Design Example Report

Title	***8 W TRIAC Dimmable High Efficiency (>85%) Power Factor Corrected Non-Isolated Buck-Boost LED Driver Using LYTSwitch™-3 LYT3325D***
Specification	195 VAC – 265 VAC Input; 72 V, 115 mA_{TYP} Output
Application	A19 LED Bulb
Author	Applications Engineering Department
Document Number	DER-524
Date	March 10, 2016
Revision	1.1

Summary and Features

- Single-stage power factor corrected, PF >0.9
- Accurate constant LED current (CC) regulation, ±5%
- Highly energy efficient, >85% at 230 V
- Low cost and low component count for compact PCB solution
- TRIAC dimmable
  - Works with a wide selection of TRIAC dimmers
- Integrated protection features
  - No-load and output short-circuit protection
  - Thermal fold-back protection
  - No damage during line brown-out or brown-in conditions
- Meets IEC 2.5 kV ring wave, 1 kV differential surge and EN55015 conducted EMI

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Table of Contents

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 low side buck-boost LED driver designed to drive a nominal LED voltage string of 72 V at 115 mA from an input voltage range of 195 VAC to 265 VAC. The LED driver utilizes the LYT3325D from the LYTSwitch-3 family of devices.

LYTSwitch-3 is a TRIAC dimmable LED driver IC with a single stage PFC function and an accurate LED current control. It incorporates a smart bleeder drive for optimum dimming performance.

DER-524 provides a single 8 W TRIAC dimmable constant current output. The key design goals were high efficiency, small PCB for compact size LED lamps 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.

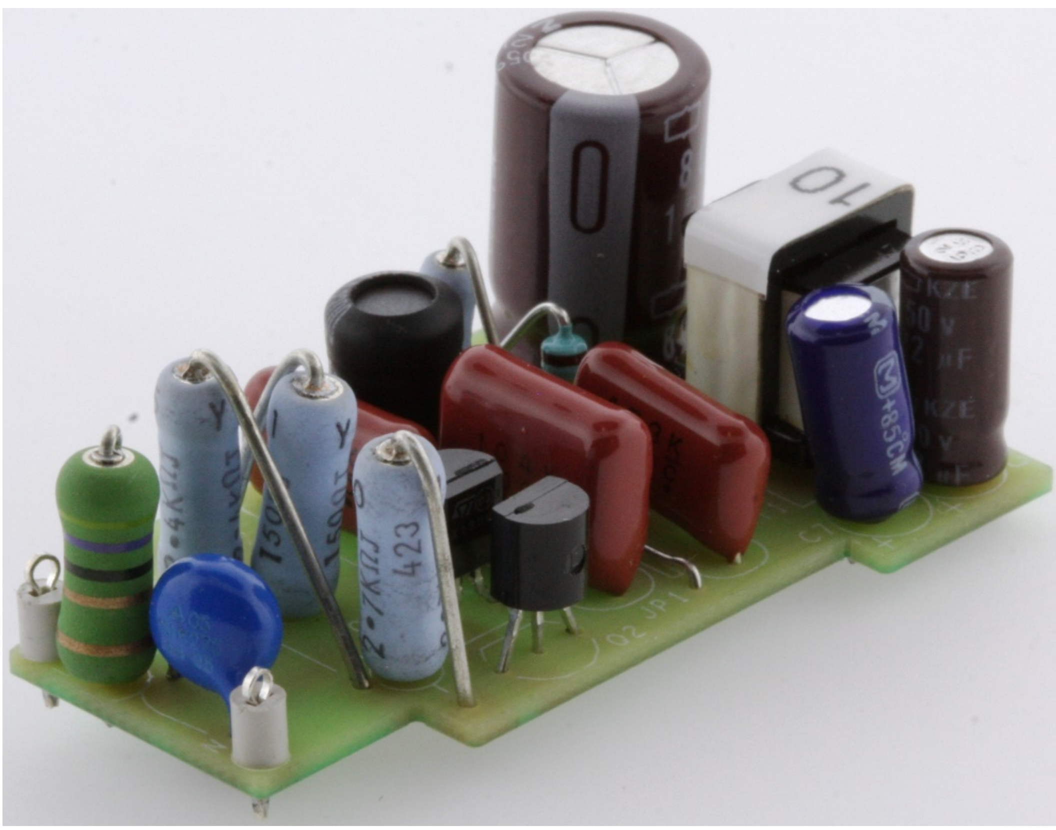

Figure 1 – Populated Circuit Board

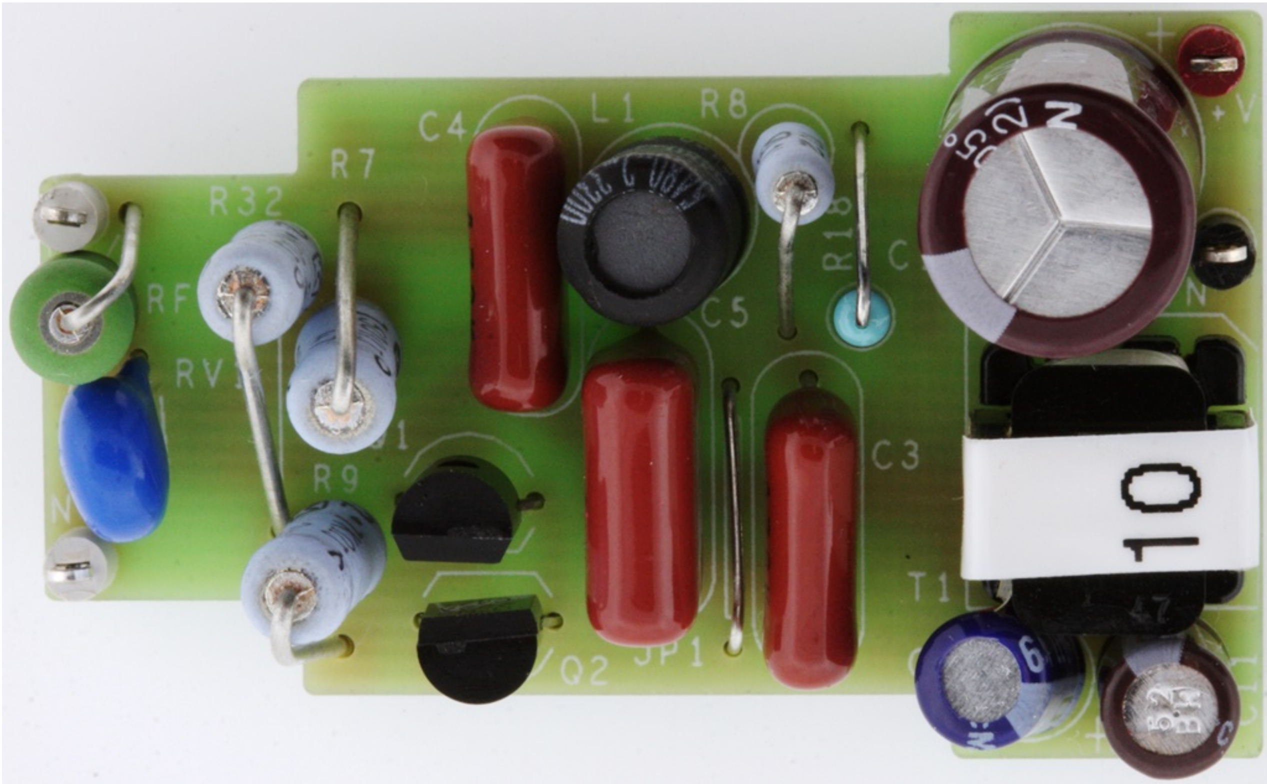

Figure 2 – Populated Circuit Board, Top View.

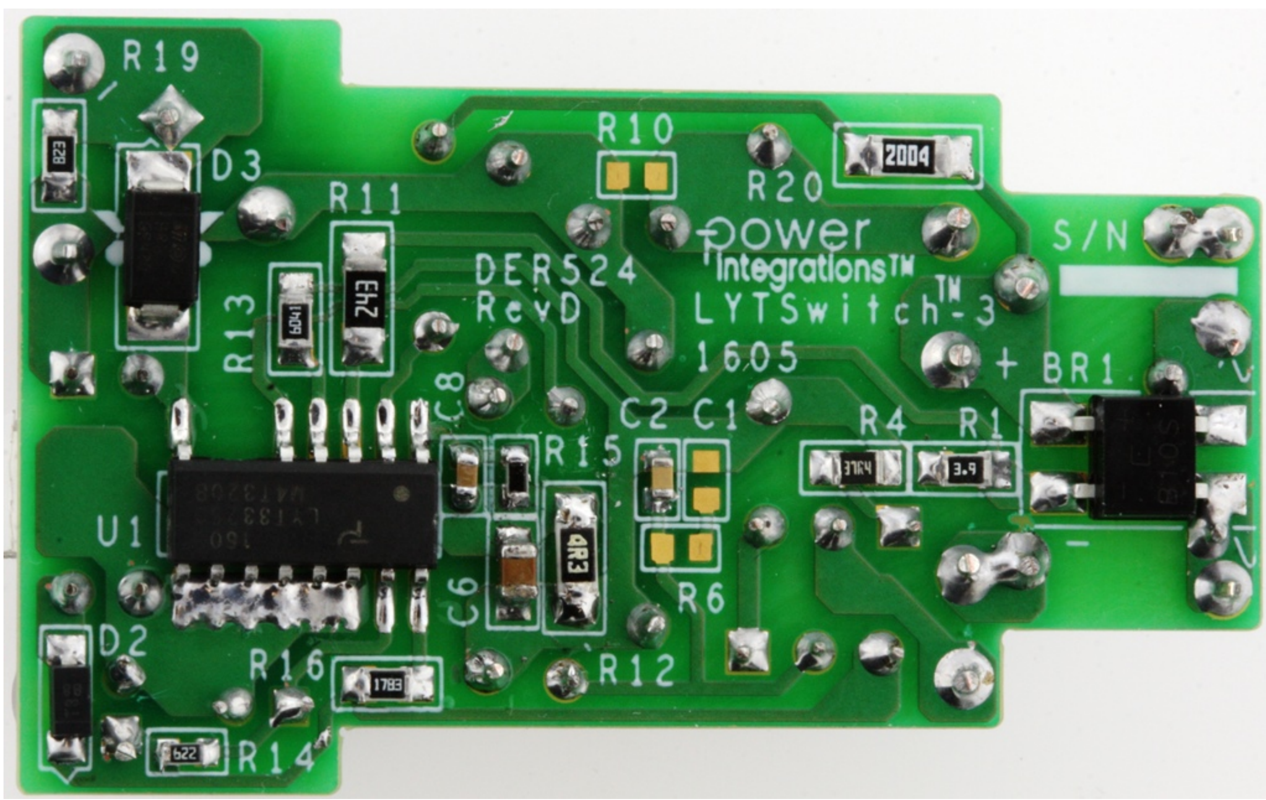

Figure 3 – Populated Circuit Board, Bottom View.

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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}	195	230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}		50/60		Hz	
Output						
Output Voltage	V_{OUT}	67	72	76	V	
Output Current	I_{OUT}	109	115	121	mA	
Total Output Power						
Continuous Output Power	P_{OUT}		8.28		W	
Efficiency						
Full Load	η		85		%	230 VAC, 50 Hz at 25 ºC.
Environmental						
Conducted EMI		CISPR 15B / EN55015B				
Safety		Isolated				
Ring Wave (100 kHz)			2.5		kV	
Differential Mode (L1-L2)			1.0		kV	
Power Factor			0.9			Measured at 230 VAC, 50 Hz.
Ambient Temperature	T_{AMB}			85	°C	Free convection, sea level.

2 Schematic

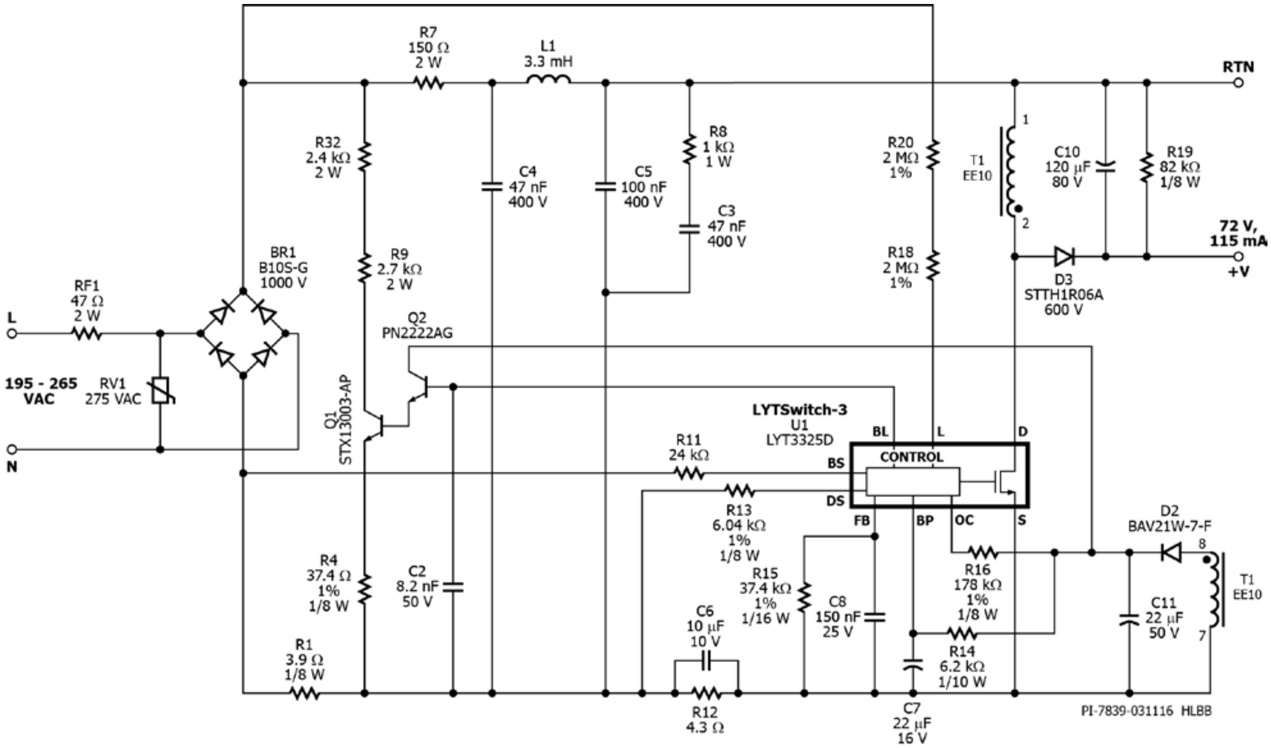

Figure 4 – Schematic

Note: Location R6 and C1 are not populated.

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3 Circuit Description

The LYTSwitch-3 LYT3325D combines a high-voltage power MOSFET switch with a power supply controller in a single SO16 package. The LYTSwitch-3 controller provides a single-stage power factor correction, LED current control and dimming control.

3.1 Input Stage

Fusible resistor RF1 provides safety protection from component failure. It also helps dampen the inrush current ringing during start up and dimming operation. Varistor RV1 acts as a voltage clamp that limits the voltage spike on the primary during line transient voltage surge events. A 275 VAC rated part was selected, being slightly above the maximum specified operating voltage (265 VAC).

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

3.2 EMI Filters

The differential choke L1, together with the input filter capacitor C4 and C5 work as an EMI π filter. These EMI filters, together with the LYTSwitch-3 frequency jittering feature ensure compliance with the EN55015 Class B emission limit.

3.3 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 deliver the primary bias supply for U1 from transformer auxiliary winding. 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, the bypass capacitor C7 is charge to ~5.25 V from IC internal high-voltage current source connected to the D pin.

To provide input line voltage information to U1, the input AC voltage is sense directly before the bridge rectifier diode through sampling resistors R20 and R21. The (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 (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 (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 (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 current exceeds the OV threshold.

3.4 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, function as a high gain active bleeder switch. The active bleeder is modulated by the LYTSwitch-3 smart bleeder drive (BL) pin in a close loop system through sensing the input voltage and current.

Resistor R4, C2, R6 and C1 work as stabilizing network for the bleeder switch for a more optimized dimming performance.

Resistor R1 senses the overall input current and fed to U1 (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.

Passive RC bleeder, R8 and C3 helps improve the dimming performance by increasing the TRIAC holding current.

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4 PCB Layout

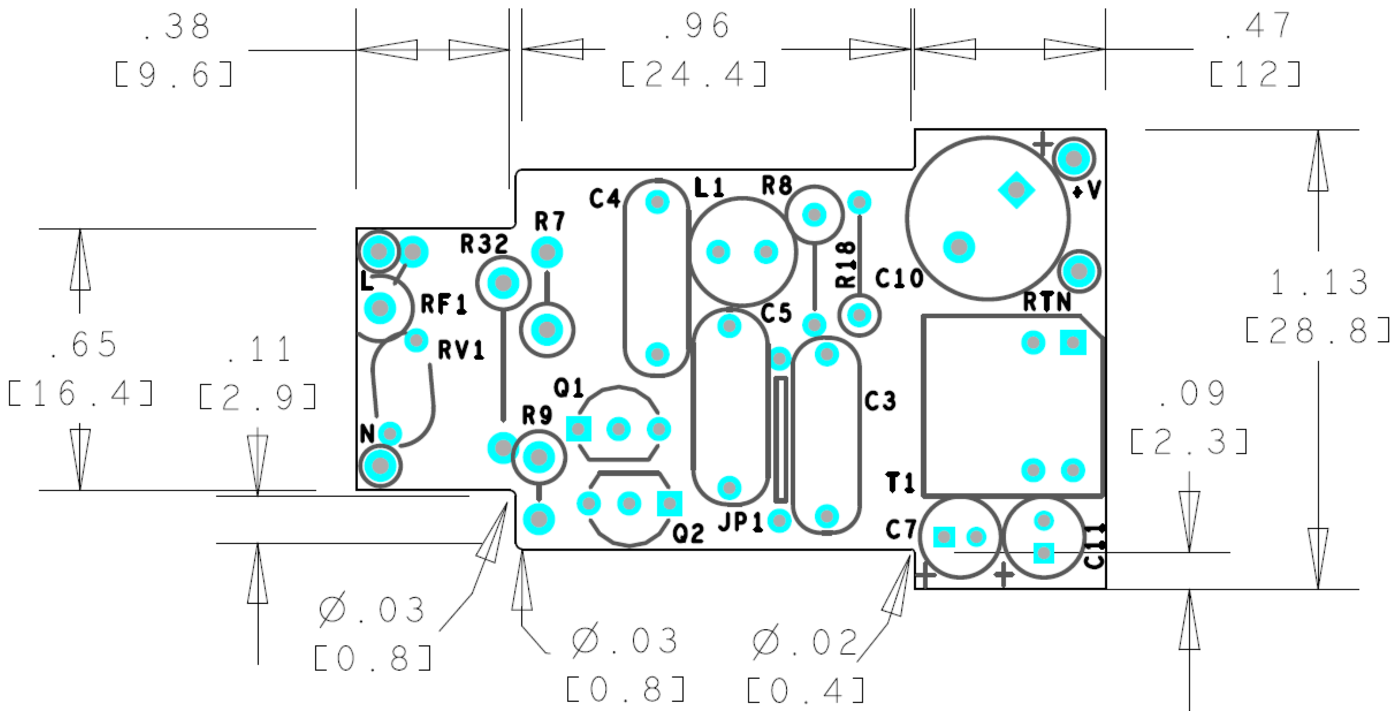

Figure 5 – Top Side.

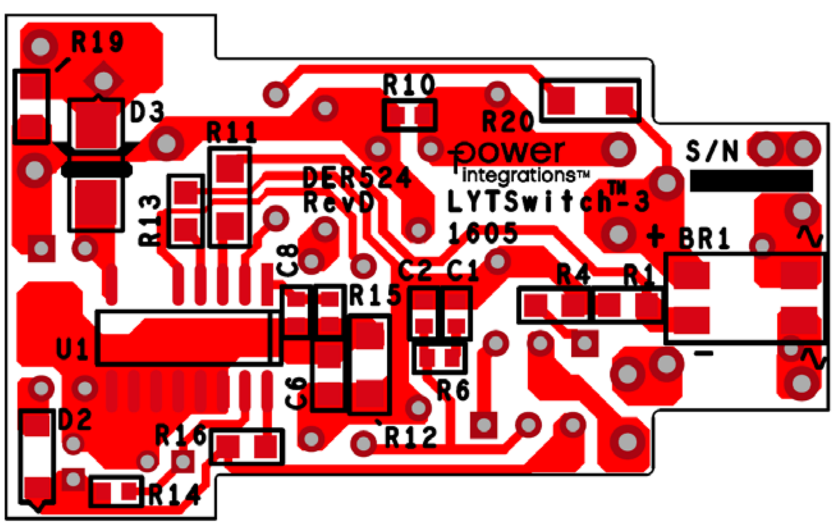

Figure 6 – Bottom Side.

5 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
1	BR1	1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip Technology
2	C2	1	8.2 nF, 50 V, Ceramic, X7R, 0603	GRM188R71C184KA01D	Murata
3	C3	1	47 nF, 400 V, Film	ECQ-E4473KF	Panasonic
4	C4	1	47 nF, 400 V, Film	ECQ-E4473KF	Panasonic
5	C5	1	100 nF, 400 V, Film	ECQ-E4104KF	Panasonic
6	C6	1	10 μF, 10 V, Ceramic, X7R, 0805	C2012X7R1A106M	TDK Corp
7	C7	1	22 μF, 16 V, Electrolytic, Gen. Purpose, (5 x 11)	ECA-1CM220	Panasonic
8	C8	1	150 nF, 25 V, Ceramic, X7R, 0603	C1608X7R1E154K080AA	TDK
9	C10	1	120 μF, 80 V, Electrolytic, Gen. Purpose, (10 x 17.5)	EKZN800ELL121MJ16S	United Chemi-con
10	C11	1	22 μF, 50 V, Electrolytic, Very Low ESR, 340 mOhm, (5 x 11)	EKZE500ELL220ME11D	Nippon Chemi-Con
11	D2	1	250 V, 0.2 A, Fast Switching, 50 ns, SOD-123	BAV21W-7-F	Diode Inc.
12	D3	1	600 V, 1 A, Ultrafast Recovery, 45 ns, DO-214AC, SMA	STTH1R06A	ST Microelectronics
13	JP1	1	Wire Jumper, Insulated, 24 AWG, 0.4 in	C2003A-12-02	Gen Cable
14	L1	1	3.3 mH, 0.095 A, 20%	RL-5480-2-3300	Renco Elect, Inc
15	Q1	1	NPN, Power BJT, 400 V, 1 A, TO-92	STX13003-AP	STMicroelectronics
16	Q2	1	NPN, Small Signal BJT, 40 V, 0.6 A, TO-92	PN2222AG	On Semiconductor
17	R1	1	3.9 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ3R9V	Panasonic
18	R4	1	37.4 Ω, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF37R4V	Panasonic
19	R7	1	150 Ω, 5%, 2 W, Metal Oxide	ERG-2SJ151	Panasonic
20	R8	1	1 kΩ, 5%, 1 W, Metal Oxide	ERG-1SJ102	Panasonic
21	R9	1	2.7 kΩ, 5%, 2 W, Metal Oxide Film	ERG-2SJ272	Panasonic
22	R11	1	24 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ243V	Panasonic
23	R12	1	4.3 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ4R3V	Panasonic
24	R13	1	6.04 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF6041V	Panasonic
25	R14	1	6.2 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ622V	Panasonic
26	R15	1	37.4 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF3742V	Panasonic
27	R16	1	178 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1783V	Panasonic
28	R18	1	2 MΩ, 1%, 1/4 W, Metal Film	RNF14D2M00	Yageo
29	R19	1	82 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ823V	Panasonic
30	R20	1	2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
31	R32	1	2.4 kΩ, 5%, 2 W, Metal Oxide Film	ERG-2SJ242	Panasonic
32	RF1	1	47 Ω, 5%, 2 W, Wirewound, Fusible	FW20A47R0JA	Bourns
33	RV1	1	430 V, 8.6 J, 5 mm, RADIAL	S05K275	Epcos
34	T1	1	Bobbin, EE10, Vertical, 8 pins (10.2mm W x 10.4mm L x 9.7mm H)	EE-1016	Yulongxin
35	U1	1	LYTSwitch-3, SO-16C	LYT3325D	Power Integrations

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6 Inductor Specification

6.1 Electrical Diagram

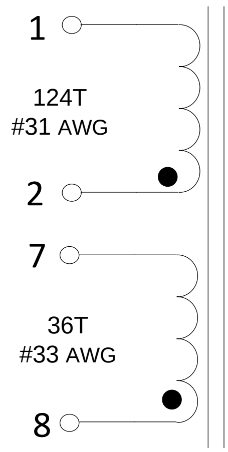

Figure 7 – Inductor Electrical Diagram.

6.2 Electrical Specifications

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V pk-pk, 100 kHz switching frequency, between pin 1 and pin 2, with all other windings open.	420 μH
Tolerance	Tolerance of primary inductance.	±5%

6.3 Material List

Item	Description
[1]	Core: EE10 P4 (Acme) or Equivalent.
[2]	Bobbin, EE10, Vertical, 8 pins: PI Part No. 25-01068-00.
[3]	Magnet Wire: #31 AWG.
[4]	Magnet Wire: #33 AWG.
[5]	Transformer Tape: 7 mm.
[6]	Transformer Tape: 4 mm.

6.4 Inductor Build Diagram

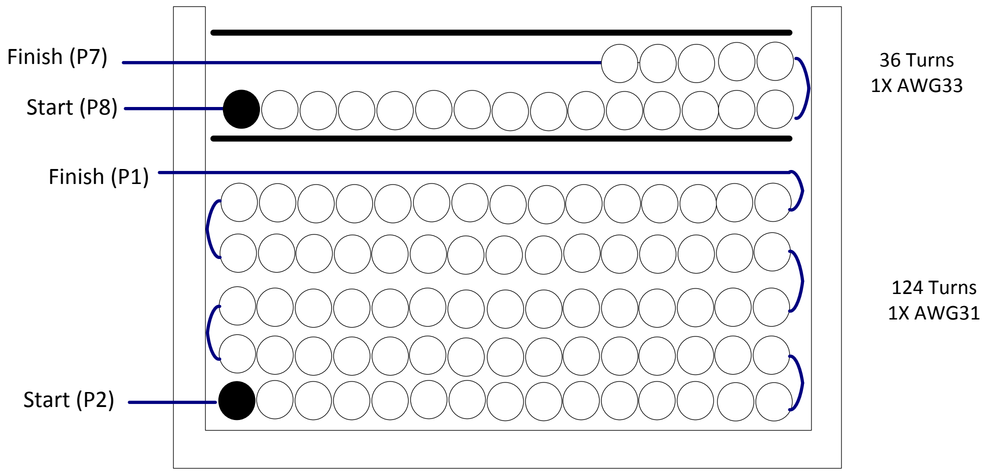

Figure 8 – Transformer Build Diagram.

6.5 Inductor Construction

Winding Directions	Bobbin is oriented on winder jig such that terminal pin 1-4 is in the left side. The winding direction is clockwise.
Winding 1	Use wire item [3], start at pin 2 and wind 124 turns in 6 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 8 and wind 36 turns from left to right, then finish the winding on pin 7.
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 423 μH.
Assemble Core	Assemble the 2 cores on the bobbin with the gapped core place on top side of the bobbin and the un-gapped core at the bottom side. Wrap the 2 cores with 2 layer of tape, Item (6).
Bobbin Tape	Add 1 Layer tape, Item (5), around the bobbin together with the core.
Pins	Pull out Terminal pin no. 3, 4, 5 and 6.
Finish	Dip the transformer assembly in varnish.

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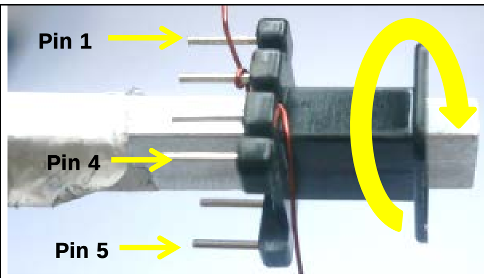
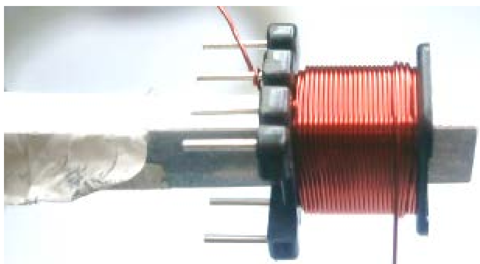
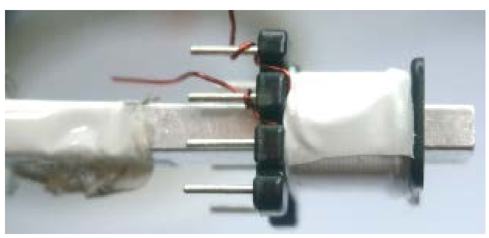
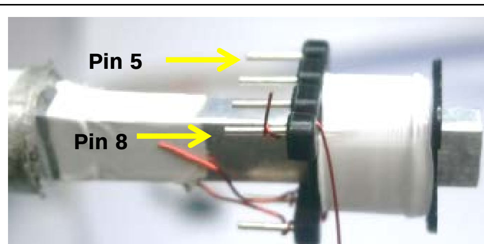
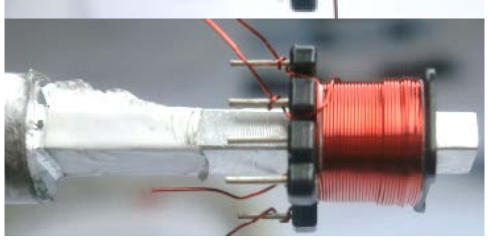
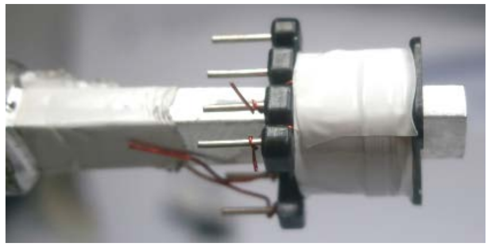
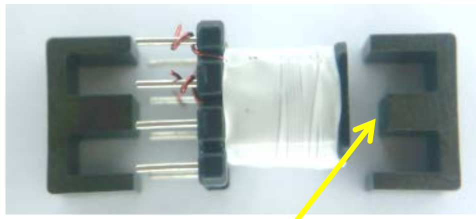
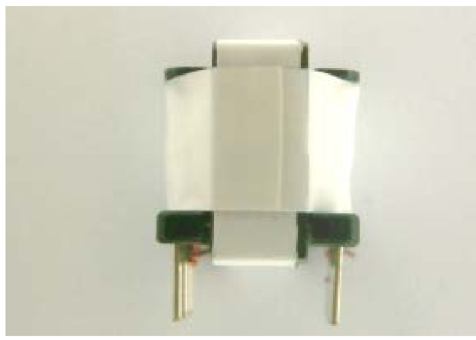
6.6 Winding Illustrations

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 2 and wind 124 turns in 6 layers, then finish the winding on pin 1.
Insulation		Add 1 layer of tape, item [5], for insulation.
Winding 2	 	Use wire item [3], start at pin 7 and wind 36 turns from left to right, then finish the winding on pin 5.

Insulation		Add 1 layer of tape, item [4], for insulation.
Assemble Core	 Gapped Core	Assemble the 2 cores on the bobbin with the gapped core place on top side of the bobbin and the un-gapped core at the bottom side. Wrap the 2 cores with 2 layer of tape, Item (6).
Bobbin Tape		Add 1 layer tape, item (5), around the bobbin together with the core.

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7 Inductor Design Spreadsheet

ACDC_LYTSwitch-3-Buck-Boost_102715; Rev.1.00; Copyright Power Integrations 2015	INPUT	INFO	OUTPUT	UNIT	ACDC_LYTSwitch-3-Buck-Boost_102615; LYTSwitch-3 Buck-Boost Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					
VACMIN	195		195	V	Minimum AC Input Voltage
VACNOM			230	V	Typical AC Input Voltage
VACMAX			265	V	Maximum AC Input Voltage
FL			50.00	Hz	Minimum line frequency
VO_MIN			64.8	V	Guaranteed minimum VO that maintains output regulation
VO			72.0	V	Worst case normal operating output voltage
VO_OVP_MIN			87.1	V	Minimum Voltage at which output voltage protection may be activated
IO	115.0		115.0	mA	Average output current specification
n			0.85	%/100	Total power supply efficiency
Z			0.50		Loss allocation factor
PO			8.28	W	Total output power
VD			0.70	V	Output diode forward voltage drop
LYTSwitch-3 DESIGN VARIABLES					
Select Breakdown Voltage	725V		725V	V	Choose between 650V and 725V
Device	LYT33X5		LYT33X5		Chosen LYTSwitch-3 Device
Final device code			LYT3325		
Select Dimming Curve Option	3		3		Minimum dim curve with Load Shut Down (LSD) enabled
RBS2			24.00	k-ohm	RBS2 resistor to select dimming curve
ILIMITMIN			1.233	A	Minimum device current limit
ILIMITTYP			1.325	A	Typical Current Limit
ILIMITMAX			1.418	A	Maximum Current Limit
TON			1.54	us	Expected on-time of MOSFET at low line and PO
FSW			107.5	kHz	Expected switching frequency at low line and PO
Duty Cycle			16.5	%	Expected operating duty cycle at low line and PO
IRMS			0.158	A	Nominal RMS current through the switch at low line
IPK			1.169	A	Worst Case Peak current (non-dimming)
KDP			1.69		Ratio between off-time of switch and reset time of core at VACNOM
KDP_DIM		Info	0.95		LYTSwitch-3 should operate in discontinuous mode (KDP > 1) for optimal performance. Verify the performance on the bench or consider changing the inductance value
ENTER INDUCTOR CORE/CONSTRUCTION VARIABLES					
Core Type	EE10		EE10		Core Type
Core Part Number			PC40EE10-Z		If custom core is used - Enter part number here
Bobbin part number			BE-10-116-CP		Bobbin Part number (if available)
AE			12.10	mm^2	Core Effective Cross Sectional Area
LE			26.10	mm	Core Effective Path Length
AL			850	nH/T^2	Ungapped Core Effective Inductance
BW			6.60	mm	Bobbin Physical Winding Width
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LPMIN			402	uH	Minimum Inductance
LP	423		423	uH	Typical value of Primary Inductance
LP Tolerance	5.0		5.0	%	Tolerance of Primary Inductance
N			124	Turns	Number of Turns
ALG			28	nH/T^2	Gapped Core Effective Inductance
BM			3295	Gauss	Operating Flux Density. Maintain value below 3300 G

BP			4199	Gauss	Calculated Worst Case Peak Flux Density (BP < 4200 G)
BAC			1647	Gauss	Worst case AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
LG			0.553	mm	Gap Length (Lg > 0.1 mm)
Layers			5.0		Estimated number of winding layers
IL_RMS			0.383	A	Worst case RMS Current through the inductor
AWG			31	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			81	Cmils	Bare conductor effective area in circular mils
CMA			211	Cmils/A	Primary Winding Current Capacity (200 < CMA < 500)
Current Density (J)			9.48	A/mm^2	Inductor Winding Current density (3.8 < J < 9.75 A/mm^2)
Bias Section					
TURNS_BIAS			36.00	Turns	
VBIAS			20.00	V	
PIVBS			128.80	V	
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			16.52	%	Duty cycle measured at minimum input voltage
IAVG			0.07	A	Input average current measured on the Mosfet at the minimum input voltage
IP			0.95	A	Peak Drain current at minimum input voltage
ISW_RMS			0.16	A	MOSFET RMS current measured at the minimum input voltage
ID_RMS			0.11	A	RMS current of freewheeling diode at minimum input voltage
IL_RMS			0.19	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			72.00	V	Load voltage measured on a prototype unit
RDS_T			4.4407	ohm	Theoretical calculation for RDS sense resistor
RDS			4.42	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			4.02	M-ohm	L pin resistor (E96 / 1%)
RFB_T			35463.58	ohm	Calculated value of RFB, using standard values for RDS, ROVP, and RL
RFB			35.70	k-ohm	Feedback pin resistor (E96 / 1%)
CFB_T			170.12	nF	Feedback pin capacitor (for 6ms time constant)
CFB			180	nF	Feedback pin capacitor E12 standard value
RSUP			13.80	k-ohm	Bias supply resistor assuming 1mA current necessary to supply BP
IOUT_MEASURED			115.0	mA	Measured average output current on the LEDs
Output Parameters					
VDRAIN			493	V	Estimated worst case drain voltage at VACMAX and VO_MAX
PIVD			508.9	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
RDAMPER			200	Ohm	Value of damper resistor
VDAMPER_RMS			9.17	V	Estimated RMS voltage drop on damper (without a bleeder present)

Note: For KDP_dim which is lower than 1, Unit performance was verified on bench and it passed the output current regulation requirement throughout the input and output voltage range. No abnormal condition was observed during dimming.

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8 Performance Data

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

8.1 Efficiency

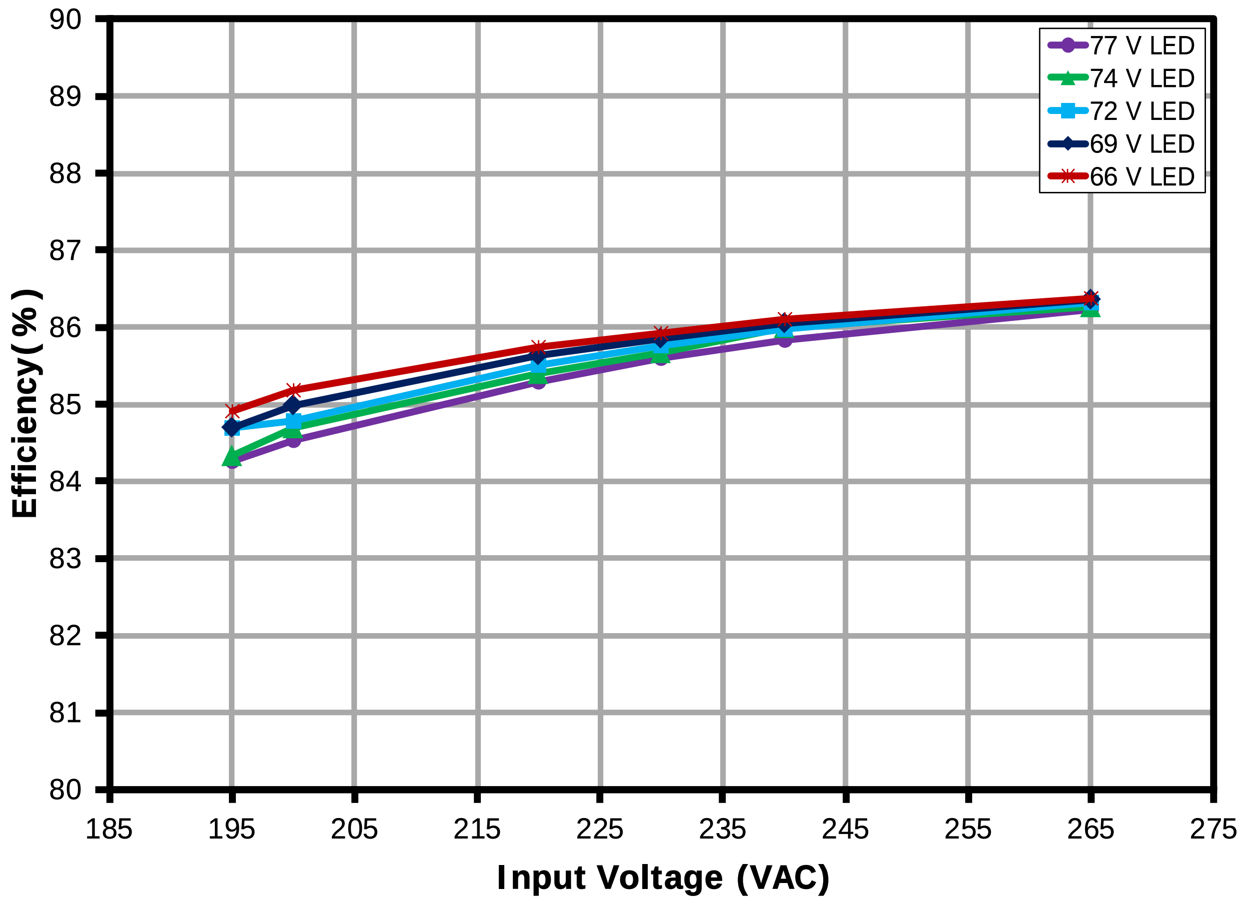

Figure 9 – Efficiency vs. Line and LED Load.

8.2 Line Regulation

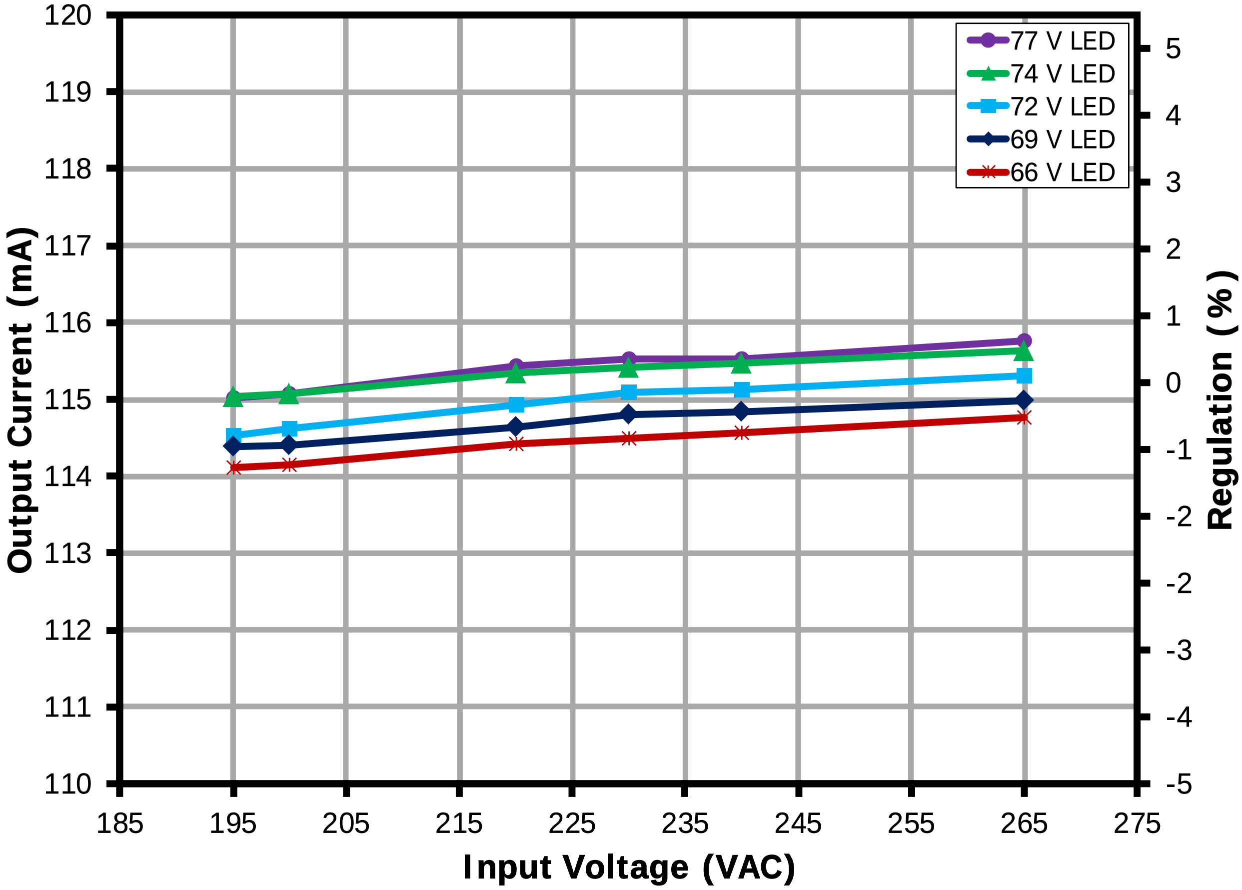

Figure 10 – Regulation vs. Line and LED Load.

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8.3 Power Factor

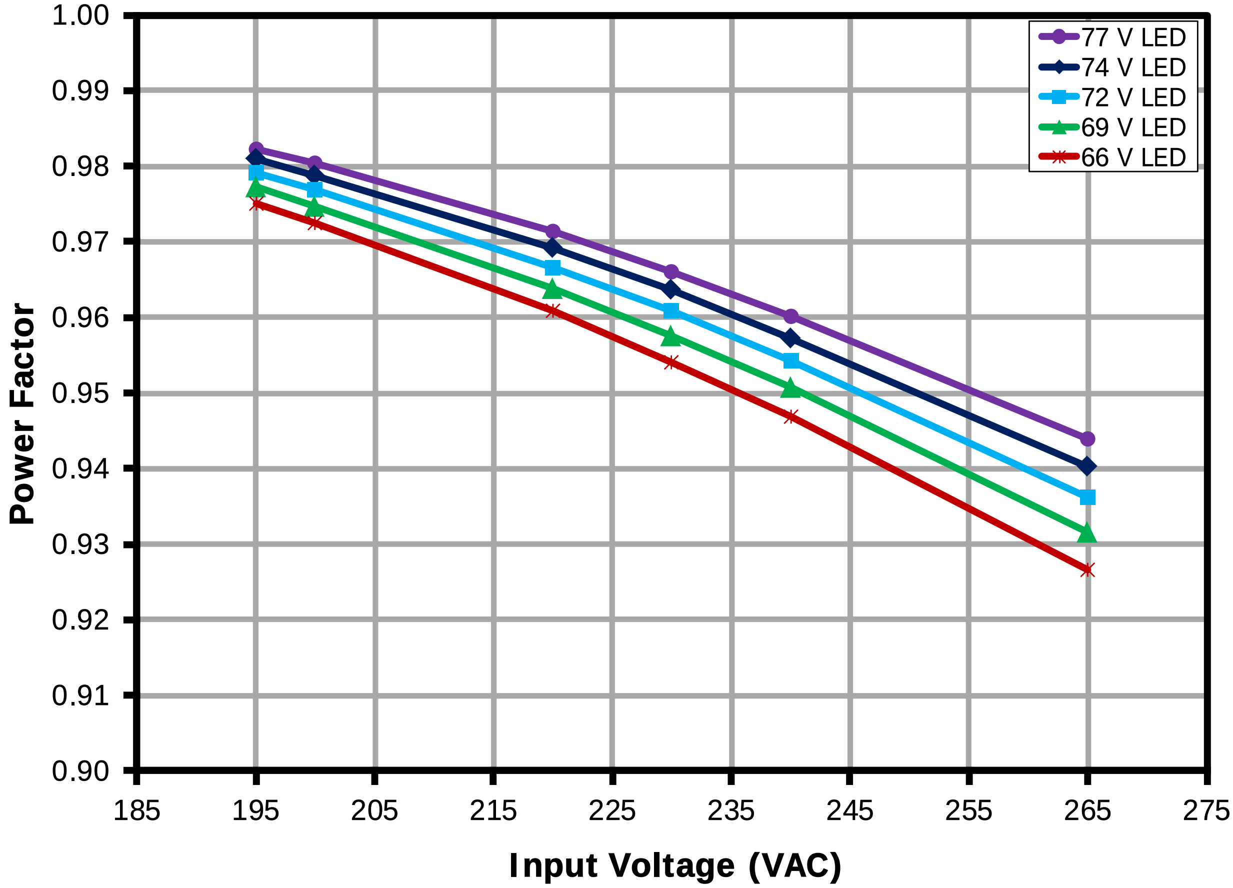

Figure 11 – Power Factor vs. Line and LED Load.

8.4 %ATHD

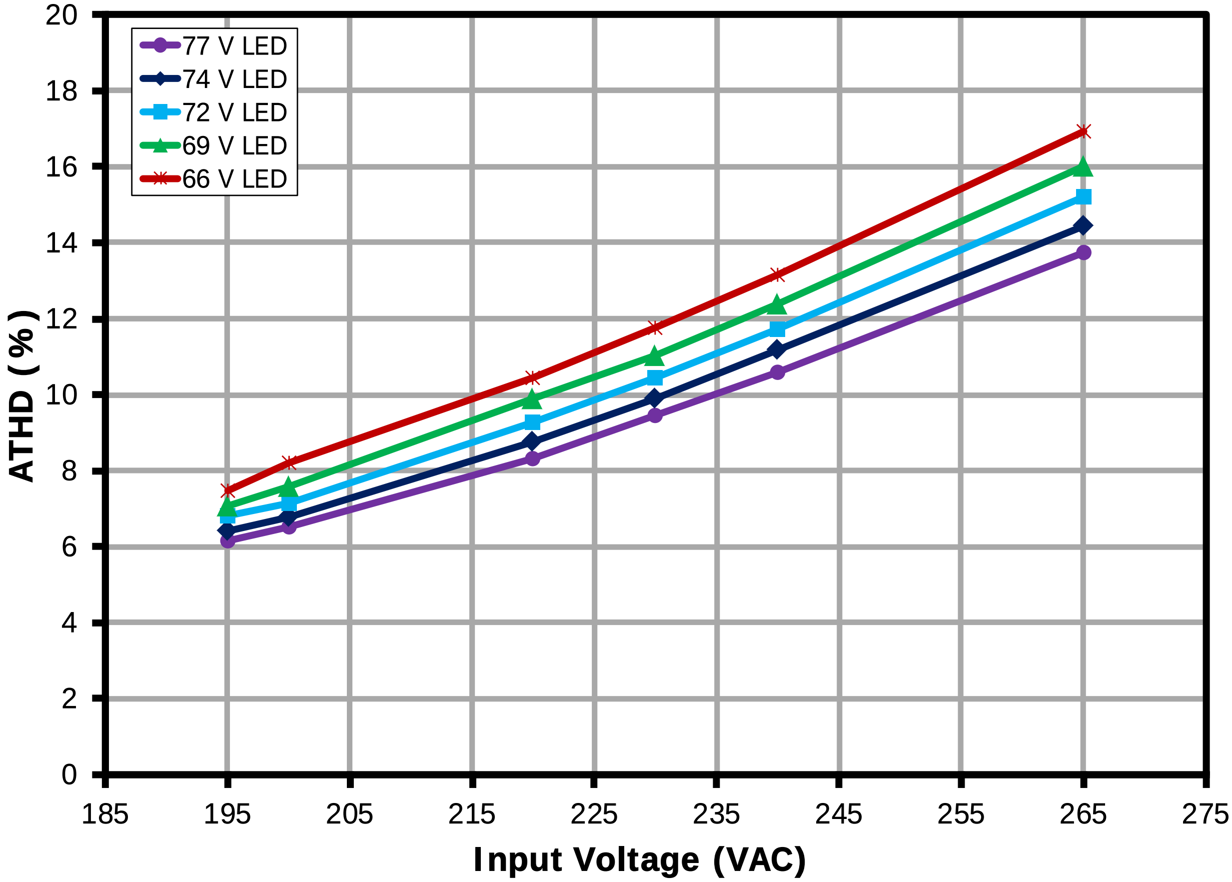

Figure 12 – %ATHD vs. Line and LED Load at 230 VAC, 50 Hz.

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8.5 Harmonics

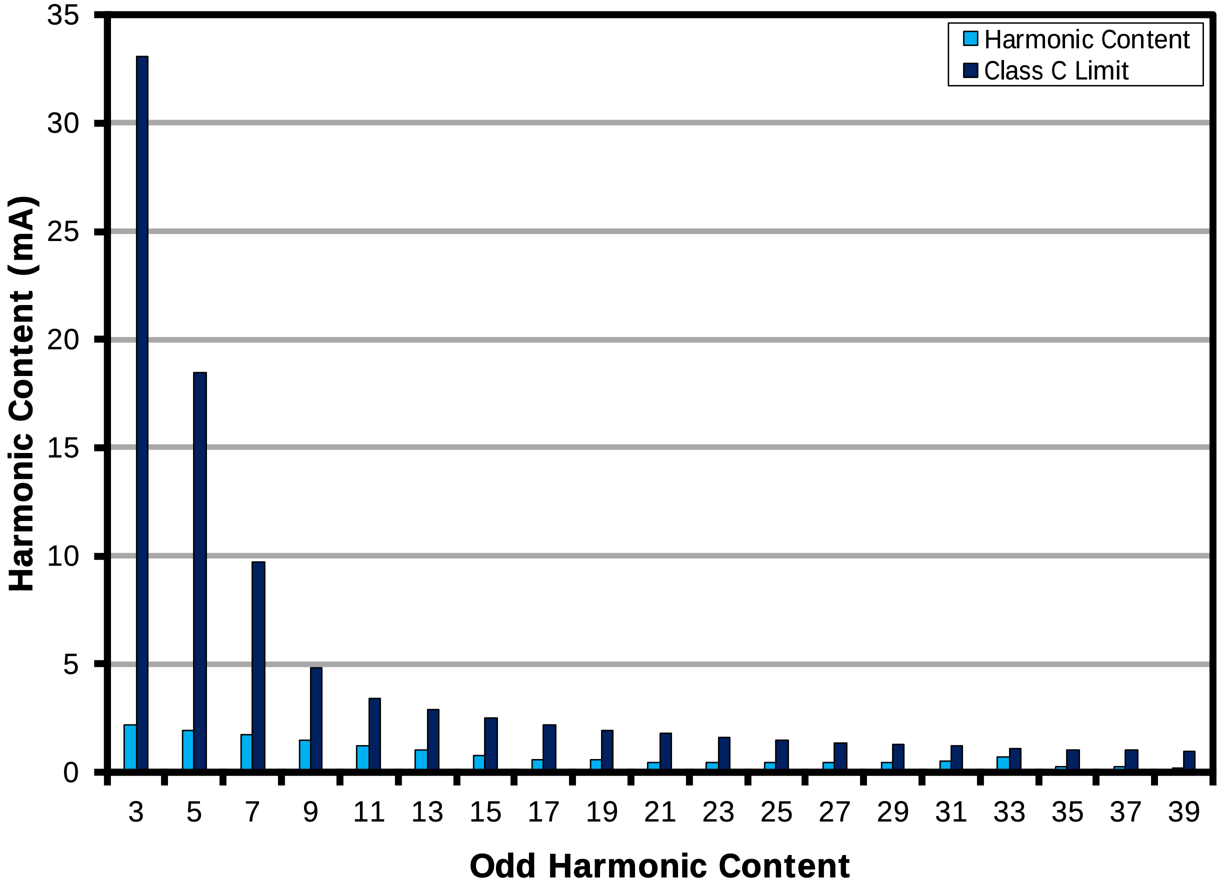

Figure 13 – 72 V LED Load Input Current Harmonics at 230 VAC, 50 Hz.

9 Test Data

9.1 Test Data, 66 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)	
195	50	194.95	46.68	8.87	0.975	7.456	65.70	114.11	7.53	84.92
200	50	199.92	45.51	8.85	0.972	8.211	65.69	114.15	7.54	85.18
220	50	219.95	41.70	8.81	0.961	10.431	65.69	114.42	7.55	85.73
230	50	229.97	40.08	8.80	0.954	11.753	65.69	114.49	7.56	85.93
240	50	239.99	38.66	8.78	0.947	13.143	65.68	114.57	7.56	86.10
265	50	265.01	35.71	8.77	0.927	16.92	65.69	114.77	7.58	86.37

9.2 Test Data, 69 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)	
195	50	194.95	48.79	9.30	0.977	7.071	68.49	114.39	7.87	84.69
200	50	199.92	47.52	9.26	0.975	7.584	68.47	114.40	7.87	84.99
220	50	219.95	43.45	9.21	0.964	9.896	68.47	114.64	7.89	85.64
230	50	229.97	41.77	9.20	0.958	11.04	68.46	114.80	7.90	85.86
240	50	239.99	40.23	9.18	0.951	12.403	68.46	114.83	7.90	86.05
265	50	265.01	37.10	9.16	0.932	16.03	68.46	114.98	7.91	86.36

9.3 Test Data, 72 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)	
195	50	194.95	50.81	9.70	0.979	6.822	71.39	114.53	8.21	84.69
200	50	199.91	49.62	9.69	0.977	7.149	71.36	114.62	8.22	84.79
220	50	219.95	45.30	9.63	0.967	9.283	71.34	114.93	8.24	85.51
230	50	229.97	43.52	9.62	0.961	10.451	71.32	115.10	8.25	85.76
240	50	239.99	41.88	9.59	0.954	11.742	71.31	115.12	8.25	85.97
265	50	265.01	38.56	9.57	0.936	15.202	71.29	115.30	8.26	86.32

9.4 Test Data, 74 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)	
195	50	194.94	53.10	10.15	0.981	6.413	74.11	115.03	8.56	84.33
200	50	199.91	51.67	10.11	0.979	6.76	74.08	115.08	8.56	84.69
220	50	219.95	47.14	10.05	0.969	8.759	74.06	115.35	8.58	85.39
230	50	229.97	45.21	10.02	0.964	9.887	74.04	115.42	8.58	85.67
240	50	239.99	43.46	9.98	0.957	11.161	74.03	115.47	8.58	86.00
265	50	265.01	39.98	9.96	0.940	14.43	74.02	115.63	8.60	86.27

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9.5 Test Data, 77 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)	
195	50	194.94	54.94	10.52	0.982	6.154	76.75	115.01	8.86	84.27
200	50	199.91	53.54	10.49	0.980	6.514	76.74	115.08	8.87	84.53
220	50	219.95	48.81	10.43	0.971	8.314	76.73	115.43	8.89	85.29
230	50	229.97	46.81	1040	0.966	9.467	76.72	115.53	8.90	85.60
240	50	239.99	45.00	10.37	0.960	10.601	76.71	115.53	8.90	85.83
265	50	265.01	41.34	10.34	0.944	13.751	76.71	115.77	8.92	86.23

9.6 Test Data, Harmonic Content at 230 VAC with 72 V LED Load

V_{IN} (V_{RMS})	Freq	I_{IN} (mA_{RMS})	P_{IN} (W)	%THD
230	50	43.97	9.727	10.255
nth Order	**mA Content**	**% Content**	**mA Limit <25 W**	**Remarks**
1	43.67			
2	0.02	0.05%		Pass
3	2.17	4.97%	33.07	Pass
5	1.95	4.47%	18.48	Pass
7	1.75	4.01%	9.73	Pass
9	1.52	3.48%	4.86	Pass
11	1.25	2.86%	3.40	Pass
13	1.01	2.31%	2.88	Pass
15	0.80	1.83%	2.50	Pass
17	0.60	1.37%	2.20	Pass
19	0.56	1.28%	1.97	Pass
21	0.44	1.01%	1.78	Pass
23	0.47	1.08%	1.63	Pass
25	0.47	1.08%	1.50	Pass
27	0.43	0.98%	1.39	Pass
29	0.44	1.01%	1.29	Pass
31	0.54	1.24%	1.21	Pass
33	0.74	1.69%	1.13	Pass
35	0.27	0.62%	1.07	Pass
37	0.24	0.55%	1.01	Pass
39	0.23	0.53%	0.96	Pass

10 Dimming Performance Data

TRIAC dimming results were taken at an input voltage of 230 VAC, 50 Hz line frequency, room temperature, and a nominal 72 V LED load.

10.1 Dimming Curve

Agilent 6812B AC source programmed as perfect leading edge dimmer

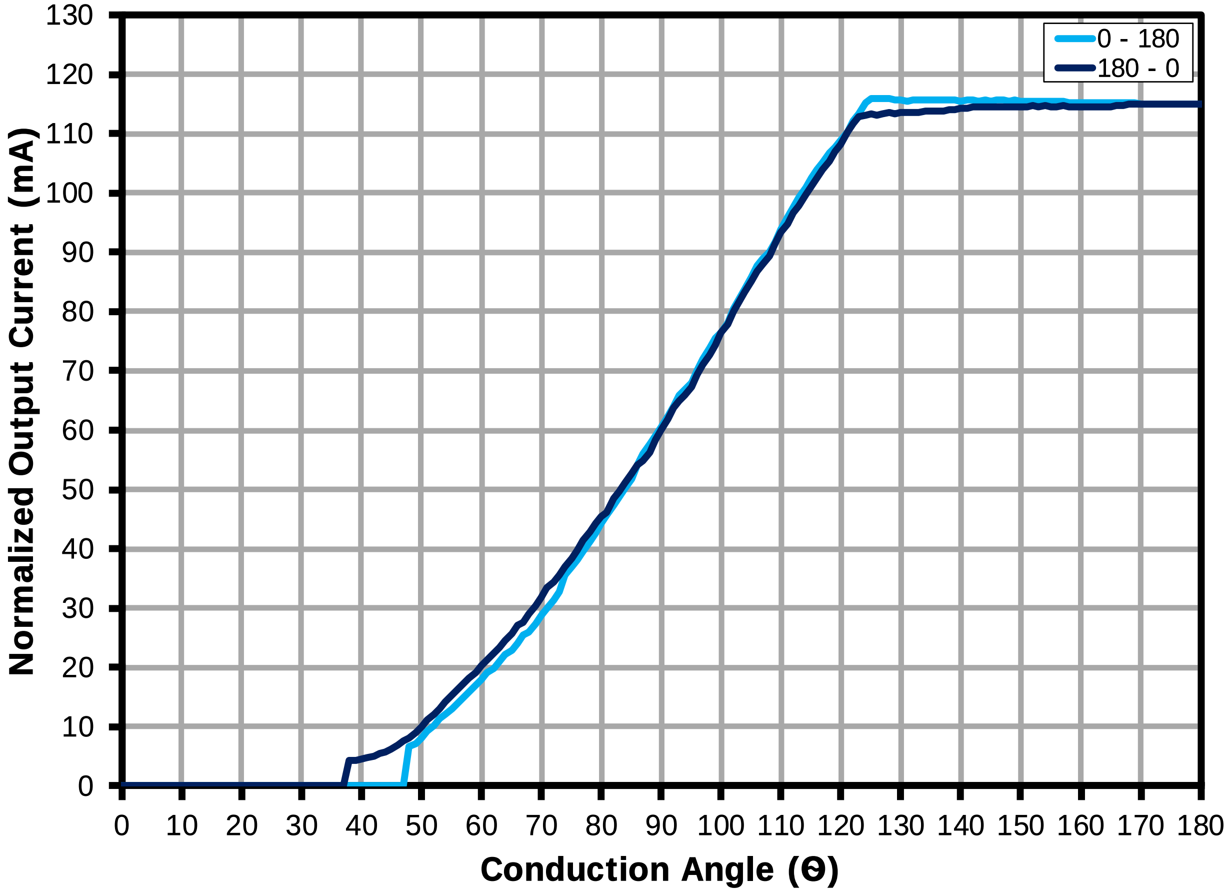

Figure 14 – Dimming Curve at 230 VAC, 50 Hz Input.

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10.2 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.

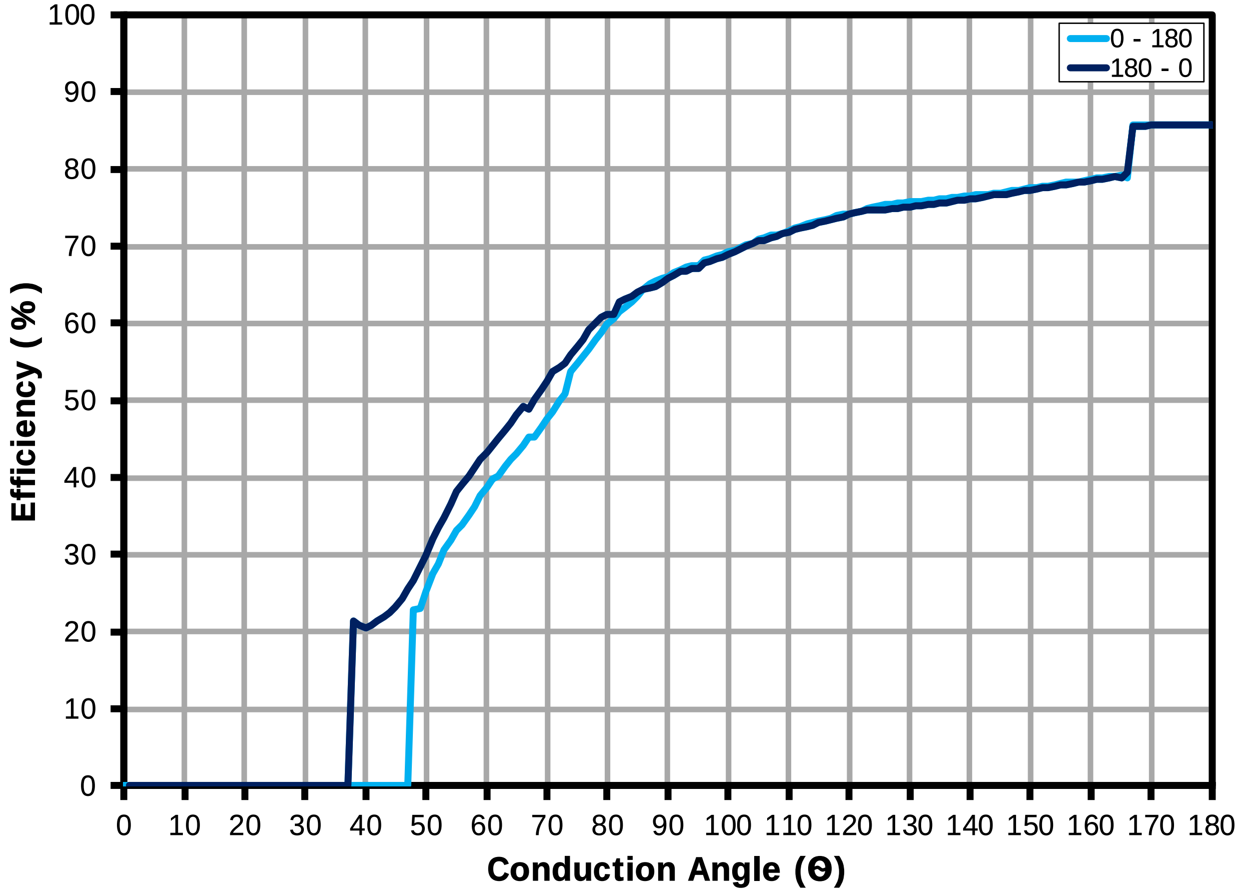

Figure 15 – Driver Efficiency at 230 VAC, 50 Hz Input.

10.3 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.

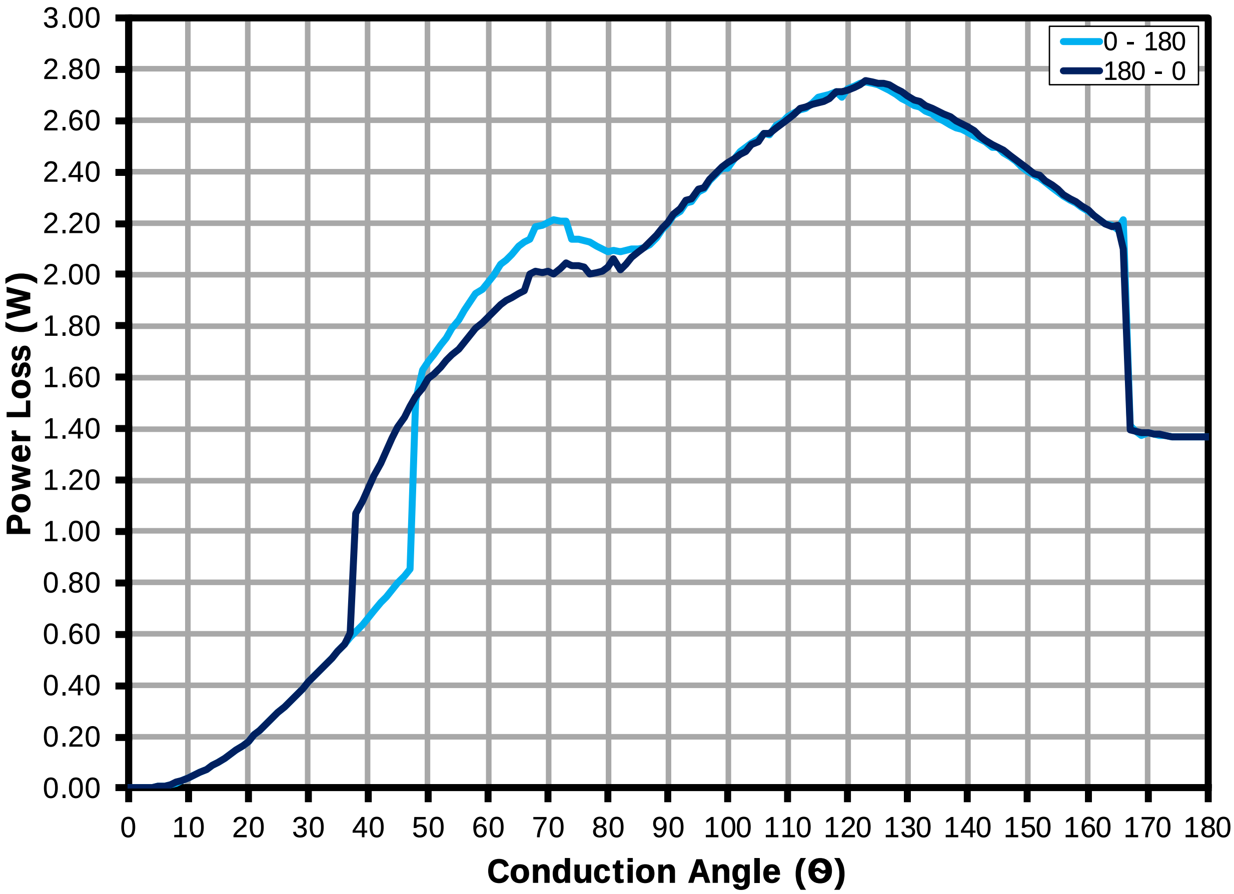

Figure 16 – Driver Power Loss at 230 VAC, 50 Hz Input.

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10.4 Driver Compatibility List

The following dimmers were tested at 75 ºC ambient temperature with utility line input (~230 VAC, 50 Hz) and 72 V LED load.

No	Brand	Model	Type	Max (mA)	Min (mA)	Dimming Ratio
1	BERKER	2875	L	116.5	9	13
2	GIRA	0307 00	T	118	10	12
3	BERKER	2830	L	116	9	13
4	GIRA	0302 00	L	116	8	15
5	GIRA	2262 00	L	115	6	19
6	GIRA	0300 00	L	116	23	5
7	PEHA	433 HAB 0A	T	110	6	18
8	BERKER	2875	L	116	8	15
9	GIRA	226200-101	L	115	4	29
10	RELCO	RT	L	114	3	38
11	BTICINO	4402N	L	115	15	8
12	IKEA	EED200LRS	L	115.8	6	19
13	EAGLERISE	SED200LRS	L	116	7	17
14	EAGLERISE	SED300FHS	L	116	5	23
15	LEEDARSON	EF-700	T	96	7	14
16	JUNG	225 TDE	T	118	9	13
17	JUNG	266 GDE	L	116	8	15
18	JUNG	225 NVDE	L	115	7	16
19	JUNG	254 UDIE 1	T	118	8	15
20	BUSCH	2247 U	L	115	6	19
21	BUSCH	2250 U	L	115	7	16
22	NIKO	310-01600	L	115	9	13
23	NIKO	310-01700	T	110	11.5	10
24	NIKO	310-01400	L	115.8	15.5	7
25	NIKO	310-01300	L	115.7	5	23
26	AU	DSP400X	L	115.7	6	19

11 Thermal Performance

11.1 Thermal Performance Scan – Open Frame Unit

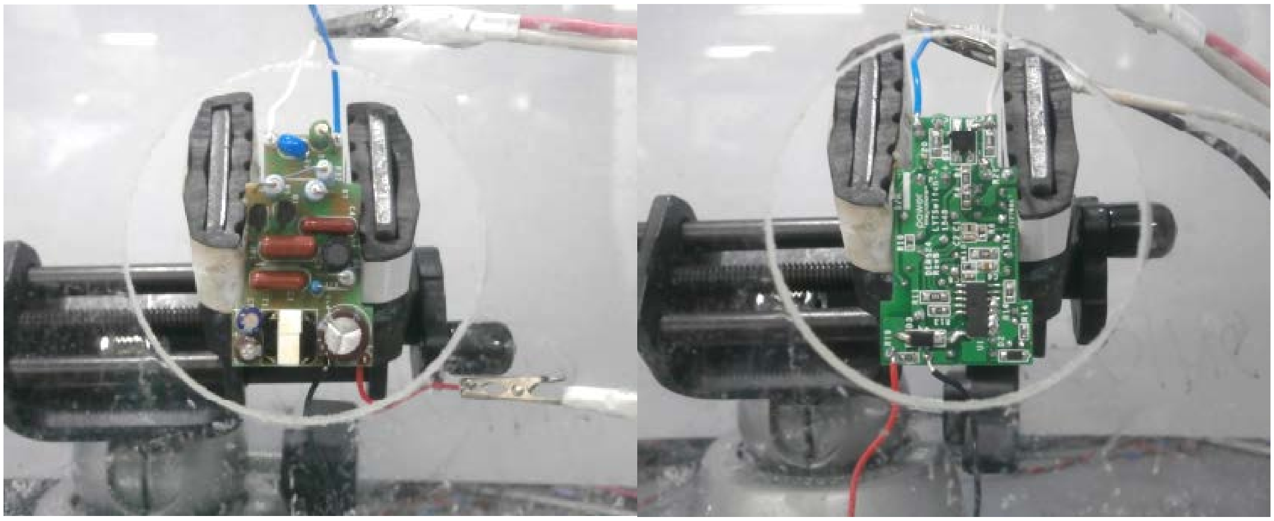

Figure 17 – Test Set-up Picture - Open Frame.

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

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11.1.1 Thermal Scan during Dimming at the Bottom Side

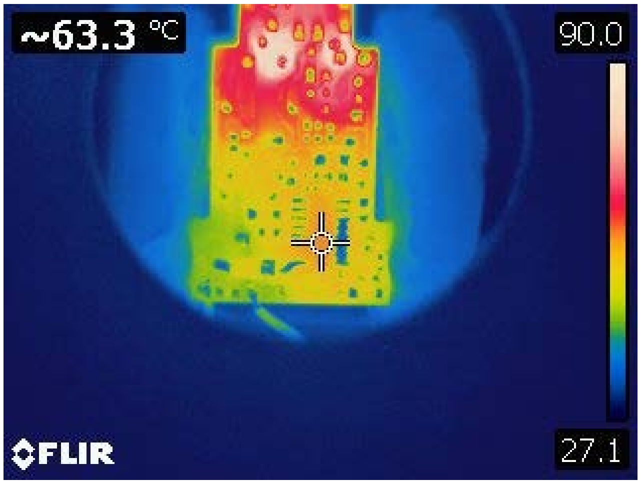

Figure 18 – 230 VAC, 72 V LED LOAD.
Spot 1: LYT3325D (U1): 63.3 ºC.

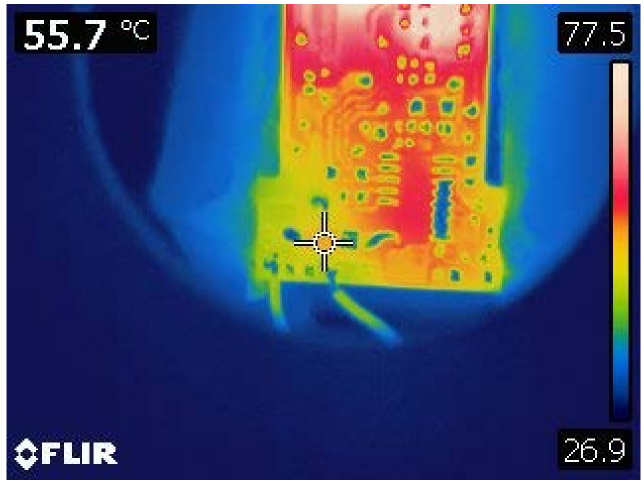

Figure 19 – 230 VAC, 72 V LED LOAD.
Spot 1: Output Diode (D3): 55.7 ºC.

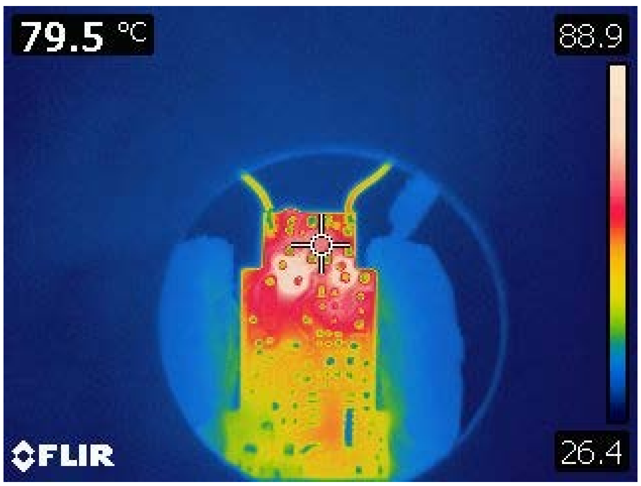

Figure 20 – 230 VAC, 72 V LED LOAD.
Spot 1: Bridge Diode (BR1): 79.5 ºC.

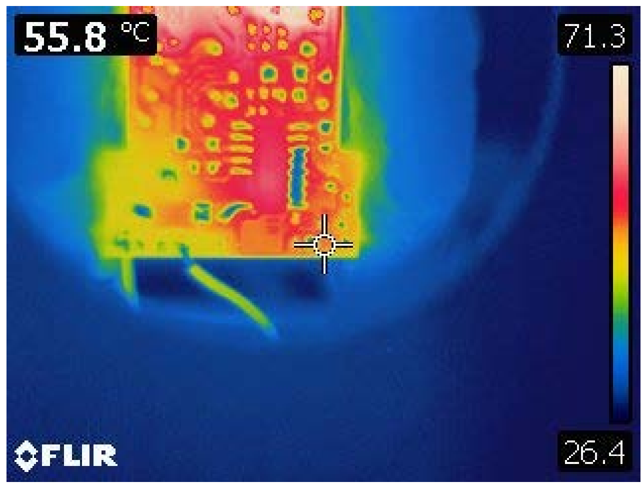

Figure 21 – 230 VAC, 72V LED LOAD.
Spot 1: Aux Diode (D1): 55.8 ºC.

11.1.2 Thermal Scan during Dimming at the Top Side

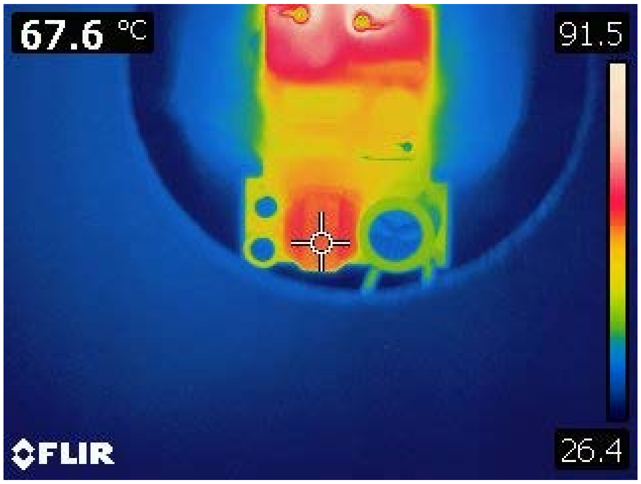

Figure 22 – 230 VAC, 72 V LED Load.
Spot 1: Transformer (T1): 67.6 ºC.

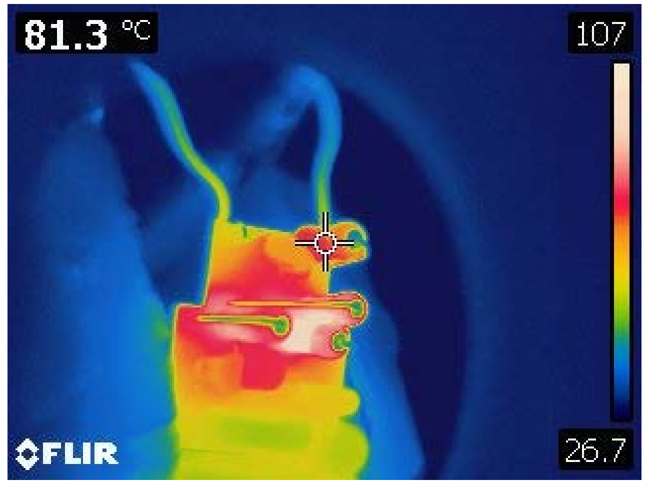

Figure 23 – 230 VAC, 72 V LED Load.
Spot 1: Fusible Resistor (RF1): 81.3 ºC.

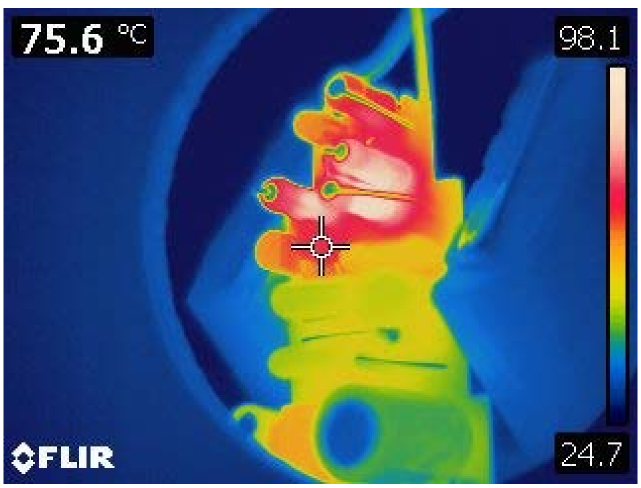

Figure 24 – 230 VAC, 72 V LED Load.
Spot 1: Bleeder Switch (Q1): 75.6 ºC.

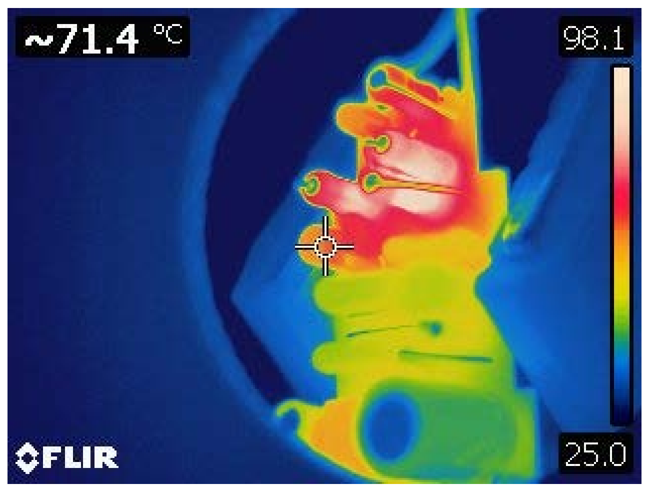

Figure 25 – 230 VAC, 72 V LED Load.
Spot 1: Bleeder Drive (Q2): 71.4 ºC.

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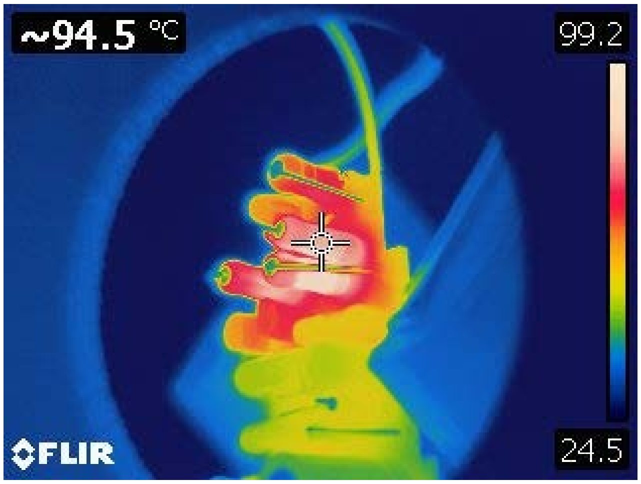

Figure 26 – 230 VAC, 72 V LED Load.
Spot 1: Bleeder (R32): 94.5 ºC.

Figure 27 – 230 VAC, 72 V LED Load.
Spot 1: Bleeder Resistor (R9): 95.4 ºC.

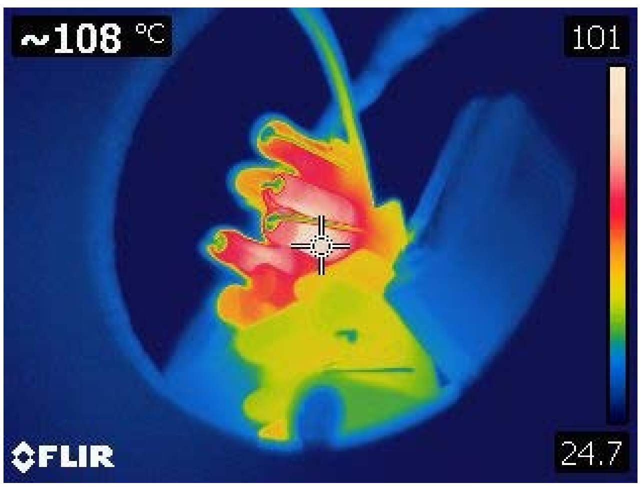

Figure 28 – 230 VAC, 72 V LED Load.
Spot 1: Damper Resistor (R7): 108 ºC.

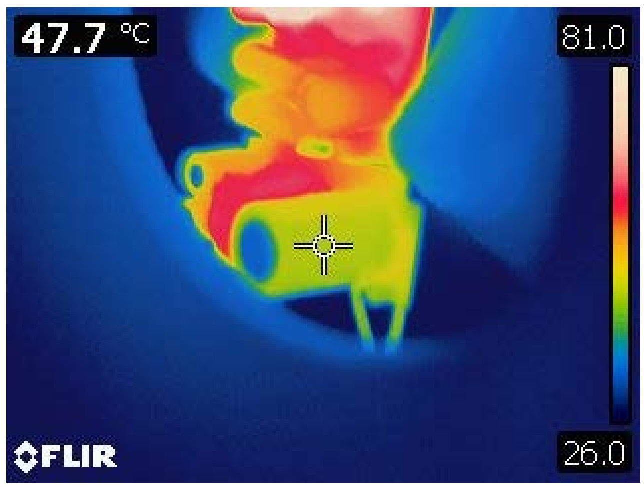

Figure 29 – 230 VAC, 72 V LED Load.
Spot 1: Output Cap (C10): 47.7 ºC.

11.2 Thermal Performance at 85 ºC Ambient

Figure 30 – Test Set-up Picture Thermal at 85 ºC Ambient- Open Frame.

Unit in open frame was placed inside the enclosure to prevent airflow that might affect the thermal measurements. Ambient temperature inside enclosure is 85 ºC. Temperature was measured using type T thermocouple.

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11.2.1 Non-Dimming Thermal Performance at 230 VAC with a 72 V LED Load

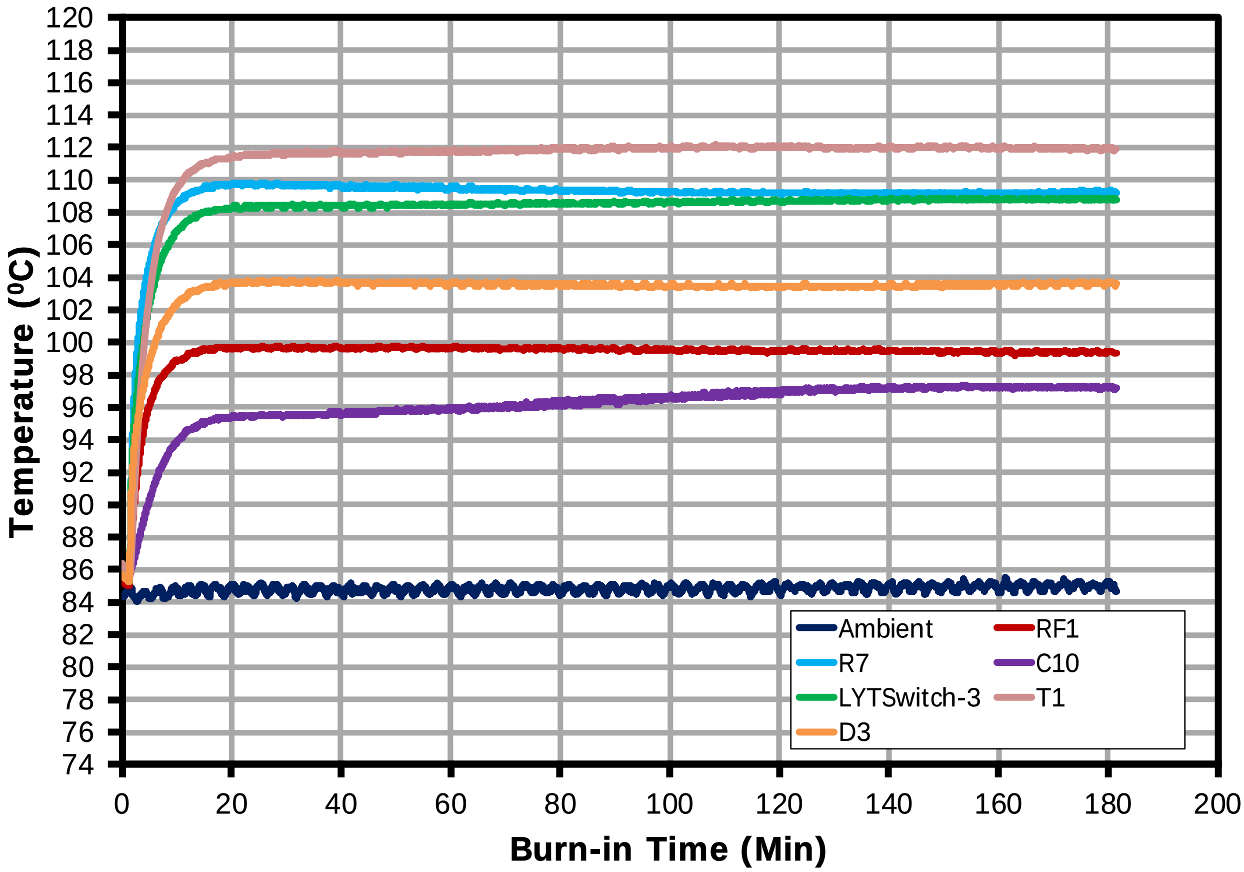

Figure 31 – Component Temperature at 230 VAC, 85 ºC Ambient.

Measurement	Ambient	RF1	C10	R7	LYTSwitch-3	D3	T1
Maximum (ºC)	85.5	99.8	97.4	109.8	108.9	103.8	112.2
Final (ºC)	84.7	99.3	97.2	109.2	108.8	103.6	111.9

11.2.2 Thermal Performance during Dimming at 230 V VAC, 120° Conduction Angle

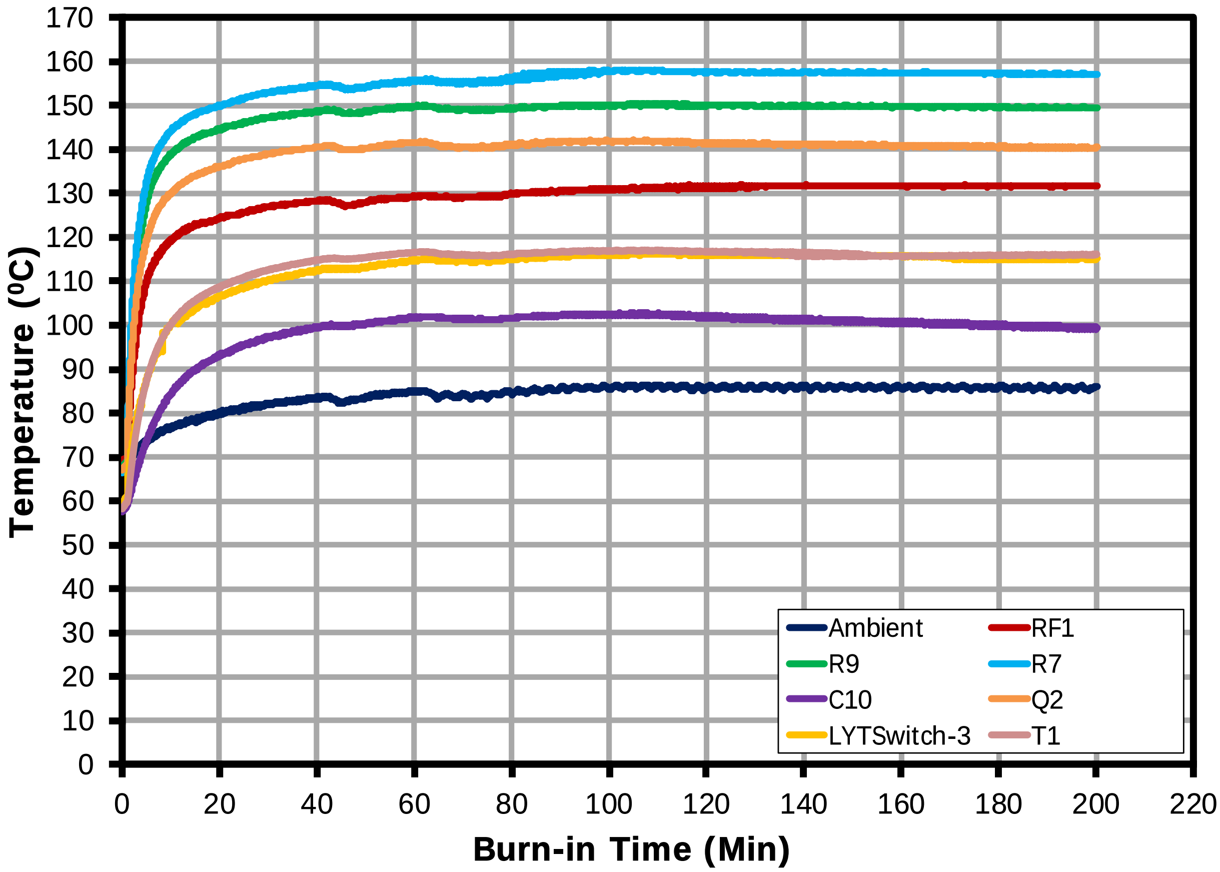

Figure 32 – Component Temperature at 230 VAC, 120° Conduction Angle, 85 °C Ambient.

Measurement	Ambient	RF1	R9	C10	R7	Q2	LYTSwitch-3	D3	Q1	T1
Maximum (°C)	86.5	131.9	150.5	102.7	158.0	142.1	116.3	109.6	138.2	117.1
Final (°C)	86.0	131.7	149.6	99.3	157.2	140.5	115.1	109.3	137.5	116.1

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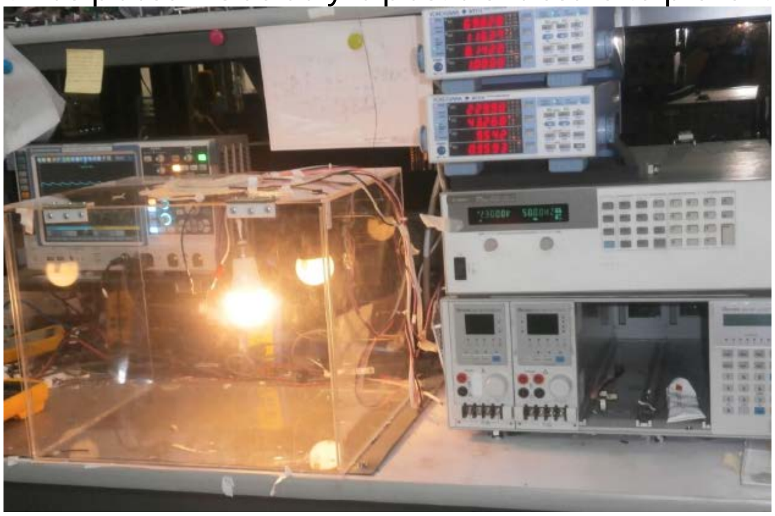
11.3 Lumen Test

The LED driver using A19 LED bulb was burned in for 12 hours at 28 ºC ambient temperature. The unit was placed inside acrylic plastic enclosure to prevent airflow.



11.4 Output Current Drift Measurement

Output current drifted by <5% based from initial measured output LED current.

Status	Output LED Current (mA)
Start	117.380
Finish	114.960
% Drift	2.062

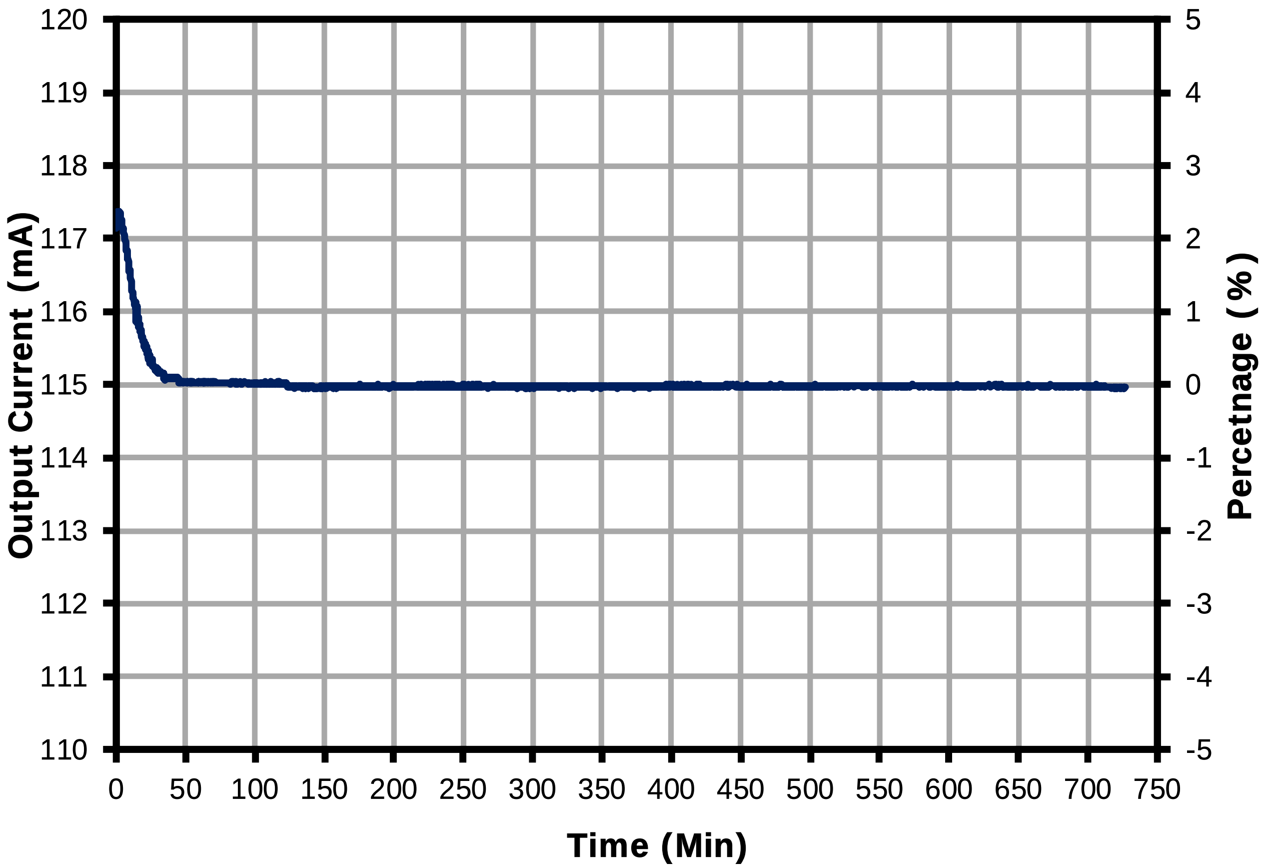


Figure 33 – Output Current Drift Plot at 230 VAC, 50 Hz.

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12 Waveforms

12.1 Input Voltage and Input Current Waveforms

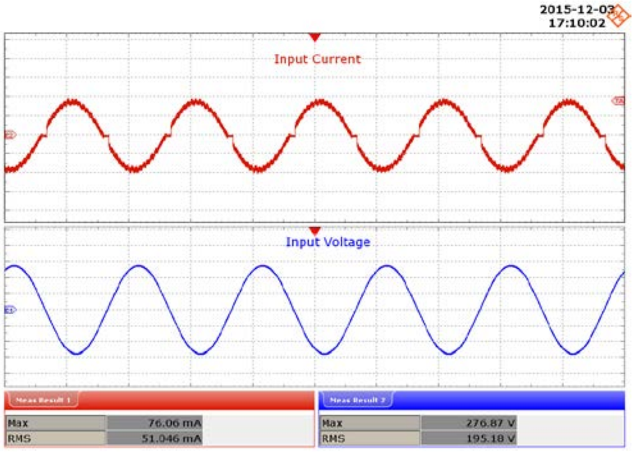

Figure 34 – 195 VAC, 72 V LED Load.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

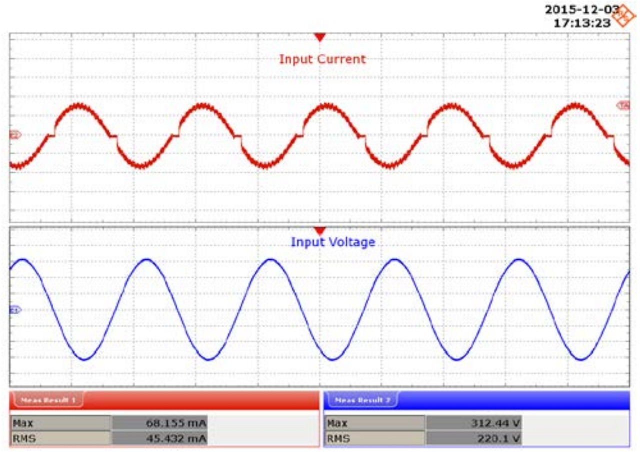

Figure 35 – 220 VAC, 72 V LED Load.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

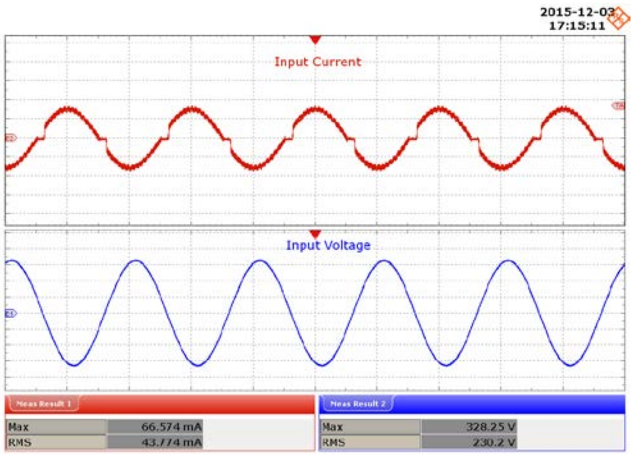

Figure 36 – 230 VAC, 72 V LED Load.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

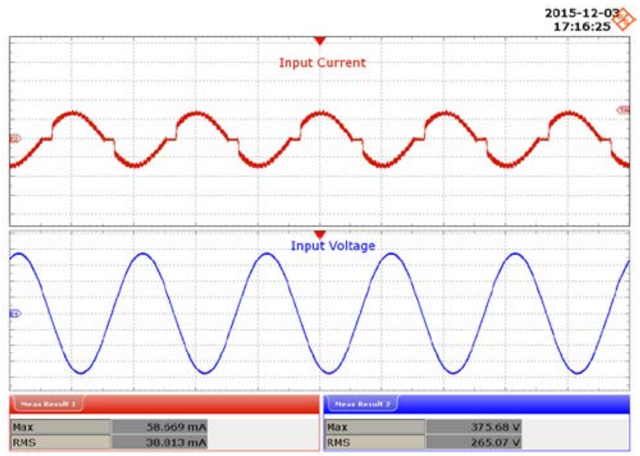

Figure 37 – 265 VAC, 72 V LED Load.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

12.2 Output Current Rise and Fall

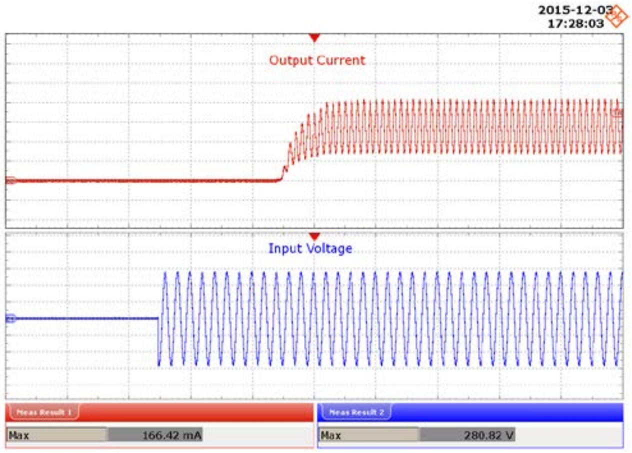

Figure 38 – 195 VAC, 72 V LED Load, Output Rise.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.

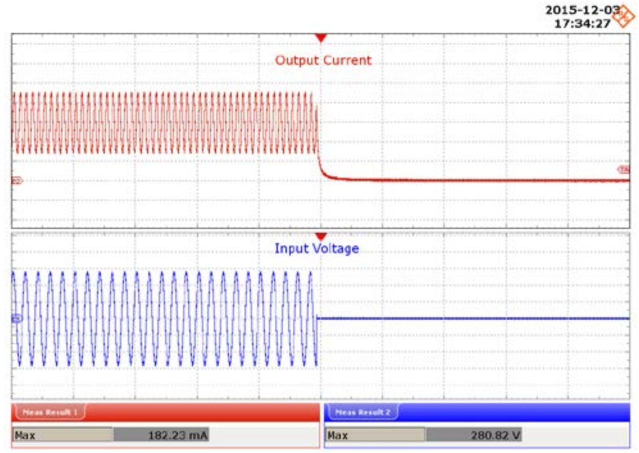

Figure 39 – 195 VAC, 72 V LED Load, Output Fall.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.

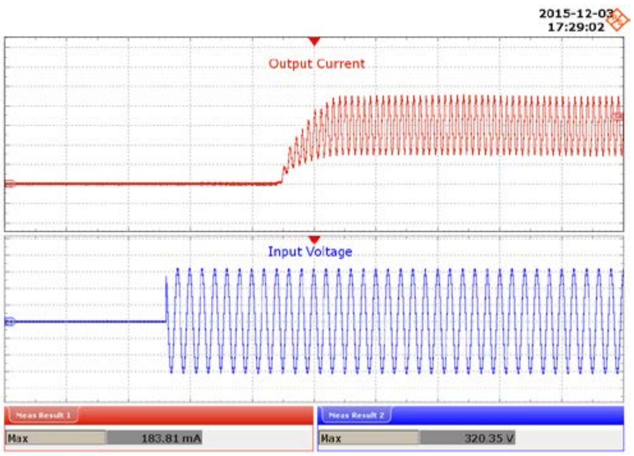

Figure 40 – 220 VAC, 72 V LED Load, Output Rise.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.

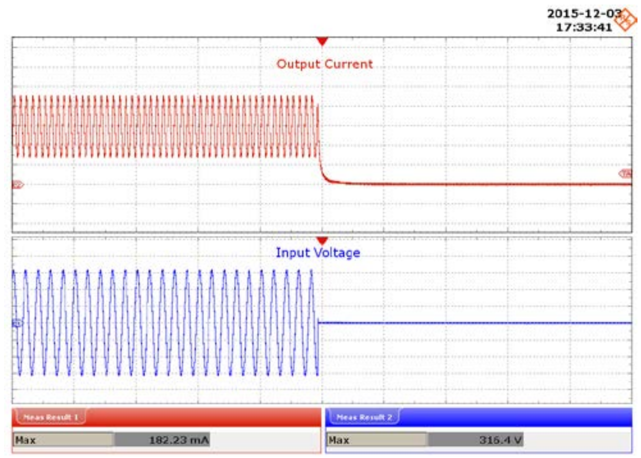

Figure 41 – 220 VAC, 72 V LED Load, Output Fall.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.

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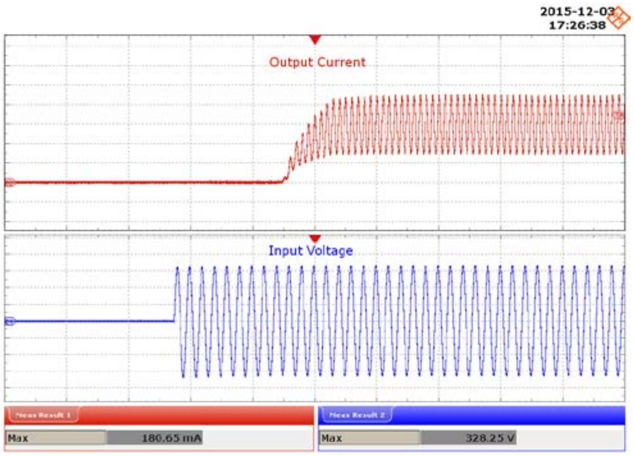

Figure 42 – 230 VAC, 72 V LED Load, Output Rise.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.

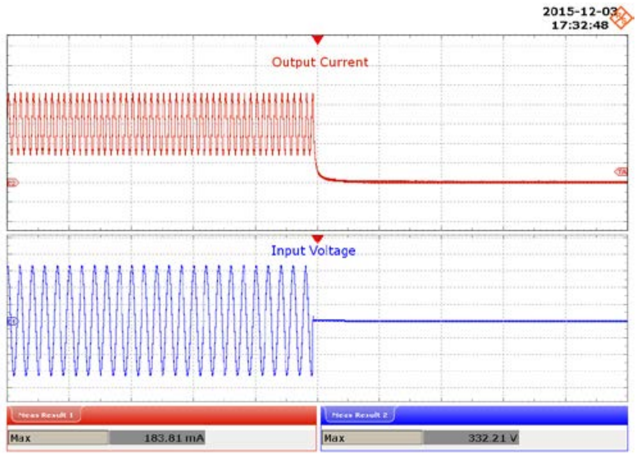

Figure 43 – 240 VAC, 72 V LED Load, Output Fall.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.

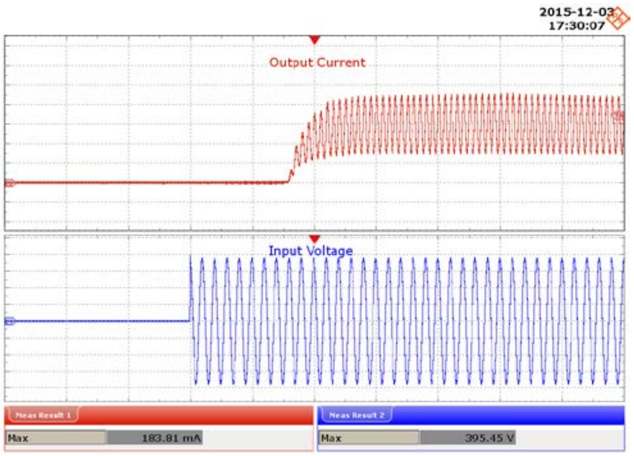

Figure 44 – 265 VAC, 72 V LED Load, Output Rise.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.

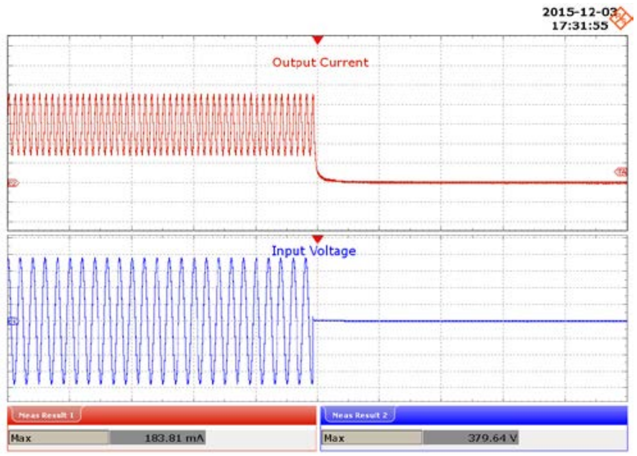

Figure 45 – 265 VAC, 72 V LED Load, Output Fall.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 100 ms / div.

12.3 Drain Voltage and Current in Normal Operation

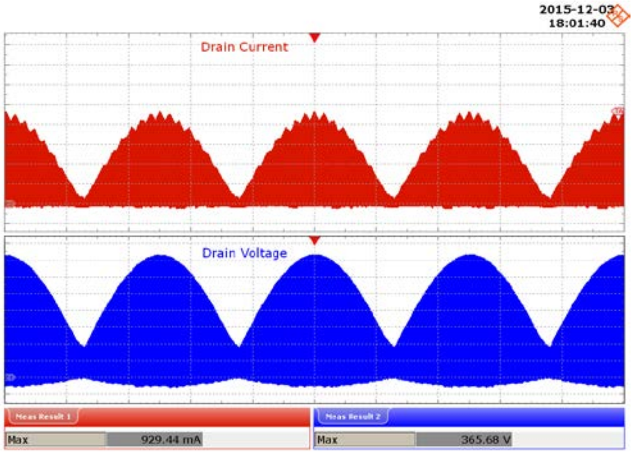

Figure 46 – 195 VAC, 72 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 ms / div.

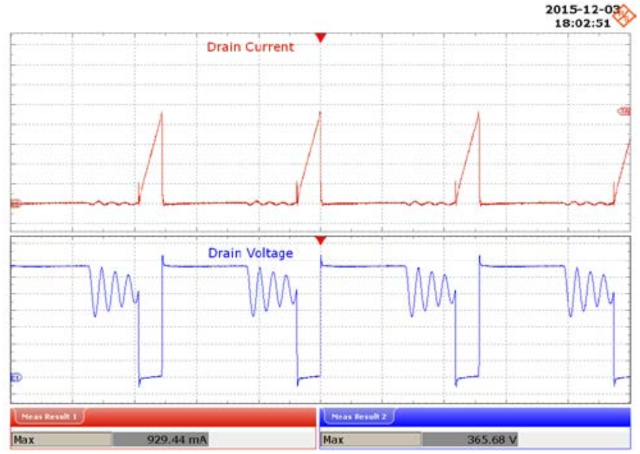

Figure 47 – 195 VAC, 72 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 µs / div.

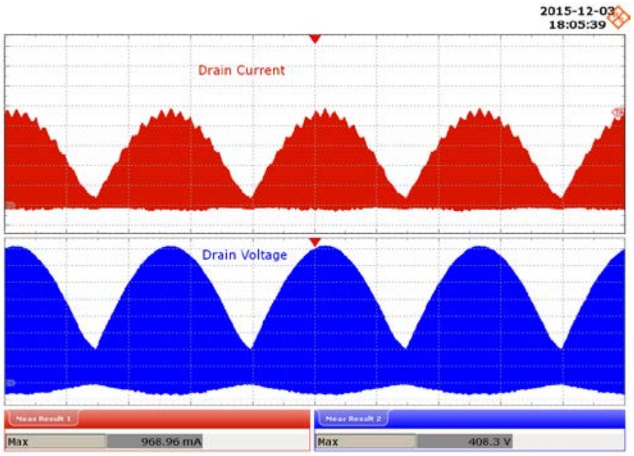

Figure 48 – 220 VAC, 72 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 ms / div.

Figure 49 – 220 VAC, 72 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 µs / div.

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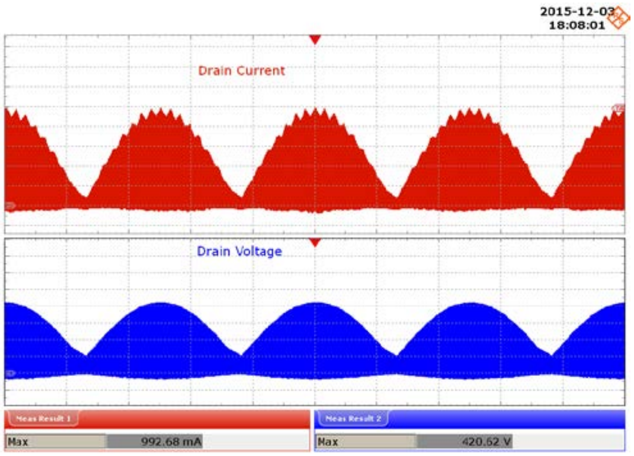

Figure 50 – 230 VAC, 72 V LED Load
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

Figure 51 – 230 VAC, 72 V LED Load
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 μs / div.

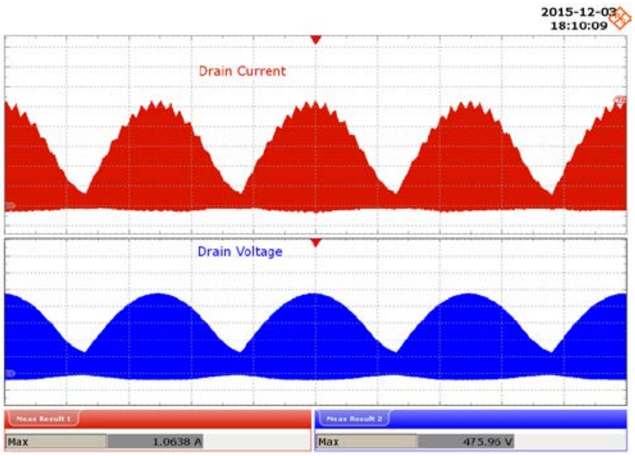

Figure 52 – 265 VAC, 72 V LED Load
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

Figure 53 – 265 VAC, 72 V LED Load
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 μs / div.

12.4 Drain Voltage and Current Start-up Profile

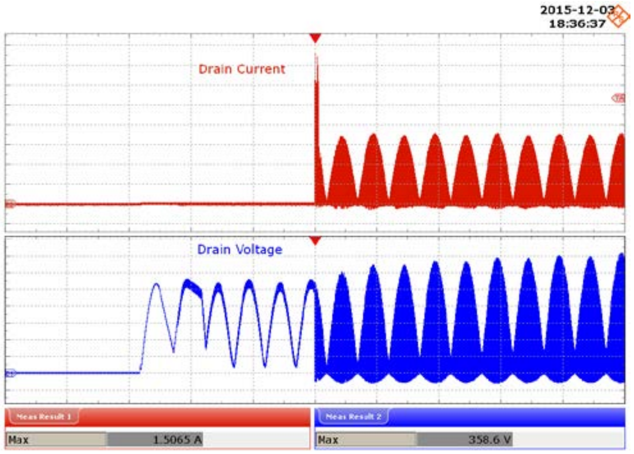

Figure 54 – 195 VAC, 72 V LED Load
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 20 ms /div.

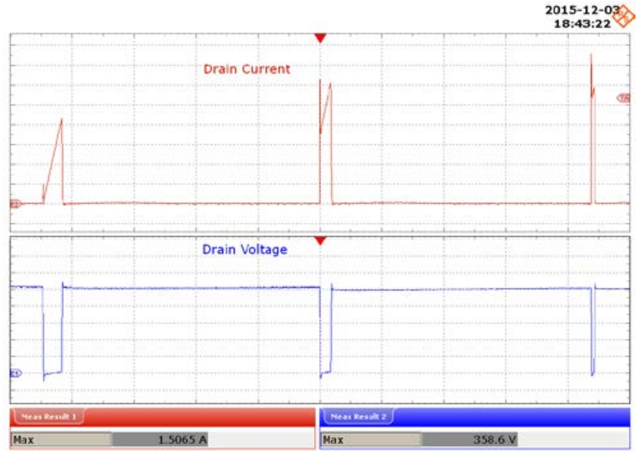

Figure 55 – 195 VAC, 72 V LED Load
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 5 μs /div.

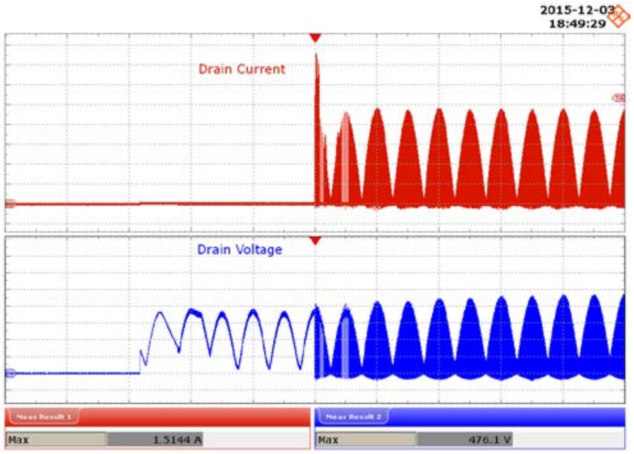

Figure 56 – 265 VAC, 72 V LED Load
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 ms /div.

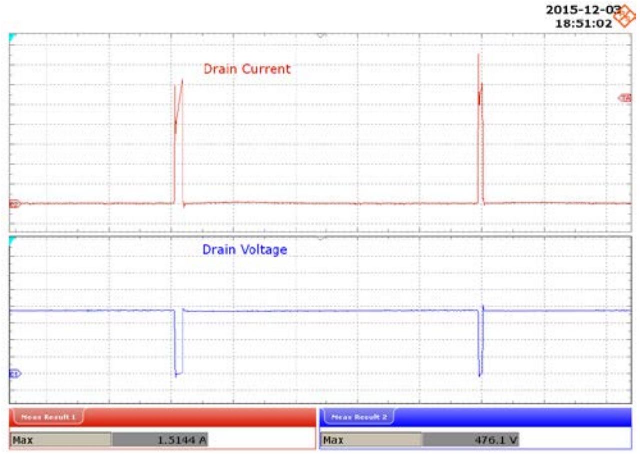

Figure 57 – 265 VAC, 72 V LED Load
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs /div.

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12.5 Drain Voltage and Current During Output Short-Circuit Condition

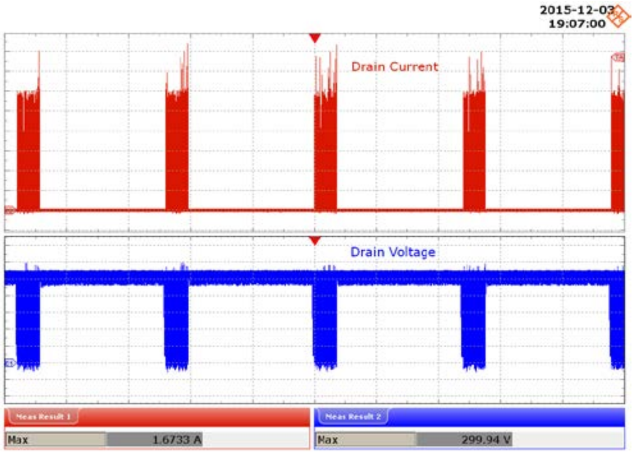

Figure 58 – 195 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

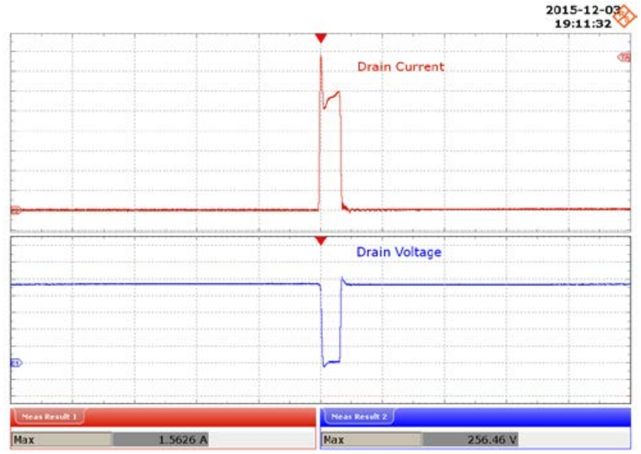

Figure 59 – 195 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 μs / div.

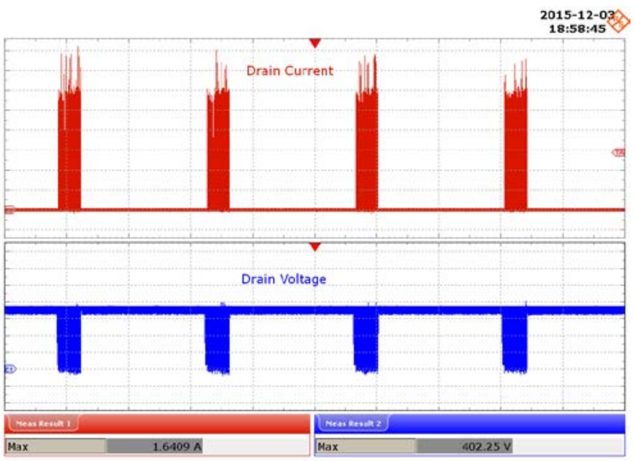

Figure 60 – 265 VAC, Output Short.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.

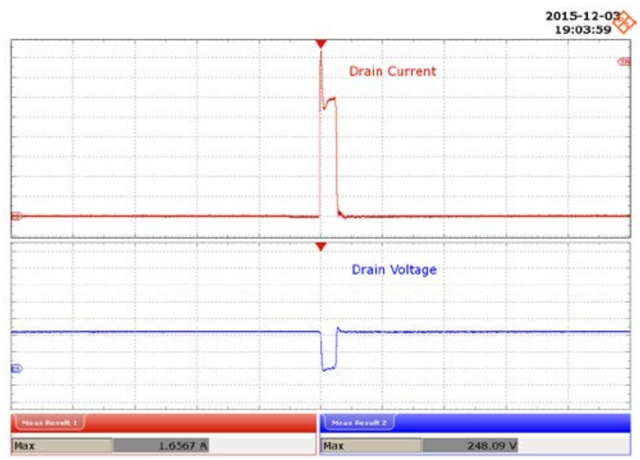

Figure 61 – 265 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 μs / div.

12.6 Output Diode Voltage and Current in Normal Operation

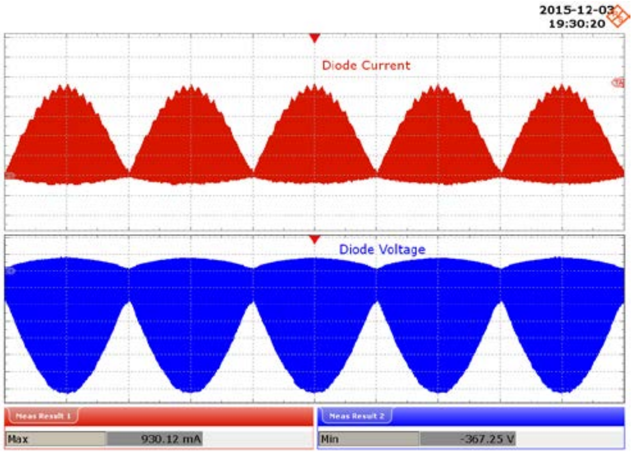

Figure 62 – 195 VAC, 72 V LED Load
Upper: I_{D3}, 200 mA / div.
Lower: V_{D3}, 50 V / div., 5 ms / div.

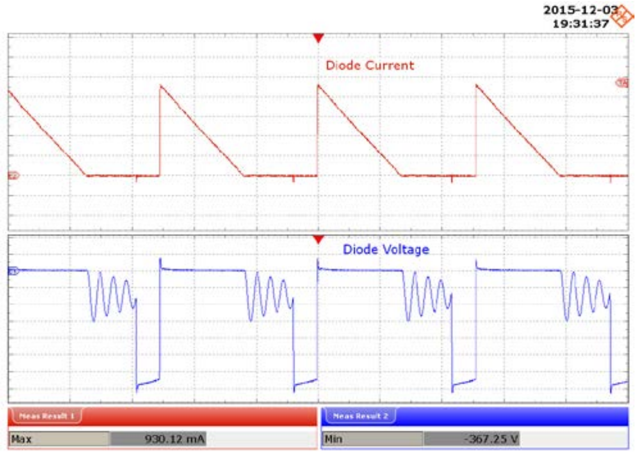

Figure 63 – 195 VAC, 72 V LED Load
Upper: I_{D3}, 200 mA / div.
Lower: V_{D3}, 50 V / div., 4 μs / div.

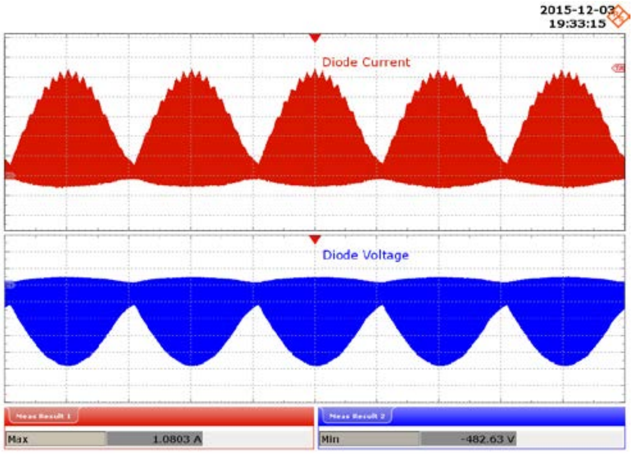

Figure 64 – 265 VAC, 72 V LED Load
Upper: I_{D3}, 200 mA / div.
Lower: V_{D3}, 100 V / div., 5 ms / div.

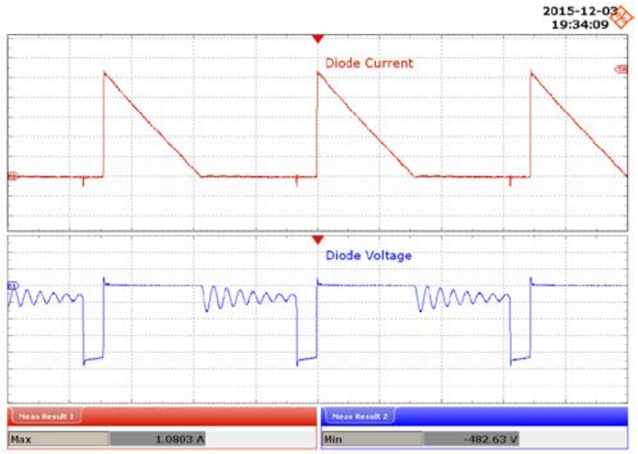

Figure 65 – 265 VAC, 72 V LED Load
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 μs / div.

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12.7 Output Voltage and Current – Open LED Load

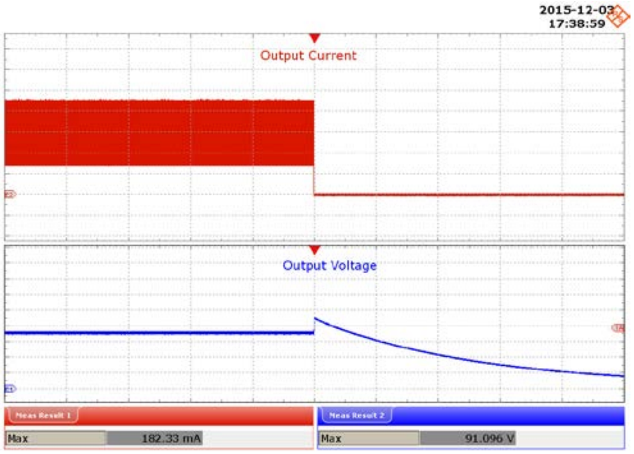

Figure 66 – 195 VAC, 72 V LED Load,
Running Open Load.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 20 V / div., 4 s / div.

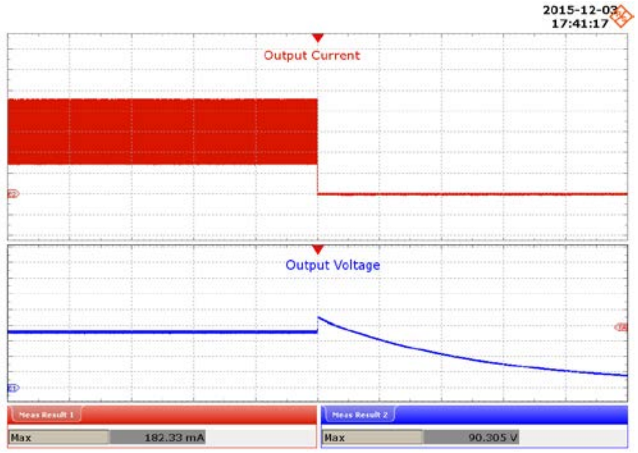

Figure 67 – 265 VAC, 72 V LED Load,
Running Open Load.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 20 V / div., 4 s / div.

12.8 Output Voltage and Current – Start-up With Open Load

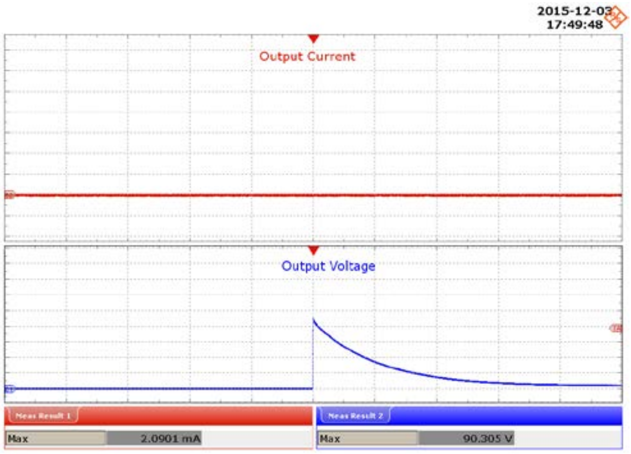

Figure 68 – 195 VAC, 72 V LED Load,
Running Open Load.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 20 V / div., 10 s / div.

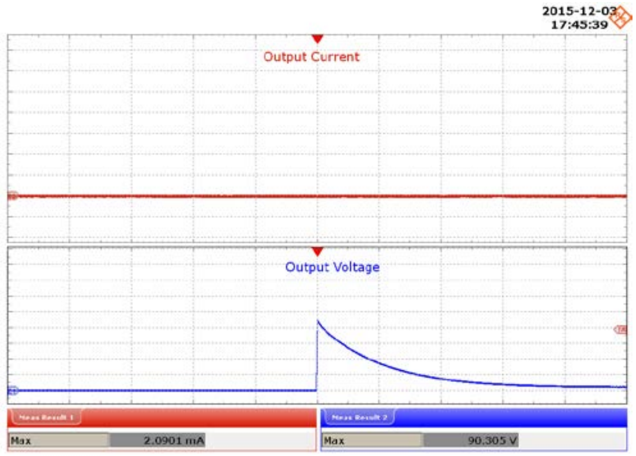

Figure 69 – 265 VAC, 72 V LED Load,
Running Open Load.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 20 V / div., 10 s / div.

12.9 Output Ripple Current

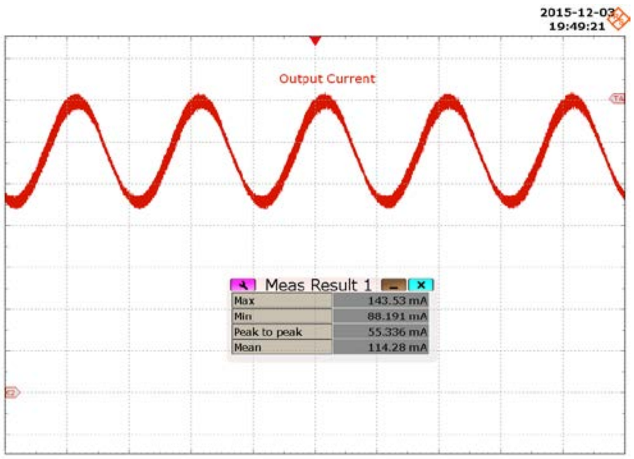

Figure 70 – 195 VAC, 50 Hz, 73 V LED Load.
Upper: I_{OUT}, 20 mA / div., 5 ms / div.

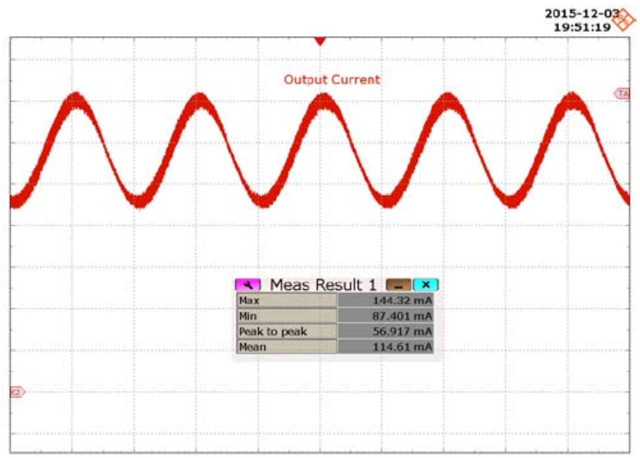

Figure 71 – 220 VAC, 50 Hz, 72 V LED Load.
Upper: I_{OUT}, 40 mA / div., 5 ms / div.

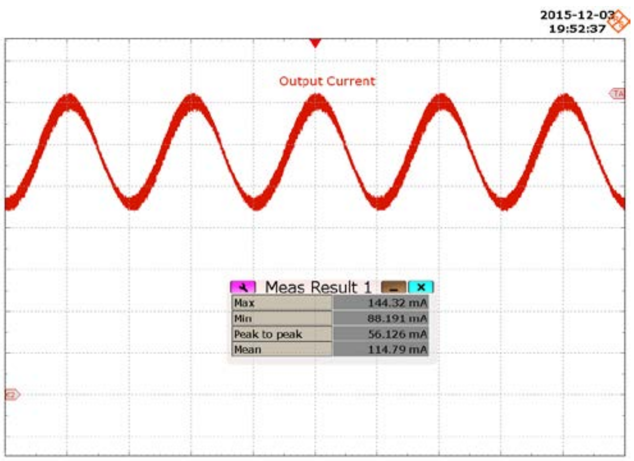

Figure 72 – 230 VAC, 50 Hz, 72 V LED Load.
Upper: I_{OUT}, 20 mA / div., 5 ms / div.

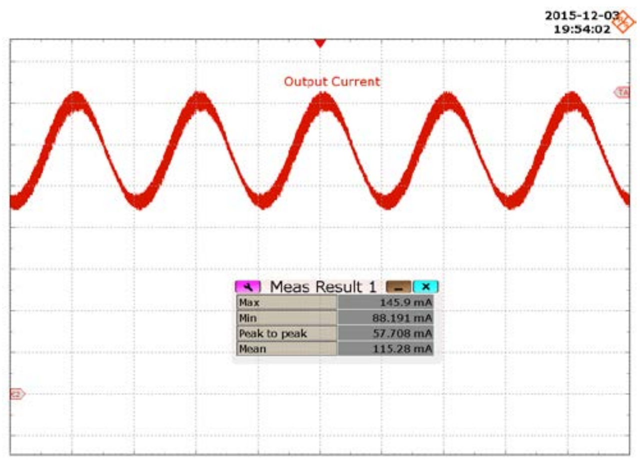

Figure 73 – 265 VAC, 50 Hz, 72 V LED Load.
Upper: I_{OUT}, 20 mA / div., 5 ms / div.

V_{IN} (VAC)	$I_{OUT(MAX)}$ (mA)	$I_{OUT(MIN)}$ (mA)	I_{MEAN}	Ripple Ratio (I_{RP-P} / I_{MEAN})	% Flicker 100 x (I_{RP-P} / $I_{O(MAX)}$ + $I_{O(MIN)}$)
195	143.53	88.19	114.28	0.48	23.88
220	144.32	87.40	114.61	0.50	24.56
230	144.32	88.19	114.79	0.49	24.14
265	145.9	88.19	115.28	0.50	24.65

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13 Dimming Waveforms

13.1 Input Voltage and Input Current Waveforms – Leading Edge Dimmer

Input: 230 VAC, 50 Hz
Output: 72 V LED load
Dimmer: Busch 2250 U

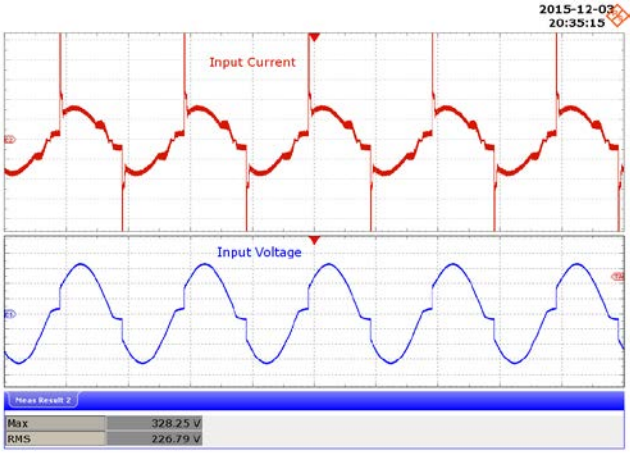

Figure 74 – 150° Conduction Angle.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

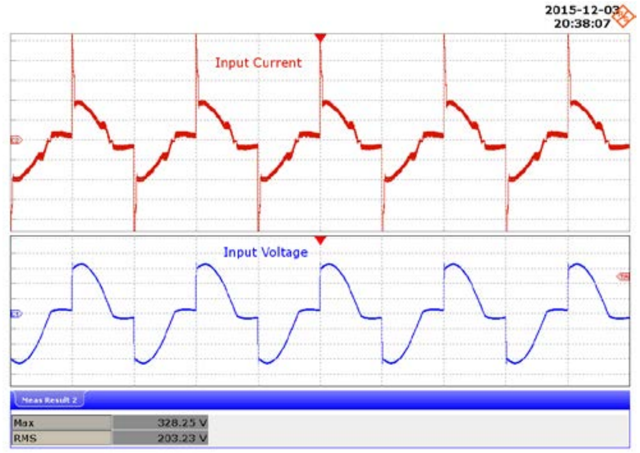

Figure 75 – 120° Conduction Angle.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

Figure 76 – 90° Conduction Angle.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

Figure 77 – 50° Conduction Angle.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

13.2 Output Current Waveforms – Leading Edge Dimmer

Input: 230 VAC, 50 Hz
Output: 72 V LED load
Dimmer: Busch 2250 U

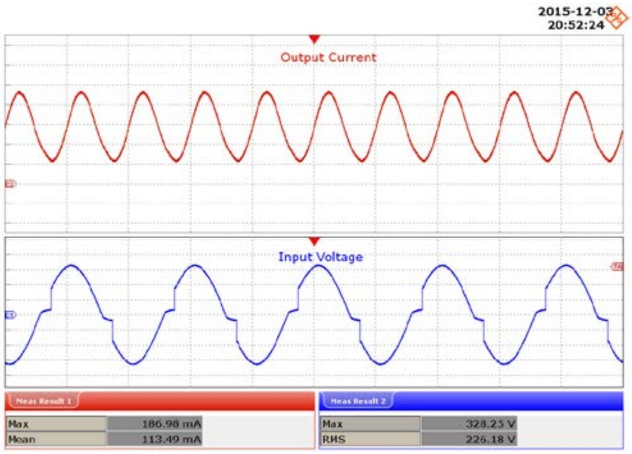

Figure 78 – 140º Conduction Angle.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

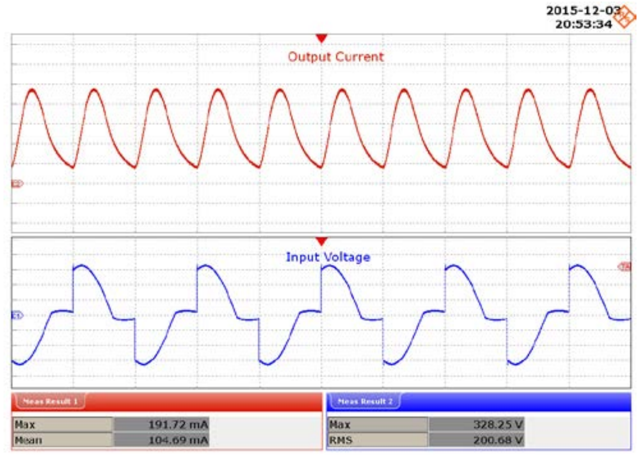

Figure 79 – 120º Conduction Angle.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

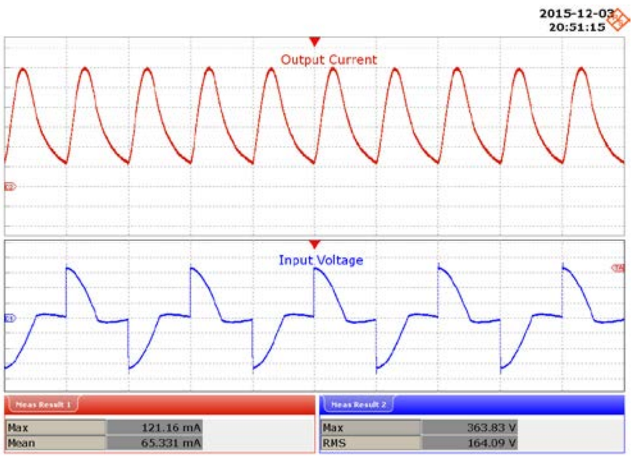

Figure 80 – 90º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

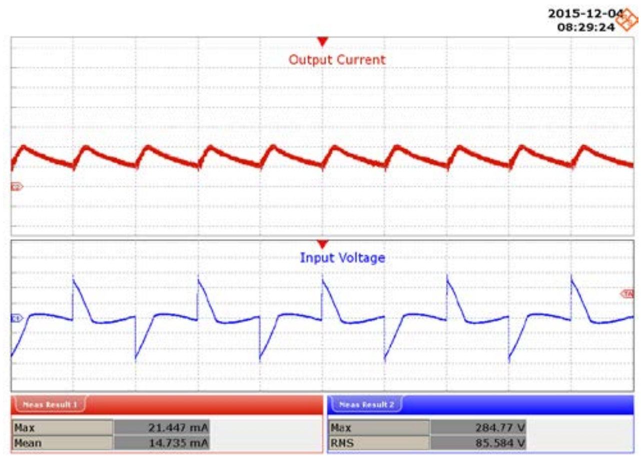

Figure 81 – 50º Conduction Angle.
Upper: I_{OUT}, 10 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

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13.3 Input Voltage and Input Current Waveforms – Trailing Edge Dimmer

Input:230 VAC, 50 Hz
Output: 72 V LED load
Dimmer: GIRA 0307 00

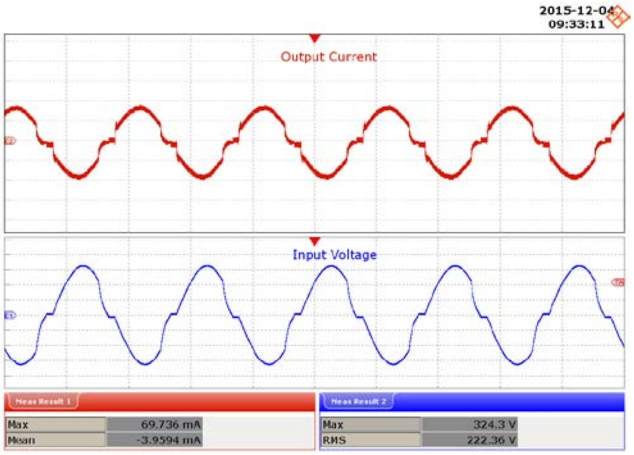

Figure 82 – 140º Conduction Angle.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

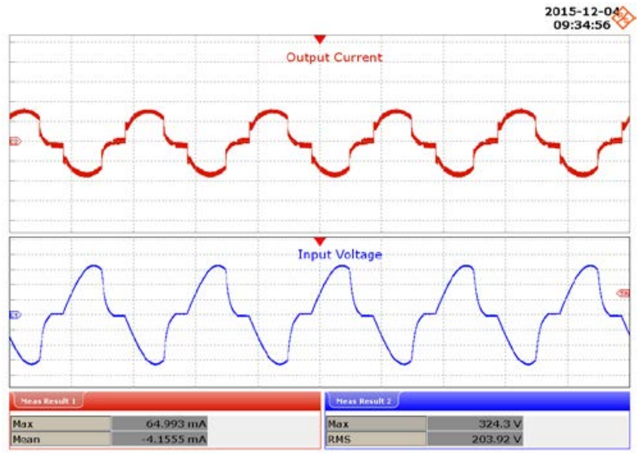

Figure 83 – 120º Conduction Angle.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

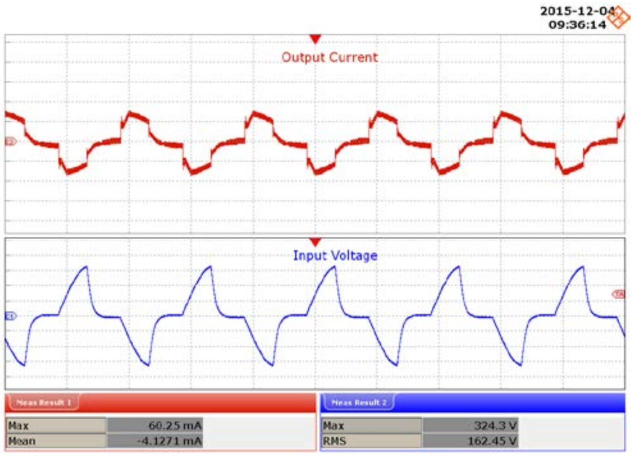

Figure 84 – 90º Conduction Angle.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

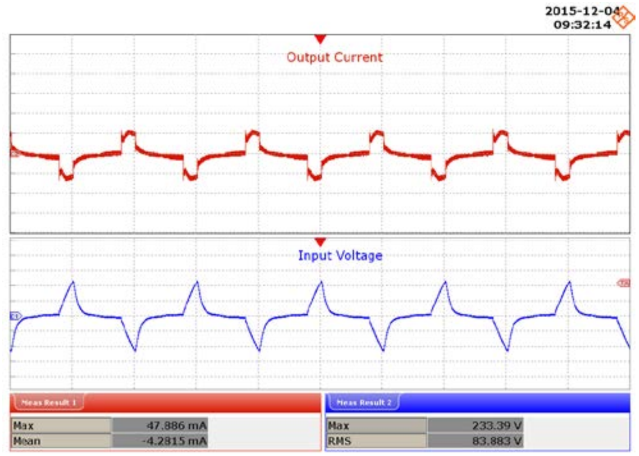

Figure 85 – 50º Conduction Angle.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

13.4 Output Current Waveforms – Trailing Edge Dimmer

Input: 230 VAC, 50 Hz
Output: 72 V LED load
Dimmer: GIRA 0307 00

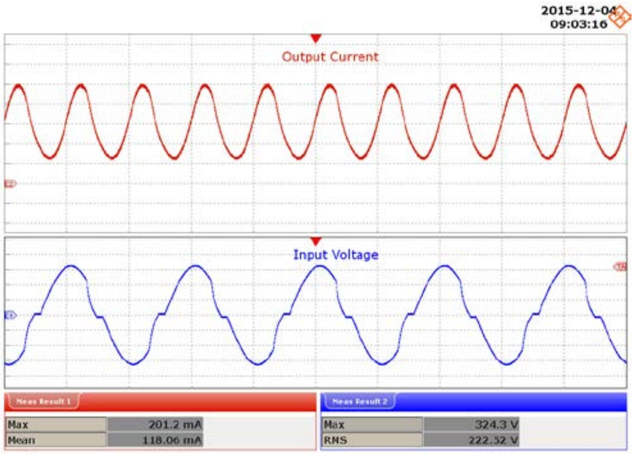

Figure 86 – 140º Conduction Angle.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

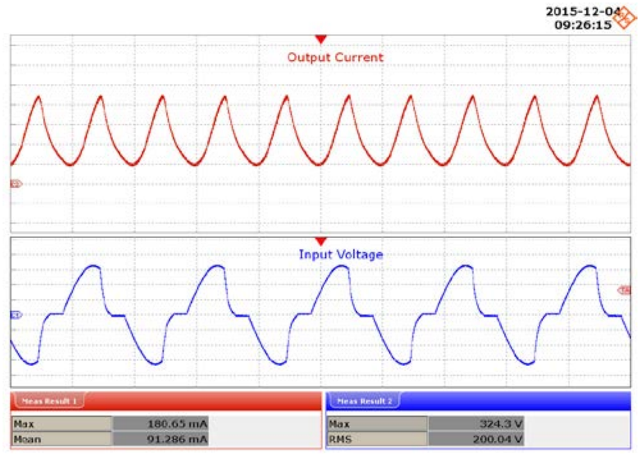

Figure 87 – 110º Conduction Angle.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

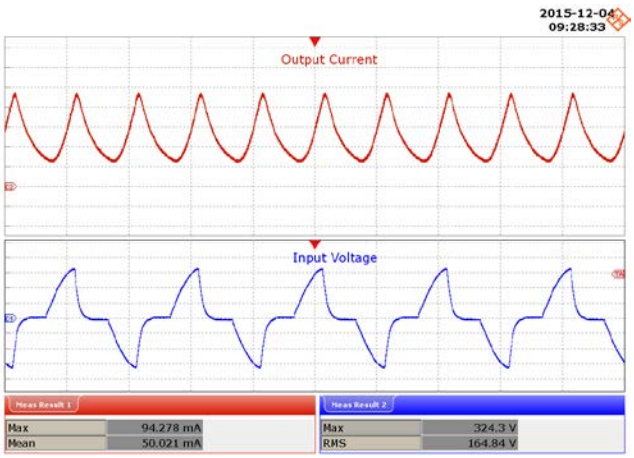

Figure 88 – 90º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

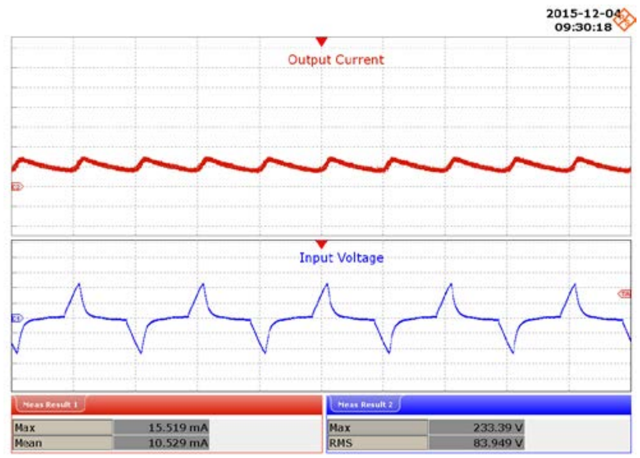

Figure 89 – 50º Conduction Angle.
Upper: I_{OUT}, 10 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

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14 AC Cycling Test

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

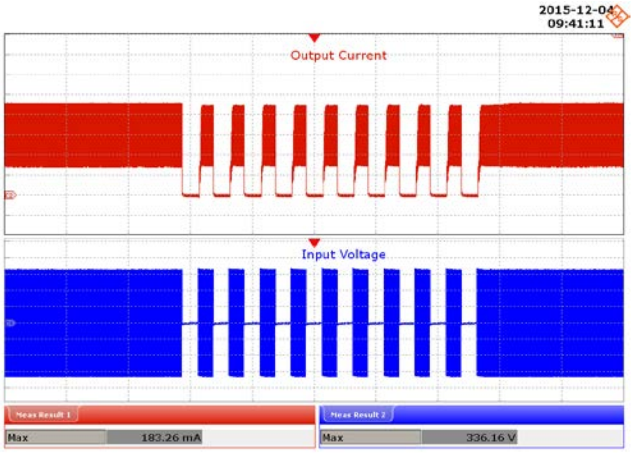

Figure 90 – 230 VAC, 72 V LED Load.
1 s On – 1 s Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 4 s / div.

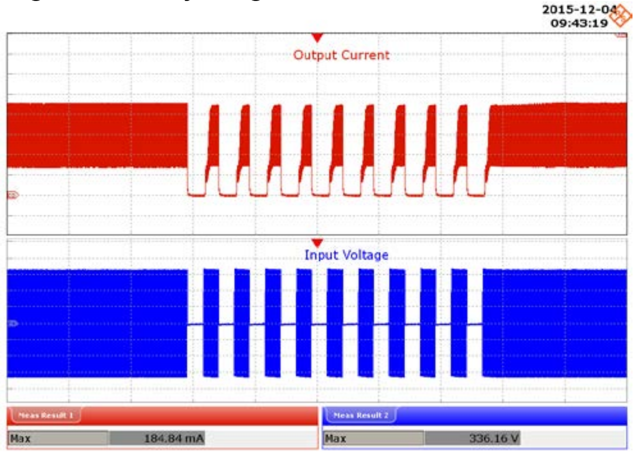

Figure 91 – 230 VAC, 72 V LED Load.
500 ms On – 500 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

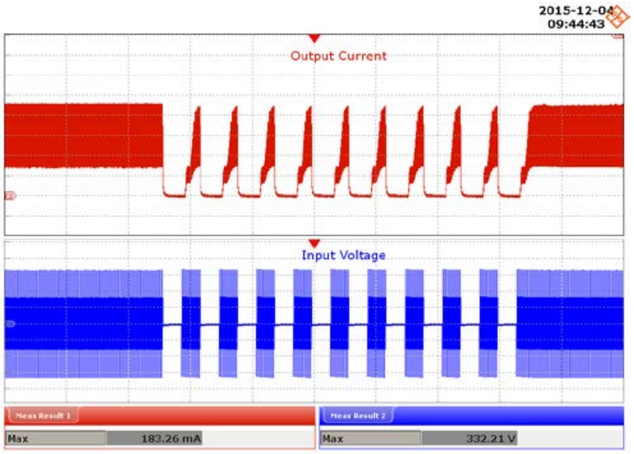

Figure 92 – 230 VAC, 72 V LED Load.
300 ms On – 300 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 1 s / div.

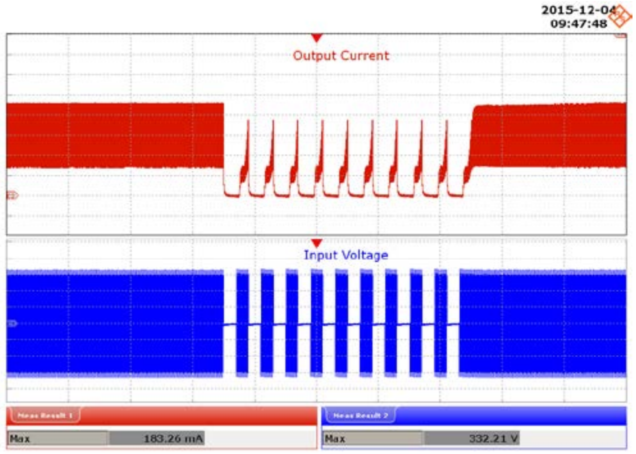

Figure 93 – 230 VAC, 72 V LED Load.
200 ms On – 200 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 1 s / div.

15 Conducted EMI

15.1 Test Set-up

15.1.1 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. 72 V LED load with input voltage set at 230 VAC.

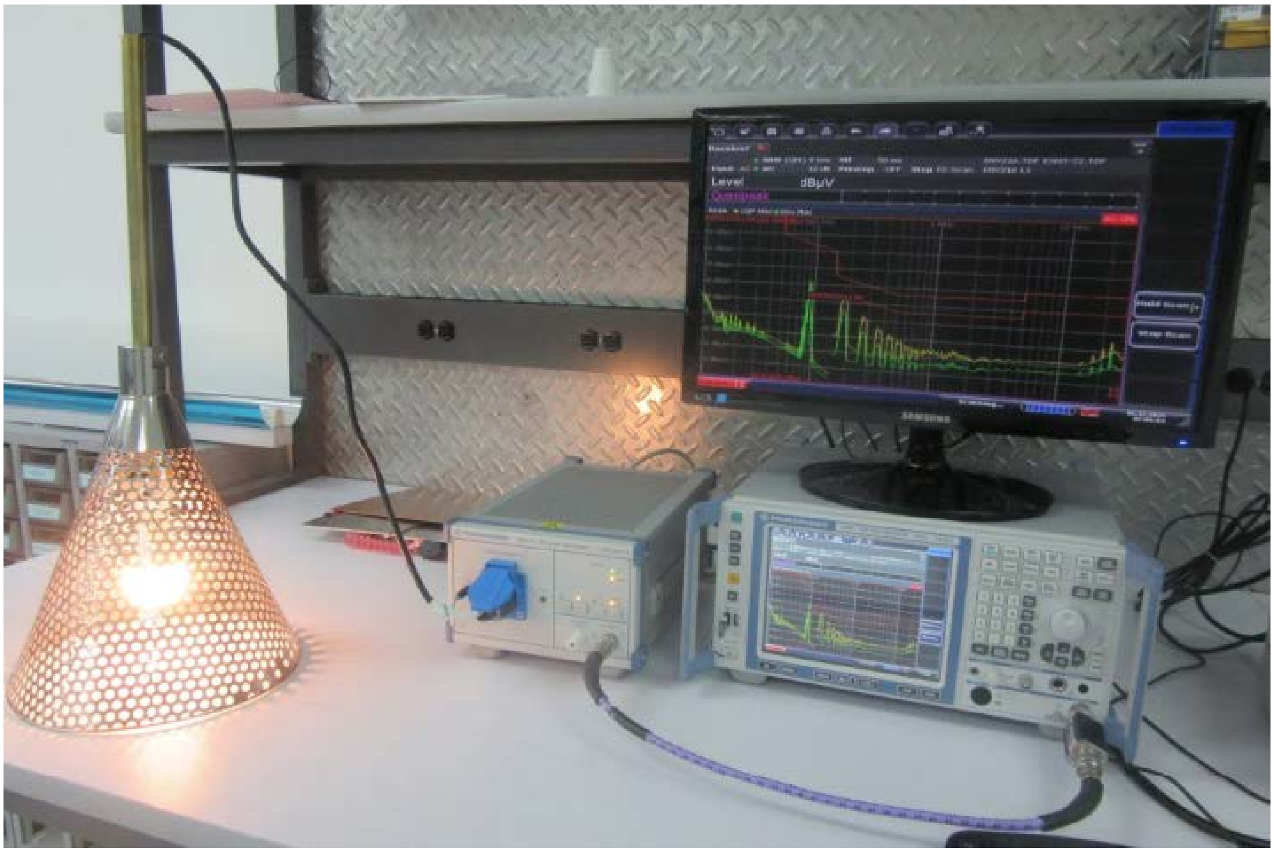

Figure 94 – Conducted EMI Test Set-up.

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15.2 EMI Test Result

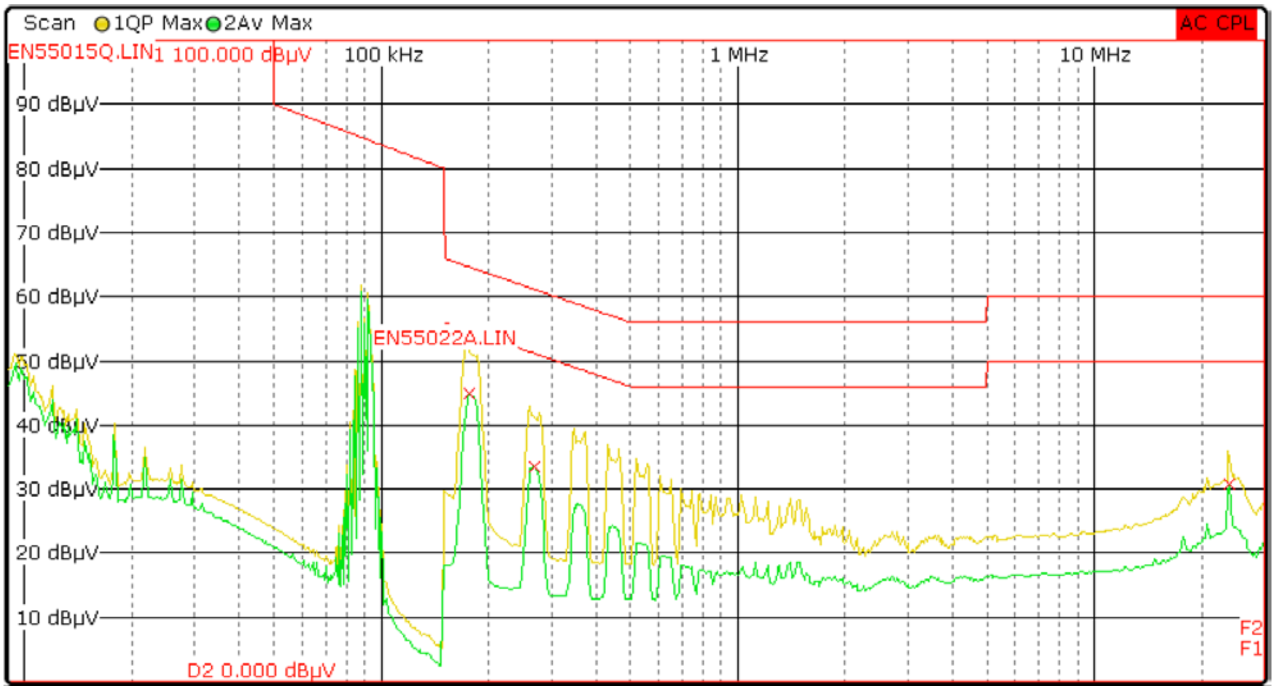

Figure 95 – Conducted EMI QP Scan at 72 V LED Load, 230 VAC, 50 Hz, and EN55015 B Limits.

Trace1: EN55015Q.LIN	Trace2: EN55022A.LIN

Trace/Detector	Frequency	Level dBµV	DeltaLimit
2 Average	177.0000 kHz	44.98 L1	-9.65 dB
1 Quasi Peak	174.7500 kHz	52.90 L1	-11.83 dB
2 Average	269.2500 kHz	33.44 L1	-17.70 dB
2 Average	24.0023 MHz	30.83 L1	-19.17 dB

Figure 96 – Conducted EMI QP Data at 72 V LED Load.

16 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

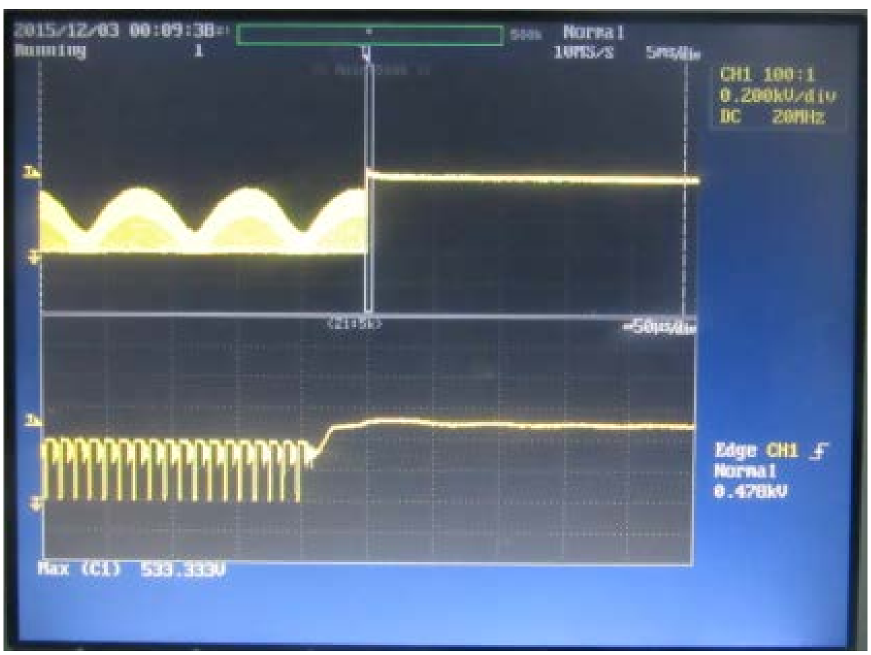

Figure 97 – +1000 kV Differential Surge, 90º Phase Angle.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.
Peak V_{DRAIN}: 533.3 V.

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17 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.

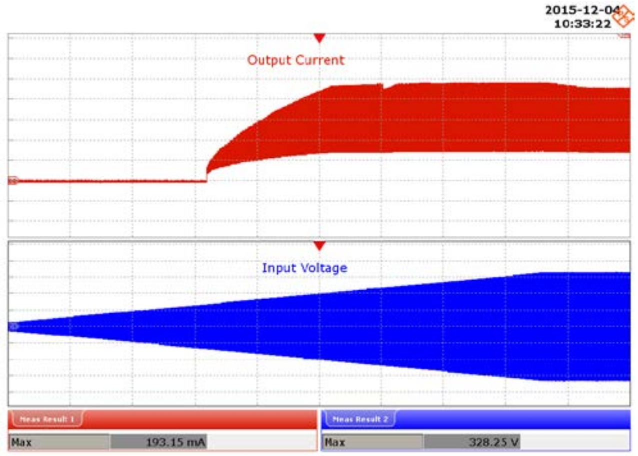

Figure 98 – Brown-in Test at 0.5 V / s. The Unit is Able to Operate Normally Without Any Failure and Without Flicker.
Ch4: V_{IN}, 100 V / div.
Ch3: I_{OUT}, 40 mA / div.
Time Scale: 50 s / div.

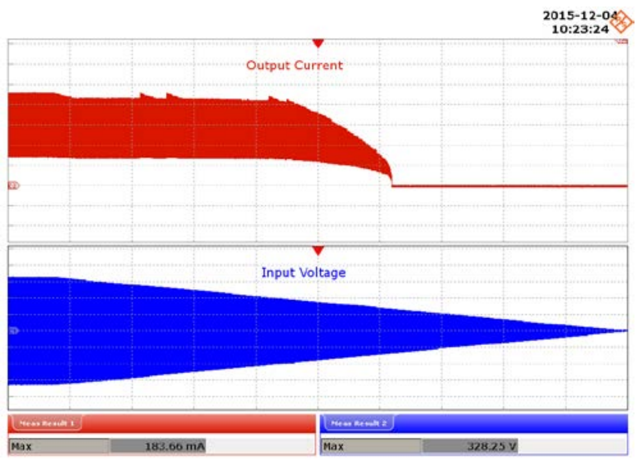

Figure 99 – Brown-out Test at 0.5 V / s. The Unit is Able to Operate Normally Without Any Failure and Without Flicker.
Ch4: V_{IN}, 100 V / div.
Ch3: I_{OUT}, 40 mA / div.
Time Scale: 50 s / div.

18 Revision History

Date	Author	Revision	Description and Changes	Reviewed
01-Mar-16	MGM	1.0	Initial Release.	Apps & Mktg
10-Mar-16	KM	1.1	Updated Schematic.	Apps & Mktg

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