Design Example Report

Title	***7.5 W TRIAC Dimmable High Efficiency Power Factor Corrected Non-Isolated Buck LED Driver Using LYTSwitch™-7 LYT7503D***
Specification	180 VAC – 265 VAC Input; 50 V, 150 mA Output
Application	A19 Dimmable LED Bulb
Author	Applications Engineering Department
Document Number	DER-558
Date	June 24, 2016
Revision	1.0

Summary and Features

- Single-stage power factor corrected, PF >0.87
- 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

Power Integrations
5245 Hellyer Avenue, San Jose, CA 95138 USA.
Tel: +1 408 414 9200   Fax: +1 408 414 9201
www.power.com

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.

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

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 50 V at 150 mA from an input voltage range of 180 VAC to 265 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 tight 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-558 is a single stage 7.5 W TRIAC dimmable LED driver with constant current output. The key design goals were design simplicity, high efficiency, low component count, accurate constant current regulation, compact PCB and acceptable dimming compatibility. The design is intended for A19 Dimmable LED Bulb applications.

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

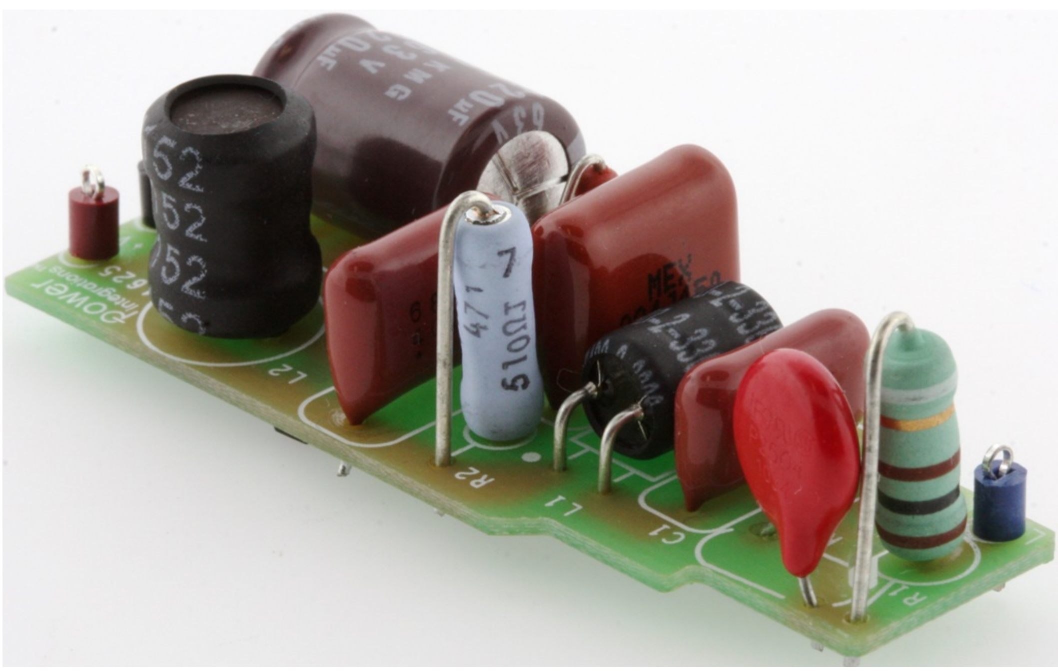


Figure 1 – Populated Circuit Board.

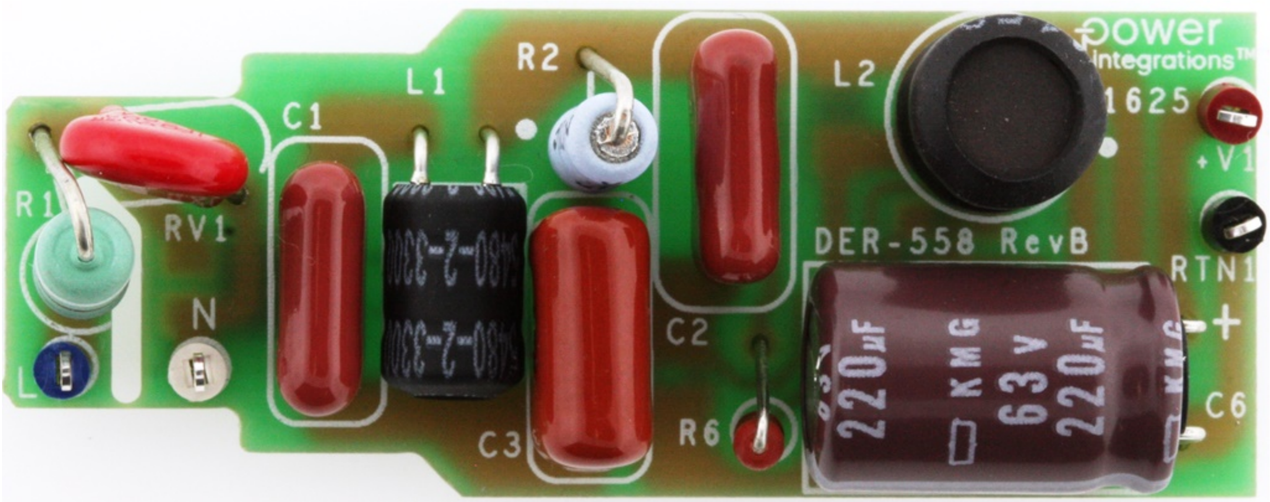


Figure 2 – Populated Circuit Board, Top View.

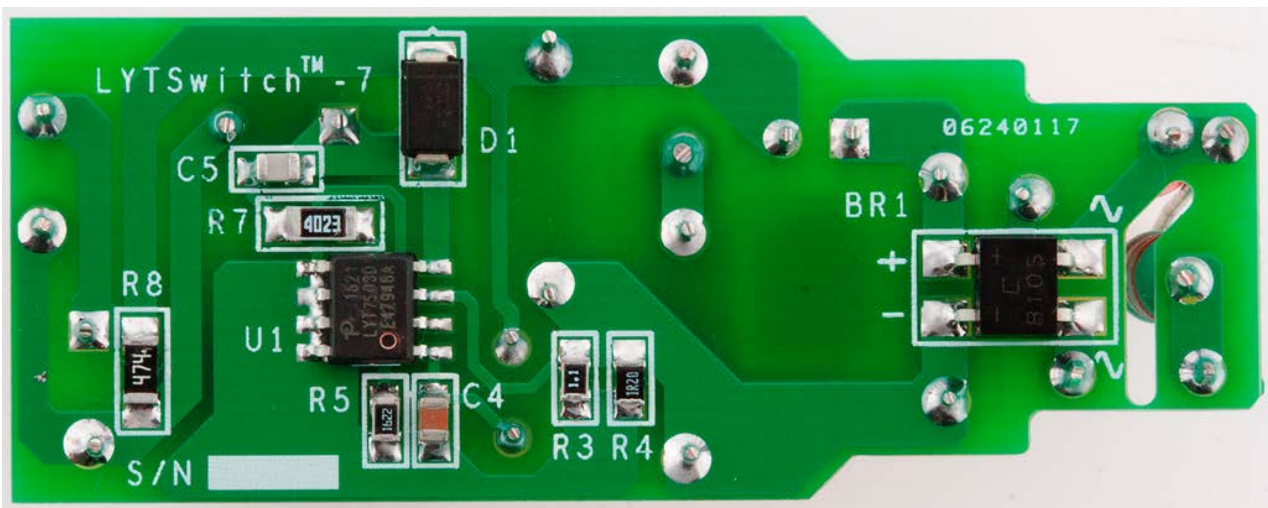


Figure 3 – Populated Circuit Board, Bottom View.

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

2 Power Supply Specification

The table below represents the minimum acceptable performance of the design. Actual performance is listed in the results section.

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	180	230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}		50		Hz	
Output						
Output Voltage	V_{OUT}		50		V	
Output Current	I_{OUT}		150		mA	
Total Output Power						
Continuous Output Power	P_{OUT}		7.5		W	
Efficiency						
Full Load	η		85.26		%	Measured at 230 VAC, 25 ºC.
Environmental						
Conducted EMI		CISPR 15B / EN55015B				
Safety		Isolated				
Ring Wave (100 kHz)			2.5		kV	
Differential Mode (L1-L2)			1.0		kV	
Power Factor			0.871			Measured at 230 VAC, 50 Hz.
Ambient Temperature	T_{AMB}		75		ºC	Free Convection, Sea Level.

3 Schematic

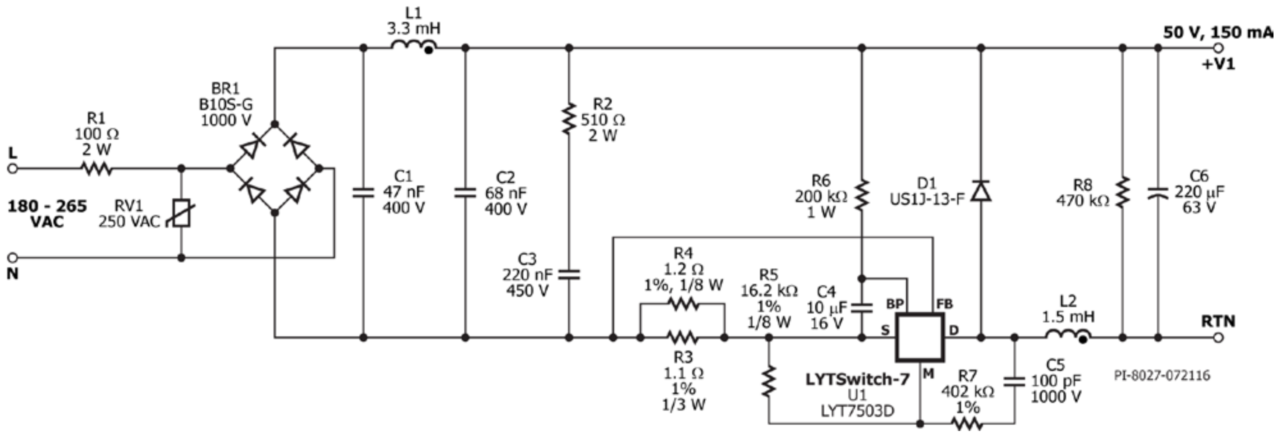


Figure 4 – Schematic.

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

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 50 V LED string, TRIAC dimmable, non-isolated buck LED driver with 150 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 R1 provides safety protection against component failures that would lead to very high input current. Varistor RV1 provides clamping during differential line surge events to limit the maximum voltage spike across the primary. The maximum clamping voltage of RV1 must be lower than the Drain-to-Source Breakdown Voltage of the internal 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 R1 damps the resonance of L1 to make it more effective in blocking high frequency noise. 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.

It is also important to note that the orientation of the EMI inductor L1 and the buck inductor L2 affects EMI. Notice the phase dots of L1 and L2 on the schematic diagram – the dot indicates the “start” of the winding while the non-dotted side is the “finish”. Based on EMI testing done for DER-558, the best orientation is that the “start” of inductor L1 must be connected to C2 (positive VOUT, +V1) while the “start” of L2 must be connected to R8 (negative VOUT, RTN).

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 R8 serves as a pre-load.

Capacitor C4 provides local decoupling for the BYPASS (BP) pin of U1, which provides power to the IC during the switch ON time. The IC internal regulator draws power from high-voltage DRAIN (D) pin and charge the bypass capacitor C4 during the power switch off time. The typical BP pin voltage is 5.22 V. To keep the IC operating normally especially during the dead zone, where $V_{IN} < V_{OUT}$, the value of capacitor should be large enough to keep the BP voltage above the $V_{BP(RESET)}$ reset value of 4.5 V. Additional bias resistor R6 was employed to maintain the BP pin voltage for very fast AC on/off power cycling event and during low conduction angle operation. Recommended minimum value for the BP capacitor is 4.7 μF.

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

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

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}) R3 and R4, and comparing the voltage drop to a fixed internal reference voltage (V_{FB_REF}) of absolute value 280 mV typical. R_{FB} can be calculated as follows:

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

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

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

The MULTIFUNCTION (M) pin monitors the line for any line over voltage 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 R7, thus line over voltage detection is calculated as; where R7 is assumed to be 402 kΩ ±1%.

$$V_{LINE\_OVP} = I_{IOV} \times R7 + V_{OUT}$$

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 R7 and R5. When an output open-load condition occurs, the voltage at the M pin will rise abruptly and when it exceeds the threshold of 2.4 V, the IC will inhibit switching instantaneously and initiate auto-restart to limit the output voltage from further rising. The overvoltage cut-off is typically 120% of the

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

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

Resistor R5 can be calculated as follows;

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

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

4.4 TRIAC Phase Dimming Control

The control mechanism of the LYTSwitch-7 LYT7503D provides inherent dimming capability which makes it suitable to use a simple RC damper (R2 and C3) network for dimming purposes. The power rating of the bleeder 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-558, the required minimum power rating of the bleeder resistor R2 is 2W.

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. Resistor R1 may be trimmed to damp this low frequency input current oscillations and help reduce/minimize flickering or shimmering.

The voltage across C4 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 R6 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 R6 to restrict the charging of BP pin capacitor C4 at low voltage/s where flickering or shimmering occurs (i.e., intentionally turning OFF the IC at low voltage levels where shimmering or flickering is a problem).

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

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

5 PCB Layout

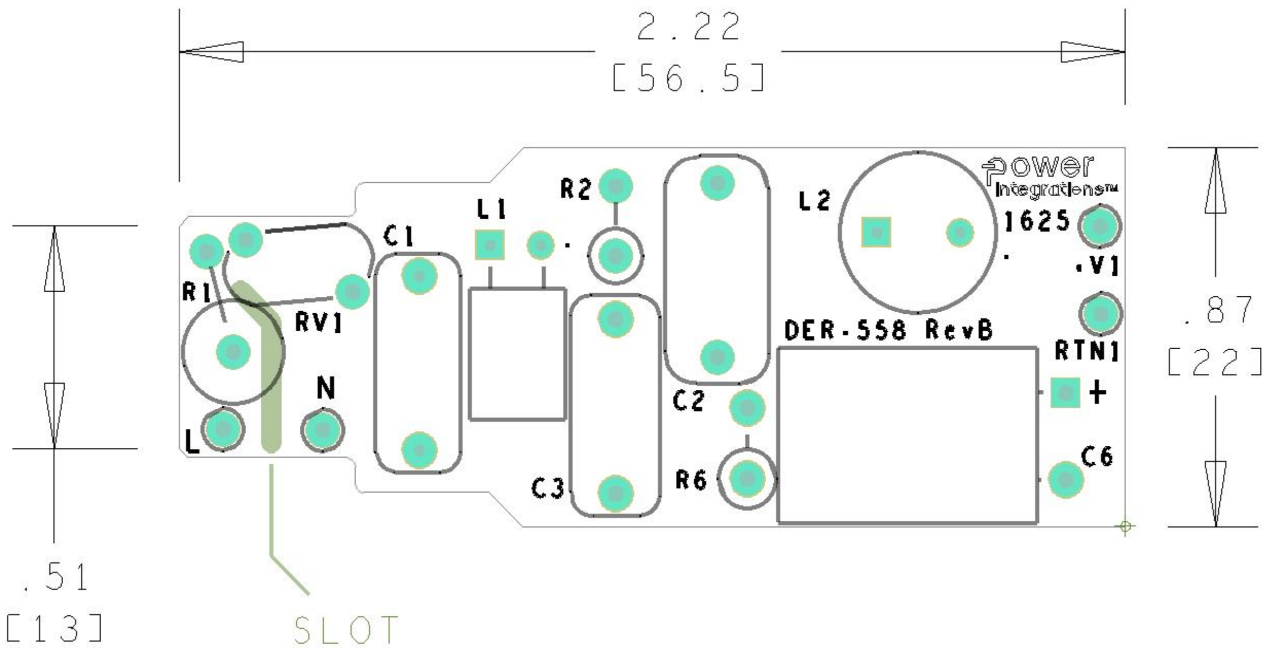


Figure 5 – Top Side.

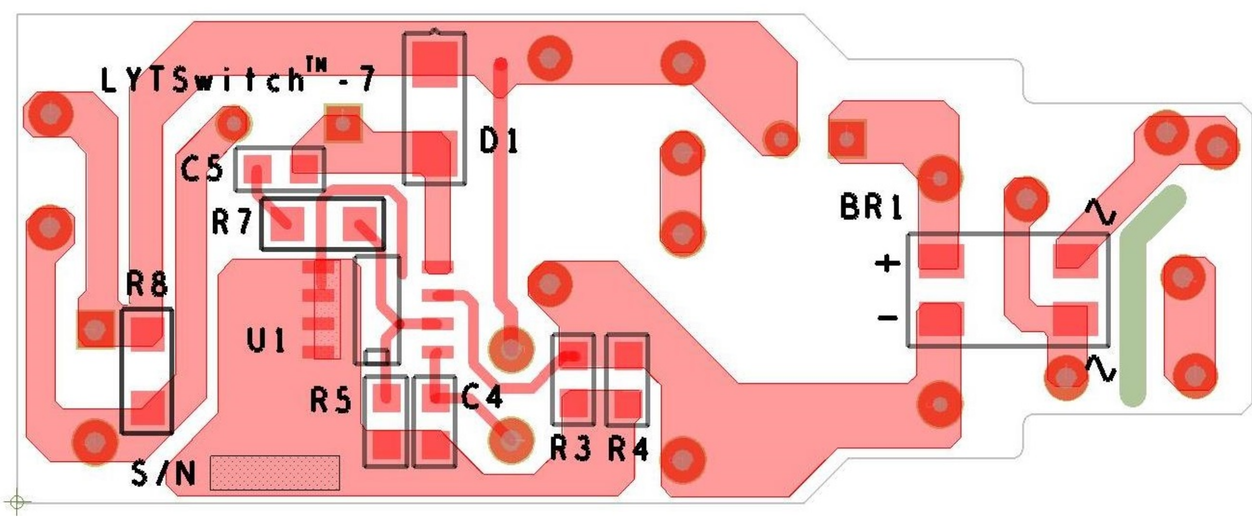


Figure 6 – Bottom Side.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	U1	LYTSwitch-7, Dimmable, SO-8	LYT7503D	Power Integrations
2	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip
3	1	D1	Diode Ultrafast, SW 600 V, 1 A, SMA	US1J-13-F	Diodes, Inc.
4	1	L1	3.3 mH, 0.095 A, 20%	RL-5480-2-3300	Renco
5	1	L2	INDUCTOR, FIXED, 1.5 MH, 430 mA, 3.8 Ω, TH	RLB9012-152KL	Bourns
6	1	C1	47 nF, 400 V, Film	ECQ-E4473KF	Panasonic
7	1	C2	68 nF, 400 V, Film	ECQ-E4683KF	Panasonic
8	1	C3	220 nF, 450 V, Film	MEXXF32204JJ	Duratech
9	1	C4	10 μF, ±10%, 16 V, X7R, Ceramic, -55°C ~ 125°C	CL21B106KOQNNNG	Samsung
10	1	C5	100 pF, 1000 V, Ceramic, NPO, 0805	C0805C101MDGACTU	Kemet
11	1	C6	220 μF, 63 V, Electrolytic, (10 x 16)	EKMG630ELL221MJ16S	United Chemi-con
12	1	R1	RES, 100 Ω, 5%, 2 W, Wirewound, Fusible	FKN2WSJR-73-100R	Yageo
13	1	R2	RES, 510 Ω, 5%, 2 W, Metal Oxide Film	ERG-2SJ511	Panasonic
14	1	R3	RES, SMD, 1.1 Ω, 1%, 1/3W, 0805	ERJ-6BQF1R1V	Panasonic
15	1	R4	RES, SMD, 1.2 Ω, 1%, 1/8W, 0805	CRCW08051R20FKEA	Vishay
16	1	R5	RES, 16.2 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1622V	Panasonic
17	1	R6	RES, 200 kΩ, 5%, 1 W, Metal Film, AXIAL	PR01000102003JR500	Yageo
18	1	R7	RES, 402 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF4023V	Panasonic
19	1	R8	RES, 470 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ474V	Panasonic
20	1	RV1	250 V, 21 J, 7 mm, RADIAL LA	V250LA4P	Littlefuse

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

7 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.

7.1 Efficiency

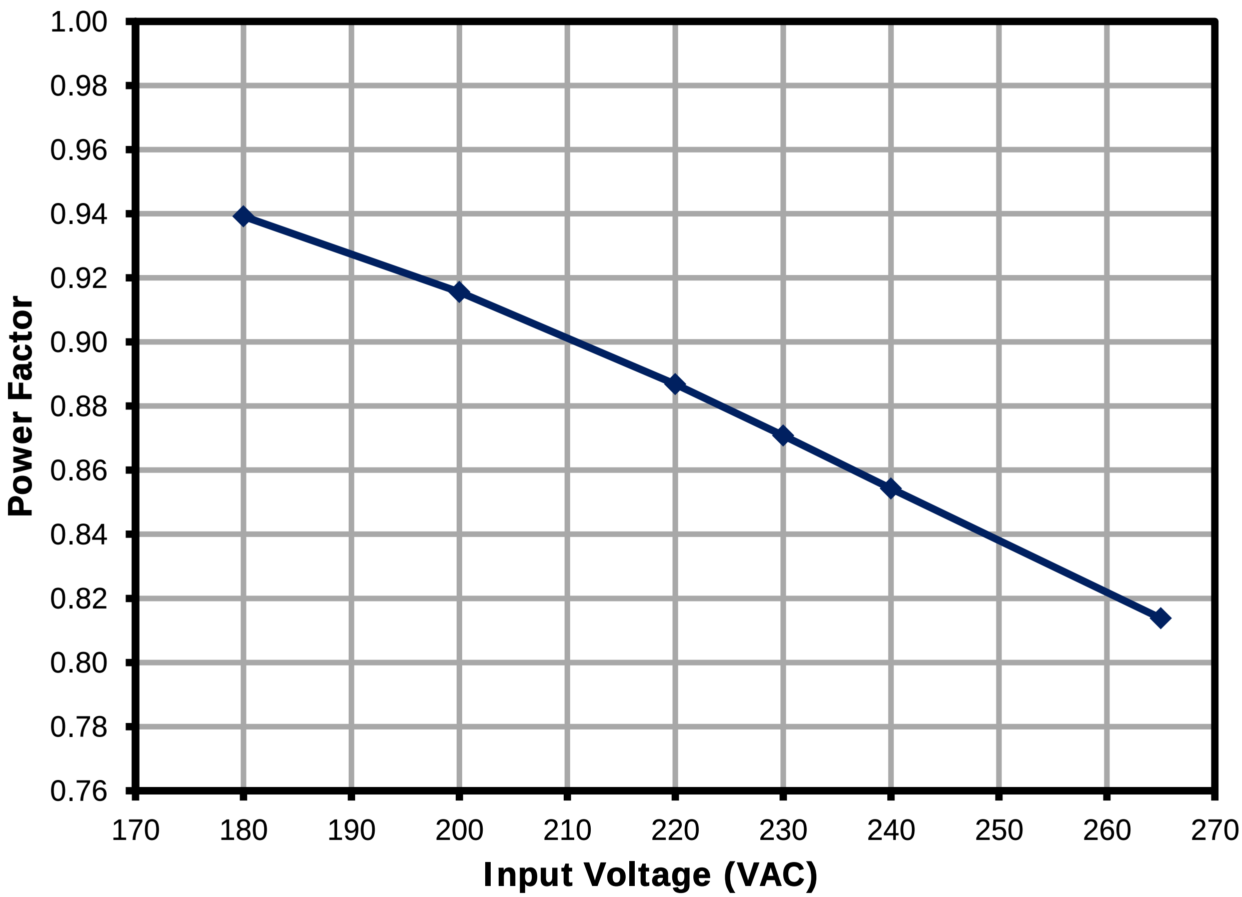


Figure 7 – Efficiency vs. Input Line Voltage.

7.2 Line Regulation

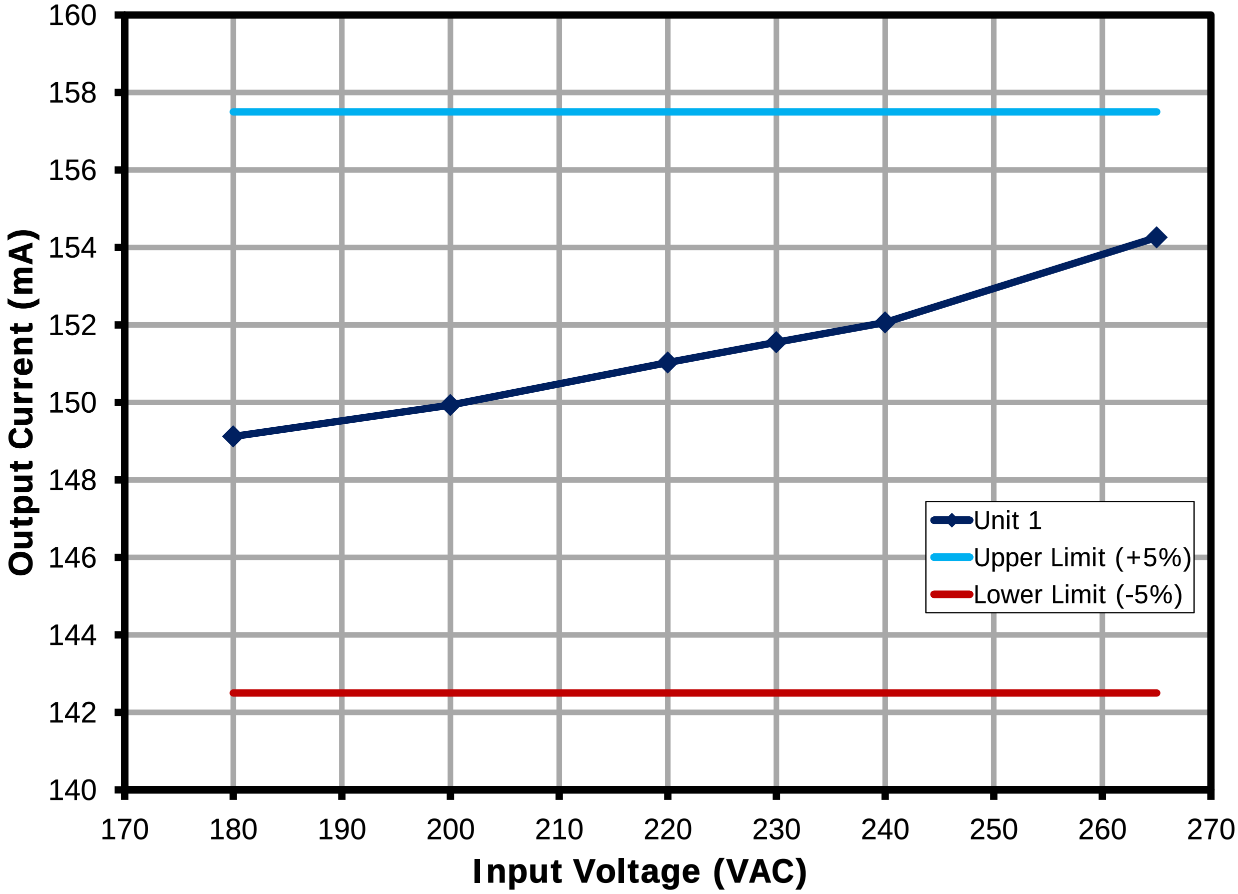


Figure 8 – Output Regulation vs. Input Line Voltage.

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

7.3 Power Factor

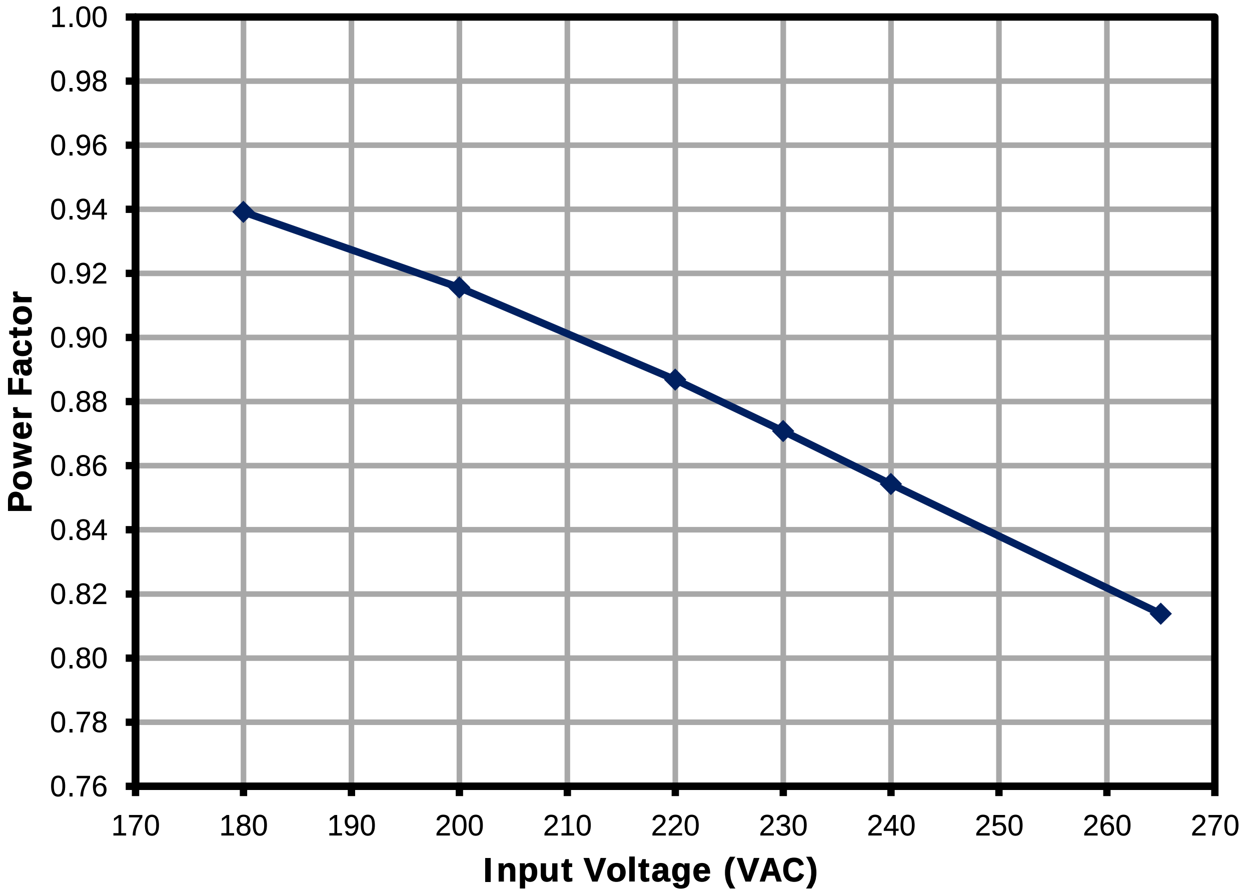


Figure 9 – Power Factor vs. Input Line Voltage.

7.4 %ATHD

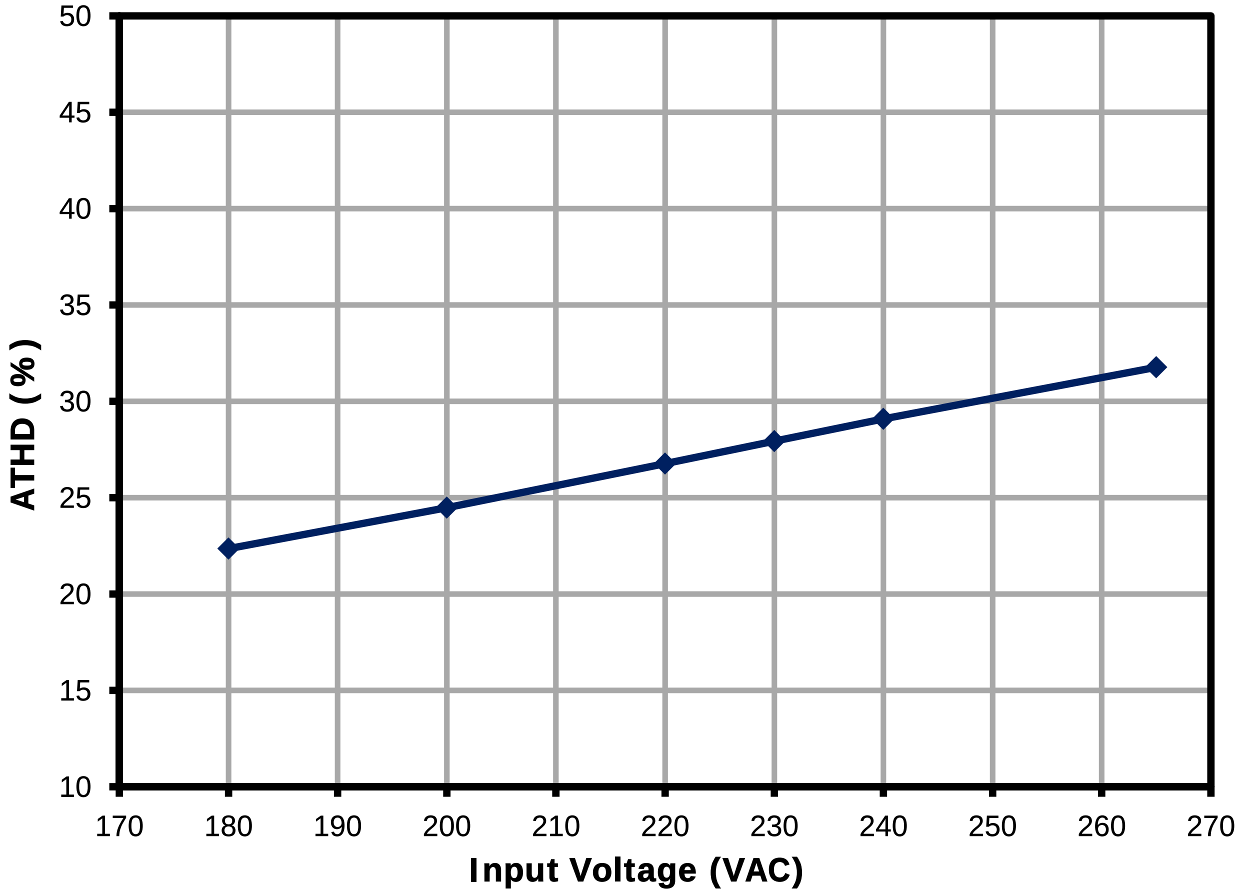


Figure 10 – %ATHD vs. Input Line Voltage

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

7.5 Harmonics

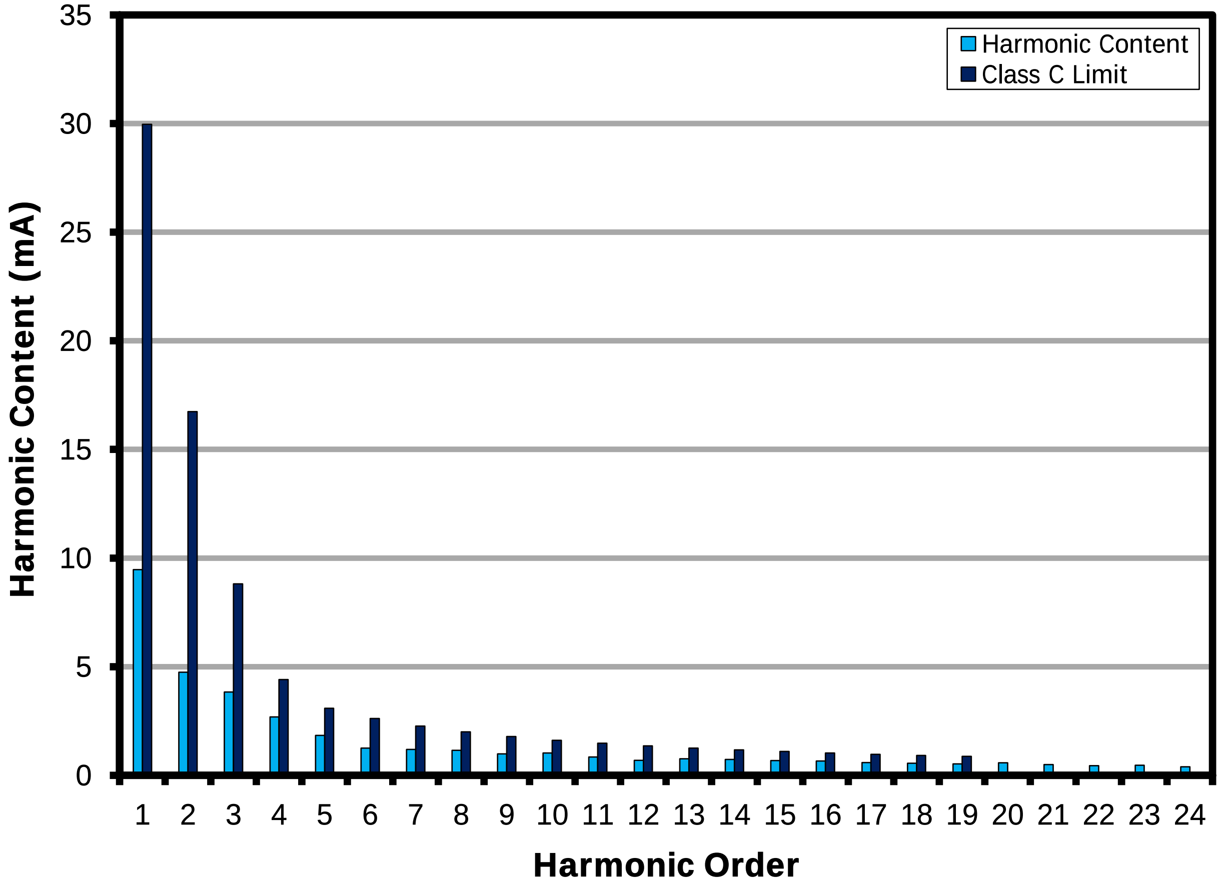


Figure 11 – Input Current Harmonics at 230 VAC, 50 Hz.

8 Test Data

8.1 Test Data, 50 V LED Load

Input		Input Measurement					LED Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
180	50	179.99	50.65	8.56	0.939	22.35	49.53	149.12	7.39	86.36
200	50	199.93	47.15	8.63	0.916	24.48	49.42	149.93	7.42	85.95
220	50	219.96	44.72	8.72	0.887	26.76	49.35	151.03	7.46	85.53
230	50	229.98	43.76	8.76	0.871	27.94	49.26	151.55	7.47	85.26
240	50	240.00	42.99	8.82	0.854	29.08	49.20	152.06	7.49	84.96
265	50	265.02	41.85	9.03	0.814	31.77	49.25	154.26	7.60	84.25

8.2 Harmonic Content at 230 VAC, 50 Hz, 50 V LED Load

V	Freq	I (mA_{RMS})	P	PF	%THD
230	50.00	43.76	8.7640	0.8708	27.937
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**
1	41.97				
2	0.02	0.05%		2.00%	
3	9.47	22.56%	29.9642	28.45%	Pass
5	4.75	11.32%	16.7447	10.00%	Pass
7	3.83	9.13%	8.8130	7.00%	Pass
9	2.69	6.41%	4.4065	5.00%	Pass
11	1.84	4.38%	3.0846	3.00%	Pass
13	1.25	2.98%	2.6100	3.00%	Pass
15	1.19	2.84%	2.2620	3.00%	Pass
17	1.15	2.74%	1.9959	3.00%	Pass
19	0.99	2.36%	1.7858	3.00%	Pass
21	1.03	2.45%	1.6157	3.00%	Pass
23	0.84	2.00%	1.4752	3.00%	Pass
25	0.69	1.64%	1.3572	3.00%	Pass
27	0.76	1.81%	1.2567	3.00%	Pass
29	0.73	1.74%	1.1700	3.00%	Pass
31	0.68	1.62%	1.0945	3.00%	Pass
33	0.66	1.57%	1.0282	3.00%	Pass
35	0.59	1.41%	0.9694	3.00%	Pass
37	0.56	1.33%	0.9170	3.00%	Pass
39	0.53	1.26%	0.8700	3.00%	Pass
41	0.58	1.38%			
43	0.49	1.17%			
45	0.44	1.05%			
47	0.46	1.10%			
49	0.39	0.93%			

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

9 Dimming Performance Data

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

9.1 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.

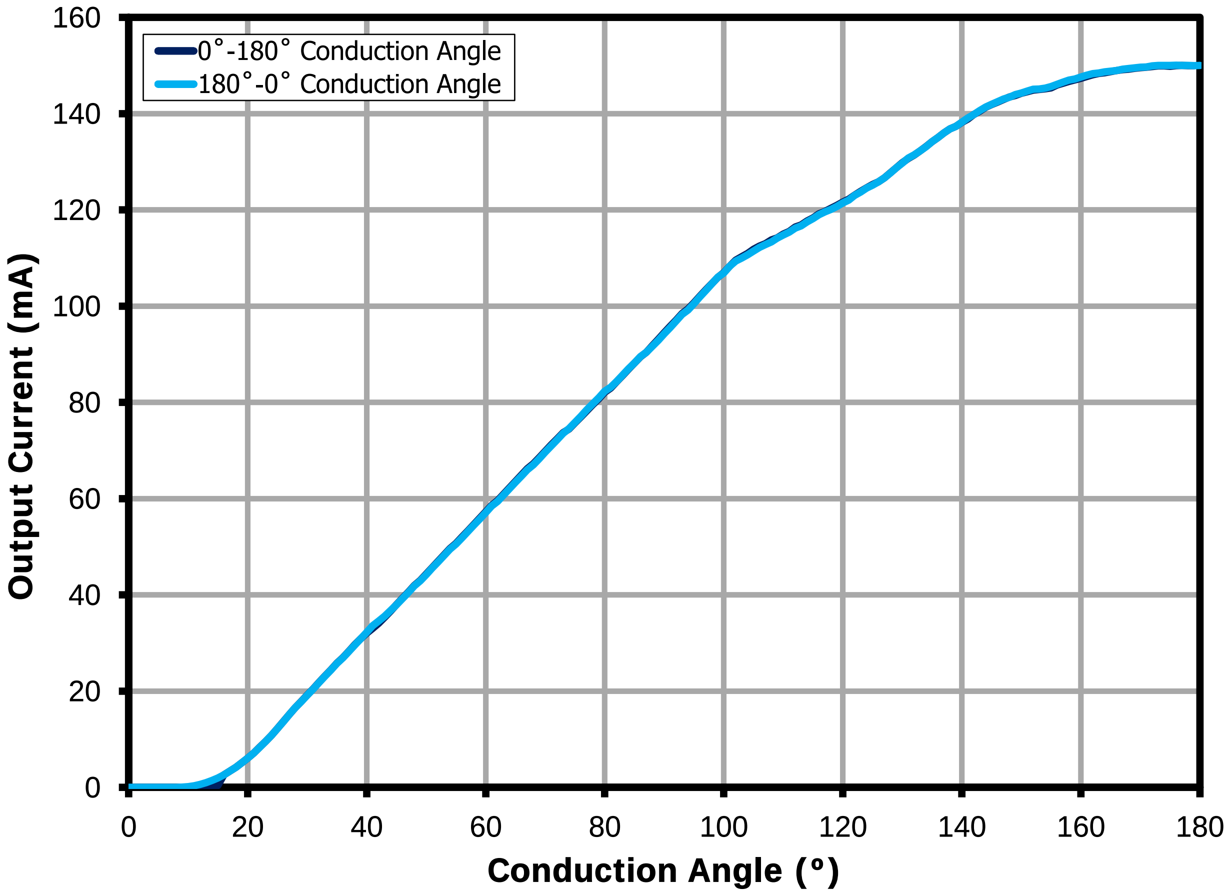


Figure 12 – Dimming Curve at 230 VAC, 50 Hz Input.

9.2 Dimming Efficiency

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

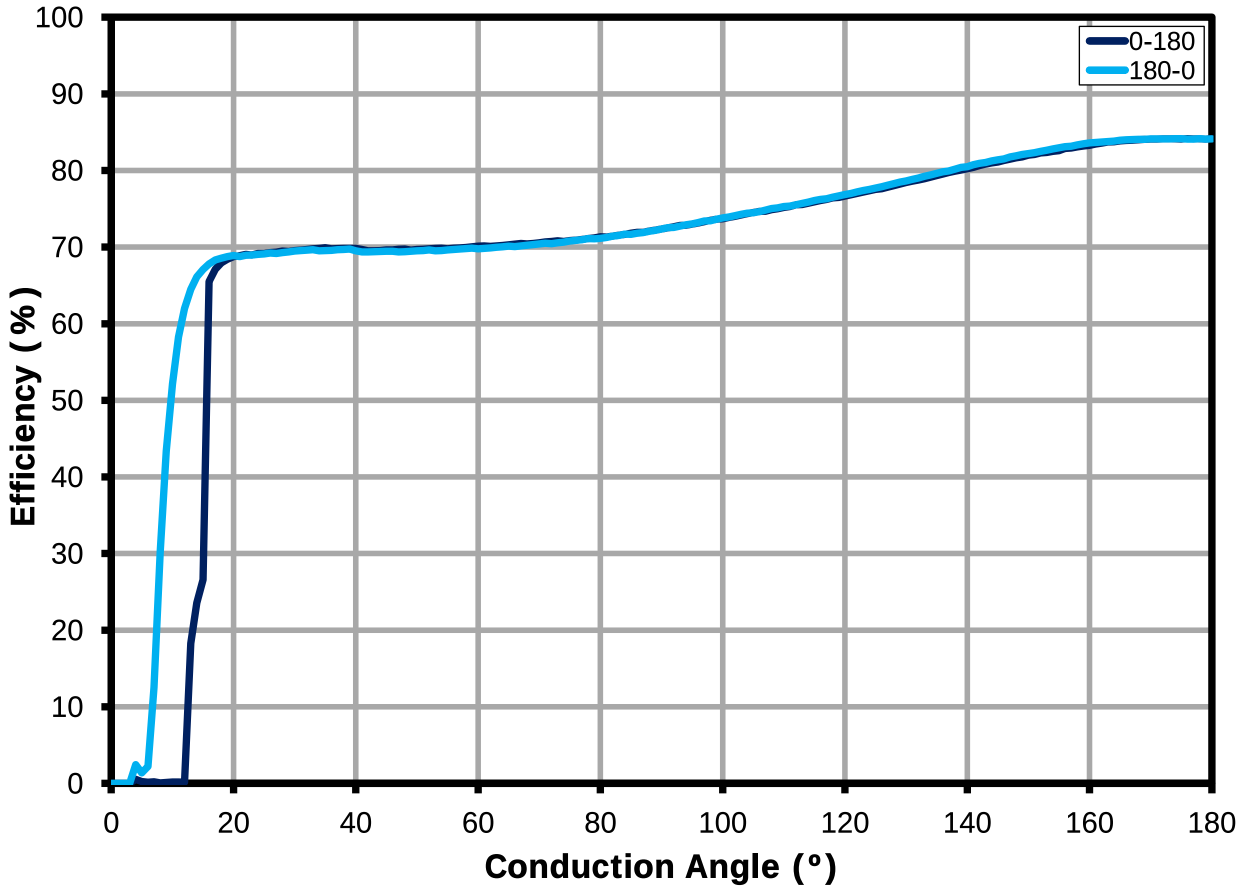


Figure 13 – Dimming Efficiency at 230 VAC, 50 Hz Input.

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

9.3 Driver Power Loss During Dimming

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

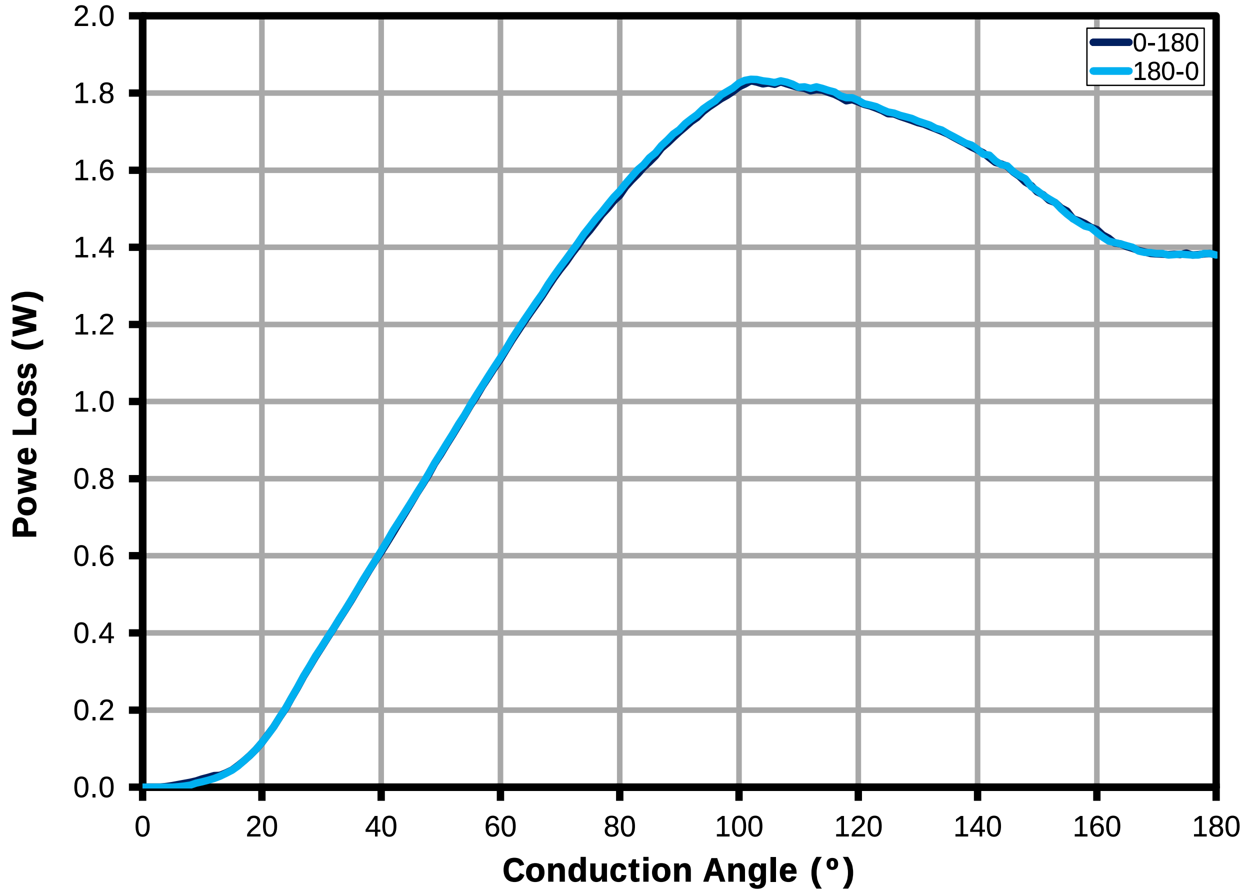


Figure 14 – Dimming Power Loss at 230 VAC, 50 Hz Input.

9.4 Dimmer Compatibility List

The following dimmers were tested at 25 ºC ambient temperature, 50 V LED load with the following AC source:

1. AC Programmable Power Source (Agilent 6812B) set at 230 V, 50 Hz
2. Utility Line Source (≈220 V, 60 Hz)

No.	Panel	Brand	Model	Type	Max (mA)	Min (mA)	Dimming Ratio
1	EU Panel 1	Berker	2875	L	142.03	29.94	5
2	EU Panel 1	Gira	2262 00	L	143.08	16.06	9
3	EU Panel 2	Jung	266 GDE	L	141.58	27.1	5
4	EU Panel 2	Jung	225 NVDE	L	140.39	16.7	8
5	EU Panel 2	Busch	2250 U	L	142.73	20.9	7
6	EU Panel 2	Busch	2247 U	L	141.65	35.4	4
7	PHILS H1	GIRA	0302 00 I01	L	141.6	28.79	5
8	IKEA PANEL	Schneider	ALB4x192	L	142.57	4.344	33
9	IKEA PANEL	EAGLERISE	SED300FHS	L	141.8	22.411	6

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

10 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 (75 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.

10.1 Non-Dimming, at Room Temperature (≈25 ºC)

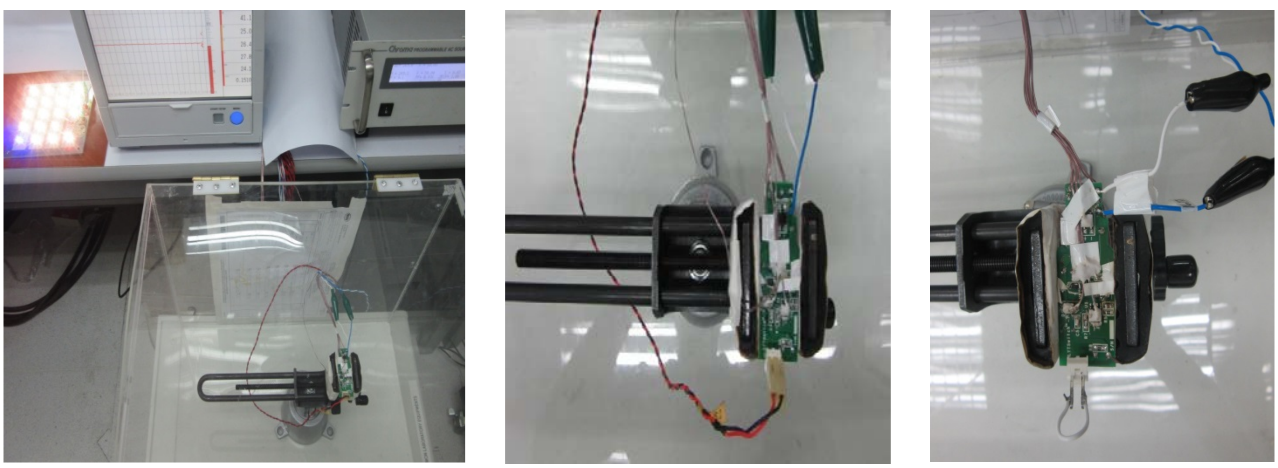
Measurement is done using T-type thermocouple and Yokogawa GP20 data logger. Chroma Programmable AC Source model 61604 is used for the input with the frequency set at 50 Hz. *See Figure 15 for the Thermal Set-up.*

Component		**Thermal Reading (ºC)**		
Part Ref	**Description**	**180 VAC**	**230 VAC**	**265 VAC**
R1	Damper	55.6	50.3	48.4
L1	Input Inductor	45.1	46.3	47.7
R2	Bleeder Resistor	48.8	52.5	55.8
L2	Buck Inductor	54.3	56.3	57.4
R6	Pull-up Resistor	58.2	69.5	79
C6	Output E-Capacitor	48.3	52.2	55.5
D1	Output Diode	51.5	54.2	56.5
U1	LYT7503D	51.9	56.1	59.4
BR1	Bridge Diode	44.7	44.3	44.5
Ambient		30	29.6	29.8
I_{OUT}	Output Current	150.4 mA	149.3 mA	148.4 mA

10.2 Non-Dimming, Output Short-Circuit, at Room Temperature (≈25 °C)

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 50 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**	**180 VAC**	**230 VAC**	**265 VAC**
R1	Damper	28.8	29.2	30
L1	Input Inductor	32.6	34.6	36.7
R2	Bleeder Resistor	34.5	37.1	39.5
L2	Buck Inductor	37.7	39.1	40.8
R6	Pull-up Resistor	57.3	75.6	91
C6	Output E-Capacitor	38.6	44.4	49.5
D1	Output Diode	38.3	40.9	43.8
U1	LYT7503D	39.6	45.3	49.8
BR1	Bridge Diode	30.3	31.7	33.1
Ambient		26.6	26.1	26.8



(a) (b) (c)

Figure 15 – Thermal Set-up. (a) Whole Set-up with the AC Power Source and the unit covered with transparent box to prevent airflow that may affect the measurement. Thermal measurement is done via T-type thermocouple and Yokogawa GP20 data logger. (b) Close-up view of the unit inside the box. (c) The unit with output short-circuited.

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

10.3 Non-Dimming, at 75 °C 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 50Hz. *See Figure 16 for the Thermal Set-up.*

Component		Thermal Reading (°C)		
Part Ref	**Description**	**180 VAC**	**230 VAC**	**265 VAC**
R1	Damper	100.7	95.5	94.4
L1	Input Inductor	90.9	92.1	93.9
R2	Bleeder Resistor	94.6	98.2	101.8
L2	Buck Inductor	100.3	102.6	104.4
R6	Pull-up Resistor	103.5	114.3	123.9
C6	Output E-Capacitor	94.5	97.9	101.5
D1	Output Diode	96.9	100.5	103.3
U1	LYT7503D	98.3	102.1	105.8
BR1	Bridge Diode	90	89.1	89.7
Ambient		76.4	76.6	76.9
I_{OUT}	Output Current	148.8 mA	147.2 mA	146.8 mA

10.4 Dimming, at 75 °C Ambient, 102° Conduction Angle

Measurement is done using T-type thermocouple and Yokogawa GP20 data logger. *See Figure 16 for the Thermal Set-up*. A TRIAC dimmer is used to set the conduction angle at 102° 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: 102°
Part Ref	**Description**	**Thermal Reading (°C)**
R1	Damper	122.3
L1	Input Inductor	106.6
R2	Bleeder Resistor	137.6
L2	Buck Inductor	97.8
R6	Pull-up Resistor	102.3
C6	Output E-Capacitor	92.8
D1	Output Diode	101.8
U1	LYT7503D	97.5
BR1	Bridge Diode	97.9
Ambient		78.6
I_{OUT}	Output Current	82.2 mA

Figure 16 – Thermal Set-up for High Ambient Temperature Measurement. 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.

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

11 Waveforms

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

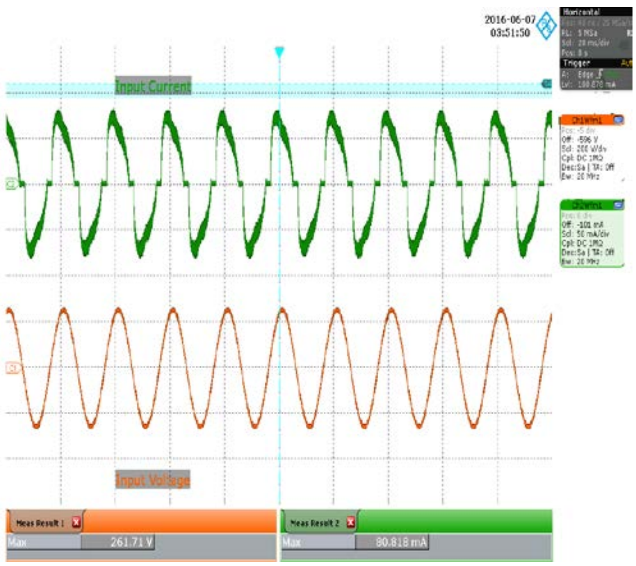


Figure 17 – 180 VAC, 50 V LED Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V / div.
Horizontal: 20 ms / div.

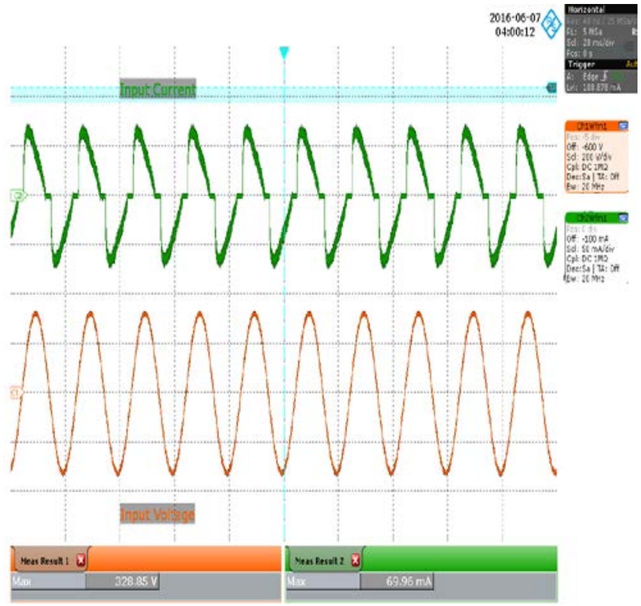


Figure 18 – 230 VAC, 50 V LED Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V / div.
Horizontal: 20 ms / div.

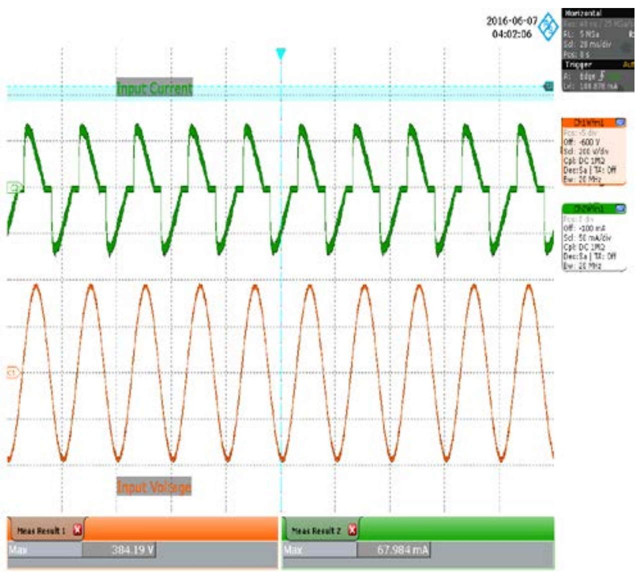


Figure 19 – 265 VAC, 50 V LED Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V / div.
Horizontal: 20 ms / div.

11.2 Input Voltage and Input Current Waveforms while Dimming

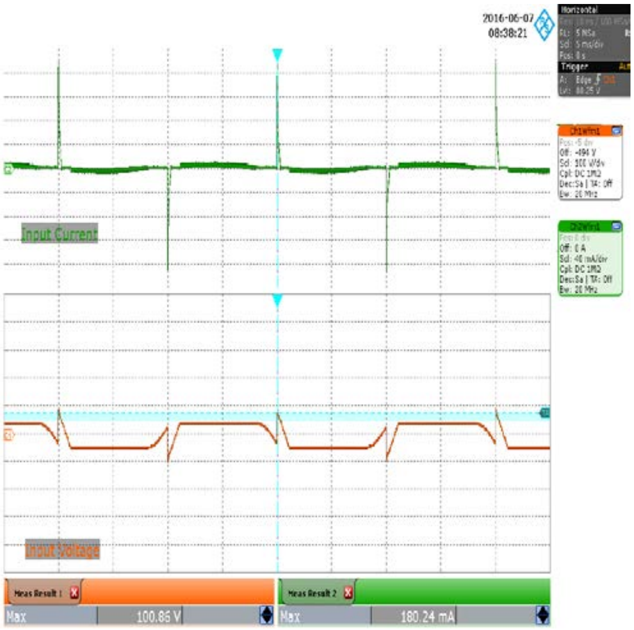


Figure 20 – 230 VAC, 50 V LED Load, Dimming.
Minimum (20º) Conduction Angle.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 5 ms / div.

Figure 21 – 230 VAC, 50 V LED Load, Dimming.
45º Conduction Angle.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 5 ms / div.

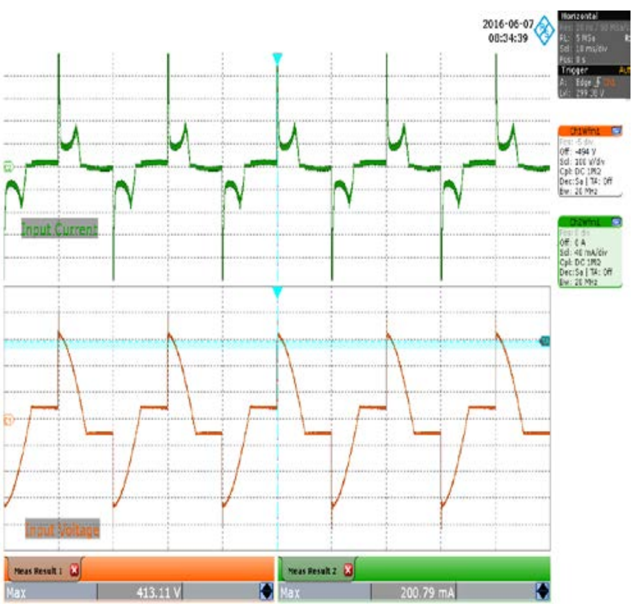


Figure 22 – 230 VAC, 50 V LED Load, Dimming.
90º Conduction Angle
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

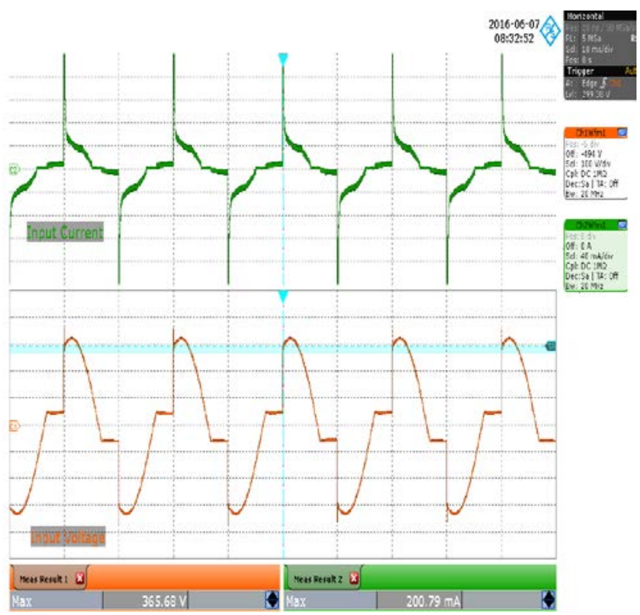


Figure 23 – 230 VAC, 50 V LED Load, Dimming.
120º Conduction Angle.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

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

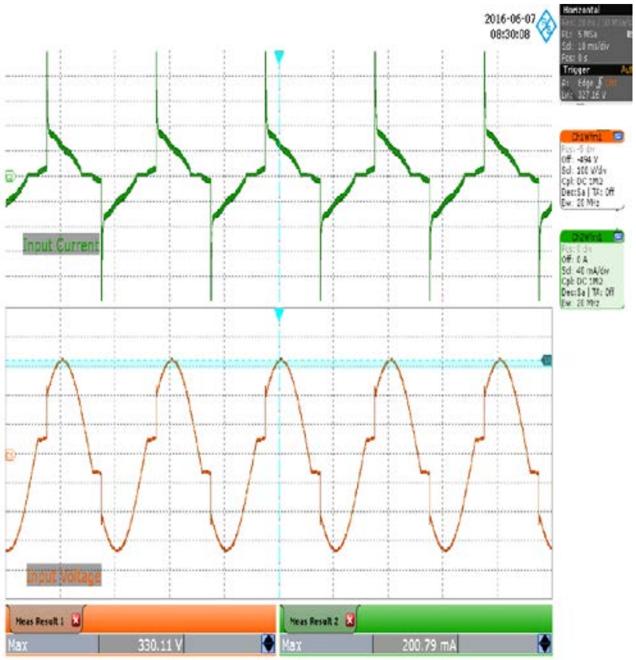


Figure 24 – 230 VAC, 50 V LED Load, Dimming.
Maximum (155º) Conduction Angle.
Upper: I_{IN}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

11.3 Output Current Rise and Fall

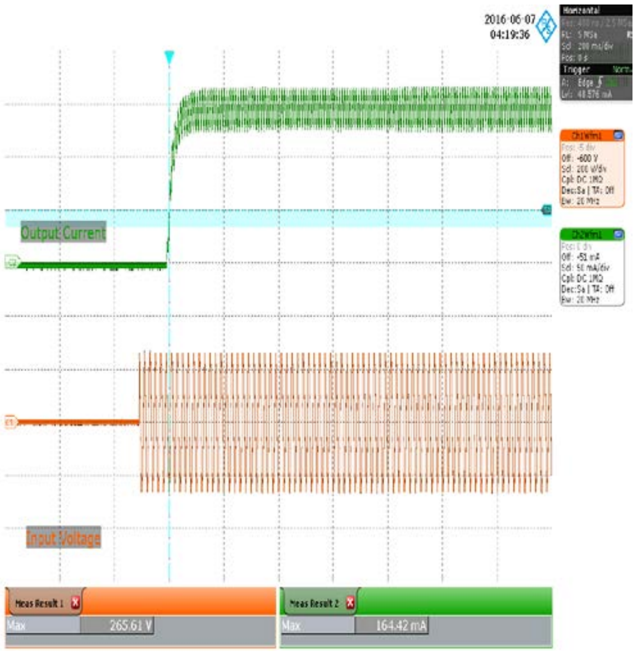


Figure 25 – 180 VAC, 50 V LED Load, Output Rise.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 200 V / div., 200 ms / div.

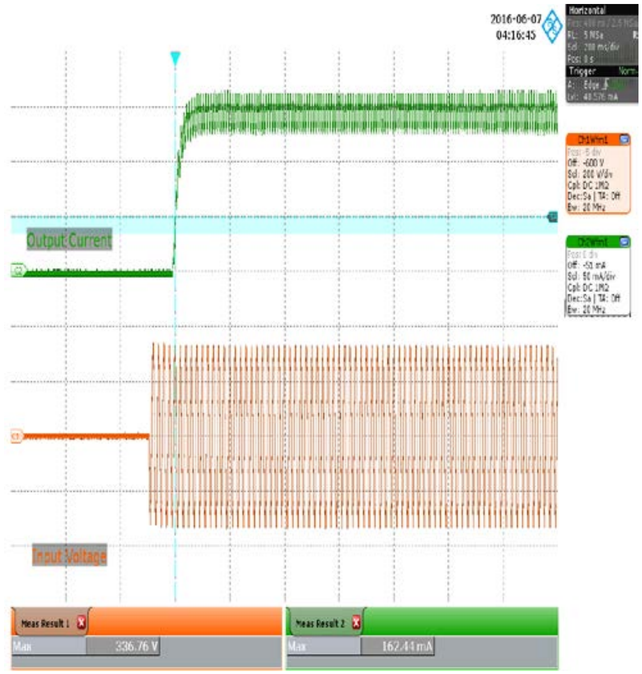


Figure 26 – 230 VAC, 50 V LED Load, Output Rise.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 200 V / div., 200 ms / div.

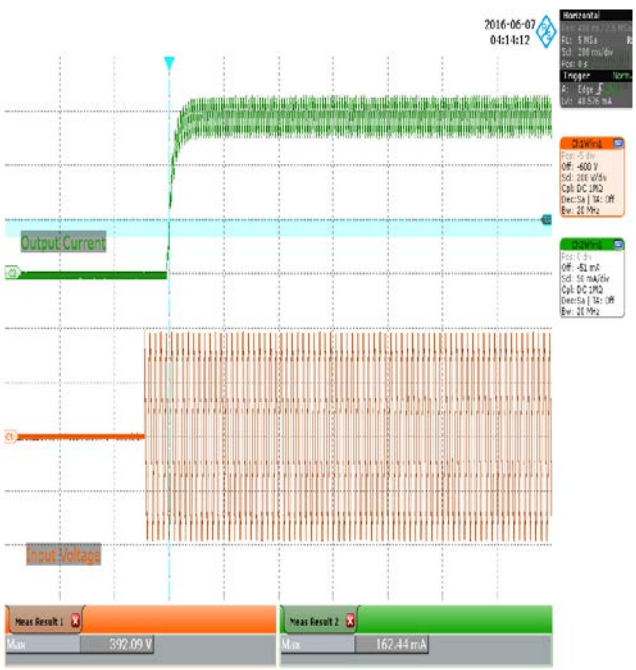


Figure 27 – 265 VAC, 50 V LED Load, Output Rise.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 200 V / div., 200 ms / div.

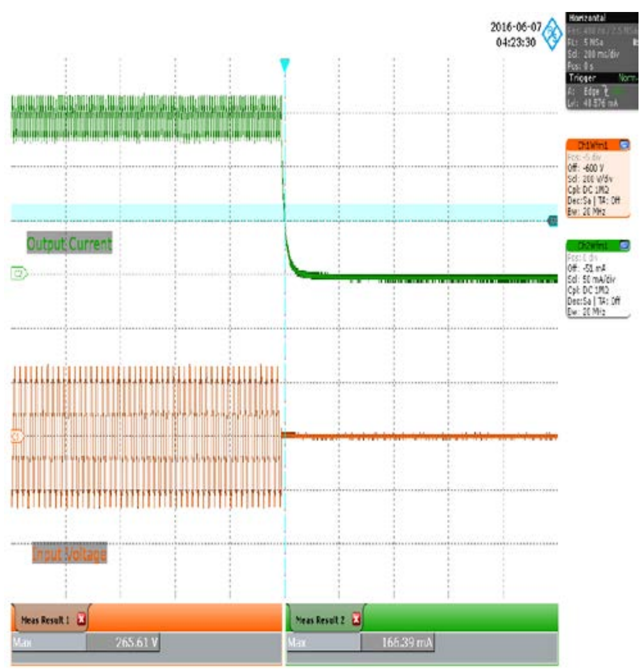


Figure 28 – 180 VAC, 50 V LED Load, Output Fall.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 200 V / div., 200 ms / div.

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

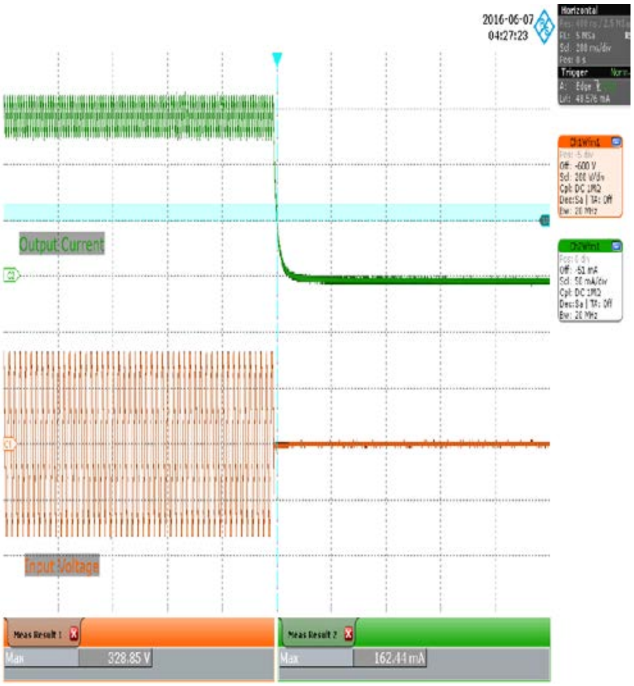


Figure 29 – 230 VAC, 50 V LED Load, Output Fall.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 200 V / div., 200 ms / div.

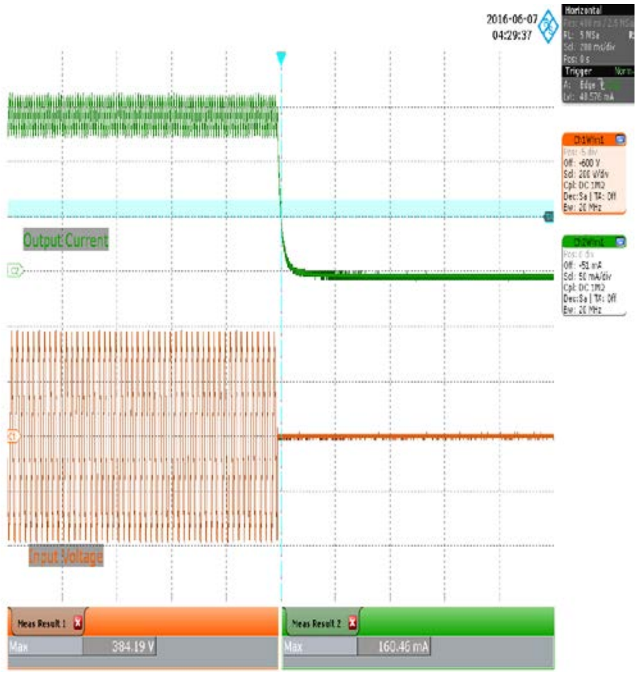


Figure 30 – 265 VAC, 50 V LED Load, Output Fall.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 200 V / div., 200 ms / div.

11.4 Drain Voltage and Current in Normal Operation

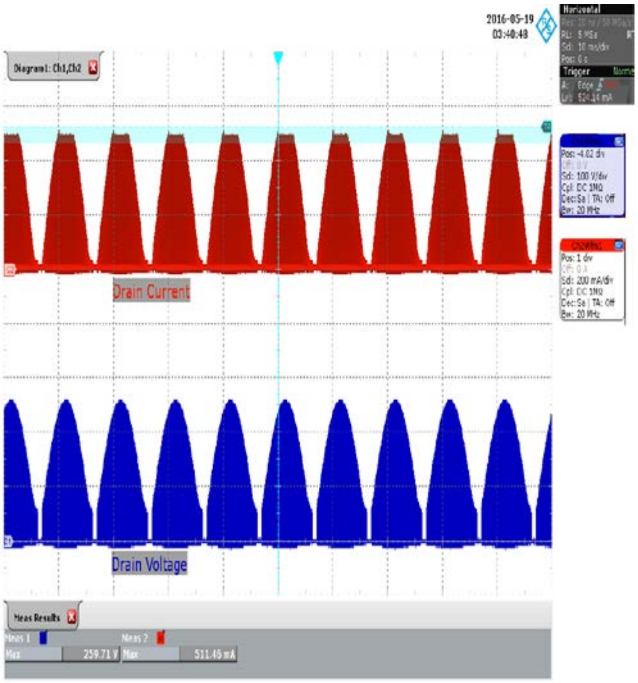


Figure 31 – 180 VAC, 50 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 ms / div.
$V_{DS(MAX)}$: 259.71 V.
$I_{D(MAX)}$: 511.46 mA.

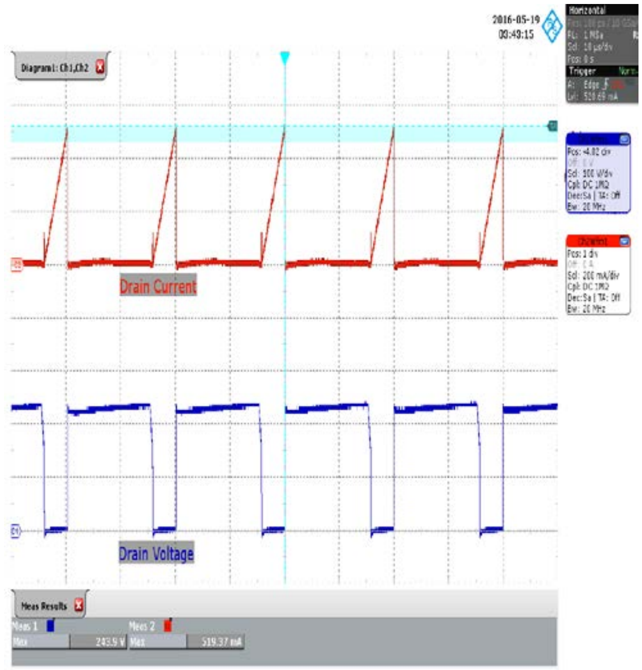


Figure 32 – 180 VAC, 50 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.
$V_{DS(MAX)}$: 243.9 V.
$I_{D(MAX)}$: 519.37 mA

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

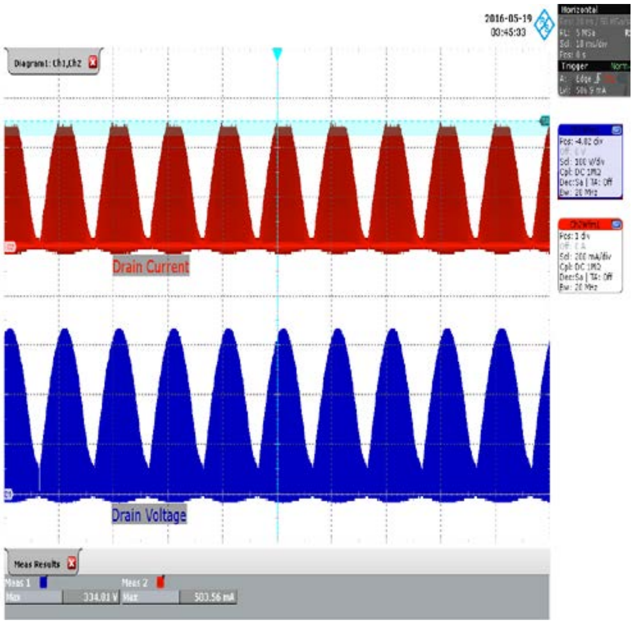


Figure 33 – 230 VAC, 50 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 ms / div.
$V_{DS(MAX)}$: 334.81 V.
$I_{D(MAX)}$: 503.56 mA.

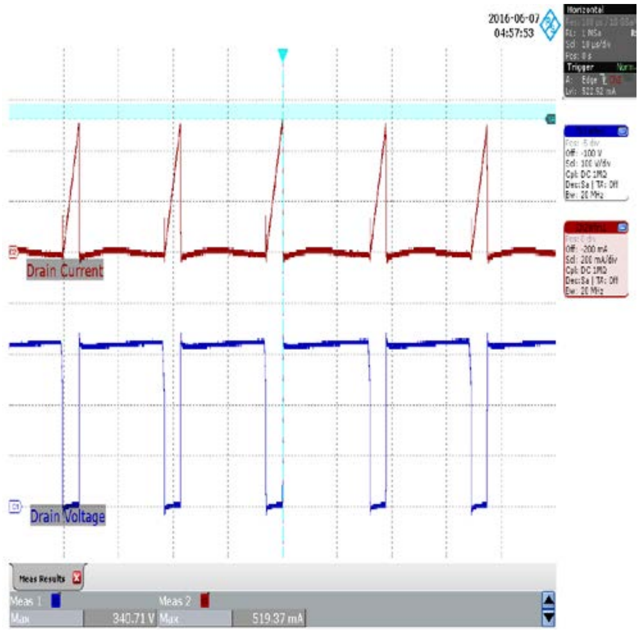


Figure 34 – 230 VAC, 50 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.
$V_{DS(MAX)}$: 340.71 V.
$I_{D(MAX)}$: 519.37 mA.

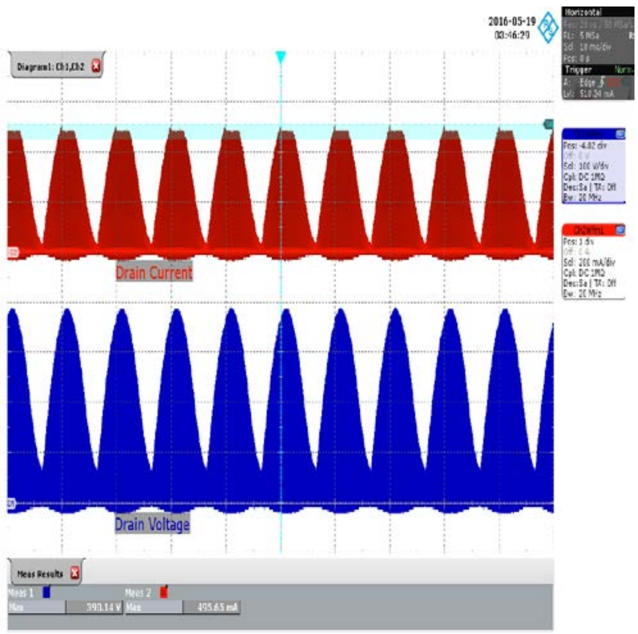


Figure 35 – 265 VAC, 50 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 ms / div.
$V_{DS(MAX)}$: 390.14 V.
$I_{D(MAX)}$: 495.65 mA.

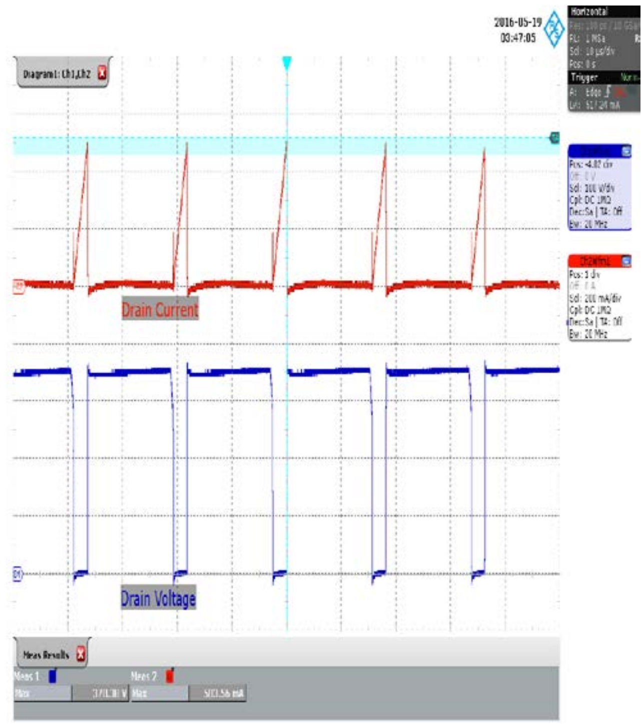


Figure 36 – 265 VAC, 50 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.
$V_{DS(MAX)}$: 370.38 V.
$I_{D(MAX)}$: 503.56 mA.

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

11.5 Drain Voltage and Current Start-up Profile

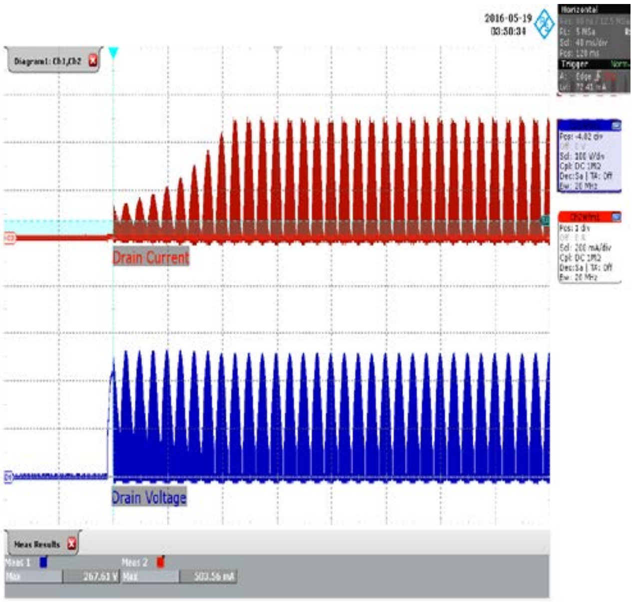


Figure 37 – 180 VAC, 50 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 40 ms / div.
$V_{DS(MAX)}$: 267.61 V.
$I_{D(MAX)}$: 503.56 mA.

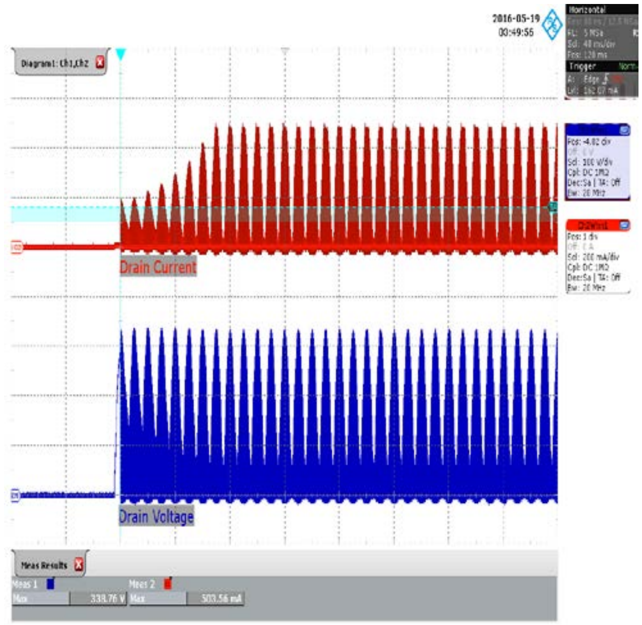


Figure 38 – 230 VAC, 50 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 40 ms / div.
$V_{DS(MAX)}$: 338.76 V.
$I_{D(MAX)}$: 503.56 mA

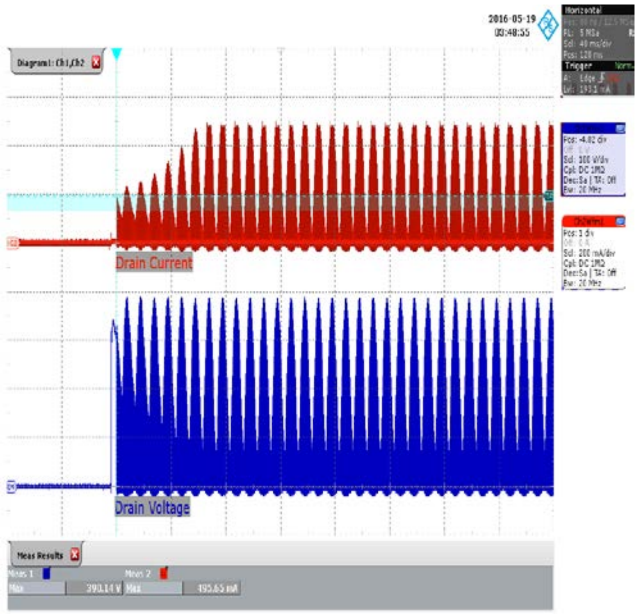


Figure 39 – 265 VAC, 50 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 40 ms / div.
$V_{DS(MAX)}$: 390.14 V.
$I_{D(MAX)}$: 495.65 mA.

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

11.6 Drain Voltage and Current During Output Short-Circuit Condition

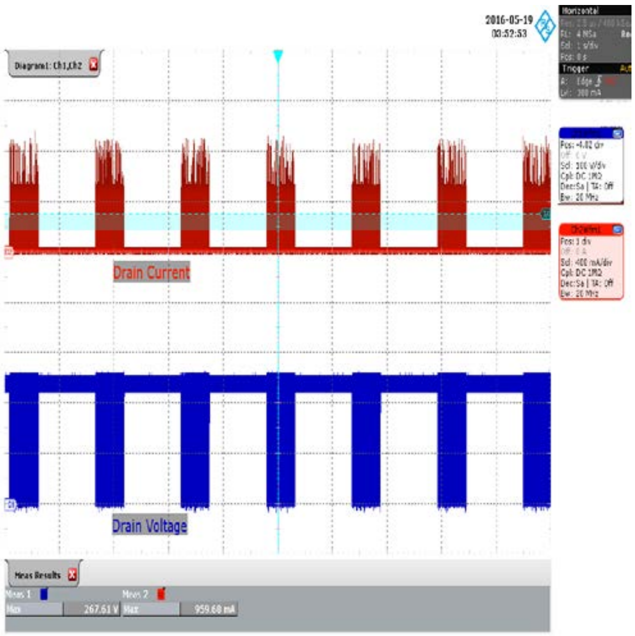


Figure 40 – 180 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.
$V_{DS(MAX)}$: 267.61 V.
$I_{D(MAX)}$: 959.68 mA.

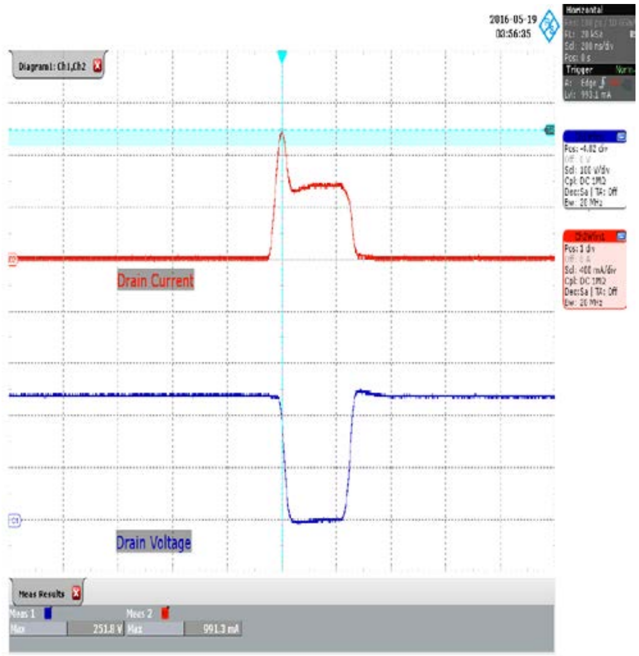


Figure 41 – 180 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 200 ns / div.
$V_{DS(MAX)}$: 251.8 V.
$I_{D(MAX)}$: 991.3 mA.

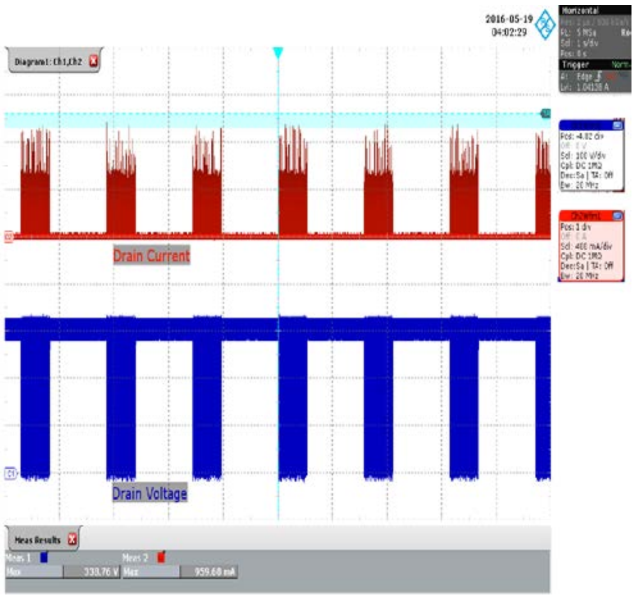


Figure 42 – 230 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.
$V_{DS(MAX)}$: 338.76 V.
$I_{D(MAX)}$: 959.68 mA.

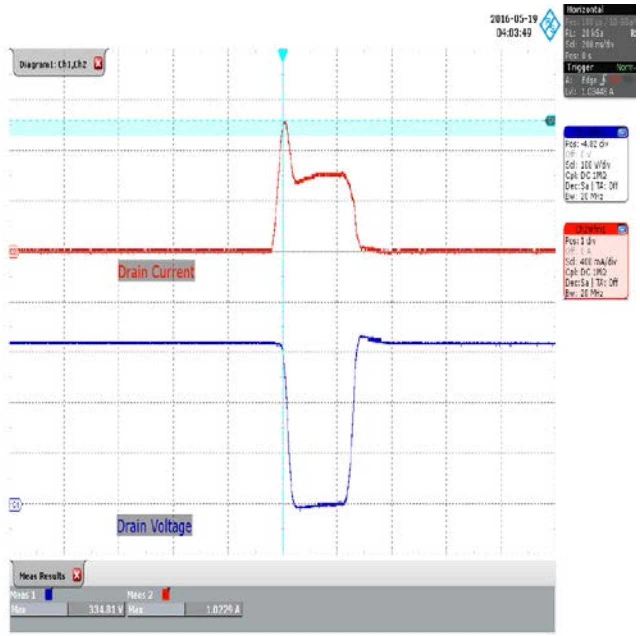


Figure 43 – 230 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 200 ns / div.
$V_{DS(MAX)}$: 334.81 V.
$I_{D(MAX)}$: 1.0229 A.

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

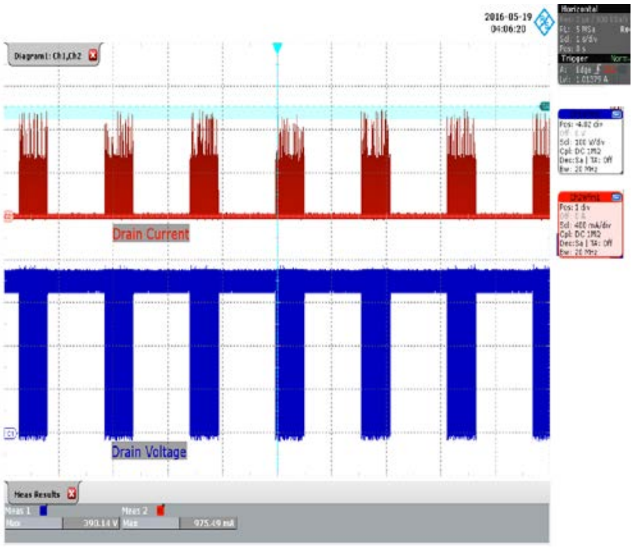


Figure 44 – 265 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.
$V_{DS(MAX)}$: 390.14 V.
$I_{D(MAX)}$: 975.49 mA.

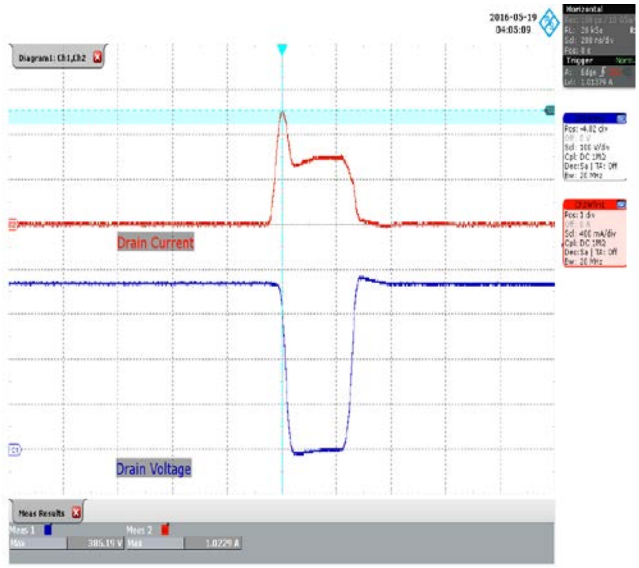


Figure 45 – 265 VAC, Output Short.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 200 ns / div.
$V_{DS(MAX)}$: 386.19 V.
$I_{D(MAX)}$: 1.0229 A.

11.7 Output Diode Voltage and Current in Normal Operation

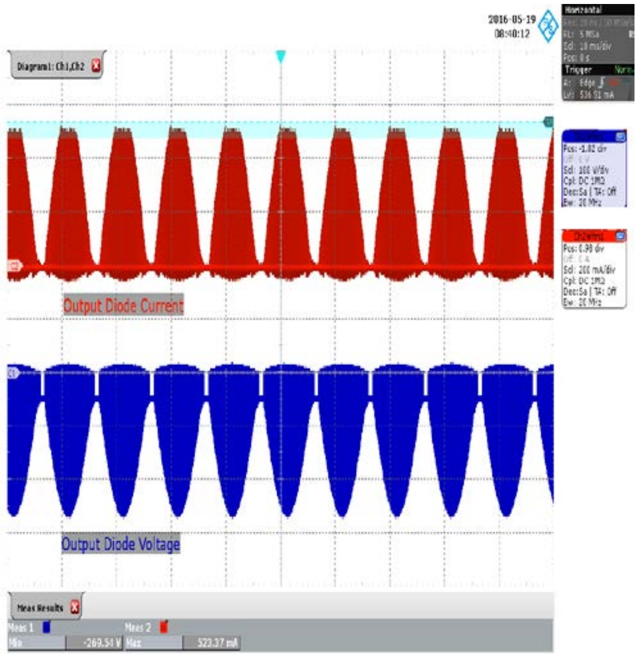


Figure 46 – 180 VAC, 50 V LED Load.
Upper: I_{DIODE}, 200 mA / div.
Lower: V_{DIODE}, 100 V / div., 10 ms / div.
V_{D1} min: -269.54 V.
$I_{D1(MAX)}$: 523.37 mA.

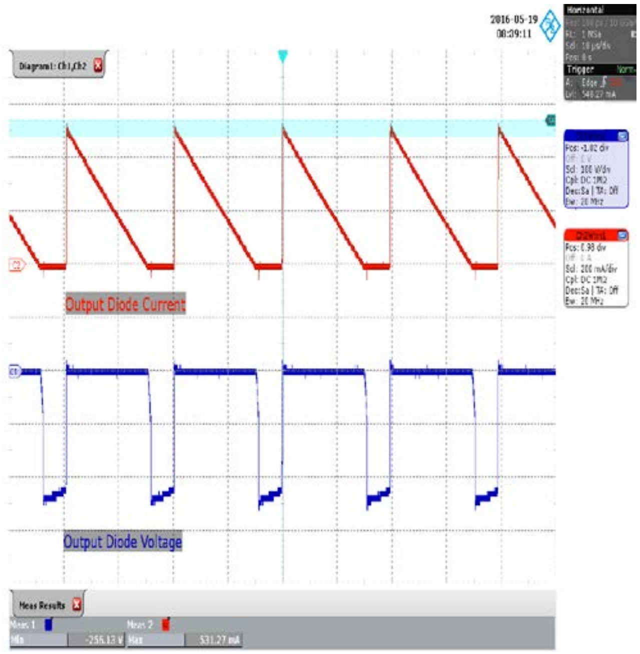


Figure 47 – 180 VAC, 50 V LED Load.
Upper: I_{DIODE}, 200 mA / div.
Lower: V_{DIODE}, 100 V / div., 10 μs / div.
V_{D1} min: -256.13 V.
$I_{D1(MAX)}$: 531.27 mA.

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

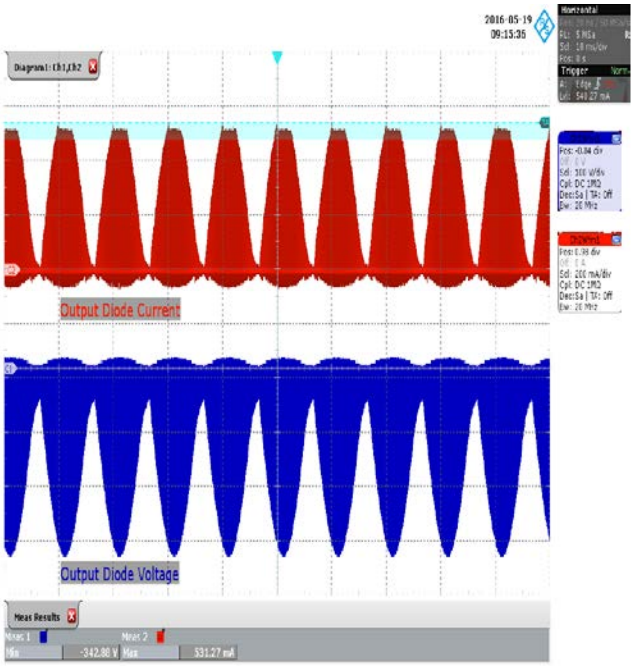


Figure 48 – 230 VAC, 50 V LED Load.
Upper: I_{DIODE}, 200 mA / div.
Lower: V_{DIODE}, 100 V / div., 10 ms / div.
V_{D1} min: -342.88 V.
$I_{D1(MAX)}$: 531.27 mA.

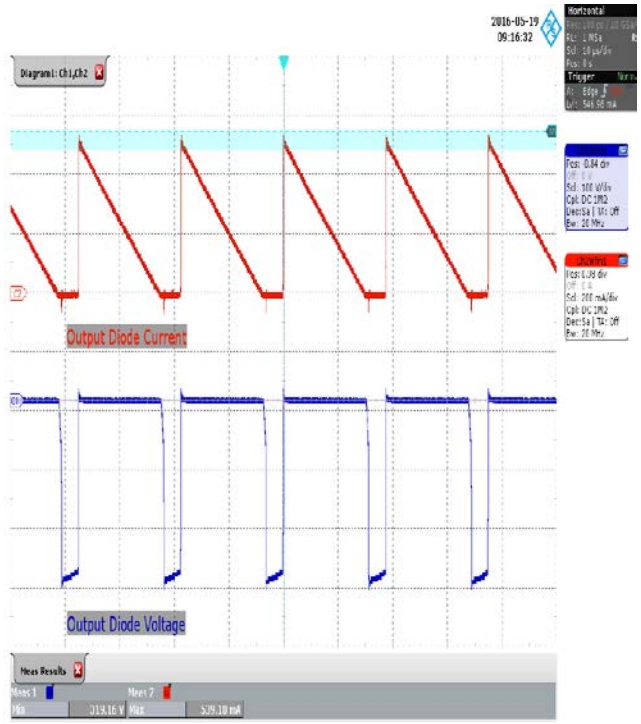


Figure 49 – 230 VAC, 50 V LED Load.
Upper: I_{DIODE}, 200 mA / div.
Lower: V_{DIODE}, 100 V / div., 10 μs / div.
V_{D1} min: -319.16 V.
$I_{D1(MAX)}$: 539.18 mA.

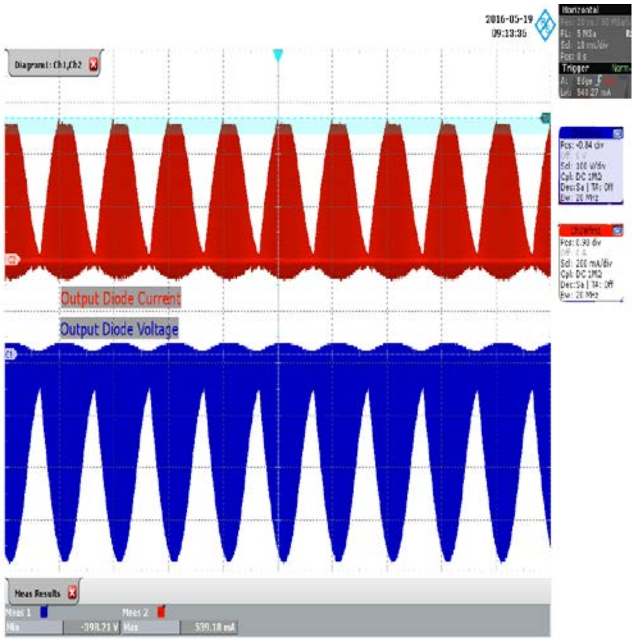


Figure 50 – 265 VAC, 50 V LED Load.
Upper: I_{DIODE}, 200 mA / div.
Lower: V_{DIODE}, 100 V / div., 10 ms / div.
V_{D1} min: -398.21 V.
$I_{D1(MAX)}$: 539.18 mA.

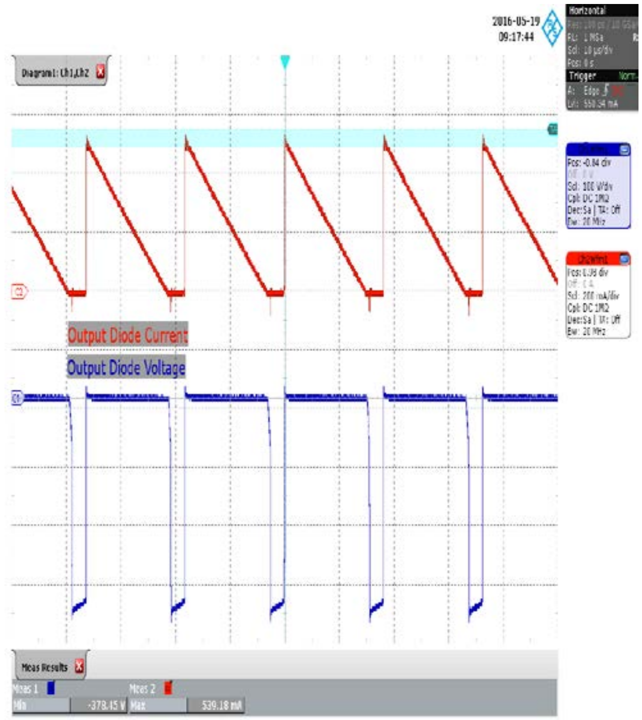


Figure 51 – 265 VAC, 50 V LED Load.
Upper: I_{DIODE}, 200 mA / div.
Lower: V_{DIODE}, 100 V / div., 10 μs / div.
V_{D1} min: -378.45 V.
$I_{D1(MAX)}$: 539.18 mA.

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

11.8 Output Voltage and Current – Open LED Load

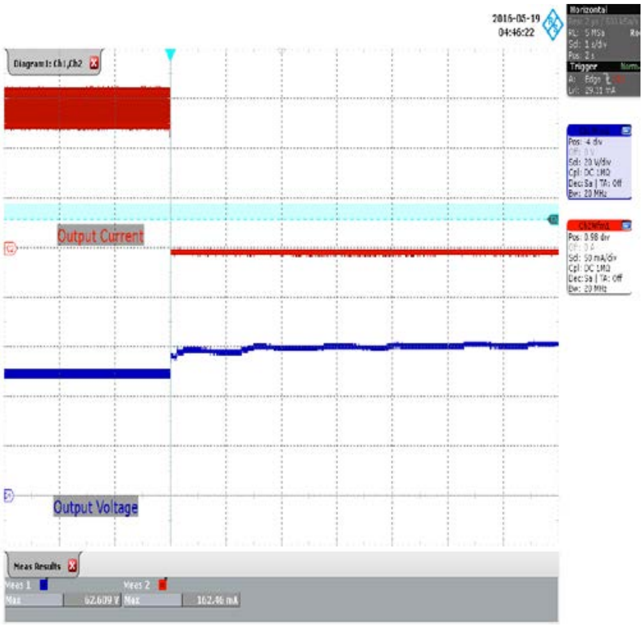


Figure 52 – 180 VAC, 50 V LED Load,
Running then Open Load.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 20 V / div., 1 s / div.
$V_{OUT(MAX)}$: 62.609 V.

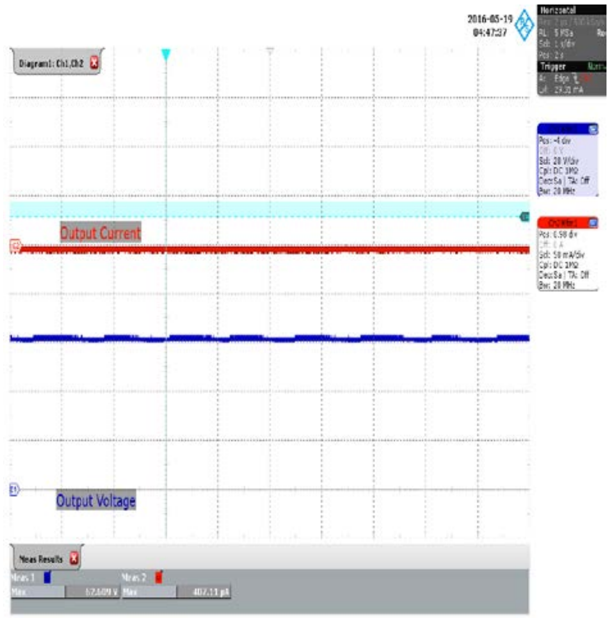


Figure 53 – 180 VAC, 50 V LED Load,
Open Load – Steady-State.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 20 V / div., 1 s / div.
$V_{OUT(MAX)}$: 62.609 V.

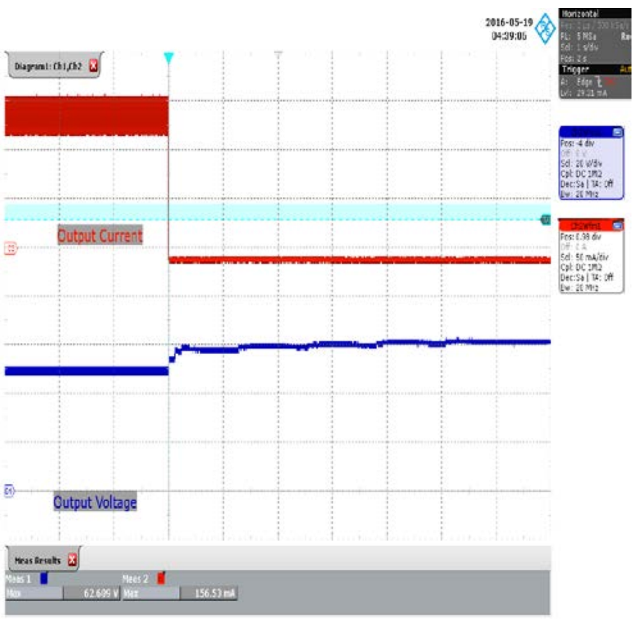


Figure 54 – 230 VAC, 50 V LED Load,
Running then Open Load.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 20 V / div., 1 s / div.
$V_{OUT(MAX)}$: 62.609 V.

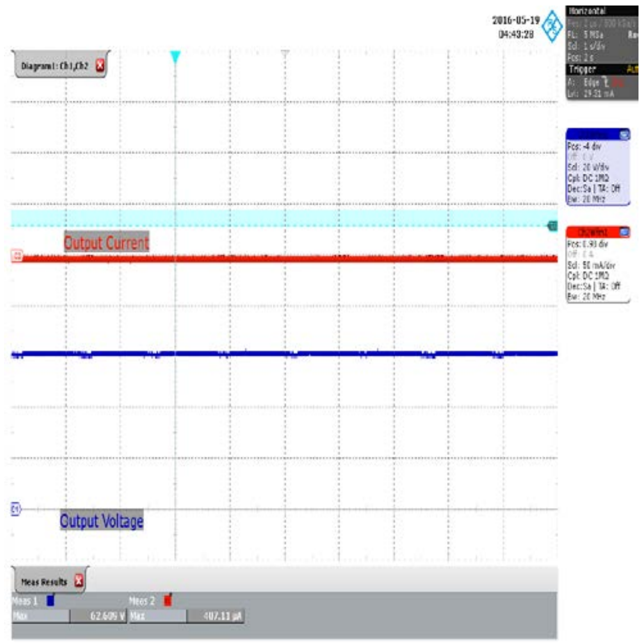


Figure 55 – 230 VAC, 50 V LED Load,
Open Load – Steady-State.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 20 V / div., 1 s / div.
$V_{OUT(MAX)}$: 62.609 V.

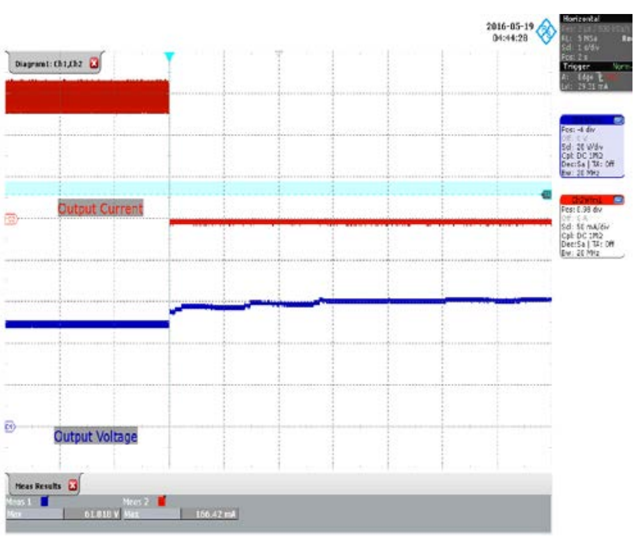


Figure 56 – 265 VAC, 50 V LED Load,
Running then Open Load.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 20 V / div., 1 s / div.
$V_{OUT(MAX)}$: 61.818 V.

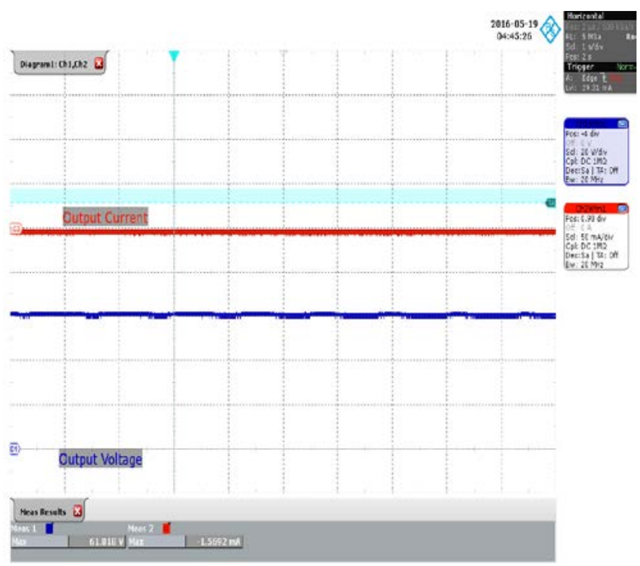


Figure 57 – 265 VAC, 50 V LED Load,
Open Load – Steady-State.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 20 V / div., 1 s / div.
$V_{OUT(MAX)}$: 61.818 V.

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

11.9 Output Ripple Current

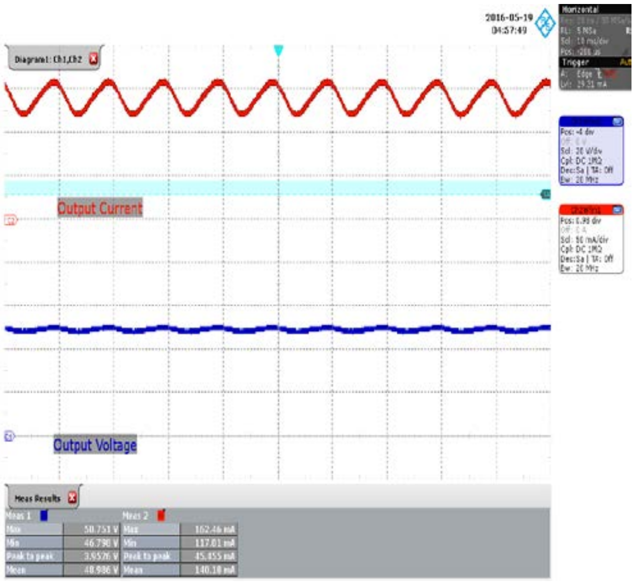


Figure 58 – 180 VAC, 50 Hz, 50 V LED Load.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 20V / div., 10 ms / div.

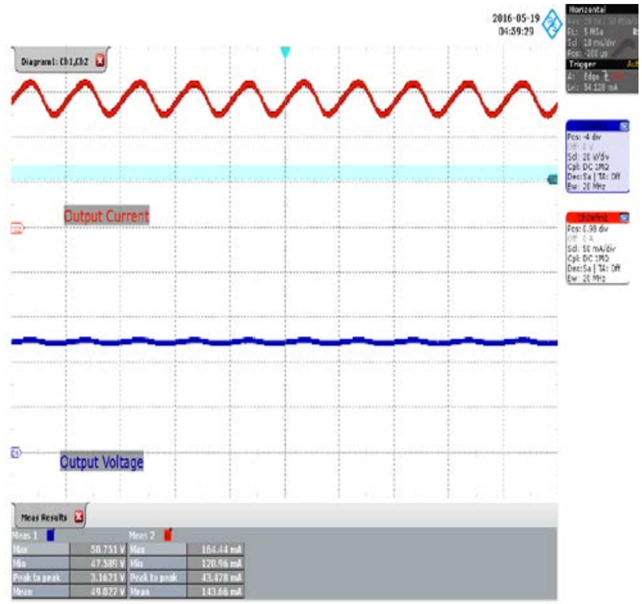


Figure 59 – 230 VAC, 50 Hz, 50 V LED Load.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 20V / div., 10 ms / div.

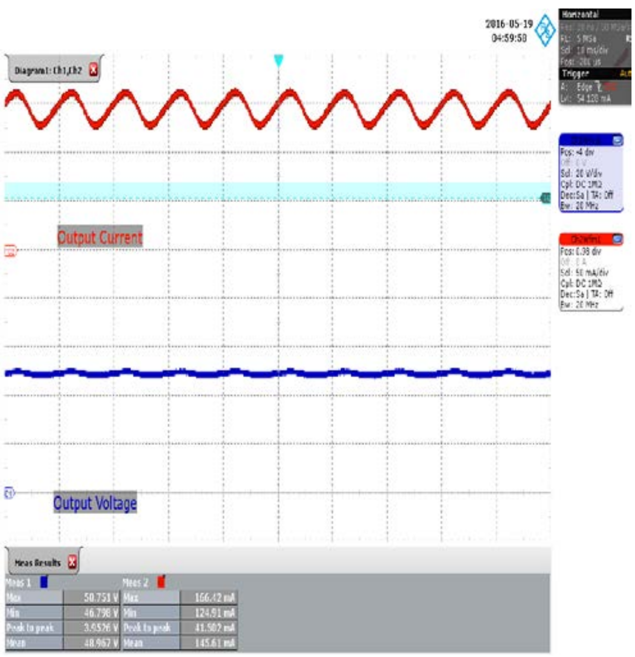


Figure 60 – 265 VAC, 50 Hz, 50 V LED Load.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 20V / div., 10 ms / div.

V_{IN} (VAC)	$I_{OUT(MAX)}$ (mA)	$I_{OUT(MIN)}$ (mA)	I_{MEAN} (mA)	Ripple Ratio (I_{RP}-$_P$/I_{MEAN})	% Flicker 100 x (I_{RP}-$_P$ / $I_{OUT(MAX)}$+$I_{OUT(MIN)}$)
180	162.46	117.01	140.18	0.32	16.26
230	164.44	120.96	143.66	0.30	15.23
265	166.42	124.91	145.61	0.29	14.25

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

12 AC Cycling Test

12.1 AC Cycling at Room Temperature (≈25 °C)

Maximum 19% 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.

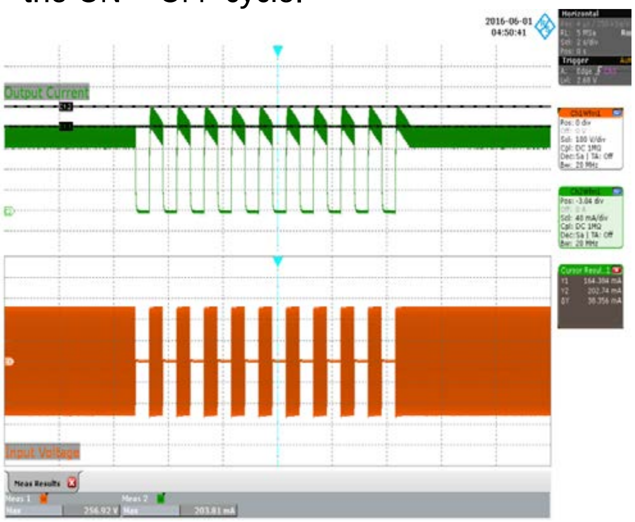


Figure 61 – 180 VAC, 50 V LED Load.
500 ms On – 500 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

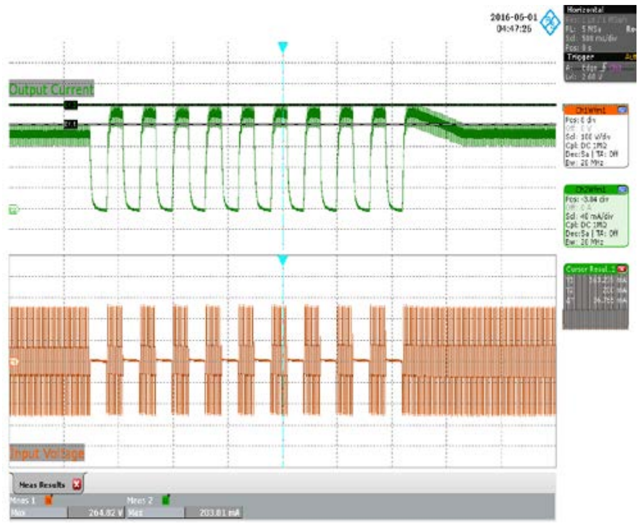


Figure 62 – 180 VAC, 50 V LED Load.
150 ms On – 150 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 500 ms / div.

Figure 63 – 230 VAC, 50 V LED Load.
500 ms On – 500 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

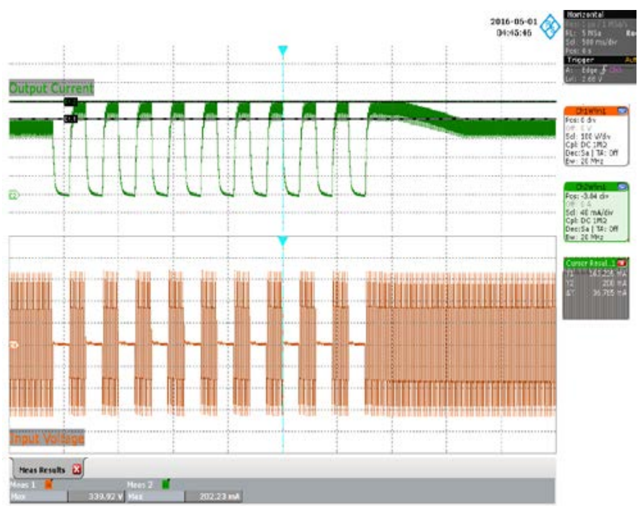


Figure 64 – 230 VAC, 50 V LED Load.
150 ms On – 150 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 500 ms / div.

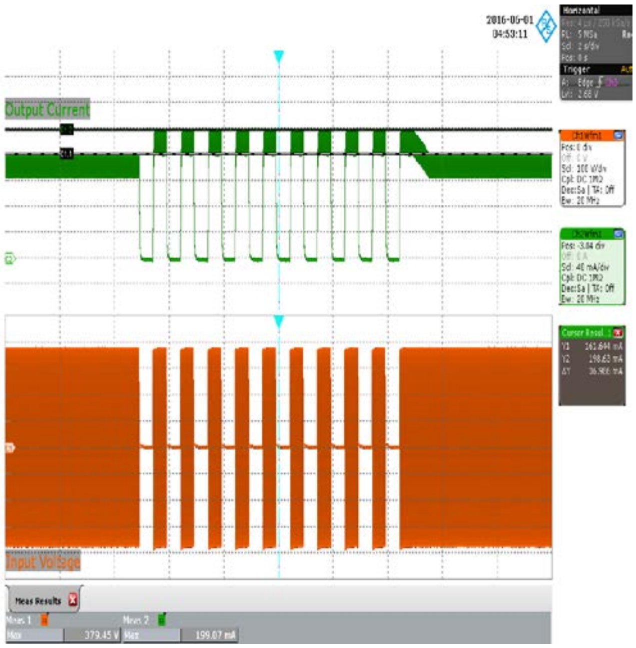


Figure 65 – 265 VAC, 50 V LED Load.
500 ms On – 500 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

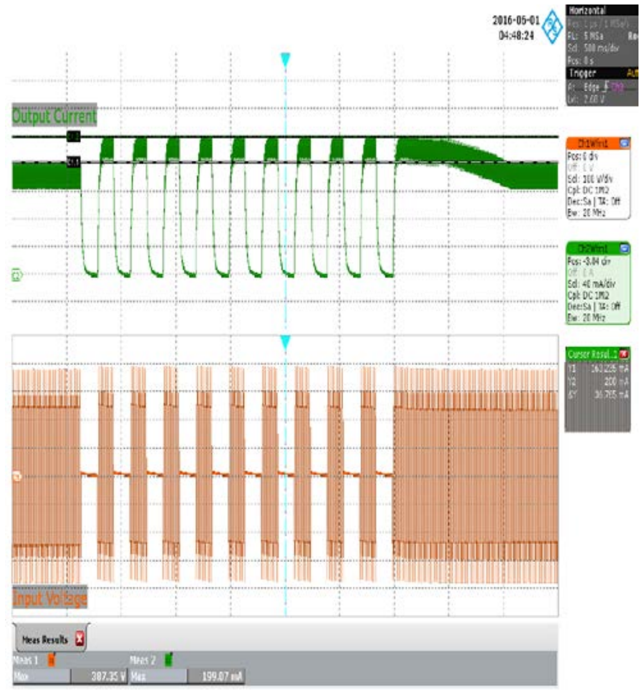


Figure 66 – 265 VAC, 50 V LED Load.
150 ms On – 150 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 500 ms / div.

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

12.2 AC Cycling at High IC Temperature (120 ºC)

Maximum 22% output current overshoot (based on peak current) was observed during on – off cycling at high IC temperature. The output current recovers immediately after the ON – OFF cycle.

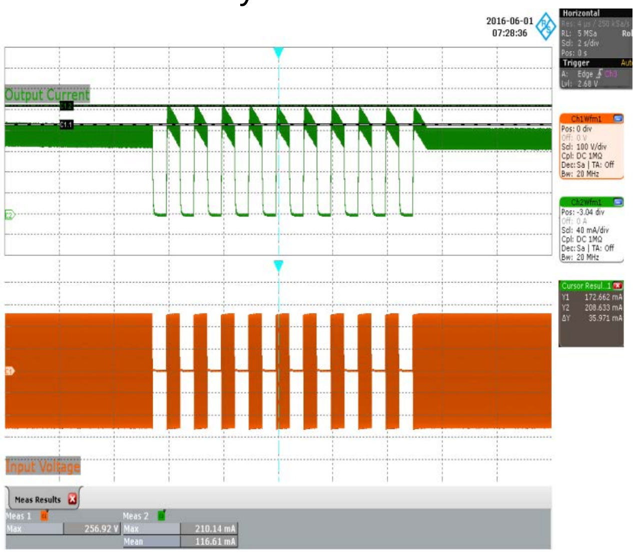


Figure 67 – 180 VAC, 50 V LED Load.
500 ms On – 500 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

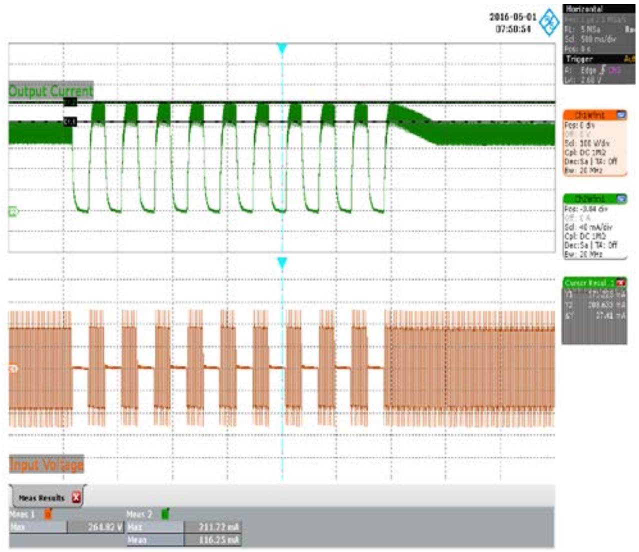


Figure 68 – 180 VAC, 50 V LED Load.
150 ms On – 150 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 500 ms / div.

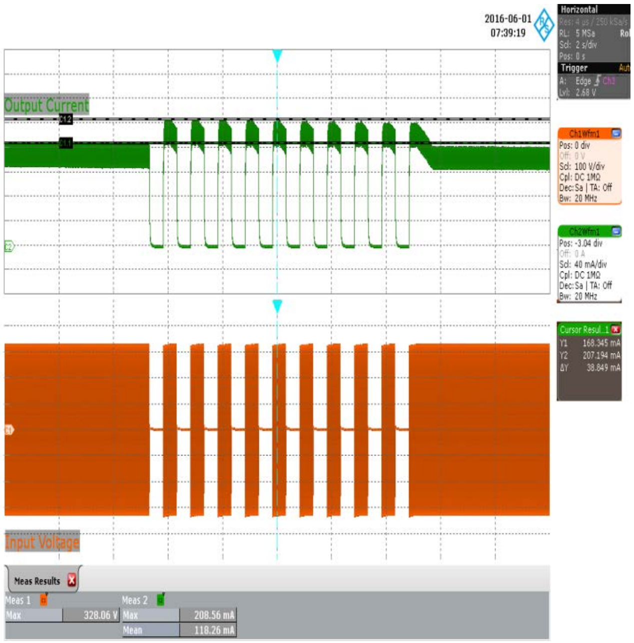


Figure 69 – 230 VAC, 50 V LED Load.
500 ms On – 500 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

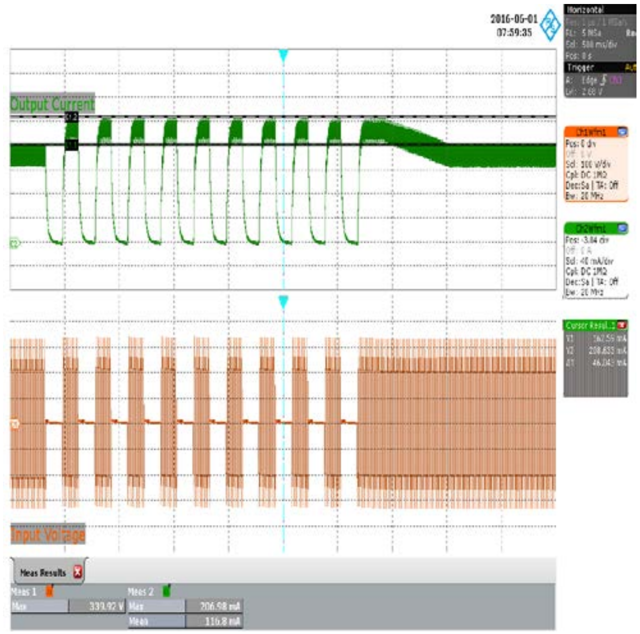


Figure 70 – 230 VAC, 50 V LED Load.
150 ms On – 150 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 500 ms / div.

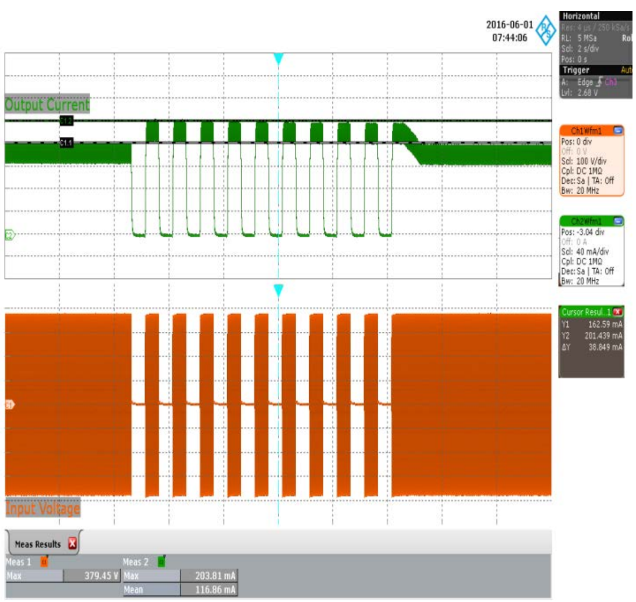


Figure 71 –265 VAC, 50 V LED Load.
500 ms On – 500 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

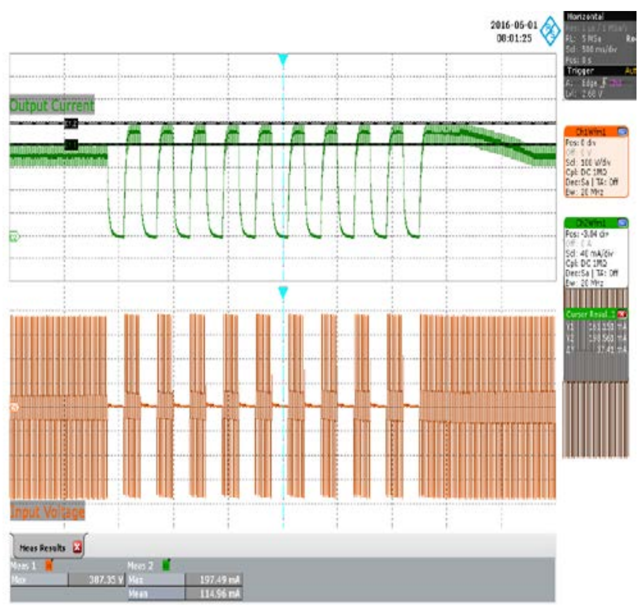


Figure 72 – 265 VAC, 50 V LED Load.
150 ms On – 150 ms Off.
Upper: I_{OUT}, 40 mA / div.
Lower: V_{IN}, 100 V / div., 500 ms / div.

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

13 Conducted EMI

13.1 Test Set-up

13.1.1 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. 50 V LED load with input voltage set at 230 VAC.

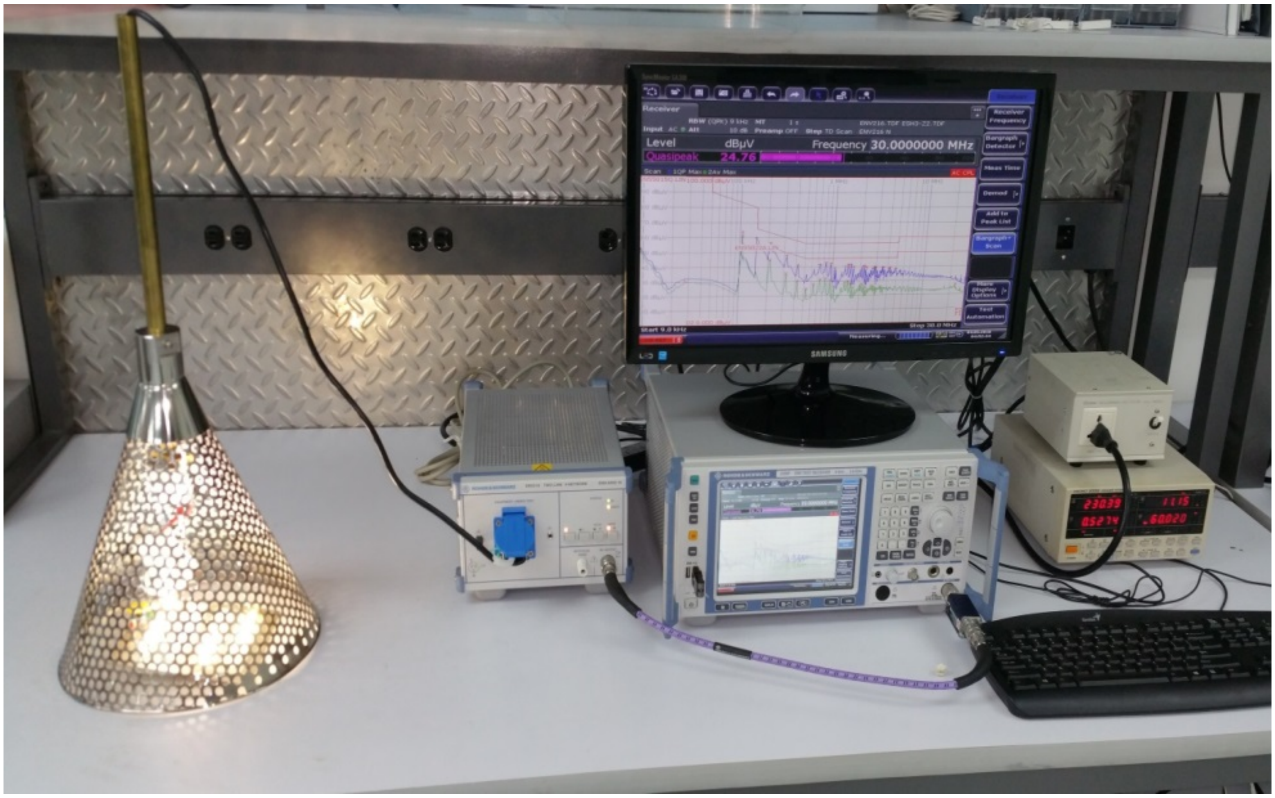


Figure 73 – Conducted EMI Test Set-up.

13.2 EMI Test Result

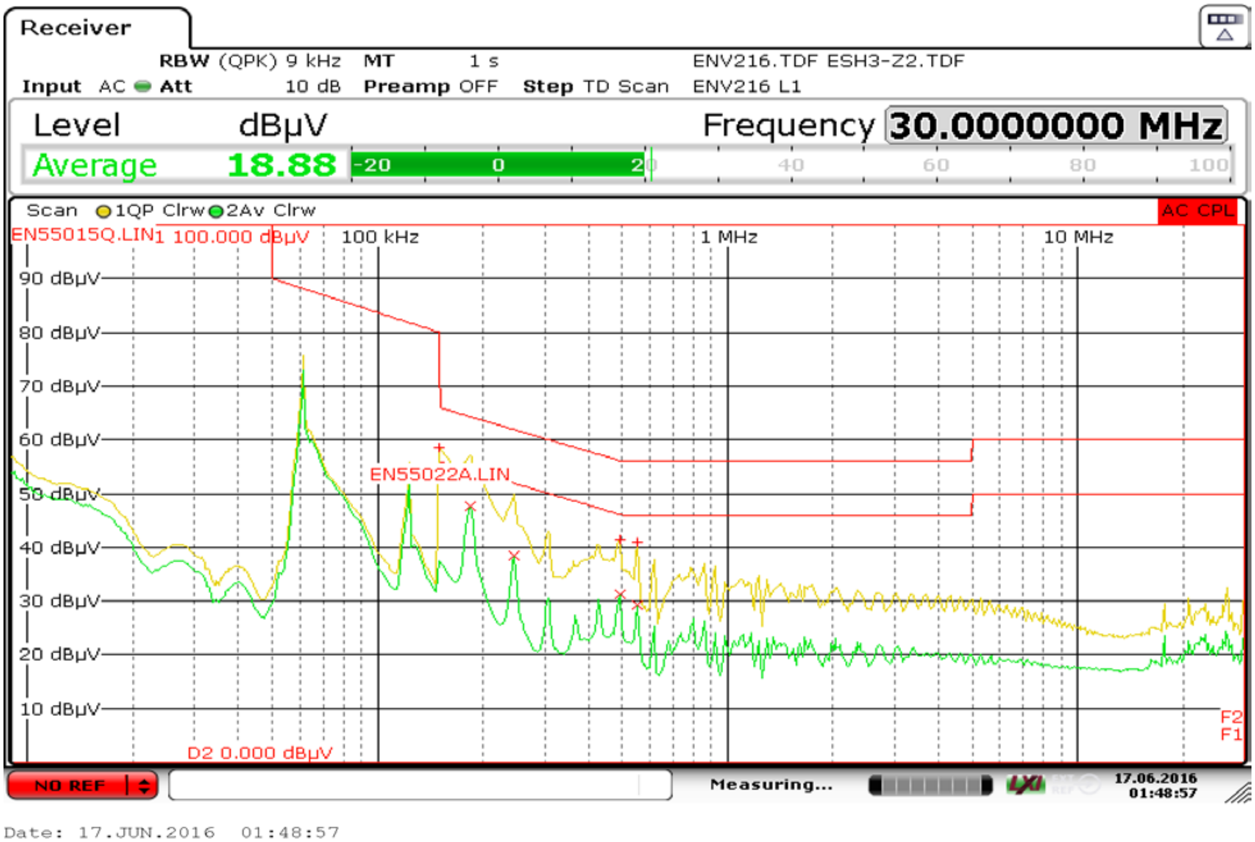


Figure 74 – Conducted EMI, 50 V LED Load with metal cone enclosure grounded, 230 VAC, 50 Hz, and EN55015 B Limits.

Trace1: EN55015Q.LIN Trace2: EN55022A.LIN

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	150.0000 kHz	58.65 L1	-7.35 dB
2 Average	183.7500 kHz	47.56 L1	-6.75 dB
2 Average	244.5000 kHz	38.50 L1	-13.44 dB
1 Quasi Peak	492.0000 kHz	41.52 L1	-14.61 dB
2 Average	492.0000 kHz	31.24 L1	-14.89 dB
2 Average	552.7500 kHz	29.23 L1	-16.77 dB
1 Quasi Peak	555.0000 kHz	40.91 L1	-15.09 dB

Figure 75 – Conducted EMI, 50 V LED Load with Metal Cone Enclosure Grounded, Final Measurement Results.

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

14 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

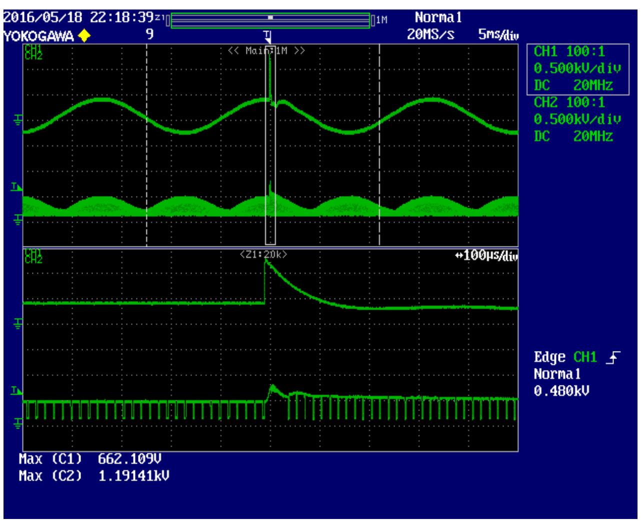


Figure 76 – +1000 kV Differential Surge, 90 ºC Phase.

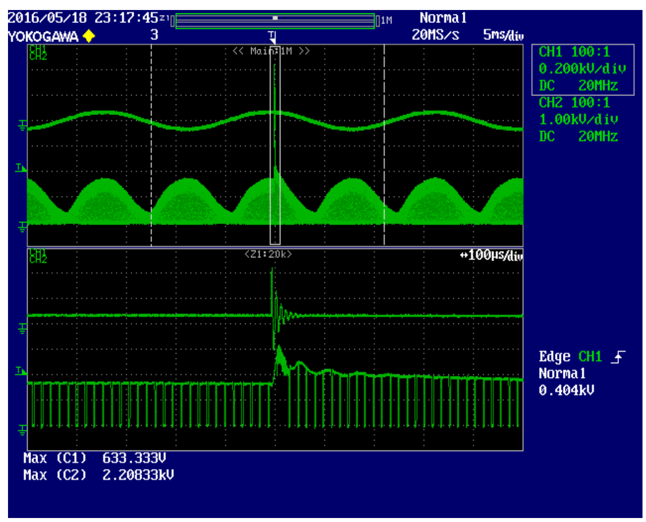


Figure 77 – +2500 kV Ring Wave, 90 ºC Phase.

15 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.

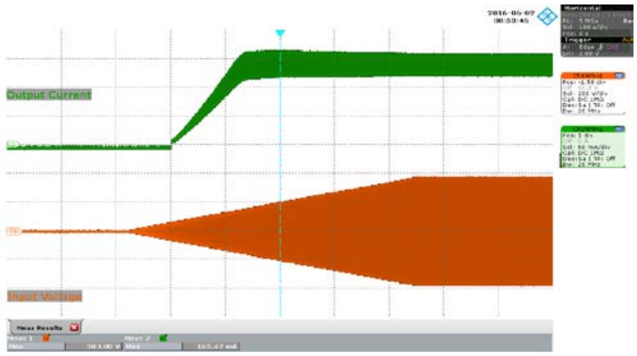


Figure 78 – Brown-in Test at 0.5 V / s.
The Unit is Able to Operate Normally
Without Any Failure
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 200 V / div.
Time Scale: 100 s / div.

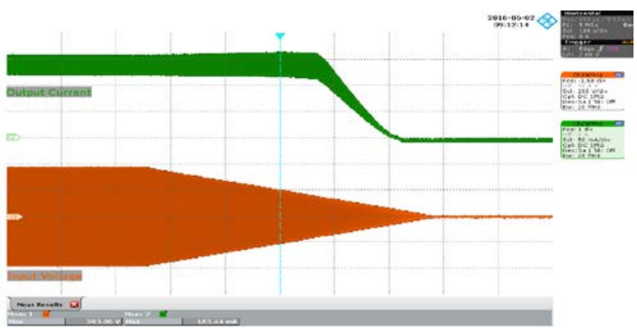


Figure 79 – Brown-out Test at 0.5 V / s.
The Unit is Able to Operate Normally
Without Any Failure
Upper: I_{OUT}, 50 mA / div.
Lower: V_{IN}, 200 V / div.
Time Scale: 100 s / div.

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

16 Revision History

Date	Author	Revision	Description and Changes	Reviewed
24-Jun-16	EDdL	1.0	Initial release	Apps & Mktg

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

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

Power Integrations Worldwide Sales Support Locations

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

GERMANY
Lindwurmstrasse 114
80337, Munich
Germany
Phone: +49-895-527-39110
Fax: +49-895-527-39200
e-mail: eurosales@power.com

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

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

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

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

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

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

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

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

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