Design Example Report

Title	*18.5 W TRIAC Dimmable High Efficiency Power Factor Corrected Non-Isolated Buck LED Driver Using LYTSwitch™-7 LYT7504D*
Specification	180 VAC – 265 VAC Input; 52 V, 355 mA Output
Application	A19 Dimmable LED Bulb
Author	Applications Engineering Department
Document Number	DER-563
Date	October 27, 2016
Revision	1.0

Summary and Features

- Single-stage power factor corrected, PF >0.9
- Accurate constant LED current (CC) regulation, ±5%
- High efficiency, >85%
- Low cost and low component count for compact PCB solution
- TRIAC dimmable
  - Works with a wide selection of TRIAC dimmers
  - Fast start-up time (<500 ms) – no perceptible delay
  - Minimum dead-band or visible pop-on effect.
- Integrated protection features
  - Open load and output short-circuit protection
  - Thermal fold-back protection
  - No damage during line brown-out or brown-in conditions
- Meets IEC 2.5 kV ring wave, 1 kV differential surge and EN55015 conducted EMI

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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

This engineering report describes a low component count, TRIAC dimmable, non-isolated buck LED driver, designed to drive a nominal LED voltage string of 52 V at 355 mA from an input voltage range of 180 VAC to 265 VAC. This LED driver utilizes the LYT7504D from the LYTSwitch-7 family of devices.

LYTSwitch-7 is a SO-8 package LED driver controller IC designed for non-isolated buck topology applications. The LYTSwitch-7 ICs provide high efficiency, high power factor, accurate LED current regulation, and inherent dimming capability. LYTSwitch-7 ICs incorporate a high-voltage power MOSFET and variable frequency / variable on-time, critical conduction mode control engine for tight current regulation, high power factor and proprietary power MOSFET utilization for high efficiency. The controller also integrates protection features such as input and output overvoltage protection, thermal fold-back, over temperature shutdown, output short-circuit and overcurrent protection.

DER-563 is a single stage 18.5 W TRIAC dimmable LED driver with constant current output. The key design goals were design simplicity, high efficiency, low component count, accurate constant current regulation, compact PCB and acceptable dimming compatibility. The design is intended for A19 dimmable LED bulb applications.

This document contains the power supply specification, schematic diagram, bill of materials, printed circuit layout, and performance data.

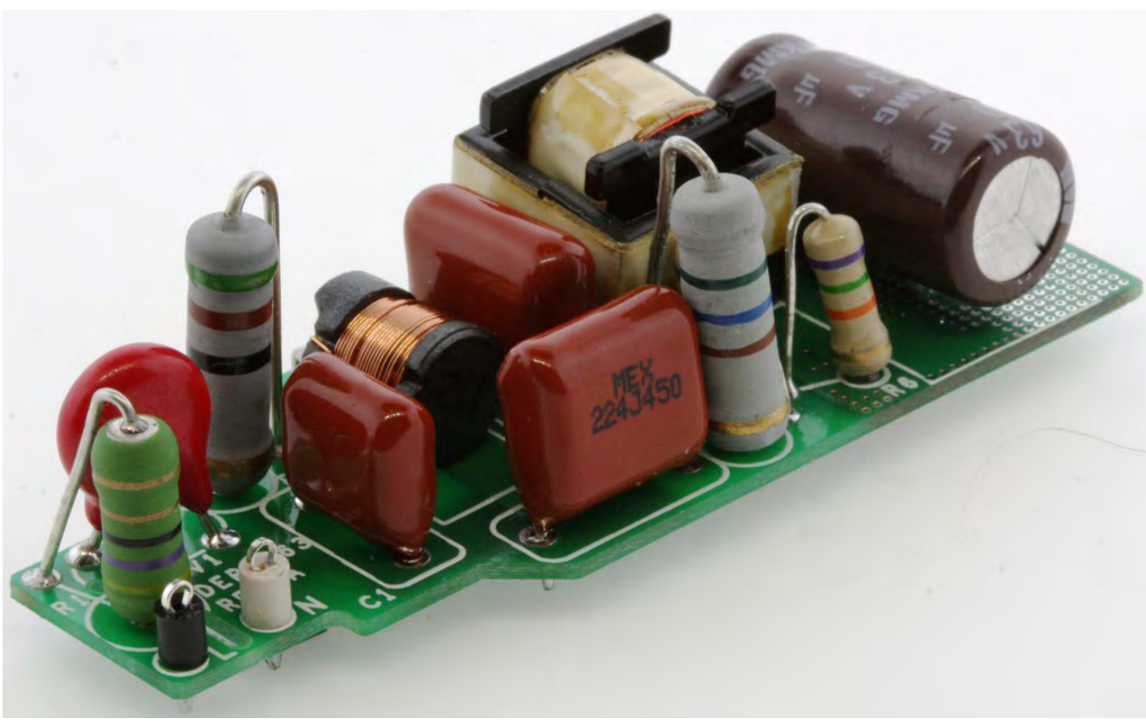

Figure 1 – Populated Circuit Board.

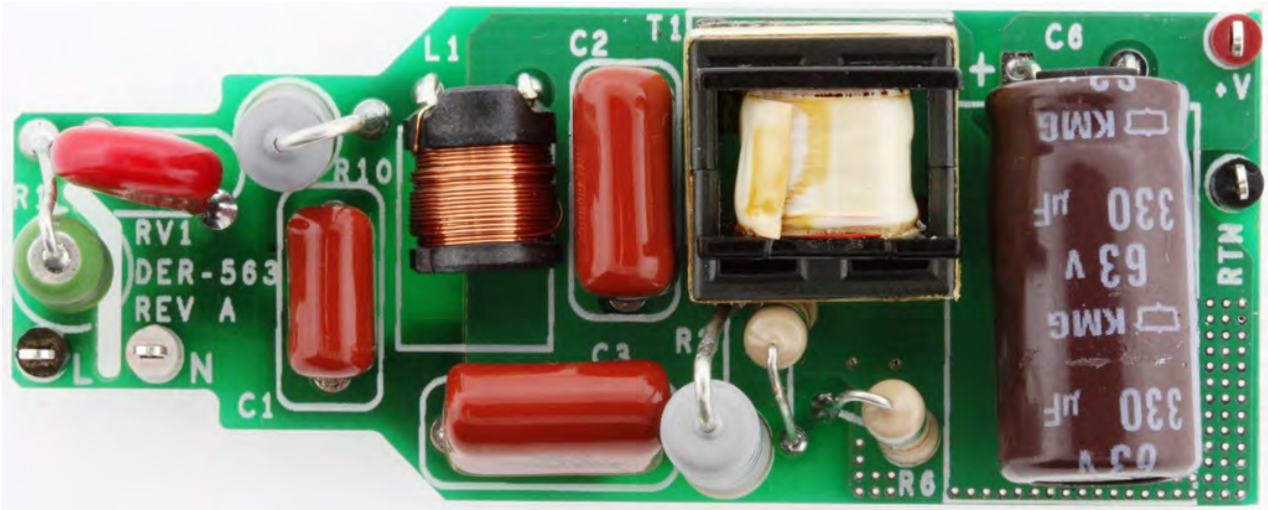

Figure 2 – Populated Circuit Board, Top View.

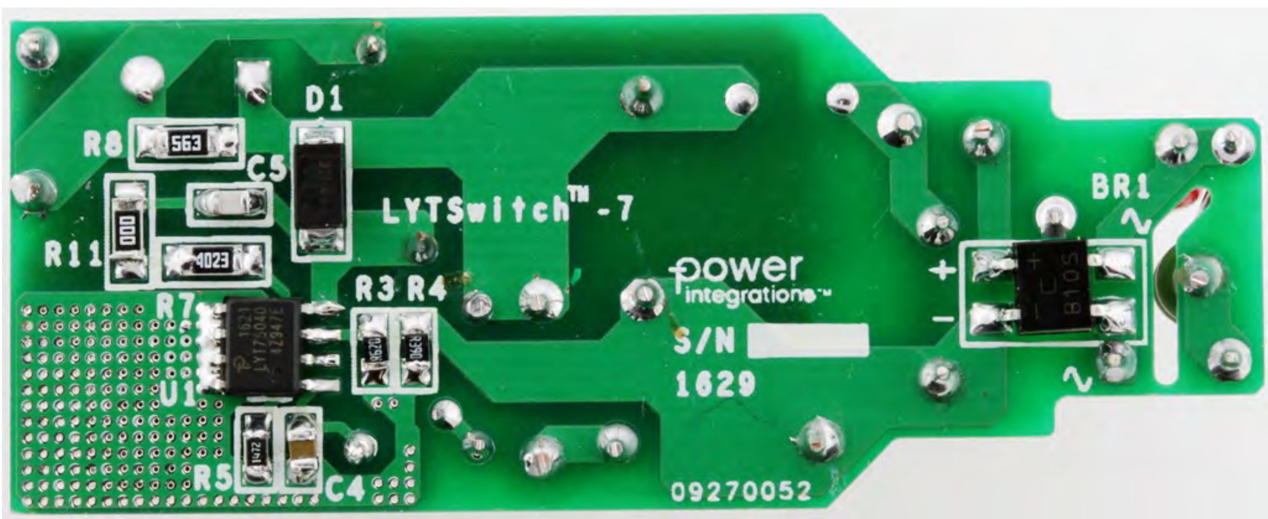

Figure 3 – Populated Circuit Board, Bottom View.

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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}	180	230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}		50		Hz	
Output						
Output Voltage	V_{OUT}		52		V	
Output Current	I_{OUT}		355		mA	
Total Output Power						
Continuous Output Power	P_{OUT}		18.5		W	
Efficiency						
Full Load	η		85		%	Measured at 230 VAC, 25 ºC.
Environmental						
Conducted EMI		CISPR 15B / EN55015B				
Safety		Isolated				
Ring Wave (100 kHz)			2.5		kV	
Differential Mode (L1-L2)			1.0		kV	
Power Factor			0.9			Measured at 230 VAC, 50 Hz.
Ambient Temperature	T_{AMB}		75		ºC	Free convection, Sea Level.

3 Schematic

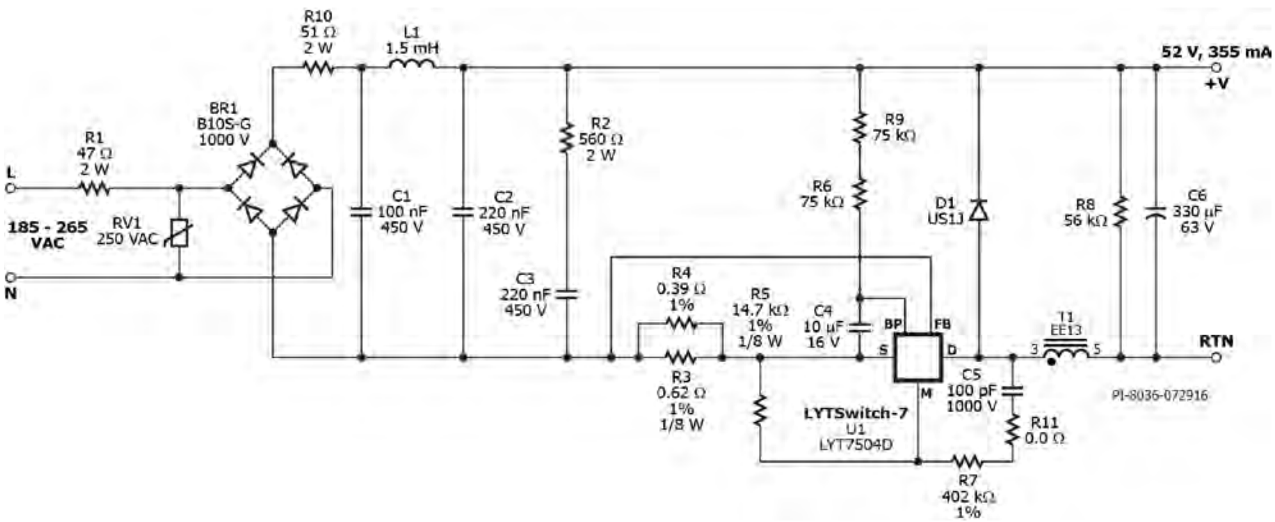

Figure 4 – Schematic.

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4 Circuit Description

The LYTSwitch-7 (U1-LYT7504D) combines a high-voltage power MOSFET switch with a variable frequency / variable on-time, critical conduction mode controller in a single SO-8 package. LYT7504D is configured to drive a 52 V LED string, TRIAC dimmable, non-isolated buck LED driver with 355 mA constant current output. The LYT7504D device was selected from the power table based on maximum output power (22 W) in the data sheet.

4.1 *Input Stage*

The fusible resistor R1 provides safety protection against component failures that would lead to very high input current. Varistor RV1 provides clamping during differential line surge events to limit the maximum voltage spike across the primary. The maximum clamping voltage of RV1 must be lower than the Drain-to-Source breakdown voltage of the internal power MOSFET of LYT7504D (725 V) to ensure sufficient overvoltage protection during line surge occurrence.

The AC input is full-wave rectified by BR1 to provide the pulsating DC input to the pi filter consisting of C1, C2 and L1. The values of C1, C2 and L1 were chosen to provide the best balance between high power factor, EMI performance, and dimming compatibility.

4.2 *EMI Filter*

The inductor L1 and capacitors, C1 and C2, form an EMI pi filter which works to filter differential mode noise. If L1 and buck inductor T1 were located near each other in the layout, then the magnetic field produce by each inductor might interfere with each other. There will be a significant external field that can cause adverse coupling. To minimize this coupling, L1 and T1 should be far from each other in layout consideration. A shielded inductor can also help. Another way to minimize the coupling is to orient the inductors' axes at right angles to each other wherever possible. Axially mounting L1 gave a better conducted EMI.

The LYTSwitch-7 ICs' variable frequency / on-time states and critical conduction mode control engine limits RFI emission to significant level which enables design to use simple EMI pi filter even for high power bulb and tube applications.

4.3 *LYTSwitch-7 Control Circuit*

The topology used for this LED driver is a low-side buck converter. During the on-time of the LYT7504D internal power MOSFET, current ramps through the buck inductor winding, charging the output capacitor, and providing current to the output load. The energy stored in the magnetic field of the inductor winding during on-time of the power MOSFET is then delivered to the load during off-time via output diode D1. The output capacitor C6 provides filtering to minimize LED ripple current while resistor R8 serves as a pre-load.

Capacitor C4 provides local decoupling for the BYPASS (BP) pin of U1, which provides power to the IC during the switch on-time. The IC internal regulator draws power from high voltage DRAIN (D) pin and charge the bypass capacitor C4 during the power switch off time. The typical BP pin voltage is 5.22 V. To keep the IC operating normally especially during the dead zone, where $V_{IN} < V_{OUT}$, the value of capacitor should be large enough to keep the BP voltage above the $V_{BP(RESET)}$ value of 4.5 V. Additional bias resistors R6 and R9 were employed to maintain the BP pin voltage for very fast AC on/off power cycling event and during low conduction angle operation. Recommended minimum value for the BP capacitor is 10 μF.

Resistor R6 and R9 can be calculated as follows, where: I_{BP_EXT} can be between 150 μA – 500 μA.

$$R6 + R9 = V_{OUT} - V_{BP} / I_{BP\_EXT}$$

Constant output current regulation is achieved through the FEEDBACK (FB) pin directly sensing the drain current during the power MOSFET on-time using external current sense resistors (R_{FB}) R3 and R4, and comparing the voltage drop to a fixed internal reference voltage (V_{FB_REF}) of absolute value 280 mV typical. R_{FB} can be calculated as follows:

$$R_{FB} = V_{FB\_REF} / k \times I_{OUT}$$

Where: k is the ratio between I_{PK} and I_{OUT}; k = 4 for LYT750x.

Trimming R_{FB} may be necessary to center I_{OUT} at the nominal input voltage.

The MULTIFUNCTION (M) pin monitors the line for any line overvoltage event. When the internal power MOSFET is in on-state, the M pin is shorted internally to SOURCE (S) pin in order to detect the rectified input line voltage derived from the voltage across the inductor, i.e. (V_{IN}-V_{OUT}) and current flowing out of the M pin is defined by resistor R7, thus line overvoltage detection is calculated as;

$V_{LINE\_OVP} = I_{IOV} \times R7 + V_{OUT}$; where R7 is assumed to be 402 kΩ ±1%.

Once the measured current exceeds the input overvoltage threshold (I_{IOV}) of 1 mA typical, the IC will inhibit switching instantaneously and initiate auto-restart to protect the internal power MOSFET of the IC.

The M pin also monitors the output for any overvoltage and undervoltage event. When the internal power MOSFET is in off-state, the output voltage is monitored through a coupling capacitor (C5) and divider resistors R7 and R5. When an output open-load condition occurs, the voltage at the M pin will rise abruptly and when it exceeds the threshold of 2.4 V, the IC will inhibit switching instantaneously and initiate auto-restart to limit the output voltage from further rising. The overvoltage cut-off is typically 120% of

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the output voltage, which is equivalent to 2 V at the M pin (V_{OUT_OVP} = V_{OUT} x 2.4 V / 2 V). Resistor R7 is set to a fixed value of 402 kΩ ±1% and R5 will determine the output overvoltage limit. Any short-circuit at the output will be detected once the M pin voltage falls below the undervoltage threshold (V_{OUV}) of 1 V typical, then the IC will inhibit switching instantaneously and initiate auto-restart to limit the average input power to less than 1 W, preventing any components from overheating.

Resistor R5 can be calculated as follows:

$R5 = 2\ V \times R7\ /\ (V_{OUT} - 2\ V)$; this is applicable only to low-side configuration buck.

Another function of the M pin is for zero current detection (ZCD). This is to ensure operation in critical conduction mode. The inductor demagnetization is sensed when the voltage across the inductor begins to collapse towards zero as flywheel diode (D1) conduction expires.

4.4 *TRIAC Phase Dimming Control*

The control mechanism of the LYTSwitch-7 LYT7504D provides inherent dimming capability which makes it suitable to use a simple RC damper (R2 and C3) to avoid the TRIAC current to fall below its holding current and turn off.

The relatively large impedance presented to the line by the LED allows significant ringing to occur due to the inrush current charging the input capacitance when the TRIAC turns on. Resistors R1 and R10 may be trimmed to damp this input current ringing and help reduce / minimize flickering or shimmering.

The voltage across C4 may be monitored for any dipping below the IC (LYT7504D) reset threshold of 4.5 V, that may cause flickering or shimmering on or near the minimum conduction angle. The value of capacitor C4 may be increased to smoothen out the voltage at BP pin of the IC. Consequently, the resistance of the pull-up resistor R6 and R9 may be made smaller to increase the charging current available to the BP pin capacitor C4. However, decreasing the resistance value of the pull-up resistor may degrade efficiency – a trade-off, therefore, should be considered.

For high leakage TRIACs, undesired restarting of the unit, characterized by a very quick burst of output currents at long intervals, may occur when the dimmer knob is positioned just below the minimum conduction angle where the unit should turn off. To address this, the pre-load resistor R8 is chosen to be very large to avoid charging of the BP pin capacitor through the internal connection to the Drain via the pre-load resistor.

5 PCB Layout

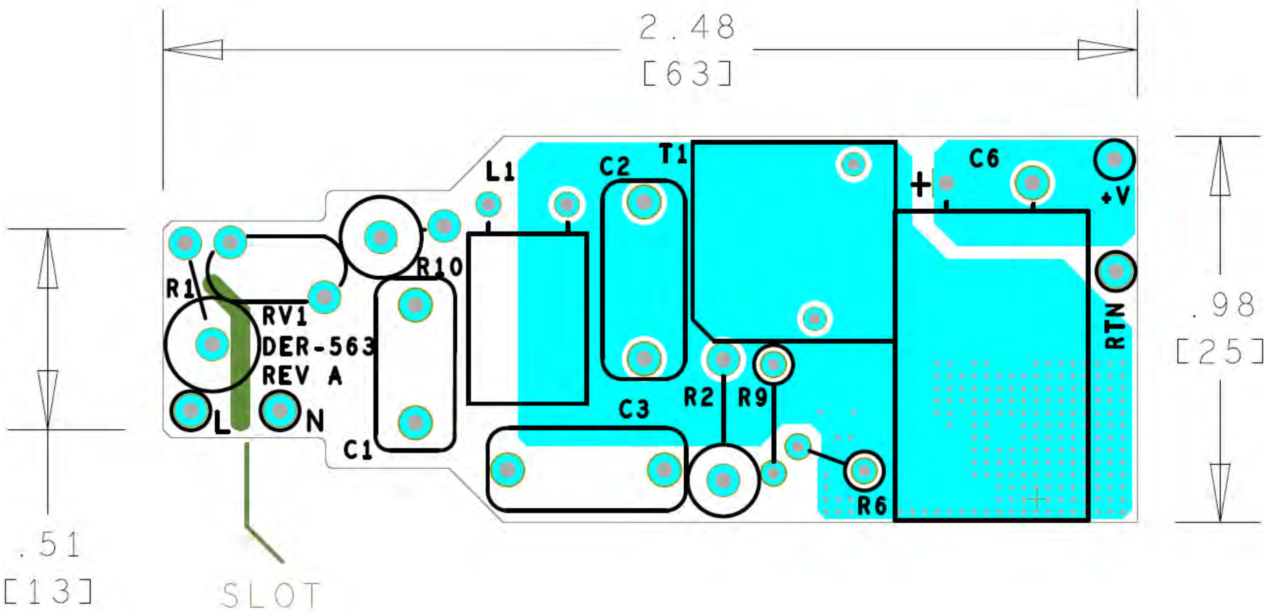

Figure 5 – Top Side.

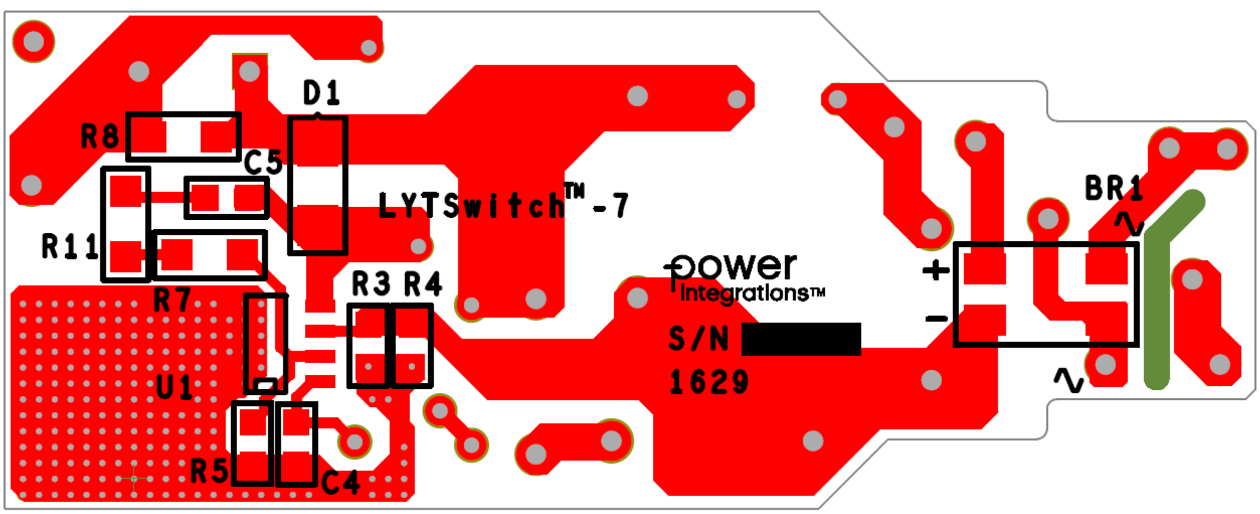

Figure 6 – Bottom Side.

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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
2	1	C1	100 nF, 450 V, Film	MEXXD31004JJ1	Duratech
3	1	C2	220 nF, 450 V, Film	MEXXF32204JJ	Duratech
4	1	C3	220 nF, 450 V, Film	MEXXF32204JJ	Duratech
5	1	C4	10 μF, ±10%, 16 V, X7R, Ceramic Capacitor, -55 °C ~ 125 °C	CL21B106KOQNNNG	Samsung
6	1	C5	100 pF, 1000 V, Ceramic, NPO, 0805	C0805C101MDGACTU	Kemet
7	1	C6	330 μF, 63 V, Electrolytic, (10 x 20)	EKMG630ELL331MJ20S	United Chemi-con
8	1	D1	Diode Ultrafast, SW 600 V, 1 A, SMA	US1J-13-F	Diodes, Inc.
9	1	L1	1.5 mH, 0.23 A, Ferrite Core	CTCH895F-152K	CT Parts
10	1	R1	RES, 47 Ω, 5%, 2 W, Wirewound, Fusible	FW20A47R0JA	Bourns
11	1	R2	RES, 560 Ω, 5%, 2 W, Metal Oxide	RSF200JB-560R	Yageo
12	1	R3	RES, SMD, 0.62 Ω, 1%, 1/8 W 0805	RL0805FR-070R62L	Yageo
13	1	R4	RES, SMD, 0.39 Ω 1%, 1/4 W, 0805	ERJ-S6QFR39V	Panasonic
14	1	R5	RES, 14.7 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1472V	Panasonic
15	1	R6	RES, 75 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-75K	Yageo
16	1	R7	RES, 402 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF4023V	Panasonic
17	1	R8	RES, 56 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ563V	Panasonic
18	1	R9	RES, 75 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-75K	Yageo
19	1	R10	RES, 51 Ω, 5%, 2 W, Metal Oxide	RSF200JB-51R	Yageo
20	1	R11	RES, 0 R, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEY0R00V	Panasonic
21	1	RV1	250 VAC, 21 J, 7 mm, RADIAL LA	V250LA2P	Littlefuse
22	1	T1	Bobbin, EE13, Horizontal, 8 pins		Janohig Electronic
23	1	U1	LYTSwitch-7, Dimmable, SO-8	LYT7504D	Power Integrations

Miscellaneous

1	1	+V	Test Point, RED, Miniature THRU-HOLE MOUNT	5000	Keystone
2	1	L	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone
3	1	N	Test Point, WHT, Miniature THRU-HOLE MOUNT	5002	Keystone
4	1	RTN	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone

7 Inductor Specification

7.1 *Electrical Diagram*

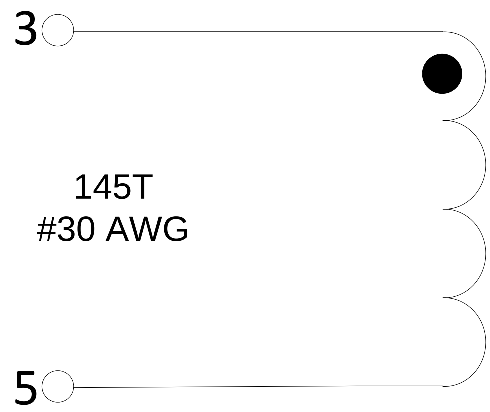

Figure 7 – Inductor Electrical Diagram.

7.2 *Electrical Specifications*

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 3 and pin 5, with all other windings open.	680 μH
Tolerance	Tolerance of Primary Inductance.	±5%

7.3 *Material List*

Item	Description
[1]	Core: EE13.
[2]	Bobbin: EE13, Horizontal, 8 pins, Part no. 25-01017-00.
[3]	Magnet Wire: #30 AWG.
[4]	Polyester Tape: 7.7 mm.
[5]	Transformer Tape: 5.5 mm.

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7.4 *Inductor Build Diagram*

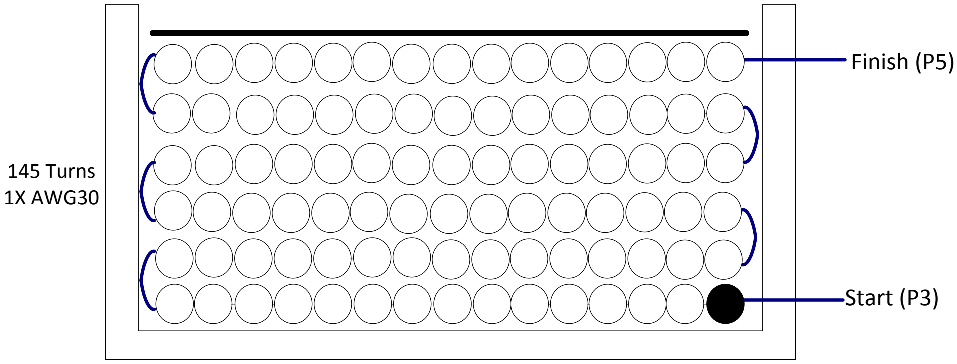
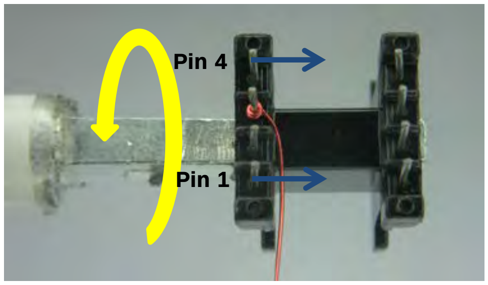
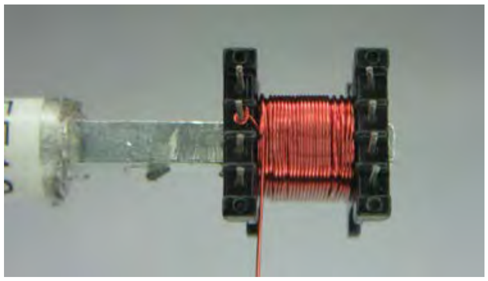
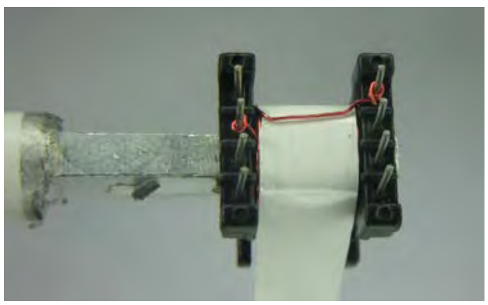
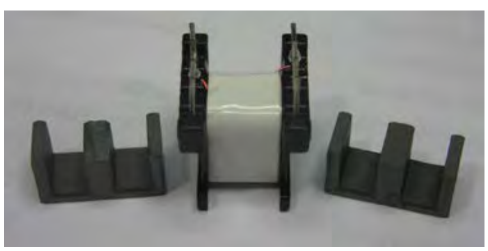


Figure 8 – Transformer Build Diagram.

7.5 *Inductor Construction*

Winding Directions	Bobbin is oriented on winder jig such that terminal pin 1-4 is in the left side. The winding direction is counter-clockwise as shown in the figure.
Winding 1	Use wire item [3], start at pin 3 and wind 145 turns, then finish the winding on pin 5.
Insulation	Add 2 layer of tape, item [4], for insulation.
Terminal Pins	Pull out terminal pins 1-2-4 and pin 6-7-8.
Core Grinding	Grind the center leg of one core until it meets the nominal inductance of 680 μH.
Core Assembly	Assemble the 2 cores on the bobbin. Wrap the 2 cores with polyester tape item [5]. To avoid the core from moving, put 2 layers of tape item [3] as shown in the figure.
Finish	Dip the transformer assembly in 2:1 thinner and varnish solution.

7.6 *Winding Illustrations*

Winding Directions		Bobbin is oriented on winder jig such that terminal pin 1-4 is in the left side. The winding direction is counter-clockwise as shown.
Winding 1		Use wire item [3], start at pin 3 and wind 145 turns, then finish the winding on pin 5.
Insulation		Add 2 layer of tape, item [4], for insulation.
Core Grinding		Grind the center leg of one core until it meets the nominal inductance of 680 μH.

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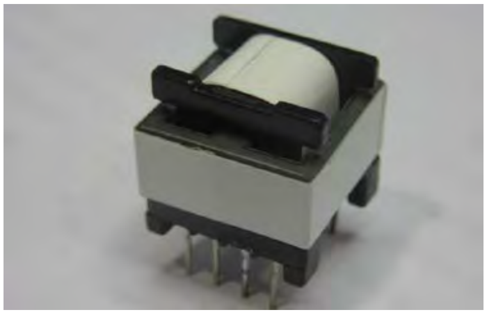
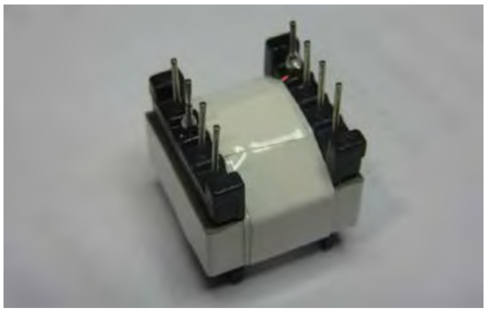
Core Assembly	 	Assemble the 2 cores on the bobbin. Wrap the 2 cores with polyester tape item [5]. See figure. To avoid the core from moving, add 2 layers of tape item [4] as shown.
Terminal Pins		Pull out terminal pins 1-2-4 and pin 6-7-8.
Finish		Dip the transformer assembly in 2:1 thinner and varnish solution.

8 Inductor Design Spreadsheet

ACDC_LYTSwitch7_Buck _031816; Rev.0.1; Copyright Power Integrations 2016	INPUT	INFO	OUTPUT	UNIT	LYTSwitch-7 Buck Design Spreadsheet
ENTER APPLICATION VARIABLES					
LINE VOLTAGE RANGE			Low Line		AC line voltage range
VACMIN	180		180	V	Minimum AC line voltage
VACTYP	230		230	V	Typical AC line voltage
VACMAX	265		265	V	Maximum AC line voltage
fL	50		50	Hz	AC mains frequency
VO	52		52	V	Worst case normal operating output voltage
IO	355		355	mA	Average output current specification
EFFICIENCY	0.85		0.85		Efficiency estimate
PO			18.46	W	Continuous output power
VD			0.70	V	Output diode forward voltage drop
ENTER LYTSWITCH-7 VARIABLES					
DEVICE BREAKDOWN VOLTAGE			725	V	This Spreadsheet supports 725V device only
DEVICE CODE	Auto		LYT7504D		Actual LYTSwitch-7 device code
ILIMITMIN			1.61	A	Minimum Current Limit
ILIMITTYP			1.75	A	Typical Current Limit
ILIMITMAX			1.88	A	Maximum Current Limit
TON			2.77	us	On-time during the fixed on-time region at VACTYP
FSW			50	kHz	Maximum switching frequency in the fixed current limit region at VACTYP
DMAX			0.73		Maximum duty cycle possible in the fixed on-time region
ENTER INDUCTOR CORE/CONSTRUCTION VARIABLES					
CORE	EE13		EE13		Enter Transformer Core
CUSTOM CORE NAME					If custom core is used - Enter part number here
AE			17.10	mm^2	Core effective cross cectional area
LE			30.20	mm	Core effective path length
AL			1130.00	nH/turn^2	Core ungapped effective inductance
AW			21.28	mm^2	Window Area of the bobbin
BW			7.40	mm	Bobbin physical winding width
LAYERS			5.0		Number of Layers
INDUCTOR DESIGN PARAMETERS					
LP_MIN_ABSOLUTE			310	uH	Absolute minimum design inductance
LP_TYP	680		680	uH	Typical design inductance
LP_TOLERANCE	5		5	%	Tolerance of the design inductance
LP_MAX			1023	uH	Absolue maximum design inductance
TURNS	145		145	Turns	Number of inductor turns
ALG			32.34	nH/turn^2	Inductance per turns squared
BMAX			4416	Gauss	Operating maximum flux density in the fixed peak current region
BAC			1850	Gauss	AC flux density in the fixed peak current region
LG			0.645	mm	Core air gap
BWE			37.00	mm	Effective bobbin width
OD			0.26	mm	Outer diameter of the wire with insulation
INS			0.05	mm	Wire insulation
DIA			0.21	mm	Outer diameter of the wire without insulation
AWG			30		AWG of the bare wire.
CM			102	Cmils	Bare wire circular mils
CMA			211	Cmils/A	Bare wire circular mils per ampere
CURRENT DENSITY			9.4	A/mm^2	Bare wire current density
BOBBIN FILL FACTOR			44.38%		Area of the bobbin occupied by wire.
CURRENT WAVEFORM SHAPE PARAMETERS					
IAVERAGE_INDUCTOR			0.35	A	Average inductor current at VACTYP obtained from half-line cycle emulation
IPEAK_MOSFET			1.28	A	MOSFET peak current at VACTYP when operating in

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					the current limit region
IRMS_MOSFET			0.21	A	MOSFET RMS current at VACTYP obtained from half-line cycle emulation
IRMS_DIODE			0.44	A	Diode RMS current at VACTYP obtained from half-line cycle emulation
IRMS_INDUCTOR			0.48	A	Inductor RMS current at VACTYP obtained from half-line cycle emulation
LYTSWITCH EXTERNAL COMPONENTS					
FB Pin Resistor					
RFB_T			0.219	Ohms	Theoretical calculation of the feedback pin sense resistor
RFB			0.221	Ohms	Standard 1% value of the feedback pin sense resistor
M Pin Components					
RUPPER			402.00	kOhms	Upper resistor on the M-pin divider network (E96 / 1%)
RLOWER	14.70		14.70	kOhms	Upper resistor on the M-pin divider network (E96 / 1%)
VO_OVP			67.3	V	VO overvoltage threshold
Line_OVP			454	V	Line overvoltage threshold
CC			100	pF	Coupling Capacitor for Low Side Buck Configuration
RPRELOAD			52	kOhms	Minimum Output Preload Resistor
CBP			10	uF	BP Capacitor
RBP			146.4	kOhms	Recommended Pull-up Resistor from DC Bus to BP pin
VOLTAGE STRESS PARAMETERS					
VDRAIN			375	V	Estimated worst case drain voltage
PIVD			375	V	Output Rectifier Maximum Peak Inverse Voltage

Note: No inductor saturation during short circuit at 75 ºC ambient.

9 Performance Data

All measurements were performed at room temperature using LED load string. 1 minute soak time was applied before measurement with AC source turned-off for 5 seconds every succeeding input line measurement.

9.1 *Efficiency*

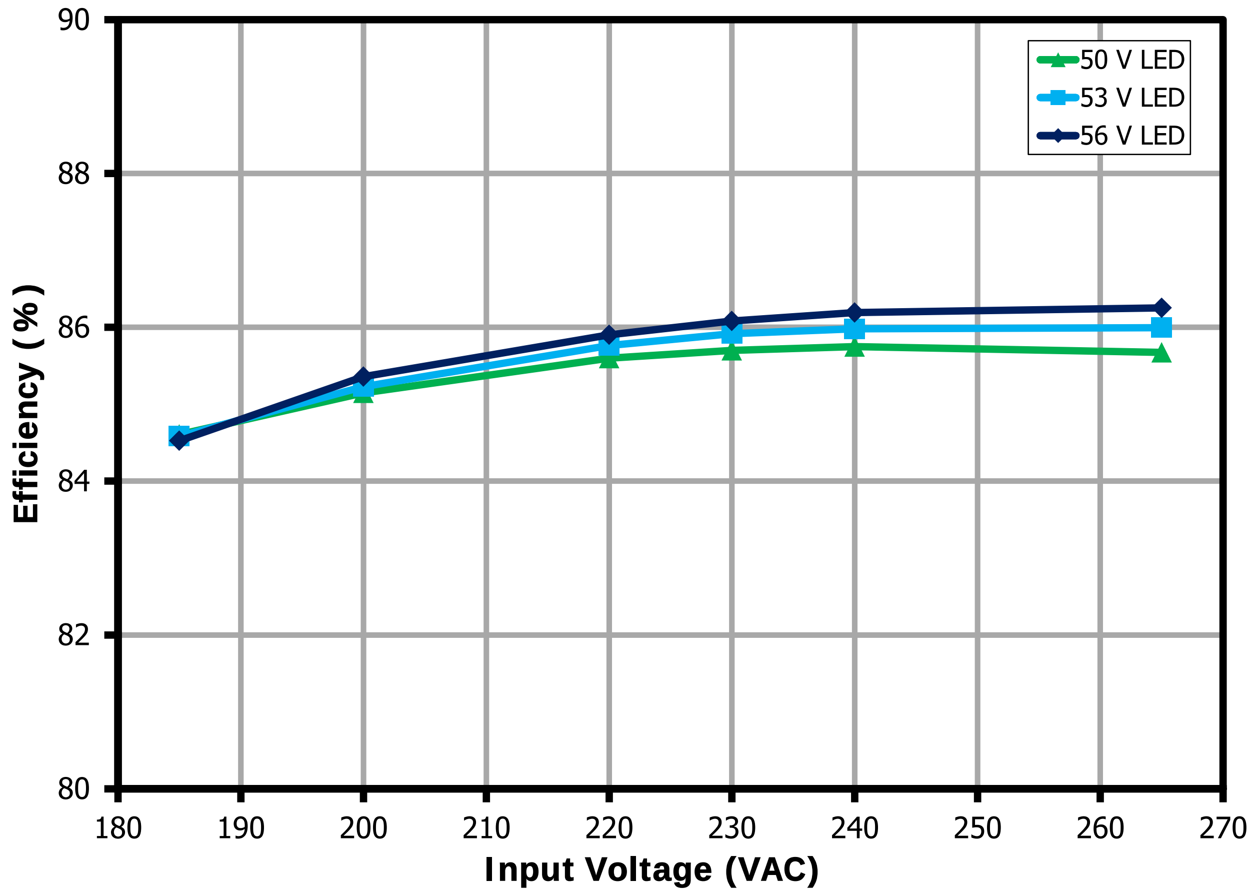

Figure 9 – Efficiency vs. Input Line Voltage.

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9.2 *Line Regulation*

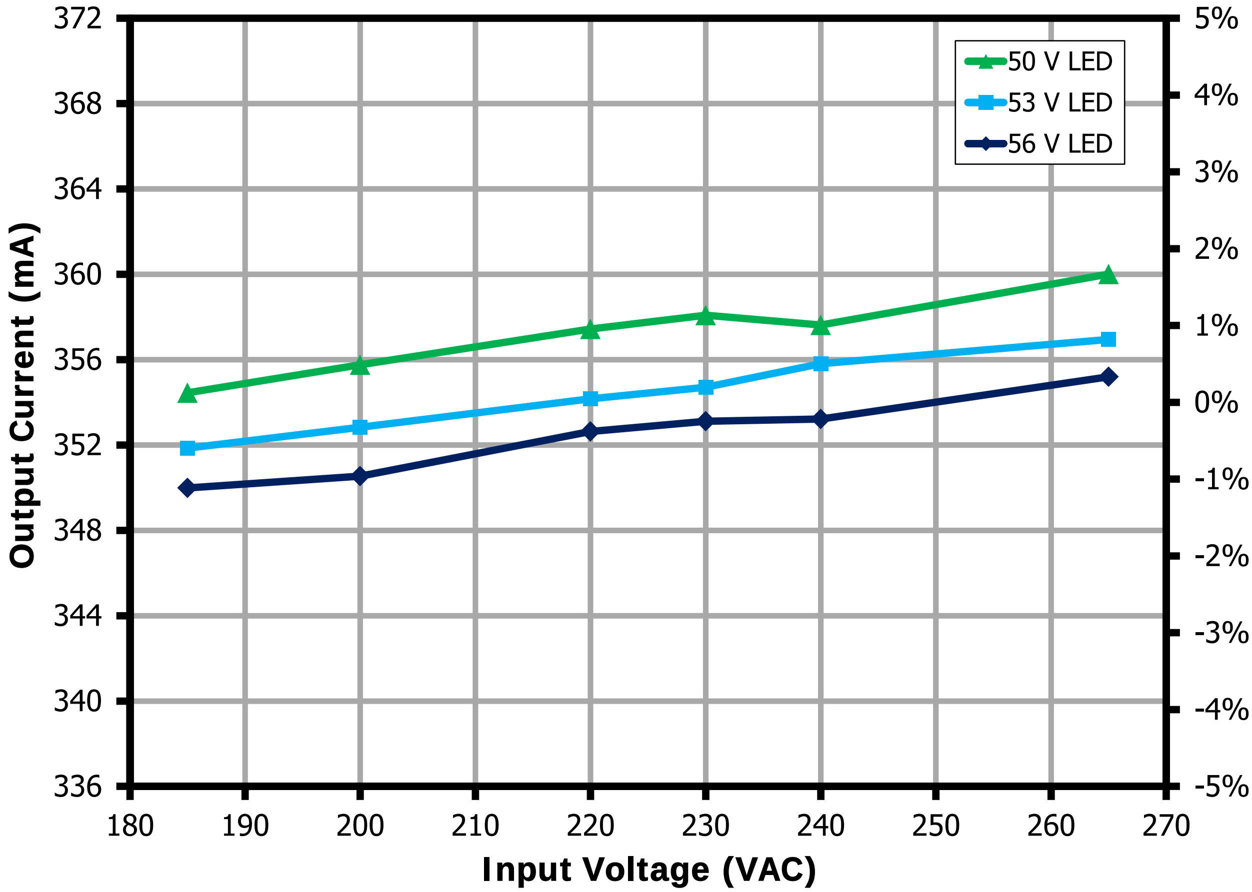

Figure 10 – Output Regulation vs. Input Line Voltage.

9.3 *Power Factor*

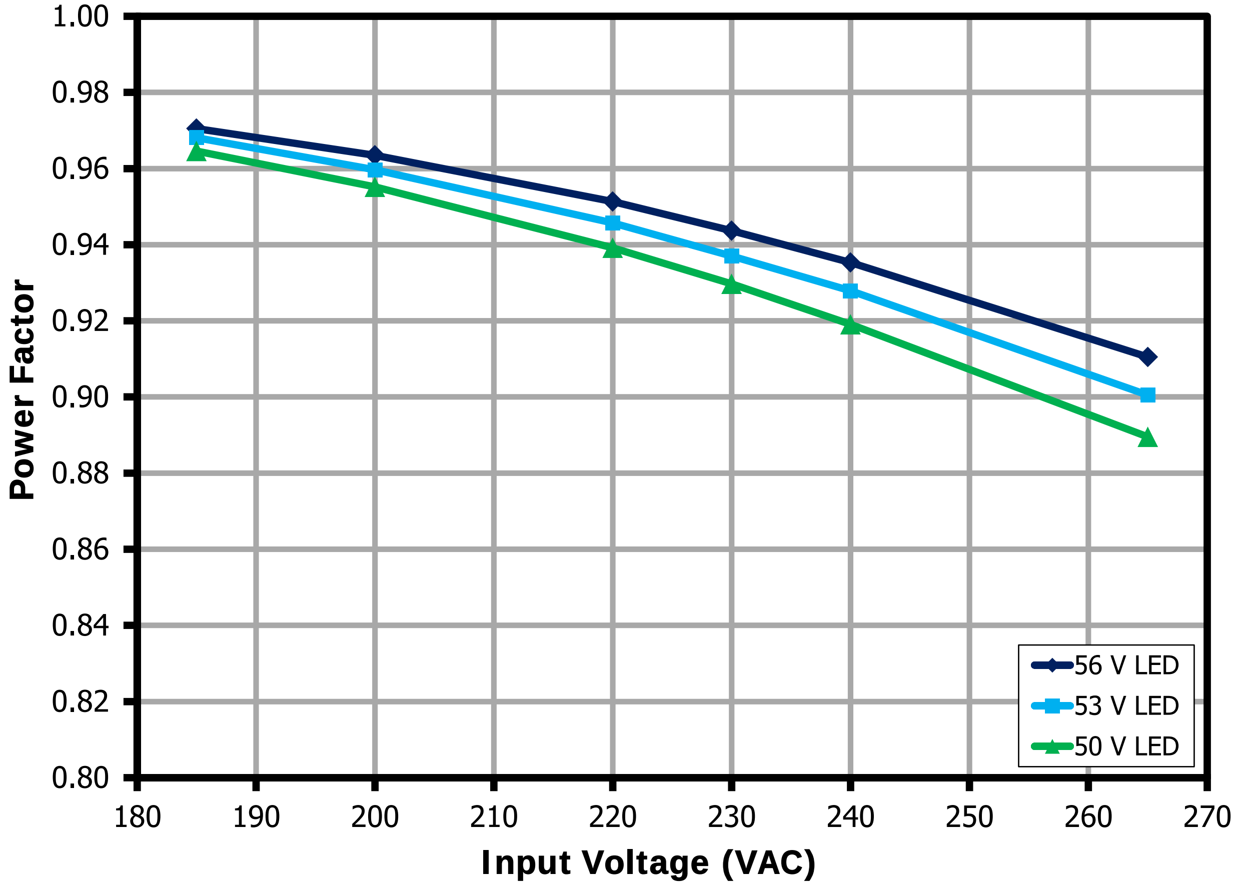

Figure 11 – Power Factor vs. Input Line Voltage.

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9.4 *%ATHD*

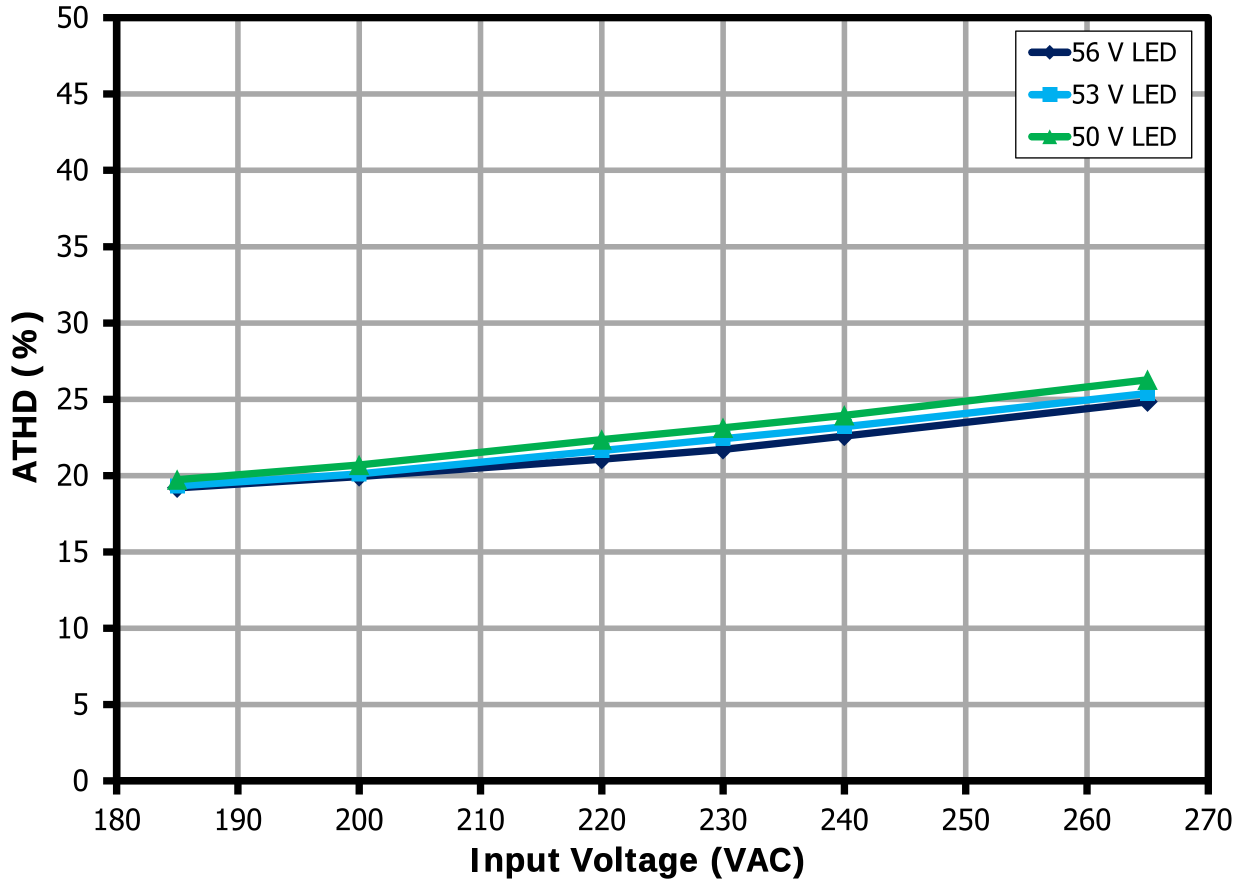

Figure 12 – %ATHD vs. Input Line Voltage.

9.5 *Harmonics*

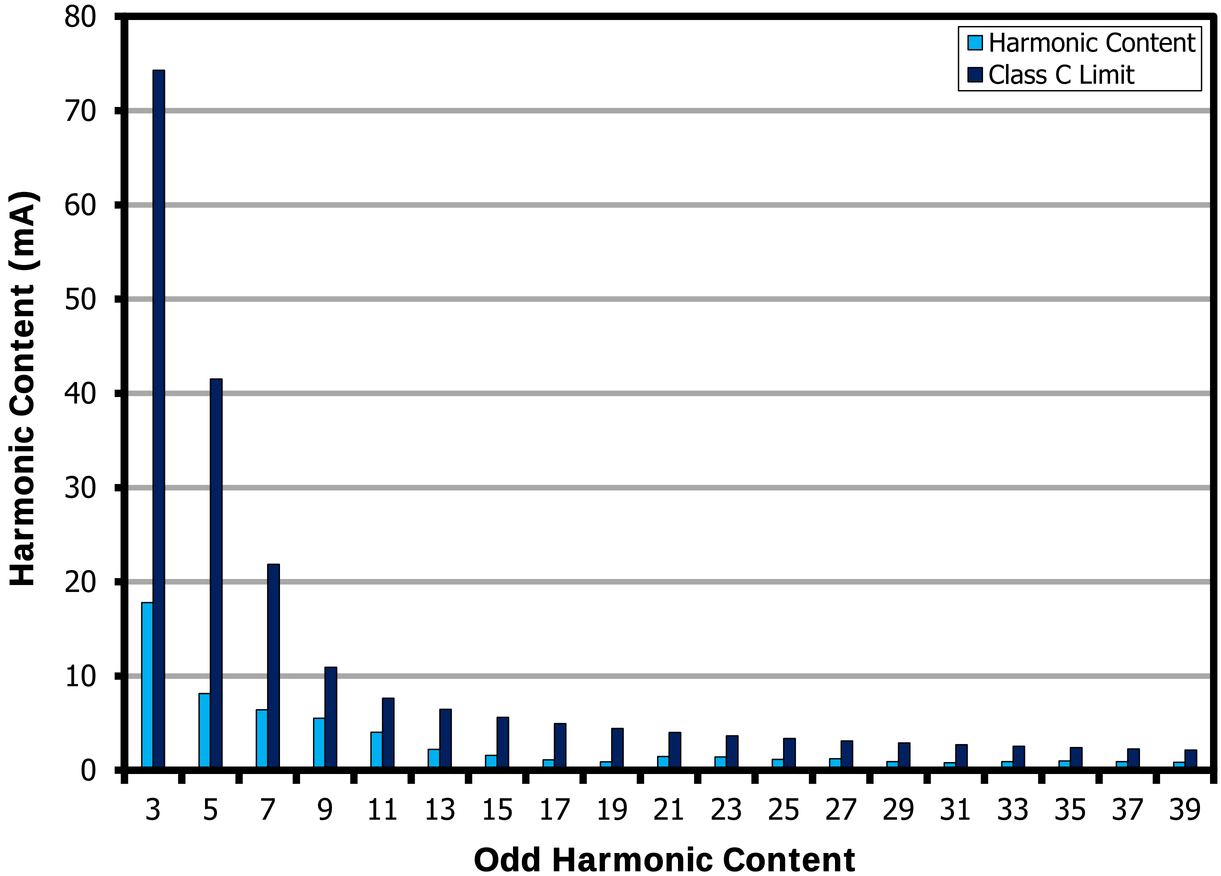

Figure 13 – Input Current Harmonics at 230 VAC, 50 Hz.

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10 Test Data

10.1 *Test Data, 50 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)	
185	50	184.86	117.06	20.87	0.965	19.73	49.73	354.45	17.66	84.61
200	50	199.93	108.93	20.80	0.955	20.70	49.70	355.76	17.71	85.15
220	50	219.87	100.72	20.80	0.939	22.36	49.72	357.44	17.80	85.60
230	50	229.89	97.37	20.81	0.930	23.13	49.72	358.08	17.83	85.70
240	50	239.91	94.15	20.76	0.919	23.95	49.69	357.62	17.80	85.75
265	50	264.92	88.86	20.94	0.890	26.28	49.75	360.01	17.94	85.67

10.2 *Test Data, 53 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)	
185	50	184.85	123.78	22.15	0.968	19.32	53.15	351.85	18.74	84.58
200	50	199.92	114.80	22.03	0.960	20.11	53.12	352.83	18.77	85.23
220	50	219.86	105.68	21.97	0.946	21.65	53.12	354.16	18.84	85.76
230	50	229.88	101.98	21.97	0.937	22.41	53.12	354.71	18.87	85.92
240	50	239.90	98.94	22.03	0.928	23.20	53.14	355.81	18.94	85.98
265	50	264.91	92.64	22.10	0.901	25.39	53.16	356.95	19.01	86.00

10.3 *Test Data, 56 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)	
185	50	184.85	131.16	23.53	0.971	19.19	56.73	349.99	19.89	84.52
200	50	199.92	120.99	23.30	0.964	19.93	56.66	350.54	19.89	85.36
220	50	219.86	111.42	23.30	0.951	21.08	56.69	352.63	20.02	85.90
230	50	229.88	107.31	23.28	0.944	21.72	56.67	353.11	20.04	86.08
240	50	239.90	103.62	23.25	0.935	22.60	56.65	353.22	20.04	86.19
265	50	264.91	96.93	23.38	0.911	24.84	56.70	355.20	20.17	86.25

10.4 *Harmonic Content at 230 VAC, 50 Hz, 50 V LED Load*

V_{IN} (V_{RMS})	Freq	I_{IN} (mA_{RMS})	P_{IN} (W)	%THD
230	50	101.26	21.852	22.03%
Harmonic Content			**Class C Limit**	
nth Order	**mA Content**	**% Content**	**mA Limit <25 W**	**Remarks**
1	98.58			
2	0.13	0.13%		
3	17.80	18.06%	74.30	Pass
5	8.15	8.27%	41.52	Pass
7	6.43	6.52%	21.85	Pass
9	5.52	5.60%	10.93	Pass
11	4.03	4.09%	7.65	Pass
13	2.23	2.26%	6.47	Pass
15	1.58	1.60%	5.61	Pass
17	1.10	1.12%	4.95	Pass
19	0.90	0.91%	4.43	Pass
21	1.47	1.49%	4.01	Pass
23	1.42	1.44%	3.66	Pass
25	1.16	1.18%	3.37	Pass
27	1.22	1.24%	3.12	Pass
29	0.92	0.93%	2.90	Pass
31	0.80	0.81%	2.71	Pass
33	0.92	0.93%	2.55	Pass
35	0.98	0.99%	2.40	Pass
37	0.93	0.94%	2.27	Pass
39	0.86	0.87%	2.16	Pass
41	0.87	0.88%		
43	0.69	0.70%		
45	0.67	0.68%		
47	0.81	0.82%		
49	0.71	0.72%		

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11 Dimming Performance Data

TRIAC dimming results were taken at an input voltage of 230 VAC, 50 Hz line frequency, room temperature, and a nominal 52 V LED load.

11.1 *Dimming Curve*

Agilent 6812B AC source programmed as perfect leading edge dimmer, and Yokogawa WT310E for input and output measurements are used for this test.

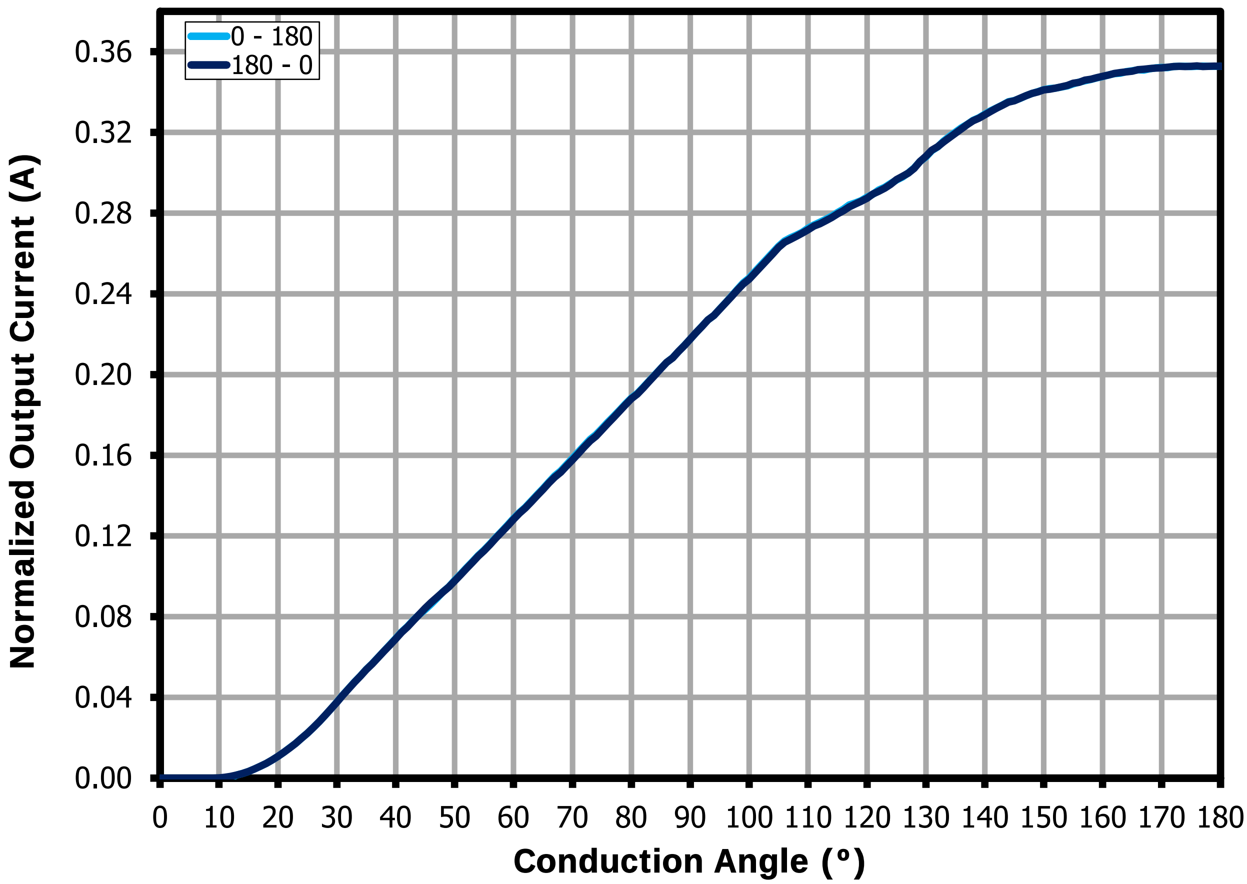

Figure 14 – Dimming Curve at 230 VAC, 50 Hz Input.

11.2 *Dimming Efficiency*

Measurements were made using a programmable AC source to provide the leading edge chopped AC input.

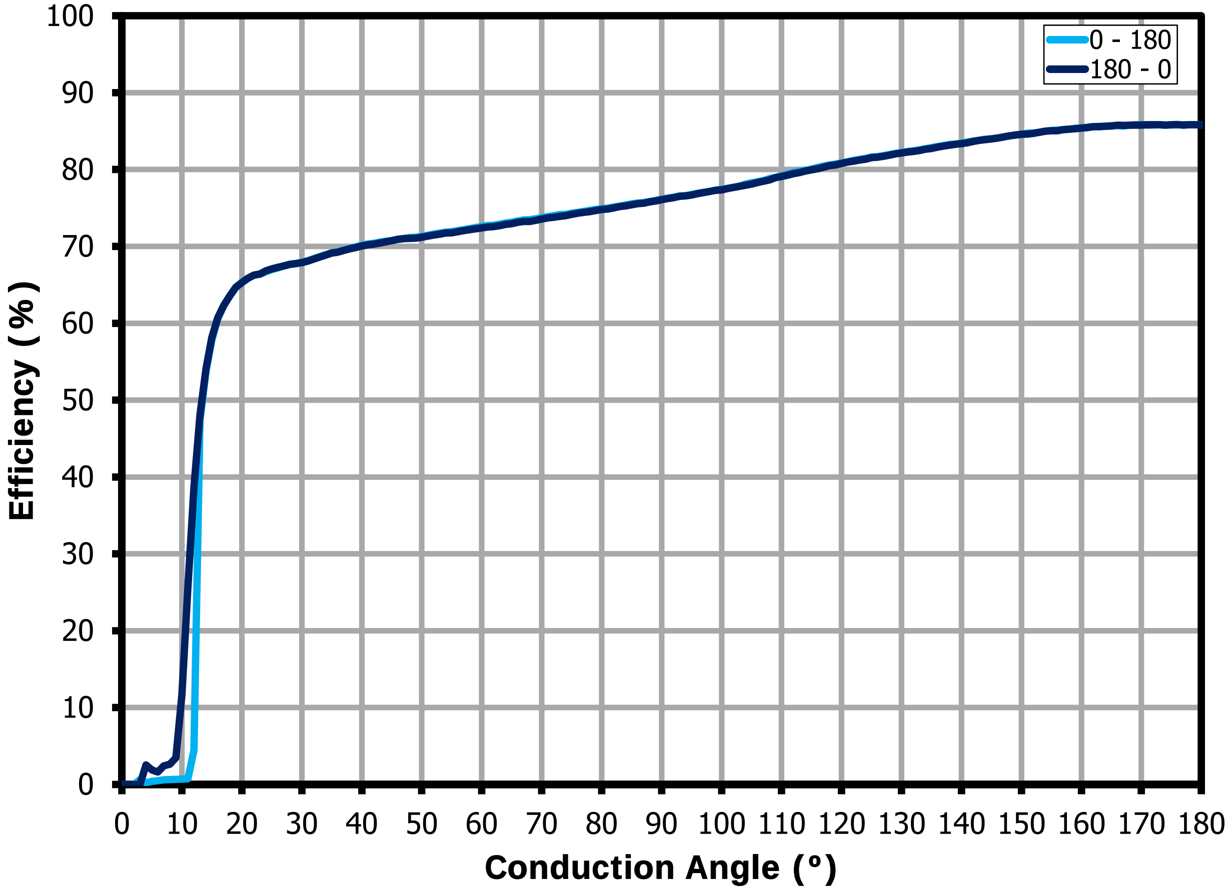

Figure 15 – Dimming Efficiency at 230 VAC, 50 Hz Input.

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11.3 *Driver Power Loss During Dimming*

Measurements were made using a programmable AC source to provide the leading edge chopped AC input.

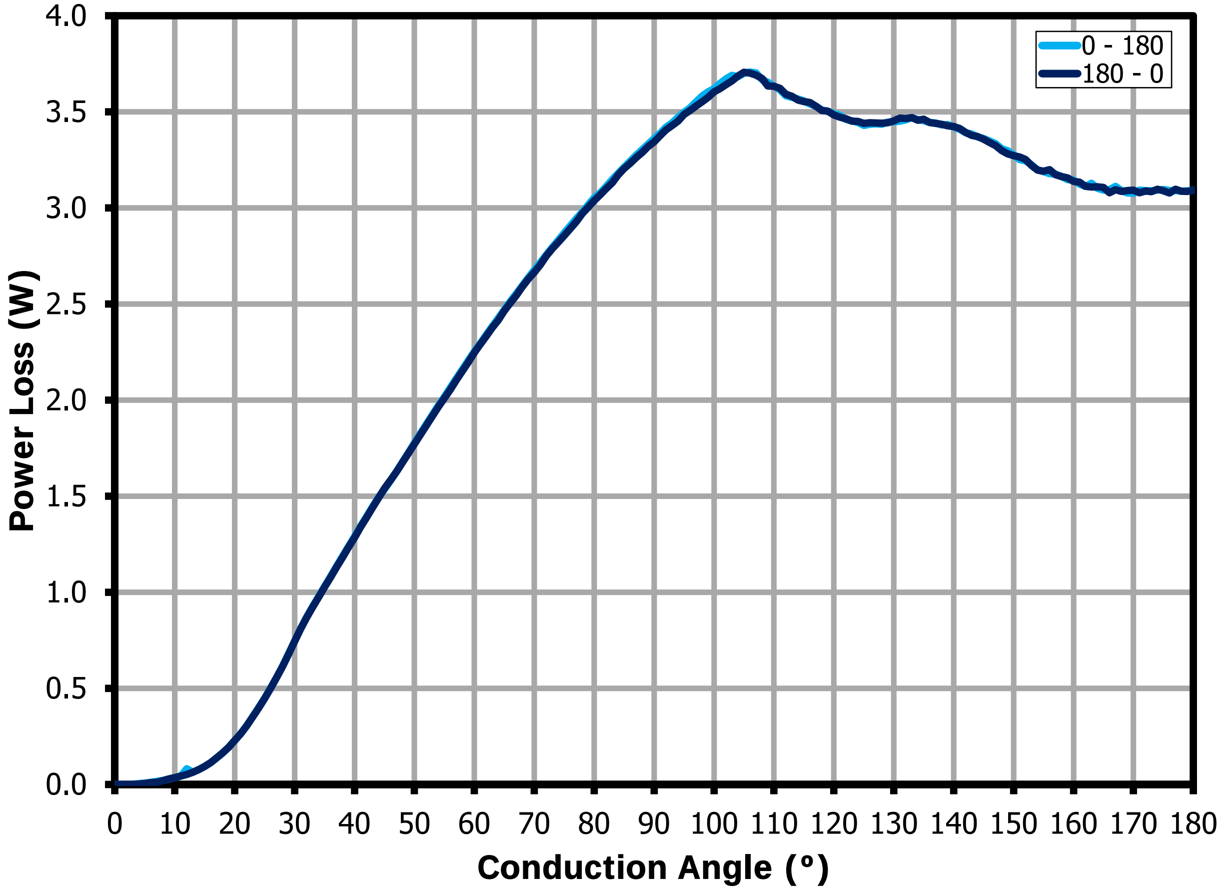

Figure 16 – Dimming Power Loss at 230 VAC, 50 Hz Input.

11.4 *Dimmer Compatibility List*

The following dimmers were tested at 25 ºC ambient temperature, 52 V LED load with the following AC source:

1. AC programmable power source (Agilent 6812B) set at 230 V, 50 Hz
2. Utility line source (≈220 V, 60 Hz)

No.	Brand	Model	Type	Max (mA)	Min (mA)	Dimming Ratio
1	Berker	2875	L	333.55	3.51	95
2	Berker	2830	L	333.21	3.67	91
3	Gira	0302 00	L	333.03	3.76	89
4	Gira	2262	L	336.36	13.25	25
5	Gira	0300 00	L	321.54	3.48	92
6	Jung	266 GDE	L	332.82	4.05	82
7	Jung	225 NVDE	L	326.62	9.60	34
8	Busch	2247 U	L	332.66	12.37	27
9	Busch	2250 U	L	338.58	8.60	39
10	Niko	310-01600	L	345.74	11.99	29
11	Au	AU-DSP400X	L	330.75	2.16	153
12	Peha	434-208013	L	310.43	8.39	37
13	Bticino	L-N-NT4402N	L	277.77	15.18	18
14	Schneider	ALB4x192	L	336.74	1.85	182

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12 Thermal Performance

12.1 Thermal Performance Scan – Open Frame Unit

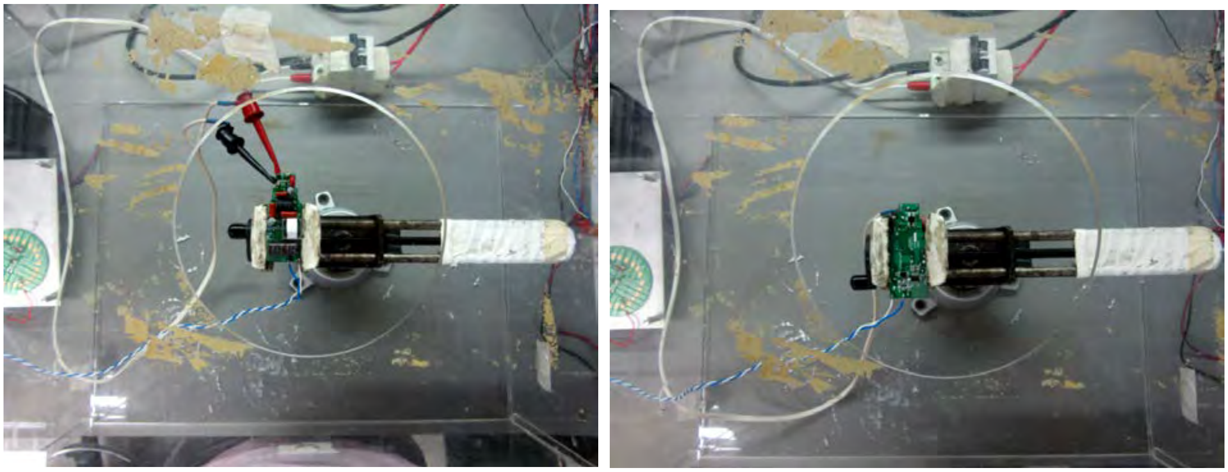

Figure 17 – Test Set-up Picture - Open Frame.

Unit in open frame was placed inside the acrylic enclosure to prevent airflow that might affect the thermal measurements. Temperature was measured using FLIR thermal camera. The ambient temperature is 25 ºC.

12.2 *Thermal Scan at Normal Operation 180 VAC, 52 V LED Load (Non-Dimming)*

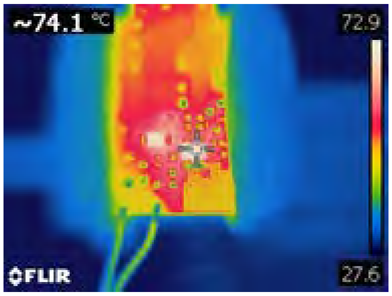

Figure 18 – LYT7504D (U1) = 74.1 °C.

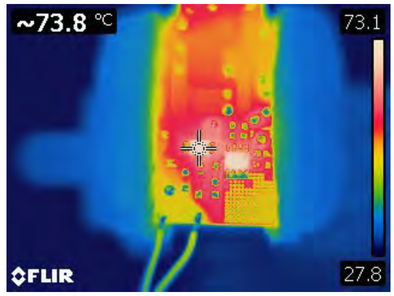

Figure 19 – Buck Diode (D1) = 73.8 °C.

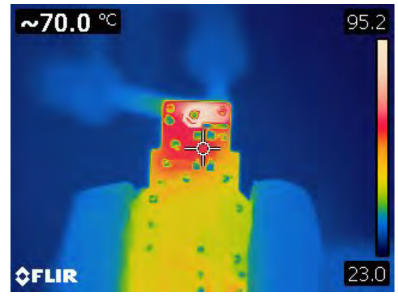

Figure 20 – Bridge Diode (BR1) = 70.0 °C.

Figure 21 – Buck Inductor (T1) = 84.7 °C.

Figure 22 – Fusible Resistor (R1) = 105 °C.

Figure 23 – Damper (R10) = 64.4 °C.

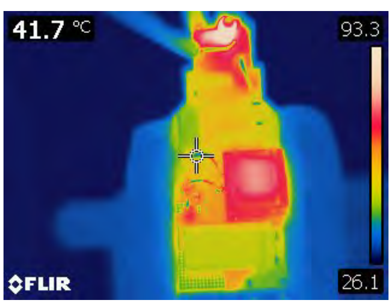

Figure 24 – Damper (R2) = 41.7 °C.

Figure 25 – BP Pull-Up (R9) = 65.6 °C.

Figure 26 – EMI Inductor (L1) = 59.2 °C.

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12.3 *Thermal Scan at Normal Operation 265 VAC, 52 V LED Load (Non-Dimming)*

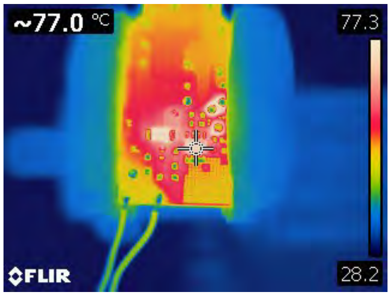

Figure 27 – LYT7504D (U1) = 77.0 °C.

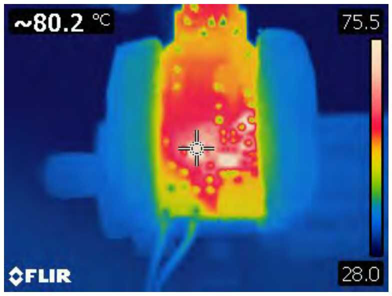

Figure 28 – Buck Diode (D1) = 80.2 °C.

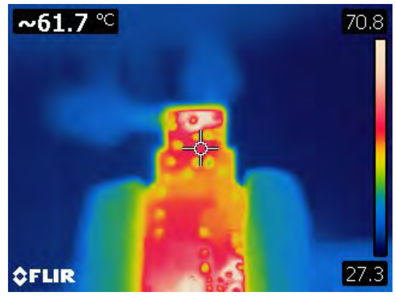

Figure 29 – Bridge Diode (BR1) = 61.7 °C.

Figure 30 – Buck Inductor (T1) = 94.2 °C.

Figure 31 – Fusible Resistor (R1) = 78.3 °C.

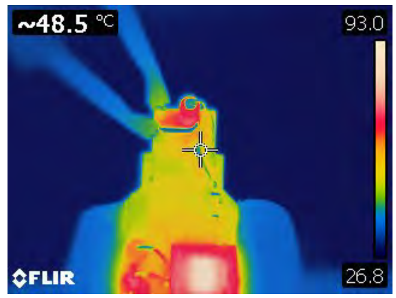

Figure 32 – Damper (R10) = 48.5 °C.

Figure 33 – Damper (R2) = 66.1 °C.

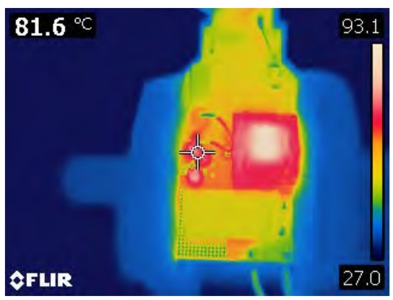

Figure 34 – BP Pull-Up (R9) = 81.6 °C.

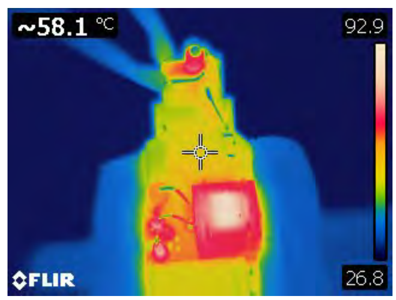

Figure 35 – EMI Inductor (L1) = 58.1 °C.

12.4 *Thermal Scan at Worst Power Loss Conduction Angle (Dimming)*

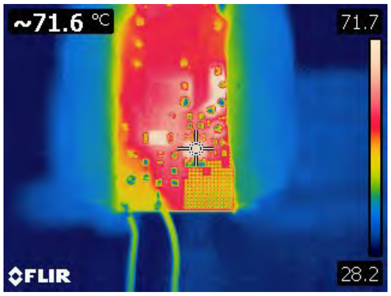

Figure 36 – LYT7504D (U1) = 71.6 °C.

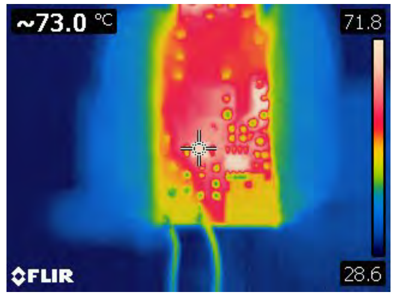

Figure 37 – Buck Diode (D1) = 73.0 °C.

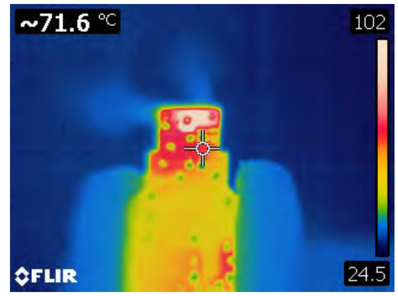

Figure 38 – Bridge Diode (BR1) = 71.6 °C.

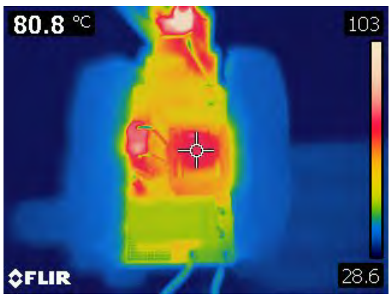

Figure 39 – Buck Inductor (T1) = 80.8 °C.

Figure 40 – Fusible Resistor (R1) =121 °C.

Figure 41 – Damper (R10) = 71.0 °C.

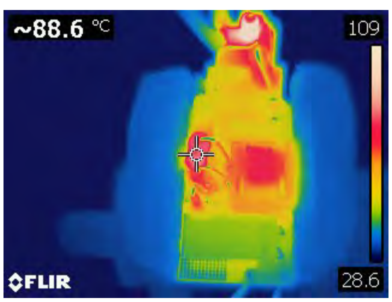

Figure 42 – Damper (R2) = 88.6 °C.

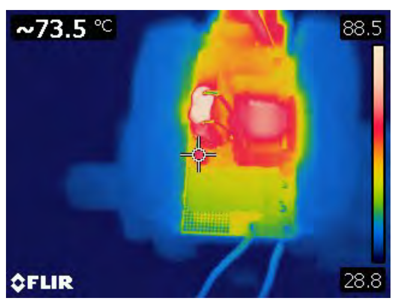

Figure 43 – BP Pull-Up (R9) = 73.5 °C.

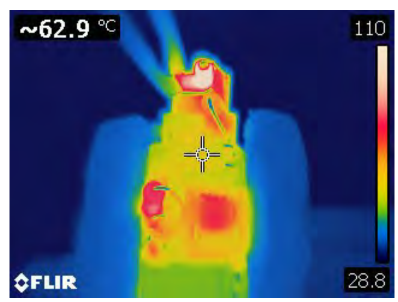

Figure 44 – EMI Inductor (L1) = 62.9 °C.

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12.5 *Thermal Scan During Output Short-Circuit at 230 VAC Input*

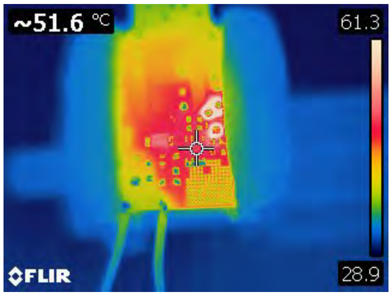

Figure 45 – LYT7504D (U1) = 51.6 °C.

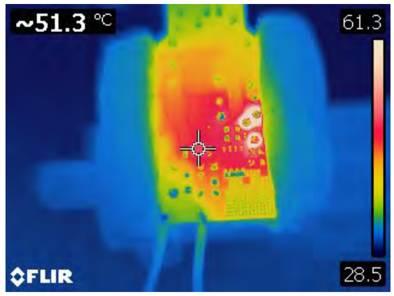

Figure 46 – Buck Diode (D1) = 51.3 °C.

Figure 47 – Buck Inductor (T1) = 52.2 °C.

12.6 *Thermal Performance at 75 ºC Ambient*

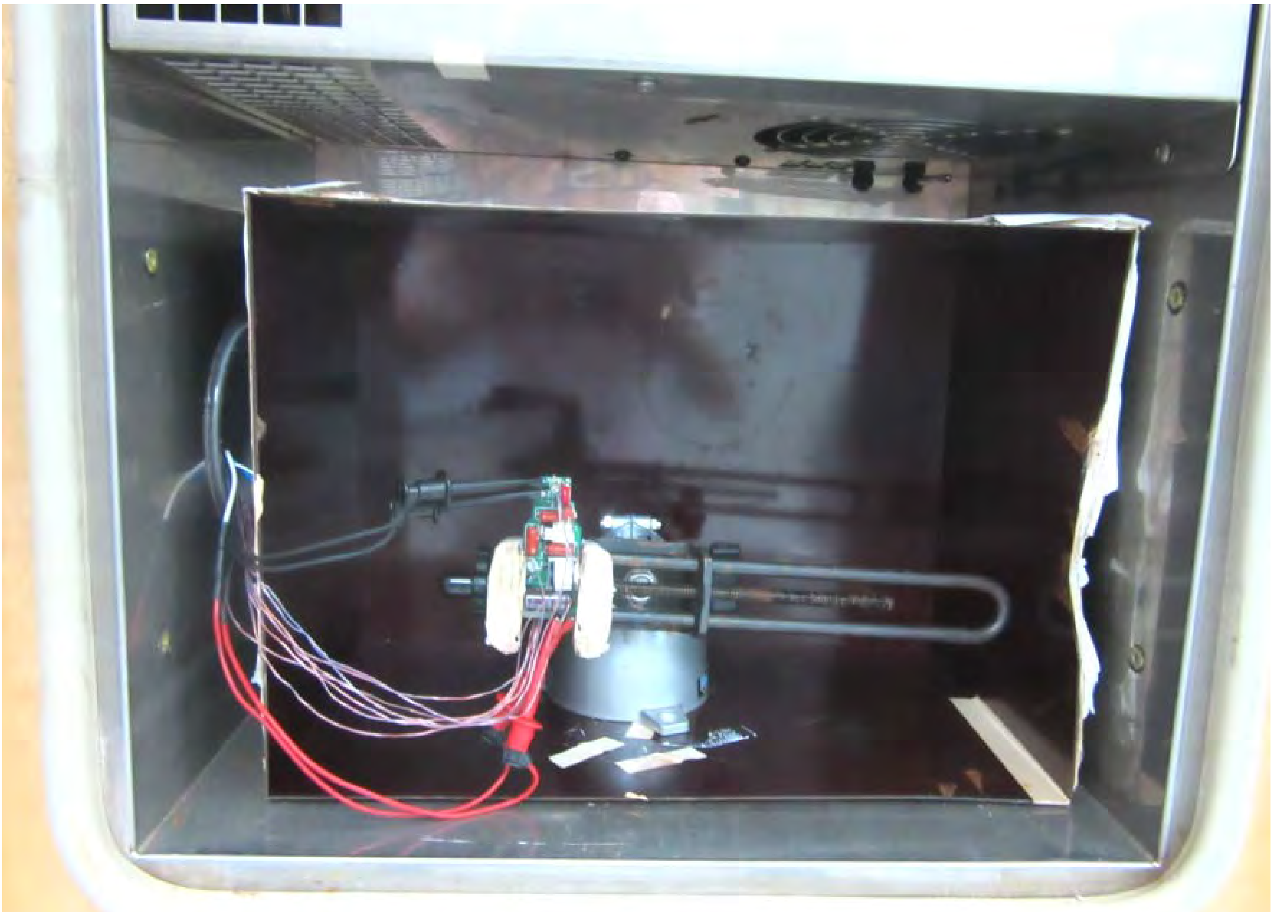

Figure 48 – Test Set-up Picture Thermal at 75 ºC Ambient - Open Frame.

Unit in open frame was placed inside the enclosure to prevent airflow that might affect the thermal measurements. Ambient temperature inside enclosure is 75 ºC. Temperature was measured using type T thermocouple.

This power level (i.e. 18.5 W) in bulb application, full potting or selected potting on some components maybe necessary to manage temperature lower.

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12.7 *Thermal Performance at 230 VAC, 52 V LED Load*

Measurement	Ambient	LYTSwitch-7	BR1	D1	L1	T1	R1 (Fuse)	R2 (Damper)	R9 (BP Pullup)	R10 (Damper)
Maximum	78.7	113.1	108.6	110.9	106.2	120.7	130.2	107.4	100.3	120.8
Final	78.4	112.4	108.4	111.2	106.3	119.3	129.2	106.5	99.9	119.8

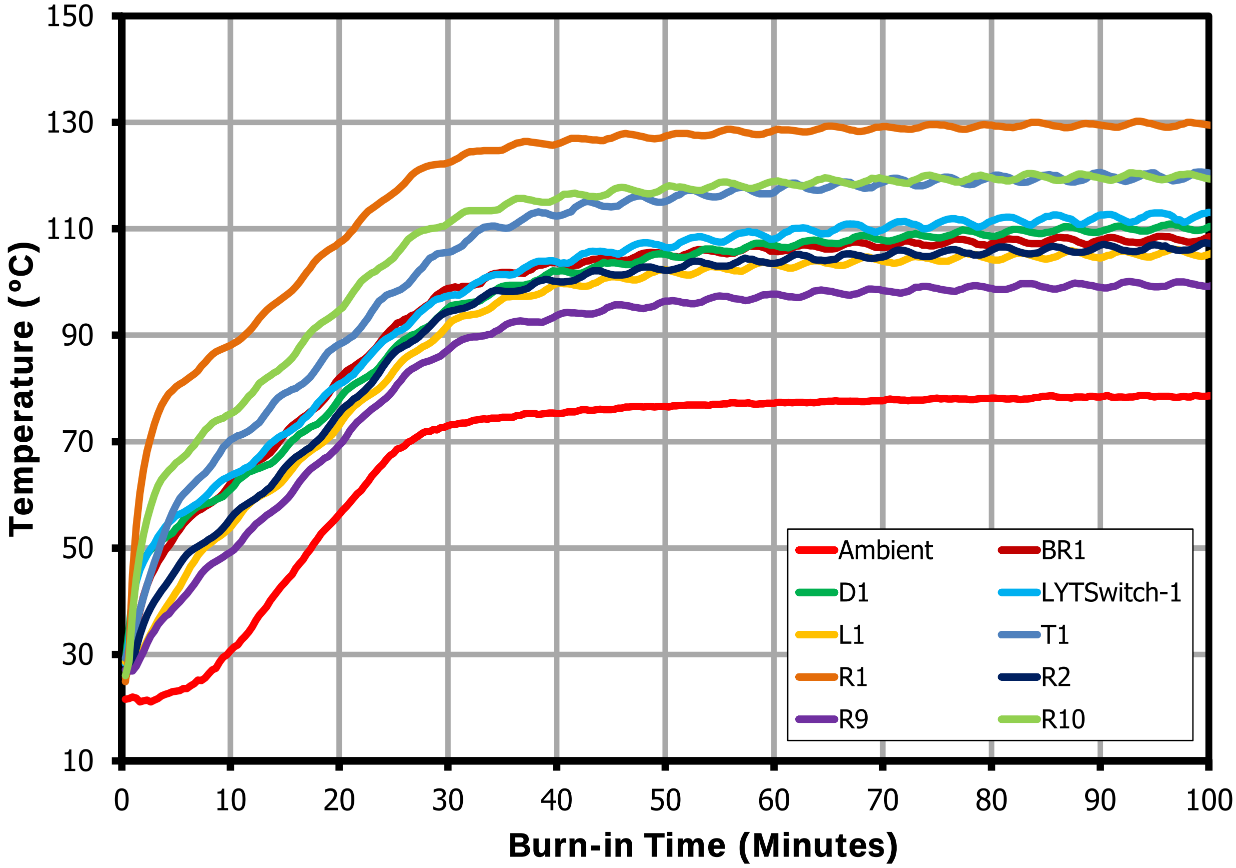

Figure 49 – Component Temperature at 230 VAC, 52 V LED Load, 75 ºC Ambient.

12.8 *Thermal Performance at 180 VAC, 52 V LED Load*

Measurement	Ambient	LYTSwitch-7	BR1	D1	L1	T1	R1 (Fuse)	R2 (Damper)	R9 (BP Pullup)	R10 (Damper)
Maximum	78.6	113.6	112.8	108.1	106.9	116.1	145.9	103.1	100.1	131.2
Final	78.5	113.6	112.4	107.5	106	116	145.7	102.7	99.5	130.7

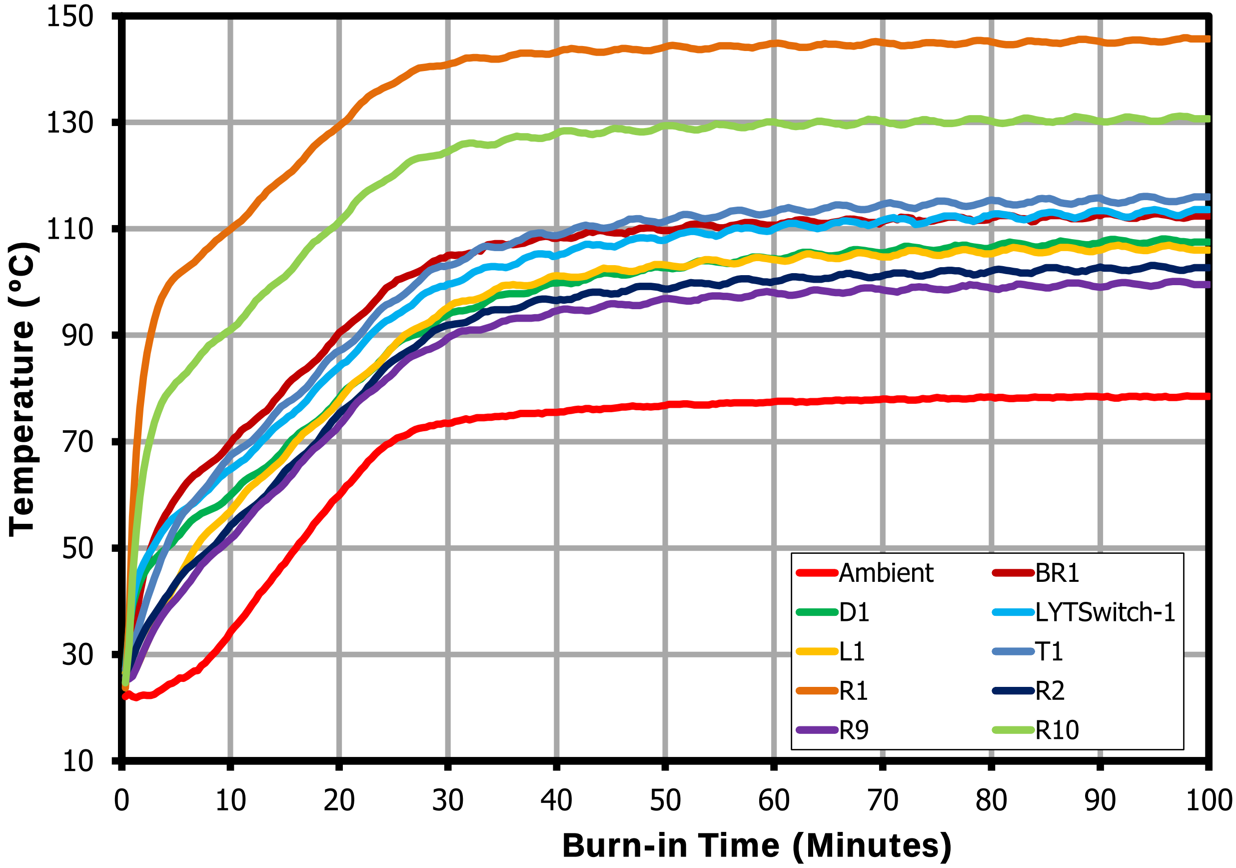

Figure 50 – Component Temperature at 180 VAC, 52 V LED Load, 75 ºC Ambient.

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12.9 *Thermal Performance at 265 VAC, 52 V LED Load*

Measurement	Ambient	LYTSwitch-7	BR1	D1	L1	T1	R1 (Fuse)	R2 (Damper)	R9 (BP Pullup)	R10 (Damper)
Maximum	78.1	115.2	108.3	113.4	107.6	124.2	125.4	112.6	101.7	117.4
Final	78	113.3	107.4	112.9	107.2	122.4	125.1	111.5	101.6	117.3

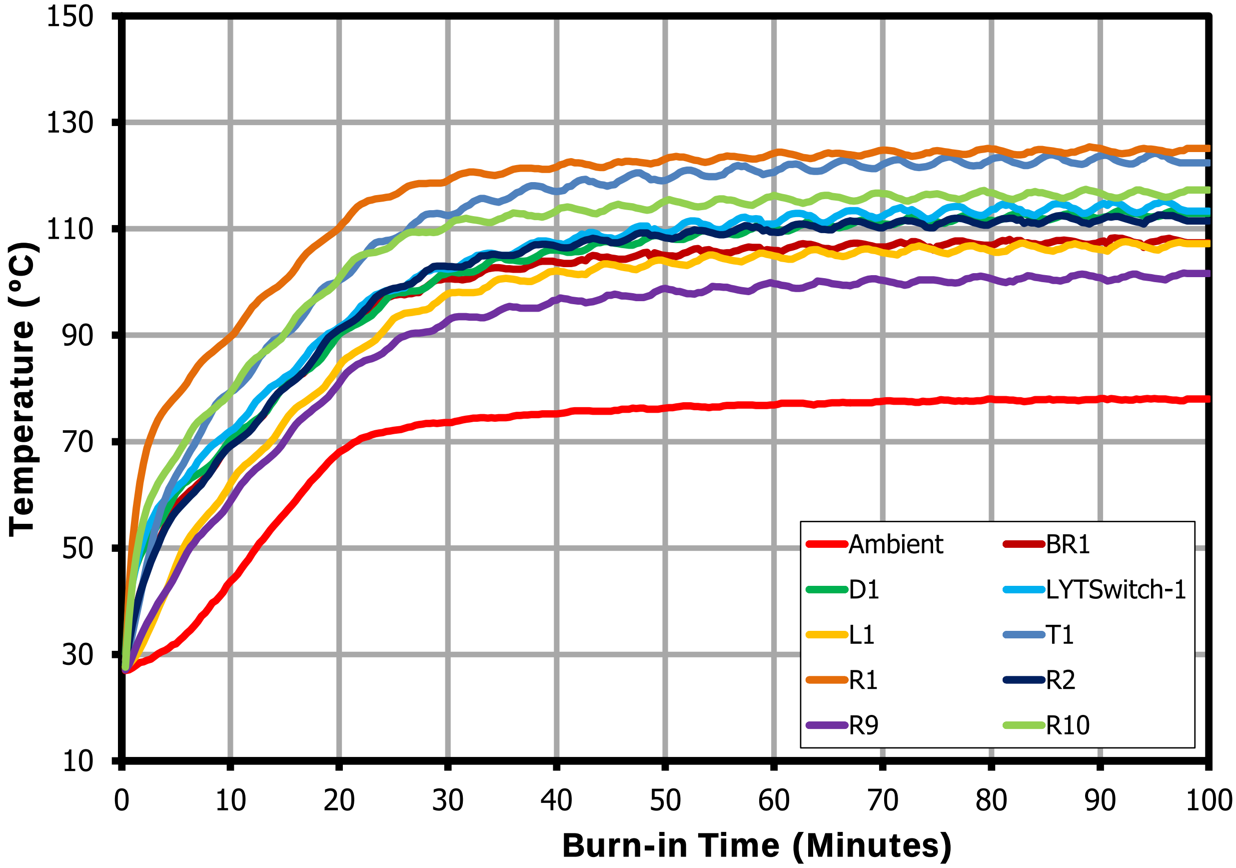

Figure 51 – Component Temperature at 265 VAC, 52 V LED Load, 75 ºC Ambient.

13 Waveforms

13.1 *Input Voltage and Input Current Waveforms*

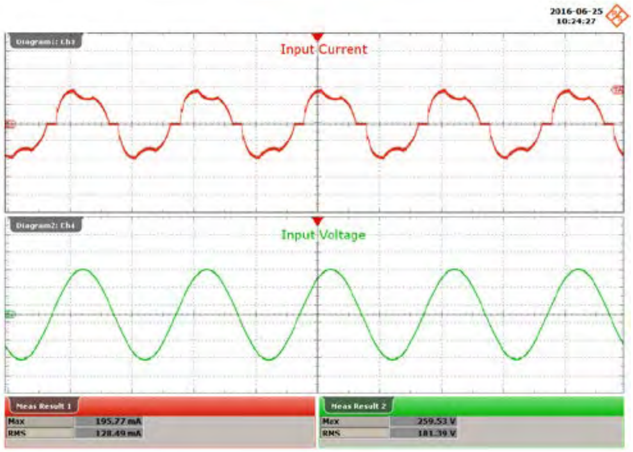

Figure 52 – 180 VAC, 52 V LED Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.
Peak I_{IN}: 196 mA_{PK}.
Peak V_{IN}: 259 V_{PK}.

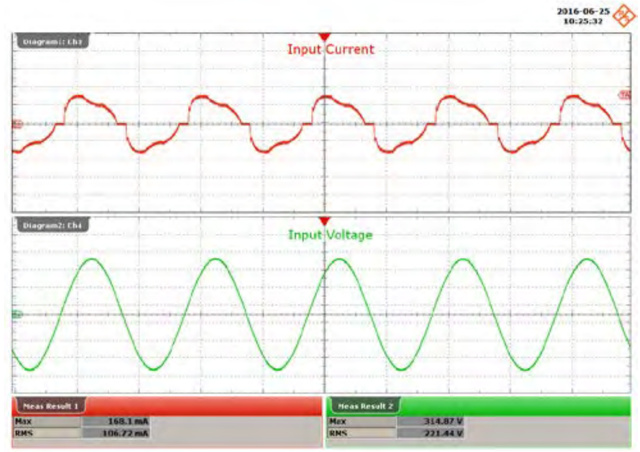

Figure 53 – 220 VAC, 52 V LED Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.
Peak I_{IN}: 168 mA_{PK}.
Peak V_{IN}: 315 V_{PK}.

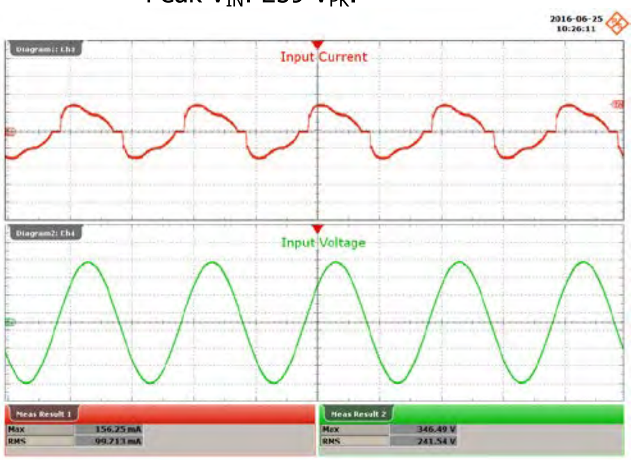

Figure 54 – 240 VAC, 52 V LED Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.
Peak I_{IN}: 156 mA_{PK}.
Peak V_{IN}: 346 V_{PK}.

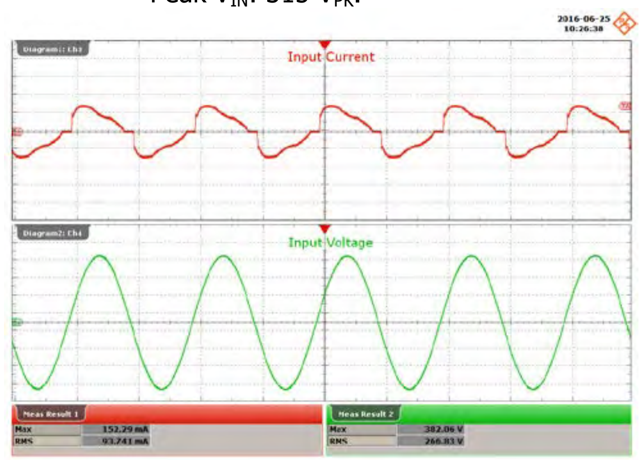

Figure 55 – 265 VAC, 52 V LED Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.
Peak I_{IN}: 152 mA_{PK}.
Peak V_{IN}: 382 V_{PK}.

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13.2 *Output Current Rise and Fall*

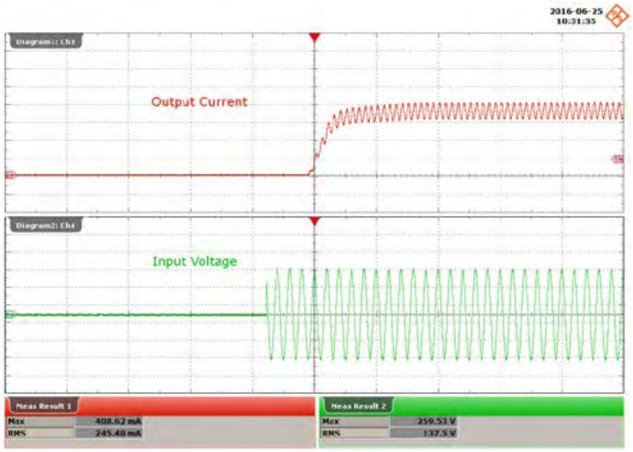

Figure 56 – 180 VAC, 52 V LED Load, Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.
Peak I_{OUT}: 409 mA_{PK}.
Peak V_{IN}: 259 V_{PK}.

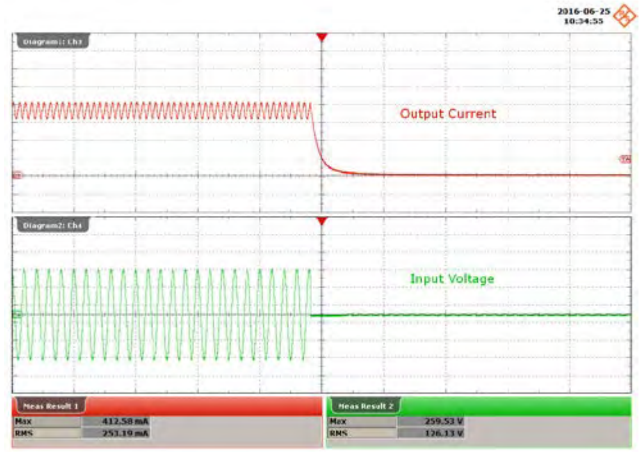

Figure 57 – 180 VAC, 52 V LED Load, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.
Peak I_{OUT}: 413 mA_{PK}.
Peak V_{IN}: 260 V_{PK}.

Figure 58 – 220 VAC, 52 V LED Load, Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.
Peak I_{OUT}: 413 mA_{PK}.
Peak V_{IN}: 314 V_{PK}.

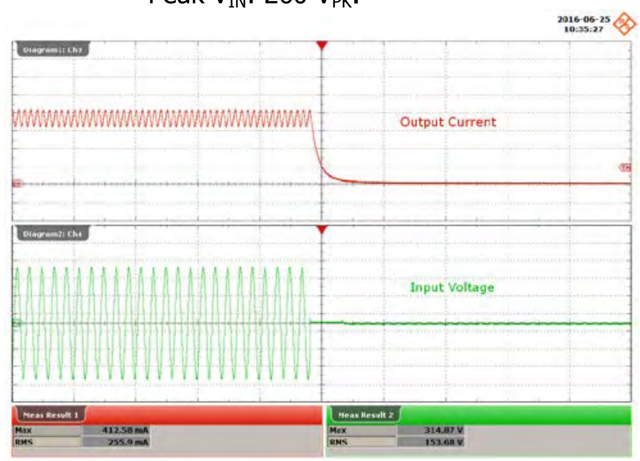

Figure 59 – 220 VAC, 52 V LED Load, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.
Peak I_{OUT}: 413 mA_{PK}.
Peak V_{IN}: 314 V_{PK}.

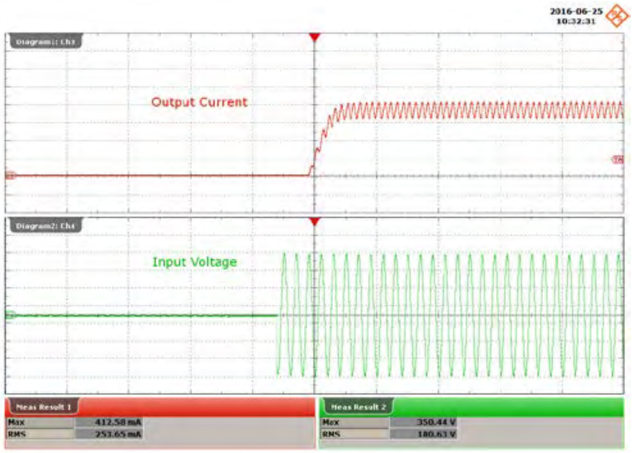

Figure 60 – 240 VAC, 52 V LED Load, Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.
Peak I_{OUT}: 413 mA_{PK}.
Peak V_{IN}: 350 V_{PK}.

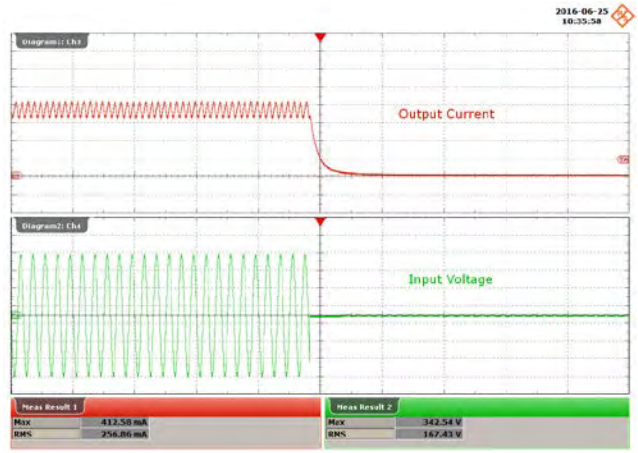

Figure 61 – 240 VAC, 52 V LED Load, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.
Peak I_{OUT}: 413 mA_{PK}.
Peak V_{IN}: 342 V_{PK}.

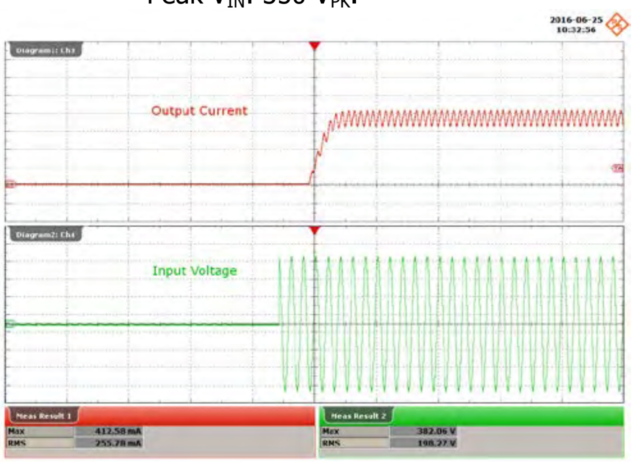

Figure 62 – 265 VAC, 52 V LED Load, Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.
Peak I_{OUT}: 413 mA_{PK}.
Peak V_{IN}: 382 V_{PK}.

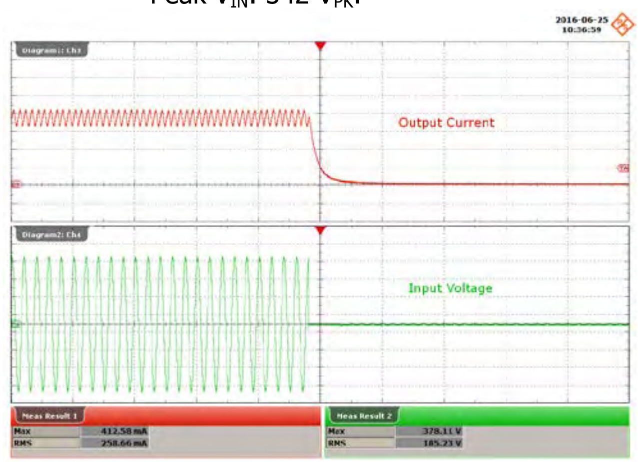

Figure 63 – 265 VAC, 52 V LED Load, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.
Peak I_{OUT}: 413 mA_{PK}.
Peak V_{IN}: 378 V_{PK}.

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13.3 *Drain Voltage and Current in Normal Operation*

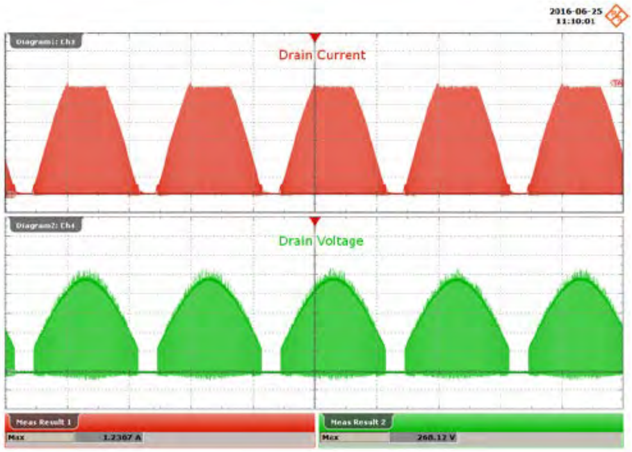

Figure 64 – 180 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 ms / div.
Peak I_{DRAIN}: 1.24 A_{PK}.
Peak V_{DRAIN}: 268 V_{PK}.

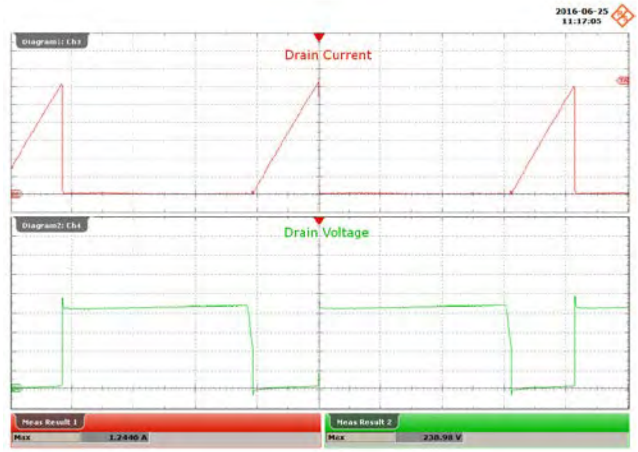

Figure 65 – 180 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.
Peak I_{DRAIN}: 1.25 A_{PK}.
Peak V_{DRAIN}: 239 V_{PK}.

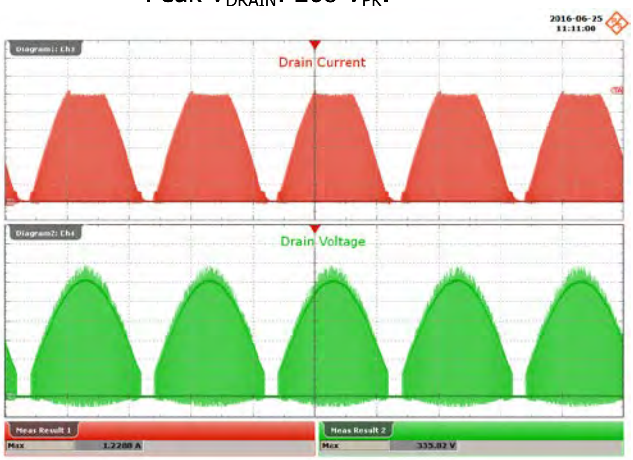

Figure 66 – 220 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Peak I_{DRAIN}: 1.23 A_{PK}.
Peak V_{DRAIN}: 336 V_{PK}.

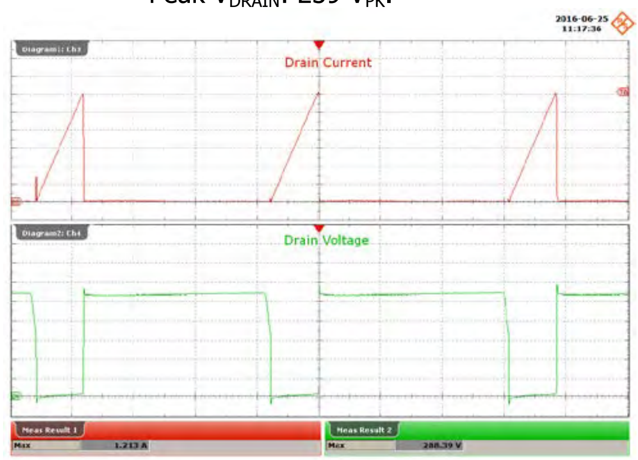

Figure 67 – 220 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.
Peak I_{DRAIN}: 1.21 A_{PK}.
Peak V_{DRAIN}: 288 V_{PK}.

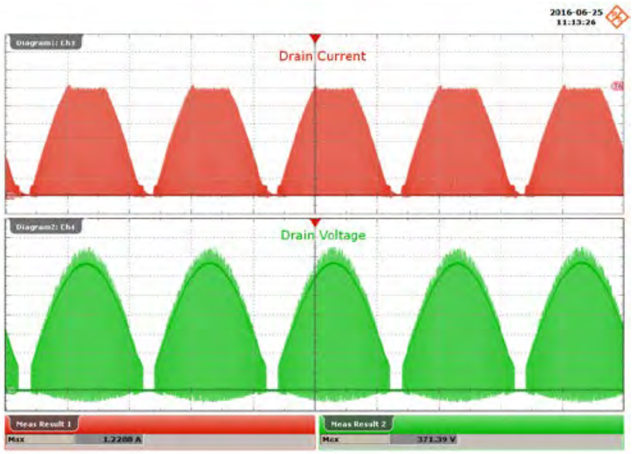

Figure 68 – 240 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 ms / div.
Peak I_{DRAIN}: 1.23 mA_{PK}.
Peak V_{DRAIN}: 371 V_{PK}.

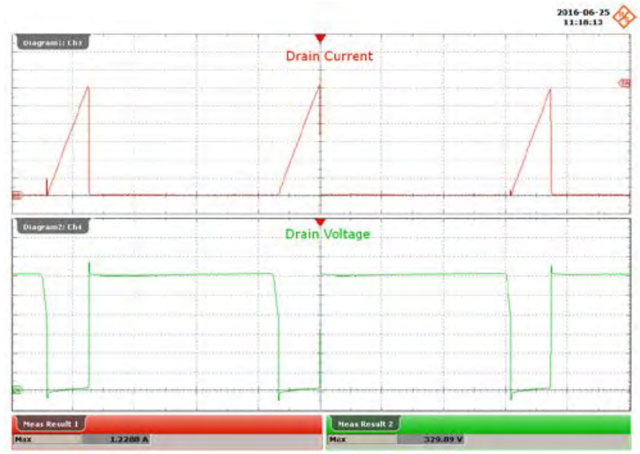

Figure 69 – 240 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.
Peak I_{DRAIN}: 1.23 mA_{PK}.
Peak V_{DRAIN}: 330 V_{PK}.

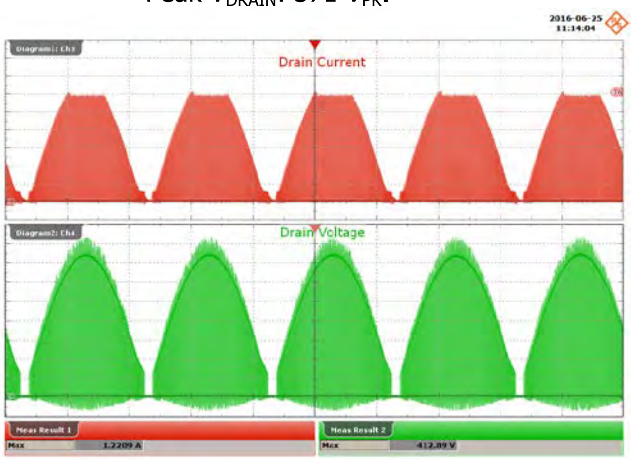

Figure 70 – 265 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 ms / div.
Peak I_{DRAIN}: 1.22 A_{PK}.
Peak V_{DRAIN}: 413 V_{PK}.

Figure 71 – 265 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.
Peak I_{DRAIN}: 1.22 A_{PK}.
Peak V_{DRAIN}: 374 V_{PK}.

13.4 *Drain Voltage and Current Start-up Profile*

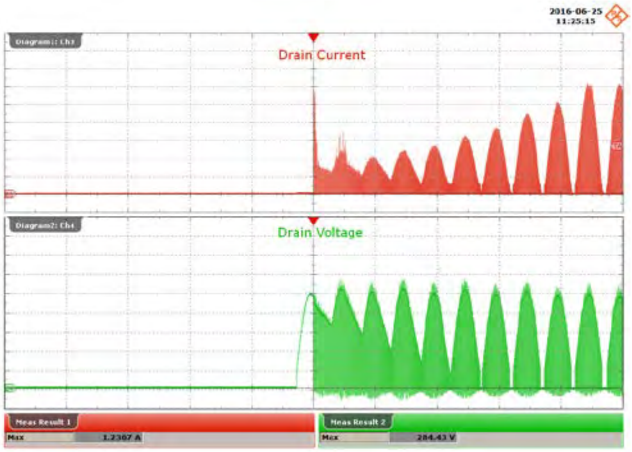

Figure 72 – 180 VAC, 52 V LED Load
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 ms /div.
Peak I_{DRAIN}: 1.24 A_{PK}.
Peak V_{DRAIN}: 284 V_{PK}.

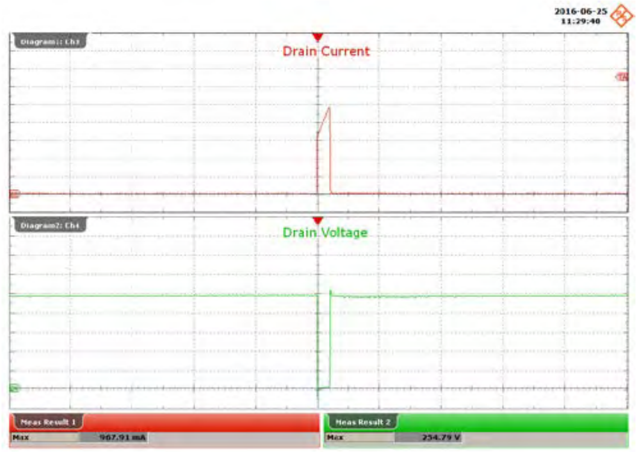

Figure 73 – 180 VAC, 52 V LED Load
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs /div.
Peak I_{DRAIN}: 968 mA_{PK}.
Peak V_{DRAIN}: 255 V_{PK}.

Figure 74 – 265 VAC, 52 V LED Load
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 ms /div.
Peak I_{DRAIN}: 1.8 A_{PK}.
Peak V_{DRAIN}: 418 V_{PK}.

Figure 75 – 265 VAC, 52 V LED Load
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 μs /div.
Peak I_{DRAIN}: 1.2 A_{PK}.
Peak V_{DRAIN}: 379 V_{PK}.

13.5 *Drain Voltage and Current During Output Short-Circuit Condition*

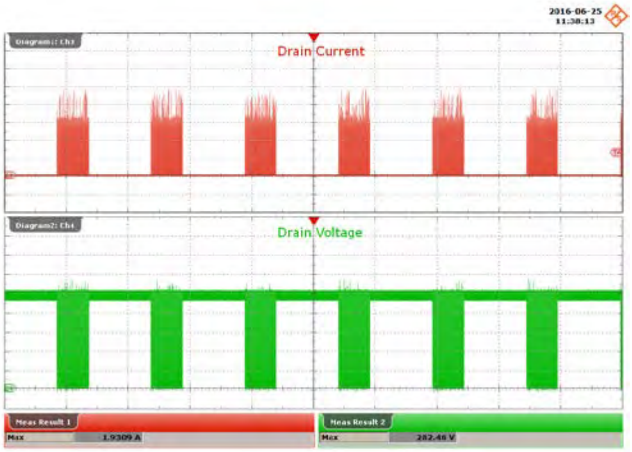

Figure 76 – 180 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Peak I_{DRAIN}: 1.94 A_{PK}.
Peak V_{DRAIN}: 283 V_{PK}.

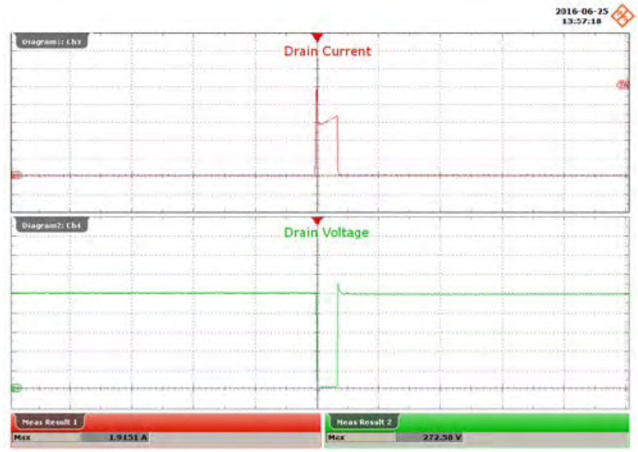

Figure 77 – 180 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 μs / div.
Peak I_{DRAIN}: 1.91 A_{PK}.
Peak V_{DRAIN}: 272 V_{PK}.

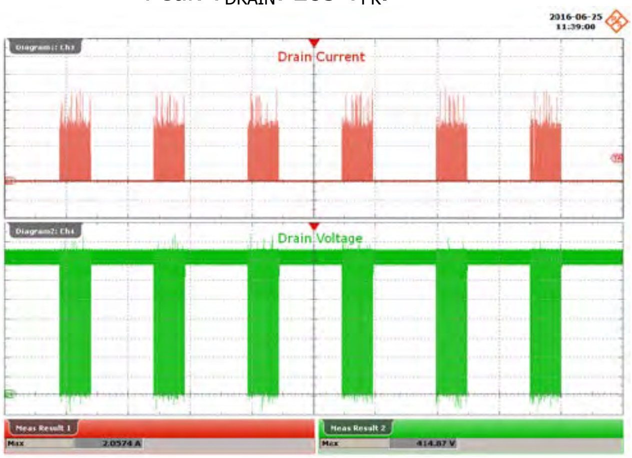

Figure 78 – 265 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Peak I_{DRAIN}: 2.05 A_{PK}.
Peak V_{DRAIN}: 415 V_{PK}.

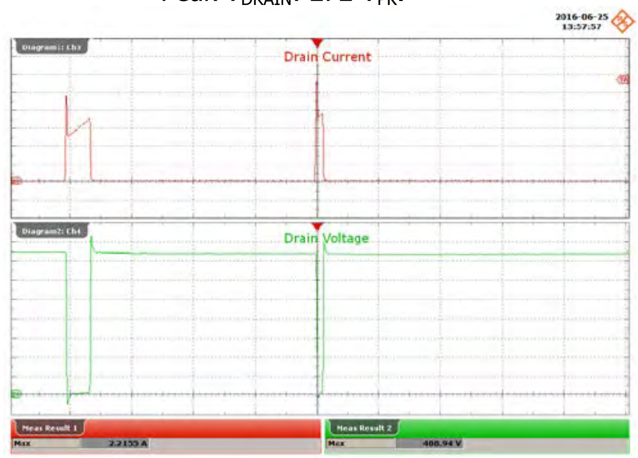

Figure 79 – 265 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 μs / div.
Peak I_{DRAIN}: 2.2 A_{PK}.
Peak V_{DRAIN}: 405 V_{PK}.

V_{IN} (VAC)	Frequency (Hz)	P_{IN} (W)
180	50	0.7994
265	50	1.2932

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13.6 *Output Diode Voltage and Current in Normal Operation*

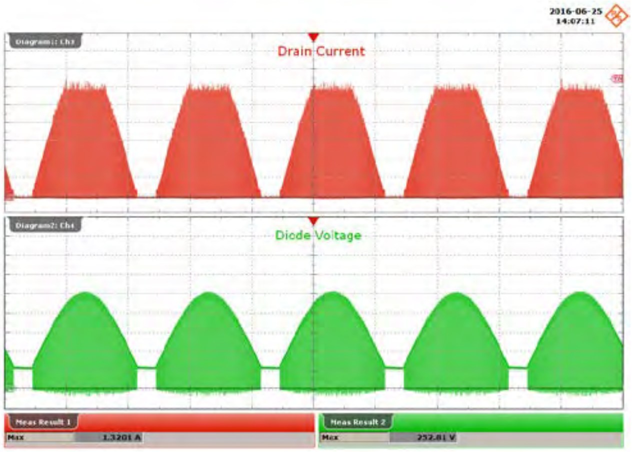

Figure 80 – 180 VAC, 52 V LED Load.
Upper: I_{D3}, 200 mA / div.
Lower: V_{D3}, 100 V / div., 5 ms / div.
Peak I_{D3}: 1.32 A_{PK}.
Peak V_{D3}: 253 V_{PK}.

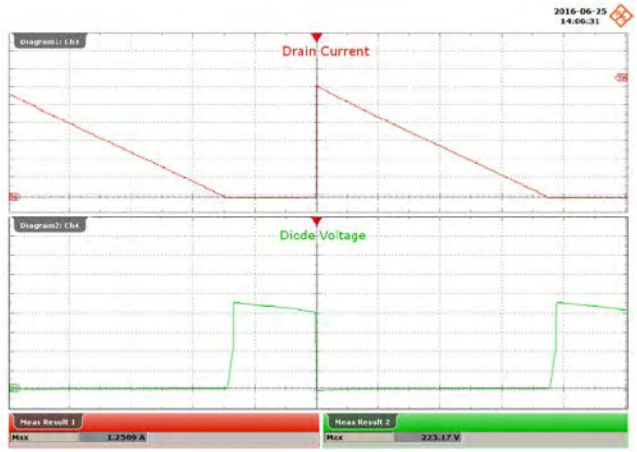

Figure 81 – 180 VAC, 52 V LED Load.
Upper: I_{D3}, 200 mA / div.
Lower: V_{D3}, 100 V / div., 4 µs / div.
Peak I_{D3}: 1.26 A_{PK}.
Peak V_{D3}: 223 V_{PK}.

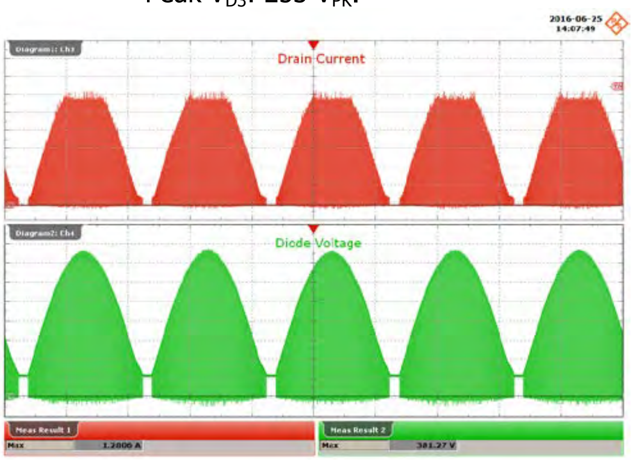

Figure 82 – 265 VAC, 52 V LED Load.
Upper: I_{D3}, 200 mA / div.
Lower: V_{D3}, 100 V / div., 5 ms / div.
Peak I_{D3}: 1.28 mA_{PK}.
Peak V_{D3}: 381 V_{PK}.

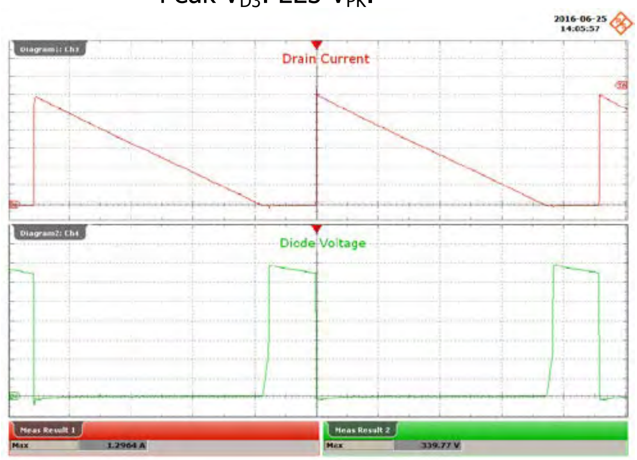

Figure 83 – 265 VAC, 52 V LED Load.
Upper: V_{DRAIN}, 200 mA / div.
Lower: I_{DRAIN}, 100 V / div., 4 µs / div.
Peak I_{DRAIN}: 1.29 mA_{PK}.
Peak V_{DRAIN}: 340 V_{PK}.

13.7 *Output Voltage and Current – Open LED Load*

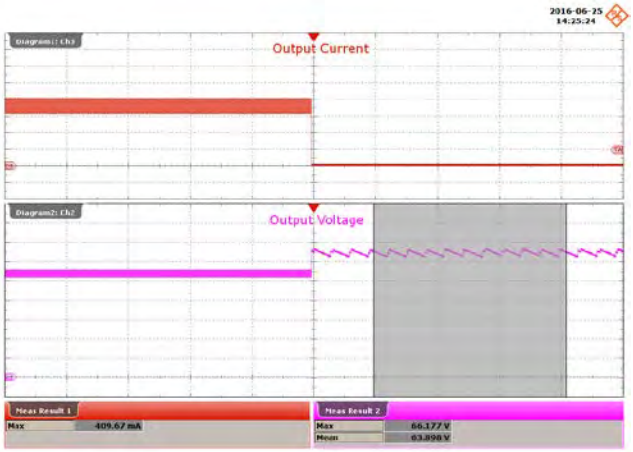

Figure 84 – 180 VAC, 52 V LED Load,
Running Open Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V / div., 500 ms / div.
Peak I_{OUT}: 409 mA_{PK}.
Peak V_{OUT}: 66.1 V_{PK}.

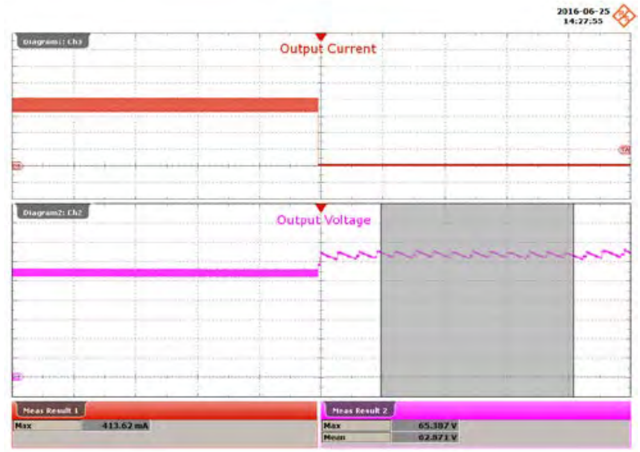

Figure 85 – 265 VAC, 52 V LED Load,
Running Open Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V / div., 500 ms / div.
Peak I_{OUT}: 413 mA_{PK}.
Peak V_{OUT}: 65.4 V_{PK}.

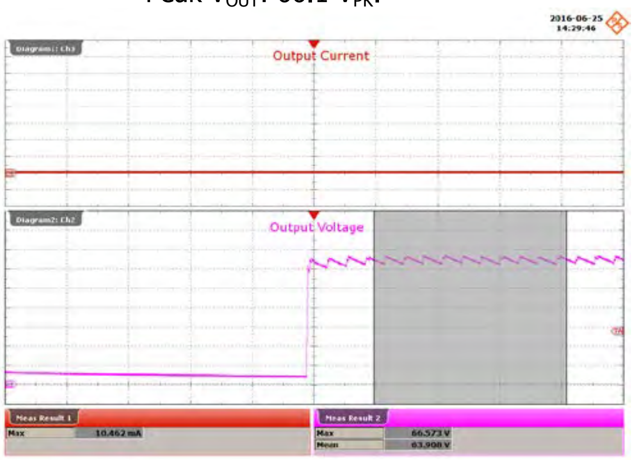

Figure 86 – 180 VAC, 52 V LED Load,
Open Load Start-up.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V / div., 500 ms / div.
Peak V_{OUT}: 66.6 V_{PK}.

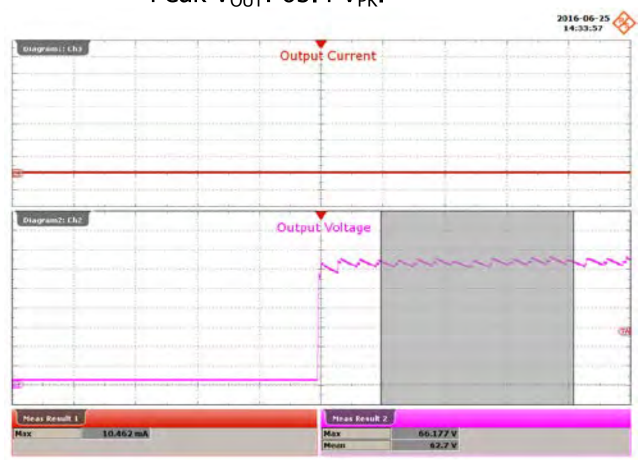

Figure 87 – 265 VAC, 52 V LED Load,
Open Load Start-up.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V / div., 500 ms / div.
Peak I_{OUT}: 74 mA_{PK}.
Peak V_{OUT}: 181 V_{PK}.

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13.8 *Output Ripple Current*

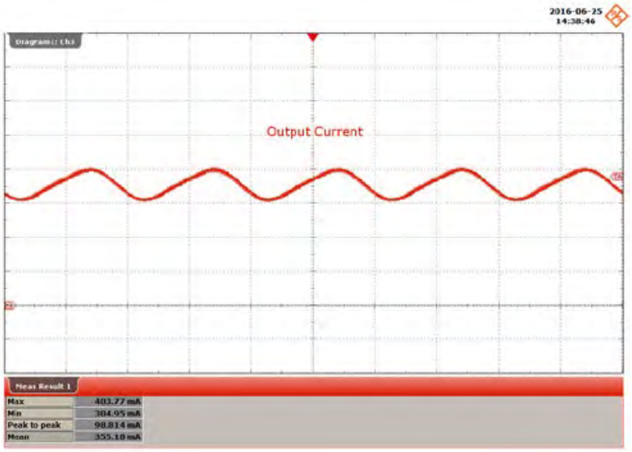

Figure 88 – 180 VAC, 50 Hz, 52 V LED Load.
I_{OUT}, 100 mA / div., 5 ms / div.

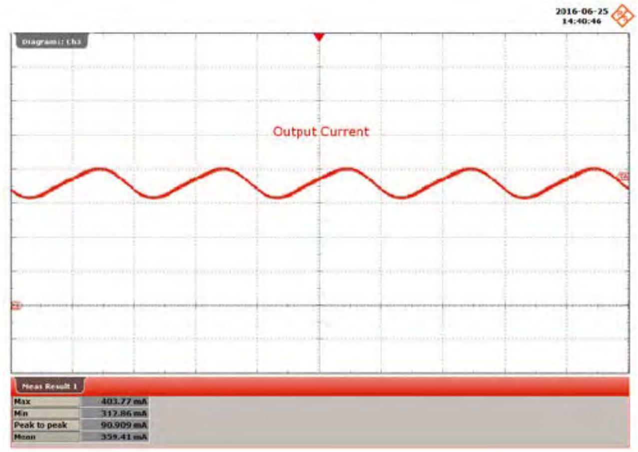

Figure 89 – 220 VAC, 50 Hz, 52 V LED Load.
I_{OUT}, 100 mA / div., 5 ms / div.

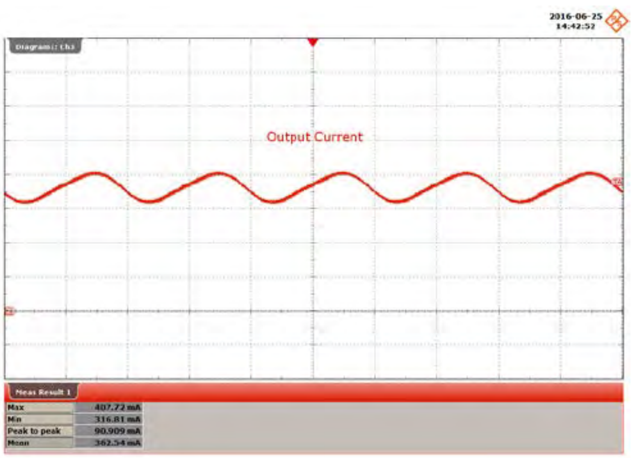

Figure 90 – 240 VAC, 50 Hz, 52 V LED Load.
I_{OUT}, 100 mA / div., 5 ms / div.

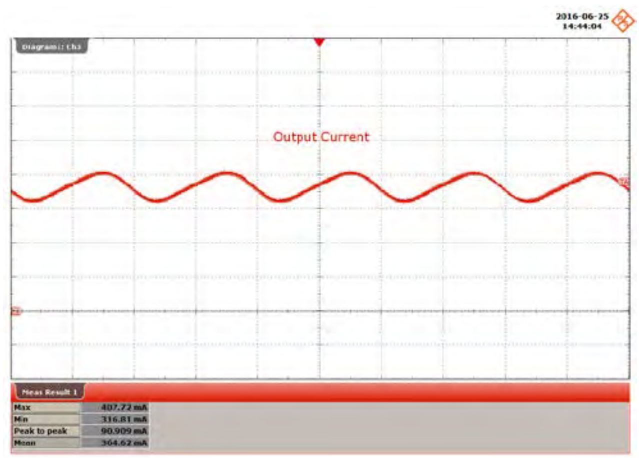

Figure 91 – 265 VAC, 50 Hz, 52 V LED Load.
I_{OUT}, 100 mA / div., 5 ms / div.

V_{IN} (VAC)	$I_{OUT(MAX)}$ (mA)	$I_{OUT(MIN)}$ (mA)	$I_{RP-P(PK-PK)}$ (mA)	I_{MEAN}	Ripple Ratio (I_{RP-P}/I_{MEAN})	% Flicker 100 x (I_{RP-P} / $I_{OUT(MAX)}$+$I_{OUT(MIN)}$)
180	403.77	304.95	98.81	355.18	0.28	13.94
220	403.77	312.86	90.91	359.41	0.25	12.69
240	407.72	316.81	90.91	362.54	0.25	12.54
265	407.72	316.81	90.91	364.62	0.25	12.54

14 Dimming Waveforms

14.1 *Input Voltage and Input Current Waveforms – Leading Edge Dimmer*

Input: 230 VAC, 50 Hz
Output: 52 V LED load
Dimmer: Berker 2875

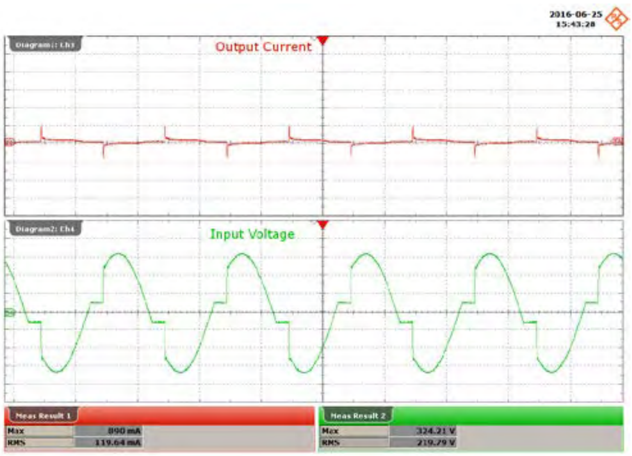

Figure 92 – 140º Conduction Angle.
Upper: I_{IN}, 1 A / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.
Peak V_{IN}: 324 V_{PK}.
V_{RMS}: 219 V.

Figure 93 – 110º Conduction Angle.
Upper: I_{IN}, 1 A / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.
Peak V_{IN}: 328 V_{PK}.
V_{RMS}: 198 V.

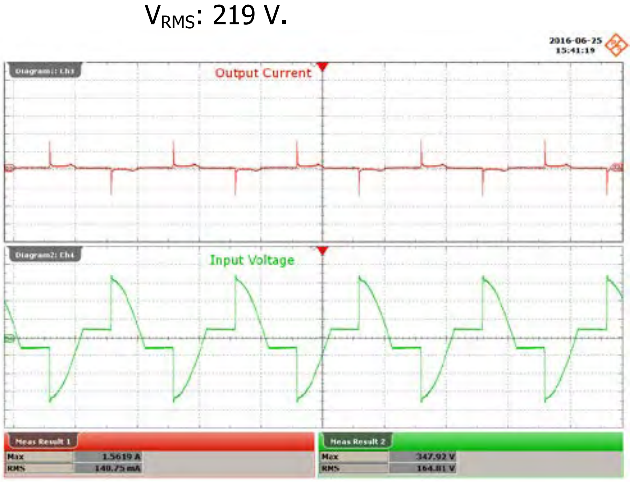

Figure 94 – 90º Conduction Angle.
Upper: I_{IN}, 1 A / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.
Peak V_{IN}: 348 V_{PK}.
V_{RMS}: 164 V.

Figure 95 – 45º Conduction Angle.
Upper: I_{IN}, 1 A / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.
Peak V_{IN}: 272 V_{PK}.
V_{RMS}: 90 V.

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14.2 *Output Current Waveforms – Leading Edge Dimmer*

Input: 230 VAC, 50 Hz
Output: 52 V LED load
Dimmer: Berker 2875

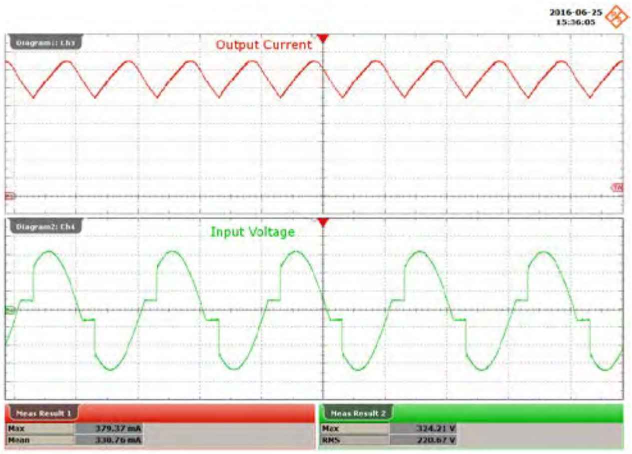

Figure 96 – 140º Conduction Angle.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.
Peak I_{OUT}: 379 mA_{PK}.
Peak V_{IN}: 330 V_{PK}.

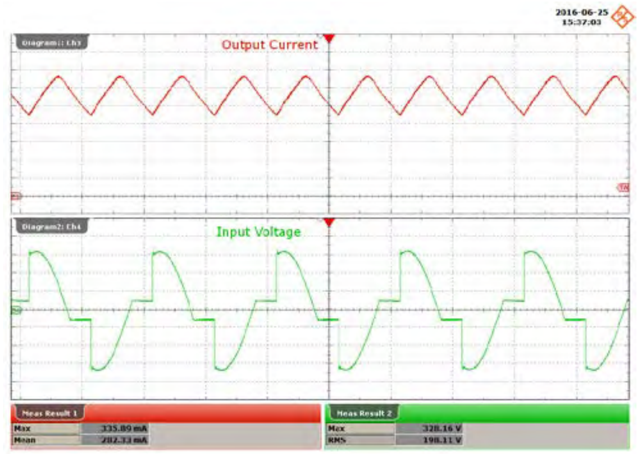

Figure 97 – 110º Conduction Angle.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.
Peak I_{OUT}: 335 mA_{PK}.
Peak V_{IN}: 328 V_{PK}.

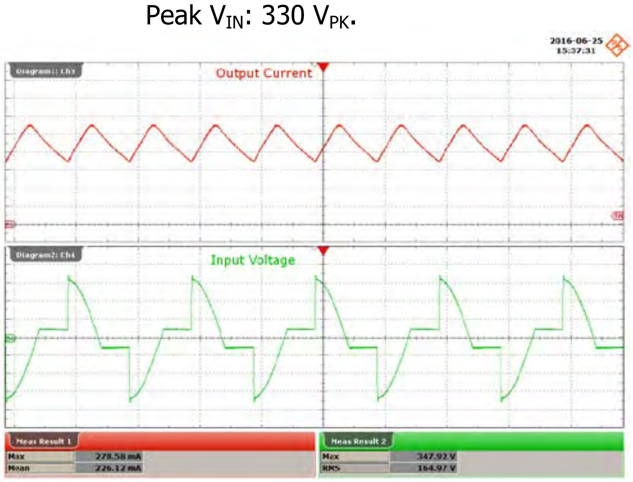

Figure 98 – 90º Conduction Angle.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.
Peak I_{OUT}: 279 mA_{PK}.
Peak V_{IN}: 347 V_{PK}.

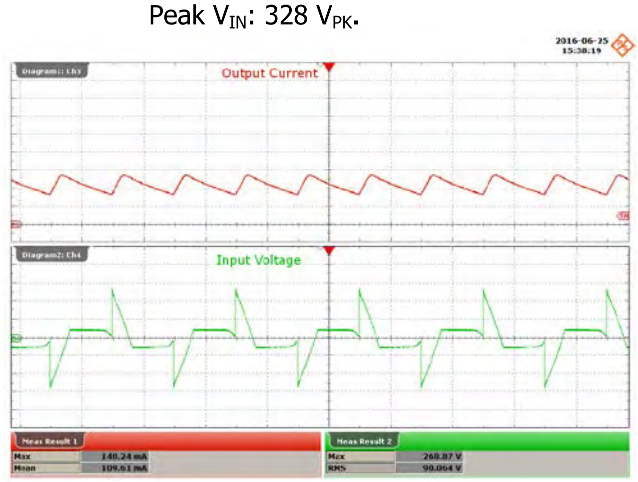

Figure 99 – 45º Conduction Angle.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.
Peak I_{OUT}: 140 mA_{PK}.
Peak V_{IN}: 268 V_{PK}.

15 AC Cycling Test

Output current overshoot within regulation during on - off cycling.

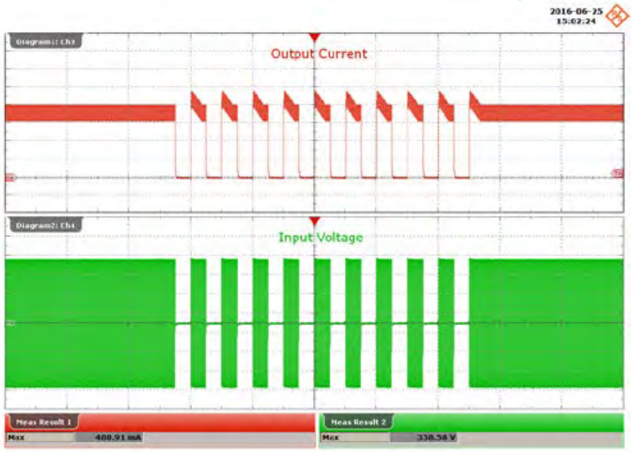

Figure 100 – 230 VAC, 52 V LED Load.
1 s On – 1 s Off.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 4 s / div.

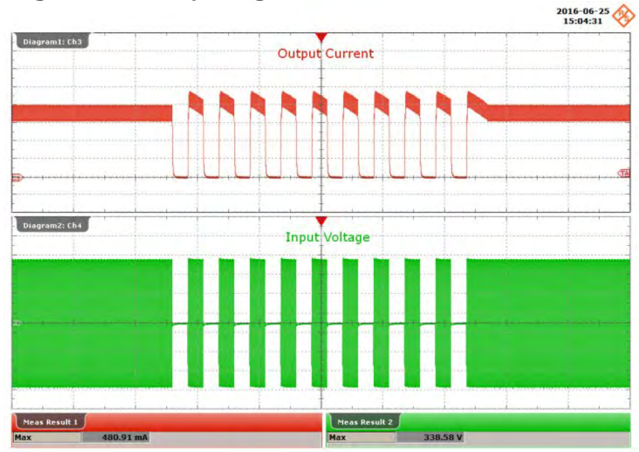

Figure 101 – 230 VAC, 52 V LED Load.
0.5 s On – 0.5 s Off.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

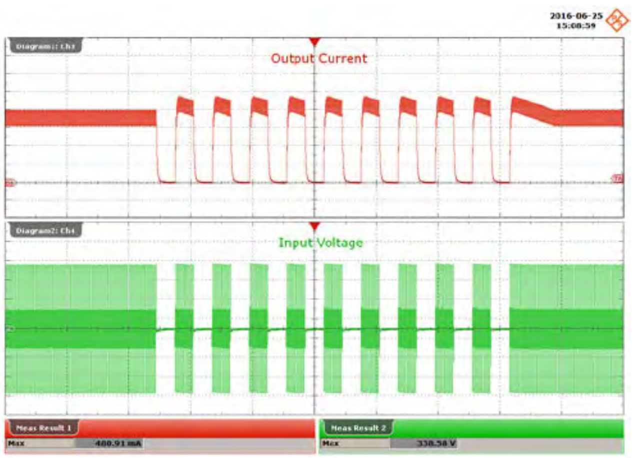

Figure 102 – 230 VAC, 52 V LED Load.
0.3 s On – 0.3 s Off.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 1 s / div.

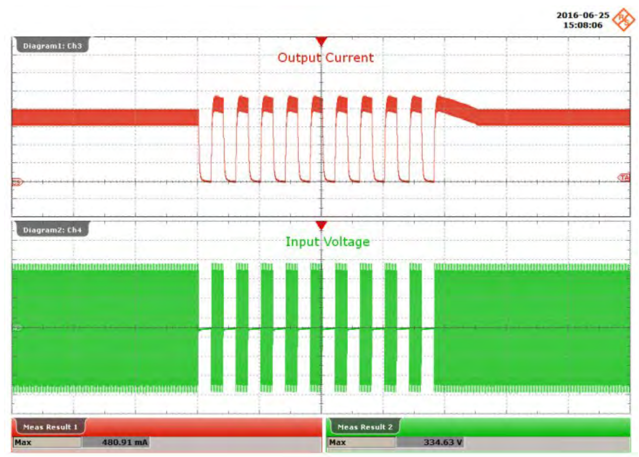

Figure 103 – 230 VAC, 52 V LED Load.
0.2 s On – 0.2 s Off.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 1 s / div.

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16 Conducted EMI

16.1 *Test Set-up*

16.1.1 Equipment and Load Used

1. Rohde and Schwarz ENV216 two line V-network.
2. Rohde and Schwarz ESRP EMI test receiver.
3. Hioki 3322 power hitester.
4. Chroma measurement test fixture, model A662003.
5. 52 V LED load with input voltage set at 230 VAC.

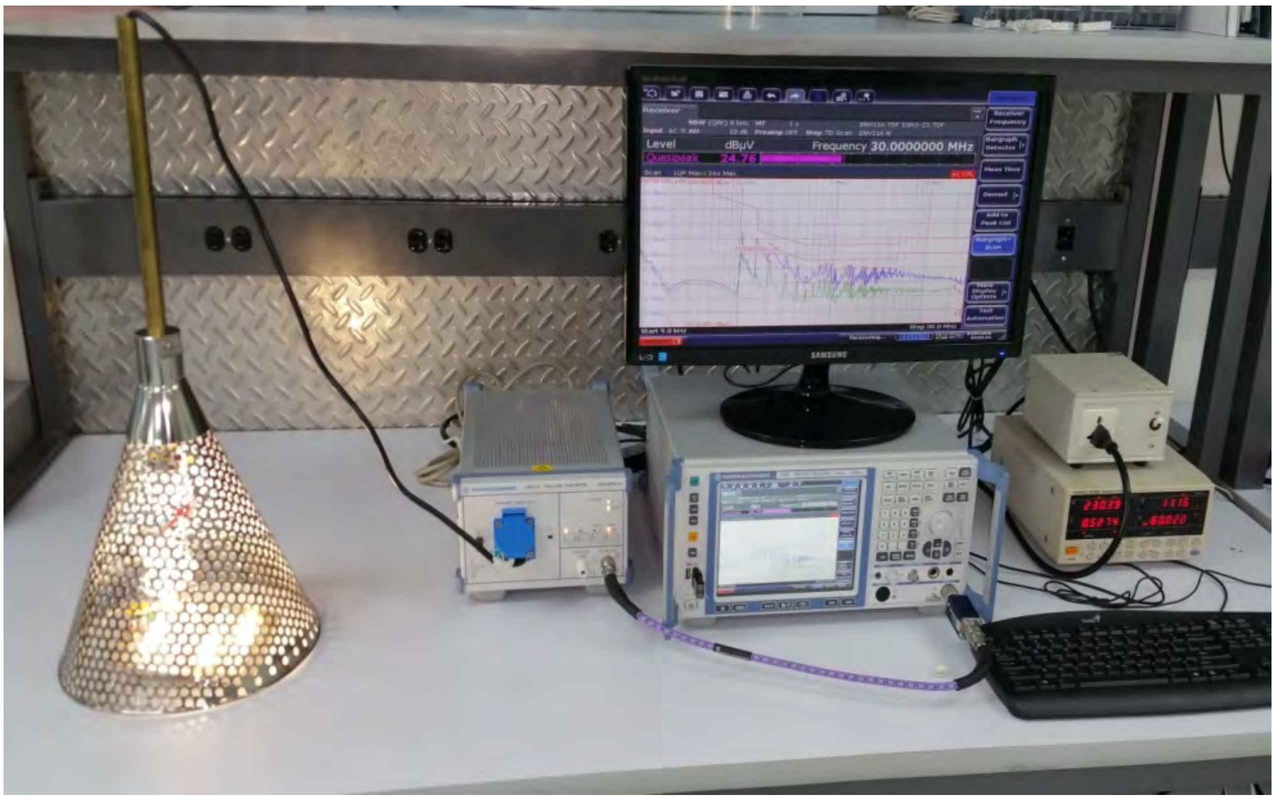

Figure 104 – Conducted EMI Test Set-up.

16.2 *EMI Test Result*

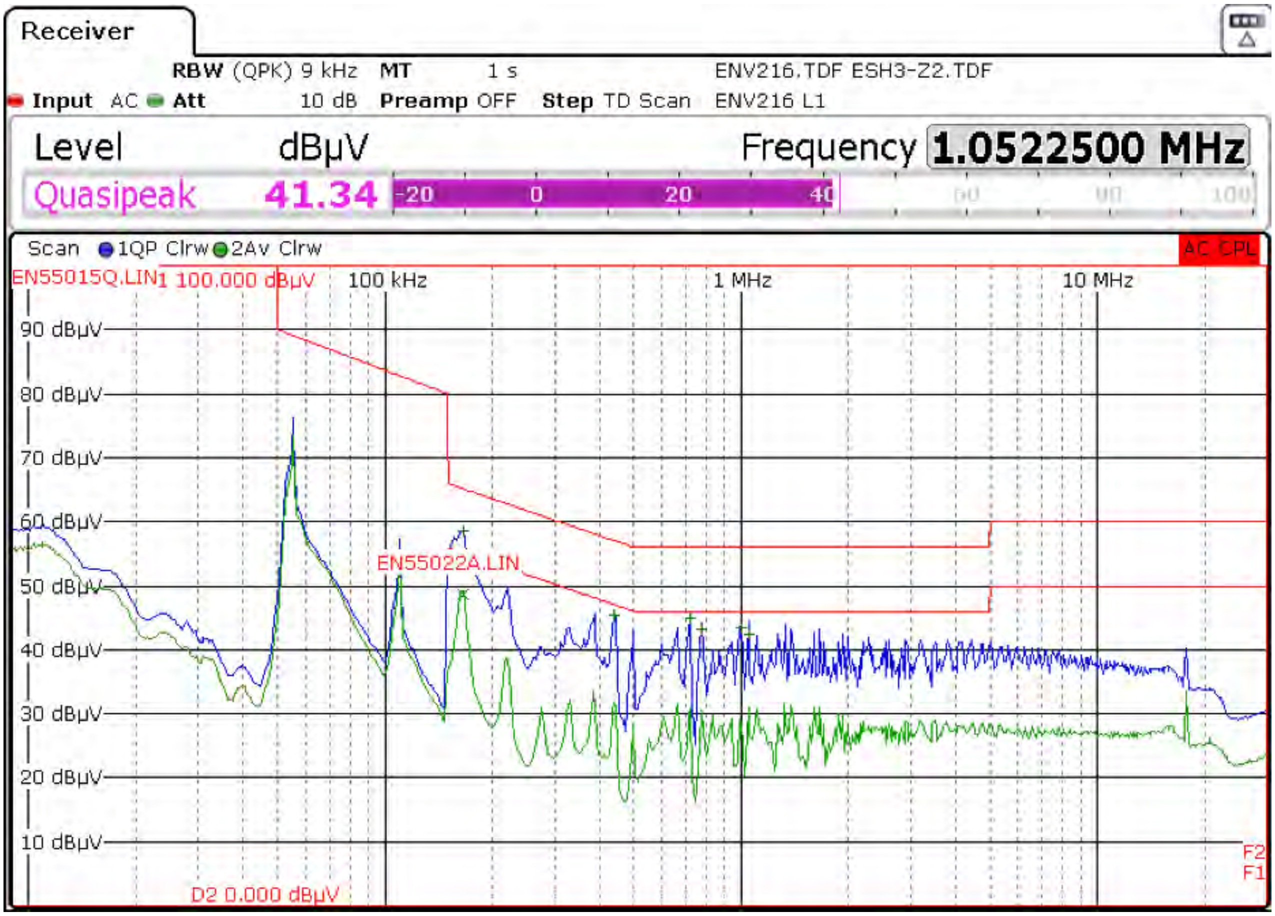

Figure 105 – Conducted EMI, 52V LED Load with Metal Cone Enclosure Grounded, 230 VAC, 50 Hz, and EN55015 B Limits.

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	165.7500 kHz	58.53 L1	-6.64 dB
2 Average	165.7500 kHz	48.60 L1	-6.57 dB
1 Quasi Peak	442.5000 kHz	45.32 L1	-11.69 dB
1 Quasi Peak	721.5000 kHz	44.97 L1	-11.03 dB
1 Quasi Peak	775.5000 kHz	43.27 L1	-12.73 dB
1 Quasi Peak	998.2500 kHz	43.31 L1	-12.69 dB
1 Quasi Peak	1.0523 MHz	42.35 L1	-13.65 dB

Figure 106 – Conducted EMI, 52 V LED Load with Metal Cone Enclosure Grounded, Final Measurement Results.

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17 Line Surge

The unit was subjected to ±2500 V, 100 kHz ring wave and ±1000 V differential surge using 10 strikes at each condition. A test failure was defined as a non-recoverable interruption of output requiring repair or recycling of input voltage.

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+1000	230	L to N	0	Pass
-1000	230	L to N	0	Pass
+1000	230	L to N	90	Pass
-1000	230	L to N	90	Pass

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2500	230	L to N	0	Pass
-2500	230	L to N	0	Pass
+2500	230	L to N	90	Pass
-2500	230	L to N	90	Pass

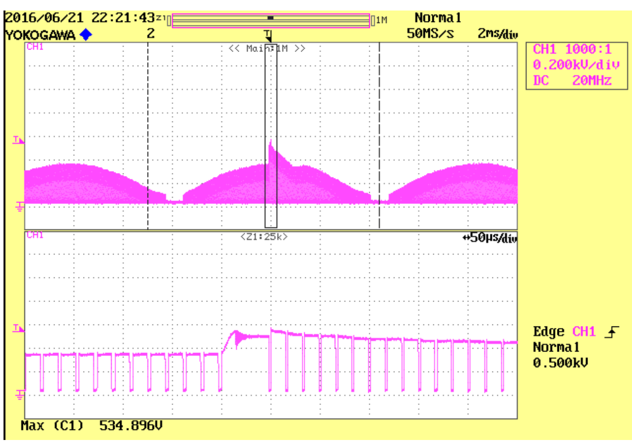

Figure 107 – +1000 kV Differential Surge, 90 ºC Phase.

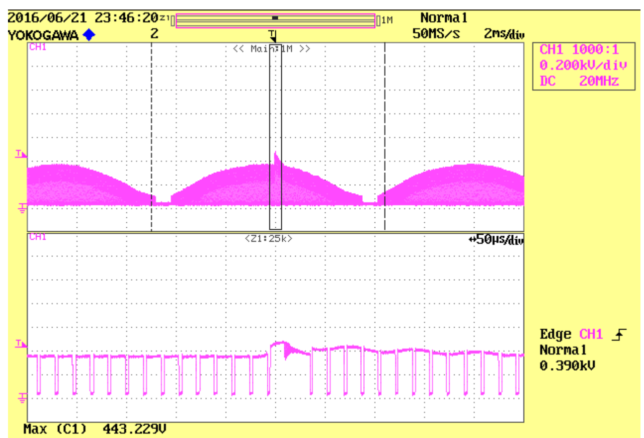

Figure 108 – +2500 kV Ring Wave, 90 ºC Phase.

18 Brown-in / Brown-out Test

No failure of any component was seen during brownout test of 1 V / sec AC cut-in and cut-off.

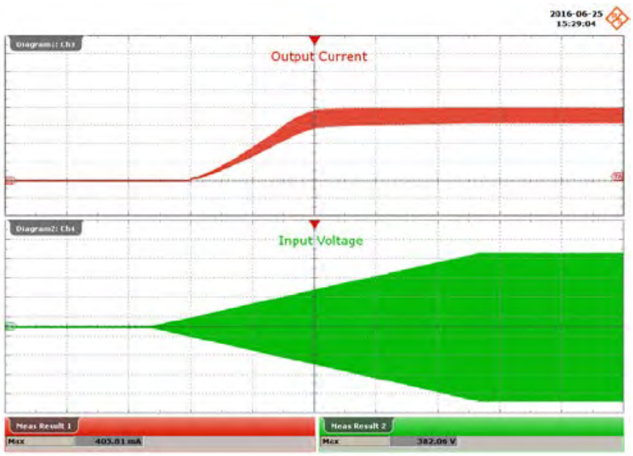

Figure 109 – Brown-In Test.
No Component Failures.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 50 s / div.

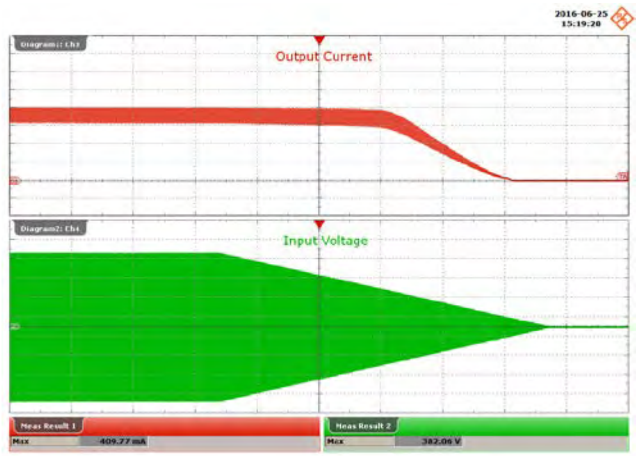

Figure 110 – Brown-Out Test.
No Component Failures.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

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19 Revision History

Date	Author	Revision	Description and Changes	Reviewed
27-Oct-16	IBB	1.0	Initial release	Apps & Mktg

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