Design Example Report

Title	***9 W High Efficiency (90%) Power Factor Corrected (>0.9) Non-Dimmable Non-Isolated Buck A19 Lamp Replacement LED Driver Using LinkSwitch™-PL LNK457DG***
Specification	195 VAC – 265 VAC Input; 60 V (Typical), 150 mA Output
Application	A19 LED Driver
Author	Applications Engineering Department
Document Number	DER-388
Date	December 5, 2013
Revision	1.0

Summary and Features

- Single-stage, power factor corrected and accurate constant current (CC) output
- Low cost, low component count and small PCB footprint solution
- Highly energy efficient, >90% at 220 VAC input
- Fast start-up time (<50 ms) – no perceptible delay
- Integrated protection and reliability features
  - One shot no-load protection
  - Hard short-circuit protected
  - Auto-recovering thermal shutdown
  - No damage during line brown-out or brown-in conditions
- PF >0.9 at 230 VAC
- ATHD <25% at 230 VAC
- Meets IEC 2.5 kV ring wave, 500 V differential line surge and EN55015 conducted EMI

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

1 Introduction

This document is an engineering report describing a non-isolated LED driver (power supply) utilizing a LNK457DG from the LinkSwitch-PL family of devices.

The DER-388 provides a single 9 W constant current output.

The key design goals were high efficiency and small size. This allowed the driver to fit into A19 sized lamps and be as close to a production design as possible.

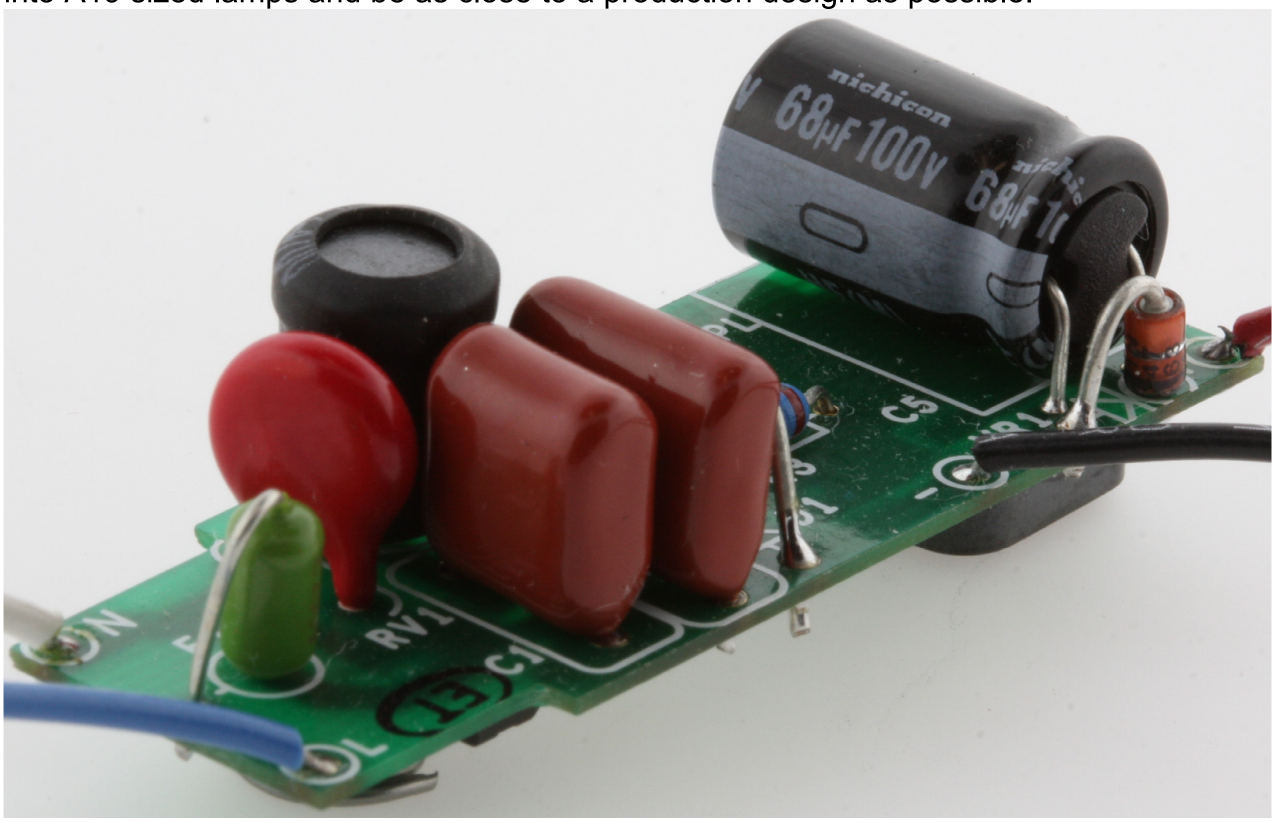

Figure 1 – PCB Assembly.

The board was optimized to operate over the high-line AC input voltage range (195 VAC to 265 VAC, 47 Hz to 63 Hz). LinkSwitch-PL IC based designs provide a high power factor (>0.9) meeting current international requirements.

The form factor of the board was chosen to meet the requirements for standard A19 LED replacement lamps. The output is non-isolated and requires the mechanical design of the enclosure to isolate the output of the supply and the LED load from the user.

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

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2 Power Supply Specifications

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	195	230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	63	Hz	
Output						
Output Voltage	V_{OUT}	54	60	66	V	
Output Current	I_{OUT}		150		mA	At 230 VAC
Total Output Power						
Continuous Output Power	P_{OUT}		9		W	
Efficiency						
Nominal	η		90		%	Measured at P_{OUT} 25 °C at 220 VAC
Environmental						
Conducted EMI		Meets CISPR22B / EN55015				
Line Surge Differential Mode (L1-L2)			500		V	1.2/50 µs surge, IEC 1000-4-5, Series Impedance: Differential Mode: 2 Ω
Ring Wave (100 kHz) Differential Mode (L1-L2)			2.5		kV	2 Ω Short-Circuit Series Impedance
Power Factor		0.9				At 230 VAC
ATHD				25	%	At 230 VAC

3 Schematic

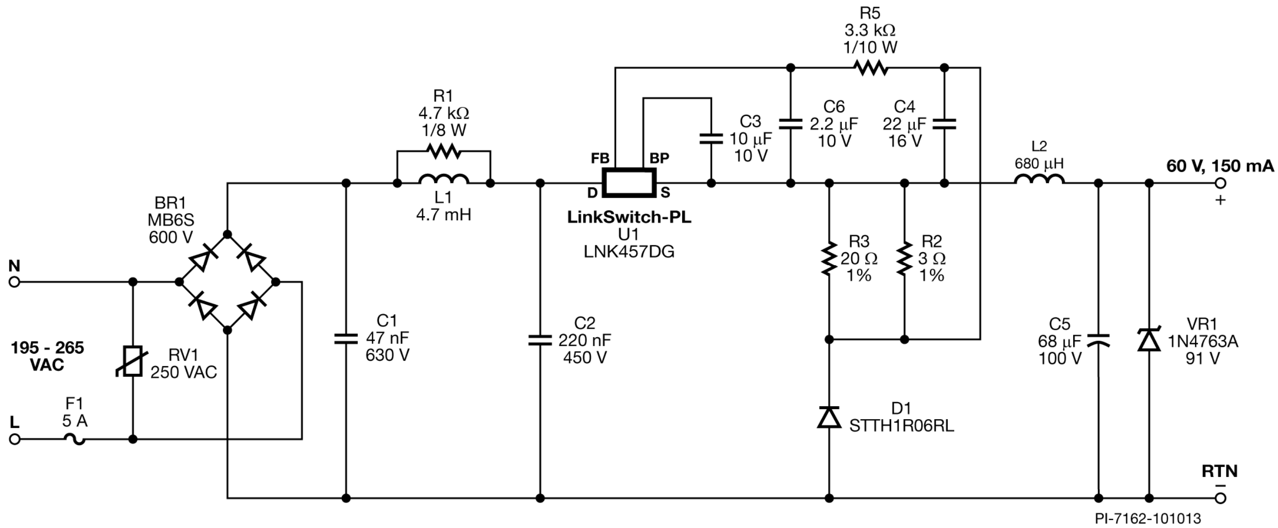

Figure 2 – Schematic for 60 V / 150 mA A19 Replacement Lamp.

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4 Circuit Description

The LinkSwitch-PL (U1) family is highly integrated power ICs intended for use in LED driver applications. The LinkSwitch-PL provides high power factor in a single-stage conversion topology while regulating the output current across the input range (195 VAC to 265 VAC) and output voltage conditions typically encountered in LED driver applications. All of the control circuitry required for these functions plus a high-voltage power MOSFET is incorporated into the IC.

4.1 Input Stage

Fuse F1 provides protection against component failure. A relatively high, fast 5 A rating was needed to prevent false opening during line surges. Fuse F1 may be replaced with a fusible resistor (2 W, 3.3 Ω) for lower cost but could lower efficiency.

The maximum input voltage is clamped by RV1 during differential line surges.

The AC input is full wave rectified by BR1 for good power factor.

Capacitor C1, C2 and differential choke L1 form the EMI filter. Total input filter capacitance is limited to low value to maintain high power factor. This input π-filter networks plus the frequency jittering feature of LinkSwitch-PL ensures compliance with Class B emission limits. Resistor R1 damps the resonance of the EMI filter, preventing peaks in the EMI spectrum when measured in a system (driver plus enclosure).

Inductor L1 is positioned after the bridge to avoid an imbalance in the EMI scan between line and neutral. This also allows the use of small high-voltage ceramic capacitors in the input filter.

4.2 Buck Topology Using LinkSwitch-PL Devices

The buck power train is composed of U1 (power switch + control), D1 (freewheeling diode), C5 (output capacitor), and L2 (inductor). The bypass capacitor C8 provides the internal supply for U1, it is charged via the drain during MOSFET off-time during start-up.

4.3 Output Feedback

The output current is sensed by the voltage drop across R2//R3 and then filtered by a low pass filter (R5 and C6). This biases the LinkSwitch-PL operating point such that the average FEEDBACK (FB) pin voltage is maintained at 290 mV in steady-state operation (150 mA output current). Bypass capacitor C4 is used to reduce dissipation across R2//R3 thus increasing efficiency.

4.4 Disconnected Load Protection

Simple one shot no-load protection is provided by a Zener (VR1) diode across the output terminals. In case of no-load, the Zener diode will short in order to protect the output capacitor from popping. U1 will be limited by the primary current limit. Note that the Zener diode will need to be replaced once fault is removed.

4.5 Overload and Short-Circuit Protection

The load is protected against overload and short-circuits via a primary current limit. During short, primary current will build-up until it reaches current limit. Refer to short-circuit waveforms for more information.

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5 PCB Layout and Outline

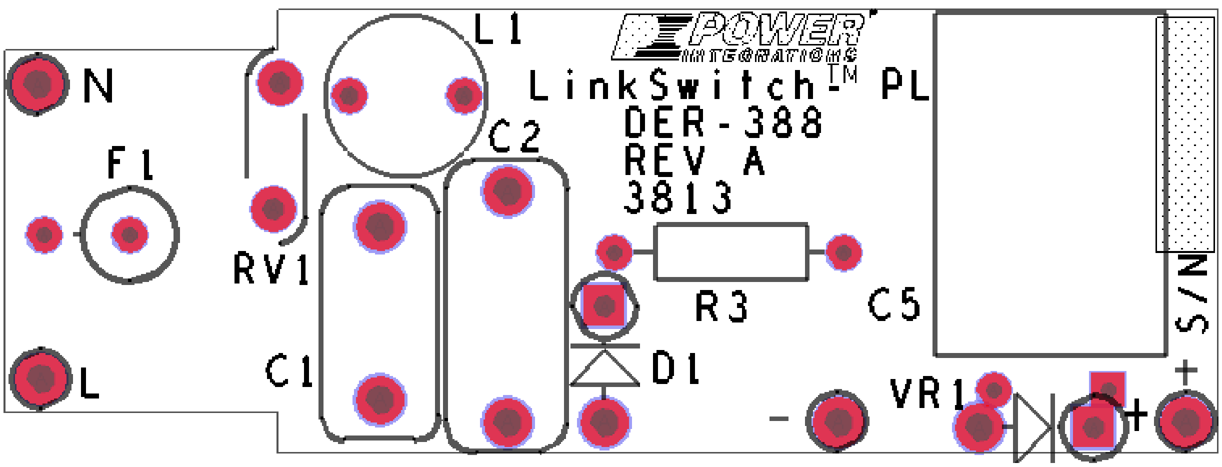

Figure 3 – Printed Circuit Layout, Top.

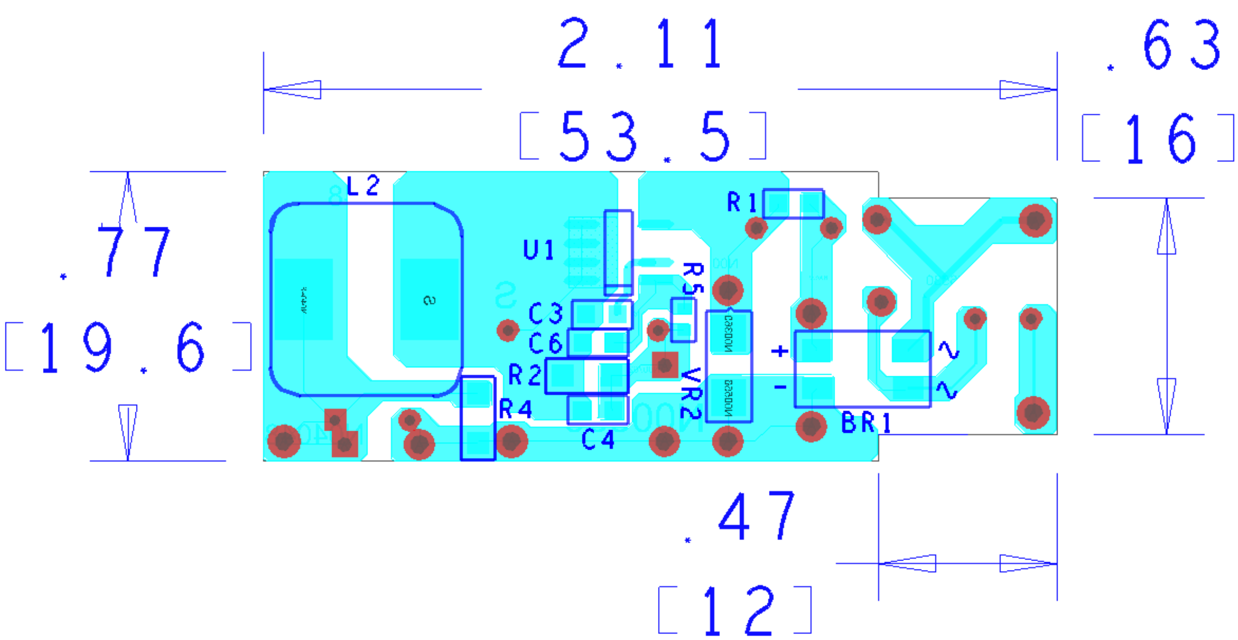

Figure 4 – Printed Circuit Layout, Bottom.

6 Populated PCB

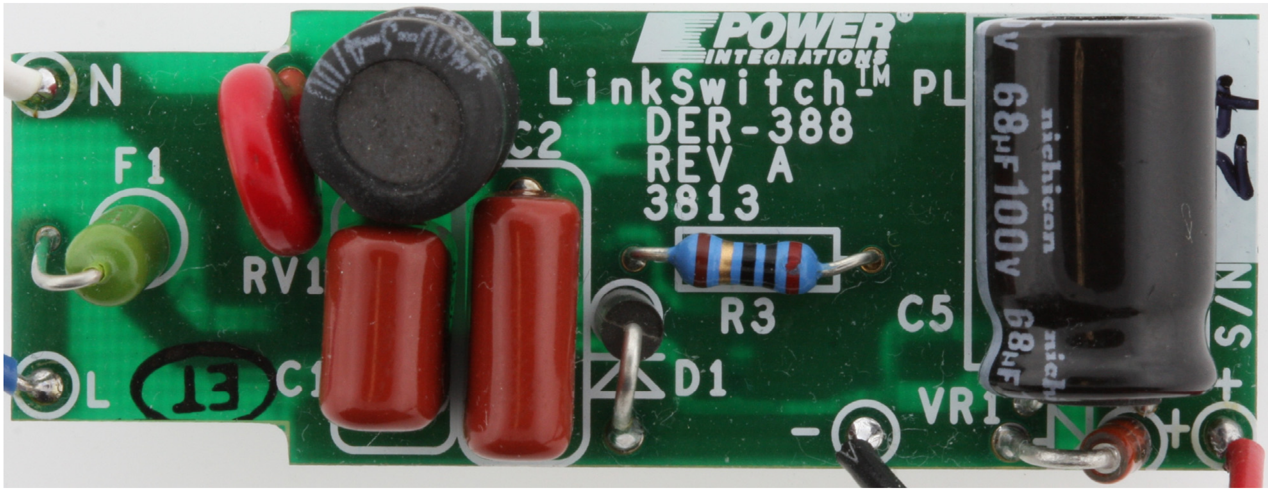

Figure 5 – Populated Circuit Board, Top.

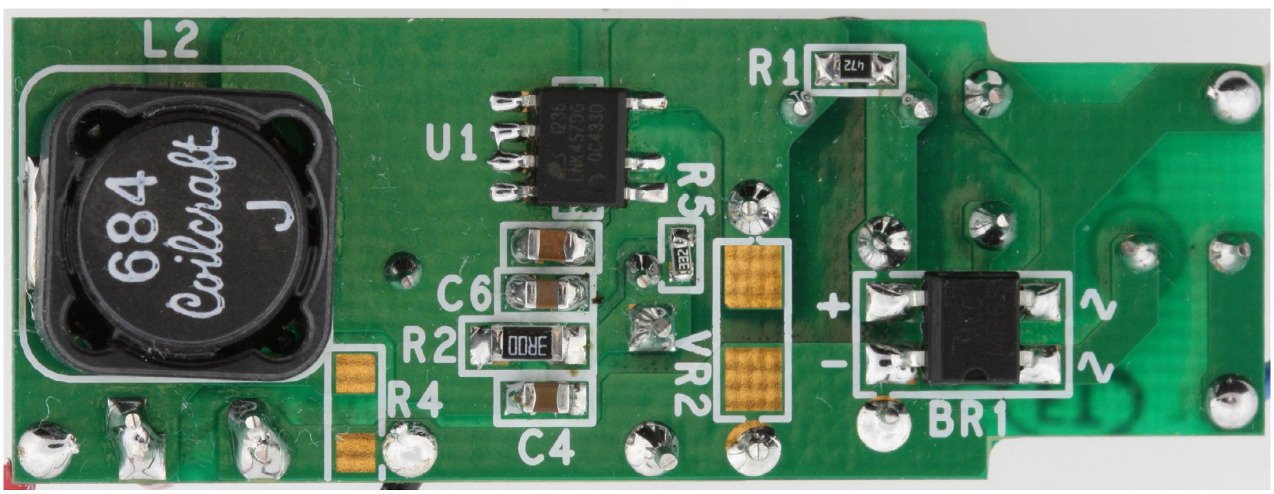

Figure 6 – Populated Circuit Board, Bottom.

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7 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
1	1	BR1	600 V, 0.5 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	MB6S-TP	Micro Commercial
2	1	C1	47 nF, 630 V, Film	MEXPD24704JJ	Duratech
3	1	C2	220 nF, 450 V, Film	MEXXF32204JJ	Duratech
4	1	C3	10 μF, 10 V, Ceramic, X7R, 0805	C2012X7R1A106M	TDK
5	1	C4	22 μF, 16 V, Ceramic, X7R, 0805	C2012X5R1C226K	TDK
6	1	C5	68 μF, 100 V, Electrolytic, (10 x 16)	UHE2A680MPD	Nichicon
7	1	C6	2.2 μF, 10 V, Ceramic, X7R, 0805	C0805C225M8RACTU	Kemet
8	1	D1	600 V, 1 A, Ultrafast Recovery, DO-41	STTH1R06RL	ST Micro
9	1	F1	5 A, 250 V, Fast, Microfuse, Axial	0263005.MXL	Littlefuse
10	1	L1	4.7 mH, 0.150 A, 20%	RL-5480-3-4700	Renco Elect
11	1	L2	680 μH	MSS1260-684KLB	Coilcraft
12	1	R1	4.7 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ472V	Panasonic
13	1	R2	3.00 Ω, 1%, 1/4 W, Thick Film, 1206	RC1206FR-073RL	Yageo
14	1	R3	20 Ω, 1%, 1/4 W, Metal Film	MFR-25FBF-20R0	Yageo
15	1	R5	3.3 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ332V	Panasonic
16	1	RV1	250 V, 21 J, 7 mm, RADIAL LA	V250LA4P	Littlefuse
17	1	U1	LinkSwitch-PL, SO-8C	LNK457DG	Power Integrations
18	1	VR1	91 V, 5%, 1 W, DO-41	1N4763A-TR	Vishay

8 Transformer Design Spreadsheet

ACDC_LinkSwitch-PL-Buck_042413; Rev.1.1; Copyright Power Integrations 2011	INPUT	INFO	OUTPUT	UNIT	ACDC_LinkSwitch-PL Buck Design Spreadsheet
ENTER APPLICATION VARIABLES					
VACMIN	195		195.00	V	Minimum AC Input Voltage
VACTYP	230		230.00	V	Typical AC Input Voltage
VACMAX	254		254.00	V	Maximum AC Input Voltage
FL			50.00	Hz	AC Mains Frequency. (between 47Hz and 63Hz)
VOMIN	54.00		54.00	V	Minimum Output Voltage of LED string
VO	60.00		60.00	V	Output Voltage of LED string
VOMAX	66.00		66.00	V	Maximum Output Voltage of LED string
IO	0.15		0.15	A	Output Current riving LED strings
PO			9.00	W	Continuous Output Power
n	0.91		0.91		Efficiency Estimate at output terminals. Under 0.7 if no better data available
Dimming Application	**No**		No		Enter Yes if design uses TRIAC dimming, otherwise select No
ENTER LinkSwitch-PL VARIABLES					
Chosen Device	**LNK457**		LNK457		Chosen LinkSwitch-II device
ILIMITMIN			0.80	A	Minimum Current Limit
ILIMITTYP			0.91	A	Typical Current Limit
ILIMITMAX			1.02	A	Maximum Current Limit
TON			2.02	us	Expected on-time of MOSFET at low line and PO
FSW			121.33	kHz	Expected switching frequency at low line and PO
Duty Cycle			24.46	%	Expected operating duty cycle at low line and PO
IRMS			0.12	A	Worst case drain RMS current at VO
IPK			0.75	A	Worst case peak primary current at VO
KDP		Info	0.87		LinkSwitch-PL must operate in discontinuous mode (KP > 1) for good power factor. Consider reducing the primary inductance.
ENTER INDUCTOR CORE/CONSTRUCTION VARIABLES					
Core Type					
Core Type	**Custom**		Custom		Enter Transformer Core
Core Part Number			0.00		If custom core is used - Enter part number here
Bobbin part number			0.00		Bobbin Part number (if available)
AE			0.00	mm^2	Core Effective Cross Sectional Area
LE			0.00	mm	Core Effective Path Length
AL			0.00	nH/turn^2	Ungapped Core Effective Inductance
BW			0.00	mm	Bobbin Physical Winding Width
INDUCTOR DESIGN PARAMETERS					
LPMIN			612.00	uH	Minimum Inductance
LPTYP	680.00		680.00	uH	Typical inductance
LP_TOLERANCE			10.00	%	Tolerance of the inductance
TURNS_TOTAL			N/A	Turns	Total number of turns
ALG			N/A	nH/turn^2	Gapped Core Effective Inductance
BM		N/A	N/A	Gauss	#DIV/0!
BP		N/A	N/A	Gauss	#DIV/0!
BAC		N/A	N/A	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur		N/A	N/A		Relative Permeability of Ungapped Core
LG		N/A	N/A	mm	#DIV/0!

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AWG		N/A	N/A		Winding Wire Gauge (Rounded to next smaller standard AWG value)
L			N/A		Number of Layers
CMA			N/A	Cmils	Current Density capacity 200 < CMA < 500
Bias Section					
Use Bias?	**No**		No		Is a Bias winding used?
TURNS_BIAS			0.00	Turns	
VBIAS			0.00	V	
PIVBS			N/A	V	
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			24.46	%	Duty cycle measured at minimum input voltage
IAVG			0.04	A	Input average current measured on the Mosfet at the minimum input voltage
IP			0.75	A	Peak Drain current at maximum input voltage
ISW_RMS			0.12	A	MOSFET RMS current measured at the minimum input voltage
ID_RMS			0.27	A	RMS current of freewheeling diode at maximum input voltage
IL_RMS			0.29	A	RMS current of the inductor at the maximum input voltage
FEEDBACK AND BYPASS PIN PARAMETERS					
RFEEDBACK			2.72	ohm	This is a first approximation for the sense resistor and will likely require fine tuning in the bench. Value calculated with typical inductance, and minimum input voltage.
CBP			1.00	uF	Minimum Bypass pin capacitor required
VOLTAGE STRESS PARAMETERS					
VDRAIN			359.21	V	Estimated worst case drain voltage
PIVS			359.21	V	Output Rectifier Maximum Peak Inverse Voltage

9 Performance Data

All measurements performed at 25 ºC room temperature otherwise specified.

9.1 Efficiency

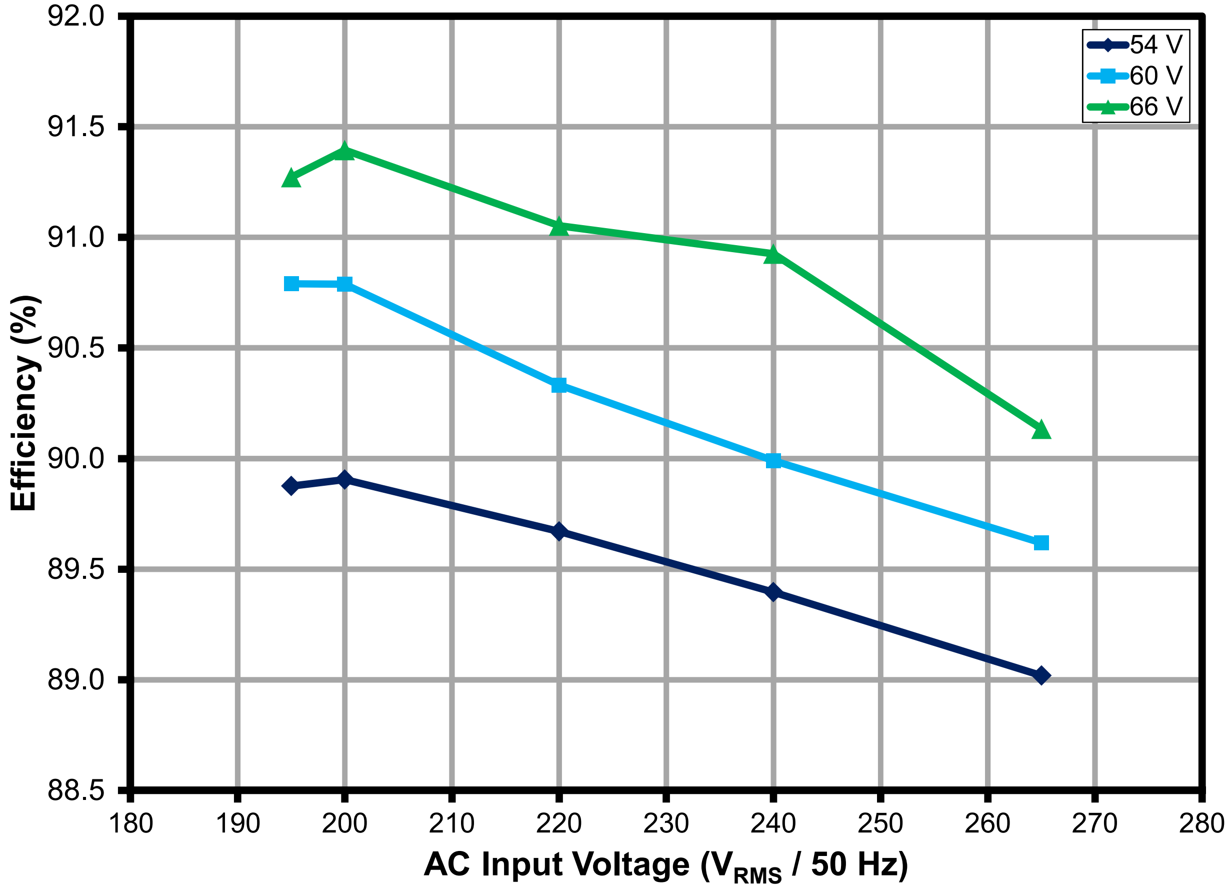

Figure 7 – Efficiency with Respect to AC Input Voltage.

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9.2 Line Regulation

The LinkSwitch-PL device regulates the output by controlling the power MOSFET on-time and switching frequency to maintain the average FEEDBACK pin at its 0.29 V threshold. Slight changes in output current may be observed when input or output conditions are changed or after AC cycling due to the device selecting a slightly different operating state (selection of on-time and frequency).

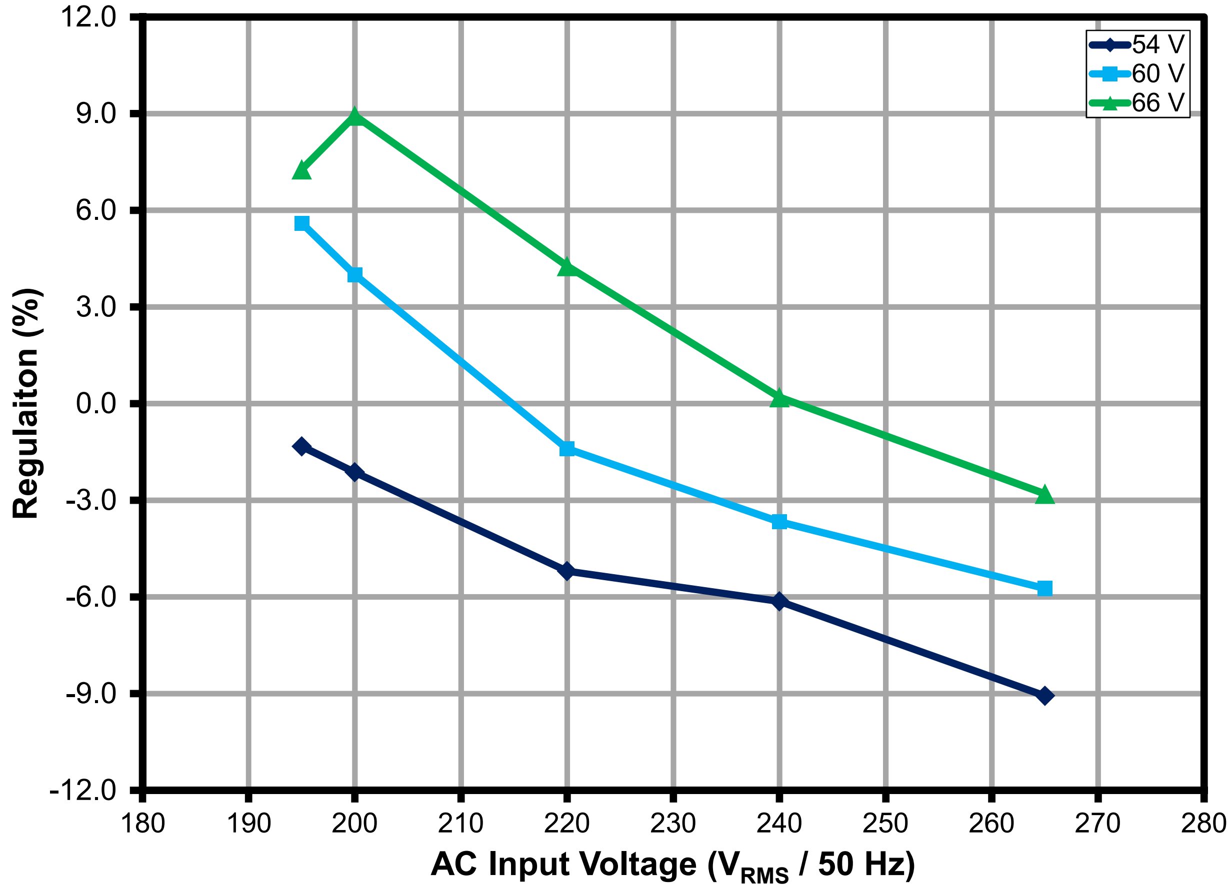

Figure 8 – Line Regulation, Room Temperature.

9.3 Power Factor

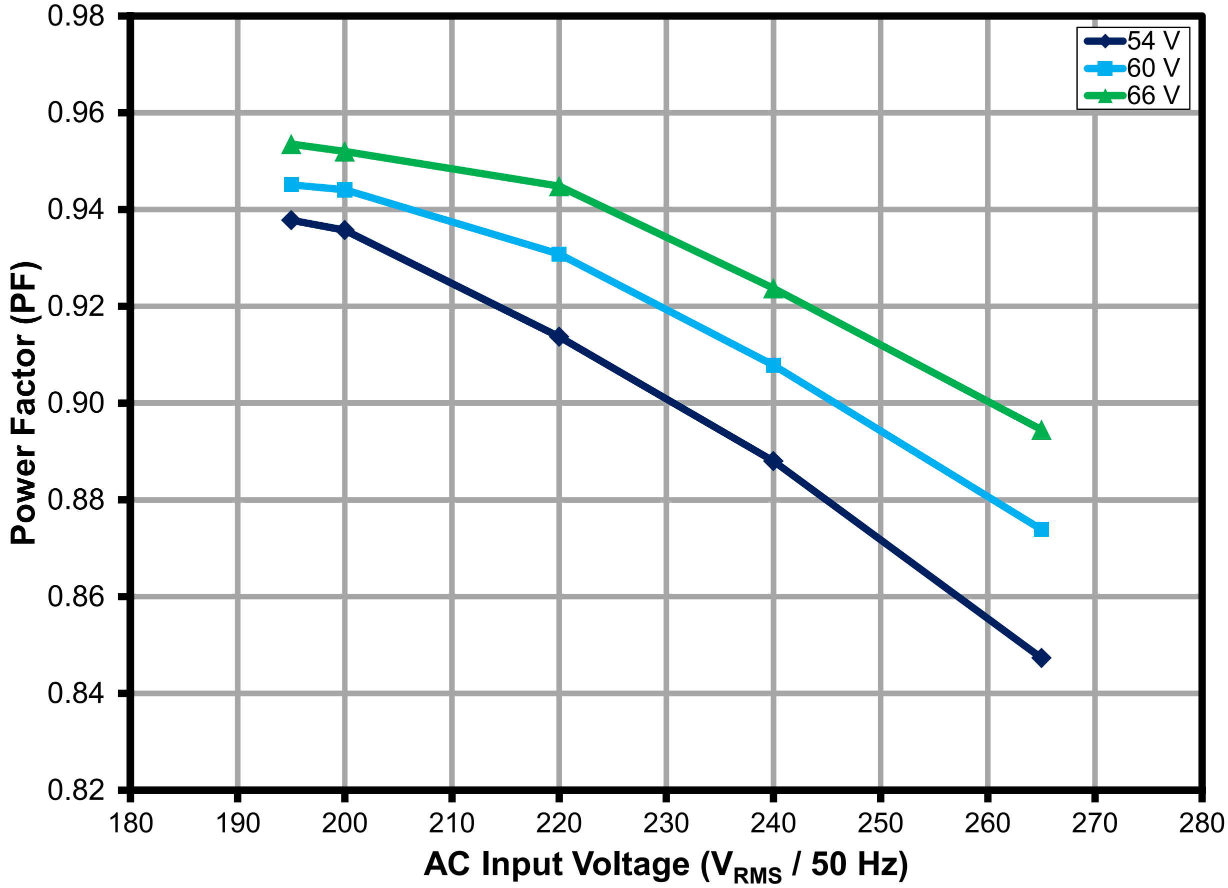

Figure 9 – High Power Factor within the Operating Range.

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9.4 %ATHD

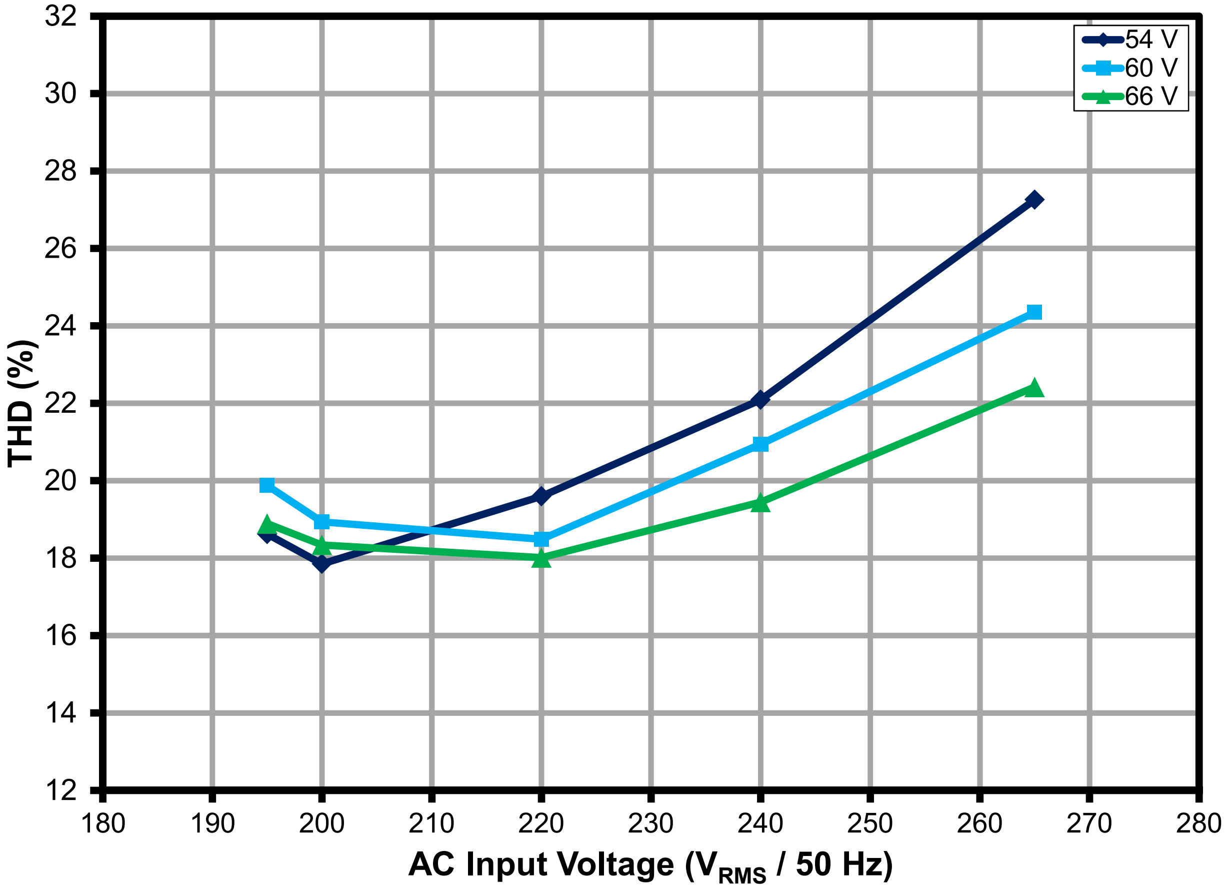

Figure 10 – Very Low %ATHD at 220 VAC.

9.5 Harmonic Content

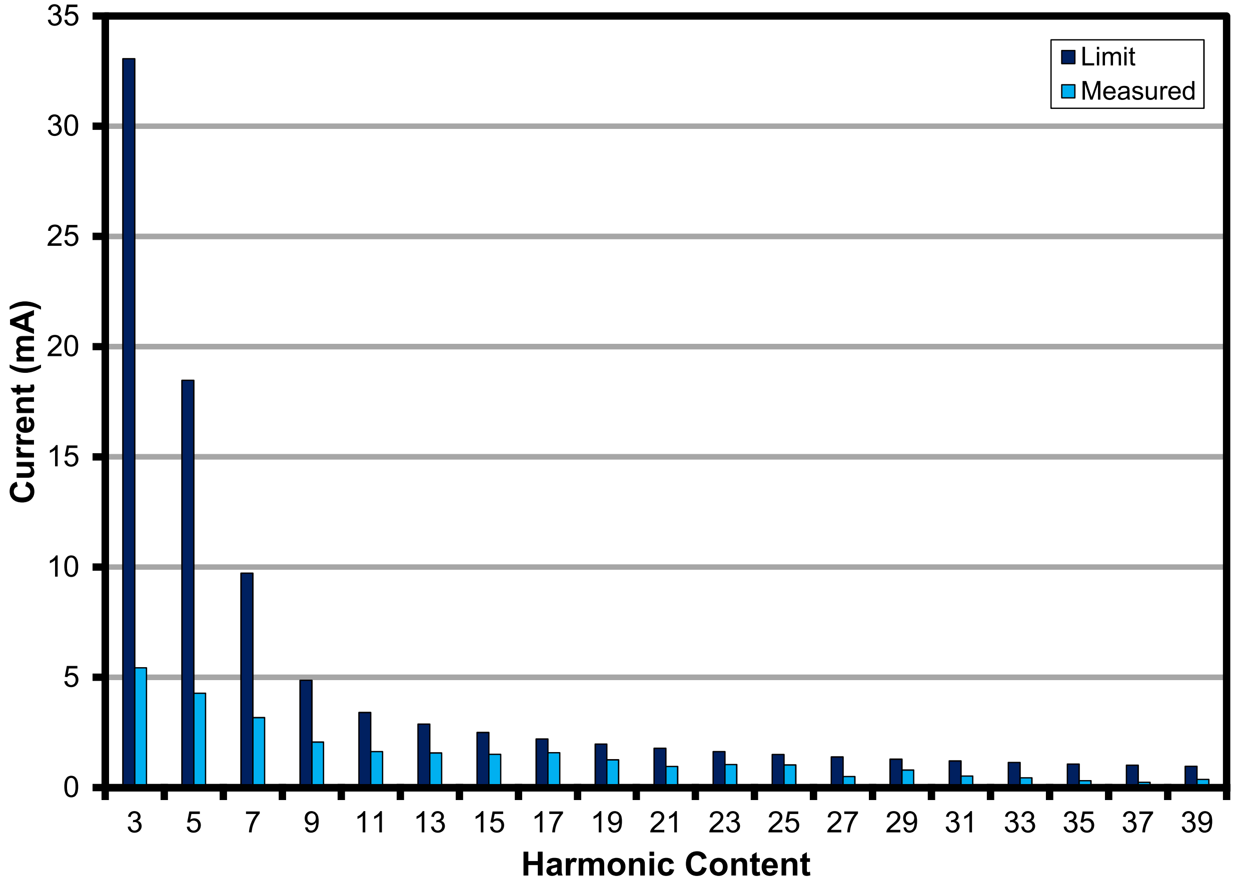

Figure 11 – Meets EN61000-3-2 Harmonics Contents Standards for <25 W Rating for 60 V LED Output.

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9.6 Harmonic Measurements

VAC (V_{RMS})	Freq (Hz)	I (mA)	P (W)	PF
230	50.00	47.73	9.14	0.925
nth Order	**mA Content**	**% Content**	**Limit (mA) <25 W**	**Remarks**
1	46.37			
2	0.04	0.09%		
3	5.58	12.02%	34.5100	Pass
5	4.23	9.11%	19.2850	Pass
7	3.27	7.05%	10.1500	Pass
9	1.99	4.30%	5.0750	Pass
11	1.79	3.86%	3.5525	Pass
13	1.37	2.95%	3.0060	Pass
15	1.79	3.86%	2.6052	Pass
17	1.52	3.28%	2.2987	Pass
19	1.33	2.86%	2.0567	Pass
21	1.08	2.34%	1.8608	Pass
23	1.06	2.29%	1.6990	Pass
25	0.88	1.89%	1.5631	Pass
27	0.86	1.85%	1.4473	Pass
29	0.69	1.49%	1.3475	Pass
31	0.73	1.57%	1.2606	Pass
33	0.38	0.82%	1.1842	Pass
35	0.32	0.69%	1.1165	Pass
37	0.55	1.18%	1.0561	Pass
39	0.24	0.52%	1.0020	Pass
41	0.36	0.77%		
43	0.35	0.75%		
45	0.21	0.45%		
47	0.28	0.61%		
49	0.29	0.63%		

Table 1 – 230 VAC Input Current Harmonic Measurement for 60 V LED.

9.7 Thermal Performance

9.8 Thermal Scans

The scan is conducted at ambient temperature of 25 ºC open frame, 195 VAC / 50 Hz input.

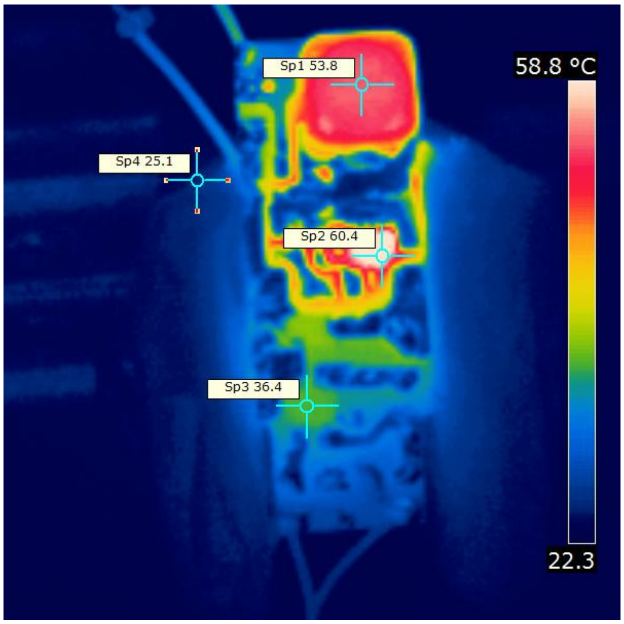

Figure 12 – SP1 – L2; Output Inductor.
SP2 – U1; LNK457DG Case Temperature.
SP3 – BR1; Bridge Case Temperature.
SP4 – Ambient Temperature.

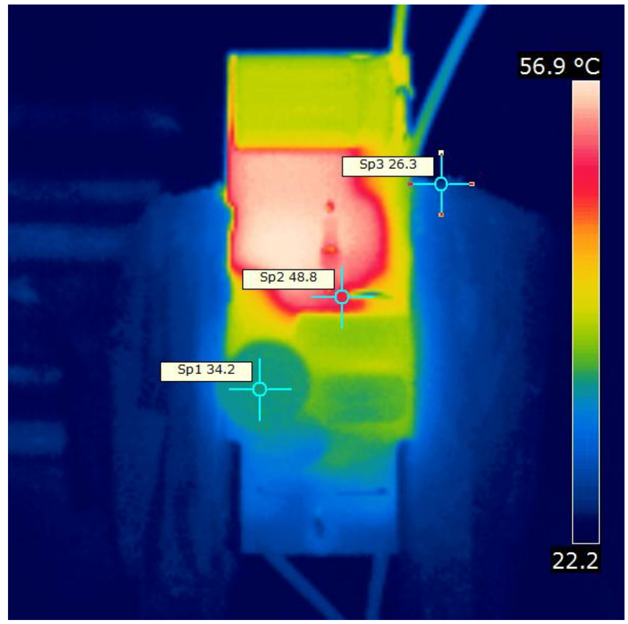

Figure 13 – SP1 – L1; Differential Choke Temperature.
SP2 – D1; Catch Diode Temperature.
SP3 – Ambient Temperature.

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10 Waveforms

10.1 Drain Voltage and Current, Normal Operation

No saturation in the inductor and design guaranteed to work in discontinuous mode within the operating input voltage.

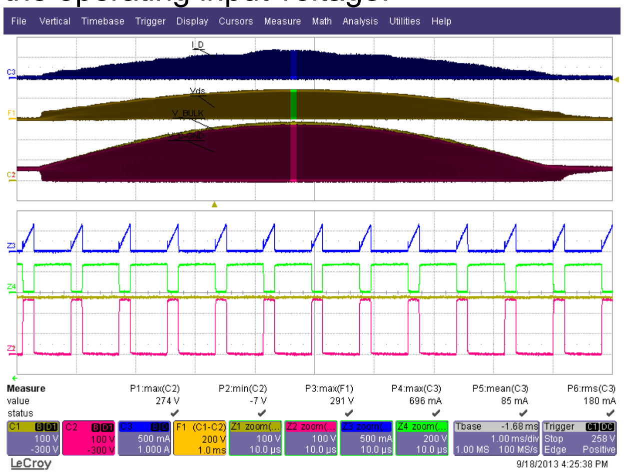

Figure 14 – 195 VAC / 50 Hz, 60 V LED String.
Ch1: V_{BULK}, 100 V / div.
Ch2: $V_{S\text{-}G}$, 100 V / div.
Ch3: I_{DRAIN}, 0.5 A / div.
F1: $V_{D\text{-}S}$, 200 V / div.
Time Scale: 1 ms / div.
Zoom Time Scale: 10 µs / div.

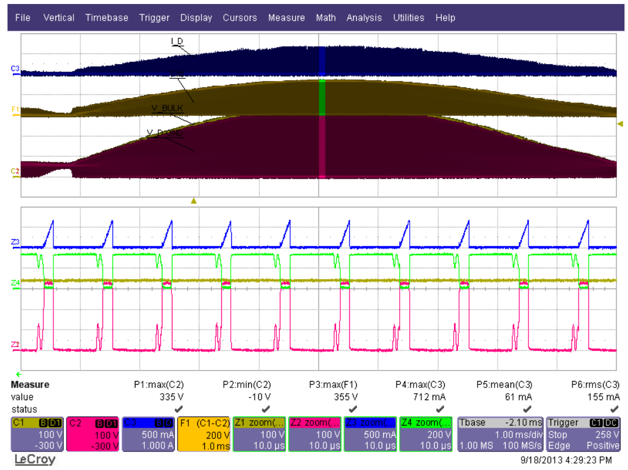

Figure 15 – 240 VAC / 50 Hz, 60 V LED String.
Ch1: V_{BULK}, 100 V / div.
Ch2: $V_{S\text{-}G}$, 100 V / div.
Ch3: I_{DRAIN}, 0.5 A / div.
F1: $V_{D\text{-}S}$, 200 V / div.
Time Scale: 1 ms / div.
Zoom Time Scale: 10 µs / div.

10.2 Drain Voltage and Current Start-up Profile

Device has a built in soft-start thereby reducing the stress in the device, transformer and output diode.

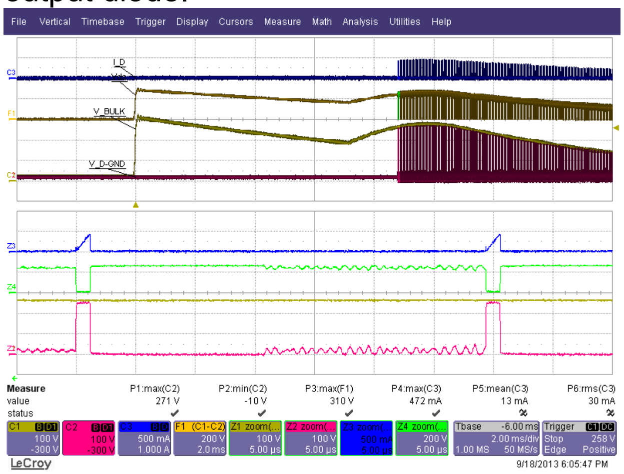

Figure 16 – 195 VAC / 50 Hz, 60 V LED String.
Ch1, Z1: V_{BULK}, 100 V / div.
Ch2, Z2: V_{S-G}, 100 V / div.
Ch3, Z3: I_{DRAIN}, 0.5 A / div.
F1: V_{D-S}, 200 V / div.
Time Scale: 2 ms / div.
Zoom Time Scale: 5 μs / div

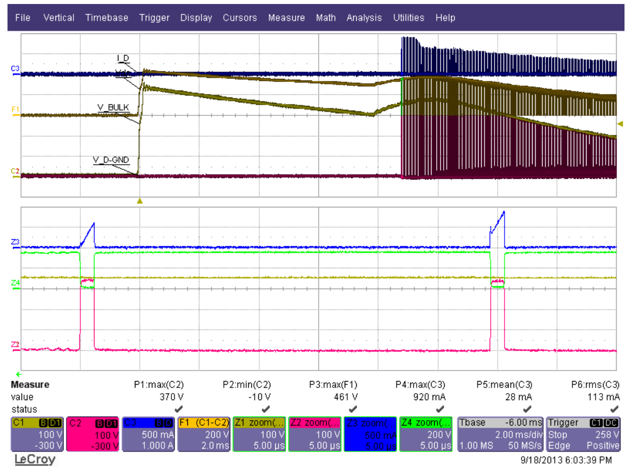

Figure 17 – 195 VAC / 50 Hz, 60 V LED String.
Ch1, Z1: V_{BULK}, 100 V / div.
Ch2, Z2: V_{S-G}, 100 V / div.
Ch3, Z3: I_{DRAIN}, 0.5 A / div.
F1: V_{D-S}, 200 V / div.
Time Scale: 2 ms / div.
Zoom Time Scale: 5 μs / div

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10.3 *Output Voltage Start-up Profile*

Start-up time <50 ms; the reference design will emit light within 50 ms at non-dimming operation.

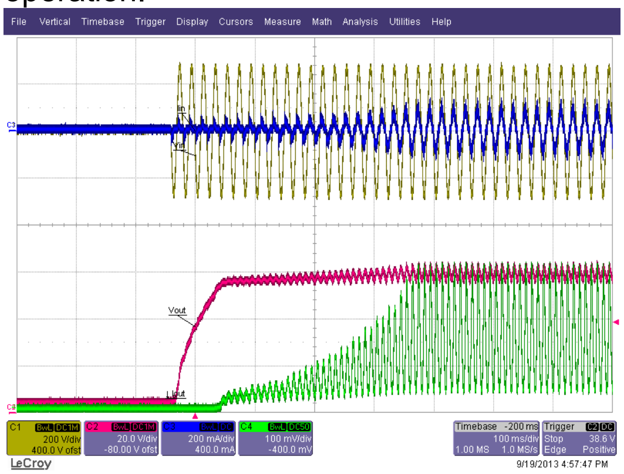

Figure 18 – 195 VAC / 50 Hz, 60 V LED.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 100 mA / div., 100 ms / div.

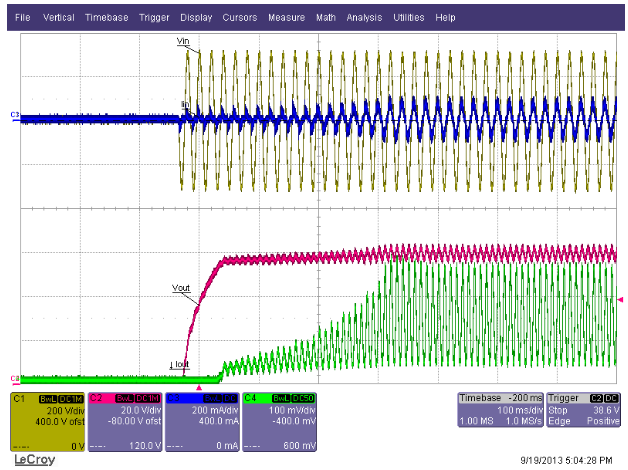

Figure 19 – 220 VAC / 50 Hz, 60 V LED.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 100 mA / div., 100 ms / div.

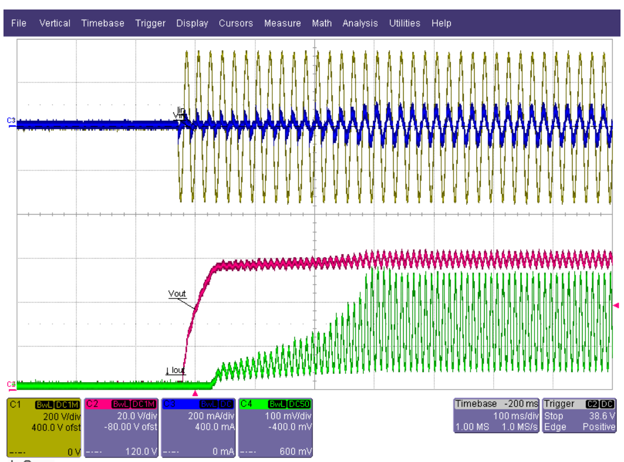

Figure 20 – 240 VAC / 50 Hz, 60 V LED.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 100 mA / div., 100 ms / div.

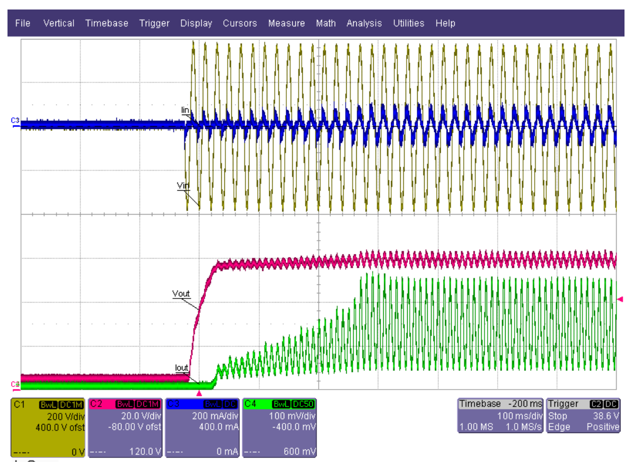

Figure 21 – 265 VAC / 50 Hz, 60 V LED.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 100 mA / div., 100 ms / div.

10.4 Input and Output Voltage and Current Profiles

Output current ripple is inversely proportional to the impedance of the LED. Verify the current ripple on the actual LED to be used in the system. Increase output capacitance for less output current ripple.

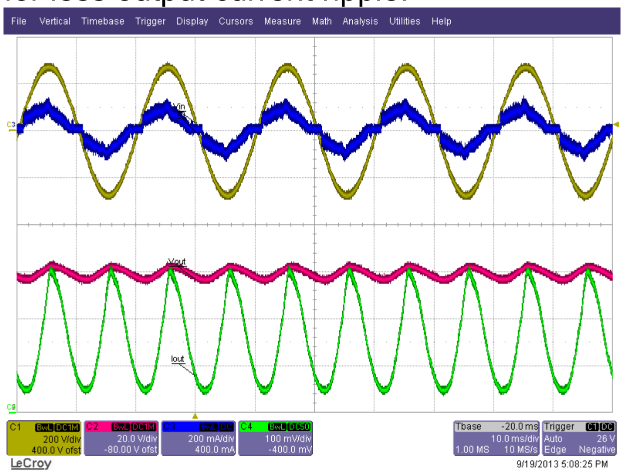

Figure 22 – 195 VAC / 50 Hz, 60 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 100 mA / div., 10 ms / div.

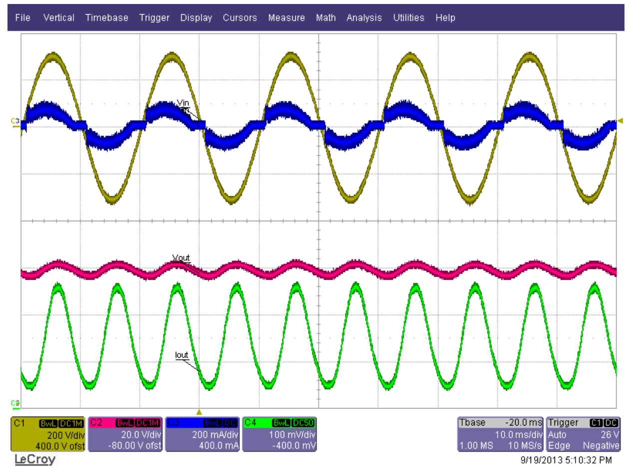

Figure 23 – 220 VAC / 50 Hz, 60 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 100 mA / div., 10 ms / div..

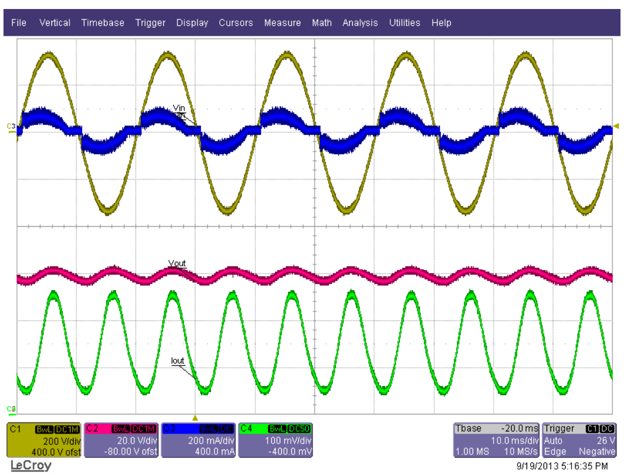

Figure 24 – 240 VAC / 50 Hz, 60 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 100 mA / div., 10 ms / div.

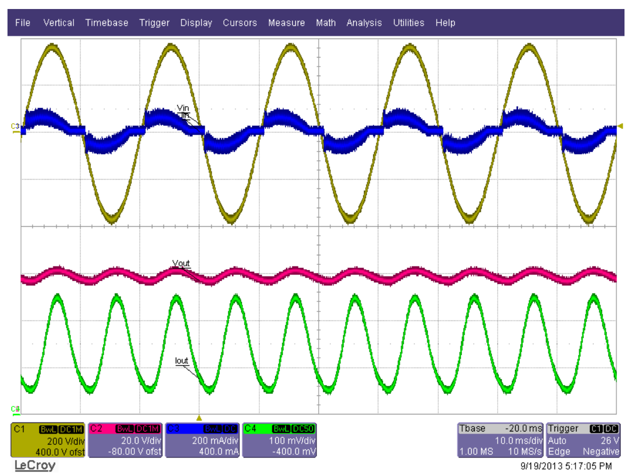

Figure 25 – 265 VAC / 50 Hz, 60 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 100 mA / div., 10 ms / div..

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10.5 Drain Voltage and Current Profile: Normal Operation to Output Short

No saturation in the inductor during short-circuit, inductor current is limited by the I_{LIM}.

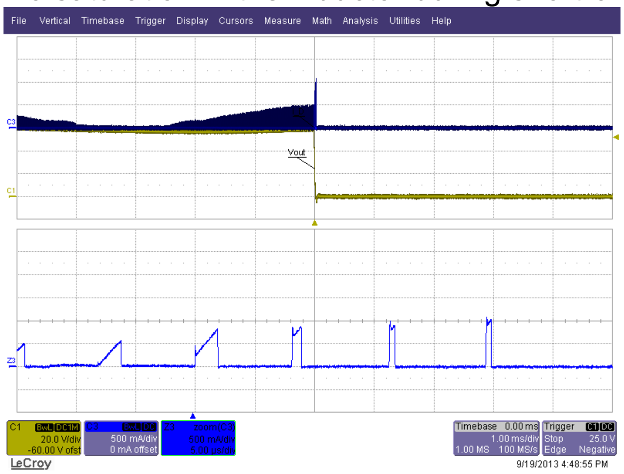

Figure 26 – 195 VAC / 50 Hz, Normal Operation then Output Short.
Ch1: V_{OUT}, 20 V / div.
Ch3: I_{DRAIN}, 0.5 A / div., 1 ms / div.
Z3: I_{DRAIN}, 0.5A / div., 5 μs / div.

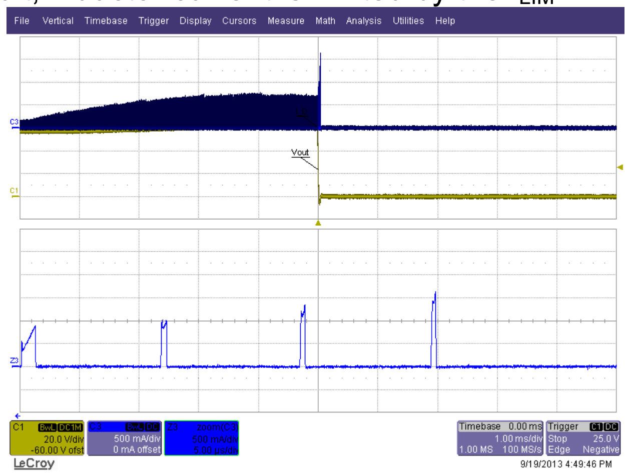

Figure 27 – 265 VAC / 50 Hz, Normal Operation then Output Short.
Ch1: V_{OUT}, 20 V / div.
Ch3: I_{DRAIN}, 0.5 A / div., 1 ms / div.
Z3: I_{DRAIN}, 0.5A / div., 5 μs / div.

10.6 Drain Voltage and Current Profile: Start-up with Output Shorted

No saturation in the inductor during start-up short-circuit due to the built-in soft-start.

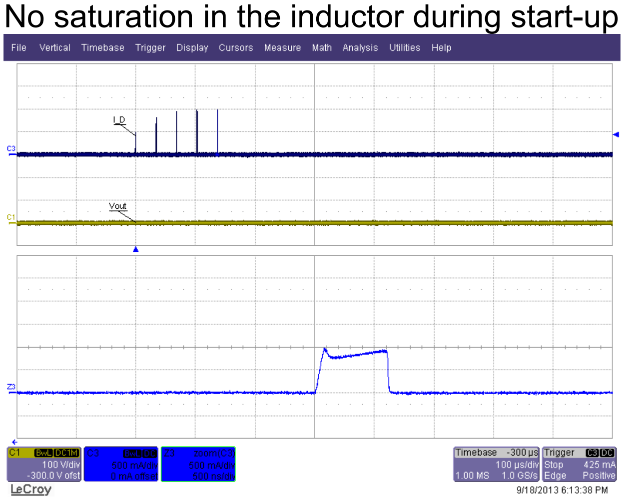

Figure 28 – 195 VAC / 50 Hz, Output Shorted.
Ch1: V_{OUT}, 100 V / div.
Ch3: I_{DRAIN}, 0.5 A / div, 100 μs / div.
Z3: I_{DRAIN}, 0.5 A / div., 500 ns / div.

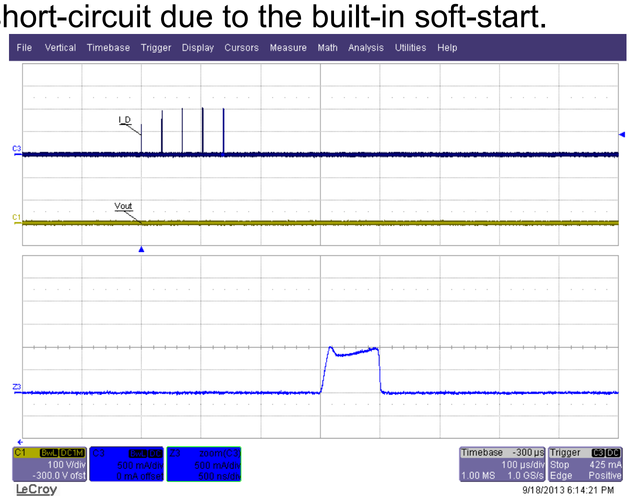

Figure 29 – 265 VAC / 50 Hz, Output Shorted.
Ch1: V_{OUT}, 100 V / div.
Ch3: I_{DRAIN}, 0.5 A / div, 10o μs / div.
Z3: I_{DRAIN}, 0.5 A / div., 500 ns / div..

10.7 No-Load Operation

One shot no-load protection. Replace VR1 after fault condition.

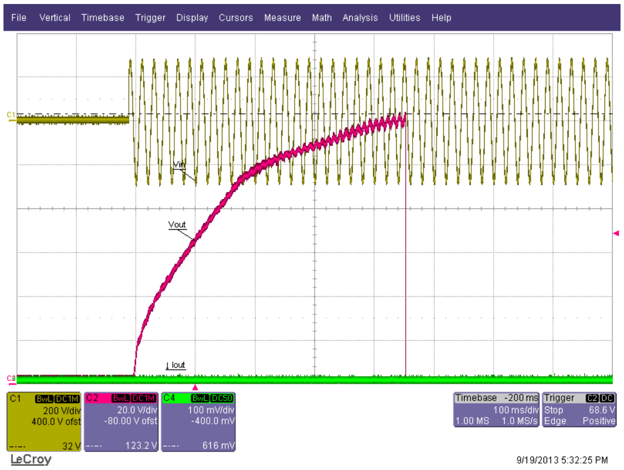

Figure 30 – 195 VAC / 50 Hz, Start-up No-load.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 0.1 A / div.
Time Scale: 100 ms / div.

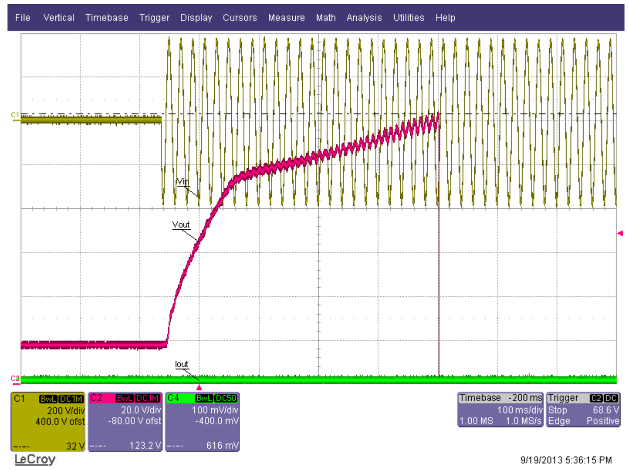

Figure 31 – 265 VAC / 50 Hz, Start-up No-load.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 0.1 A / div.
Time Scale: 100 ms / div.

Figure 32 – 195 VAC / 50 Hz, Normal Running then No-load.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 0.1 A / div.
Time Scale: 100 ms / div.

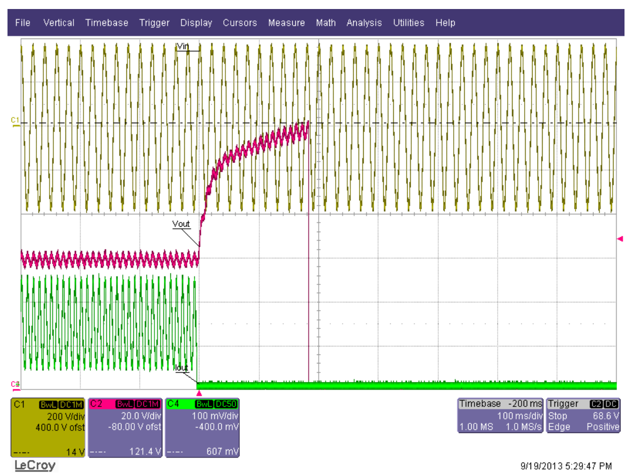

Figure 33 – 265 VAC / 50 Hz, Normal Running then No-load.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 0.1 A / div.
Time Scale: 100 ms / div.

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10.8 AC Cycling

The reference design has no perceptible delay.

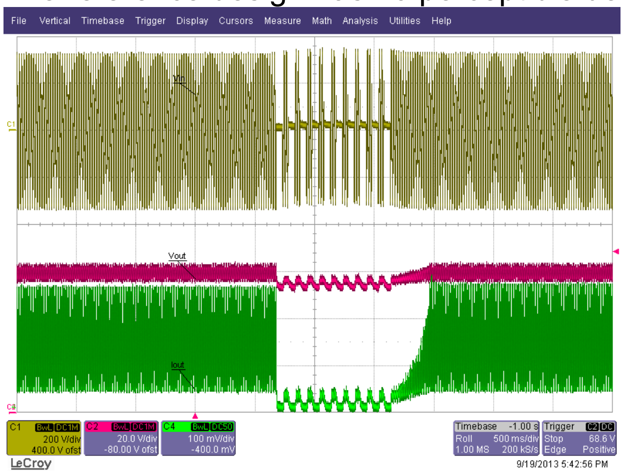

Figure 34 – 230 VAC / 50 Hz,
50 ms On – 50 ms Off.
Load: 60 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 500 ms / div.

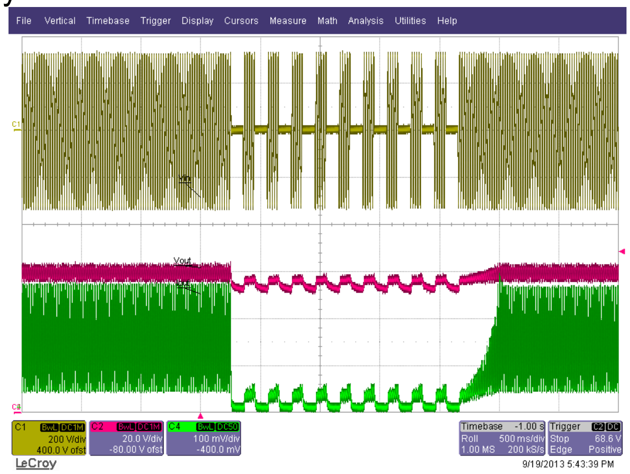

Figure 35 – 230 VAC / 50 Hz,
100 ms On – 100 ms Off.
Load: 60 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 500 ms / div.

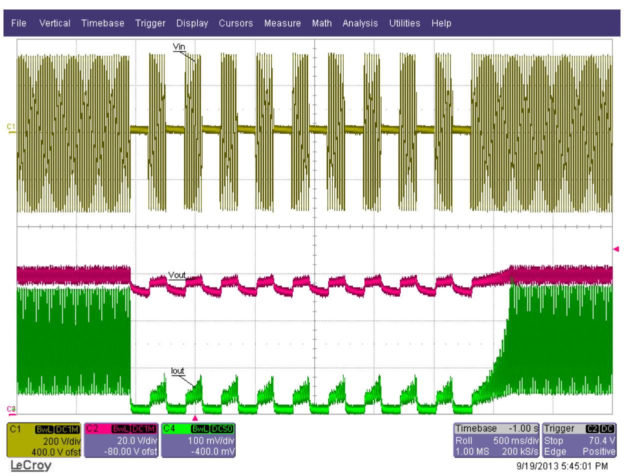

Figure 36 – 230 VAC / 50 Hz,
150 ms On – 150 ms Off.
Load: 60 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 500 ms / div.

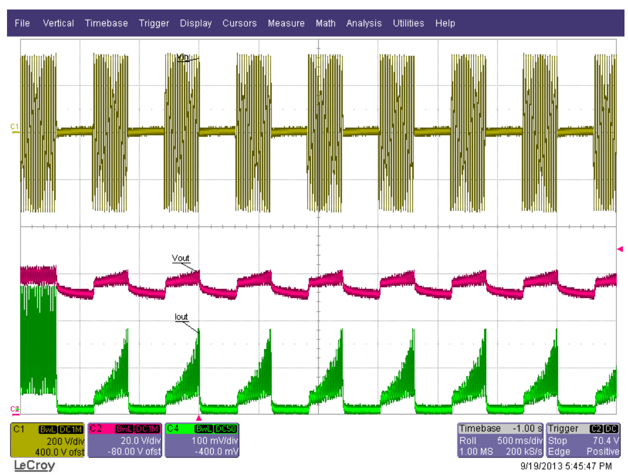

Figure 37 – 230 VAC / 50 Hz,
300 ms On – 300 ms Off.
Load: 60 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 500 ms / div.

10.9 Brown-out

No device failure during the test. UUT operates normally within operating input voltage range.

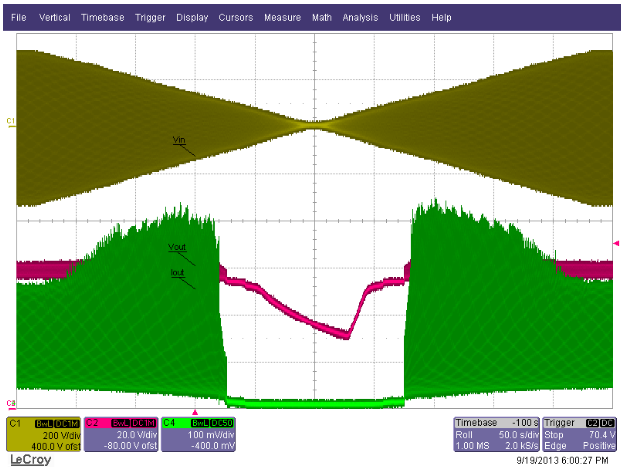

Figure 38 – 230 VAC / 50 Hz,1 V / s Slew Rate.
Load: 60 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 50 s / div.

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10.10 Line Surge

Input voltage was set at 230 VAC / 60 Hz. Output was loaded with 60 V LED string and operation was verified following each surge event.

Differential input line 1.2 / 50 μs surge testing was completed on one test unit to IEC61000-4-5.

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+500	230	L to N	0	Pass
-500	230	L to N	270	Pass
+500	230	L to N	90	Pass
-500	230	L to N	180	Pass

Differential input line ring surge testing was completed on one test unit to IEC61000-4-5.

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	270	Pass
+2500	230	L to N	90	Pass
-2500	230	L to N	180	Pass

Unit operated normally under all test conditions.

11 Conducted EMI

11.1 Equipment

Receiver:

Rohde & Schwartz
ESPI - Test Receiver (9 kHz – 3 GHz)
Model No: ESPI3

LISN:

Rohde & Schwartz
Two-Line-V-Network
Model No: ENV216

11.2 EMI Test Set-up

The LED driver is placed in a conical metal housing (for self-ballasted lamps; CISPR15 Edition 7.2).

Figure 39 – Conducted Emissions Measurement Set-up.

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11.3 EMI Test Result

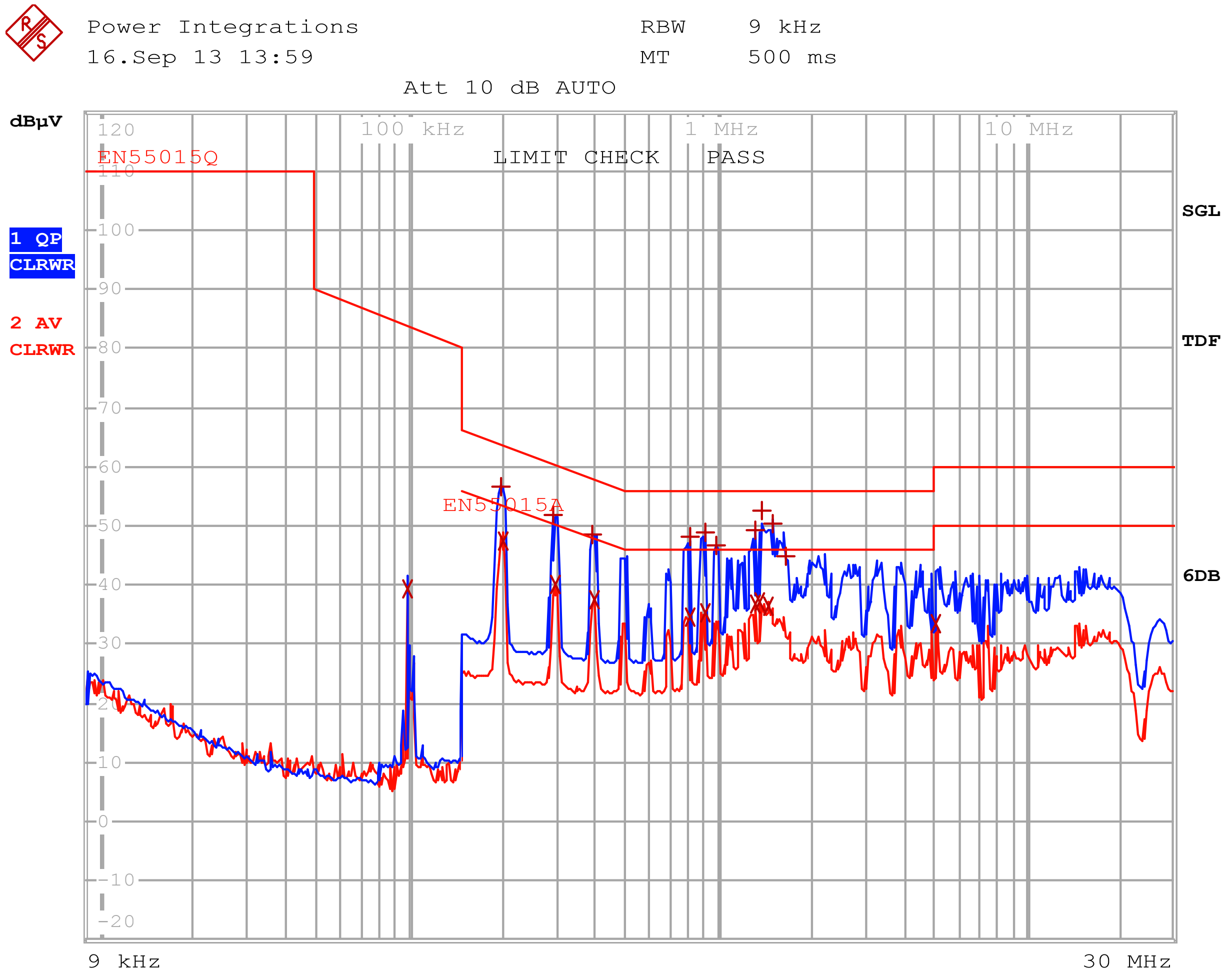

Figure 40 – Conducted EMI, 60 V Output / 150 mA Steady-State Load, 230 VAC, 60 Hz, and EN55015 Limits.

EDIT PEAK LIST (Final Measurement Results)					
Trace1:		EN55015Q			
Trace2:		EN55015A			
Trace3:		---			
TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	99.0133127137 kHz	39.20	L1 gnd	
1	Quasi Peak	196.231331718 kHz	56.71	L1 gnd	-7.05
2	Average	200.175581485 kHz	47.55	L1 gnd	-6.04
1	Quasi Peak	292.161713188 kHz	51.74	L1 gnd	-8.71
2	Average	298.034163623 kHz	40.09	L1 gnd	-10.19
1	Quasi Peak	389.890938834 kHz	48.52	N gnd	-9.54
2	Average	393.789848222 kHz	37.68	L1 gnd	-10.29
1	Quasi Peak	806.126927408 kHz	47.99	N gnd	-8.00
2	Average	806.126927408 kHz	34.40	N gnd	-11.59
1	Quasi Peak	908.363999266 kHz	49.07	N gnd	-6.92
2	Average	908.363999266 kHz	35.32	L1 gnd	-10.67
1	Quasi Peak	983.628047757 kHz	46.57	N gnd	-9.42
1	Quasi Peak	1.31265544283 MHz	49.15	N gnd	-6.84
2	Average	1.31265544283 MHz	36.65	L1 gnd	-9.34
2	Average	1.36595451756 MHz	37.14	L1 gnd	-8.85
1	Quasi Peak	1.37961406273 MHz	52.43	L1 gnd	-3.56
2	Average	1.46448812765 MHz	36.52	L1 gnd	-9.47
1	Quasi Peak	1.49392433901 MHz	50.23	N gnd	-5.76
1	Quasi Peak	1.66672409735 MHz	44.78	N gnd	-11.21
2	Average	5.02963192899 MHz	33.42	N gnd	-16.57

Figure 41 – Conducted EMI, 60 V / 150 mA Steady-State Load Steady-State Load, 230 VAC, 60 Hz, and EN55015 Limits. Line and Neutral Scan Design Margin Measurement.

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12 Revision History

Date	Author	Revision	Description and Changes	Reviewed
05-Dec-13	JDC	1.0	Initial Release	Apps & Mktg

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

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