Design Example Report

Title	***4.68 W TRIAC Dimmable High Efficiency Power Factor Corrected Non-Isolated LED Driver Using LYTSwitch™-7 LYT7503D***
Specification	90 VAC – 132 VAC Input; 52 V, 90 mA Output
Application	Candelabra
Author	Applications Engineering Department
Document Number	DER-540
Date	August 16, 2016
Revision	1.1

Summary and Features

- Single-stage power factor corrected, PF >0.93
- Accurate constant LED current (CC) regulation, ±5%
- High efficiency, >85%
- Low cost and low component count for compact PCB solution
- TRIAC dimmable
  - Works with a wide selection of TRIAC dimmers
  - Fast start-up time (<500 ms) – no perceptible delay
  - Minimum dead-band or visible pop on effect.
- Integrated protection features
  - Open load and output short-circuit protection
  - Thermal fold-back protection
  - No damage during line brown-out or brown-in conditions
- Meets IEC 2.5 kV ring wave, 1 kV differential surge and EN55015 conducted EMI

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

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1 Introduction

This engineering report describes a low component count, TRIAC dimmable, non-isolated buck LED driver, designed to drive a nominal LED voltage string of 52 V at 90 mA from an input voltage range of 90 VAC to 132 VAC. This LED driver utilizes the LYT7503D from the LYTSwitch-7 family of devices.

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

DER-540 is a single stage 4.68 W TRIAC dimmable LED driver with constant current output. The key design goals were design simplicity, high efficiency, low component count, accurate constant current regulation, compact PCB and acceptable dimming compatibility. The design is intended for Candelabra Lamp Bulb applications.

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

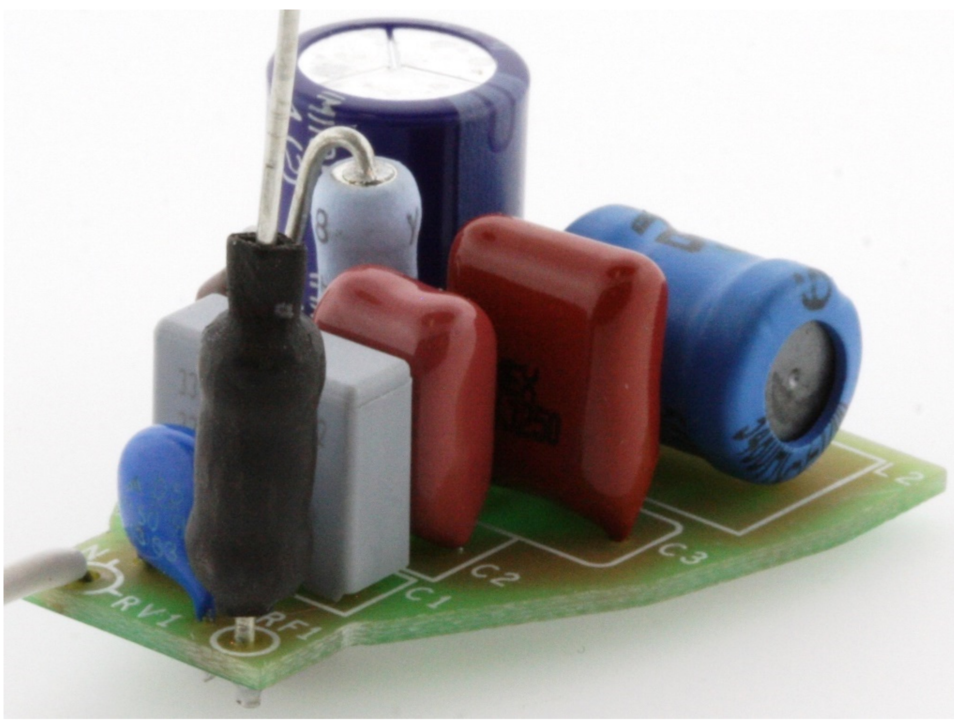

Figure 1 – Populated Circuit Board.

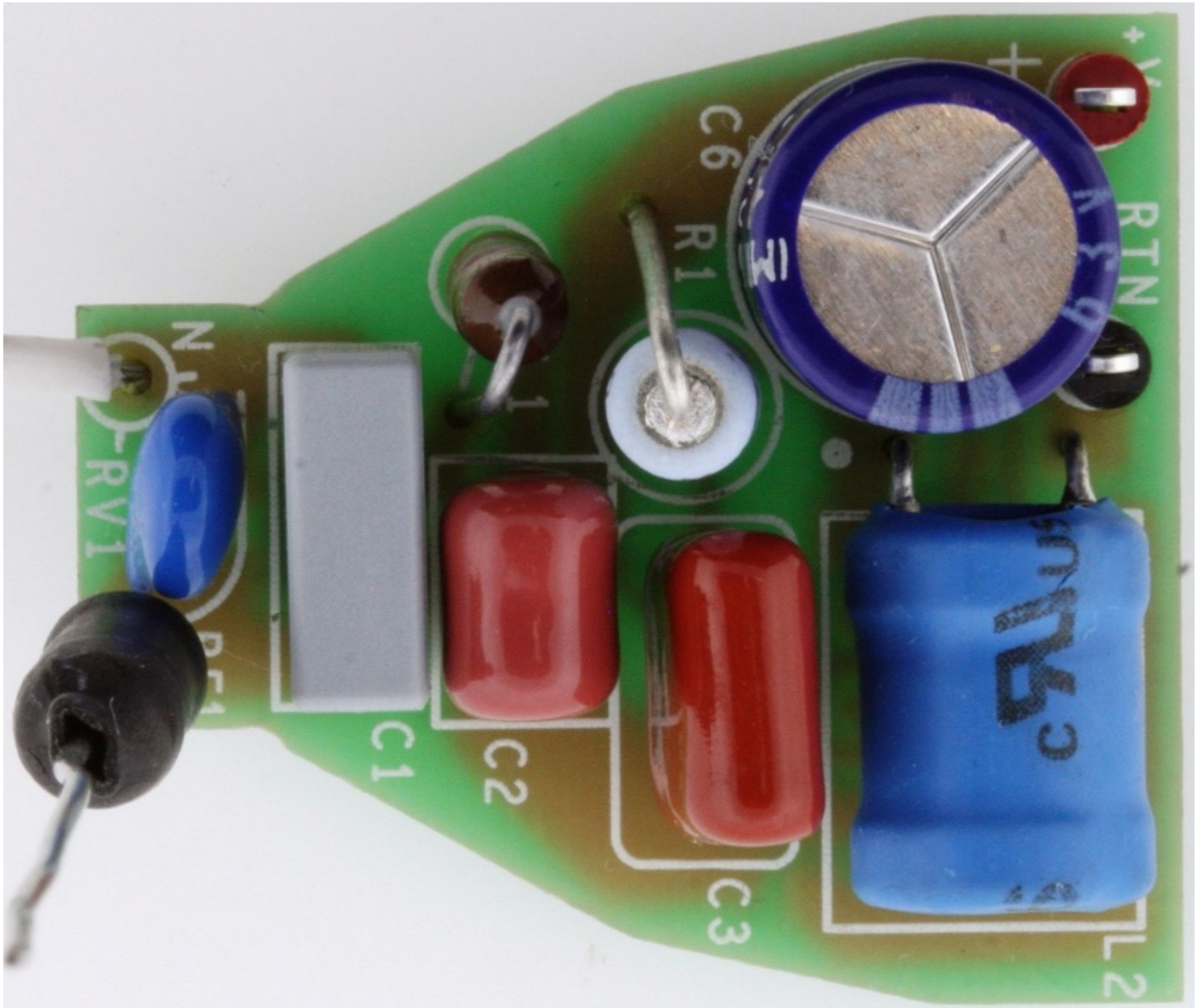

Figure 2 – Populated Circuit Board, Top View.

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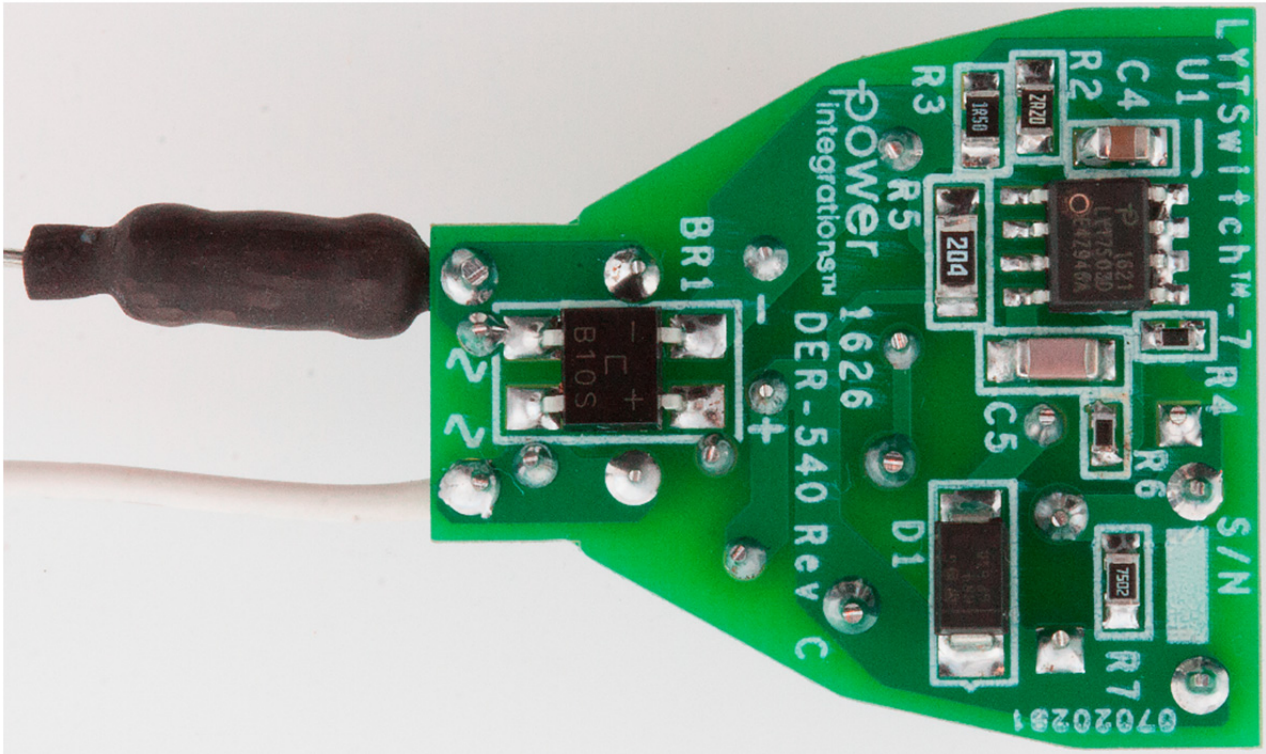

Figure 3 – Populated Circuit Board, Bottom View.

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}		60		Hz	
Output						
Output Voltage	V_{OUT}		52		V	
Output Current	I_{OUT}		90		mA	
Total Output Power						
Continuous Output Power	P_{OUT}		4.68		W	
Efficiency						
Full Load	η		85.8		%	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			0.95			Measured at 115 VAC, 60 Hz.
Ambient Temperature	T_{AMB}		85		ºC	Free Convection, Sea Level.

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3 Schematic

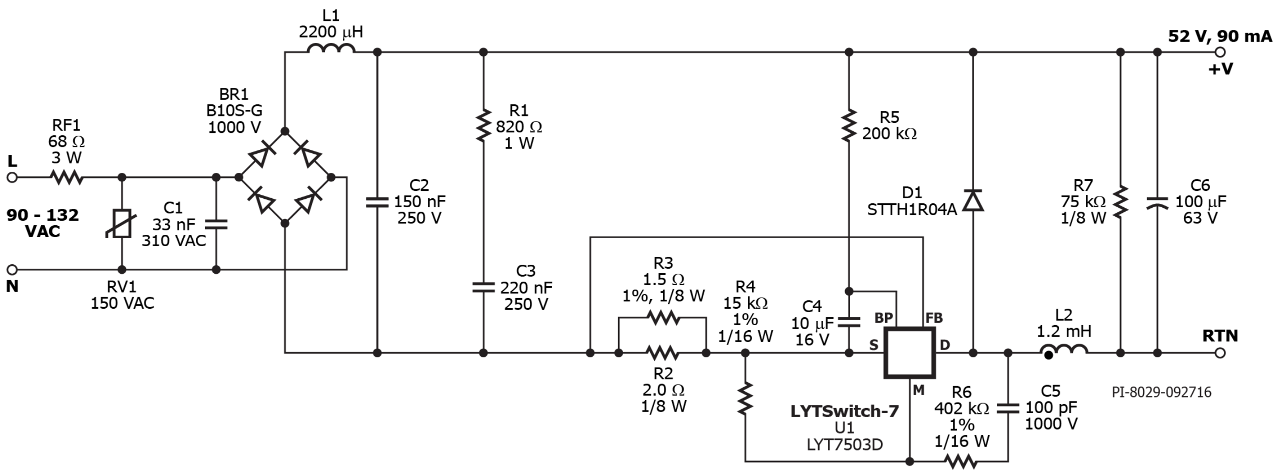

Figure 4 – Schematic.

4 Circuit Description

The LYTSwitch-7 (U1-LYT7503D) combines a high-voltage power MOSFET switch with a variable frequency / variable on-time, critical conduction mode controller in a single SO-8 package. LYT7503D is configured to drive a 52 V LED string, TRIAC dimmable, non-isolated buck LED driver with 90 mA constant current output. The LYT7503D device was selected from the power table based on maximum output power (15 W) in the data sheet.

4.1 Input Stage

The fusible resistor RF1 provides safety protection against component failures that would lead to very high input current. Varistor RV1 provides clamping during differential line surge events to limit the maximum voltage spike across the primary. The maximum clamping voltage of RV1 must be lower than the Drain-to-Source breakdown voltage of the internal MOSFET of LYT7503D (725 V) to ensure sufficient overvoltage protection during line surge occurrence.

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

4.2 EMI Filter

The inductor L1 and capacitors, C1 and C2, form an EMI pi filter which works to filter differential mode noise. Resistor RF1 damps the resonance of L1 to make it more effective in blocking high frequency noise. Also, the orientation of the EMI inductor L1 and the buck inductor L2 affects EMI. LYTSwitch-7's variable frequency/on-time states and critical conduction code control engine limit RFI emission to significant level which enables design to use simple EMI pi filter even for high power bulb and tube applications.

4.3 LYTSwitch-7 Primary Control Circuit

The topology used for this LED driver is a low-side buck converter. During the ON-time of the LYT7503D internal MOSFET, current ramps through the buck inductor winding, charging the output capacitor, and providing current to the output load. The energy stored in the magnetic field of the inductor winding during ON-time of the MOSFET is then delivered to the load during OFF-time via output diode D1. The output capacitor C6 provides filtering to minimize LED ripple current while resistor R7 serves as a pre-load.

Capacitor C4 provides local decoupling for the BYPASS (BP) pin of U1, which provides power to the IC during the switch ON-time. The IC internal regulator draws power from high-voltage DRAIN (D) pin and charge the bypass capacitor C4 during the power switch off time. The typical BP pin voltage is 5.22 V. To keep the IC operating normally especially during the dead zone, where $V_{IN} < V_{OUT}$, the value of capacitor should be large enough to keep the BP voltage above the $V_{BP(RESET)}$ value of 4.5 V. Additional bias resistor R5 was employed to maintain the BP pin voltage for very fast AC on/off power cycling

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event and during low conduction angle operation. Recommended minimum value for the BP capacitor is 4.7 μF.

Resistor R5 can be calculated as follows, where: I_{BP_EXT} can be between 150 μA – 500 μA.

$$R5 = V_{OUT} - V_{BP} / I_{BP\_EXT}$$

Constant output current regulation is achieved through the FEEDBACK (FB) pin directly sensing the Drain current during the MOSFET on-time using external current sense resistors (R_{FB}) R2 and R3, and comparing the voltage drop to a fixed internal reference voltage (V_{FB_REF}) of absolute value 280 mV typical. Resistor value of R_{FB} can be calculated as follows:

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

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

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

MULTIFUNCTION (M) pin monitors the line for any line overvoltage event. When the internal MOSFET is in ON-state, the M pin is shorted internally to SOURCE (S) pin in order to detect the rectified input line voltage derived from the voltage across the inductor, i.e. (V_{IN}-V_{OUT}) and current flowing out of the M pin is defined by resistor R6, thus line overvoltage detection is calculated as; where R6 is assumed to be 402 kΩ ±1%.

$$V_{LINE\_OVP} = I_{IOV} \times R6 + V_{OUT}$$

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

The M pin also monitors the output for any overvoltage and undervoltage event. When the internal MOSFET is in off-state, the output voltage is monitored through a coupling capacitor (C5) and divider resistors R4 and R6. When an output open-load condition occurs, the voltage at the M pin will rise abruptly and when it exceeds the threshold of 2.4 V, the IC will inhibit switching instantaneously and initiate auto-restart to limit the output voltage from further rising. The overvoltage cut-off is typically 120% of the output voltage, which is equivalent to 2 V at the M pin ($V_{OUT\_OVP} = V_{OUT} \times 2.4 V / 2 V$). Resistor R6 is set to a fixed value of 402 kΩ ±1% and R4 will determine the output overvoltage limit. Any short circuit at the output will be detected once the M pin voltage falls below the undervoltage threshold (V_{OUV}) of 1 V typical, then the IC will inhibit switching instantaneously and initiate auto-restart to limit the average input power to less than 1 W, preventing any components from overheating.

Resistor R4 can be calculated as follows

$R4 = 2\ V \times R6 / (V_{OUT} - 2\ V)$; this is applicable only to low-side configuration buck.

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

4.4 TRIAC Phase Dimming Control

The control mechanism of the LYTSwitch-7 LYT7503D provides inherent dimming capability which makes it suitable to use a simple RC damper (R1 and C3) network for dimming purposes. The power rating of the damper resistor must be taken into consideration as it takes on some current from the input as dimming commences. Thermal measurement of this component at the worst-case dimming angle is, therefore, recommended. For DER-540, the required minimum power rating of the damper resistor R1 is 1W.

Flickering and/or shimmering are the main problems that may be encountered while dimming. Several factors are to be considered in solving this problem. Some of them are stated below.

During TRIAC dimming, input current oscillations may be present (possibly due to the EMI filter L1 resonating with the internal capacitance of the dimmer) which may cause flickering or shimmering of the LED output. Fusible resistor RF1 may be trimmed to damp this low frequency input current oscillations and help reduce/minimize flickering or shimmering.

The voltage across BP pin may be monitored for any dipping below the IC (LYT7503D) reset threshold of 4.5 V, that may cause flickering or shimmering on or near the minimum conduction angle. The value of capacitor C4 may be increased to smoothen out the voltage at BP pin of the IC. Consequently, the resistance of the pull-up resistor R5 may be made smaller to increase the charging current available to the BP pin capacitor C4. However, decreasing the resistance value of the pull-up resistor may degrade efficiency – a trade-off, therefore, should be considered. A Zener diode may also be connected in series with the pull-up resistor R5 to restrict the charging of BP pin capacitor C4 at low voltages where flickering or shimmering occurs (i.e., intentionally turning OFF the IC at low voltage levels where shimmering or flickering is a problem).

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5 PCB Layout

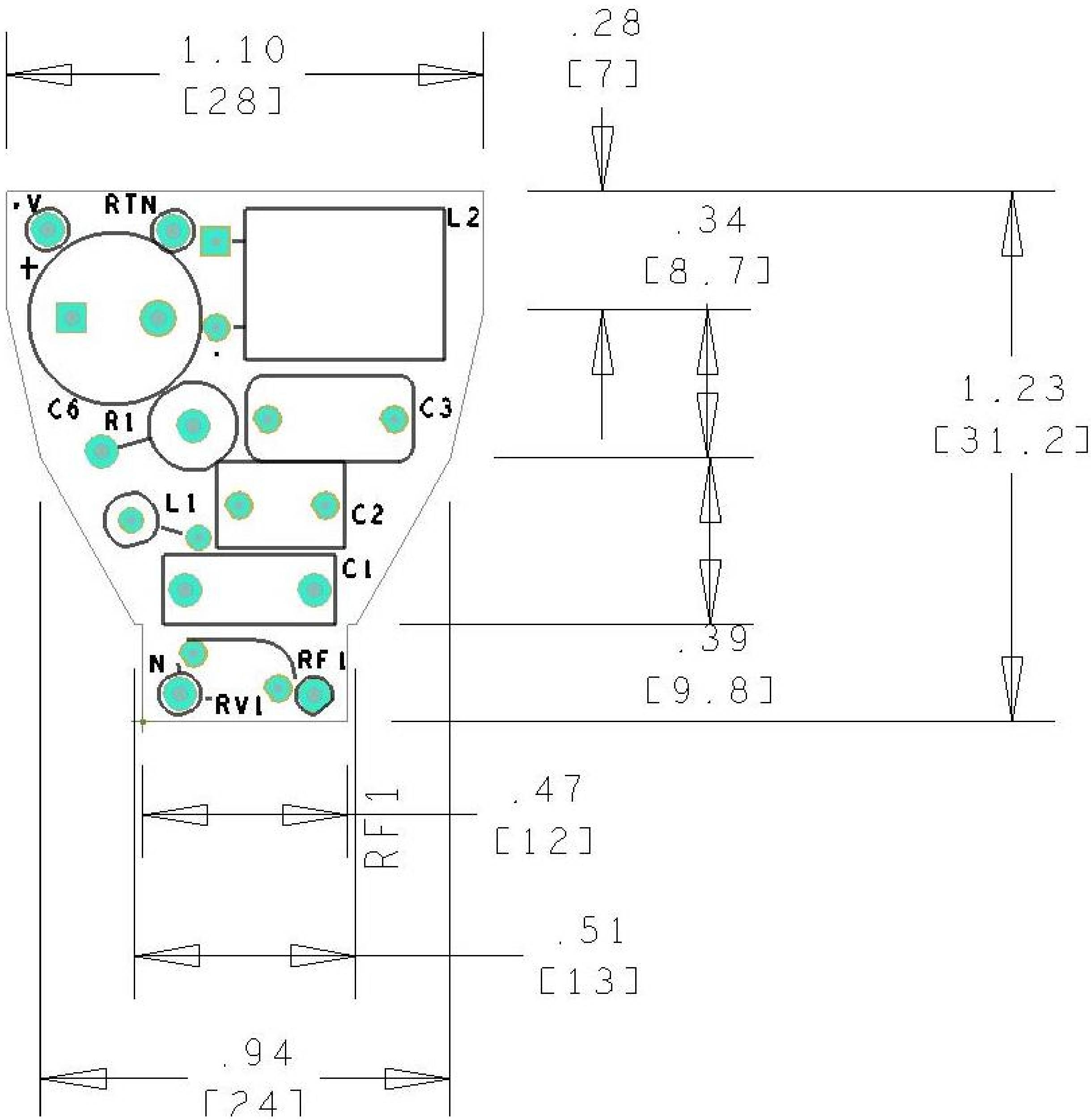

Figure 5 – Top Side.

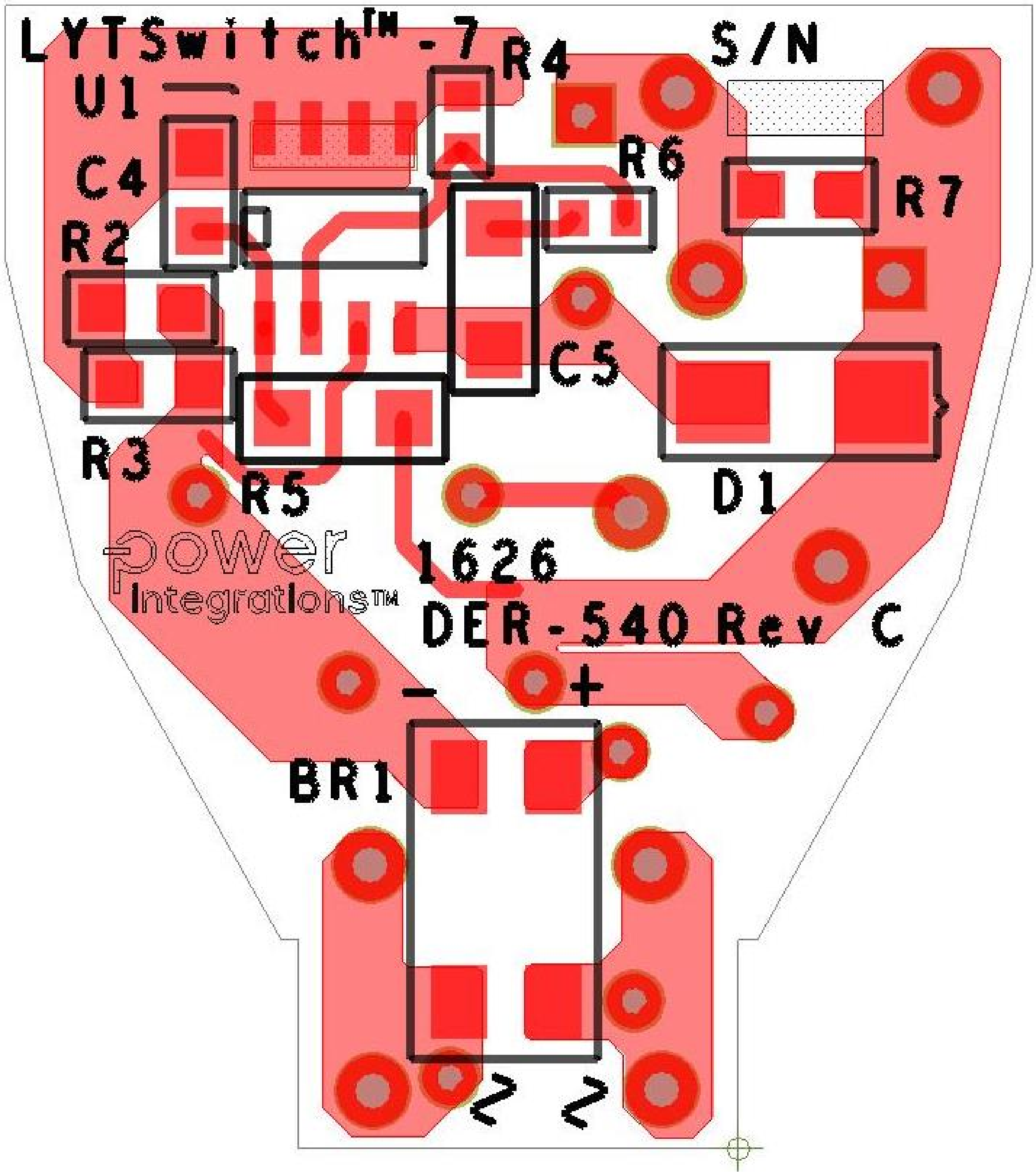

Figure 6 – Bottom Side.

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6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip
2	1	C1	33 nF, 310 VAC, Polyester Film, X2	BFC233920333	Vishay
3	1	C2	150 nF, 250 V, Radial, Film	B32529C3154J	Epcos
4	1	C3	220 nF, 250V, 5%, Film	MEXID3220JJ	Duratech
5	1	C4	10 μF, ±10%, 16 V, X7R, , -55°C ~ 125°C, MLCC 0805	CL21B106KOQNNNG	Samsung
6	1	C5	100 pF, 1000 V, Ceramic, NPO, 1206	102R18N101JV4E	Johanson Dielectrics
7	1	C6	100 μF, 63 V, Electrolytic, Low ESR, 255 mΩ	ELXZ630ELL101MJC5S	Nippon Chemi-Con
8	1	D1	Diode, GEN PURP, 400 V, 1 A, SMA, Fast Recovery	STTH1R04A	ST Micro
9	1	L1	2200 μH, 80 mA, 34.7 Ohm, Axial Ferrite Inductor	B78108S1225J	Epcos
10	1	L2	1.2 mH, 0.490 A, 10%	RL-5480HC-3-1200	Renco
11	1	R1	RES, 820 Ω, 5%, 1 W, Metal Oxide	RSF100JB-820R	Yageo
12	1	R2	RES, 2.00 R, 1/8 W, Thick Film, 0805	RC0805FR-072RL	Yageo
13	1	R3	RES, SMD, 1.5 Ω, 1%, ±250ppm/°C, 1/8W, 0805	MCR10ERTFL1R50	Rohm Semi
14	1	R4	RES, 15 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1502V	Panasonic
15	1	R5	RES, 200 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ204V	Panasonic
16	1	R6	RES, 402 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF4023V	Panasonic
17	1	R7	RES, 75 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ753V	Panasonic
18	1	RF1	RES, 68 Ω, 5%, 3 W, AXIAL, Wire wound, Fusible, Axial, ±200ppm/°C	AC03000006809JACCS	Vishay
19	1	RV1	150 VAC, 7.5 J, 5 mm, RADIAL	S05K150E2	Epcos
20	1	U1	LYTSwitch-7, Dimmable, SO-8	LYT7503D	Power Integrations

7 Design Spreadsheet

ACDC_LYTSwitch7_Buck _062416; Rev.0; Copyright Power Integrations 2016	INPUT	INFO	OUTPUT	UNIT	LYTSwitch-7 Buck Design Spreadsheet
ENTER APPLICATION VARIABLES					
LINE VOLTAGE RANGE			Low Line		AC line voltage range
VACMIN	**90**		90	V	Minimum AC line voltage
VACTYP	**115**		115	V	Typical AC line voltage
VACMAX	**132**		132	V	Maximum AC line voltage
FL	**60**		60	Hz	AC mains frequency
VO	**52**		52	V	Output Voltage
IO	**90**		90	mA	Average output current specification
EFFICIENCY			0.90		Efficiency estimate
PO			4.68	W	Continuous output power
VD	**1.00**		1.00	V	Output diode forward voltage drop
ENTER LYTSWITCH-1 VARIABLES					
DEVICE BREAKDOWN VOLTAGE			725	V	This Spreadsheet supports 725V device only
DEVICE	**Auto**		LYT7503D		Actual LYTSwitch-7 device
ILIMITMIN			1.06	A	Minimum Current Limit
ILIMITTYP			1.15	A	Typical Current Limit
ILIMITMAX			1.24	A	Maximum Current Limit
TON			2.95	us	On-time during the fixed on-time region at VACTYP
FSW			109	kHz	Maximum switching frequency in the fixed current limit region at VACTYP
DMAX			0.89		Maximum duty cycle possible in the fixed on-time region
ENTER INDUCTOR CORE/CONSTRUCTION VARIABLES					
CORE	**Off the shelf**		Off the shelf		Enter Transformer Core
CUSTOM CORE NAME					If custom core is used - Enter part number here
AE			0.00	mm^2	Core effective cross sectional area
LE			0.00	mm	Core effective path length
AL			0.00	nH/ turn^2	Core ungapped effective inductance
AW			0.00	mm^2	Window Area of the bobbin
BW			0.00	mm	Bobbin physical winding width
LAYERS			8.0		Number of Layers
INDUCTOR DESIGN PARAMETERS					
LP_MIN			502	uH	Absolute minimum design inductance
LP_TYP	**1200**		1200	uH	Typical design inductance
LP_TOLERANCE			10	%	Tolerance of the design inductance
LP_MAX			1337	uH	Absolute maximum design inductance
TURNS			NA	Turns	Number of inductor turns
ALG			NA	nH/turn^2	Inductance per turns squared
BMAX			NA	Gauss	!!! Warning. Maximum flux density is too high. Increase NP or use bigger core size
BAC			NA	Gauss	AC flux density in the fixed peak current region
LG			NA	mm	Core air gap
BWE			NA	mm	Effective bobbin width
OD			NA	mm	Outer diameter of the wire with insulation
INS			NA	mm	Wire insulation
DIA			NA	mm	Outer diameter of the wire without insulation
AWG			NA		AWG of the bare wire.
CM			NA	Cmils	Bare wire circular mils
CMA			NA	Cmils/A	Bare wire circular mils per ampere
CURRENT DENSITY			NA	A/mm^2	Bare wire current density
BOBBIN FILL FACTOR			NA		Area of the bobbin occupied by wire

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CURRENT WAVEFORM SHAPE PARAMETERS					
IAVERAGE_INDUCTOR			0.09	A	Average inductor current at VACTYP obtained from half-line cycle emulation
IPEAK_MOSFET			0.32	A	MOSFET peak current at VACTYP when operating in the current limit region
IRMS_MOSFET			0.08	A	MOSFET RMS current at VACTYP obtained from half-line cycle emulation
IRMS_DIODE			0.10	A	Diode RMS current at VACTYP obtained from half-line cycle emulation
IRMS_INDUCTOR			0.13	A	Inductor RMS current at VACTYP obtained from half-line cycle emulation
LYTSWITCH EXTERNAL COMPONENTS					
FB Pin Resistor					
RFB_T			0.864	Ohms	Theoretical calculation of the feedback pin sense resistor
RFB			0.866	Ohms	Standard 1% value of the feedback pin sense resistor
M Pin Components					
RUPPER	402.00		402.00	kOhms	Use 1% tolerance
RLOWER	**15.00**		15.00	kOhms	Lower resistor on the M-pin divider network (E96 /1%)
VO_OVP			65.7	V	VO overvoltage threshold
Line_OVP			454	V	Line overvoltage threshold
CC			100	pF	Coupling Capacitor for Low Side Buck Configuration
RPRELOAD			52	kOhms	Minimum Output Preload Resistor
CBP			10	uF	BP Capacitor
RBP			146.4	kOhms	Recommended Pull-up Resistor from DC Bus to BP pin
VOLTAGE STRESS PARAMETERS					
VDRAIN			187	V	Estimated worst case drain voltage
PIVD			187	V	Output Rectifier Maximum Peak Inverse Voltage

8 Performance Data

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

8.1 Efficiency

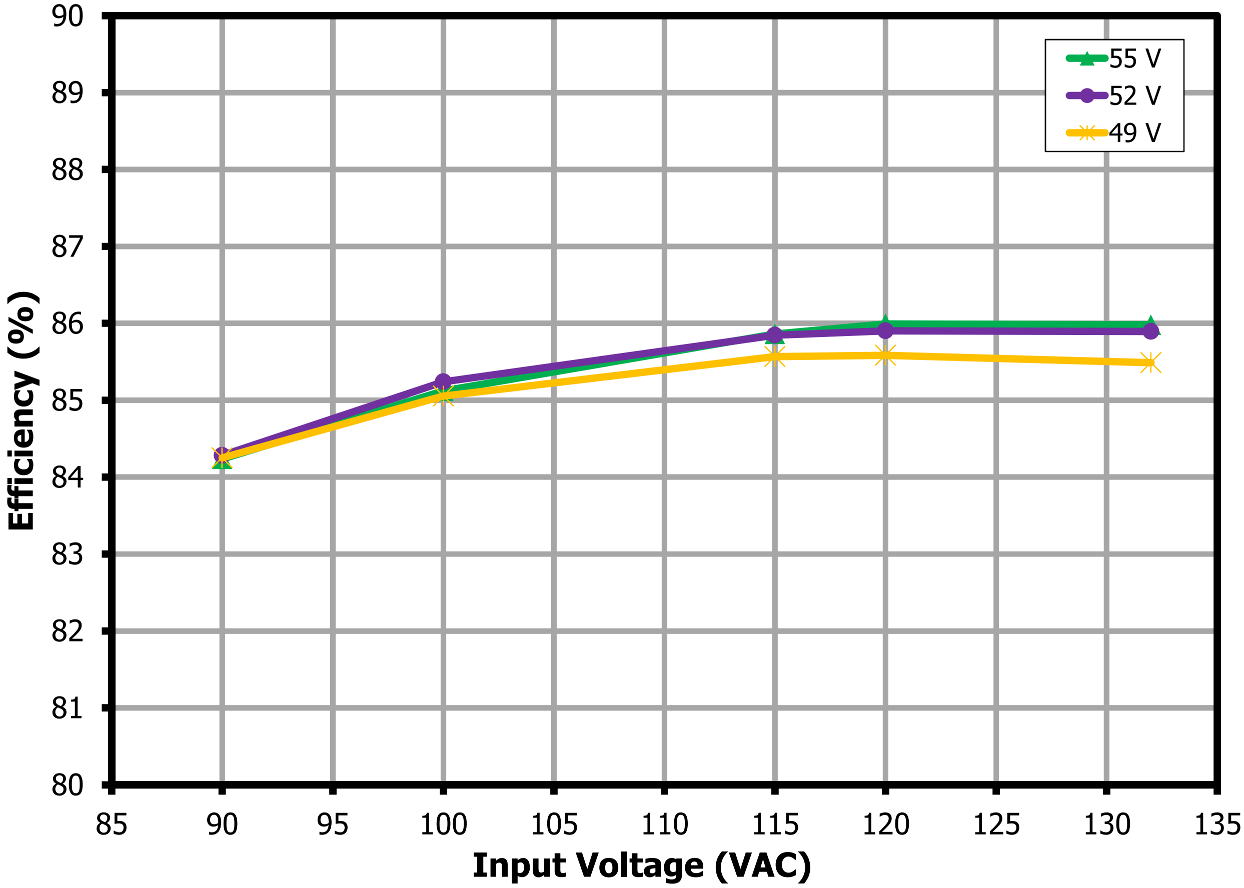

Figure 7 – Efficiency vs. Input Line Voltage.

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8.2 Line Regulation

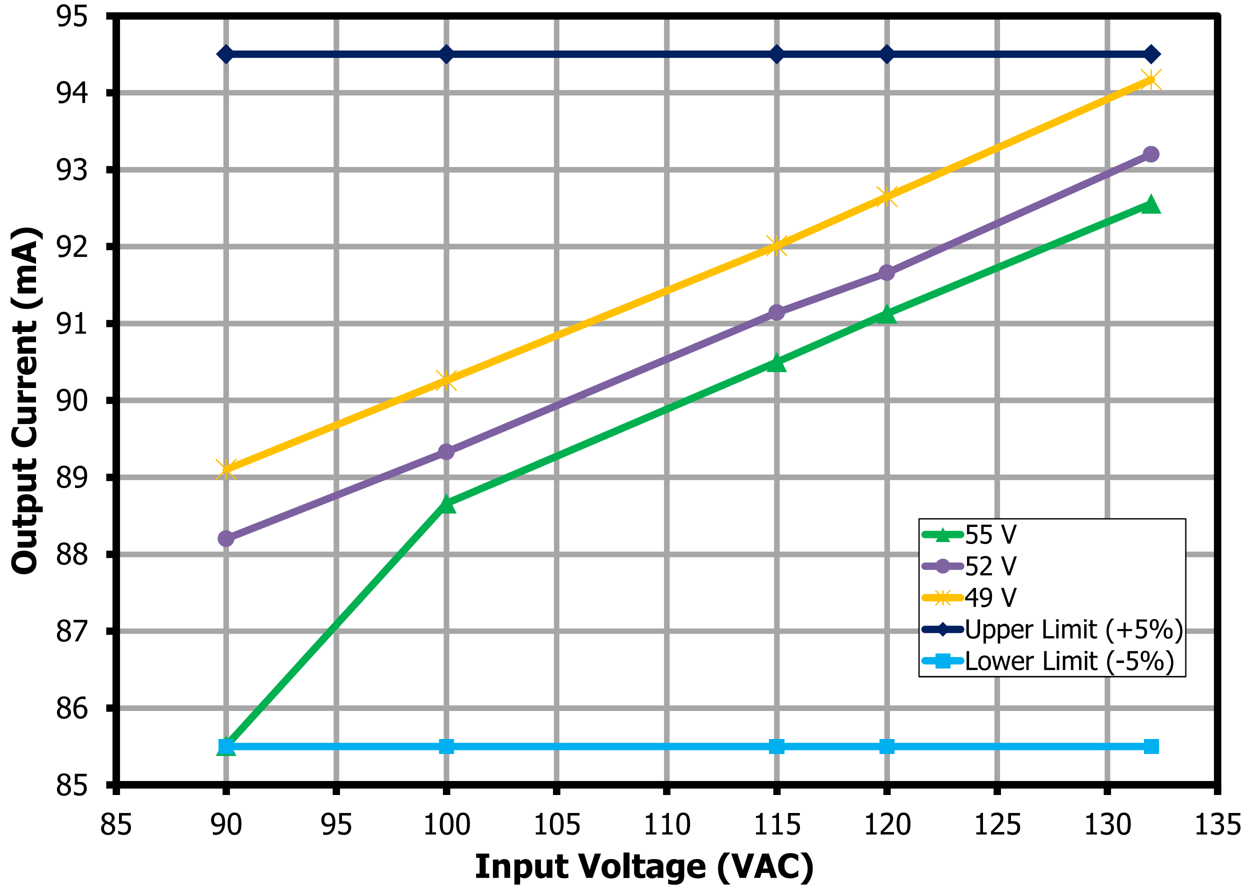

Figure 8 – Output Regulation vs. Input Line Voltage.

8.3 Power Factor

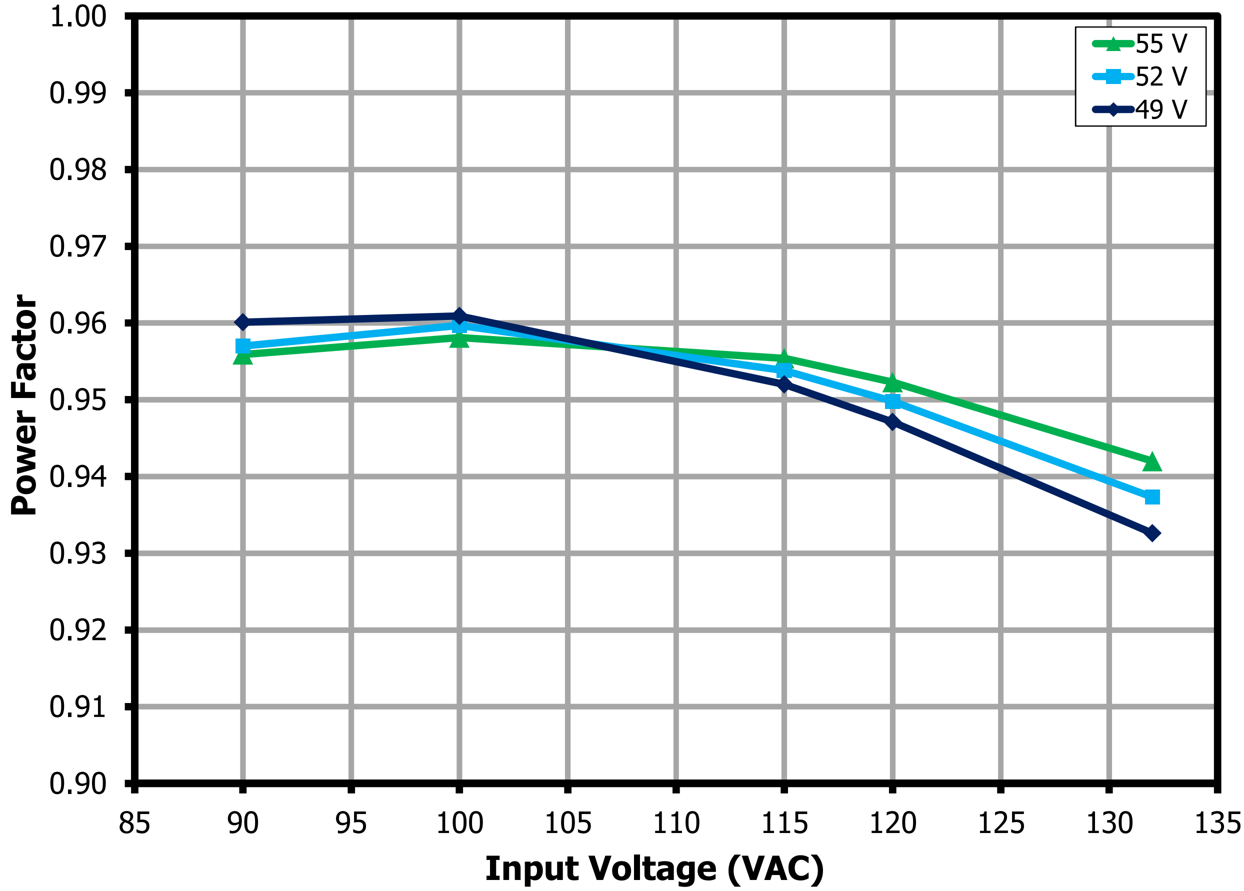

Figure 9 – Power Factor vs. Input Line Voltage.

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8.4 %ATHD

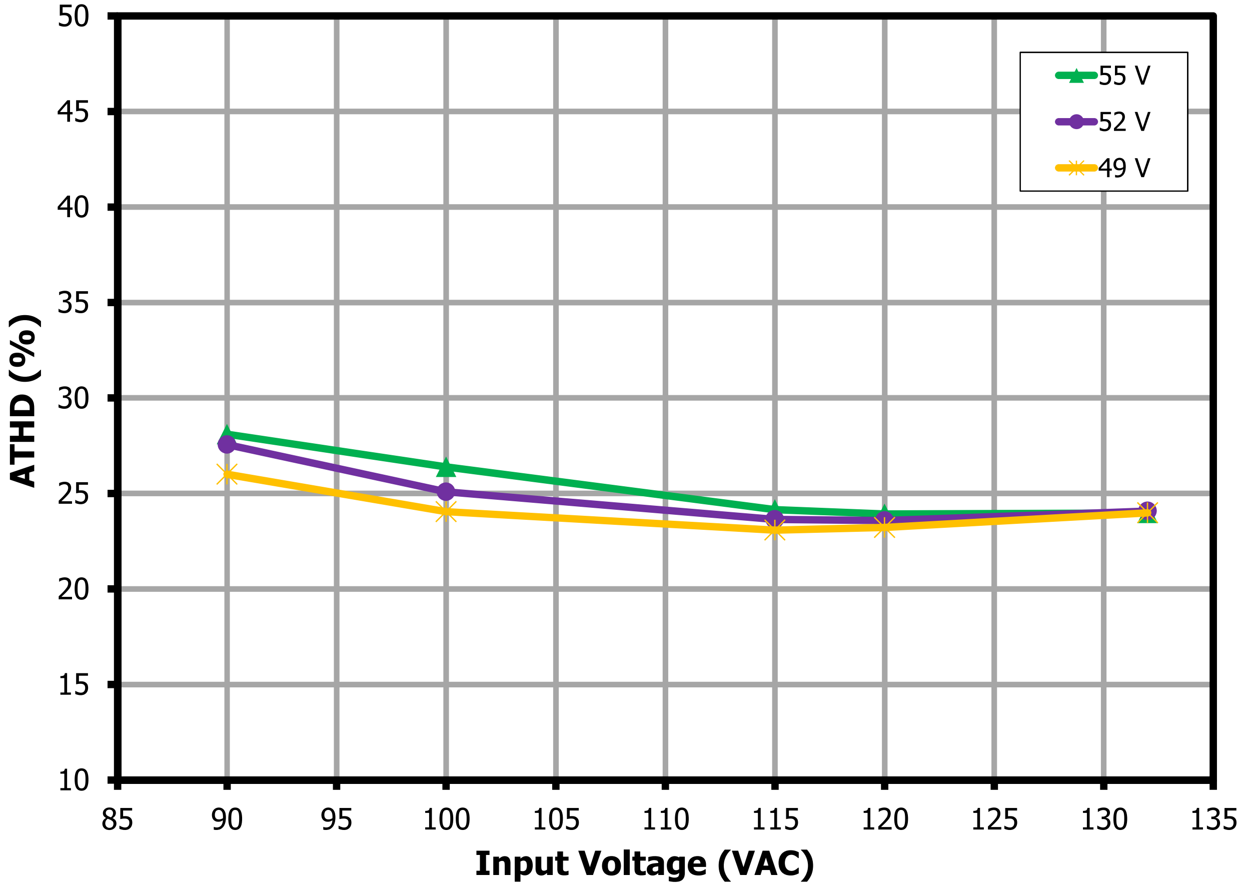

Figure 10 – %ATHD vs. Input Line Voltage.

8.5 Harmonics

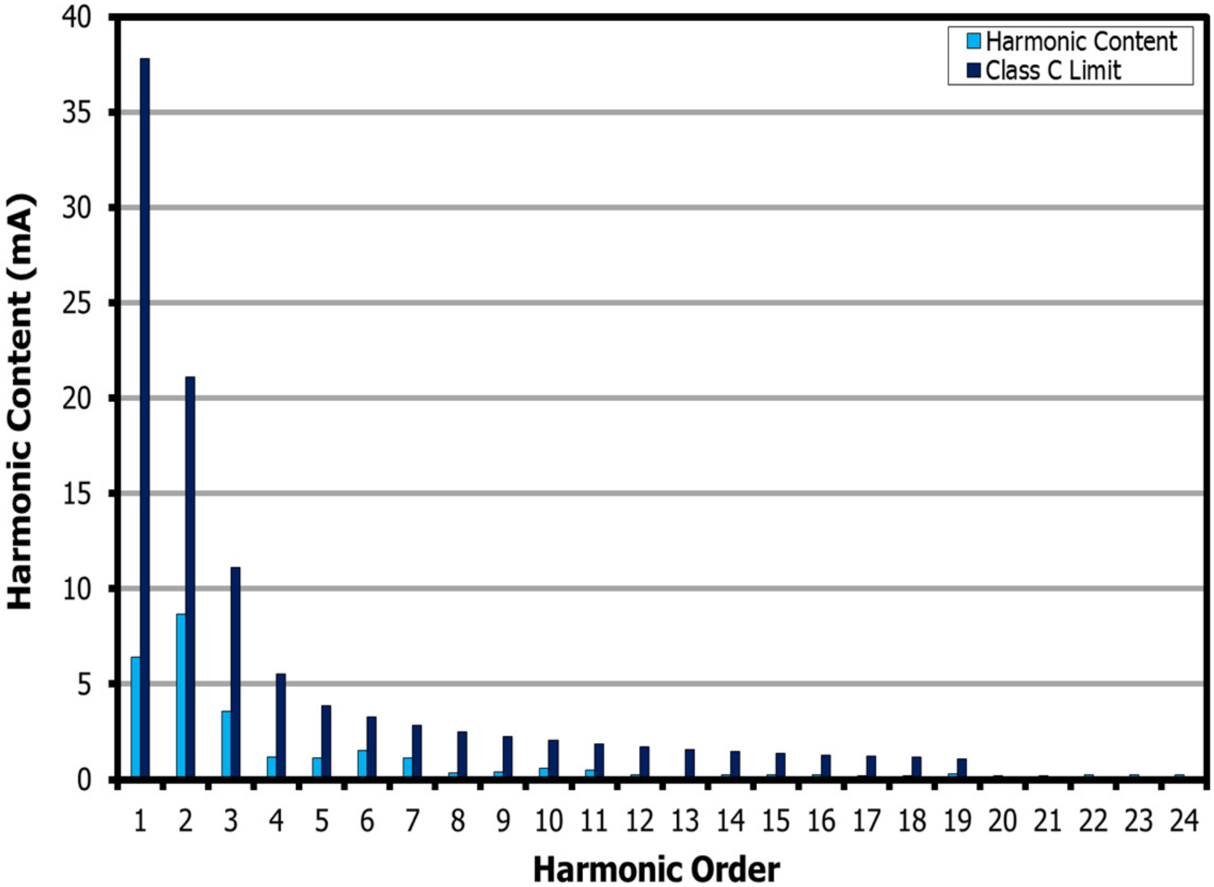

Figure 11 – Input Current Harmonics at 115 VAC, 60 Hz.

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9 Test Data

9.1 Test Data, 49 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	89.94	61.10	5.28	0.960	26.01	49.75	89.10	4.45	84.25
100	60	99.96	55.19	5.30	0.961	24.05	49.82	90.26	4.51	85.05
115	60	114.95	49.16	5.38	0.952	23.08	49.90	92.01	4.60	85.57
120	60	119.99	47.67	5.42	0.947	23.21	49.93	92.65	4.64	85.58
132	60	131.98	44.84	5.52	0.933	23.99	49.99	94.17	4.72	85.49

9.2 Test Data, 52 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	89.94	64.16	5.52	0.957	27.55	52.63	88.20	4.65	84.28
100	60	99.96	57.71	5.54	0.960	25.08	52.70	89.33	4.72	85.24
115	60	114.95	51.22	5.62	0.954	23.64	52.78	91.14	4.82	85.84
120	60	120.00	49.53	5.65	0.950	23.59	52.80	91.66	4.85	85.90
132	60	131.98	46.47	5.75	0.937	24.08	52.86	93.20	4.94	85.89

9.3 Test Data, 55 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	89.94	65.56	5.64	0.956	28.10	55.38	85.51	4.75	84.24
100	60	99.96	60.56	5.80	0.958	26.39	55.56	88.66	4.94	85.12
115	60	114.95	53.52	5.88	0.955	24.15	55.65	90.50	5.05	85.86
120	60	119.99	51.74	5.91	0.952	23.94	55.67	91.13	5.08	85.99
132	60	131.98	48.36	6.01	0.942	23.97	55.74	92.56	5.17	85.98

9.4 Harmonic Content, 115 VAC, 60 Hz, 52 V LED Load

V	Freq	I (mA_{RMS})	P	PF	%THD
115	60.00	50.77	5.5610	0.9530	23.898
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**
1	47.90				
2	0.11	0.23%		2.00%	
3	6.41	13.39%	37.8148	28.45%	Pass
5	8.67	18.10%	21.1318	10.00%	Pass
7	3.58	7.47%	11.1220	7.00%	Pass
9	1.19	2.47%	5.5610	5.00%	Pass
11	1.13	2.35%	3.8927	3.00%	Pass
13	1.51	3.15%	3.2938	3.00%	Pass
15	1.14	2.38%	2.8546	3.00%	Pass
17	0.37	0.76%	2.5188	3.00%	Pass
19	0.39	0.81%	2.2537	3.00%	Pass
21	0.61	1.28%	2.0390	3.00%	Pass
23	0.50	1.04%	1.8617	3.00%	Pass
25	0.26	0.53%	1.7128	3.00%	Pass
27	0.12	0.25%	1.5859	3.00%	Pass
29	0.25	0.53%	1.4765	3.00%	Pass
31	0.27	0.56%	1.3813	3.00%	Pass
33	0.27	0.56%	1.2976	3.00%	Pass
35	0.22	0.46%	1.2234	3.00%	Pass
37	0.21	0.43%	1.1573	3.00%	Pass
39	0.30	0.62%	1.0979	3.00%	Pass
41	0.20	0.41%			
43	0.21	0.43%			
45	0.23	0.47%			
47	0.26	0.54%			
49	0.26	0.53%			

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10 Dimming Performance Data

TRIAC dimming results were taken at an input voltage of 115 VAC, 60 Hz line frequency, room temperature, and a nominal 52 V LED load.

10.1 Dimming Curve

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

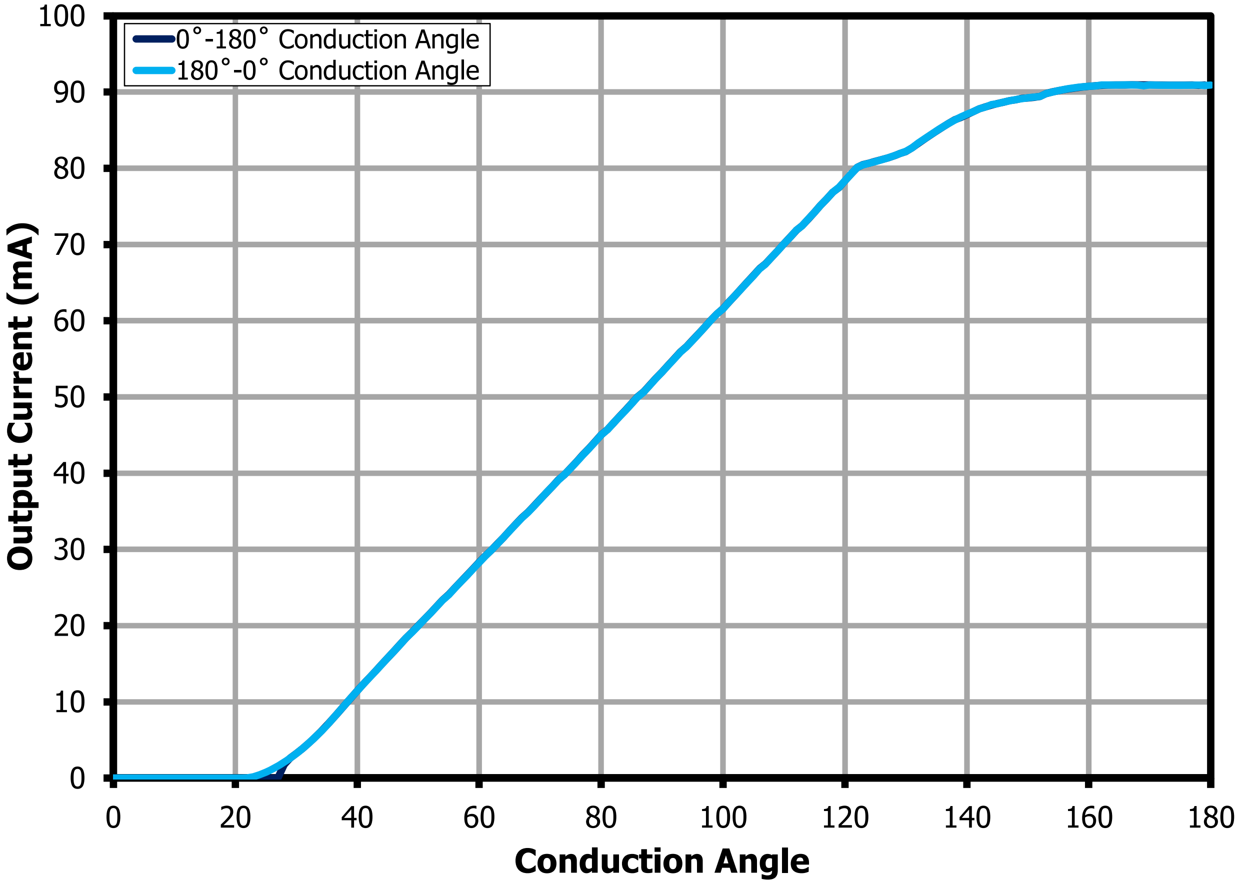

Figure 12 – Dimming Curve at 115 VAC, 60 Hz Input.

10.2 Dimming Efficiency

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

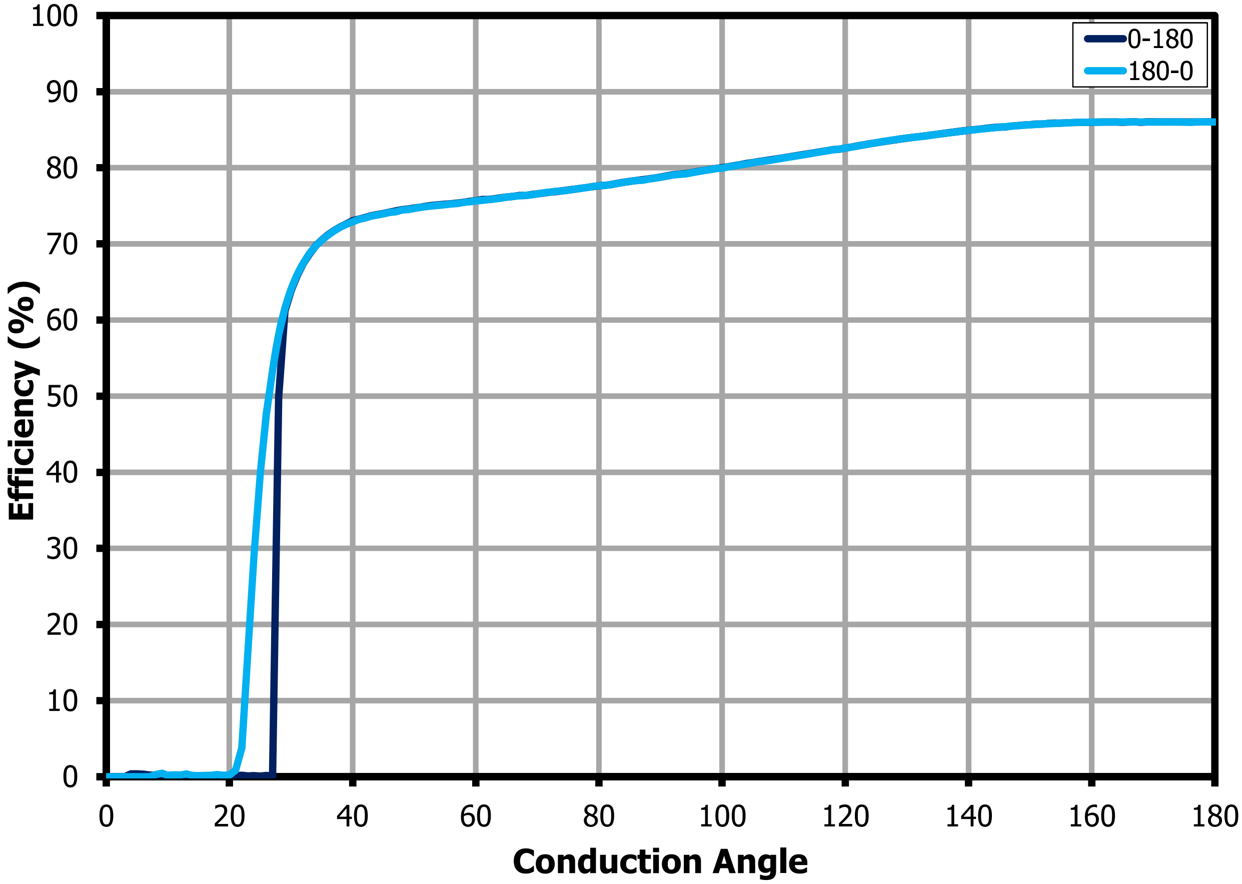

Figure 13 – Dimming Efficiency at 115 VAC, 60 Hz Input.

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10.3 Driver Power Loss During Dimming

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

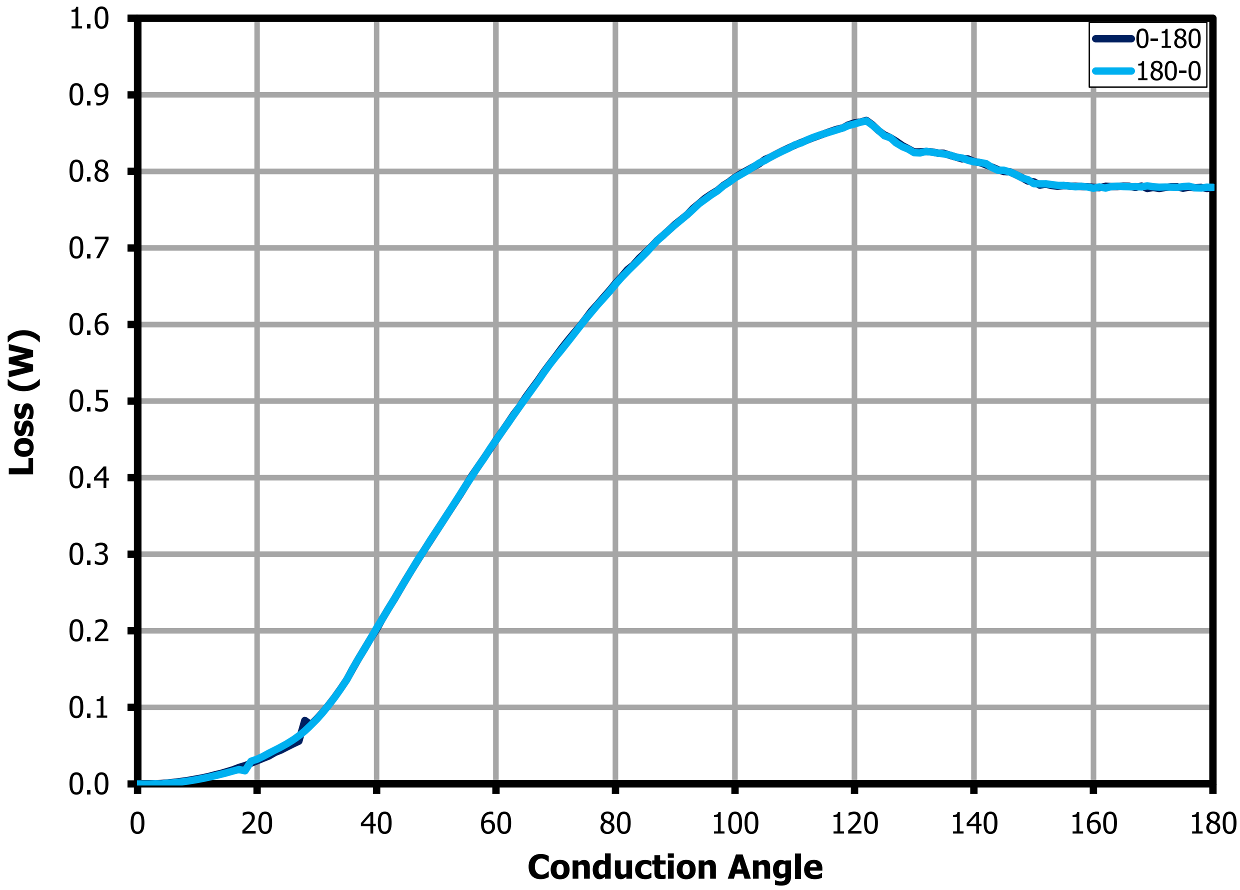

Figure 14 – Dimming Power Loss at 115 VAC, 60 Hz Input.

10.4 Dimmer Compatibility List

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

1. AC Programmable Power Source (Agilent 6812B) set at 115 V, 60 Hz
2. Utility Line Source (≈110 V, 60 Hz)

DER-540 is compatible to the following Leading-Edge Dimmers:

NO.	Panel	Brand	Model	Type	Max (mA)	Min (mA)	Dimming Ratio
1	PHILS-L1	LUTRON	AY-10PNL-WH	L	88.85	12.35	7
2	PHILS-L1	LUTRON	AY-10P-WH	L	83.4	8	10
3	PHILS-L1	LUTRON	AYLV-600P-WH	L	81.1	4.87	17
4	PHILS-L1	LUTRON	AYLV-603P-WH	L	79.8	4.6	17
5	PHILS-L2	LUTRON	DVPDC-203P-WH	L	88.07	43.1	2
6	PHILS-L2	LUTRON	DVW-603PGH-WH	L	60.2	3.94	15
7	PHILS-L2	LUTRON	DVWCL-153PH-WH	L	77.64	1.44	54
8	PHILS-L2	LUTRON	CTCL-153P-WH	L	76.98	1.38	56
9	PHILS-L3	LUTRON	MACL-153M-WH	L	62.92	0.3	210
10	PHILS-L3	LUTRON	NT-1000	L	83.32	6.04	14
11	PHILS-L3	LEVITON	R02-06613-PLW	L	88.51	4.76	19
12	PHILS-L4	LUTRON	S-103PNL-WH	L	81.18	17.59	5
13	PHILS-L4	LUTRON	S-103P-WH	L	81.02	19.036	4
14	PHILS-L4	LUTRON	S-10P-WH	L	77.69	14.95	5
15	PHILS-L4	LUTRON	S-600PH-WH	L	79.35	2.69	29
16	PHILS-L7	COOPER	DAL06P-C2	L	86.75	15.34	6
17	PHILS-L7	COOPER	SAL06P	L	86.61	12.97	7
18	PHILS-L7	LEVITON	IPL06	L	80.6	4.76	17
19	PHILS-L7	LEVITON	6674	L	81.63	4.49	18
20	US Panel 9	LEGRAND	HCL453PTCCCV6	L	76.4	26.7	3
21	US Panel 9	LEGRAND	H703PTCCCV6	L	81.63	3.7	22
22	US Panel 9	LEGRAND	H1103PTCCCV6	L	81.49	3.7	22
23	US Panel 9	LUTRON	SCL-153P-WH	L	75.31	1.16	65
24	US Panel 10	LUTRON	N-600-WH	L	86	13.43	6
25	US Panel 10	LUTRON	NT-603P-WH	L	84.5	9.1	9
26	US Panel 10	LUTRON	DV-10P-WH	L	82.07	12.87	6
27	US Panel 10	LUTRON	DVF-103P-WH	L	89.75	31.5	3
28	US Panel 10	LEVITON	1PL06-10Z	L	81.67	4.27	19
29	US Panel 10	LEVITON	6672	L	84.72	8.69	10
30	PHILS-L5	COOPER	SLC03P-W-K-L	L	79.67	44.46	2
31	PHILS-L5	LUTRON	TG-10PR-WH	L	80.67	8.99	9
32	PHILS-L5	LUTRON	TGCL-153PH-WH	L	75.8	1.23	62
33	US Panel 1	COOPER	R106PL-W-K	L	82.75	1.63	51
34	US Panel 1	LEVITON	1P106-1LZ	L	86.25	16.19	5
35	US Panel 3	LUTRON	NT-600-WH	L	86.01	14.17	6
36	US Panel 11	LEVITON	6674	L	82.73	4.64	18
37	US Panel 11	LEVITON	TBL03	L	86.82	9.14	9
38	US Panel 11	LUTRON	CTCL-153P-WH	L	76.76	1.15	67

DER-540 is also compatible to the following trailing-edge type dimmers:

NO.	Panel	Brand	Model	Type	Max (mA)	Min (mA)	Dimming Ratio
1	PHILS-L6	LUTRON	SPSELV-600-WH	T	81.57	12.743	6
2	US Panel 10	LUTRON	NTELV-600-WH	T	91.13	17.62	5
3	US Panel 3	LUTRON	LXELV-600PL-WH	T	64.43	8.73	7
4	US Panel 3	LUTRON	NTELV-300-WH	T	90.96	16.17	6
5	US Panel 3	LUTRON	DVELV-300P-WH	T	91.05	8.08	11
6	US Panel 3	LUTRON	SELV-300P-WH	T	90.63	8.43	11
7	US Panel 11	LEVITON	6615	T	88.24	24.6	4

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11 Thermal Performance

Thermal measurements were performed at the minimum, nominal, and maximum input line voltages with the unit enclosed in a box to prevent airflow. Measurements were taken with the ambient temperature set at room temp (≈25 ºC), and at high temp (≈85 ºC). The unit was soaked for 1 hour to allow component temperatures to stabilize. Thermal measurement was also taken at high temperature while the unit is subjected to a dimming angle where the highest dimming loss occurs.

11.1 Non-Dimming, Room Temperature (≈25 ºC)

Measurement is done using T-type thermocouple and Yokogawa GP20 data logger. Chroma Programmable AC Source model 61604 is used for the input with the frequency set at 60 Hz. *See Figure 15 for the Thermal Set-up.*

Component		Thermal Reading (°C)		
Part Ref	**Description**	**90Vac**	**115Vac**	**132Vac**
RF1	Damper	49.3	42.7	40.6
BR1	Bridge Diode	43.7	40.4	39.7
L1	Input Inductor	52	46.8	45.8
R1	Damper Resistor	41.1	40.9	41.9
L2	Buck Inductor	38.6	39.9	41
C6	Output E-Cap	35.9	36.1	36.8
D1	Output Diode	39.2	39.3	40.1
U1	LYT7503D	44.1	44.9	46.4
Ambient		28.6	27.8	27.5
I_{OUT}	Output Current	88.4 mA	91.7 mA	93.8 mA

11.2 Non-Dimming, Output Short-Circuit, Room Temperature (≈25 ºC)

Measurement is done using T-type thermocouple and Yokogawa GP20 data logger. Chroma Programmable AC Source model 61604 is used for the input with the frequency set at 60 Hz. The output terminals are short circuited while the test is being conducted. The Output Short-Circuit Protection of LYT7503D with auto-restart feature ensures very low power consumption of the device to avoid over-heating of components. *See Figure 15 for the Thermal Set-up.*

Component		Thermal Reading (°C)		
Part Ref	**Description**	**90Vac**	**115Vac**	**132Vac**
RF1	Damper	26.1	27.4	26.3
BR1	Bridge Diode	27.7	29	28.2
L1	Input Inductor	30	30.9	30.3
R1	Damper Resistor	30.8	31.3	30.7
L2	Buck Inductor	33	31.9	31.5
C6	Output E-Cap	29.3	29.8	29.3
D1	Output Diode	32.4	32.4	31
U1	LYT7503D	32.7	34	34.8
Ambient		24.2	24.3	24.5

11.3 Non-Dimming, 85 ºC Ambient

Measurement is done using T-type thermocouple and Yokogawa GP20 data logger. Chroma Programmable AC Source model 61604 is used for the input with the frequency set at 60 Hz. *See Figure 15 for the Thermal Set-up.*

Component		**Thermal Reading (°C)**		
Part Ref	**Description**	**90Vac**	**115Vac**	**132Vac**
RF1	Damper	106.6	100	98.2
BR1	Bridge Diode	100	96.9	96.4
L1	Input Inductor	109.5	103.9	103
R1	Damper Resistor	97.7	97.7	98.9
L2	Buck Inductor	94.1	94.9	95.8
C6	Output E-Cap	91.9	91.9	92.5
D1	Output Diode	95.6	95.4	96.1
U1	LYT7503D	100	100.5	101.9
Ambient		87.2	86.8	87.2
I_{OUT}	Output Current	87.5mA	90.8 mA	92.8 mA

11.4 Dimming, 85 ºC Ambient, 122º Conduction Angle

Measurement is done using T-type thermocouple and Yokogawa GP20 data logger. *See Figure 15 for the Thermal Set-up*. A TRIAC dimmer is used to set the conduction angle at 122° where maximum dimming loss occurs. *Refer to Section 9.3 of this document to see the graph of driver power loss during dimming.*

Component		**Conduction Angle: 122°**
Part Ref	**Description**	**Thermal Reading (°C)**
RF1	Damper	103.3
BR1	Bridge Diode	98.7
L1	Input Inductor	108.2
R1	Damper Resistor	102.7
L2	Buck Inductor	95.1
C6	Output E-Cap	93.5
D1	Output Diode	97.1
U1	LYT7503D	99.9
Ambient		87.3
I_{OUT}	Output Current	75.8 mA

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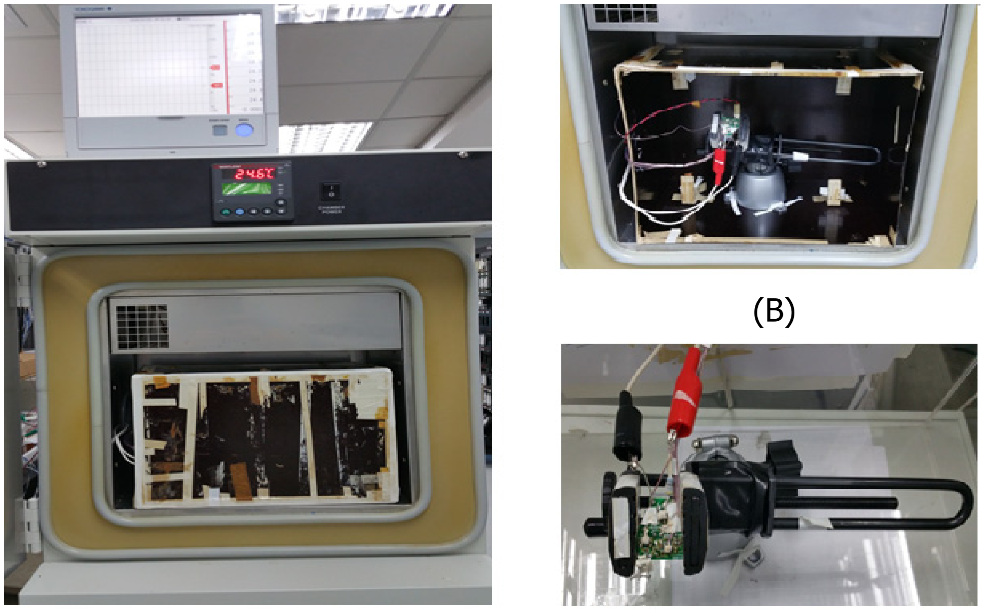

(B)

(A) (C)

Figure 15 – Thermal set-up for temperature measurement. (A) The unit is placed in a covered box – to prevent airflow that may affect the thermal reading – before placing inside the TPS TUJ-A-WF4 thermal chamber. (B) The unit inside the box without the cover. (C) Thermal set-up of the unit with output short-circuit.

12 Waveforms

12.1 Input Voltage and Input Current Waveforms (Non-Dimming)

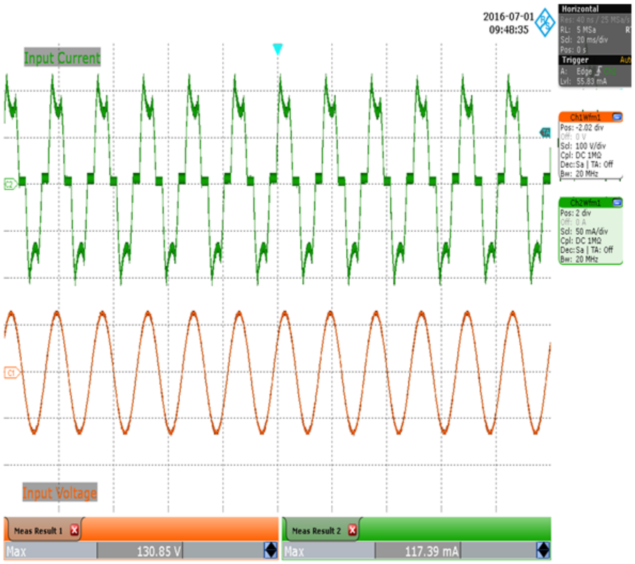

Figure 16 – 90 VAC, 52 V LED Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V / div.
Horizontal: 20 ms / div.

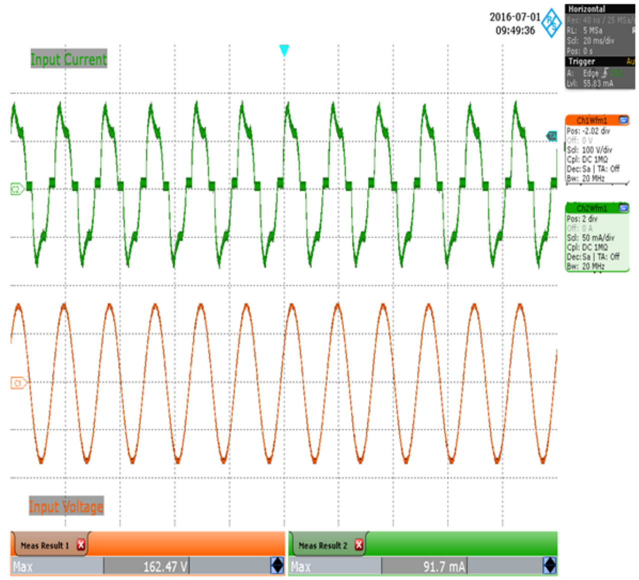

Figure 17 – 115 VAC, 52 V LED Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V / div.
Horizontal: 20 ms / div.

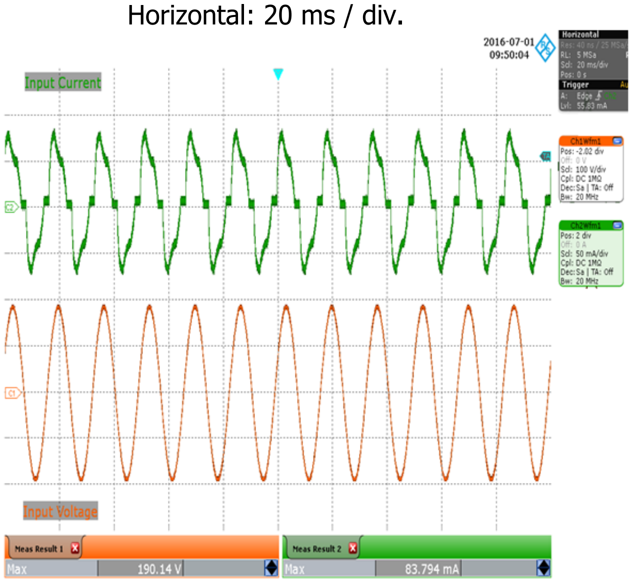

Figure 18 – 132 VAC, 52 V LED Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V / div.
Horizontal: 20 ms / div.

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12.2 Input Voltage and Input Current Waveforms while Dimming

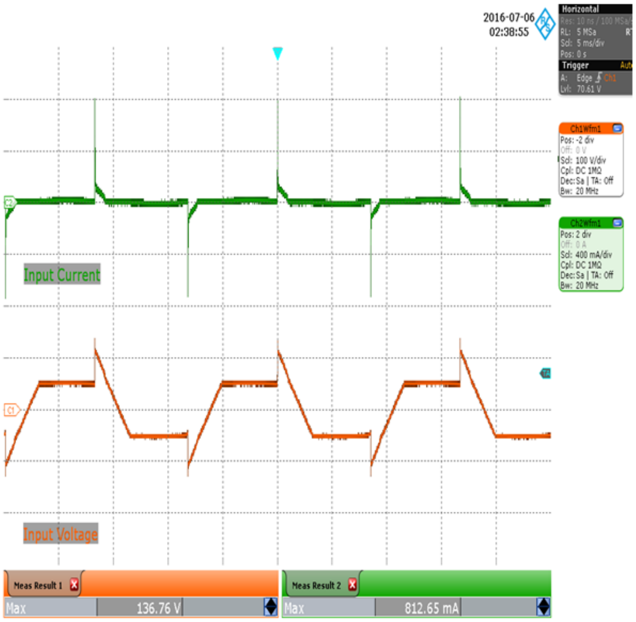

Figure 19 – 115 VAC, 52 V LED Load, Dimming, Minimum (45°) Conduction Angle.
Upper: I_{IN}, 400 mA / div.
Lower: V_{IN}, 100 V / div., 5 ms / div.

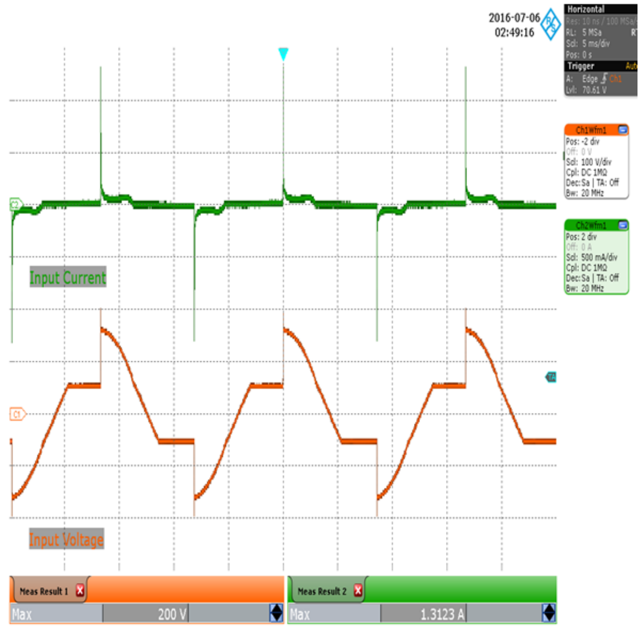

Figure 20 – 115 VAC, 52 V LED Load, Dimming, 90° Conduction Angle.
Upper: I_{IN}, 500 mA / div.
Lower: V_{IN}, 100 V / div., 5 ms / div.

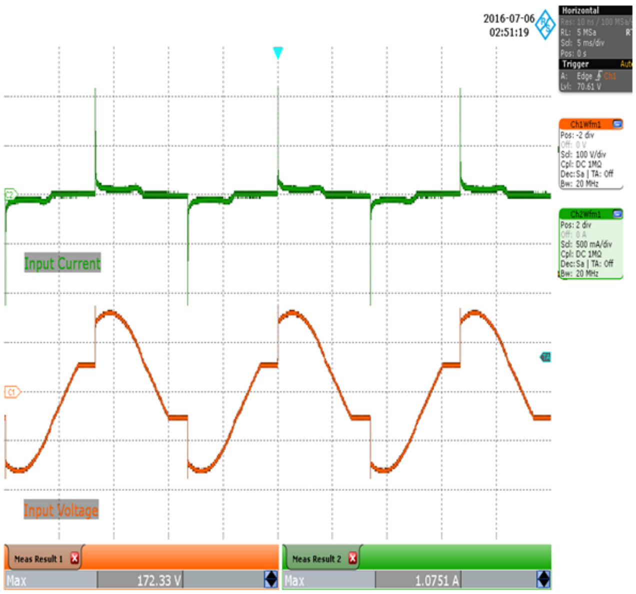

Figure 21 – 115 VAC, 52 V LED Load, Dimming, 120° Conduction Angle.
Upper: I_{IN}, 500 mA / div.
Lower: V_{IN}, 100 V / div., 5 ms / div.

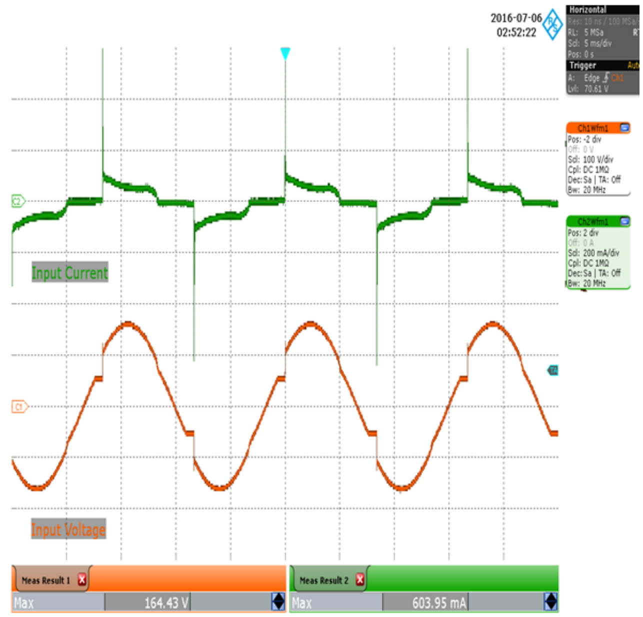

Figure 22 – 115 VAC, 52 V LED Load, Dimming, Maximum (140°) Conduction Angle.
Upper: I_{IN}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 5 ms / div.

12.3 Output Current Rise and Fall

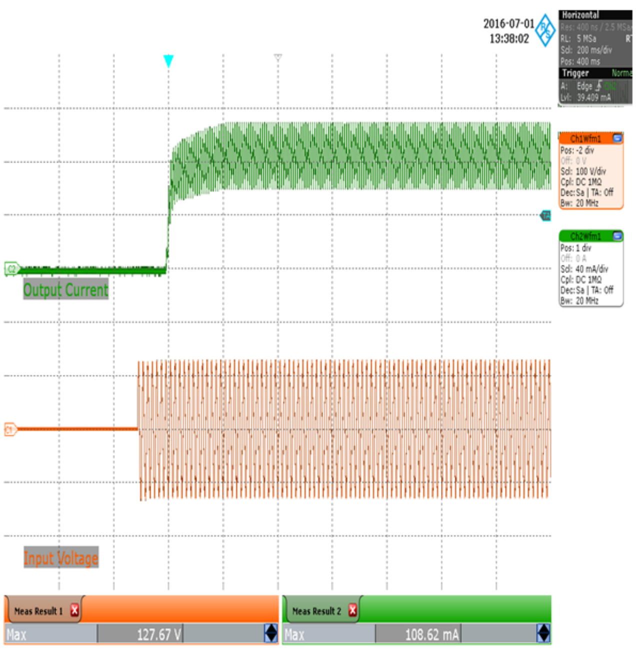

Figure 23 – 90 VAC, 52 V LED Load, Output Rise.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.

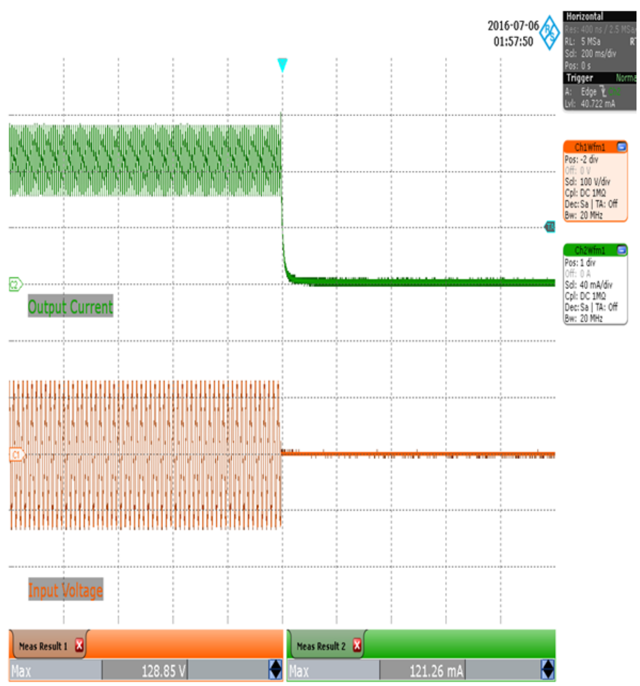

Figure 24 – 90 VAC, 52 V LED Load, Output Fall.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.

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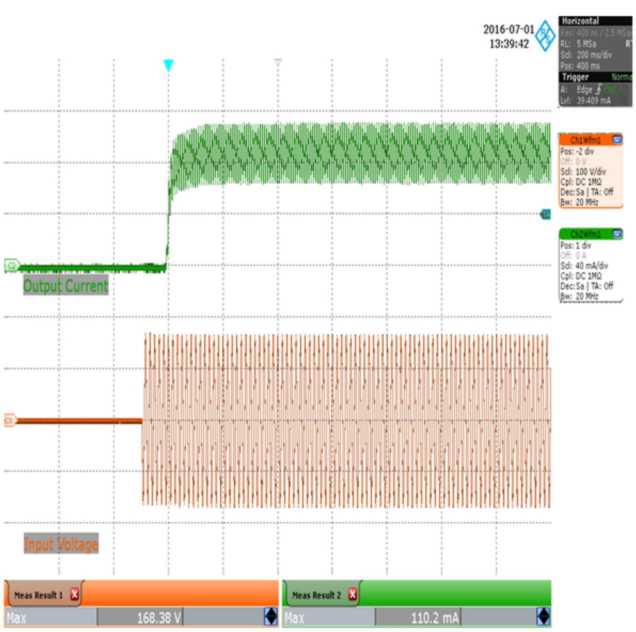

Figure 25 – 115 VAC, 52 V LED Load, Output Rise.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.

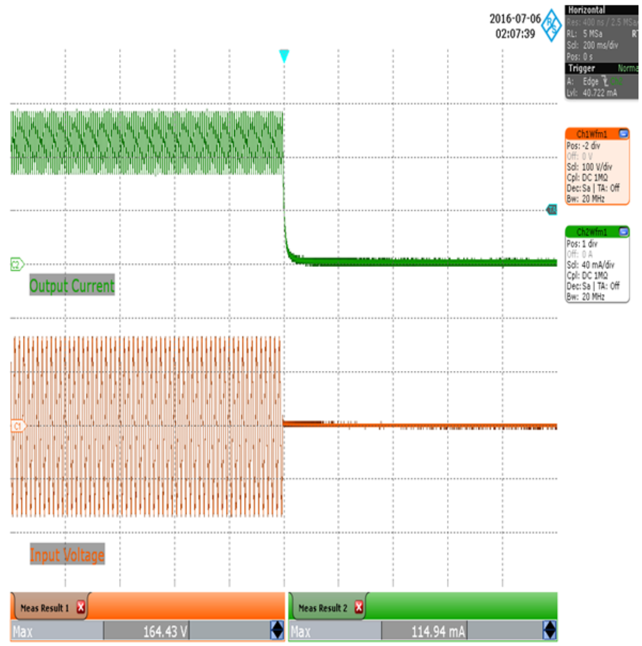

Figure 26 – 115 VAC, 52 V LED Load, Output Fall.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.

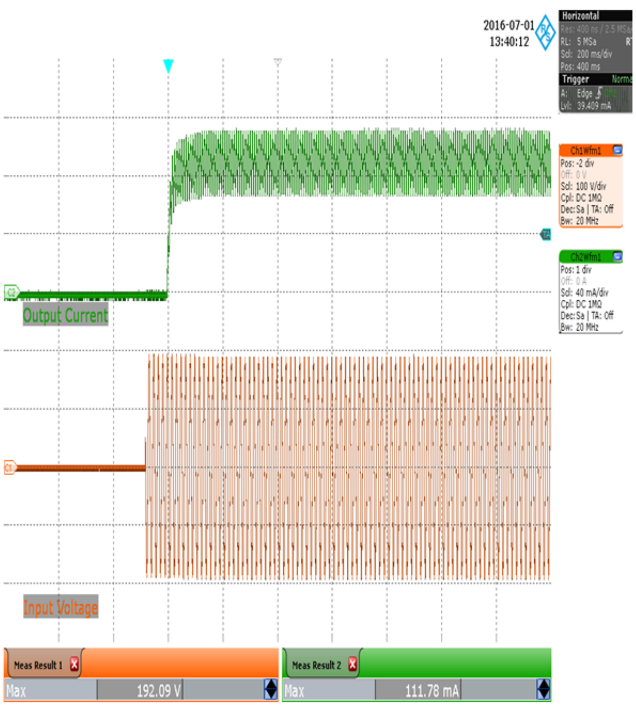

Figure 27 – 132 VAC, 52 V LED Load, Output Rise.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.

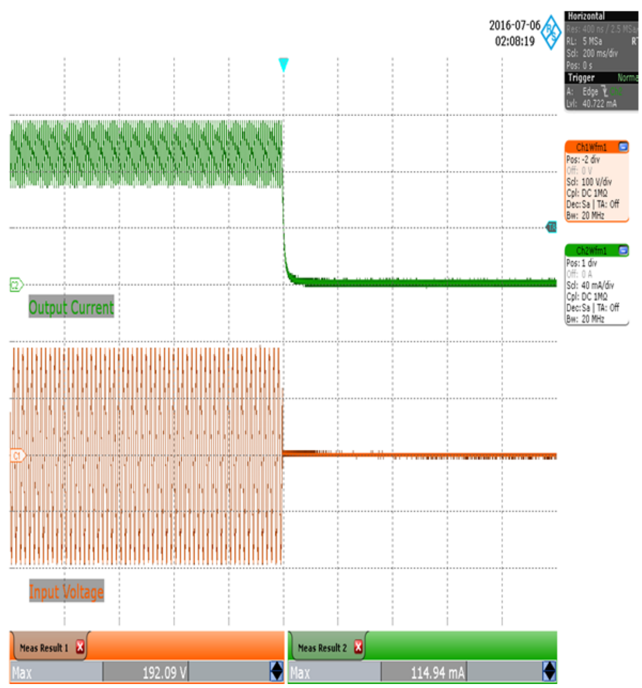

Figure 28 – 132 VAC, 52 V LED Load, Output Fall.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.

12.4 Drain Voltage and Current in Normal Operation

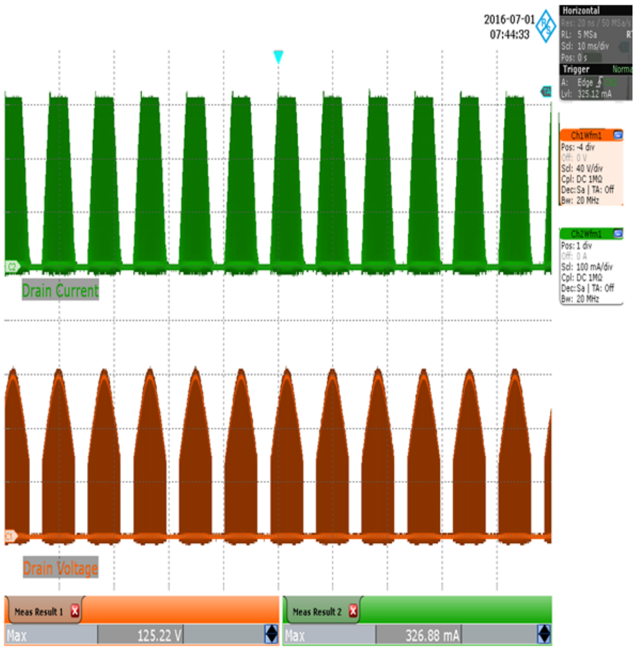

Figure 29 – 90 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 40 V / div., 10 ms / div.
$V_{DS(MAX)}$: 125.22 V.
$I_{D(MAX)}$: 326.88 mA.

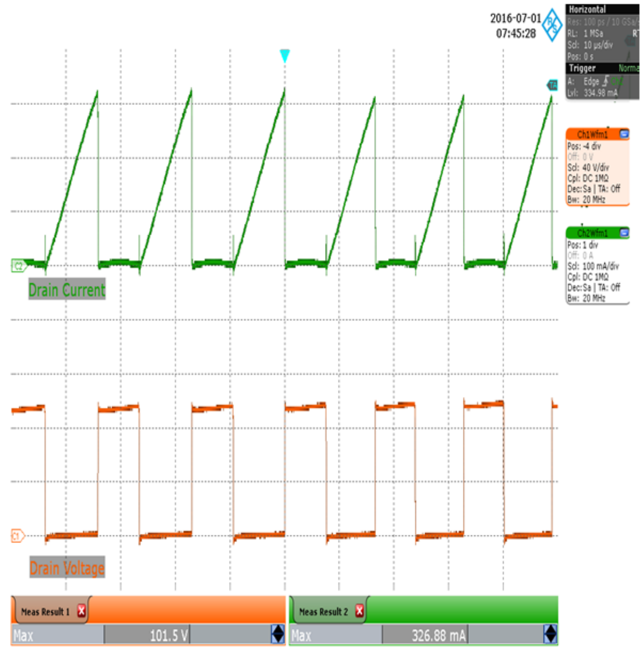

Figure 30 – 90 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 40 V / div., 10 μs / div.
$V_{DS(MAX)}$: 101.5 V.
$I_{D(MAX)}$: 326.88 mA.

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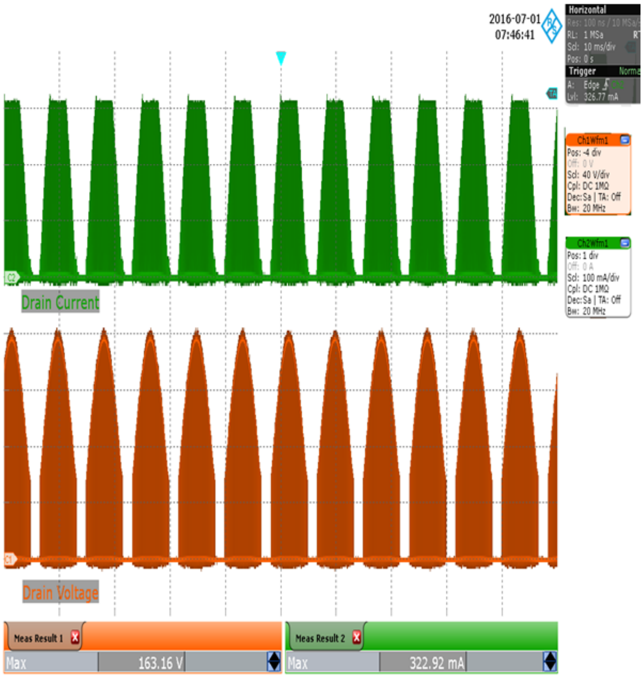

Figure 31 – 115 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 40 V / div., 10 ms / div.
$V_{DS(MAX)}$: 163.16 V,
$I_{D(MAX)}$: 322.92 mA

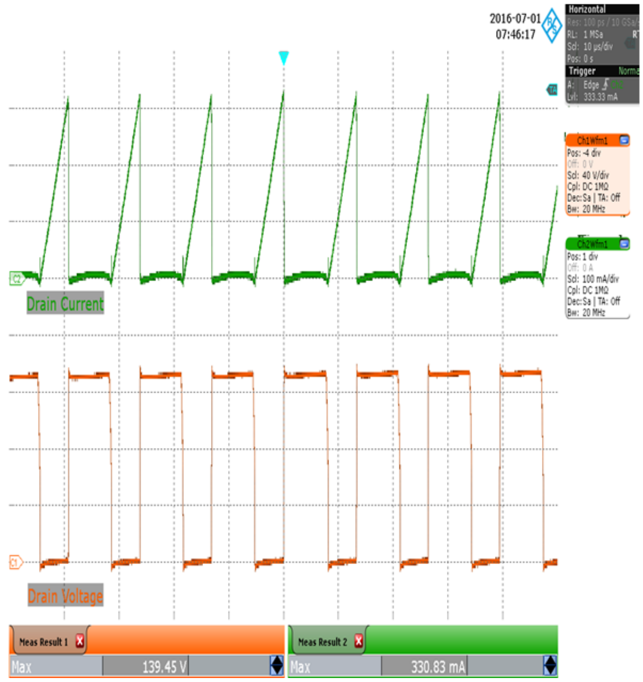

Figure 32 – 115 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 40 V / div., 10 μs / div.
$V_{DS(MAX)}$: 139.45 V.
$I_{D(MAX)}$: 330.83 mA.

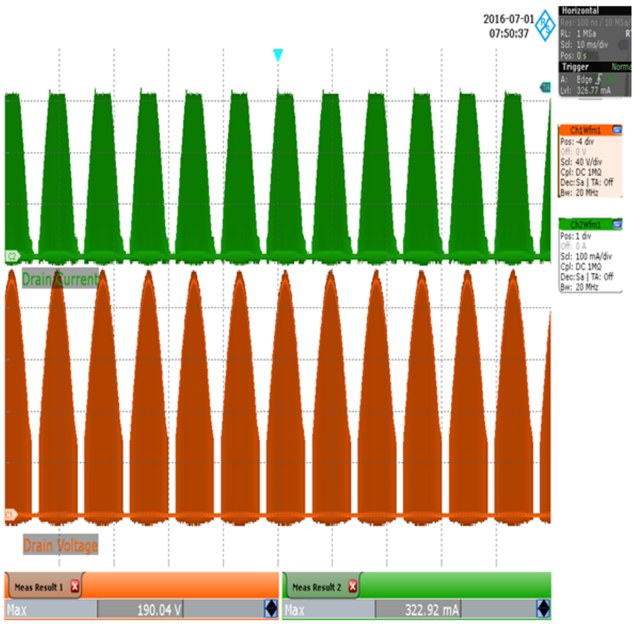

Figure 33 – 132 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 40 V / div., 10 ms / div.
$V_{DS(MAX)}$: 190.04 V.
$I_{D(MAX)}$: 322.92 mA.

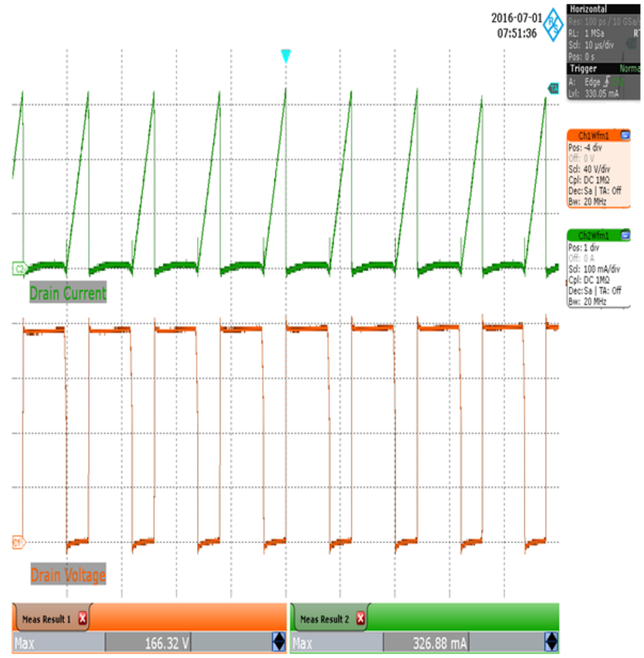

Figure 34 – 132 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 40 V / div., 10 μs / div.
$V_{DS(MAX)}$: 166.32 V.
$I_{D(MAX)}$: 326.88 mA.

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12.5 Drain Voltage and Current Start-up Profile

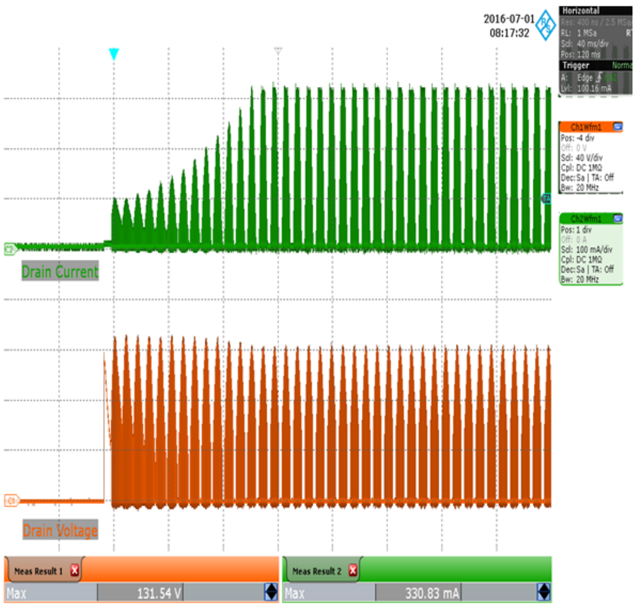

Figure 35 – 90 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 40 V / div., 40 ms / div.
$V_{DS(MAX)}$: 131.54 V.
$I_{D(MAX)}$: 330.83 mA.

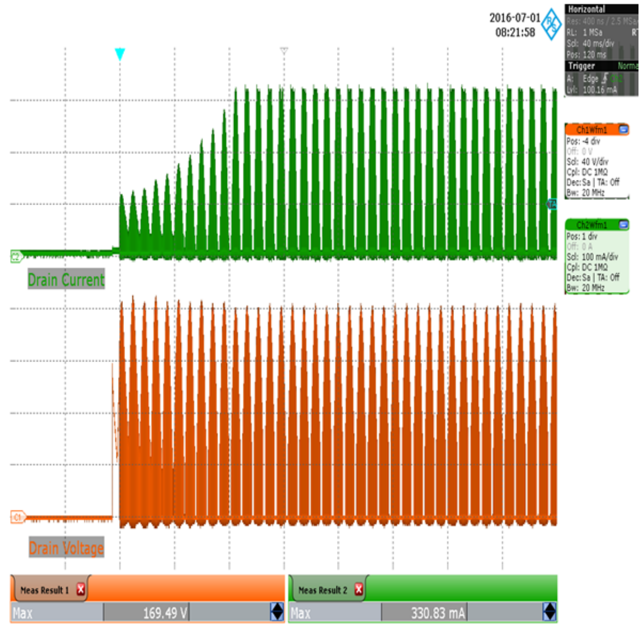

Figure 36 – 115 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 40 V / div., 40 ms / div.
$V_{DS(MAX)}$: 169.49 V.
$I_{D(MAX)}$: 330.83 mA.

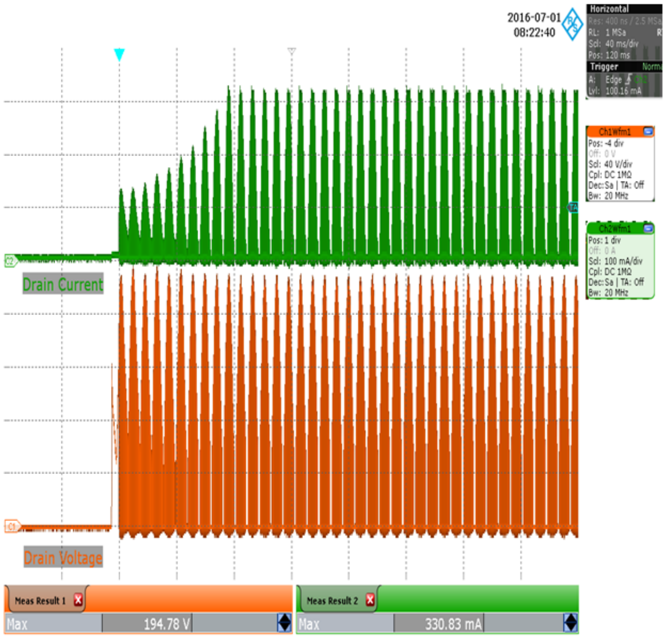

Figure 37 – 132 VAC, 52 V LED Load.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 40 V / div., 40 ms / div.
$V_{DS(MAX)}$: 194.78 V.
$I_{D(MAX)}$: 330.83 mA.

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12.6 Drain Voltage and Current During Output Short-Circuit Condition

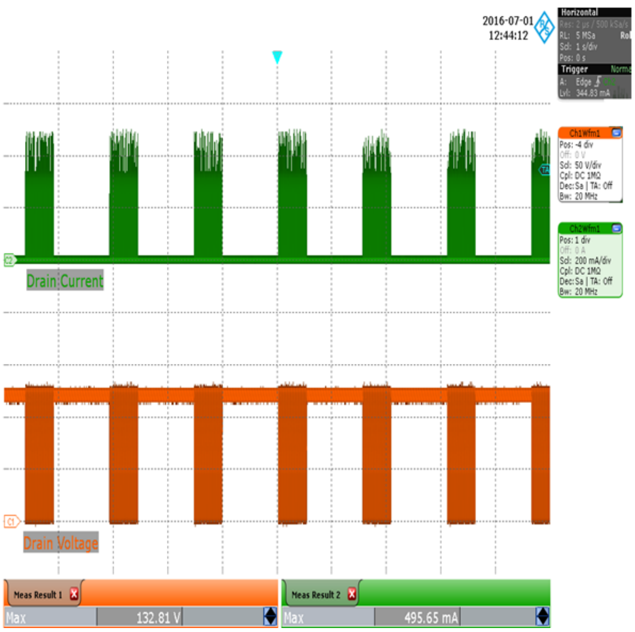

Figure 38 – 90 VAC, Output Short.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 1 s / div.
$V_{DS(MAX)}$: 132.81 V.
$I_{D(MAX)}$: 495.65 mA.

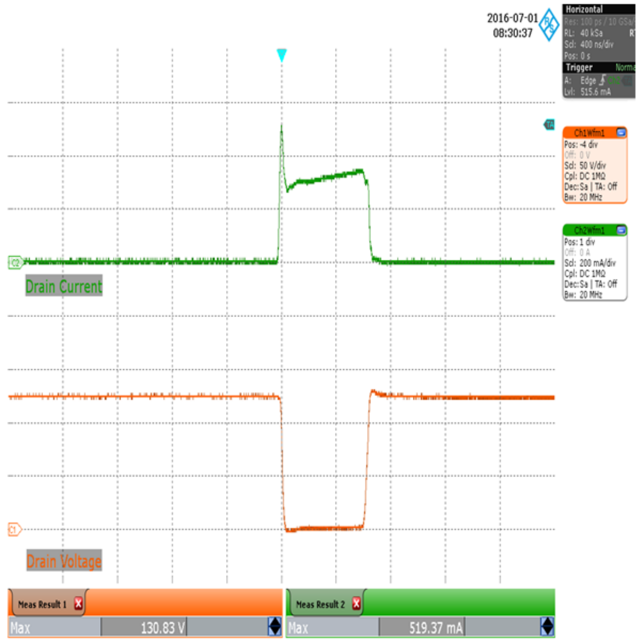

Figure 39 – 90 VAC, Output Short.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 400 ns / div.
$V_{DS(MAX)}$: 130.83 V.
$I_{D(MAX)}$: 519.37 mA.

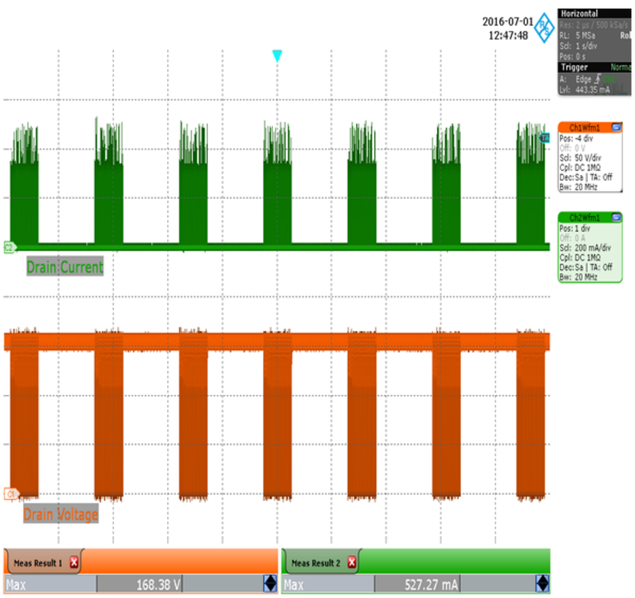

Figure 40 – 115 VAC, Output Short.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 1 s / div.
$V_{DS(MAX)}$: 168.38 V.
$I_{D(MAX)}$: 527.27 mA.

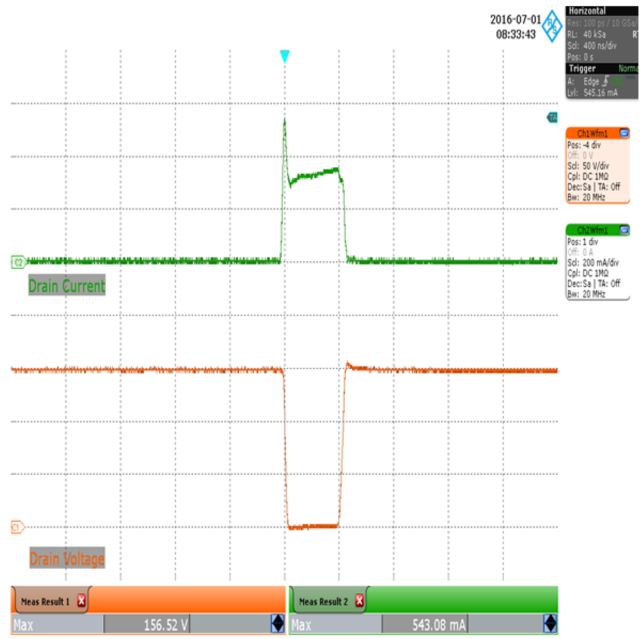

Figure 41 – 115 VAC, Output Short.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 400 ns / div.
$V_{DS(MAX)}$: 156.52 V.
$I_{D(MAX)}$: 543.08 mA.

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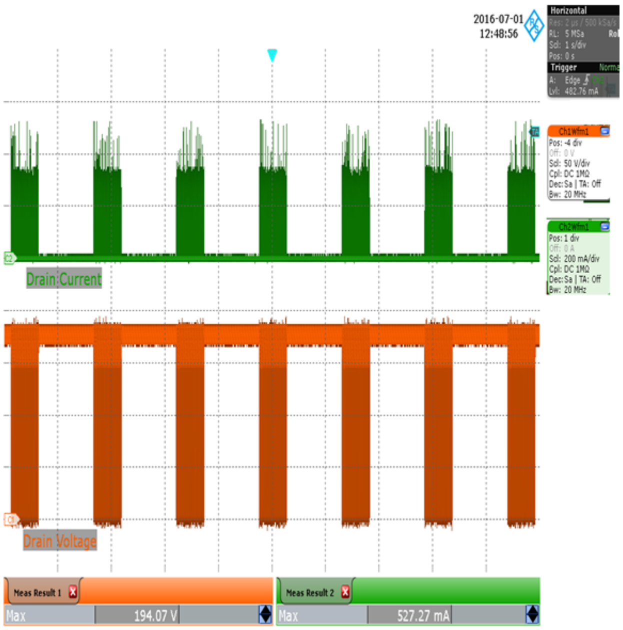

Figure 42 – 132 VAC, Output Short.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 1 s / div.
$V_{DS(MAX)}$: 194.07 V.
$I_{D(MAX)}$: 527.27 mA.

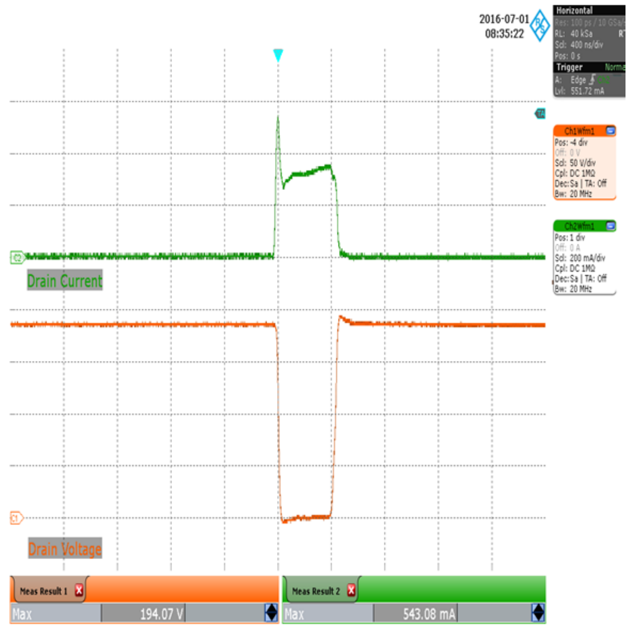

Figure 43 – 132 VAC, Output Short.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 400 ns / div.
$V_{DS(MAX)}$: 194.07 V.
$I_{D(MAX)}$: 543.08 A.

12.7 Output Diode Voltage and Current in Normal Operation

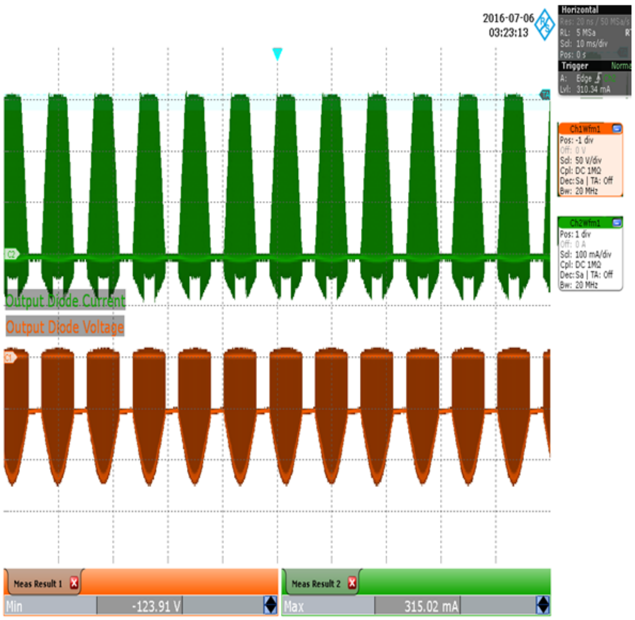

Figure 44 – 90 VAC, 52 V LED Load.
Upper: I_{DIODE}, 100 mA / div.
Lower: V_{DIODE}, 50 V / div., 10 ms / div.
$V_{D1(MIN)}$: -123.91 V.
$I_{D1(MAX)}$: 315.02 mA.

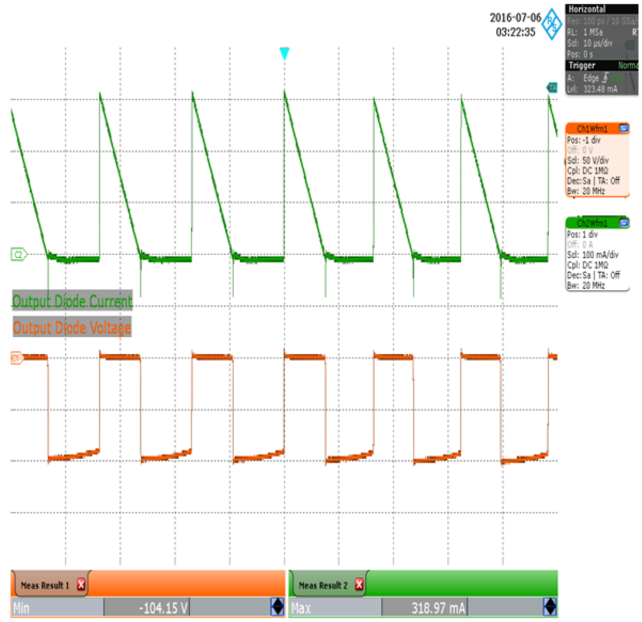

Figure 45 – 90 VAC, 52 V LED Load.
Upper: I_{DIODE}, 100 mA / div.
Lower: V_{DIODE}, 50 V / div., 10 μs / div.
$V_{D1(MIN)}$: -104.15 V.
$I_{D1(MAX)}$: 318.97 mA.

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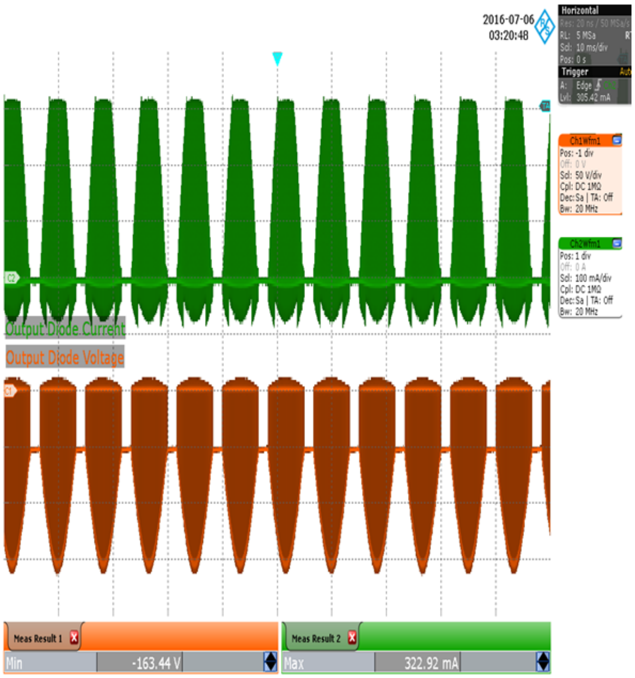

Figure 46 – 115 VAC, 52 V LED Load.
Upper: I_{DIODE}, 100 mA / div.
Lower: V_{DIODE}, 50 V / div., 10 ms / div.
$V_{D1(MIN)}$: -163.44 V.
$I_{D1(MAX)}$: 322.92 mA.

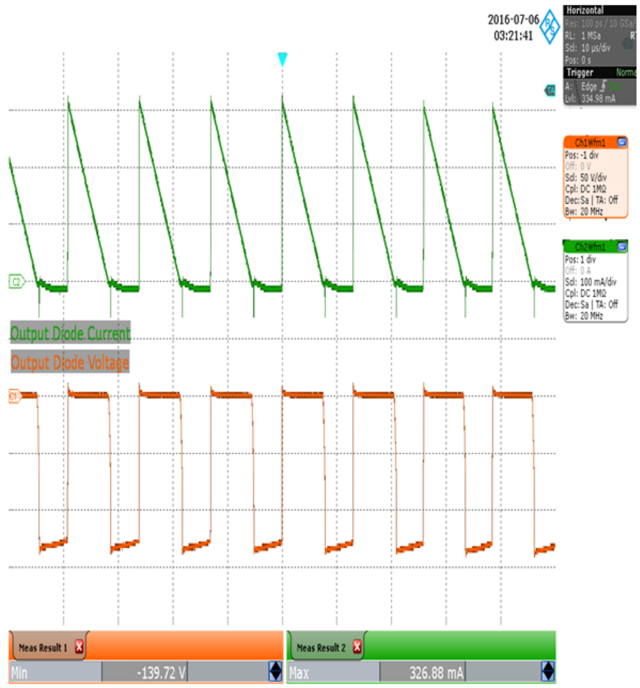

Figure 47 – 115 VAC, 52 V LED Load.
Upper: I_{DIODE}, 100 mA / div.
Lower: V_{DIODE}, 50 V / div., 10 µs / div.
$V_{D1(MIN)}$:: -139.72 V.
$I_{D1(MAX)}$: 326.68 mA.

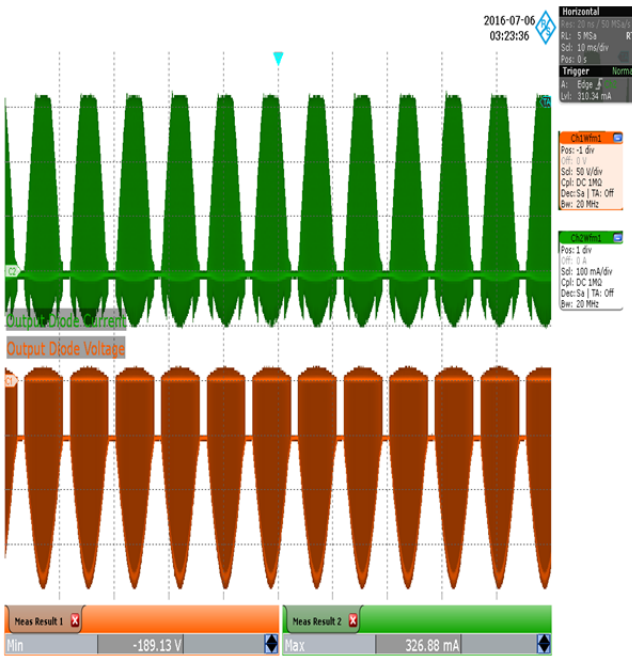

Figure 48 – 132 VAC, 52 V LED Load.
Upper: I_{DIODE}, 100 mA / div.
Lower: V_{DIODE}, 50 V / div., 10 ms / div.
$V_{D1(MIN)}$: -189.13 V.
$I_{D1(MAX)}$: 326.88 mA.

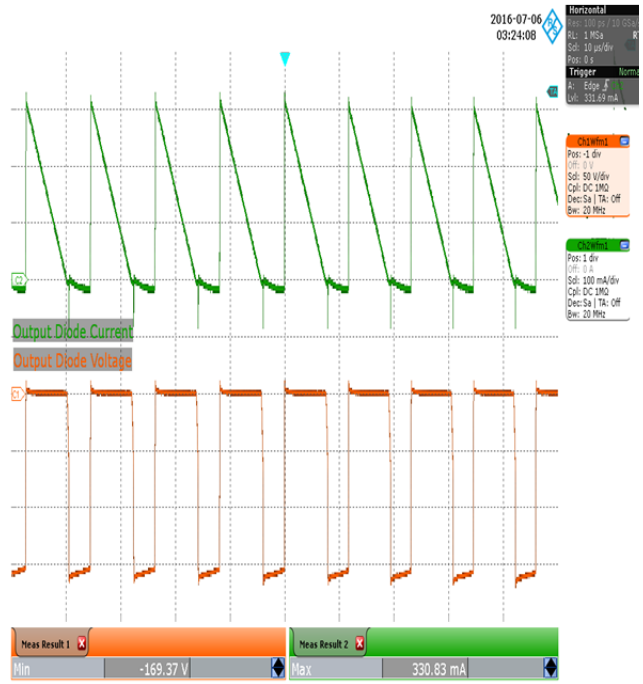

Figure 49 – 132 VAC, 52 V LED Load.
Upper: I_{DIODE}, 100 mA / div.
Lower: V_{DIODE}, 50 V / div., 10 μs / div.
$V_{D1(MIN)}$: -169.37 V.
$I_{D1(MAX)}$: 330.83 mA.

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12.8 Output Voltage and Current – Open LED Load

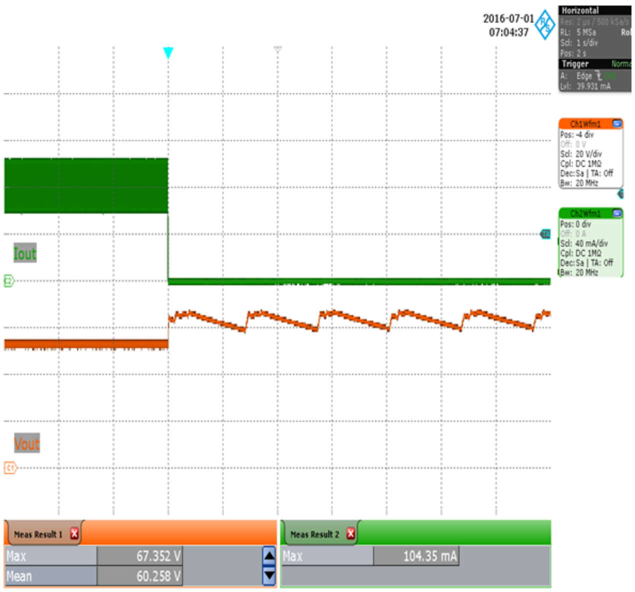

Figure 50 – 90 VAC, 52 V LED Load,
Running then Open Load.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 20 V / div., 1 s / div.
$V_{OUT(MAX)}$: 67.352 V.
$V_{OUT(MEAN)}$: 60.258 V.

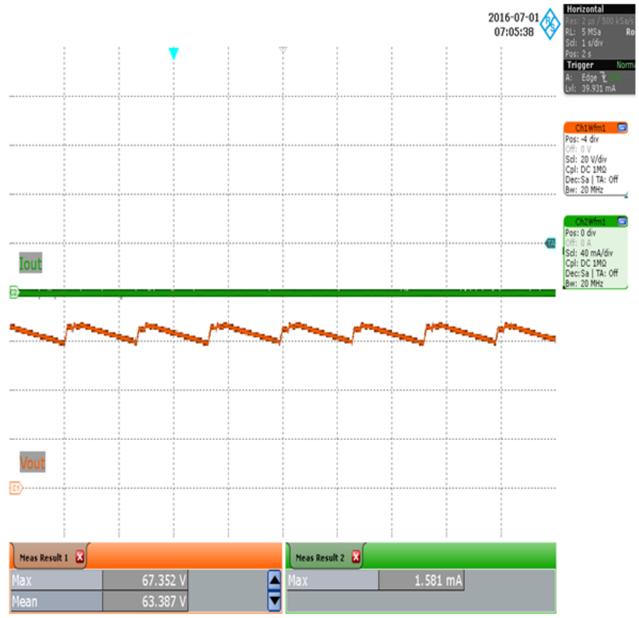

Figure 51 – 90 VAC, 52 V LED Load,
Open Load – Steady-State.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 20 V / div., 1 s / div.
$V_{OUT(MAX)}$: 67.352 V.
$V_{OUT(MEAN)}$: 63.387 V.

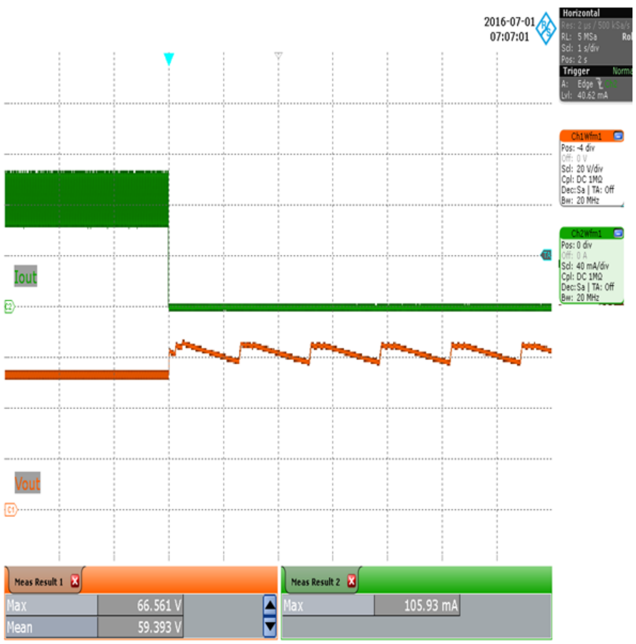

Figure 52 – 115 VAC, 52 V LED Load, Running then Open Load.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 20 V / div., 1 s / div.
$V_{OUT(MAX)}$: 66.561 V.
$V_{OUT(MEAN)}$: 59.393 V.

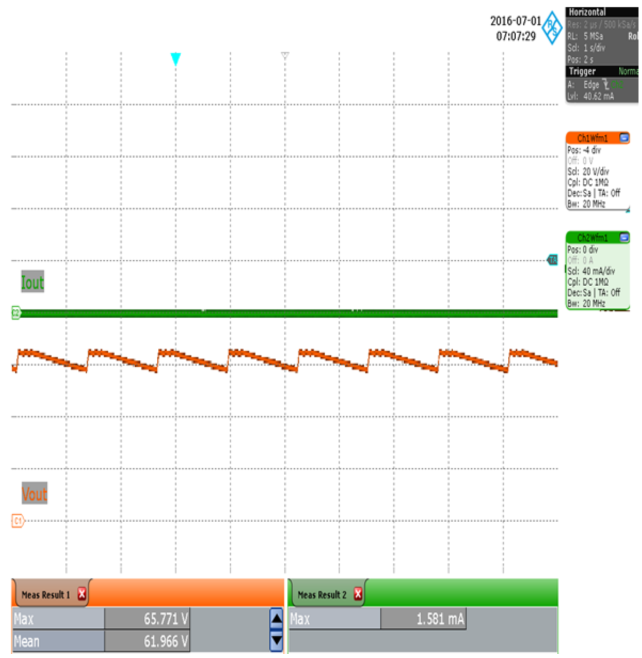

Figure 53 – 115 VAC, 52 V LED Load, Running then Open Load.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 20 V / div., 1 s / div.
$V_{OUT(MAX)}$: 65.771 V.
$V_{OUT(MEAN)}$: 61.966 V.

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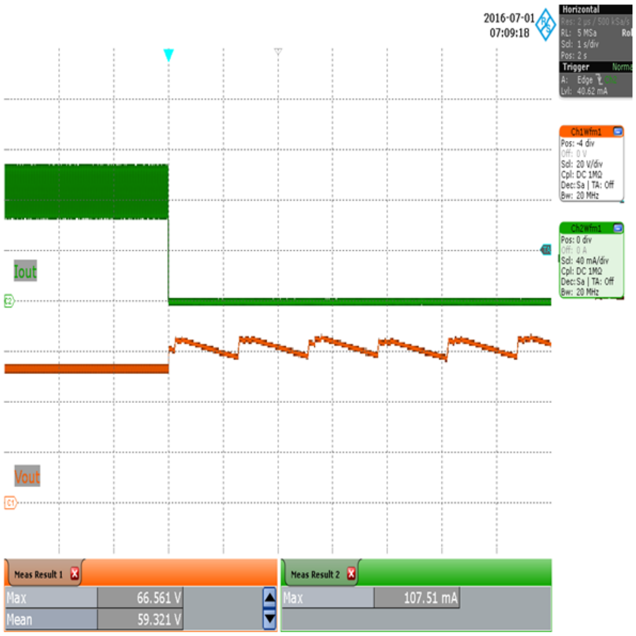

Figure 54 – 132 VAC, 52 V LED Load,
Running then Open Load.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 20 V / div., 1 s / div.
$V_{OUT(MAX)}$: 66.561 V.
$V_{OUT(MEAN)}$: 59.321 V.

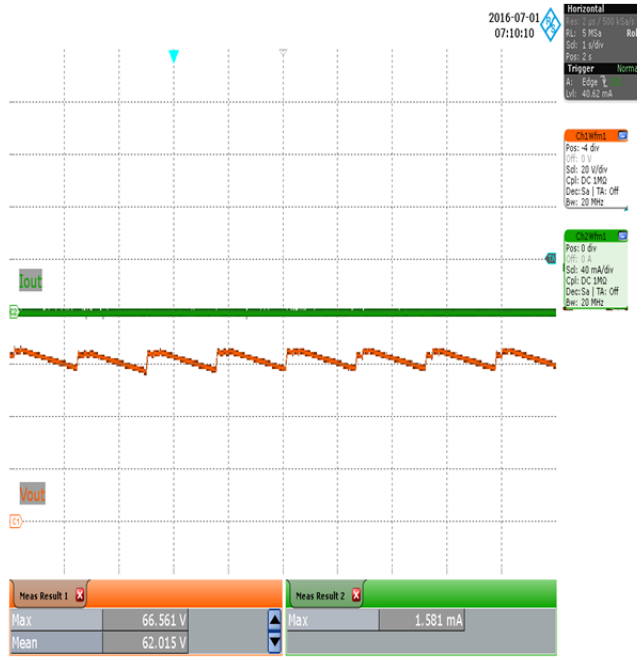

Figure 55 – 132 VAC, 52 V LED Load,
Open Load – Steady-State.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 20 V / div., 1 s / div.
$V_{OUT(MAX)}$: 66.561 V.
$V_{OUT(MEAN)}$: 61.015 V.

12.9 Output Ripple Current

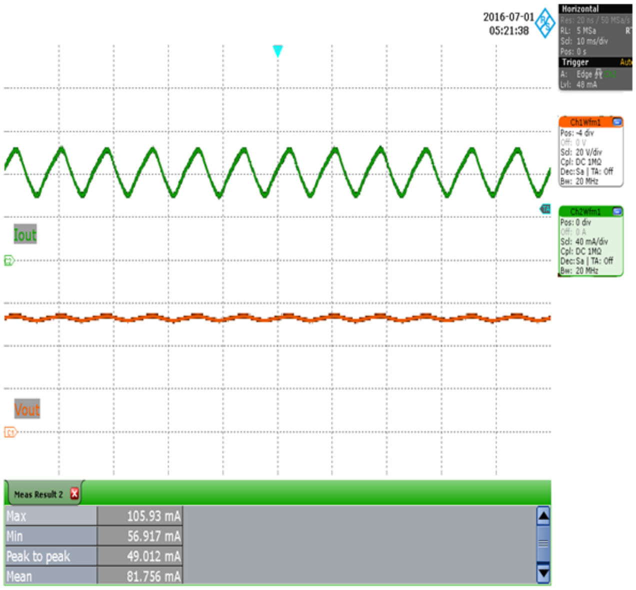

Figure 56 – 90 VAC, 60 Hz, 52 V LED Load.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 20V / div., 10 ms / div.

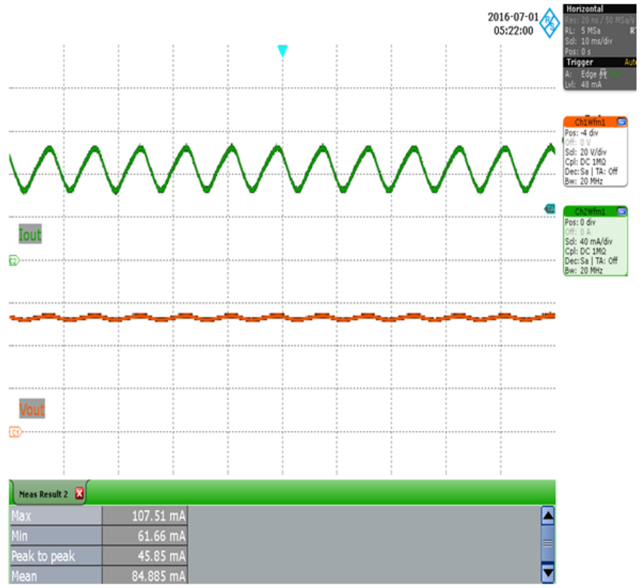

Figure 57 – 115 VAC, 60 Hz, 52 V LED Load.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 20V / div., 10 ms / div.

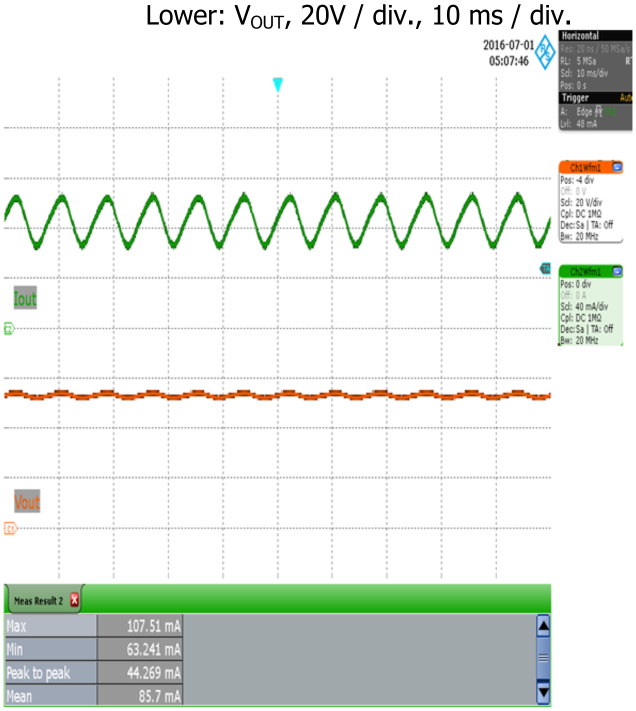

Figure 58 – 132 VAC 60 Hz, 52 V LED Load.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{OUT}, 20V / div., 10 ms / div.

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V_{IN} (VAC)	$I_{O(MAX)}$ (mA)	$I_{O(MIN)}$ (mA)	I_{MEAN} (mA)	Ripple Ratio (I_{RP-P}/I_{MEAN})	% Flicker 100 x (I_{RP-P} / $I_{O(MAX)}+I_{O(MIN)}$)
90	105.93	56.92	81.76	0.60	30.10
115	107.51	61.66	84.89	0.54	27.10
132	107.51	63.24	85.7	0.52	25.93

13 AC Cycling Test

13.1 AC Cycling, Room Temperature (≈25 ºC)

Maximum 16.67% output current overshoot (based on peak current) was observed during ON - OFF cycling at room temperature. The output current recovers immediately after the ON - OFF cycle.

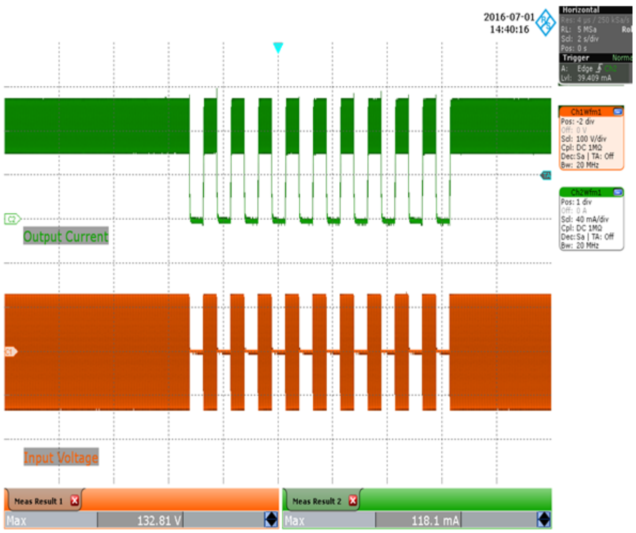

Figure 59 – 90 VAC, 52 V LED Load.
500 ms On – 500 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

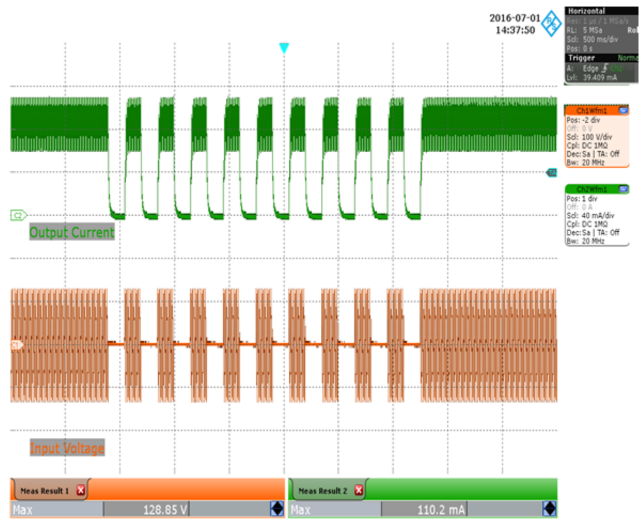

Figure 60 – 90 VAC, 52 V LED Load.
150 ms On – 150 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 500 ms / div.

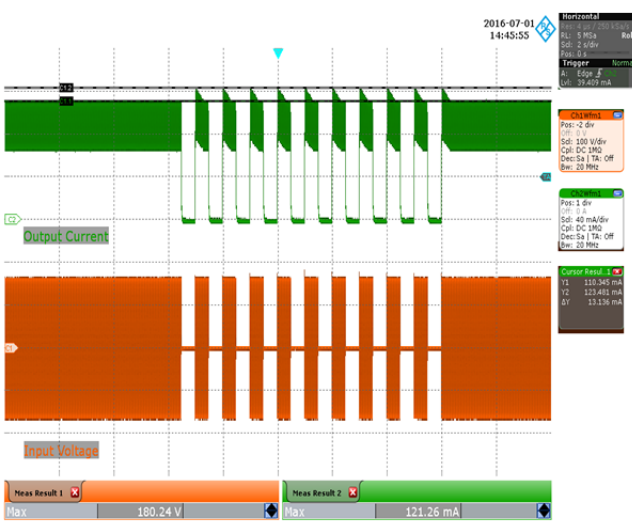

Figure 61 – 115 VAC, 52 V LED Load.
500 ms On – 500 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

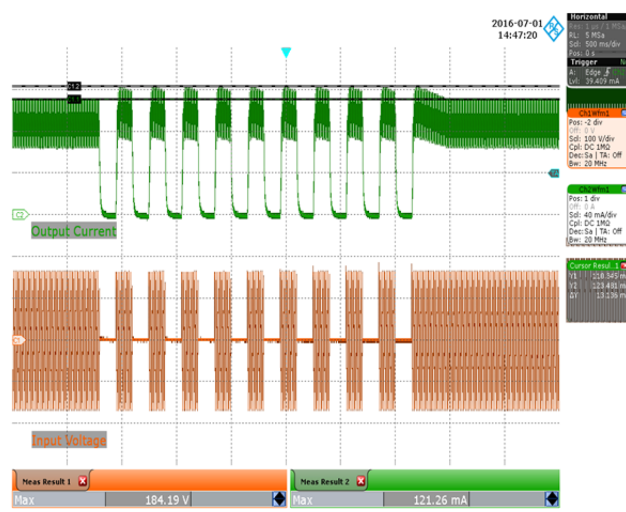

Figure 62 – 115 VAC, 52 V LED Load.
150 ms On – 150 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 500 ms / div.

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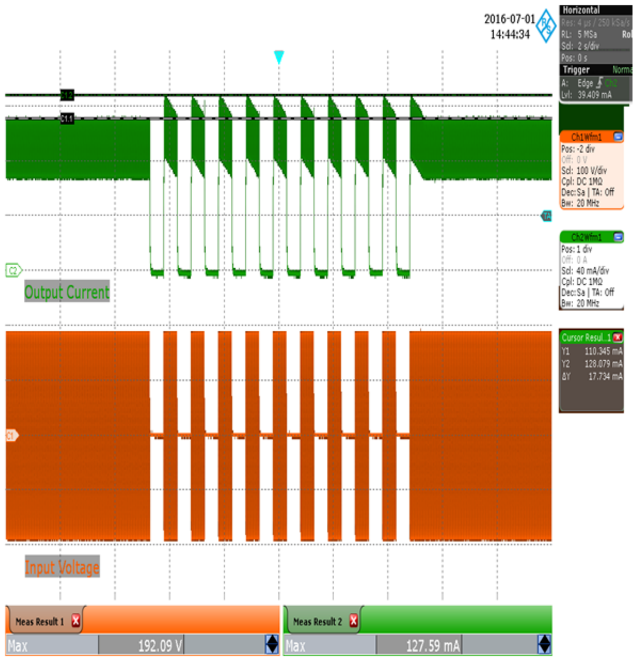

Figure 63 – 132 VAC, 52 V LED Load.
500 ms On – 500 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

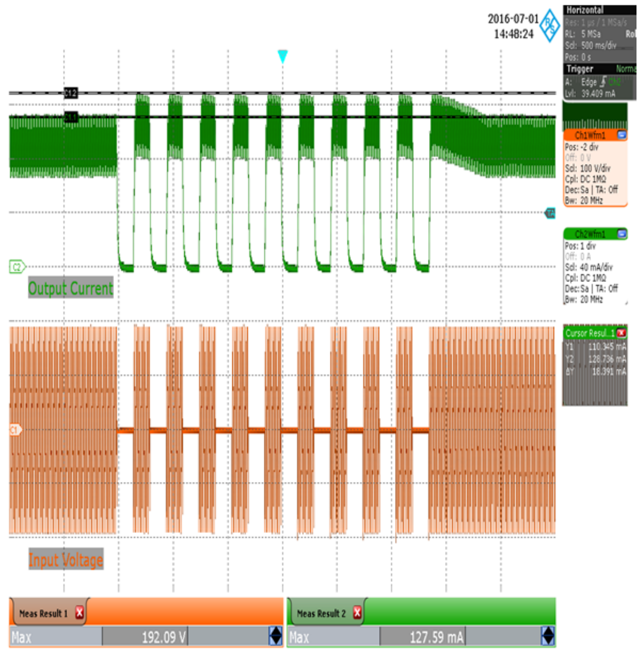

Figure 64 – 132 VAC, 52 V LED Load.
150 ms On – 150 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 500 ms / div.

14 Conducted EMI

14.1 Test Set-up

14.1.1 Equipment and Load Used

1. Rohde and Schwarz ENV216 two line V-network.
2. Rohde and Schwarz ESRP EMI test receiver.
3. Hioki 3322 power hitester.
4. Chroma measurement test fixture, model A662003.
5. 52 V LED load with input voltage set at 115 VAC.

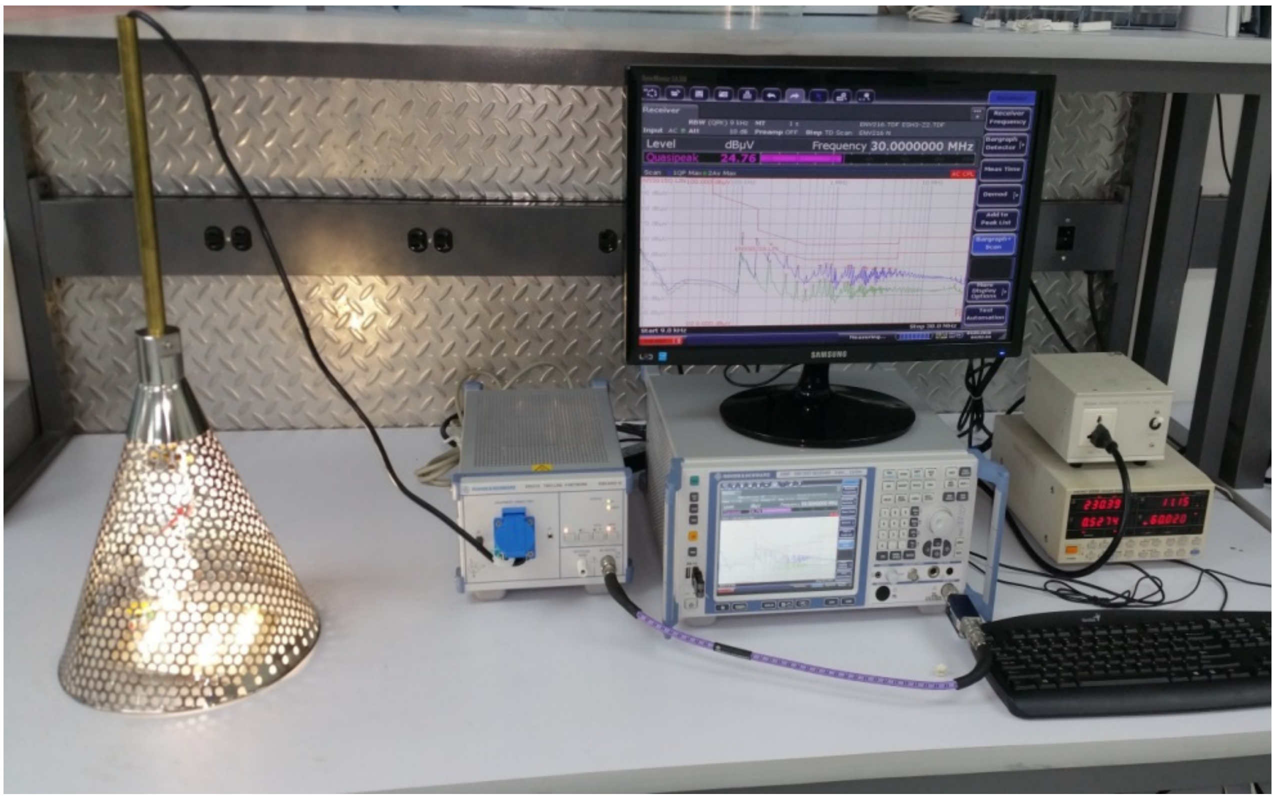

Figure 65 – Conducted EMI Test Set-up.

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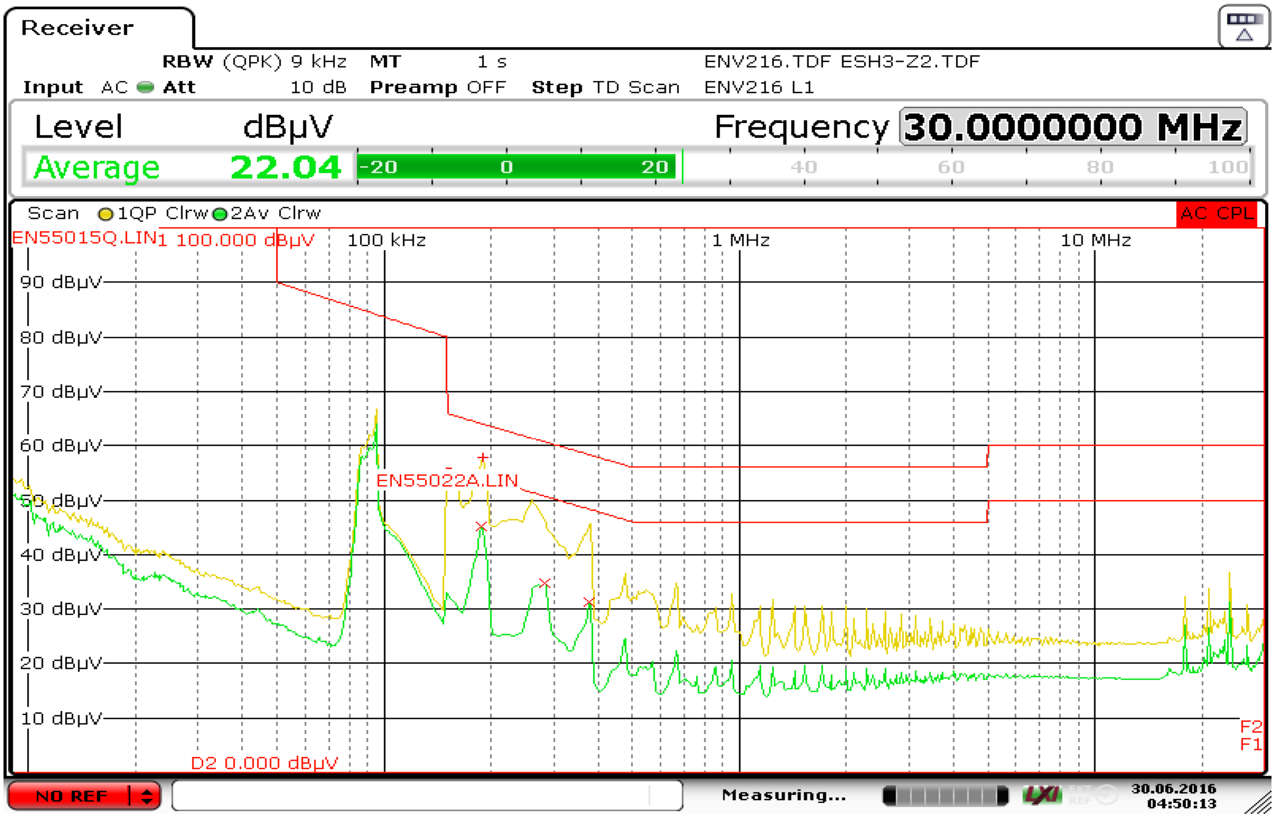
14.2 EMI Test Result



Date: 30.JUN.2016 04:50:13

Figure 66 – Conducted EMI, 52 V LED Load with Metal Cone Enclosure Grounded, 115 VAC, 60 Hz, and EN55015 B Limits.

Trace1: EN55015Q.LIN Trace2: EN55022A.LIN

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	150.0000 kHz	55.05 L1	-10.95 dB
2 Average	188.2500 kHz	45.07 L1	-9.04 dB
1 Quasi Peak	190.5000 kHz	57.70 L1	-6.31 dB
2 Average	282.7500 kHz	34.81 L1	-15.92 dB
2 Average	379.5000 kHz	31.34 L1	-16.95 dB

Figure 67 – Conducted EMI, 52 V LED Load with Metal Cone Enclosure Grounded, Final Measurement Results.

15 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

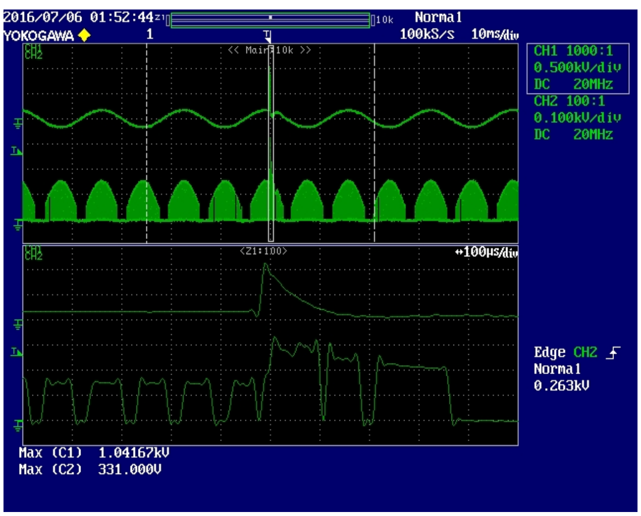


Figure 68 – +1000 kV Differential Surge, 90º Phase.

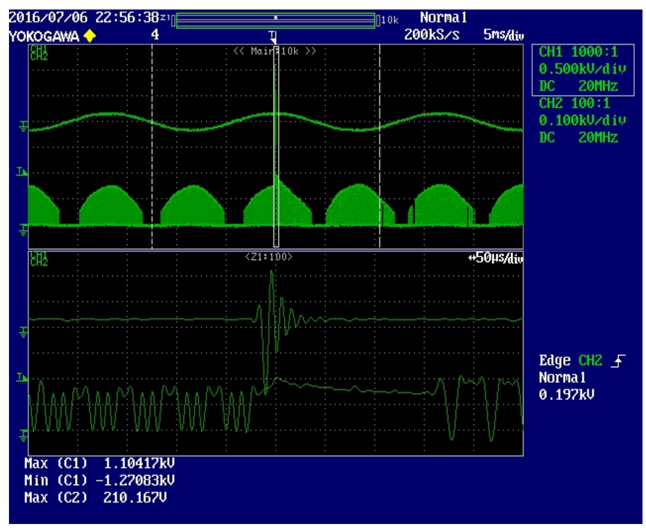


Figure 69 – +2500 kV Ring Wave, 90º Phase.

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16 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.

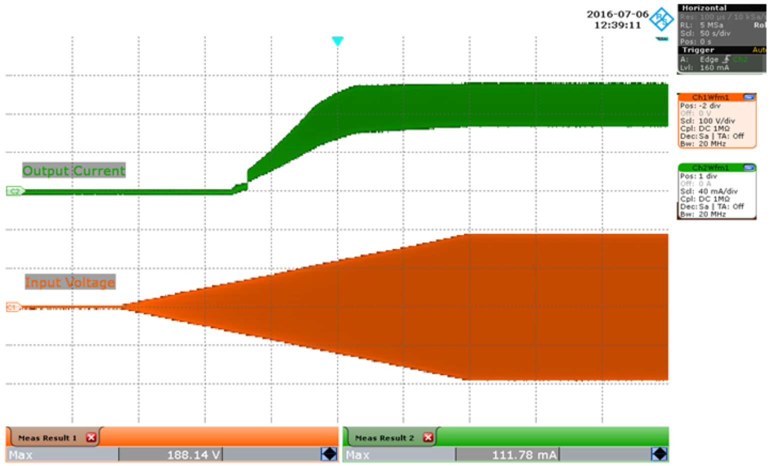

Figure 70 – Brown-in Test at 0.5 V / s.
The Unit is Able to Operate Normally Without Any Failure
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

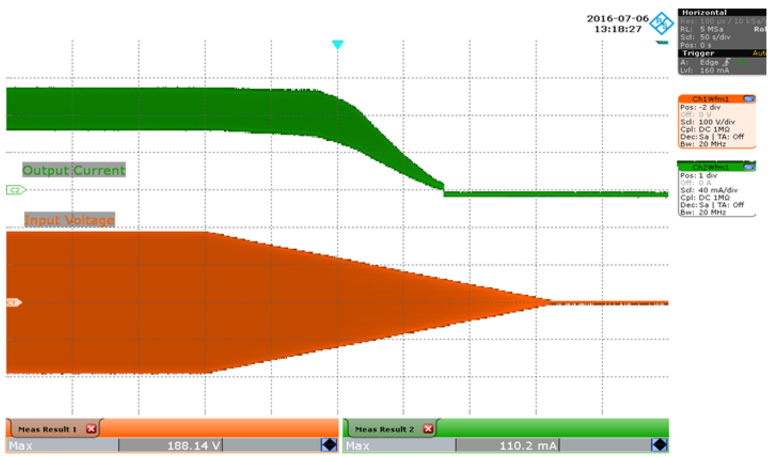

Figure 71 – Brown-out Test at 0.5 V / s.
The Unit is Able to Operate Normally Without Any Failure.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

17 Revision History

Date	Author	Revision	Description and Changes	Reviewed
19-Jul-16	EDdL	1.0	Initial release.	Apps & Mktg
16-Aug-16	EDdL	1.1	Updated RF1 and R2 Values.	

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