Design Example Report

Title	***10 W TRIAC Dimmable High Efficiency (>85%) Power Factor Corrected Buck-Boost LED Driver Using LYTSwitch™-3 LYT3316D***
Specification	90 VAC – 132 VAC Input; 36 V – 40 V, 260 mA_{TYP} Output
Application	Down Light
Author	Applications Engineering Department
Document Number	DER-500
Date	March 1, 2016
Revision	1.0

Summary and Features

- Single-stage power factor corrected, PF >0.9
- Accurate constant LED current (CC) regulation, ±5%
- Highly energy efficient, >85% at 115 V
- 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
- A-THD <10% at 120 VAC
- Meets IEC 2.5 kV ring wave, 1 kV differential surge
- Meets EN55015 conducted EMI with LED heat sink grounded

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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 TRIAC dimmable, non-isolated buck-boost LED driver designed to drive a nominal LED voltage string of 38 V at 260 mA from an input voltage range of 90 VAC to 132 VAC. The LED driver utilizes the LYT3316D from the LYTSwitch-3 family of devices.

The LYTswitch-3 is a TRIAC dimmable LED driver IC with a single stage PFC function and an accurate LED current control.

The DER-500 provides a single 10 W TRIAC dimmable constant current output. The key design goals were high efficiency, low component temperature and excellent dimming compatibility.

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

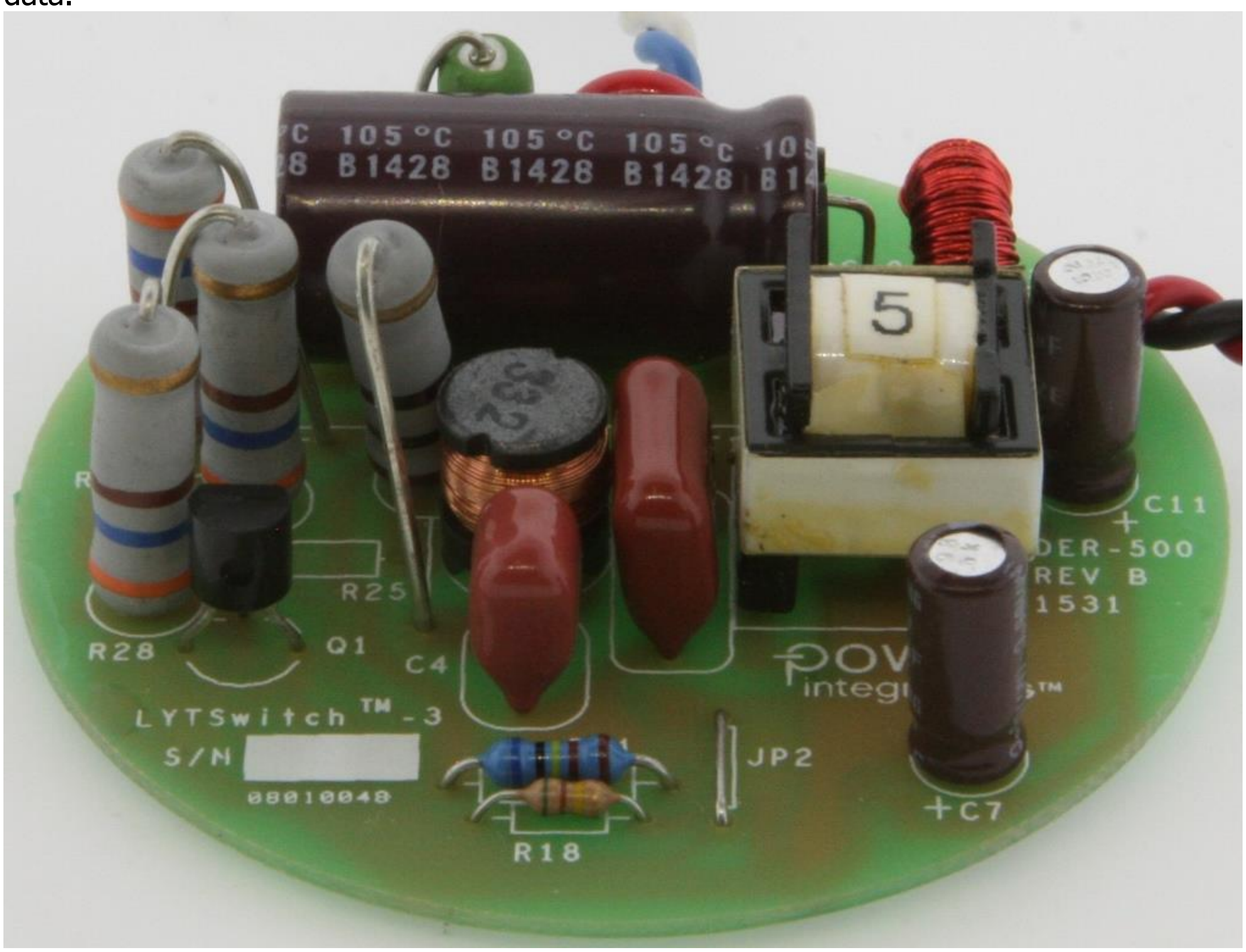

Figure 1 – Populated Circuit Board.

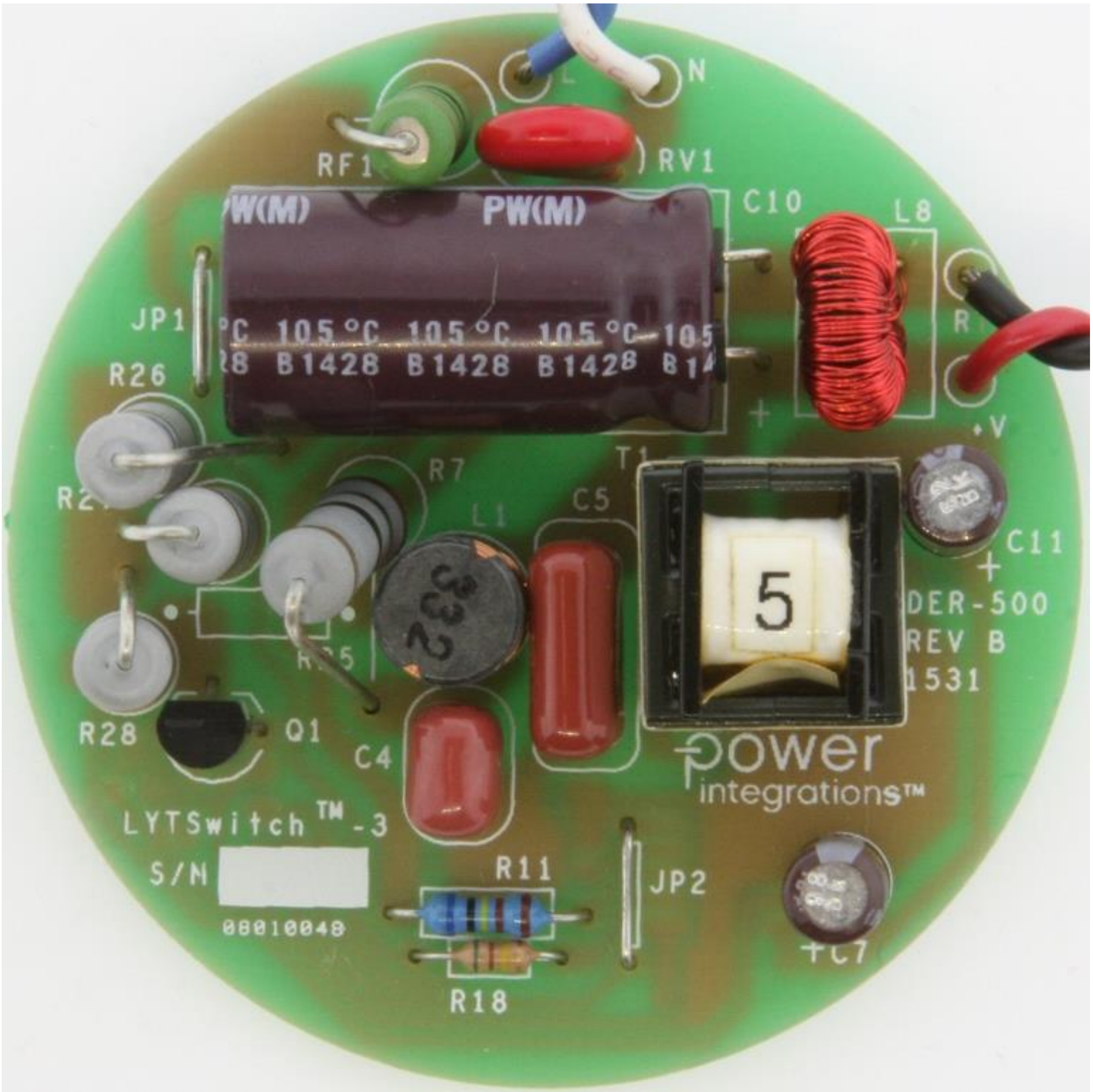

Figure 2 – Populated Circuit Board, Top View.

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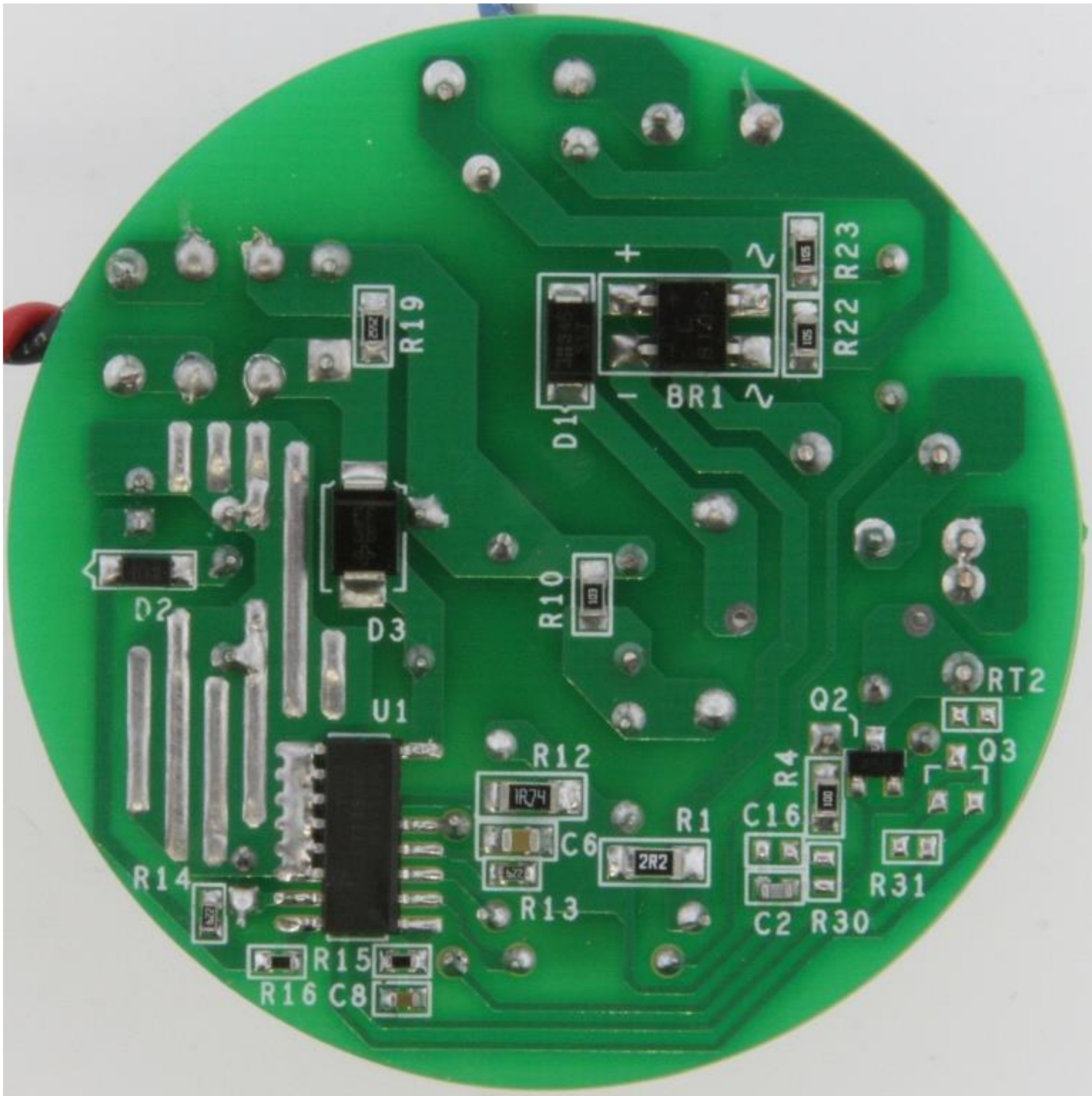

Figure 3 – Populated Circuit Board, Bottom View.

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}**	90	115	132	VAC	2 Wire – no P.E.
Frequency	**f_{LINE}**		50/60		Hz	
Output						
Output Voltage	**V_{OUT}**	36	38	40	V	
Output Current	**I_{OUT}**	247	260	273	mA	
Total Output Power						
Continuous Output Power	**P_{OUT}**		10		W	
Efficiency						
Full Load	η		85		%	Measured at 115 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 115 VAC, 60 Hz.
Ambient Temperature	**T_{AMB}**			40	°C	Free Convection, Sea Level.

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3 Schematic

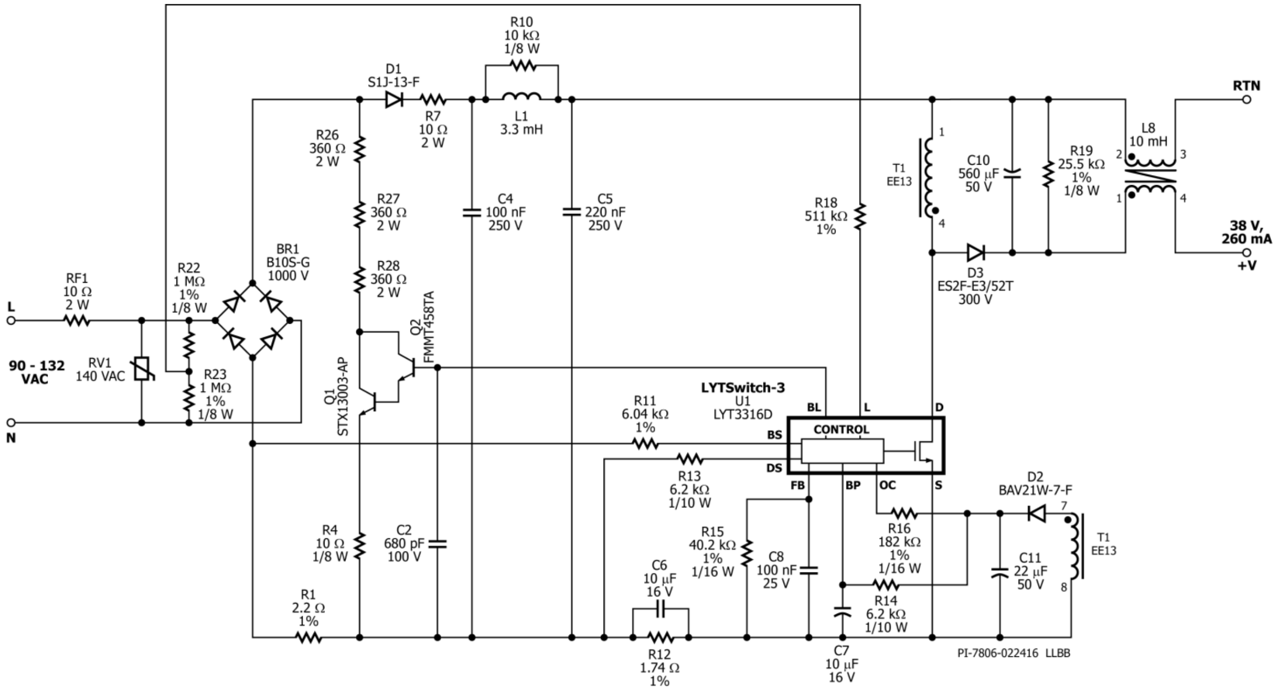

Figure 4 – Schematic.

4 Circuit Description

The LYTSwitch-3 LYT3316D combines a high-voltage power MOSFET switch with a power supply controller in a single package. The LYTswitch-3 controller provides single-stage power factor correction, LED current control and dimming control.

4.1 Input Stage

Fusible resistor RF1 provides protection against component failure. It also helps dampen the inrush current ringing during start-up and dimming operation. Varistor RV1 acts as a clamp to limit the maximum voltage spike on the primary during differential line surge events. A 140 VAC rated part was selected, being slightly above the maximum specified operating voltage (132 VAC).

The AC input is full wave rectified by BR1 to achieve good power factor and low THD.

4.2 EMI Filters

The differential choke L1, together with the input filter capacitor C4 and C5 work as an EMI π filter. Resistor R10 damps the LC resonances cause by filter components and the AC line impedance which would cause an increase in conducted EMI measurements. These EMI filters, together with the LYTSwitch-3 frequency jittering feature ensure compliance with the EN55015 Class B emission limit.

For a grounded LED heat sink requirement, a common mode choke (L8) is needed to suppress common mode noise current intensified by a grounded the systems LED load.

4.3 LYTSwitch-3 Primary Control Circuit

The topology is a buck-boost with a low-side switch. The primary winding finish terminal (no dot end) of the transformer (T1) is connected to the DC bus and the start (dotted end) terminal to the DRAIN (D) pin of the LYTSwitch-3 IC. During the on-time of the power MOSFET, current ramps through the primary winding, storing energy which is then delivered to the output load via output diode D3 during the power MOSFET off-time. Output capacitor C10 provides output voltage filtering minimizing the output LED ripple current.

Diode D2 and C11 generate a primary bias supply for U1 from an auxiliary winding on the transformer. The use of an external bias supply (via R14) is recommended to give the lowest device dissipation and provide sufficient supply to U1 during deep dimming condition.

Capacitor C7 provides local decoupling for the BYPASS (BP) pin of U1, which is the supply pin for the IC. During start-up, C7 is charged to ~5.25 V from an internal high-voltage current source connected to the D pin.

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To provide input line voltage information to U1, the input AC voltage is sense directly before the bridge rectifier diode through sampling resistors R22 and R23. The LINE-SENSE (L) pin current set through resistor R18 is use to activate input OVP functions, to detect the presence of dimmer and to control the output LED current with respect to line.

With reference to the FEEDBACK (FB) pin full conduction preset threshold of 300 mV, R12 senses the output LED current through U1 drain current and then fed into the U1 DRIVER CURRENT SENSE (DS) pin via R13 to maintain the output constant current regulation. The capacitor C10 provides voltage filtering to generate a DC reference voltage and to reduce ripple voltage spike that could mistrigger the bleeder drive. The FB pin threshold is reduced linearly with respect to input conduction angle.

IC U1 OUTPUT COMPENSATION (OC) pin senses the output voltage through R16 for the output OVP functions at open load and for optimized LED current regulation. Output OVP is activated with the IC latching off when the OC pin voltage exceeds the OV threshold.

4.4 TRIAC Phase Dimming Control with LYTSwitch-3 Smart Bleeder Drive

Due to the much lower power consumed by LED based lighting, the current drawn by the lamp is below the holding current of the TRIAC in many dimmers. This causes undesirable behavior such as limited dimming range and/or flicker. 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.

LYTSwitch-3 provides excellent dimming performance with its close loop smart bleeder to maintain the TRIAC holding current.

Transistor Q1, together with Q2 in Darlington connection, function as a high gain active bleeder switch. The active bleeder is modulated by the LYTSwitch-3 smart BLEEDER CONTROL (BL) pin in a close loop system through sensing the input voltage and current.

Resistor R4 and C2 work as a bleeder switch stabilizing network for a more optimized dimming performance.

Resistor R1 senses the overall input current and fed to U1 BLEEDER CURRENT SENSE (BS) pin through resistor R11. The overall current includes the active bleeder current and the U1 switch current. These current are sensed in order to keep the TRIAC current above its holding current level by modulating the bleeder dissipation in a closed loop system.

IC U1 BL pin drives the external bleeder switch in order to maintain the driver input current above the holding current of the TRIAC dimmer.

Fusible resistor RF1 and R7 dampens the driver input current ringing when TRIAC dimmer turns on. Diode D1 serves as a blocking diode to prevent current to be drawn from the input bulk capacitors C4 and C5 as the bleeder turns on.

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5 PCB Layout

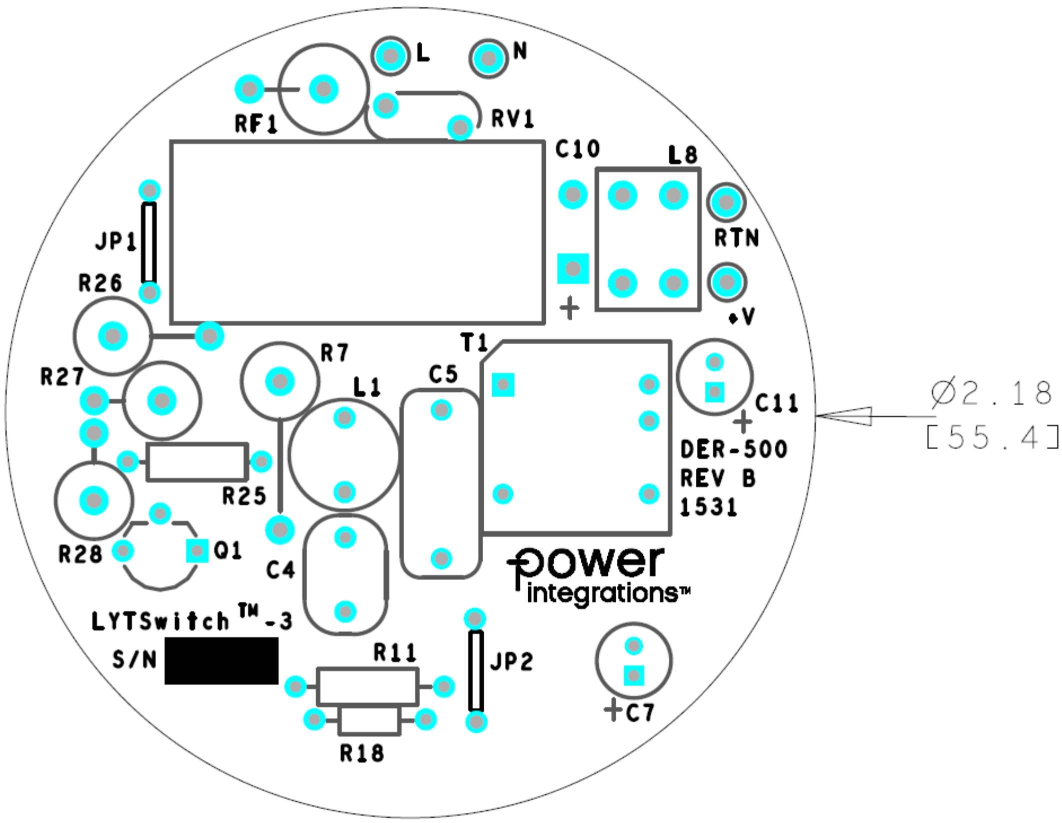

Figure 5 – Top Side.

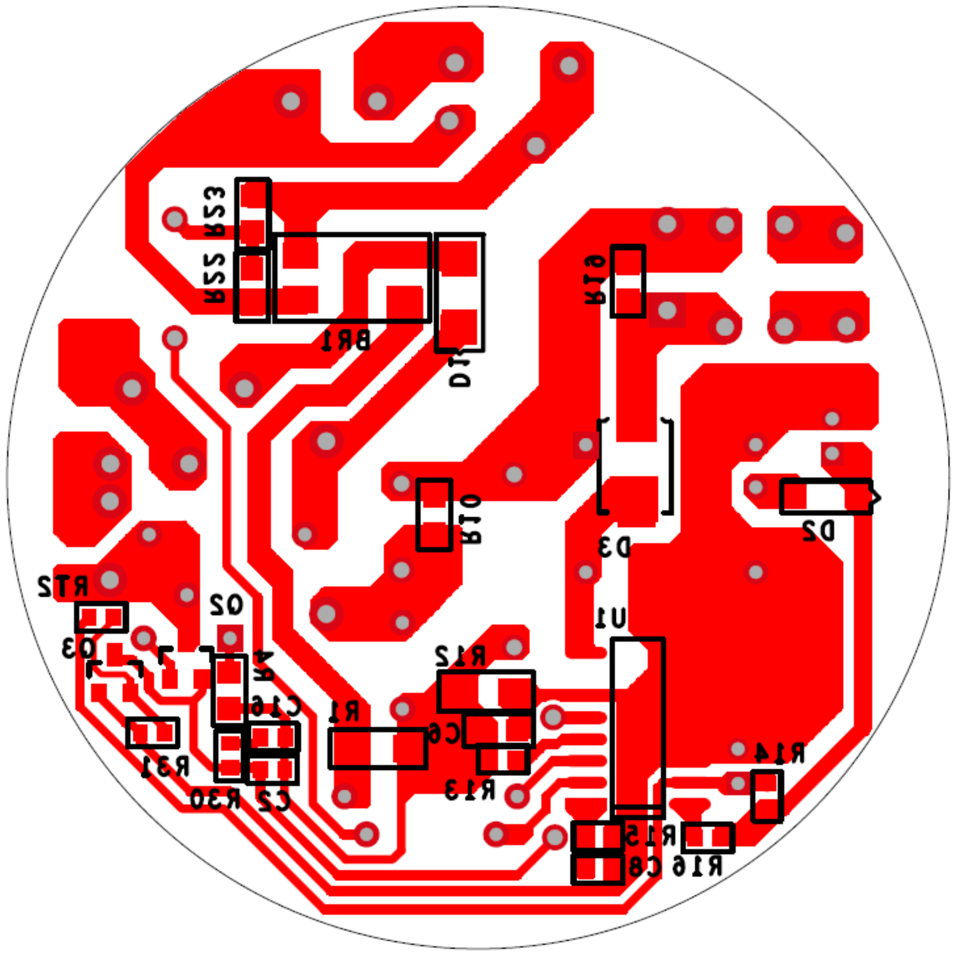

Figure 6 – Bottom Side.

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6 Bill of Materials

Item	Ref Des	Qty	Description	Mfg Part Number	Manufacturer
1	BR1	1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip
2	C2	1	680 pF 100 V, Ceramic, NPO, 0603	CGA3E2C0G2A681J	TDK
3	C4	1	100 nF, 250 V, Film	ECQ-E2104KB	Panasonic
4	C5	1	220 nF, 250 V, Film	ECQ-E2224KF	Panasonic
5	C6	1	10 μF, 16 V, Ceramic, X5R, 0805	GRM21BR61C106KE15L	Murata
6	C7	1	10 uF, 16 V, Electrolytic, Gen. Purpose, (5 x 11)	EKMG160ELL100ME11D	United Chemi-Con
7	C8	1	100 nF, 25 V, Ceramic, X7R, 0603	VJ0603Y104KNXAO	Vishay
8	C10	1	560 μF, 50 V, Electrolytic, Gen. Purpose, (12.5 x 25)	UPW1H561MHD	Nichicon
9	C11	1	22 μF, 50 V, Electrolytic, Very Low ESR, 340 mΩ, (5 x 11)	EKZE500ELL220ME11D	Nippon Chemi-Con
10	D1	1	600 V, 1 A, Standard Recovery, SMA	S1J-13-F	Diodes, Inc.
11	D2	1	250 V, 0.2 A, Fast Switching, 50 ns, SOD-123	BAV21W-7-F	Diodes, Inc.
12	D3	1	300 V, 2 A, Ultrafast Recovery, 50 ns, SMB Case	ES2F-E3/52T	Vishay
13	L1	1	3.3 mH, 0.15 A, Ferrite Core	CTCH895F-332K	CT Parts
14	L8	1	10 mH, Common mode choke, 0.415" OD, 9.53 mm O.D. x 4.75 mm I.D. x 3.18 mm L		
15	Q1	1	NPN, Power BJT, 400 V, 1 A, TO-92	STX13003-AP	ST Micro
16	Q2	1	NPN, HP, 400V, 225Ma, SOT23-3	FMMT458TA	Diodes-Zetex
17	R1	1	2.2 Ω, 1%, 1/4 W, Thick Film, 1206	RC1206FR-072R2L	Yago
18	R4	1	10 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ100V	Panasonic
19	R7	1	10 Ω, 5%, 2 W, Metal Oxide	RSF200JB-10R	Yageo
20	R10	1	10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
21	R11	1	6.04 k, 1%, 1/4 W, Metal Film	MFR-25FBF-6K04	Yageo
22	R12	1	1.74 Ω, 1%, 1/4 W, Thick Film, 1206	RC1206FR-071R74L	Yageo
23	R13	1	6.2 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ622V	Panasonic
24	R14	1	6.2 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ622V	Panasonic
25	R15	1	40.2 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF4022V	Panasonic
26	R16	1	182 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1823V	Panasonic
27	R18	1	RES, 510 k, 5%, 1/8 W, Carbon Film	CF18JT510K	Stackpole
28	R19	1	25.5 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF2552V	Panasonic
29	R22	1	1 MΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1004V	Panasonic
30	R23	1	1 MΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1004V	Panasonic
31	R26	1	360 Ω, 5%, 2 W, Metal Oxide	RSF200JB-360R	Yageo
32	R27	1	360 Ω, 5%, 2 W, Metal Oxide	RSF200JB-360R	Yageo
33	R28	1	360 Ω, 5%, 2 W, Metal Oxide	RSF200JB-360R	Yageo
34	RF1	1	10 Ω, 5%, 2 W, Wirewound, Fusible	FW20A10R0JA	Bourns
35	RV1	1	140 V, 12 J, 7 mm, RADIAL	V140LA2P	Littlefuse
36	T1	1	Bobbin, EE13, Horizontal, 8 pins		Janohig Electronic
37	U1	1	LYTSwitch-3, SO-16C	LYT3316D	Power Integrations

7 Inductor Specification

7.1 Electrical Diagram

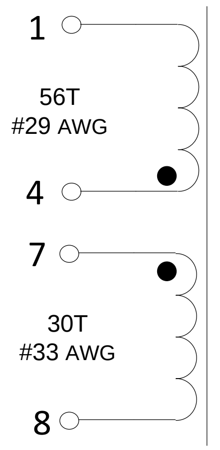

Figure 7 – Inductor Electrical Diagram.

7.2 Electrical Specifications

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V pk-pk, 100 kHz switching frequency, between pin 1 and pin 4, with all other windings open.	184 μH
Tolerance	Tolerance of Primary Inductance.	±5%

7.3 Materials List

Item	Description
[1]	Core: EE13.
[2]	Bobbin, EE13, Horizontal, 8 pins, Part No: 25-01017-00.
[3]	Magnet Wire: #29 AWG.
[4]	Magnet Wire: #33 AWG.
[5]	Transformer tape: 7.4 mm.
[6]	Transformer tape: 5.5 mm.

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7.4 Inductor Build Diagram

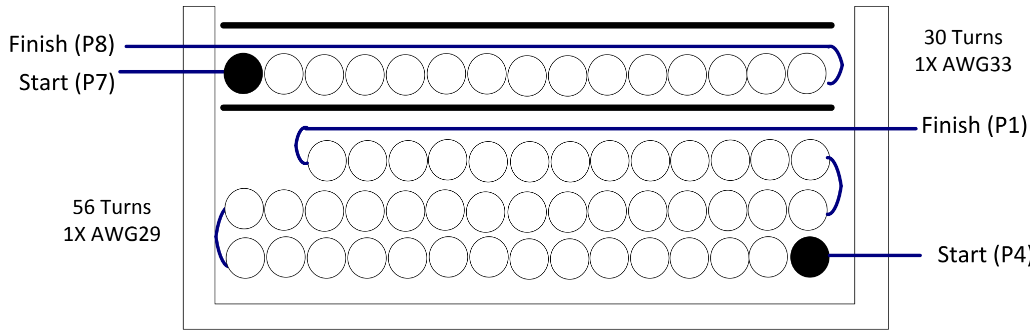
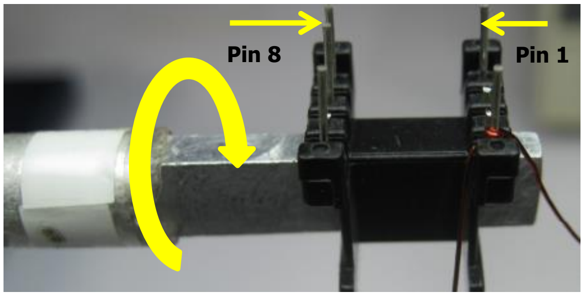
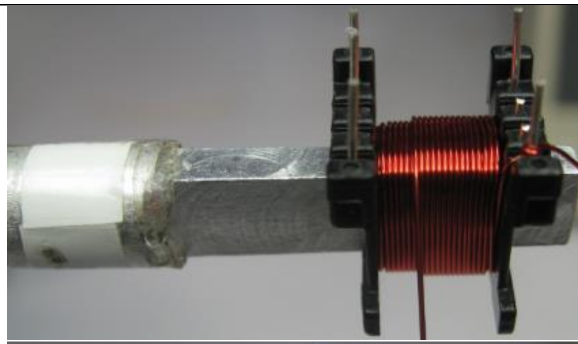
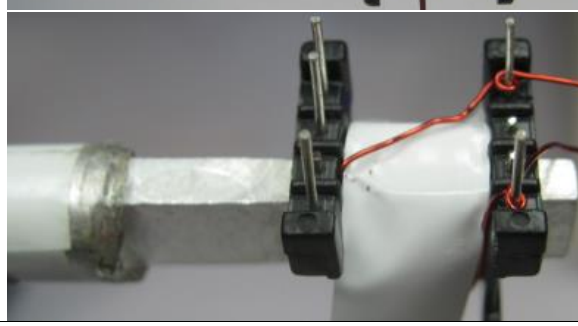
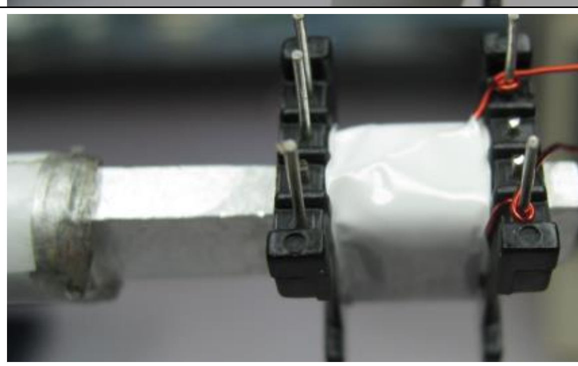


Figure 8 – Transformer Build Diagram.

7.5 Inductor Construction

Winding Directions	Bobbin is oriented on winder jig such that terminal Pin 1-4 is in the right side. The winding direction is clockwise.
Winding 1	Use wire item [3], start at pin 4 and wind 56 turns in 3 layers, then finish the winding on pin 1.
Insulation	Add 1 layer of tape, item [5], for insulation.
Winding 2	Use wire item [4], start at pin 7 and wind 30 turns from left to right, then finish the winding on pin 8.
Insulation	Add 1 layer of tape, item [5], for insulation.
Core Grinding	Grind the center leg of one core until it meets the nominal inductance of 184 μH.
Assemble Core	Assemble the 2 cores on the bobbin and wrap with 2 layer of tape, item (6).
Pins	Pull out terminal pin number 2, 3 and 6.
Finish	Dip the transformer assembly in varnish.

7.6 Transformer Illustrations

Winding Directions		Bobbin is oriented on winder jig such that terminal pin 1-4 is in the right side. The winding direction is clockwise.
Winding 1		Use wire item [3], start at pin 4 and wind 56 turns in 3 layers, then finish the winding on pin 1.
Insulation		Add 1 layer of tape, item [5], for insulation.

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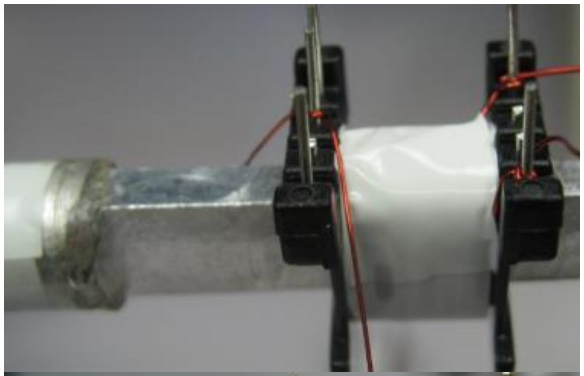
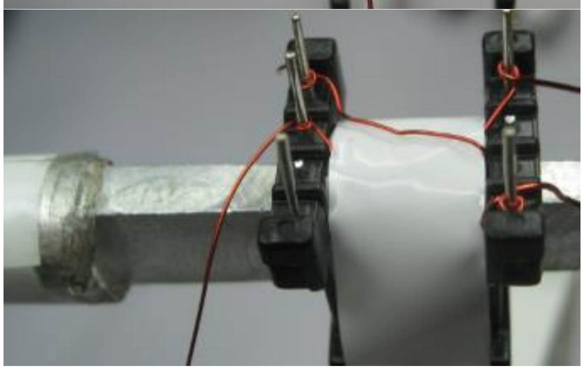
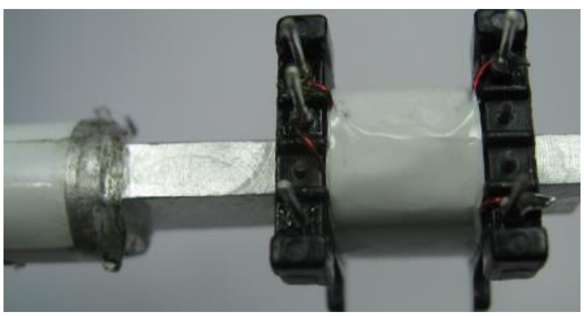
Winding 2	 	Use wire item [4], start at pin 7 and wind 30 turns from left to right, then finish the winding on pin 8.
Insulation		Add 1 layer of tape, item [5], for insulation.

8 Common Mode Choke Specification

8.1 Electrical Diagram

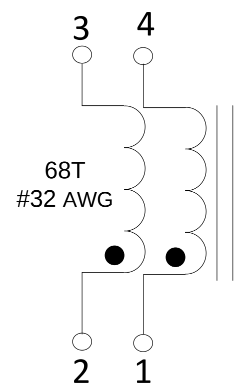


Figure 9 – Inductor Electrical Diagram.

8.2 Electrical Specifications

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V pk-pk, 100 kHz switching frequency, between pin 1 and pin 4 or pin 2 and pin 3 with all other windings open.	9.0-11.0 mH

8.3 Material List

Item	Description
[1]	Toroid Core: 32-00275-00.
[2]	Magnet Wire: #32 AWG.

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8.4 Inductor Build Diagram

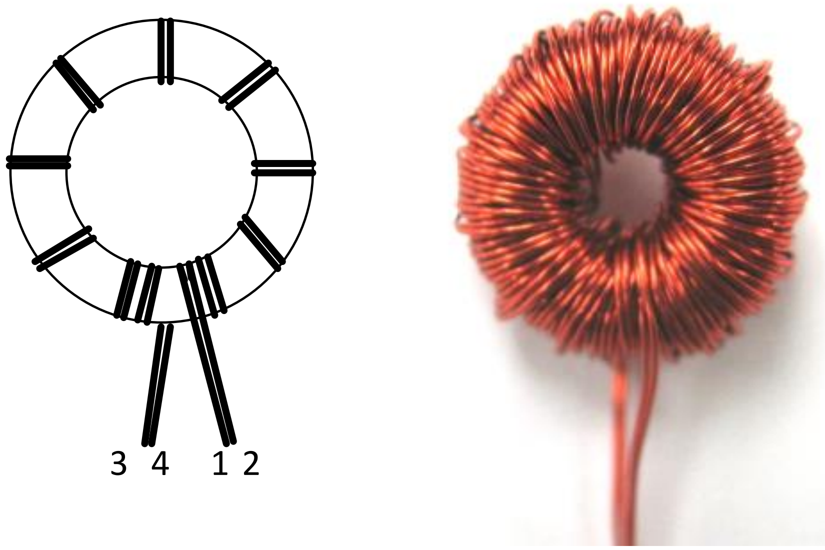

Figure 10 – Inductor Build Diagram.

8.5 Inductor Construction

Wind 68 turns of item 2 in bifilar as shown in above figure.

9 Inductor Design Spreadsheet

ACDC_LYTSwitch-3-Buck_040915; Rev.0.94; Copyright Power Integrations 2015	**INPUT**	**INFO**	**OUTPUT**	**UNIT**	**ACDC_LYTSwitch-3 Buck Design Spreadsheet**
ENTER APPLICATION VARIABLES					
VACMIN	90.00		90.00	V	Minimum AC Input Voltage
VACNOM			115.00	V	Typical AC Input Voltage
VACMAX	132.00		132.00	V	Maximum AC Input Voltage
FL			50.00	Hz	Minimum line frequency
VO_MIN			34.2	V	Guaranteed minimum VO that maintains output regulation
VO	38.0		38.0	V	Worst case normal operating output voltage
VO_OVP_MIN			47.2	V	Minimum Voltage at which output voltage protection may be activated
IO	260.0		260.0	mA	Average output current specification
n			0.85	%/100	Total power supply efficiency
Z			0.50		Loss allocation factor
PO			9.88	W	Total output power
VD			0.70	V	Output diode forward voltage drop
ENTER LYTSwitch-3 VARIABLES					
Select Breakdown Voltage	**650**		650	V	Choose between 650V and 725V
Device	**LYT33X6**		LYT33X6		Chosen LYTSwitch-3 Device
Final device code			**LYT3316**		
Select Dimming Curve Option	**1**		**1**		Dimming curve 1
RBS2			6.04	k-ohm	RBS2 resistor to select dimming curve
ILIMITMIN			1.769	A	Minimum device current limit
ILIMITTYP			1.902	A	Typical Current Limit
ILIMITMAX			2.035	A	Maximum Current Limit
TON			2.31	us	Expected on-time of MOSFET at low line and PO
FSW			120.0	kHz	Expected switching frequency at low line and PO
Duty Cycle			27.7	%	Expected operating duty cycle at low line and PO
IRMS			0.324	A	Nominal RMS current through the switch at low line
IPK			1.679	A	Worst Case Peak current
ENTER INDUCTOR CORE/CONSTRUCTION VARIABLES					
Core Type	**EE13**		EE13		Core Type
Core Part Number			PC40EE13-Z		If custom core is used - Enter part number here
Bobbin part number			BE-13		Bobbin Part number (if available)
AE			17.10	mm^2	Core Effective Cross Sectional Area
LE			30.20	mm	Core Effective Path Length
AL			1130	nH/T^2	Ungapped Core Effective Inductance
BW			7.40	mm	Bobbin Physical Winding Width
INDUCTOR DESIGN PARAMETERS					
LPMIN			173	uH	Minimum Inductance
LP	184		184	uH	Typical value of Primary Inductance
LP Tolerance	6.00		6	%	Tolerance of Primary Inductance
N			56	Turns	Number of Turns
ALG			59	nH/T^2	Gapped Core Effective Inductance
BM			3226	Gauss	Operating Flux Density. Maintain value below 3300 G
BP			4145	Gauss	Calculated Worst Case Peak Flux Density (BP < 4200 G)
BAC			1613	Gauss	Worst case AC Flux Density for Core Loss Curves (0.5 X

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					Peak to Peak)
LG			0.366	mm	Gap Length (Lg > 0.1 mm)
Layers			2.8		Estimated number of winding layers
IL_RMS			0.704	A	Worst case RMS Current through the inductor
AWG			28	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			161	Cmils	Bare conductor effective area in circular mils
CMA			229	Cmils/A	Primary Winding Current Capacity (200 < CMA < 500)
Current Density (J)			8.69	A/mm^2	Inductor Winding Current density (3.8 < J < 9.75 A/mm^2)
Bias Section					
TURNS_BIAS			30.00	Turns	Number of turns of Bias Winding
VBIAS			20.00	V	Bias Voltage. Check performance at minimum VO and maximum VAC.
PIVBS			120.01	V	Output Rectifier Maximum Peak Inverse Voltage (calculated at maximum VAC)
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			27.74	%	Duty cycle measured at minimum input voltage
IAVG			0.15	A	Input average current measured on the Mosfet at the minimum input voltage
IP			1.51	A	Peak Drain current at minimum input voltage
ISW_RMS			0.32	A	MOSFET RMS current measured at the minimum input voltage
ID_RMS			0.18	A	RMS current of freewheeling diode at minimum input voltage
IL_RMS			0.37	A	RMS current of the of the inductor at the minimum input voltage
FEEDBACK AND BYPASS PIN PARAMETERS					
n_MEASURED			0.85		Measured efficiency (this value is used for resistor calculations only)
VBIAS_MEASURED			20.00	V	Bias voltage (across the bias capacitor) measured on a prototype unit
VOUT_MEASURED			38.00	V	Load voltage measured on a prototype unit
RDS_T			1.7172	ohm	Theoretical calculation for RDS sense resistor
RDS			1.74	ohm	Rds resistor calculation assuming E96 / 1%
CDS			10.00	uF	Cds Capacitor Calculation
ROVP			182.00	k-ohm	OC pin resistor (E96 / 1%)
RL			2.00	M-ohm	L pin resistor (E96 / 1%)
RFB_T			39640.93	ohm	Calculated value of RFB, using RDS_T
RFB			39.20	k-ohm	Feedback pin resistor (E96 / 1%)
CFB_T			151.36	nF	Feedback pin capacitor (for 6ms time constant)
CFB			150	nF	Feedback pin capacitor E12 standard value
RSUP			13.80	k-ohm	Bias supply resistor assuming 1mA current necessary to supply BP
VOLTAGE STRESS PARAMETERS					
VDRAIN			265	V	Estimated worst case drain voltage at VACMAX and VO_MAX
PIVD			258.1	V	Peak Inverse Voltage at VO_MAX on output diode
BLEEDER COMPONENTS					
I_HOLD			40.00	mA	Required bleeder holding current
RBS1			3.00	Ohm	Exact value of RBS1 resistor

10 Performance Data

All measurements were performed at room temperature using LED loads string. 30 minutes soak time was applied before measurement with AC Source turned-off for 3 seconds every succeeding input line measurement.

10.1 Efficiency

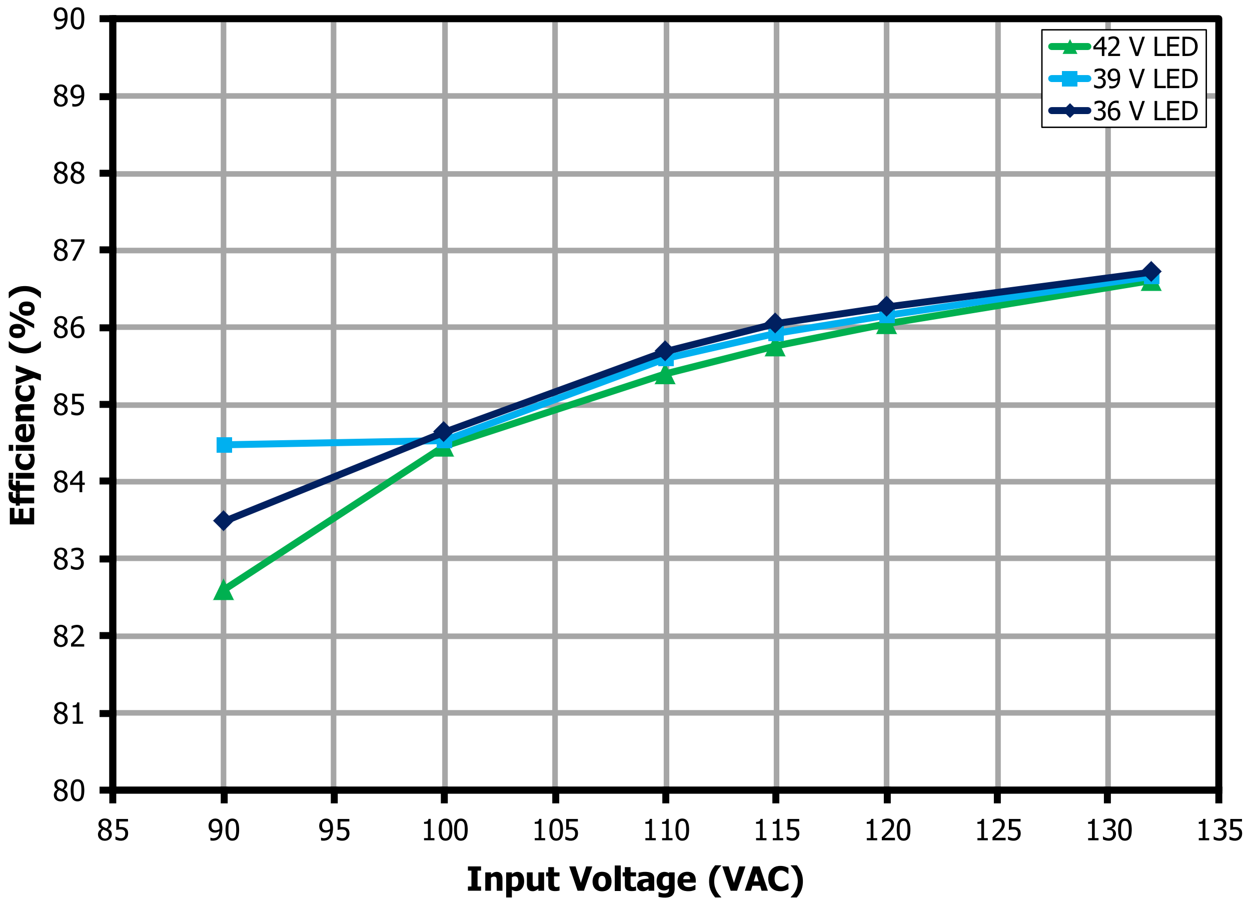

Figure 11 – Efficiency vs. Line and LED Load.

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10.2 Line Regulation

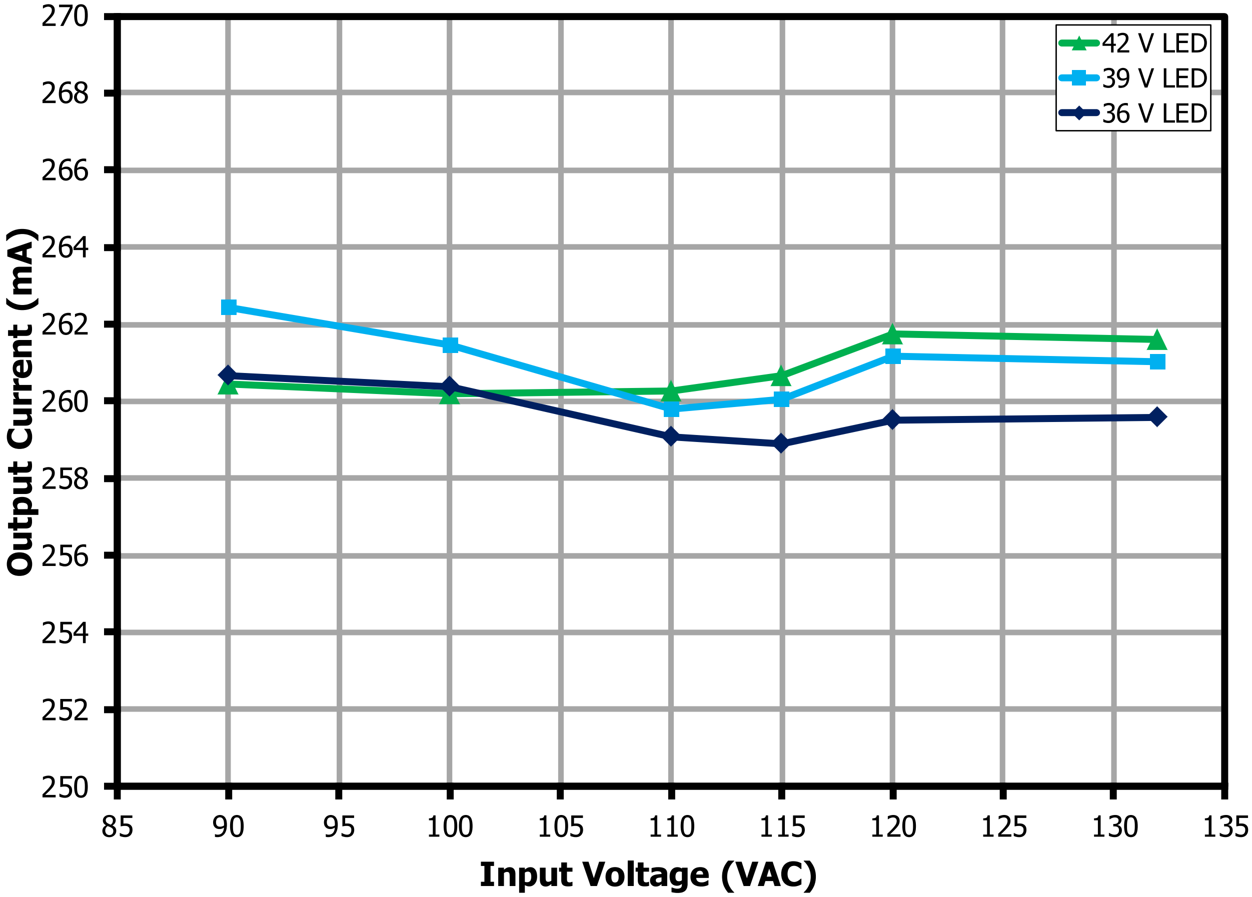

Figure 12 – Regulation vs. Line and LED Load.

10.3 Power Factor

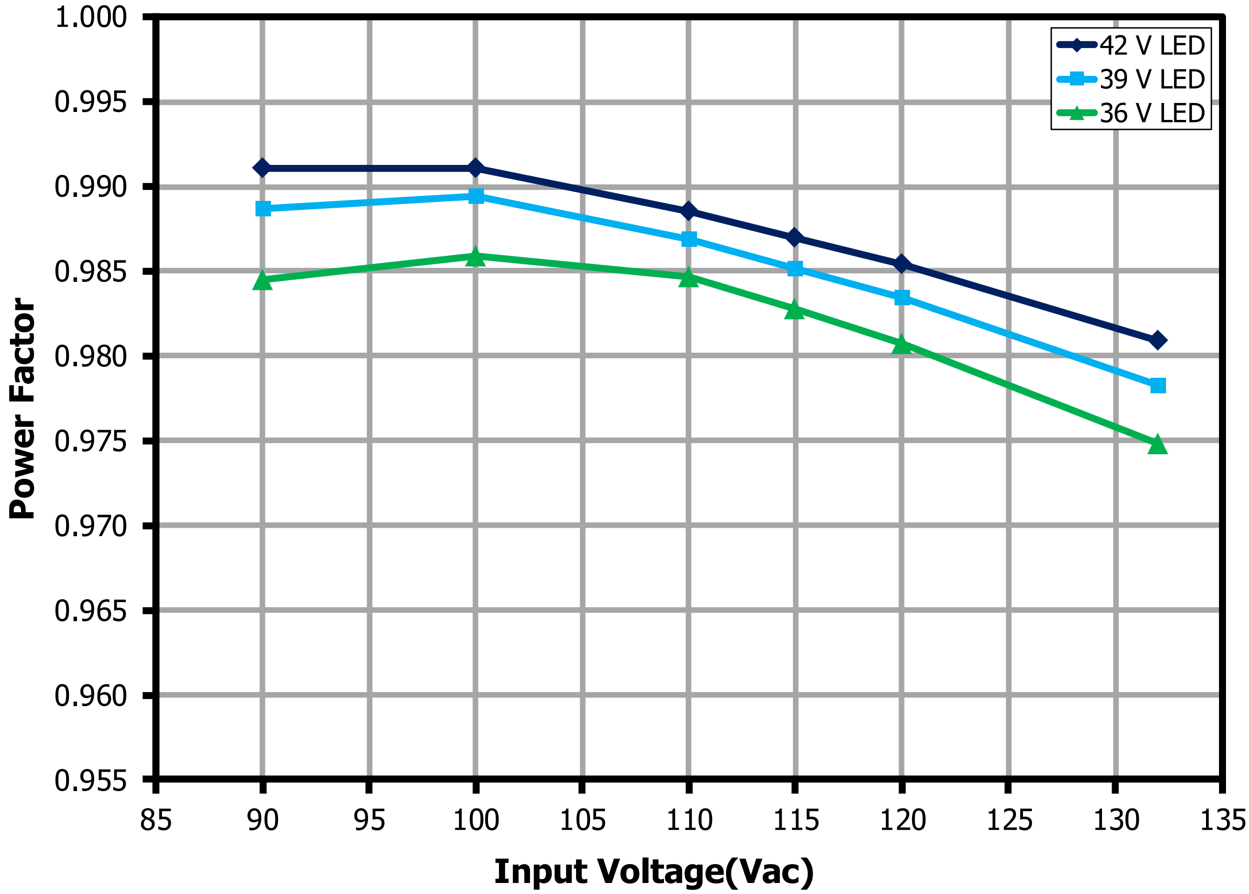

Figure 13 – Power Factor vs. Line and LED Load.

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10.4 %ATHD

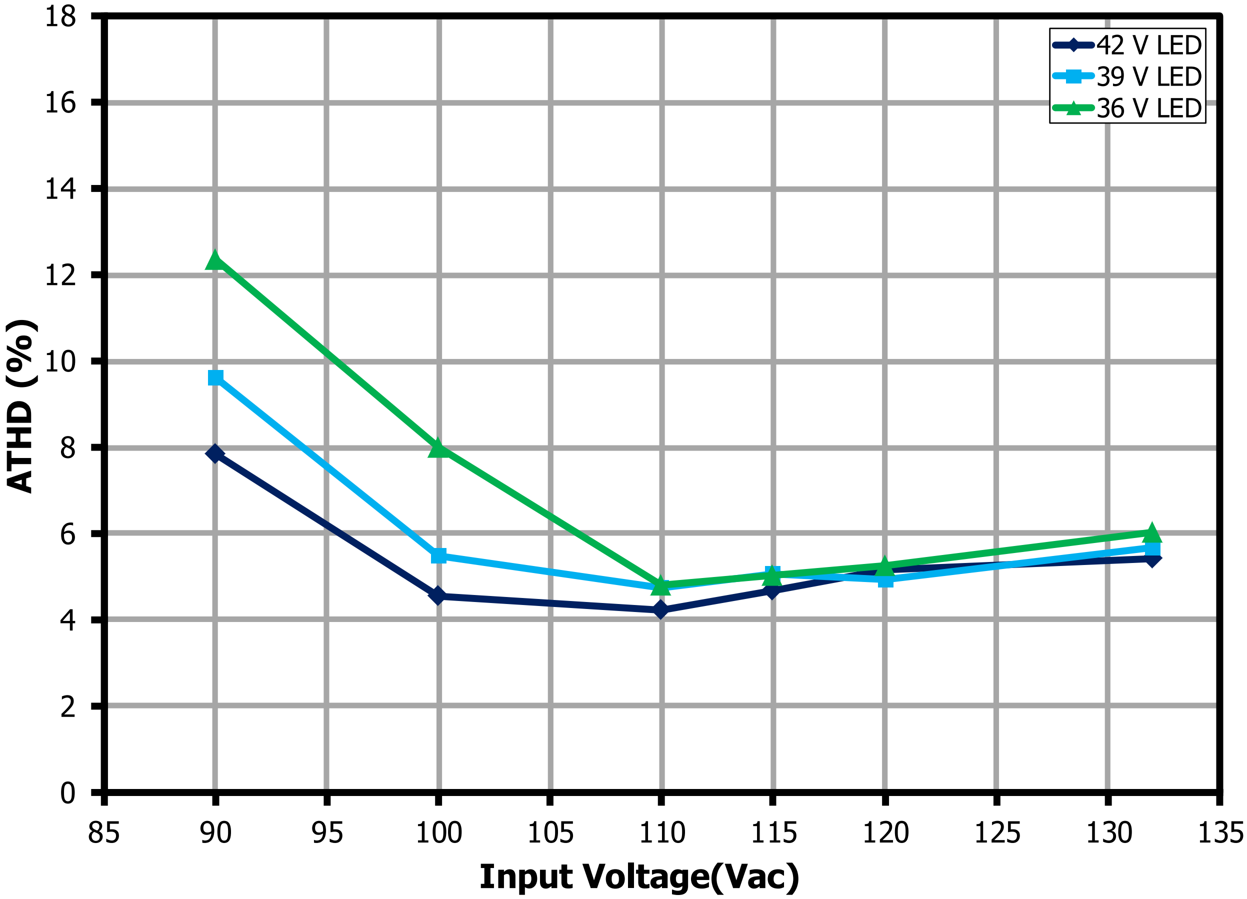

Figure 14 – %ATHD vs. Line and LED Load at 120 VAC, 60 Hz.

10.5 Harmonics

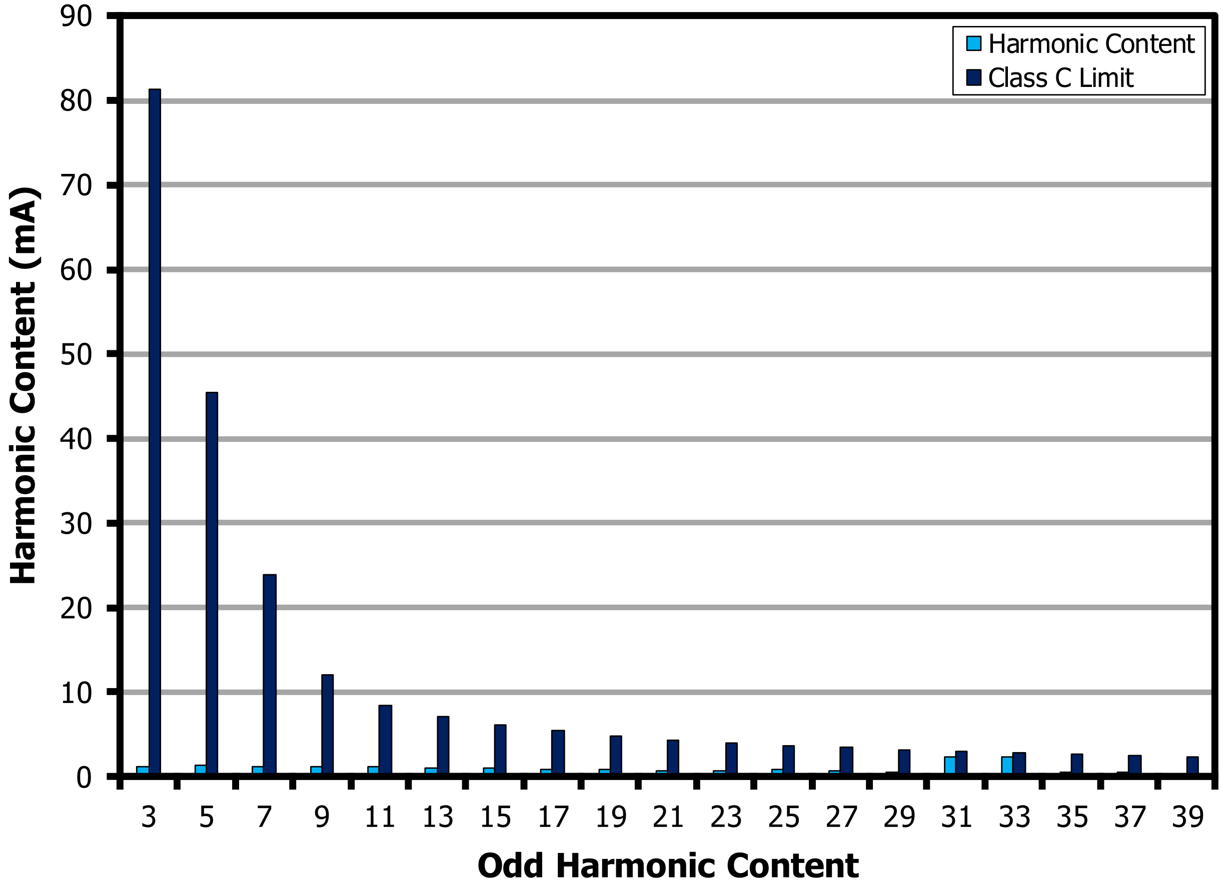

Figure 15 – 39 V LED Load Input Current Harmonics at 120 VAC, 60 Hz.

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11 Test Data

11.1 Test Data, 42 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)	
90	60	89.85	149.34	13.30	0.991	7.85	42.07	260.46	10.98	82.59
100	60	99.88	131.17	12.98	0.991	4.55	42.06	260.18	10.97	84.46
110	60	109.90	118.17	12.84	0.989	4.22	42.04	260.26	10.97	85.40
115	60	114.87	112.91	12.80	0.987	4.68	42.03	260.67	10.98	85.77
120	60	119.93	108.40	12.81	0.985	5.17	42.03	261.75	11.02	86.05
132	60	131.92	98.30	12.72	0.981	5.43	42.02	261.59	11.02	86.60

11.2 Test Data, 39 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)	
90	60	89.86	137.97	12.26	0.989	9.60	39.36	262.44	10.36	84.48
100	60	99.88	123.36	12.19	0.989	5.49	39.32	261.47	10.31	84.54
110	60	109.91	110.17	11.95	0.987	4.75	39.29	259.80	10.23	85.61
115	60	114.88	105.25	11.91	0.985	5.07	39.27	260.05	10.24	85.93
120	60	119.93	101.14	11.93	0.983	4.94	39.26	261.18	10.28	86.17
132	60	131.92	91.82	11.85	0.978	5.67	39.25	261.04	10.27	86.66

11.3 Test Data, 36 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)	
90	60	89.86	128.93	11.41	0.985	12.36	36.42	260.65	9.52	83.48
100	60	99.89	114.05	11.23	0.986	8.02	36.41	260.36	9.51	84.65
110	60	109.92	101.95	11.03	0.985	4.80	36.40	259.07	9.45	85.68
115	60	114.89	97.22	10.98	0.983	5.04	36.39	258.89	9.45	86.04
120	60	119.94	93.31	10.98	0.981	5.26	36.39	259.52	9.47	86.26
132	60	131.93	84.90	10.92	0.975	6.04	36.38	259.58	9.47	86.72

11.4 Test Data, Harmonic Content at 120 VAC with 39 V LED Load

V_{IN} (V_{RMS})	Freq	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%THD
120	60	101.47	11.970	0.984	3.983
nth Order	**mA Content**	**% Content**	**mA Limit <25 W**	**% Limit >25 W**	**Remarks**
1	100.34				
2	0.12	0.12%		2.00%	Pass
3	1.13	1.13%	81.40	29.51%	Pass
5	1.30	1.30%	45.49	10.00%	Pass
7	1.14	1.14%	23.94	7.00%	Pass
9	1.17	1.17%	11.97	5.00%	Pass
11	1.12	1.12%	8.38	3.00%	Pass
13	0.95	0.95%	7.09	3.00%	Pass
15	0.99	0.99%	6.14	3.00%	Pass
17	0.86	0.86%	5.42	3.00%	Pass
19	0.80	0.80%	4.85	3.00%	Pass
21	0.76	0.76%	4.39	3.00%	Pass
23	0.76	0.76%	4.01	3.00%	Pass
25	0.89	0.89%	3.69	3.00%	Pass
27	0.65	0.65%	3.41	3.00%	Pass
29	0.52	0.52%	3.18	3.00%	Pass
31	2.37	2.36%	2.97	3.00%	Pass
33	2.28	2.27%	2.79	3.00%	Pass
35	0.45	0.45%	2.63	3.00%	Pass
37	0.44	0.44%	2.49	3.00%	Pass
39	0.22	0.22%	2.36	3.00%	Pass

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12 Dimming Performance Data

TRIAC dimming results were taken at an input voltage of 120 VAC, 60 Hz line frequency, room temperature, and a nominal 39 V LED load.

12.1 Dimming Curve

Agilent 6812B AC source programmed as perfect leading edge dimmer.

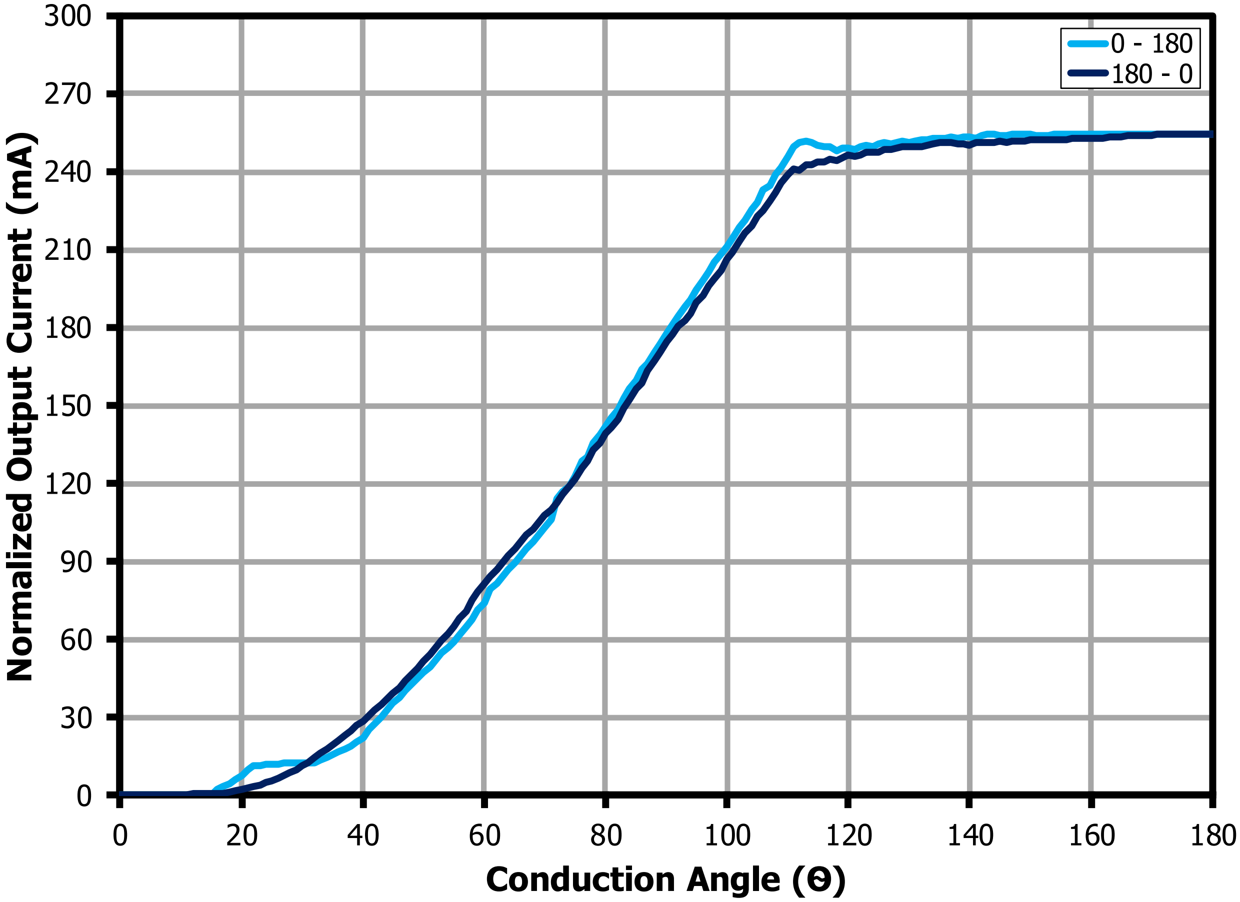

Figure 16 – Dimming Curve at 120 VAC, 60 Hz Input.

12.2 Dimming Efficiency

Measurements were made using a programmable AC source to provide the leading edge chopped AC input. For this test, the bleeder is already active.

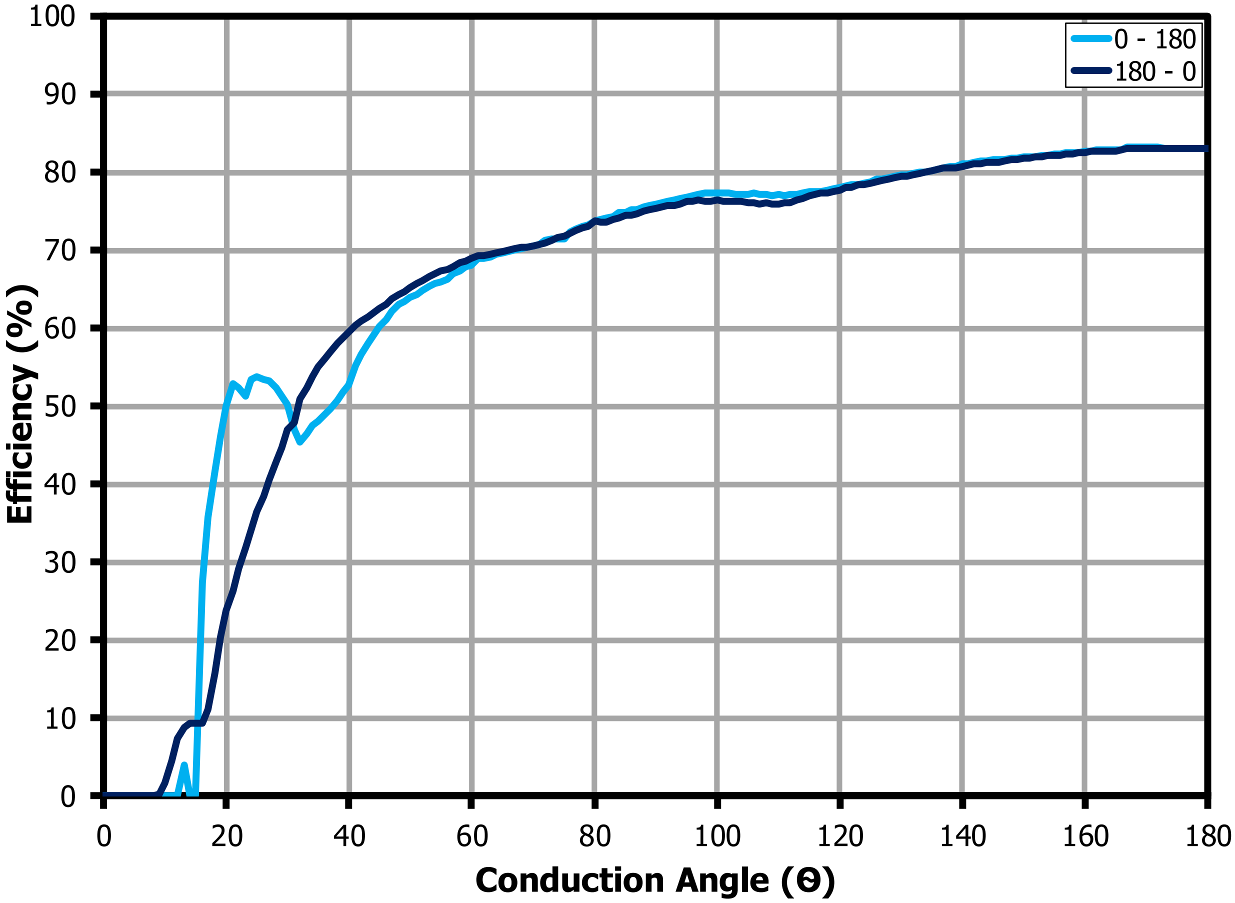

Figure 17 – Driver Efficiency at 120 VAC, 60 Hz Input.

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12.3 Driver Power Loss During Dimming

Measurements were made using a programmable AC source to provide the leading edge chopped AC input. For this test, the bleeder is already active.

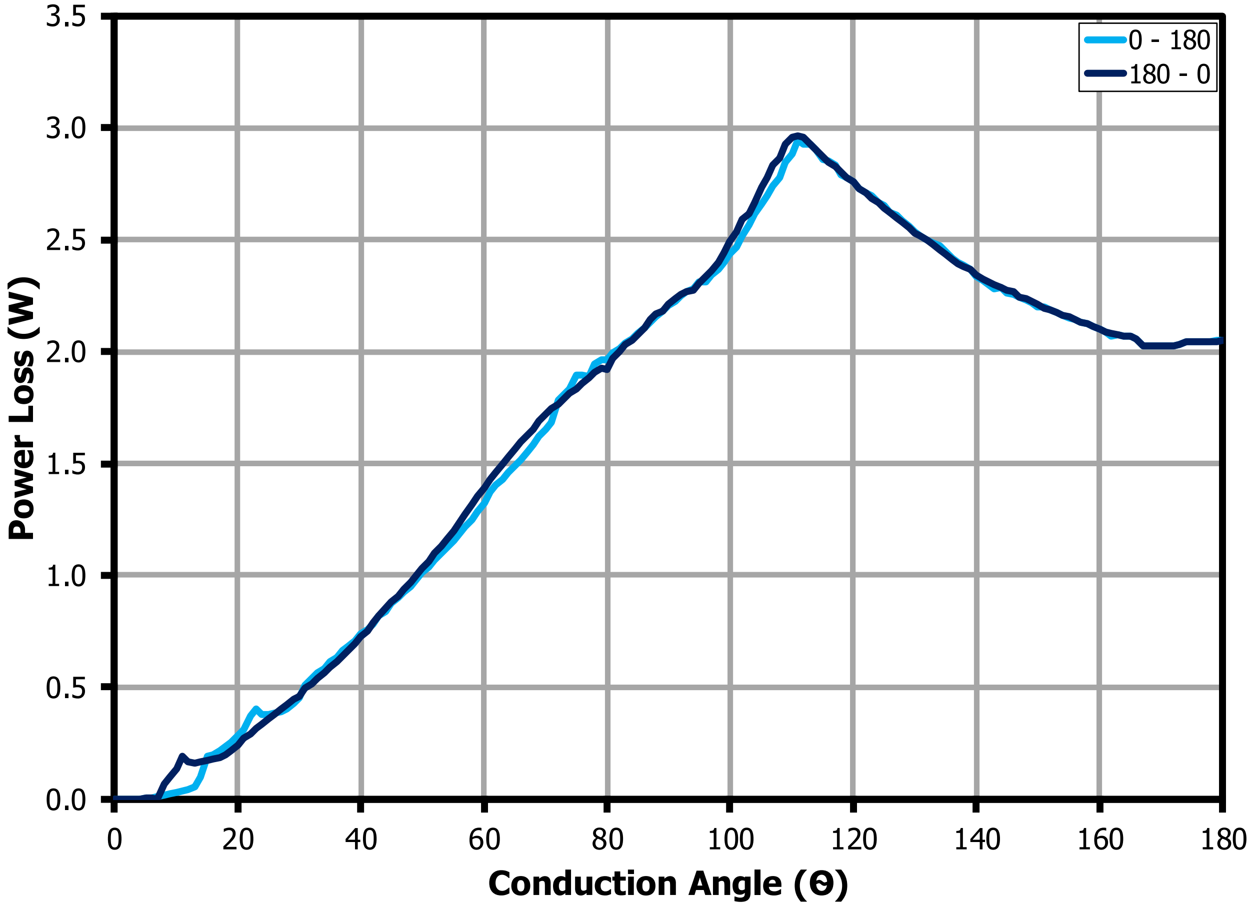

Figure 18 – Driver Power Loss at 120 VAC, 60 Hz Input.

12.4 Driver Compatibility List

The following dimmers were tested at 25 ºC and 40 ºC ambient temperature with utility line input (120 VAC, 60 Hz) and 39 V System LED Load.

No	Panel	Brand	Model	Type	Max (mA)	Min (mA)
1	US Panel 9	LEGRAND	HCL453PTCCCV6	L	263	71.8
2	US Panel 9	LEGRAND	H703PTCCCV6	L	263	2.68
3	US Panel 9	LEGRAND	H1103PTCCCV6	L	263	2.98
4	US Panel 9	LEVITON	1PE04-1LZ	T	268	30
5	US Panel 9	LEVITON	1PM10-1LZ	L	259	53
6	US Panel 9	LUTRON	AYCL-153P-WH	L	263	21
7	US Panel 9	LUTRON	SCL-153P-WH	L	261	22
8	US Panel 9	LUTRON	RRD-10ND-WH	L	264	9
9	US Panel 9	LUTRON	RRD-6NA-WH	T	272	6.3
10	US Panel 9	LEVITON	VPM10-1LZ	L	264	21
11	US Panel 10	LUTRON	N-600-WH	L	263	11.85
12	US Panel 10	LUTRON	NTELV-600-WH	T	276	12.62
13	US Panel 10	LUTRON	NT-603P-WH	L	263	16
14	US Panel 10	LEVITON	1PSD6-1LZ	L	260	34
15	US Panel 10	LEVITON	1PVD6-1LZ	L	260	25
16	US Panel 10	LEVITON	1PL06-10Z	L	263	23
17	US Panel 10	LEVITON	6672	L	261	45
18	US Panel 11	LEVITON	6674	L	263	26
19	US Panel 11	LEGRAND	HLV703PW	L	261.5	36
20	US Panel 11	LEVITON	6641	L	260	7
21	US Panel 11	LEVITON	6602	L	263	8
22	US Panel 11	LEVITON	TBL03	L	263	32
23	US Panel 11	LEVITON	6615	T	265	44
24	US Panel 11	LUTRON	CTCL-153P-WH	L	262	22
25	US Panel 1	COOPER	R106PL-W-K	L	262	40
26	US Panel 1	LEVITON	9530WS-K	L	261	19
27	US Panel 1	LEVITON	601-6631-1	L	264	0.2
28	US Panel 1	LEVITON	AT106-1LA	L	261	20
29	US Panel 1	LEVITON	6683	L	263	56
30	US Panel 1	LEVITON	1P106-1LZ	L	261	24
31	US Panel 1	LEVITON	6681	L	263	3
32	US Panel 1	LEVITON	6633_PLW	L	263	6.5
33	US Panel 2	G.E.	18023	L	263	3
34	US Panel 2	G.E.	18022	L	262	13
35	US Panel 2	LUTRON	MRF2-6ND-120-BI	L	263	9
36	US Panel 2	LUTRON	RRD-6NA-WH	T	270	15
37	US Panel 2	LUTRON	D-600P-WH	L	264	3
38	US Panel 2	LUTRON	DVCL-153P-WH	L	264	26
39	US Panel 2	LUTRON	AY-600PNL-WH	L	263	18
40	US Panel 4	LUTRON	LGCL-153PLH-WH	L	261	25
41	US Panel 4	LEVITON	6681	L	258	22
42	US Panel 4	LUTRON	S-600P-WH	L	264	2.3
43	US Panel 4	LUTRON	MACL-753-WH	L	260	24
44	US Panel 3	LUTRON	S-600P-WH	L	261	49
45	US Panel 3	LUTRON	MA-600-WH	L	261	8
46	US Panel 3	LUTRON	LXELV-600PL-WH	T	217	14
47	US Panel 3	LUTRON	NTELV-300-WH	T	228	6
48	US Panel 3	LUTRON	NT-600-WH	L	261	75
49	US Panel 3	LUTRON	DVELV-300P-WH	T	233	13
50	US Panel 3	LUTRON	SELV-300P-WH	T	224	13
51	US Panel 3	LUTRON	CTCL-153P-WH	L	261	22

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13 Thermal Performance

Thermal measurements were performed with the power supply operating at 40 ºC room temperature with a 39 V system LED load.

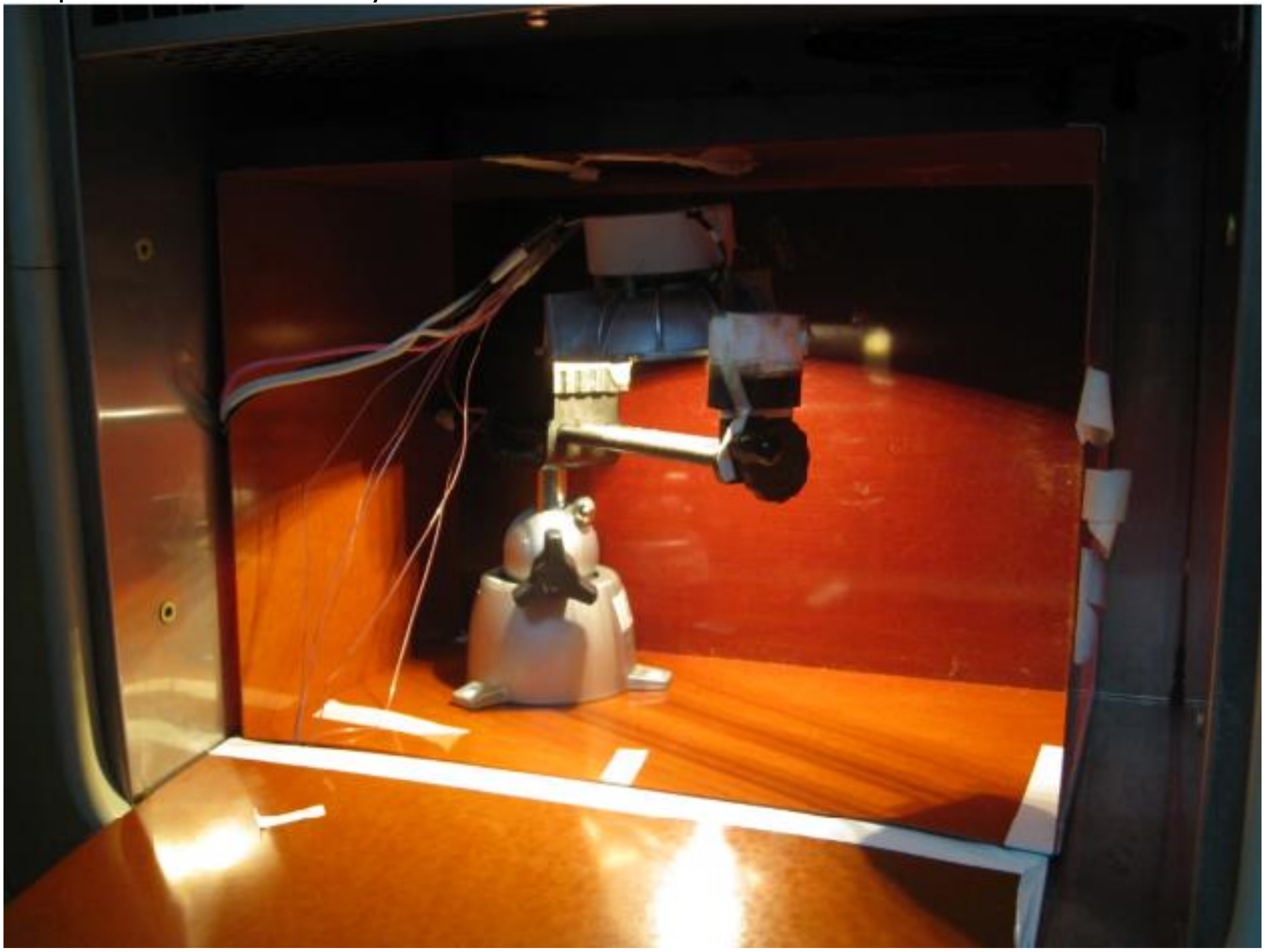

Figure 19 – Set-up Picture.

Unit was placed inside enclosure to prevent airflow. Chamber temperature set at 40 ºC. Thermocouple probe place inside the enclosure 3 inches away from the LED bulb.

13.1 Non-Dimming Thermal Performance at 90 VAC with a 39 V LED Load

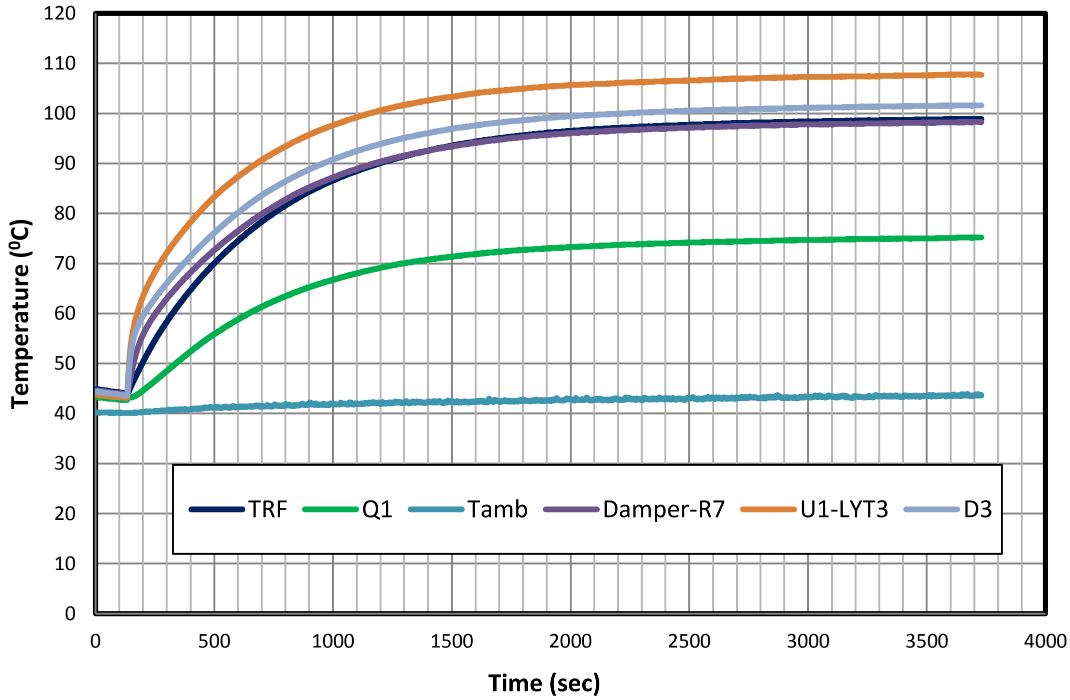

Figure 20 – Component Temperature at 90 VAC, 40 ºC Ambient.

Thermal Measurement (ºC)	Transformer	Q1	Damper (R7)	Ambient	LYTSwitch-3 (U1)	D3
Maximum	98.9	75.2	98.3	43.9	107.8	101.6
Normalized	98.9	75.2	98.3	43.6	107.7	101.6

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13.2 Non-Dimming Thermal Performance at 132 VAC with a 39 V LED Load

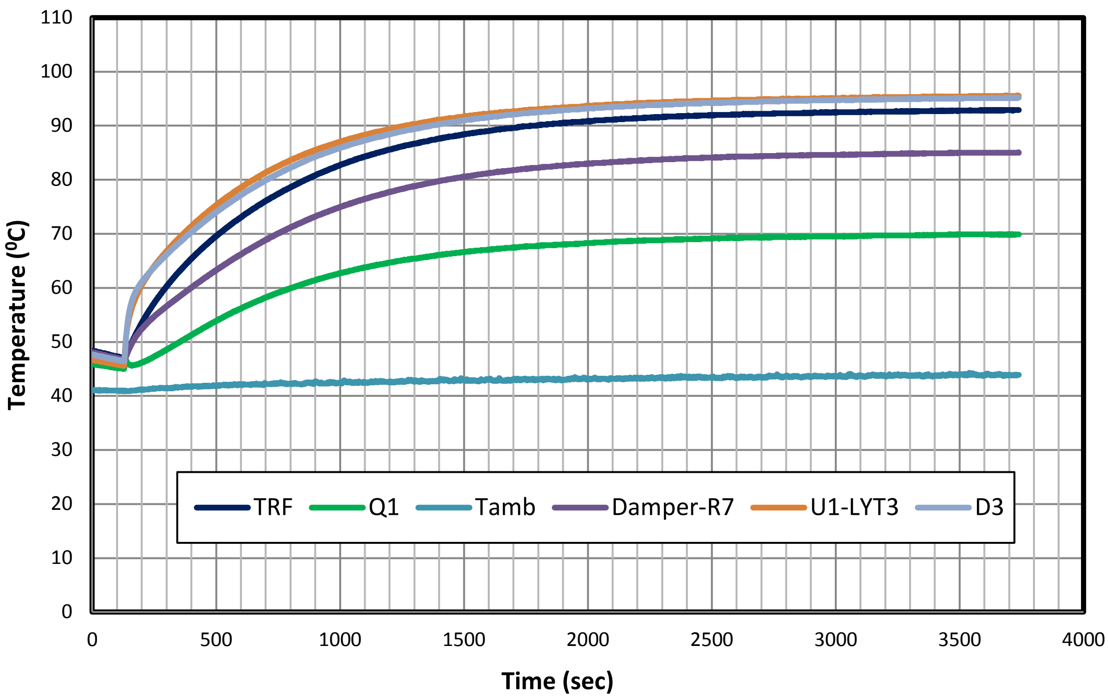
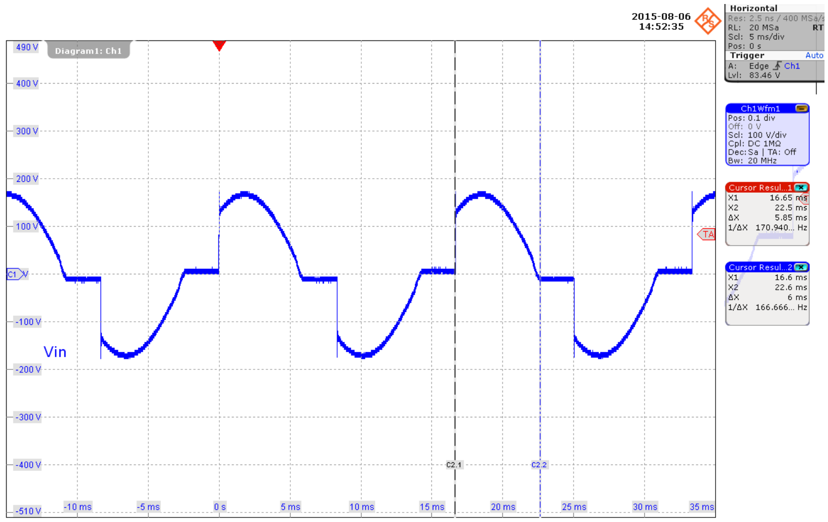


Figure 21 – Component Temperature at 132 VAC, 40 ºC Ambient.

Thermal Measurement (ºC)	Transformer	Q1	Damper (R7)	Ambient	LYTSwitch-3 (U1)	D3
Maximum	92.9	69.9	85.1	44.3	95.6	95.2
Normalized	92.9	69.9	85.0	43.9	95.5	95.2

13.3 Dimming Thermal Performance at 120 VAC, 130º Conduction Angle



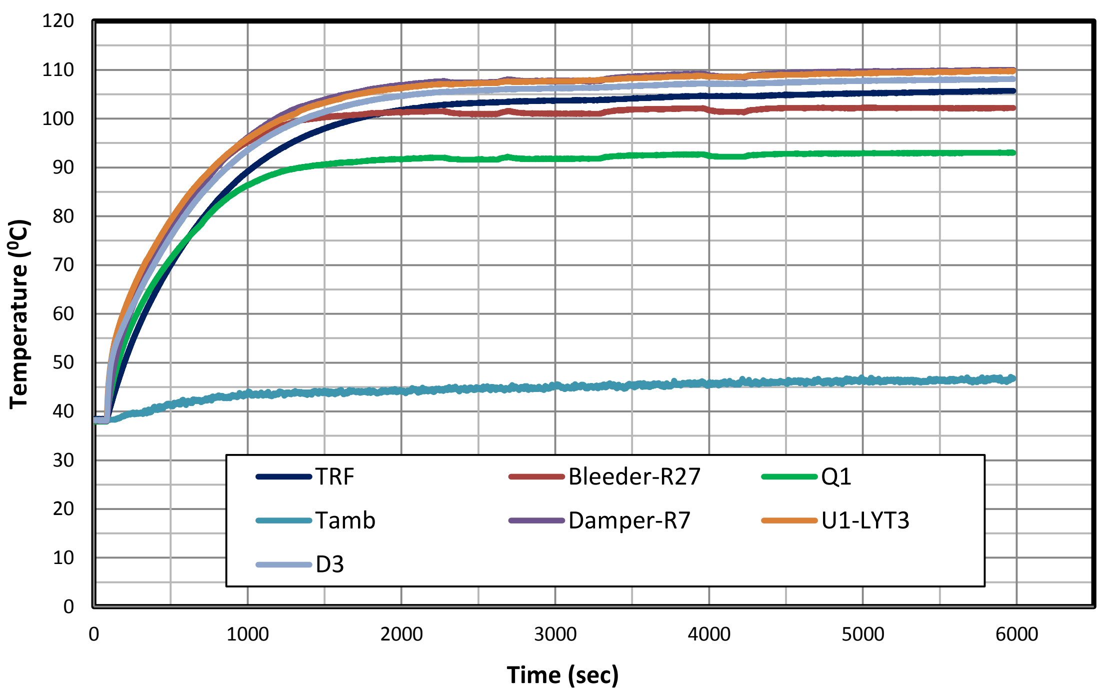


Figure 22 – Component Temperature at 120 VAC, 130º Conduction Angle, 40 ºC Ambient.

Thermal Measurement (ºC)	Transformer	Bleeder (R27)	Q1	Damper-R7	Ambient	LYTSwitch-3 (U1)	D3
Maximum	105.7	102.3	93.1	110.0	47.1	109.8	108.2
Normalized	105.7	102.2	93.0	110.0	46.8	109.8	108.1

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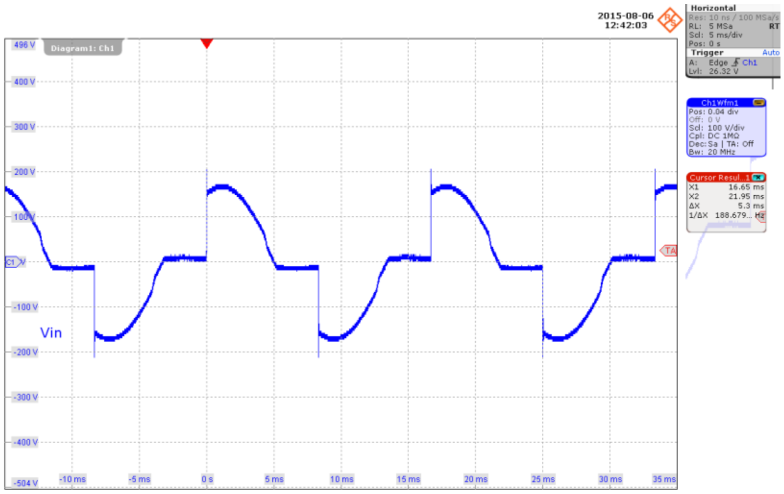
13.4 Dimming Thermal Performance at 120 VAC, 115º Conduction Angle



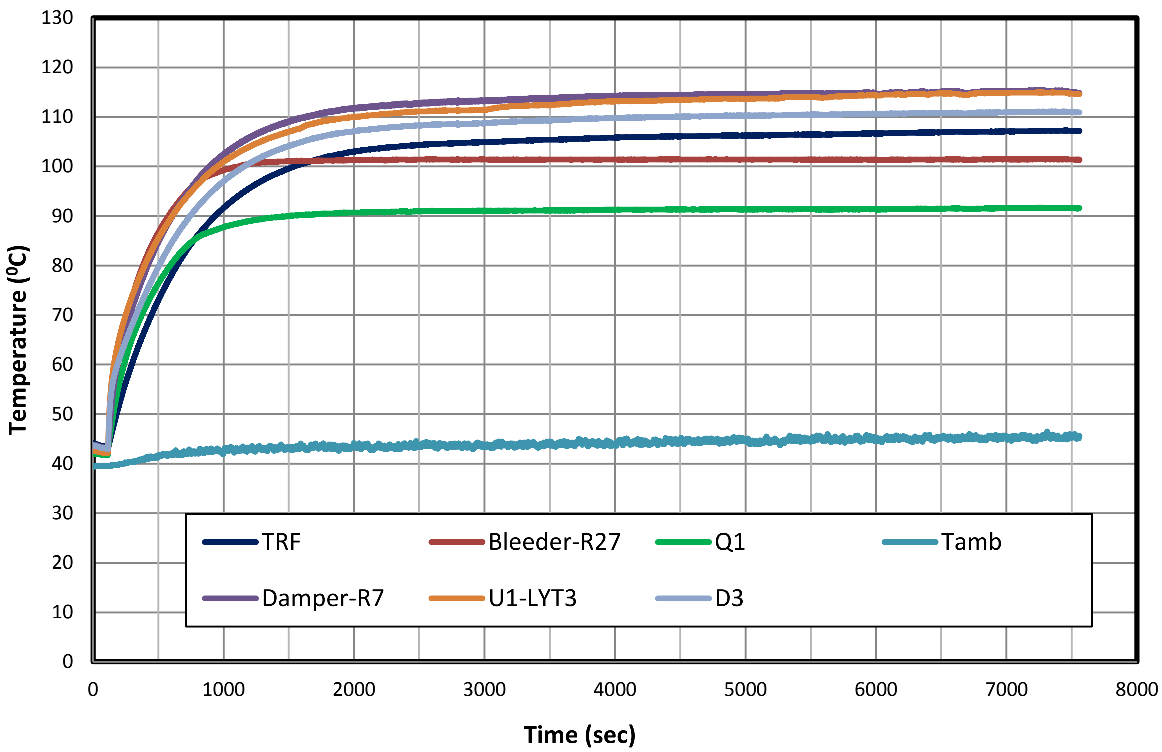


Figure 23 – Component Temperature at 120 VAC, 115° Conduction Angle, 40 ºC Ambient.

Thermal Measurement (ºC)	Transformer	Bleeder-R27	Q1	Damper (R7)	Ambient	LYTSwitch-3 (U1)	D3
Maximum	107.3	101.5	91.7	115.4	46.5	115.0	111.1
Normalized	107.2	101.3	91.6	114.8	45.6	114.6	110.9

13.5 10 Hour Burn-in at 25 ºC Ambient

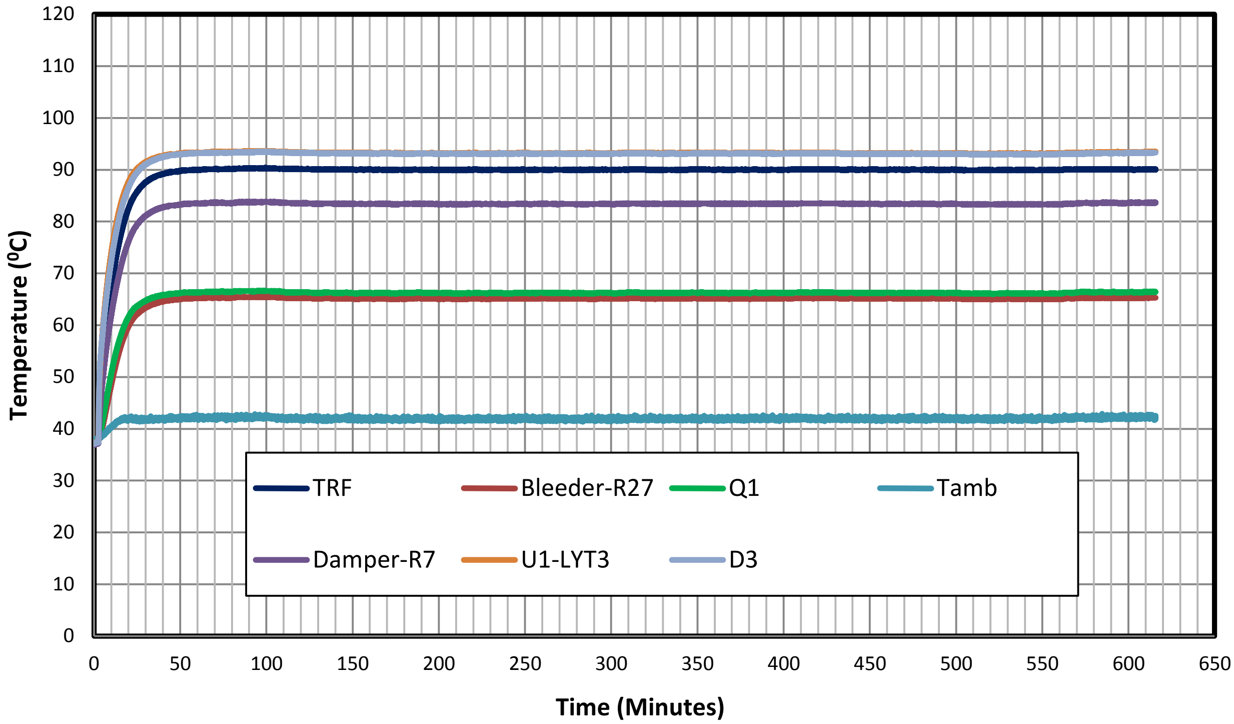


Figure 24 – Component Temperatures at 120 VAC, 25 ºC Ambient, 10 Hour Burn-in Test.

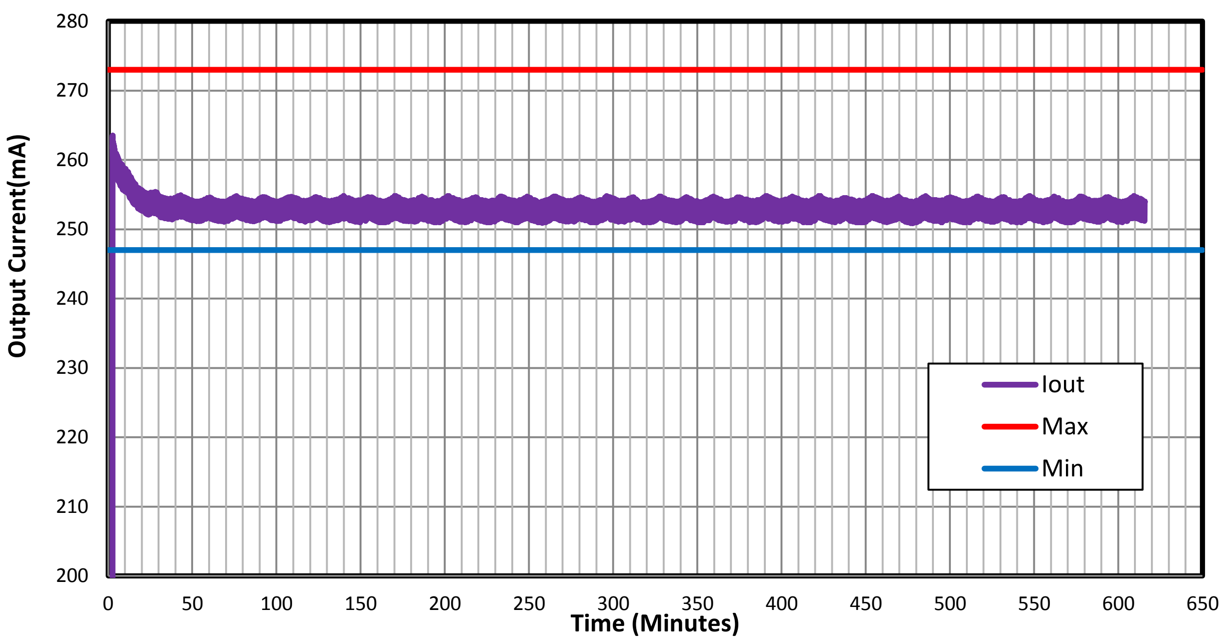


Figure 25 – Output Current Plot at 120 VAC, 25 ºC Ambient, 10 Hour Burn-in Test.

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14 Waveforms

14.1 Input Voltage and Input Current Waveforms

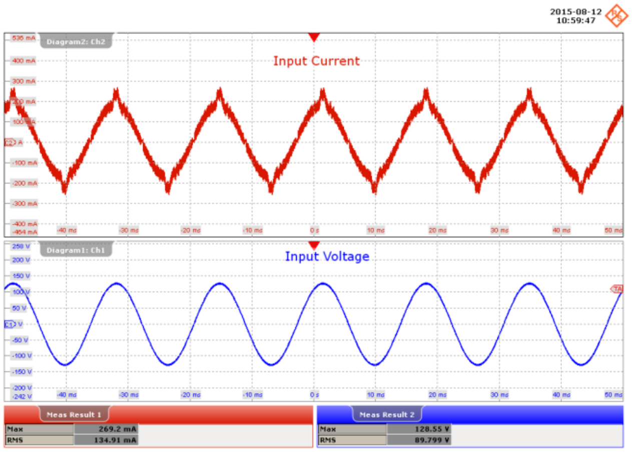

Figure 26 – 90 VAC, 39 V LED Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V / div., 10 ms / div.
Peak I_{IN}: 269.2 mA.
Peak V_{IN}: 128.55 V.

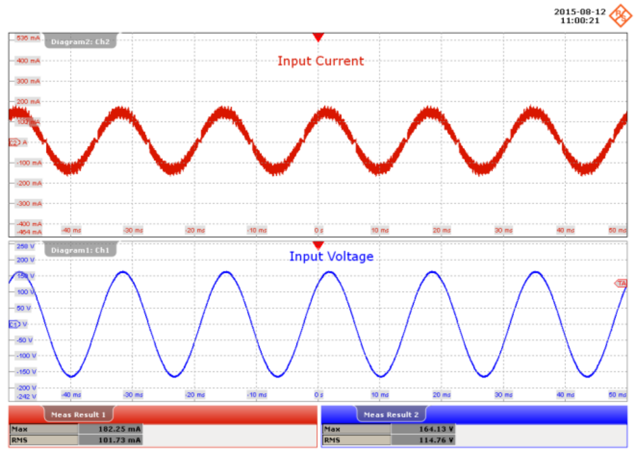

Figure 27 – 115 VAC, 39 V LED Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V / div., 10 ms / div.
Peak I_{IN}: 182.25 mA.
Peak V_{IN}: 164.13 V.

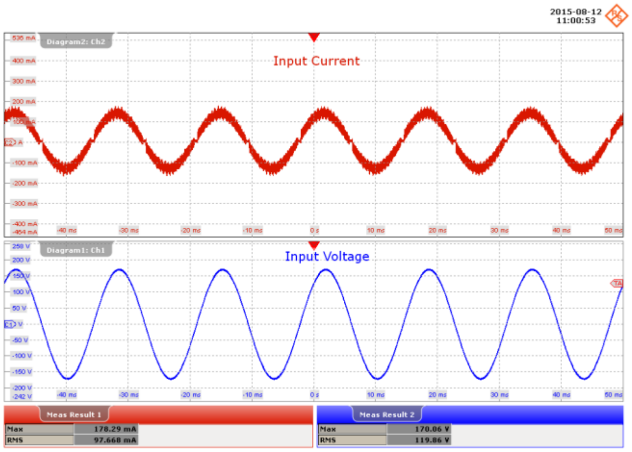

Figure 28 – 120 VAC, 39 V LED Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V / div., 10 ms / div.
Peak I_{IN}: 178.29 mA.
Peak V_{IN}: 170.06 V.

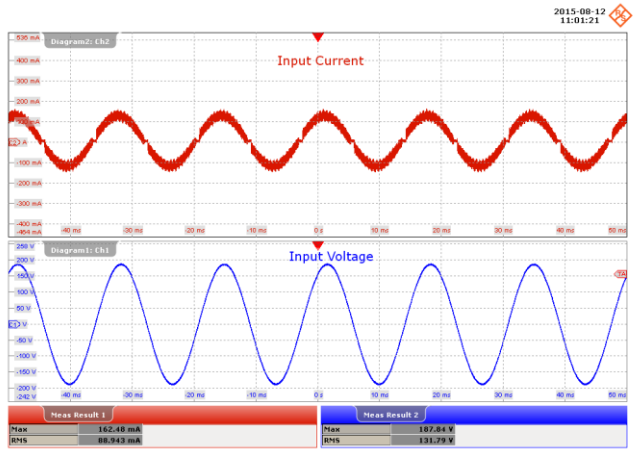

Figure 29 – 132 VAC, 39 V LED Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V / div., 10 ms / div.
Peak I_{IN}: 162.48 mA.
Peak V_{IN}: 187.84 V.

14.2 Output Current Rise and Fall

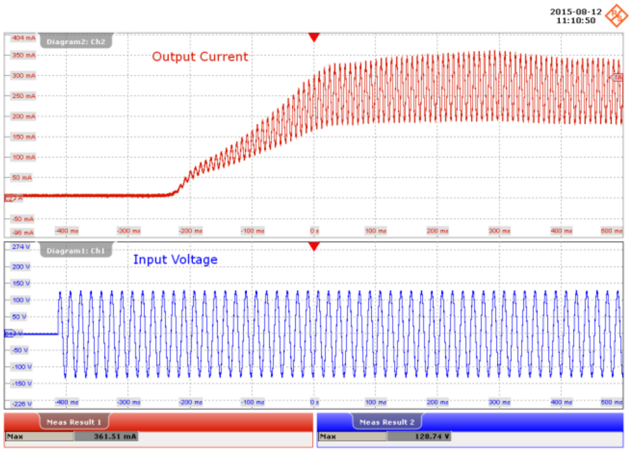

Figure 30 – 90 VAC, 39 V LED Load, Output Rise.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.
Peak I_{OUT}: 361.51 mA.
Peak V_{IN}: 128.74 V.

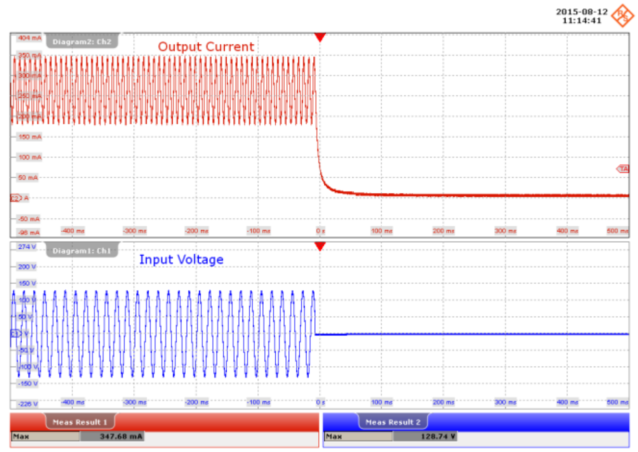

Figure 31 – 90 VAC, 39 V LED Load, Output Rise.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.
Peak I_{OUT}: 347.68 mA.
Peak V_{IN}: 128.74 V.

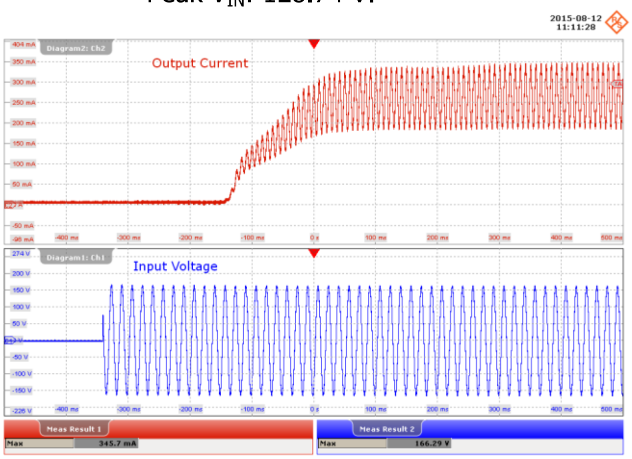

Figure 32 – 115 VAC, 39 V LED Load, Output Rise.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.
Peak I_{OUT}: 345.7 mA.
Peak V_{IN}: 166.29 V.

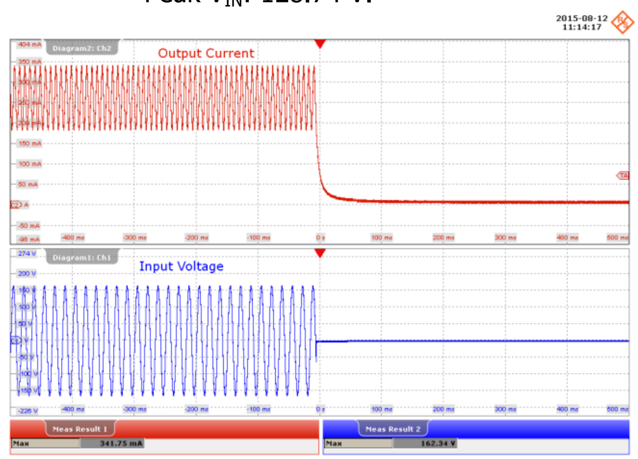

Figure 33 – 115 VAC, 39 V LED Load, Output Rise.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.
Peak I_{OUT}: 341.75 mA.
Peak V_{IN}: 162.34 V.

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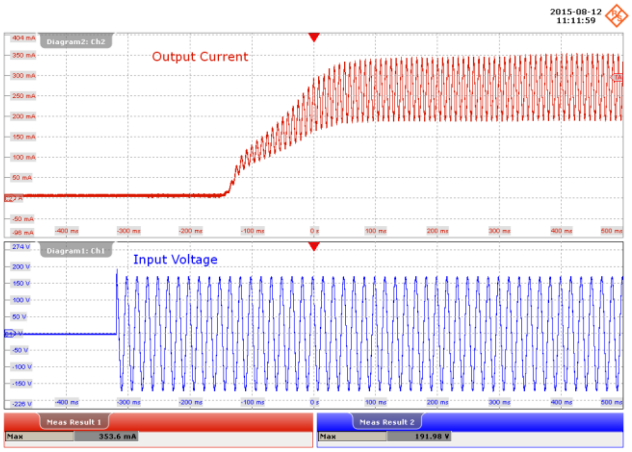

Figure 34 – 120 VAC, 39 V LED Load, Output Rise.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.
Peak I_{OUT}: 353.6 mA.
Peak V_{IN}: 191.98 V.

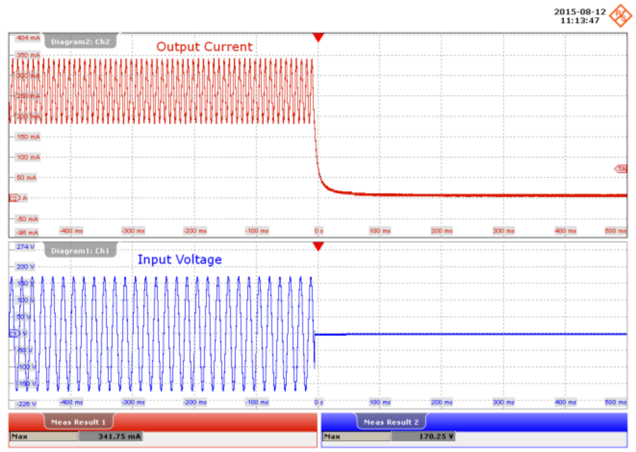

Figure 35 – 120 VAC, 39 V LED Load, Output Fall.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.
Peak I_{OUT}: 341.75 mA.
Peak V_{IN}: 170.25 V.

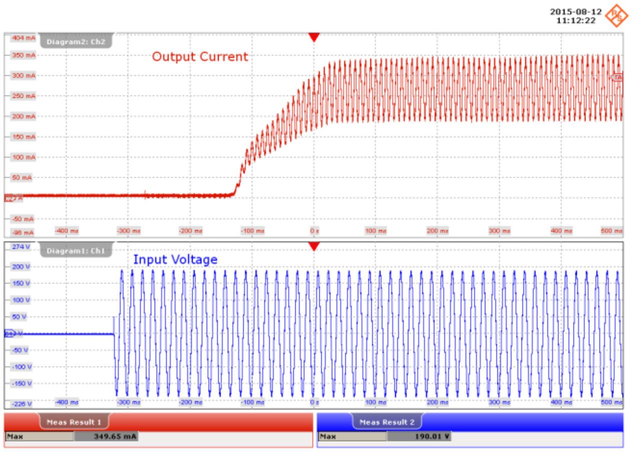

Figure 36 – 132 VAC, 39 V LED Load, Output Rise.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.
Peak I_{OUT}: 349.65 mA.
Peak V_{IN}: 190.01 V.

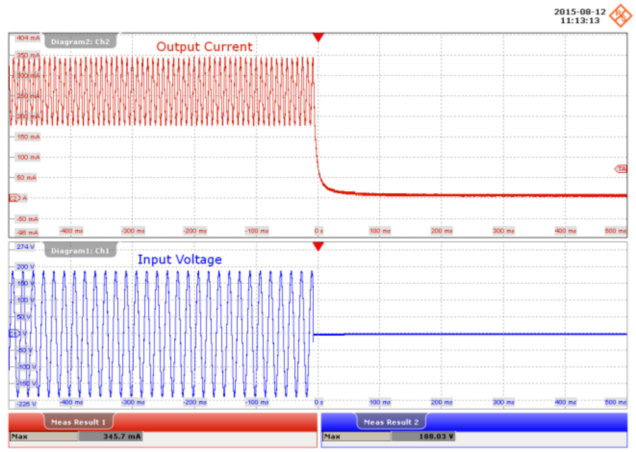

Figure 37 – 132 VAC, 39 V LED Load, Output Fall.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 100 ms / div.
Peak I_{OUT}: 345.7 mA.
Peak V_{IN}: 188.03 V.

14.3 Drain Voltage and Current in Normal Operation

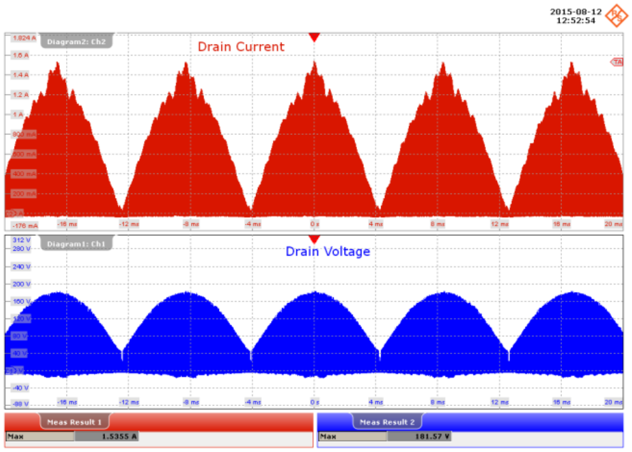

Figure 38 – 90 VAC, 39 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 40 V / div., 4 ms / div.
Peak I_{DRAIN}: 1.535 A.
Peak V_{DRAIN}: 181.75 V.

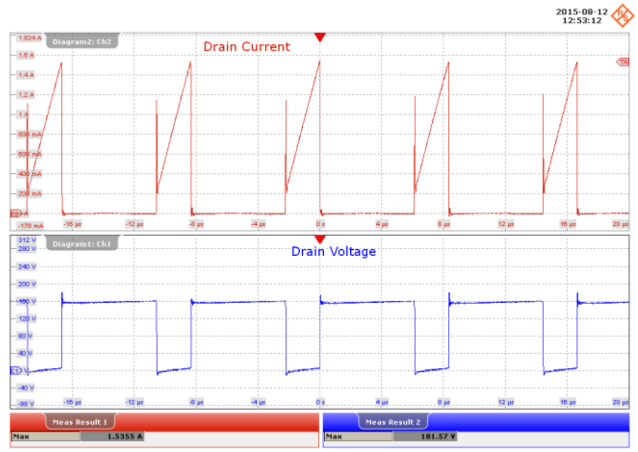

Figure 39 – 90 VAC, 39 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 40 V / div., 4 μs / div.
Peak I_{DRAIN}: 1.535 A.
Peak V_{DRAIN}: 181.75 V.

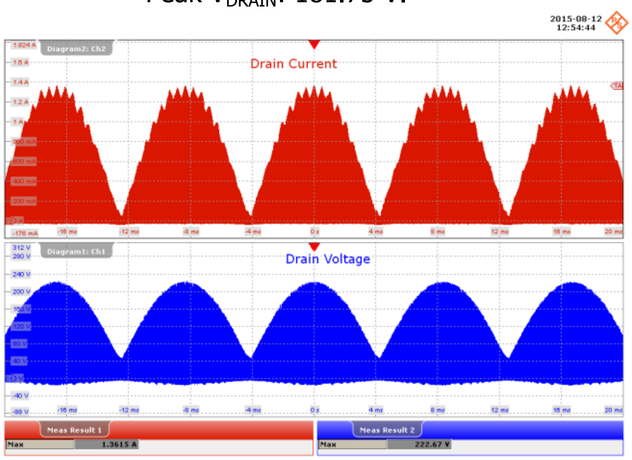

Figure 40 – 115 VAC, 39 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 40 V / div., 4 ms / div.
Peak I_{DRAIN}: 1.3615 A.
Peak V_{DRAIN}: 222.67 V.

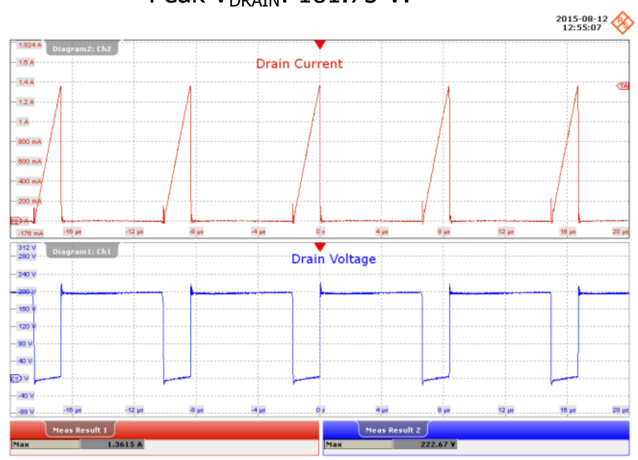

Figure 41 – 115 VAC, 39 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 40 V / div., 4 μs / div.
Peak I_{DRAIN}: 1.3615 A.
Peak V_{DRAIN}: 222.67 V.

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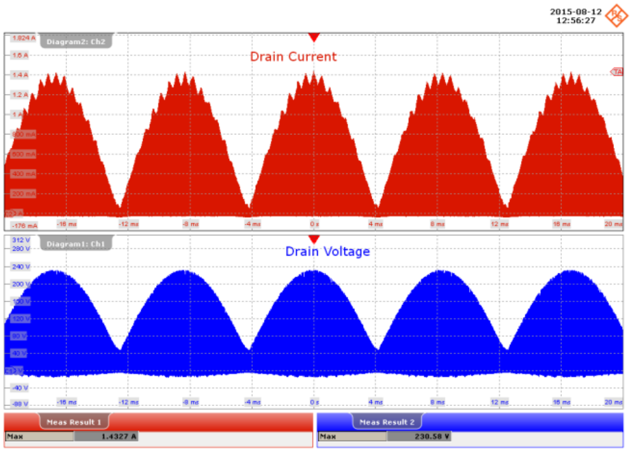

Figure 42 – 120 VAC, 39 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 40 V / div., 4 ms / div.
Peak I_{DRAIN}: 1.4327 A.
Peak V_{DRAIN}: 230.58 V.

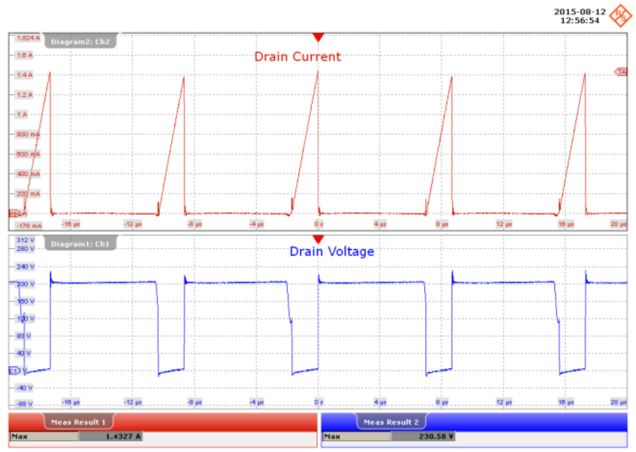

Figure 43 – 120 VAC, 39 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 40 V / div., 4 μs / div.
Peak I_{DRAIN}: 1.4327 A.
Peak V_{DRAIN}: 230.58 V.

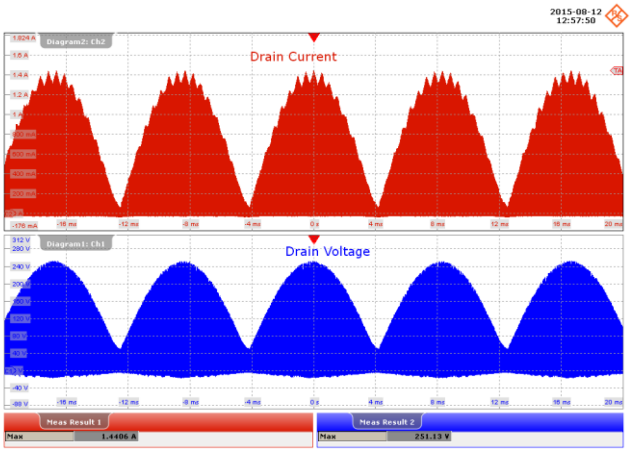

Figure 44 – 132 VAC, 39 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 40 V / div., 4 ms / div.
Peak I_{DRAIN}: 1.4406 A.
Peak V_{DRAIN}: 251.13 V.

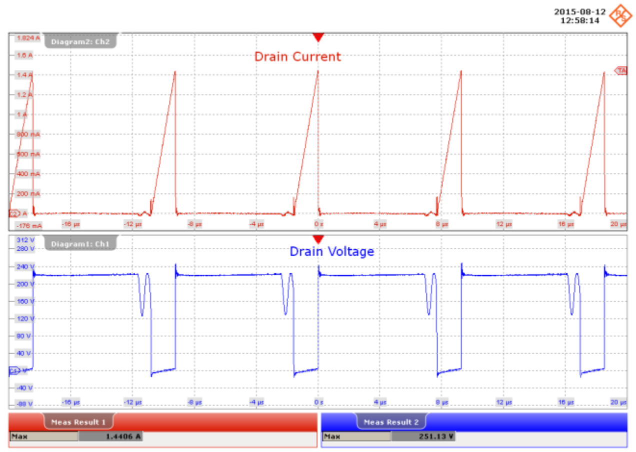

Figure 45 – 132 VAC, 39 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 40 V / div., 4 μs / div.
Peak I_{DRAIN}: 1.4406 A.
Peak V_{DRAIN}: 251.13 V.

14.4 Drain Voltage and Current Start-up Profile

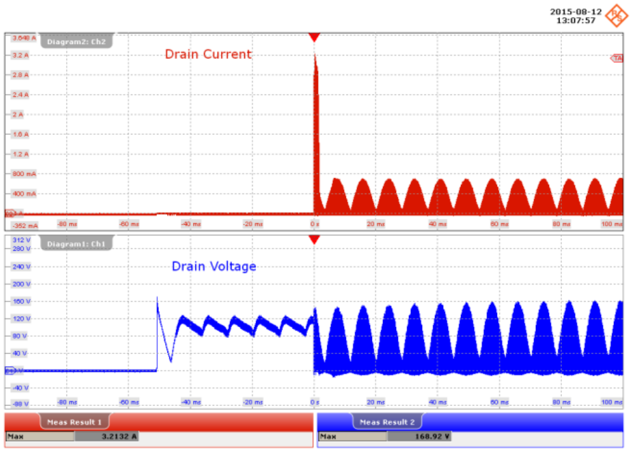

Figure 46 – 90 VAC, 39 V LED Load, Start-up.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 40 V / div., 20 ms / div.
Peak I_{DRAIN}: 3.2132 A.
Peak V_{DRAIN}: 168.92 V.

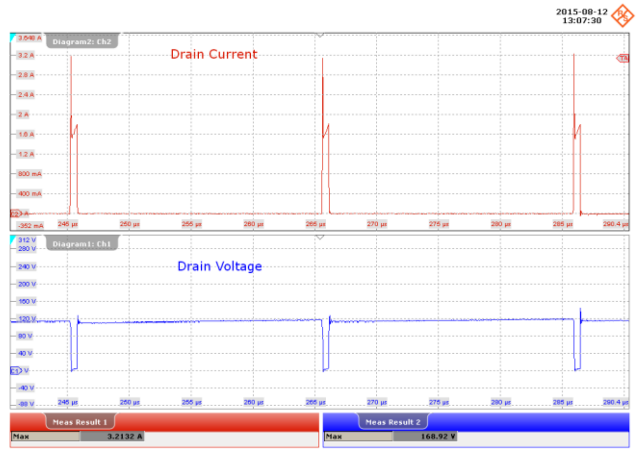

Figure 47 – 90 VAC, 39 V LED Load, Start-up.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 40 V / div., 20 ms / div.
Peak I_{DRAIN}: 3.2132 A.
Peak V_{DRAIN}: 168.92 V.

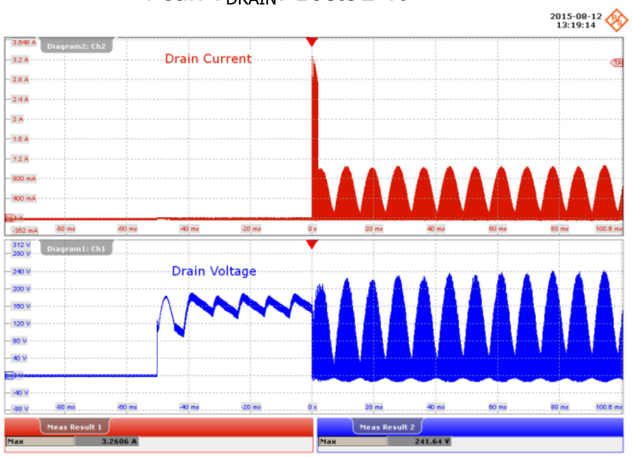

Figure 48 – 132 VAC, 39 V LED Load, Start-up.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 40 V / div., 20 ms / div.
Peak I_{DRAIN}: 3.26 A.
Peak V_{DRAIN}: 241.64 V.

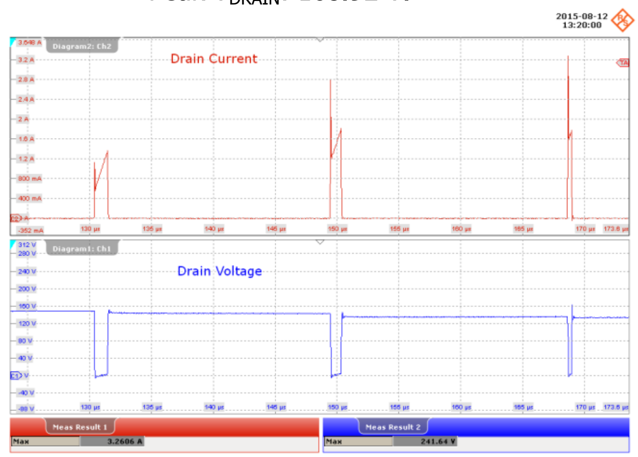

Figure 49 – 132 VAC, 39 V LED Load, Start-up.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 40 V / div., 20 ms / div.
Peak I_{DRAIN}: 3.2606 A.
Peak V_{DRAIN}: 241.64 V.

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14.5 Drain Voltage and Current during Output Short-Circuit Condition

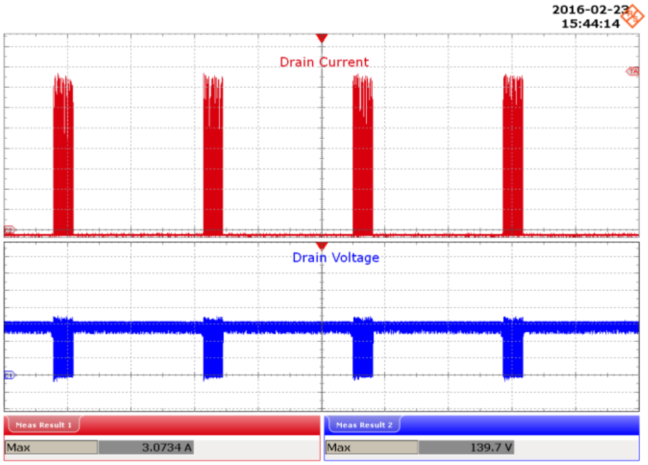

Figure 50 – 90 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 40 V / div., 1s / div.

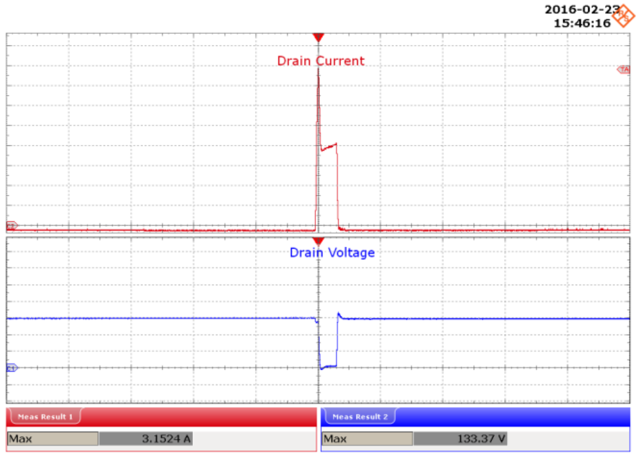

Figure 51 – 90 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 40 V / div., 1 µs / div.

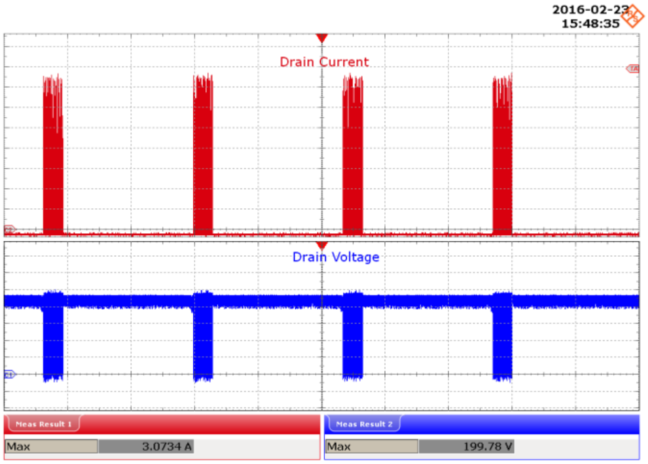

Figure 52 – 132 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 40 V / div., 1 s / div.

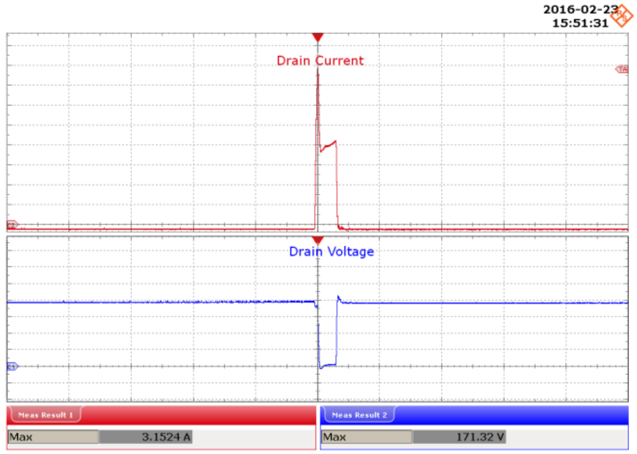

Figure 53 – 132 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 40 V / div., 1 µs / div.

14.5.1 Output Voltage and Current - Open LED Load

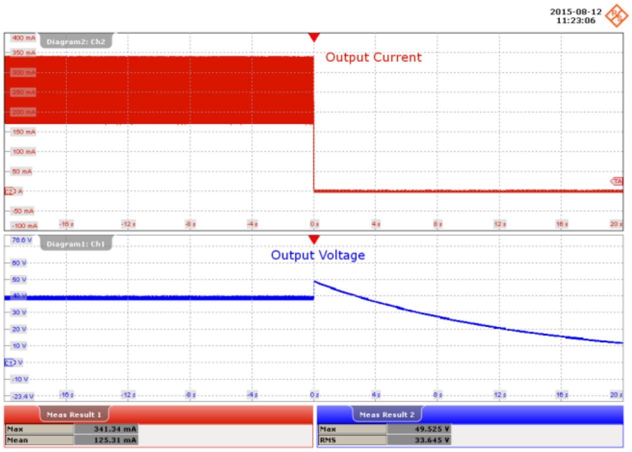

Figure 54 – 90 VAC, 39 V LED Load,
Running Open Load.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 10 V / div., 4 s / div.
Peak I_{OUT}: 341.34 mA.
Peak V_{OUT}: 49.525 V.

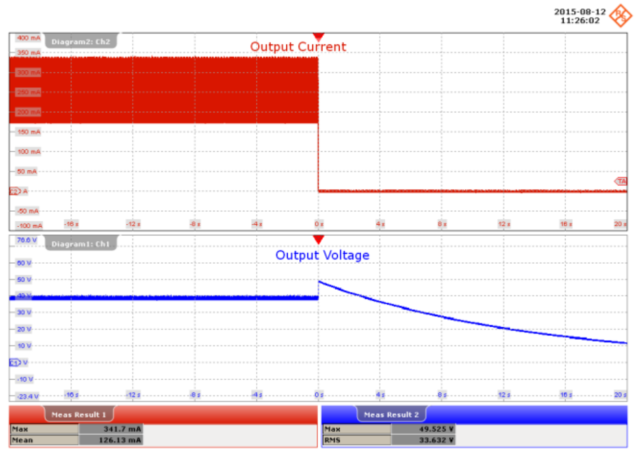

Figure 55 – 132 VAC, 39 V LED Load,
Running Open Load.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 10 V / div., 4 s / div.
Peak I_{OUT}: 341.7 mA.
Peak V_{OUT}: 49.525 V.

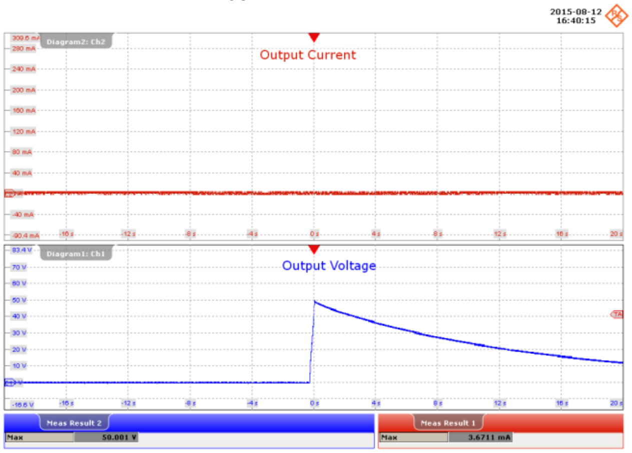

Figure 56 – 90 VAC, 39 V LED Load,
Open Load Start-up.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 10 V / div., 4 s / div.
Peak V_{OUT}: 50 V.

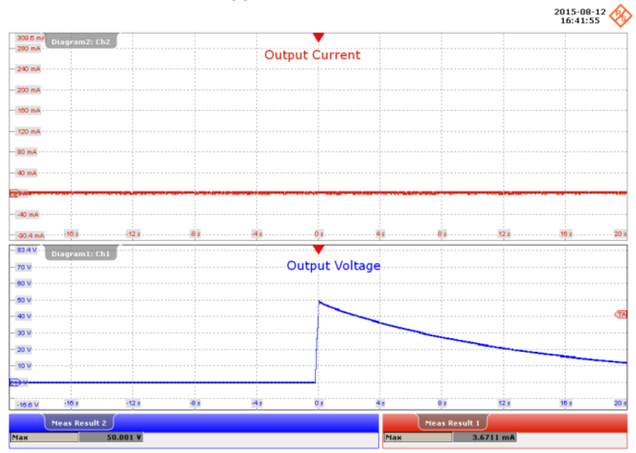

Figure 57 – 132 VAC, 39 V LED Load,
Open Load Start-up.
Upper: I_{OUT}, 10 mA / div.
Lower: V_{OUT}, 20 V / div., 4 s / div.
Peak V_{OUT}: 50 V.

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14.6 Output Ripple Current

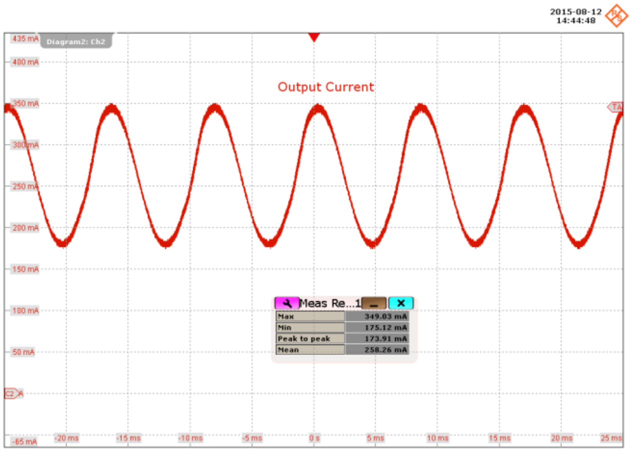

Figure 58 – 90 VAC, 60 Hz, 39 V LED Load.
Upper: I_{OUT}, 50 mA / div., 5 ms / div.

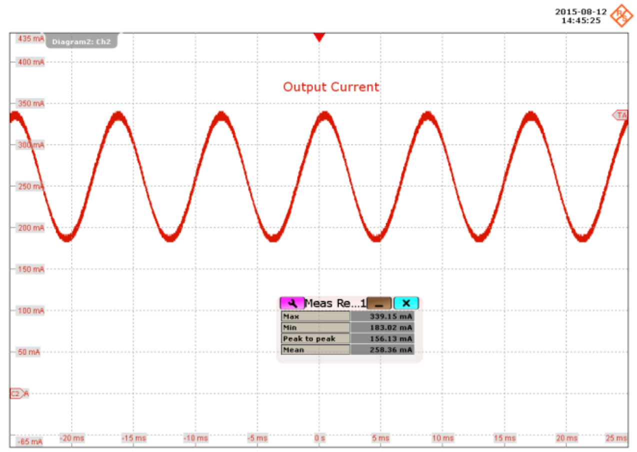

Figure 59 – 115 VAC, 60 Hz, 39 V LED Load.
Upper: I_{OUT}, 50 mA / div., 5 ms / div

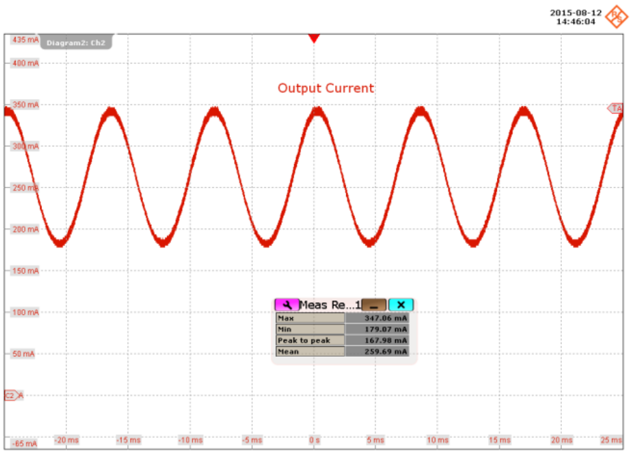

Figure 60 – 120 VAC, 60 Hz, 39 V LED Load.
Upper: I_{OUT}, 50 mA / div., 5 ms / div

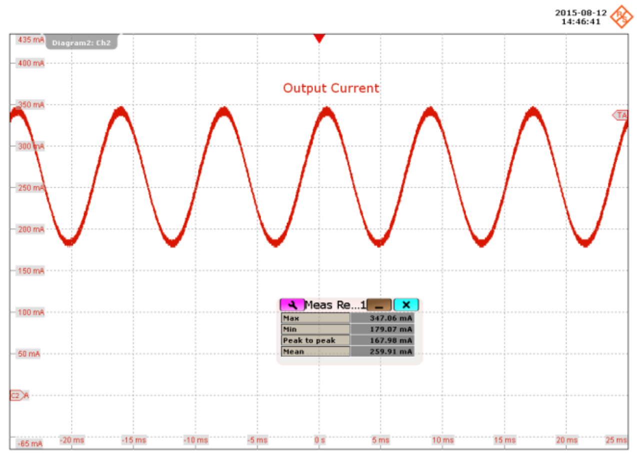

Figure 61 – 132 VAC, 60 Hz, 39 V LED Load.
Upper: I_{OUT}, 50 mA / div., 5 ms / div

V_{IN}	$I_{O(MAX)}$ (mA)	$I_{O(MIN)}$ (mA)	I_{MEAN}	Ripple Ratio (I_{RP-P}/I_{MEAN})	% Flicker 100 x (I_{RP-P} / $I_{O(MAX)}+I_{O(MIN)}$)
90 VAC	349	175	258.26	0.67	33.21
115 VAC	339	183	258.36	0.60	29.91
120 VAC	347	179	259.69	0.65	31.94
132 VAC	347	179	259.91	0.65	31.94

15 Dimming Waveforms

15.1 Input Voltage and Input Current Waveforms – Leading Edge Dimmer

Input: 120 VAC, 60 Hz
Output: 96 V LED load
Dimmer: Leviton 6681

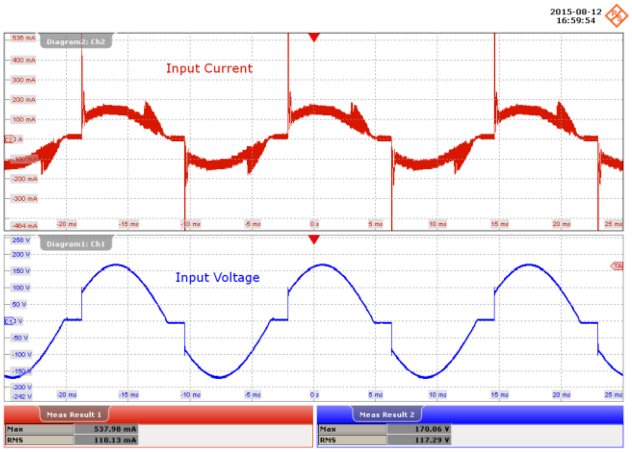

Figure 62 – 150º Conduction Angle.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V / div., 5 ms / div.
Peak V_{IN}: 170.06 V.
V_{RMS}: 117.29 V

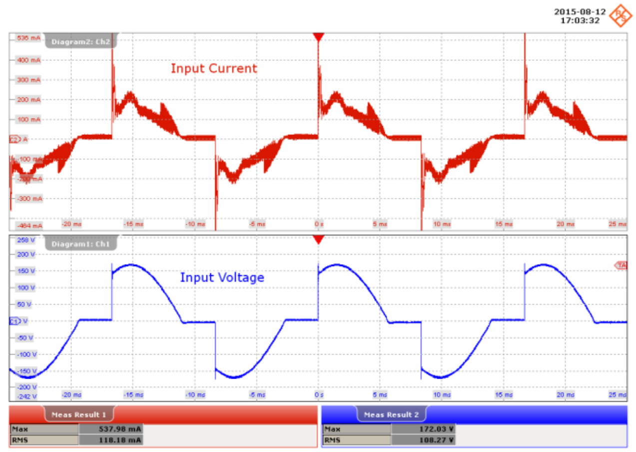

Figure 63 – 120º Conduction Angle.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V / div., 5 ms / div.
Peak V_{IN}: 172.03 V.
V_{RMS}: 108.27 V

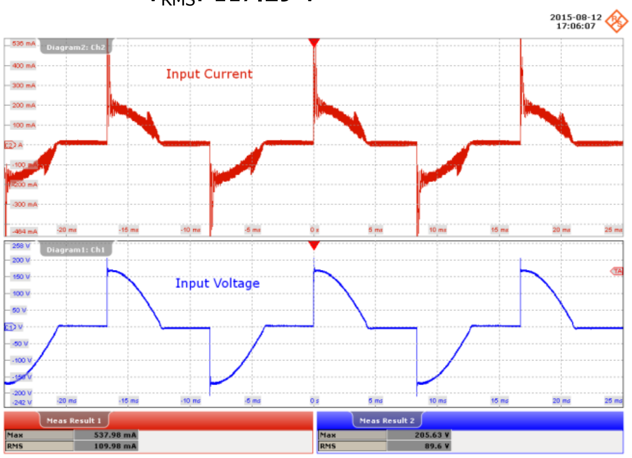

Figure 64 – 90º Conduction Angle.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V / div., 5 ms / div.
Peak V_{IN}: 205.63 V.
V_{RMS}: 89.6 V

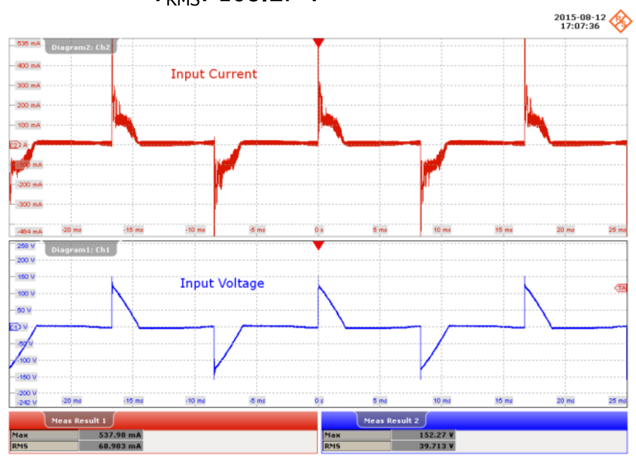

Figure 65 – 45º Conduction Angle.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V / div., 5 ms / div.
Peak V_{IN}: 152.27 V.
V_{RMS}: 39.713 V

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15.2 Output Current Waveforms – Leading Edge Dimmer

Input: 120 VAC, 60 Hz
Output: 96 V LED load
Dimmer: Leviton 6681

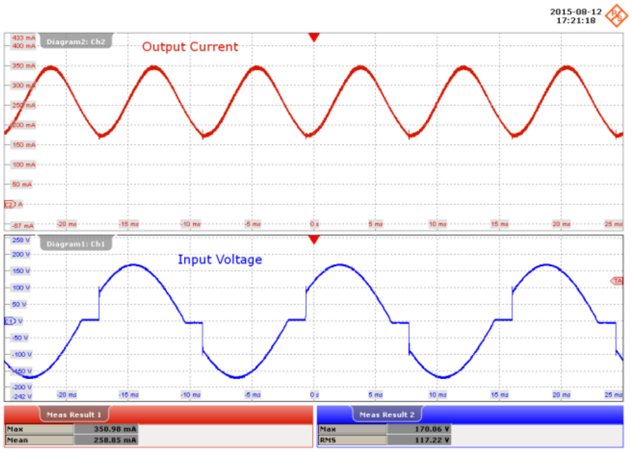

Figure 66 – 150º Conduction Anglel
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 4 ms / div.
Peak I_{OUT}: 350.98 mA
Peak V_{IN}: 170.06 V.

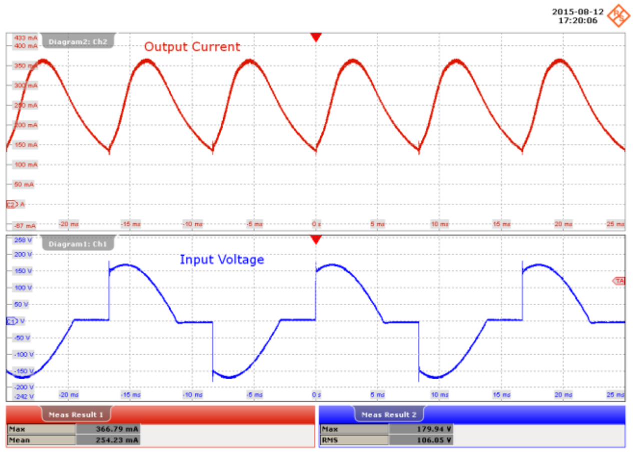

Figure 67 – 120º Conduction Anglel
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 4 ms / div.
Peak I_{OUT}:366.79 mA
Peak V_{IN}: 179.94 V.

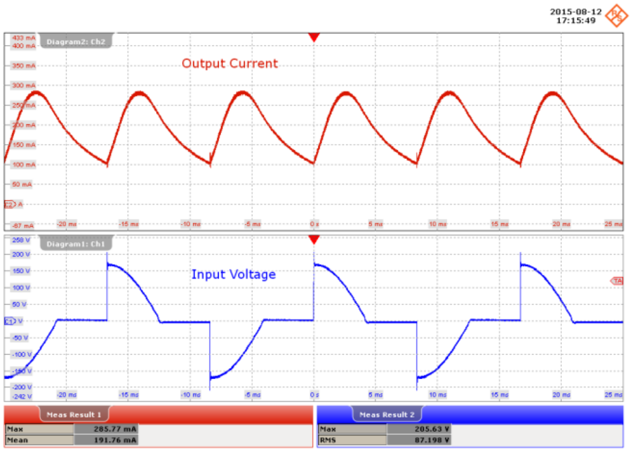

Figure 68 – 90º Conduction Angle.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 4 ms / div.
Peak I_{OUT}: 285.77 mA
Peak V_{IN}: 205.63 V.

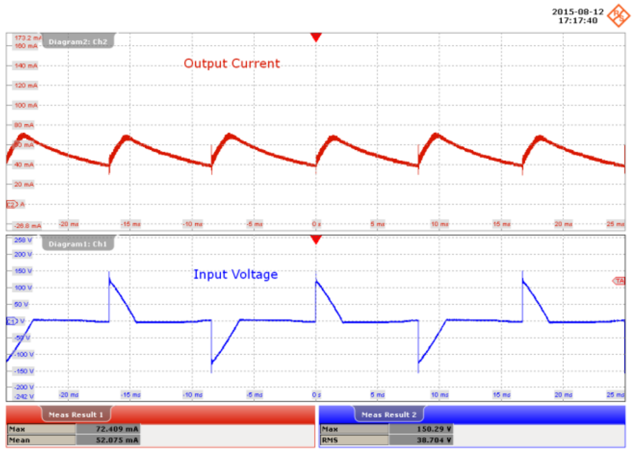

Figure 69 – 45º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V / div., 4 ms / div.
Peak I_{OUT}: 72.409 mA
Peak V_{IN}: 150.29 V.

15.3 Input Voltage and Input Current Waveforms – Trailing Edge Dimmer

Input: 120 VAC, 60 Hz
Output: 96 V LED load
Dimmer: Lutron DVELV-300P-WH

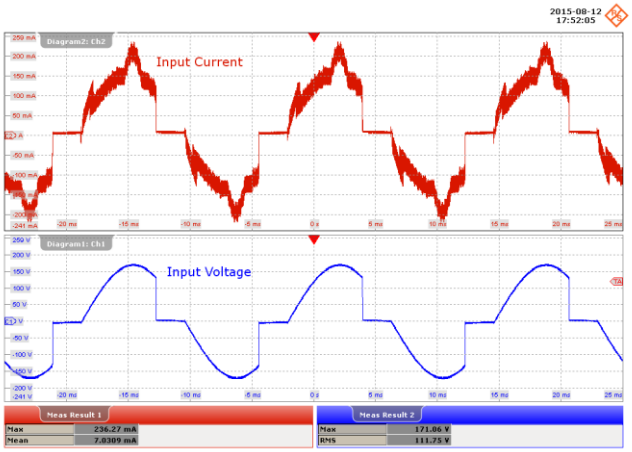

Figure 70 – 130º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 4 ms / div.
Peak V_{IN}: 171.06 V.
V_{RMS}: 111.75 V.

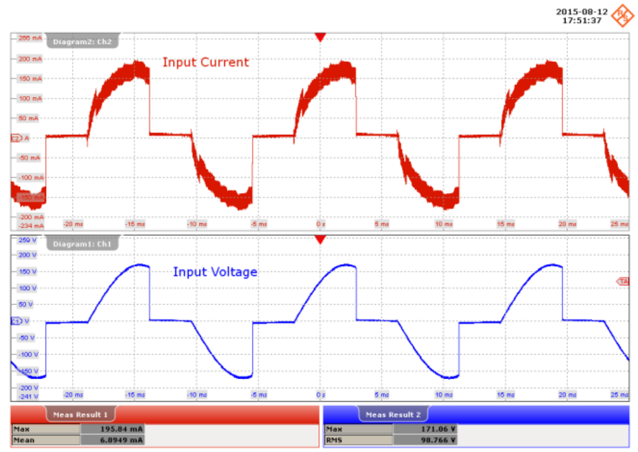

Figure 71 – 110º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 4 ms / div.
Peak V_{IN}: 171.06 V.
V_{RMS}: 98.766 V.

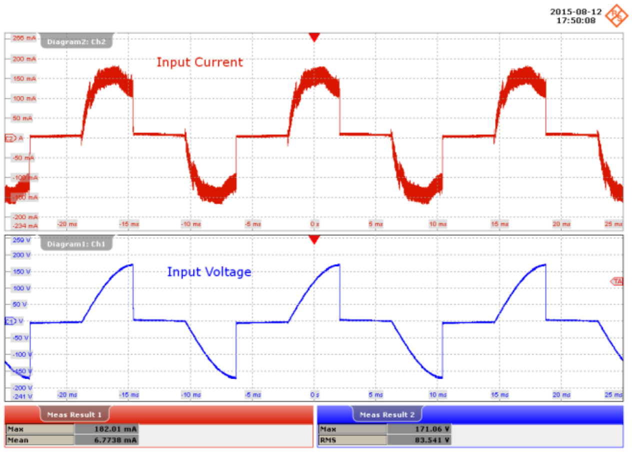

Figure 72 – 90º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 4 ms / div.
Peak V_{IN}: 171.06 V.
V_{RMS}: 83.541 V.

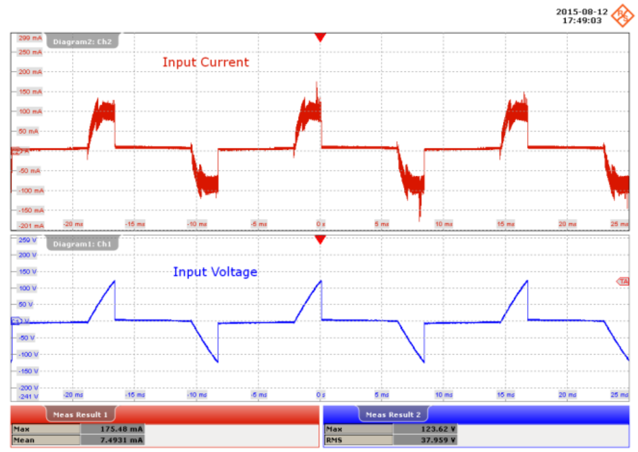

Figure 73 – 45º Conduction Angle.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 50 V / div., 4 ms / div.
Peak V_{IN}: 123.62 V.
V_{RMS}: 37.959 V.

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15.4 Output Current Waveforms – Trailing Edge Dimmer

Input: 120 VAC, 60 Hz
Output: 96 V LED load
Dimmer: Lutron DVELV-300P-WH

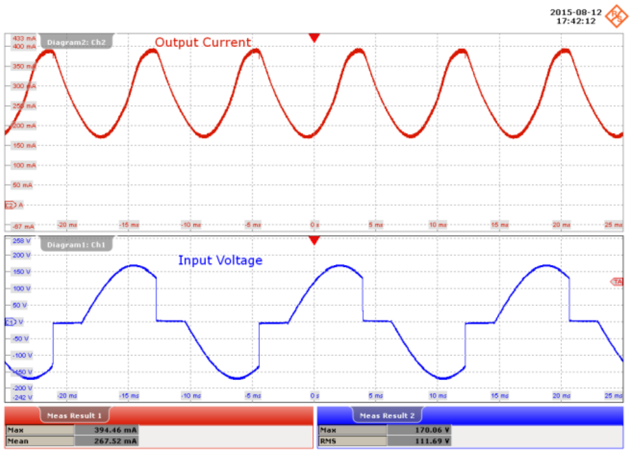

Figure 74 – 120º Conduction Angle.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 4 ms / div.
Peak I_{OUT}: 394.46 mA.
Peak V_{IN}: 170.06 V.

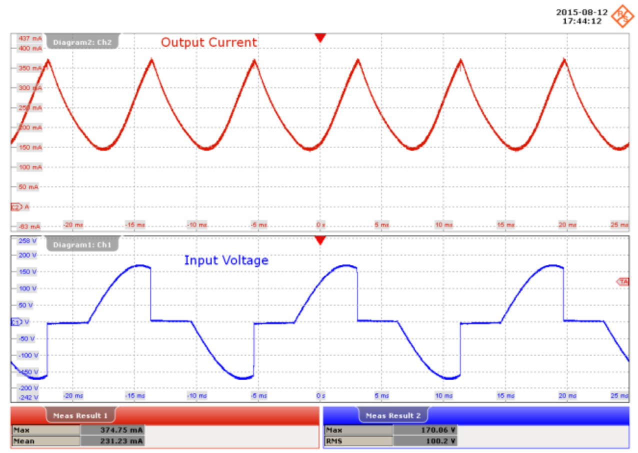

Figure 75 – 105º Conduction Angle.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 4 ms / div.
Peak I_{OUT}: 374.75 mA.
Peak V_{IN}:170.06 V.

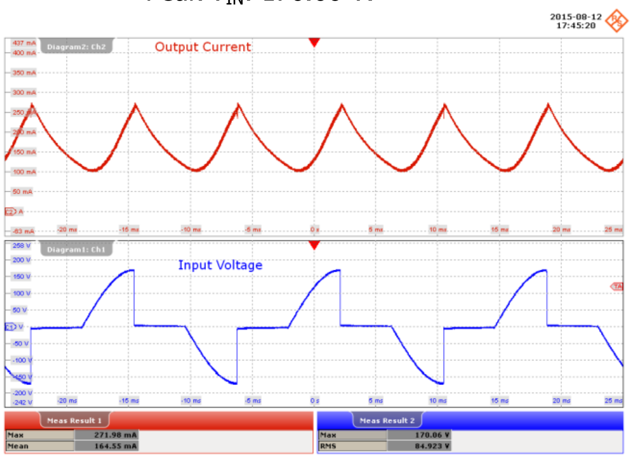

Figure 76 – 90º Conduction Angle.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 4 ms / div.
Peak I_{OUT}: 271.98 mA.
Peak V_{IN}: 170.06 V.

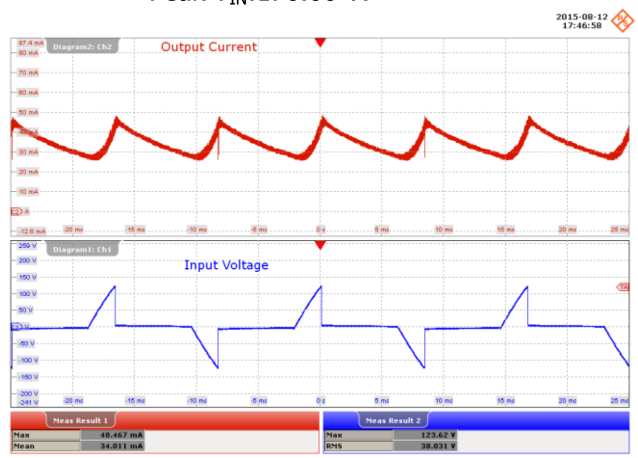

Figure 77 – 45º Conduction Angle.
Upper: I_{OUT}, 10 mA / div.
Lower: V_{IN}, 50 V / div., 4 ms / div.
Peak I_{OUT}: 48.467 mA.
Peak V_{IN}:123.62 V.

16 AC Cycling Test

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

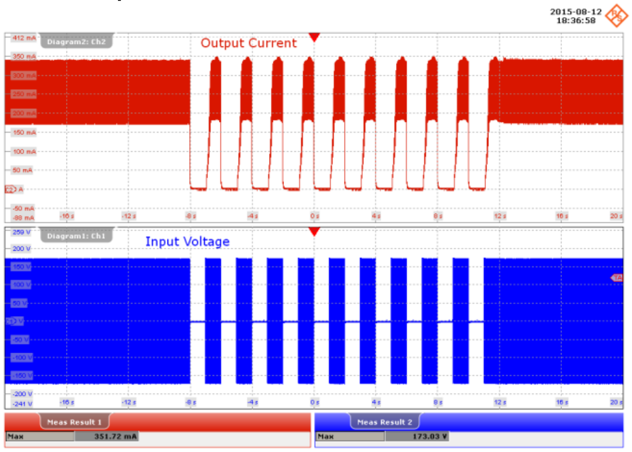

Figure 78 – 120 VAC, 39 V LED Load.
1 s On – 1 Sec Off.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 2 s / div.
Peak I_{OUT}: 351.72 mA.
Peak V_{IN}: 173.03 V.

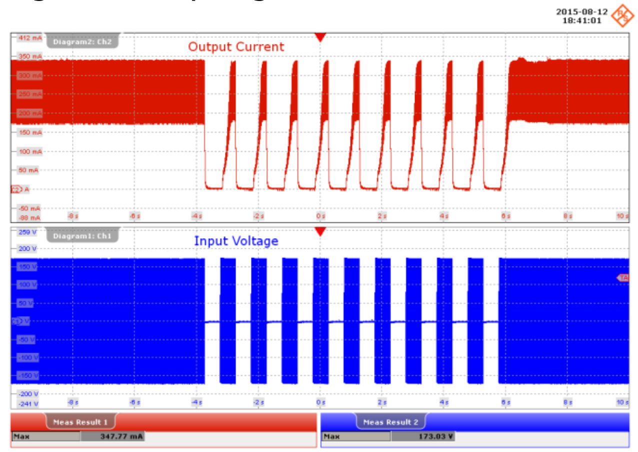

Figure 79 – 120 VAC, 39 V LED Load.
500 ms On – 500 ms Off.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 4 s / div.
Peak I_{OUT}: 347.77 mA.
Peak V_{IN}: 173.03 V.

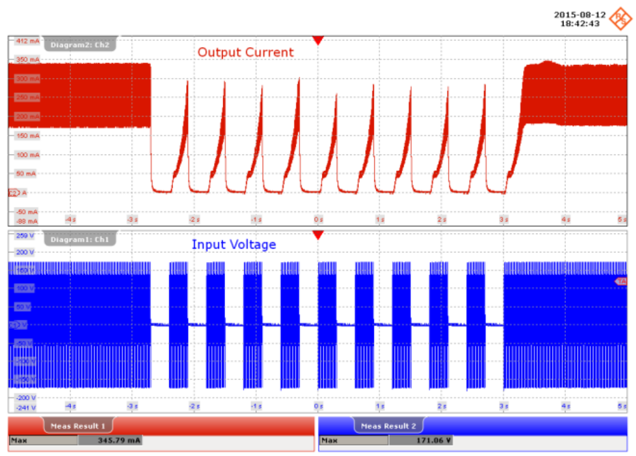

Figure 80 – 120 VAC, 39 V LED Load.
1 s On – 1 Sec Off.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 50 V / div., 2 s / div.
Peak I_{OUT}: 345.79 mA.
Peak V_{IN}: 171.06 V.

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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. 39 V LED load with input voltage set at 115 VAC.

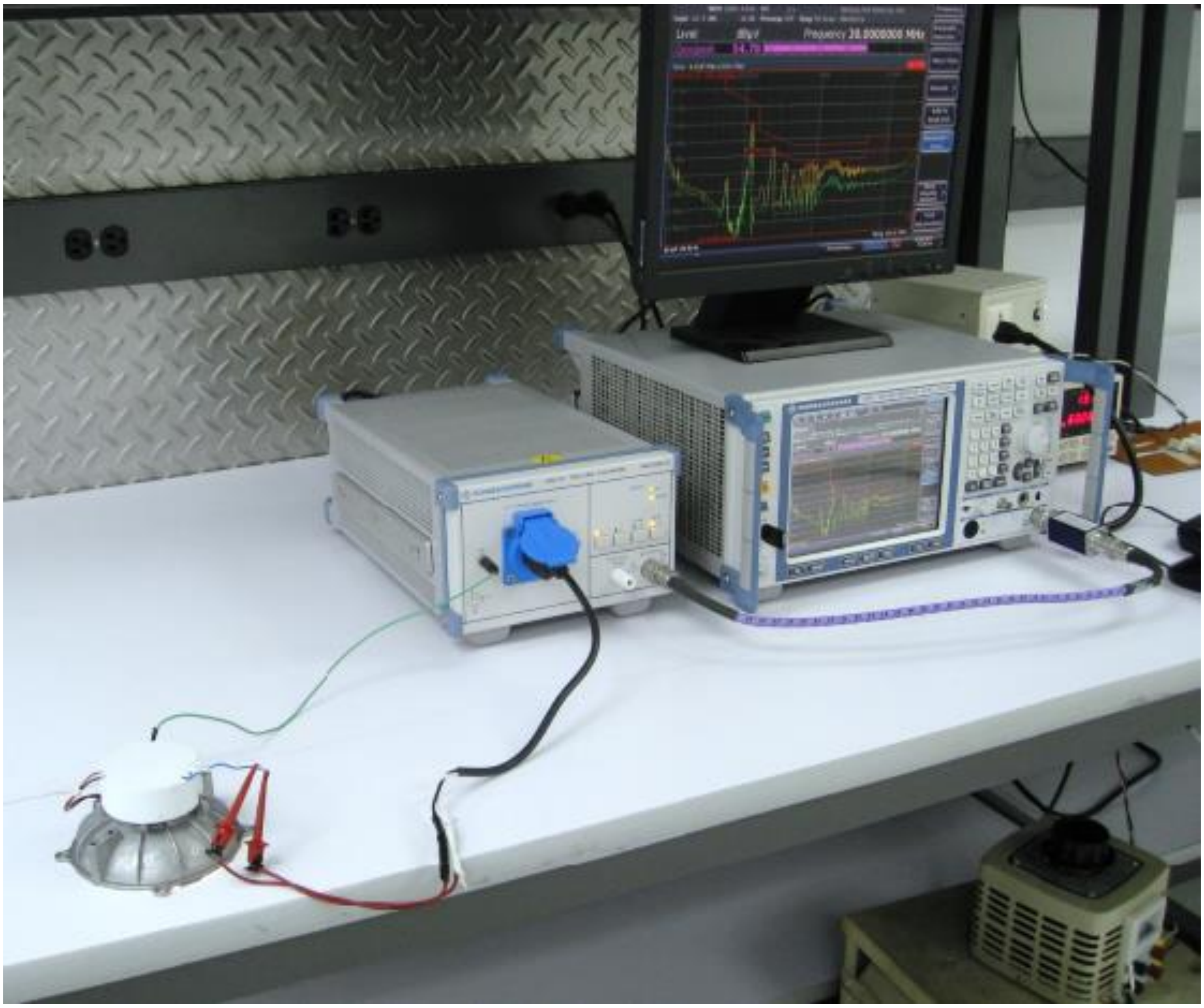

Figure 81 – Conducted EMI Test Set-up.

17.2 EMI Test Result

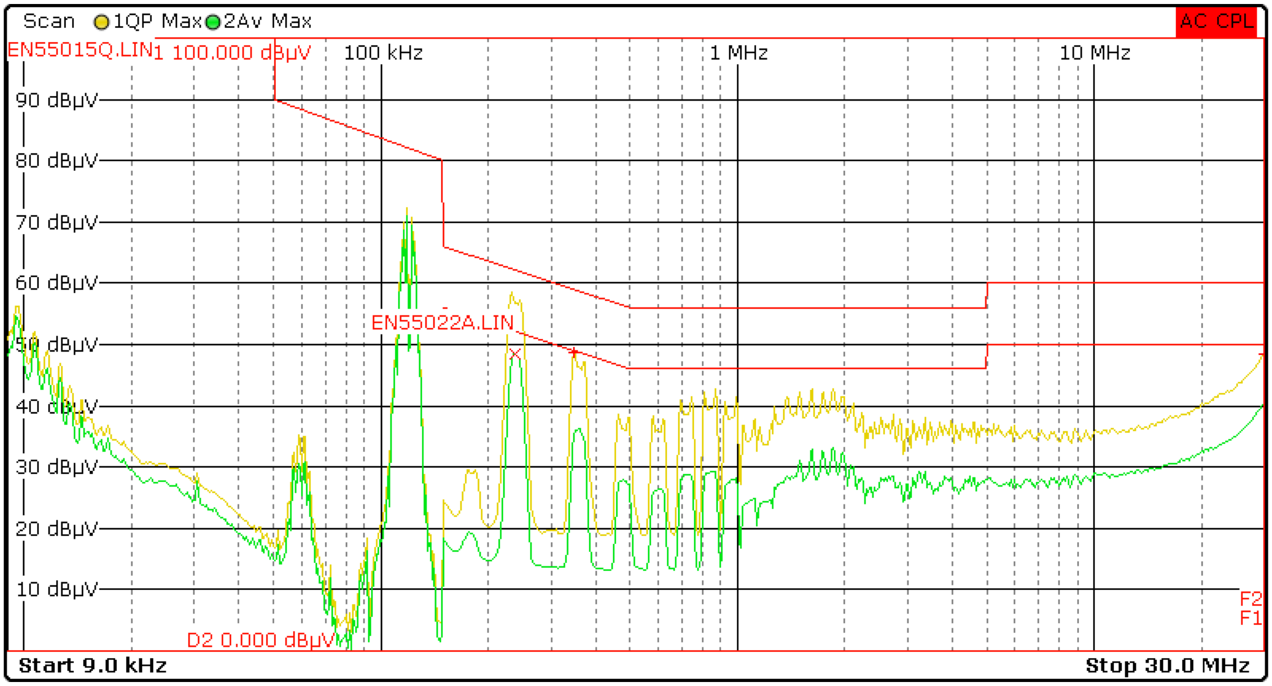

Figure 82 – Conducted EMI, 39 V LED Load, 115 VAC, 60 Hz, and EN55015 B Limits.

Trace/Detector	Frequency	Level dBµV	DeltaLimit
2 Average	237.7500 kHz	48.38 N	-3.79 dB
1 Quasi Peak	348.0000 kHz	48.63 N	-10.38 dB
1 Quasi Peak	29.9760 MHz	48.37 N	-11.63 dB

Figure 83 – Conducted EMI at Line 1, 39 V LED Load, Final Measurement Results.

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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)
+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 84 – +1000 kV Differential Surge, 90 ºC Phase.
Lower: V_{DRAIN}, 100 V / div., 5 µs / div.
Peak V_{DRAIN}: 438.28 V.

19 Brown-in / Brown-out Test

No failure of any component was seen during brownout test of 0.5 V / sec AC cut-in and cut-off.

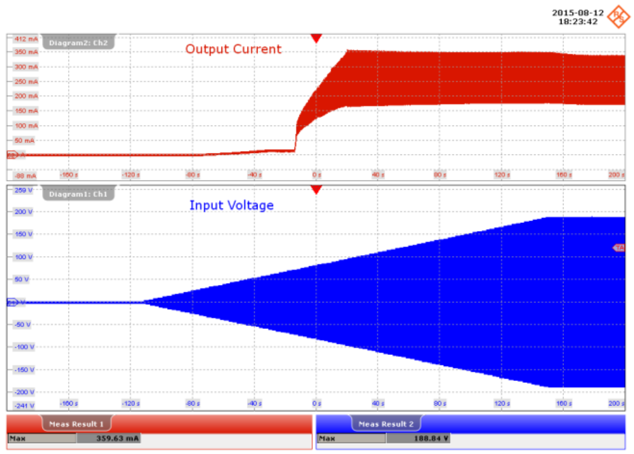

Figure 85 – Brown-in Test at 0.5 V / s. The Unit is Able to Operate Normally Without Any Failure and Without Flicker.
Ch4: V_{IN}, 50 V / div.
Ch3: I_{OUT}, 50 mA / div.
Time Scale: 50 s / div.

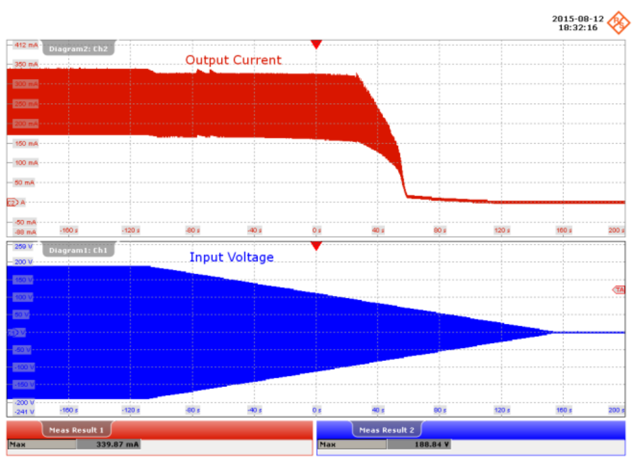

Figure 86 – Brown-out Test at 0.5 V / s. The Unit is Able to Operate Normally Without Any Failure and Without Flicker.
Ch4: V_{IN}, 50 V / div.
Ch3: I_{OUT}, 50 mA / div.
Time Scale: 50 s / div.

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20 Revision History

Date	Author	Revision	Description and Changes	Reviewed
01-Mar-16	MGM	1.0	Initial release	Apps & Mktg

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

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