Design Example Report

Title	***7.5 W, Non-Isolated Tapped-Buck, TRIAC Dimmable, Power Factor Corrected (>0.95) LED Driver Using LYTSwitch^{TM}-4 LYT4311E***
Specification	90 VAC – 132 VAC Input; 15 V, 500 mA Output
Application	PAR20 LED Driver
Author	Applications Engineering Department
Document Number	DER-360
Date	June 10, 2013
Revision	1.0

Summary and Features

- High efficiency, ≥85% at 120 VAC
- Broad dimmer compatibility (within NEMA SSL6 dimming curves) with wide selection of U.S. TRIAC-based dimmers
    - High dimming ratio 1000:1
- Enhanced user experience
  - Flicker-free, monotonic dimming
  - Fast monotonic start-up (<200 ms) – no perceptible delay
  - Turn-on and turn-off at almost the same dimming angle – no pop-on or dead-time
- Low cost
  - Single-stage combined PFC and accurate primary side regulated constant current output
- Integrated protection and reliability features
  - Output open circuit / output short-circuit protected with auto-recovery
  - Fast acting line input overvoltage shutdown extends voltage withstand during line faults
    - Withstand ±2500 V ring wave and ±500 V differential surge without a MOV
  - Auto-recovering thermal shutdown with large hysteresis protects both components and printed circuit board
- Meets IEC 61000-4-5 ring wave, IEC 61000-3-2 C THD and IEC CISPR 15 / EN55015 B 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.

1 Introduction

The document describes an isolated, high power factor (PF), TRIAC-dimmable LED driver designed to drive a nominal LED string voltage of 15 V at 500 mA from an input voltage range of 90 VAC to 132 VAC. The LED driver utilizes the LYT4311E from the LYTSwitch-4 family of ICs.

The topology used is a low component count single-stage power factor corrected tapped-buck configuration that delivers high efficiency, high power factor, and low THD

High power factor and low THD is achieved by employing the LYTSwitch-4 IC which also provides a sophisticated range of protection features including auto-restart for open control loop and output short-circuit conditions. Line overvoltage provides extended line fault and surge withstand, and accurate hysteretic thermal shutdown ensures safe average PCB temperatures under all conditions.

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

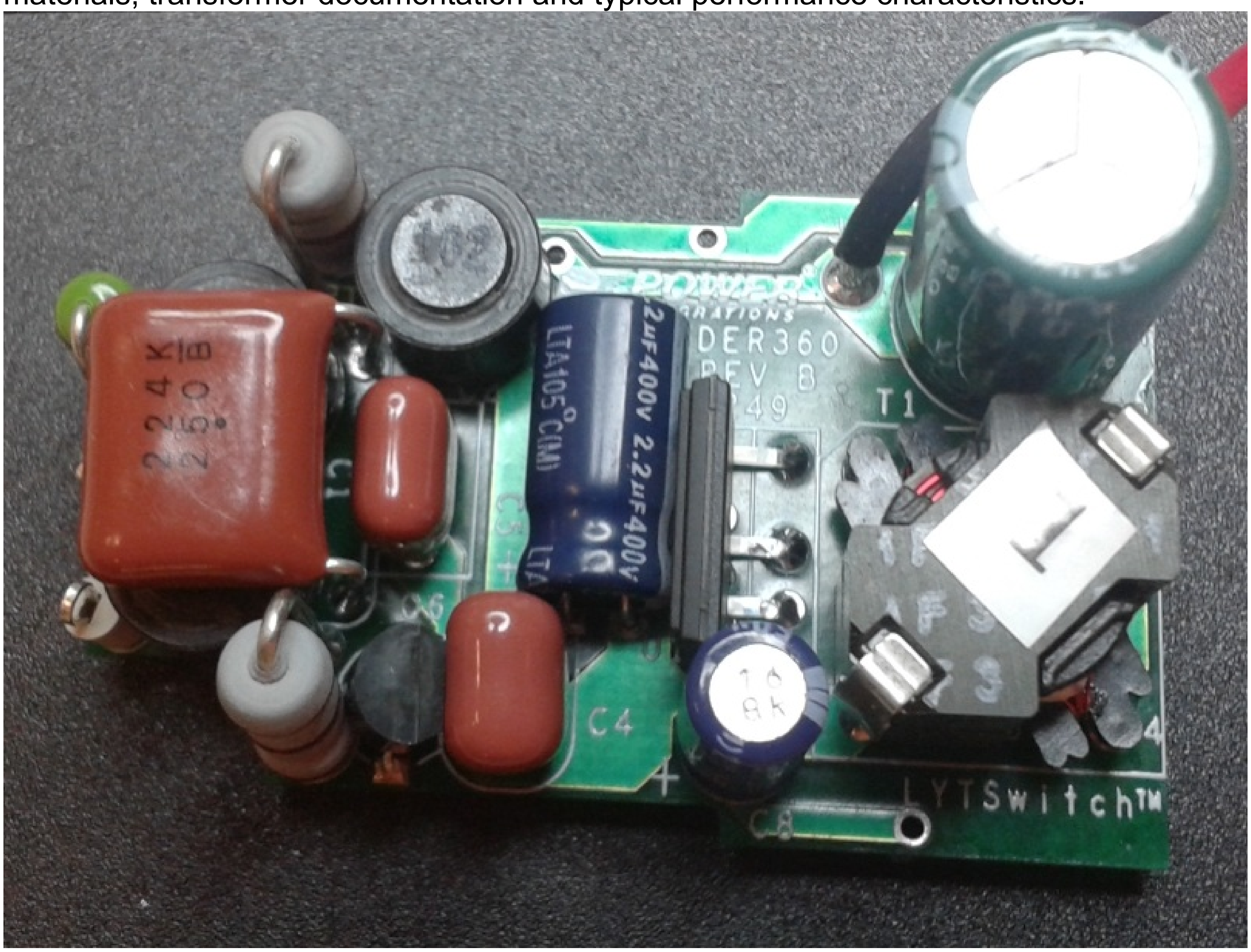

Figure 1 – Populated Circuit Board Photograph.

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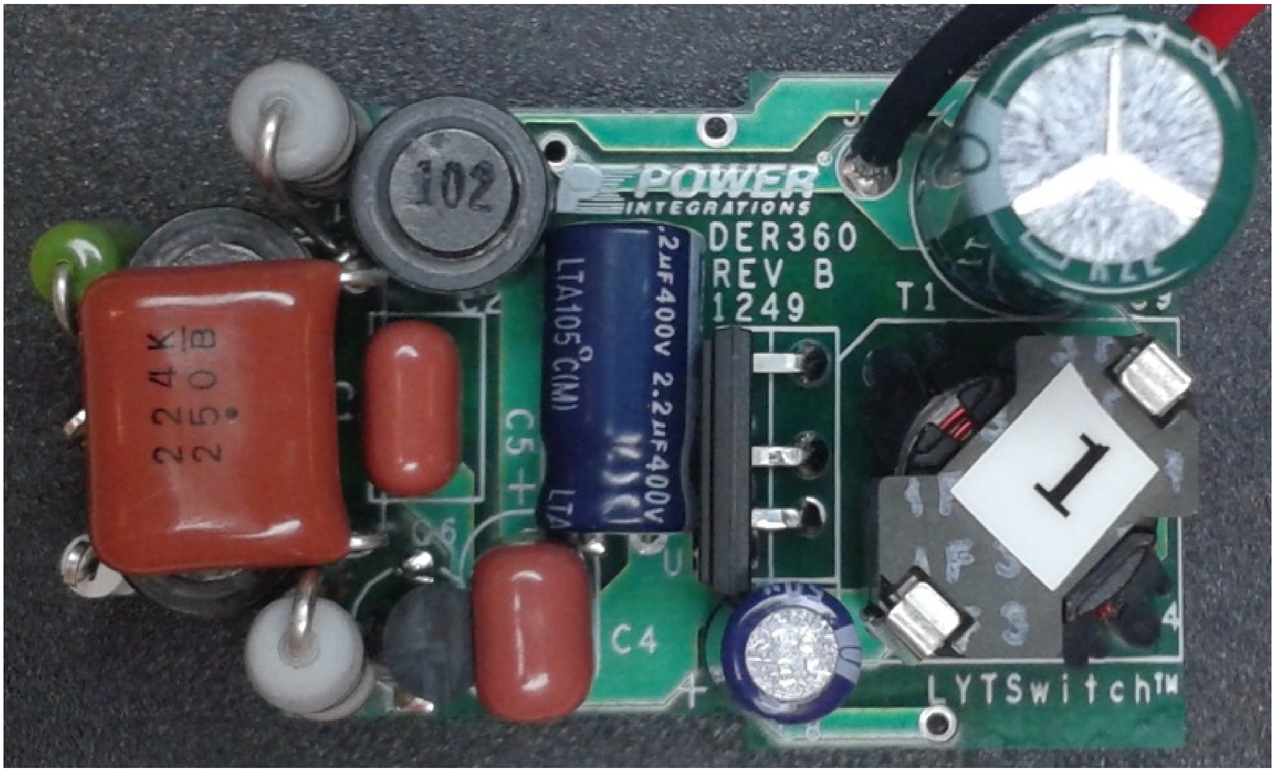

Figure 2 – Populated Circuit Board Photograph (Top View).

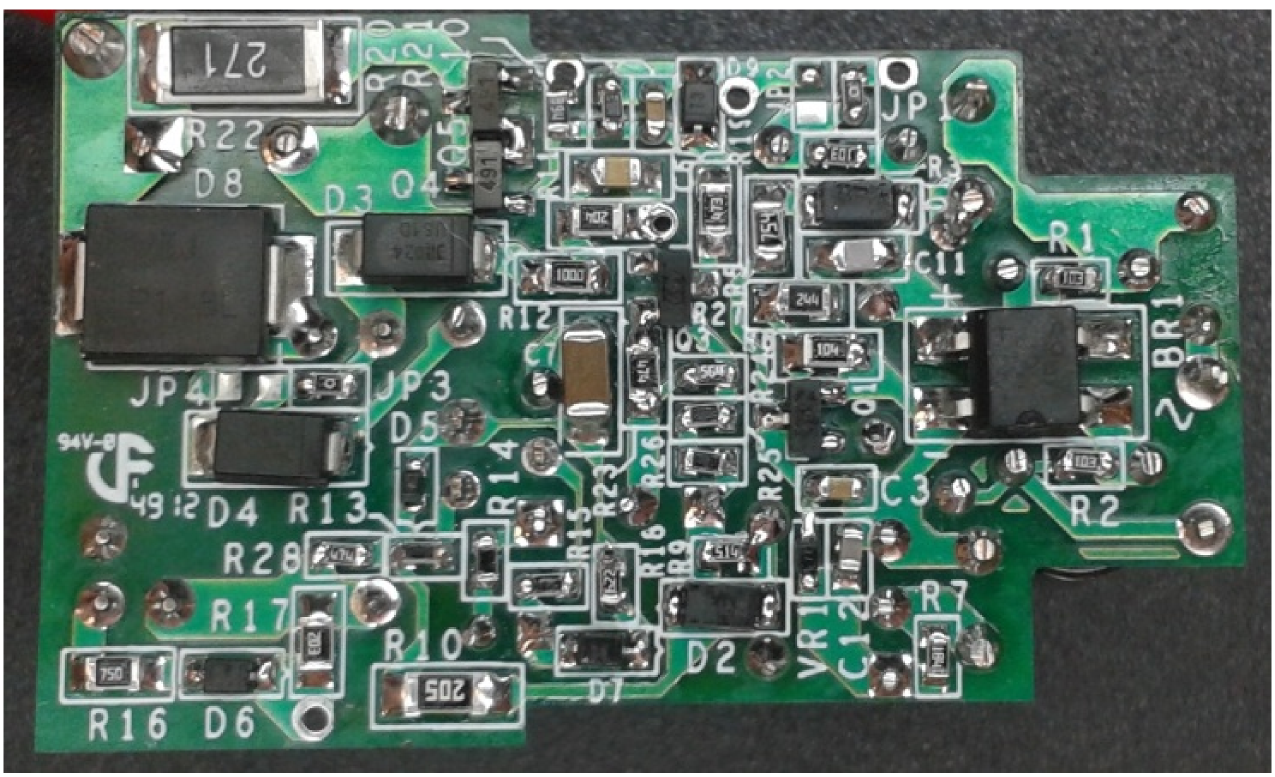

Figure 3 – Populated Circuit Board Photograph (Bottom View).

2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90	120	132	VAC	
Frequency	f_{LINE}		60		Hz	
Output						
Output Voltage	V_{OUT}	12	15	18	V	
Output Current	I_{OUT}		500		mA	
Total Output Power						
Continuous Output Power	P_{OUT}		7.5		W	
Efficiency						
Full Load	η		85		%	V_{OUT} = 15, V_{IN} = 120 VAC, 25 °C ambient
Environmental						
Conducted EMI		CISPR 15B / EN55015B				
Safety		Isolated				
Ring Wave (100 kHz)						
Differential Mode (L1-L2)			2.5		kV	
Common Mode (L1/L2-PE)						
Differential Surge (1.2 / 50 μs)			500		V	
Power Factor			0.95			Measured at $V_{OUT(TYP)}$, $I_{OUT(TYP)}$ and 120 VAC, 60 Hz
Harmonic Currents		EN 61000-3-2 Class D (C)				Class C specifies Class D Limits when P_{IN} <25 W
Ambient Temperature	T_{AMB}		40		°C	Free convection, sea level

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3 Schematic

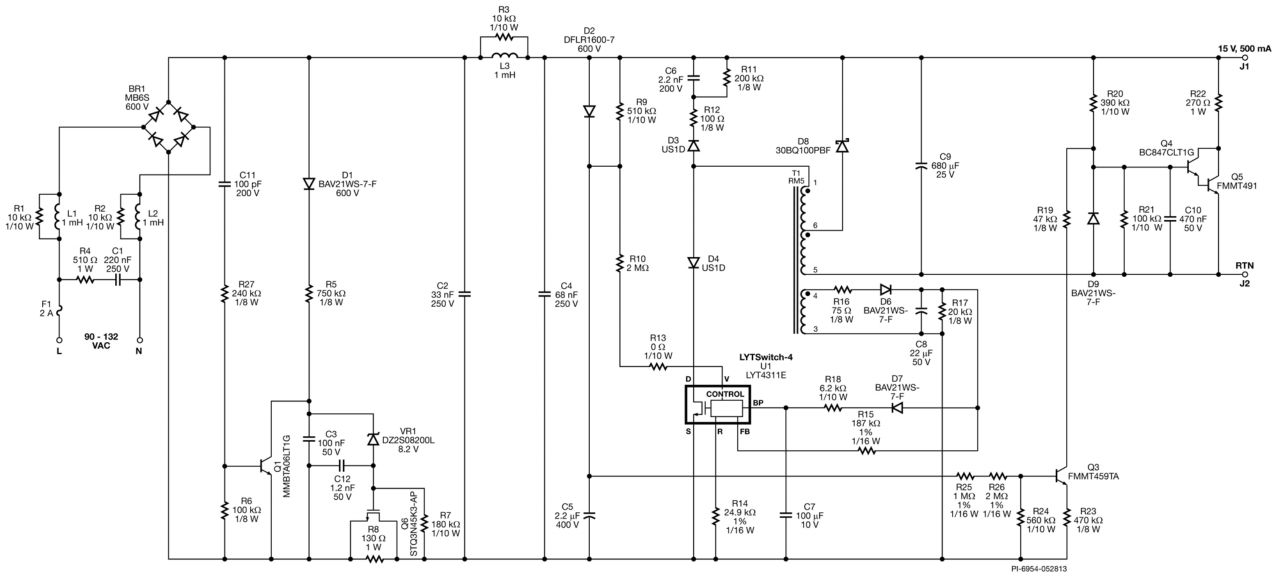

Figure 4 – Schematic.

4 Circuit Description

The LYTSwitch-4 device is a controller with an integrated 650 V power MOSFET for use in LED-driver applications. The LYTSwitch-4 IC is configured for use in a single-stage tapped-buck topology which provides a primary-side regulated constant current output while maintaining a high power factor from the AC input.

4.1 Input Filtering

Fuse F1 provides protection from component failure. A relatively high current rating was selected to prevent failure during differential (1.2 μs / 50 μs) line surge. The fast acting line overvoltage detection of the LYTSwitch-4 IC in conjunction with D2 and C5 peak detector capacitor provides a clamp to limit the maximum voltage stress across the mosfet of the IC. A value of 2.2 μF on C5 can withstand 500 V surges, while 4.7 μF can withstand 1 kV surge. Optional additional 140 VAC rated MOV (Metal Oxide Varistor) RV1 can be used for >1000 V differential line surge requirements. Diode bridge BR1 rectifies the AC line voltage with capacitor C4 providing a low-impedance path (decoupling) for the primary switching current.

EMI filtering is provided by inductors L1, L2, and L3, and capacitors C2 and C4. Resistor R1, R2 and R3 across L1, L2 and L3 respectively damp any LC resonances due to the filter components and the AC line impedance which would otherwise cause increased conducted EMI measurements.

4.2 LYTSwitch-4 Primary

The topology chosen in this design is a low-side tapped-buck configured to provide low THD, unity power factor, and constant current output for the input voltage range of 90 VAC to 132 VAC.

The tapped-buck converter offers the advantage of reduced magnetic component size, reduced current stress on the main switch U1, and reduced voltage stress on the output diode D8. The reduced current stress on the main switch enables the use of a smaller switching device for more cost-effectiveness of the design. The lower voltage stress on the output diode enables the use of a low V_F (Schottky) device for improved efficiency.

Inductor T1 is the main inductor of the buck converter. It consists of three windings, primary, secondary, and bias windings. The ratio is chosen to be 5:1 (primary to secondary ratio) to enable the use of a 100 V output diode while keeping the maximum voltage of U1 LYT4311E still well below its maximum value.

Output diode D8 conducts every time U1 is off and transfers energy to the load. Diode D4 is necessary to prevent reverse current from flowing through U1 while the voltage across C4 (rectified input AC) falls below the output voltage. A voltage clamp circuit was also added to limit the voltage spike created by the leakage inductance of T1. The voltage clamp network is formed by diode D3, capacitor C6, and resistors R11, R12.

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To provide peak line voltage information to U1, the incoming rectified AC peak charges C5 via D2. This is then fed into the VOLTAGE MONITOR (V) pin of U1 as a current via R10. Resistor R9 is a discharge path for C5 when there is line sag to make the V pin respond quicker in reducing the power.

The line overvoltage shutdown function, sensed via the V pin current, extends the rectified line voltage withstand (during surges and line swells) to the 650 BV_{DSS} rating of the internal power MOSFET. The fast acting line-overvoltage detection of the LYTSwitch-4 IC in conjunction with D2 and C5 peak-detector capacitor provides a clamp to limit the maximum voltage stress across the MOSFET of the IC. A value of 2.2 μF on C5 can withstand 500 V surges, while 4.7 μF can withstand 1 kV surge. Optional additional 140 VAC rated MOV (Metal Oxide Varistor) RV1 can be used for >1000 V differential line surge requirement.

Capacitor C7 provides local decoupling for the BYPASS (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 DRAIN (D) pin of U1. LYT4311E being the lowest device in the family has a fixed power mode. However, capacitor C8 is chosen to be 100 μF to enable the device to operate in a low-conduction angle during dimming. The use of an external bias supply (via D7 and R18) is recommended to give the lowest device dissipation and provide sufficient supply to U1 during deep dimming conditions. Diode D7 is used to isolate C7 from C8 during start-up and resistor R18 limits the current supplied to the BP pin from the bias winding.

The V pin current and the FEEDBACK (FB) pin current are used internally to control the average output LED current. For phase angle dimming applications, a 49.9 kΩ resistor is used on the REFERENCE (R) pin (R14) and 2 MΩ (R10) on the V pin to provide a linear relationship between input voltage and the output current. This maximizes the dimming range when used with TRIAC dimmers. However, in this design 24.99 kΩ was used for tighter CC regulation. High dimming ratio was accomplished using an active pre load on the output.

4.3 Feedback

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). The flyback voltage on the bias winding is rectified by D6 and filtered by R16 and C8. Resistor R15 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 whilst maintaining a high input power factor.

4.4 Output Rectification

The transformer secondary winding is rectified by D8 and filtered by capacitor C9. For designs where lower ripple is required, the output capacitance value can be increased.

4.5 TRIAC Phase Dimming Control Compatibility

The requirement to provide output dimming with low-cost, TRIAC-based, leading edge phase dimmers introduced a number of tradeoffs in the design.

Due to the much lower power consumed by LED-based lighting, the current drawn by the lamp can fall below the holding current of the TRIAC within the dimmer. This causes undesirable behavior such as the lamp turning off before the end of the dimmer control range and/or flickering as the TRIAC fires inconsistently. The relatively large impedance the LED lamp presents to the line allows significant ringing to occur due to the inrush current charging the input capacitance when the TRIAC turns on. This too can cause similar undesirable behavior as the ringing may cause the TRIAC current to fall to zero.

To overcome these issues, active damper and passive bleeder circuits were added. The drawback of these circuits is increased dissipation and therefore reduced efficiency of the supply. For non-dimming applications these components can simply be omitted.

The new PI proprietary active damper consists of main components Q6 and R8. Where Q6 is fully on when there is no TRIAC connected, bypassing R8 which will keep the power dissipation, low thereby making the system efficiency high. A TRIAC is detected through C11, R27 and R6 which will momentarily drive Q1 on keeping C3 grounded and gate Q6 low allowing R8 to be in series with TRIAC to act a damping element to current ringing every time the TRIAC turns on.

The passive bleeder circuit is comprised of C1 and R4. This keeps the input current above the TRIAC holding current while the driver input current increases during each AC half-cycle preventing the TRIAC switch from oscillating at the start (and end) of each conduction angle period.

4.6 Active Pre-Load

The new PI proprietary active pre-load in this driver is used for shaping the dimming curve and increasing dimming ratio while maintaining high efficiency during normal operation. The circuit can be used also for non-isolated converters such as buck, buck-boost and tapped-buck.

The active pre-load circuit detects the input peak voltage from C5, via divider R25, R26 and R24 which is proportional to the dimmer’s conduction angle; the information is processed via Q3, R23, R19 and C10 to give an average signal which is used to linearly drive a Darlington (Q4, Q5) which loads the output via a resistor (R22).

During non-dimming operation (full conduction), the active bleeder is not connected across the output therefore maintaining high efficiency operation. The bleeder turns on at

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a programmed dimming angle (dimming ~<70º conduction angle). The active bleeder will be biased linearly down to the lowest conduction angle the TRIAC can operate, thus increasing dim ratio.

The circuit also acts as a bleeder for leaky TRIAC as the Darlington will be biased via R20 and loads R22 when a voltage builds up at the output due to the small leakage energy from the TRIAC.

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5 PCB Layout

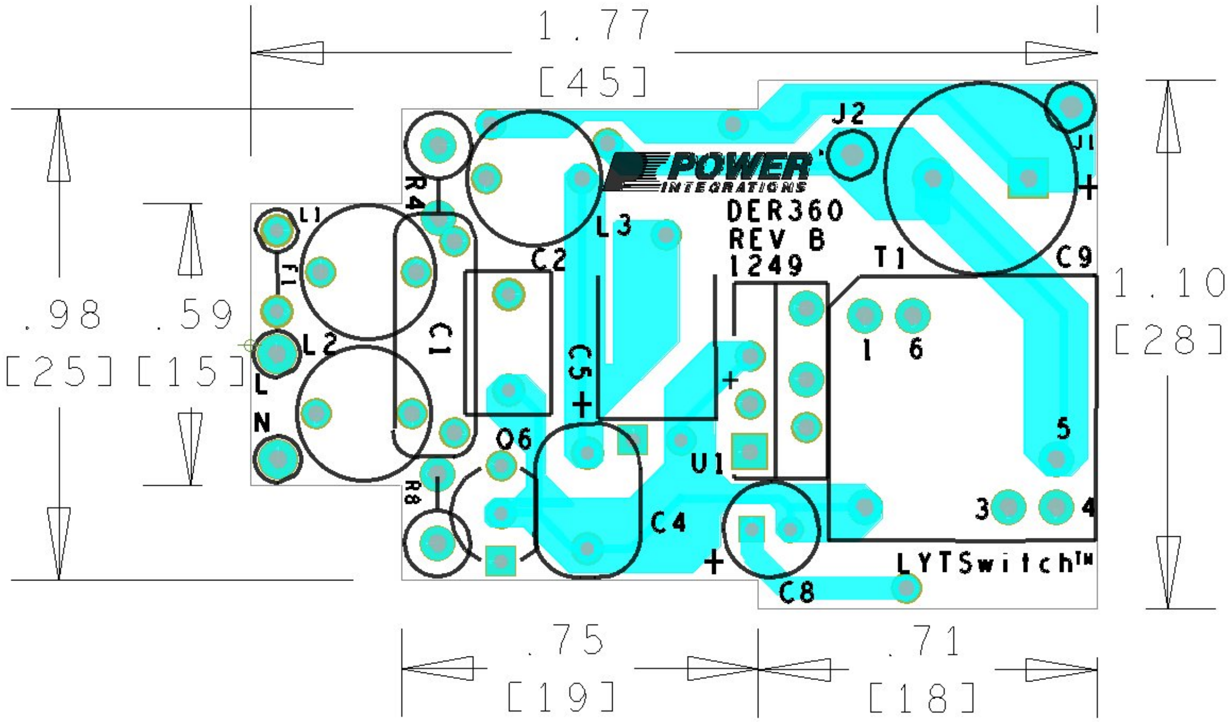

Figure 5 – Top Side.

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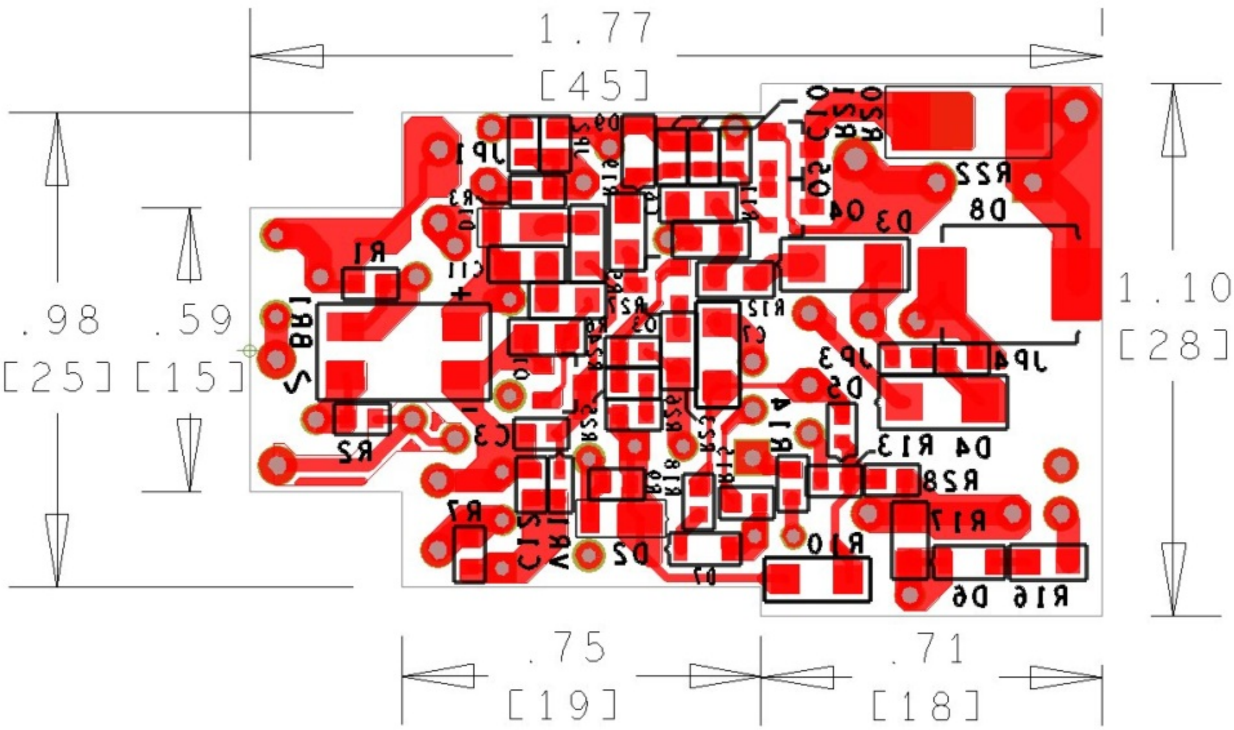

Figure 6 – Bottom Side.

Note: PCB can be configured to buck, buck-boost or tapped-buck topology. See jumper configuration.

CONFIGURATION:

BUCK: JP1=C; JP2=O; JP3=O; JP4=C

BUCK-BOOST : JP1=O; JP2=C; JP3=O; JP4=C

TAPPED-BUCK: JP1=C; JP2=O; JP3=C; JP4=O

NOTE: For Buck and Buck-Boost
configuration do not install
D12, R41, R4, C13

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	600 V, 0.5 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	MB6S-TP	Micro Commercial
2	1	C1	220 nF, 250 V, Film	ECQ-E2224KF	Panasonic
3	1	C2	33 nF, 250 V, Film	ECQ-E2333KB	Panasonic
4	1	C3	100 nF 50 V, Ceramic, X7R, 0603	C1608X7R1H104K	TDK
5	1	C4	68 nF, 250 V, Polyester Film	ECQ-E2683KB	Panasonic
6	1	C5	2.2 μF, 400 V, Electrolytic, (6.3 x 11)	TAB2GM2R2E110	Ltec
7	1	C6	2.2 nF, 200 V, Ceramic, X7R, 0805	08052C222KAT2A	AVX
8	1	C7	100 μF, 10 V, Ceramic, X5R, 1206	C3216X5R1A107M	TDK
9	1	C8	22 μF, 50 V, Electrolytic, (5 x 11)	UPW1H220MDD	Nichicon
10	1	C9	680 μF, 25 V, Electrolytic, Low ESR, 52 mΩ, (10 x 20)	ZGD1EM681G160	Ltec
11	1	C10	470 nF, 50 V, Ceramic, X7R, 0603	UMK107B7474KA-TR	Taiyo Yuden
12	1	C11	100 pF, 200 V, Ceramic, COG, 0805	08052A101JAT2A	AVX
13	1	C12	1.2 nF 50 V, Ceramic, NPO, 0603	CGJ3E2C0G1H122J	TDK
14	1	D1	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
15	1	D2	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
16	1	D3	Diode ULTRA FAST, SW, 200 V, 1 A, SMA	US1D-13-F	Diodes, Inc.
17	1	D4	Diode ULTRA FAST, SW, 200 V, 1 A, SMA	US1D-13-F	Diodes, Inc.
18	1	D6	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diode Inc.
19	1	D7	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
20	1	D8	100 V, 3 A, Schottky, SMC	30BQ100PBF	Vishay
21	1	D9	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
22	1	F1	Fuse, Pico, 2 A, 250 V, Fast, Axial	0263002.MXL	Littlefuse
23	1	JP1	0 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEY0R00V	Panasonic
24	1	JP3	0 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEY0R00V	Panasonic
25	1	L1	1 mH, 0.23 A, Ferrite Core	CTSCH875DF-102K	CT Parts
26	1	L2	1 mH, 0.23 A, Ferrite Core	CTSCH875DF-102K	CT Parts
27	1	L3	1 mH, 0.23 A, Ferrite Core	CTSCH875DF-102K	CT Parts
28	1	Q1	NPN, Small Signal BJT, 80 V, 0.15 A,SOT-23	MMBTA06LT1G	Diodes, Inc.
29	1	Q3	NPN, Small Signal BJT, 450 V, 0.5 A,SOT-23	FMMT459TA	Diodes, Inc.
30	1	Q4	NPN, Small Signal BJT, 45 V, 0.1 A, SOT-23	BC847CLT1G	On Semi
31	1	Q5	NPN,60 V 1000 MA, SOT-23	FMMT491TA	Zetex
32	1	Q6	450 V, 0.6 A, 3.8 Ω, N-Channel, TO-92	STQ3N45K3-AP	ST Micro
33	1	R1	10 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ103V	Panasonic
34	1	R2	10 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ103V	Panasonic
35	1	R3	10 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ103V	Panasonic
36	1	R4	510 Ω, 5%, 1 W, Metal Oxide	RSF100JB-510R	Yageo
37	1	R5	750 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ754V	Panasonic
38	1	R6	100 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ104V	Panasonic
39	1	R7	180 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ184V	Panasonic
40	1	R8	130 Ω, 5%, 1 W, Metal Oxide	RSF100JB-130R	Yageo
41	1	R9	510 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ514V	Panasonic
42	1	R10	2 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ205V	Panasonic
43	1	R11	200 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ204V	Panasonic
44	1	R12	100 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ101V	Panasonic
45	1	R13	0 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEY0R00V	Panasonic
46	1	R14	24.9 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2492V	Panasonic

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47	1	R15	187 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1873V	Panasonic
48	1	R16	75 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ750V	Panasonic
49	1	R17	20 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ203V	Panasonic
50	1	R18	6.2 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ622V	Panasonic
51	1	R19	47 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ473V	Panasonic
52	1	R20	390 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ394V	Panasonic
53	1	R21	100 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ104V	Panasonic
54	1	R22	270 Ω, 5%, 1 W, Thick Film, 2512	ERJ-1TYJ271U	Panasonic
55	1	R23	470 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ474V	Panasonic
56	1	R24	560 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ564V	Panasonic
57	1	R25	1.00 MΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1004V	Panasonic
58	1	R26	2.00 MΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2004V	Panasonic
59	1	R27	240 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ244V	Panasonic
60	1	T1	Bobbin, RM5, Vertical, 6 pins	P-501	Pin Shine
61	1	U1	LYTSwitch-4, eSIP-7C	LYT4311E	Power Integrations
62	1	VR1	8.2 V, 5%, 150 mW, SSMINI-2	DZ2S08200L	Panasonic

7 Transformer Specification

7.1 Electrical Diagram

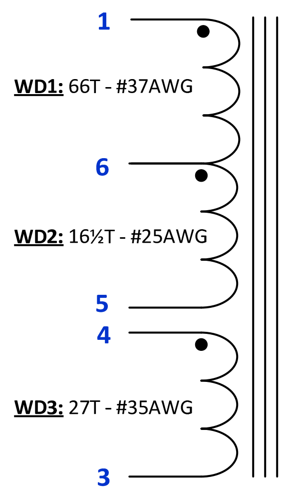

Figure 7 – Transformer Electrical Diagram.

7.2 Electrical Specifications

Inductance	Pins 1-5, all other windings open, measured at 100 kHz, 0.4 RMS.	1.2 mH ±5%
Resonant Frequency	Pins 1-5, all other windings open.	1,200 kHz (Min.)

7.3 Materials

Item	Description
[1]	Core: RM5/I-3F3 PIN SHINE.
[2]	Bobbin: RM5-Vertical, 6 pins (3/3). AllStar Magnetics P/N: P501.
[3]	Clip: AllStar Magnetics P/N: CLI/P-RM4/5/I.
[4]	Magnet wire: #37 AWG - Double coated.
[5]	Magnet wire: #25 AWG - Double coated.
[6]	Magnet wire: #35 AWG - Double coated.
[7]	Tape: 3M 1298 Polyester Film, 4.5 mm wide, 2.0 mils thick, or equivalent.
[8]	Varnish: Dolph BC-359 or equivalent.

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7.4 Transformer Build Diagram

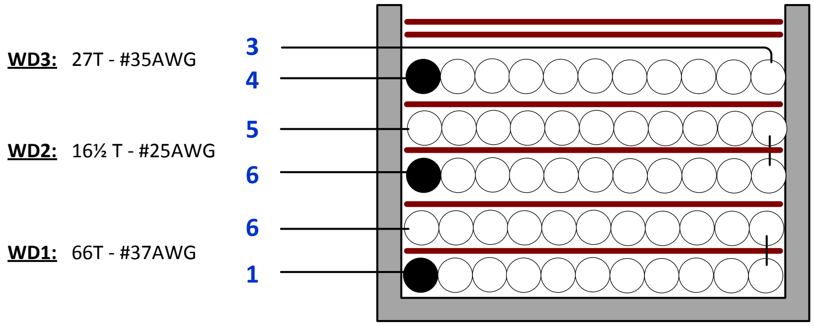

Figure 8 – Transformer Build Diagram.

7.5 Transformer Construction

Winding Preparation	Place the bobbin on the mandrel with the pin side is on the left side. Winding direction is clockwise direction.
WD1	Start at pin 1, wind 33 turns of wire item [4] from left to right, place 1 layer tape item [7], then continue wind another 33 turns from right to left, and end at pin 6.
Insulation	Place 1 layer of tape item [7].
WD2	Start at pin 6, wind 8 turns of wire item [5] from left to right, place 1 layer tape item [7], then continue wind another 8 ½ turns from right to left, and end at pin 5.
Insulation	Place 1 layer of tape item [7].
WD3	Start at pin 4, wind 27 turns of wire item [6] from left to right in 1 layer. At the last turn bring the wire back to the left and end at pin 3.
Final Assembly	Grind, assemble, and secure core halves with clips item [3]. Varnish with item [8].

8 Transformer Design Spreadsheet

ACDC_LYTSwitch_Tapped Buck_110112; Rev.0.3; Copyright Power Integrations 2012	INPUT	INFO	OUTPUT	UNIT	ACDC_LYTSwitch_110112: LYTSwitch Tapped Buck Design Spreadsheet
ENTER APPLICATION VARIABLES					
Dimming required	**YES**		**YES**		Select "YES" option if dimming is required. Otherwise select "NO".
VACMIN	90		90	V	Minimum AC Input Voltage
VACMAX	132		132	V	Maximum AC input voltage
fL			50	Hz	AC Mains Frequency
VO	15.00			V	Typical output voltage of LED string at full load
VO_MAX			18.75	V	Maximum LED string Voltage. Ensure that the maximum LED string voltage is below VO_MAX
VO_MIN			11.25	V	Minimum LED string Voltage. Ensure that the minimum LED string voltage is above VO_MIN
V_OVP			20.63	V	Over-voltage setpoint
IO	0.50				Typical full load LED current
PO			7.5	Watts	!!! For 115/230V INPUT : REDUCE PO<2.5W (larger LYTSwitch)
n	0.86		0.86		Estimated efficiency of operation
ENTER LYTSwitch VARIABLES					
LYTSWITCH	**LYT4311E**				Selected LYTSwitch device. If Dimming is required, select device from LNK40X family, Otherwise select device from LNK41X family
Current Limit Mode	**RED**		RED		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN			0.750	A	Minimum current limit
ILIMITMAX			0.940	A	Maximum current limit
fS			132000	Hz	Switching Frequency
fSmin			124000	Hz	Minimum Switching Frequency
fSmax			140000	Hz	Maximum Switching Frequency
IV			79.82	uA	V pin current
Rv			2	M-ohms	Upper V pin resistor
IFB			114.22	uA	FB pin current (75 uA < IFB < 250 uA)
R7			36.77	k-ohms	IFB setting resistor (See RDR254 schematic)
R8			35.35	k-ohms	Upper resistor in base divider (See RDR254 schematic)
R9			90.90	k-ohms	Lower resistor in base divider (See RDR254 schematic)
VDS			10	V	LYTSwitch on-state Drain to Source Voltage
VD	0.60			V	Output Winding Diode Forward Voltage Drop
VDB	0.70			V	Bias Winding Diode Forward Voltage Drop
Key Design Parameters					
KP			0.95		Ripple to Peak Current Ratio (0.4 < KRP < 1.3)
LP			1200	uH	Primary Inductance
KP Expected			0.81		Ripple to Peak Current Ratio (0.4 < KRP < 1.3)
Expected IO (average)			0.500	A	Expected Average Output Current
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**RM5**		**RM5**		Selected Core for inductor
Core		#N/A		*P/N:*	#N/A
Bobbin		#N/A		*P/N:*	#N/A
AE	0.23		0.23	cm^2	Core Effective Cross Sectional Area
LE	0.21		0.21	cm	Core Effective Path Length
AL	1450.00		1450	nH/T^2	Ungapped Core Effective Inductance
BW	4.50		4.5	mm	Bobbin Physical Winding Width
M			0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	6.00		6		Number of Primary Layers

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DC INPUT VOLTAGE PARAMETERS					
VMIN			127	V	Peak input voltage at VACMIN
VMAX			187	V	Peak input voltage at VACMAX
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.12		Minimum duty cycle at peak of VACMIN
IAVG			0.50	A	Average Primary Current
IP			0.39	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
ISP			1.96	A	Peak Secondary Current (calculated at minimum input voltage VACMIN)
IRMS			0.50	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP	1200.00		1200	uH	Primary Inductance
N_RATIO	5.00		5		Turns Ratio
NP	83.00		83		Total Number of Turns in the winding
NS			17		Secondary winidng turns
ALG			174	nH/T^2	Gapped Core Effective Inductance
BM			2459	Gauss	Maximum Flux Density at PO, VMIN (BM<3000)
BP			3381	Gauss	Peak Flux Density (BP<4200)
BAC			1168	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			105		Relative Permeability of Ungapped Core
LG			0.15	mm	Gap Length (Lg > 0.1 mm)
BWE			27	mm	Effective Bobbin Width
OD			0.33	mm	Maximum Primary Wire Diameter including insulation
INS			0.05	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.27	mm	Bare conductor diameter
AWG			30	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			102	Cmils	Bare conductor effective area in circular mils
CMA			203	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)

9 Performance Data

All measurements were performed at room temperature using an LED e-load. The table in Section 9.5 shows complete test data values.

9.1 Efficiency

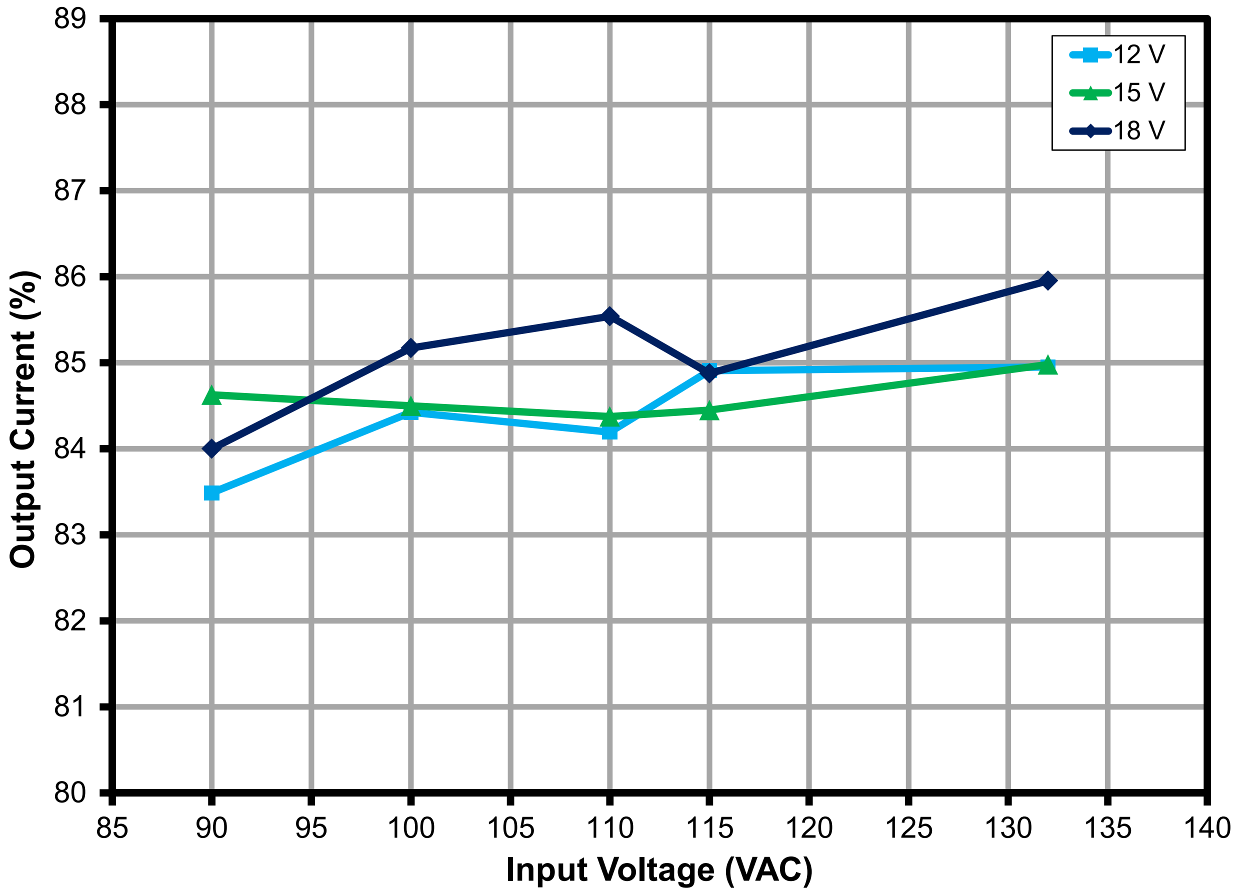

Figure 9 – Efficiency vs. Line.

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9.2 Line and Load Regulation

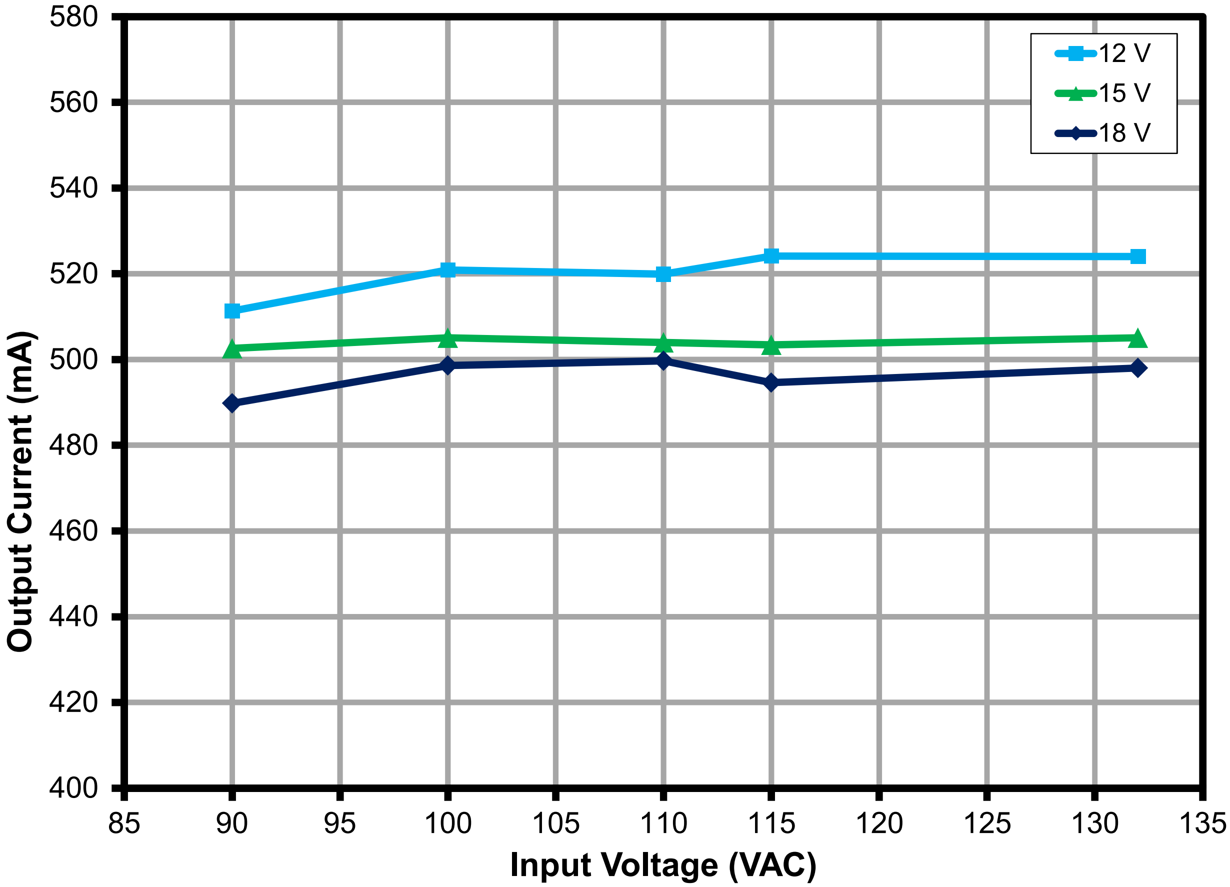

Figure 10 – Regulation vs. Line and Load.

9.3 Power Factor

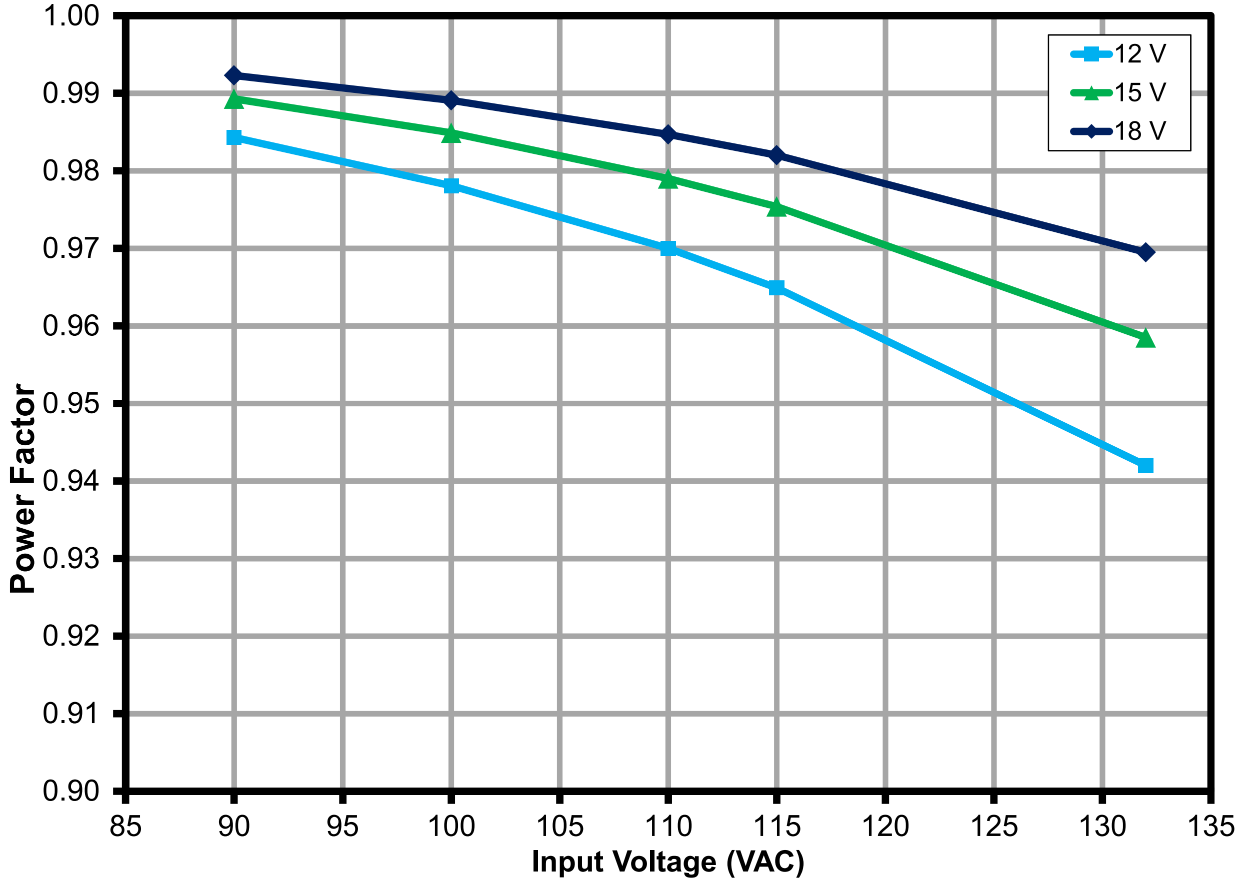

Figure 11 – Power Factor vs. Line and Load

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9.4 A-THD

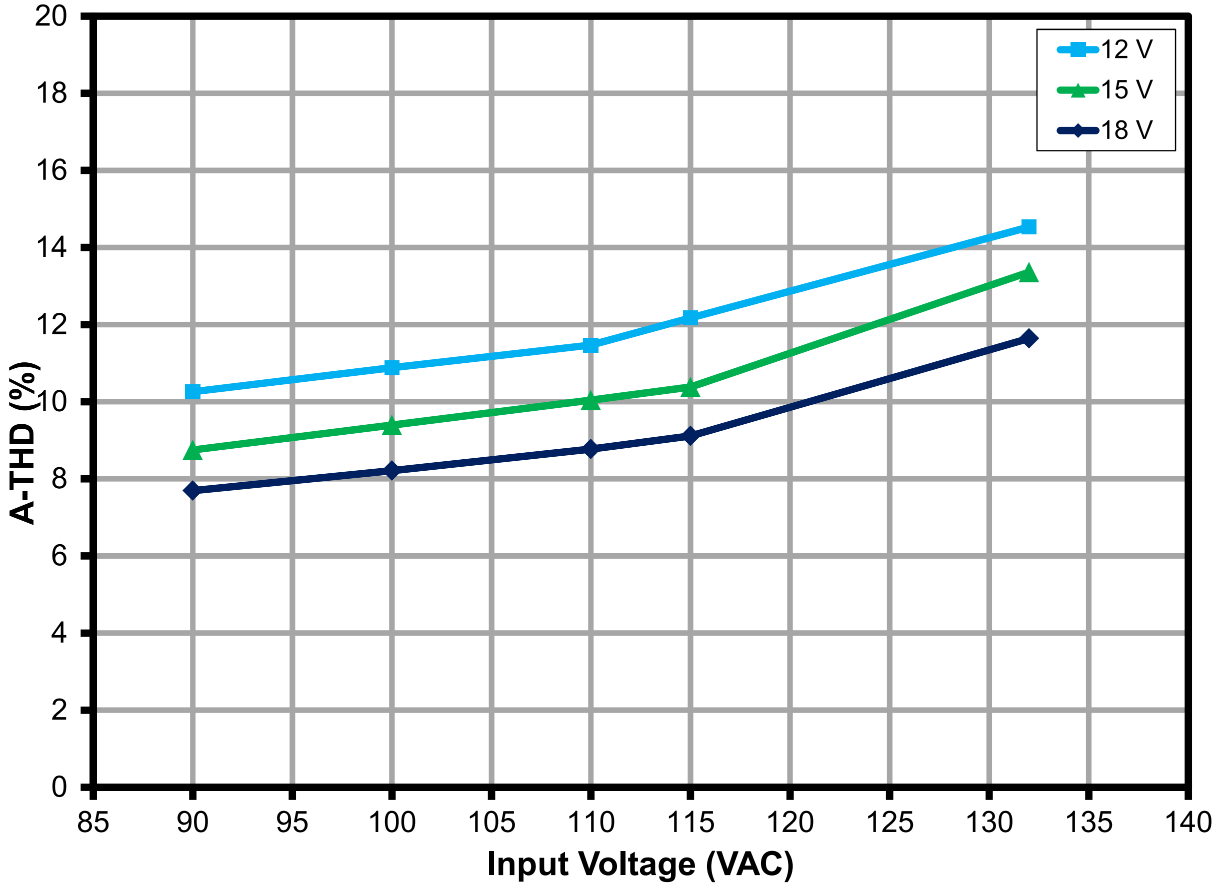

Figure 12 – A-THD vs. Line and Load.

9.5 Test Data

All measurements were taken with the board at open frame, 25 °C ambient, and 60 Hz line frequency.

9.5.1 Test Data, 12 V LED Load

Input		Input Measurement					Load Measurement			
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency (%)
90	60	89.94	84.34	7.467	0.984	10.26	12.0030	511.300	6.234	83.49
100	60	99.94	77.03	7.530	0.978	10.88	12.0150	520.900	6.357	84.42
110	60	109.94	70.66	7.535	0.970	11.47	12.0140	519.900	6.344	84.19
115	60	114.94	67.92	7.533	0.965	12.17	12.0200	524.100	6.396	84.91
132	60	131.93	60.53	7.522	0.942	14.53	12.0180	524.000	6.390	84.95

9.5.2 Test Data, 15 V LED Load

Input		Input Measurement					Load Measurement			
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency (%)
90	60	89.94	101.68	9.048	0.989	8.75	15.0100	502.600	7.657	84.63
100	60	99.94	92.53	9.108	0.985	9.39	15.0120	505.100	7.696	84.50
110	60	109.94	84.54	9.100	0.979	10.04	15.0110	504.000	7.678	84.37
120	60	114.94	80.98	9.079	0.975	10.38	15.0100	503.400	7.667	84.45
132	60	131.92	71.55	9.047	0.959	13.36	15.0130	505.100	7.688	84.98

9.5.3 Test Data, 18 V LED Load

Input		Input Measurement					Load Measurement			
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency (%)
90	60	89.94	119.19	10.637	0.992	7.69	17.9890	489.800	8.935	84.00
100	60	99.93	108.13	10.688	0.989	8.21	18.0060	498.600	9.103	85.17
110	60	109.95	98.49	10.664	0.985	8.77	18.0070	499.700	9.122	85.54
120	60	114.93	94.20	10.632	0.982	9.11	17.9980	494.600	9.024	84.88
132	60	131.92	82.61	10.565	0.970	11.64	18.0040	498.000	9.081	85.95

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10 Dimming Performance Data

TRIAC dimming results were taken at an input voltage of 120 VAC, 60 Hz line frequency, room temperature, and a nominal 15 V LED load.

The output current High Limit I_{OUT} (HL) and Low Limit I_{OUT} (LL) were incorporated based on the USA NEMA publication SSL6-2010 section 4 page 9 for dimming performance system requirements for reference. The standard however refers to 120 VAC operating input voltage and pertains to the limits as relative light output. The limits incorporated on the succeeding graphs assumes that 100% relative light output falls on the maximum operating output current of 500 mA and 0 mA as 0% light output, and input line of 120 VAC, 60 Hz.

10.1 Dimming Curve with Simulated (Using Agilent 6812B AC Source) Leading Edge Dimmer

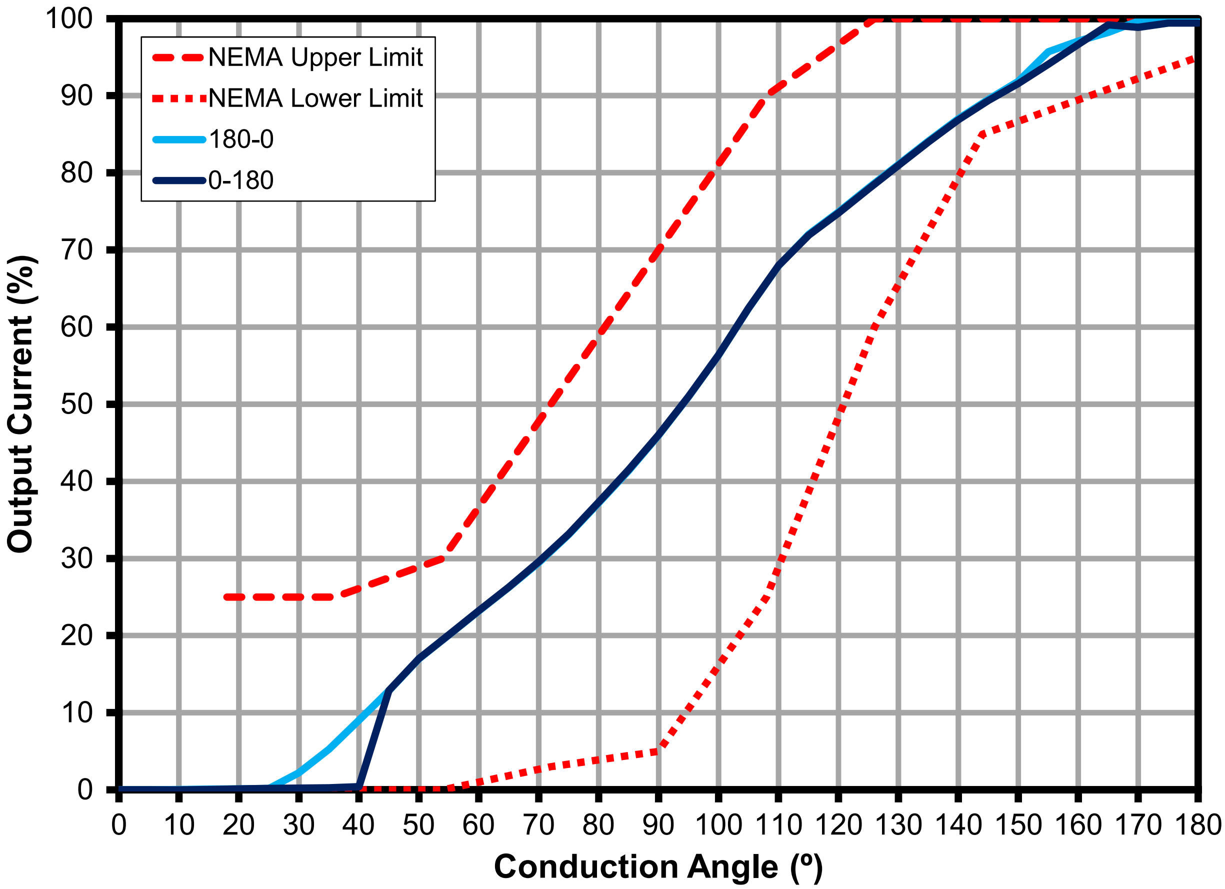

Figure 13 – Dimming Curve at 120 VAC, 60 Hz Input.

10.2 Fast Start-up (<200 ms) with TRIAC-Based Dimmer

A TRIAC-based U.S. dimmer model DVWCL-153-PLH (Lutron) was used with the thumb-wheel adjust set to minimum turn-on (i.e. <30 degrees) which guarantees the LED driver is off when it is switched to ON position. The test was made by turning/sliding the dimmer knob as quickly as possible from minimum to maximum position then measuring the time from the point the dimmer started conducting to the point the output current started rising.

Input voltage: 120 VAC / 60 Hz

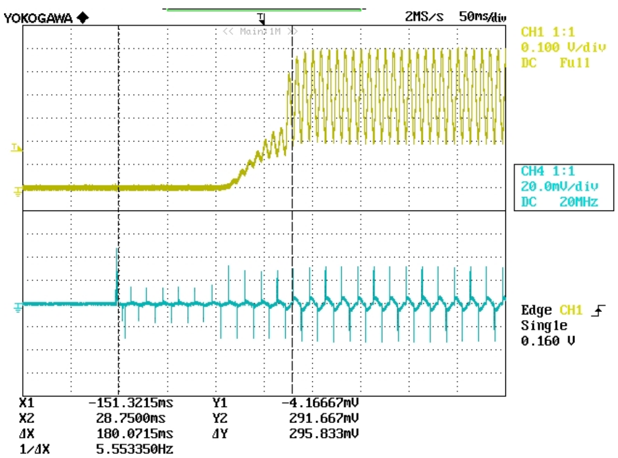

Figure 14 – Measured Start-up Time 180 ms.
Flicking the Switch ON, Dimmer at Full Conduction.
Upper: I_{OUT}, 100 mA / div.
Lower: I_{IN}, 20 mA, 50 ms / div.

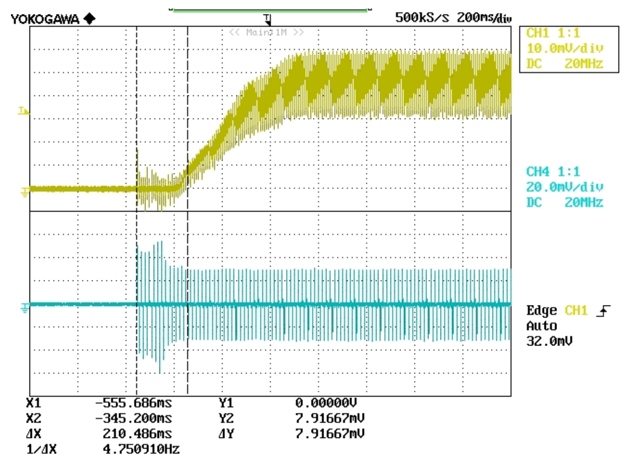

Figure 15 – Measured Start-up Time 210 ms.
Flicking the Switch ON, Dimmer at 10% Load.
Upper: I_{OUT}, 10 mA / div.
Lower: I_{IN}, 20 mA, 200 ms / div.

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10.3 Pop-on Point with TRIAC-based Dimmer

Pop-on per NEMA SSL-6 definition is the lowest dimmer setting above minimum at which the lamp transitions from off to dimmed.

This particular test was conducted using 120 V / 60 Hz TRIAC dimmer model SLV-603P (Lutron U.S. dimmer).

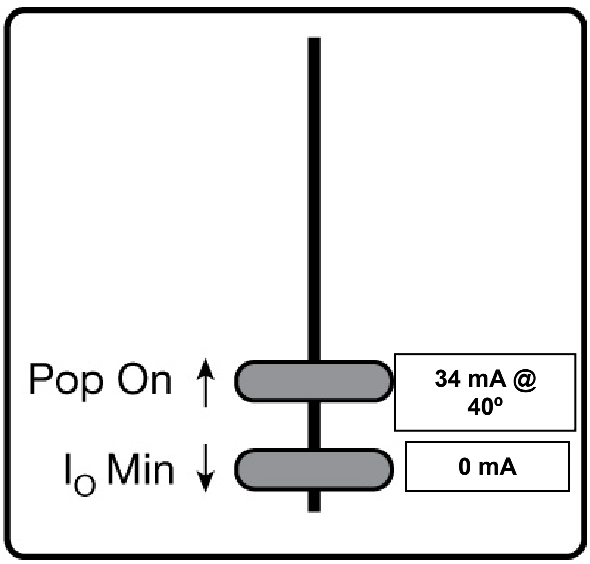

Figure 16 – 40º Conduction Angle was Measured at Pop-on Point.

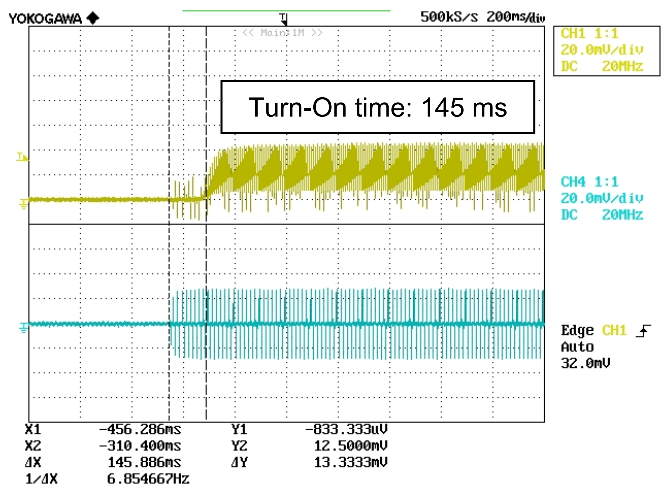

Figure 17 – 40º Conduction Turn-on Time 145 ms.
Upper: I_{OUT}, 20 mA / div.
Lower: I_{IN}, 100 mA / div., 200 ms / div.

10.4 Output Current and Input Current Waveforms with Dimmer

Input: 120 VAC, 60 Hz Programmable AC source
Output: 15 V LED Load
Dimmer: LUTRON GL-600WH

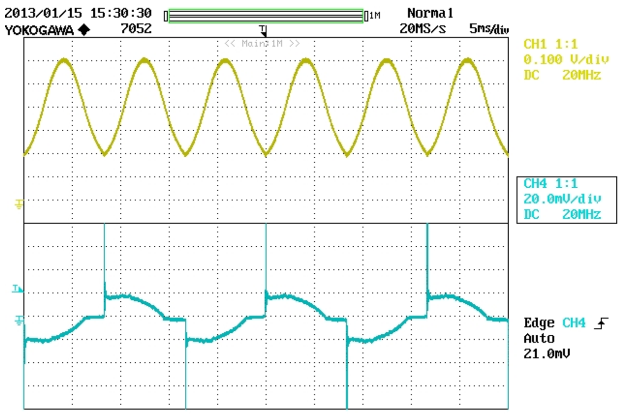

Figure 18 – Maximum Conduction Angle (147º).
Upper: I_{OUT}, 100 mA / div.
Lower: I_{IN}, 200 mA, 5 ms / div.

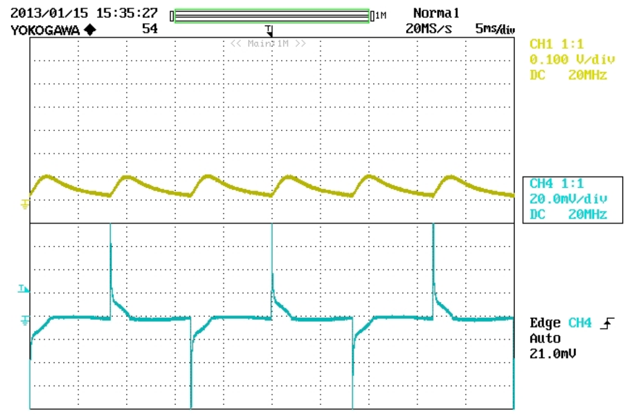

Figure 19 – Minimum Conduction Angle (40º).
Upper: I_{OUT}, 100 mA / div.
Lower: I_{IN}, 200 mA, 5 ms / div.

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10.5 Compatibility List

The following U.S. TRIAC-based dimmers were tested with programmable AC source (120 VAC, 60 Hz) and 15 V LED load.

Dimmer Brand	Type	Remarks	Power	Part Number	I_{MIN} (mA)	I_{MAX} (mA)	Dim Ratio	Remark
LUTRON	L	Lutron 600-Watt Slide Dimmer LG-600PH-LA	600W	LG-600PH-WH	0.40	430	1075	pass
LUTRON	L	Lutron Skylark Incandescent 600W 3-Way Preset Dimmer with On/Off	600W	S-603P-WH	0.40	440	1100	pass
LUTRON	T	Lutron SLV-600P-WH 600-Watt Skylark Magnetic Low-Voltage Single-Pole Dimmer	600W	SLV600P-WH	0.40	443	1108	pass
LUTRON	L	Slide-to-Off Single Pole Skylark Dimmer Switch (RFI suppression)	600W	S-600-WH	0.40	470	1175	pass
LUTRON	L	Lutron Skylark 5-Amp White Gloss Dimmer	600W	S-600PH-WH	0.40	440	1100	pass
LUTRON	L	Cfl&led Dimmer, Paddle/slide, 120V, 600W	600W	DVWCL-153-PLH-WH	0.40	432	1080	pass
LUTRON	L	600W Diva Dimmer, 3-Way - Ivory	600W	DV-603P-WH	0.40	430	1075	pass
LUTRON	L	Lutron Diva DV-600P-WH Incand 600 Watt Single Pole Light Dimmer in White	600W	DV-600P-WH	0.40	431	1078	pass
LUTRON	L	Ivry Toggle Dimmer 1p Preset	600W	TG-600PH-WH	4.70	448	95	pass
LUTRON	T	Lutron Ariadni AY-600P-WH Incand Preset 600 Watt Single Pole Light Dimmer in White	600W	AY-600P-WH	6.70	439	66	pass
LUTRON	L	Glyder Incandescent Single Pole 600 Watts Preset Dimmer, White	600W	GL-600P-WH	0.40	436	1090	pass
LEVITON	L	SureSlide 600W Incandescent Dimmer	600W	R62-06633-1LW	0.40	483	1208	pass
LEVITON	L	SureSlide 600W Incandescent Slide Dimmer, Single-Pol	600W	R62-06631-1LW	0.40	454	1135	pass
LEVITON	L	IllumaTech Incandescent Preset Slide Dimmer	600W	R60-IPI06-1LM	47.00	478	10	pass
LEVITON	L	IllumaTech Rotary Controls 120V AC 60Hz	600W	R52-RPI06-1LW	9.00	491	55	pass
LEVITON	L	Leviton 600-Watt 3-Way Lighted White/Ivory Push Dimmer	600W	R60-06684-1IW	0.40	485	1213	pass
LEVITON			600W	6683	0.40	471	1178	pass
LEVITON	L	SURESLIDE" MAGNETIC LOW VOLTAGE DIMMER *600VA, 120V AC, 60Hz	450W	R02-06613-PLW	0.40	479	1198	pass
COOPER				SLC03P-W-K-L	0.40	447	1118	pass
LUTRON	L	Lutron 15-Amp White Slide Dimmer	600W	GL-600-WH	0.40	465	1163	pass
LUTRON	L	Diva, Screw Base Compact Fluorescent Dimming with Philips® DIMMABLE Energy Saver CFL, Single Pole/3-Way, 200W, White	200W	DVPDC-203P-WH	117.00	467	4	pass
LUTRON	L	Lyneo Lx Single Pole Dimmer 600W	500W	LX-600PL-WH	22.50	458	20	pass
LUTRON	L	Single Pole - Incandescent - Push On/Off - 600 Watt - White	600W	D-600P-WH	0.40	422	1055	pass
LUTRON			600W	CTCL-153PDH	2.00	432	216	pass
LUTRON			600W	S-600P	0.40	436	1090	pass
LUTRON				TGLV-600P	0.40	448	1120	pass
LUTRON			450W	TGLV-600PR	0.40	441	1103	pass
LUTRON	L	Lutron Diva Satin 5-Amp Desert Stone Preset Dimmer	300W	TT-300NLH-WH	0.40	472	1180	pass
LUTRON	L	Lutron Credenza 300-Watt White Lamp	300W	TT-300H-WH	0.40	473	1183	pass

		Dimmer						
LUTRON	L	Nova, Slide-To-Off Dimmers, Magnetic Low Voltage, Neon/Cold Cathode, Single Pole, 1000VA, White	800W	NLV-1000-WH	0.40	455	1138	pass
LUTRON	L	Lutron 15-Amp White Slide Dimmer	600W	GL-600-WH	0.40	465	1163	pass
LUTRON		S-600P			0.40	434	1085	pass
LUTRON		S-600P			0.40	465	1163	pass
Cooper		S106P			0.40	457	1143	pass
LUTRON		Skylark, Dimmers with On/Off Switch, Incandescent/Halogen, 3-Way, 1000W, White	1000	S-103P-WH	44.00	451	10	pass
LUTRON		Skylark, Dimmers with On/Off Switch & Locator Light, Incandescent/Halogen, Single Pole, 600W, White	600	S-600PNLH-WH	0.40	441	1103	pass
LUTRON		Skylark, Dimmers with On/Off Switch & Locator Light, Incandescent/Halogen, 3-Way, 600W, White	600	S-603PNL-WH	0.40	441	1103	pass
LUTRON		Skylark, Dimmers with On/Off Switch, Magnetic Low Voltage, 3-Way, 600VA, White	600	SLV-603P-WH	0.40	438	1095	pass
LUTRON		Skylark, Slide-To-Off Dimmers, Incandescent/Halogen, Eco-Dim, Single Pole/3-Way, 600W, Clamshell Packing, White	600	S-603PGH-WH	0.40	309	773	pass
LUTRON		Ariadni, Dimmers, Magnetic Low Voltage, Single Pole, 600VA, White	600	AYLV-600P-WH	0.40	443	1108	pass
LUTRON		Ariadni, Dimmers, Magnetic Low Voltage, 3-Way, 600VA, White	600	AYLV-603P-WH	0.40	430	1075	pass
LUTRON		Ariadni, Dimmers with Locator Light, Incandescent/Halogen, 3-Way, 600W, White	600	AY-603PNL-WH	0.40	411	1028	pass
LUTRON		Ariadni, Dimmers, Incandescent/Halogen, Eco-dim, Single Pole/3-Way, 600W, White	600	AY-603PG-WH	1.00	270	270	pass
LUTRON		Ariadni, Dimmers, Incandescent/Halogen, 3-Way, 600W, White	600	AY-603P-WH	7.50	426	57	pass
LUTRON		Ariadni, Dimmers with Locator Light, Incandescent/Halogen, Single Pole, 600W, White	600	AY-600PNL-WH	1.70	438	258	pass
LUTRON		Diva, Dimmers with Locator Light, Electronic Low Voltage, Single Pole, 300W, White	300	DVELV-300P-WH	3.00	442	147	pass
LUTRON		Diva, Dimmers with Locator Light, Magnetic Low Voltage, Single Pole, 1000VA, White	1000	DVLV-10P-WH	0.50	423	846	pass
LUTRON		Diva, Dimmers with Locator Light, Magnetic Low Voltage, 3-Way, 1000VA, White	1000	DVLV-103P-WH	0.40	428	1070	pass
LUTRON		Diva, Dimmers with Locator Light, Magnetic Low Voltage, 3-Way, 600VA, White	600	DVLV-603P-WH	0.40	432	1080	pass
LUTRON		Skylark, Slide-To-Off Dimmers, Incandescent/Halogen, Single Pole, 1000W, White	1000	S-1000-WH	0.40	467	1168	pass
LUTRON		Skylark, Dimmers with On/Off Switch, Electronic Low Voltage, Single Pole, 300W, White	300	SELV-300P-WH	2.80	435	155	pass
LUTRON		Skylark, Dimmers with On/Off Switch, Incandescent/Halogen, Single Pole, 600W, White	600	S-600P-WH	0.40	433	1083	pass
LUTRON		Skylark, Dimmers with On/Off Switch & Locator Light, Incandescent/Halogen, 3-	1000	S-103PNL-WH	43.00	445	10	pass

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		Way,1000W, White						
LUTRON		Spacer System, Dimmers with IR Receiver, Magnetic Low Voltage, Single Location, 1000VA(800W), White		SPSLV-1000-WH	59.00	450	8	pass
LUTRON		Spacer System, Dimmers with IR Receiver, Magnetic Low Voltage, Single Location, 600VA(450W), White		SPSLV-600-WH	60.00	438	7	pass
LUTRON		Spacer System, Dimmer with IR Receiver, Electronic Low Voltage, Single Location, 600W, White		SPSELV-600-WH	32.00	450	14	pass
LUTRON		Glyder, Slide-To-Off Dimmers, Magnetic Low Voltage, Single Pole, 600W, White	600	GLV-600-WH	0.40	463	1158	pass

Figure 20 – U.S. TRIAC-Based Dimmers Compatibility List.

10.6 IR Thermal Profile

These images were captured while the unit was running with 15 V LED load for more than 2 hours (25 °C). The unit was placed on bench without enclosure for the conditions specified.

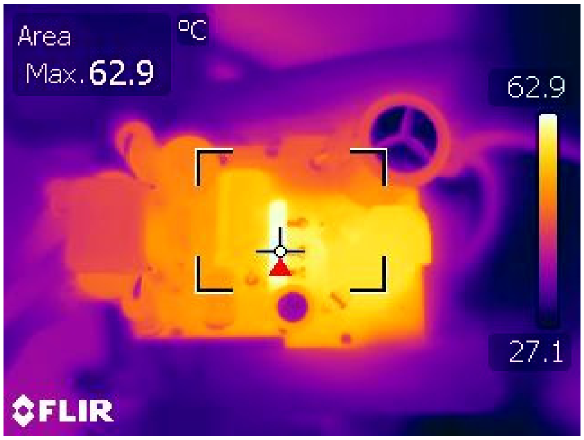

Figure 21 – Non-Dimming.
V_{IN} = 90 VAC, 60 Hz, 15 V LED Load.
U1 was Hottest Device.

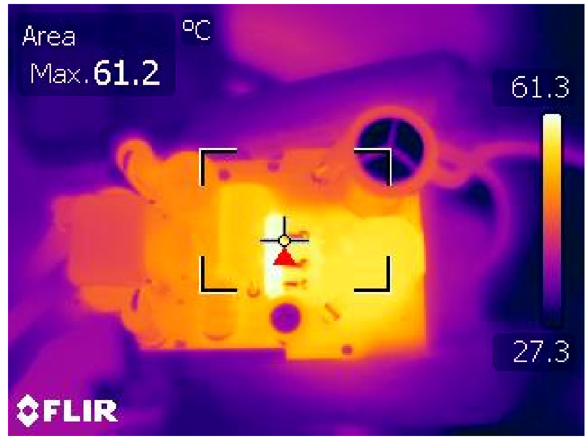

Figure 22 – Non-Dimming.
V_{IN} = 132 VAC, 60 Hz, 15 V LED Load.
U1 was Hottest Device.

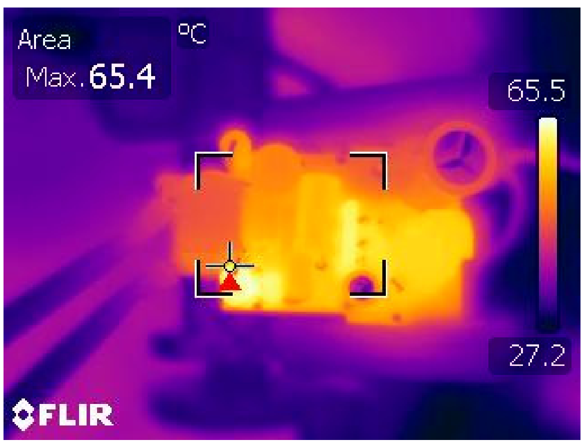

Figure 23 – With TRIAC Dimmer Connected.
V_{IN} = 120 VAC, 60 Hz, 15 V LED.
Load at Full Conduction.
R4 was Hottest Device.

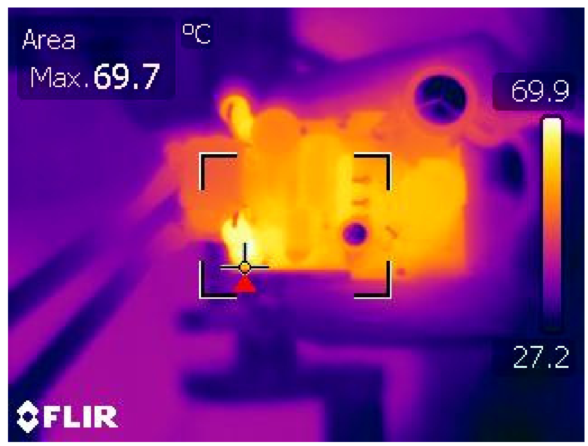

Figure 24 – With TRIAC Dimer Connected.
V_{IN} = 120 VAC, 60 Hz, 15 V LED.
Load at 90º Phase Conduction.
R4 Damper was Hottest Device.

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10.7 Output Current and Output Voltage Waveform at Normal Operation

Input Condition	I_{OUT}, Mean (mA)	I_{OUT} Ripple: $(I_{MAX}-I_{MIN})/(I_{MAX}+I_{MIN})*100\%$
90 VAC, 60 Hz	487	51%
120 VAC, 60 Hz	504	50%
132 VAC, 60 Hz	508	50%

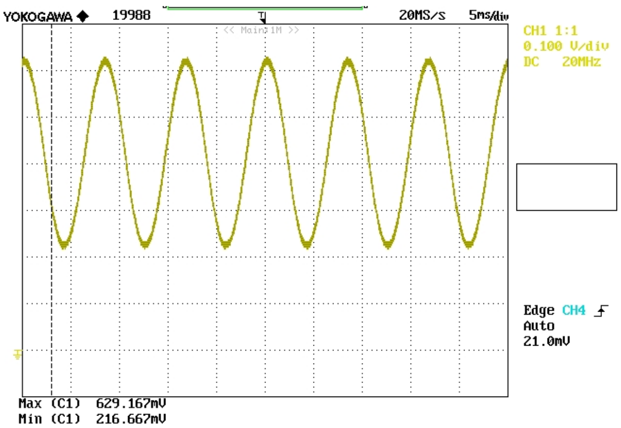

Figure 25 – 90 VAC, 60 Hz Full Load.
Ch1: I_{OUT}, 100 mA / div.

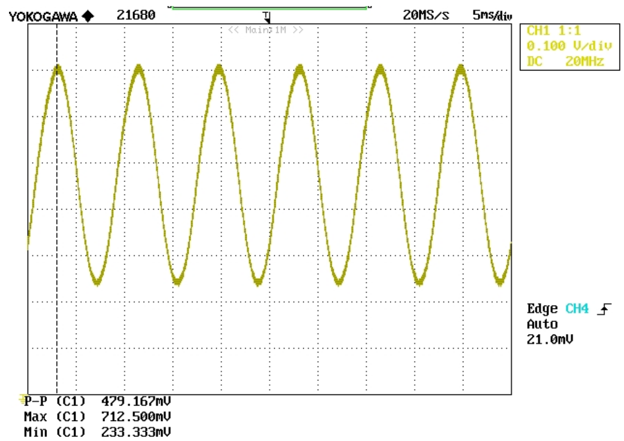

Figure 26 – 120 VAC, 60 Hz Full Load.
Ch1: I_{OUT}, 100 mA / div.

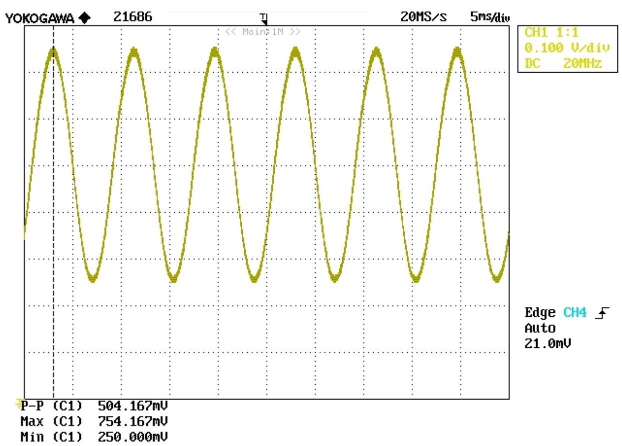

Figure 27 – 132 VAC, 60 Hz Full Load.
Ch1: I_{OUT}, 100 mA / div.

10.8 Output Voltage and Output Current Waveform at Start-up

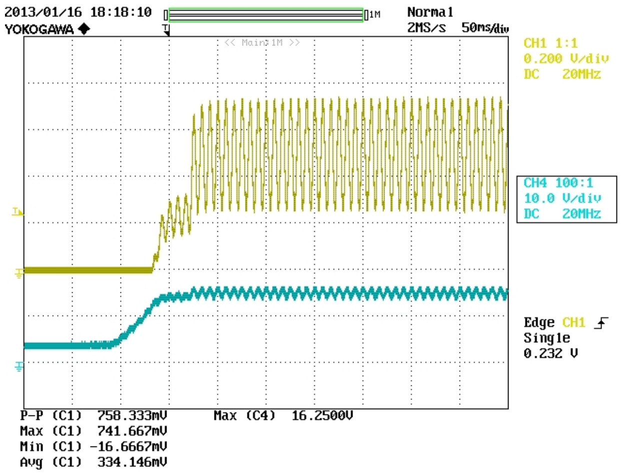

Figure 28 – 90 VAC, 60 Hz.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 10 V, 50 ms / div.

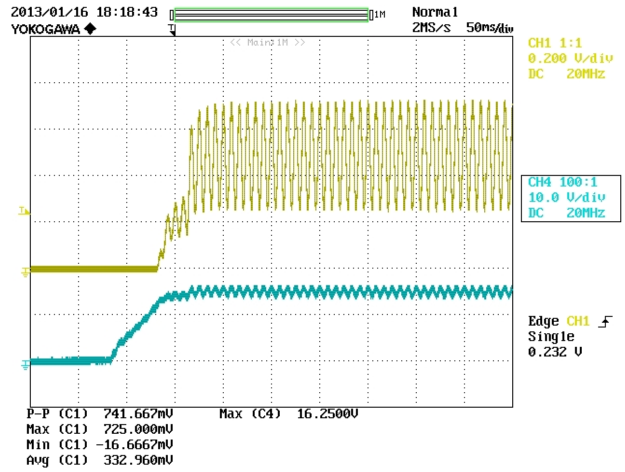

Figure 29 – 132 VAC, 60 Hz.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 10 V, 50 ms / div.

10.9 Drain Voltage and Current at Normal Operation

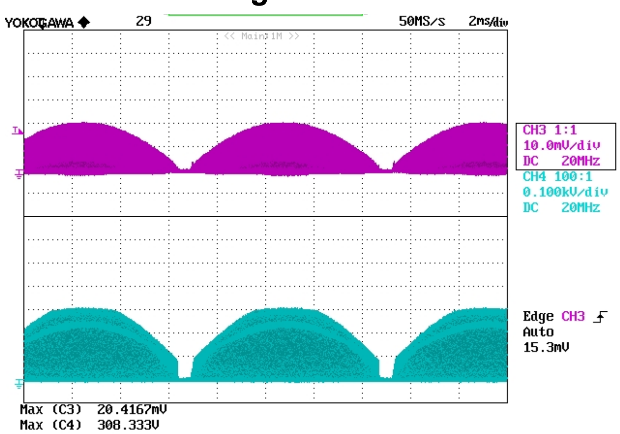

Figure 30 – 120 VAC, 60 Hz.
Upper: I_{DRAIN}, 0.5 A / div.
Lower: V_{DRAIN}, 100 V, 2 ms / div.

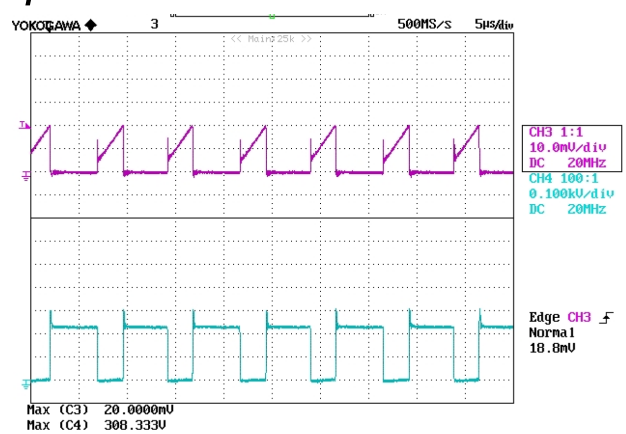

Figure 31 – 120 VAC, 60 Hz.
Upper: I_{DRAIN}, 0.5 A / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

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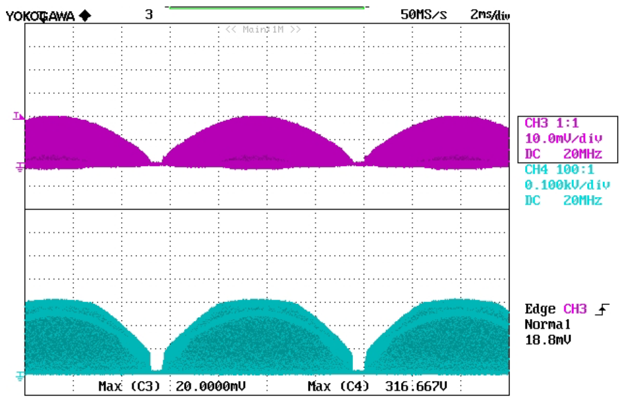

Figure 32 – 132 VAC, 60 Hz.
Upper: I_{DRAIN}, 0.5 A / div.
Lower: V_{DRAIN}, 100 V, 2 ms / div.

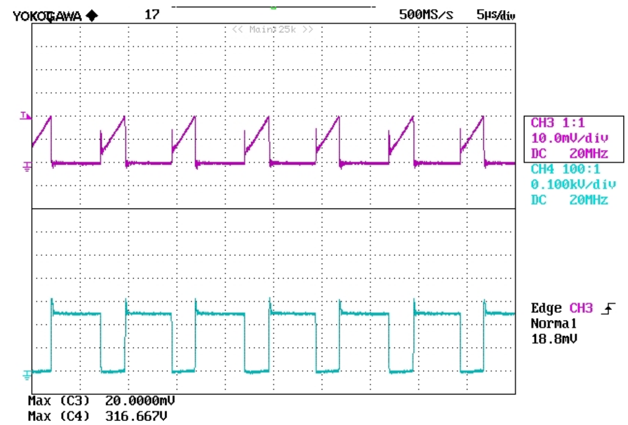

Figure 33 – 132 VAC, 60 Hz.
Upper: I_{DRAIN}, 0.5 A / div.
Lower: V_{DRAIN}, 100 V / div., 5 µs / div.

10.10 Drain Voltage and Current at Start-up

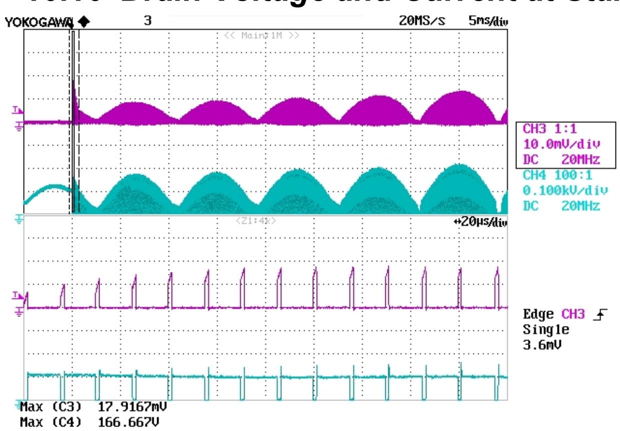

Figure 34 – 90 VAC, 60 Hz Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.

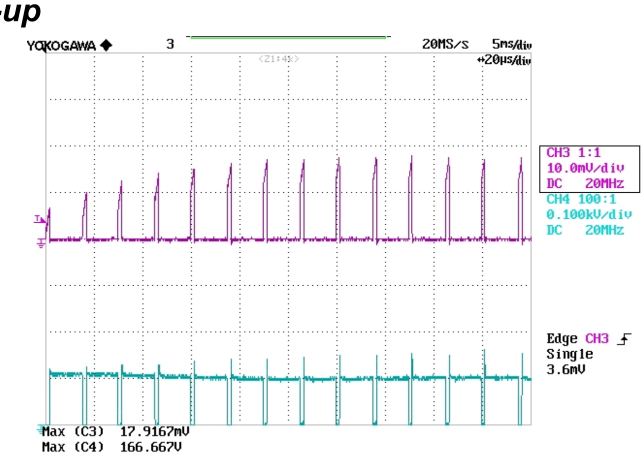

Figure 35 – 90 VAC, 60 Hz Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 10 µs / div.

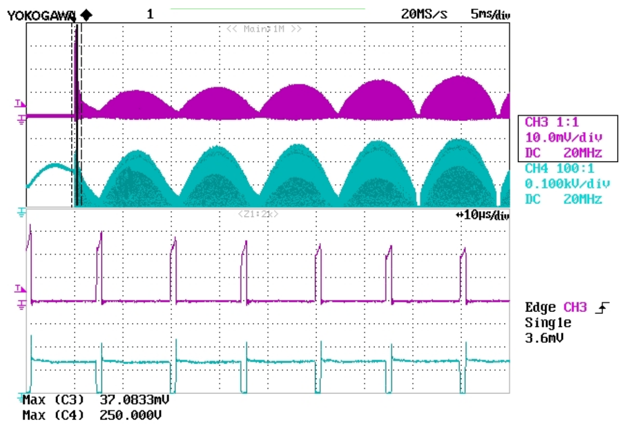

Figure 36 – 132 VAC, 60 Hz Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.

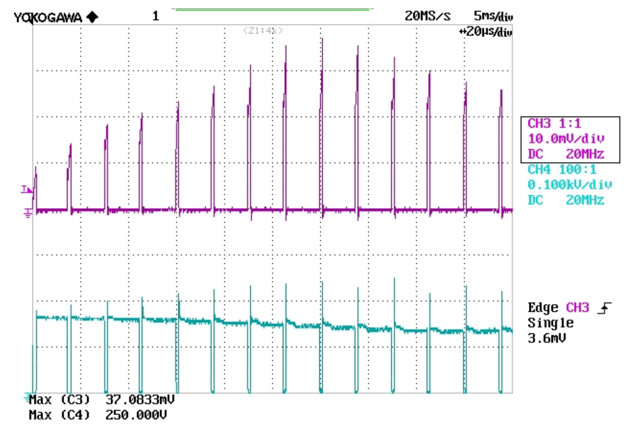

Figure 37 – 132 VAC, 60 Hz Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 20 μs / div.

10.11 Drain Voltage and Current at Output Short Condition

During output short condition, the I_{FB} current falls below the $I_{FB(AR)}$ threshold and enters the auto-restart condition. During this condition, to minimize power dissipation on the power components, the auto-restart circuit turns the power supply on and off at an auto-restart duty cycle of typically DC_{AR} for as long as the fault condition persists.

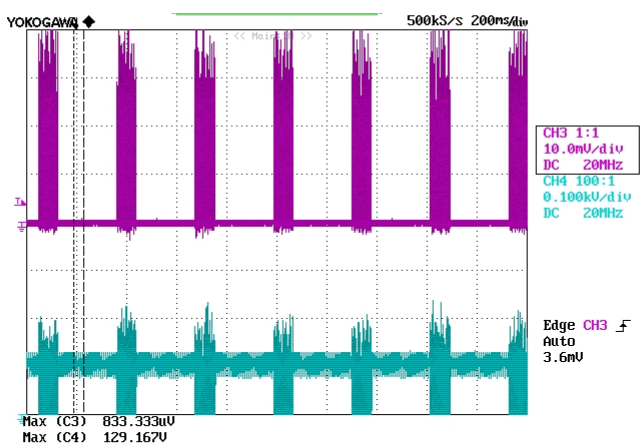

Figure 38 – 90 VAC, 60 Hz Output Short Condition.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V, 200 ms / div.

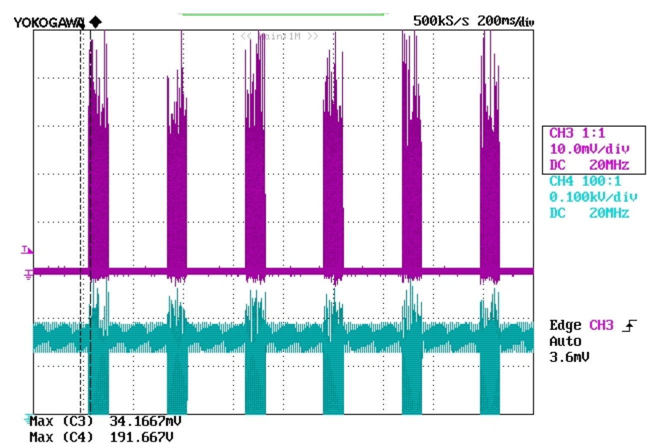

Figure 39 – 132 VAC, 60 Hz Output Short Condition.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V, 200 ms / div.

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10.12 Output Diode Voltage and Current Waveform at Normal Operation

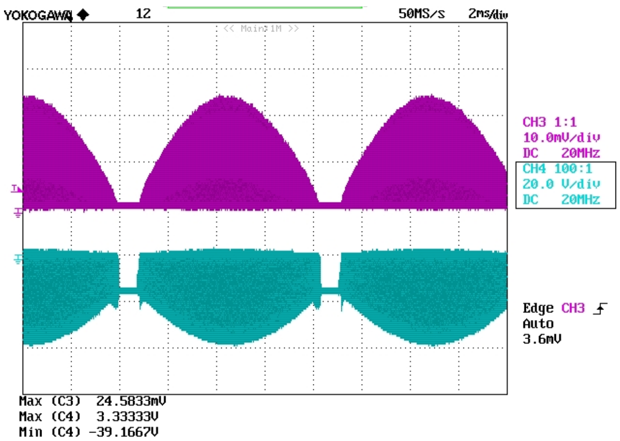

Figure 40 – 90 VAC, 60 Hz.
Upper: I_{D8}, 1 A / div.
Lower: V_{D8}, 20 V, 2 ms / div.

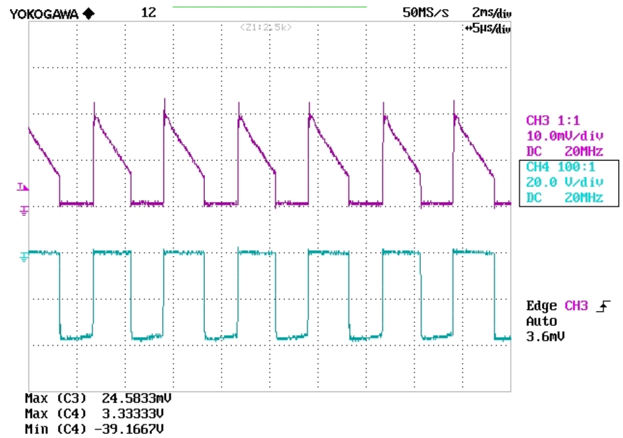

Figure 41 – 90 VAC, 60 Hz.
Upper: I_{D8}, 1 A / div.
Lower: V_{D8}, 100 V / div., 5 μs / div.

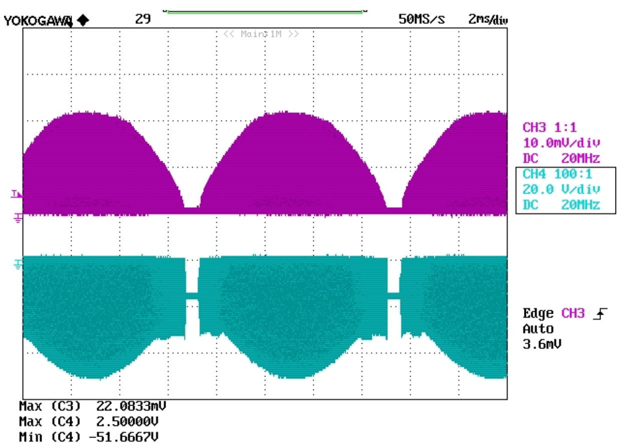

Figure 42 – 132 VAC, 60 Hz.
Upper: I_{D8}, 1 A / div.
Lower: V_{D8}, 20 V, 2 ms / div.

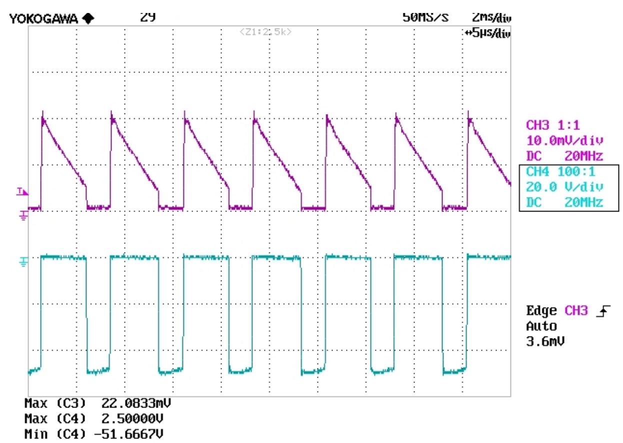

Figure 43 – 132 VAC, 60 Hz.
Upper: I_{D8}, 1 A / div.
Lower: V_{D8}, 20 V / div., 5 μs / div.

11 Non-Dimming Waveforms

11.1 Output Current and Input Current Waveforms

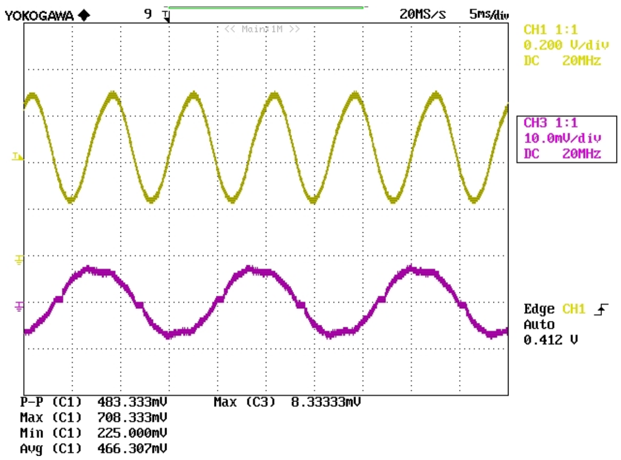

Figure 44 – 90 VAC, 15 V LED Load.
Upper: I_{OUT}, 200 mA / div.
Lower: I_{IN}, 200 mA, 5 ms / div.

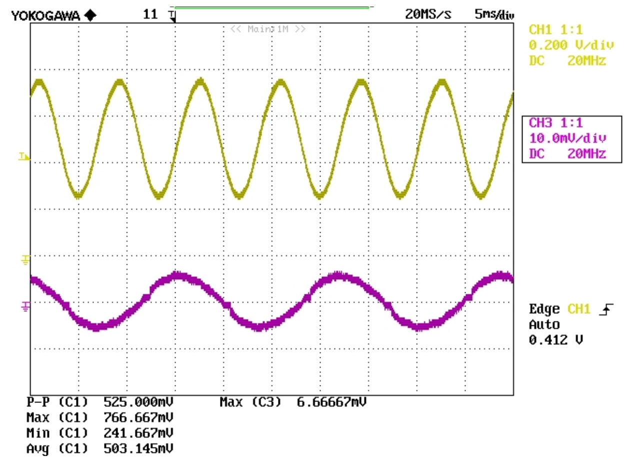

Figure 45 – 132 VAC, 15 V LED Load.
Upper: I_{OUT}, 200 mA / div.
Lower: I_{IN}, 200 mA, 5 ms / div.

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12 Conducted EMI

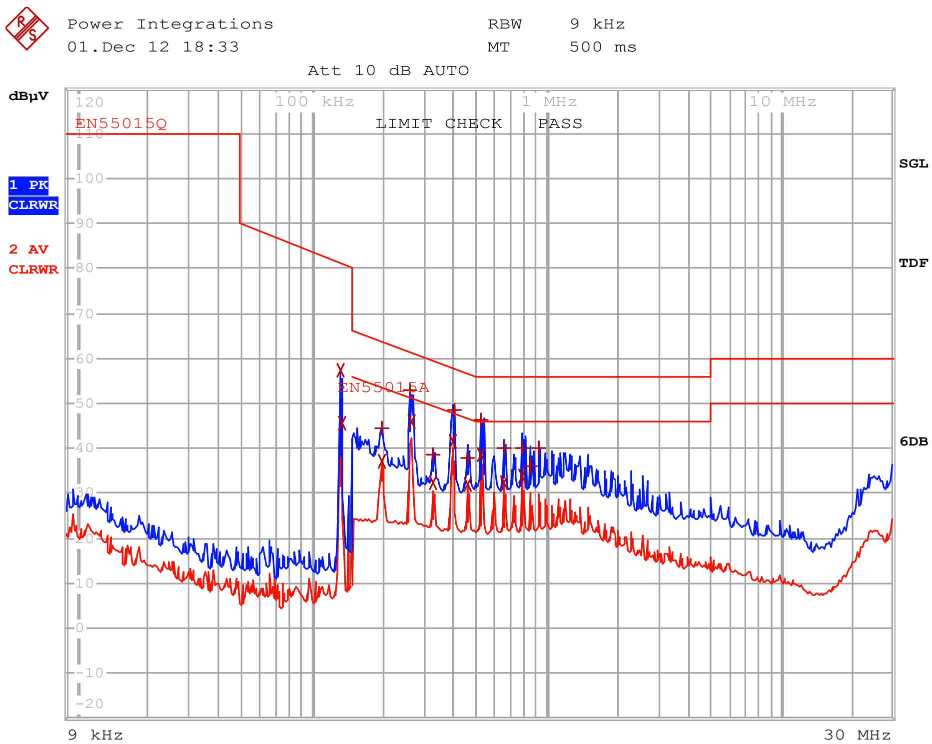
The design met the limits for conducted electromagnetic emission (EMI) with a frequency range of 9 kHz to 30 MHz as per described in the CISPR 15 / IEC: 2005 Standard.

12.1 Test Set-up

The unit was tested using a 15 V LED load at an input voltage of 120 VAC, 60 Hz at room temperature. The unit was placed inside a conical metal housing as shown in Figure 46.

Figure 46 – EMI Test Set-up with the Unit and LED Load Placed Inside a Conical Metal Housing as Described in CISPR 15 / IEC: 2005 Standard.

12.2 Test Result



EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	132.133649648 kHz	57.19	L1 gnd	
2	Average	134.789536006 kHz	45.68	L1 gnd	
1	Quasi Peak	196.231331718 kHz	44.44	N gnd	-19.32
2	Average	198.193645035 kHz	37.14	N gnd	-16.54
1	Quasi Peak	261.871472881 kHz	52.91	N gnd	-8.46
2	Average	264.49018761 kHz	45.80	N gnd	-5.48
1	Quasi Peak	329.215131266 kHz	38.61	N gnd	-20.85
2	Average	329.215131266 kHz	32.32	N gnd	-17.15
2	Average	397.727746704 kHz	41.44	N gnd	-6.45
1	Quasi Peak	401.705024172 kHz	48.70	N gnd	-9.11
1	Quasi Peak	457.177788726 kHz	37.94	N gnd	-18.79
2	Average	461.749566613 kHz	31.99	N gnd	-14.67
1	Quasi Peak	525.514079005 kHz	46.29	N gnd	-9.70
2	Average	525.514079005 kHz	38.77	N gnd	-7.22
1	Quasi Peak	654.11570866 kHz	40.21	N gnd	-15.79
2	Average	660.656865747 kHz	32.28	N gnd	-13.71
1	Quasi Peak	790.243042258 kHz	40.22	N gnd	-15.77
2	Average	790.243042258 kHz	33.82	N gnd	-12.17
1	Quasi Peak	855.719977385 kHz	36.08	N gnd	-19.91
1	Quasi Peak	917.447639259 kHz	40.04	N gnd	-15.95

Figure 47 – Conducted EMI, 15 V LED Load, 120 VAC, 60 Hz, and EN55015 B Limits**.**

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13 Line Surge

The unit was subjected to ±2500 V 100 kHz ring wave and ±500 V differential surge at 120 VAC using 10 strikes at each condition. A test failure was defined as a non-recoverable interruption of output, requiring supply repair or recycling of input voltage.

The unit tested passed both ±2500 V 100 kHz ring wave and ±500 V differential surge with and without MOV.

Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Type	Test Result (Pass/Fail)
+2500	120	L1, L2	0	100 kHz Ring Wave (500 A)	Pass
-2500	120	L1, L2	0	100 kHz Ring Wave (500 A)	Pass
+2500	120	L1, L2	90	100 kHz Ring Wave (500 A)	Pass
-2500	120	L1, L2	90	100 kHz Ring Wave (500 A)	Pass

Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Type	Test Result (Pass/Fail)
+500	120	L1, L2	0	Surge (2 Ω)	Pass
-500	120	L1, L2	0	Surge (2 Ω)	Pass
+500	120	L1, L2	90	Surge (2 Ω)	Pass
-500	120	L1, L2	90	Surge (2 Ω)	Pass

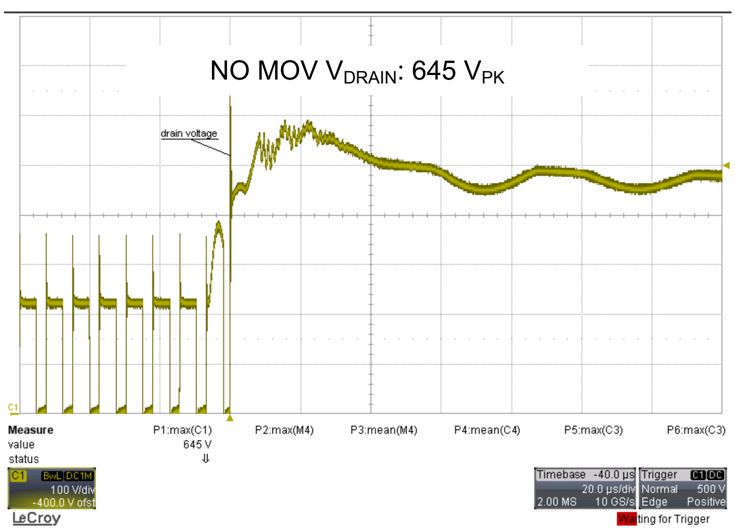

Figure 48 – No MOV +500 V 1.2 µs / 50 µs Differential Surge.

14 Revision History

Date	Author	Revision	Description and Changes	Reviewed
10-Jun-13	ME	1.0	Initial release	Apps & Mktg

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