Design Example Report

Title	***12 W High Power Factor Non-Isolated Buck-Boost, TRIAC Dimmable LED Driver Using LYTSwitch™-4 LYT4322E***
Specification	190 VAC – 265 VAC Input; 120 V_{TYP}, 100 mA Output
Application	A19 LED Driver
Author	Applications Engineering Department
Document Number	DER-412
Date	June 9, 2014
Revision	1.0

Summary and Features

- Single-stage power factor correction combined with constant current (CC) output
- TRIAC dimmable
  - Works with a wide selection of TRIAC dimmers from 300 W to 1200 W
  - Fast start-up time (<200 ms) – no perceptible delay
- Integrated protection and reliability features
  - Output short-circuit protected with auto-recovery
  - Auto-recovering thermal shutdown with large hysteresis
  - No damage during brown-out conditions
- PF >0.9 at 230 VAC
- Meets ring wave and differential line surge and EN55015 conducted EMI

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

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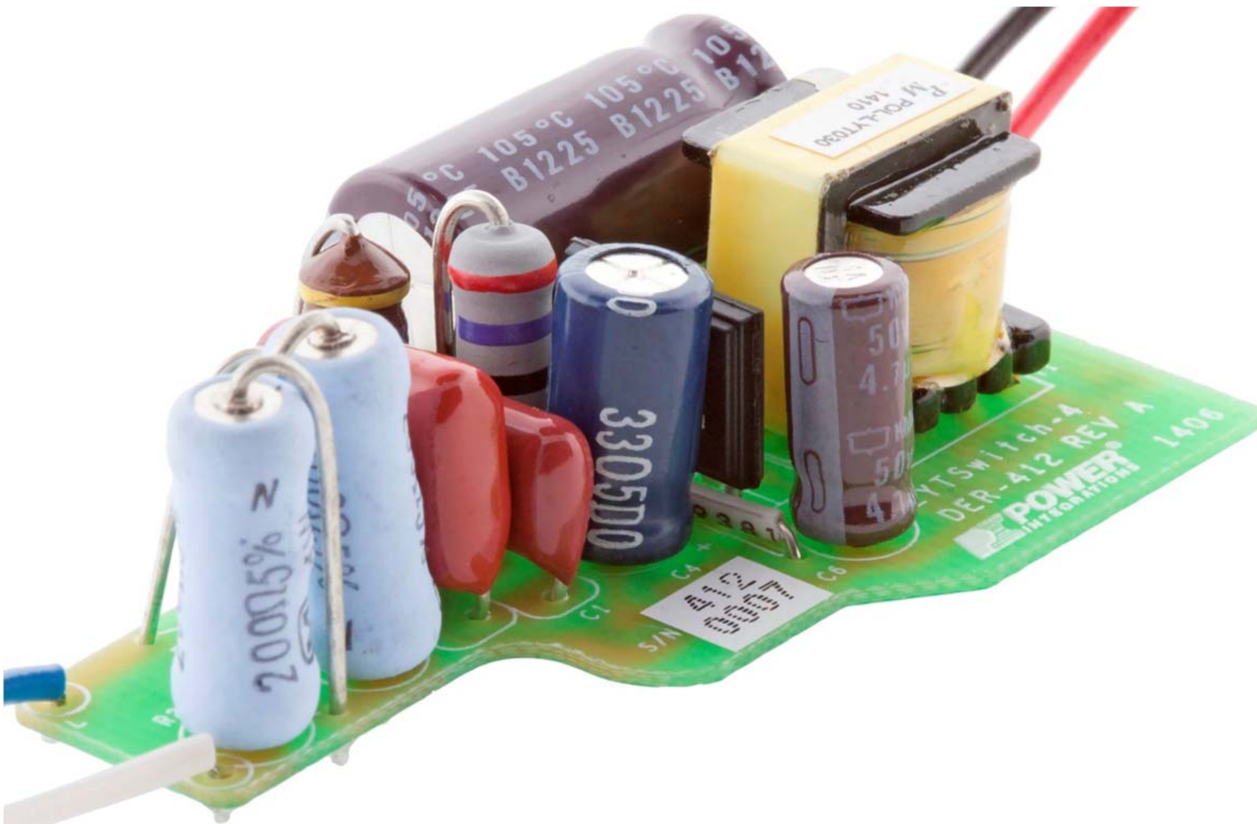
1 Introduction

The document describes a non-isolated, high power factor (PF), TRIAC dimmable LED driver designed to drive a nominal LED string voltage of 120 V at 100 mA from an input voltage range of 190 VAC to 265 VAC (50 Hz typical). The LED driver utilizes the LYT4322E from the LYTSwitch-4 family of ICs.

The topology used is a single-stage non-isolated buck-boost that meets high power factor, constant current regulation, and dimming requirements for this design.

This document contains the LED driver specification, schematic, PCB details, bill of materials, transformer documentation and typical performance characteristics.



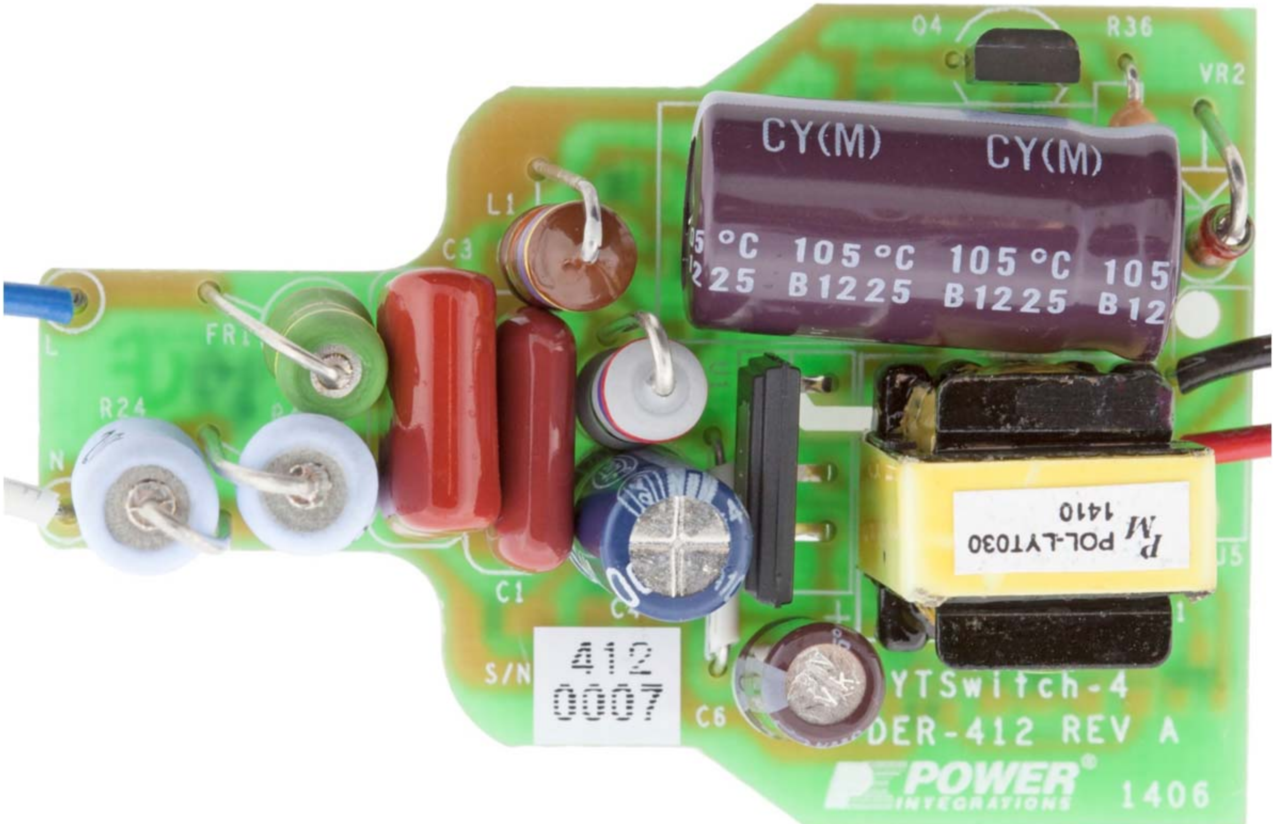


Figure 1 – Populated Circuit Board, Top View.

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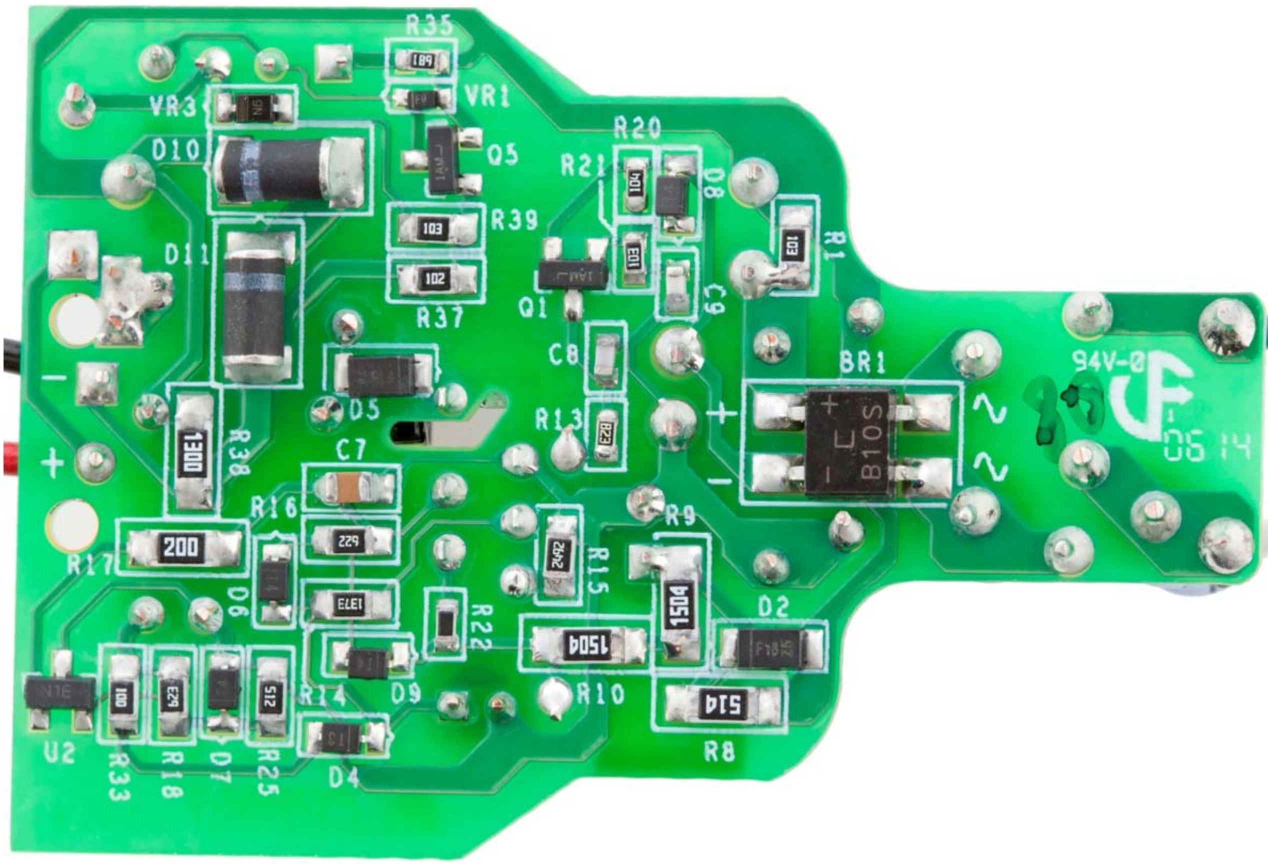

Figure 2 – Populated Circuit Board, Bottom View.

2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	190	230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}		50		Hz	
Output						
Output Voltage	V_{OUT}		120		V	
Output Current	I_{OUT}	93	100	107	mA	V_{OUT} = 120 V, V_{IN} = 230 VAC, 25 °C
Total Output Power						
Continuous Output Power	P_{OUT}		12		W	
Efficiency						
Full Load	η	84	85		%	Measured at P_{OUT} 25 °C, No Dimmer, 230 VAC Input
Environmental						
Conducted EMI		CISPR 15B / EN55015B				
Safety		Non-Isolated				
Ring Wave (100 kHz)						
Differential Mode (L1-L2)			2.5		kV	
Differential Surge			500		V	
Power Factor			0.9			Measured at $V_{OUT(TYP)}$, $I_{OUT(TYP)}$ and 230 VAC, 50 Hz
Ambient Temperature	T_{AMB}		40		°C	Free convection, open frame *Potting should be considered on final assembly to increase operating temperature and reduce thermal stress on dampers R24 and R40

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3 Schematic

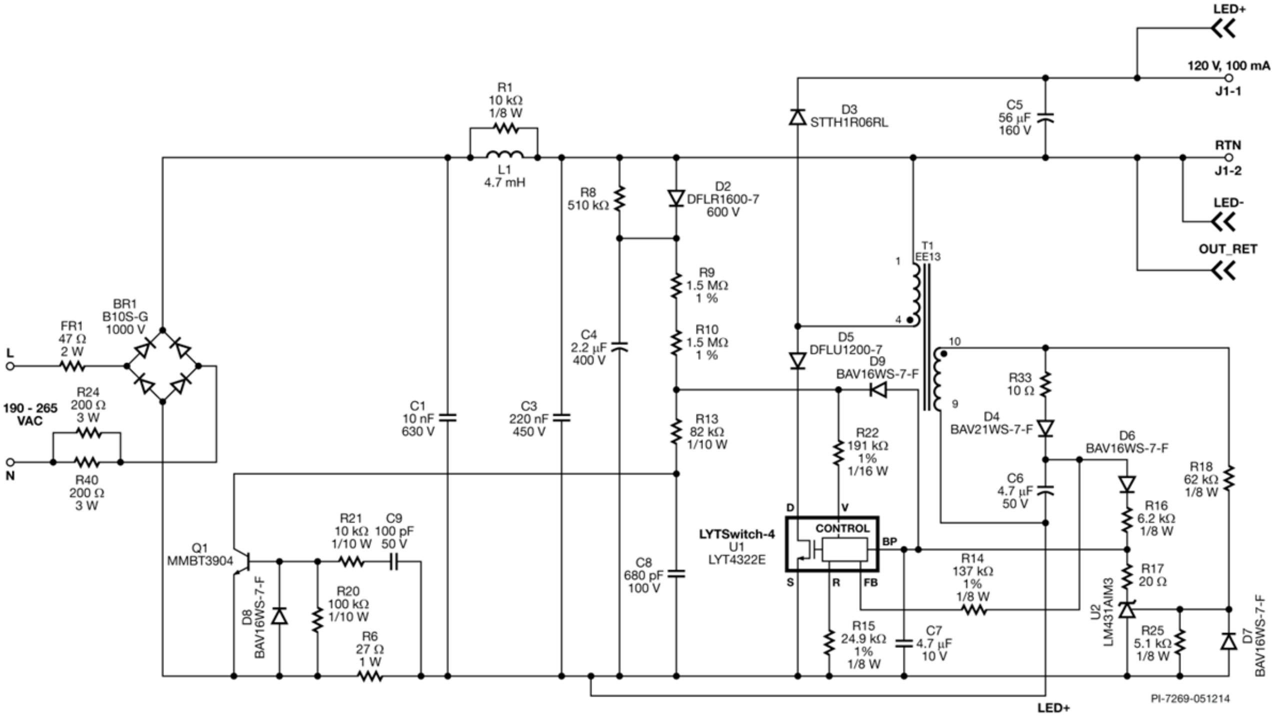

Figure 3 – Schematic.

Note: JP1 is 0 Ω 1206 smd resistor in R38 location if optional turn-off circuit is not used.

4 Circuit Description

The LYTSwitch-4 LYT4322E device is a controller with an integrated 725 V power MOSFET for use in LED driver applications. The LYTSwitch-4 LYT4322E is configured for use in a single-stage buck-boost topology and provides a regulated constant current output while maintaining high power factor from the AC input.

4.1 Input EMI Filtering

Fusible resistor FR1 provides protection from component failure during abnormal conditions. Diode bridge BR1 rectifies the AC line voltage with capacitor C3 providing a low impedance path (decoupling) for the primary switching current. A low value of input capacitance (sum of C1 and C3) is necessary to maintain a power factor of greater than 0.9. EMI filtering is provided by inductor L1 and capacitors C1 and C3.

4.2 Power Circuit

The topology chosen in this design is a low-side switch buck-boost configured to provide high power factor, and constant current output for the input voltage range of 190 VAC to 265 VAC.

Output Diode D3 conducts every time U1 is off and transfers energy to the load. Diode D5 is necessary to prevent reverse current from flowing through U1 while the voltage across C3 (rectified input AC) falls below the output voltage.

To provide peak line voltage information to U1, the incoming rectified AC peak charges C4 via D2. This is then fed into the VOLTAGE MONITOR (V) pin of U1 as a current via R9, and R10. Resistors R9 and R10 are chosen to give an I_V of ~100 μA at 230 VAC input (from PIXls spreadsheet).

The line overvoltage shutdown function, sensed via the V pin current, extends the rectified line voltage withstand (during surges and line swells) to the 725 BV_{DSS} rating of the internal power MOSFET.

Capacitor C7 provides local decoupling for the BP pin of U1 which is the supply pin for the internal controller. During start-up, C7 is charged to ~6 V from an internal high-voltage current source connected to the D pin of U1.

The REFERENCE pin of U1 is tied to ground (SOURCE) via 24.9 kΩ value resistor R15.

4.3 Output Feedback

The feedback is derived from a bias winding rectified and filtered by network formed by diode D4, and capacitor C6. The output voltage information across capacitor C6 is converted to feedback current via resistor R14. This current is used by LYT4322E to regulate the output current of the converter.

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4.4 TRIAC Phase Dimming Control Compatibility

The requirements to provide output dimming with low cost, TRIAC based, leading edge and trailing edge phase dimmers introduced some trade-offs in the design.

Due to the much lower power consumed by LED based lighting, the current drawn by the overall lamp is below the holding current of the TRIAC within many dimmers. This causes undesirable behavior such as limited dimming range and/or flickering. The relatively large impedance presented to the line and the dimmer by the LED allows significant ringing to occur due to the inability of the LED driver to damp the response of the LC networks within the dimmer and within the driver normally required for EMI. This effect can cause similar undesirable behavior, as the ringing may cause the TRIAC current to fall to zero and turn off.

To overcome these issues, the passive damper and lossless active bleeder were incorporated.

Resistor R24 and R40 are used to dampen the input network during TRIAC dimming.

Additional damping is provided by increasing the processed power during the leading edge portion of the ac input. This method emulates the behavior of a passive RC bleeder but without its associated loss and disadvantages in dimming.

4.5 No-Load/ Open Load Protection

The output voltage is detected on the bias winding through the turns ratio of main and the bias winding. Voltage regulator U2 will force the BP pin in auto-restart to regulate the output voltage. Divider R25 and R18 sets the detection threshold. Diode D7 protects U2 from a reverse current when the voltage reverses on bias winding during turn on. R17 is used to limit the maximum current into U2.

4.6 Optional Turn-off Circuit

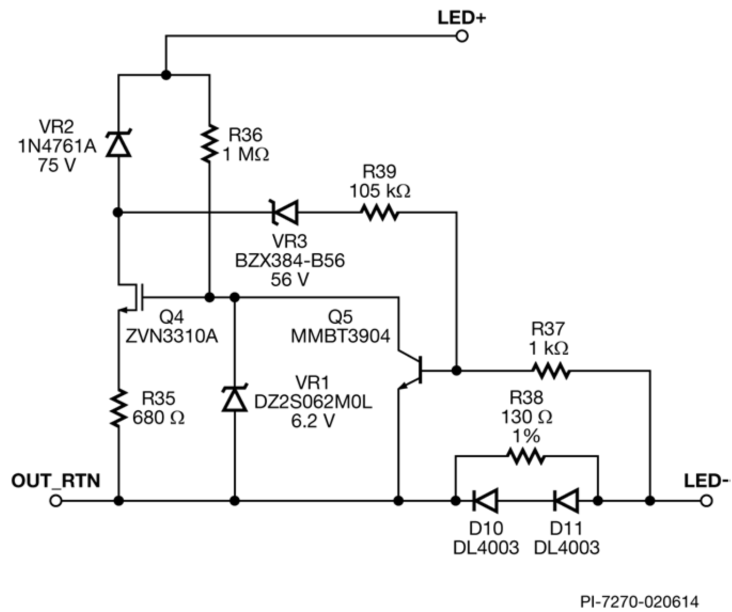

Figure 4 – Turn-off Circuit.

An active pre-load that turns off the LED current during deep dimming is also incorporated into this design. This turn-off circuit is used to avoid output light shimmer when the driver is used with dimmers that have conduction angles below 30º. At conduction angle of ≤30º, the dimmer conduction angle is more susceptible to variations due to line noise and the fact that power processed by the driver becomes too low to satisfy the dimmer holding current. This can lead to shimmering in the light output at very low conduction angle. To avoid this behavior, the output current to the LED is terminated when the output current drops to ~5 mA. This output current threshold is set by resistor R38. If the voltage drop on R38 falls below 0.65 V ($Q5_{Vbe}$), Q5 turns off, and Q4 turns-on. When Q4 is on, the output is shunted to VR2 + $Q4_{VDS}$ + ~4 V. At this level, the LED should turn off and all the output current is diverted to Q4 branch. Resistor R35 is chosen to allow the Q4 branch to draw 4 V / R35 of current. This current is slightly higher than the 5 mA threshold to avoid bouncing between Q4 branch and the output. R35 voltage is limited by Q4VGT – VR1. This configuration also limits the maximum dissipation on the Q4 branch.

Diode D10 and D11 was employed to limit the voltage drop on R38 to two diode drop for efficiency and protection for R38 during output short condition. VR3 and R39 were used to shut down the preload during open load condition. Zener diode VR3 is chosen such that VR2 + VR3 are greater than the maximum LED voltage. Resistor R36 biases Q4 when Q5 is off.

The output current however can be on the <1 mA range. This happens when dimmer is started at the minimum dimmer position. This happens when the preload is active and

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drawing 4 V / R35 of current. The damper should be designed not to shimmer at I_{OUT} of > 4 V / R35 to avoid shimmer.

If the driver is used with dimmers that have minimum conduction angle of 45 or higher at 230 VAC, 50 Hz line, the turn-off circuit can be omitted with R38 replaced with a jumper resistor.

5 PCB Layout

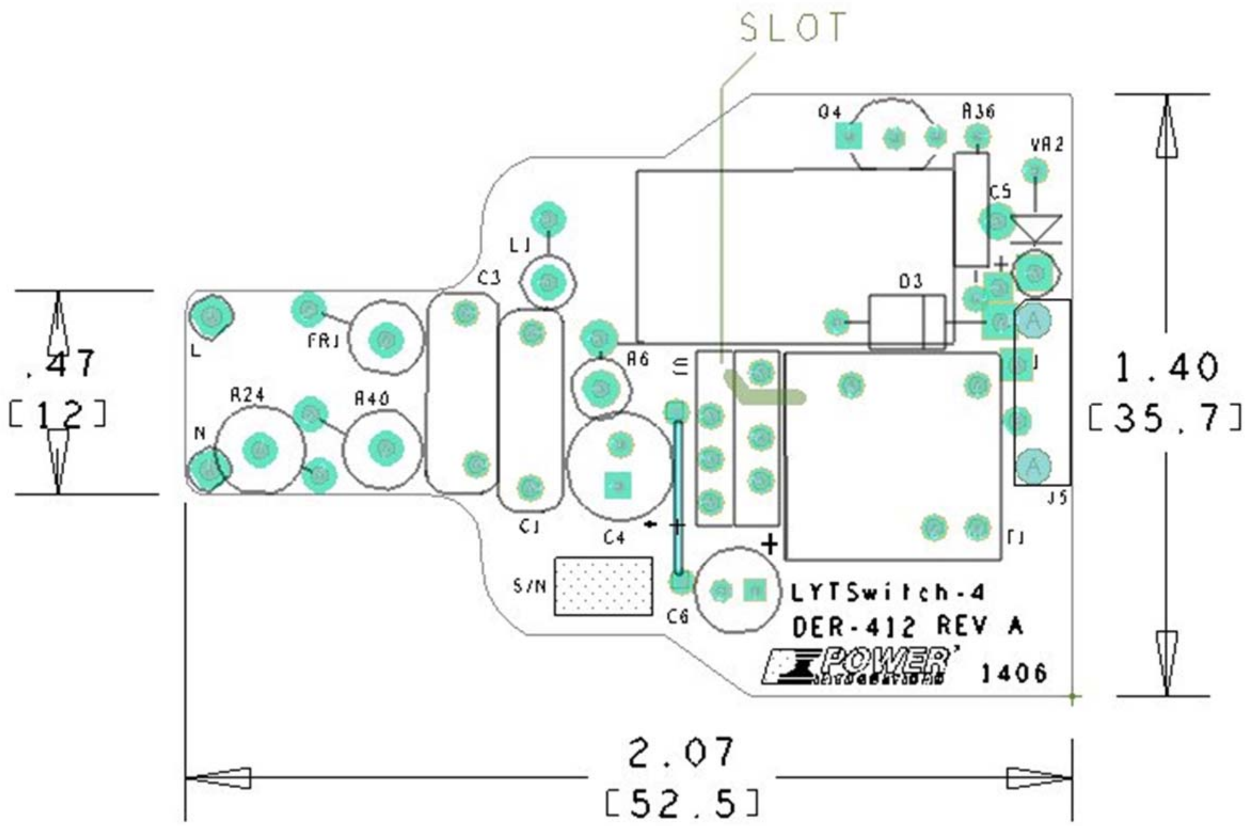

Figure 5 – Top Side.

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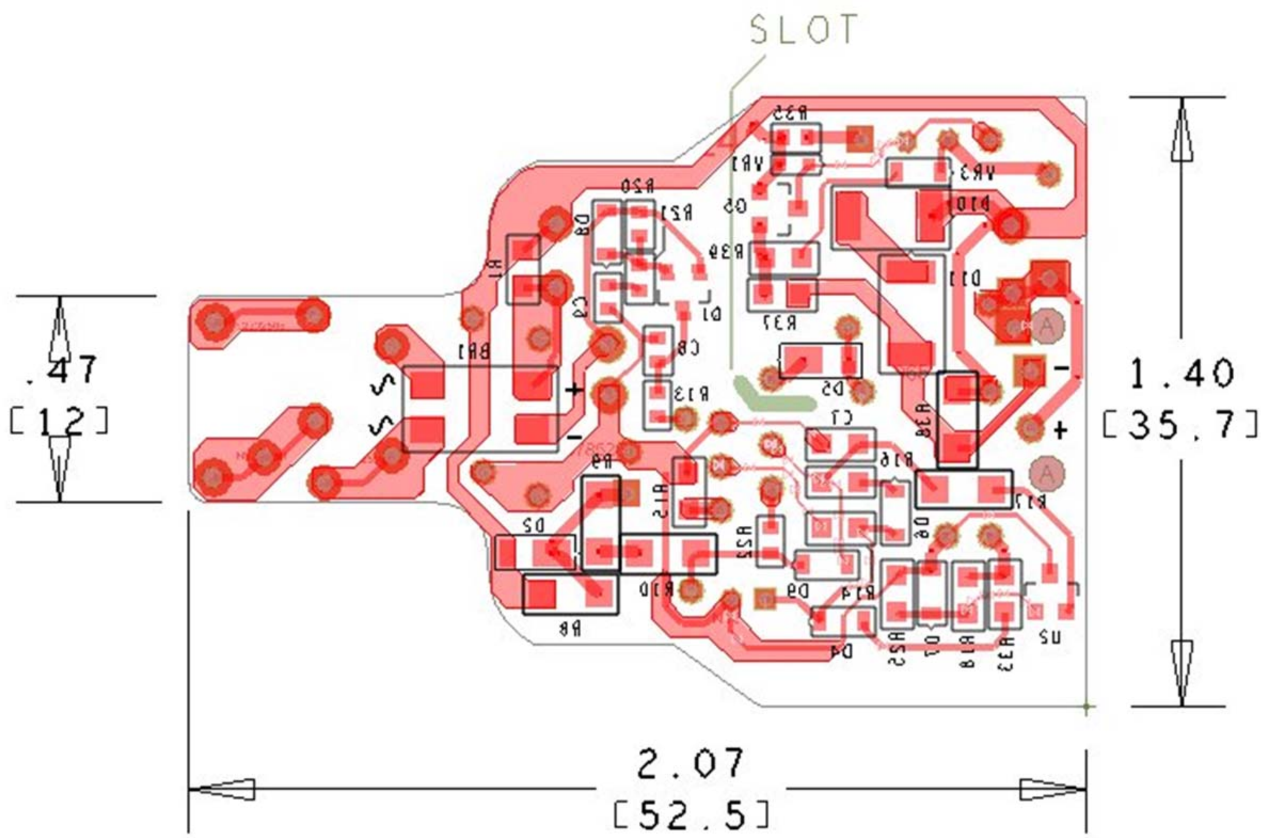

Figure 6 – Bottom Side.

6 Bill of Materials

6.1 BOM Without the Turn-off Circuit

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip
2	1	C1	10 nF, 630 V, Film	ECQ-E6103KF	Panasonic
3	1	C3	220 nF, 450 V, Film	MEXXF32204JJ	Duratech
4	1	C4	2.2 μF, 400 V, Electrolytic, (6.3 x 11)	TAB2GM2R2E110	Ltec
5	1	C5	56 μF, 160 V, Electrolytic, Gen. Purpose, (10 x 20)	UCY2C560MPD1TD	Nichicon
6	1	C6	4.7 μF, 50 V, Electrolytic, Gen. Purpose, (5 x 11)	EKMG500ELL4R7ME11D	Nippon Chemi-Con
7	1	C7	4.7 μF, 10 V, Ceramic, X7R, 0805	CL21A475KBQNNNE	Samsung
8	1	C8	680 pF 100 V, Ceramic, NPO, 0603	CGA3E2C0G2A681J	TDK
9	1	C9	100 pF 50 V, Ceramic, NPO, 0603	CC0603JRNPO9BN101	Yageo
10	1	D2	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
11	1	D3	600 V, 1 A, Ultrafast Recovery, DO-41	STTH1R06RL	ST Micro
12	1	D4	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
13	1	D5	DIODE, UFAST, 200 V, 1 A, POWERDI123	DFLU1200-7	Diodes, Inc.
14	1	D6	75 V, 0.15 A, Switching,SOD-323	BAV16WS-7-F	Diodes, Inc.
15	1	D7	75 V, 0.15 A, Switching,SOD-323	BAV16WS-7-F	Diodes, Inc.
16	1	D8	75 V, 0.15 A, Switching,SOD-323	BAV16WS-7-F	Diodes, Inc.
17	1	D9	75 V, 0.15 A, Switching,SOD-323	BAV16WS-7-F	Diodes, Inc.
18	1	FR1	47 Ω, 5%, 2 W, Wirewound, Fusible	FW20A47R0JA	Bourns
19	1	R38	0 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEY0R00V	Panasonic
20	1	L1	4.7 mH, 90 mA, 20 Ohm, RF Inductor	B82144A2475J	Epcos
21	1	Q1	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3904LT1G	On Semi
22	1	R1	10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
23	1	R6	27 Ω, 5%, 1 W, Metal Oxide	RSF100JB-27R	Yageo
24	1	R8	510 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ514V	Panasonic
25	1	R9	1.50 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1504V	Panasonic
26	1	R10	1.50 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1504V	Panasonic
27	1	R13	82 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ823V	Panasonic
28	1	R14	137 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1373V	Panasonic
29	1	R15	24.9 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF2492V	Panasonic
30	1	R16	6.2 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ622V	Panasonic
31	1	R17	20 R, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ200V	Panasonic
32	1	R18	62 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ623V	Panasonic
33	1	R20	100 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ104V	Panasonic
34	1	R21	10 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ103V	Panasonic
35	1	R22	191 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1913V	Panasonic
36	1	R24	200 Ω, 5%, 3 W, Metal Oxide	ERG-3SJ201	Panasonic
37	1	R25	5.1 k, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ512V	Panasonic
38	1	R33	10 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ100V	Panasonic
39	1	R40	200 Ω, 5%, 3 W, Metal Oxide	ERG-3SJ201	Panasonic
40	1	T1	Bobbin, EE13, Vertical, 10 pins Transformer Transformer	P-1302-2 SNX-R1731 POL-LYT030	Pin Shine Santronics Premier Magnetics
41	1	U1	LYTSwitch-4, eSIP-7C	LYT4322E	Power Integrations
42	1	U2	IC, REG ZENER SHUNT ADJ SOT-23	LM431AIM3/NOPB	National Semi
43	1	WIRE 24AWG	Wire, UL1007, #24 AWG, Red, PVC, 3 in	1007-24/7-2	Anixter
44	1	WIRE	Wire, UL1007, 24AWG, Blk, PVC, 3 in	1007-24/7-0	Anixter

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		24AWG			
45	1	WIRE 24AWG	Wire, UL1007, #24 AWG, Blu, PVC, 3 in	1007-24/7-6	Anixter
46	1	WIRE 24AWG	Wire, UL1007, #24 AWG, Wht, PVC, 3in	1007-24/7-9	Anixter

6.2 BOM With Turn-off Circuit

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip
2	1	C1	10 nF, 630 V, Film	ECQ-E6103KF	Panasonic
3	1	C3	220 nF, 450 V, Film	MEXXF32204JJ	Duratech
4	1	C4	2.2 μF, 400 V, Electrolytic, (6.3 x 11)	TAB2GM2R2E110	Ltec
5	1	C5	56 μF, 160 V, Electrolytic, Gen. Purpose, (10 x 20)	UCY2C560MPD1TD	Nichicon
6	1	C6	4.7 μF, 50 V, Electrolytic, Gen. Purpose, (5 x 11)	EKMG500ELL4R7ME11D	Nippon Chemi-Con
7	1	C7	4.7 μF, 10 V, Ceramic, X7R, 0805	CL21A475KBQNNNE	Samsung
8	1	C8	680 pF 100 V, Ceramic, NPO, 0603	CGA3E2C0G2A681J	TDK
9	1	C9	100 pF 50 V, Ceramic, NPO, 0603	CC0603JRNPO9BN101	Yageo
10	1	D2	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
11	1	D3	600 V, 1 A, Ultrafast Recovery, DO-41	STTH1R06RL	ST Micro
12	1	D4	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
13	1	D5	DIODE, UFAST, 200 V, 1 A, POWERDI123	DFLU1200-7	Diodes, Inc.
14	4	D6 D7 D8 D9	75 V, 0.15 A, Switching, SOD-323	BAV16WS-7-F	Diodes, Inc.
15	2	D10 D11	200 V, 1 A, Rectifier, Glass Passivated, DO-213AA (MELF)	DL4003-13-F	Diodes, Inc.
16	1	FR1	47 R, 5%, 2 W, Wirewound, Fusible	FW20A47R0JA	Bourns
17	1	L1	4.7 mH, 90 mA, 20 Ω, RF Inductor	B82144A2475J	Epcos
18	2	Q1 Q5	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3904LT1G	On Semi
19	1	Q4	100 V, 0.2 A, 10 Ω, N-Channel, TO-92	ZVN3310A	Diodes, Inc.
20	2	R1 R39	10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
21	1	R6	27 Ω, 5%, 1 W, Metal Oxide	RSF100JB-27R	Yageo
22	1	R8	510 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ514V	Panasonic
23	2	R9 R10	1.50 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1504V	Panasonic
24	1	R13	82 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ823V	Panasonic
25	1	R14	137 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1373V	Panasonic
26	1	R15	24.9 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF2492V	Panasonic
27	1	R16	6.2 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ622V	Panasonic
28	1	R17	20 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ200V	Panasonic
29	1	R18	62 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ623V	Panasonic
30	1	R20	100 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ104V	Panasonic
31	1	R21	10 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ103V	Panasonic
32	1	R22	191 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1913V	Panasonic
33	2	R24 R40	200 Ω, 5%, 3 W, Metal Oxide	ERG-3SJ201	Panasonic
34	1	R25	5.1 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ512V	Panasonic
35	1	R33	10 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ100V	Panasonic
36	1	R35	680 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ681V	Panasonic

37	1	R36	1 MΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-1M0	Yageo
38	1	R37	1 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ102V	Panasonic
39	1	R38	130 Ω, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1300V	Panasonic
40	1	T1	Bobbin, EE13, Vertical, 10 pins Transformer Transformer	P-1302-2 SNX-R1731 POL-LYT030	Pin Shine Santronics Premier Magnetics
41	1	U1	LYTSwitch-4, eSIP-7C	LYT4322E	Power Integrations
42	1	U2	IC, REG ZENER SHUNT ADJ SOT-23	LM431AIM3/NOPB	National Semi
43	1	VR1	6.2 V, 5%, 150 mW, SSMINI-2	DZ2S062M0L	Panasonic
44	1	VR2	75 V, 5%, 1 W, DO-41	1N4761A-TR	Vishay
45	1	VR3	56 V, 2%, 300 mW, SOD323	BZX384-B56,115	NXP Semi
46	1	WIRE 24AWG	Wire, UL1007, #24 AWG, Red, PVC, 3 in	1007-24/7-2	Anixter
47	1	WIRE 24AWG	Wire, UL1007, #24 AWG, Blk, PVC, 3 in	1007-24/7-0	Anixter
48	1	WIRE 24AWG	Wire, UL1007, #24 AWG, Blu, PVC, 3 in	1007-24/7-6	Anixter
49	1	WIRE 24AWG	Wire, UL1007, #24 AWG, Wht, PVC, 3 in	1007-24/7-9	Anixter

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7 Inductor 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	190		190	V	Minimum AC Input Voltage
VACMAX			265	V	Maximum AC input voltage
fL			50	Hz	AC Mains Frequency
VO	120		120	V	Typical output voltage of LED string at full load
VO_MAX			132.00	V	Maximum expected LED string Voltage.
VO_MIN			108.00	V	Minimum expected LED string Voltage.
V_OVP			142.37	V	Over-voltage protection setpoint
IO	0.1		0.10	A	Typical full load LED current
PO			12.0	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	FULL		FULL		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN			0.79	A	Minimum current limit
ILIMITMAX			0.92	A	Maximum current limit
fS			132000	Hz	Switching Frequency
fSmin			124000	Hz	Minimum Switching Frequency
fSmax			140000	Hz	Maximum Switching Frequency
IV			100.7	uA	V pin current
RV	3.2		3.2	M-ohms	Upper V pin resistor
RV2			1000000000000	M-ohms	Lower V pin resistor
IFB	177		177.0	uA	FB pin current (85 uA < IFB < 210 uA)
RFB1			124.3	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	1.18		1.18		Ripple to Peak Current Ratio (For PF > 0.9, 0.4 < KP < 0.9)
LP			960	uH	Primary Inductance
VOR	120.5		120.5	V	Reflected Output Voltage.
Expected IO (average)			0.10	A	Expected Average Output Current
KP_VNOM		Info	1.00		!!! Info. PF at high line may be less than 0.9. Decrease KP for higher PF
TON_MIN			1.84	us	Minimum on time at maximum AC input voltage
PCLAMP			0.09	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
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	4		4		Number of Primary Layers
NS	150		150		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			269	V	Peak input voltage at VACMIN
VMAX			375	V	Peak input voltage at VACMAX
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.28		Minimum duty cycle at peak of VACMIN
IAVG			0.07	A	Average Primary Current
IP			0.60	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
IRMS			0.15	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			960	uH	Primary Inductance
LP_TOL			10		Tolerance of primary inductance
NP			150		Primary Winding Number of Turns
NB			32		Bias Winding Number of Turns
ALG			43	nH/T^2	Gapped Core Effective Inductance
BM			2256	Gauss	Maximum Flux Density at PO, VMIN (BM<3100)
BP			3444	Gauss	Peak Flux Density (BP<3700)
BAC			1128	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1588		Relative Permeability of Ungapped Core
LG			0.48	mm	Gap Length (Lg > 0.1 mm)
BWE			29.6	mm	Effective Bobbin Width
OD			0.20	mm	Maximum Primary Wire Diameter including insulation
INS			0.04	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.16	mm	Bare conductor diameter
AWG			35	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			32	Cmils	Bare conductor effective area in circular mils
CMA			210	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 600)
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)					
Lumped parameters					
ISP			0.60	A	Peak Secondary Current
ISRMS			0.22	A	Secondary RMS Current
IRIPPLE			0.20	A	Output Capacitor RMS Ripple Current (based on Expected IO)
CMS			44	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			0.05	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire

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VOLTAGE STRESS PARAMETERS					
VDRAIN			620	V	Estimated Maximum Drain Voltage assuming maximum LED string voltage (Includes Effect of Leakage Inductance)
PIVS			517	V	Output Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike)
PIVB			110	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			3.20	M-ohms	Upper V Pin Resistor Value
RV2			1000000000000	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			0.10	A	Measured Output Current at VAC1
IO_VAC2			0.10	A	Measured Output Current at VAC2
RV1 (new)			3.20	M-ohms	New RV1
RV2 (new)			16729.30	M-ohms	New RV2
V_OV			256.2	V	Typical AC input voltage at which OV shutdown will be triggered
V_UV			53.6	V	Typical AC input voltage beyond which power supply can startup
FB pin resistor Fine Tuning					
RFB1			124	k-ohms	Upper FB Pin Resistor Value
RFB2			1000000000000	k-ohms	Lower FB Pin Resistor Value
VB1			22.4	V	Test Bias Voltage Condition1
VB2			27.6	V	Test Bias Voltage Condition2
IO1			0.10	A	Measured Output Current at Vb1
IO2			0.10	A	Measured Output Current at Vb2
RFB1 (new)			124.3	k-ohms	New RFB1
RFB2(new)			1000000000000	k-ohms	New RFB2
Input Current Harmonic Analysis					
Harmonic			Max Current (mA)	Limit (mA)	
1st Harmonic			62.70	N/A	Fundamental (mA)
3rd Harmonic			16.03	48.00	PASS. 3rd Harmonic current content is lower than the limit
5th Harmonic			8.1	26.82	PASS. 5th Harmonic current content is lower than the limit
7th Harmonic			5.0	14.12	PASS. 7th Harmonic current content is lower than the limit
9th Harmonic			3.44	7.06	PASS. 9th Harmonic current content is lower than the limit
11th Harmonic			2.53	4.94	PASS. 11th Harmonic current content is lower than the limit
13th Harmonic			1.93	4.18	PASS. 13th Harmonic current content is lower than the limit
15th Harmonic			1.53	3.62	PASS. 15th Harmonic current content is lower than the limit
THD			29.6	%	Estimated total Harmonic Distortion (THD)

8 Inductor Specification

8.1 Electrical Diagram

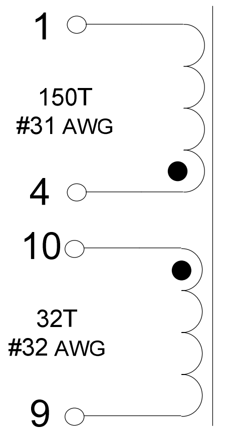

Figure 7 – Inductor Electrical Diagram.

8.2 Electrical Specifications

Primary Inductance	Pins 1-4, all other windings open, measured at 100 kHz, 0.4 V_{RMS} AL = 42.667 nH/n^2	960 μH ±5%

8.3 Materials

Item	Description
[1]	Core: EE13 NC2H or equivalent.
[2]	Bobbin: EE13; 5/5 pin vertical. PI PN: 25-01023-00
[3]	Magnet Wire: #31 AWG.
[4]	Magnet Wire: #32 AWG.
[5]	Tape, Polyester film, 3M 1350F-1 or equivalent, 7.4 mm wide.
[6]	Dolph BC-359 or equivalent.

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8.4 Inductor Build Diagram

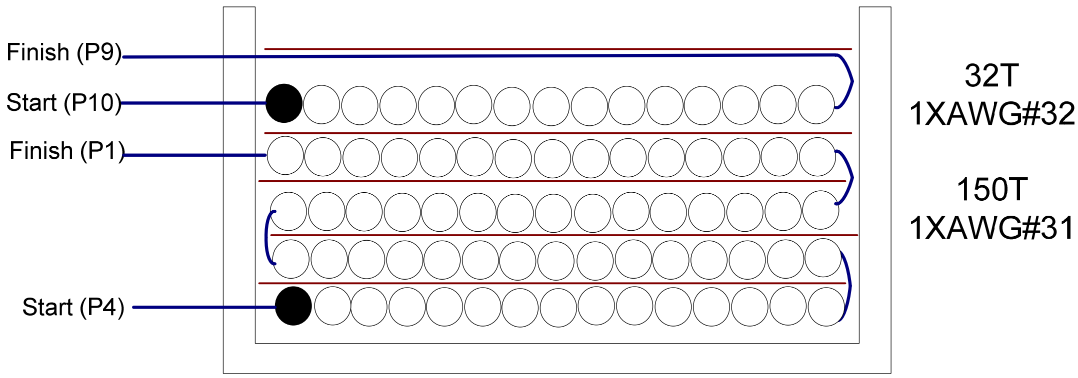

Figure 8 – Inductor Build Diagram.

8.5 Inductor Construction

Bobbin Preparation	Place the bobbin item [2] on the mandrel with pin side on the left and winding direction is clockwise direction.
Winding1	Use wire item [3], start at pin 4 wind 150 turns in ~4 layers and at the last turn terminate the wire at pin 1. Apply 1 layer of tape item [5] between layers
Winding2	Use wire item [4], start at pin 10 wind 32 turns in ~1 layer, and at the last turn terminate the wire at pin 9. Apply 1 layer of tape item [5] between layers
Finish	Grind core to get 960 μH inductance, secure the core with tape. Dip impregnate using varnish item[6]
Pins	Cut pins 2, 3, 5, 6, 7, 8.

9 Performance Data

All measurements performed at room temperature using an LED load. The following data were measured using customer LED load of ~120 V output voltage. Refer to the table on Section 9.4 for the complete set of test data values.

9.1 Efficiency

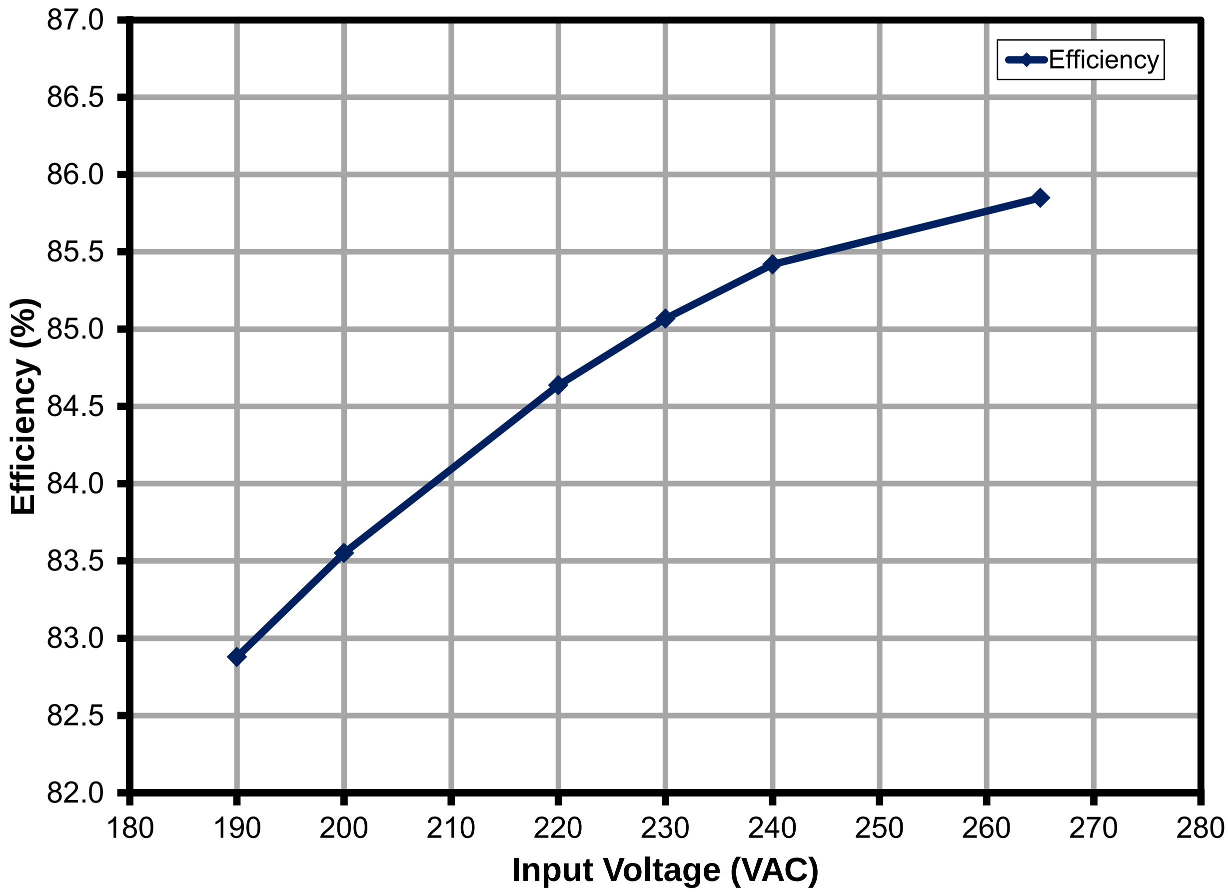

Figure 9 – Efficiency vs. Line.

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9.2 Line Regulation

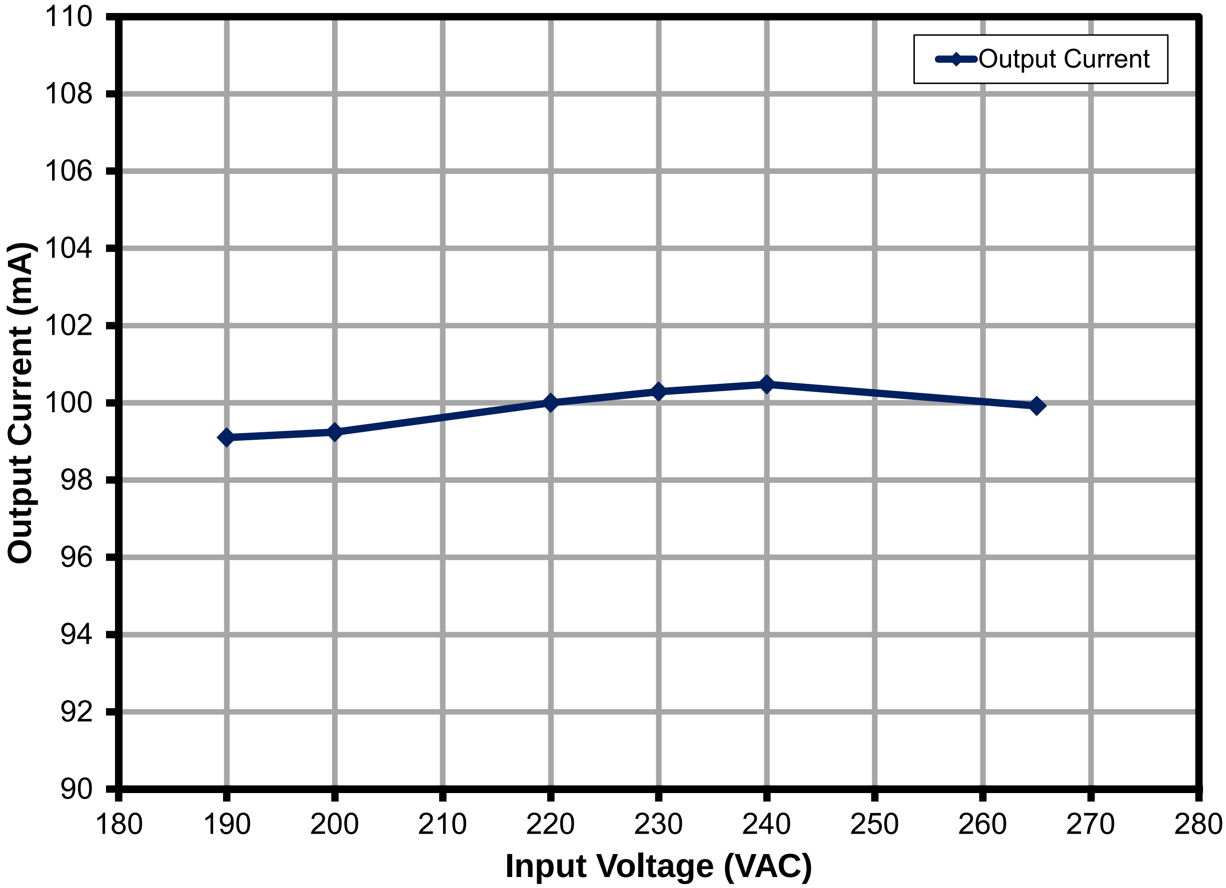

Figure 10 – Regulation vs. Line.

9.3 Power Factor

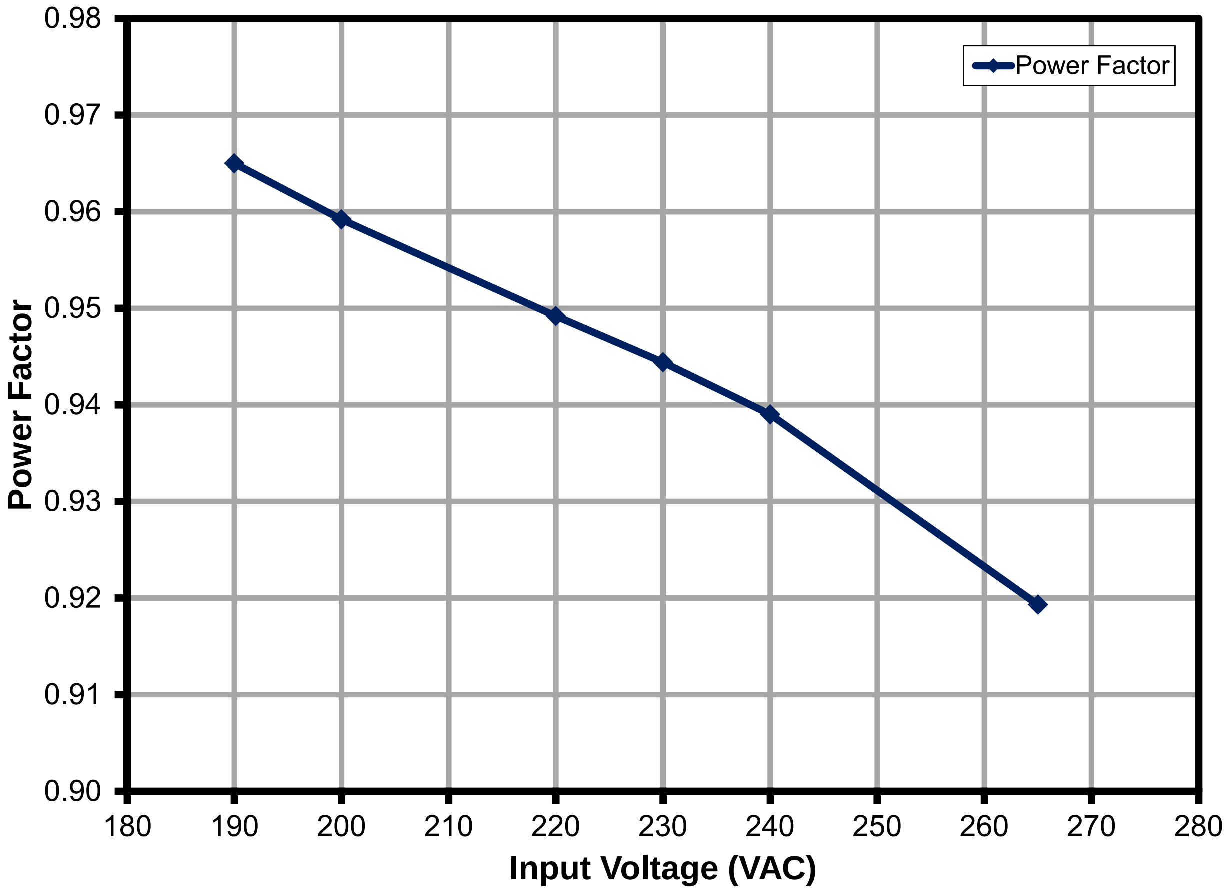

Figure 11 – Power Factor vs. Line.

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9.4 Test Data

All measurements were taken with the board at open frame, 25 ºC ambient, 50 Hz line frequency, and customer supplied LED load

Input Measurement					Load Measurement			Calculation		
V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	P_{CAL} (W)	Efficiency (%)	Loss (W)
190.11	76.22	13.983	0.965	22.45	116.7400	99.100	11.589	11.57	82.88	2.39
200.08	72.16	13.849	0.959	23.58	116.3900	99.240	11.571	11.55	83.55	2.28
220.11	65.86	13.760	0.949	24.43	116.2500	100.000	11.646	11.63	84.64	2.11
230.16	63.10	13.715	0.944	24.31	116.1300	100.290	11.667	11.65	85.07	2.05
240.13	60.65	13.675	0.939	24.05	116.0400	100.480	11.681	11.66	85.42	1.99
265.15	55.44	13.512	0.919	24.63	115.9000	99.920	11.600	11.58	85.85	1.91

10 Dimming Performance Data

TRIAC dimming results were taken with input voltage of 230 VAC, 60 Hz line frequency, room temperature, and nominal ~120 V LED load.

10.1 Dimming Curve

Taken using a programmable AC source providing the leading edge chopped AC input.

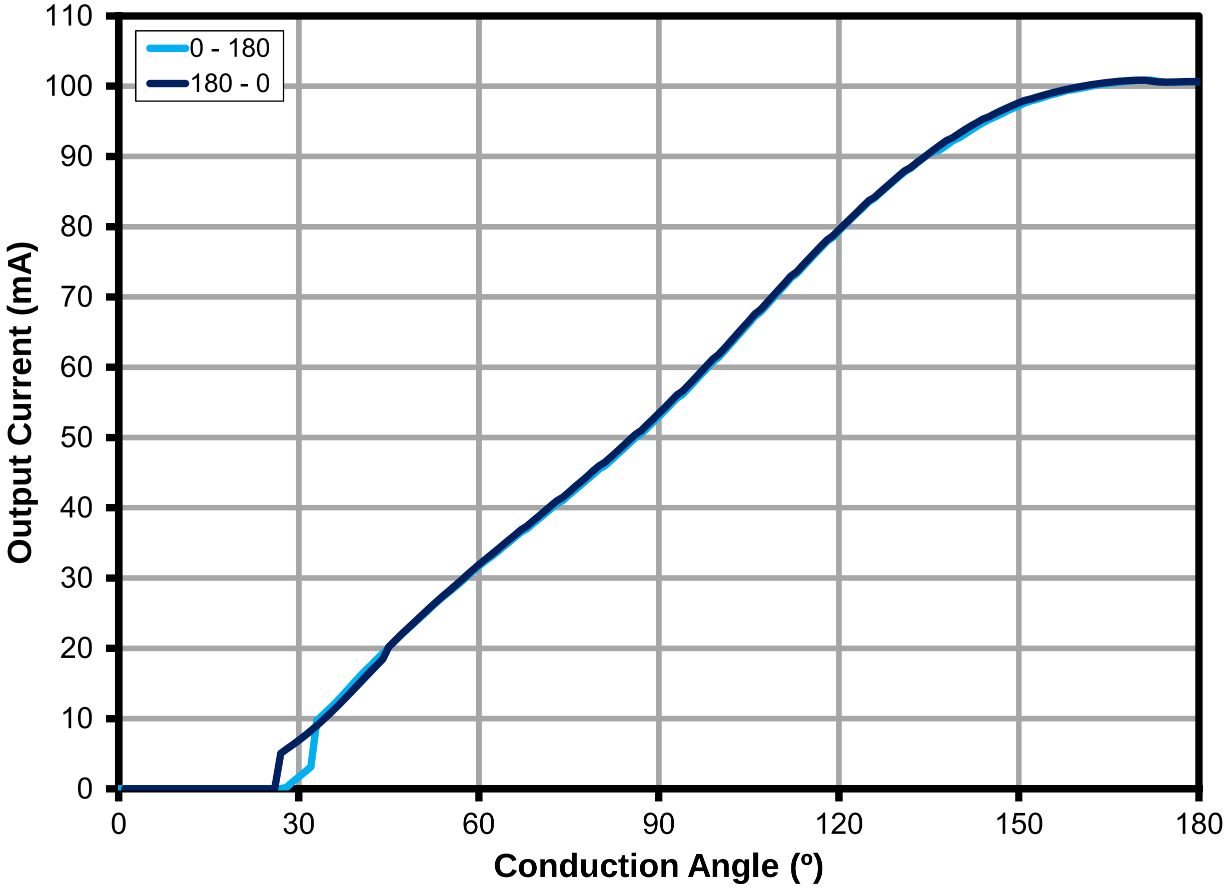

Figure 12 – Leading Edge Dimming Characteristics.

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10.2 *Dimming Efficiency*

Measured using a programmable AC source providing the leading edge chopped AC input. Note that dimming efficiency varies with the dimmer used.

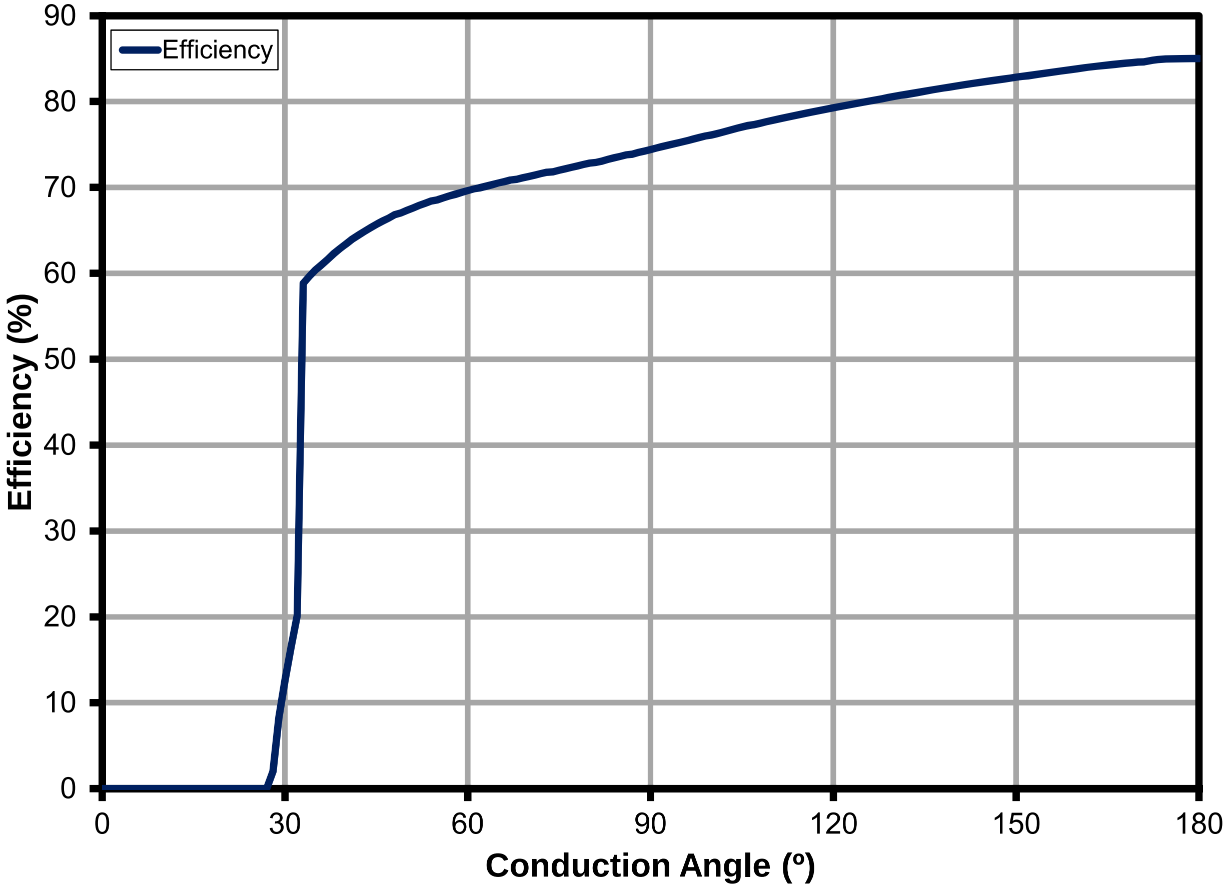

Figure 13 – Driver Efficiency as a function of Conduction Angle.

10.3 Driver Power Loss during Dimming

Measured using a programmable AC source providing the leading edge chopped AC input. Note the increase in power loss at ~30 due to turn-off circuit.

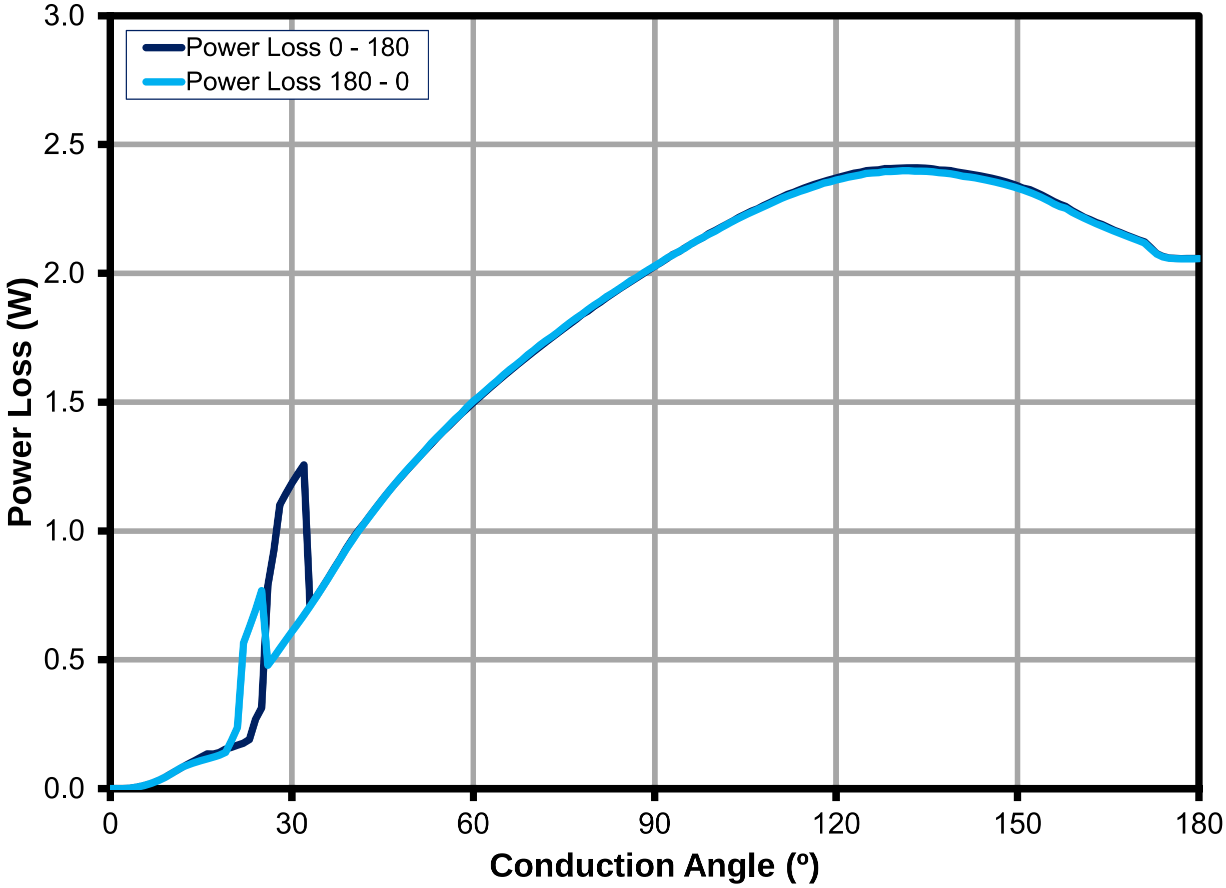

Figure 14 – Driver Power Loss as a function of Conduction Angle.

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10.4 Dimmer Compatibility List

The unit was tested with the following high-line dimmers at 230 VAC, 50 Hz input and ~120 V LED load.

Dimmers	Type	I_{OUT} (mA)		DR
		Max	Min	
BERKER 2830 10	LE	97	28	3.46
JUNG 225 NV DE	LE	95	19	5.00
JUNG 254 UDIE 1	TE	95	20	4.75
JUNG 266 G DE	LE	97	23	4.22
BUSCH 2200 UJ-212	LE	97	33	2.94
BUSCH 2250 U	LE	98	19	5.16
BUSCH 2247 U	LE	97	28	3.46
GIRA 2262 00 / IO1	LE	97	15	6.47
GIRA 0300 00 / IO1	LE	97	32	3.03
GIRA 0302 00 / IO1	LE	98	24	4.08
GIRA 1176 00/I03	TE	95	26	3.65
310-013	LE	99	27.5	3.60
310-017	TE	92	29	3.17
310-014	LE	99	33	3.00
310-016	LE	99	30	3.30
KOPP 8033	LE	93	25	3.72
BUSCH 691 U-101	ELEC	92	21	4.38
BUSCH 6513 U-102	TE	97	22	4.41
PEHA 433HAB	TE	93	31	3.00
PEHA 433HAB Oa	TE	86	21	4.10
REV 300W	LE	97	1	97.00
2250	LE	98	21	4.67
400W	LE	93	6	15.50
572499	LE	99	16	6.19
6513	TE	97	23	4.22
2875	LE	97	23	4.22
TCL	LE	100	21	4.76
SEN BO LANG	LE	100	35	2.86
EBA HUANG	LE	100	1	100.00
SB ELECT	LE	99	1	99.00
MYONGBO	LE	100	34	2.94
KBE	LE	100	5	20.00
CLIPMEI	LE	100	22	4.55
MANK	LE	100	37	2.70
32E450LM	LE	94	22	4.27
32E450TM	TE	92	20	4.60
32E2CFLDM	TE	91	20	4.55
32E450UDM	TE	95	24	3.96
SED200LRS	LE	99	1	99.0
WDE200L-1	LE	99	1	99.0
SED300FHS	LE	97	6	16.2
EED100PRS	LE	99	1	99.0
E0902 DIM	LE	97	17	5.7
WDE300F-1	LE	99	1	99.0

11 Thermal Performance

The following reading were taken at open frame, room temperature condition

11.1 230 VAC, 50 Hz: No Dimmer Connected

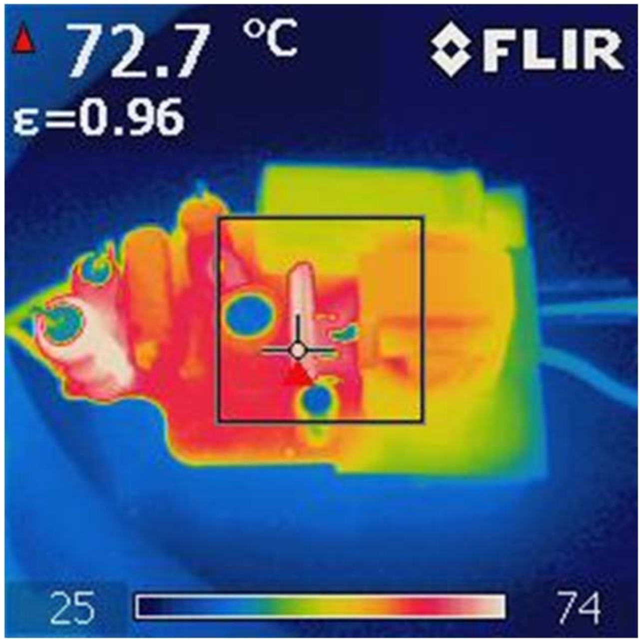

Figure 15 – U1: LYT4322E**.**

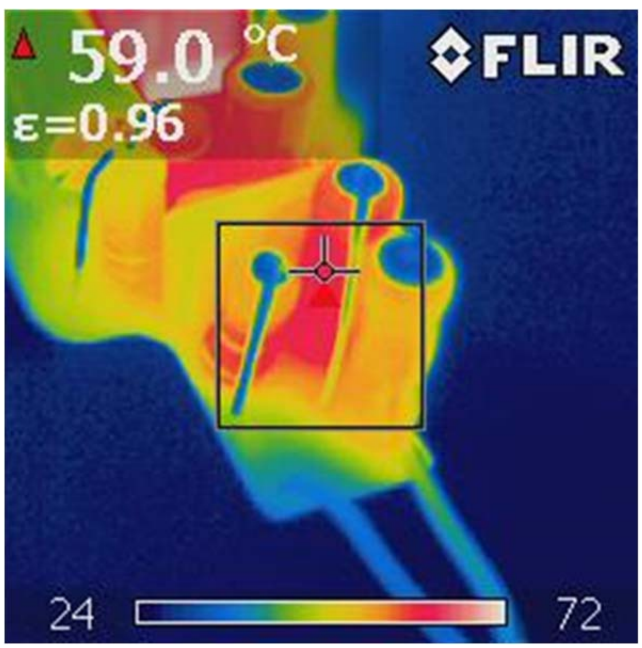

Figure 16 – R24: Damper Resistor.

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11.2 230 VAC, 50 Hz: Dimmer Connected, 90º Conduction Angle

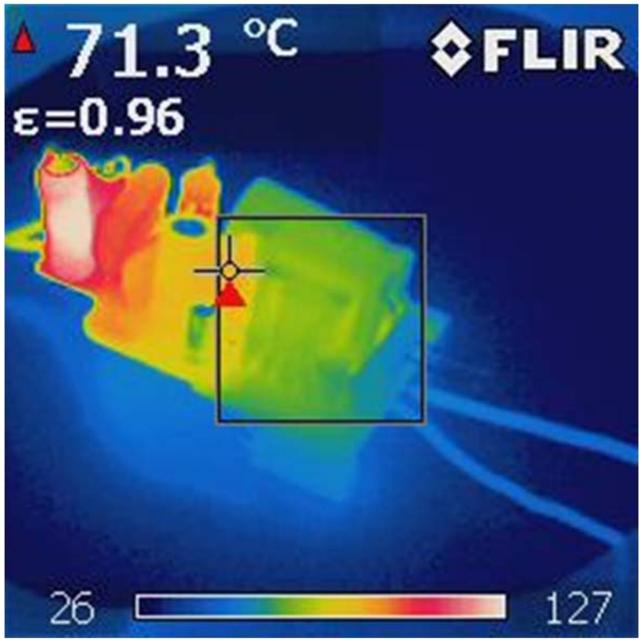

Figure 17 – U1: LYT4322E.

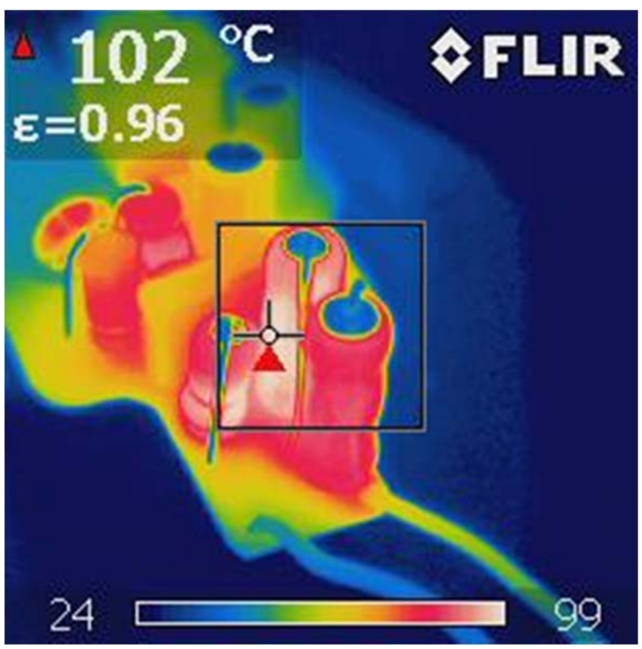

Figure 18 – R24: Damper Resistor.

12 Non-Dimming (No Dimmer Connected) Waveforms

12.1 Input Voltage and Input Current Waveforms

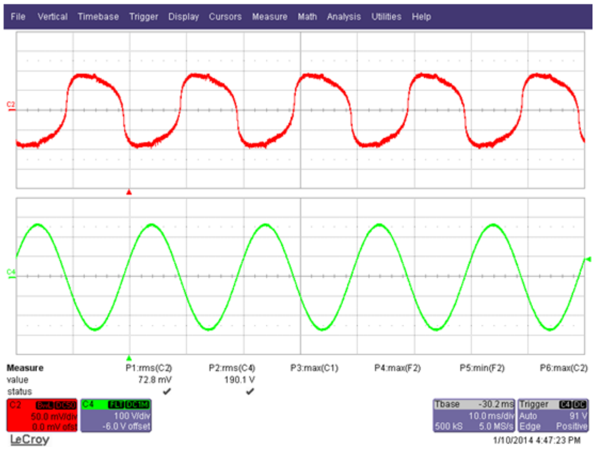

Figure 19 – 190 VAC, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 10 ms / div.

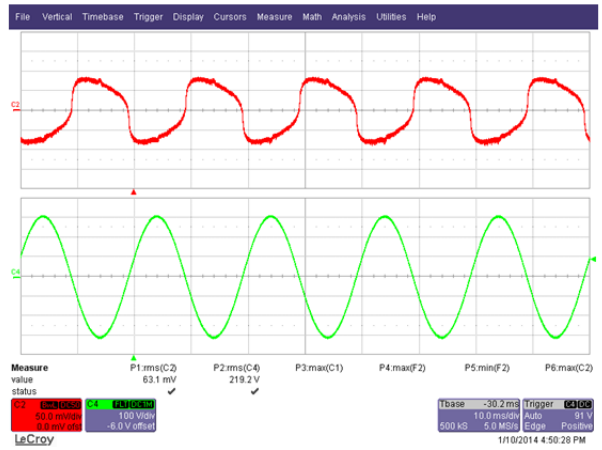

Figure 20 – 220 VAC, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 10 ms / div.

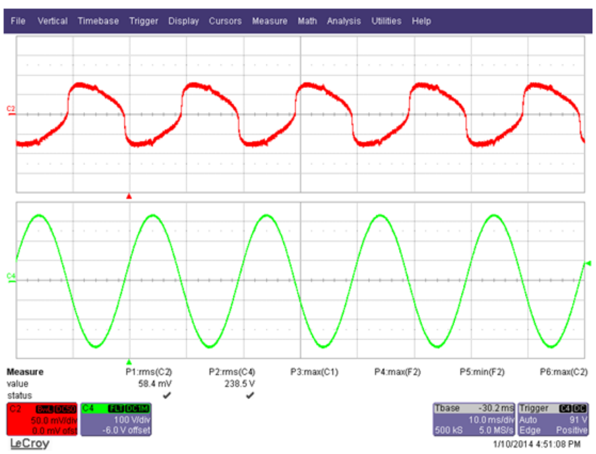

Figure 21 – 240 VAC, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 10 ms / div.

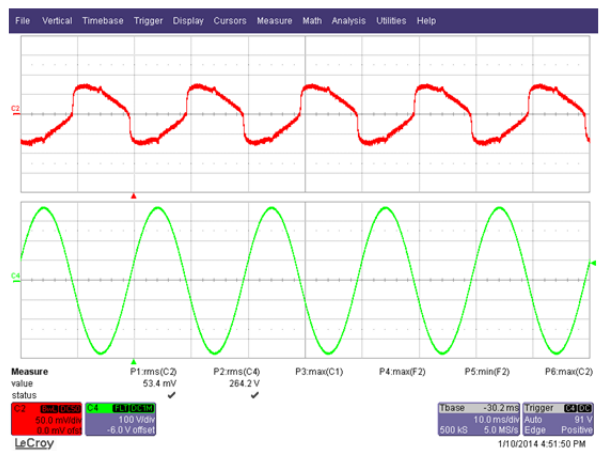

Figure 22 – 265 VAC, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 10 ms / div.

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12.2 Output Current and Output Voltage at Normal Operation

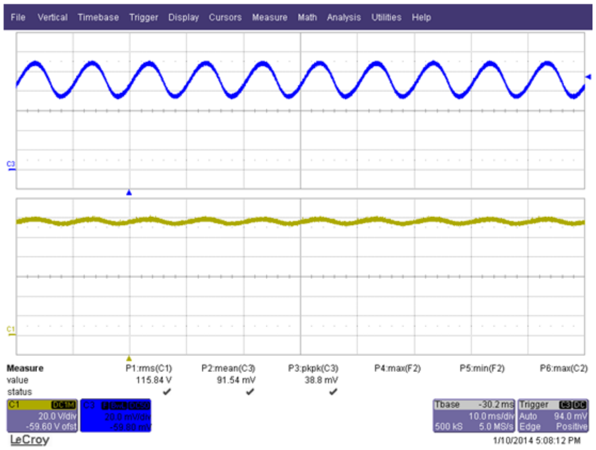

Figure 23 – 190 VAC, 50 Hz. Full Load.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{OUT}, 20 V, 10 ms / div.

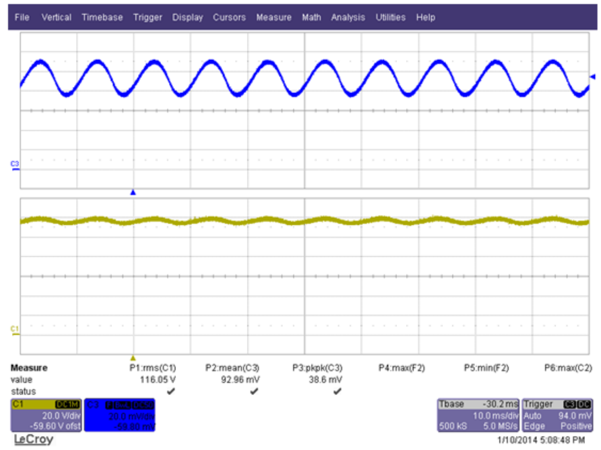

Figure 24 – 220 VAC, 50 Hz. Full Load.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{OUT}, 20 V, 10 ms / div.

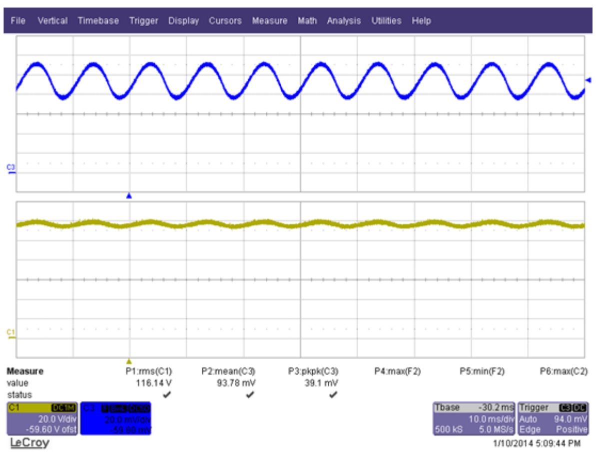

Figure 25 – 240 VAC, 50 Hz. Full Load.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{OUT}, 20 V, 10 ms / div.

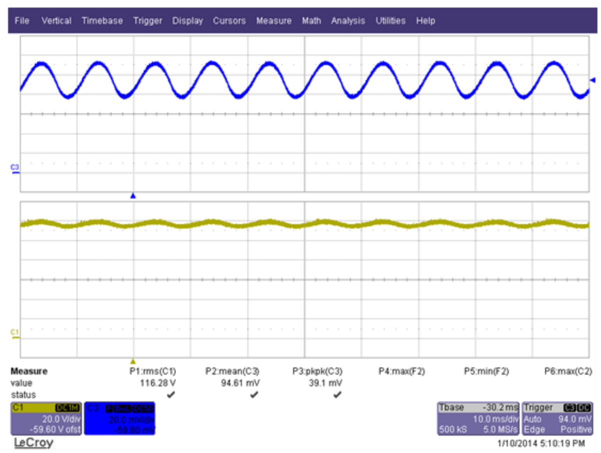

Figure 26 – 265 VAC, 50 Hz. Full Load.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{OUT}, 20 V, 10 ms / div.

12.3 Output Current Rise and Fall

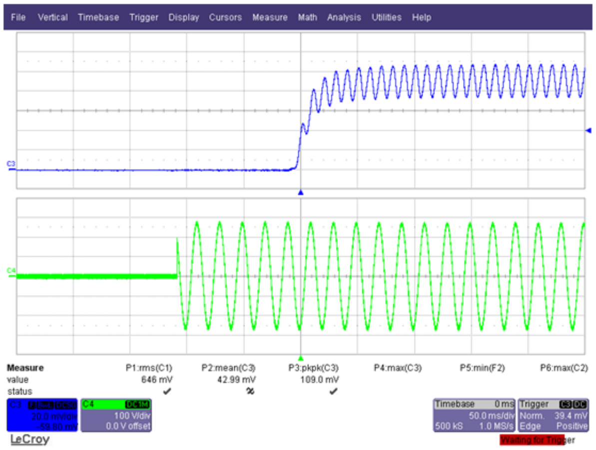

Figure 27 – 190 VAC Output Rise.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 100 V, 50 ms / div.

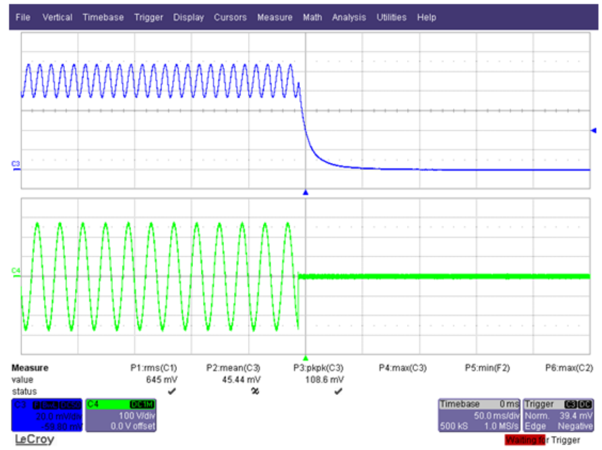

Figure 28 – 90 VAC Output Fall.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 200 V, 100 ms / div.

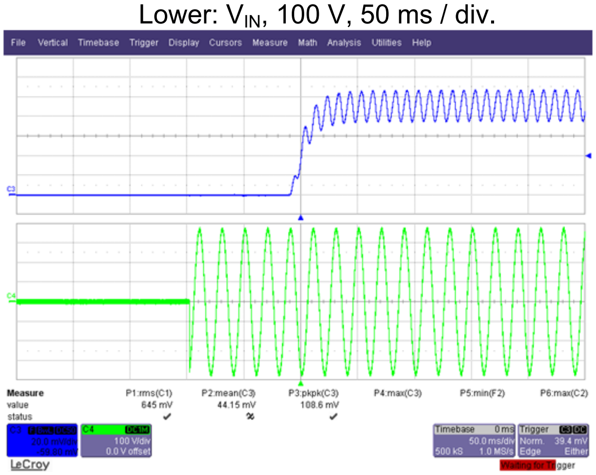

Figure 29 – 265 VAC Output Rise.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 100 V, 50 ms / div.

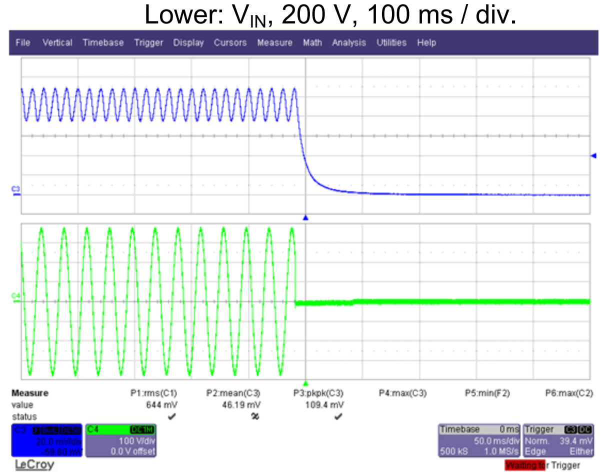

Figure 30 – 265 VAC Output Fall.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 100 V, 50 ms / div.

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12.4 Drain Voltage and Current at Normal Operation

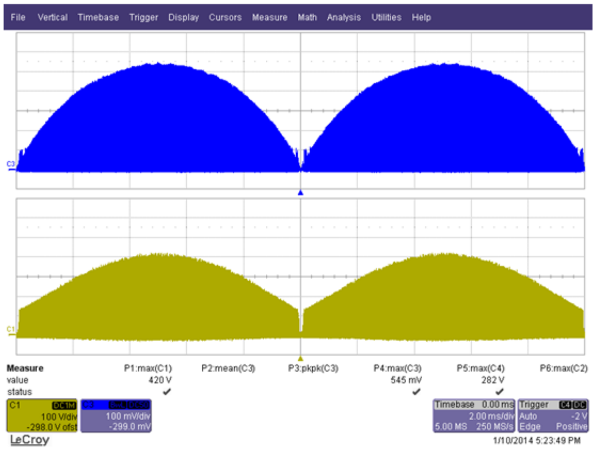

Figure 31 – 190 VAC, 50 Hz.
Upper: I_{DRAIN}, 0.1 A / div.
Lower: V_{DRAIN}, 100 V, 2 ms / div.

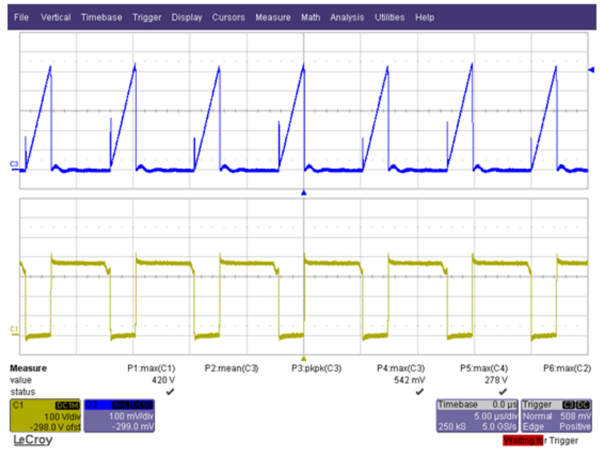

Figure 32 – 190 VAC, 50 Hz.
Upper: I_{DRAIN}, 0.1 A / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

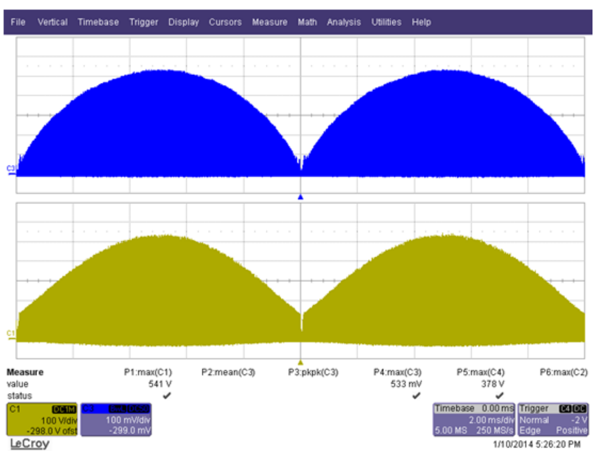

Figure 33 – 265 VAC, 50 Hz.
Upper: I_{DRAIN}, 0.1 A / div.
Lower: V_{DRAIN}, 100 V, 2 ms / div.

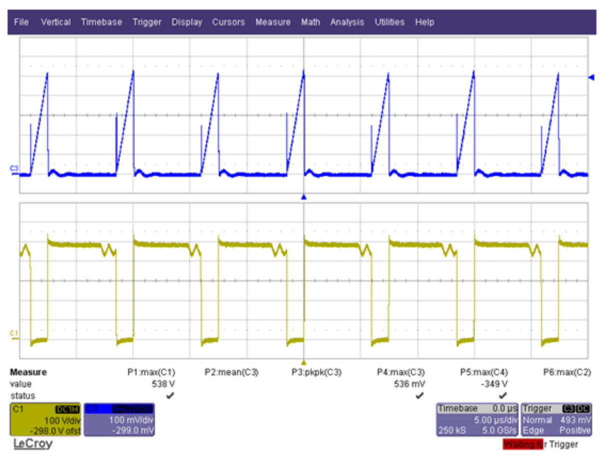

Figure 34 – 265 VAC, 50 Hz.
Upper: I_{DRAIN}, 0.1 A / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

12.5 Start-up Drain Voltage and Current

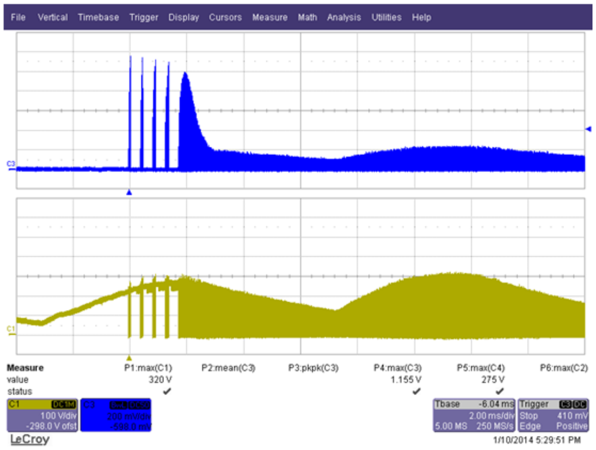

Figure 35 – 190 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 2 ms / div.

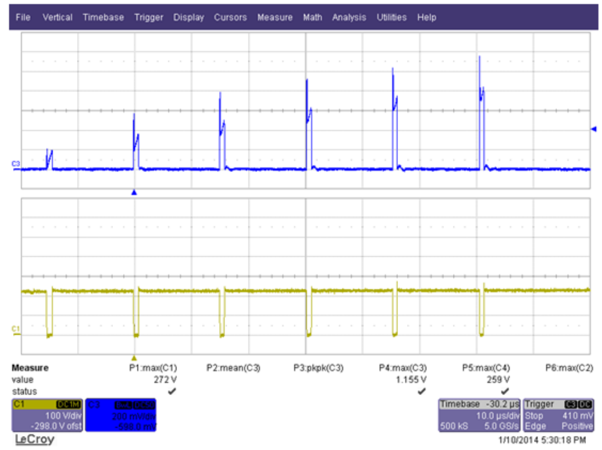

Figure 36 – 190 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 10 µs / div.

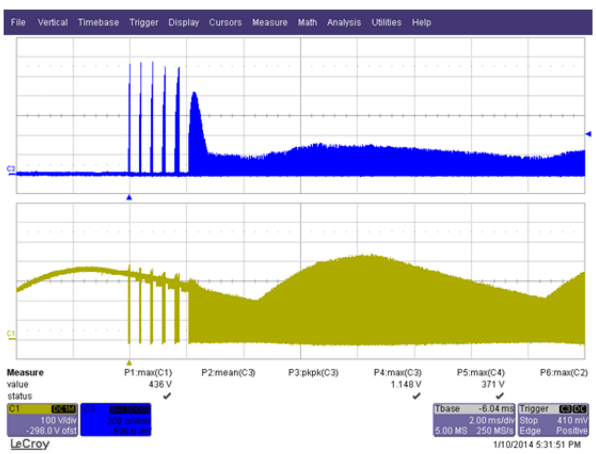

Figure 37 – 265 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 2 ms / div.

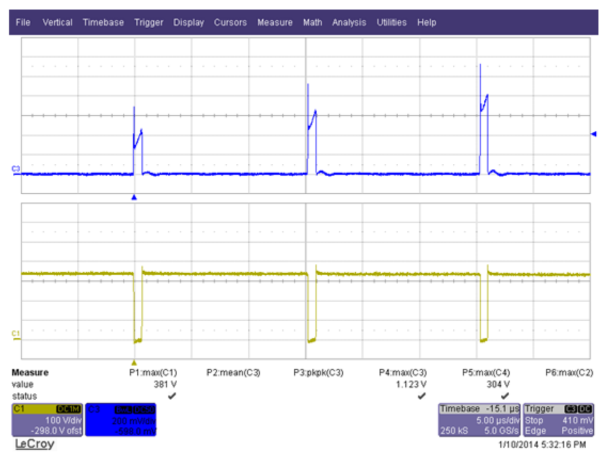

Figure 38 – 265 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 5 µs / div.

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12.6 Drain Current and Drain Voltage during Output Short Condition

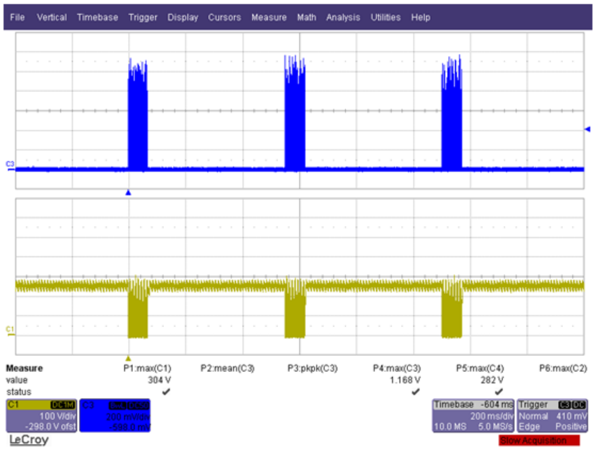

Figure 39 – 190 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 200ms / div.

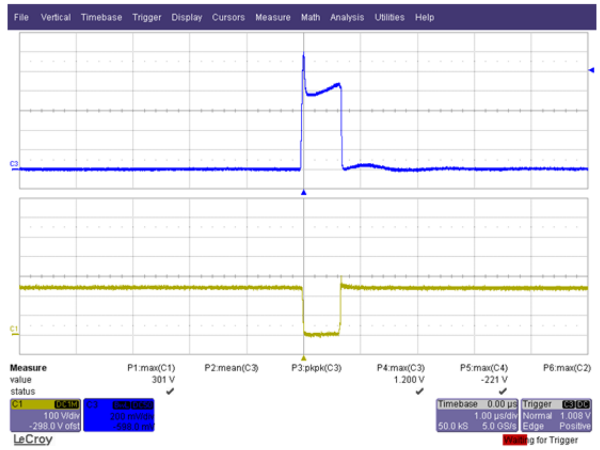

Figure 40 – 190 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 1 µs / div.

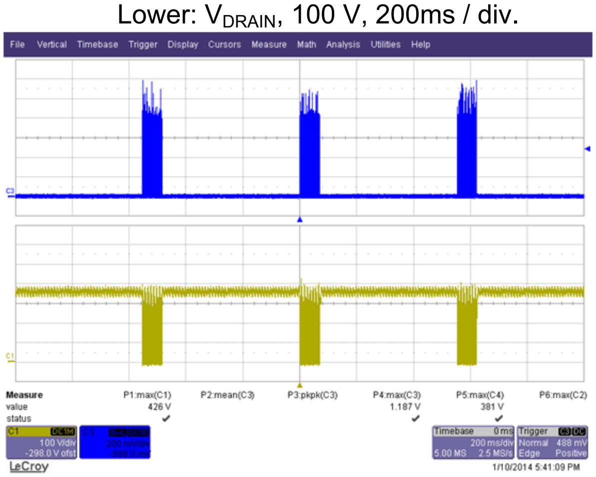

Figure 41 – 265 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: $V_{DRAIN,}$ 100 V, 5ms / div.

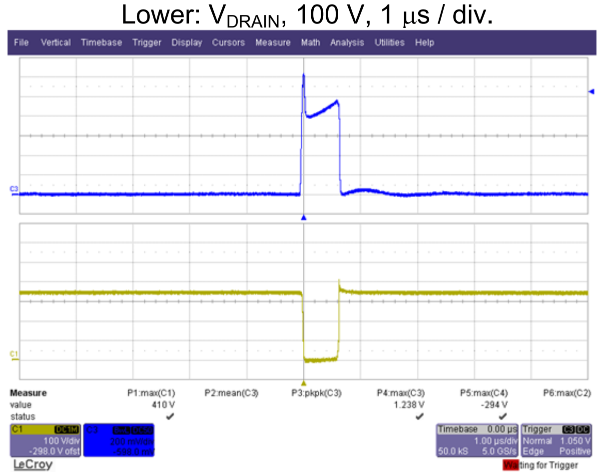

Figure 42 – 265 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: $V_{DRAIN,}$ 100 V, 1 µs / div.

12.7 Open Load Characteristic

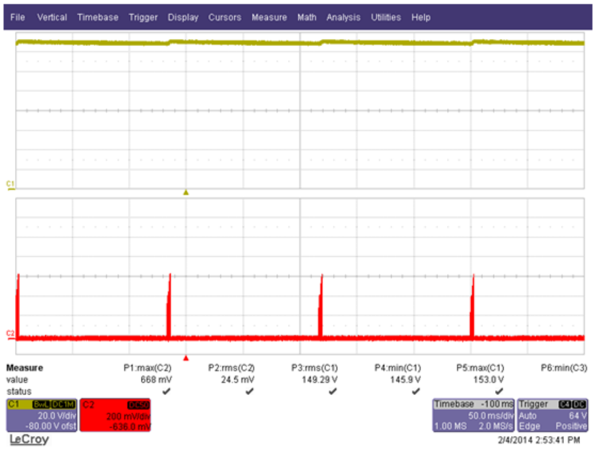

Figure 43 – 190 VAC, 50 Hz Open Load Condition.
Upper: V_{OUT}, 50 V / div.
Lower: I_{DRAIN}, 200 mA, 100ms / div.

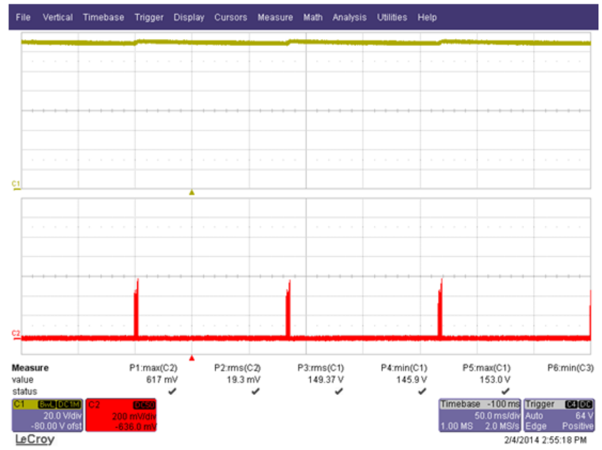

Figure 44 – 265 VAC, 50 Hz Output Short Condition.
Upper: V_{OUT}, 50 V / div.
Lower: I_{DRAIN}, 200 mA, 200ms / div.

12.8 Brown-out/ Brown-in

No failure of any component during brownout test of 0.5 V / sec AC cut-in and cut-off.

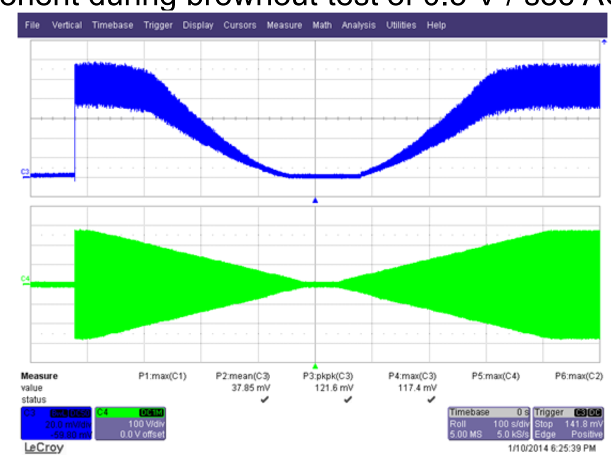

Figure 45 – Brown-out Test at 0.5 V / s. The Unit is Able to Operate Normally Without Any Failure and Without Flicker.
Ch4: V_{IN}; 100 V / div.
Ch2: I_{OUT}; 20 mA / div.
Time Scale: 100 s / div.

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13 Dimming Waveforms

13.1 Input Voltage and Input Current Waveforms – Leading Edge Dimmer

Input: 230 VAC, 50 Hz
Output: 120 V LED Load
Dimmer: WDE300F-1

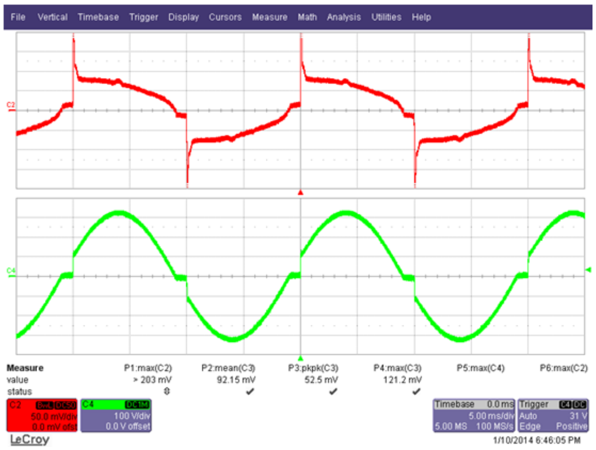

Figure 46 – 162º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

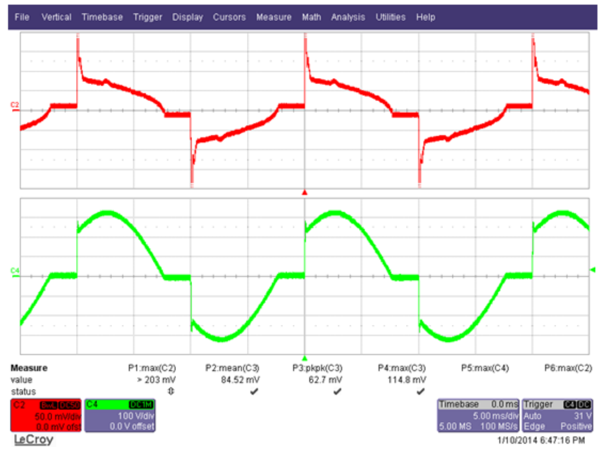

Figure 47 – 135º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

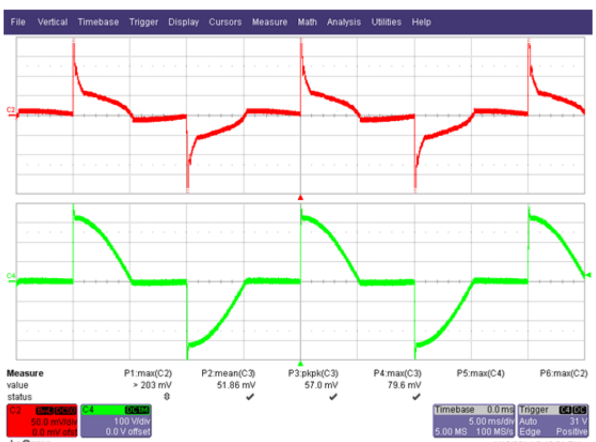

Figure 48 – 90º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

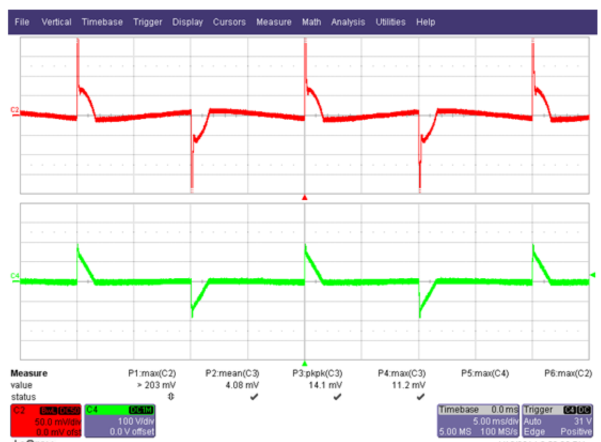

Figure 49 – 30º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

13.2 Output Current Waveforms – Leading Edge Dimmer

Input: 230 VAC, 50 Hz
Output: 120 V LED Load
Dimmer: WDE300F-1

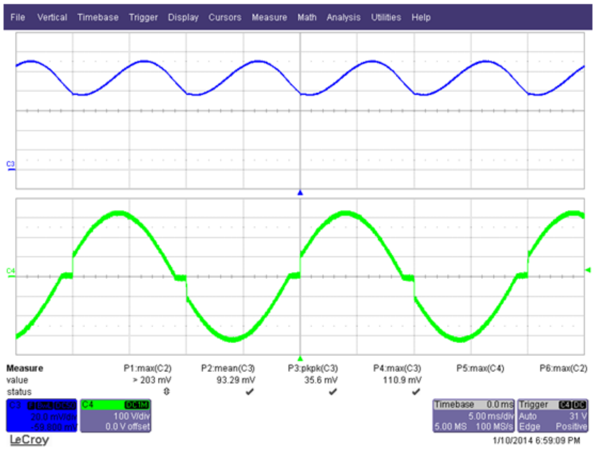

Figure 50 – 162º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

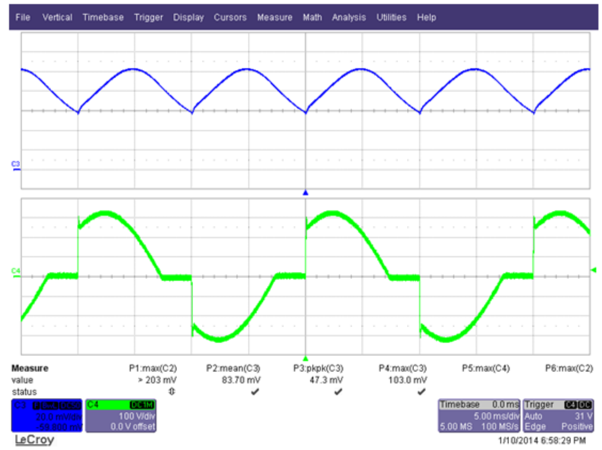

Figure 51 – 135º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

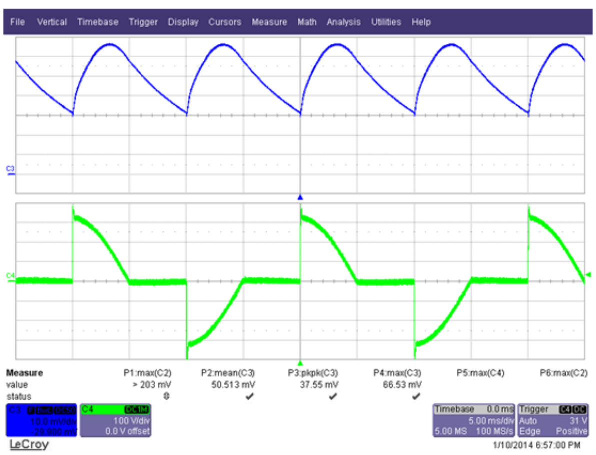

Figure 52 – 90º Conduction Angle.
Upper: I_{OUT}, 10 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

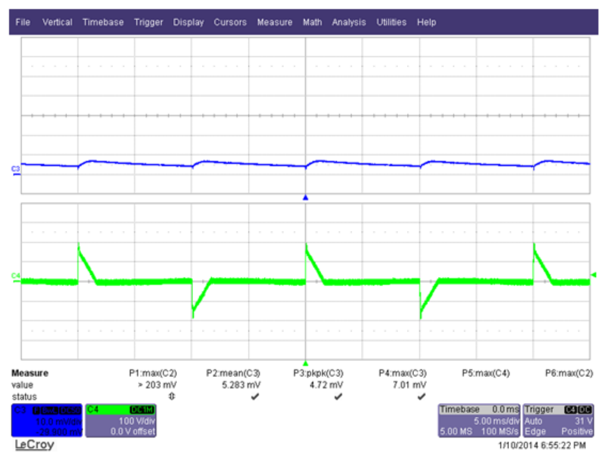

Figure 53 – 30º Conduction Angle.
Upper: I_{OUT}, 10 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

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13.3 Input Voltage and Input Current Waveforms – Trailing Edge Dimmer

Input: 230 VAC, 50 Hz
Output: 120 V LED Load
Dimmer: PEHA 433HAB

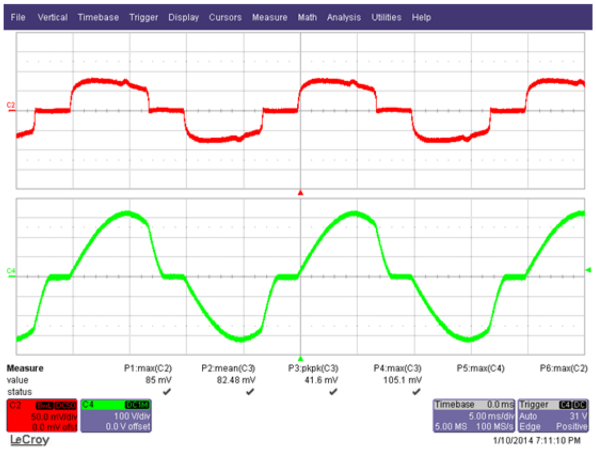

Figure 54 – 124° Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

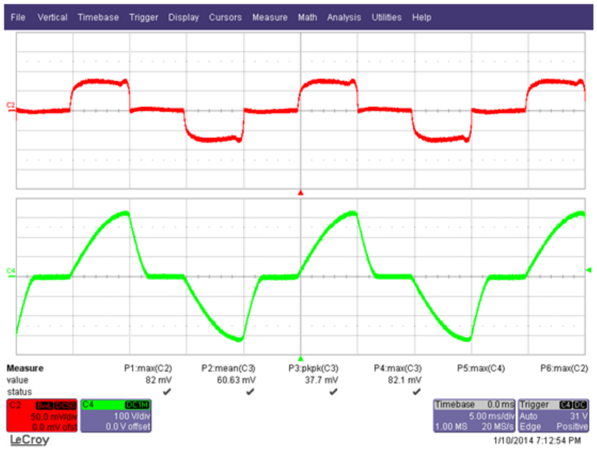

Figure 55 – 120° Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

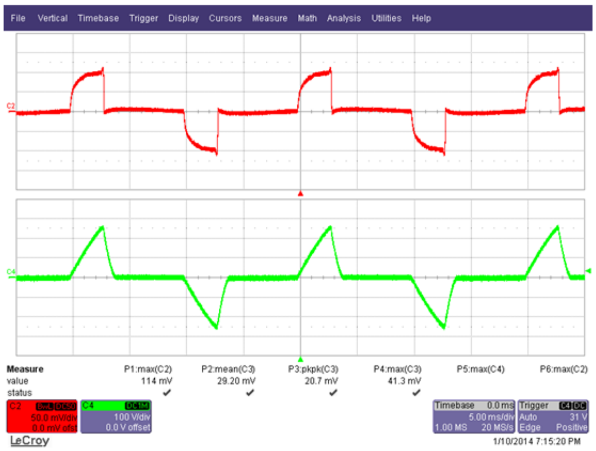

Figure 56 – 54° Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

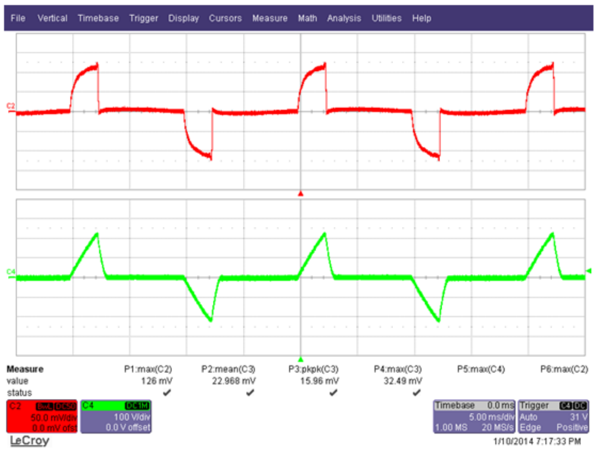

Figure 57 – 43° Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

13.4 Output Current Waveforms – Trailing Edge Dimmer

Input: 230 VAC, 50 Hz
Output: 120 V LED Load
Dimmer: PEHA 433HAB

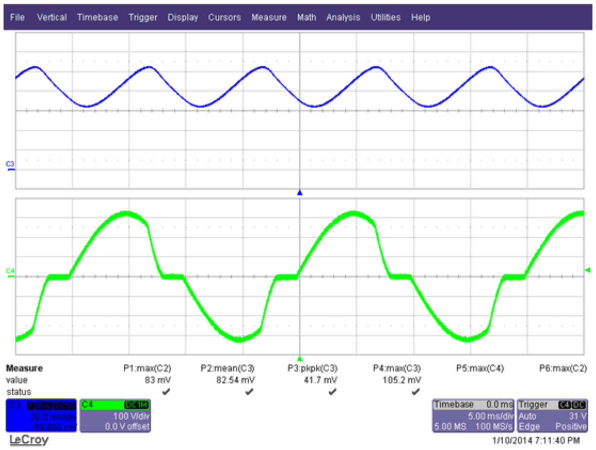

Figure 58 – 124º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

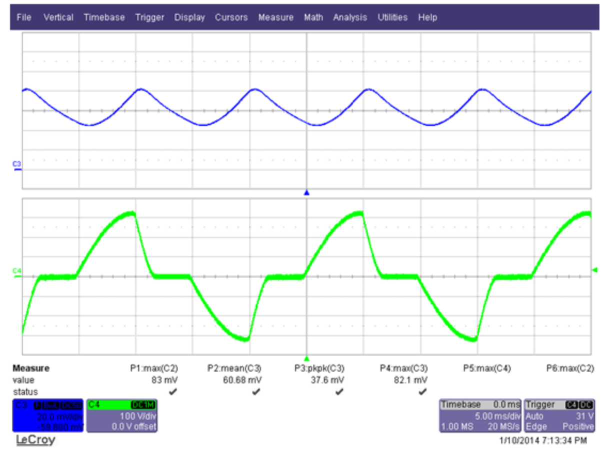

Figure 59 – 90º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

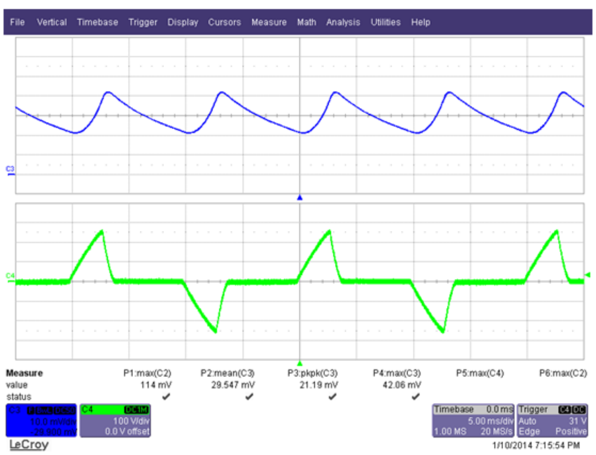

Figure 60 – 54º Conduction Angle.
Upper: I_{OUT}, 10 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

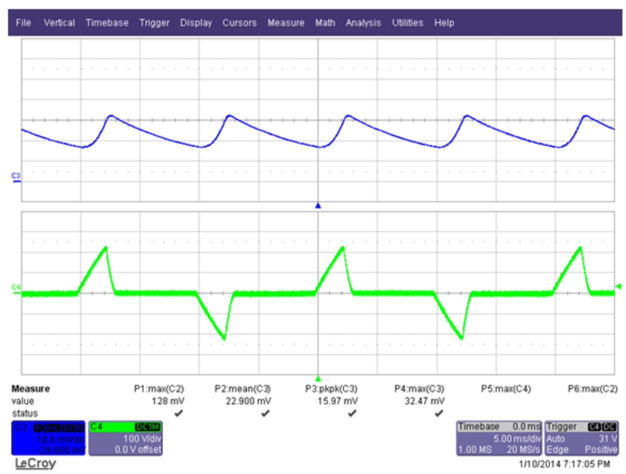

Figure 61 – 43º Conduction Angle.
Upper: I_{OUT}, 10 mA / div.
Lower: V_{IN}, 100 V, 5 ms / div.

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13.5 Drain Current Waveforms – Leading Edge Dimmer

Input: 230 VAC, 50 Hz
Output: 120 V LED Load
Dimmer: WDE300F-1

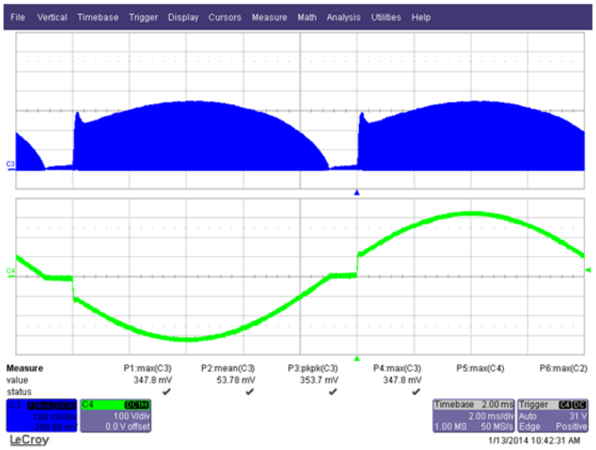

Figure 62 – 162º Conduction Angle.
Upper: U1 I_{DS}, 100 mA / div.
Lower: V_{IN}, 100 V, 2 ms / div.

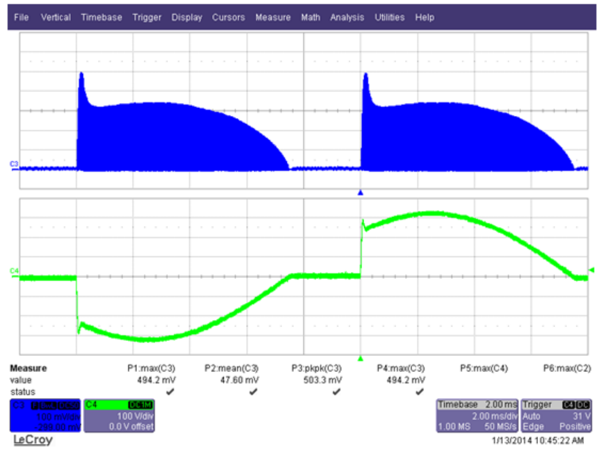

Figure 63 – 135º Conduction Angle.
Upper: U1 I_{DS}, 100 mA / div.
Lower: V_{IN}, 100 V, 2 ms / div.

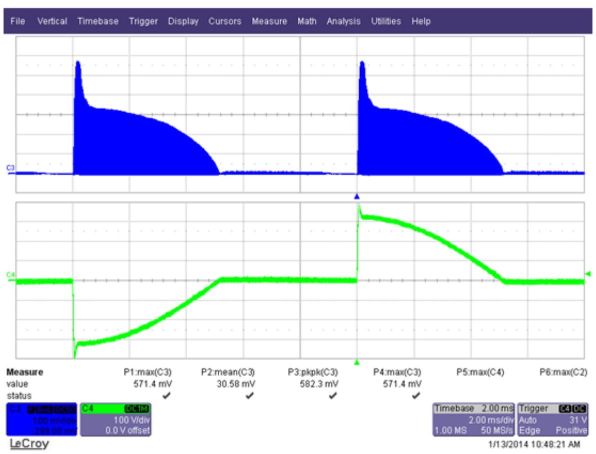

Figure 64 – 90º Conduction Angle.
Upper: U1 I_{DS}, 100 mA / div.
Lower: V_{IN}, 100 V, 2 ms / div.

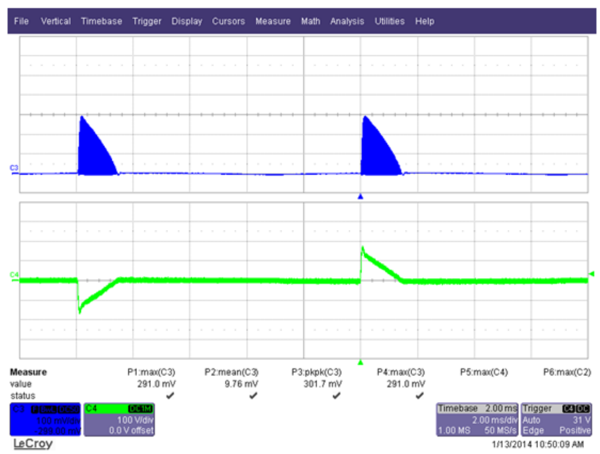

Figure 65 – 30º Conduction Angle.
Upper: U1 I_{DS}, 100 mA / div.
Lower: V_{IN}, 100 V, 2 ms / div.

14 Conducted EMI

14.1 Test Set-up

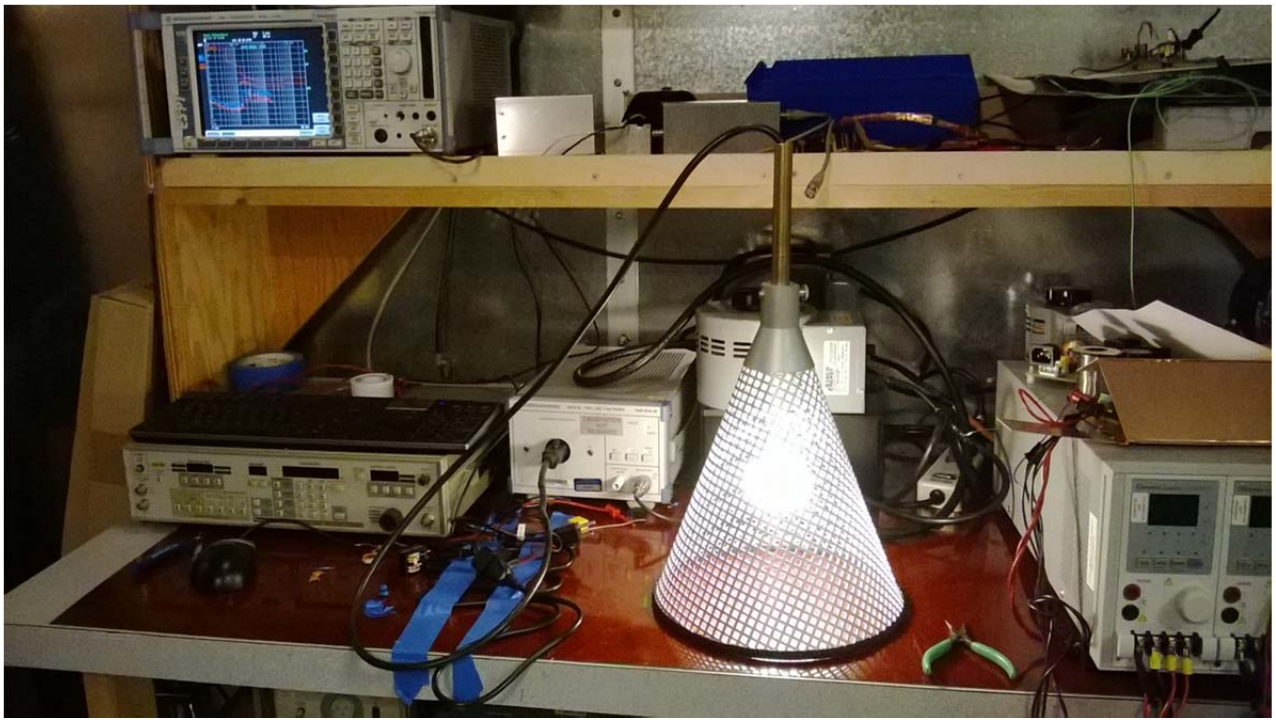

Figure 66 – Conducted EMI Test Set-up.

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14.2 Test Result

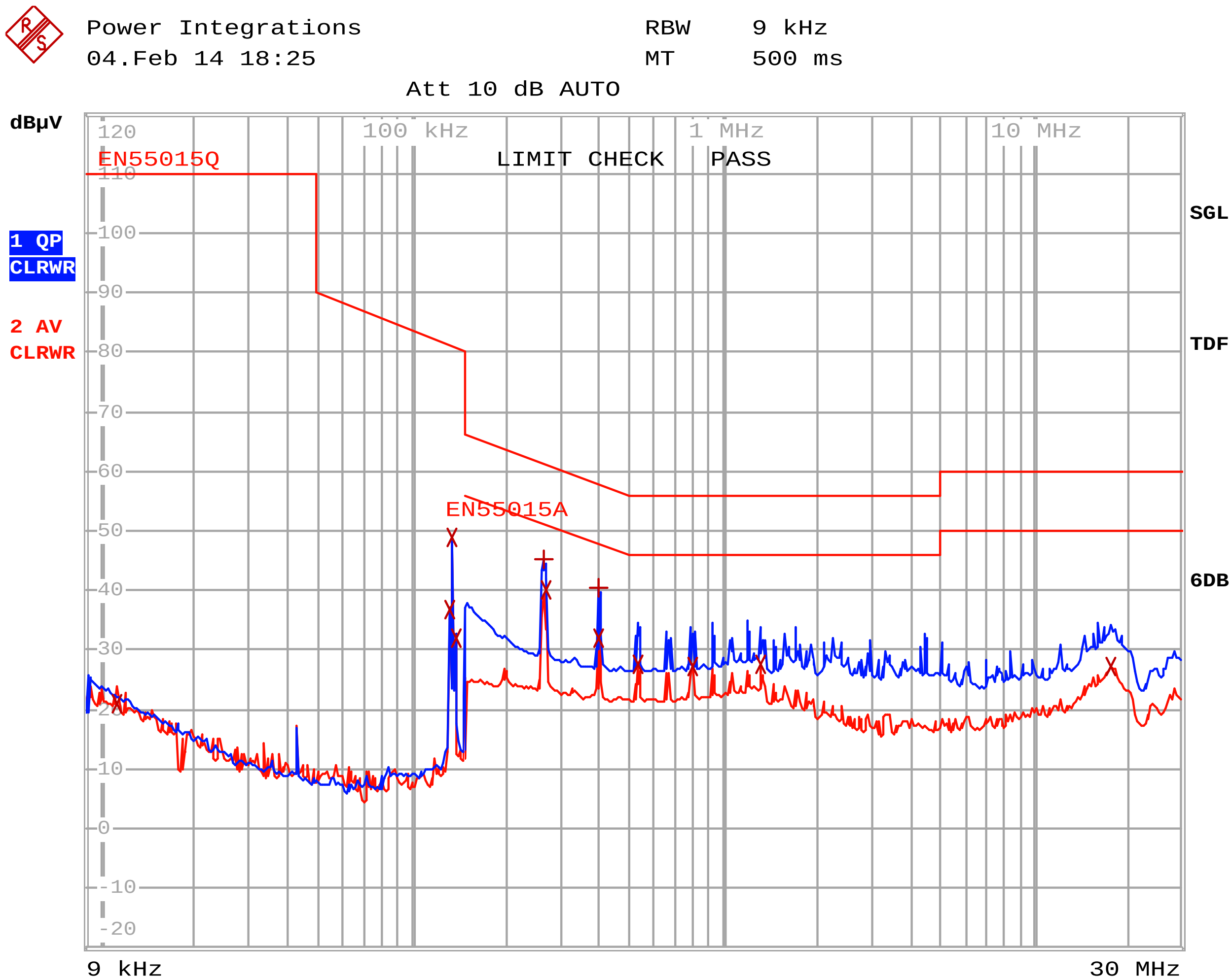

Figure 67 – Conducted EMI, ~120 V LED Load, 230 VAC, 60 Hz, and EN55015 B Limits.

EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	11.2024427378 kHz	21.11	N gnd	
2	Average	130.825395691 kHz	36.71	L1 gnd	
2	Average	133.454986145 kHz	48.99	N gnd	
2	Average	137.49880568 kHz	31.99	L1 gnd	
1	Quasi Peak	264.49018761 kHz	45.08	L1 gnd	-16.20
2	Average	267.135089486 kHz	40.14	L1 gnd	-11.06
1	Quasi Peak	397.727746704 kHz	40.55	L1 gnd	-17.34
2	Average	397.727746704 kHz	32.14	L1 gnd	-15.76
2	Average	530.769219795 kHz	27.42	L1 gnd	-18.57
2	Average	798.145472681 kHz	27.29	L1 gnd	-18.70
2	Average	1.32578199726 MHz	27.47	L1 gnd	-18.52
2	Average	17.7971587654 MHz	27.14	L1 gnd	-22.85

Figure 68 – Conducted EMI, Final Measurement Results.

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15 Line Surge

Differential input line 500 V surge testing was completed on a single test unit to IEC61000-4-5. Input voltage was set at 230 VAC / 60 Hz.

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

Differential ring input line surge testing was completed on a single test unit to IEC61000-4-5. Input voltage was set at 230 VAC / 60 Hz. Output was loaded at full load and operation was verified following each surge event.

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2500	230	L to N	90	Pass
-2500	230	L to N	90	Pass
+2500	230	L to N	0	Pass
-2500	230	L to N	0	Pass

Unit passed under all test conditions.

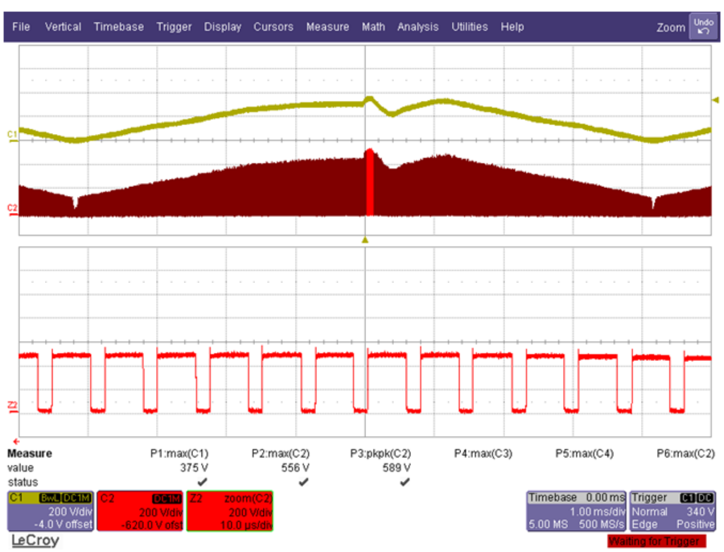

Figure 69 – 500 V Differential Surge. 589 V maximum VDS.

16 Revision History

Date	Author	Revision	Description and Changes	Reviewed
9-Jun-14	CA	1.0	Initial Release	Apps & Mktg

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