Design Example Report

Title	***9 W, Wide-Range, Isolated Flyback With Switched Valley-Fill, Bluetooth Track Light Using LYTSwitch™-6 LYT6063C With LensVector Beam Shaping Lens***
Specification	90 VAC – 265 VAC Input; 30 V 300 mA Output
Application	Lighting Control
Author	Applications Engineering Department
Document Number	DER-646
Date	March 27, 2018
Revision	1.0

Summary and Features

- Single-stage flyback
- <3% CC tolerance
- <5% ripple current at full load
- >0.9 PF at 230 VAC
- <20% A-THD at 230 VAC
- Bluetooth-controlled dimming
- Beam-shaping technology by LensVector

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Table of Contents

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

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1 Introduction

This document is an engineering report describing a Wide-Range Bluetooth low-energy (BLE) smart track lighting system using LYTSwitch-6 LYT6063C and beam-shaping control from LensVector. This demo board is intended as a general purpose evaluation platform for LYTSwitch-6.

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

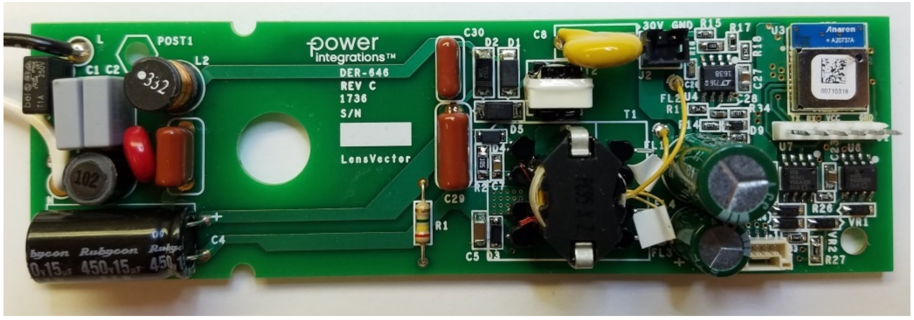

Figure 1 – Populated Circuit Board Photograph, Top.

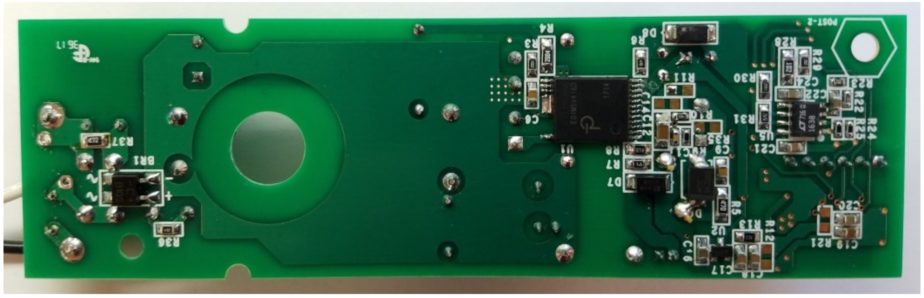

Figure 2 – Populated Circuit Board Photograph, Bottom.

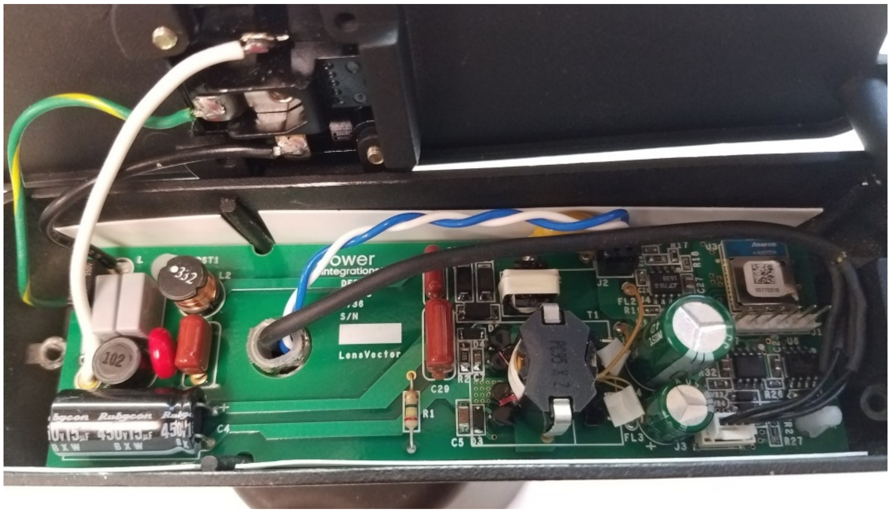

Figure 3 – Populated Circuit Board Photograph, Retrofitted on Intense Lighting Track Light.

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		265	VAC	3-Wire
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (230 VAC)				0.3	W	
Output						
Output Voltage	V_{OUT}		30		V	±5%
Output Current	I_{OUT}	291	300	309	mA	±3%
Output Current Flicker	$\%_{FLICKER}$			10	%	Measured at Full Load.
Total Output Power						
Continuous Output Power	P_{OUT}		9		W	
Efficiency						
Full Load	η	82	84		%	Measured at P_{OUT} 25 °C.
LensVector						
Beam-Angle Range		10		52	°	With Soraa 01343 LED Bulb.
Dimming Range		0		100	%	Via Bluetooth.
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Isolated				
Line Surge Differential Mode (L1-L2)				±2	kV	1.2/50 µs Surge, IEC 1000-4-5, Series Impedance: Differential Mode: 2 Ω.
Ring Wave (100 kHz) Differential Mode (L1-L2)				±2.5	kV	500 A Short-Circuit. Series Impedance: Differential Mode: 12 Ω.
Ambient Temperature	T_{AMB}		25		°C	Free Convection, Sea Level.

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3 Schematic

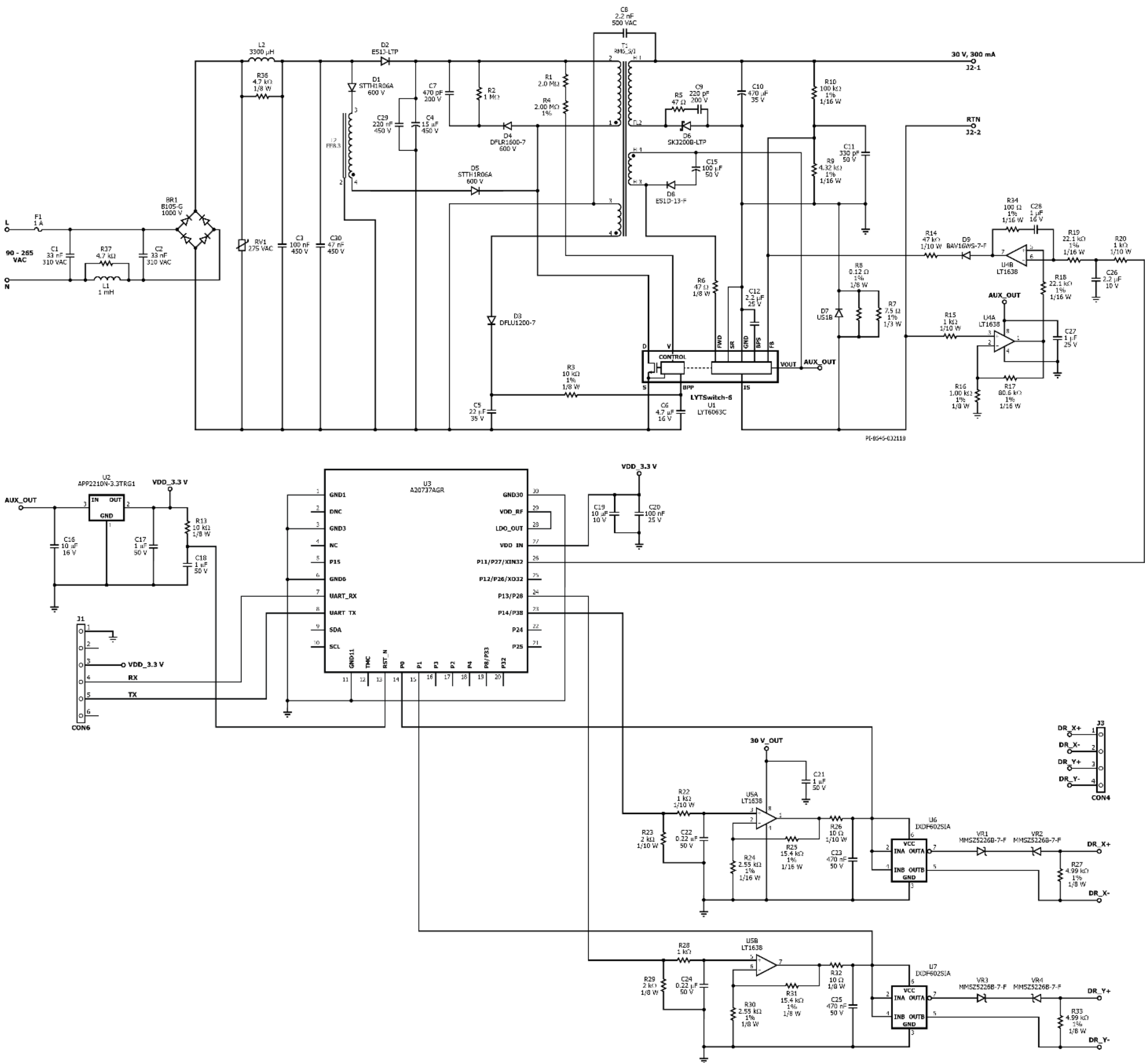

Figure 4 – Schematic.

4 Circuit Description

LYTSwitch-6 LYT6063C incorporates a high-voltage power MOSFET switch, along with both primary-side and secondary-side controllers in one device. This IC also includes an innovative new technology, FluxLink™, which safely bridges the isolation barrier and eliminates the need for an optocoupler. The LYTSwitch-6 IC is configured to drive a 9 W flyback power supply with switched valley-fill power factor correction providing a high power factor, 30 V, 300 mA constant voltage, constant current supply throughout the input range of 90 VAC to 265 VAC.

4.1 *Input EMI Filter and Rectifier*

The input fuse F1 provides safety protection from component failures. Varistor RV1 acts as a voltage clamp that limits the voltage spike on the primary during line surge events. The AC input voltage is full wave rectified by BR1. The varistor is placed after BR1 to protect the rectifier during 2.5 kV ring-wave test. Without the varistor, the voltage across the bridge might exceed 1 kV due to the excitation of the L-C filter and might cause the bridge rectifier to fail short.

The bulk capacitor C4 provides input line ripple voltage filtering for a stable flyback DC supply voltage. It also stores additional energy generated by the PFC during the power switch turn-off time. The value was chosen based on a 1.5 μF / W rule-of-thumb. Bypass capacitor C29 is added due to the long trace from the bulk capacitor to the transformer T1.

A 2-stage pi (π) filter is used for EMI suppression. The first stage filter is comprised C1, C2, L1 and R37. The second stage is formed by C3, C30, L2 and R36. Resistors R36 and R37 damp the self-resonance of the inductors to avoid noise peaking in the conducted EMI plot at their resonant frequency. Common mode noise is suppressed by Y-Capacitor C8 connected between primary GND and secondary winding FL1. Ground plane was also added at the bottom PCB to prevent EMI noise from the switching components from coupling to the earth-connected metal housing.

Rectifier diode D2 provides charging current to the bulk capacitor (C4) from the input rectified voltage. It also serves as blocking diode to isolate the bulk capacitor from the PFC circuit which is critical in order to achieve high power factor. The input capacitance of the PFC (C3 + C30) also affects overall power factor and has to be minimized as possible. Use 10 nF / W as a rule-of-thumb and check if it is sufficient to pass EMI.

4.2 *LYTSwitch-6 Primary-Side Control*

The primary controller on LYTSwitch-6 IC is a Quasi-Resonant (QR) flyback controller that has the ability to operate in continuous conduction mode (CCM). The controller uses both variable frequency and variable current control schemes. The primary controller consists of a frequency jitter oscillator, a receiver circuit magnetically coupled to the

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secondary controller, a current limit controller, 5 V regulator on the PRIMARY BYPASS (BPP) pin, audible noise reduction engine for light load operation, bypass overvoltage detection circuit, a lossless input line sensing circuit, current limit selection circuitry, over-temperature protection, leading edge blanking, secondary output diode / SR FET short protection circuit and a 650 V power MOSFET.

One side of the transformer T1 primary is connected to the positive output terminal of the bulk capacitor C4 while the other side is connected to the integrated 650 V power MOSFET inside the LYTSwitch-6 U1. A low cost RCD clamp formed by D4, C7 and R2 limits the peak drain leakage voltage spike due to the effects of transformer leakage inductance.

The INPUT OVERVOLTAGE (V) pin is used for overvoltage sensing and protection. A 4 MΩ resistor (R1 + R4) tied to the bulk capacitor C4 sets the I_{OV-} threshold. It is set to trigger at around 460 V.

At start-up, the internal high-voltage current source charges the BPP pin capacitor C6. A value of 4.7 μF sets the operation to increased current limit mode. Auxiliary winding from transformer T1 is rectified by D3 and C5 to provide bias supply to BPP via current limiting resistor R3. This decreases the no-load consumption.

4.3 *LYTSwitch-6 Secondary-Side Control*

The secondary-side control consists of a transmitter circuit that is magnetically coupled to the primary receiver, a constant voltage (CV) and a constant current (CC) control circuit, a 4.4 V regulator on the SECONDARY BYPASS (BPS) pin, synchronous rectifier MOSFET driver, QR mode circuit, oscillator and timing functions, and a host of integrated protection features.

The secondary winding of transformer T1 is rectified by a low V_F Schottky diode D6 and then filtered by the output capacitor C10. An R-C snubber (R5 and C9) is connected across the output diode to reduce the voltage stress on the diode and the FORWARD (FWD) pin especially during cold start-up, when the switching operation may enter continuous mode (CCM).

SYNCHRONOUS RECTIFIER DRIVER (SR) pin is tied to GND to disable the SR drive function and protection. A 200 V Schottky diode D6 is used as secondary rectifier due to the difficulty of finding a suitable high-voltage rated (>150 V) logic-level SR FET.

The IC is powered through a 4.4 V regulator (VBPS) by either the OUTPUT VOLTAGE (VOUT) pin or the FWD pin connections to the BPS pin. The BPS pin is connected to an external decoupling capacitor C12 and fed internally from the regulator block.

A separate supply from the secondary auxiliary winding, rectified by D8 and C15, is used for VOUT pin supply and for FWD pin sensing via R6. This is to prevent the VOUT and FWD pins from exceeding the maximum voltage limitations (27 V and 150 V, respectively).

The mid-point of an external resistor divider network R9 and R10 is tied to the FEEDBACK (FB) pin to regulate the output voltage. The internal voltage comparator reference voltage is VREF (1.265 V). Capacitor C11 is added for noise filtering.

The external current sense resistors R7 and R8 connected between the ISENSE (IS) and SECONDARY GROUND (GND) pins regulate the output current in constant current regulator mode. Diode D7 clamps the IS pin to a safe level during output short-circuit condition.

4.4 *Intelligent Quasi-Resonant Mode Switching*

In order to improve conversion efficiency and reduce switching losses, the LYTSwitch-6 IC features a means to allow switching when the voltage across the primary switch is near its minimum voltage when the converter operates in critical (CRM) or discontinuous conduction mode (DCM). This mode of operation is automatically detected in CRM or DCM and disabled once the converter operates in continuous-conduction mode (CCM).

Rather than detecting the magnetizing ring valley on the primary-side, the peak voltage of the FWD pin voltage as it rises above the output voltage level is used to gate secondary request to initiate the switch ON cycle in the primary controller. The secondary controller detects when the controller enters in discontinuous-mode and opens secondary cycle request windows corresponding to minimum switching voltage across the primary power MOSFET.

Quasi-Resonant (QR) mode is enabled for the first four resonant rings. QR switching is disabled after the 4th relaxation event, at which point switching may occur at any time a secondary request is initiated. The secondary controller includes blanking of ~1 μs to prevent false detection of primary ON cycle when the FWD pin rings below ground.

4.5 *PFC Circuit Operation*

A typical non-PF flyback power supply usually incorporates a large bulk capacitor to convert the rectified AC into DC with low ripple voltage. The power is then drawn from the energy stored in the capacitor and the only time it draws current from the input supply is when the capacitor needs to be recharged. Typical charging time is 3 ms. The discontinuity of the input current and the huge peak it draws when charging the bulk capacitor limits the system power factor to about 0.5 at full-load.

Unlike a two-stage PFC + flyback design, the solution implemented in this design uses LYTSwitch-6 switching action to drive both the flyback and PFC circuits.

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The PFC circuit is composed of the blocking diodes D1 and D5, and the PFC inductor T2. When the LYTSwitch-6 MOSFET turns ON, the peak Drain current is the sum of the peak current supplied by the main transformer T1 ($I_{PRIMARY}$) and the peak current coming from the PFC inductor T2 (I_{PFC}).

$$I_{PK\_DRAIN} = I_{PK\_PRIMARY} + I_{PK\_PFC}$$

$I_{PRIMARY}$ is given by:

$$I_{PK\_PRIMARY} = \frac{V_{BULK} * t_{on}}{L_{PRIMARY}}$$

I_{PFC} is given by:

$$I_{PK\_PFC} = \frac{V_{AC} * \sqrt{2} * \sin(2 * \pi * FL * t) * t_{on}}{L_{PFC}}$$

At the input supply zero-crossing, the PFC current is zero and $I_{PRIMARY}$ = I_{DRAIN}. As the line goes from 0 to 90 degree phase angle, I_{PFC} increases while $I_{PRIMARY}$ decreases. I_{DRAIN}, which is also the I_{LIMIT}, is a function of the switching frequency f_{sw}. With the added PFC circuit, the f_{SW} goes from $f_{SW(MIN)}$ (based on $L_{PRIMARY}$ alone) at 0 degree phase angle, to $f_{SW(MAX)}$ at a phase angle close to 90 degrees. Hence, I_{DRAIN} also increases with phase angle.

When the LYTSwitch-6 MOSFET turns OFF, the stored energy on T2 is delivered to the load via direct energy transfer between the primary and secondary winding of the flyback transformer T1. The voltage across T2, V_{PFC} is given by:

$$V_{PFC} = V_{BULK} + VOR - V_{AC} * \sqrt{2} * \sin(2 * \pi * FL * t)$$

The input current is the sum of the PFC current I_{PFC} and the bulk current I_{BULK}. After going through the EMI filter, the smoothed input current waveform follows that of the input voltage with a peak due to the charging of the capacitor. The rms current is much lower than that of a regular flyback, and the power factor easily goes >80% at low-line and >90% at high-line.

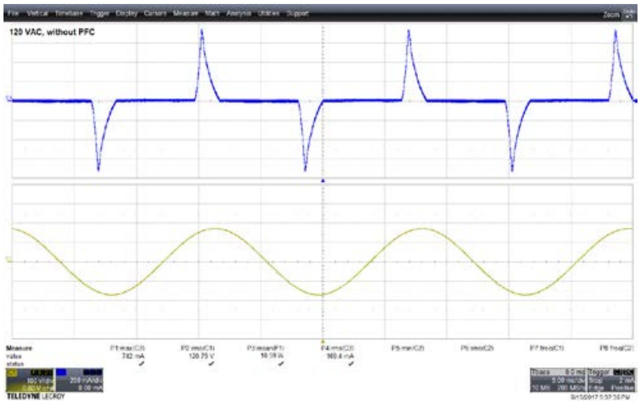

Figure 5 – 120 VAC, Full Load, Without PFC.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.
Power Factor: 0.52.

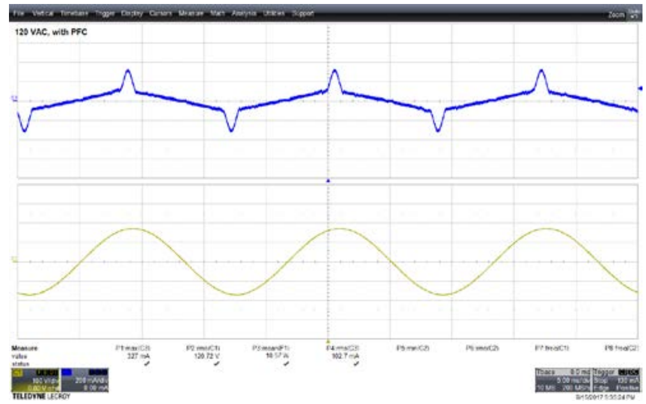

Figure 6 – 120 VAC, Full Load, With PFC.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.
Power Factor: 0.86.

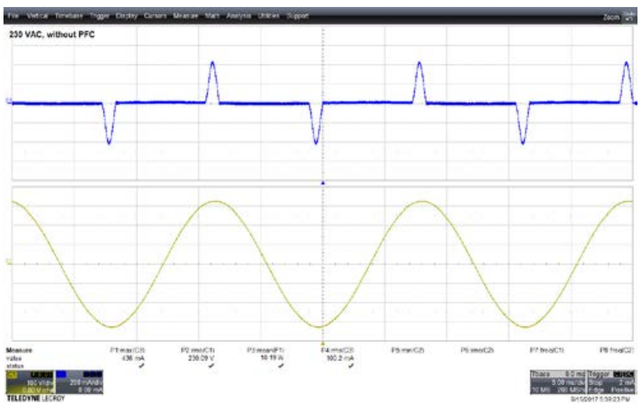

Figure 7 – 230 VAC, Full Load, Without PFC.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.
Power Factor: 0.44.

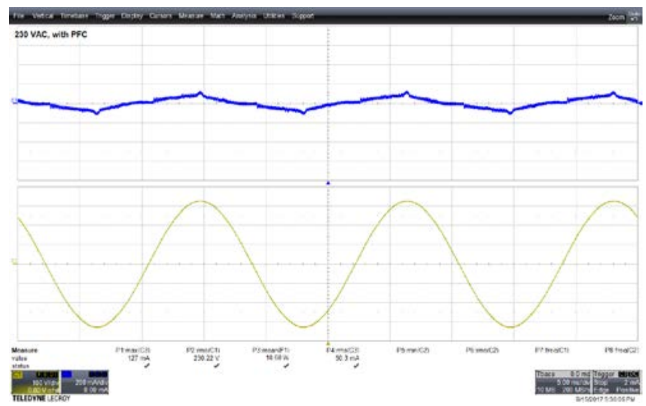

Figure 8 – 230 VAC, Full Load, With PFC.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.
Power Factor: 0.92.

4.6 *Bluetooth Low Energy (BLE) Module Circuit Block*

The Bluetooth module U3 uses Anaren A20737A for dimming and beam-shaping control. The 3.3 V regulator circuit that supplies the module consists of U2, C16, and C17. C19 and C20 are decoupling capacitors of the BLE module. The reset pin RST_N is pulled-up to 3.3 V via R13. Capacitor C18 is added for noise immunity. Programming is done via J1 header.

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4.6.1 Pin Functions

Pin Number	Description
7	UART_RX. Used for programming.
8	UART_TX. Used for programming.
13	RST_N. Reset pin. Requires pull-up to VDD.
14	P0. Configured as a square-wave output for LensVector.
15	P1. Configured as a square-wave output for LensVector.
23	P14/38. Provides PWM pulse for LensVector.
24	P13/28. Provides PWM pulse for LensVector.
26	P11/27. Provides PWM pulse for LED dimming.

Table 1 – Bluetooth Module Pin Description.

4.7 *Dimming Control*

Dimming is done by sensing the output current, amplifying the signal, comparing it with a variable reference and injecting current into the FB pin.

Output current is sensed through IS pin which has a threshold of 35 mV. The signal is then passed through the non-inverting amplifier circuit R15, R16, R17, U4, and C27. The gain is set by R16 and R17 to 81.6 or about 2.9 V maximum. The output of the op-amp (pin 1) connects to the positive input (pin 5) through R18. The signal going to the negative input (pin 6) comes from PWM output (pin 26) of the Bluetooth module. Resistor R20 and C26 convert the PWM signal to DC voltage before connecting to the op-amp via R19. The op-amp output (pin 7) is connected to the FB pin via D9 and R14.

At start-up, pin 26 of the Anaren module is set to 3.3 V so that U4B output (pin 7) is low and there will be no current injection. Dimming will start once the rectified PWM output goes below the 2.9 V reference and the current is injected in the feedback.

The feedback voltage will go up as current is injected. This will normally bring the output voltage down in CV mode. However, since the LED load is a constant voltage, it can't bring the voltage down. Instead, the output current goes down as a consequence.

The current injection loop has to be slow enough in order not to trigger feedback overvoltage protection when doing a step load from 100% to 0%. This is done by increasing the value of R14 and adding R34 and C28 to the op-amp feedback

A low-input offset operational amplifier is also recommended to reduce unit-to-unit variability. It is also important to place the dimming circuit close to the IS pin and FB pin to prevent noise from disturbing the loop.

4.8 *LensVector Beam-Shaping Control*

LensVector technology allows dynamic spatial control into directional and downlighting products. It controls the beam shape from 10º to 52º. The minimum beam angle is defined by the optics used.

A 30 V, 300 mA, MR16, LED bulb with 10º narrow spot beam angle (p/n: Soraa 01343) is used as the light source.

Beam-shaping works by modulating the voltage on two drivers - DR_X and DR_Y. Pin 14 (P0) and pin 15 (P1) of the Bluetooth module provide 100 Hz squarewave that has 90º phase difference to set the timing.

Pin 23 (P14) and pin 24 (P13) are PWM outputs that control the voltage amplitude going to the drivers. R22, C22, R28, C24 converts the PWM output to DC before it gets amplified by the operational amplifier U5.

Pull-down resistors R23 and R29 are added to prevent any noise from getting amplified and causing higher power dissipation. Alternatively, the BLE module pins 23 and 24 may be pulled-down internally.

The DC signal goes through an amplifier with a gain of 7 to bring the voltage up to about 24 V at full scale. R24 and R25 set the gain for X-amplitude; R30 and R31 set the gain for Y-amplitude. Capacitor C21 is the decoupling capacitor of the op-amp U5.

The corresponding outputs get filtered with R26, C23, R32 and C25 before going to gate drivers U6 and U7. These gate drivers convert the signal into an AC square wave to drive the LensVector lens.

Zener diode VR1, VR2, R27, VR3, VR4 and R33 ensure that the drive voltage goes down to 0 V when the PWM signal goes low.

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5 PCB Layout

PCB copper thickness is 2 oz (2.8 mils / 70 µm).

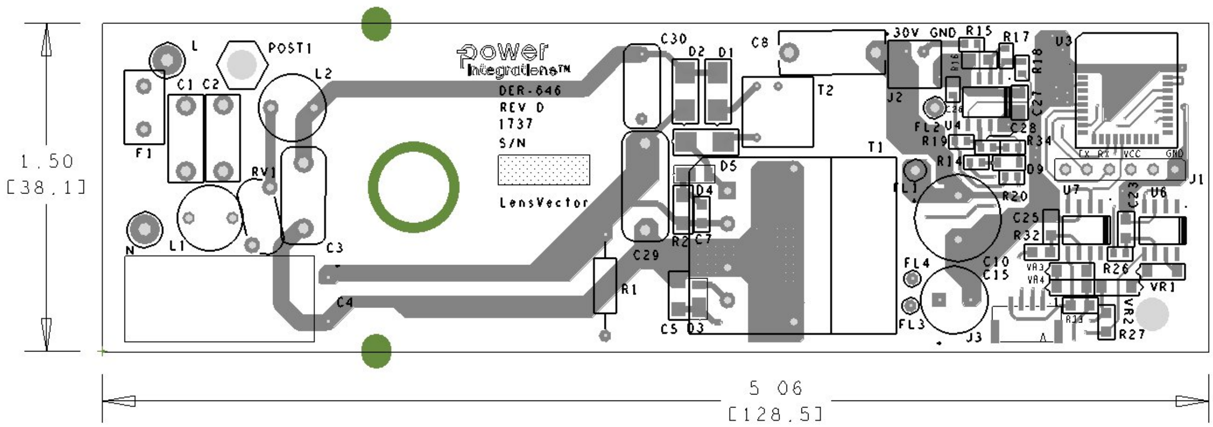

Figure 9 – Printed Circuit Layout, Top.

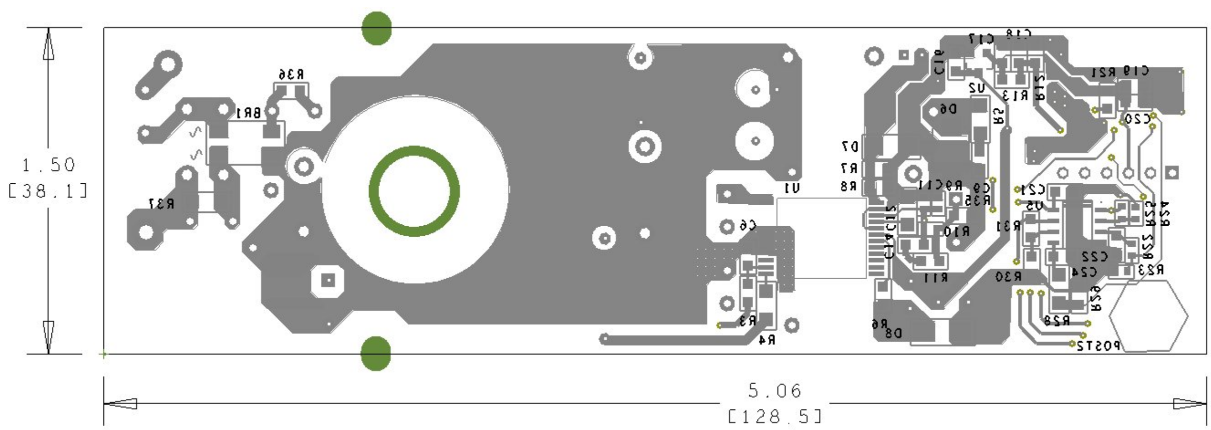

Figure 10 – Printed Circuit Layout, Bottom.

6 Bill of Materials

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	33 nF, 310 VAC, Polyester Film, X2	BFC233920333	Vishay
3	1	C2	33 nF, 310 VAC, Polyester Film, X2	BFC233920333	Vishay
4	1	C3	100 nF, 450 V, Film	MEXXD31004JJ1	Duratech
5	1	C4	15 μF, 450 V, Electrolytic, 20 %, (10 x 22 mm)	450BXW15MEFR10X20	Rubycon
6	1	C5	22 μF, 35 V, Ceramic, X5R, 1206	C3216X5R1V226M160AC	TDK
7	1	C6	4.7 μF, 16 V, Ceramic, X7R, 0805	GRM21BR71C475KA73L	Murata
8	1	C7	470 pF, 200 V, Ceramic, X7R, 0805	C0805C471K2RACTU	Kemet
9	1	C8	CAP, Ceramic Disc, 2.2nF, ±20% ,760VAC, Y5U (E)	VY1222M47Y5UQ63V0	Vishay
10	1	C9	220 pF, ±10%, 200V, X7R, Ceramic, 0805	CL21B221KDCNFNC	Samsung
11	1	C10	470 μF, 35 V, Electrolytic, Low ESR, 23 mΩ, (10 x 20)	EKZE350ELL471MJ20S	Nippon Chemi-Con
12	1	C11	330 pF 50 V, Ceramic, X7R, 0603	CC0603KRX7R9BB331	Yageo
13	1	C12	2.2 μF, 25 V, Ceramic, X7R, 1206	TMK316B7225KL-T	Taiyo Yuden
14	1	C15	100 μF, 50 V, Electrolytic, Low ESR, 74 mΩ, (8 x 11.5)	EKZE500ELL101MHB5D	Nippon Chemi-Con
15	1	C16	10 μF, ±10%, 16V, X7R, Ceramic Capacitor, 0805	CL21B106KOQNNNE	Samsung
16	1	C17	1 μF,50 V, Ceramic, X7R, 0805	C2012X7R1H105M085AC	TDK
17	1	C18	1 μF,50 V, Ceramic, X7R, 0805	C2012X7R1H105M085AC	TDK
18	1	C19	10 μF, 10 V, Ceramic, X7R, 0805	C2012X7R1A106M	TDK
19	1	C20	100 nF, 25 V, Ceramic, X7R, 0805	08053C104KAT2A	AVX
20	1	C21	1 μF,50 V, Ceramic, X7R, 0805	C2012X7R1H105M085AC	TDK
21	1	C22	0.22 μF, 50 V, Ceramic, X7R, 0805	GRM21BR71H224KA01L	Murata
22	1	C23	470 nF, 50 V, Ceramic, X7R, 0805	GRM21BR71H474KA88L	Murata
23	1	C24	0.22 μF, 50 V, Ceramic, X7R, 0805	GRM21BR71H224KA01L	Murata
24	1	C25	470 nF, 50 V, Ceramic, X7R, 0805	GRM21BR71H474KA88L	Murata
25	1	C26	2.2 μF, 10 V, Ceramic, X7R, 0603	GRM188R71A225KE15D	Murata
26	1	C27	1 μF, 25 V, Ceramic, X5R, 0805	C2012X5R1E105K	TDK
27	1	C28	1 μF 16 V, Ceramic, X7R, 0603	C1608X7R1C105M	TDK
28	1	C29	220 nF, 450 V, Film	MEXXF32204JJ	Duratech
29	1	C30	47 nF, 450VDC, 5%, Film	MEXXD2470	Duratech
30	1	D1	600 V, 1 A, Ultrafast Recovery, 45 ns, DO-214AC, SMA	STTH1R06A	ST Micro
31	1	D2	600 V, 1 A, Super Fast, 35 ns, DO-214AC, SMA	ES1J-LTP	Micro Commercial
32	1	D3	Diode, Ultrafast, 200 V, 1 A, POWERDI123	DFLU1200-7	Diodes, Inc.
33	1	D4	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
34	1	D5	600 V, 1 A, Ultrafast Recovery, 45 ns, DO-214AC, SMA	STTH1R06A	ST Micro
35	1	D6	200 V, 3 A, Diode SCHOTTKY 1A 200V, SMB	SK3200B-LTP	Micro Commercial
36	1	D7	Diode Ultrafast, 1 A, 100 V, SMA	US1B-13-F	Diodes, Inc.
37	1	D8	200 V, 1 A, Ultrafast Recovery, 25 ns, DO-214AC	ES1D-13-F	Diodes, Inc.
38	1	D9	75 V, 0.15 A, Switching,SOD-323	BAV16WS-7-F	Diodes, Inc.
39	1	F1	1 A, 250 V, Slow, Long Time Lag, RST 1	RST 1	Belfuse
44	1	J1	6 Position (1 x 6) header, 0.1 pitch, Vertical	26-48-1061	Molex
45	1	J2	2 Position (1 x 2) header, 2 mm pitch, Vertical	DF3A-2P-2DSA	Hirose Electric
46	1	J3	4 Positions, Header Connecto,r 0.049" (1.25 mm)	BM04B-GHS-TBT(LF)(SN)(N)	JST Sales America
47	1	L	Test Point, BLK, THRU-HOLE MOUNT	5011	Keystone
48	1	L1	1 mH, 0.23 A, Ferrite Core	CTSCH875DF-102K	CT Parts
49	1	L2	INDUCTOR 3300UH .28A 8095 RAD	744772332	Wurth
50	1	N	Test Point, WHT, THRU-HOLE MOUNT	5012	Keystone
51	1		Post, PCB, Female, Hex, 6-32, snap, 0.50"L, Nylon	561-0500A	Eagle Hardware
52	1		Post, PCB, Female, Threaded, Hex, M3, 5mmL, Nylon	CBTS010A	Essentra
53	1	R1	RES, 2.0 MΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-2M0	Yageo
54	1	R2	RES, 1 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ105V	Panasonic
55	1	R3	RES, 10 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1002V	Panasonic

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56	1	R4	RES, 2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
57	1	R5	RES, 47 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ470V	Panasonic
58	1	R6	RES, 47 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ470V	Panasonic
59	1	R7	RES, SMD, 7.5 Ω, 1%, 1/3W, 0805	ERJ-6BQF7R5V	Panasonic
60	1	R8	RES,0.12 Ω, ±1%, 0.125W, 1/8W, 0805	RL0805FR-070R12L	Yageo
61	1	R9	RES, 4.32 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF4321V	Panasonic
62	1	R10	RES, 100 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1003V	Panasonic
63	1	R13	RES, 10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
64	1	R14	RES, 47 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ473V	Panasonic
65	1	R15	RES, 1 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
66	1	R16	RES, 1.00 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1001V	Panasonic
67	1	R17	RES, 80.6 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF8062V	Panasonic
68	1	R18	RES, 22.1 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2212V	Panasonic
69	1	R19	RES, 22.1 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2212V	Panasonic
70	1	R20	RES, 1 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
71	1	R22	RES, 1 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
72	1	R23	RES, 2 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ202V	Panasonic
73	1	R24	RES, 2.55 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2551V	Panasonic
74	1	R25	RES, 15.4 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1542V	Panasonic
75	1	R26	RES, 10 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ100V	Panasonic
76	1	R27	RES, 4.99 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF4991V	Panasonic
77	1	R28	RES, 1 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ102V	Panasonic
78	1	R29	RES, 2 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ202V	Panasonic
79	1	R30	RES, 2.55 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF2551V	Panasonic
80	1	R31	RES, 15.4 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1542V	Panasonic
81	1	R32	RES, 10 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ100V	Panasonic
82	1	R33	RES, 4.99 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF4991V	Panasonic
83	1	R34	RES, 100 Ω, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1000V	Panasonic
84	1	R36	RES, 4.7 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ472V	Panasonic
85	1	R37	RES, 4.7 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ472V	Panasonic
86	1	RV1	275 VAC, 23 J, 7 mm, RADIAL	V275LA4P	Littlefuse
87	1	T1	Bobbin, RM6_S/I, Vertical, 8 pins w 2 pin clip	CPV-RM6S/I-1S-8PD-TZ	Ferroxcube
88	1	T2	Bobbin, EE8.3, Vertical, 6 pins (8.2 mm W x 8.2 mm L x 6.9 mm H)	EE-0802	Zhenhui
89	1	U1	LYTSwitch-6 Integrated Circuit, InSOP24D	LYT6063C	Power Integrations
90	1	U2	IC, REG, LDO, 3.3 V, 0.3 A, SOT23-3	P2210N-3.3TRG1	Diodes, Inc.
91	1	U3	RF TXRX MOD, BLUETOOTH, TRACE ANT	A20737AGR	Anaren
92	1	U4	DUAL Op Amp R-R IN/OUT DUAL 8-SOIC	LT1638CS8#PBF	Linear Tech
93	1	U5	DUAL Op Amp R-R IN/OUT DUAL 8-SOIC	LT1638CS8#PBF	Linear Tech
94	1	U6	IC, Low-Side Gate Driver,Dual Channel	IXDF602SIA	IXYS
95	1	U7	IC, Low-Side Gate Driver,Dual Channel	IXDF602SIA	IXYS
96	1	VR1	DIODE ZENER, 3.3 V, 500 mW, SOD123	MMSZ5226B-7-F	Diodes, Inc.
97	1	VR2	DIODE ZENER, 3.3 V, 500 mW, SOD123	MMSZ5226B-7-F	Diodes, Inc.
98	1	VR3	DIODE ZENER, 3.3 V, 500 mW, SOD123	MMSZ5226B-7-F	Diodes, Inc.
99	1	VR4	DIODE ZENER, 3.3 V, 500 mW, SOD123	MMSZ5226B-7-F	Diodes, Inc.

7 Transformer Specification

7.1 *Flyback Transformer (T1)*

7.1.1 Electrical Diagram

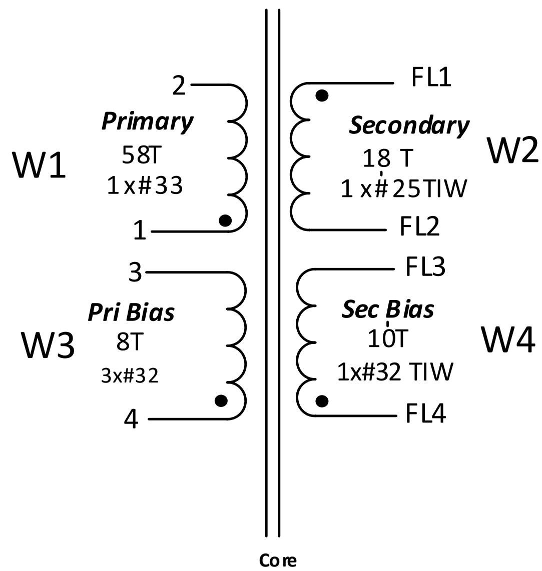

Figure 11 – Transformer Electrical Diagram.

7.1.2 Electrical Specifications

Primary Inductance	Pins 1-2, all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	1040 µH ±3%
Resonant Frequency	Pins 1-2, all other windings open.	1000 kHz (Min.)
Primary Leakage Inductance	Pins 1-2, with pins FL1 to FL4 shorted, measured at 100 kHz, 0.4 V_{RMS}.	20 µH (Max.)

7.1.3 Material List

Item	Description
[1]	Core: RM6S/I, PC95 or Equivalent.
[2]	Bobbin: RM6S/I, Vertical, 8 Pins.
[3]	Magnet Wire: #33 AWG.
[4]	Magnet Wire: #32 AWG.
[5]	Triple-Insulated Wire: #25 T.I.W.
[6]	Triple-Insulated Wire: #32 T.I.W.
[7]	Insulation Tape: Polyester Film, 6.2 mm Wide
[8]	Clip: RM6S/I Clip With Pin.
[9]	Varnish.

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7.1.4 Build Diagram

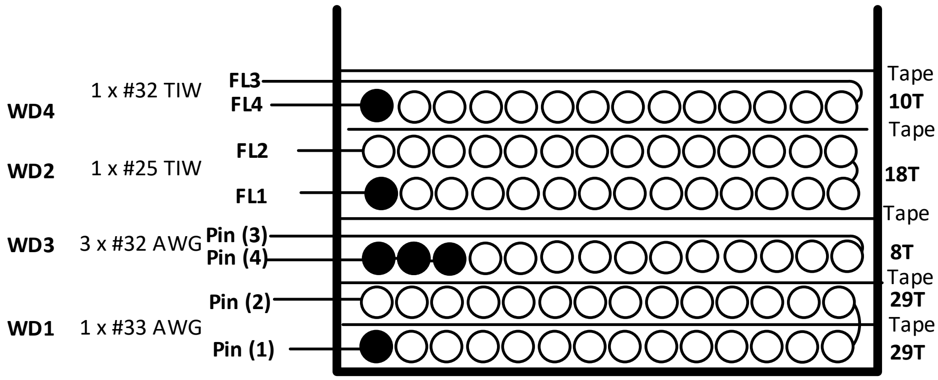

Figure 12 – Transformer Build Diagram.

7.1.5 Construction

Primary	Start at pin 1. Wind 29 turns of Item [3] in 1 layer. Add 1 layer of Item [7]. Continue winding another 29 turns of Item [3]. Finish on pin 2.
Basic Insulation	Use 1 layer of Item [7] for basic insulation.
Primary Bias Winding	Start at pin 4. Wind 8T trifilar turns of Item [4]. Finish on pin 3.
Basic Insulation	Use 1 layer of Item [7] for basic insulation.
Secondary Winding	Start at FL1. Wind 18T turns of Item [5] (2 layers). Finish on FL2.
Basic Insulation	Use 1 layer of Item [7] for basic insulation.
Secondary Bias Winding	Start at FL4. Wind 10T turns of Item [6] (1 layer). Finish on FL3.
Outer Wrap	Wrap windings with 2 layers of Item [7].
Final Assembly	Assemble and secure core halves with Item [8].
Varnish	Dip varnish uniformly in Item [9]. Do not vacuum impregnate.

7.2 *PFC Inductor (T2)*

7.2.1 Electrical Diagram

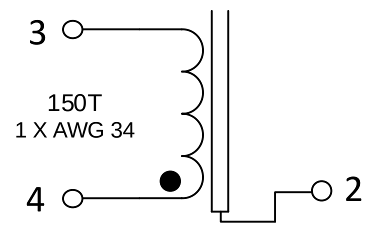

Figure 13 – Transformer Electrical Diagram.

7.2.2 Electrical Specifications

Primary Inductance	Pins 3-4, measured at 100 kHz, 0.4 V_{RMS}.	1000 µH, ±3%

7.2.3 Material List

Item	Description
[1]	Core: EE 8.3.
[2]	Bobbin: EE 8.3, Vertical, 6 Pins.
[3]	Magnet Wire: #34 AWG.
[4]	Jumper Wire.
[5]	Insulation Tape: Polyester Film, 4.78 mm Wide.
[6]	Varnish.

7.2.4 Build Diagram

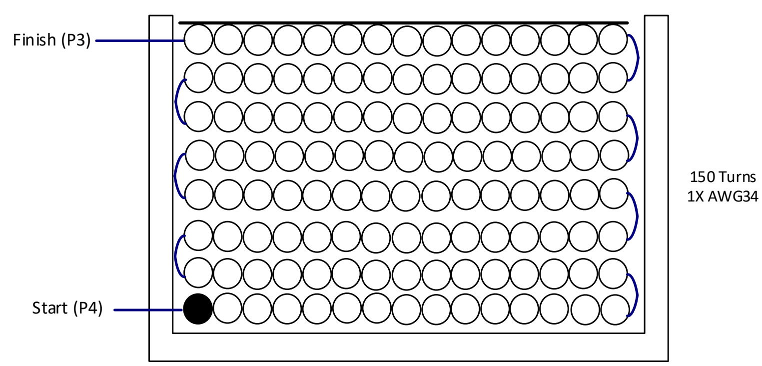

Figure 14 – Transformer Build Diagram.

7.2.5 Construction

Primary	Start at pin 4. Wind 150 turns of Item [3]. Finish on pin 3.
Outer Wrap	Wrap windings with 2 layers of Item [5].
Core Ground	Start at pin 2. Wrap Item [4] around the core.
Final Assembly	Assemble and secure core halves.
Varnish	Dip varnish uniformly in Item [6]. Do not vacuum impregnate.

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8 Transformer Design Spreadsheet

1	ACDC_Flyback_PF_LYTSwitch-6_011918; Rev.1.2;	INPUT	OUTPUT	UNITS	Switched Valley-Fill Single Stage PFC (SVF S^2PFC)
2	Application Variables				
3	VACMIN		90	V	Minimum Input AC Voltage
4	VACNOM		230	V	Nominal AC Voltage (For universal designs low line nominal voltage is displayed)
5	VACMAX		265	V	Maximum Input AC Voltage
6	VACRANGE		UNIVERSAL		Input Voltage Range
7	FL		50	Hz	Line Frequency
8	CIN	15.0000	15.0000	µF	Minimum Input Capacitance
9	V_CIN		450	V	Input Capacitance Recommended Voltage Rating
10	VO	30.00	30.00	V	Output Voltage
11	IO	0.30	0.30	A	Output Current
12	PO		9.00	W	Total Output Power
13	N	0.85	0.85		Estimated Efficiency
14	Z		0.50		Loss Allocation Factor
15	Parametric Calculations Basis				
16	ILIMcalcBASIS	Nom	Nom		ILIM Calculations Basis - NOM,MAX or MIN only
17	PARcalcBASIS	Worst_Case	Worst_Case		Parametric Calculations Basis - VACNOM,VACMAX,VACMIN or Worst Case only
18	Primary Controller Section				
19	DEVICE_MODE	Increased	Increased		Device Current Limit Mode
20	DEVNAME	Auto	LYT6063C		PI Device Name
21	RDSON		8.74	ohms	Device RDSON at 100degC
22	ILIMITMIN		0.590	A	Minimum Current Limit
23	ILIMITTYP		0.650	A	Typical Current Limit
24	ILIMITMAX		0.709	A	Maximum Current Limit
25	BVDSS		650	V	Drain-Source Breakdown Voltage
26	VDS		2.00	V	On state Drain to Source Voltage
27	VDRAIN		540.77	V	Peak Drain to Source Voltage during Fet turn off
28	Worst Case Electrical Parameters				
29	Boost Converter				
30	IBOOSTRMS		111.39	mA	Boost RMS current
31	IBOOSTMAX		330.34	mA	Boost PEAK current
32	IBOOSTAVG		64.22	mA	Boost AVG current
33	IINRMS		164.20	mA	Input RMS current
34	PF_est		0.7267		Estimated Power Factor
35	Flyback Converter				
36	FSMIN	53000	53000	Hz	Minimum Switching Frequency in a Line Period
37	FSMAX		112154.91	Hz	Maximum Switching Frequency in a line period
38	IFETRMS		199.87	mA	Fet RMS current
39	IFETMAX		656.95	mA	Fet PEAK current
40	IPRIRMS		148.37	mA	Primary Winding RMS current
41	IPRIMAX		599.28	mA	Primary Winding PEAK current
42	IPRIMIN		327.38	mA	Primary Winding Minimum current
43	ISECRMS		0.60	A	Secondary RMS current
44	ISECMAX		1.95	A	Secondary PEAK current
45	Boost Choke Construction Parameters				
46	RATIO_LBST_LFB	0.9600	0.9600		Boost Inductance and Flyback Primary Inductance Ratio

47	LBOOSTMIN		951.87	µH	Minimum Boost Inductance
48	LBOOSTNOM		1001.97	µH	Nominal Boost Inductance
49	LBOOSTMAX		1052.07	µH	Maximum Boost Inductance
50	LBOOSTTOL	5.00	5.00	%	Boost Inductance Tolerance
51	**Boost Core and Bobbin Selection**				
52	CR_TYPE_BOOST	Custom	Custom		Boost Core
53	CR_PN_BOOST	EE8.3	EE8.3		Boost Core Code
54	AE_BOOST	7.00	7.00	mm²	Boost Core Cross Sectional Area
55	LE_BOOST	19.20	19.20	mm	Boost Core Magnetic Path Length
56	AL_BOOST	610.00	610.00	nH/turns²	Boost Core Ungapped Core Effective Inductance
57	VE_BOOST		9999.00	mm3	Boost Core Volume
58	BOBBINID_BOOST		Custom		Bobbin
59	AW_BOOST	6.96	6.96	mm²	Window Area of Bobbin
60	BW_BOOST	4.78	4.78	mm	Bobbin Width
61	MARGIN_BOOST		0.00	mm	Safety Margin Width
62	**Boost Winding Details**				
63	NBOOST	150.00	150.00		Boost Choke Turns
64	BP_BOOST		3295.51	Gauss	Boost Peak Flux Density
65	ALG_BOOST		44.53	nH/turns²	Boost Core Ungapped Core Effective Inductance
66	LG_BOOST		0.18	mm	Boost Core Gap Length
67	L_BOOST		6.50		Number of Boost Layers
68	AWG_BOOST		34.00		Boost Winding Wire AWG
69	OD_BOOST_INSULATED		0.20	mm	Boost Winding Wire Output Diameter with Insulation
70	OD_BOOST_BARE		0.16	mm	Boost Winding Wire Output Diameter without Insulation
71	CMA_BOOST		359.72	Circular Mils/A	Boost Winding Wire CMA
72	**Flyback Transformer Construction Parameters**				
73	VOR	96	96	V	Secondary Voltage Reflected in the Primary Winding
74	LP_MIN		991.54	µH	Minimum Flyback Inductance
75	LP_NOM		1043.72	µH	Nominal Flyback Inductance
76	LP_MAX		1095.91	µH	Maximum Flyback Inductance
77	LP_TOL	5.00	5.00	%	Flyback Inductance Tolerance
78	**Flyback Core and Bobbin Selection**				
79	CR_TYPE	RM6S/I	RM6S/I		Flyback Core
80	CR_PN		RM6S/I-3F3		Flyback Core Code
81	AE		37.00	mm²	Flyback Core Cross Sectional Area
82	LE		29.20	mm	Flyback Core Magnetic Path Length
83	AL		2150.00	nH/turns²	Flyback Core Ungapped Core Effective Inductance
84	VE		1090.00	mm3	Flyback Core Volume
85	BOBBINID		Ferroxcube		Flyback Bobbin
86	AW		14.20	mm²	Flyback Window Area of Bobbin
87	BW		6.30	mm	Flyback Bobbin Width
88	MARGIN		0.00	mm	Safety Margin Width
89	**Flyback Winding Details**				
90	NP		58.00		Primary Turns
91	BP		3705.85	Gauss	Flyback Peak Flux Density
92	BM		3614.35	Gauss	Flyback Maximum Flux Density
93	ALG		310.26	nH/turns²	Flyback Core Ungapped Core Effective Inductance
94	LG		0.13	mm	Flyback Core Gap Length
95	L		2.00		Number of Flyback Layers
96	AWG		33.00		Primary Winding Wire AWG
97	OD		0.22	mm	Primary Winding Wire Output

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					Diameter with Insulation
98	DIA		0.18	mm	Primary Winding Wire Output Diameter without Insulation
99	CMA		340.36	Circular Mils/A	Primary Winding Wire CMA
100	NB		8.00		Bias Turns
101	L_BIAS		1.00		Number of Flyback Bias Winding Layers
102	NS	18	18		Secondary Turns
103	AWGS		29.00		Secondary Winding Wire AWG
104	ODS		0.29	mm	Secondary Winding Wire Output Diameter with Insulation
105	DIAS		0.59	mm	Secondary Winding Wire Output Diameter without Insulation
106	CMAS		212.85	Circular Mils/A	Secondary Winding Wire CMA
107	**Primary Components Selection**				
108	**Line Undervoltage**				
109	BROWN_IN_REQUIRED	80.00	80.00	V	Required AC RMS line voltage brown-in threshold
110	RLS		2.00	MOhm	Two Resistors of this Value in Series to the V-pin
111	BROWN_IN_ACTUAL		80.16	V	Actual AC RMS brown-in threshold
112	BROWN_OUT_ACTUAL		72.50	V	Actual AC RMS brown-out threshold
113	**Line Overvoltage**				
114	OVERVOLTAGE_LINE		334.21	V	Actual AC RMS line over-voltage threshold
115	**Bias Voltage**				
116	VBIAS		12.0	V	Rectified Bias Voltage
117	VF_BIASDIODE		0.70	V	Bias Winding Diode Forward Drop
118	VRRM_BIASDIODE		63.69	V	Bias diode reverse voltage
119	CBIAS		22.0	µF	Bias winding rectification capacitor
120	CBPP		4.70	µF	BPP pin capacitor
121	**Bulk Capacitor Zener Clamp**				
122	Use_Clamp	No	No		Bulk Capacitor Clamp Needed? Yes, No or N/A
123	VZ1_V		9999.00	V	Zener 1 Voltage Rating (In Series with Zener 2)
124	PZ1_W		9999.00	W	Zener 1 Minimum Power Rating
125	VZ2_V		9999.00	V	Zener 2 Voltage Rating
126	PZ2_W		9999.00	W	Zener 2 Minimum Power Rating
127	RZ		9999.00	ohms	Resistor in series with Zener 1 and Zener 2
128	**Secondary Components Selection**				
129	**Feedback Components**				
130	RFB_UPPER	100.00	100.00	kOhm	Upper feedback 1% resistor
131	RFB_LOWER		4.40	kOhm	Lower feedback 1% resistor
132	CFB_LOWER		330.0	pF	Lower feedback resistor decoupling at least 5V-rating capacitor
133	CBPS		2.2	µF	BPS pin capacitor
134	**Secondary Auxiliary Section - For VO > 24V ONLY**				
135	**Sec Aux Diode**				
136	VAUX	16.00	16.00	V	Rectified auxiliary voltage
137	VF_AUX		0.70	V	Auxiliary winding diode forward drop
138	VRRM_AUXDIODE		76.61	V	Auxiliary diode reverse voltage
139	CAUX		22.00	µF	Auxiliary winding rectification

					capacitor
140	NAUX_SEC		10		Secondary Aux Turns
141	L_AUX		1.00		Number of Flyback Aux Winding Layers
142	AWGSAUX		38		Secondary Aux Winding AWG
143	**Output Parameters**				
144	VOUT_ACTUAL		12.00	V	Actual Output Voltage
145	IO		0.30	A	Actual Output Current
146	ISECRMS		0.60	A	Secondary RMS current for output
147	**Output Components**				
148	VF		0.70	V	Output diode forward drop
149	VRRM		146.31	V	Output diode reverse voltage
150	COUT		75.47	µF	Output Capacitor - Capacitance
151	COUT_VOpercentRip		2.50	%	Output Capacitor Ripple % of VOUT
152	ICOUTrms		0.52	A	Output Capacitor Estimated Ripple Current
153	ESRmax		385.60	mohms	Output Capacitor Maximum Recommended ESR
154	**Errors, Warnings, Information**				
155	IDS_INFO				Although the design has passed the user should validate functionality on the bench. Please check the variables listed.
156	IDS_WARN		OVERVOLTAGE_LINE		Design variables whose values exceed electrical/datasheet specifications.
157	IDS_ERR				The list of design variables which result in an infeasible design.

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9 Performance Data

All measurements performed at room temperature.

9.1 *Electrical Test Data*

9.1.1 System (Including Bluetooth Module and LensVector)

Input		Input Measurement					Output Measurement				
VAC (RMS)	Freq (Hz)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	PF	% THD	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	% I Reg	Efficiency (%)
90	60	90.08	138.82	10.56	0.845	58.9	29.14	300.06	8.74	0.02	82.78
100	60	100.03	122.22	10.44	0.854	57.19	29.06	300.03	8.72	0.01	83.56
110	60	110.07	109.2	10.35	0.862	55.32	29.00	300.05	8.70	0.017	84.05
115	60	115.05	103.53	10.31	0.866	54.54	28.95	300.05	8.69	0.017	84.23
120	60	120.03	98.37	10.28	0.87	52.89	28.90	300.01	8.67	0.003	84.38
132	60	132.05	87.98	10.23	0.881	49.56	28.86	300.05	8.66	0.017	84.61
180	50	180.11	61.55	10.22	0.922	34.79	28.82	300.12	8.65	0.04	84.67
200	50	200.1	54.79	10.23	0.933	27.13	28.79	300.17	8.64	0.057	84.46
220	50	220.19	49.7	10.26	0.938	20.95	28.75	300.18	8.63	0.06	84.09
230	50	230.13	47.67	10.28	0.937	18.5	28.72	300.2	8.62	0.067	83.90
240	50	240.17	45.97	10.3	0.933	17.67	28.69	300.17	8.61	0.057	83.62
265	50	265.17	42.77	10.389	0.916	18.41	28.67	300.17	8.61	0.057	82.84

9.1.2 LYTSwitch-6 Power Section Only

Input		Input Measurement					Output Measurement				
VAC (RMS)	Freq (Hz)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	PF	% THD	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	% I Reg	Efficiency (%)
90	60	90.08	139.69	10.62	0.844	58.89	29.58	300.11	8.88	0.037	83.60
100	60	100.03	123.1	10.49	0.852	57.68	29.47	300.08	8.84	0.027	84.33
110	60	110.07	109.8	10.39	0.86	55.77	29.37	300.08	8.81	0.027	84.82
115	60	115.05	103.99	10.34	0.864	54.53	29.28	300.05	8.79	0.017	85.00
120	60	120.03	98.72	10.29	0.868	53.47	29.21	300.08	8.76	0.027	85.18
132	60	132.05	88.21	10.24	0.879	50.36	29.14	300.09	8.74	0.03	85.40
180	50	180.1	61.65	10.21	0.92	35.27	29.07	300.14	8.73	0.047	85.46
200	50	200.07	54.82	10.22	0.932	27.91	29.02	300.21	8.71	0.07	85.27
220	50	220.17	49.67	10.25	0.937	21.31	28.97	300.2	8.70	0.067	84.88
230	50	230.13	47.61	10.26	0.936	18.88	28.92	300.22	8.68	0.073	84.66
240	50	240.18	45.87	10.27	0.933	17.82	28.88	300.23	8.67	0.077	84.42
265	50	265.16	42.65	10.36	0.916	18.3	28.85	300.22	8.66	0.073	83.63

9.2 *Efficiency*

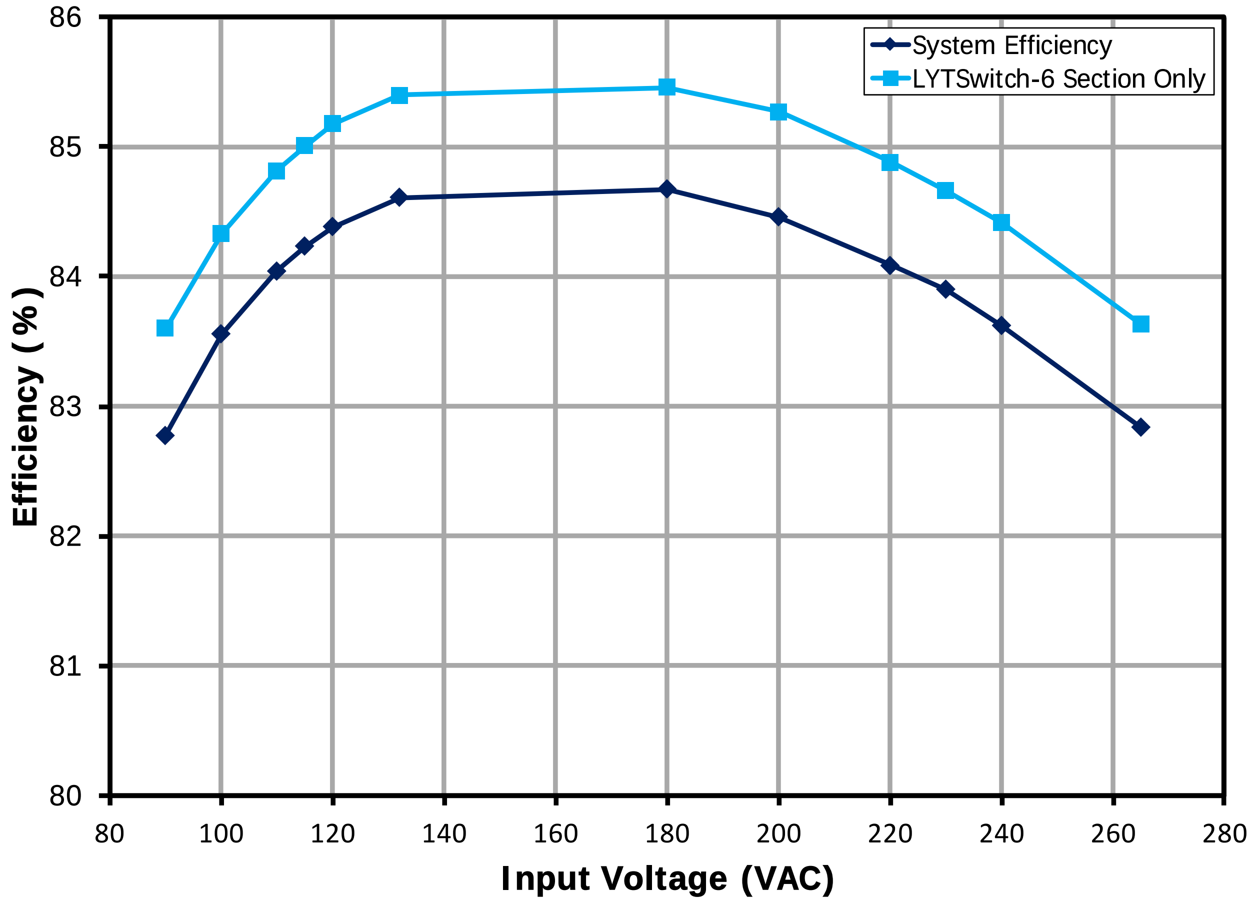

Figure 15 – Efficiency vs Line Voltage, Full Load.

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9.3 *Output Current Regulation*

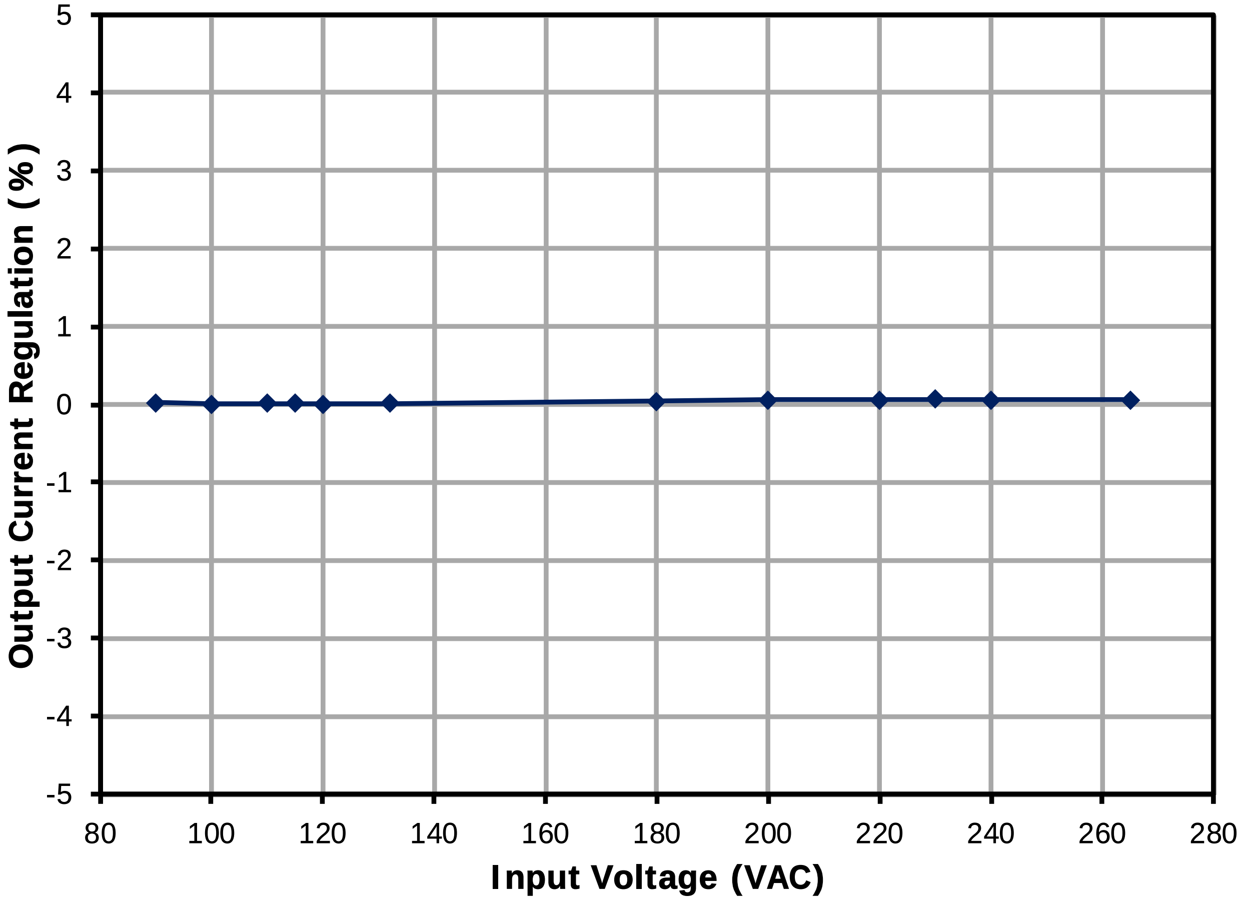

Figure 16 – Output Current Regulation vs Line Voltage, Full Load.

9.4 *Power Factor*

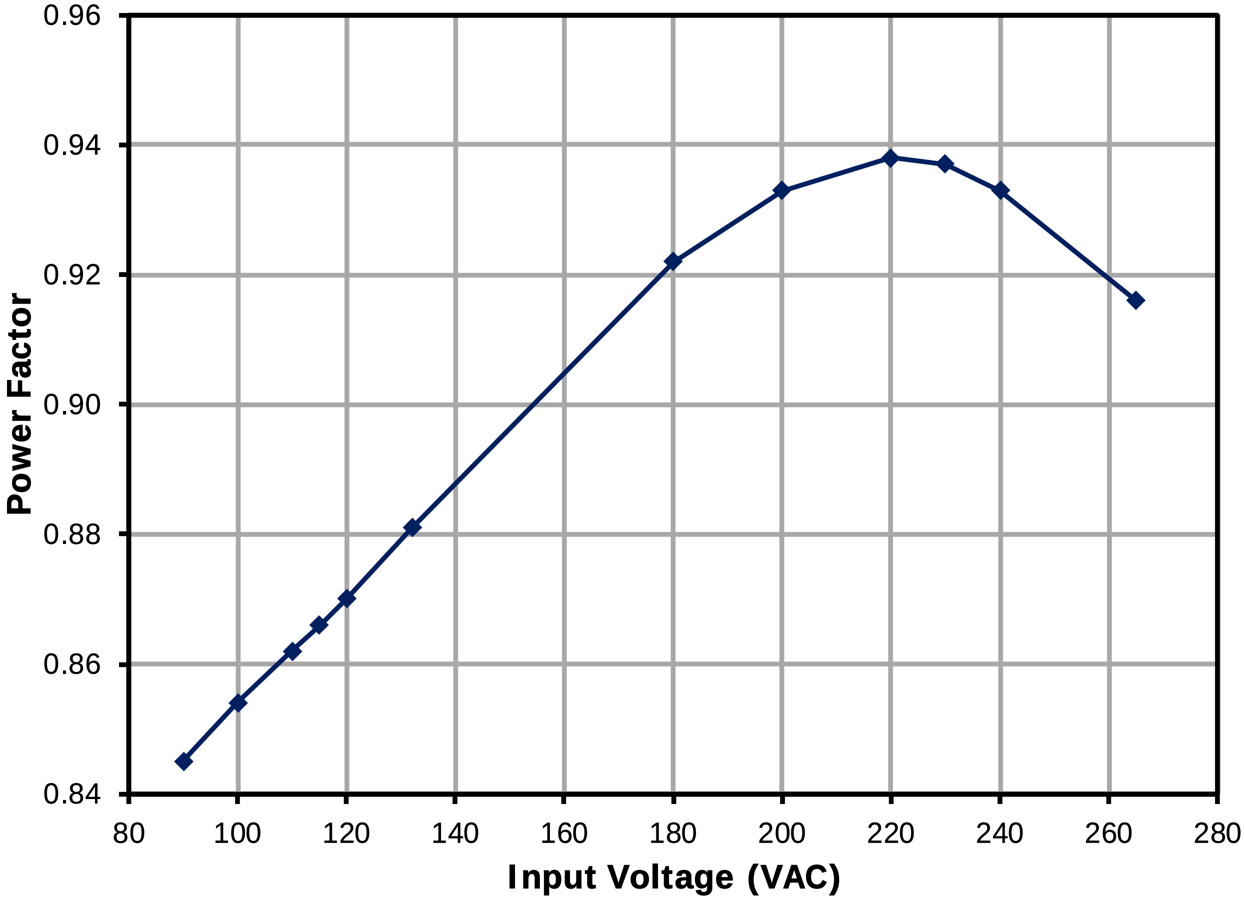

Figure 17 – Power Factor vs Line Voltage, Full Load.

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9.5 *A-THD*

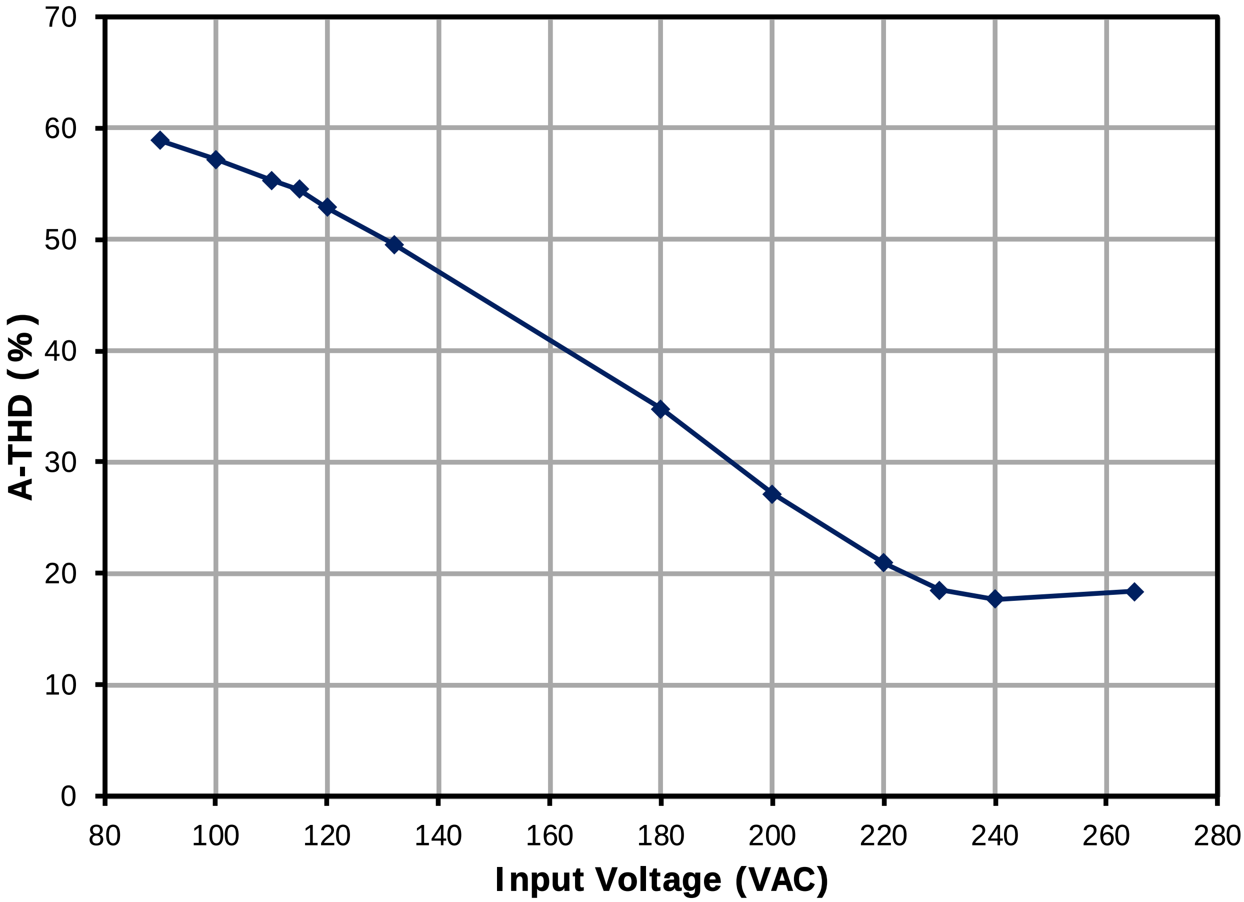

Figure 18 – A-THD (%) vs Line Voltage, Full Load.

9.6 *Input Current Harmonics at 230 VAC*

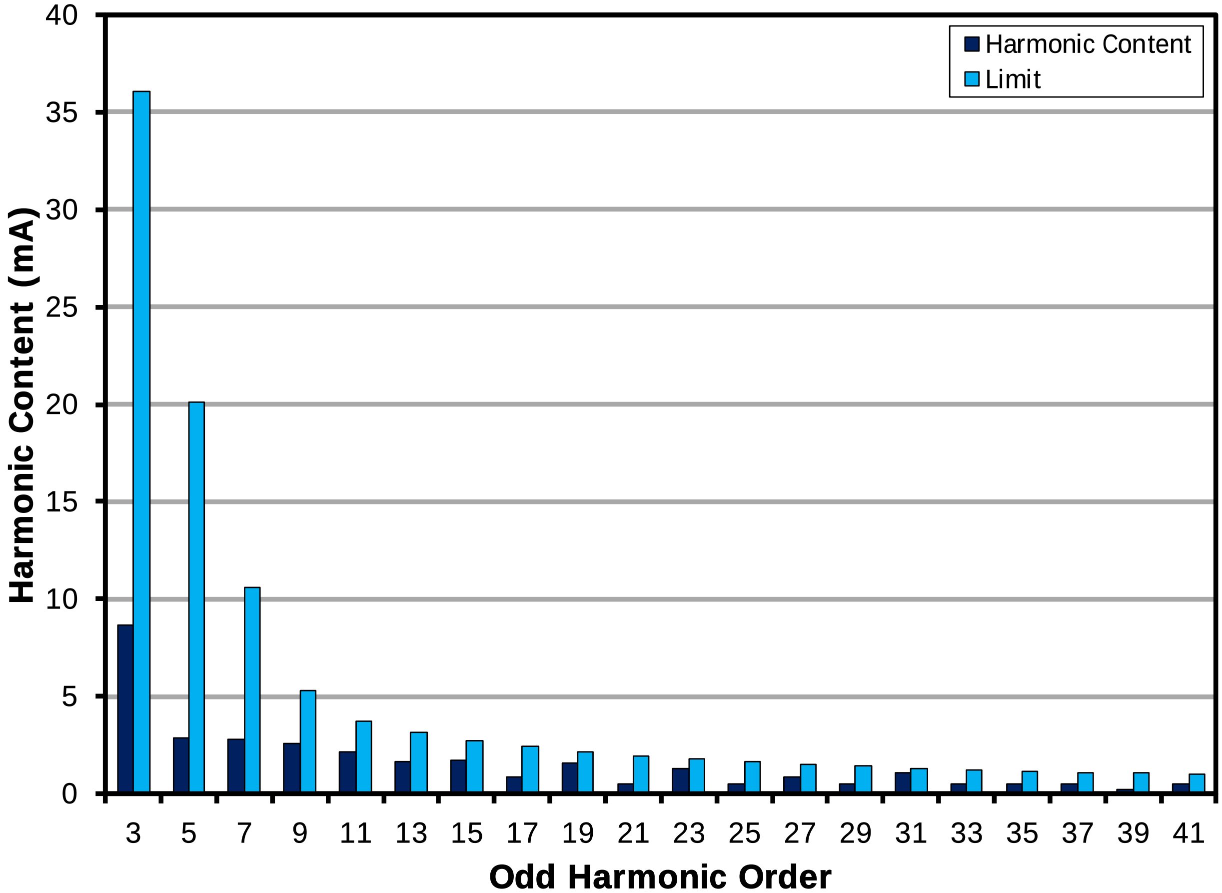

Figure 19 – Input Current Harmonics at 230 VAC, Full Load.

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9.7 *No-Load Input Power*

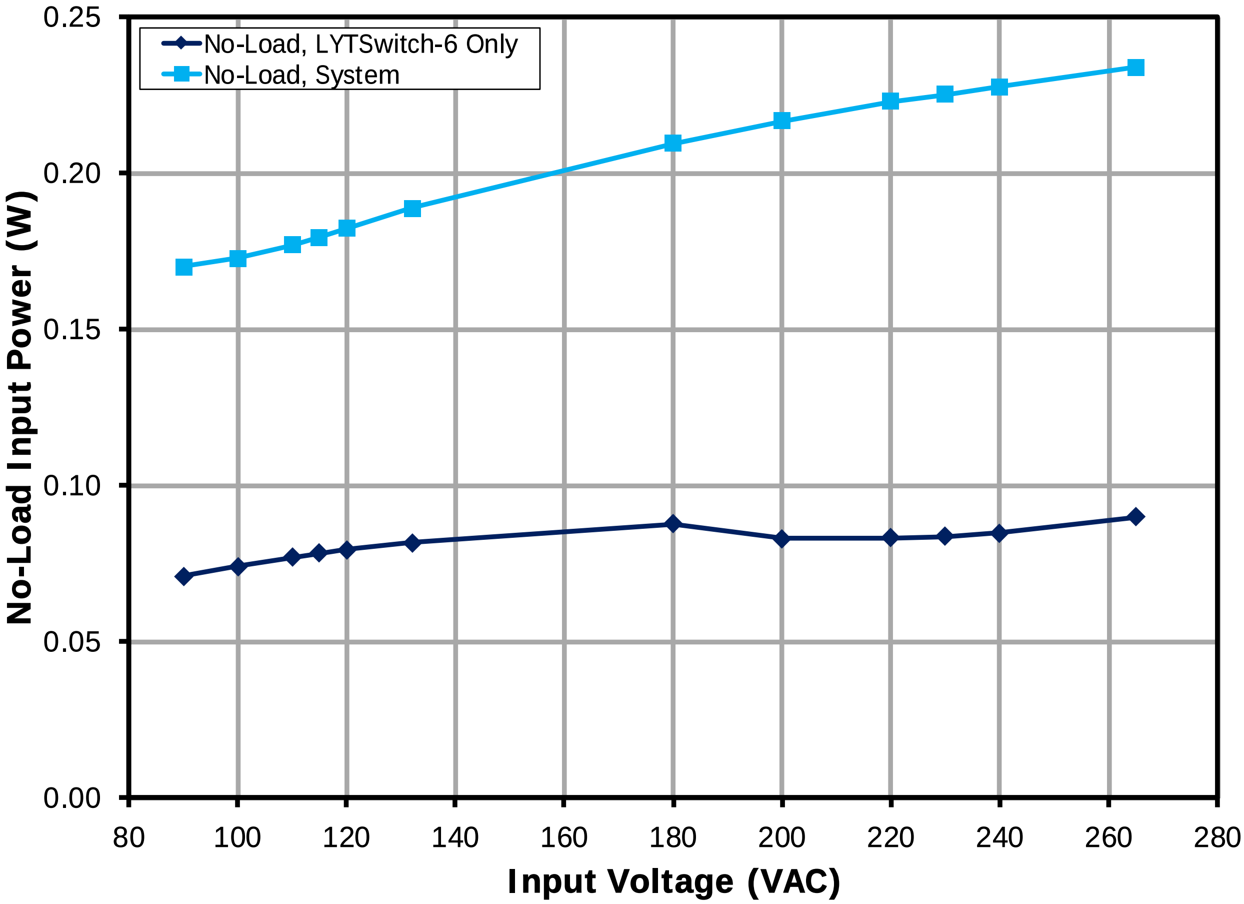

Figure 20 – No Load Input Power vs Line Voltage.

9.8 *CV/CC*

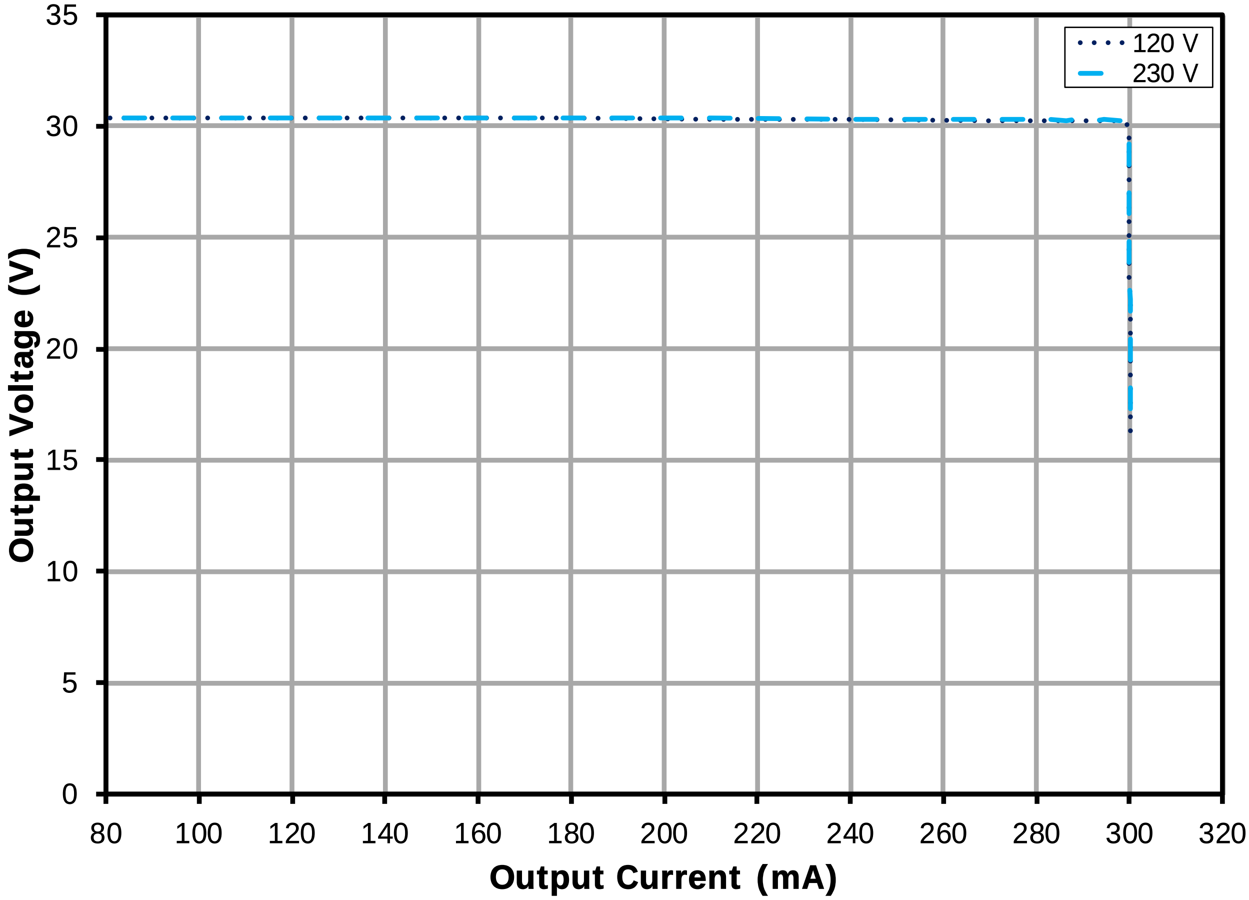

Figure 21 – CV/CC Curve.

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9.9 *Dimming Curve via Bluetooth Control*

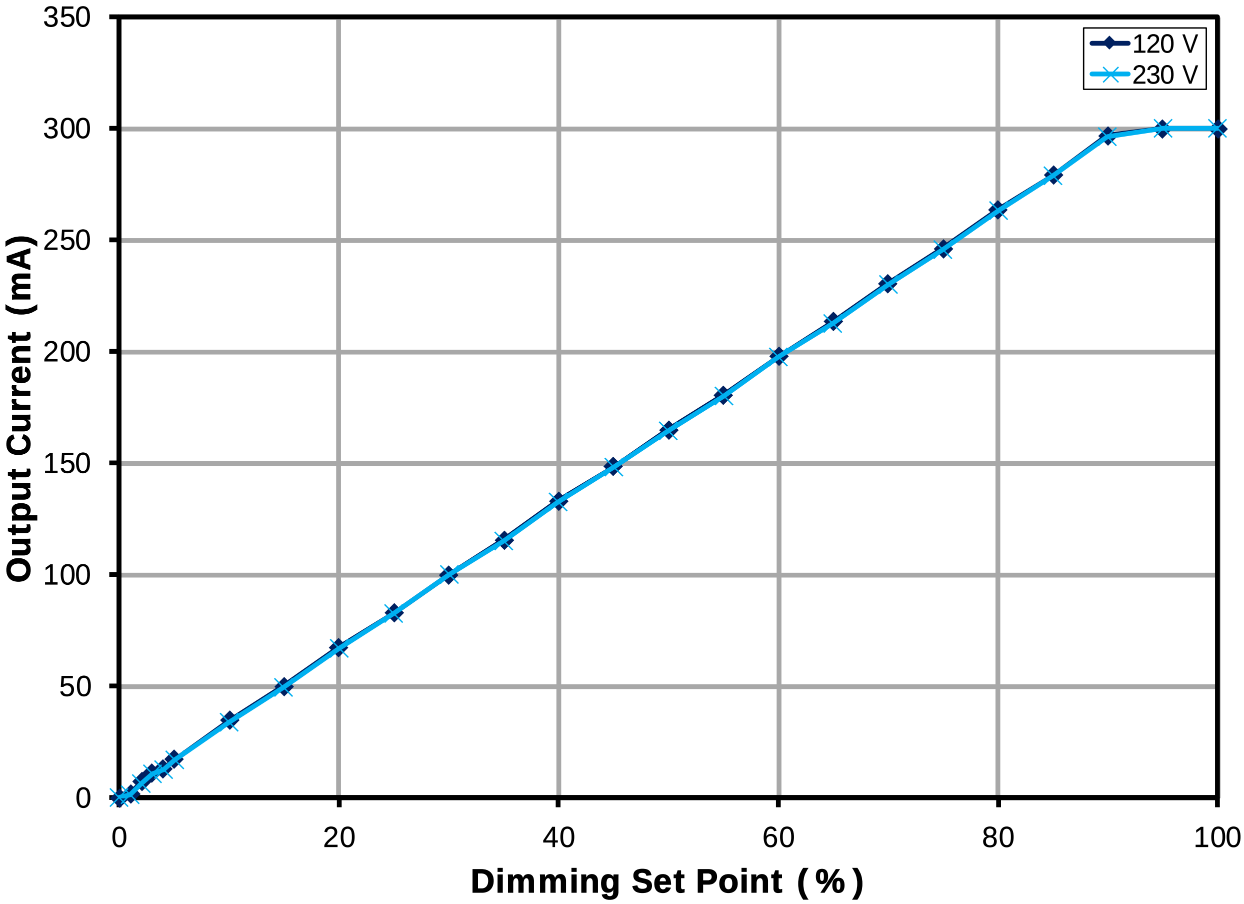

Figure 22 – Dimming Profile.

10 Thermal Performance

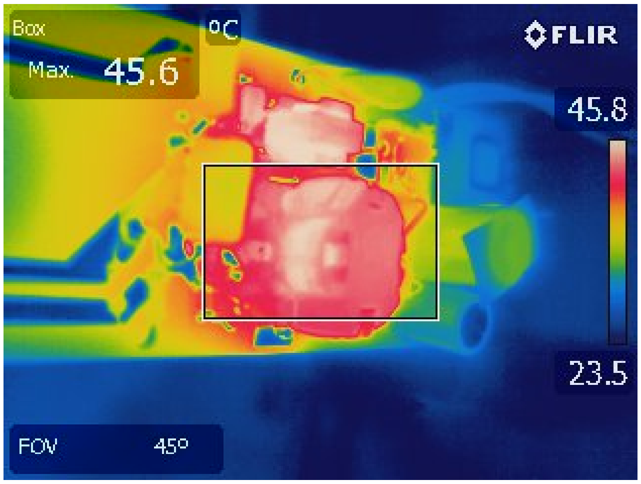

Figure 23 – 90 VAC, Full Load.
Flyback Transformer T1: 45.6 ºC.

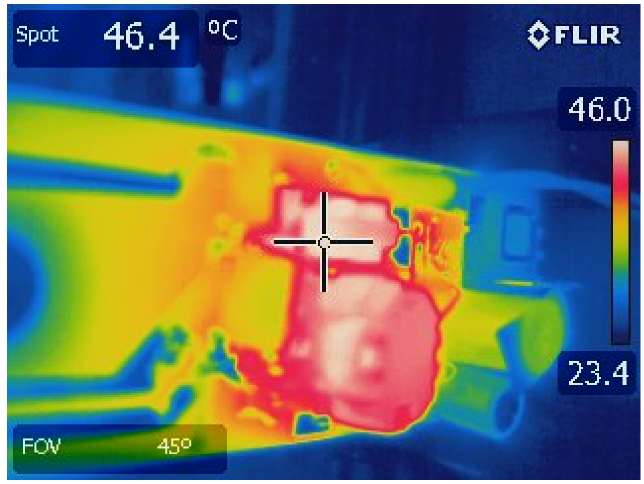

Figure 24 – 90 VAC, Full Load.
PFC Inductor T2: 46.4 ºC.

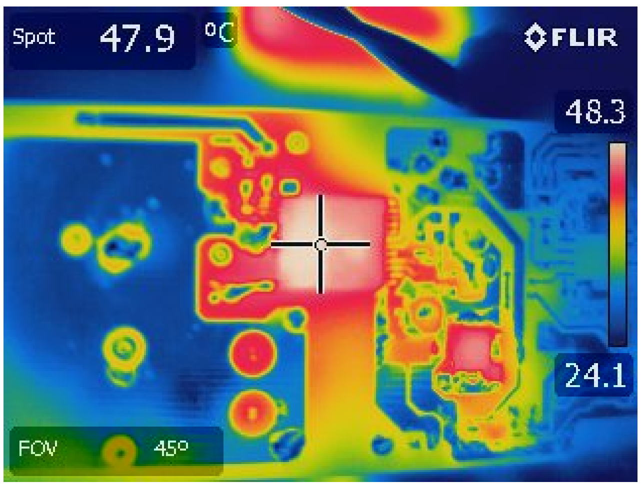

Figure 25 – 90 VAC, Full Load.
LYTSwitch-6 U1: 47.9 ºC.

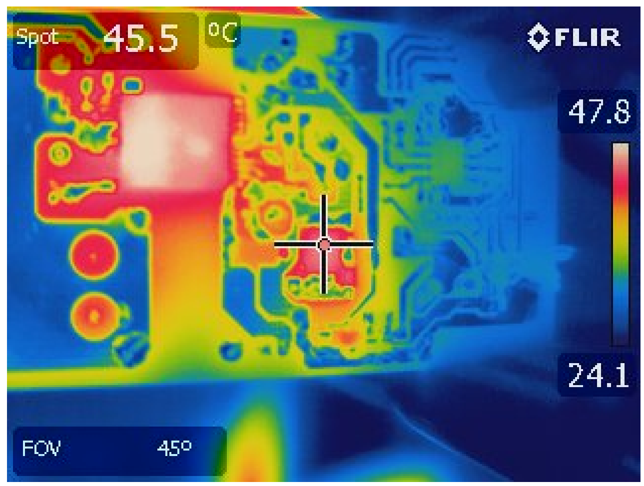

Figure 26 – 90 VAC, Full Load.
Output Diode D6: 45.5 ºC.

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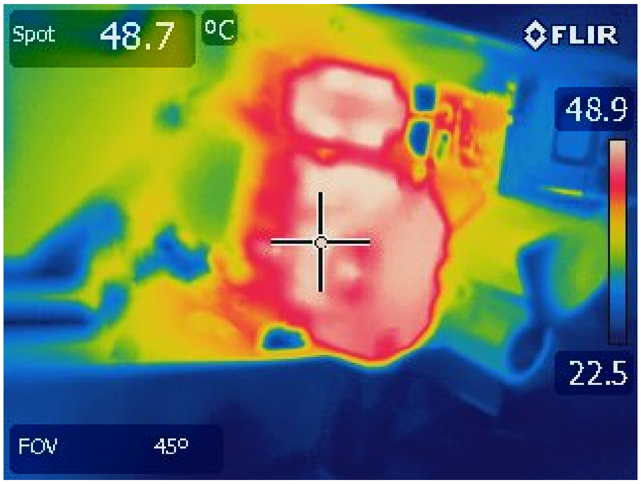

Figure 27 – 265 VAC, Full Load.
Flyback Transformer T1: 48.7 ºC.

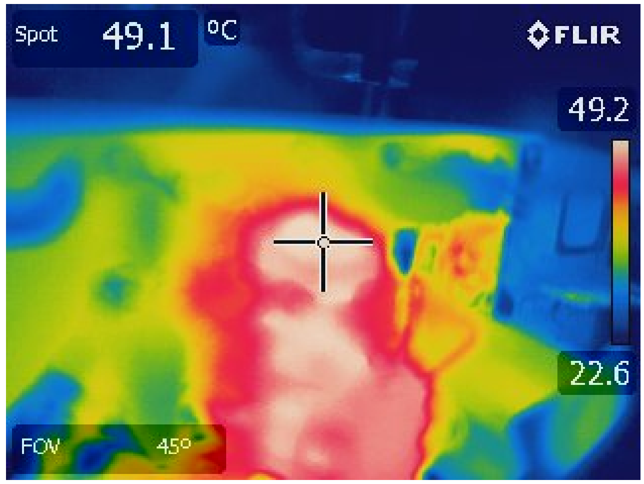

Figure 28 – 265 VAC, Full Load.
PFC Inductor T2: 49.1 ºC.

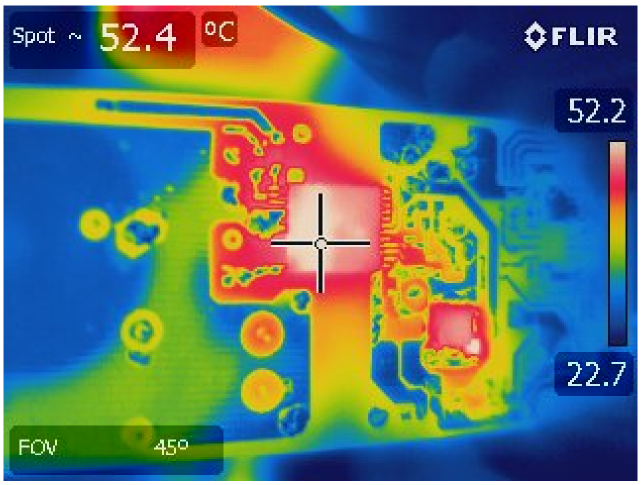

Figure 29 – 265 VAC, Full Load.
LYTSwitch-6 U1: 52.4 ºC.

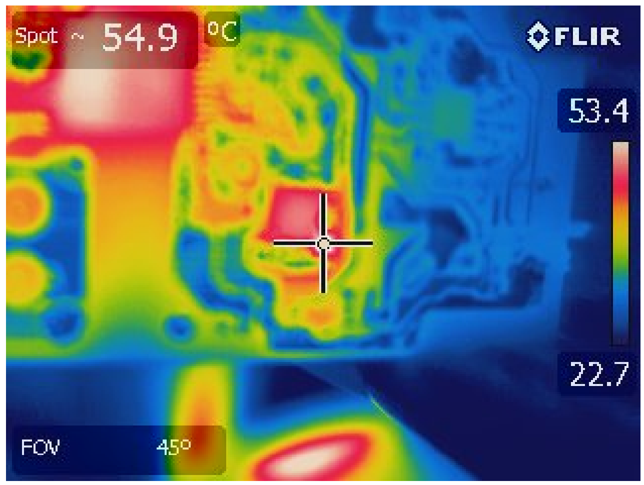

Figure 30 – 265 VAC, Full Load.
Output Diode Snubber: 54.9 ºC.

11 **Waveforms**

11.1 *Input Voltage and Current, Full Load*

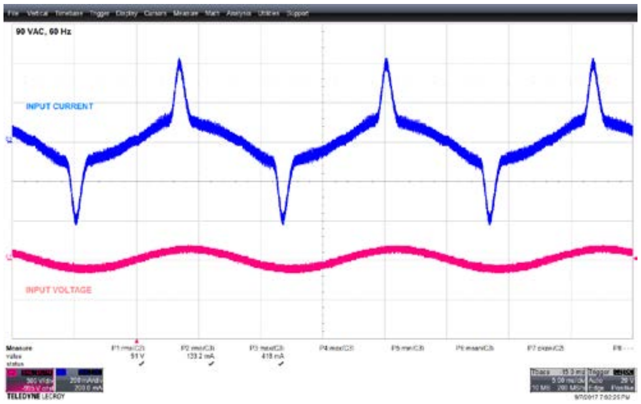

Figure 31 – 90 VAC, Full Load.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 200 V, 5 µs / div.

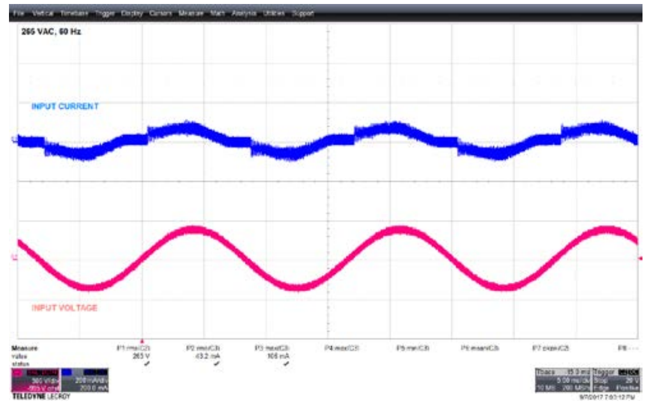

Figure 32 – 265 VAC, Full Load.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 200 V, 5 µs / div.

11.2 *Drain Voltage and Current, Normal Operation*

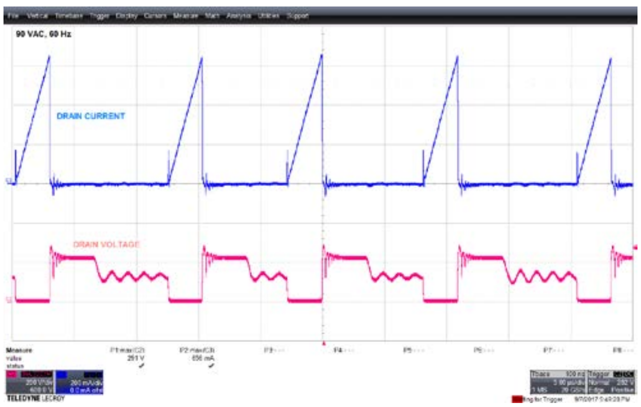

Figure 33 – 90 VAC, Full Load.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 200 V, 5 µs / div.

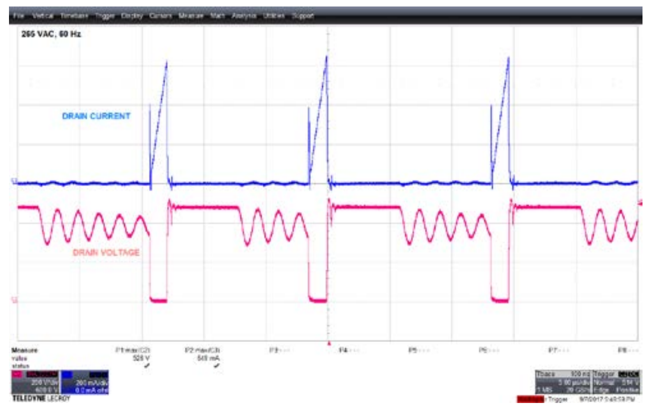

Figure 34 – 265 VAC, Full Load.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 200 V, 5 µs / div.

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11.3 *Drain Voltage and Current, Normal Operation, Envelope*

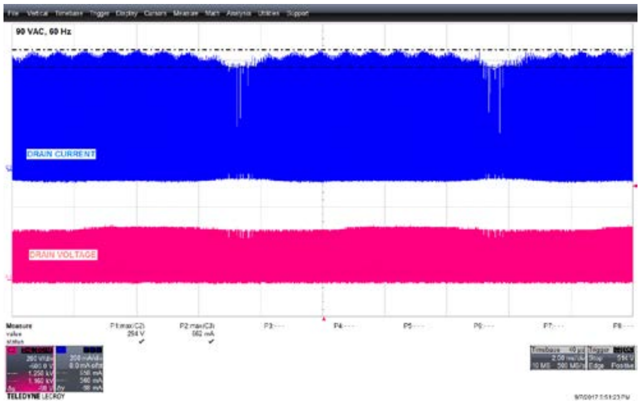

Figure 35 – 90 VAC, Full Load.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 200 V, 2 ms / div.

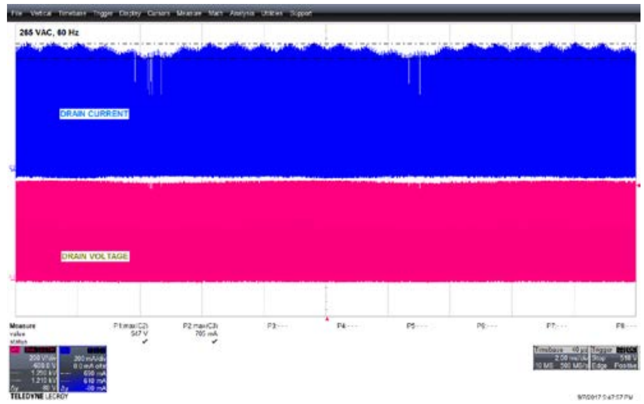

Figure 36 – 265 VAC, Full Load.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 200 V, 2 ms / div.

11.4 *Drain Voltage and Current, Start-up Profile*

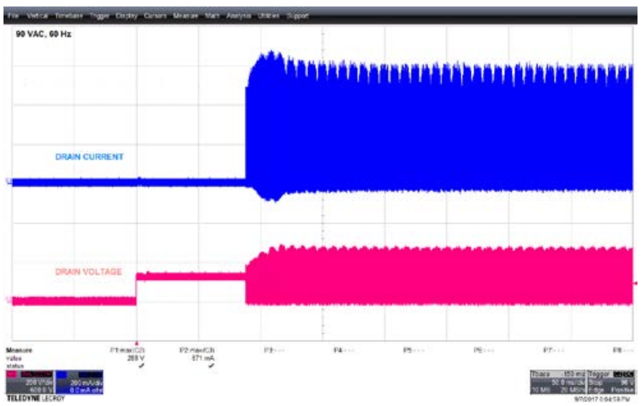

Figure 37 – 90 VAC, Full Load.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 200 V, 50 ms / div.

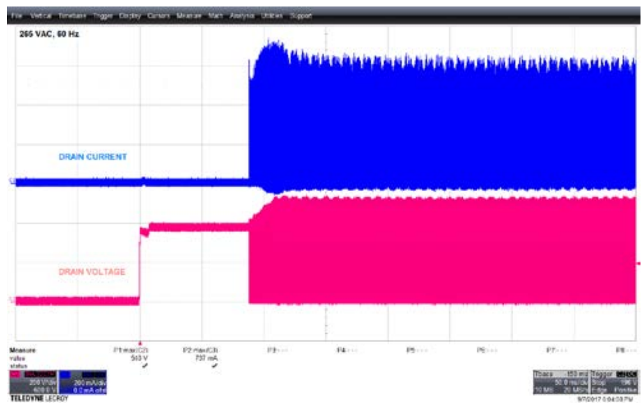

Figure 38 – 265 VAC, Full Load.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 200 V, 50 ms / div.

11.5 *Drain Voltage and Current, Output Short*

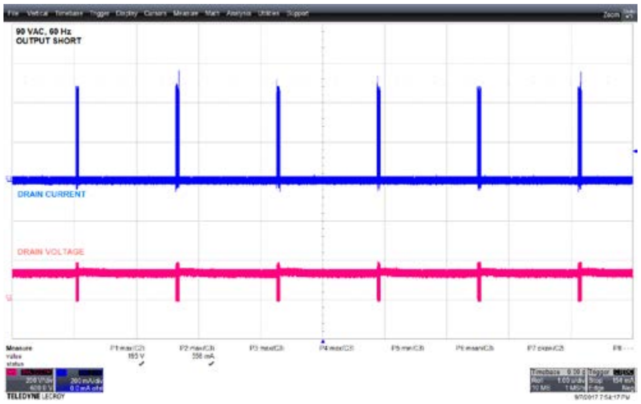

Figure 39 – 90 VAC, Output Short.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 200 V, 1 s / div.

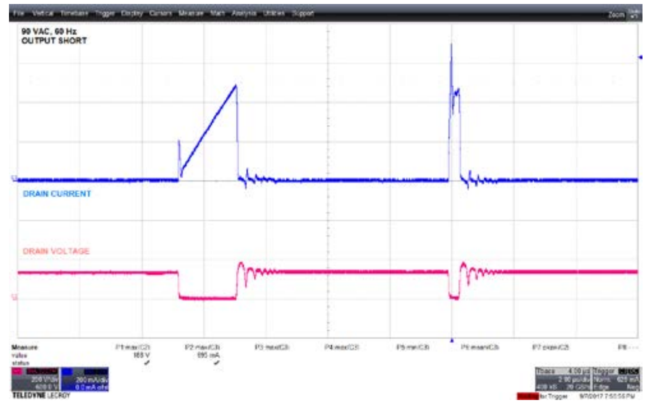

Figure 40 – 90 VAC, Output Short.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 200 V, 2 µs / div.

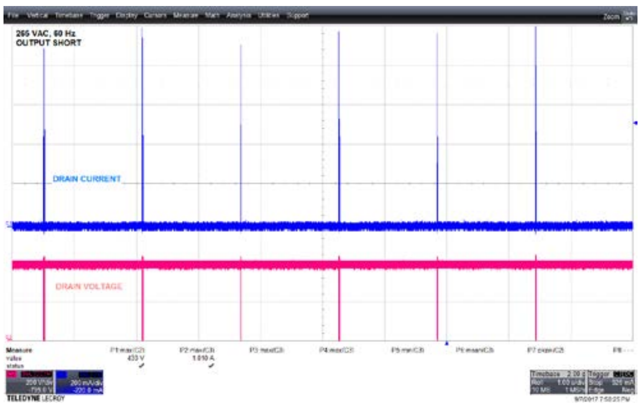

Figure 41 – 90 VAC, Output Short.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 200 V, 1 s / div.

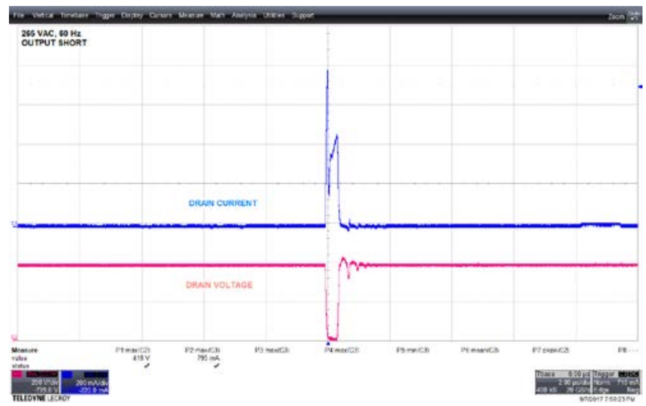

Figure 42 – 90 VAC, Output Short.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 200 V, 2 µs / div.

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11.6 *Output Voltage and Current, Normal Operation*

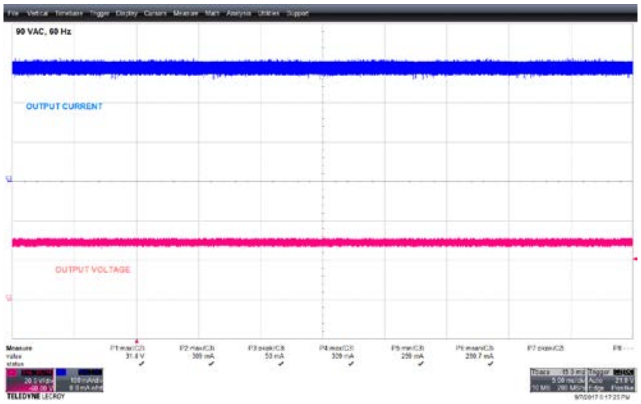

Figure 43 – 90 VAC, Full Load.
Upper: I_{OUT}, 0.1 A / div.
Lower: V_{OUT}, 20 V, 5 ms / div.

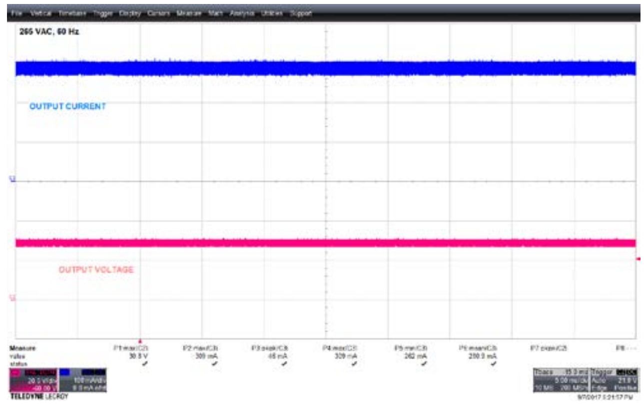

Figure 44 – 265 VAC, Full Load.
Upper: I_{OUT}, 0.1 A / div.
Lower: V_{OUT}, 20 V, 5 ms / div.

11.7 *Output Voltage and Current, Start-up Profile*

The output current step during start-up is due to the initialization delay of the Bluetooth module that provides PWM dimming.

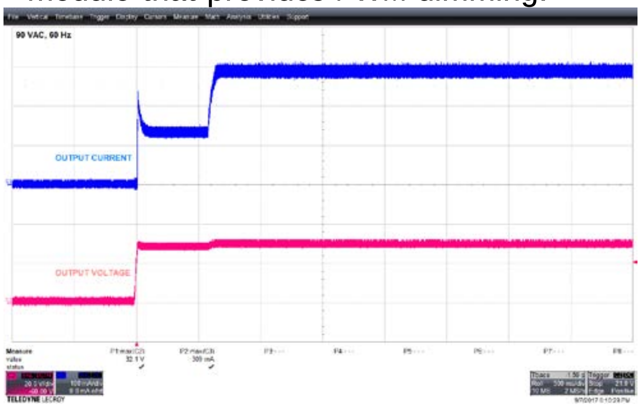

Figure 45 – 90 VAC, Full Load.
Upper: I_{OUT}, 0.1 A / div.
Lower: V_{OUT}, 20 V, 500 ms / div.

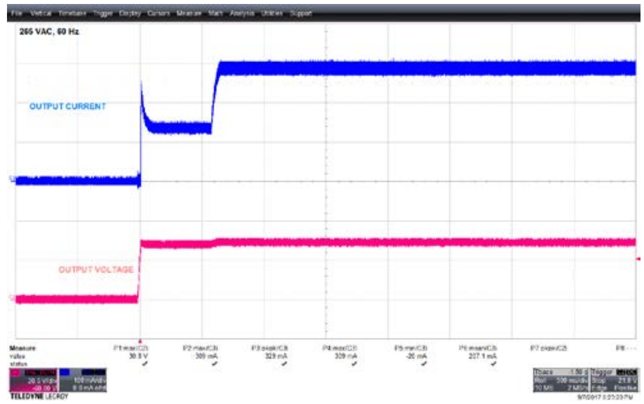

Figure 46 – 265 VAC, Full Load.
Upper: I_{OUT}, 0.1 A / div.
Lower: V_{OUT}, 20 V, 500 ms / div.

11.8 *Output Voltage and Current, Power Cycling, 1s ON / 1s OFF*

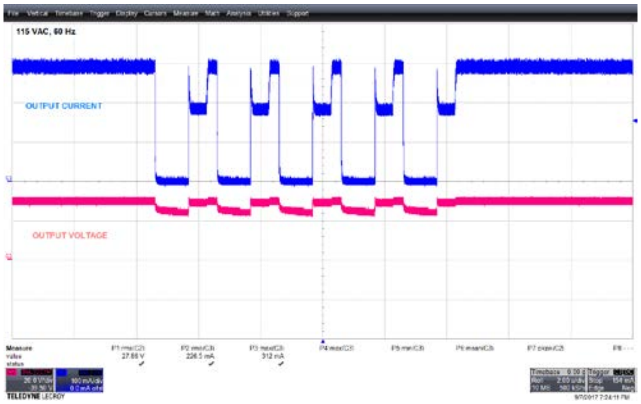

Figure 47 – 115 VAC, Full Load.
Upper: I_{OUT}, 0.1 A / div.
Lower: V_{OUT}, 20 V, 2 s / div.

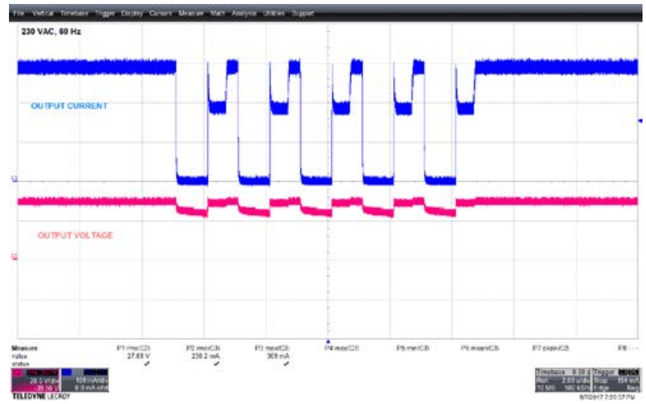

Figure 48 – 230 VAC, Full Load.
Upper: I_{OUT}, 0.1 A / div.
Lower: V_{OUT}, 20 V, 2 s / div.

11.9 *Brown-Out, Brown-In*

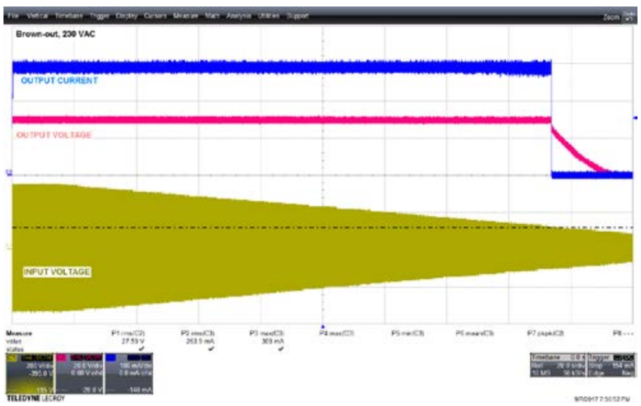

Figure 49 – Brown-out, Full Load.
Upper: I_{OUT}, 0.1 A / div.
Lower: V_{OUT}, 20 V, 2 s / div.

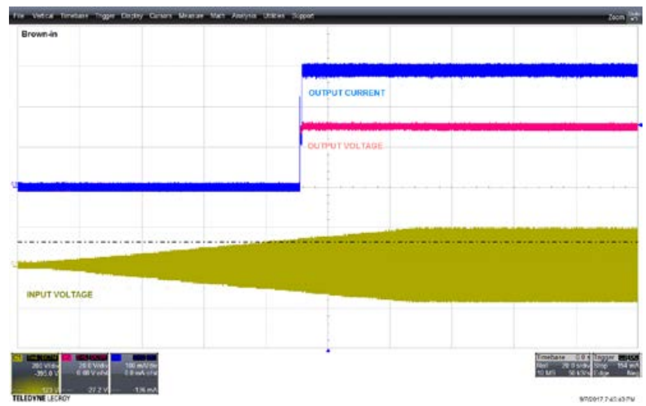

Figure 50 – Brown-in, Full Load.
Upper: I_{OUT}, 0.1 A / div.
Lower: V_{OUT}, 20 V, 2 s / div.

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11.10 *Bulk Voltage, No-Load*

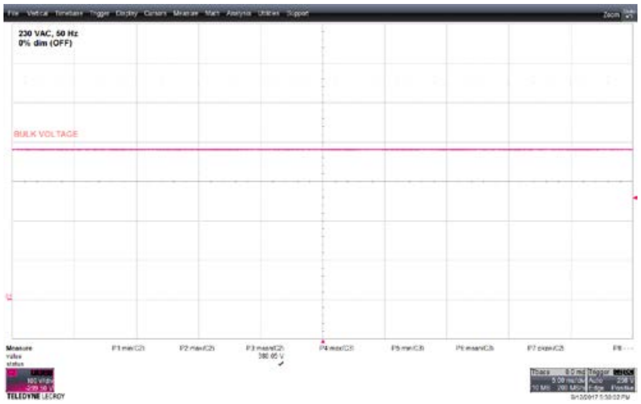

Figure 51 – 230 VAC, No-Load.
Bulk Voltage, 100 V / div.
V_{BULK}: 380.05 V.

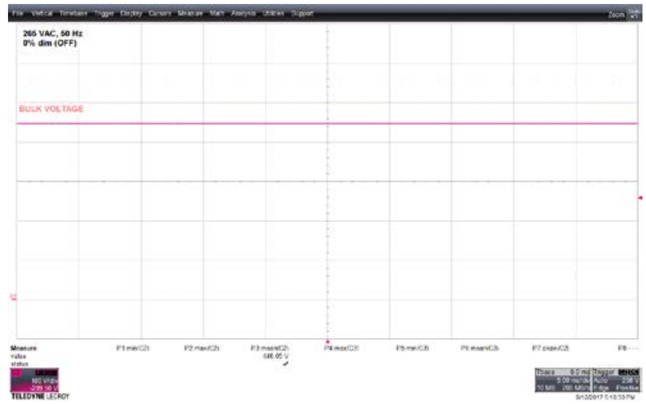

Figure 52 – 265 VAC, No-Load.
Bulk Voltage, 100 V / div.
V_{BULK}: 446.05 V.

11.11 *LensVector*

Figure 53 – 120 VAC, 0% Beam Angle Setting (Narrow).

Figure 54 – 120 VAC, 25% Beam Angle Setting.

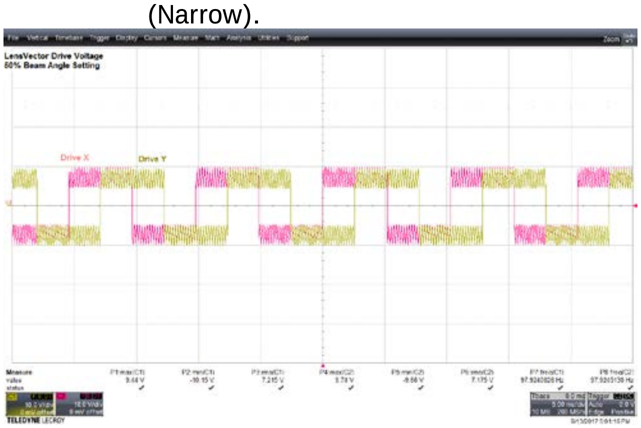

Figure 55 – 120 VAC, 50% Beam Angle Setting.

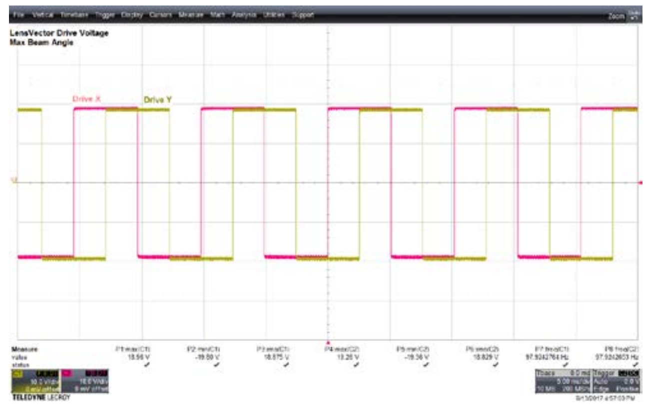

Figure 56 – 120 VAC, Max Beam Angle Setting.

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11.12 *Output Ripple Current*

$$\% \, Flicker = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} * 100$$

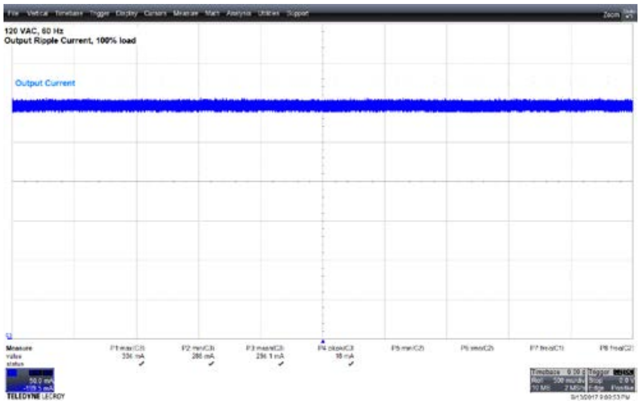

Figure 57 – 120 VAC, 100% Load. 0.5 s / div.
Blue: I_{OUT}, 0.05 A / div.
% Flicker: 3.1%.

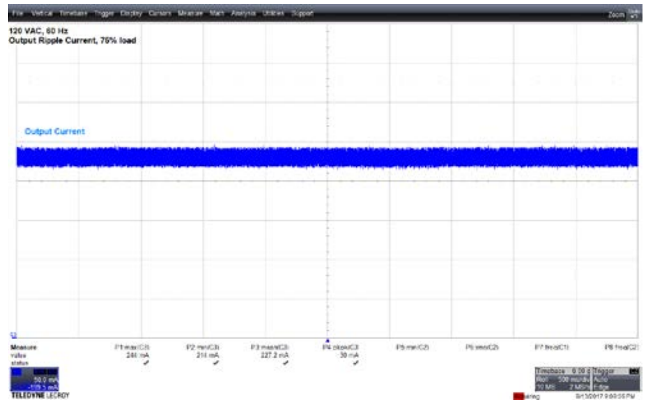

Figure 58 – 120 VAC, 75% Load. 0.5 s / div.
Blue: I_{OUT}, 0.05 A / div.
% Flicker: 6.5%.

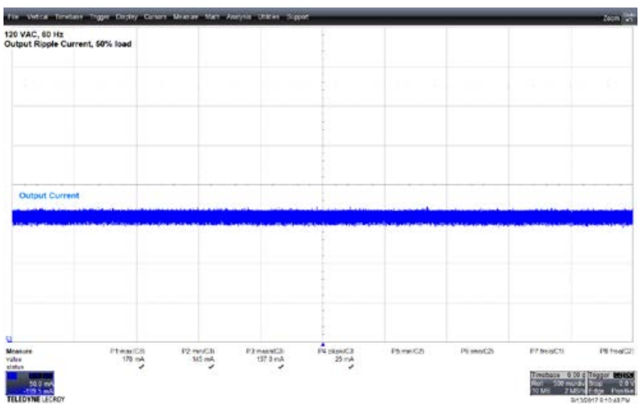

Figure 59 – 120 VAC, 50% Load. 0.5 s / div.
Blue: I_{OUT}, 0.05 A / div.
% Flicker: 7.9%.

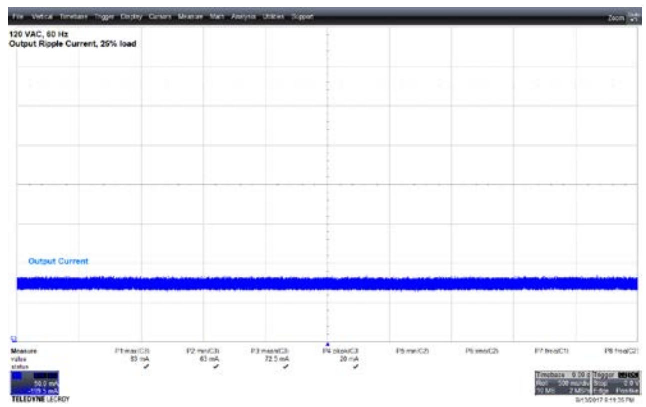

Figure 60 – 120 VAC, 25% Load. 0.5 s / div.
Blue: I_{OUT}, 0.05 A / div.
% Flicker: 13.7%.

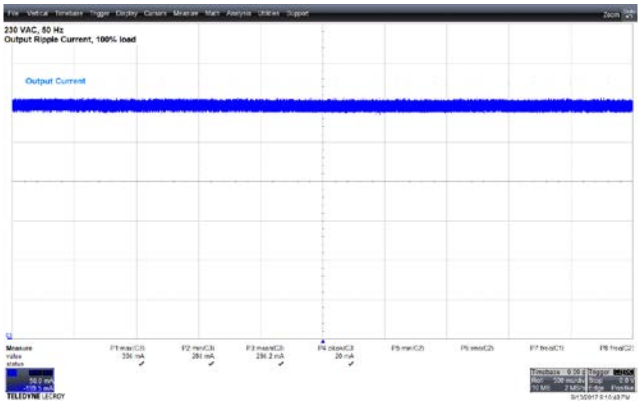

Figure 61 – 230 VAC, 100% Load. 0.5 s / div.
Blue: I_{OUT}, 0.05 A / div.
% Flicker: 3.4%.

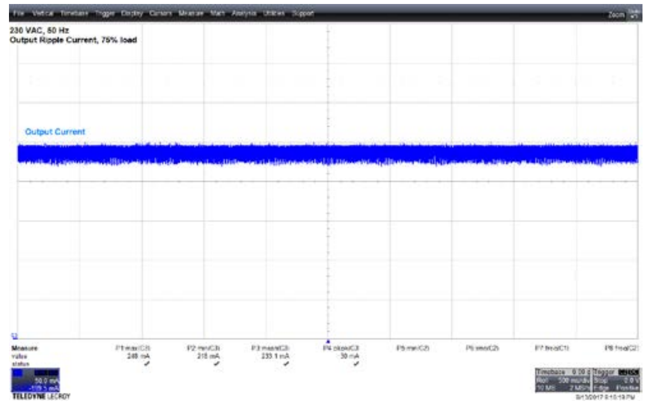

Figure 62 – 230 VAC, 75% Load. 0.5 s / div.
Blue: I_{OUT}, 0.05 A / div.
% Flicker: 6.4%.

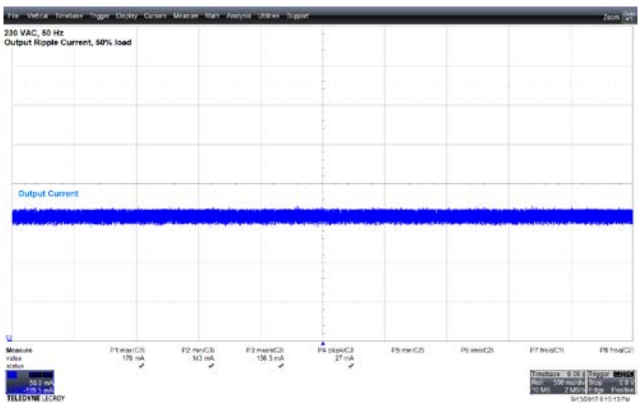

Figure 63 – 230 VAC, 50% Load. 0.5 s / div.
Blue: I_{OUT}, 0.05 A / div.
% Flicker: 8.6%.

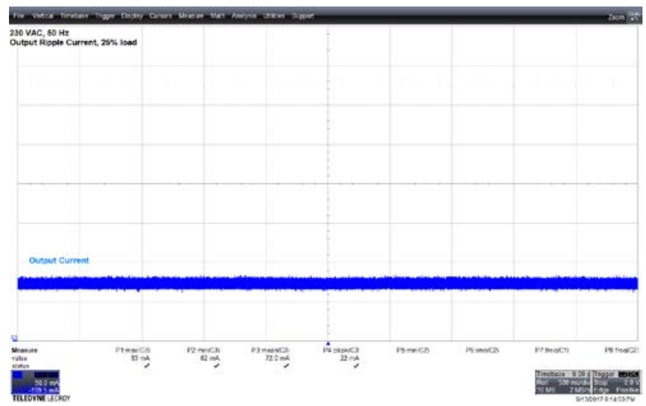

Figure 64 – 230 VAC, 25% Load. 0.5 s / div.
Blue: I_{OUT}, 0.05 A / div.
% Flicker: 14.5%.

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12 Conducted EMI

The unit was tested inside the actual track light housing.

Figure 65 – Conducted EMI Set-up.

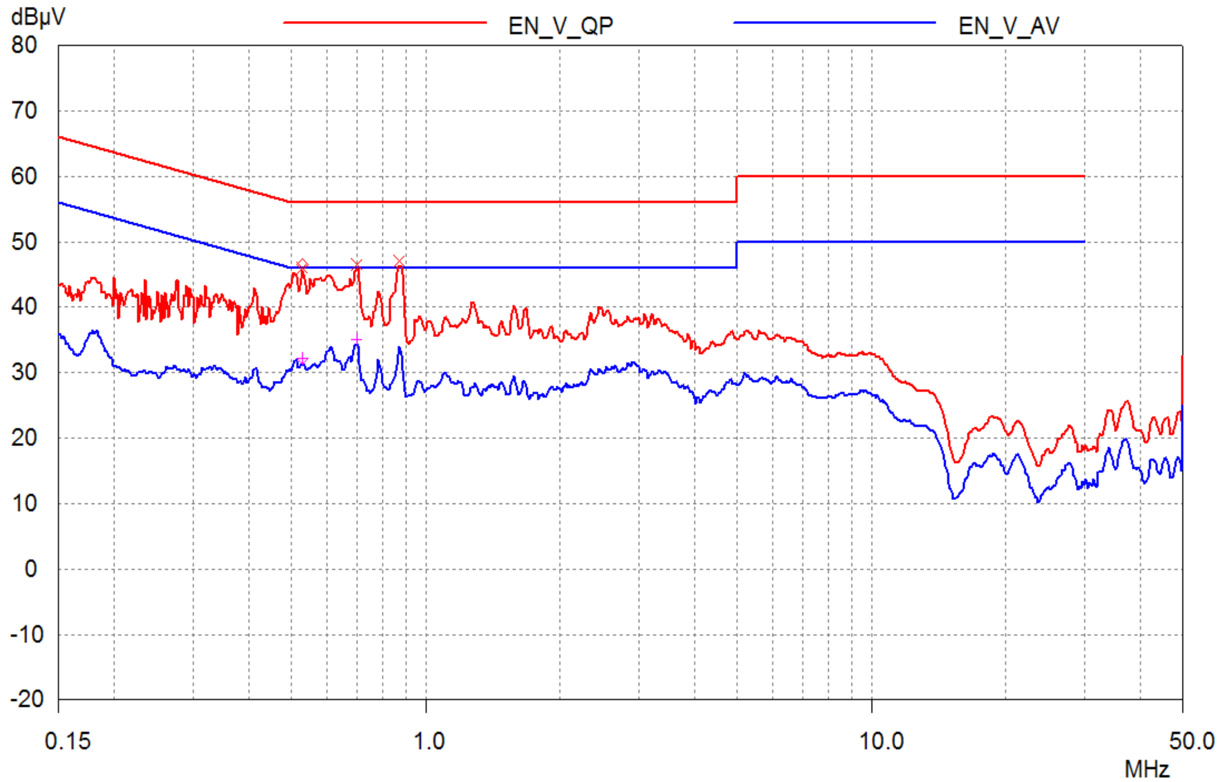

Figure 66 – Conducted EMI, Actual BLE Load, 115 VAC, 60 Hz, and EN55022 B Limits.

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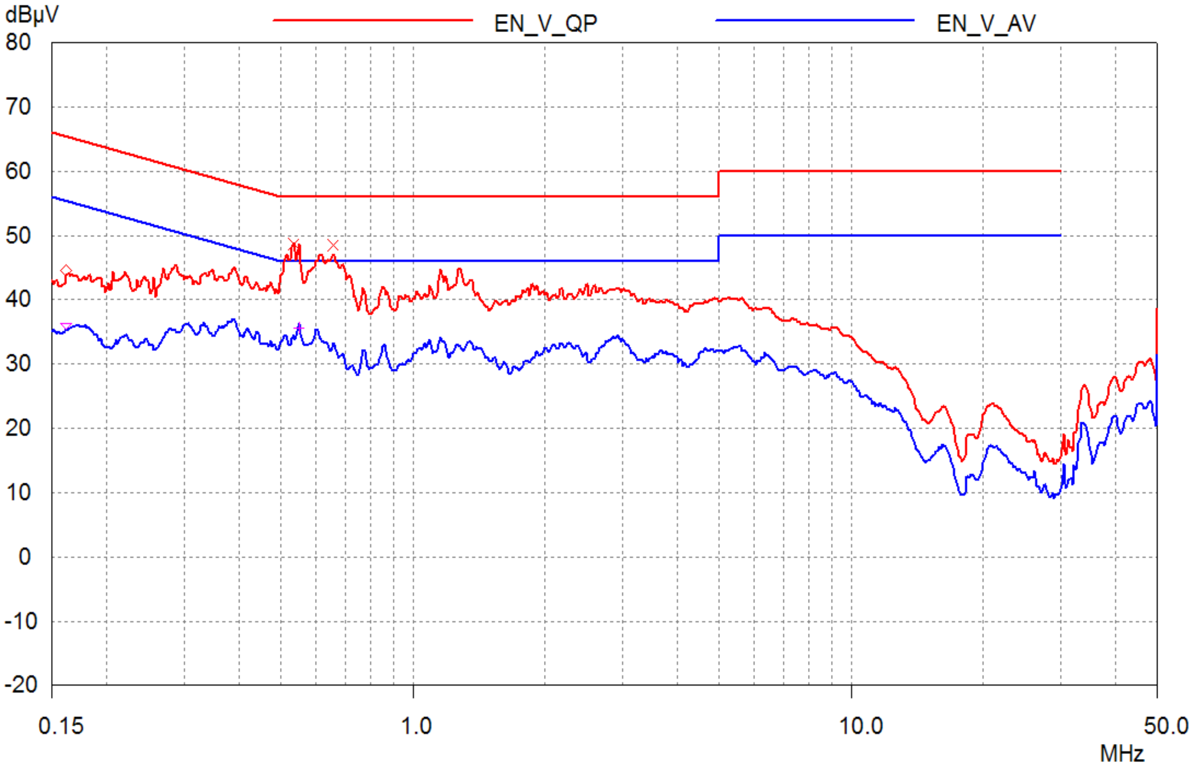

Figure 67 – Conducted EMI, Actual BLE Load, 230 VAC, 60 Hz, and EN55022 B Limits.

14 Line Surge

The unit was subjected to ±2500 V; 100 kHz ring wave and ±2000 V differential surge using 10 strikes at each condition. A test failure was defined as a non-recoverable interruption of output requiring repair or recycling of input voltage.

14.1 *Differential Surge Test Results*

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2000	230	L to N	0	Pass
-2000	230	L to N	0	Pass
+2000	230	L to N	90	Pass
-2000	230	L to N	90	Pass

14.2 *Ring Wave Surge Test Results*

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

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14.3 *2 kV Differential Surge Test Waveforms*

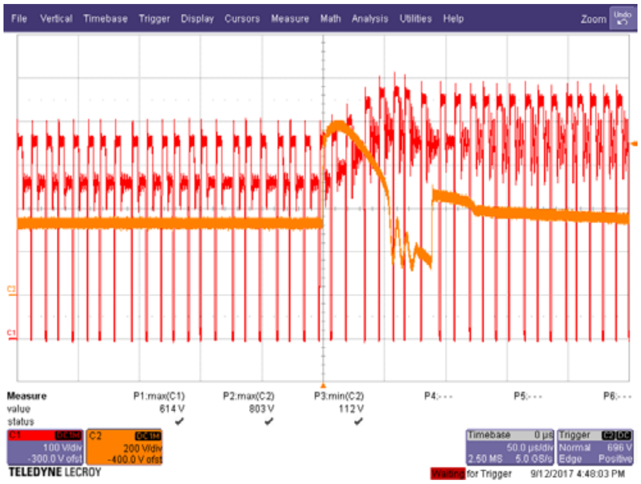

Figure 68 – (+)2 kV Differential Surge,
90º Phase Angle.
CH1: V_{DRAIN}, 100 V / div., 50 µs / div.
Peak V_{DRAIN}: 614 V.

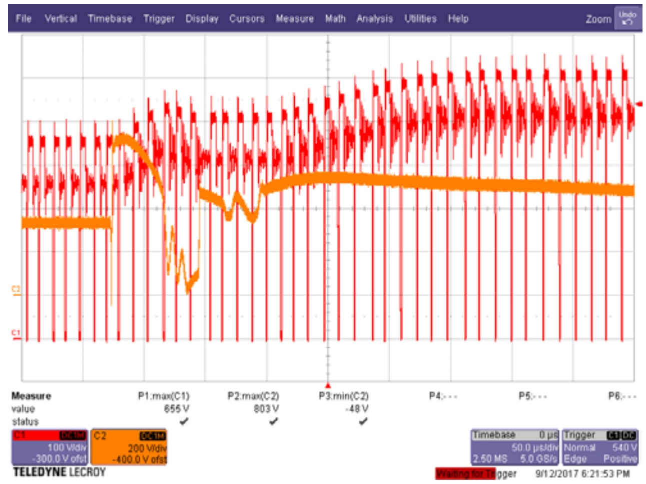

Figure 69 – (+)2 kV Differential Wave Surge,
0º Phase Angle.
CH1: V_{DRAIN}, 100 V / div., 50 µs / div.
Peak V_{DRAIN}: 655 V.

14.4 *2.5 kV Ring Wave Surge Test*

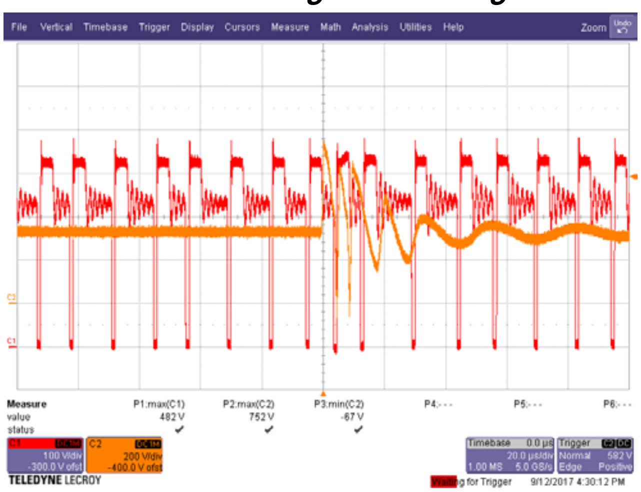

Figure 70 – (+) 2.5 kV Ring Wave Surge,
90º Phase Angle.
CH1: V_{DRAIN}, 100 V / div., 20 µs / div.
Peak V_{DRAIN}: 482 V.

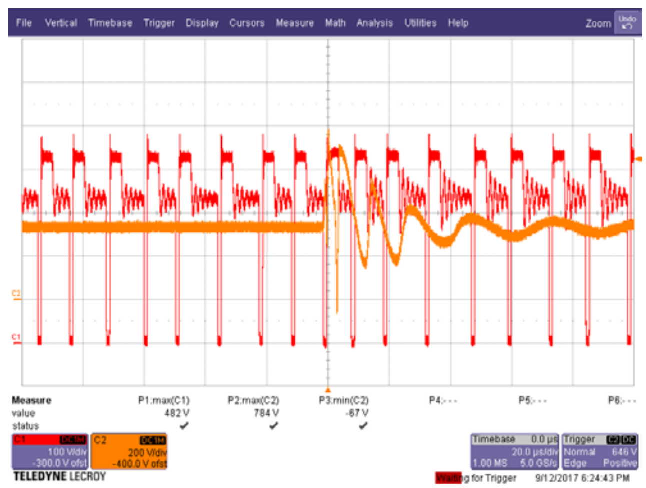

Figure 71 – (-) 2.5 kV Ring Wave Surge,
90º Phase Angle.
CH1: V_{DRAIN}, 100 V / div., 20 µs / div.
Peak V_{DRAIN}: 482 V.

15 Revision History

Date	Author	Revision	Description & changes	Reviewed
27-Mar-18	Donnie	1.0	Initial Release.	Apps & Mktg

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