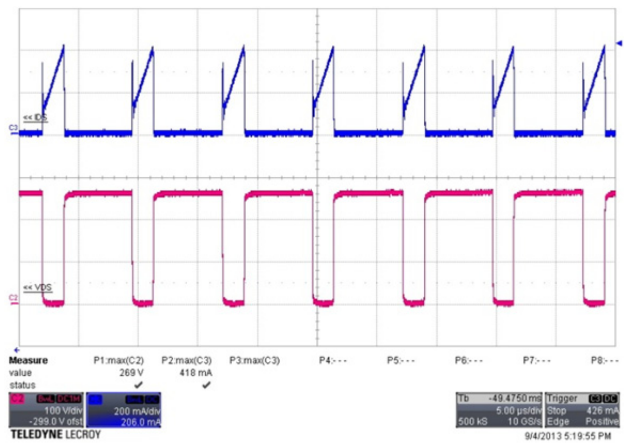

Figure 28 – 190 VAC, 50 Hz.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

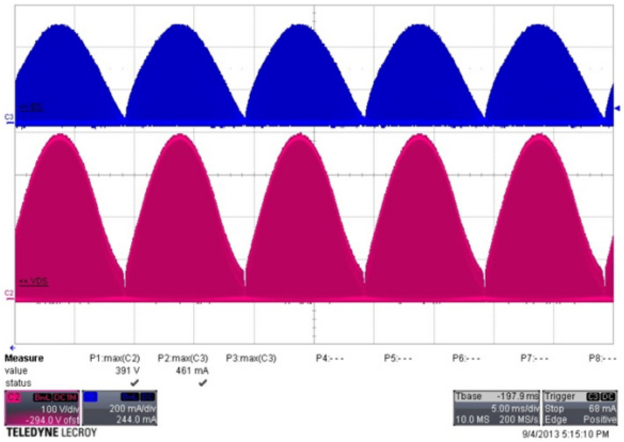

Figure 29 – 265 VAC, 50 Hz.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.

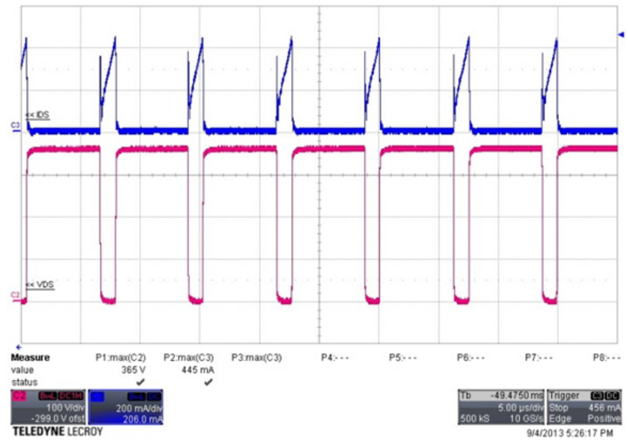

Figure 30 – 265 VAC, 50 Hz.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

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11.5 Start-up Drain Voltage and Current

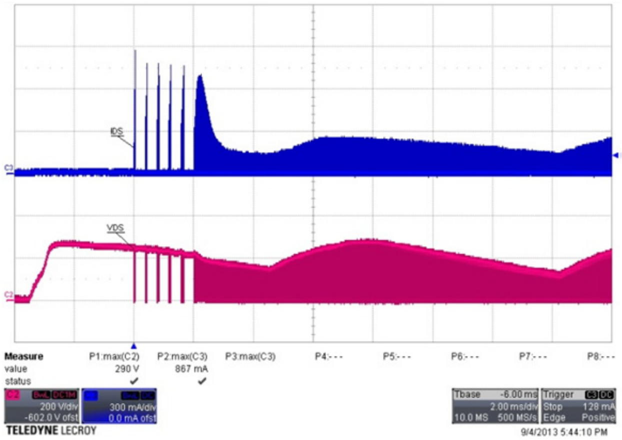

Figure 31 – 190 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 300 mA / div.
Lower: V_{DRAIN}, 200 V, 2 ms / div.

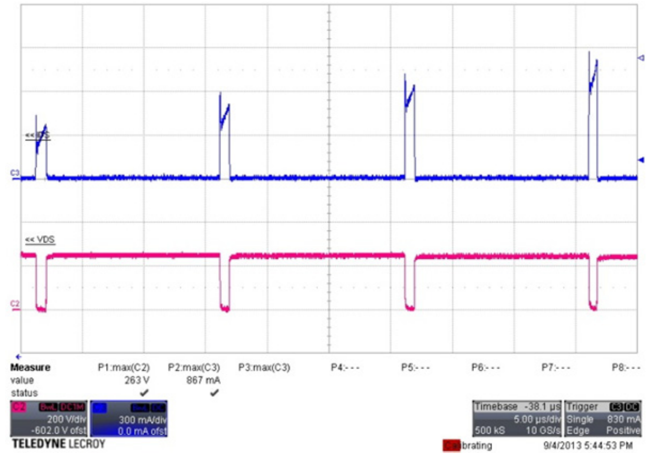

Figure 32 – 190 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 300 mA / div.
Lower: V_{DRAIN}, 200 V, 5 μs / div.

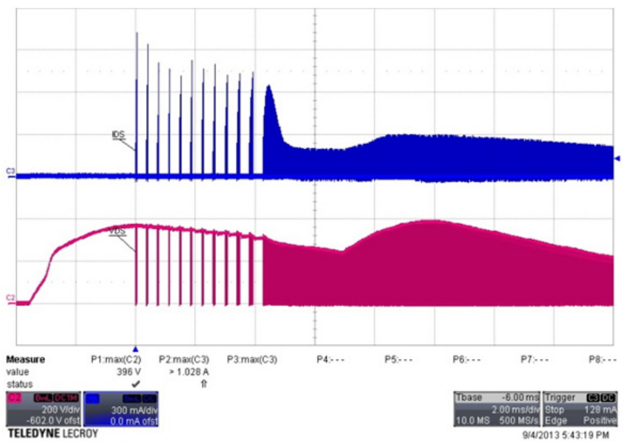

Figure 33 – 265 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 300 mA / div.
Lower: V_{DRAIN}, 200 V, 2 ms / div.

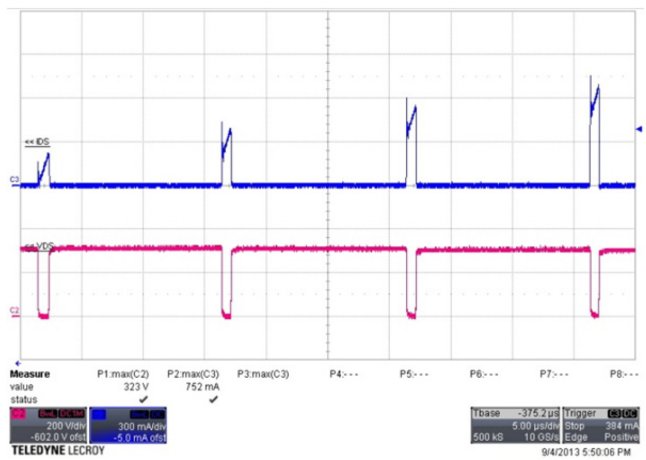

Figure 34 – 265 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 300 mA / div.
Lower: V_{DRAIN}, 200 V, 5 μs / div.

11.6 Drain Current and Drain Voltage During Output Short Condition

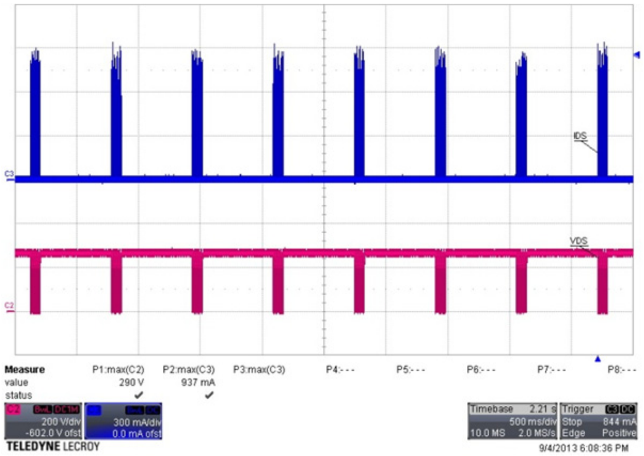

Figure 35 – 190 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 200 ms / div.

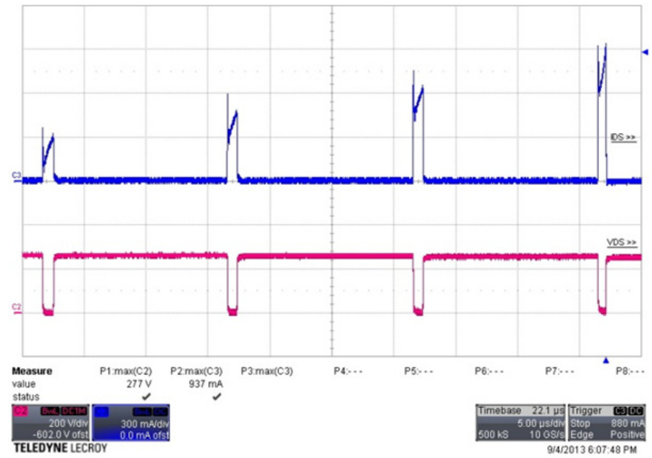

Figure 36 – 190 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 10 µs / div.

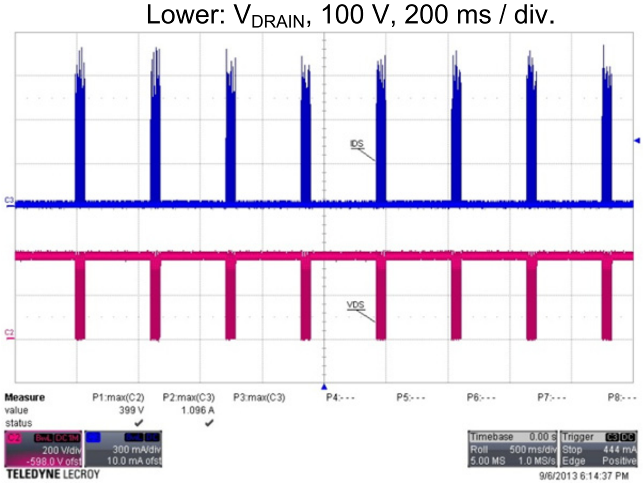

Figure 37 – 265 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 300 mA / div.
Lower: V_{DRAIN}, 200 V, 500 ms / div.

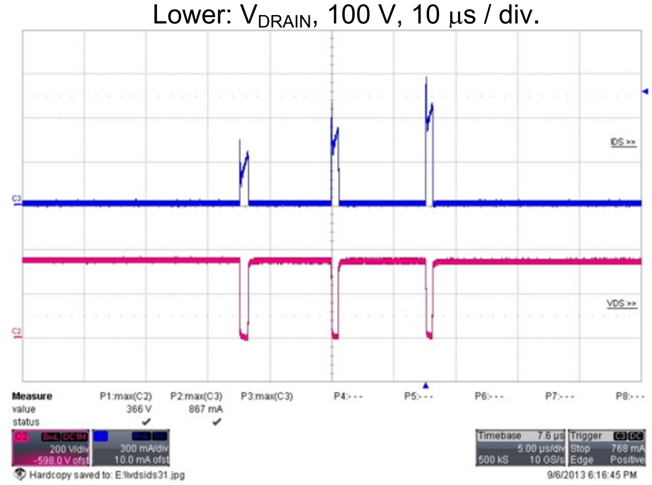

Figure 38 – 265 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 300 mA / div.
Lower: V_{DRAIN}, 200 V, 5 µs / div.

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11.7 Output Diode Current and Voltage Waveforms

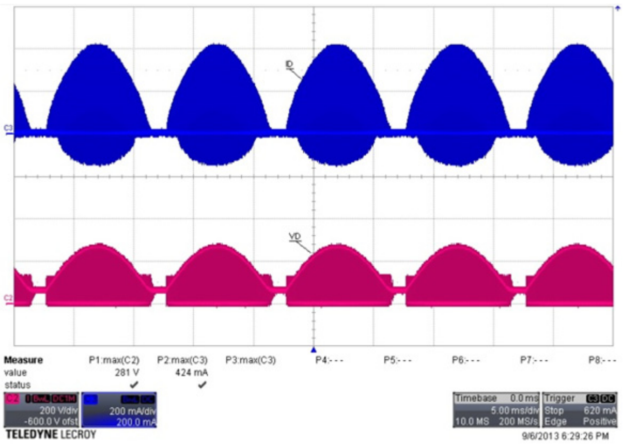

Figure 39 – 190 VAC, 50 Hz.
Upper: I_{D7}, 0.2 A / div.
Lower: V_{D7}, 200 V, 5 ms / div.

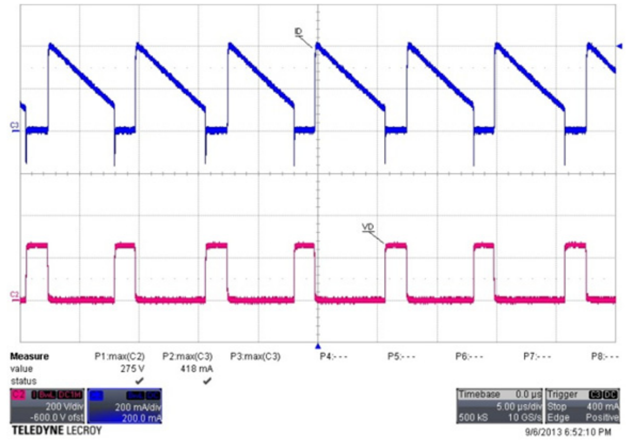

Figure 40 – 190 VAC, 50 Hz.
Upper: I_{D7}, 0.2 A / div.
Lower: V_{D7}, 200 V / div., 5 μs / div.

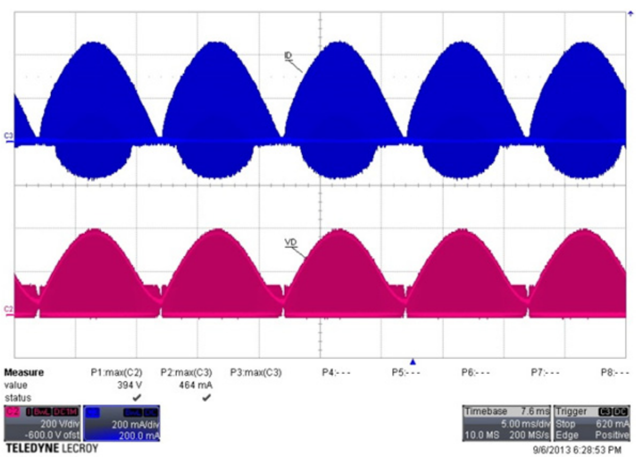

Figure 41 – 265 VAC, 50 Hz.
Upper: I_{D7}, 0.2 A / div.
Lower: V_{D7}, 200 V, 5 ms / div.

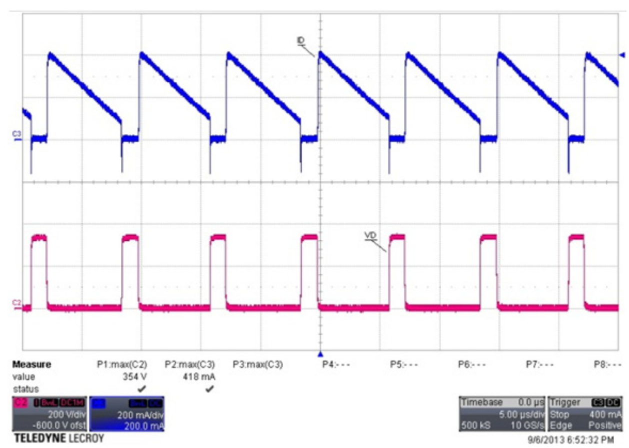

Figure 42 – 265 VAC, 50 Hz.
Upper: I_{D7}, 0.2 A / div.
Lower: V_{D7}, 200 V / div., 5 μs / div.

11.8 Brown-out

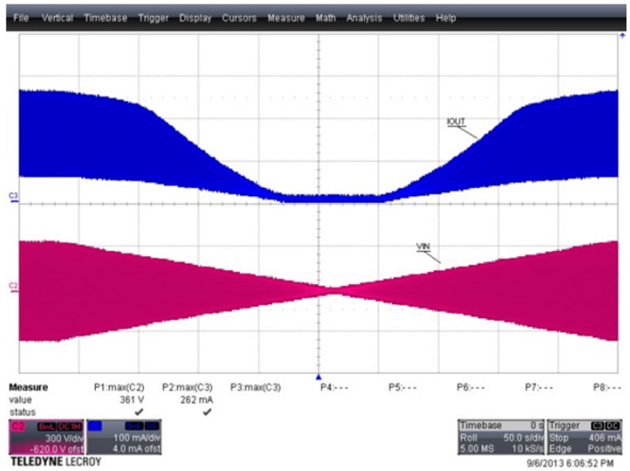

Figure 43 – 230 VAC, 50 Hz.
CH3: I_{OUT}, 100 mA / div.
CH2: V_{IN}, 300 V / div.

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12 Dimming Waveforms

12.1 Input Voltage and Input Current Waveforms

Input: 230 VAC, 50 Hz
Output: 60 V LED Load

Dimmer: MERTEN 572499 400 W

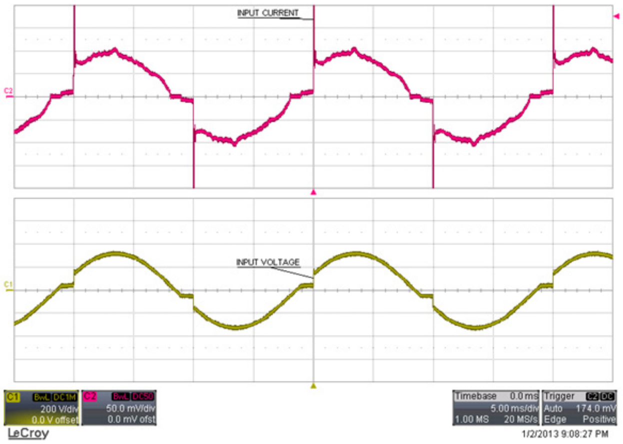

Figure 44 – 160º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

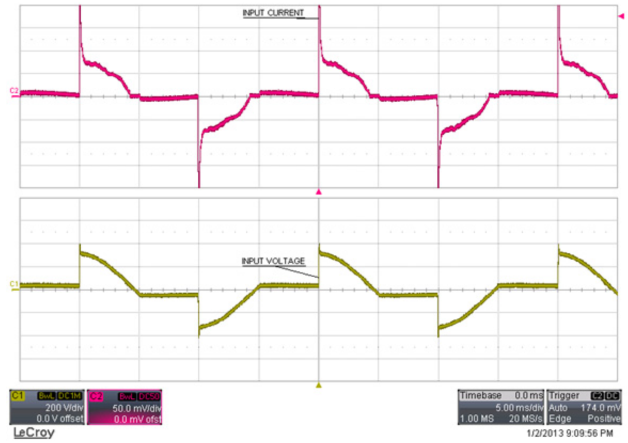

Figure 45 – 90º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

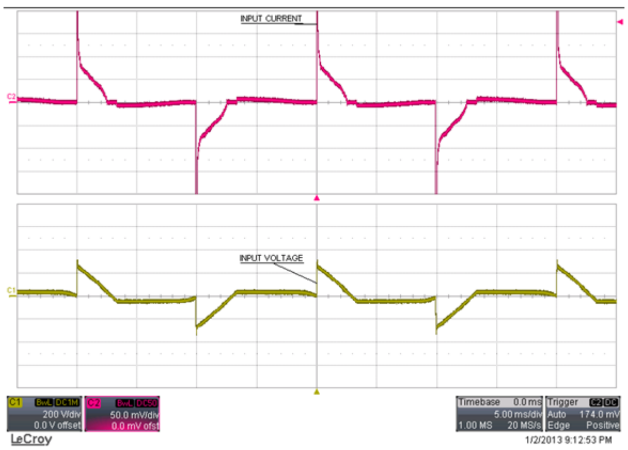

Figure 46 – 60º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

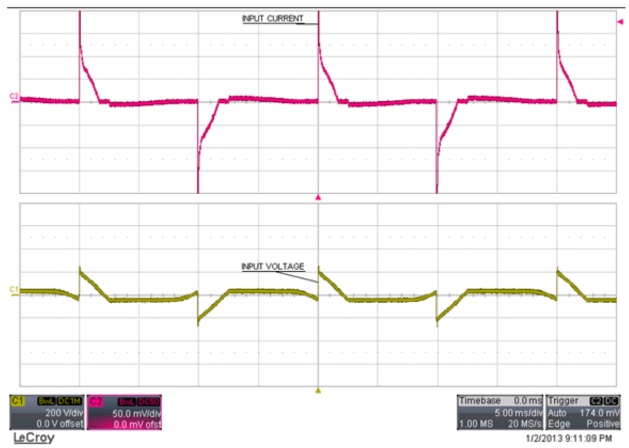

Figure 47 – 45º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

13 Conducted EMI

13.1 Test Set-up

The unit was tested using LED load (~60 V V_{OUT}) with input voltage of 230 VAC, 60 Hz at room temperature.

Figure 48 – EMI Test Set-up with the Unit and LED Load Placed Inside the Cone.

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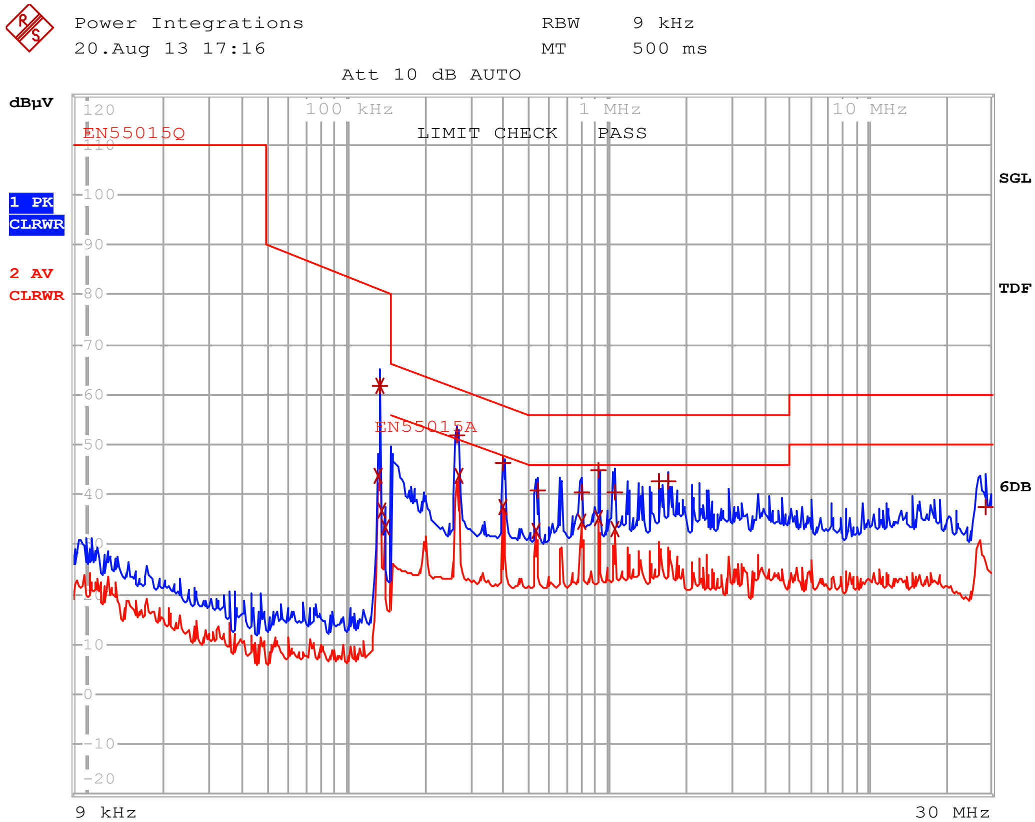
13.2 Test Result



EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	130.825395691 kHz	43.89	N gnd	
1	Quasi Peak	133.454986145 kHz	61.61	N gnd	-19.44
2	Average	133.454986145 kHz	61.69	N gnd	
2	Average	136.137431366 kHz	36.63	L1 gnd	
2	Average	140.262531674 kHz	33.46	N gnd	
1	Quasi Peak	264.49018761 kHz	51.66	N gnd	-9.62
2	Average	267.135089486 kHz	43.65	L1 gnd	-7.55
1	Quasi Peak	397.727746704 kHz	46.24	L1 gnd	-11.65
2	Average	397.727746704 kHz	37.33	L1 gnd	-10.56
2	Average	530.769219795 kHz	32.63	L1 gnd	-13.36
1	Quasi Peak	536.076911993 kHz	40.66	L1 gnd	-15.33
1	Quasi Peak	798.145472681 kHz	40.50	L1 gnd	-15.49
2	Average	798.145472681 kHz	34.48	L1 gnd	-11.51
1	Quasi Peak	926.622115652 kHz	45.02	L1 gnd	-10.97
2	Average	926.622115652 kHz	35.47	L1 gnd	-10.52
1	Quasi Peak	1.06512822736 MHz	40.27	L1 gnd	-15.72
2	Average	1.06512822736 MHz	33.14	L1 gnd	-12.85
1	Quasi Peak	1.58583078933 MHz	42.46	L1 gnd	-13.53
1	Quasi Peak	1.71722750422 MHz	42.82	L1 gnd	-13.17
1	Quasi Peak	28.4089539309 MHz	37.36	L1 gnd	-22.63

Figure 49 – Conducted EMI, 60 V LED Load, 230 VAC, 60 Hz, and EN55015 B Limits.

14 Line Surge Test

The unit was subjected to ±2500 V, 100 kHz ring wave and ±500 V differential surge at 230 VAC using 10 strikes at each condition. A test failure was defined as a non-recoverable interruption of output requiring supply repair or recycling of input voltage.

Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Type	Test Result (Pass/Fail)
+2500	230	L1, L2	0	100 kHz Ring Wave (500 A)	Pass
-2500	230	L1, L2	90	100 kHz Ring Wave (500 A)	Pass
+2500	230	L1, L2	0	100 kHz Ring Wave (500 A)	Pass
-2500	230	L1, L2	90	100 kHz Ring Wave (500 A)	Pass

Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Type	Test Result (Pass/Fail)
+500	230	L1, L2	0	Surge (2Ω)	Pass
-500	230	L1, L2	90	Surge (2Ω)	Pass
+500	230	L1, L2	0	Surge (2Ω)	Pass
-500	230	L1, L2	90	Surge (2Ω)	Pass

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15 Revision History

Date	Author	Revision	Description and Changes	Reviewed
05-Dec-13	ME	1.0	Initial Release	Apps & Mktg

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