Design Example Report

Title	***Two-Wire (No Neutral), Wide-Range, Non-Isolated Flyback, Bluetooth Wall Switch Using LinkSwitch™-TN2 LNK3202D***
Specification	90 VAC – 277 VAC Input
Application	Lighting Control
Author	Applications Engineering Department
Document Number	DER-622
Date	May 02, 2018
Revision	1.1

Summary and Features

- Compatible with 2-wire (no neutral), home/building wiring
- Non-isolated LNK3202D power supply with half-wave rectifier
- Low-component count with integrated 725 V MOSFET, current-sensing, and protection
- Wide-range AC input
- 3 W to 250 W load
- <300 μA standby current (with 15 mW BLE load) at 230 VAC
- <75 μA no-load input current at 230 VAC
- <15 mW no-load input power at 230 VAC

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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 two-wire (no neutral) Bluetooth low-energy (BLE) smart wall switch using LinkSwitch-TN2 LNK3202D. This demo board is intended as a general purpose evaluation platform for LinkSwitch-TN2.

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

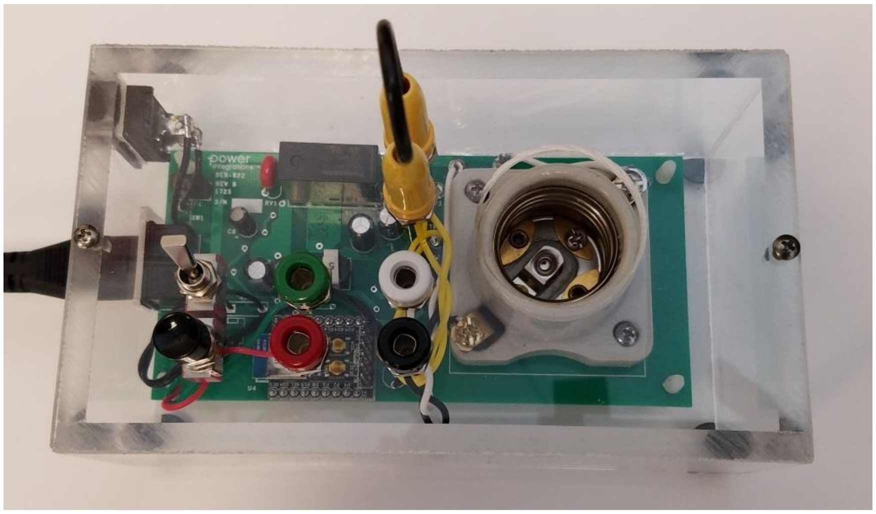

Figure 1 – Populated Circuit Board Photograph, Top.

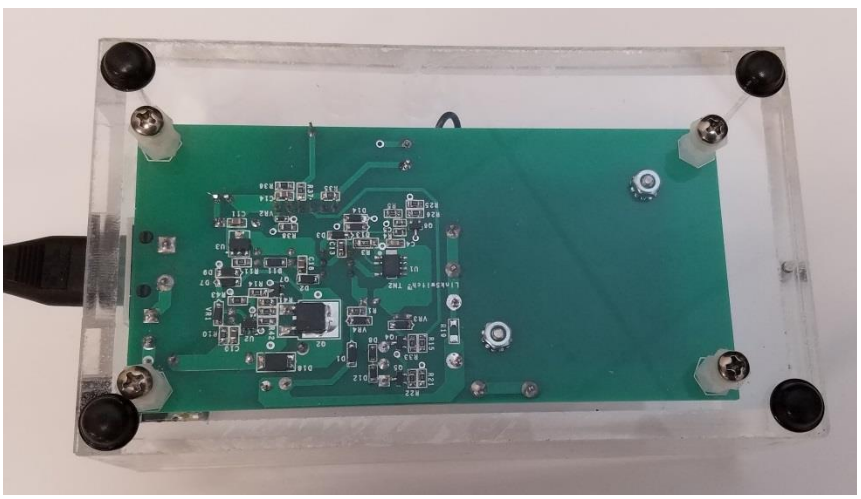

Figure 2 – Populated Circuit Board Photograph, Bottom.

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		277	VAC	
Frequency	f_{LINE}	47	50/60	64	Hz	
Rated Load						
Resistive Load		3		250	W	
LED Bulb		3	5		W	
LinkSwitch-TN2 Block						
Output Voltage 1	V_{OUT1}		3.8		V	
Output Current 1	I_{OUT1}		5	50	mA	
Output Voltage 2	V_{OUT2}		12		V	
Output Current 2	I_{OUT2}		20		mA	Peak Load.
3.3 V LDO Voltage	V_{OUT3}		3.3		V	
3.3 V LDO Current	I_{OUT3}		5	50	mA	
No-Load Input Current			65	75	μA	At 230 VAC, After 5 Minutes.
			70	80	μA	At 120 VAC, after 5 Minutes.
No-Load Input Power			12		mW	At 230 VAC, after 5 Minutes.
			5		mW	At 120 VAC, after 5 Minutes.
BLE Module						
Power Consumption			16		mW	
Ambient Temperature	T_{AMB}		40		ºC	Free Convection, Sea Level.

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3 Schematic

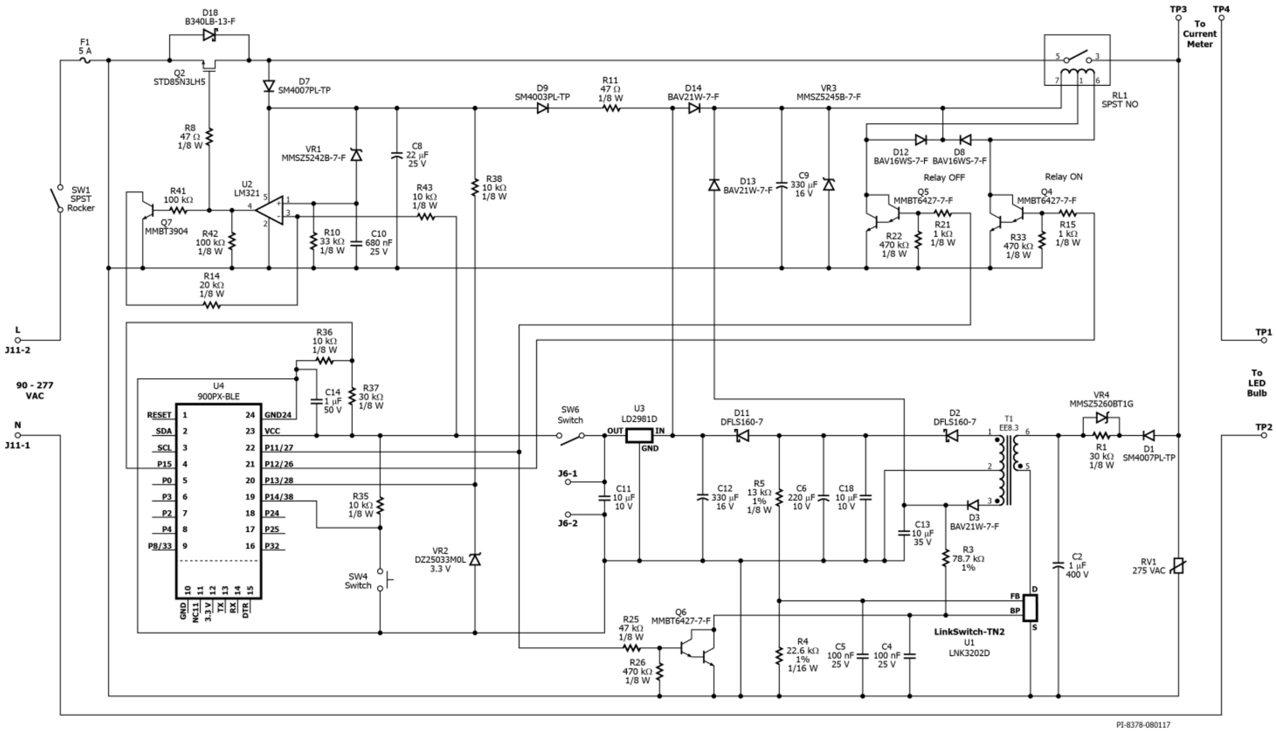

Figure 3 – Schematic.

4 Circuit Description

4.1 ***LinkSwitch-TN2 Block***

4.1.1 Input Stage

The input is half-wave rectified by diode D1. Resistor R1 reduces the peak input current which effectively reduces the input RMS current. A value of 30 kΩ was chosen to provide the maximum current reduction that can still deliver the required load power. At cold start-up, large inrush current may be present. Zener diode VR4 bypasses the input resistor R1 during start-up to be able to operate the circuit properly. The Zener voltage rating is chosen to be higher than the voltage drop on R1 at nominal load. Capacitor C2 provides energy storage as well as EMI filtering. Fuse RV1 provides surge protection.

4.1.2 LinkSwitch-TN2 Circuit Operation

The controller IC, U1, is configured as a non-isolated flyback switch regulator. Flyback was chosen over buck converter due to better power factor performance of the former which essentially reduces the input RMS current.

The main flyback rail is formed by the controller U1, transformer T1, diode D2, and capacitor C6. Capacitor C18 helps reduce the output ripple on the 3.8 V output.

During normal operation, the IC is powered by the DRAIN (D) pin and charges the BYPASS (BP) pin capacitor C4. The BP pin capacitor, with a value of 100 nF, programs the current limit to increased mode to provide higher power despite of having a very small transformer T1.

4.1.3 Bias Supply

Transformer T1, D3, and C13 provide 12 V auxiliary supply to externally bias the BP through R3. The value of R3 is tuned to provide the lowest no-load input current by setting the BP current between 80 μA and 100 μA. The bias supply also charges the capacitor C9 through D13 which provides the energy to the relay coils.

4.1.4 Feedback

Output voltage is sampled by the FEEDBACK (FB) pin through the feedback resistors R4 and R5. Capacitor C5 provides noise filtering.

4.2 ***Low Drop-Out Regulator Block***

The 3.3 V regulator consists of C12, U3, and C11. When the relay is OFF, the input to the LDO comes from LinkSwitch-TN2 through D11. When the relay is ON, the supply comes from Q2 regulator via D9 and R11.

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4.3 *Relay Circuit Block*

A 12 V, 2-coil, latching relay RL1 from Panasonic (ADW1203HT) was used. Unlike conventional relay, latching type remembers its last state even when the power is gone, similar to that of a regular wall switch.

Another advantage of using a latching relay is lower power consumption. The coils only need to be energized for around 10 ms and as soon as the relay is latched, the supply can be disconnected.

Transistor Q5, R21, R22 drives the relay OFF while Q4, R15, R33 drives the relay ON. Diode D8 and D12 provide protection from inductive kick. Zener diode VR3 prevents damage to the coil in case the voltage exceeds its maximum rating. When the relay is OFF, the coil is energized from LinkSwitch-TN2 via D13. When the relay is ON, it comes from Q2 regulator via D14.

4.4 *Regulator Circuit Block*

When the relay is OFF, LinkSwitch-TN2 provides 3.3 V and 12 V outputs to power the Bluetooth module and the relay, respectively. As soon as the relay turns ON, however, LinkSwitch-TN2 will turn OFF since the input to the device comes from the relay contacts voltage, which is at 0 V. An auxiliary regulator circuit is necessary to supply the power when the relay is ON.

There are several ways to implement the regulator circuit. The most important consideration is thermal performance. Since Q2 is in series with the line, it must handle the load current, which can be as high as 5 A. The op-amp U2 circuit block controls Q2 switching to allow low-power dissipation by fully turning ON the MOSFET once the threshold set by VR1 + 3.3 V is exceeded. The ON duration is set to about 10 ms by tuning the R-C circuit R10 and C10, tuning C8, and using hysteresis on the input comprised of Q7, R14, R41, R42, and R43. Diode D18 is added to prevent the load current from passing through Q2 body diode once the MOSFET turns OFF. The diode has to be rated to handle the load current. R8 is the series gate resistor.

The regulator circuit used in this DER has some restrictions.

a. Since the MOSFET is turned ON and OFF every other line cycle, some non-PF LED bulbs might shimmer. The pseudo-zero-crossing detection set by tuning the ON-time duration is sufficient to prevent shimmer in most bulbs, but some non-PF bulbs may disrupt the timing and may cause shimmer.

b. At higher power bulb load (>250 W), the regulator voltage across C8 may drop below 9 V, which may prevent the relay from properly turning ON/OFF.

c. There is a minimum load required to operate the switch properly. Unlike conventional wall switch with line and neutral, the bulb load is required to close the power loop. If the load is too small, it presents a high impedance or open-circuit; hence, the BLE switch will not work.

d. It is not advisable to use smart bulbs with the wall switch. When the smart bulb is remotely turned OFF, for example, it usually goes into low-power mode and the BLE switch might stop working because the load drops below the minimum requirement.

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

This DER uses Anaren Integrated Radio (AIR) module A20737A based on Broadcom (Cypress) SoC transceiver BCM20737A. The module is compliant to Bluetooth v4.1 Core Specifications.

The daughter board U4 from KD Circuits BLEA20737 was used to streamline the programming and layout aspects.

4.5.1 Pin Functions

Pin Number	Description
P14/38	Configured as Digital Input. Detects the push-button switch SW4 state. R35 is the pull-up resistor.
P13/28	Configured as ADC Input. The pin detects the relay state by sensing the voltage across C8 via R38. VR2 clamps the voltage to 3.3 V to protect the pin from overvoltage.
P12/26	Configured as Digital Output. Provides a pulse to turn ON the latching relay.
P11/27	Configured as Digital Output. Provides a pulse to turn OFF the latching relay and to reset the BP pin to clear any fault condition. Q6, R25 and R26 form the reset circuit.
P15	ADC reference voltage formed by R36 and R37 voltage divider.

Table 1 – Bluetooth Module Pin Description.

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4.5.2 Application Flowchart

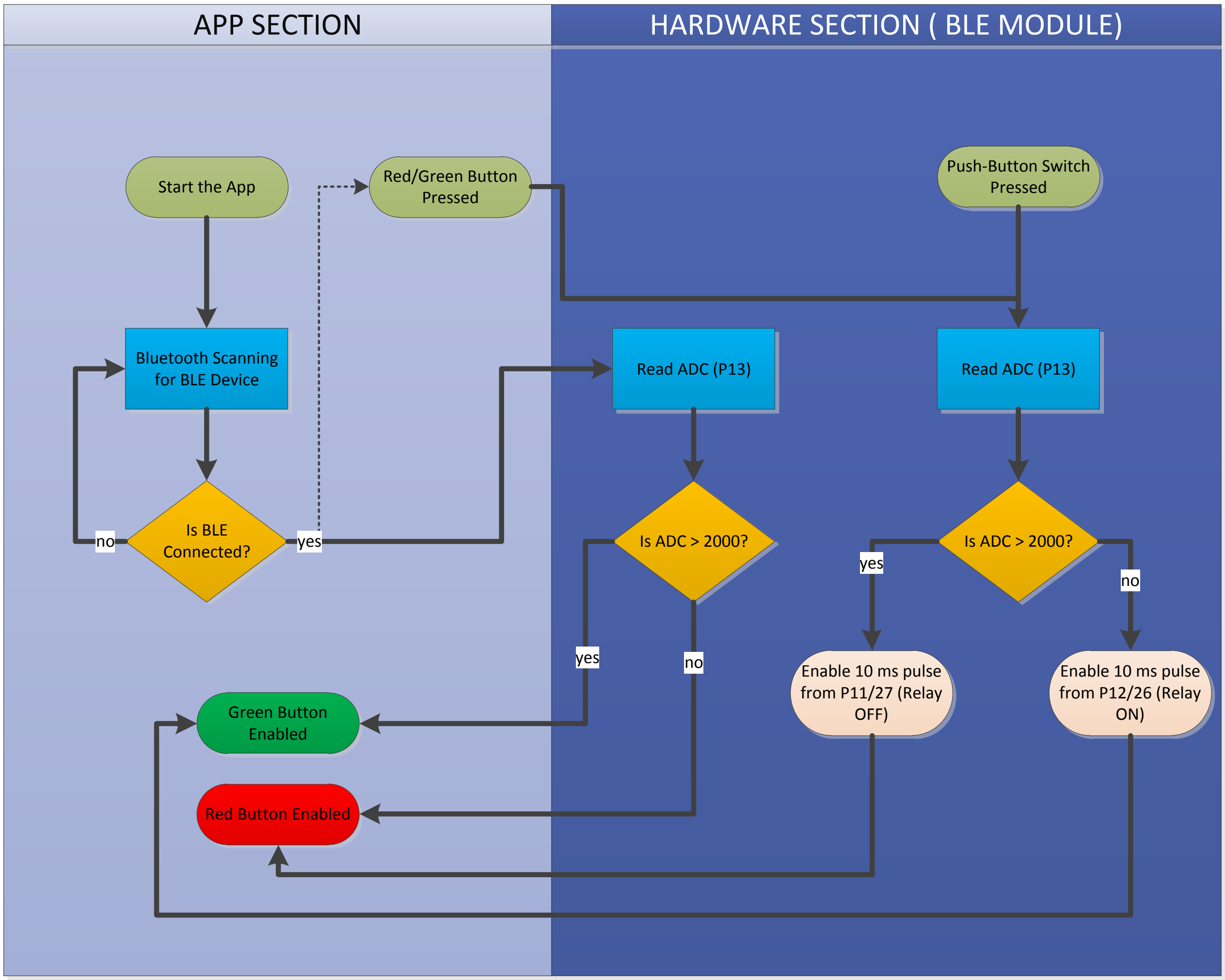

Figure 4 – BLE Application Flowchart.

4.6 ***Using the App***

This DER comes with a companion app to test the Bluetooth functionality.

Step 1: Power-up the BLE wall switch.

Step 2: Install Anaren Atmosphere App on Android or IOS devices that support Bluetooth 4.0 or higher.

Step 3: Turn-ON the Bluetooth on the mobile device.

Step 4: Open the Anaren App and log-in using the following credential:
Username: powerintegrations
Password: powerint12!

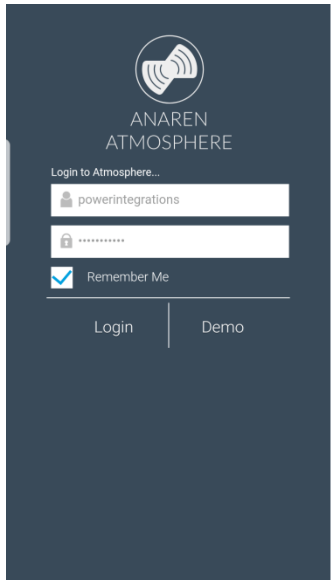

Figure 5 – Log-in Section.

Step 5: Wait for "Connected" status to appear. If it does not connect after 10 seconds, recycle the AC and restart the app.

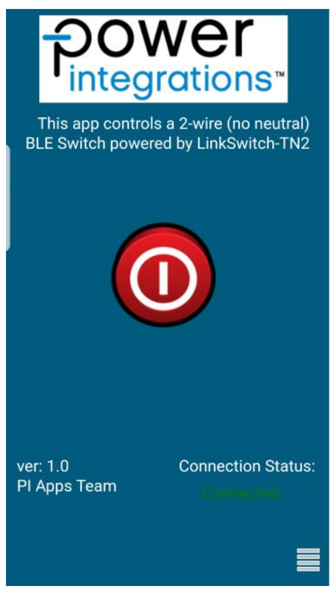

Figure 6 – "Connected" Status.

Step 6: Press the red/green button to toggle the wall switch.

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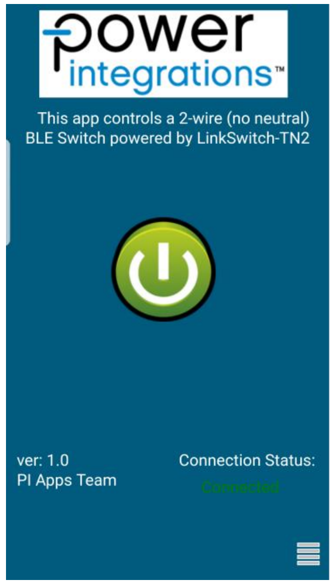

Figure 7 – Switch-ON.

4.7 ***Using the Demo Board***

4.7.1 Demo Board Components

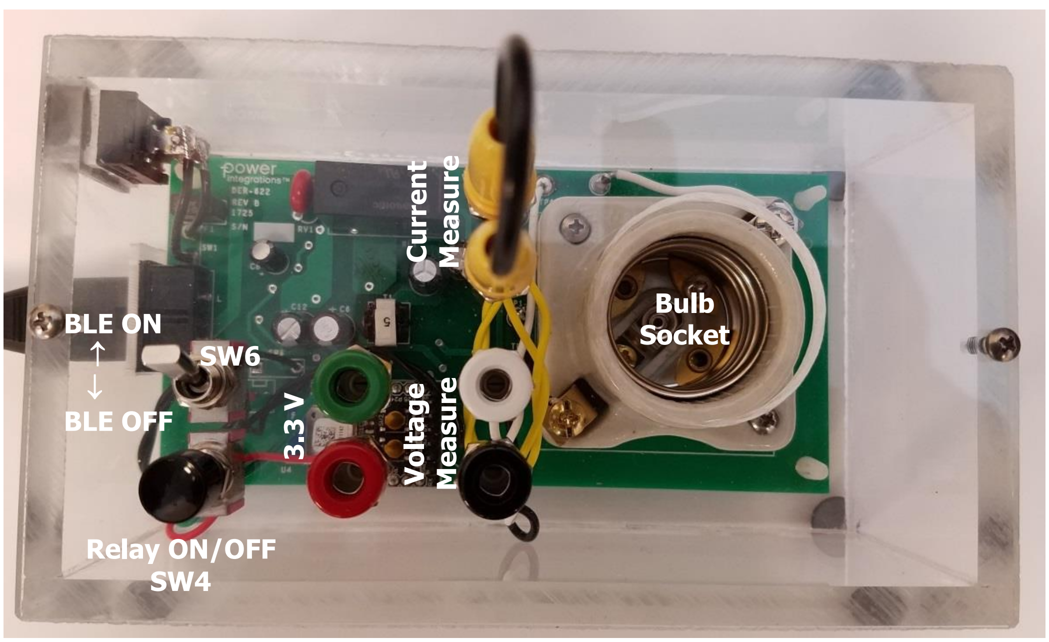

Figure 8 – Demo Board Components, Top.

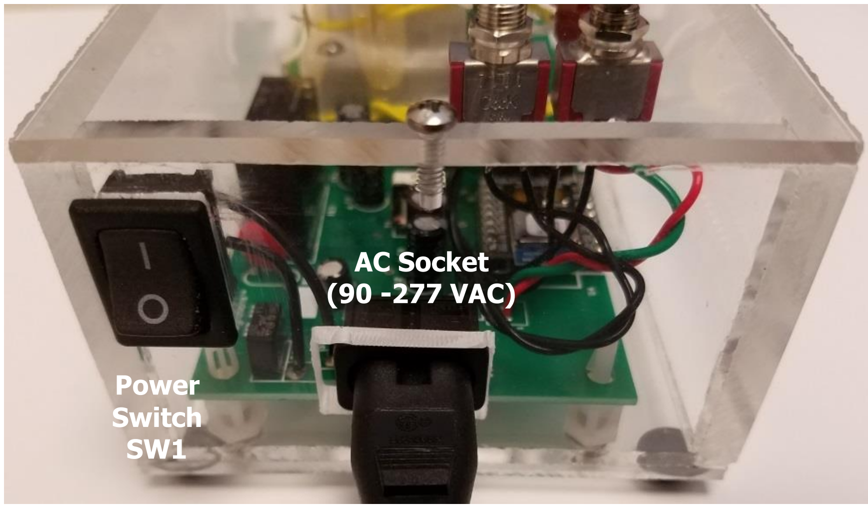

Figure 9 – Demo Board Components, Front.

4.7.2 Power-up Procedure

1. Connect the bulb.
2. Connect a jumper between the yellow banana jacks.
3. Apply nominal input voltage (120 VAC or 230 VAC).
4. Turn on the power switch SW1.
5. Put the toggle switch in BLE ON position.
6. Press the push-button switch SW4 to turn ON/OFF the bulb.
7. Use the smartphone app to control the bulb remotely.

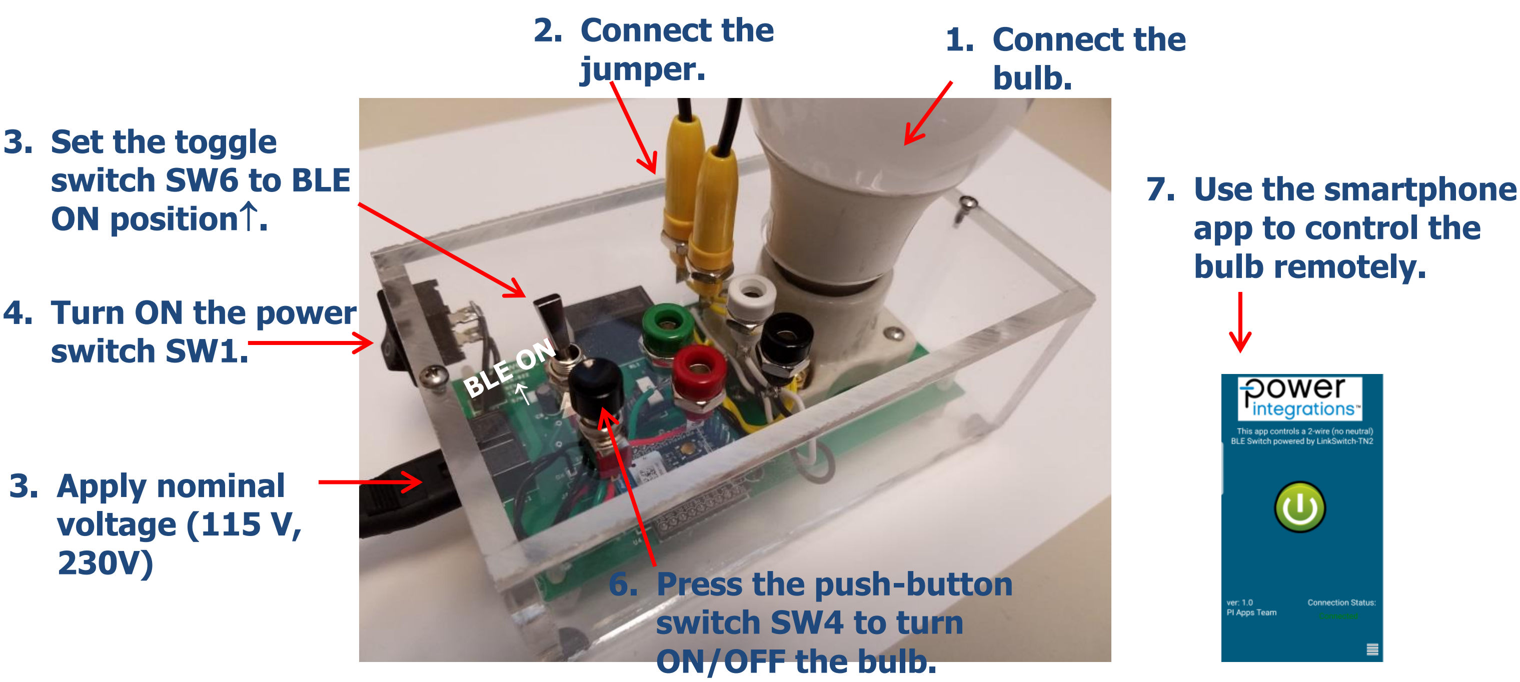

Figure 10 – Power-up Procedure.

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4.7.3 Input Current Measurement Procedure

1. Make sure that the relay is in OFF position (bulb is OFF).
2. Turn OFF the power switch SW1.
3. Remove the jumper cables between the yellow banana jacks.
4. Connect a true RMS current meter to the yellow banana jacks.
5. Set the current meter to μA (AC).
6. Set the power switch SW1 to ON position.
7. If the toggle switch SW6 is in BLE ON position, the measured input current will include the Bluetooth module power consumption.
8. If the toggle switch SW6 is in BLE OFF position, the measured input current is the no-load consumption.
9. Allow at least 5 minutes before taking measurements in order to allow the unit to settle.

Figure 11 – Input Current, No-Load, 230 VAC.

Figure 12 – Input Current, With BLE Load, 230 VAC.

4.7.4 Using the 3.3 V Output to Supply Other Wireless Module

1. Set the toggle switch SW6 to BLE OFF position.
2. Connect the red jack to the 3.3 V supply rail (VCC) of the target module.
3. Connect the green jack to the GND rail of the target module.

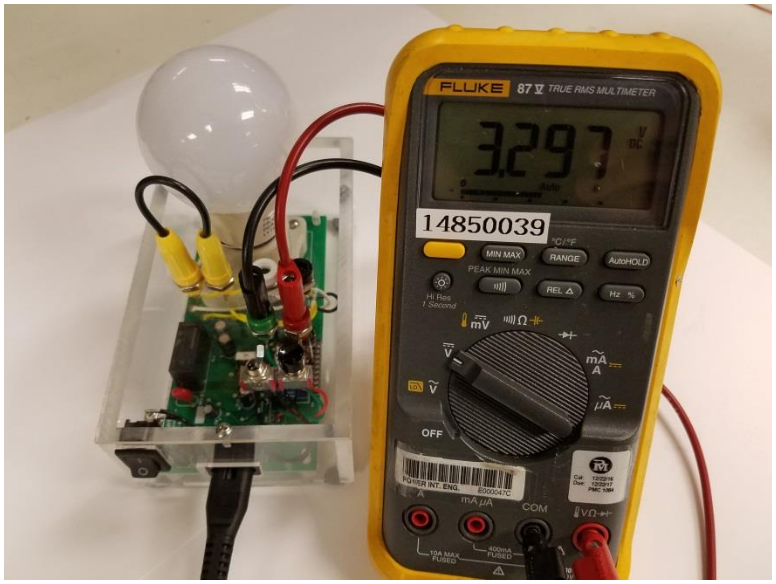

Figure 13 – 3.3 V Output Measurement.

4.7.5 Measuring the Input Voltage

1. Connect a volt meter to the black and white banana jacks.
2. When the bulb is OFF, the measured voltage is the leakage voltage.
3. When the bulb is ON, the measured voltage is the supply voltage.

Figure 14 – Leakage Voltage, Bulb is OFF.

Figure 15 – Input Voltage, Bulb is ON.

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5 PCB Layout

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

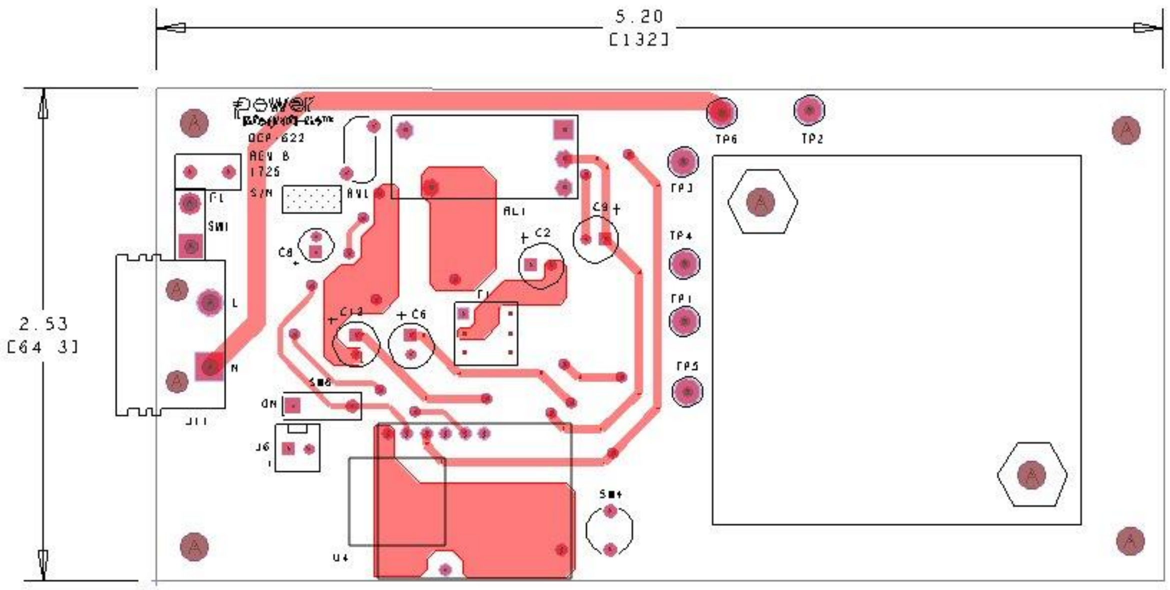

Figure 16 – Printed Circuit Layout, Top.

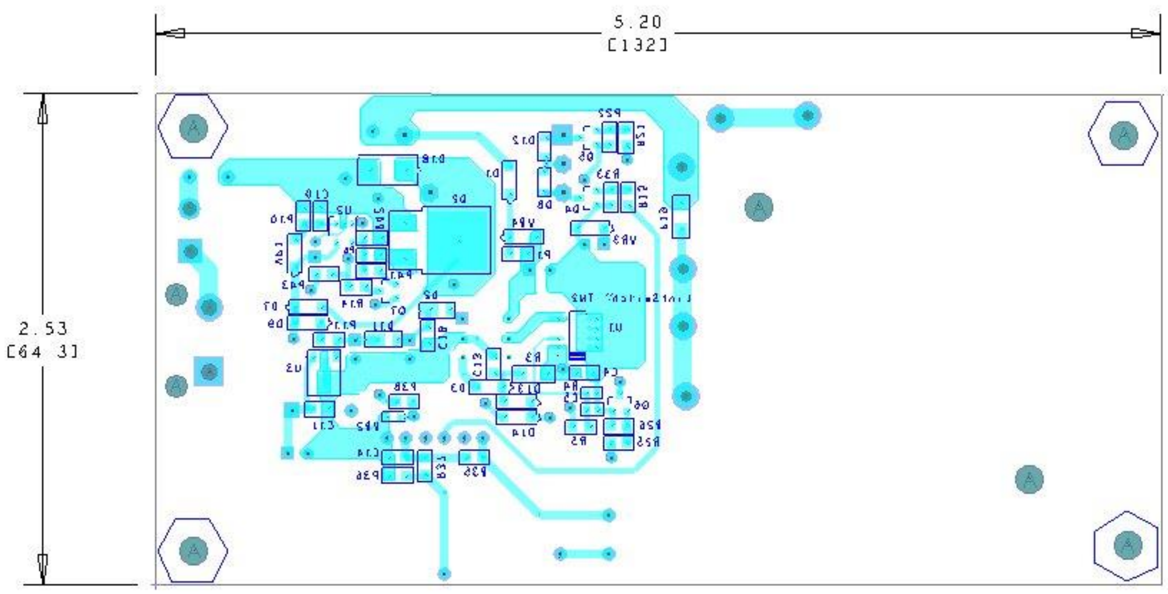

Figure 17 – Printed Circuit Layout, Bottom.

6 Bill of Materials

6.1 *Electrical BOM*

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	C2	1 μF, 400 V, Electrolytic, (6.3 x 11)	EKMG401ELL1R0MF11D	United Chemi-Con
2	1	C4	100 nF, 25 V, Ceramic, X7R, 0805	08053C104KAT2A	AVX
3	1	C5	100 nF, 25 V, Ceramic, X7R, 0603	VJ0603Y104KNXAO	Vishay Vitramon
4	1	C6	220 μF, 10 V, Electrolytic, Very Low ESR, 130 mΩ, (6.3 x 11)	EKZE100ELL221MF11D	Nippon Chemi-Con
5	1	C8	22 μF, 25 V, Electrolytic, 20 %, Gen. Purpose, (5 x 7 mm)	EEA-GA1E220	Panasonic
6	1	C9	330 uF, 16 V, Alum	UVY1C331MED	Nichicon
7	1	C10	680 nF,25 V, Ceramic, X7R, 0805	GRM219R71E684KA88D	Murata
8	1	C11	10 μF, 10 V, Ceramic, X7R, 0805	C2012X7R1A106M	TDK
9	1	C12	330 μF, 16 V, Alum	UVY1C331MED	Nichicon
10	1	C13	10 μF, 35 V, Ceramic, X5R, 0805	C2012X5R1V106K085AC	TDK
11	1	C14	1 μF,50 V, Ceramic, X7R, 0805	C2012X7R1H105M085AC	TDK
12	1	C18	10 μF, 10 V, Ceramic, X7R, 0805	C2012X7R1A106M	TDK
13	1	D1	1000 V, 1 A, Standard Recovery, SOD-123FL	SM4007PL-TP	Micro Commercial
14	1	D2	60 V, 1 A, DIODE SCHOTTKY, PWRDI 123	DFLS160-7	Diodes Inc.
15	1	D3	250 V, 0.2 A, Fast Switching, 50 ns, SOD-123	BAV21W-7-F	Diodes, Inc.
16	1	D7	1000V, 1 A, Standard Recovery, SOD-123FL	SM4007PL-TP	Micro Commercial
17	1	D8	75 V, 0.15 A, Switching,SOD-323	BAV16WS-7-F	Diodes, Inc.
18	1	D9	200V, 1 A, Standard Recovery, SOD-123FL	SM4003PL-TP	Micro Commercial
19	1	D11	60 V, 1 A, DIODE SCHOTTKY, PWRDI 123	DFLS160-7	Diodes, Inc.
20	1	D12	75 V, 0.15 A, Switching,SOD-323	BAV16WS-7-F	Diodes, Inc.
21	1	D13	250 V, 0.2 A, Fast Switching, 50 ns, SOD-123	BAV21W-7-F	Diodes, Inc.
22	1	D14	250 V, 0.2 A, Fast Switching, 50 ns, SOD-123	BAV21W-7-F	Diodes, Inc.
23	1	D18	40 V, 3 A, Schottky, SMD, DO-214AA	B340LB-13-F	Diodes, Inc.
24	1	F1	5 A, 250 V, Slow, Long Time Lag,RST	RST 5	Belfuse
25	1	Q2	30 V, 80 A, 5.0 mΩ, N-Channel, DPAK	STD85N3LH5	ST
26	1	Q4	NPN, DARL NPN 40 V SMD SOT23-3	MMBT6427-7-F	Diodes, Inc.
27	1	Q5	NPN, DARL NPN 40 V SMD SOT23-3	MMBT6427-7-F	Diodes, Inc.
28	1	Q6	NPN, DARL NPN 40 V SMD SOT23-3	MMBT6427-7-F	Diodes, Inc.
29	1	Q7	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3904LT1G	On Semi
30	1	R1	RES, 30 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ303V	Panasonic
31	1	R3	RES, 78.7 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF7872V	Panasonic
32	1	R4	RES, 22.6 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2262V	Panasonic
33	1	R5	RES, 13 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1302V	Panasonic
34	1	R8	RES, 47 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ470V	Panasonic
35	1	R10	RES, 33 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ333V	Panasonic
36	1	R11	RES, 47 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ470V	Panasonic
37	1	R14	RES, 20 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ203V	Panasonic
38	1	R15	RES, 1 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ102V	Panasonic
39	1	R21	RES, 1 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ102V	Panasonic
40	1	R22	RES, 470 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ474V	Panasonic
41	1	R25	RES, 47 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ473V	Panasonic
42	1	R26	RES, 470 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ474V	Panasonic
43	1	R33	RES, 470 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ474V	Panasonic
44	1	R35	RES, 10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
45	1	R36	RES, 10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
46	1	R37	RES, 30 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ303V	Panasonic
47	1	R38	RES, 10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
48	1	R41	RES, 100 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ104V	Panasonic

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49	1	R42	RES, 100 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ104V	Panasonic
50	1	R43	RES, 10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
51	1	RL1	RELAY, GP, Dual coil, SPST (NO), 16 A, 12 VDC coils, 277 VAC, PCPin	ADW1212HTW	Panasonic
52	1	RV1	275 VAC, 23 J, 7 mm, RADIAL	V275LA4P	Littlefuse
53	1	SW1	SWITCH, Rocker, SPST, 10A, 125V, Snap-in, Panel Mount	SRB22A2FBBNN	ZF Electronics
55	1	SW4	Pushbutton Switches ON-(ON) SPDT SLDR MT	8121SHZGE	C&K
54	1	SW6	SWITCH TOGGLE SPDT 5A 120V, Panel Mount	7101P3YZQE	C&K
56	1	T1	Bobbin, EE8.3, Vertical, 6 pins (8.2 mm W x 8.2 mm L x 6.9 mm H) Transformer	EE-0802 PNK-32023	Zhenhui Premier Magnetics
57	1	U1	LinkSwitch-TN2, SO-8C	LNK3202D	Power Integrations
58	1	U2	OP AMP SINGLE LOW PWR SOT23-5	LM321MF	National Semi
59	1	U3	IC, REG, LDO, Pos, 3.3 V, 100 mA, SOT89-3	LD2981ABU33TR	ST Micro
60	1	U4	DEVELOPMENT MODULE FOR ANAREN A20737AGR	BLEA20737	KD Circuits
61	1	VR1	DIODE ZENER 12V 500MW SOD123	MMSZ5242B-7-F	Diodes, Inc.
62	1	VR2	3.3 V, 5%, 150 mW, SSMINI-2	DZ2S033M0L	Panasonic
63	1	VR3	DIODE ZENER 15 V 500 mW SOD123	MMSZ5245B-7-F	Diodes, Inc.
64	1	VR4	DIODE ZENER 43 V 500 mW SOD123	MMSZ5260BT1G	ON Semi

6.2 *Mechanical BOM*

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	6		Post, Circuit Board, Female, Hex, 6-32, snap, 0.375L, Nylon	561-0375A	Eagle Hardware
2	1	TP1	Test Point, BLK,THRU-HOLE MOUNT	5011	Keystone
3	1	TP2	Test Point, WHT,THRU-HOLE MOUNT	5012	Keystone
4	1	TP3	Test Point, RED,THRU-HOLE MOUNT	5010	Keystone
5	1	TP4	Test Point, RED,THRU-HOLE MOUNT	5010	Keystone
6	1	J6	2 Position (1 x 2) header, 0.1 pitch, Vertical	22-23-2021	Molex
7	1	J11	Power Entry Connector Receptacle, Male Pins, IEC 320-C8, Non-Polarized, Panel Mount, Snap-In; Through Hole, Right Angle	RAPC322X	Switchcraft
8	2		CONN JACK BANANA INSUL NYLON YEL	108-0907-001	Cinch Connectivity Solutions Johnson
9	1		CONN JACK BANANA INSUL NYLON WHI	108-0901-001	Cinch Connectivity Solutions Johnson
10	1		CONN JACK BANANA INSUL NYLON BLA	108-0903-001	Cinch Connectivity Solutions Johnson
11	1		CONN JACK BANANA INSUL NYLON GRE	108-0904-001	Cinch Connectivity Solutions Johnson
12	1		CONN JACK BANANA INSUL NYLON RED	108-0902-001	Cinch Connectivity Solutions Johnson
14	1		Switch Caps BLACK SWITCH CAP	752702000	C&K
17	1		Light Bulb Socket	14695K18	McMaster-Carr
18	4		BUMPER CYLINDRICAL 0.44" DIA BLK	SJ-5003 (BLACK)	3M
19	2		SCREW MACHINE PHIL 4-40 X 5/16 SS	PMSSS 440 0031 PH	Building Fasteners
20	4		SCREW MACHINE PHIL 6-32 X 5/16 SS	PMSSS 632 0031 PH	Building Fasteners
21	2		SCREW MACHINE PHIL 4-40 X 3/4 SS	PMSSS 440 0075 PH	Building Fasteners
22	2		Nut, Hex, Kep 4-40, S ZN Cr3 plating RoHS	4CKNTZR	Any RoHS Compliant Mfg.
23	1				Tap Plastics

7 Transformer Specification

7.1 *Electrical Diagram*

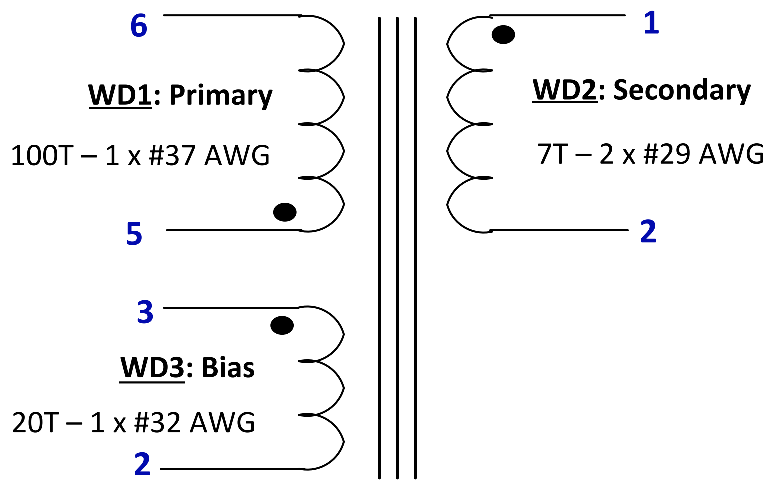

Figure 18 – Transformer Electrical Diagram.

7.2 *Electrical Specifications*

Primary Inductance	Pins 5-6, all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	620 µH, ±7%
Resonant Frequency	Pins 5-6, all other windings open.	1400 kHz (Min.)
Primary Leakage Inductance	Pins 5-6, with pins 1-2-3 shorted, measured at 100 kHz, 0.4 V_{RMS}.	20 µH (Max.)

7.3 *Material List*

Item	Description
[1]	Core: EE8.3.
[2]	Bobbin: EE8.3, Vertical, 6 pins (8.2 mm W x 8.2 mm L x 6.9 mm H).
[3]	Magnet Wire: #37 AWG.
[4]	Magnet Wire: #29 AWG.
[5]	Magnet Wire: #32 AWG.
[6]	Polyester Tape: 4.5 mm.
[7]	Varnish.

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7.4 ***Build Diagram***

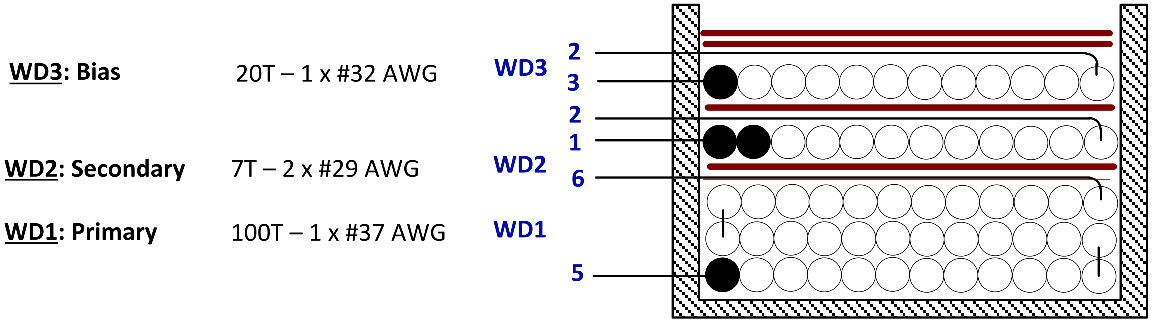

Figure 19 – Transformer Build Diagram.

7.5 ***Construction***

Primary	Start at pin 5. Wind 100 turns of item [3] in approximately 3 layers. Finish on pin 6.
Basic Insulation	Use 1 layer of item [6] for basic insulation.
Secondary Winding	Start at pin 1. Wind 7T bifilar turns of item [4] (1 layer). Finish on pin 2.
Basic Insulation	Use 1 layer of item [6] for basic insulation.
Bias Winding	Start at pin 3. Wind 20T turns of item [5] (1 layer). Finish on pin 2.
Outer Wrap	Wrap windings with 2 layers of tape [item [6].
Final Assembly	Assemble and secure core halves so that the tape wrapped E core is at the bottom of the transformer.
Varnish	Dip varnish uniformly in item [7]. Do not vacuum impregnate.

8 Transformer Design Spreadsheet

1	ACDC_LinkSwitchTN2_Flyback_021417; Rev.1.1; Copyright Power Integrations 2017	INPUT	INFO	OUTPUT	UNIT	ACDC_LinkSwitchTN2 Flyback Design Spreadsheet
2	**ENTER APPLICATION VARIABLES**					
3	LINE VOLTAGE RANGE			UNIVERSAL		AC line voltage range
4	VACMIN			85.00	Volts	Minimum AC line voltage
5	VACTYP			115.00	Volts	Typical AC line voltage
6	VACMAX			277.00	Volts	Maximum AC line voltage
7	fL			50	Hertz	AC mains frequency
8	TIME_BRIDGE_CONDUCTION			2.39	mseconds	Input bridge rectifier diode conduction time
9	LINE RECTIFICATION	F		F		Select 'F'ull wave rectification or 'H'alf wave rectification
10	VOUT	3.80		3.80	Volts	Output voltage
11	IOUT	0.065		0.065	Amperes	Average output current specification
12	CC THRESHOLD VOLTAGE			0.00	Volts	Voltage drop across the sense resistor
13	OUTPUT CABLE RESISTANCE			0.00	Ohms	Enter the resistance of the output cable (if used)
14	EFFICIENCY			0.80		Efficiency Estimate at output terminals. Under 0.8 if no better data available
15	LOSS ALLOCATION FACTOR			0.50		The ratio of power losses during the MOSFET off-state to the total system losses
16	POUT			0.25	Watts	Continuous Output Power
17	CIN			1.00	uFarads	Input capacitor
18	VMIN			98.71	Volts	Valley of the rectified VACMIN
19	VMAX			391.74	Volts	Peak of the VACMAX
20	FEEDBACK	BIAS		BIAS		Select the type of feedback required
21	BIAS WINDING	YES		YES		Select whether a bias winding is required
25	**LINKSWITCH-TN2 VARIABLES**					
26	CURRENT LIMIT MODE	STD		STD		Pick between RED(Reduced) or STD(Standard) current limit mode of operation
27	PACKAGE	SO-8C		SO-8C		Device package
28	GENERIC DEVICE	Auto		LNK3202		Device series
29	DEVICE CODE			LNK3202D		Device code
30	VOR	64		64	Volts	Voltage reflected to the primary winding when the MOSFET is off
31	VDSON			10.0	Volts	MOSFET on-time drain to source voltage
32	VDSOFF			546.1	Volts	MOSFET off-time drain to source voltage
33	ILIMITMIN			0.126	Amperes	Minimum current limit
34	ILIMITTYP			0.136	Amperes	Typical current limit
35	ILIMITMAX			0.146	Amperes	Maximum current limit
36	FSMIN			62000	Hertz	Minimum switching frequency
37	FSTYP			66000	Hertz	Typical switching frequency
38	FSMAX			72000	Hertz	Maximum switching frequency
39	RDSON			88.40	Ohms	MOSFET drain to source resistance
43	**PRIMARY WAVEFORM PARAMETERS**					
44	MODE OF OPERATION			DCM		Mode of operation
45	KRP/KDP			12.338		Measure of continuous/discontinuous mode of operation
46	KP_TRANSIENT			4.313		KP under conditions of a transient
47	DMAX			0.055		Maximum duty cycle
48	TIME_ON			0.891	useconds	MOSFET conduction time at the minimum line

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						voltage
49	TIME_ON_MIN			0.298	useconds	MOSFET conduction time at the maximum line voltage
50	IAVG_PRIMARY			0.003	Amperes	Average input current
51	IRMS_PRIMARY			0.017	Amperes	Root mean squared value of the primary current
52	LPRIMARY_MIN			565	uH	Minimum primary inductance
53	LPRIMARY_TYP			627	uH	Typical primary inductance
54	LPRIMARY_MAX			690	uH	Maximum primary inductance
55	LPRIMARY_TOL			10		Primary inductance tolerance
59	**SECONDARY WAVEFORM PARAMETERS**					
60	IPEAK_SECONDARY			2.086	Amperes	Peak secondary current
61	IRMS_SECONDARY			0.333	Amperes	Root mean squared value of the secondary current
62	PIV_SECONDARY			30.03	Volts	Peak inverse voltage on the secondary diode, not including the leakage spike
63	VF_SECONDARY			0.70	Volts	Secondary diode forward voltage drop
67	**TRANSFORMER CONSTRUCTION PARAMETERS**					
68	Core selection					
69	CORE	EE8		EE8		Select the transformer core
70	BOBBIN			B-EE8-H		Select the bobbin
71	AE			7.00	mm^2	Cross sectional area of the core
72	LE			19.20	mm	Effective magnetic path length of the core
73	AL			610.0	nH/(turns^2)	Ungapped effective inductance of the core
74	VE			0.0	mm^3	Volume of the core
75	AW			0.00	mm^2	Window area of the bobbin
76	BW			4.78	mm	Width of the bobbin
77	MLT			0.00	mm	Mean length per turn of the bobbin
78	MARGIN			0.00	mm	Safety margin
80	**Primary winding**					
81	NPRIMARY			100		Prmary number of turns
82	BMAX_TARGET			1500	Gauss	Target value of the magnetic flux density
83	BMAX_ACTUAL			1308	Gauss	Actual value of the magnetic flux density
84	BAC			654	Gauss	AC flux density
85	ALG			63	nH/T^2	Gapped core effective inductance
86	LG			0.126	mm	Core gap length
87	LAYERS_PRIMARY	3		3		Number of primary layers
88	AWG_PRIMARY			37		Primary winding wire AWG
89	OD_PRIMARY_INSULATED			0.140	mm	Primary winding wire outer diameter with insulation
90	OD_PRIMARY_BARE			0.113	mm	Primary winding wire outer diameter without insulation
91	CMA_PRIMARY		Info	1160	mil^2/Amperes	The primary winding wire CMA is higher than 500 mil^2/Amperes: Decrease the primary layers or wire thickness
93	**Secondary winding**					
94	NSECONDARY	7		7		Secondary turns
95	AWG_SECONDARY			31		Secondary winding wire AWG
96	OD_SECONDARY_INSULATED			0.532	mm	Secondary winding wire outer diameter with insulation
97	OD_SECONDARY_BARE			0.227	mm	Secondary winding wire outer diameter without insulation
98	CMA_SECONDARY			239	mil^2/Amperes	Secondary winding CMA
100	**Bias winding**					
101	NBIAS	20		20		Bias turns
102	VF_BIAS			0.70	Volts	Bias diode forward voltage drop
103	VBIAS			12.86	Volts	Bias winding voltage
104	PIVB			91.2	Volts	Peak inverse voltage on the bias diode
105	CBP			0.1	uF	BP pin capacitor
109	**FEEDBACK PARAMETERS**					

110	DIODE_BIAS			1N4003-4007		Recommended diode is 1N4003. Place diode on return leg of bias winding for optimal EMI
111	RUPPER			16200	ohms	CV bias resistor for CV/CC circuit. See LinkSwitch-TN2 Design Guide
112	RLOWER			3000	ohms	Resistor to set CC linearity for CV/CC circuit. See LinkSwitch-TN2 Design Guide

Notes: Rupper and Rlower values were increased to reduce the input current consumption. The ratio has been maintained. The actual configuration is non-isolated flyback. Feedback sensing is taken from the output voltage.

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9 Performance Data

All measurements performed at room temperature, 60 Hz input frequency. Unless otherwise specified, the data is taken with the relay in OFF position.

9.1 *System-Level Performance*

9.1.1 Input Current vs. Line, Actual BLE Load

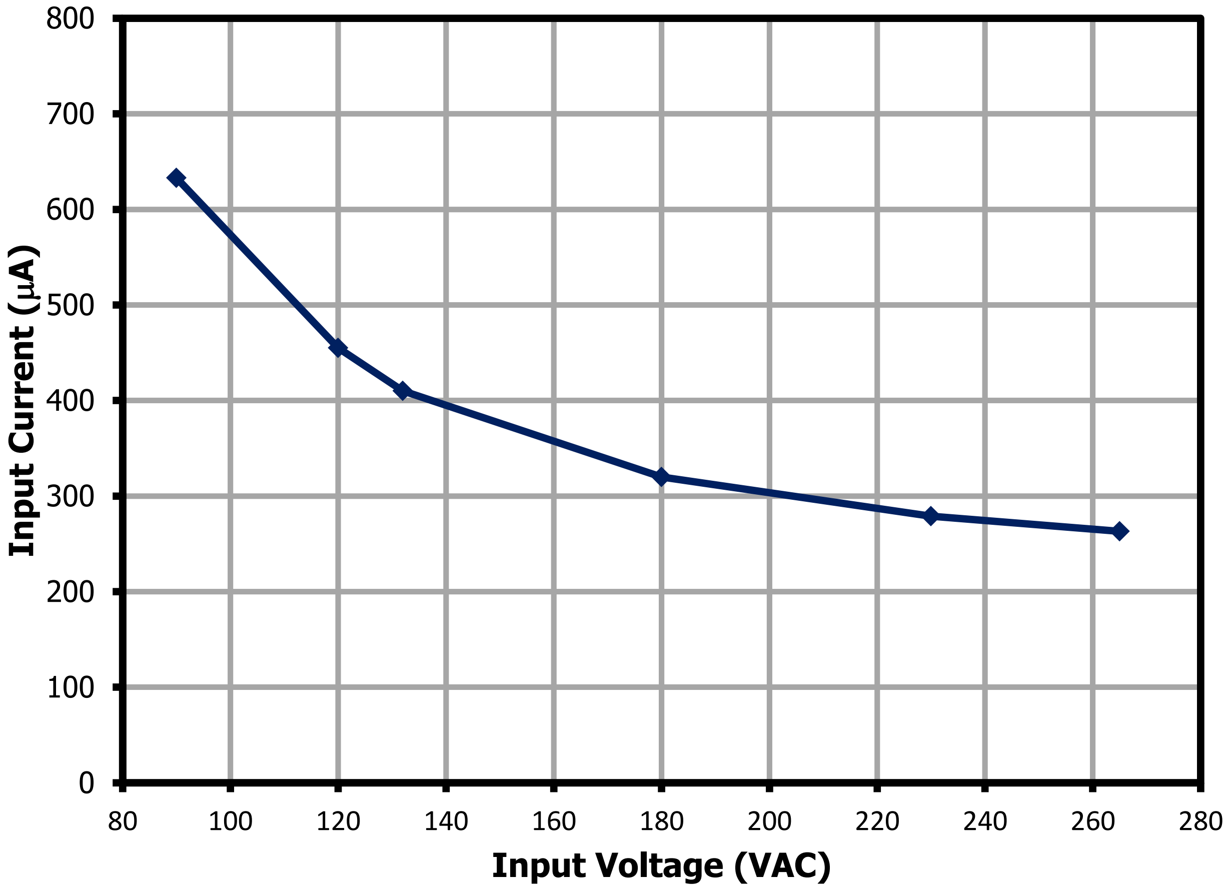

Figure 20 – Input Current vs. Line, Actual BLE Load.

9.2 *LinkSwitch-TN2 Power Supply Performance*

9.2.1 Input Current vs. Load (Simulated Load on 3.3 V LDO)

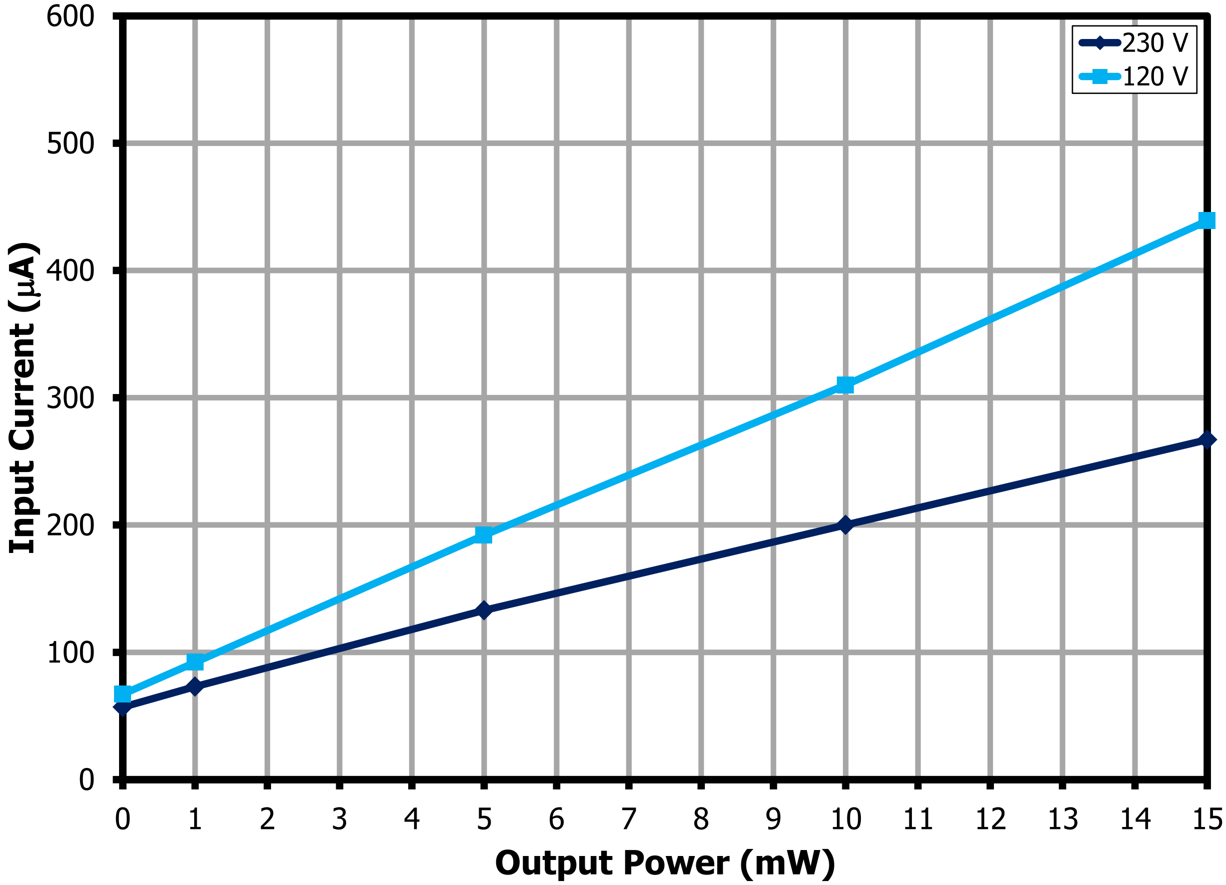

Figure 21 – Input Current vs. Load.

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9.2.2 Input Power vs. Load (Simulated Load on 3.3 V LDO)

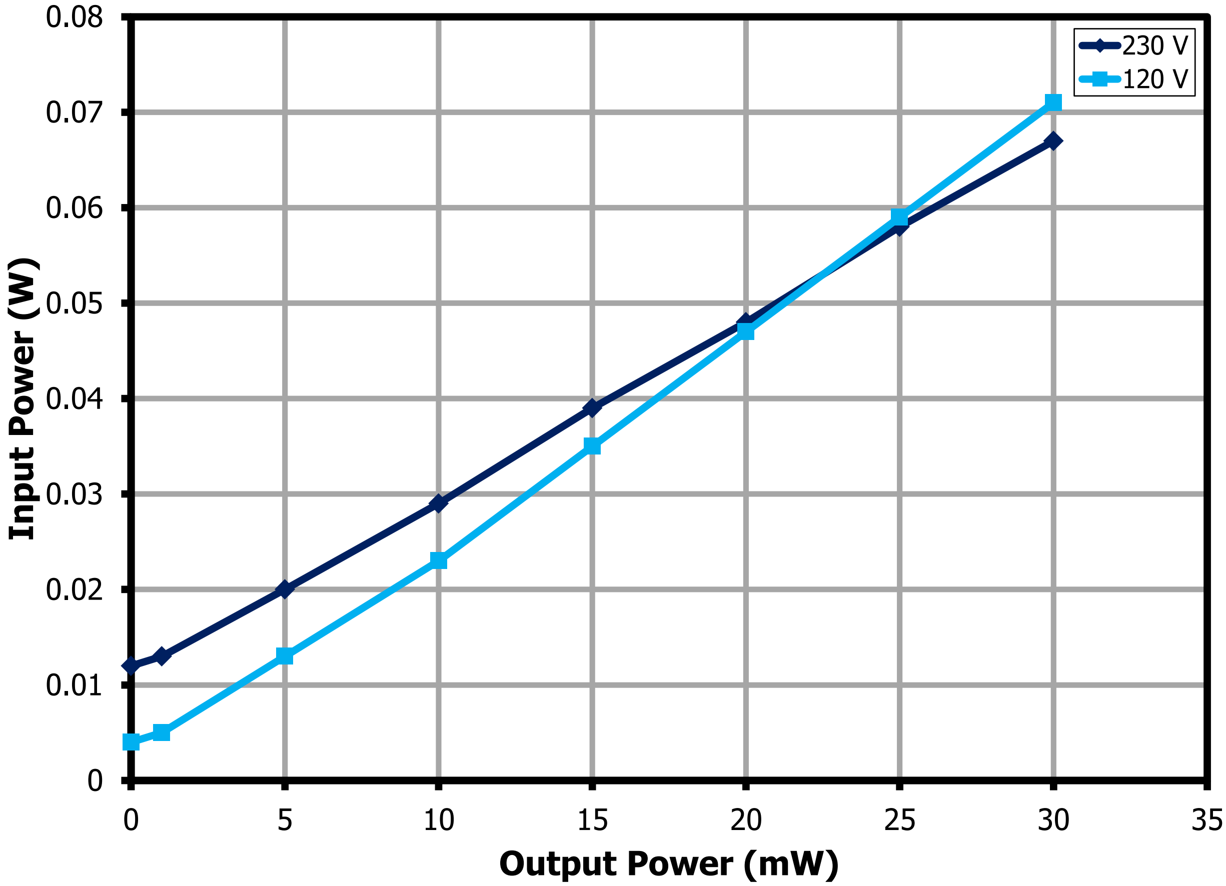

Figure 22 – Input Power vs. Load.

9.2.3 3.8 V Output Regulation vs. Load (Simulated Load on 3.3 V LDO)

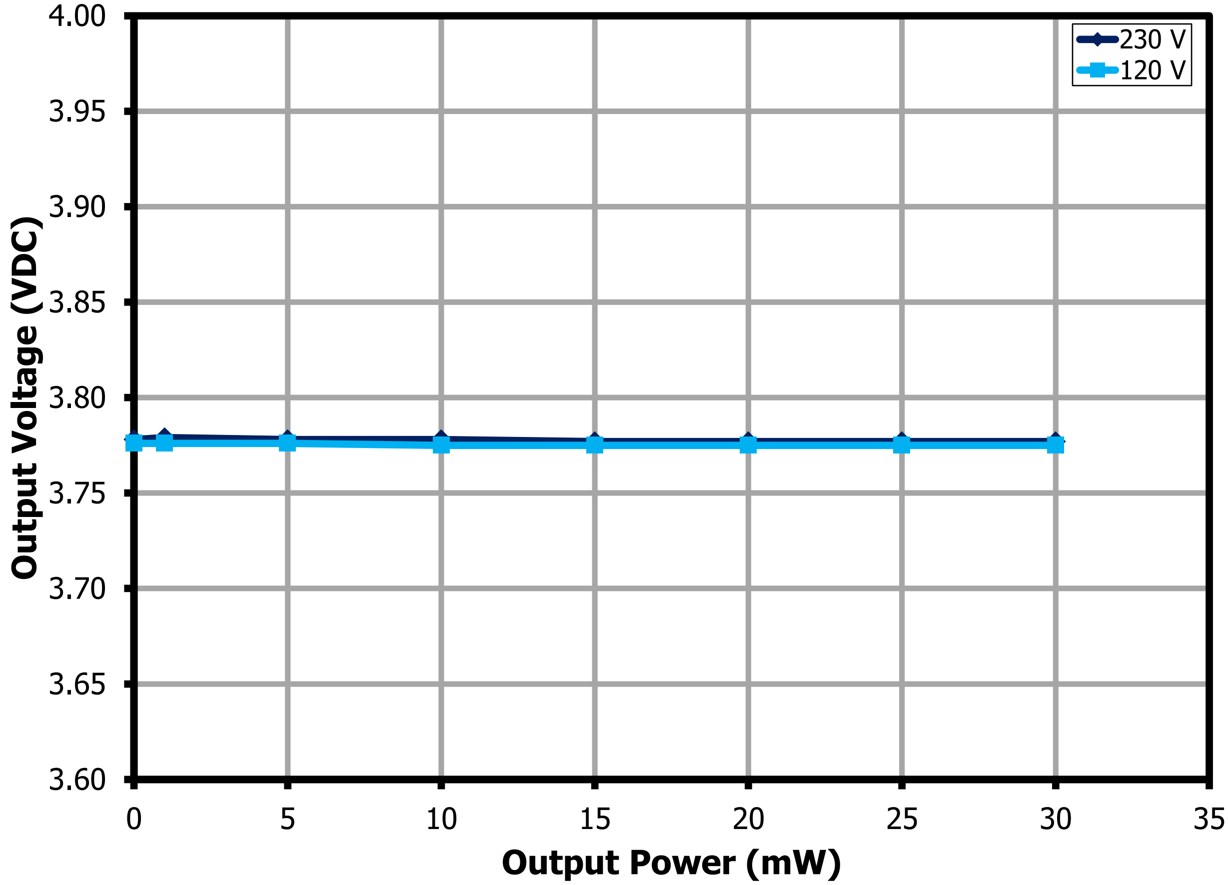

Figure 23 – 3.8 V Regulation vs Load.

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9.2.4 12 V Output Regulation vs. Load (Simulated Load on 3.3 V LDO)

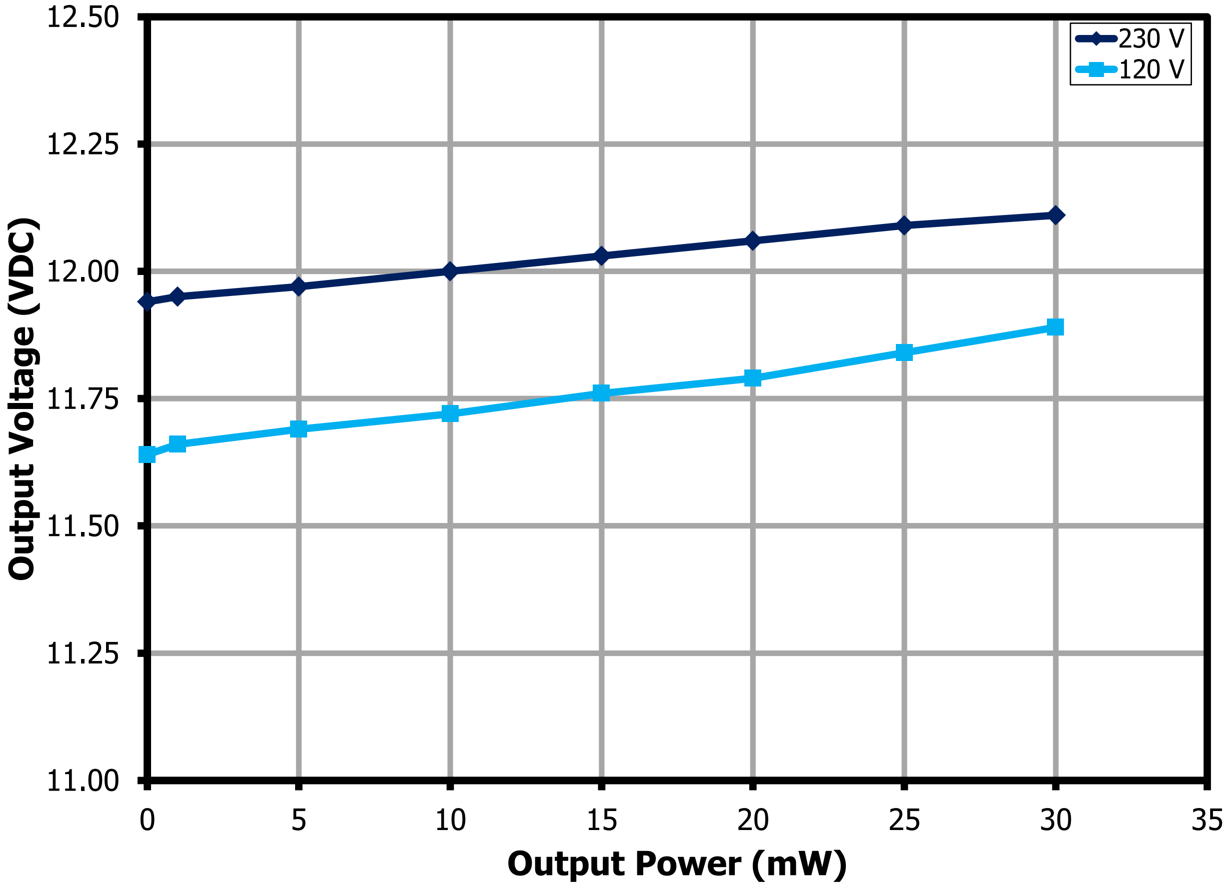

Figure 24 – 12 V Regulation vs. Load.

10 Thermal Performance

Input: 115 VAC, 60 Hz
Load: 4 x 75 W Incandescent Lamps
Ambient: 25 ºC
Hottest Component: D18 (41.9 ºC)

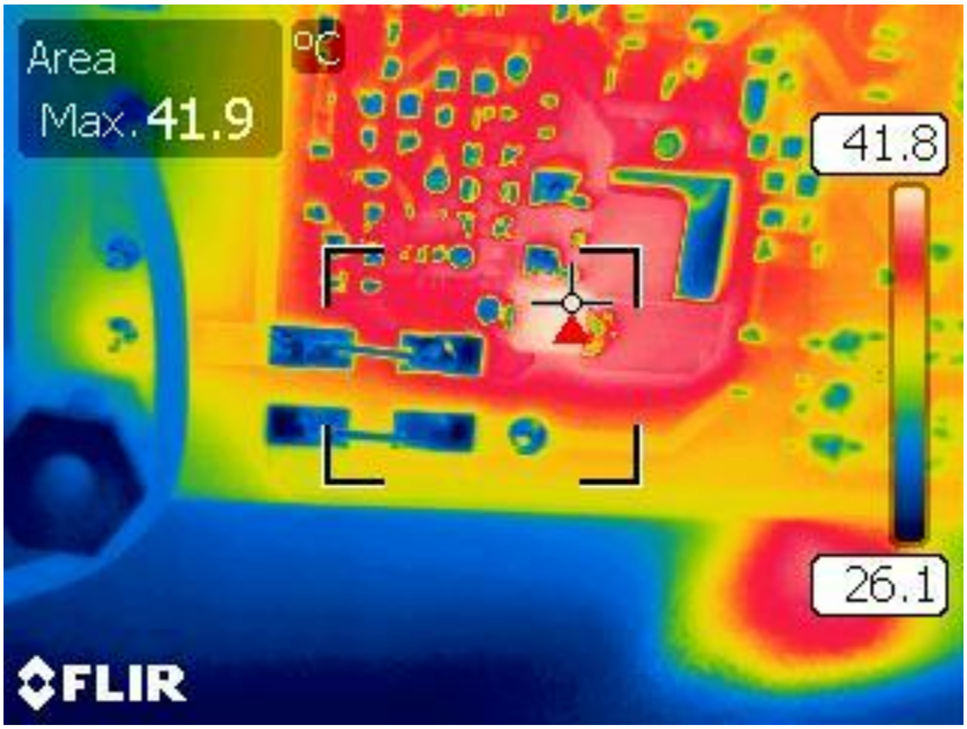

Figure 25 – Thermal Measurements.

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11 Waveforms, LinkSwitch-TN2

11.1 *LinkSwitch-TN2 Power Supply Section*

11.1.1 Drain Voltage and Current, Normal Operation

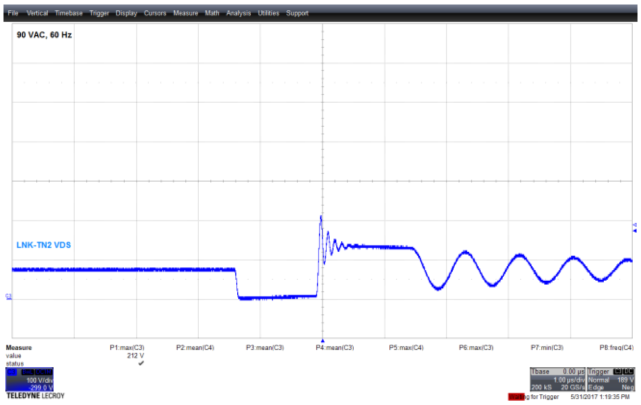

Figure 26 – 90 VAC, BLE Load.
CH3: V_{DRAIN}, 100 V / div.

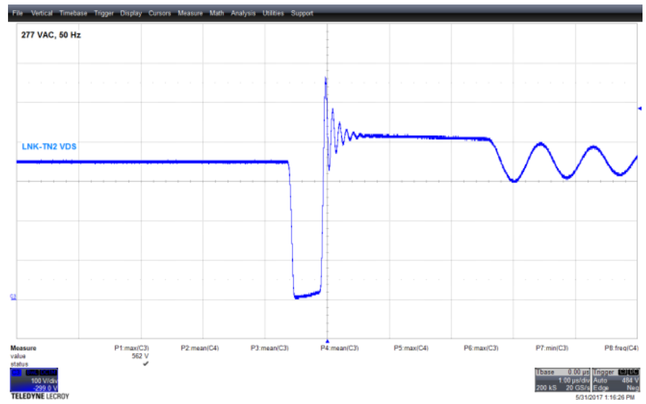

Figure 27 – 277 VAC, BLE Load.
CH3: V_{DRAIN}, 100 V / div.

11.1.2 Output Voltage, Normal Operation

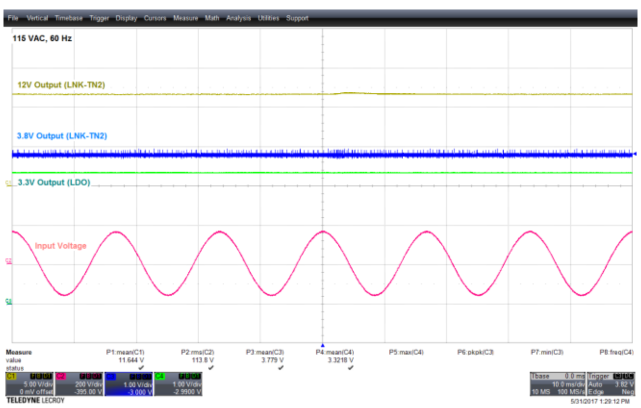

Figure 28 – 115 VAC, BLE Load.
CH1: 12 V_{OUT}, 5 V / div.
CH2: V_{IN}, 200 V / div.
CH3: 3.8 V_{OUT}, 1 V / div.
CH4: 3.3 V LDO Output, 1 V / div.
10 ms / div.

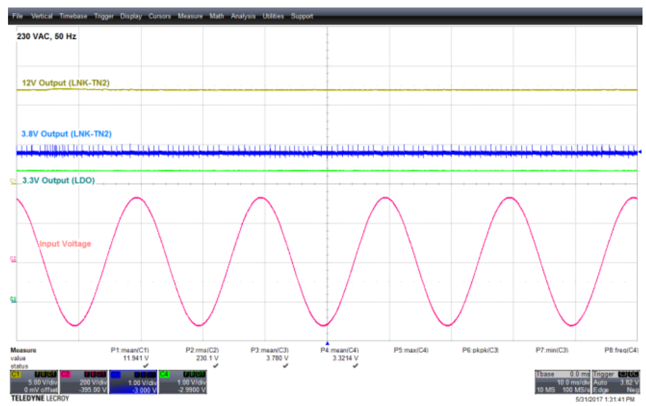

Figure 29 – 230 VAC, BLE Load.
CH1: 12 V_{OUT}, 5 V / div.
CH2: V_{IN}, 200 V / div.
CH3: 3.8 V_{OUT}, 1 V / div.
CH4: 3.3 V LDO Output, 1 V / div.
10 ms / div.

11.1.3 Output Voltage Start-up Profile

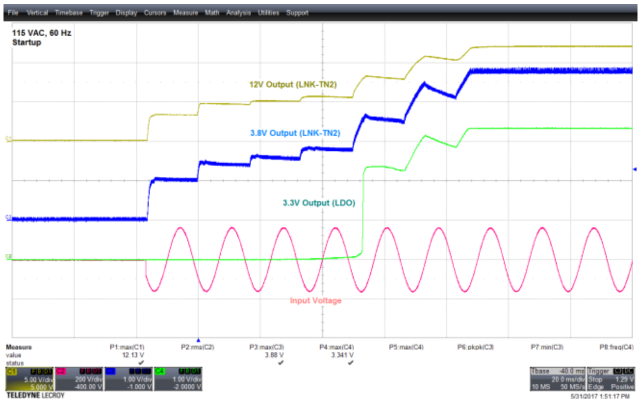

Figure 30 – 115 VAC, BLE Load.
CH1: 12 V_{OUT}, 5 V / div.
CH2: V_{IN}, 200 V / div.
CH3: 3.8 V_{OUT}, 1 V / div.
CH4: 3.3 V LDO Output, 1 V / div.

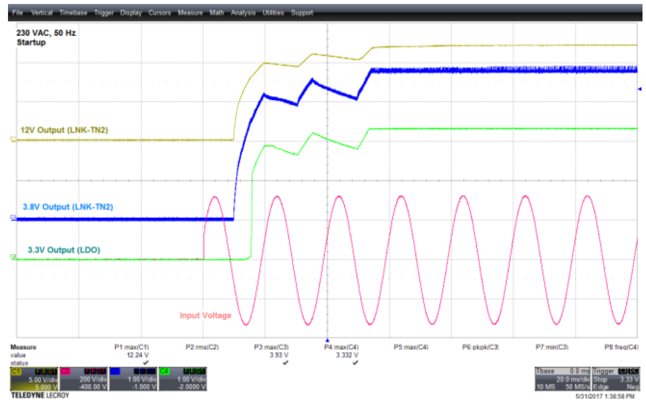

Figure 31 – 230 VAC, BLE Load.
CH1: 12 V_{OUT}, 5 V / div.
CH2: V_{IN}, 200 V / div.
CH3: 3.8 V_{OUT}, 1 V / div.
CH4: 3.3 V LDO Output, 1 V / div.

11.1.4 Output Voltage, Relay OFF-ON-OFF Transition

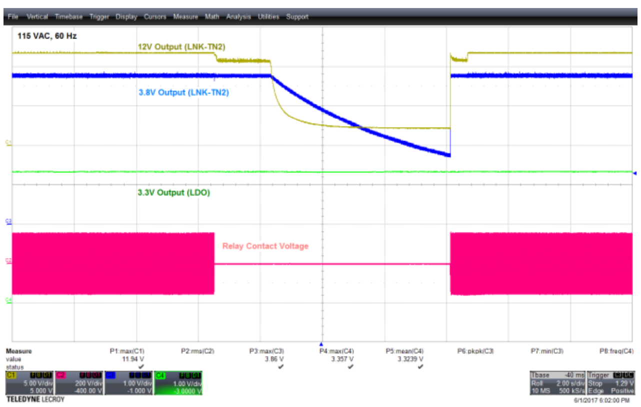

Figure 32 – 115 VAC, BLE Load.
CH1: 12 V_{OUT}, 5 V / div.
CH2: Relay Voltage, 200 V / div.
CH3: 3.8 V_{OUT}, 1 V / div.
CH4: 3.3 V LDO Output, 1 V / div.

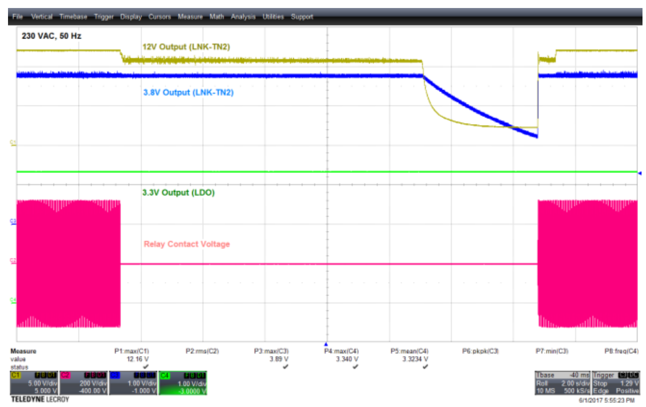

Figure 33 – 230 VAC, BLE Load.
CH1: 12 V_{OUT}, 5 V / div.
CH2: Relay Voltage, 200 V / div.
CH3: 3.8 V_{OUT}, 1 V / div.
CH4: 3.3 V LDO Output, 1 V / div.

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11.1.5 LDO Input Voltage, Relay OFF-ON-OFF Transition

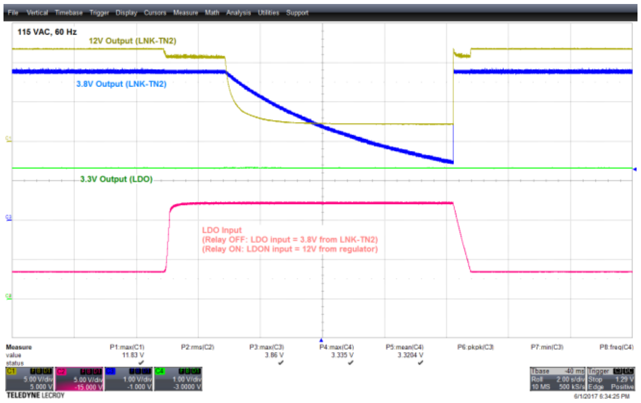

Figure 34 – 115 VAC, BLE Load.
CH1: 12 V_{OUT}, 5 V / div.
CH2: LDO Input, 5 V / div.
CH3: 3.8 V_{OUT}, 1 V / div.
CH4: 3.3 V LDO Output, 1 V / div.

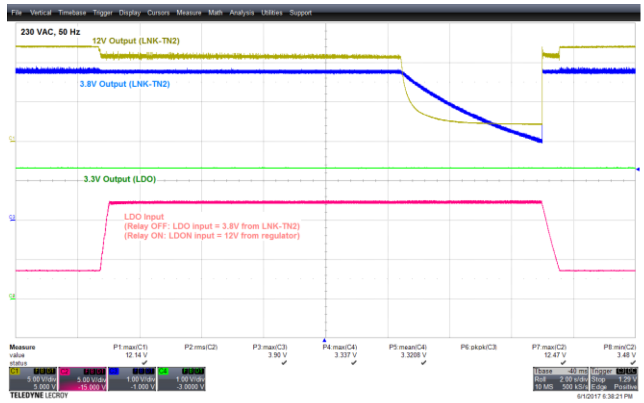

Figure 35 – 230 VAC, BLE Load.
CH1: 12 V_{OUT}, 5 V / div.
CH2: LDO Input, 5 V / div.
CH3: 3.8 V_{OUT}, 1 V / div.
CH4: 3.3 V LDO Output, 1 V / div.

11.1.6 LDO Input Voltage, Relay Multiple ON-OFF Transition

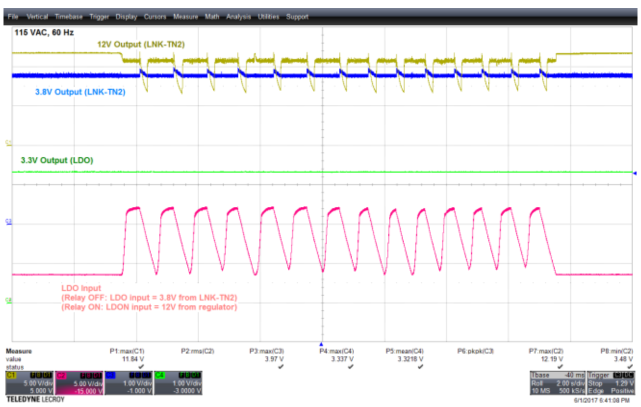

Figure 36 – 115 VAC, BLE Load.
CH1: 12 V_{OUT}, 5 V / div.
CH2: LDO Input, 5 V / div.
CH3: 3.8 V_{OUT}, 1 V / div.
CH4: 3.3 V LDO Output, 1 V / div.

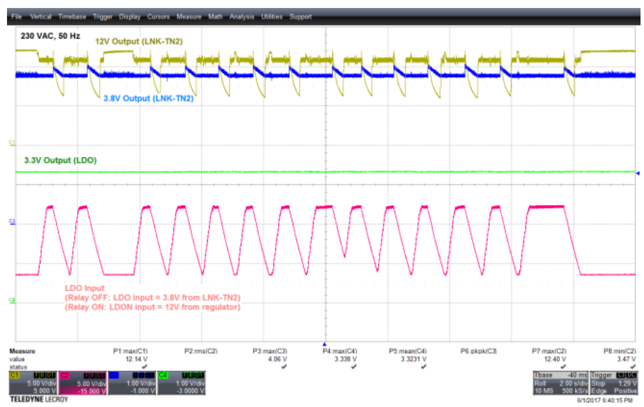

Figure 37 – 230 VAC, BLE Load.
CH1: 12 V_{OUT}, 5 V / div.
CH2: LDO Input, 5 V / div.
CH3: 3.8 V_{OUT}, 1 V / div.
CH4: 3.3 V LDO Output, 1 V / div.

11.2 ***Regulator Waveforms***

11.2.1 MOSFET Regulator, 7 W Bulb

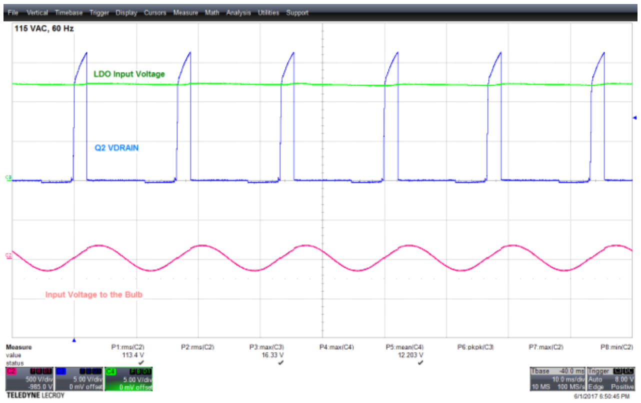

Figure 38 – 115 VAC, BLE Load.
CH2: $V_{IN(BULB)}$, 200 V / div.
CH3: Q2 VDS, 5 V / div.
CH4: LDO Input, 5 V / div.

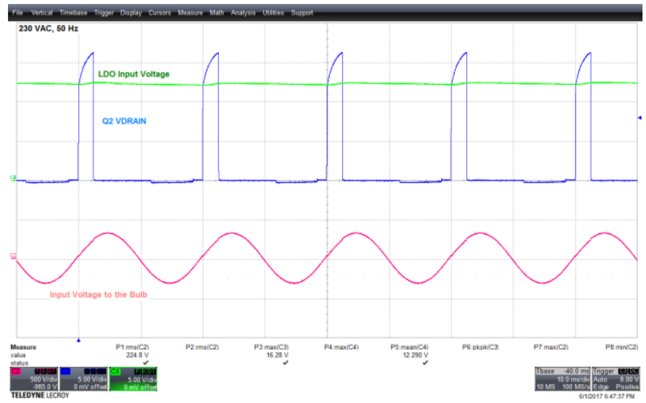

Figure 39 – 230 VAC, BLE Load.
CH2: $V_{IN(BULB)}$, 200 V / div.
CH3: Q2 VDS, 5 V / div.
CH4: LDO Input, 5 V / div.

11.2.2 MOSFET Regulator, 250 W Incandescent Bulb

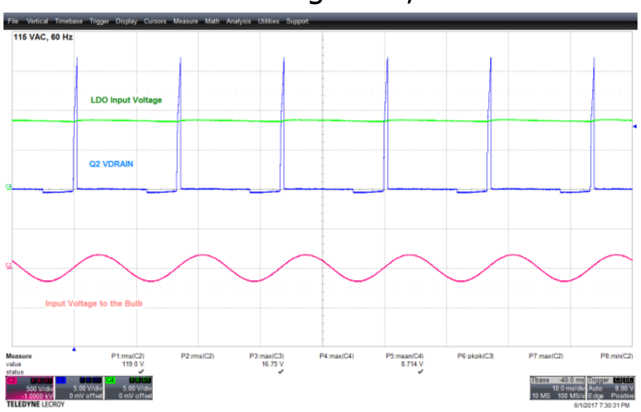

Figure 40 – 115 VAC, BLE Load.
CH2: $V_{IN(BULB)}$, 200 V / div.
CH3: Q2 VDS, 5 V / div.
CH4: LDO Input, 5 V / div.

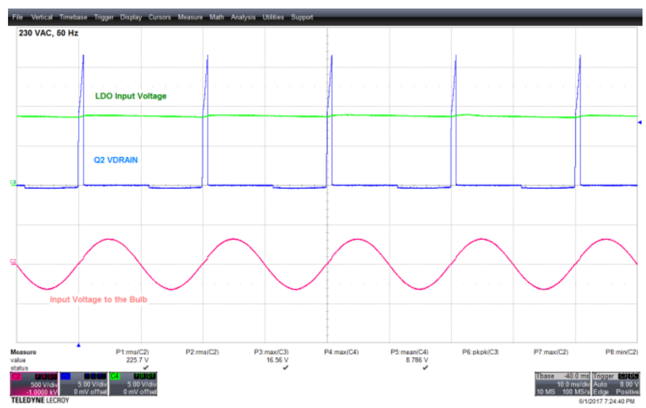

Figure 41 – 230 VAC, BLE Load.
CH2: $V_{IN(BULB)}$, 200 V / div.
CH3: Q2 VDS, 5 V / div.
CH4: LDO Input, 5 V / div.

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11.3 ***Relay Control***

11.3.1 Relay ON Transition

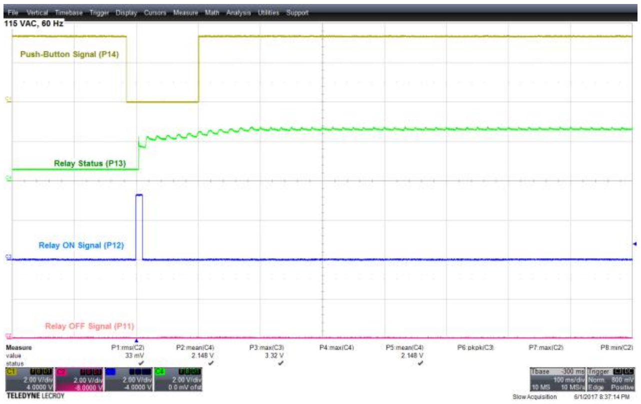

Figure 42 – 115 VAC, BLE Load.
CH1: Push-Button Switch Signal.
CH2: Relay OFF Pulse (P11/27).
CH3: Relay OFF Pulse (P12/26).
CH4: Relay Status (P13/28)

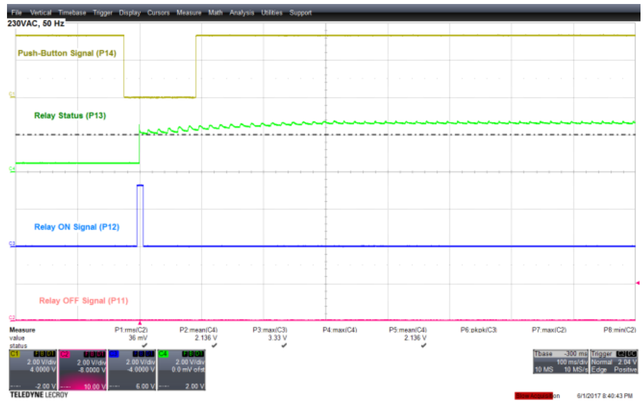

Figure 43 – 115 VAC, BLE Load.
CH1: Push-Button Switch Signal.
CH2: Relay OFF Pulse (P11/27).
CH3: Relay OFF Pulse (P12/26).
CH4: Relay Status (P13/28).

11.3.2 Relay OFF Transition

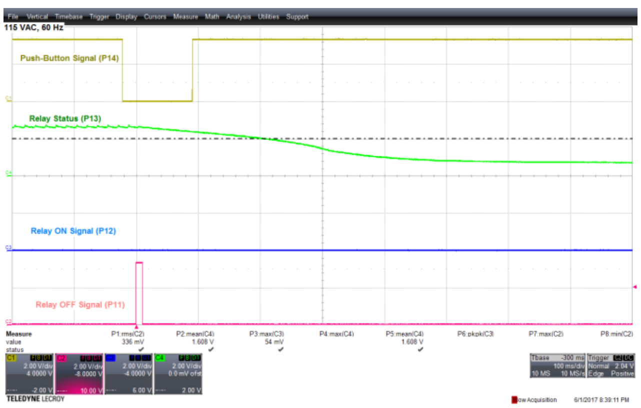

Figure 44 – 230 VAC, BLE Load.
CH1: Push-Button Switch Signal.
CH2: Relay OFF Pulse (P11/27).
CH3: Relay OFF Pulse (P12/26).
CH4: Relay Status (P13/28).

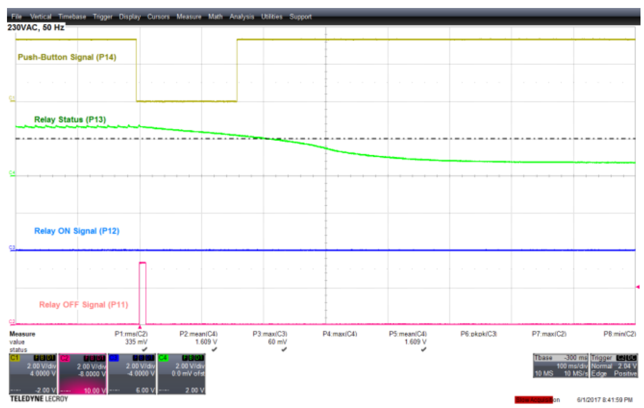

Figure 45 – 230 VAC, BLE Load.
CH1: Push-Button Switch Signal.
CH2: Relay OFF Pulse (P11/27).
CH3: Relay OFF Pulse (P12/26).
CH4: Relay Status (P13/28).

11.3.3 Relay ON and OFF Transition

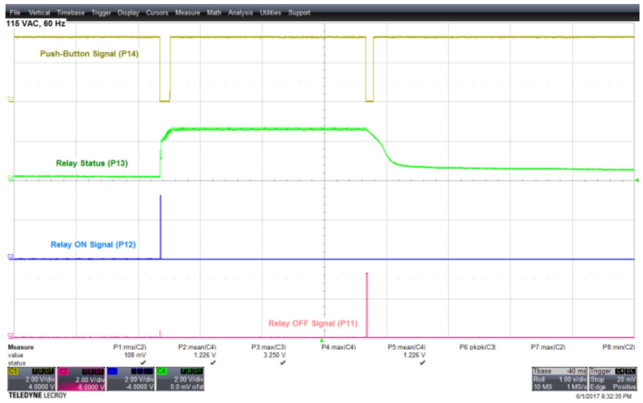

Figure 46 – 230 VAC, BLE Load.
CH1: Push-Button Switch Signal.
CH2: Relay ON Pulse (P12/26).
CH3: Relay OFF Pulse (P11/27).
CH4: Relay Status (P13/28).

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12 Conducted EMI

The unit was tested with actual BLE load and the relay in OFF position.

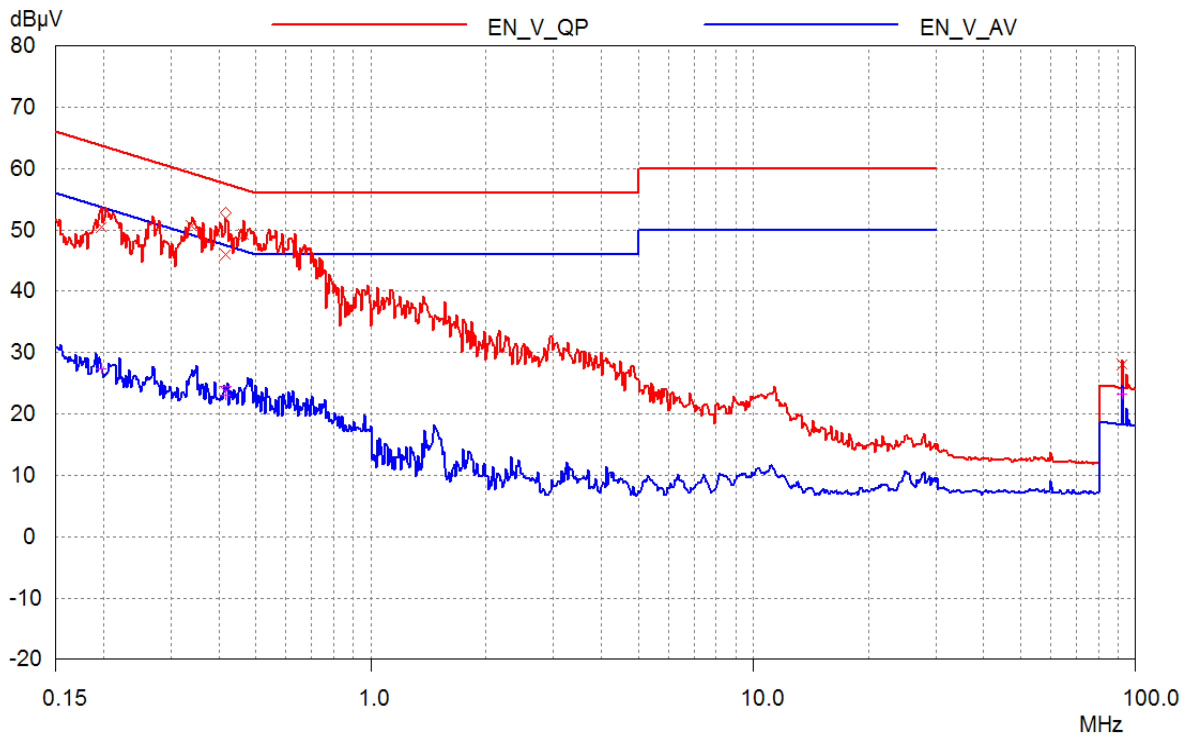

Figure 47 – Conducted EMI, Actual BLE Load, 115 VAC, 60 Hz, and EN55022 B Limits.

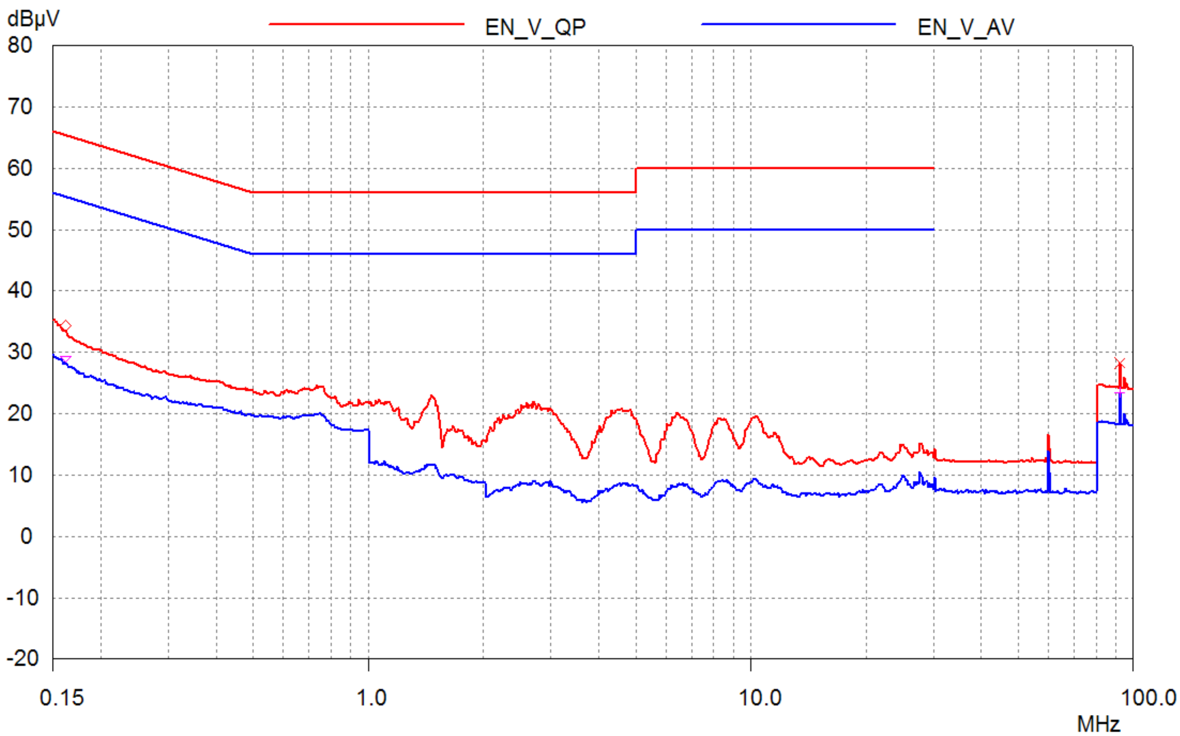

Figure 48 – Conducted EMI, Actual BLE Load, 230 VAC, 60 Hz, and EN55022 B Limits.

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13 Line Surge

The unit was subjected to ± 500 V differential surges at 230 VAC, 60 Hz with 10 strikes at each condition.

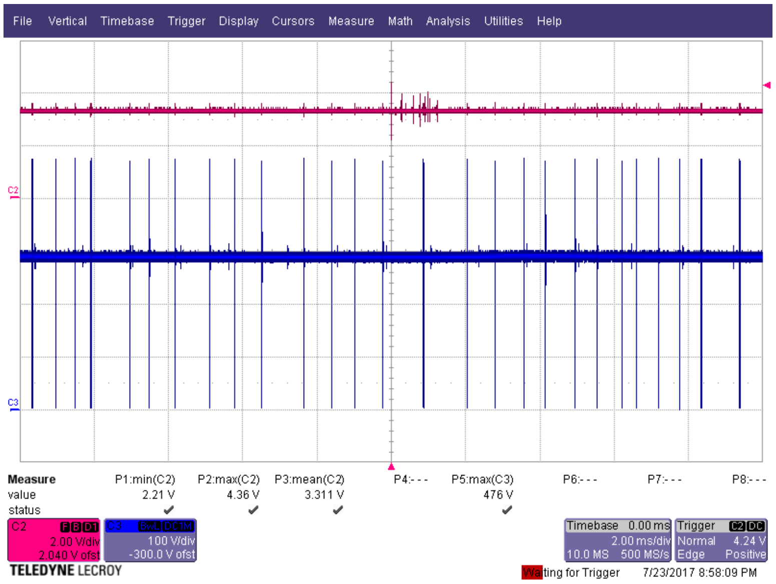

Figure 49 – +500 V Differential Surge, 230 VAC, 60 Hz, 90º Phase Angle, Actual BLE Load.
CH2: 3.3 V LDO Output, 2 V / div.
CH3: V_{DRAIN}, 100 V / div.

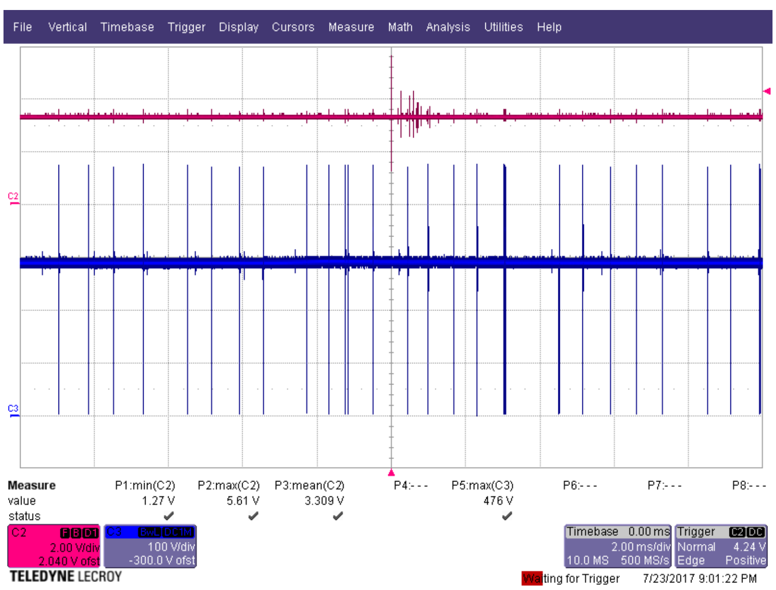

Figure 50 – -500 V Differential Surge, 230 VAC, 60 Hz, 270º Phase Angle, Actual BLE Load.
CH2: 3.3 V LDO Output, 2 V / div.
CH3: V_{DRAIN}, 100 V / div.

14 Revision History

Date	Author	Revision	Description & changes	Reviewed
08-Aug-17	DS	1.0	Initial Release.	Apps & Mktg
02-May-18	KM	1.1	Added Magnetics Supplier for T1	

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