Design Example Report

Title	***8.5 W Power Factor Corrected TRIAC Dimmable Non-Isolated Buck-Boost; Lossless Bleeder and Turn-off Circuit LED Driver Using LYTSwitch™-4 LYT4322E***
Specification	190 VAC – 265 VAC Input; 72 V (Typical), 115 mA Output
Application	A19 Lamp Replacement
Author	Applications Engineering Department
Document Number	DER-409
Date	April 23, 2014
Revision	1.0

Summary and Features

- Lossless bleeder
- Programmed turnoff to avoid shimmer
- Single-stage, power factor corrected and accurate constant current (CC) output
- Low cost, low component count and small PCB footprint solution
- Highly energy efficient
  - >84% at 220 VAC input
  - PF >0.9 at 230 VAC
  - ATHD <28% at 230 VAC
- Fast start-up time (<300 ms) – no perceptible delay
- Integrated protection and reliability features
  - No-load protection
  - Hard short-circuit protected
  - Auto-recovering thermal shutdown
  - No damage during line brown-out or brown-in conditions
- Meets IEC 2.5 kV ring wave, 500 V differential line surge and EN55015 conducted EMI

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Table of Contents

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.

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1 Introduction

This document describes a cost effective LED dimmable power supply driver utilizing the LYTSwitch^{TM}-4 family (LYT4322E) in a highly compact buck-boost topology. The board is designed in a single sided printed circuit board (PCB) for manufacturability in a single process wave soldering and cost effective PCB.

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.

The DER-409 provides a single 8 W constant current output of 115 mA at 72 V nominal LED voltage.

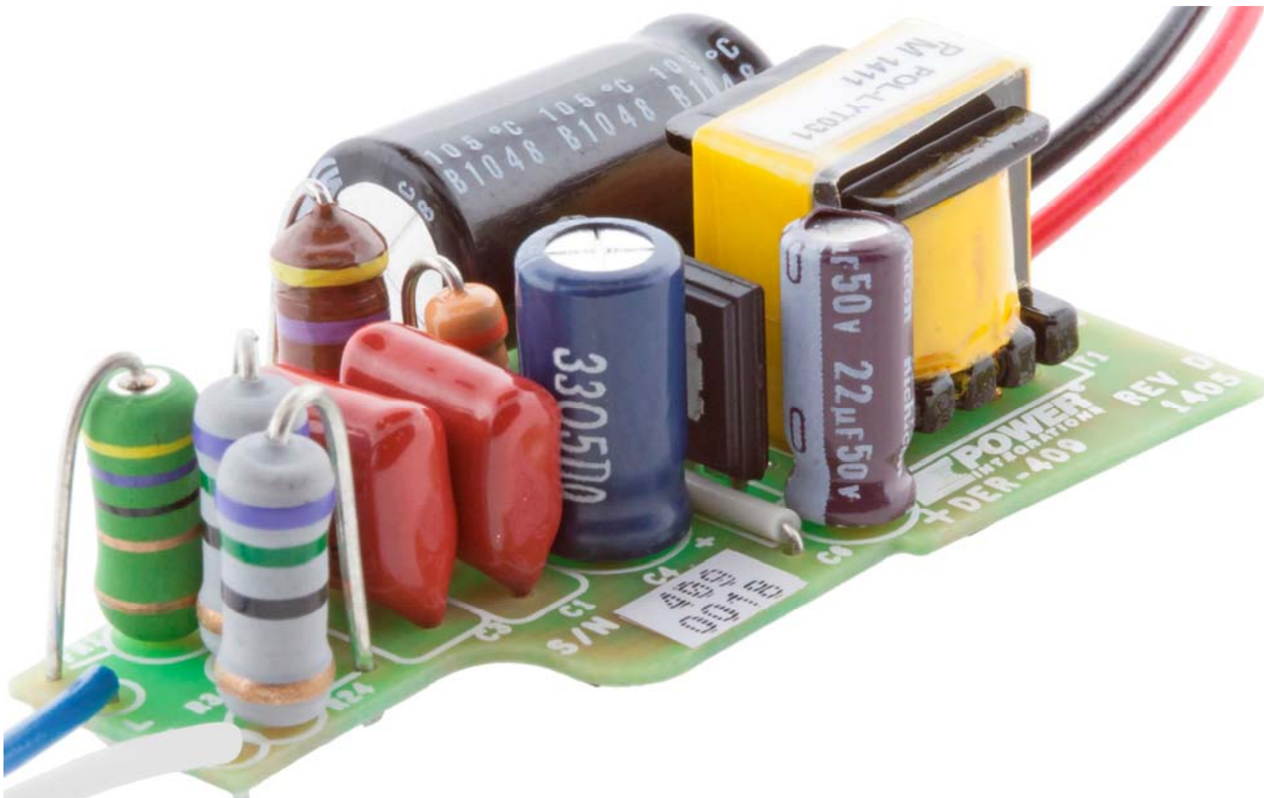

Figure 1 – PCB Assembly.

The board was optimized to operate over the high-line AC input voltage range (195 VAC to 265 VAC, 47 Hz to 63 Hz). LYTSwitch-4 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 layout, PIXls 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}	190	230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	63	Hz	
Output						
Output Voltage	V_{OUT}	64	72	80	V	At 230 VAC
Output Current	I_{OUT}		115		mA	
Total Output Power						
Continuous Output Power	P_{OUT}		8.5		W	
Efficiency						
Nominal	η		84		%	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

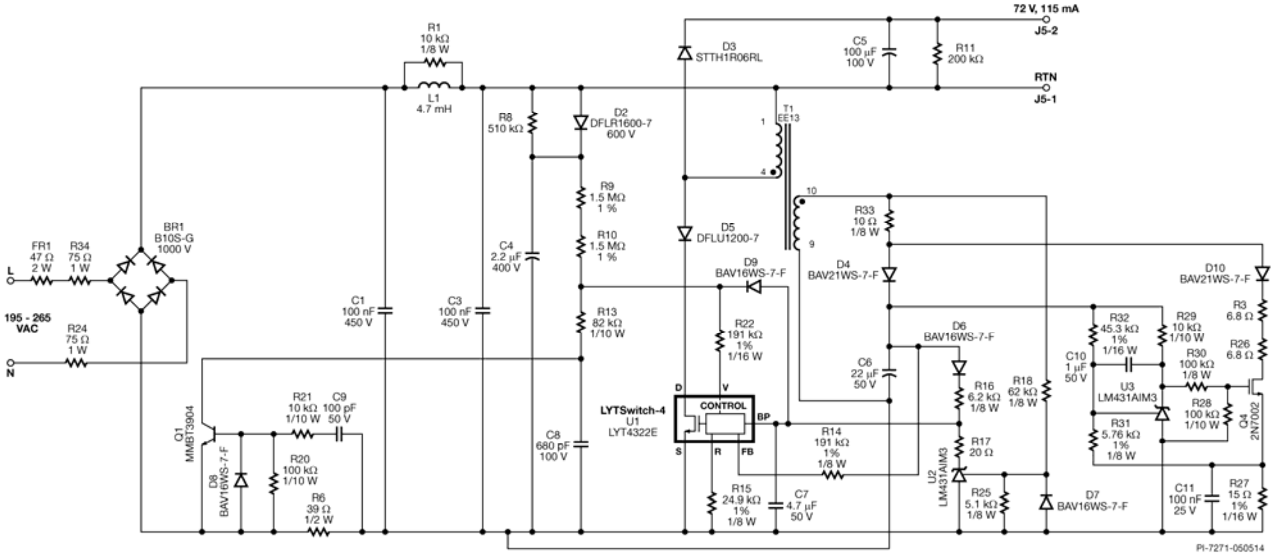

Figure 2 – Schematic for 72 V / 115 mA A19 Replacement Lamp.

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4 Circuit Description

Low cost highly compatible dimmable LED driver power supply uses LYT4322E (U1) in a buck-boost configuration to deliver a constant 115 mA current at an output voltage of 72 VDC. The power supply is designed for non-Isolated driving LEDs, which should always be driven with a constant current (CC). The non-isolated driver requires proper insulation for the driver and the metal housing of retrofit lamp to meet safety compliance.

4.1 Input Stage

Fusible resistor FR1 provides protection against component failure. This fusible resistor resistance helps to aid the damping of the ringing during dimming.

The passive damping resistance and the total effective capacitance is enough to suppress the differential line surges of 500 V and 2.5 kV differential line surge. Add a MOV right after FR1 if greater than 500 V differential line surges will be applied.

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

Capacitor C1, C3 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 LYTSwitch-4 ensures compliance with Class B emission limits. Resistor R1 damp 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 Dimming Compatibility- Active Bleeder, Passive Damper

The compatibility of dimmable LED driver to the majority of high line dimmers in the market is achieved by adding a passive damper and a lossless active bleeder to damp the ringing coming from the leading edge dimmer. This helps to limit the peak input current and ringing to avoid unwanted flicker (TRIAC on and off operation within half line AC cycle). The holding current of major dimmers is achieved based from the proprietary drain current of characteristic of LYTSwitch-4.

Active damper can be used if higher efficiency is needed. Refer to DER-350 (MOSFET active damper) or DER-353 (SCR active damper) for reference.

Using the dynamic characteristic of the V pin of the IC by pulling a time limited proportionate amount of current off it during TRIAC turn on increases power drawn from the input to maintain the TRIAC on satisfying the required latching and holding current of the TRIAC. This is achieved by pumping more current during TRIAC turn-on through the DRAIN pin. The fast response of LYTSwitch-4 via the V pin is utilized to shape the input current, which is controlled through a damper current detection circuit of components R6, C9, R21, R20, D8, Q1 and R13. Resistor R6 is the sense damper resistor that triggers Q1 to pull down the V pin in the initial voltage spike of TRIAC. This forces the IC to deliver more power while V pin is pulled down. Diode D9 and R22 are employed to keep the V pin voltage from dipping <1 V, disabling the Remote ON/OFF feature. The period of peak power is dictated by the time constant of R21 and C9. Diode D8 and R20 resets C9 every AC half-cycle.

4.3 LYTSwitch-4

LYTSwitch-4 ICs are optimized to achieve a simple and cost effective dimmable LED driver with good line and temperature regulation. The LYTSwitch-4 family has built-in thermal limit to protect the power supply in case the bulb is subjected to an excessive operating temperature. Refer to **http://www.powerint.com/sites/default/files/product-docs/lytswitch-4_family_datasheet.pdf** for more detailed information.

The buck-boost converter stage consists of the integrated power MOSFET switch within the LYTSwitch-4 (U1) IC, a freewheeling diode (D3 fast freewheeling diode was selected to minimize switching losses during turn on), power inductor/transformer T1 and output capacitor (C5). The converter is operating mostly in CM in order to minimize the rms loss during conduction time.

The LYTSwitch-4 IC peak detector circuit C4, D2 and R8 provides the analogue information for the input voltage and it suppresses the line surge voltage during line disturbance for meeting IEC 1000-4-5.

The line overvoltage shutdown function extends the rectified line voltage withstand (during surges and line swells) to the 725 BV_{DSS} rating of the internal power MOSFET for high line family.

4.4 Output Feedback

Instead of regulating the output current via a sense resistor, the LYTSwitch-4 IC has a proprietary approach in controlling the output current in order to achieve good efficiency. That is by measuring the equivalent output voltage through the bias winding of T1. The bias winding voltage is used to sense the output voltage indirectly, eliminating secondary side feedback components. The voltage on the bias winding is proportional to the output voltage (set by the turn ratio between the bias and secondary windings).Resistor R14 converts the bias voltage into a current which is fed into the FB pin of U1. The internal engine within U1 combines the FB pin current, the V pin current, and internal drain current information to provide a constant output current while maintaining high input power factor.

4.5 Dimming Turn-off Circuit

Shimmer due to dimmer imbalanced conduction angle and line-induced noise in deep dimming is inevitable below 8 mA output current. The severity of shimmer depends on the degree of the dimmer imbalance conduction angle and the magnitude of the line noise, that is the higher the magnitude the more the shimmer becomes pronounce. A turn-off circuit was introduced to avoid this condition by limiting a 10:1 dimming ratio; the unit is turned off once the output current falls below 10 mA.

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The output current detection relies on the LED voltage drop. During dimming the LED voltage decreases as the output current decreases so the bias auxiliary voltage across C6 also decreases. A tight reference IC LM431 (U3) is used to detect the threshold of the auxiliary voltage (approximately 22 V in this design) to turn-on Q4. Note that U3 is used as a comparator at the same time and guarantees Q4 in off state at normal operation. The threshold is set across the voltage divider of R32 and R31.

Initial state of Q4 is on to avoid shimmer during pop-on. This also bleeds the power from the leakage of dimmer until the peak bleeding current is above 30 mA Q4 is turned-off. The maximum bleeding power is set at R27 which guarantees pop-on output current above 15 mA. C11 is used to average the signal from the switching bleeder.

The bleeder resistor (R3 and R26) is connected before diode D4 to block $I_{FB(AR)}$ during turn-on. Blocking diode (D10) is also used in series with the bleeder resistor to avoid reverse current during forward voltage.

Resistor divider R30 and R28 guarantees below 1 V if cathode of U3 is pulled down. Capacitor C10 limits the bandwidth response to have a smooth transition for Q4.

Tune the circuit with the actual LED load if possible to set the auxiliary threshold correctly.

Pre-load resistor (R11) at the output is needed to guarantee $V_{OUT} < V_{LED}$ due to the leakage of the dimmer. This eliminates possible shimmering from leaky dimmers. Refer to waveforms in section 12.3.3 for illustration of leakage from dimmers.

4.6 Shorted Load and Overload Protection

The part enters auto-restart whenever the FB current falls below the $I_{FB(AR)}$ threshold for longer than the ~76 ms. The load is protected against overload and short-circuits via a primary current limit. During a short, primary current will build-up until it reaches current limit. Refer to short-circuit waveforms for more information.

4.7 No-Load Protection

In the event of no-load operation, the output voltage is regulated at 100 V. The output voltage is detected on the bias winding through the turns ratio of main and the bias winding. Zener regulator U2 will force the BP pin in auto-restart to regulate the output voltage. Divider R25 and R18 sets the overvoltage protection (OVP) threshold. Diode D7 protects U2 from a reverse current when the voltage reverses on bias winding during turn on. R17, the bias resistor and limiting resistor for U2

5 PCB Layout and Outline

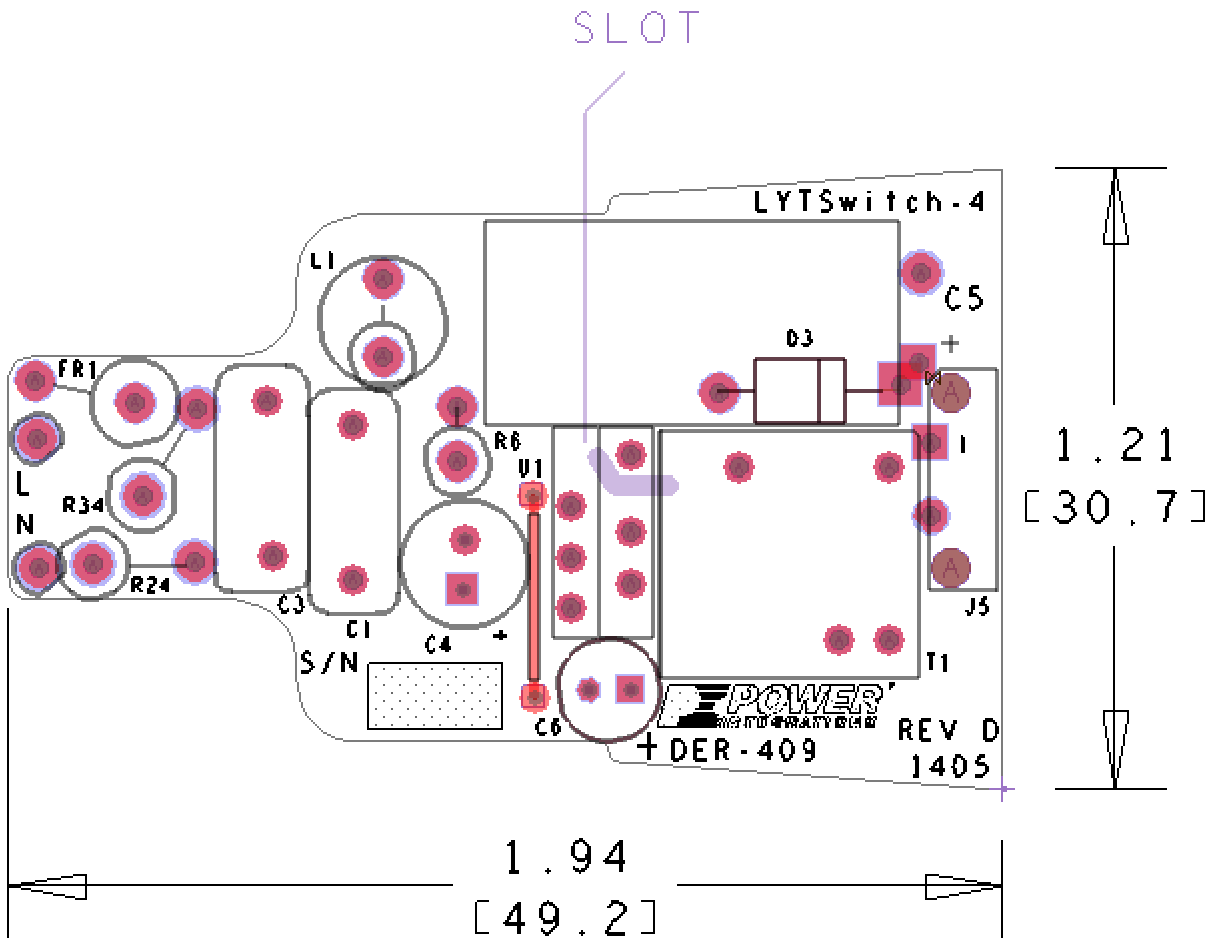

Figure 3 – Top Printed Circuit Layout.

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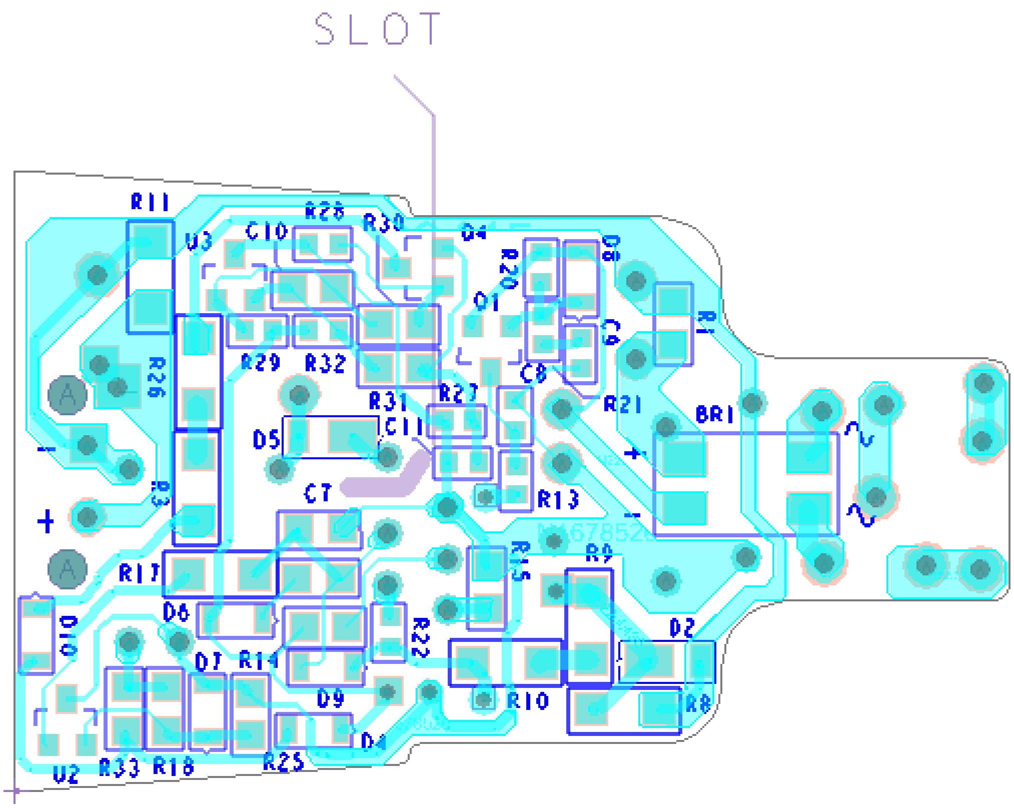

Figure 4 – Bottom Printed Circuit Layout.

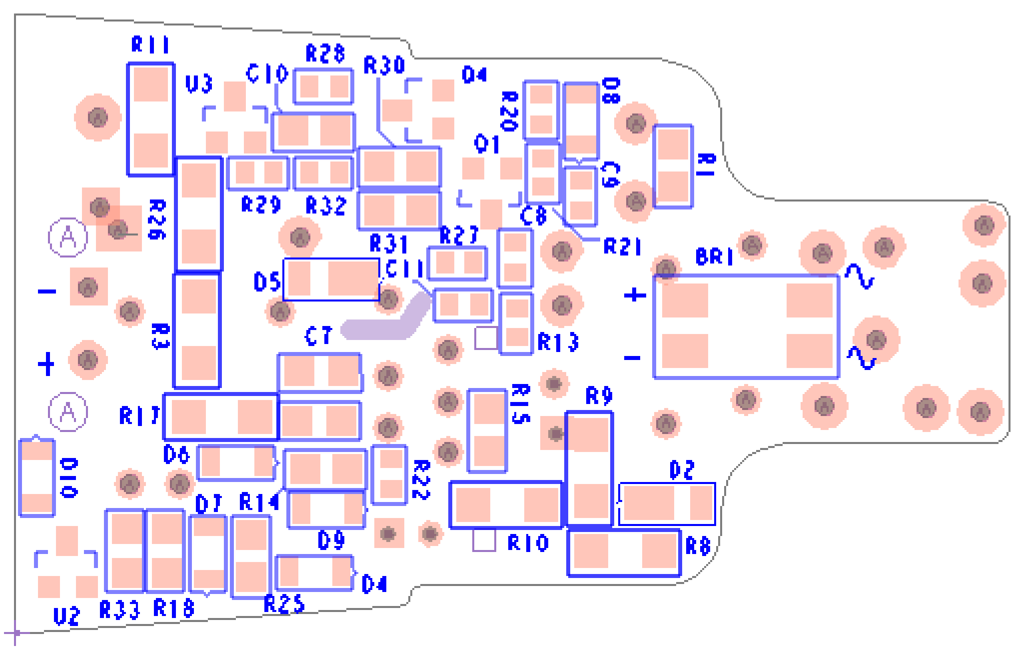

Figure 5 – Bottom Component Legend.

6 Populated PCB

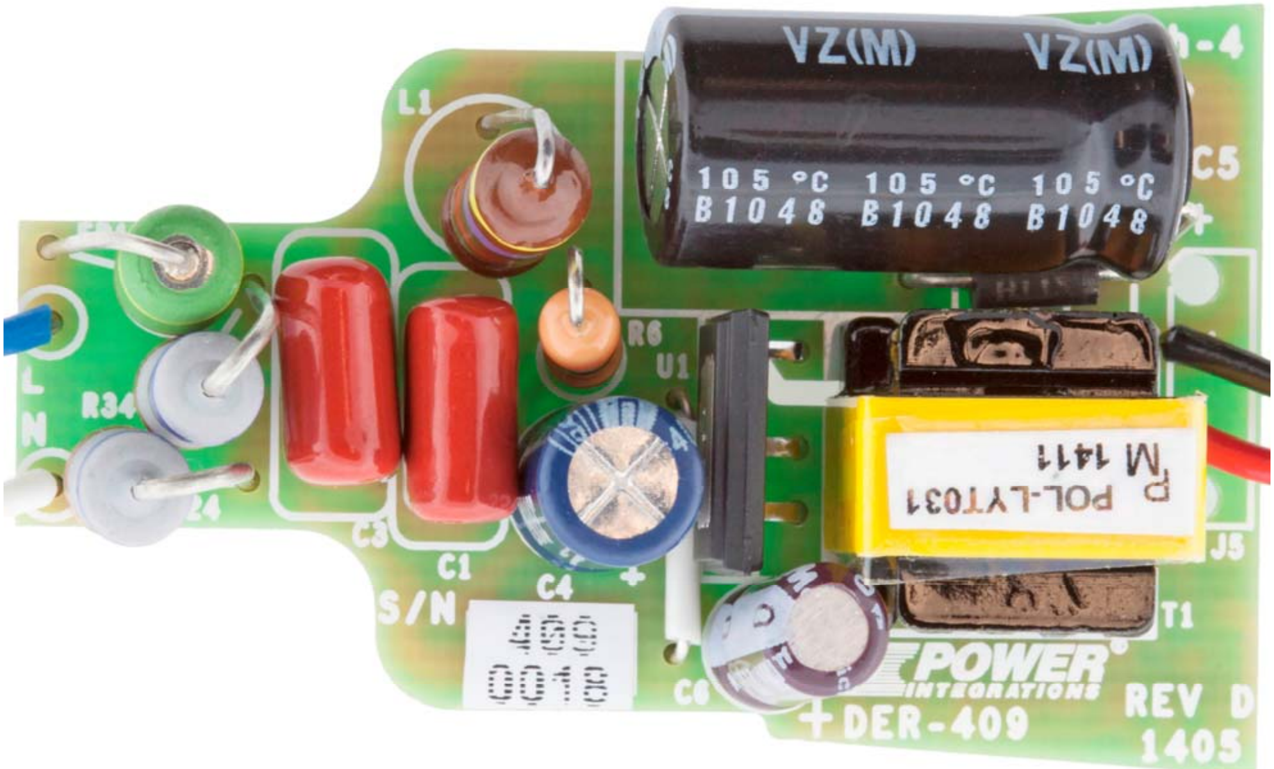

Figure 6 – Populated Circuit Board (Top Side).

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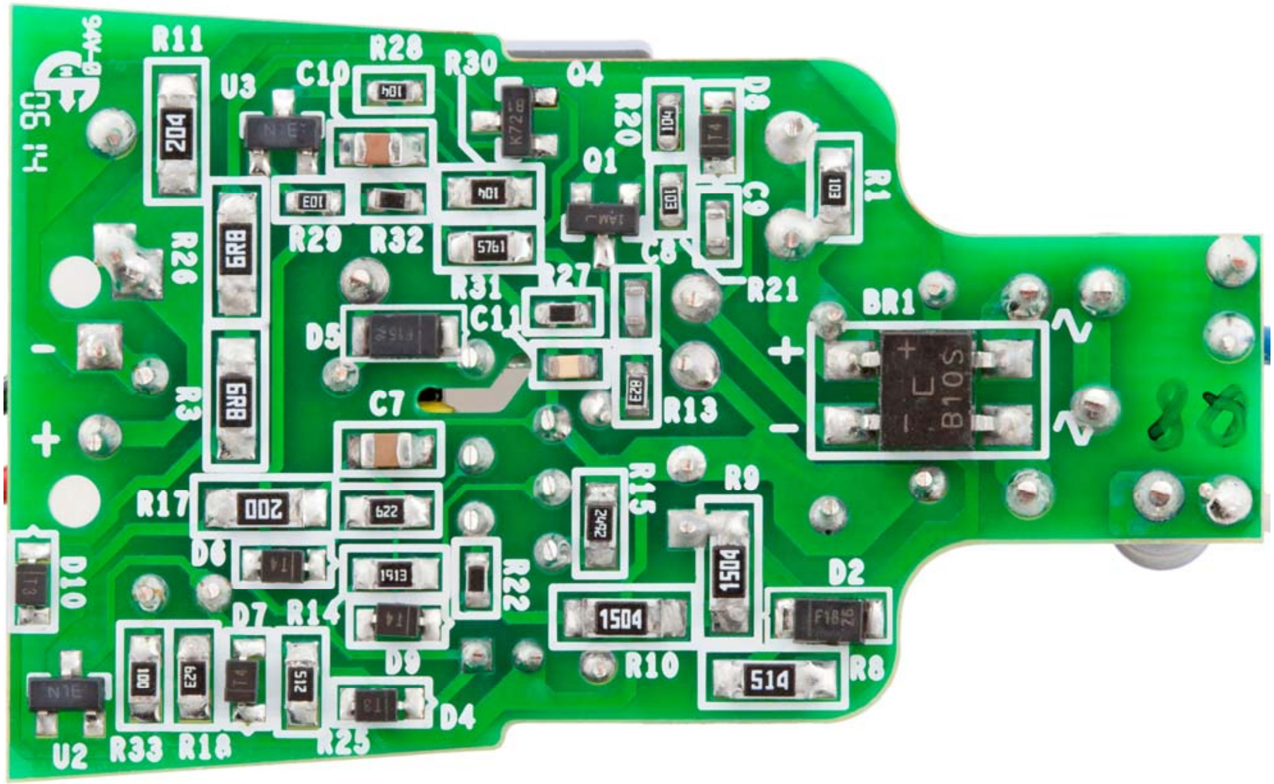

Figure 7 – Populated Circuit Board (Bottom Side).

7 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
1	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip
2	2	C1 C3	100 nF, 450 V, Film	MEXXD31004JJ1	Duratech
3	1	C4	2.2 μF, 400 V, Electrolytic, (6.3 x 11)	TAB2GM2R2E110	Ltec
4	1	C5	100 μF, 100 V, Electrolytic, Gen. Purpose, (10 x 20)	UVZ2A101MPD	Nichicon
5	1	C6	22 μF, 50 V, Electrolytic, (5 x 11)	UPW1H220MDD	Nichicon
6	1	C7	4.7 μF, 50 V, Ceramic, X7R, 0805	CL21A475KBQNNNE	Samsung
7	1	C8	680 pF 100 V, Ceramic, NPO, 0603	CGA3E2C0G2A681J	TDK
8	1	C9	100 pF 50 V, Ceramic, NPO, 0603	CC0603JRNPO9BN101	Yageo
9	1	C10	1 μF, 50 V, Ceramic, X7R, 0805	C2012X7R1H105M	TDK
10	1	C11	100 nF, 25 V, Ceramic, X7R, 0603	VJ0603Y104KNXAO	Vishay
11	1	D2	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
12	1	D3	600 V, 1 A, Ultrafast Recovery, DO-41	STTH1R06RL	ST Micro
13	2	D4 D10	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diode Inc.
14	1	D5	DIODE, Ultrafast, 200 V, 1 A, POWERDI123	DFLU1200-7	Diodes Inc
15	4	D6 D7 D8 D9	75 V, 0.15 A, Switching, SOD-323	BAV16WS-7-F	Diode Inc.
16	1	FR1	47 Ω, 5%, 2 W, Wirewound, Fusible	FW20A47R0JA	Bourns
17	1	L1	4.7 mH, 90 mA, 20 Ω, RF Inductor	B82144A2475J	Epcos
18	1	Q1	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3904LT1G	On Semi
19	1	Q4	60 V, 115 mA, SOT23-3	2N7002-7-F	Diodes, Inc.
20	1	R1	10 k Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
21	2	R3 R26	6.8 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ6R8V	Panasonic
22	1	R6	39 Ω, 5%, 1/2 W, Carbon Film	CFR-50JB-39R	Yageo
23	1	R8	510 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ514V	Panasonic
24	2	R9 R10	1.50 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1504V	Panasonic
25	1	R11	200 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ204V	Panasonic
26	1	R13	82 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ823V	Panasonic
27	1	R14	191 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1913V	Panasonic
28	1	R15	24.9 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF2492V	Panasonic
29	1	R16	6.2 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ622V	Panasonic
30	1	R17	20 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ200V	Panasonic
31	1	R18	62 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ623V	Panasonic
32	2	R20 R28	100 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ104V	Panasonic
33	2	R21 R29	10 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ103V	Panasonic
34	1	R22	191 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1913V	Panasonic
35	2	R24 R34	75 Ω, 5%, 1 W, Metal Oxide	RSF100JB-75R	Yageo
36	1	R25	5.1 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ512V	Panasonic
37	1	R27	15 Ω, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF15R0V	Panasonic
38	1	R30	100 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ104V	Panasonic
39	1	R31	5.76 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF5761V	Panasonic
40	1	R32	45.3 k, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF4532V	Panasonic
41	1	R33	10 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ100V	Panasonic
42	1	T1	Bobbin, EE13, Vertical, 10 pins Transformer Transformer	P-1302-2 SNX-R1733 POL-LYT031	Pin Shine Santronics Premier Magnetics
43	1	U1	LYTSwitch-4, eSIP-7C	LYT4322E	Power Integrations
44	2	U2 U3	IC, REG ZENER SHUNT ADJ SOT-23	LM431AIM3/NOPB	National Semi

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Mechanical Parts					
1	1	WIRE(V-)	Wire, UL1007, #24 AWG, Blk, PVC, 3"	1007-24/7-0	Anixter
2	1	WIRE (L)	Wire, UL1007, #24 AWG, Blu, PVC, 3"	1007-24/7-6	Anixter
3	1	WIRE(V+)	Wire, UL1007, #24 AWG, Red, PVC, 3"	1007-24/7-2	Anixter
4	1	WIRE(N)	Wire, UL1007, #24 AWG, Wht, PVC, 3"	1007-24/7-9	Anixter
5	1	J1	Jumper 10 mm; 0.4 in, insulated		
6	1	PCB	FR4, 0.31, 1 Oz Cu (1.21” X 1.94“)		

8 Transformer Design Spreadsheet

ACDC_LYTSwitch-4_HL_012114; Rev.1.2; Copyright Power Integrations 2014	INPUT	INFO	OUTPUT	UNIT	LYTSwitch-4_HL_012114: Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					
Dimming required	YES		YES		Select 'YES' option if dimming is required. Otherwise select 'NO'.
VACMIN			195	V	Minimum AC Input Voltage
VACMAX			265	V	Maximum AC input voltage
fL			50	Hz	AC Mains Frequency
VO	72		72	V	Typical output voltage of LED string at full load
VO_MAX			79.20	V	Maximum expected LED string Voltage.
VO_MIN			64.80	V	Minimum expected LED string Voltage.
V_OVP			87.12	V	Over-voltage protection setpoint
IO	0.12		0.12	A	Typical full load LED current
PO			8.3	W	Output Power
n	0.85		0.85		Estimated efficiency of operation
VB			25	V	Bias Voltage
ENTER LYTSwitch VARIABLES					
LYTSwitch	LYT4322		LYT4322		Selected LYTSwitch
Current Limit Mode	RED		RED		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN			0.65	A	Minimum current limit
ILIMITMAX			0.76	A	Maximum current limit
fS			132000	Hz	Switching Frequency
fSmin			124000	Hz	Minimum Switching Frequency
fSmax			140000	Hz	Maximum Switching Frequency
IV			86.4	uA	V pin current
RV	3.73		3.73	M-ohms	Upper V pin resistor
RV2			1E+012	M-ohms	Lower V pin resistor
IFB	116		116.0	uA	FB pin current (85 uA < IFB < 210 uA)
RFB1			189.7	k-ohms	FB pin resistor
VDS			10	V	LYTSwitch on-state Drain to Source Voltage
VD			0.50	V	Output Winding Diode Forward Voltage Drop (0.5 V for Schottky and 0.8 V for PN diode)
VDB			0.70	V	Bias Winding Diode Forward Voltage Drop
Key Design Parameters					
KP	1.04		1.04		Ripple to Peak Current Ratio (For PF > 0.9, 0.4 < KP < 0.9)
LP			846	uH	Primary Inductance
VOR	72		72	V	Reflected Output Voltage.
Expected IO (average)		Info	0.11	A	Expected Average Output current is outside 5% tolerance band. Change IFB to 124 for better current regulation set-point
KP_VNOM		Info	1.00		!!! Info. PF at high line may be less than 0.9. Decrease KP for higher PF
TON_MIN			1.22	us	Minimum on time at maximum AC input voltage
PCLAMP			0.06	W	Estimated dissipation in primary clamp
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	EE13		EE13		Select Core Size
Custom Core					Enter Custom core part number (if applicable)
AE			0.171	cm^2	Core Effective Cross Sectional Area

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LE			3.02	cm	Core Effective Path Length
AL			1130	nH/T^2	Ungapped Core Effective Inductance
BW			7.4	mm	Bobbin Physical Winding Width
M			0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L			3		Number of Primary Layers
NS	106		106		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			276	V	Peak input voltage at VACMIN
VMAX			375	V	Peak input voltage at VACMAX
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.21		Minimum duty cycle at peak of VACMIN
IAVG			0.05	A	Average Primary Current
IP			0.52	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
IRMS			0.12	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			846	uH	Primary Inductance
LP_TOL			10		Tolerance of primary inductance
NP			105		Primary Winding Number of Turns
NB			38		Bias Winding Number of Turns
ALG			76	nH/T^2	Gapped Core Effective Inductance
BM			2460	Gauss	Maximum Flux Density at PO, VMIN (BM<3100)
BP			3570	Gauss	Peak Flux Density (BP<3700)
BAC			1230	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1588		Relative Permeability of Ungapped Core
LG			0.26	mm	Gap Length (Lg > 0.1 mm)
BWE			22.2	mm	Effective Bobbin Width
OD			0.21	mm	Maximum Primary Wire Diameter including insulation
INS			0.04	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.17	mm	Bare conductor diameter
AWG			34	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			40	Cmils	Bare conductor effective area in circular mils
CMA			349	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 600)
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)					
Lumped parameters					
ISP			0.52	A	Peak Secondary Current
ISRMS			0.20	A	Secondary RMS Current
IRIPPLE			0.17	A	Output Capacitor RMS Ripple Current (based on Expected IO)
CMS			41	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			33	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.18	mm	Secondary Minimum Bare Conductor Diameter
ODS			0.07	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
VOLTAGE STRESS PARAMETERS					
VDRAIN			529	V	Estimated Maximum Drain Voltage assuming maximum LED string voltage (Includes Effect of Leakage Inductance)
PIVS			464	V	Output Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike)

PIVB			164	V	Bias Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike)
FINE TUNING (Enter measured values from prototype)					
V pin Resistor Fine Tuning					
RV1			3.73	M-ohms	Upper V Pin Resistor Value
RV2			1E+012	M-ohms	Lower V Pin Resistor Value
VAC1			115.0	V	Test Input Voltage Condition1
VAC2			230.0	V	Test Input Voltage Condition2
IO_VAC1			0.12	A	Measured Output Current at VAC1
IO_VAC2			0.12	A	Measured Output Current at VAC2
RV1 (new)			3.73	M-ohms	New RV1
RV2 (new)			19500.10	M-ohms	New RV2
V_OV			298.2	V	Typical AC input voltage at which OV shutdown will be triggered
V_UV			62.0	V	Typical AC input voltage beyond which power supply can startup
FB pin resistor Fine Tuning					
RFB1			190	k-ohms	Upper FB Pin Resistor Value
RFB2			1E+012	k-ohms	Lower FB Pin Resistor Value
VB1			22.4	V	Test Bias Voltage Condition1
VB2			27.6	V	Test Bias Voltage Condition2
IO1			0.12	A	Measured Output Current at Vb1
IO2			0.12	A	Measured Output Current at Vb2
RFB1 (new)			189.7	k-ohms	New RFB1
RFB2(new)			1.00E+12	k-ohms	New RFB2
Input Current Harmonic Analysis					
Harmonic			Max Current (mA)	Limit (mA)	
1st Harmonic			41.39	N/A	Fundamental (mA)
3rd Harmonic			11.37	47.60	PASS. 3rd Harmonic current content is lower than the limit
5th Harmonic			6.0	26.60	PASS. 5th Harmonic current content is lower than the limit
7th Harmonic			3.9	14.00	PASS. 7th Harmonic current content is lower than the limit
9th Harmonic			2.74	7.00	PASS. 9th Harmonic current content is lower than the limit
11th Harmonic			2.07	4.90	PASS. 11th Harmonic current content is lower than the limit
13th Harmonic			1.63	4.15	PASS. 13th Harmonic current content is lower than the limit
15th Harmonic			1.32	3.59	PASS. 15th Harmonic current content is lower than the limit
THD			32.4	%	Estimated total Harmonic Distortion (THD)

Notes:

- The flyback spreadsheet was used to generate the buck-boost inductor by selecting VOR value equal to VO.
- Primary number of turns (NP) of the flyback transformer is the number of turns to be used for the inductor T1 WDG1.
- The calculated bias turns are still valid for the bias winding WDG2.
- Inductor RMS current is $\sqrt{IRMS^2 + ISRMS^2}$.

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9 Inductor Specification

9.1 Electrical Diagram

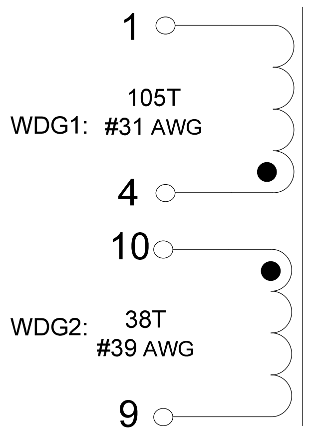

Figure 8 – Transformer Electrical Diagram.

9.2 Electrical Specifications

Primary Inductance	Pins 1-4, all other windings open, measured at 100 kHz, 0.4 $V_{RMS.}$ AL = 77 nH/N^2	850 µH ±5%

9.3 Materials

Item	Description
[1]	Core: EE13; NC2H or equivalent.
[2]	Bobbin: EE13; 5/5 pin Vertical, Pin Shine, P-1302-2 or equivalent.
[3]	Magnet Wire: # 31 AWG.
[4]	Magnet Wire: # 39 AWG.
[5]	Transformer tape: 7.4 mm.
[6]	Transformer tape: 5.5 mm.
[7]	Varnish.

9.4 Inductor Build Diagram

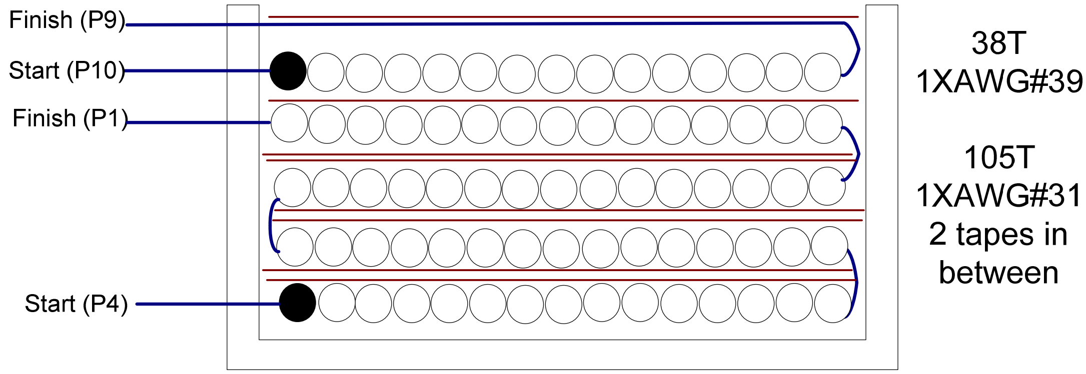

Figure 9 – Transformer Build Diagram.

9.5 Inductor Construction

Bobbin Preparation	For the purpose of these instructions, bobbin is oriented on winder such that pin 1 side is on the left. Winding direction is counter-clockwise. Follow the pin number assignment in the specification.
Pin Preparation	Cut pins number 2, 3, 5, 6, 7 and 8.
WDG 1	Start at pin 4. Wind 105 turns of item [3] and terminate at pin 1. Note that there is two turns of transformer tape item[5] per layer
Insulation	Add 1 layer of tape of item [5].
WDG 2	Start at pin 10. Wind 38 turns of item [4] and terminate at pin 9.
Taping	Add 1 layer of tape to secure the winding.
Final Assembly	Grind the core to get the specified inductance. Secure the core with tape [6].
Varnish	Dip the inductor for varnish [7] and dry.

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10 Performance Data

All measurements performed at 25 ºC room temperature otherwise specified.

10.1 Efficiency

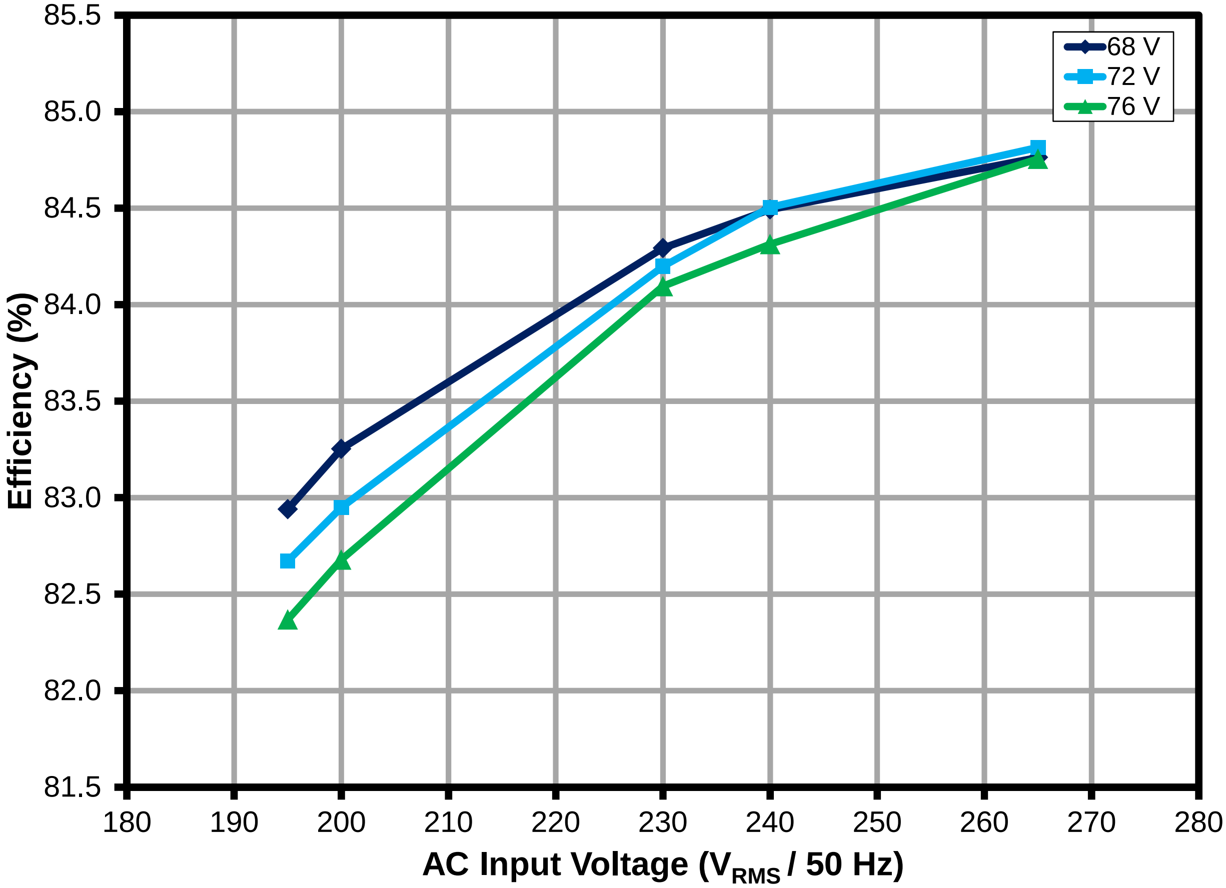

Figure 10 – Efficiency with Respect to AC Input Voltage.

10.2 Line Regulation

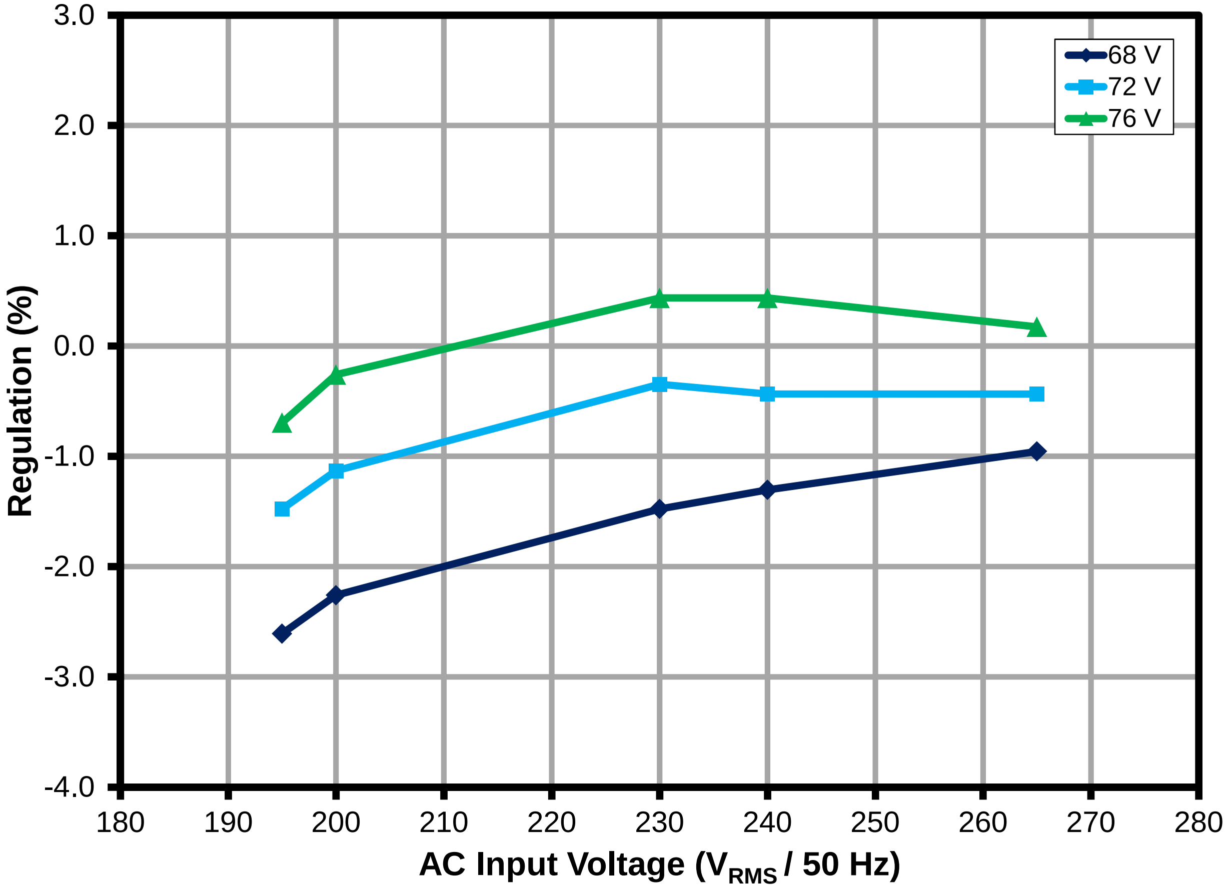

Figure 11 – Line Regulation, Room Temperature.

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10.3 Power Factor

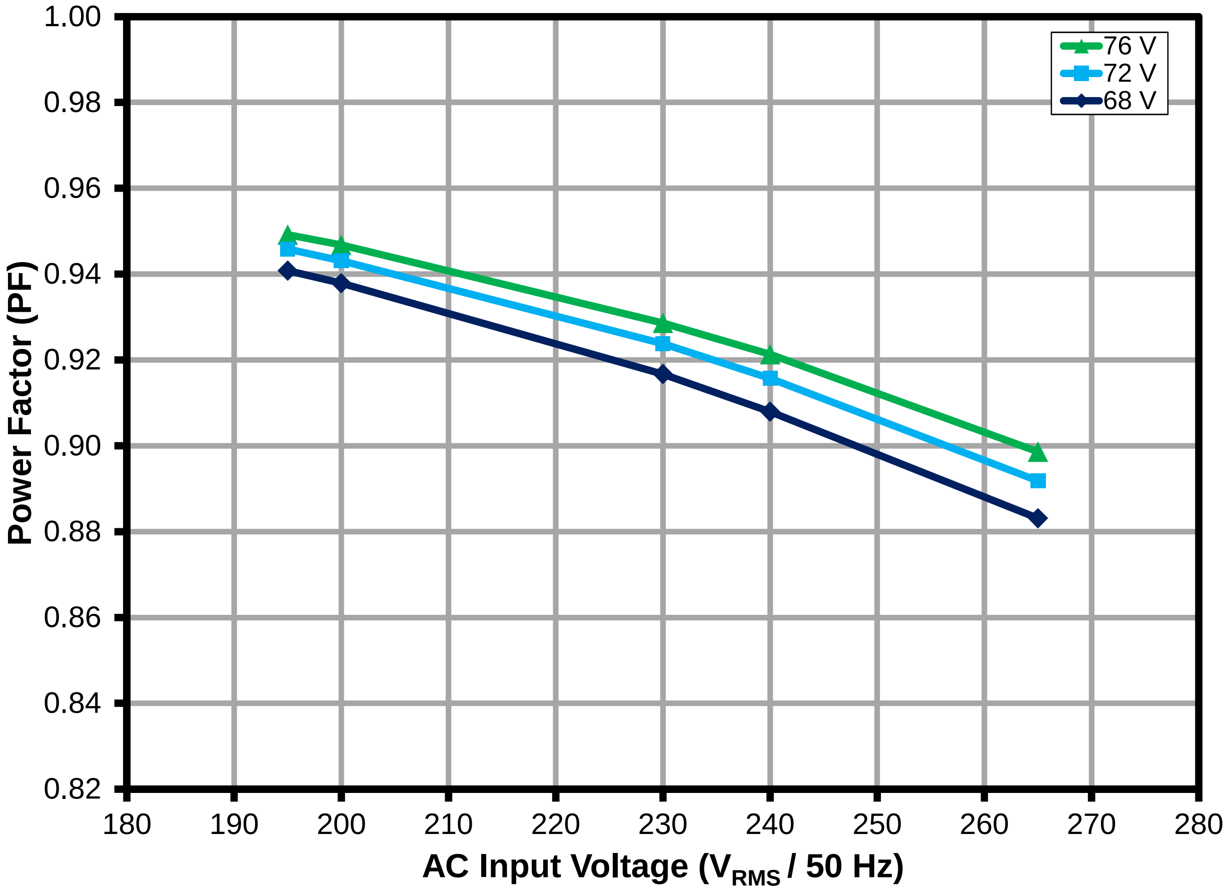

Figure 12 – High Power Factor within the Operating Range.

10.4 %ATHD

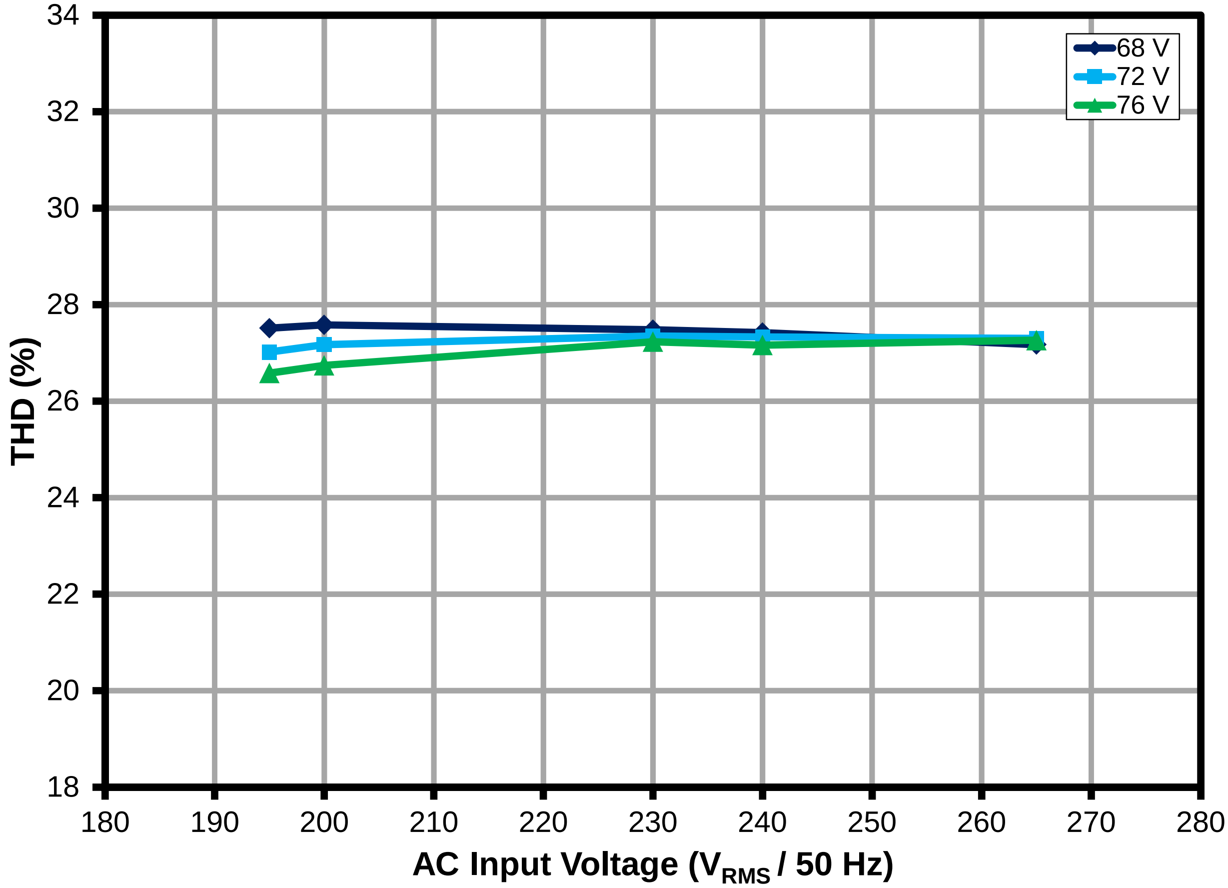

Figure 13 – Very Low %ATHD at 220 VAC.

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10.5 Harmonic Content

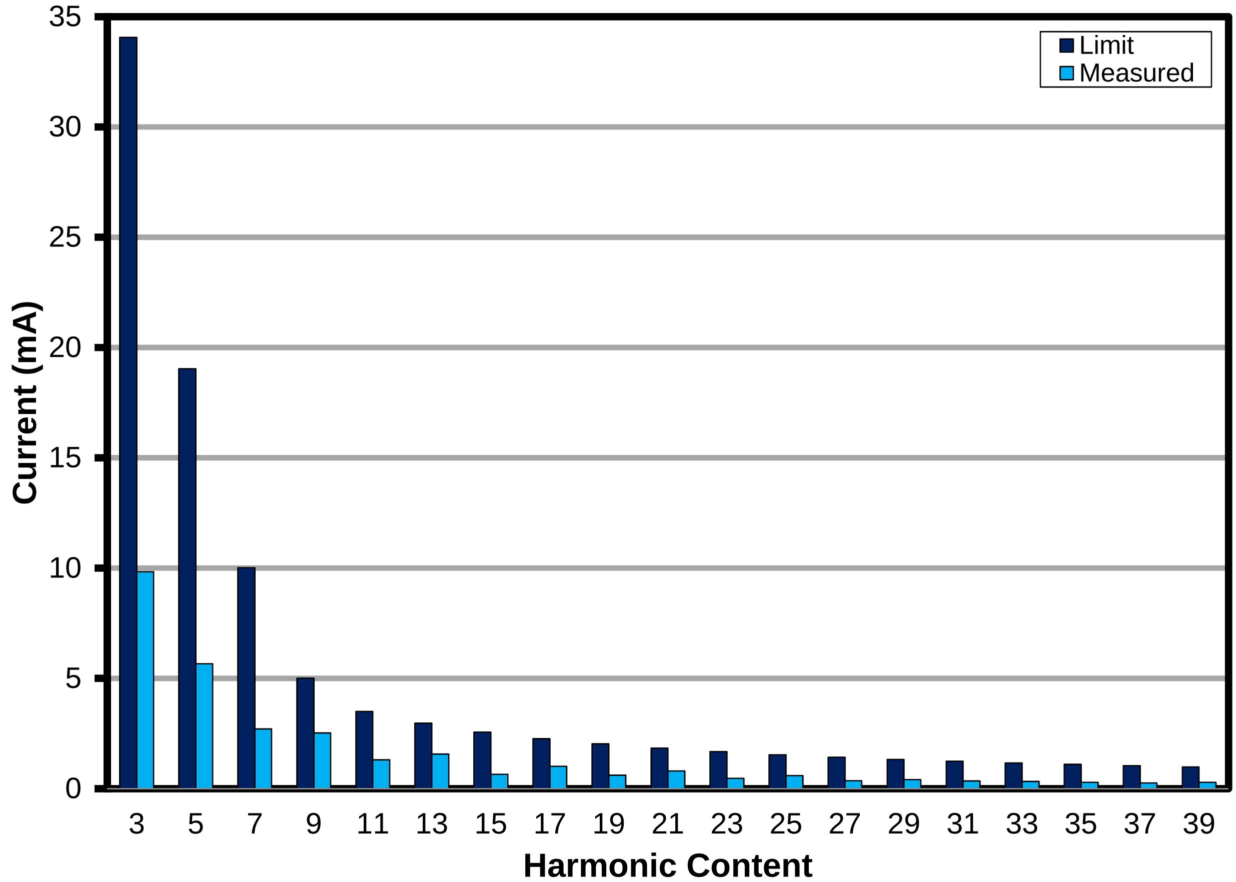

Figure 14 – Meets EN61000-3-2 Harmonics Contents Standards for <25 W Rating for 72 V LED Output.

10.6 Harmonic Measurements

VAC (V_{RMS})	Freq (Hz)	I (mA)	P	PF
230	50.00	47.08	10.0170	0.9253
nth Order	**mA Content**	**% Content**	**Limit (mA) <25 W**	**Remarks**
1	45.44			
2	0.01	0.02%		
3	9.83	21.64%	34.0578	Pass
5	5.66	12.46%	19.0323	Pass
7	2.71	5.95%	10.0170	Pass
9	2.52	5.55%	5.0085	Pass
11	1.31	2.88%	3.5060	Pass
13	1.57	3.46%	2.9666	Pass
15	0.65	1.43%	2.5710	Pass
17	1.01	2.23%	2.2686	Pass
19	0.61	1.35%	2.0298	Pass
21	0.80	1.77%	1.8365	Pass
23	0.47	1.03%	1.6768	Pass
25	0.59	1.30%	1.5426	Pass
27	0.36	0.79%	1.4284	Pass
29	0.41	0.89%	1.3298	Pass
31	0.35	0.77%	1.2440	Pass
33	0.33	0.72%	1.1687	Pass
35	0.29	0.64%	1.1019	Pass
37	0.26	0.56%	1.0423	Pass
39	0.29	0.63%	0.9889	Pass
41	0.25	0.54%		
43	0.23	0.51%		
45	0.19	0.41%		
47	0.20	0.44%		
49	0.18	0.39%		

Table 1 – 230 VAC Input Current Harmonic Measurement for 72 V LED.

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10.7 Thermal Performance

10.8 Thermal Scans

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

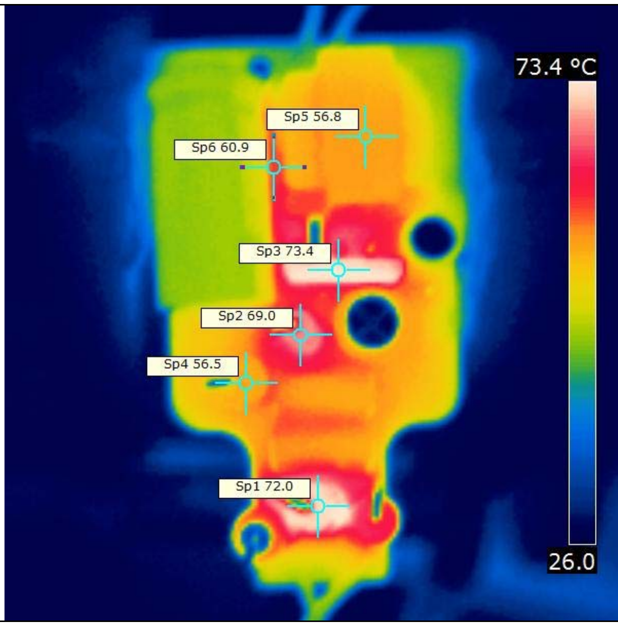

Figure 15 – SP1 – R24; Damper Resistor.
SP2 – R6; Sense Damper Resistor.
SP3 – U1; LYT4322E Case Temperature.
SP4 – L1; EMI Inductor.
SP5 – T1; Power Inductor.
SP6 – D3; Output Diode.

Figure 16 – SP1 – BR1; Bridge Rectifier.
SP2 – D5; Blocking Diode.
SP3 – D4; Auxiliary Rectifier.

11 Waveforms

11.1 Drain Voltage and Current, Normal Operation

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

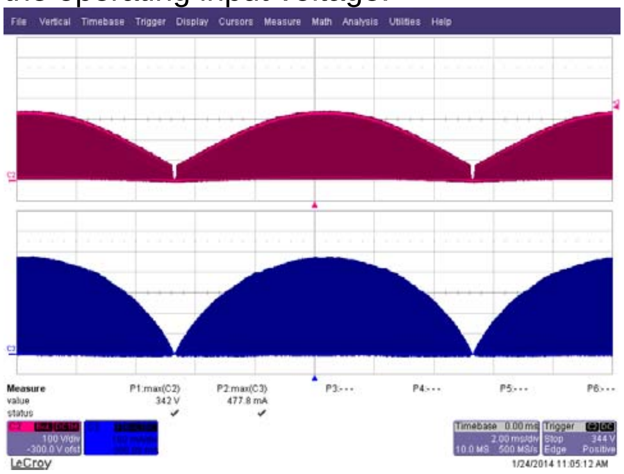

Figure 17 – 195 VAC / 50 Hz, 72 V LED String.
Ch2: $V_{S\text{-}G}$, 100 V / div.
Ch3: I_{DRAIN}, 0.1 A / div.
Time Scale: 2 ms / div.

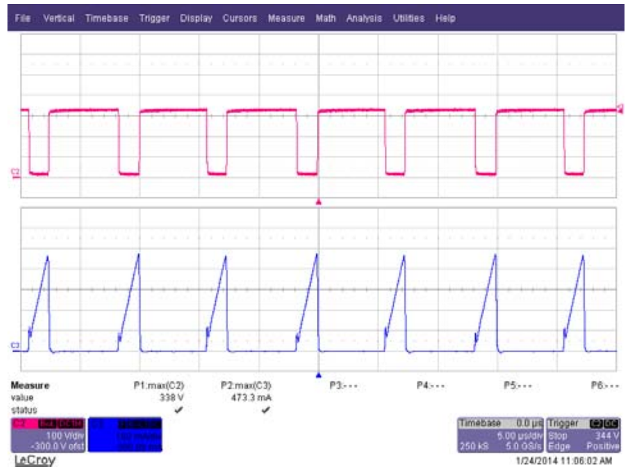

Figure 18 – 195 VAC / 50 Hz, 72 V LED String.
Ch2: $V_{S\text{-}G}$, 100 V / div.
Ch3: I_{DRAIN}, 0.1 A / div.
Time Scale: 5 µs / div.

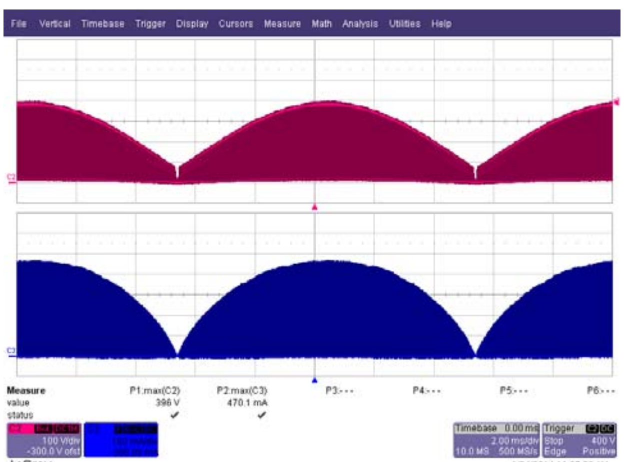

Figure 19 – 230 VAC / 50 Hz, 72 V LED String.
Ch2: $V_{S\text{-}G}$, 100 V / div.
Ch3: I_{DRAIN}, 0.1 A / div.
Time Scale: 2 ms / div.

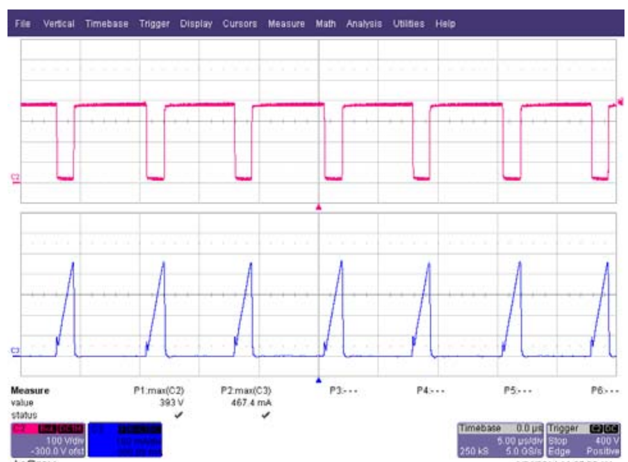

Figure 20 – 230 VAC / 50 Hz, 72 V LED String.
Ch2: $V_{S\text{-}G}$, 100 V / div.
Ch3: I_{DRAIN}, 0.1 A / div.
Time Scale: 5 µs / div.

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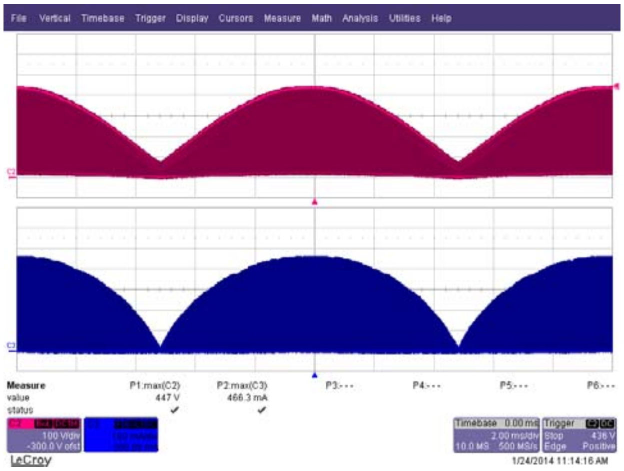

Figure 21 – 265 VAC / 50 Hz, 72 V LED String.
Ch2: $V_{S\text{-}G}$, 100 V / div.
Ch3: I_{DRAIN}, 0.1 A / div.
Time Scale: 2 ms / div.

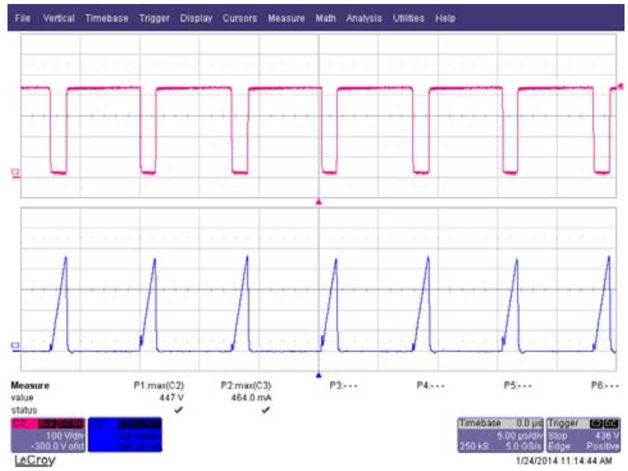

Figure 22 – 265 VAC / 50 Hz, 72 V LED String.
Ch2: $V_{S\text{-}G}$, 100 V / div.
Ch3: I_{DRAIN}, 0.1 A / div.
Time Scale: 5 μs / div.

11.2 Drain Current, During Dimming

For leading edge dimming, the drain current mimics the regular RC bleeder to avoid TRIAC misfire.

Figure 23 – 230 VAC / 50 Hz, 72 V LED String.
Ch1: V_{IN}, 100 V / div.
Ch3: I_{DRAIN}, 0.2 A / div.
Ch3: I_{DRAIN}, 0.05 A / div.
Time Scale: 2 ms / div.

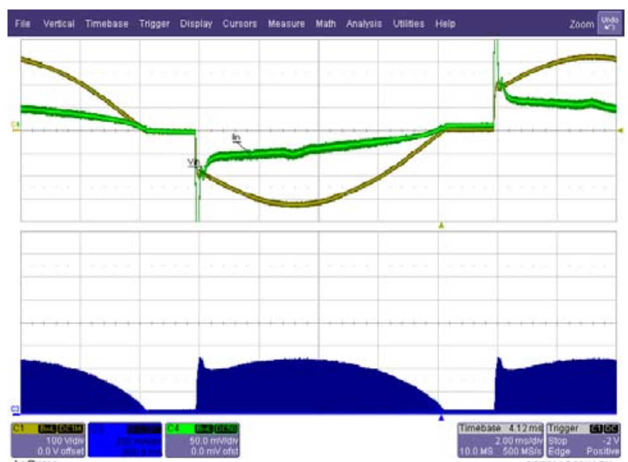

Figure 24 – 230 VAC / 50 Hz, 72 V LED String.
Ch1: V_{IN}, 100 V / div.
Ch3: I_{DRAIN}, 0.2 A / div.
Ch3: I_{DRAIN}, 0.05 A / div.
Time Scale: 2 ms / div.

11.3 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.

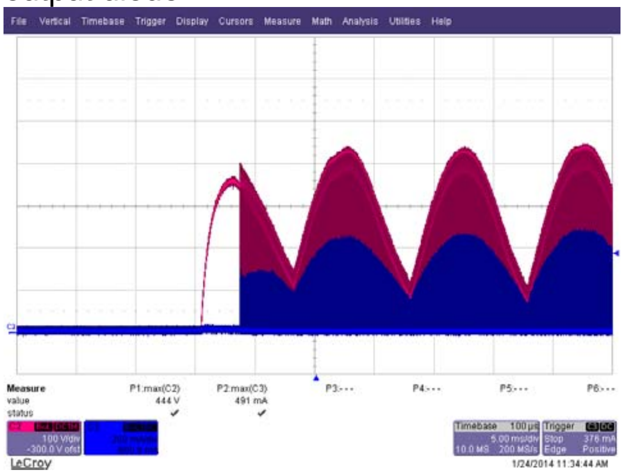

Figure 25 – 265 VAC / 50 Hz, 72 V LED String.
Ch2: $V_{S\text{-}G}$, 100 V / div.
Ch3: I_{DRAIN}, 0.1 A / div.
Time Scale: 5 ms / div.

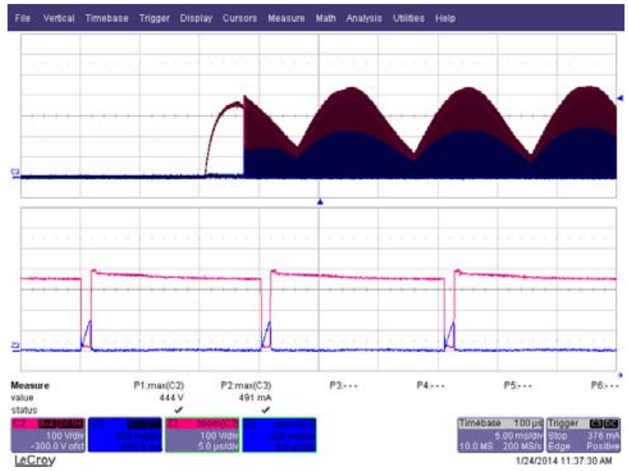

Figure 26 – 265 VAC / 50 Hz, 72 V LED String.
Ch2, Z2: $V_{S\text{-}G}$, 100 V / div.
Ch3, Z3: I_{DRAIN}, 0.1 A / div.
Time Scale: 5 ms / div.
Zoom Time Scale: 5 μs / div

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11.4 Output Voltage Start-up Profile

Start-up time <300 ms; the reference design will emit light within 300 ms at non-dimming operation.

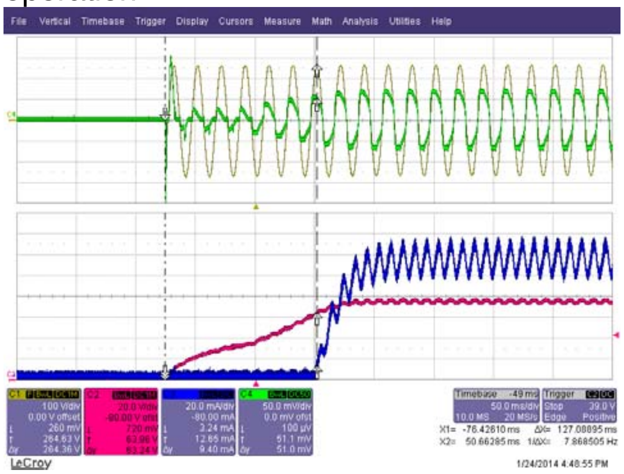

Figure 27 – 195 VAC / 50 Hz, 72 V LED.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{OUT}, 20 mA / div.
Ch4: I_{IN}, 50 mA / div., 50 ms / div.

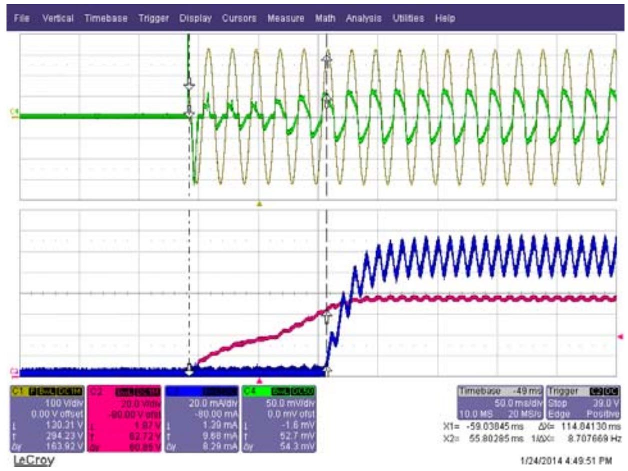

Figure 28 – 220 VAC / 50 Hz, 72 V LED.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{OUT}, 20 mA / div.
Ch4: I_{IN}, 50 mA / div., 50 ms / div.

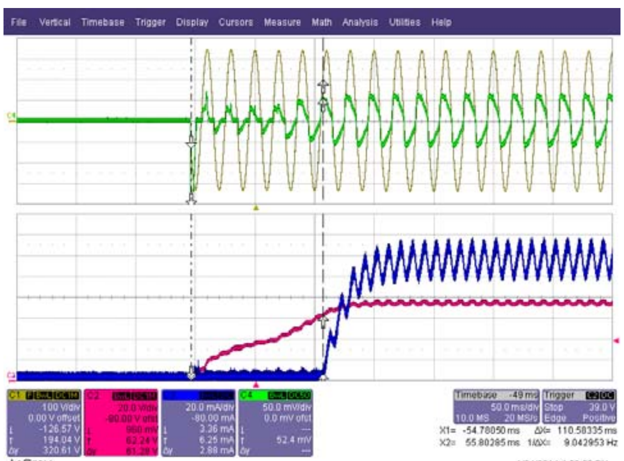

Figure 29 – 240 VAC / 50 Hz, 72 V LED.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{OUT}, 20 mA / div.
Ch4: I_{IN}, 50 mA / div., 50 ms / div.

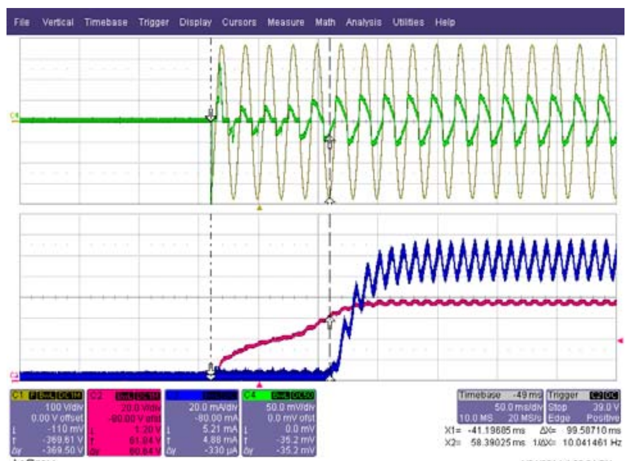

Figure 30 – 265 VAC / 50 Hz, 72 V LED.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{OUT}, 20 mA / div.
Ch4: I_{IN}, 50 mA / div., 50 ms / div.

11.5 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.

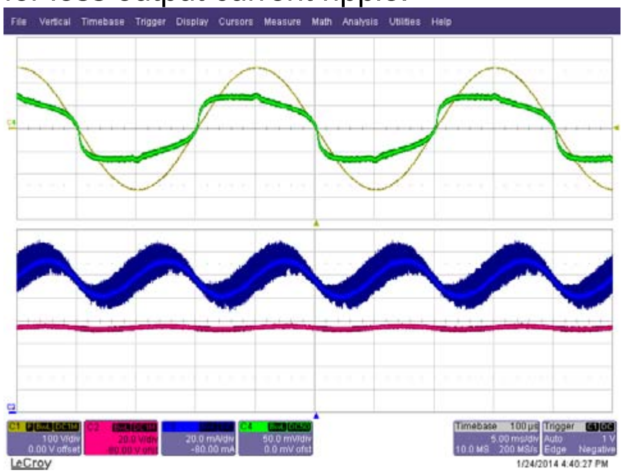

Figure 31 – 195 VAC / 50 Hz, 72 V LED String.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{OUT}, 20 mA / div.
Ch4: I_{IN}, 50 mA / div., 5 ms / div.

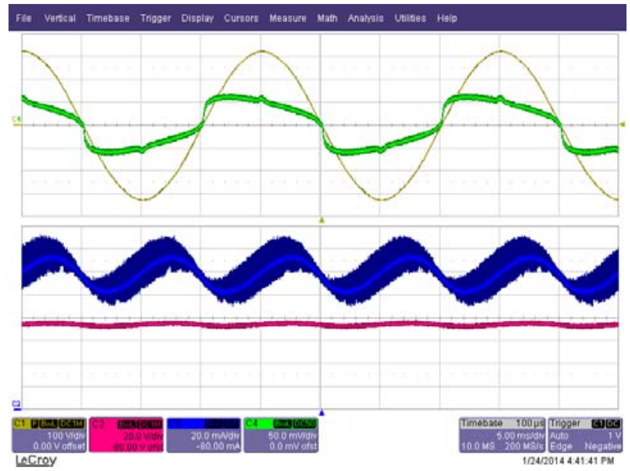

Figure 32 – 230 VAC / 50 Hz, 72 V LED String.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{OUT}, 20 mA / div.
Ch4: I_{IN}, 50 mA / div., 5 ms / div.

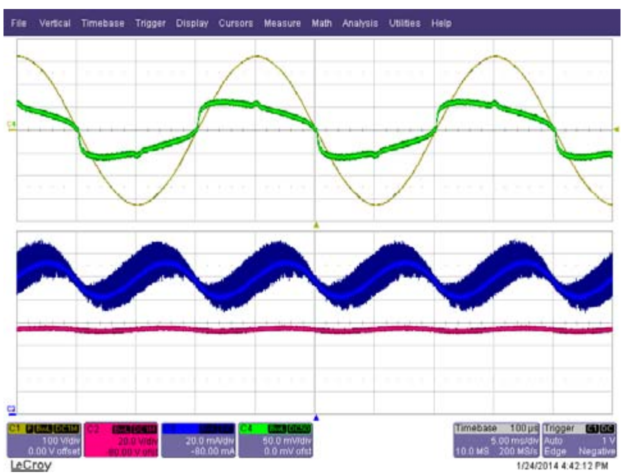

Figure 33 – 240 VAC / 50 Hz, 72 V LED String.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{OUT}, 20 mA / div.
Ch4: I_{IN}, 50 mA / div., 5 ms / div.

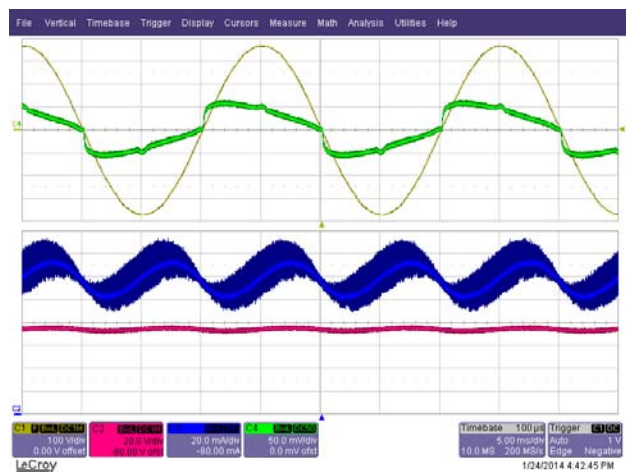

Figure 34 – 265 VAC / 50 Hz, 72 V LED String.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{OUT}, 20 mA / div.
Ch4: I_{IN}, 50 mA / div., 5 ms / div.

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11.6 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.

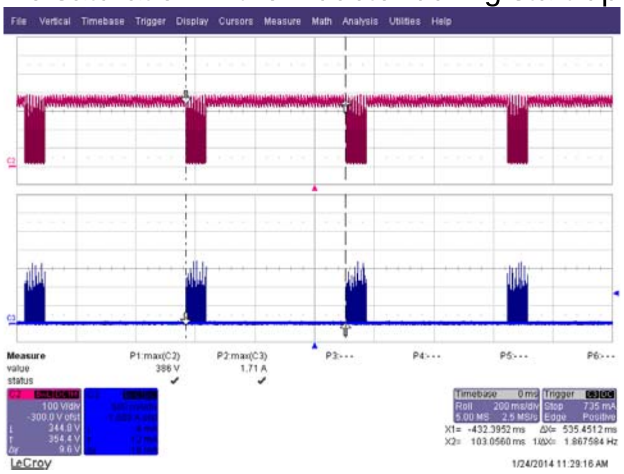

Figure 35 – 265 VAC / 50 Hz, Output Shorted.
Ch1: V_{DRAIN}, 100 V / div.
Ch3: I_{DRAIN}, 0.5 A / div,
Time Scale: 200 ms / div.

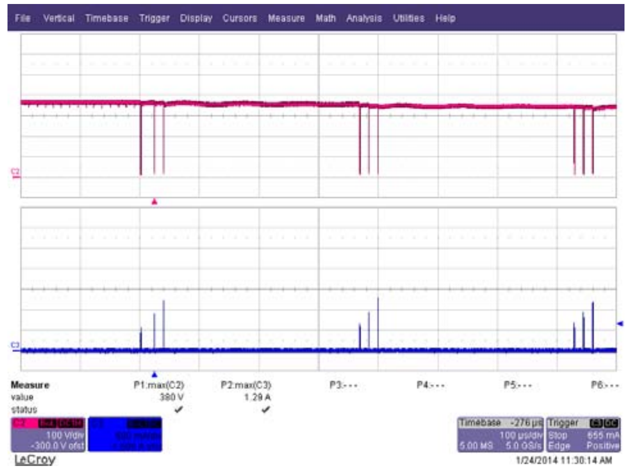

Figure 36 – 265 VAC / 50 Hz, Output Shorted.
Ch1: V_{DRAIN}, 100 V / div.
Ch3: I_{DRAIN}, 0.5 A / div,
Time Scale: 100 μs / div.

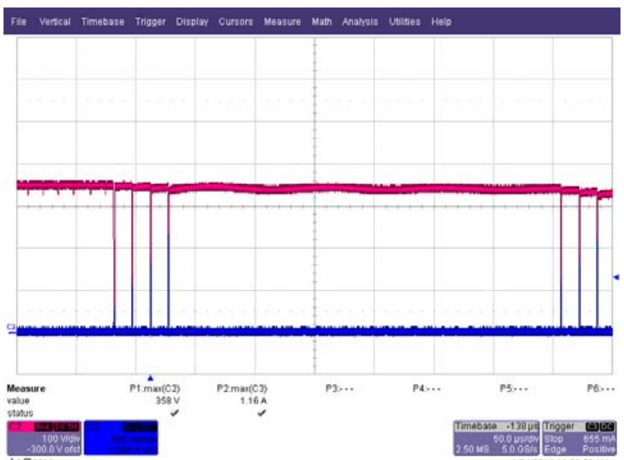

Figure 37 – 265 VAC / 50 Hz, Output Shorted.
Ch1: V_{DRAIN}, 100 V / div.
Ch3: I_{DRAIN}, 0.5 A / div,
Time Scale: 50 μs / div.

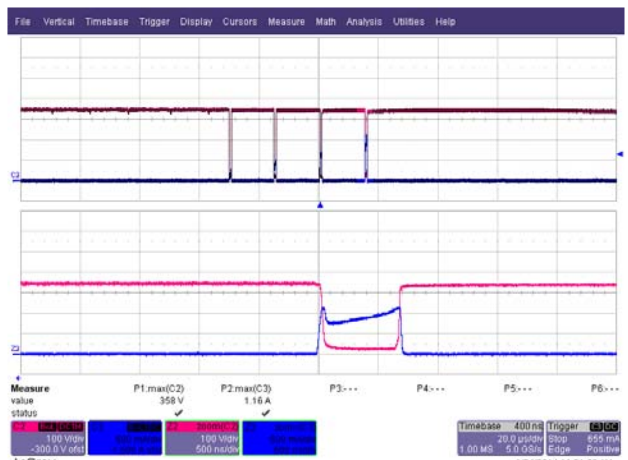

Figure 38 – 265 VAC / 50 Hz, Output Shorted.
Ch1: V_{DRAIN}, 100 V / div.
Ch3: I_{DRAIN}, 0.5 A / div,
Time Scale: 100 μs / div.

11.7 No-Load Operation

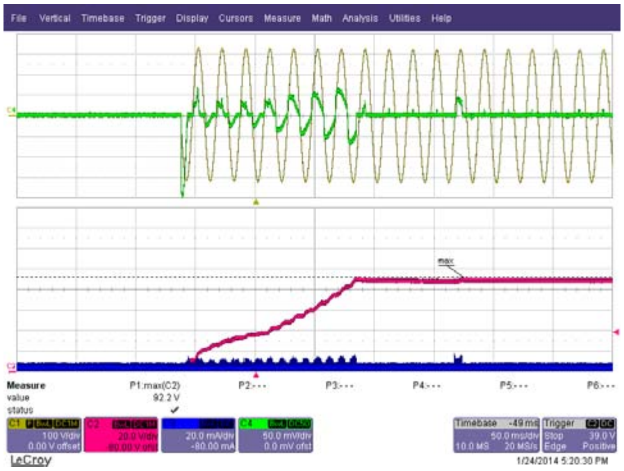

Figure 39 – 230 VAC / 50 Hz, Start-up No-load.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{OUT}, 0.02 A / div.
Ch4: I_{IN}, 0.05 A / div.
Time Scale: 50 ms / div.

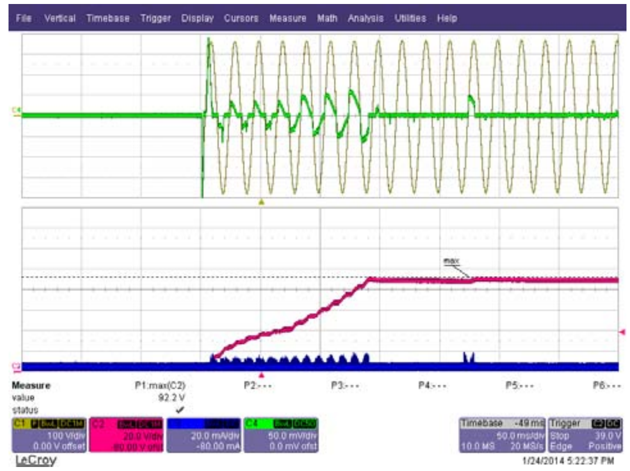

Figure 40 – 265 VAC / 50 Hz, Start-up No-load.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{OUT}, 0.02 A / div.
Ch4: I_{IN}, 0.05 A / div.
Time Scale: 50 ms / div.

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11.8 AC Cycling

The reference design has no perceptible delay.

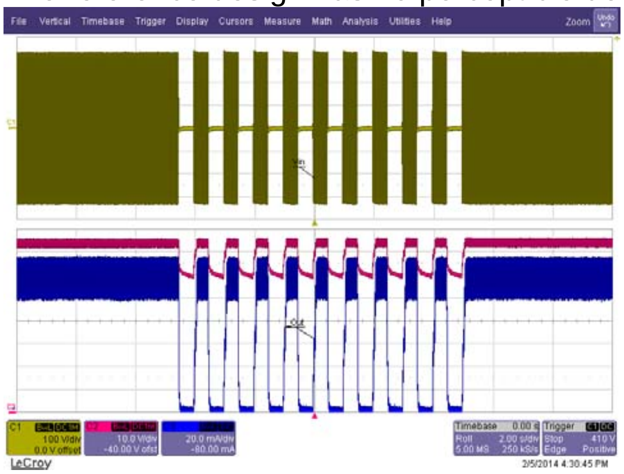

Figure 41 – 230 VAC / 50 Hz,
500 ms On – 500 ms Off.
Load: 72 V LED String.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 10 V / div.
Ch4: I_{OUT}, 20 mA / div.
Time Scale: 2 s / div.

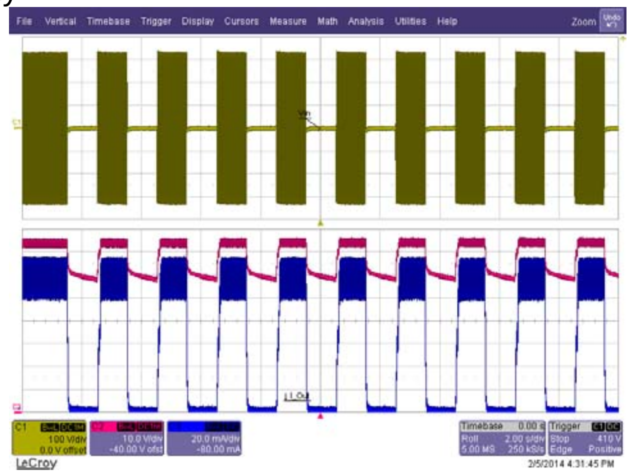

Figure 42 – 230 VAC / 50 Hz,
1 s On – 1 s Off.
Load: 72 V LED String.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 10 V / div.
Ch4: I_{OUT}, 20 mA / div.
Time Scale: 2 s / div.

11.9 Line Sag and Surge

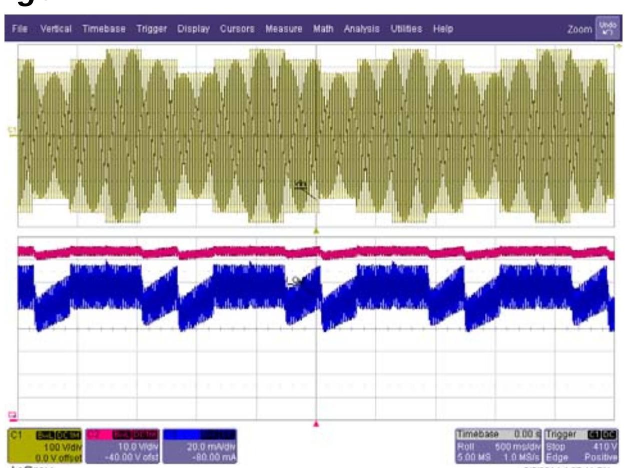

Figure 43 – 300 ms; 190, 230, 265 VAC
Load: 72 V LED String.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 10 V / div.
Ch4: I_{OUT}, 20 mA / div.
Time Scale: 50 s / div.

11.10 Brownout

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

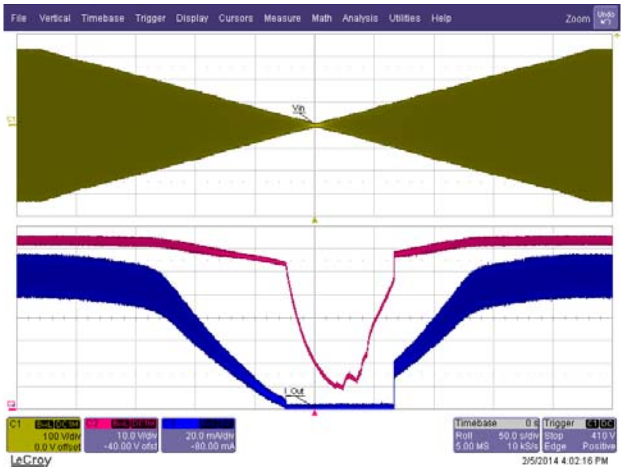

Figure 44 - 230 VAC / 50 Hz,
1 V / s Slew Rate.
Load: 72 V LED String.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 10 V / div.
Ch4: I_{OUT}, 20 mA / div.
Time Scale: 50 s / div.

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11.11 Differential Line Surge

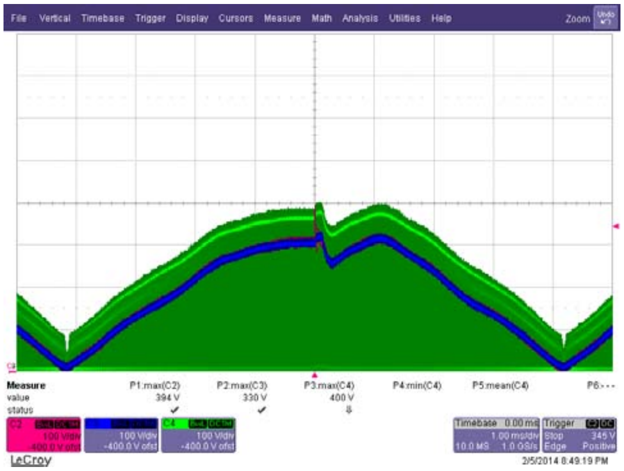

Figure 45 – 230 VAC / 50 Hz,
Load: 72 V LED String.
Ch2: V_{BR}, 100 V / div.
Ch3: V_{BULK}, 100 V / div.
Ch4: V_{DRAIN}, 100 V / div.
Time Scale: 1 ms / div.

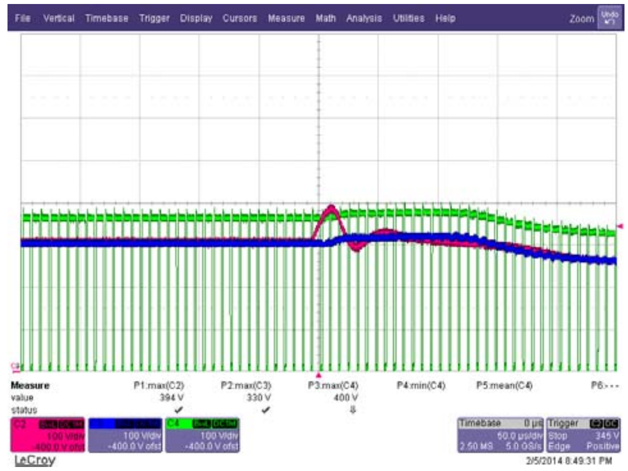

Figure 46 – 230 VAC / 50 Hz,
Load: 72 V LED String.
Ch2: V_{BR}, 100 V / div.
Ch3: V_{BULK},100 V / div.
Ch4: V_{DRAIN},100 V / div.
Time Scale: 50 μs / div..

11.12 Differential Ring Surge

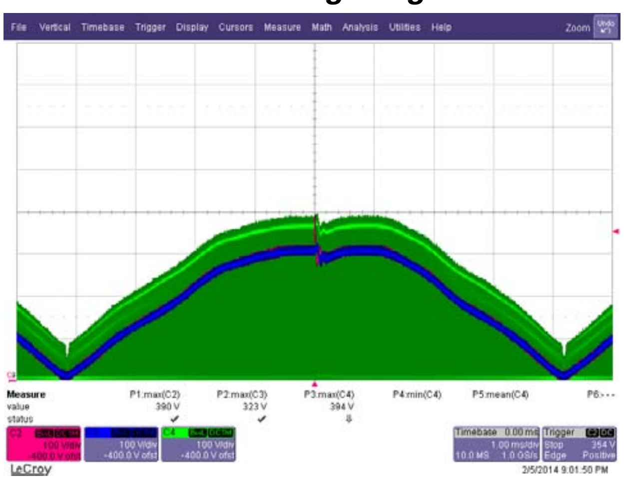

Figure 47 – 230 VAC / 50 Hz,
Load: 72 V LED String.
Ch2: V_{BR}, 100 V / div.
Ch3: V_{BULK}, 100 V / div.
Ch4: V_{DRAIN}, 100 V / div.
Time Scale: 1 ms / div.

Figure 48 – 230 VAC / 50 Hz,
Load: 72 V LED String.
Ch2: V_{BR}, 100 V / div.
Ch3: V_{BULK},100 V / div.
Ch4: $V_{DRAIN,}$100 V / div.
Time Scale: 50 μs / div..

12 Dimming

12.1 Dimming Compatibility

Minimum brightness in LED is limited by the dimmers minimum conduction. Verified at 230 V / 50 Hz line input, dimming ratio will vary depending on the input voltage due to dimmers dependency in RMS input voltage level.

Location Commonly Used	Part Number	Type	Max I_{OUT}	Min I_{OUT}	Ratio
Australia	Clipsal - 32E450LM	L	108.9	26.97	4.04:1
Australia	Clipsal - 32E450TM	T	106.1	24.01	4.42:1
Australia	Clipsal - 32E2CFLDM	T	104.7	23.56	4.44:1
Australia	Clipsal - 32E450UDM	T	109.6	28.96	3.78:1
China	TCL	L	113.3	25.08	4.52:1
China	SEN BO LANG	L	114.1	41.5	2.75:1
China	EBA HUANG	L	114	8.5	13.41:1
China	SB ELECT	L	120.8	8.5	14.21:1
China	MYONGBO	L	113.6	40.2	2.83:1
China	KBE	L	114.1	8	14.26:1
China	CLIPMEI	L	114.3	25.6	4.46:1
China	MANK	L	114.4	44.6	2.57:1
Europe	Berker 2830 10	L	110.6	32.1	3.45:1
Europe	Jung 225 NV DE	L	108.9	22.6	4.82:1
Europe	Jung 254 UDIE 1	T	103.6	32.4	3.2:1
Europe	Jung 266 G DE	L	117.8	28.62	4.12:1
Europe	Busch 2200 UJ-212	L	118	38.27	3.08:1
Europe	Busch 2250 U	L	112.6	22.2	5.07:1
Europe	Busch 2247 U	L	110.8	32.8	3.38:1
Europe	Gira 2262 00 I01	L	117.6	18.45	6.37:1
Europe	Gira 0300 00 IO1	L	110.9	37.13	2.99:1
Europe	Gira0302 00 IO1	L	111.9	28.26	3.96:1
Europe	GIRA 1176 00 I03	T	109	32.2	3.39:1
Europe	Niko 310-013	L	113.4	31.6	3.59:1
Europe	Niko 310-017	T	95.6	35.4	2.7:1
Europe	Niko 310-014	L	113.3	38.6	2.94:1
Europe	Ikea - SED200LRS	L	106.8	6.15	17.37:1
Europe	Ikea - WDE200L-1	L	113.1	7	16.16:1
Europe	Ikea - SED300FHS	L	110.6	6.75	16.39:1
Europe	Ikea - EED100PRS	L	112.9	9.25	12.21:1
Europe	Ikea - WDE300F-1	L	112	8	14:1
Europe	Ikea - E0902 DIM	L	110.9	20.47	5.42:1
Germany	Berker - KOPP 8033	L	105.1	28.82	3.65:1
Germany	Busch - 6513 U-102	T	110.6	28.75	3.85:1
Germany	PEHA - 433HAB 0A	T	108.1	36.8	2.94:1
Germany	PEHA - 433HAB 0A	T	101	25.77	3.92:1
Germany	REV - 600W	T	111.1	8	13.89:1
Germany	Busch - 2250	L	11.8	24.2	0.49:1
Germany	Merten - 572499	L	114.2	19.76	5.78:1
Germany	Busch - 6513	T	111.2	29.07	3.83:1

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Germany	Berker - 2875	L	111.2	27.08	4.11:1
Italy	Relco - RM34DMA	L	114.3	36	3.18:1
Italy	Relco - RTM34LED DAXS	L	99.6	13.65	7.3:1
Italy	Relco - RM34DMA	L	114.6	37.5	3.06:1
Italy	Relco - RTS34.43 RLI	L	114.9	25.58	4.49:1
Italy	Relco - RT34DSL	L	115	36.5	3.15:1
Korea	ANAM	L	113.6	47.5	2.39:1
Korea	SHIN SUNG	L	114.8	44.9	2.56:1
Korea	SS7	L	114.3	37.5	3.05:1

12.2 Dimming Curve

Dimming curve characteristic from ideal AC source emulating leading edge TRIAC dimmer

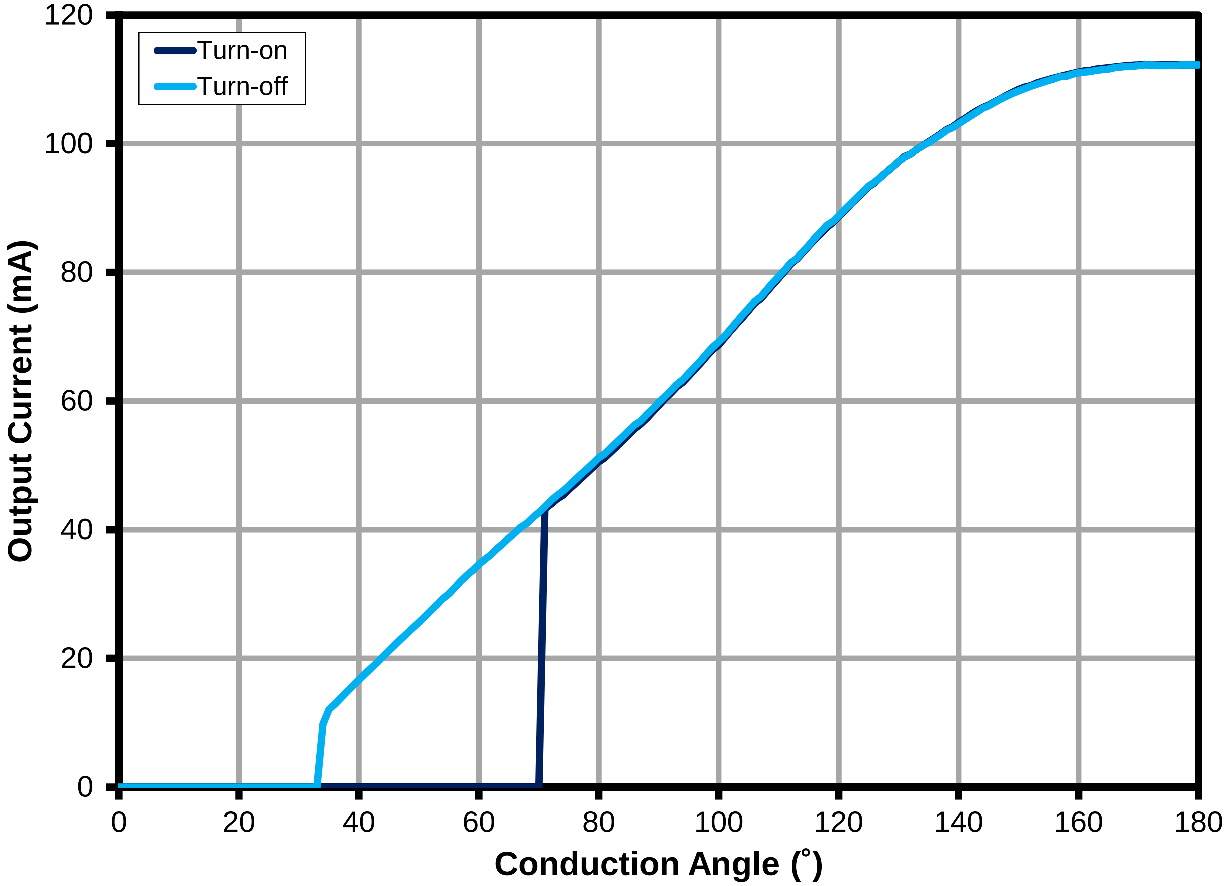

Figure 49 – Dimming Curve Characteristic from Ideal AC Source and Dimmer.

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12.3 Dimming Waveform Sample

12.3.1 Leading Edge Dimming

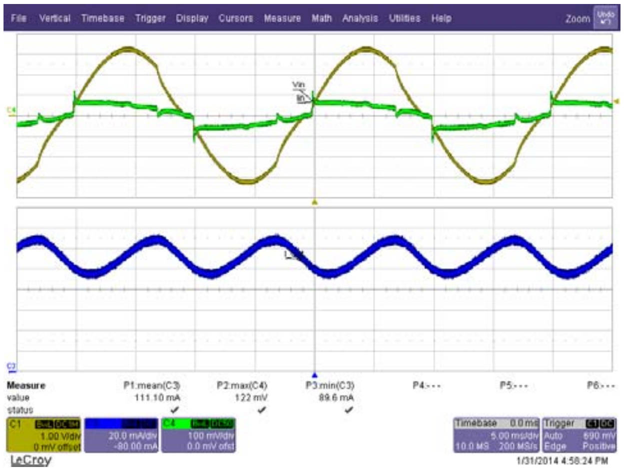

Figure 50 – 230 VAC / 50 Hz, GIRA 1176 00 I03.
Ch1: V_{IN}, 100 V / div.
Ch3: I_{OUT}, 0.02 A / div.
Ch4: I_{IN}, 0.1 A / div.
Time Scale: 5 ms / div.

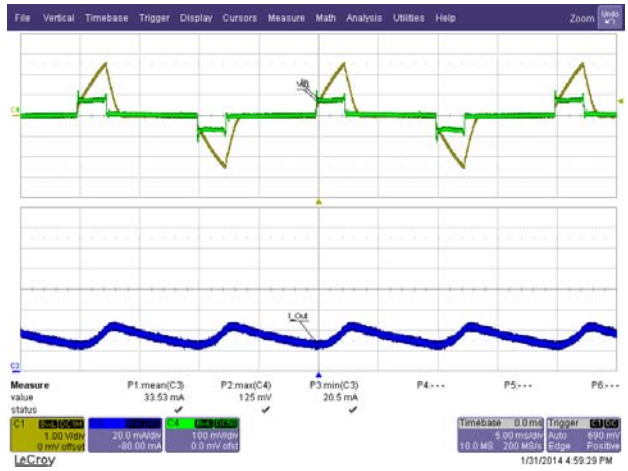

Figure 51 – 230 VAC / 50 Hz, GIRA 1176 00 I03.
Ch1: V_{IN}, 100 V / div.
Ch3: I_{OUT}, 0.02 A / div.
Ch4: I_{IN}, 0.1 A / div.
Time Scale: 5 ms / div.

12.3.2 Trailing Edge Dimming

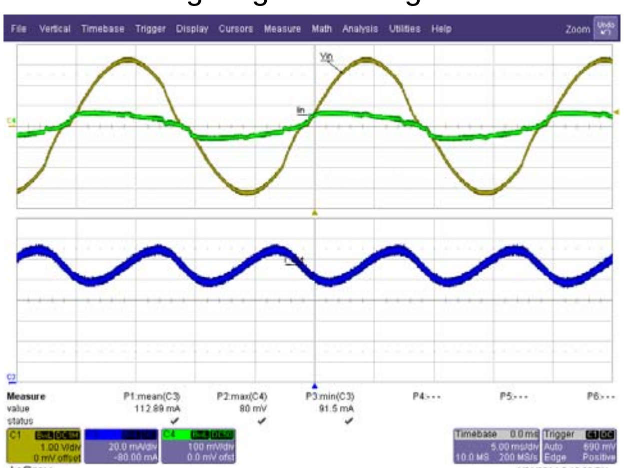

Figure 52 – 230 VAC / 50 Hz, Busch 6513 U-102.
Ch1: V_{IN}, 100 V / div.
Ch3: I_{OUT}, 0.02 A / div.
Ch4: I_{IN}, 0.1 A / div.
Time Scale: 5 ms / div.

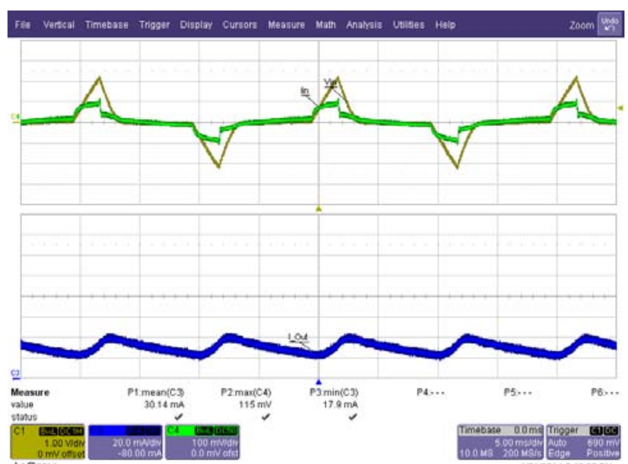

Figure 53 – 230 VAC / 50 Hz, Busch 6513 U-102.
Ch1: V_{IN}, 100 V / div.
Ch3: I_{OUT}, 0.02 A / div.
Ch4: I_{IN}, 0.1 A / div.
Time Scale: 5 ms / div.

12.3.3 Leakage from Dimmer when Turned-Off

Dimmers characteristic varies from one model to another. Some dimmers have leakage current through the pilot indicator lamp connected across the TRIAC and some dimmers have leakage from the emi capacitor connected across TRIAC or both. Proper input impedance matching and bleeding should be used in order to mitigate unwanted premature operation of the LED driver while the dimmer is off. The turn-off circuit described in section 4.5 and the preload in the output bleed the leakage energy from the dimmer.

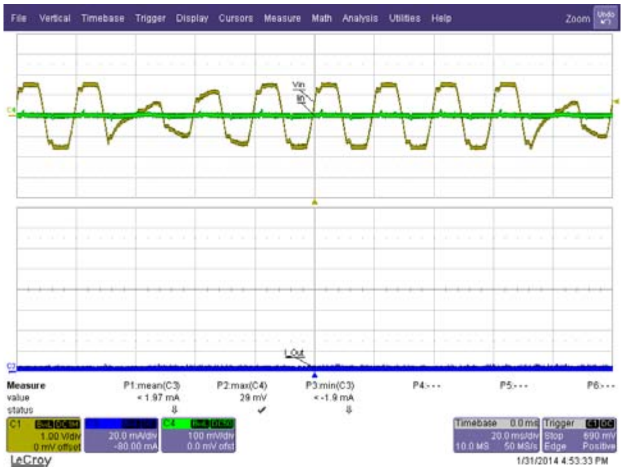

Figure 54 – 230 VAC / 50 Hz, Leakage from GIRA 1176 00 I03.
Ch1: V_{IN}, 100 V / div.
Ch3: I_{OUT}, 0.02 A / div.
Ch4: I_{IN}, 0.1 A / div.
Time Scale: 20 ms / div.

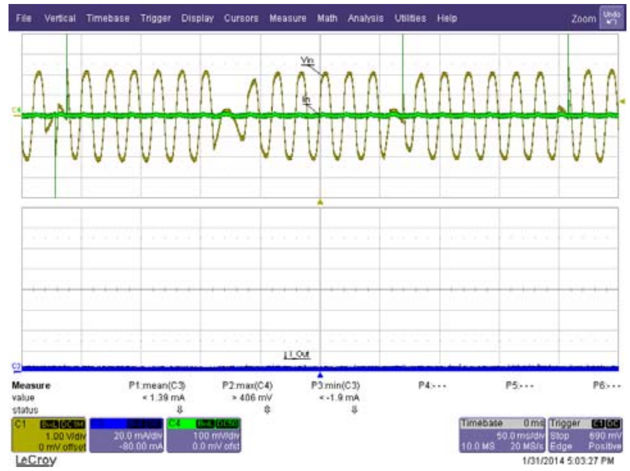

Figure 55 – 230 VAC / 50 Hz, Leakage from Niko 310-013.
Ch1: V_{IN}, 100 V / div.
Ch3: I_{OUT}, 0.02 A / div.
Ch4: I_{IN}, 0.1 A / div.
Time Scale: 50 ms / div.

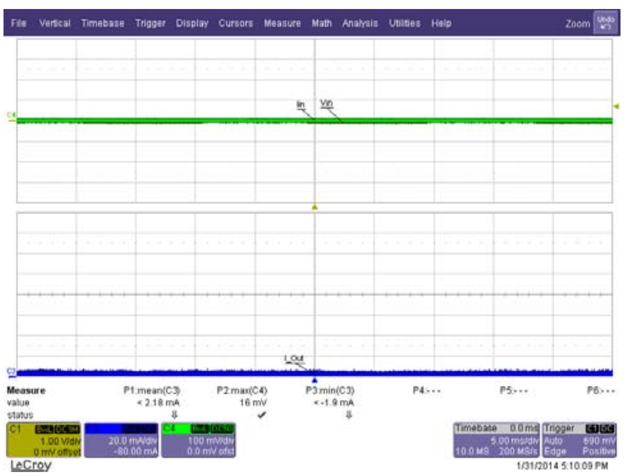

Figure 56 – 230 VAC / 50 Hz, Some Dimmers Such as Niko 310-017 Have No Significant Leakage Voltage.
Ch1: V_{IN}, 100 V / div.
Ch3: I_{OUT}, 0.02 A / div.
Ch4: I_{IN}, 0.1 A / div.
Time Scale: 5 ms / div.

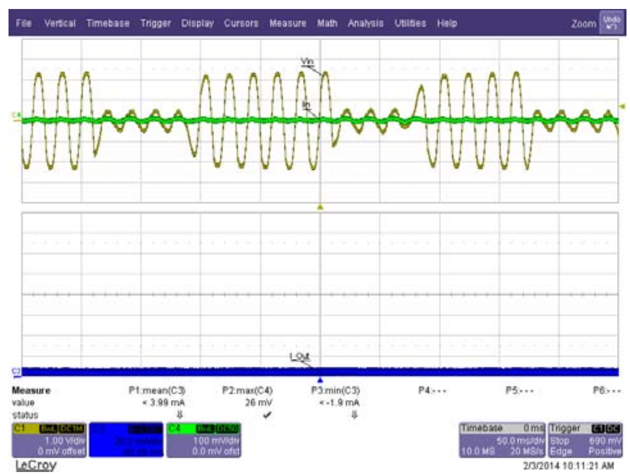

Figure 57 – 230 VAC / 50 Hz, Leakage from RTM34LED DAXS.
Ch1: V_{IN}, 100 V / div.
Ch3: I_{OUT}, 0.02 A / div.
Ch4: I_{IN}, 0.1 A / div.
Time Scale: 50 ms / div.

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13 Line Surge

Input voltage was set at 230 VAC / 60 Hz. Output was loaded with 72 V LED string and operation was verified following each surge event. Two units were tested to confirm the results.

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.

14 Conducted EMI

14.1 Equipment

Receiver:

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

LISN:

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

14.2 EMI Test Set-up

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

Figure 58 – Conducted Emissions Measurement Set-up.

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14.3 EMI Test Result

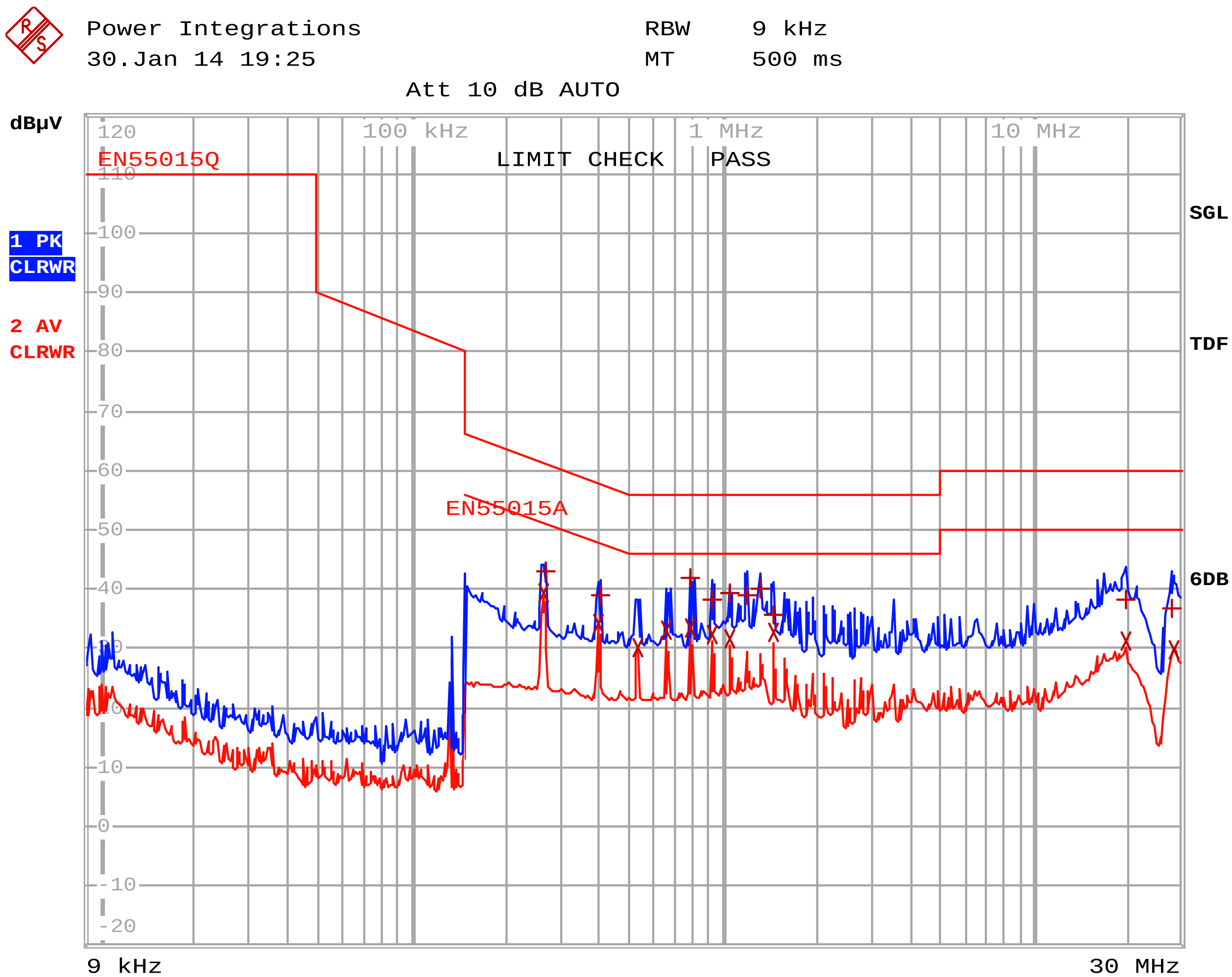

Figure 59 – Conducted EMI, 72 V Output / 115 mA Steady-State Load, 230 VAC, 60 Hz, and EN55015 Limits.

EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBμV		DELTA LIMIT dB
2	Average	264.49018761 kHz	39.50	L1 gnd	-11.78
1	Quasi Peak	267.135089486 kHz	43.18	L1 gnd	-18.01
2	Average	397.727746704 kHz	34.31	N gnd	-13.58
1	Quasi Peak	401.705024172 kHz	38.88	N gnd	-18.93
2	Average	530.769219795 kHz	30.03	N gnd	-15.96
2	Average	660.656865747 kHz	33.10	L1 gnd	-12.89
1	Quasi Peak	790.243042258 kHz	41.79	L1 gnd	-14.20
2	Average	790.243042258 kHz	33.36	L1 gnd	-12.63
1	Quasi Peak	926.622115652 kHz	38.32	L1 gnd	-17.67
2	Average	926.622115652 kHz	32.29	L1 gnd	-13.70
1	Quasi Peak	1.05458240332 MHz	39.27	L1 gnd	-16.72
2	Average	1.05458240332 MHz	31.51	L1 gnd	-14.48
1	Quasi Peak	1.1883298484 MHz	38.79	L1 gnd	-17.20
1	Quasi Peak	1.31265544283 MHz	39.93	L1 gnd	-16.06
2	Average	1.44998824519 MHz	32.61	L1 gnd	-13.38
1	Quasi Peak	1.46448812765 MHz	35.55	L1 gnd	-20.44
1	Quasi Peak	19.8557266951 MHz	38.17	L1 gnd	-21.82
2	Average	19.8557266951 MHz	31.10	L1 gnd	-18.89
1	Quasi Peak	27.8491853062 MHz	36.73	N gnd	-23.26
2	Average	28.4089539309 MHz	29.68	N gnd	-20.31

Figure 60 – Conducted EMI, 72 V / 115 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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15 Revision History

Date	Author	Revision	Description and Changes	Reviewed
23-Apr-14	JDC	1.0	Initial Release	Apps & Mktg

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

PATENT INFORMATION

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