Design Example Report

Title	***7 W Dim-to-Warm Buck-Boost LED Driver Using LYTSwitch™-7 LYT7503D***
Specification	100 VAC – 132 VAC; 54 V_{TYP}, 130 mA_{TYP} Output
Application	A19 Bulb
Author	Applications Engineering Department
Document Number	DER-588
Date	June 27, 2017
Revision	1.0

Summary and Features

- Single-stage power factor corrected, PF >0.9 at 120 VAC
- Accurate constant current regulation, ±5% at low line input
- TRIAC dimmable
  - Works with a wide selection of TRIAC dimmers
- Meets <30% flicker requirement
- Highly energy efficient, >85% at 120 VAC
- Low cost and low component count for compact PCB solution
- Integrated protection features
  - No-load / open-load output protection
  - Output short-circuit protection
  - Overcurrent protection
  - Thermal fold-back protection
  - Over temperature protection
  - No damage during line brown-out or brown-in conditions
- Meets IEC 2.5 kV ring wave, 1 kV differential surge
- Meets EN55015 conducted EMI

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5245 Hellyer Avenue, San Jose, CA 95138 USA.
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PATENT INFORMATION

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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.

1 Introduction

This engineering report describes a low cost, dimmable buck-boost LED driver designed to drive a 54 V LED voltage string at 130 mA output current from an input voltage range of 100 VAC to 132 VAC. The LED driver utilizes the LYT7503D from the LYTSwitch-7 family of devices. The key design goals were high efficiency, accurate constant current regulation, excellent dimming performance, and low component count.

The document contains the power supply specification, schematic, bill of materials, transformer documentation, printed circuit layout, spreadsheet, and design performance data.

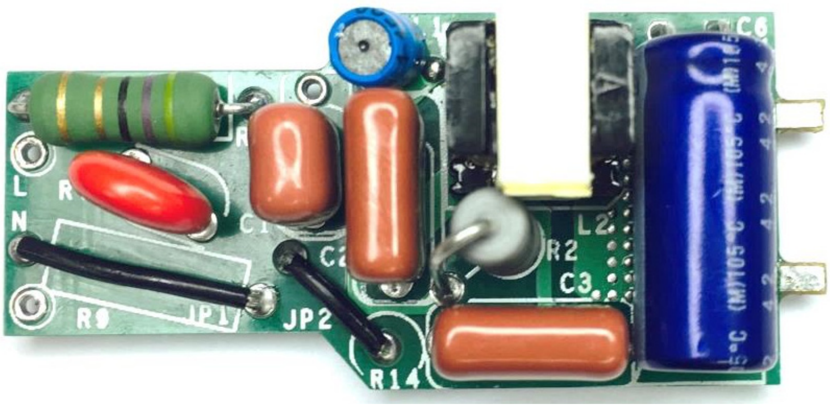

Figure 1 – Populated Circuit Board, Top View.

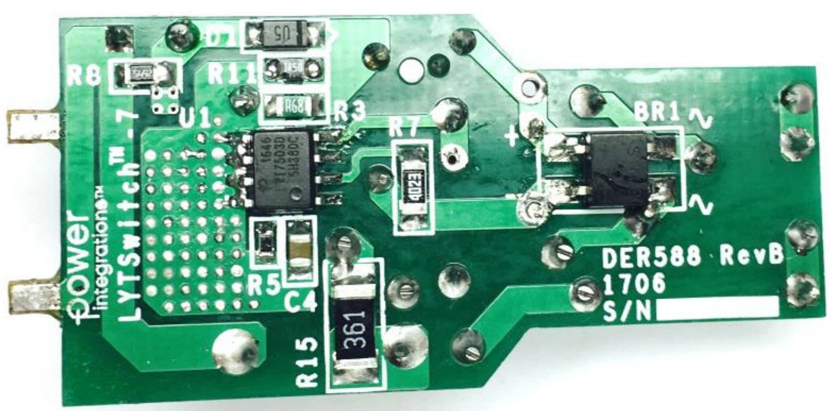

Figure 2 – Populated Circuit Board, Bottom View.

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Figure 3 – Populated Circuit Board, Side View.

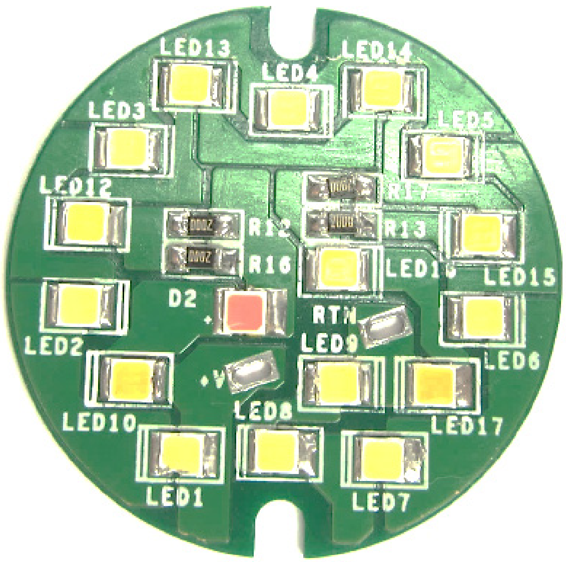

Figure 4 – LED Load PCB, Top View.

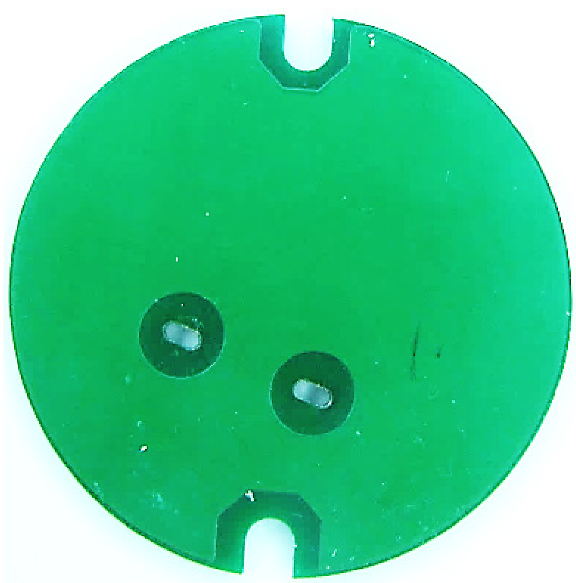

Figure 5 – LED Load PCB, Bottom View.

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}	100	120	132	VAC	2 Wire – no P.E.
Frequency	f_{LINE}		60		Hz	
Output						
Output Voltage	V_{OUT}		54		V	
Output Current	I_{OUT}		130		mA	
Total Output Power						
Continuous Output Power	P_{OUT}		7.02		W	
Efficiency						
Full Load	η		85		%	120 V / 60 Hz at 25 ºC.
Environmental						
Conducted EMI		CISPR 15B / EN55015B				
Safety		Non – Isolated				
Ring Wave (100 kHz)			2.5		kV	
Differential Mode (L1-L2)			1		kV	
Power Factor			0.90			Measured at 120 VAC, 60 Hz.
Ambient Temperature	T_{AMB}			75	ºC	Free Convection, Sea Level.

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3 Schematic

3.1 *Buck-Boost LED Driver*

The schematic below is a low-line design of non-isolated buck LED driver excluding high-line provisional components. These components are used for high-line application only. Bigger footprints are allotted to EMI filter for high-line. Additional slots for damper resistors are added to minimize input current ringing which is higher at high-line input.

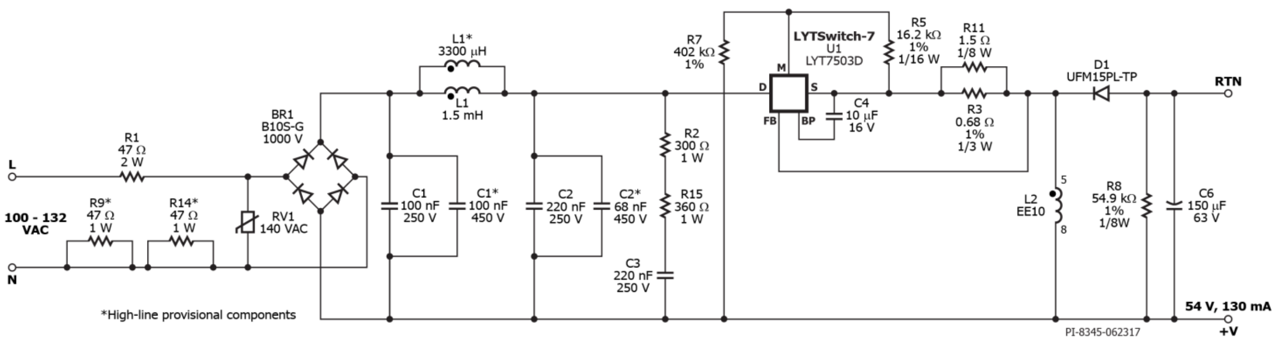

Figure 6 – LED Driver Schematic.

3.2 *Dim-to-Warm 54 V LED Load*

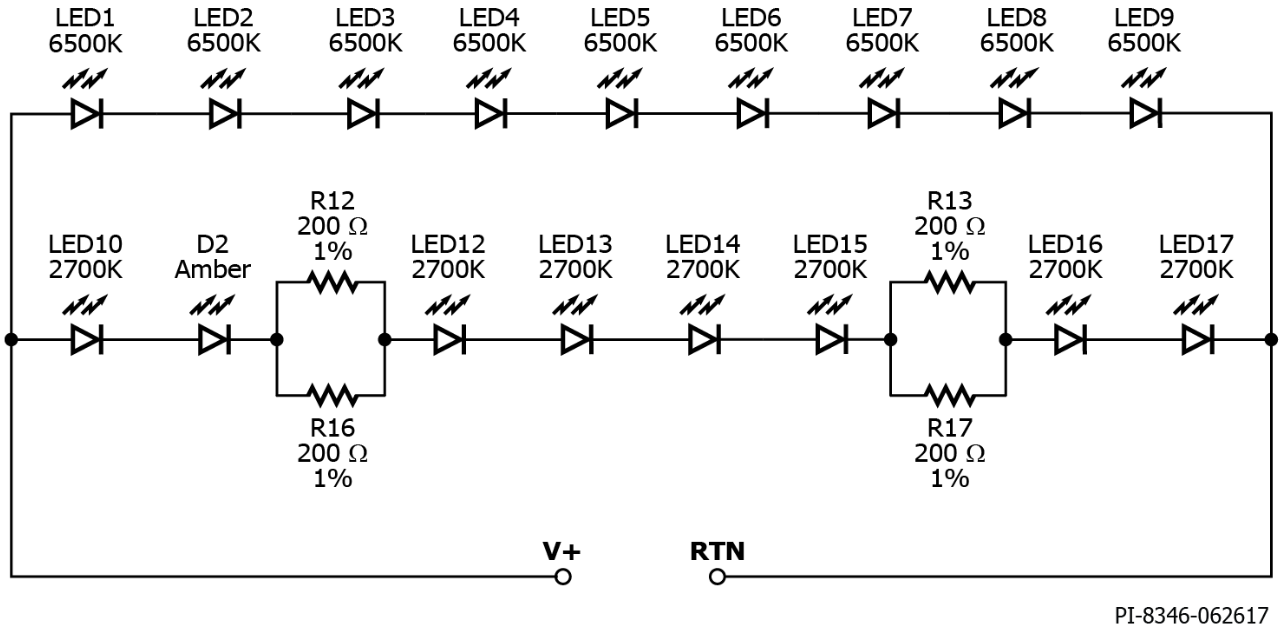

Figure 7 – 54 V LED Load Schematic.

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4 Circuit Description

LYT7503D from the LYTSwitch-7 family of devices combines a high-voltage power MOSFET and variable frequency / variable on-time, critical conduction mode controller in a single SO-8 package. The LYT7503D was configured to drive a 54 V buck-boost LED driver with an output current of 130 mA.

4.1 *Input Stage*

The input fusible resistor R1 serves as a safety protection from component failures. Its value is chosen such that it could serve as a damper to reduce ringing at the input which could cause dimmer incompatibility. Varistor RV1 (140 V rated) acts as a voltage clamp which limits the voltage spikes on the input during line transient surge events. The full wave bridge rectifier BR1 rectifies the input AC to a pulsating DC, provides good power factor and low total harmonic distortion.

4.2 *EMI Filter*

A pi filter is composed of a differential choke inductor L1 and input filter capacitors C1 and C2. The EMI filter, together with the LYTSwitch-7's variable frequency / variable on-time and critical conduction mode control engine ensures compliance with the EN55015 Class B emission limit. Its values were chosen to achieve a balance between dimmer compatibility, power factor and efficiency.

4.3 *LYTSwitch-7 Control Circuit*

The LED driver circuit is a high-side buck-boost topology. During switch on-time of the power MOSFET, current ramps through inductor L2 storing energy in it. Energy stored in the inductor is delivered to the output load via the output diode D1 during MOSFET switch off-time.

The output capacitor C6 is used as a filter to minimize the output current ripple. The value of the output capacitor is chosen to ensure that the LED current is within percent flicker requirements. A pre-load resistor with a value of 54.9 kΩ is used to provide good dimming compatibility while maintaining efficiency within specification.

Capacitor C4 provides local decoupling for the BYPASS (BP) pin of U1, and provides power to the IC during the switch on-time. The IC internal regulator draws power from high voltage DRAIN (D) pin to charge the bypass capacitor C4 during the power switch off time. The typical BP pin voltage is ~5.25 V. The value of capacitor should be large enough to keep the BP pin voltage above reset value $V_{BP(RESET)}$ ~4.6 V, when controller is switching at maximum frequency or max T_{on} conditions and also during deep dimming.

Constant output current regulation is achieved through inductor force peak current limit with a device constant ratio between the peak current period and the dead zone period. The FEEDBACK (FB) pin directly senses the source or inductor current when the power MOSFET is on using external current sense resistors R3 and R11. This is to set a constant inductor peak current I_{PK} by comparing the sensed voltage with the reference current limit threshold ($V_{FBth} \geq 0.28$ V, I_{PK}=0.28 V / R_{SENSE}).

The MULTIFUNCTION (M) pin detects AC line overvoltage. During on-state of the power MOSFET, the M pin is internally connected to the SOURCE (S) pin and detects the rectified input voltage and current flowing out of M pin set by R5.

The line overvoltage trigger point (VLINE_OVP) is calculated by;

$$V_{LINE\_OVP} = I_{IOV} \times R_5 + V_{OUT}$$

Resistor R7 is set at 402 kΩ ±1%. Once the detected current exceeds the input overvoltage threshold (I_{IOV} = 1 mA typical), the IC will instantaneously inhibit switching and initiate auto-restart as protection to internal power MOSFET and the LED load from voltage overstress.

When the power MOSFET is at off-state, the M pin also provides zero current detection (ZCD), and output OVP detection through sampling resistors R5 and R7. The ZCD is to guarantee critical conduction mode operation which means that the power MOSFET must be turned on immediately once inductor has been demagnetized. The inductor demagnetization is sensed when the voltage across the inductor begins to collapse towards zero as flywheel diode (D1) conduction expires. The ZCD threshold is when M pin voltage is V_M <0.25 V (negative edge triggered).

The OVP detection is achieved through R5 and R7. The OVP threshold is typically set at 120% of steady-state value (2.0 V). Resistor R7 is set to a fixed value of 402 kΩ ±1% to minimize power loss during MOSFET on-duration. The value of R_5 is calculated below.

$$R_5 = 2V \times R_7 / (V_{OUT} - 2V)$$

In case of output short-circuit, pulse skipping mode is enabled when SOA event is triggered. If output short-circuit persists for more than 2 SOA events then 100 ms auto-restart delay is enabled before the next switching attempt. If SOA fault persists following two 100 ms auto-restart attempts then the delay is increased to 1s.

4.4 *TRIAC Phase Dimming Control*

The average output current control mechanism of the LYTSwitch-7 LYT7503D provides inherent dimming capability with TRIAC phase-cut dimmers. The peak current limit on-time duration varies with respect to dimming conduction angle providing a natural dimming performance.

Due to a 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 dimming range and/or flicker. RC passive damper (R2, R15, and C3) serves as an impedance load to prevent the TRIAC current from falling below its holding current.

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. This effect can cause similar undesirable behavior, as the ringing may cause the TRIAC current to fall below its holding current and turn off. Fusible resistor R1 is needed to dampen the driver input current ringing when TRIAC dimmer turns on.

4.5 *Dim-to-Warm Operation*

The LED load schematic is designed to emit dim tone slowly deviating to warm tone of bulb during dimming. Dim-to-warm indicates conduction angle from maximum to minimum.

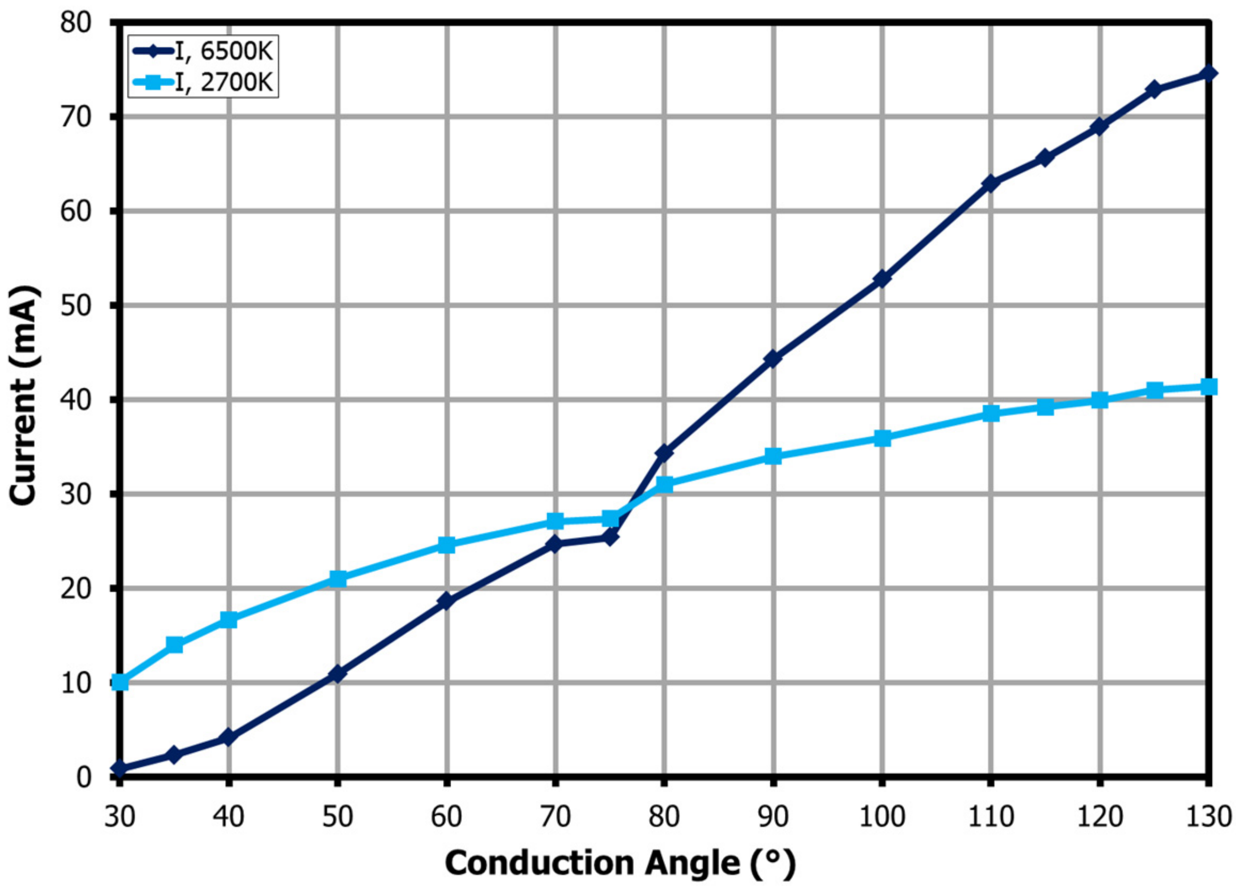

Figure 8 – Current across 6500K and 2700K LED vs. Conduction Angle.
Dimmer used LUTRON D-600PH-DK.

At dim tone, maximum conduction angle, 6500K string has a higher current across its 9 LEDs than 2700K string with 8 LEDs. As the conduction angle approaches 75°, the 6500K and 2700K string will eventually have the same current across the LEDs.

From 75° to minimum conduction angle, the current across 6500K string decreases, thus decreasing luminous flux.

At warm tone, minimum conduction angle, the 2700K string dominates the overall tone (warm) of the bulb due to its series resistors allowing a current across this LED string vs. 6500K LED string without R.

The amber LED, D2, in series with 2700K, enhances the warm tone during deep dimming. The location of the amber LED is at the center of PCB to equally distribute its warm tone. The chosen amber LED has 610nm in wavelength which indicates color in visible spectrum. Kelvin (K) indicates color temperature in white LEDs. A lower Kelvin means the light appears more yellow.

4.5.1 Test Data, Current vs. Conduction Angle

V_{IN} (VAC)	Conduction Angle (°)	I (mA) 6500K	I (mA) 2700K
102.6	130	74.50	41.40
101.1	125	72.83	41.00
98.66	120	68.93	39.90
95.95	115	65.60	39.20
92.91	110	62.86	38.50
85.91	100	52.76	35.90
77.78	90	44.31	34.00
68.7	80	34.30	31.00
63.87	75	25.40	27.40
57.88	70	24.70	27.10
48.64	60	18.63	24.60
38.27	50	10.95	21.00
28.15	40	4.21	16.70
23.31	35	2.34	14.00
18.68	30	0.90	10.10

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5 PCB Layout

5.1 *Buck-Boost LED Driver*

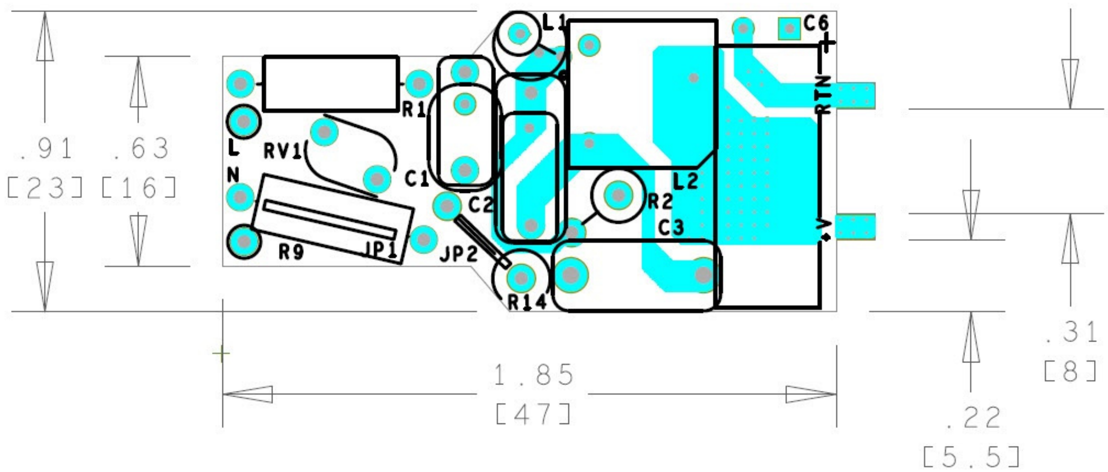

Figure 9 – Top Side.

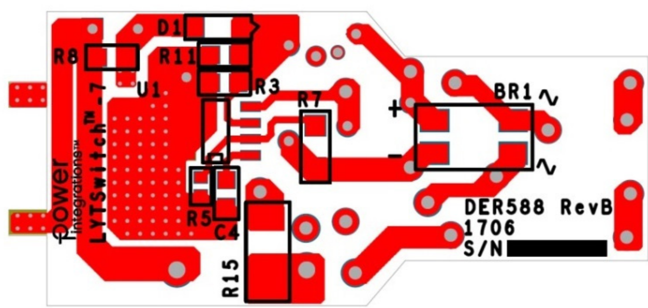

Figure 10 – Bottom Side.

5.2 *Dim-to-Warm 54 V LED Load*

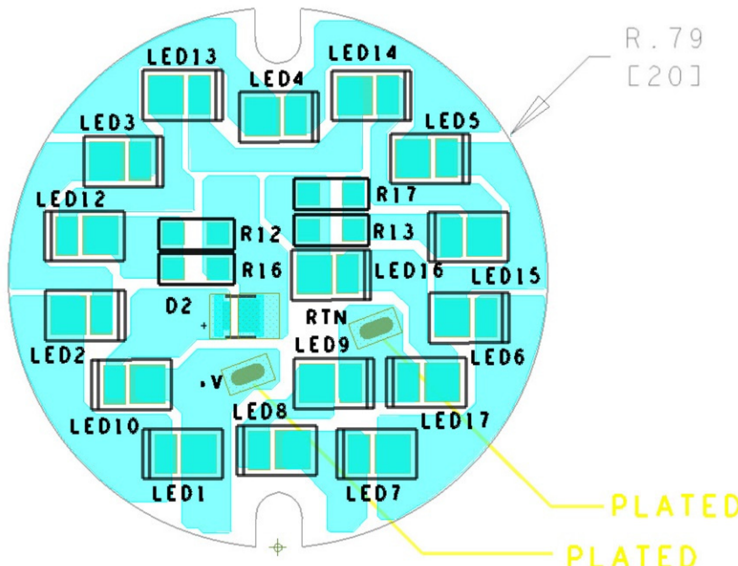

Figure 11 – Top Side.

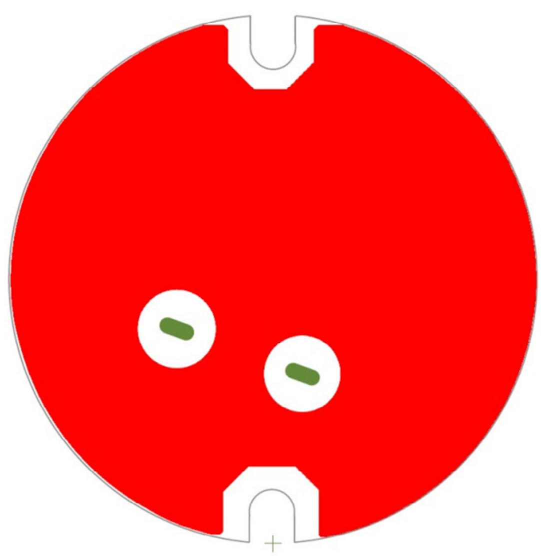

Figure 12 – Bottom Side.

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6 Bill of Materials

6.1 *LED Driver*

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, 250 V, Film	ECQ-E2104KB	Panasonic
3	2	C2, C3	220 nF, 250 V, Film	ECQ-E2224KF	Panasonic
4	1	C4	10 µF, ±10%, 16 V, X7R, Ceramic Capacitor, -55°C ~ 125°C, Surface Mount, MLCC 0805 (2012 Metric), 0.079" L x 0.049" W (2.00 mm x 1.25 mm)	CL21B106KOQNNNE	Samsung
5	1	C6	150 uF, 63, Electrolytic, Low ESR, 210 mΩ, (8 x 20)	ELXZ630ELL151MH20D	Nippon Chemi-Con
6	1	D1	600 V, 1 A, Ultrafast Recovery, 75 ns, SOD-123	UFM15PL-TP	Micro Commercial
7	1	L1	1.5 mH, Mini-Drum, High Current	RL-5480HC-1-150	Renco
8	1	JP1	Wire Jumper, Insulated, #24 AWG, 0.5 in, PVDF BLACK 100'	R24BLK-0100	Jonard Tools
9	1	JP2	Wire Jumper, Insulated, #24 AWG, 0.3 in, PVDF BLACK 100'	R24BLK-0100	Jonard Tools
10	1	L2	Bobbin, EE10, Vertical, 8 pins	EE-1016	Yulongxin
			(10.2 mm W x 10.4 mm L x 9.7 mm H)		
11	1	R1	RES, 47 Ω, 5%, 2 W, Wirewound, Fusible	FW20A47R0JA	Bourns
12	1	R2	RES, 300 Ω, 5%, 1 W, Metal Oxide	RSF100JB-73-300R	Yageo
13	1	R3	RES, 0.68 Ω 1/3W, 1%,Thick Film, 0805	RL1220S-R68-F	Susumu
14	1	R5	RES, 16.2 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1622V	Panasonic
15	1	R7	RES, 402 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF4023V	Panasonic
16	1	R8	RES, 54.9 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF5492V	Panasonic
17	1	R11	RES, 1.5 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ1R5V	Panasonic
18	1	R15	RES, 360 Ω, ±5%, 1 W, 2010 (5025 Metric,) Automotive AEC-Q200, Pulse Withstanding, Thick Film	CRCW2010360RJNEFHP	Vishay
19	1	RV1	140 VAC, 12 J, 7 mm, RADIAL	V140LA2P	Littlefuse
20	1	U1	LYTSwitch-7, Dimmable, SO-8	LYT7503	Power Integrations
21	1	L	Wire, UL1007, #24 AWG, Wht, PVC, Length To be specified by designer	1007-24/7-9	Anixter
22	1	N	Wire, UL1007, #24 AWG, Blk, PVC, Length To be specified by designer	1007-24/7-0	Anixter

6.2 *LED Load*

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	9	LED1, LED2, LED3, LED4, LED5, LED6, LED7, LED8, LED9	LED Lighting - White, Cool 6500K 6.2V 75mA 1212	LNJ03004GDD1	Panasonic
2	7	LED10, LED12, LED13. LED14, LED15, LED16, LED17	LED Lighting - White, Cool 2700K 6.2V 75mA 1212	LNJ03004GLD1	Panasonic
3	1	D2	LD, Lighting Color DURIS® S 5, Amber, 610 nm,6.25 V, 150 mA (200mA max), 50lm/W,2-SMD, No Lead	GA PSLR31.13-HUJQ-A1A2-1	OSRAM Opto Semi
4	4	R12, R13, R16, R17	RES, 200 Ω, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2000V	Panasonic

6.3 *Mechanical*

Item	Ref Des	Description
1	Mechanical Specification Assembly	Assy, 7 W Buck Boost, DER-588

7 Mechanical Assembly Specification

7.1 *Mechanical Assembly Diagram*

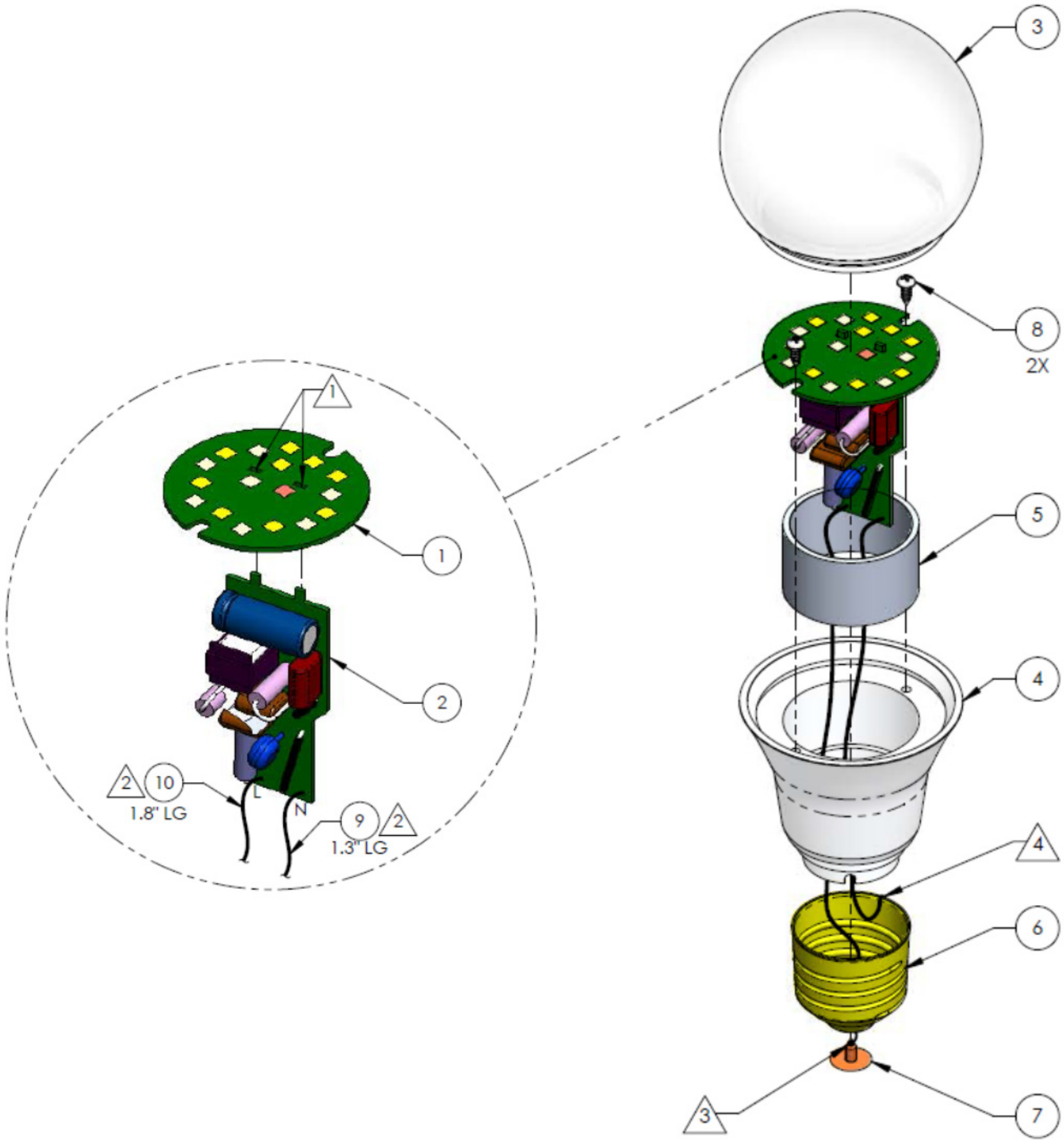

Figure 13 – Mechanical Assembly Diagram.

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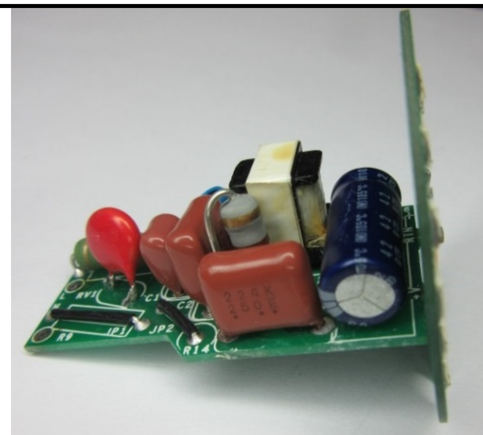
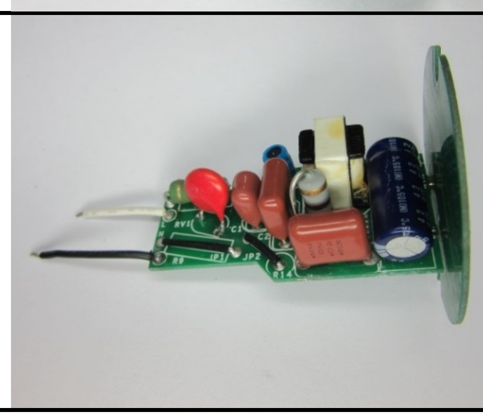
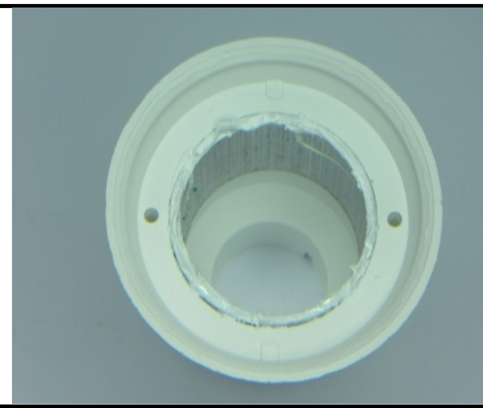
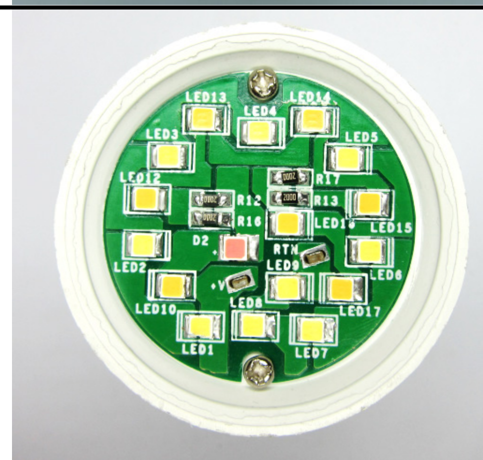
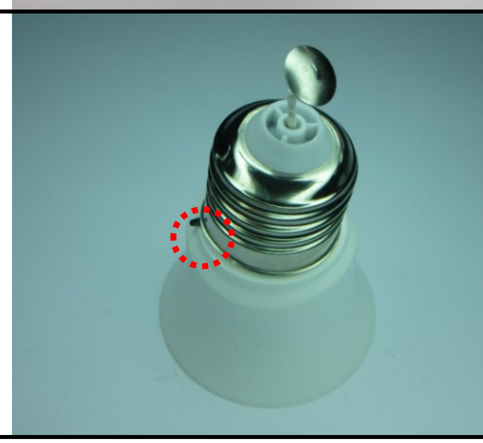
7.2 *Material List*

Item	Description
[1]	54 V LED Load PCB, DER-588.
[2]	7 W Buck-Boost PCB, DER-588.
[3]	Lens.
[4]	Body Enclosure (LED Driver Housing).
[5]	Internal Heat Sink.
[6]	Screw Cap.
[7]	Electrical Contact.
[8]	LED Load Screw (2 pcs).
[9]	Wire, Jumper, Insulated, #24 AWG, Black.
[10]	Wire, Jumper, Insulated, #24 AWG, White.

7.3 *Mechanical Assembly Instructions*

PCB Installation	Install buck-boost PCB to LED load PCB as shown. Make sure that the PCBs are perpendicular to each other.	
Input Wire Installation 1	Connect input wire to buck-boost PCB. L wire, item [10], at L terminal and N wire, item [9] to N terminal.	

Internal heat sink Placement	Place the heat sink, item [5], inside the body enclosure, item [4]. Put a thin layer of thermal grease on the area in contact with LED Load.	
LED Load Attachment	Secure the LED Load on the bulb case notches using the right screw size, item [8], as shown.	
Input Wire Installation 2a	Feed L wire into the hole of screw cap, item [6]. Allot excess N wire to edge of screw cap as shown in red circle. Solder L wire to electrical contact.	

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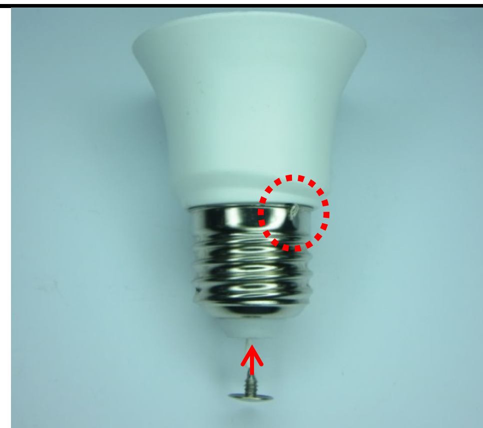
Input Wire Installation 2b	Solder N wire to edge of screw cap. Install electrical contact, with soldered L wire, to screw cap.	
Lens Attachment and Screw Cap Crimping	Attach the lens, item [3]. Make sure it is sealed properly. Lock the screw cap, item [6], onto the bulb enclosure using the base crimp tool designed for E27 lamp. Lens attachment can also be done after screw cap crimping.	
Finish	Place a proper label with necessary details.	

8 Inductor Specification

8.1 *Electrical Diagram*

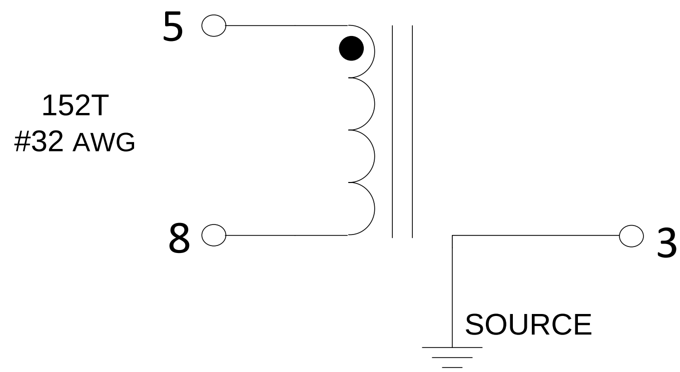


Figure 14 – Inductor Electrical Diagram.

8.2 *Electrical Specifications*

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 5 and pin 8.	1000 μH
Tolerance	Tolerance of Primary Inductance.	±10%

8.3 *Material List*

Item	Description
[1]	Core: EE10.
[2]	Bobbin: EE10, Vertical, 8 pins.
[3]	Magnet Wire: #32 AWG.
[4]	Transformer Tape: 6.5 mm.
[5]	Transformer Tape: 4.5 mm.

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8.4 *Inductor Build Diagram*

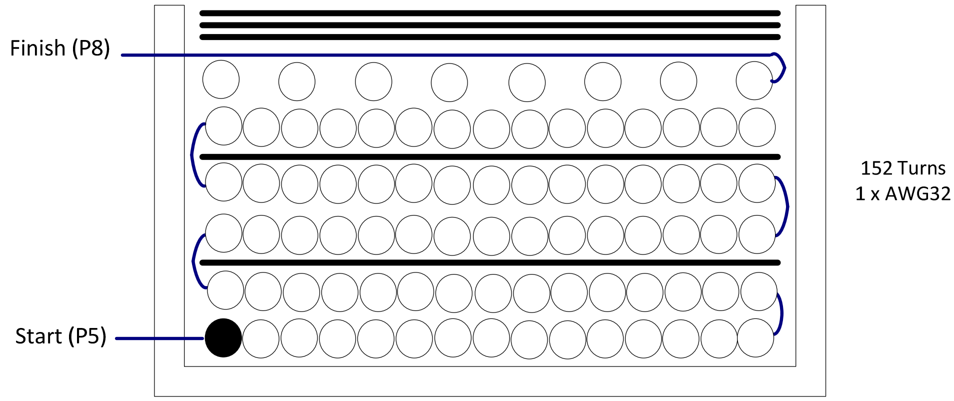
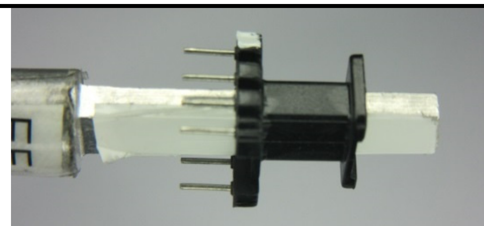
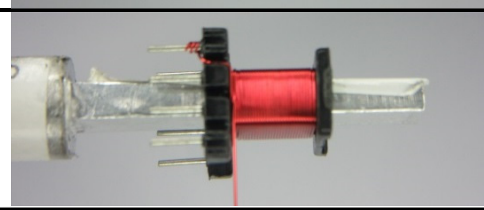
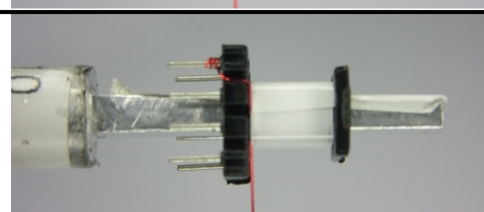
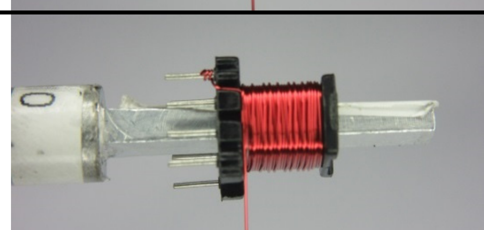
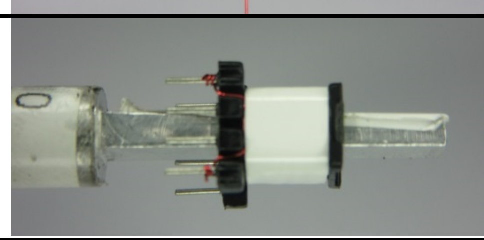
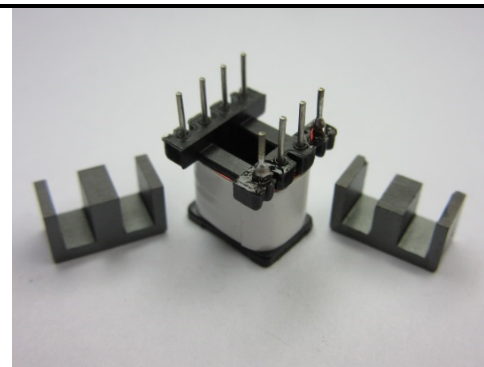
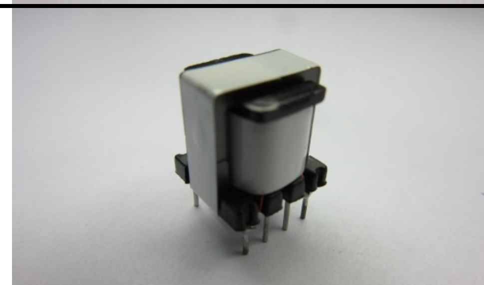
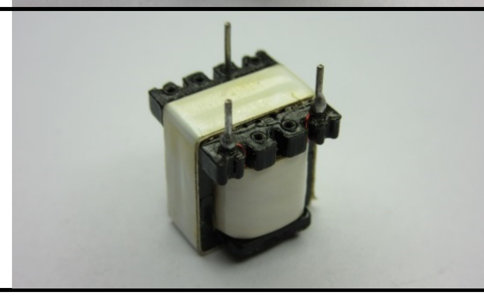


Figure 15 – Inductor Build Diagram.

8.5 *Inductor Construction*

Winding Directions	Bobbin, item [2], is oriented on winder jig such that terminal pin 1-4 is on the left side. The winding direction is counterclockwise.	
Winding 1	Use wire item [3], start at pin 5 and wind 2 layers across the bobbin width.	
Insulation	Add 1 layer of tape, item [4], for insulation.	
Winding 1	Repeat the 2-layer winding and adding insulation until 152 turns. On the last layer spread winding evenly across the bobbin width. Terminate the winding on pin 8.	
Insulation	Add 3 layers of tape, item [4], for insulation.	

Core Grinding	Grind the center leg of one core, item [1], until it meets the nominal inductance of 1000 μH.	
Assemble Core	Assemble the 2 cores on the bobbin and wrap with 3 layers of tape, item [5].	
Pins	Pull out terminal pin no. 1, 2, 4, 6, and 7.	
Finish	Dip the transformer assembly in varnish.	

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9 Inductor Design Spreadsheet

ACDC_LYTSwitch7_ BuckBoost_012517; Rev.1.0; Copyright Power Integrations 2017	INPUT	INFO	OUTPUT	UNIT	LYTSwitch-7 Buck-Boost Design Spreadsheet
ENTER APPLICATION VARIABLES					
LINE VOLTAGE RANGE			Universal		AC line voltage range
VACMIN	**100**		100	V	Minimum AC line voltage
VACTYP	**120**		120	V	Typical AC line voltage
VACMAX	**132**		132	V	Maximum AC line voltage
FL			50	Hz	AC mains frequency
VO	**54**		54	V	Output Voltage
IO	**130**		130	mA	Average output current specification
EFFICIENCY			0.85		Efficiency estimate
PO			7.02	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	**Auto**		LYT7503D		Actual LYTSwitch-7 device
ILIMITMIN			1.06	A	Minimum Current Limit
ILIMITTYP			1.15	A	Typical Current Limit
ILIMITMAX			1.24	A	Maximum Current Limit
TON				us	On-time during the fixed on-time region at VACTYP
FSW			81.47	kHz	Maximum switching frequency in the fixed current limit region at VACTYP
DMAX			0.2763		Maximum duty cycle possible in the fixed on-time region
ENTER INDUCTOR CORE/CONSTRUCTION VARIABLES					
CORE	**EE10**		EE10		Enter Transformer Core
CUSTOM CORE NAME					If custom core is used - Enter part number here
AE			12.10	mm^2	Core effective cross cectional area
LE			26.10	mm	Core effective path length
AL			850.00	nH/turn^2	Core ungapped effective inductance
AW			11.88	mm^2	Window Area of the bobbin
BW			6.60	mm	Bobbin physical winding width
LAYERS			6.0		Number of Layers
INDUCTOR DESIGN PARAMETERS					
LP_MIN			446	uH	Absolute minimum design inductance
LP_TYP	**1000**		1000	uH	Typical Inductance
LP_TOLERANCE			10	%	Tolerance of the design inductance
LP_MAX			2114	uH	Absolue maximum design inductance
TURNS			152	Turns	Number of inductor turns
ALG			43.28	nH/turn^2	Inductance per turns squared
BMAX			3690	Gauss	Actual saturation flux density in the fixed peak current region
BAC			1850	Gauss	AC flux density in the fixed peak current region
LG			0.333	mm	Core air gap
BWE			39.60	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			32		AWG of the bare wire.
CM			64	Cmils	Bare wire circular mils
CMA			248	Cmils/A	Bare wire circular mils per ampere
CURRENT DENSITY			4.8	A/mm^2	Bare wire current density
BOBBIN FILL FACTOR			86.84%		Area of the bobbin occupied by wire

CURRENT WAVEFORM SHAPE PARAMETERS					
IPEAK_MOSFET			0.51	A	MOSFET peak current at VACTYP when operating in the current limit region
IRMS_MOSFET			0.1570	A	MOSFET RMS current at VACTYP obtained from half-line cycle emulation
IRMS_DIODE			0.1346	A	Diode RMS current at VACTYP obtained from half-line cycle emulation
IRMS_INDUCTOR			0.2579	A	Inductor RMS current at VACTYP obtained from half-line cycle emulation
LYTSWITCH EXTERNAL COMPONENTS					
FB Pin Resistor					
RFB_T			0.545	Ohms	Theoretical calculation of the feedback pin sense resistor
RFB			0.549	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			14.30	kOhms	Lower resistor on the M-pin divider network (E96 /1%)
VO_OVP			69.2	V	VO overvoltage threshold
Line_OVP			456	V	Line overvoltage threshold
CC			100	pF	Coupling Capacitor for Low Side Buck Configuration
RPRELOAD			54	kOhms	Minimum Output Preload Resistor
CBP			10	uF	BP Capacitor
RBP			154	kOhms	Recommended Pull-up Resistor from DC Bus to BP pin
VOLTAGE STRESS PARAMETERS					
VDRAIN			241	V	Estimated worst case drain voltage
PIVD			241	V	Output Rectifier Maximum Peak Inverse Voltage

Note: The LYTSwitch-7 family of ICs is optimized for single line operation. Warning and info tags in the inductor spreadsheet are due to universal operation. The design was done to optimize regulation, efficiency, and dimming performance at low line.

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10 Performance Data

All measurements were performed at room temperature using 54 V LED load. 1 minute soak time was applied before measurement with AC source turned-off for 5 seconds every succeeding input line measurement.

10.1 *Efficiency*

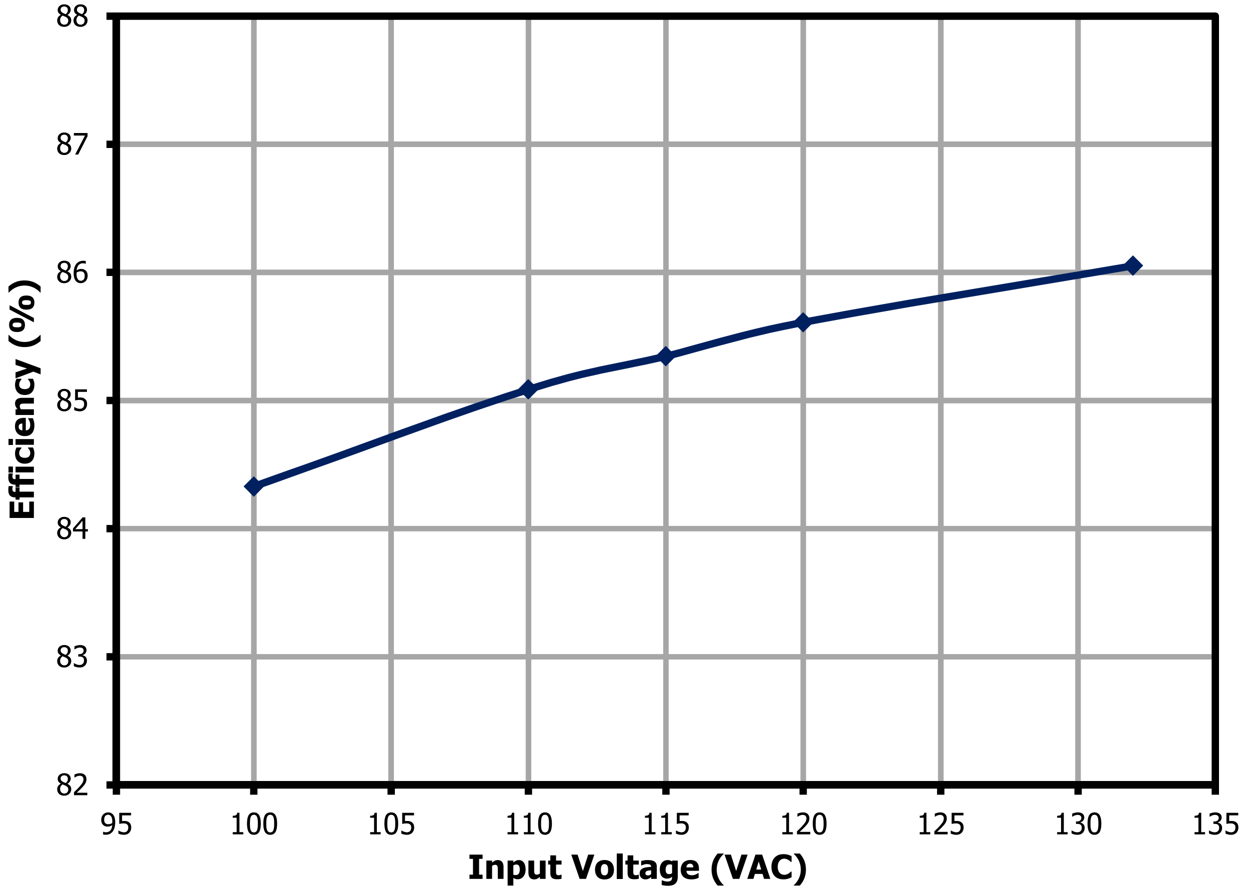

Figure 16 – Efficiency vs. Line.

10.2 *Load Regulation*

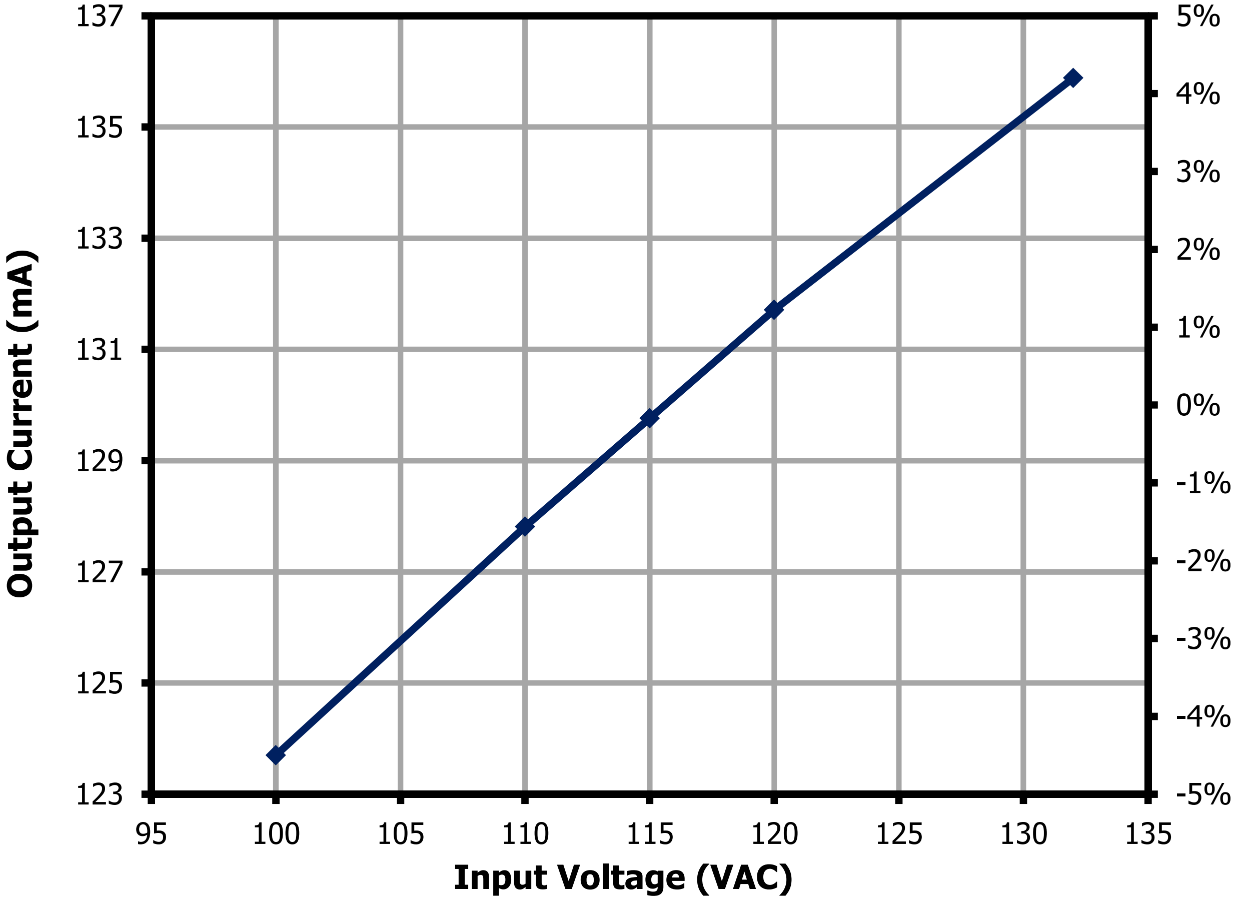

Figure 17 – Load Regulation vs. Line.

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10.3 *Power Factor*

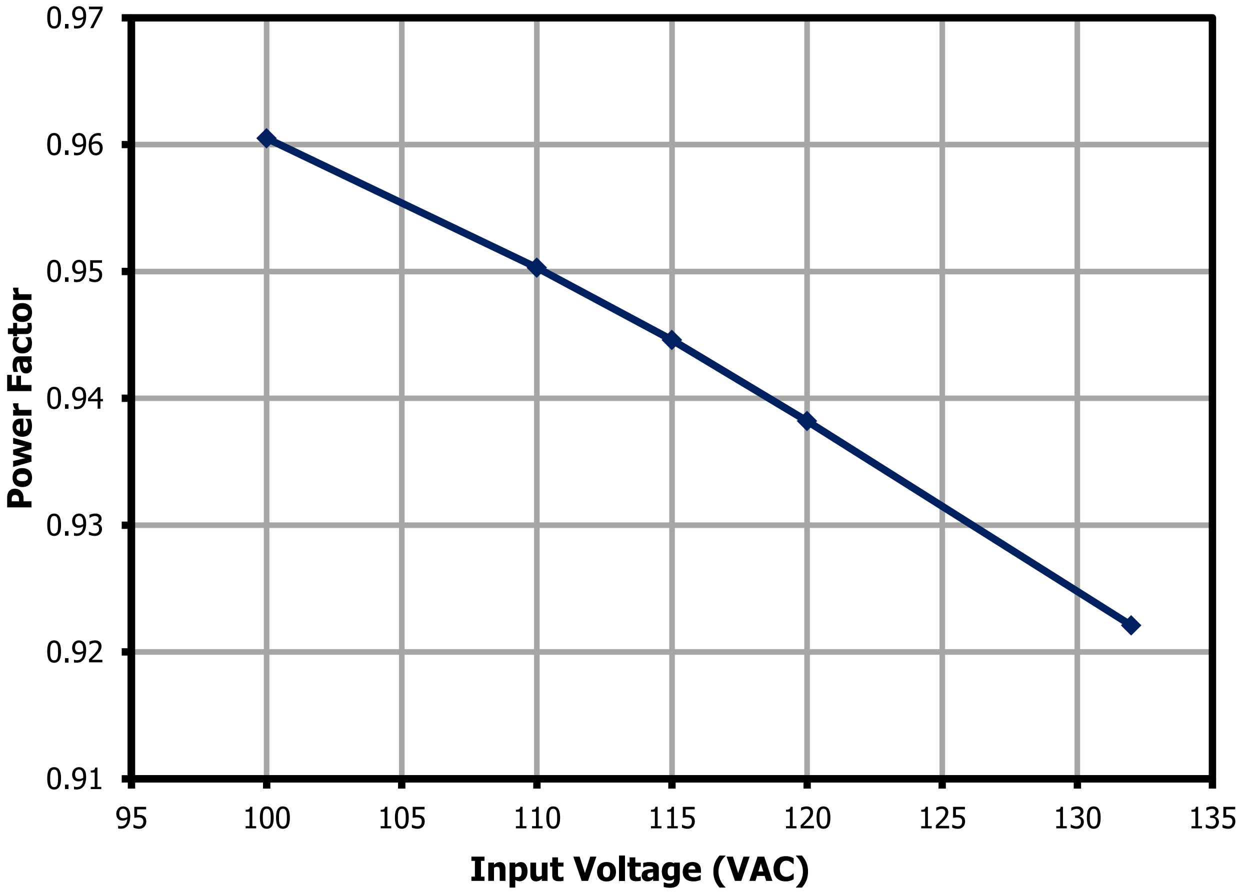

Figure 18 – Power Factor vs. Line.

10.4 *%ATHD*

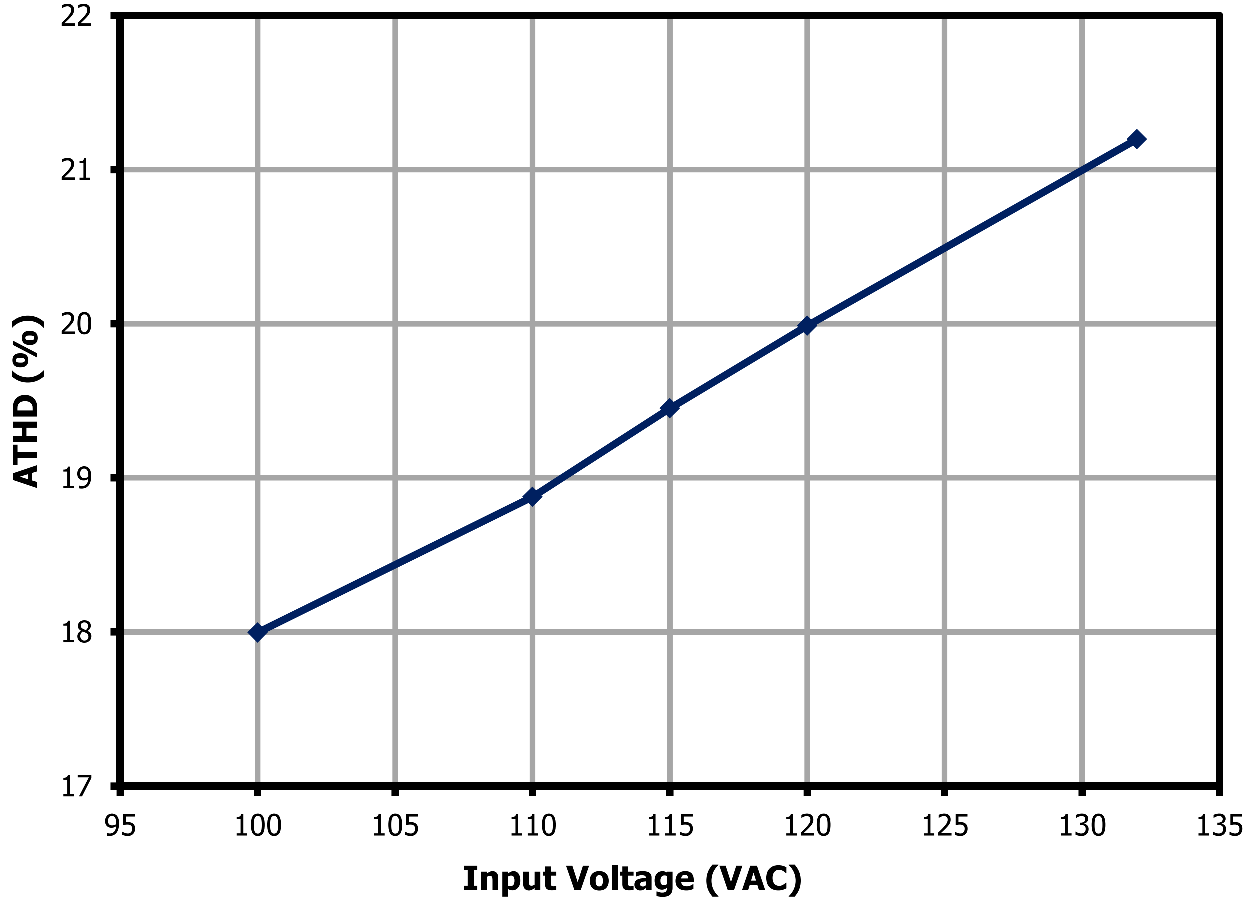

Figure 19 – %ATHD vs. Line.

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10.5 *Individual Harmonics Content*

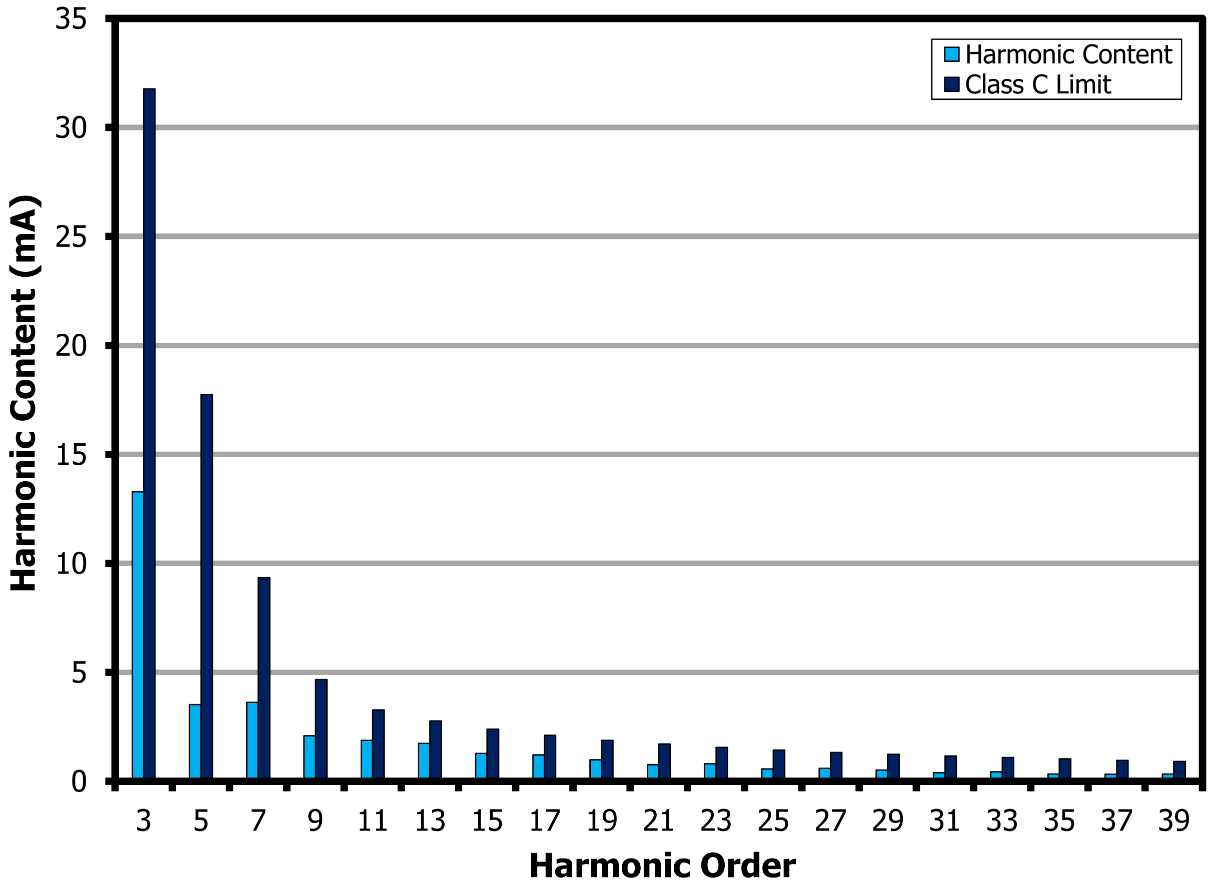

Figure 20 – 54 V LED Load Input Current Harmonics at 120 VAC, 60 Hz.

11 Test Data

11.1 *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)	
100	60	99.97	82.76	7.95	0.961	18	54.12	123.70	6.70	84.33
110	60	109.99	78.28	8.18	0.950	18.876	54.41	127.81	6.96	85.09
115	60	114.96	76.29	8.28	0.945	19.451	54.42	129.76	7.07	85.35
120	60	120.01	74.31	8.37	0.938	19.986	54.32	131.71	7.16	85.61
132	60	131.99	70.97	8.64	0.922	21.198	54.64	135.88	7.43	86.05

11.2 *Test Data, Harmonic Content at 120 VAC with 54 V LED Load*

V	Freq	I (mA_{RMS})	P	PF	%THD
120	60.00	74.31	8.367	0.938	19.986
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**
1	72.82				
2	0.04	0.08%		2.00%	
3	13.29	16.10%	31.77	28.38%	Pass
5	3.52	10.16%	17.75	10.00%	Pass
7	3.63	5.84%	9.34	7.00%	Pass
9	2.09	2.76%	4.67	5.00%	Pass
11	1.89	2.28%	3.27	3.00%	Pass
13	1.74	2.72%	2.77	3.00%	Pass
15	1.28	2.10%	2.40	3.00%	Pass
17	1.21	1.63%	2.12	3.00%	Pass
19	0.99	1.23%	1.89	3.00%	Pass
21	0.76	1.48%	1.71	3.00%	Pass
23	0.81	1.13%	1.56	3.00%	Pass
25	0.57	1.09%	1.44	3.00%	Pass
27	0.60	1.02%	1.33	3.00%	Pass
29	0.52	0.74%	1.24	3.00%	Pass
31	0.40	1.86%	1.16	3.00%	Pass
33	0.44	1.21%	1.09	3.00%	Pass
35	0.34	0.60%	1.03	3.00%	Pass
37	0.33	0.70%	0.97	3.00%	Pass
39	0.34	0.63%	0.92	3.00%	Pass

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12 Dimming Performance

12.1 *Dimming Curve*

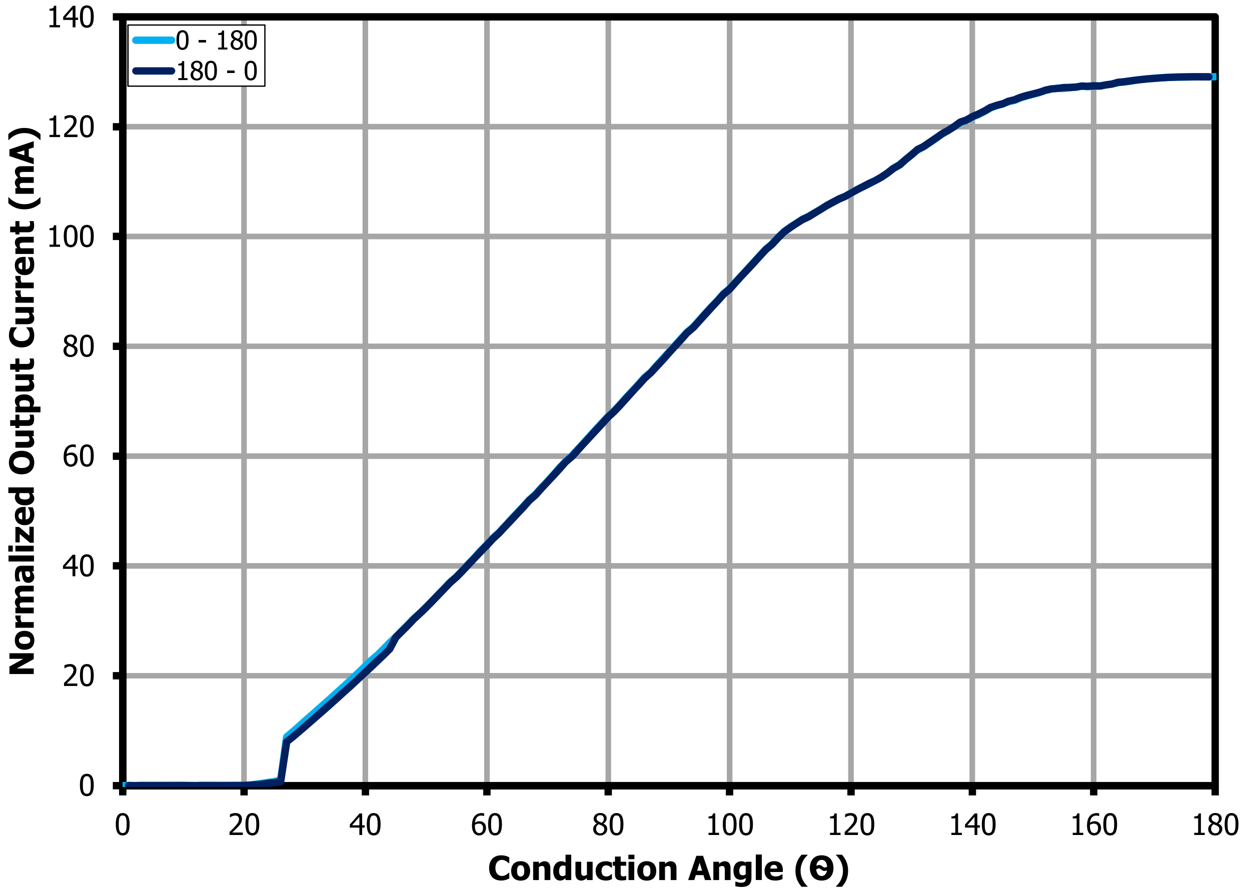

Figure 21 – Dimming Curve at 120 VAC, 60 Hz Input.

12.2 *Dimming Efficiency*

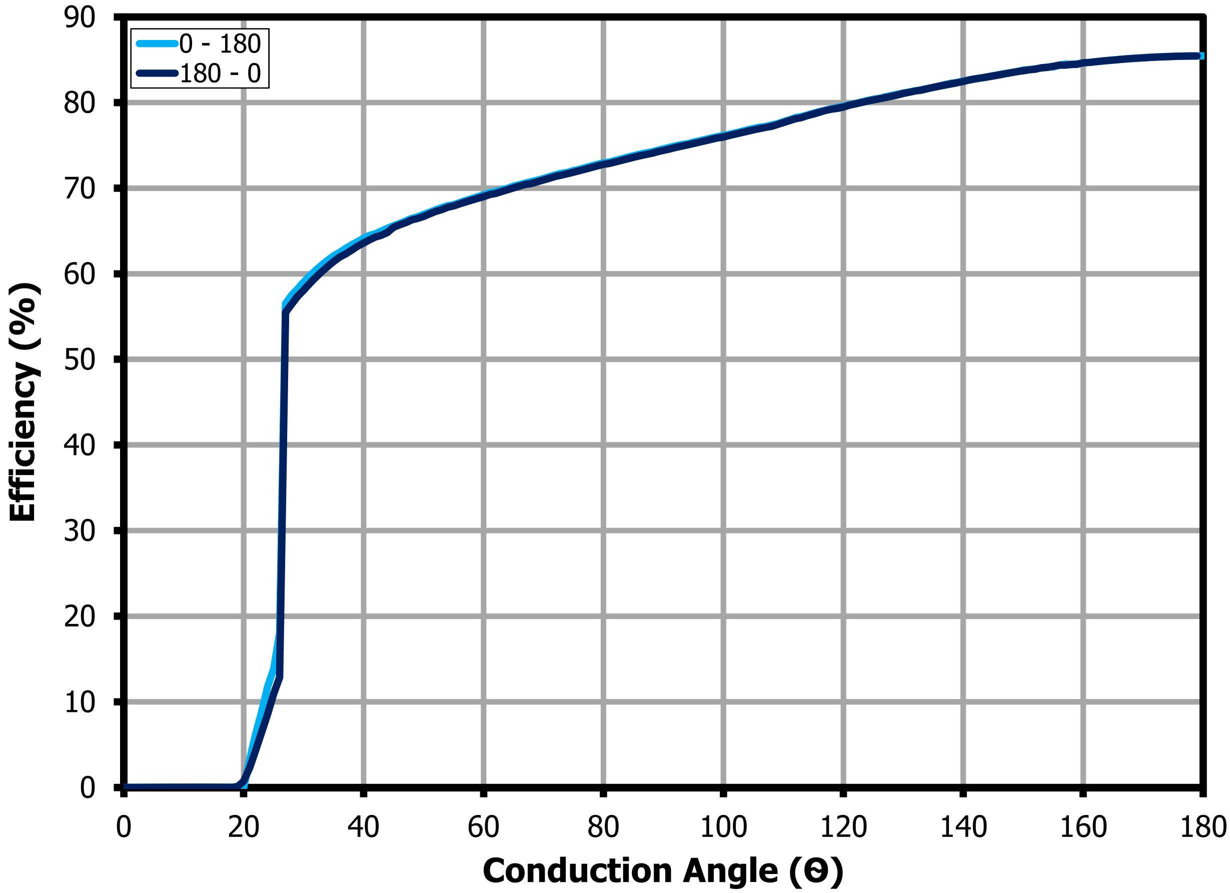

Figure 22 – Dimming Efficiency at 120 VAC, 60 Hz Input.

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12.3 *Dimming System Loss*

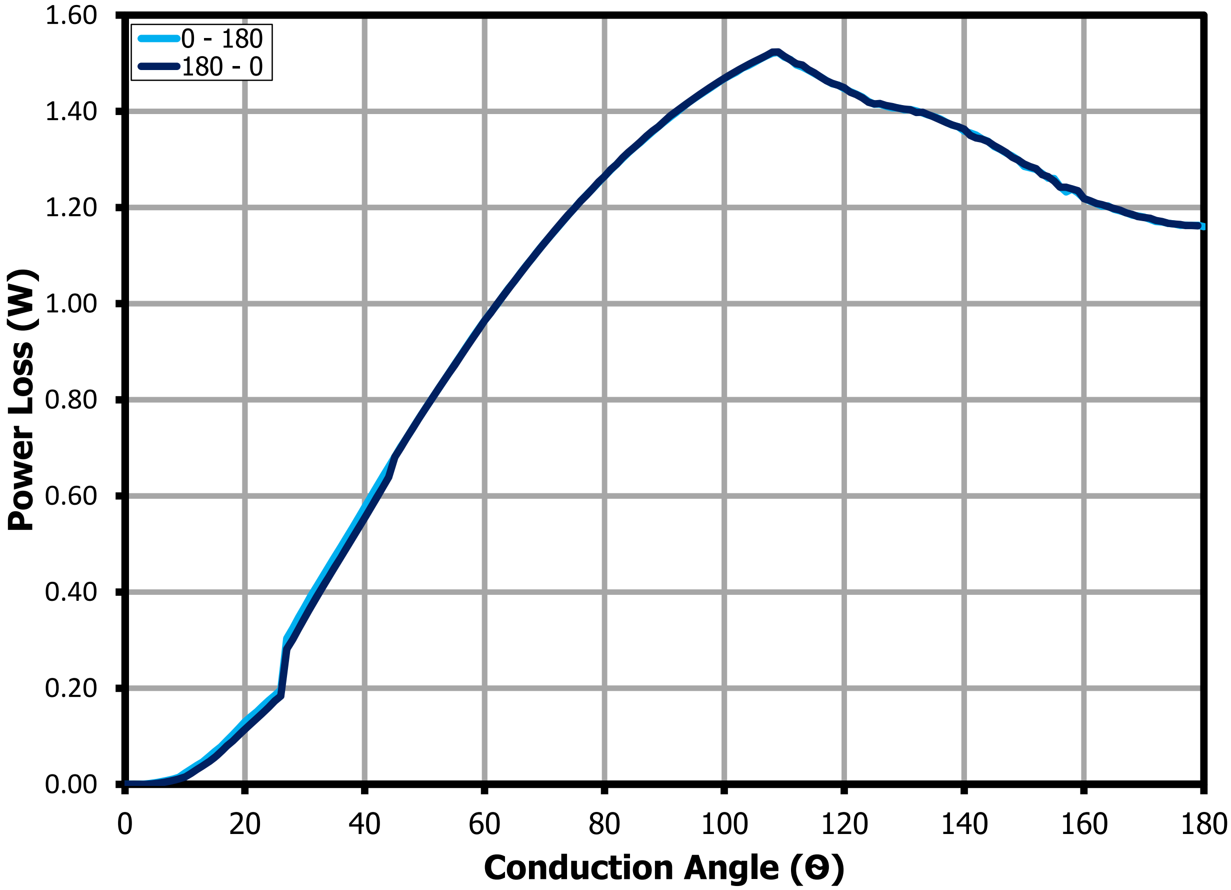

Figure 23 – Dimming Power Loss at 120 VAC, 60 Hz Input.

12.4 *Dimming Scoresheet*

No	Brand	Model	Type	Max (mA)	Min (mA)	Remarks
1	LEVITON	601-6631-1	L	120.82	9.2	No Flicker
2	LEVITON	6683	L	120.9	9.25	No Flicker
3	LEVITON	6633_PLW	L	126.2	11.3	No Flicker
4	G.E.	18023	L	120	12.4	No Flicker
5	LUTRON	D-600P-WH	L	112.3	12.6	No Flicker
6	LUTRON	AY-600PNL-WH	L	116.7	12.9	No Flicker
7	LUTRON	NT-600-WH	L	123.3	15.24	No Flicker
8	LUTRON	MA-600-WH	L	119.3	11.4	No Flicker
9	LUTRON	N-600-WH	L	123	14	No Flicker
10	LUTRON	NT-603P-WH	L	119.3	15.36	No Flicker
11	LEVITON	6602	L	127.4	10	No Flicker
12	LUTRON	AY-603PG-WH	L	103.1	10.2	No Flicker
13	LUTRON	AY-603P-WH	L	120.8	10.9	No Flicker
14	LUTRON	LG-600PH-WH	L	117.21	9.5	No Flicker
15	LUTRON	DV-600P-WH	L	116.8	10.4	No Flicker
16	LUTRON	DV-603P-WH	L	117.1	10	No Flicker
17	LUTRON	MA-1000-WH	L	118.6	11.8	No Flicker
18	LUTRON	MAW-600H-WH	L	118.5	11.2	No Flicker
19	LEVITON	R02-06613-PLW	L	123.8	10.8	No Flicker
20	LUTRON	S-600PH-WH	L	117.8	11.7	No Flicker
21	LUTRON	S-600-PNLH-WH	L	119.5	11.9	No Flicker
22	LUTRON	S-6000P-WH	L	118	10.8	No Flicker
23	LUTRON	S-6000-WH	L	115.3	10.3	No Flicker
24	LUTRON	S-603PGH-WH	L	102.5	10	No Flicker
25	LUTRON	S-603PNLH-WH	L	119.21	11.3	No Flicker
26	LUTRON	D-600PH-DK	L	111.2	9	No Flicker
27	LEVITON	6681	L	121.1	11.6	No Flicker
28	COOPER	S106P	L	123.65	9.5	No Flicker
29	LUTRON	SLV-603P-WH	L	120.24	8.5	No Flicker
30	LEVITON	81000-W	L	119.8	9.3	No Flicker
31	LEVITON	1PL06-10Z	L	115.3	16.1	No Flicker
32	LUTRON	S-103PNL-WH	L	98.8	4.5	No Flicker

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13 Thermal Performance – Inside Bulb Case

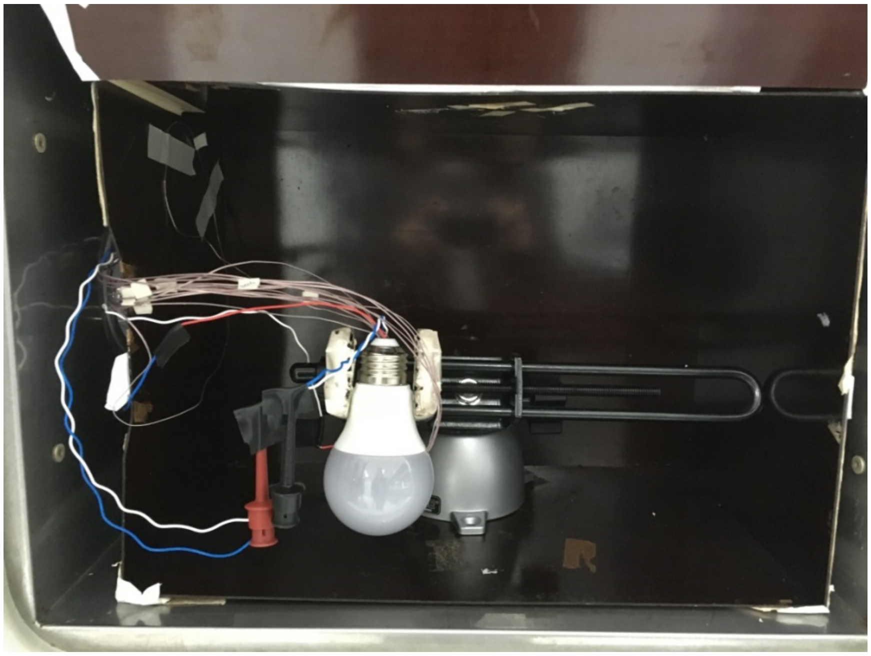

Figure 24 – Thermal Test Set-up Inside the Chamber

The bulb was placed inside the enclosure to prevent airflow that might affect the thermal measurements. Ambient temperature inside enclosure is 25 ºC and 40 ºC at 110 VAC utility line with dimming. Temperature was measured using T-type thermocouple. The measurement was gathered after 1 hour soak time and at 110° conduction angle using Lutron dimmer, DV-600P-WH.

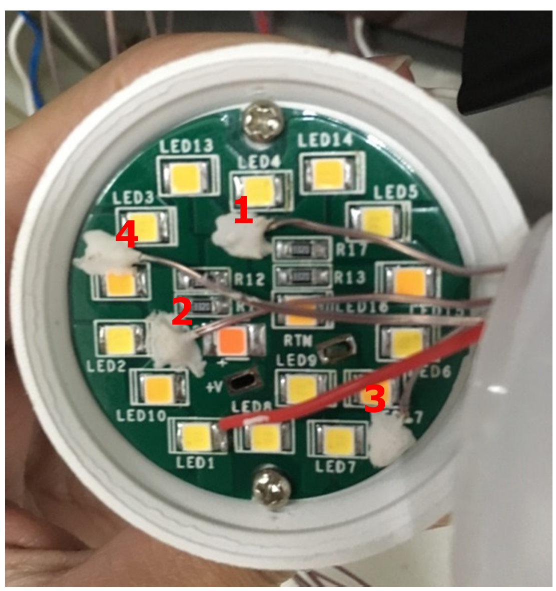

Figure 25 – Test Points for LED Load.

13.1 *Thermal Performance at 110 VAC with a 54 V LED Load, 25 ºC Ambient*

Reference	Max (ºC)	Final (ºC)
Ambient	27.1	26.4
R1 (Fusible Damper)	94.1	94
BR1 (Bridge Diode)	86.6	86.6
R2 (Bleeder)	98.2	97.9
R15 (Bleeder)	96.3	95.7
D1 (Freewheel Diode)	98.4	98.2
U1 (LYT7503D)	103.3	103.1
L2 (Inductor Winding)	97.5	97.3
Lens Inside (Ambient)	46.3	45.5
Body Inside (Ambient)	91.5	91.5
TP1 (Test Point)	103.3	101.6
TP2	100.5	98.9
TP3	96.8	95.3
TP4	99.1	97.5
Iout	0.1156	0.1058

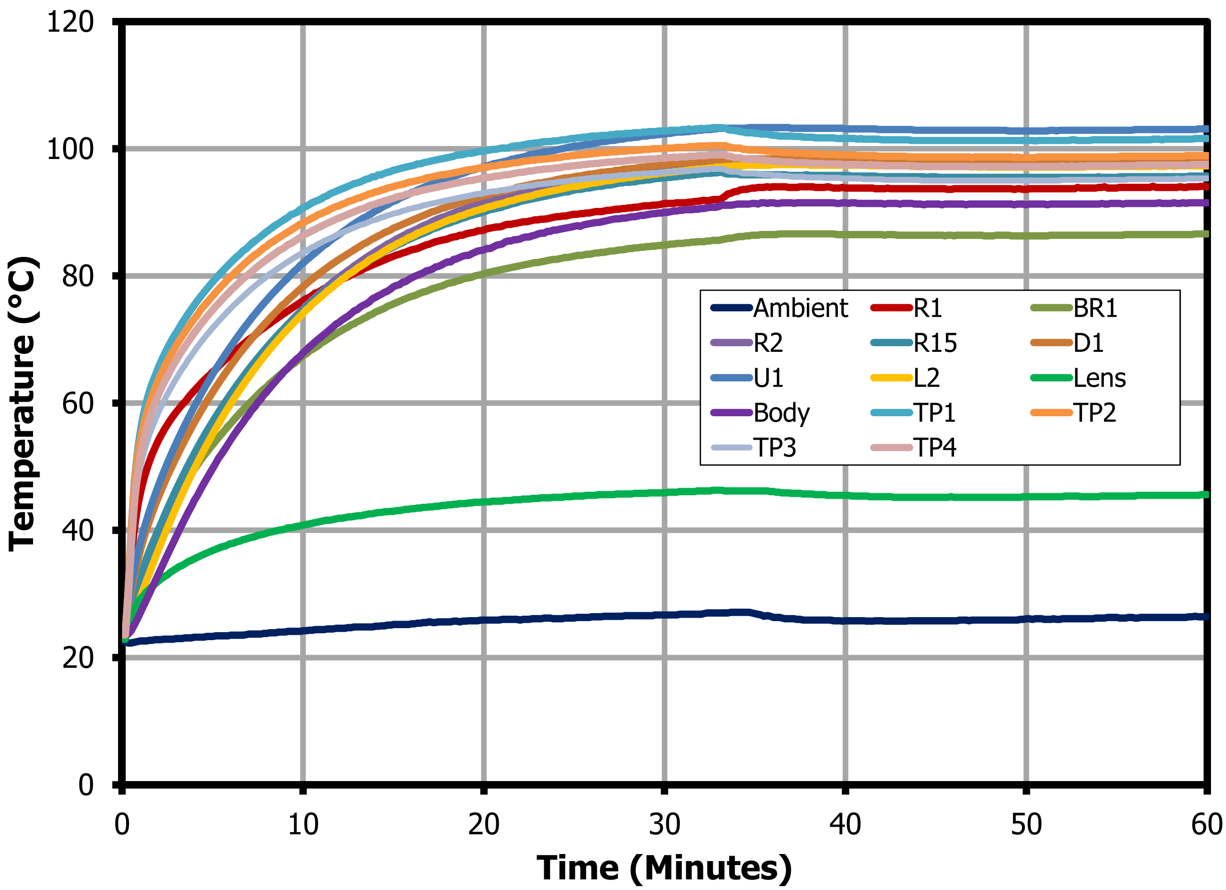

Figure 26 – Component Temperature at 110 VAC, 54 V LED Load, 25 ºC Ambient.

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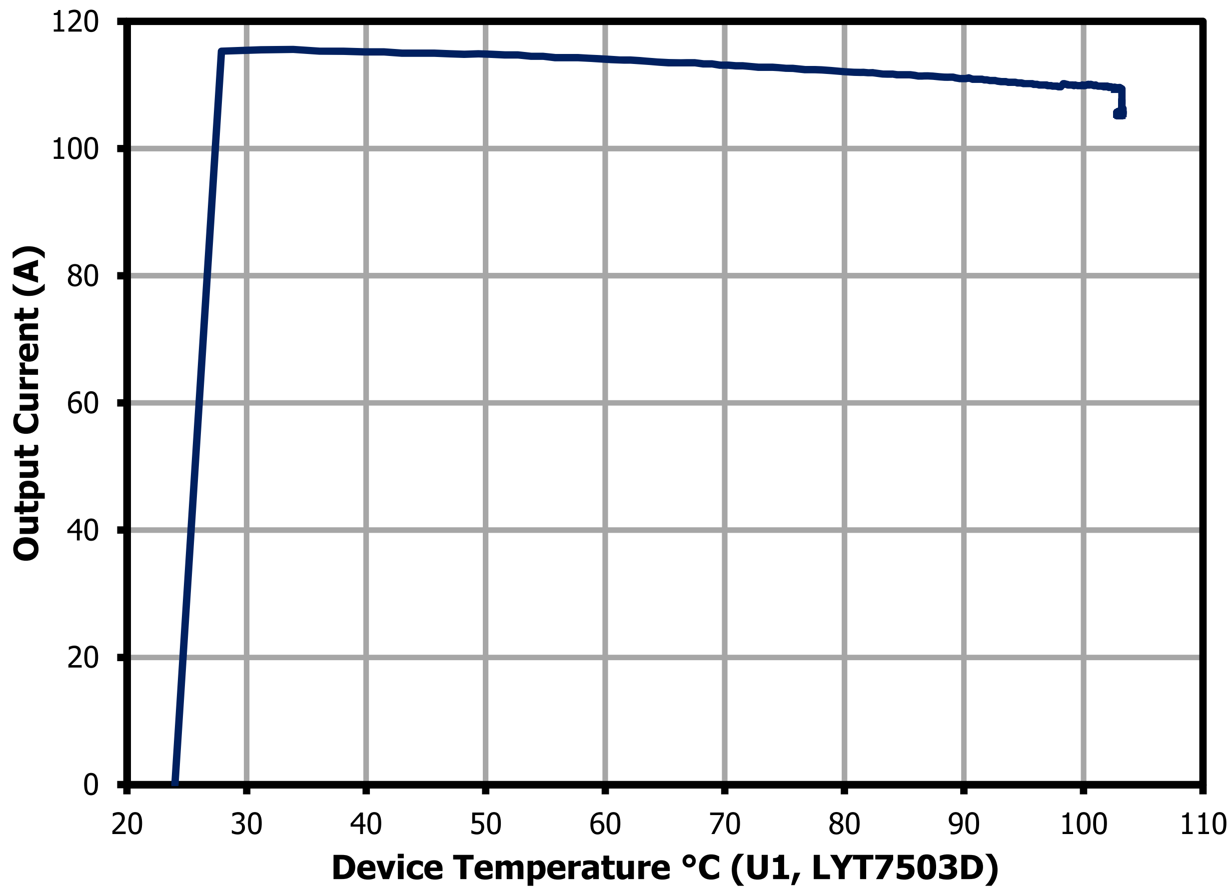

Figure 27 – Output Current vs Device Temperature (LYT7503D), 110° Conduction Angle, 25 ºC Ambient.

13.2 *Thermal Performance at 110 VAC with a 54 V LED Load, 40 ºC Ambient*

Reference	Max (ºC)	Final (ºC)
Ambient	40.8	40.8
R1 (Fusible Damper)	105.4	105.3
BR1 (Bridge Diode)	97.5	97.5
R2 (Bleeder)	111.1	111.1
R15 (Bleeder)	105.9	105.9
D1 (Freewheel Diode)	109.6	109.6
U1 (LYT7503D)	115.2	115.2
L2 (Inductor Winding)	110.3	110.3
Lens Inside (Ambient)	60.8	60.7
Body Inside (Ambient)	101.9	101.9
TP1 (Test Point)	114	114
TP2	112.7	112.7
TP3	110.5	110.5
TP4	109.9	109.9
Iout	0.1155	0.1087

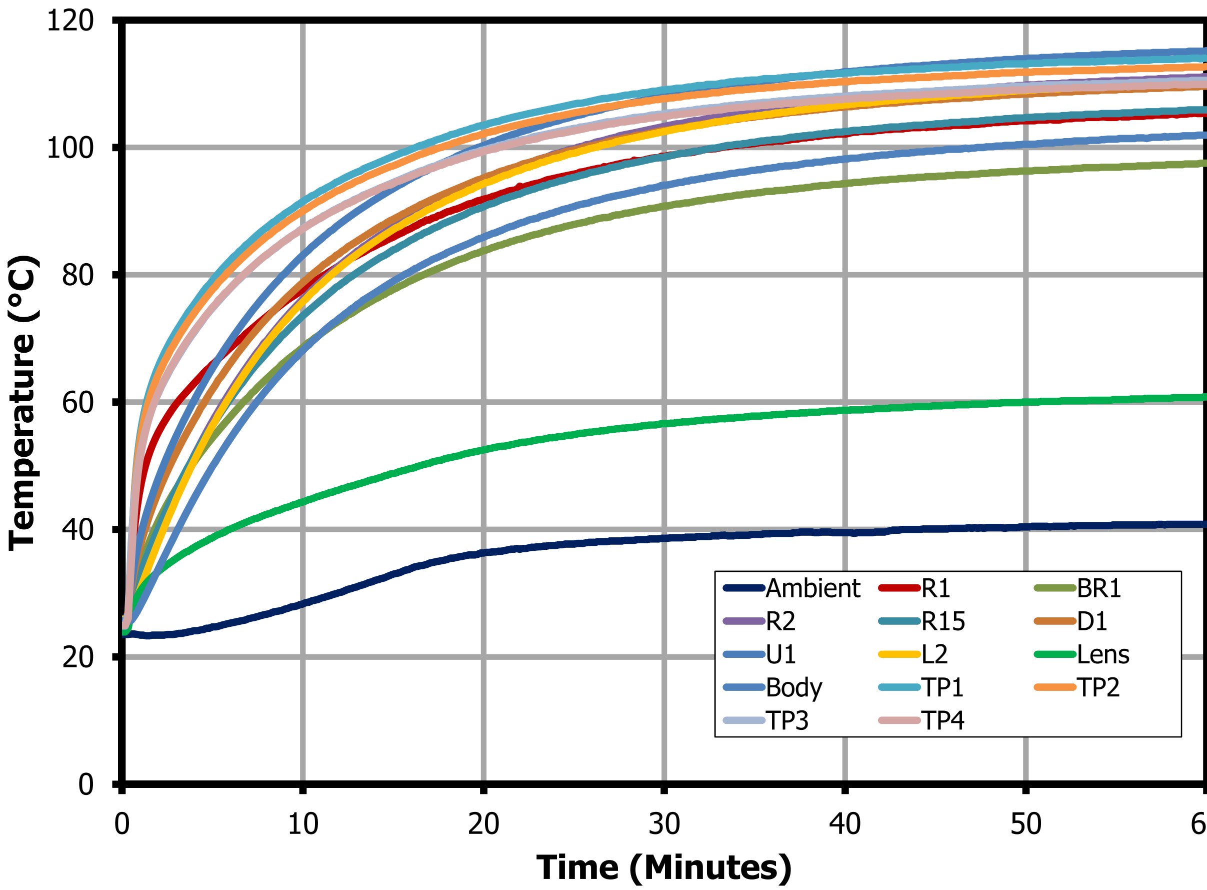

Figure 28 – Component Temperature at 110 VAC, 54 V LED Load, 40 ºC Ambient.

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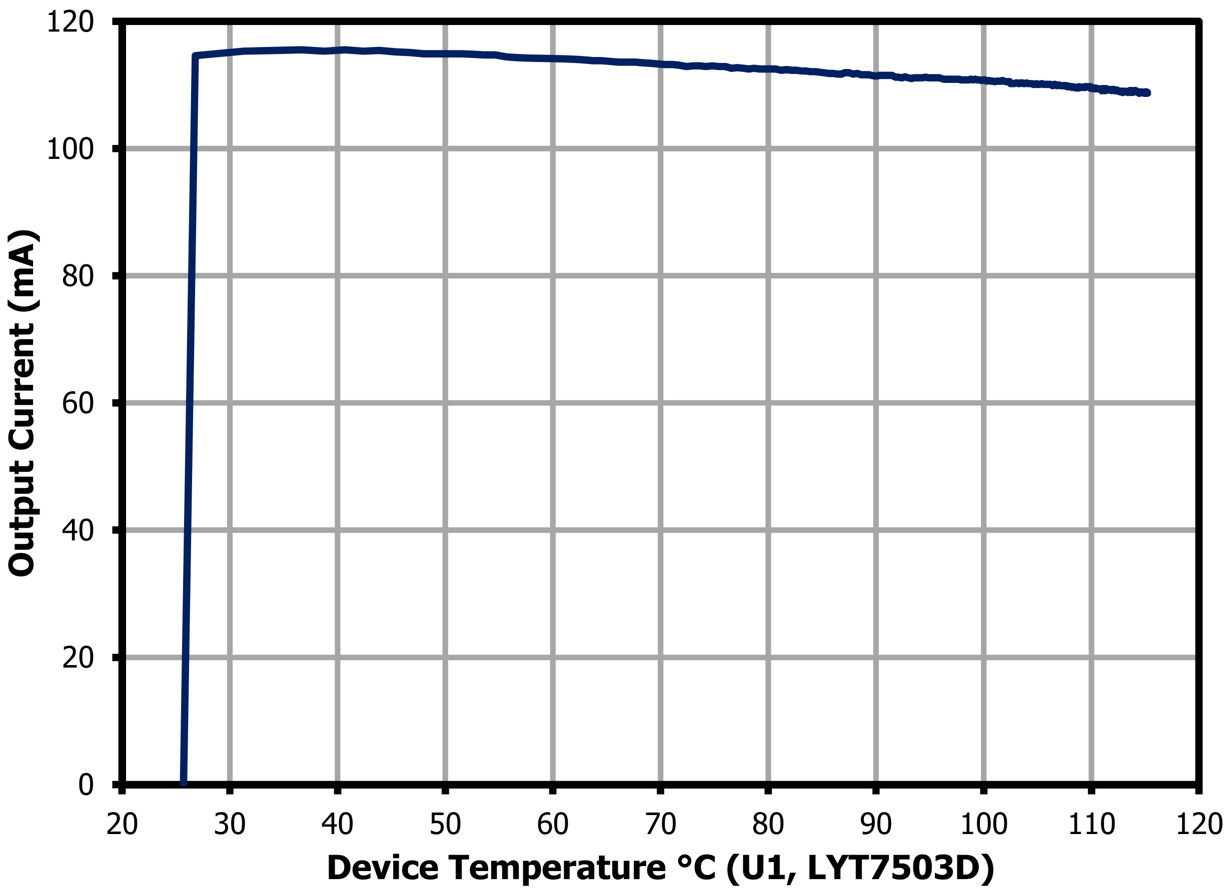

Figure 29 – Output Current vs Device Temperature (LYT7503D), 110° Conduction Angle, 40 ºC Ambient.

14 Waveforms

14.1 *Input Voltage and Input Current Waveforms*

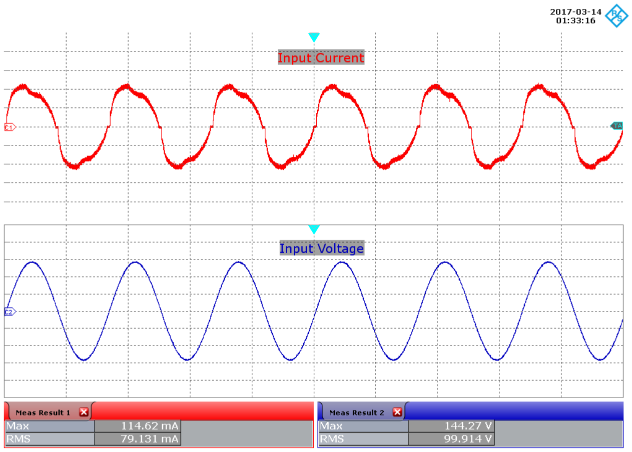

Figure 30 – 100 VAC, 54 V LED Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 10 ms / div.

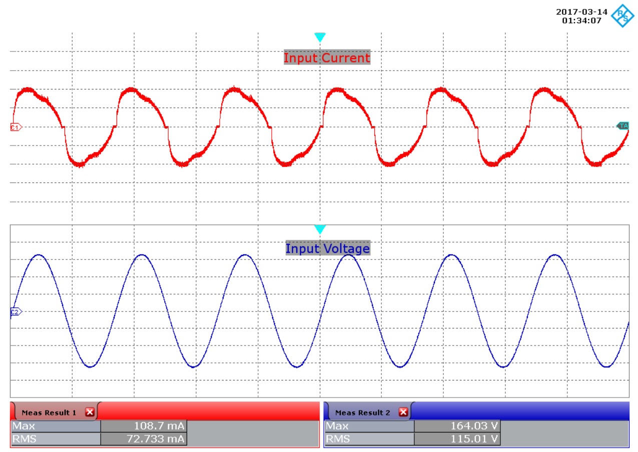

Figure 31 – 115 VAC, 54 V LED Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 10 ms / div.

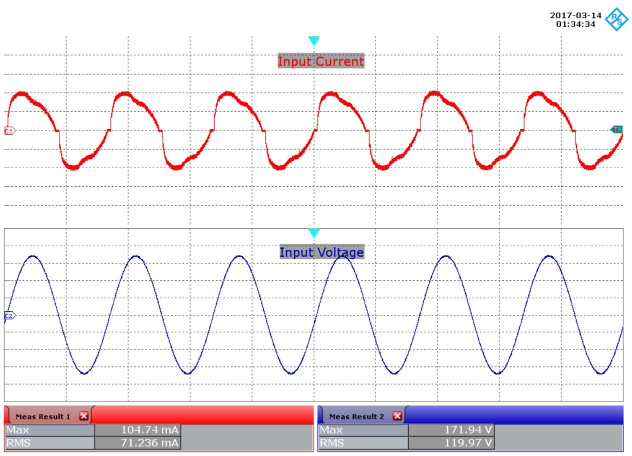

Figure 32 – 120 VAC, 54 V LED Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 10 ms / div.

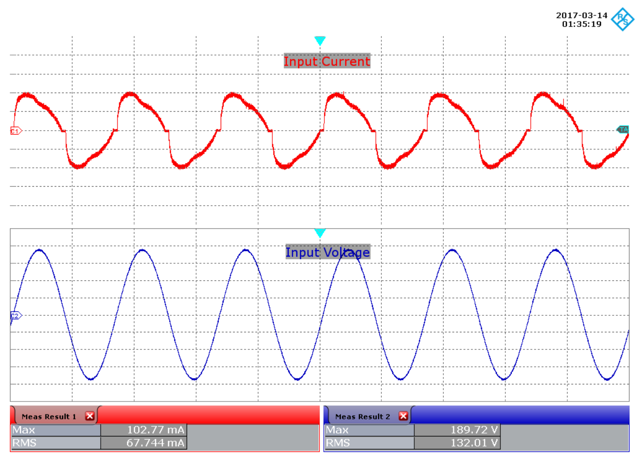

Figure 33 – 132 VAC, 54 V LED Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 10 ms / div.

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14.2 *Start-up Profile*

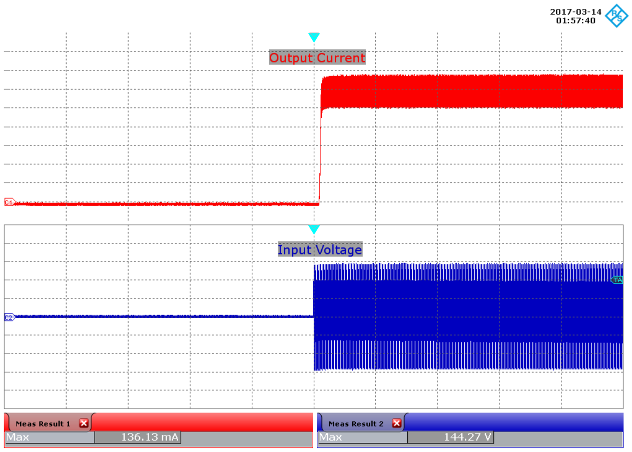

Figure 34 – 100 VAC, 54 V LED, Output Rise.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 1 s / div.

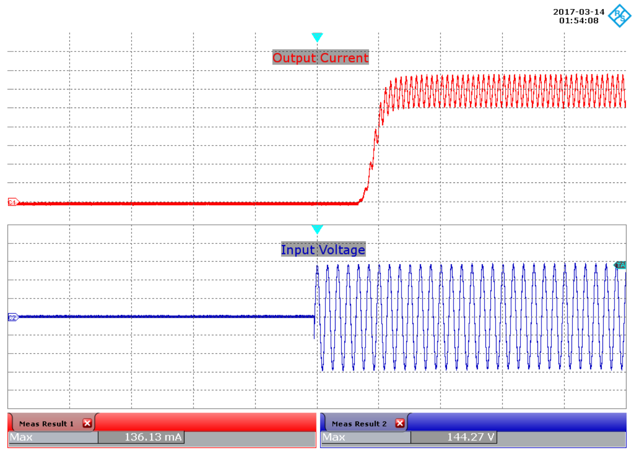

Figure 35 – 100 VAC, 54 V LED, Output Rise.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.

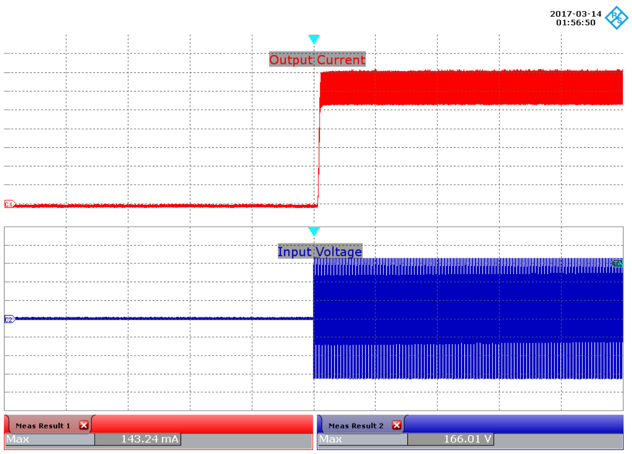

Figure 36 – 115 VAC, 54 V LED, Output Rise.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 1 s / div.

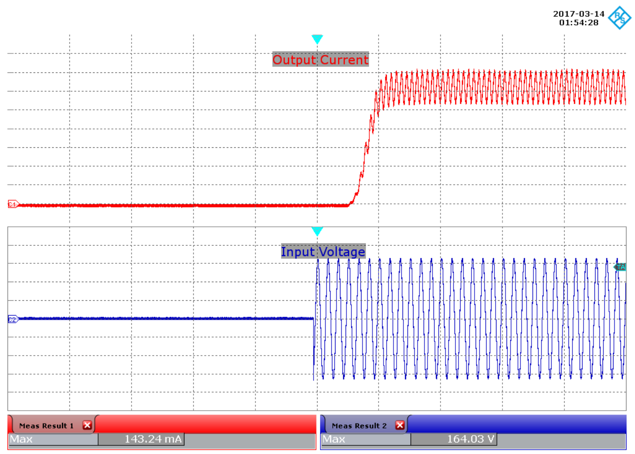

Figure 37 – 115 VAC, 54 V LED, Output Rise.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.

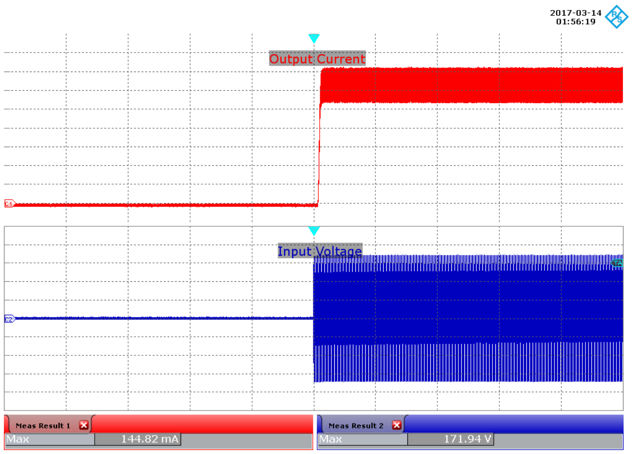

Figure 38 – 120 VAC, 54 V LED, Output Rise.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 1 s / div.

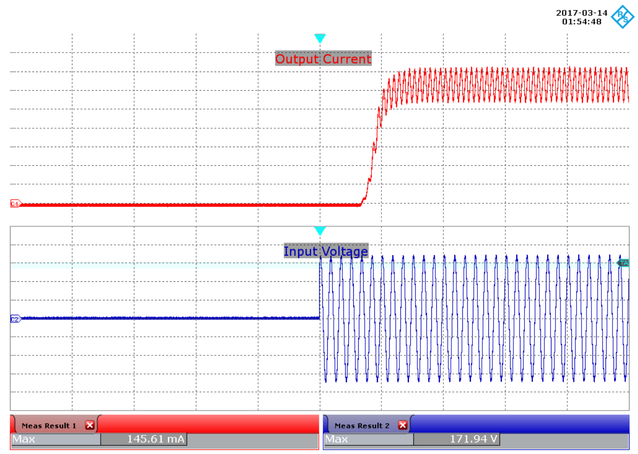

Figure 39 – 120 VAC, 54 V LED, Output Rise.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.

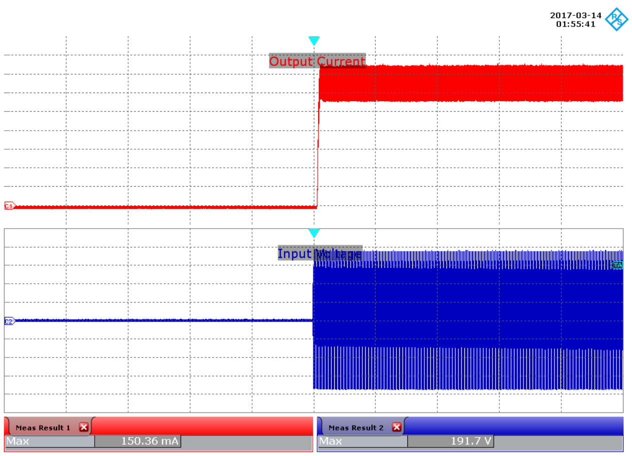

Figure 40 – 132 VAC, 54 V LED, Output Rise.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 1 s / div.

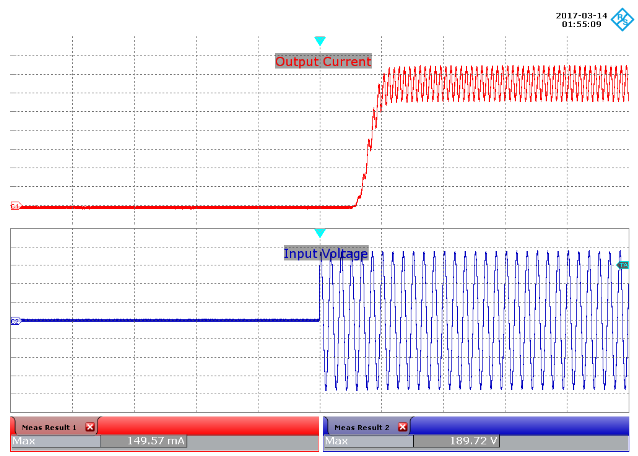

Figure 41 – 132 VAC, 54 V LED, Output Rise.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.

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14.3 *Output Current Fall*

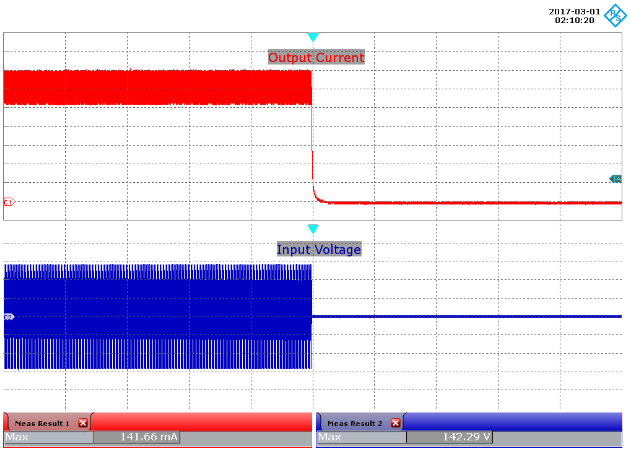

Figure 42 – 100 VAC, 54 V LED, Output Fall.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 1 s / div.

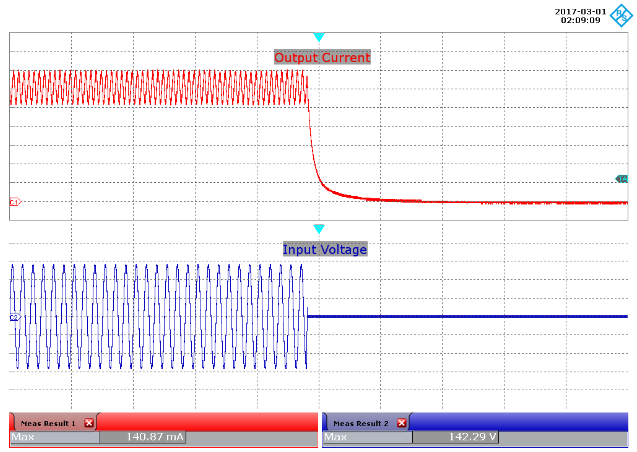

Figure 43 – 100 VAC, 54 V LED, Output Fall.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.

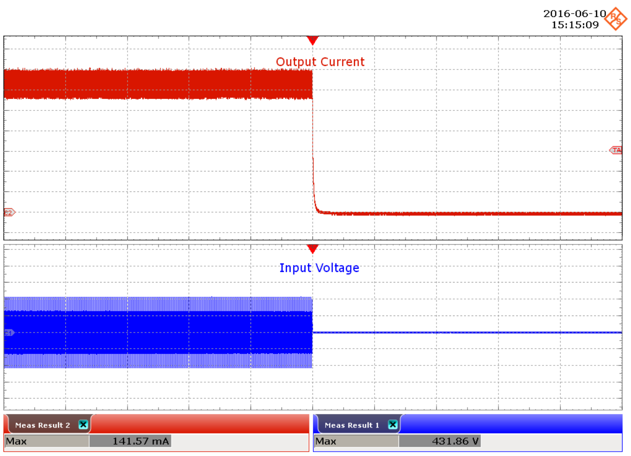

Figure 44 – 115 VAC, 54 V LED, Output Fall.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 1 s / div.

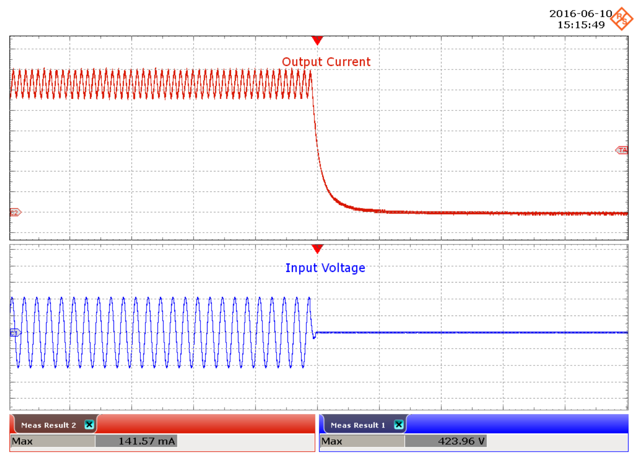

Figure 45 – 115 VAC, 54 V LED, Output Fall.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.

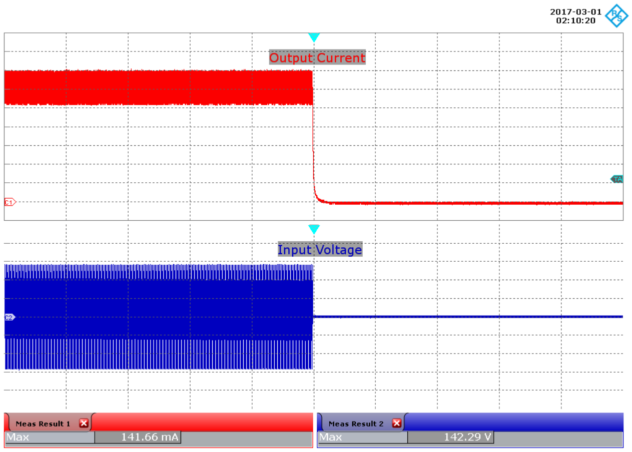

Figure 46 – 120 VAC, 54 V LED, Output Fall.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 1 s / div.

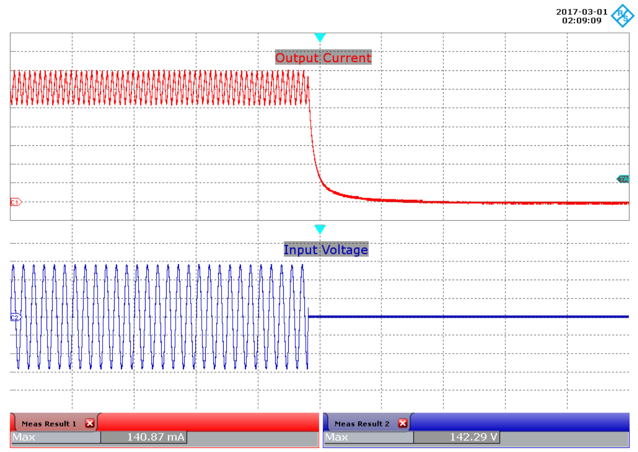

Figure 47 – 120 VAC, 54 V LED, Output Fall.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.

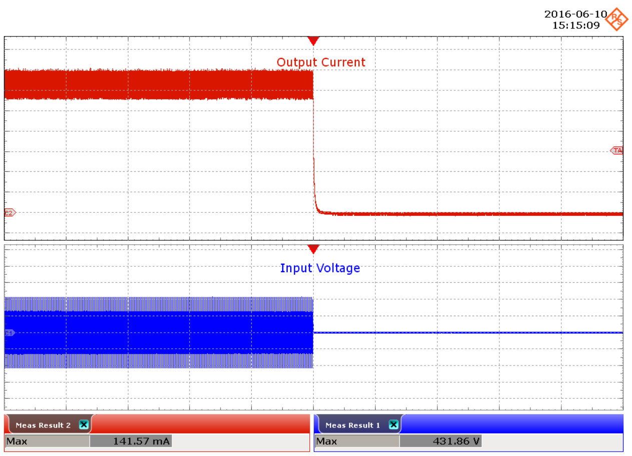

Figure 48 – 132 VAC, 54 V LED, Output Fall.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 1 s / div.

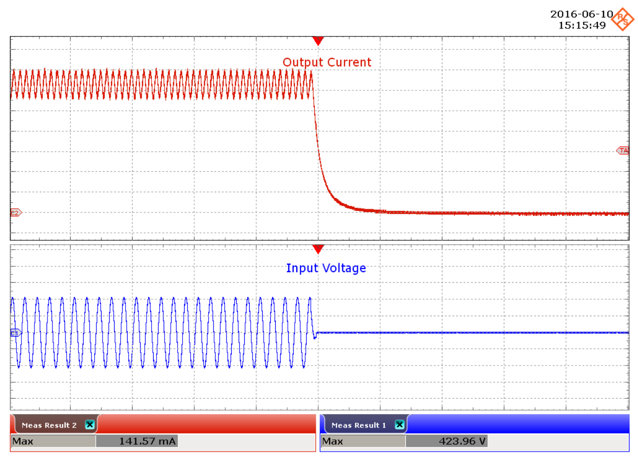

Figure 49 – 132 VAC, 54 V LED, Output Fall.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.

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14.4 *Drain Voltage and Current in Normal Operation*

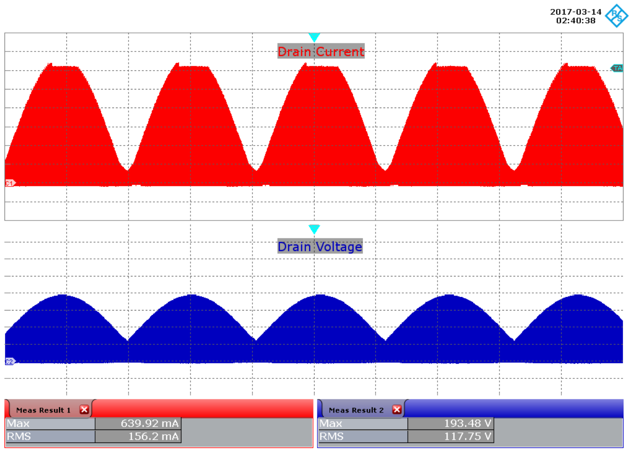

Figure 50 – 100 VAC, 54 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 ms / div.

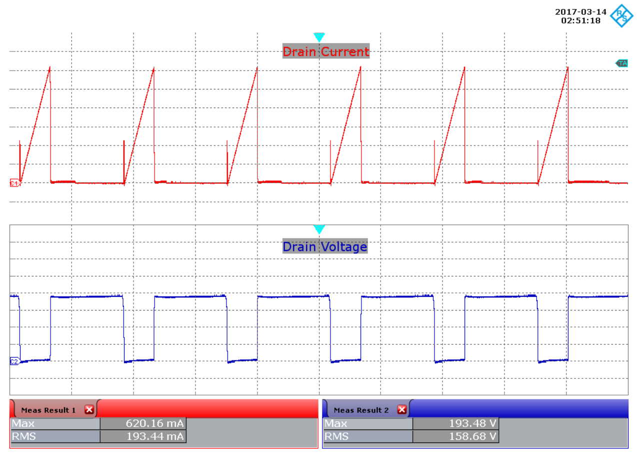

Figure 51 – 100 VAC, 54 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 50 V / div., 10 μs / div.

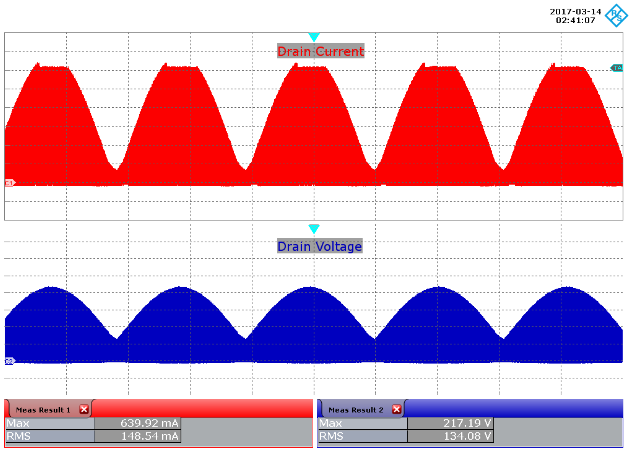

Figure 52 – 115 VAC, 54 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 ms / div.

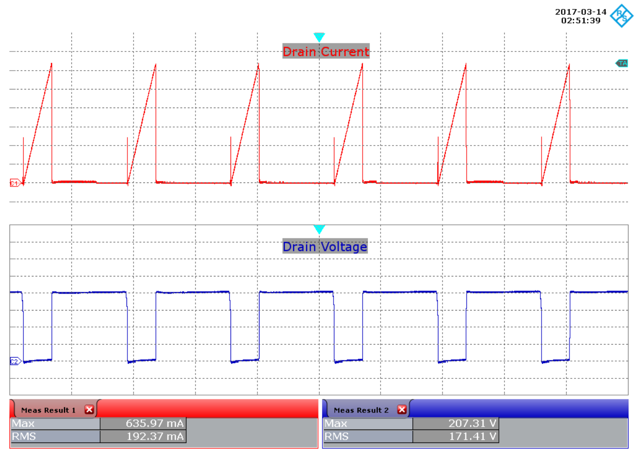

Figure 53 – 115 VAC, 54 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 50 V / div., 10 μs / div.

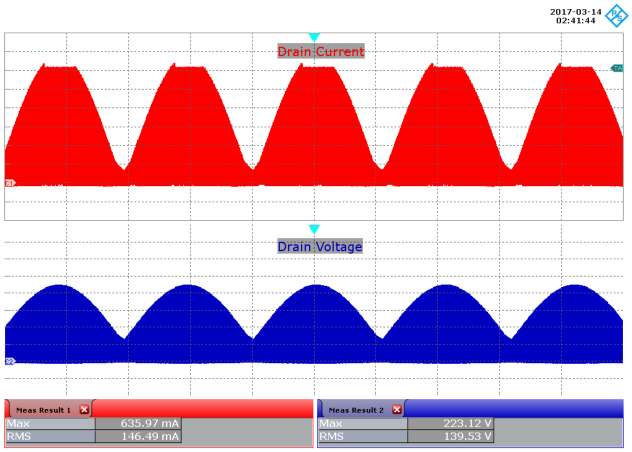

Figure 54 – 120 VAC, 54 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 ms / div.

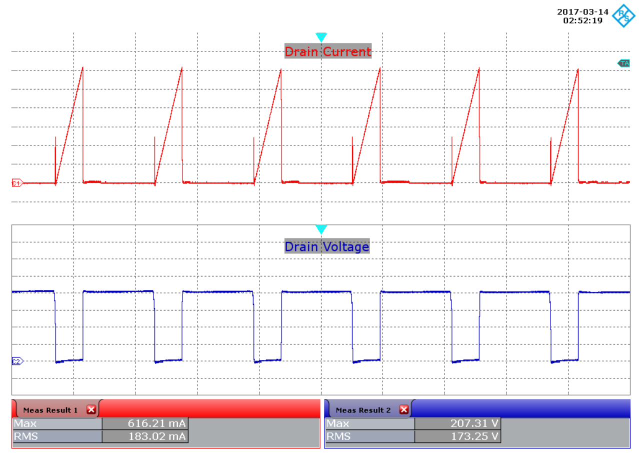

Figure 55 – 120 VAC, 54V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 50 V / div., 10 μs / div.

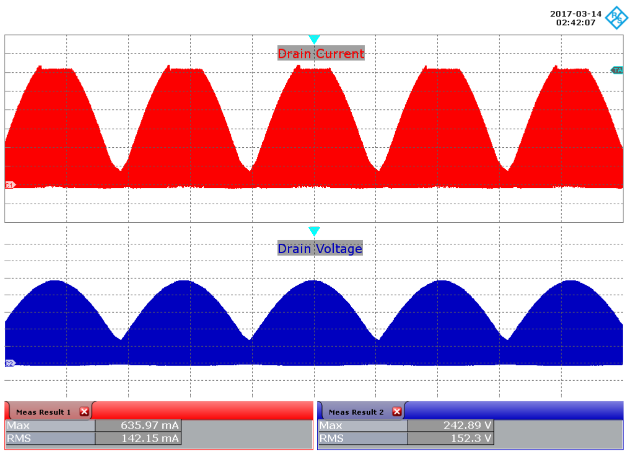

Figure 56 – 132 VAC, 54 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 ms / div.

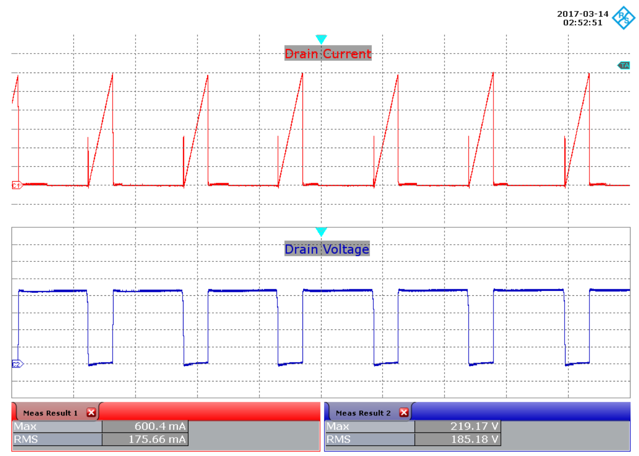

Figure 57 – 132 VAC, 54 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 50 V / div., 10 μs / div.

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14.5 *Drain Voltage and Current Start-up Profile*

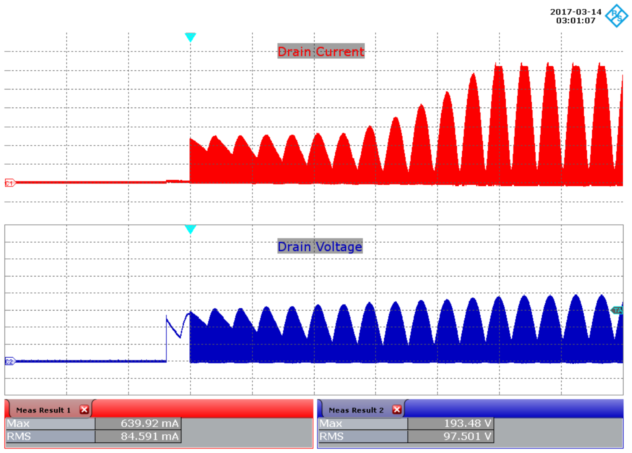

Figure 58 – 100 VAC, 54 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 50 V / div., 20 ms / div.

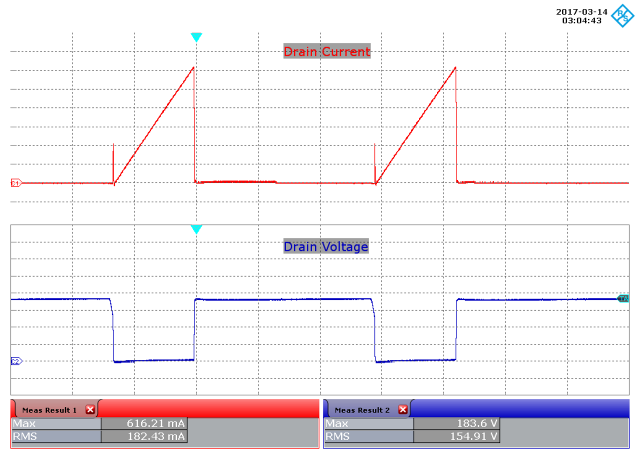

Figure 59 – 100 VAC, 54 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 μs / div.

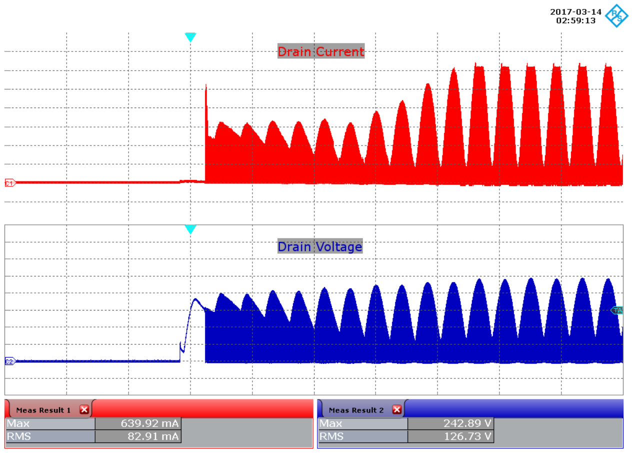

Figure 60 – 132 VAC, 54 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 50 V / div., 20 ms / div.

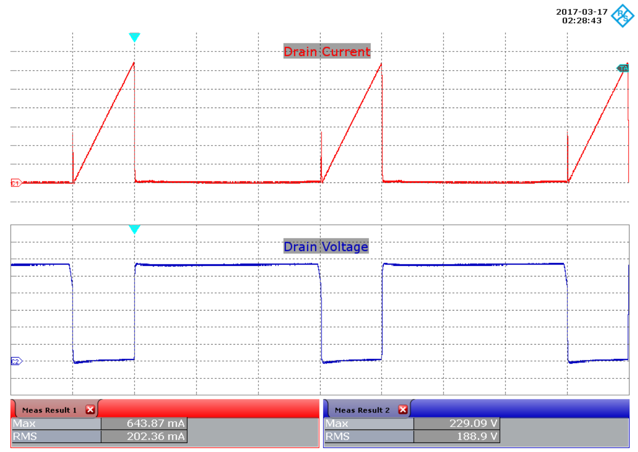

Figure 61 – 132 VAC, 54 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 μs / div.

14.6 *Drain Voltage and Current at Output Short-Circuit*

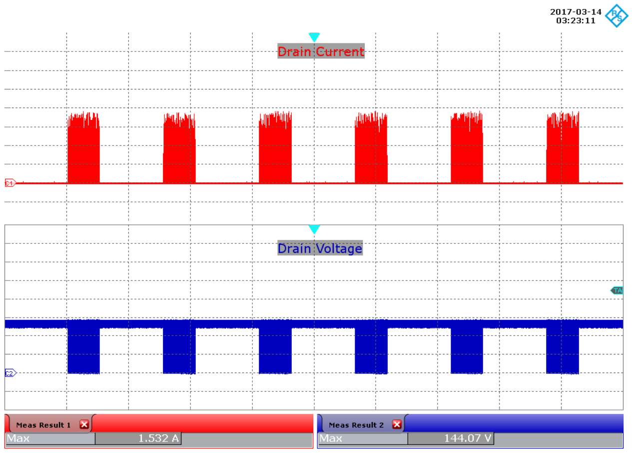

Figure 62 – 100 VAC, Output Short-Circuit.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 50 V / div., 1 s / div.

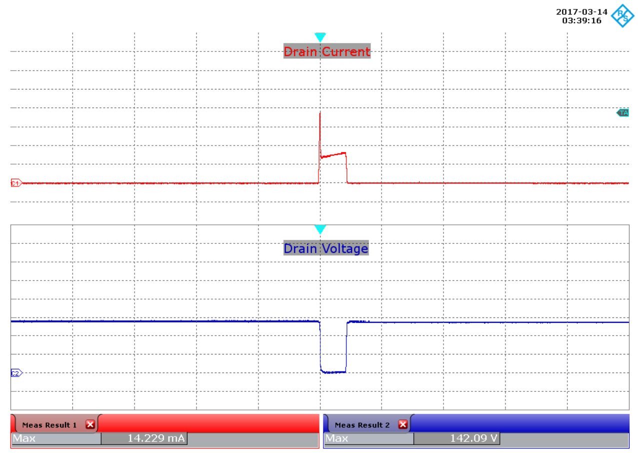

Figure 63 – 100 VAC, Output Short-Circuit.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 50 V / div., 2 µs / div.

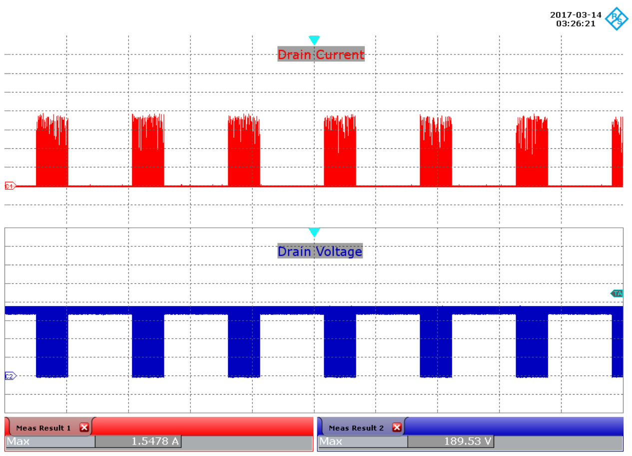

Figure 64 – 132 VAC, Output Short-Circuit.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 50 V / div., 1 s / div.

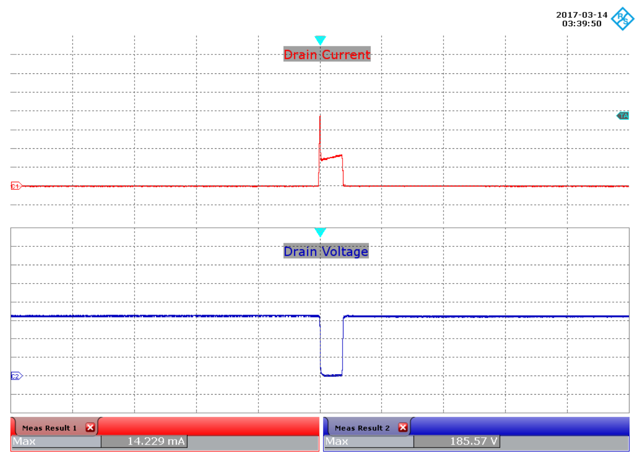

Figure 65 – 132 VAC, Output Short-Circuit.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 50 V / div., 2 µs / div.

Input		Input Measurement		
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)
100	60	99.98	19.43	0.609
115	60	114.97	11.57	0.535
120	60	120.02	9.94	0.471
132	60	132.00	7.52	0.388

Soak Time: 60 s.

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14.7 *Output Diode Voltage and Current in Normal Operation*

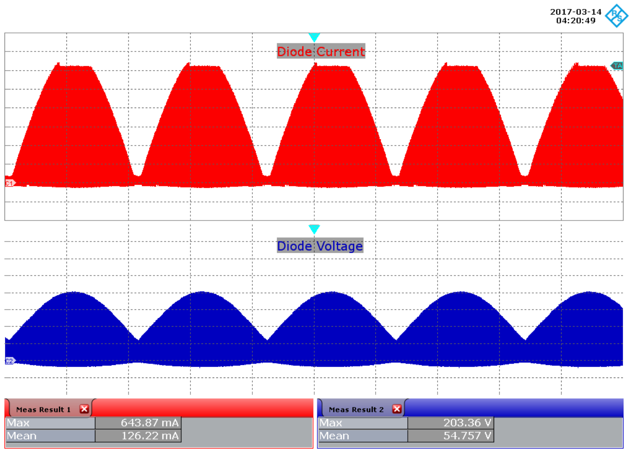

Figure 66 – 100 VAC, 54 V LED Load.
Upper: I_{D1}, 100 mA / div.
Lower: V_{D1}, 50 V / div., 4 ms / div.

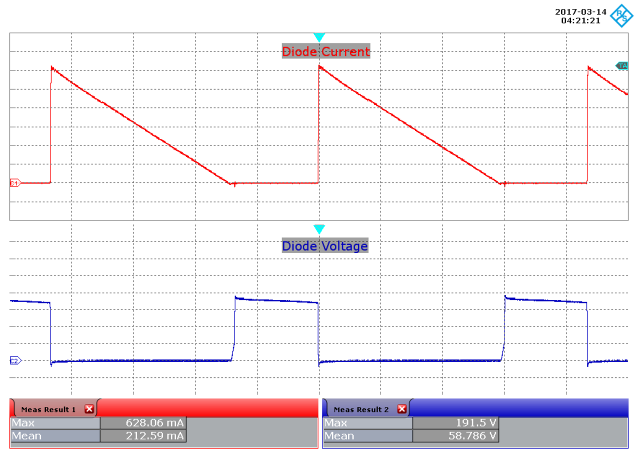

Figure 67 – 100 VAC, 54 V LED Load.
Upper: I_{D1}, 100 mA / div.
Lower: V_{D1}, 50 V / div., 10 μs / div.

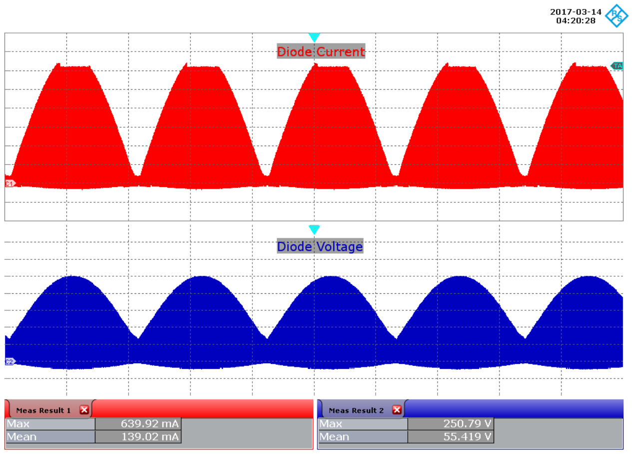

Figure 68 – 132 VAC, 54 V LED Load.
Upper: I_{D1}, 100 mA / div.
Lower: V_{D1}, 50 V / div., 4 ms / div.

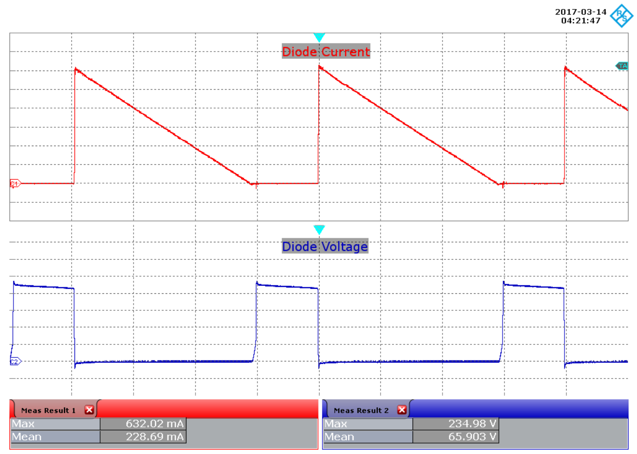

Figure 69 – 132 VAC, 54 V LED Load.
Upper: I_{D1}, 100 mA / div.
Lower: V_{D1}, 50 V / div., 4 μs / div.

14.8 *Output Voltage and Current – Open Output LED Load*

Maximum measured no-load output voltage is below the surge voltage rating of the output capacitor.

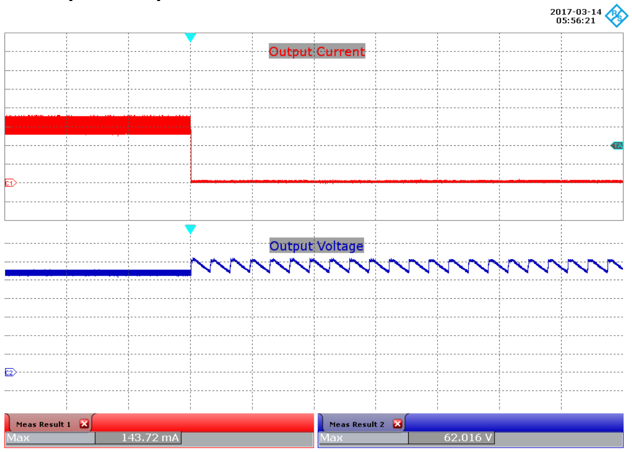

Figure 70 – 100 VAC, 54 V LED Load, Running Open Load. Upper: I_{OUT}, 40 mA / div. Lower: V_{OUT}, 10 V / div., 4 s / div.

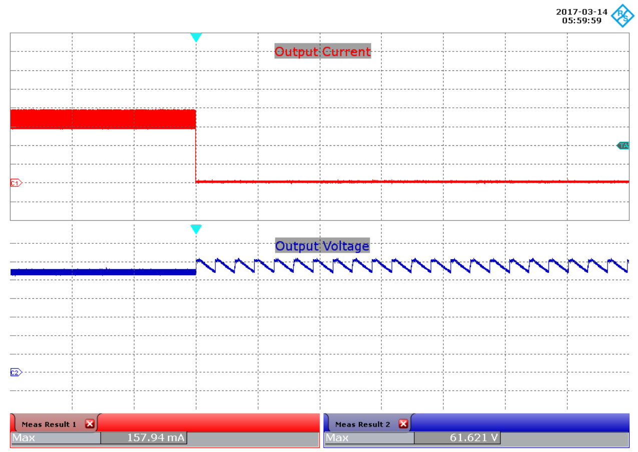

Figure 71 – 132 VAC, 54 V LED Load, Running Open Load. Upper: I_{OUT}, 40 mA / div. Lower: V_{OUT}, 10 V / div., 4 s / div.

14.9 *Output Voltage and Current – Start-up at Open Output Load*

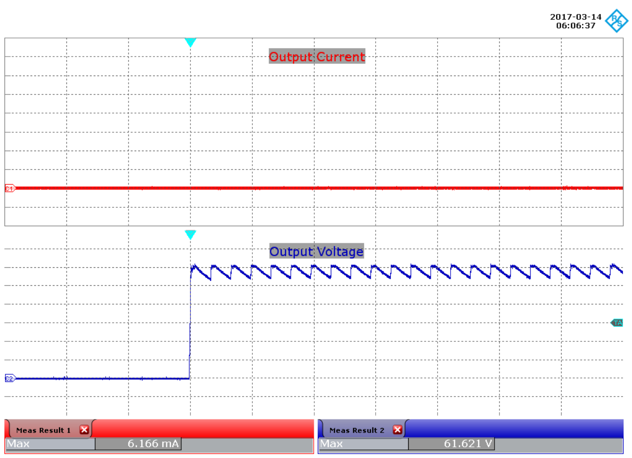

Figure 72 – 100 VAC, Open Load, Open Load Start-up. Upper: I_{OUT}, 40 mA / div. Lower: V_{OUT}, 10 V / div., 4 s / div.

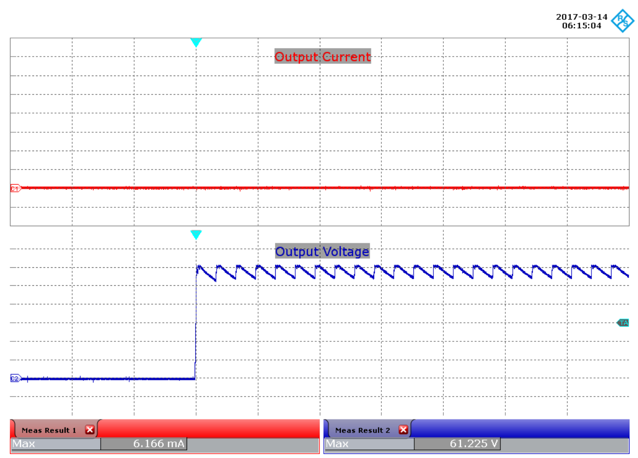

Figure 73 – 132 VAC, Open Load, Open Load Start-up. Upper: I_{OUT}, 40 mA / div. Lower: V_{OUT}, 10 V / div., 4 s / div.

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14.10 *Output Ripple Current*

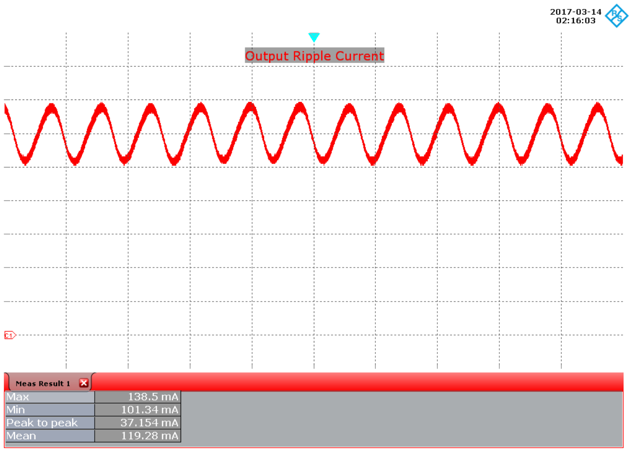

Figure 74 – 100 VAC, 60 Hz, 54 V LED Load.
Upper: I_{OUT}, 20 mA / div., 10 ms / div.

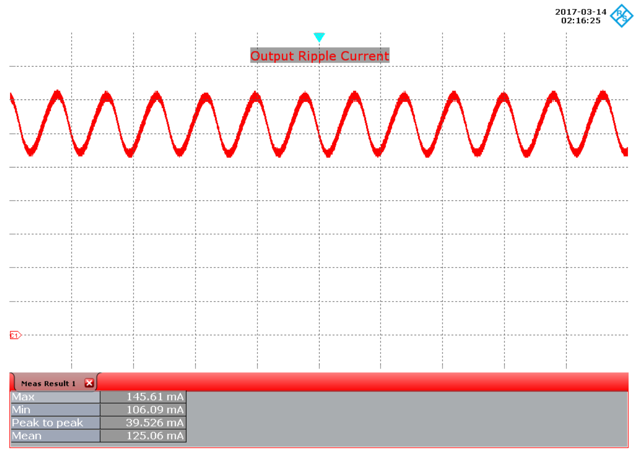

Figure 75 – 115 VAC, 60 Hz, 54 V LED Load.
Upper: I_{OUT}, 20 mA / div., 10 ms / div.

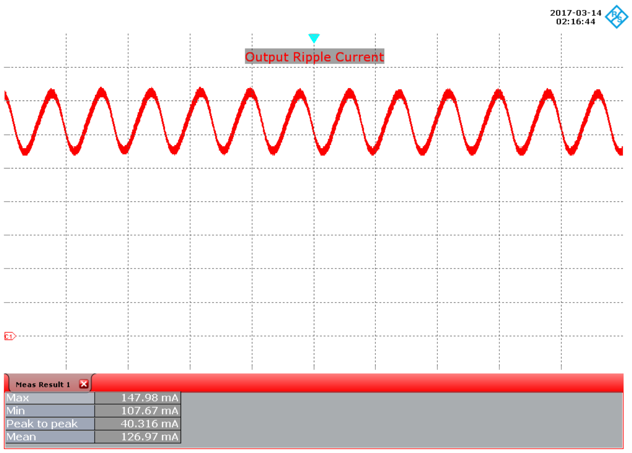

Figure 76 – 120 VAC, 60 Hz, 54 V LED Load.
Upper: I_{OUT}, 20 mA / div., 10 ms / div.

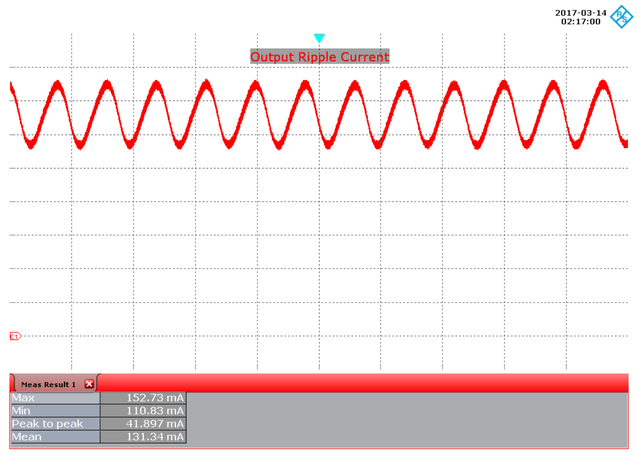

Figure 77 – 132 VAC, 60 Hz, 54 V LED Load.
Upper: I_{OUT}, 20 mA / div., 10 ms / div.

V_{IN} (VAC)	$I_{OUT(MAX)}$ (mA)	$I_{OUT(MIN)}$ (mA)	I_{MEAN}	% Flicker 100 x (I_{RP-P} / $I_{OUT(MAX)}$+$I_{OUT(MIN)}$)
100	138.5	101.34	119.28	15.58
115	145.61	106.09	125.06	15.80
120	147.98	107.67	126.97	15.87
132	152.73	110.83	131.34	15.95

15 Dimming Waveforms

15.1 *Lutron SLV-603P-WH*

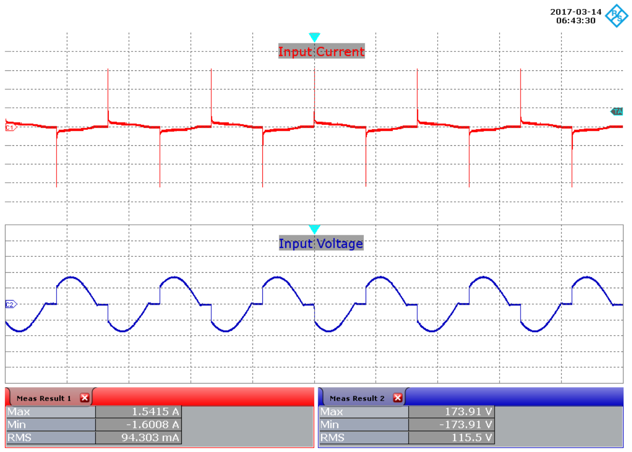

Figure 78 – 120 VAC, 60 Hz, 54 V LED Load.
Maximum Conduction Angle.
Upper: I_{IN}, 500 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

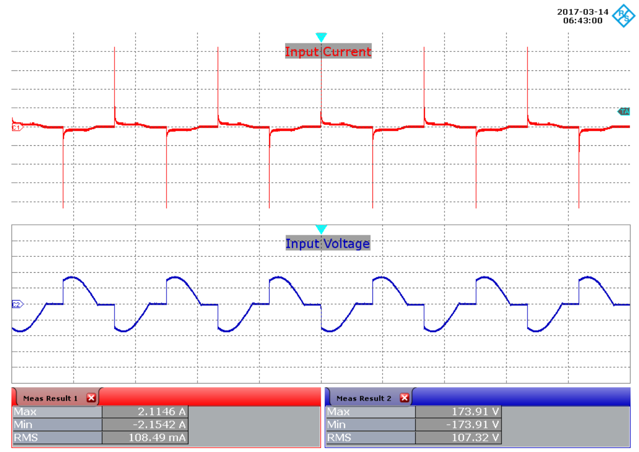

Figure 79 – 120 VAC, 60 Hz, 54 V LED Load.
120° Conduction Angle.
Upper: I_{IN}, 500 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

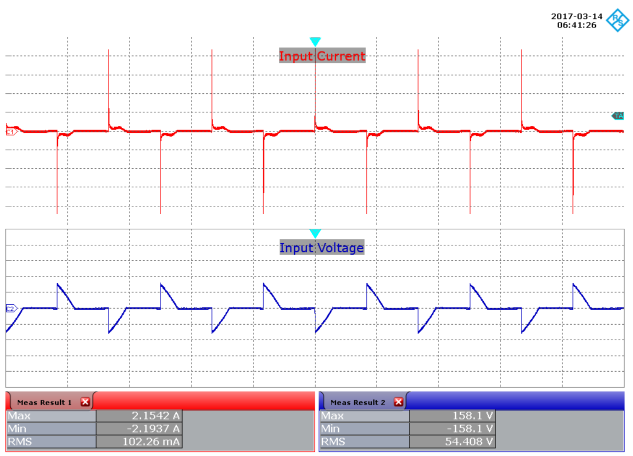

Figure 80 – 120 VAC, 60 Hz, 54 V LED Load.
60° Conduction Angle.
Upper: I_{IN}, 500 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

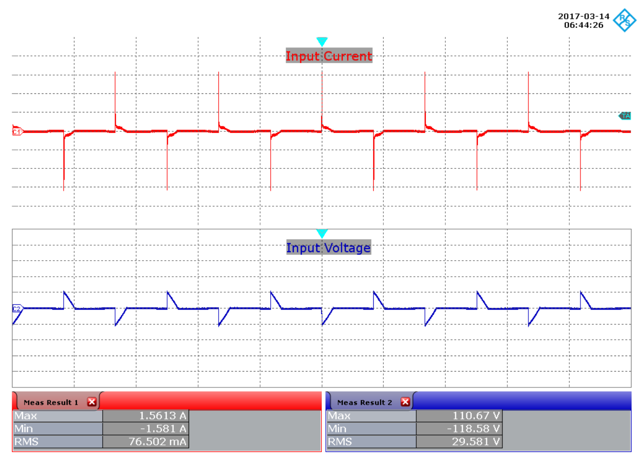

Figure 81 – 120 VAC, 60 Hz, 54 V LED Load.
Minimum Conduction Angle.
Upper: I_{IN}, 500 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

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16 AC Cycling Test at Non-Dimming

No output current overshoot was observed during on - off cycling.

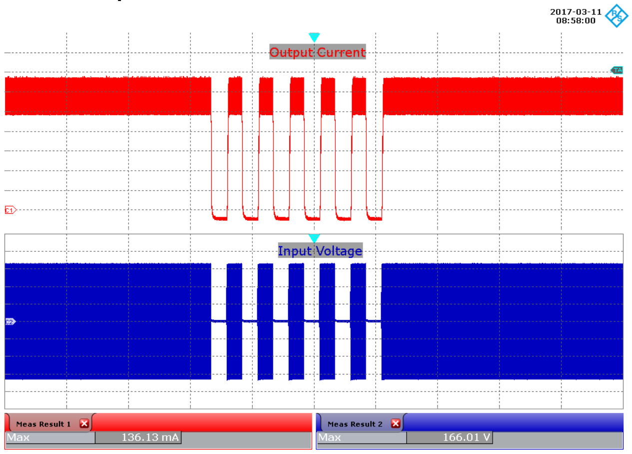

Figure 82 – 100 VAC, 54 V LED Load.
1 s On – 1 s Off.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 4 s / div.

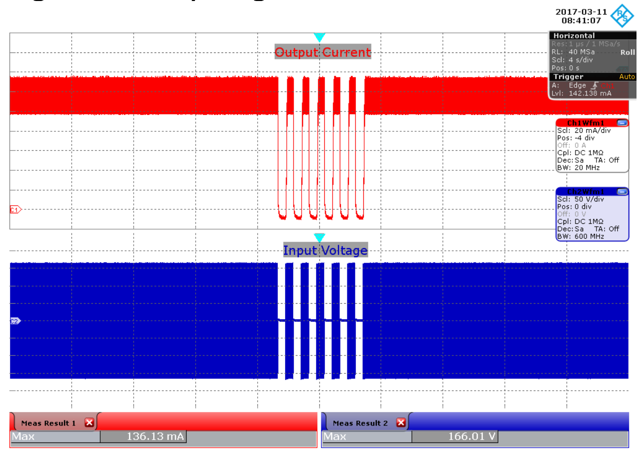

Figure 83 – 100 VAC, 54 V LED Load.
0.5 s On – 0.5 s Off.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 4 s / div.

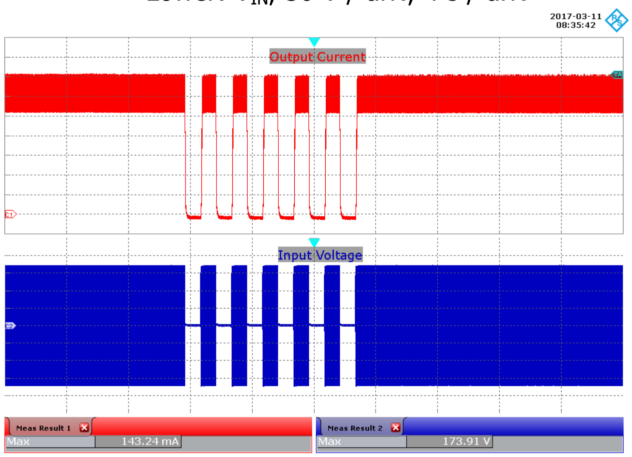

Figure 84 – 120 VAC, 54 V LED Load.
1 s On – 1 s Off.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 4 s / div.

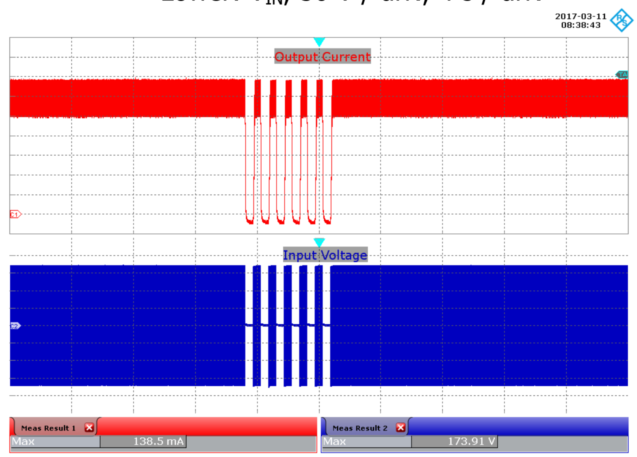

Figure 85 – 120 VAC, 54 V LED Load.
0.5 s On – 0.5 s Off.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 4 s / div.

17 Conducted EMI

17.1 *Test Set-up*

17.1.1 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.
5. 54 V LED load with input voltage set at 120 VAC.

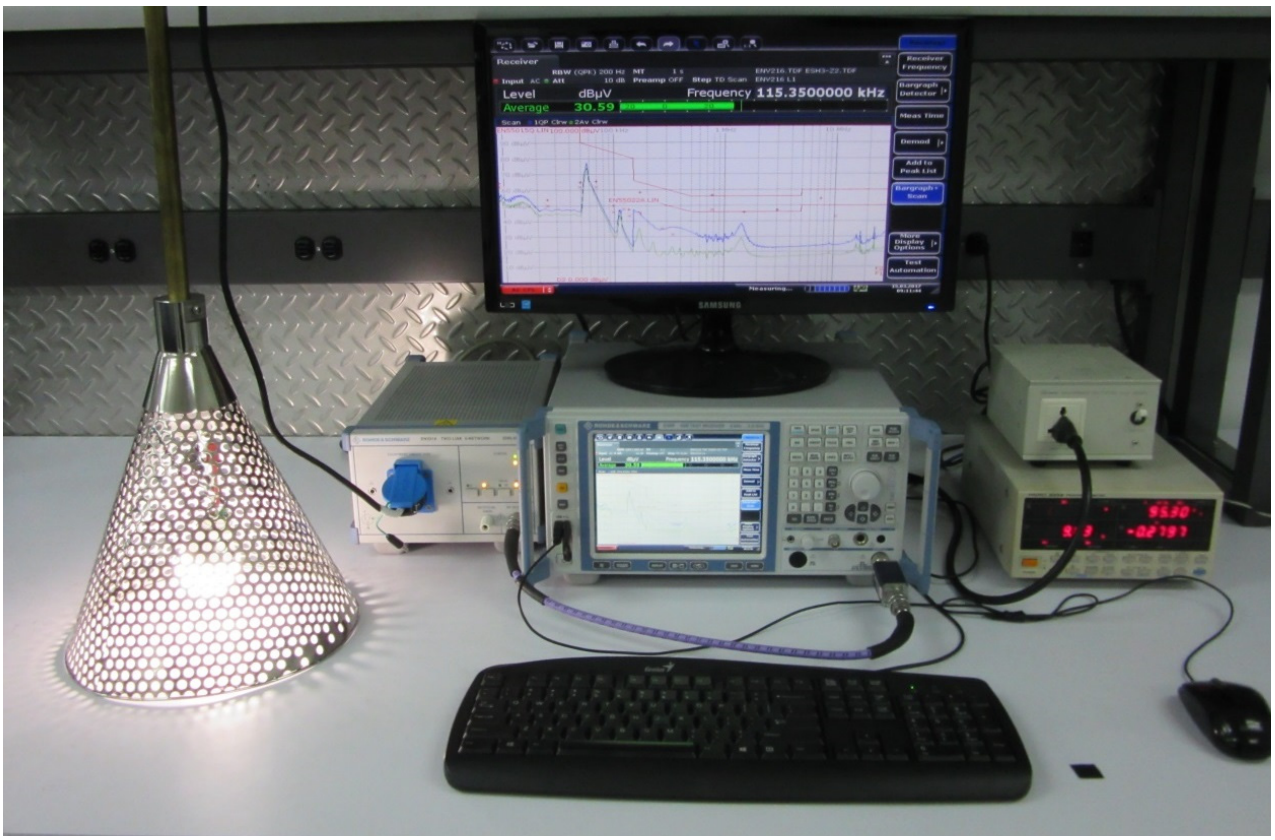

Figure 86 – Conducted EMI Test Set-up.

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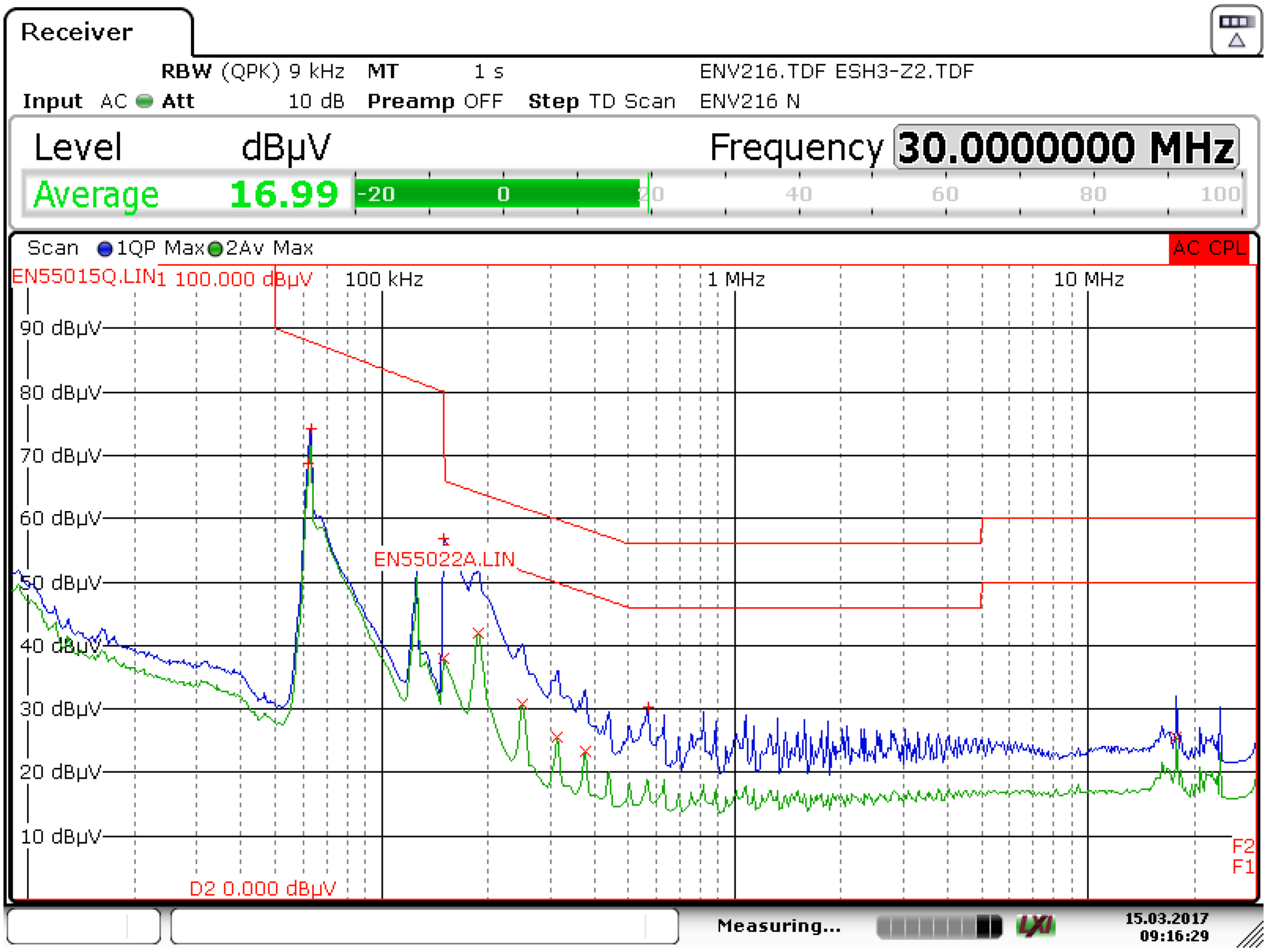
17.2 *EMI Test Result*



Date: 15.MAR.2017 09:16:29

Figure 87 – Conducted EMI QP Scan at 54 V LED Load, 120 VAC, 60 Hz, and EN55015 B Limits.

Trace1: EN55015Q.LIN Trace2: EN55022A.LIN

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	150.0000 kHz	56.84 N	-9.16 dB
2 Average	188.2500 kHz	42.02 N	-12.09 dB
1 Quasi Peak	63.0500 kHz	74.19 N	-13.70 dB
2 Average	150.0000 kHz	37.87 N	-18.13 dB
1 Quasi Peak	62.0500 kHz	68.63 L1	-19.40 dB
2 Average	251.2500 kHz	30.66 N	-21.06 dB
2 Average	17.8198 MHz	25.68 N	-24.32 dB
2 Average	314.2500 kHz	25.44 N	-24.42 dB
2 Average	377.2500 kHz	23.22 N	-25.12 dB
1 Quasi Peak	568.5000 kHz	30.27 N	-25.73 dB

Figure 88 – Conducted EMI Data at 120 VAC, 54 V LED Load.

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18 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)
+1 kV	120	L to N	0	Pass
-1 kV	120	L to N	0	Pass
+1 kV	120	L to N	90	Pass
-1 kV	120	L to N	90	Pass

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2500	120	L to N	0	Pass
-2500	120	L to N	0	Pass
+2500	120	L to N	90	Pass
-2500	120	L to N	90	Pass

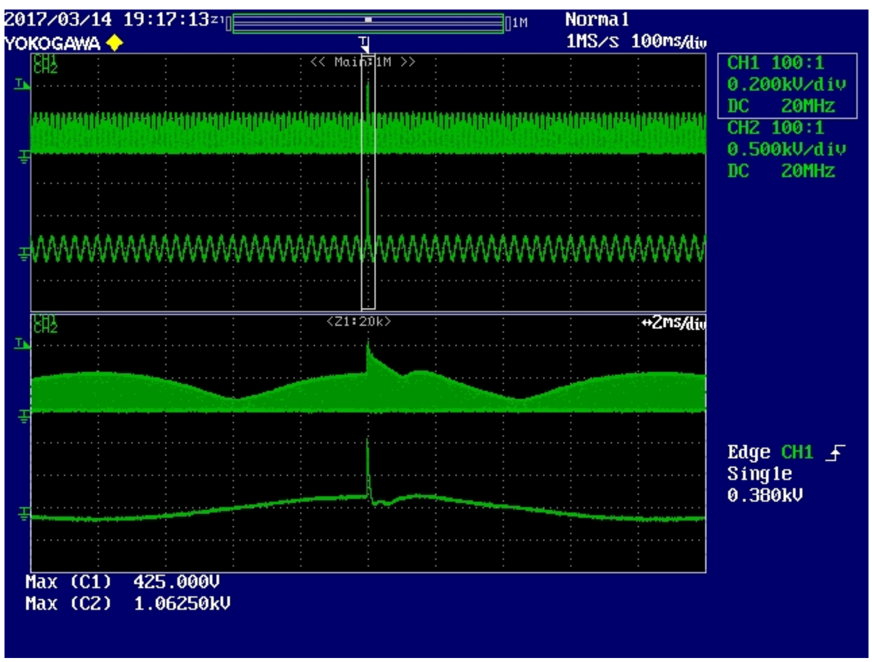

Figure 89 – +1 kV Differential Surge at Worst Case Input (120 VAC), 90º Phase Angle.
V_{DRAIN}, 200 V / div., 100 ms / div.
Peak V_{DRAIN}: 425 V.

19 Brown-in / Brown-out Test

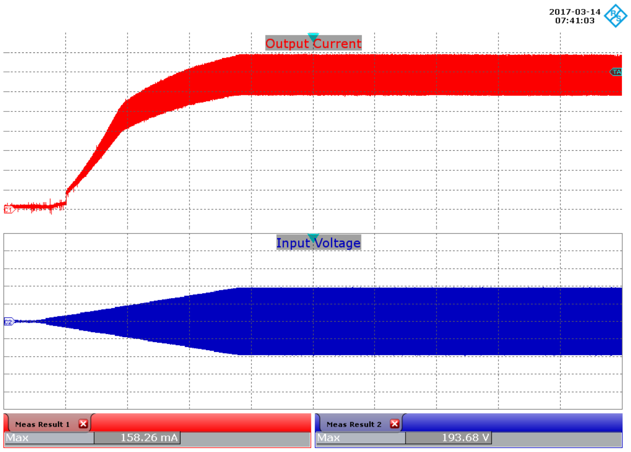

Figure 90 – Brown-in Test at 1 V / s.
Ch1: I_{OUT}, 20 mA / div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 40 s / div.

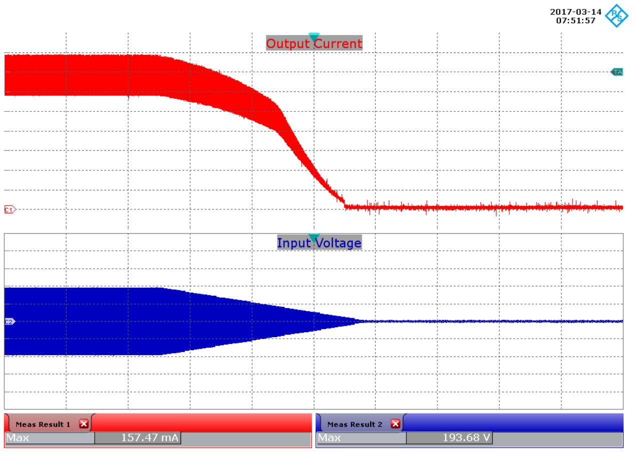

Figure 91 – Brown-out Test at 1 V / s.
Ch1: I_{OUT}, 20 mA / div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 40 s / div.

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20 Revision History

Date	Author	Revision	Description and Changes	Reviewed
27-Jun-17	CA	1.0	Initial release	Apps & Mktg

Power Integrations, Inc.
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

For the latest updates, visit our website: www.power.com

Power Integrations Worldwide Sales Support Locations

WORLD HEADQUARTERS
5245 Hellyer Avenue
San Jose, CA 95138, USA.
Main: +1-408-414-9200
Customer Service:
Phone: +1-408-414-9665
Fax: +1-408-414-9765
e-mail: usasales@power.com

CHINA (SHANGHAI)
Rm 2410, Charity Plaza, No. 88,
North Caoxi Road,
Shanghai, PRC 200030
Phone: +86-21-6354-6323
Fax: +86-21-6354-6325
e-mail: chinasales@power.com

CHINA (SHENZHEN)
17/F, Hivac Building, No. 2, Keji Nan
8th Road, Nanshan District, Shenzhen,
China, 518057
Phone: +86-755-8672-8689
Fax: +86-755-8672-8690
e-mail: chinasales@power.com

GERMANY (AC-DC/LED Sales)
Lindwurmstrasse 114
80337, Munich
Germany
Phone: +49-895-527-39110
Fax: +49-895-527-39200
e-mail: eurosales@power.com

GERMANY (IGBT Driver Sales)
HellwegForum 1
59469 Ense, Germany
Tel: +49-2938-64-39990
Email: igbt-driver.sales@power.com

INDIA
#1, 14th Main Road
Vasanthanagar
Bangalore-560052
India
Phone: +91-80-4113-8020
Fax: +91-80-4113-8023
e-mail: indiasales@power.com

ITALY
Via Milanese 20, 3rd. Fl.
20099 Sesto San Giovanni (MI) Italy
Phone: +39-024-550-8701
Fax: +39-028-928-6009
e-mail: eurosales@power.com

JAPAN
Kosei Dai-3 Building
2-12-11, Shin-Yokohama,
Kohoku-ku, Yokohama-shi,
Kanagawa 222-0033
Japan
Phone: +81-45-471-1021
Fax: +81-45-471-3717
e-mail: japansales@power.com

KOREA
RM 602, 6FL
Korea City Air Terminal B/D,
159-6
Samsung-Dong, Kangnam-Gu,
Seoul, 135-728 Korea
Phone: +82-2-2016-6610
Fax: +82-2-2016-6630
e-mail: koreasales@power.com

SINGAPORE
51 Newton Road,
#19-01/05 Goldhill Plaza
Singapore, 308900
Phone: +65-6358-2160
Fax: +65-6358-2015
e-mail: singaporesales@power.com

TAIWAN
5F, No. 318, Nei Hu Rd.,
Sec. 1
Nei Hu District
Taipei 11493, Taiwan R.O.C.
Phone: +886-2-2659-4570
Fax: +886-2-2659-4550
e-mail: taiwansales@power.com

UK
Cambridge Semiconductor,
a Power Integrations company
Westbrook Centre, Block 5,
2nd Floor
Milton Road
Cambridge CB4 1YG
Phone: +44 (0) 1223-446483
e-mail: eurosales@power.com