Design Example Report

Title	***12 W High Efficiency, High Power Factor, Isolated Flyback Power Supply Using LYTSwitch^{TM}-6 LYT6065C***
Specification	90 VAC – 265 VAC Input; 27 V, 450 mA Output
Application	Smart Lighting with Casambi CBM-001
Author	Applications Engineering Department
Document Number	DER-630
Date	May 21, 2018
Revision	1.0

Summary and Features

- Accurate constant voltage regulation
- Fast transient load response
- High power factor
- Highly energy efficient
- Low standby power
- Low component count
- Integrated protection and reliability features
    - Output short-circuit
    - Line and output OVP
    - Line surge or line overvoltage
    - Over temperature shutdown with hysteretic automatic power recovery
- No damage during line brown-out or brown-in conditions
- Meets IEC 2.5 kV ring wave, 1 kV differential surge
- Meets EN55015 conducted EMI

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PATENT INFORMATION

The products and applications illustrated herein (including transformer construction and circuits external to the products) may be covered by one or more U.S. and foreign patents, or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations' patents may be found at www.powerint.com. Power Integrations grants its customers a license under certain patent rights as set forth at <http://www.powerint.com/ip.htm>.

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

1 Introduction

This engineering report describes a 12 W isolated flyback power supply with a single-stage power factor correction circuit for smart lighting applications. The power supply is designed to provide a 27 V constant voltage output across 0 mA to 450 mA output current load and throughout the input voltage from 90 VAC to 265 VAC.

The power supply IC controller device, LYTSwitch-6, combines primary, secondary and feedback circuits in a single surface-mounted off-line flyback switcher IC. It incorporates the primary MOSFET, the primary-side controller and a secondary-side synchronous rectification controller. The device also includes an innovative new technology, FluxLink™, which safely bridges the isolation barrier and eliminates the need for an optocoupler.

DER-630 using a LYTSwitch-6 IC is a universal input flyback converter design added with a switched valley-fill PFC circuit. This design offers a highly efficient constant voltage supply with a fast transient load response. Through the PFC circuit, the design achieves high power factor across universal input. The key design goals were high efficiency and high power factor across the input voltage range.

The document contains the power supply specification, schematic, bill of materials, transformer documentation, printed circuit layout, sample actual application circuit in Appendix section, and performance data.

Figure 1 – Populated Circuit Board.

Figure 2 – Populated Circuit Board, Top View.

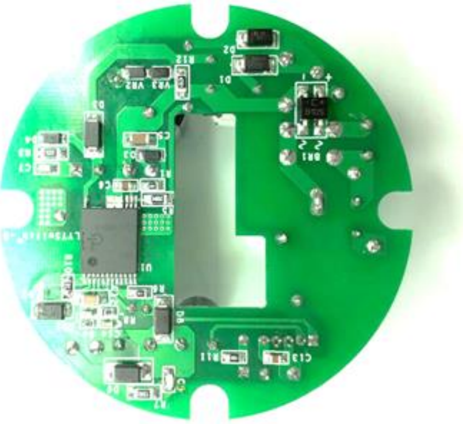


Figure 3 – Populated Circuit Board, Bottom View.

2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input			115/60			
Voltage	V_{IN}	90		265	Vac/Hz	2 Wire – no P.E.
Frequency	f_{LINE}		230/50			
Output						
Output Voltage	V_{OUT}		27		V	
Output Current (Full Load)	I_{OUT}		450		mA	
Output Power						
Continuous Output Power	P_{OUT}		12		W	
Full Load Efficiency	η		86		%	Measured at 115 V / 60 Hz and 230 V / 50 Hz.
Average Efficiency	η		85		%	Passed DOE Level VI.
Environmental						
Conducted EMI		CISPR 15B / EN55015B				
Safety		Isolated				
Ring Wave (100 kHz)			2.5		kV	Measured at 115 V / 60 Hz
Differential Mode Surge (L1-L2)			1.0		kV	
Power Factor			0.9			Measured at 115 V / 60 Hz and 230 V / 50 Hz.
Ambient Temperature	T_{AMB}			75	ºC	Free Air Convection, Sea Level.

3 Schematic

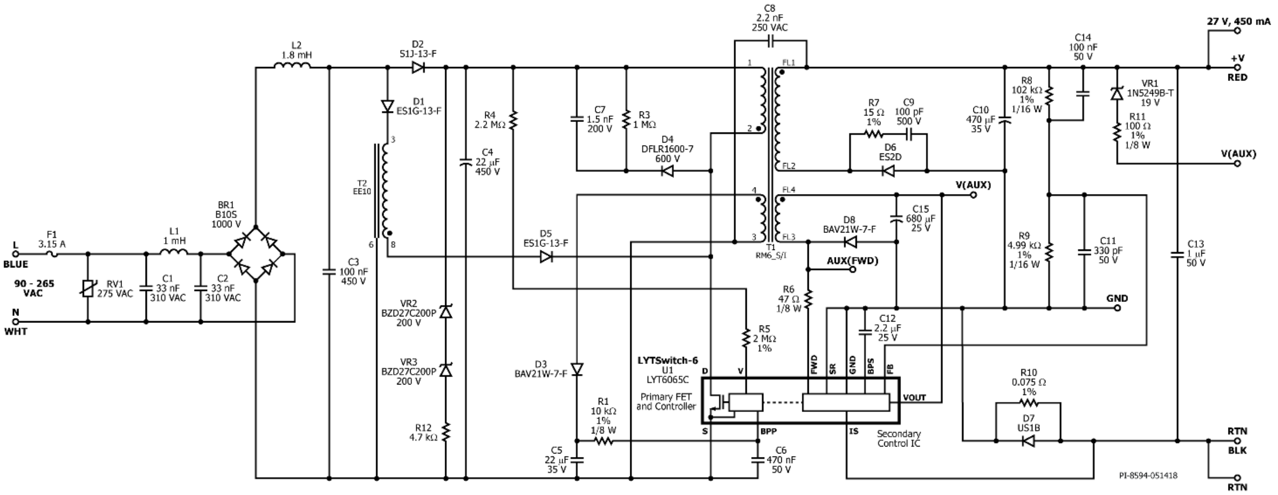


Figure 4 – Schematic.

4 Circuit Description

The LYTSwitch-6 IC (LYT6065C) incorporates the primary power MOSFET (650 V), the primary-side controller and a secondary-side synchronous rectification controller. 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 device is configured to drive a 12 W flyback power supply with added switched valley-fill PFC circuit providing a high power factor, 27 V constant voltage 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-side during line transient voltage surge events. A 275 V rated part was selected, being slightly above the maximum specified operating input voltage (265 V). The AC input voltage is full wave rectified by BR1 to achieve good power factor and low THD.

The bulk capacitor C4 provides input line ripple voltage filtering for a stable flyback DC supply voltage and helps reduce EMI noise. It also stores excess energy generated by the PFC during the power switch turn off time.

Capacitor C1, C2, C3, L1, and, L2 provide EMI filtering to suppress differential and common mode noise caused by the PFC and flyback switching action. Common mode noise is suppressed by Y-capacitor C8. These together with the LYTSwitch-6 frequency jitter and electronically quiet SOURCE pins ensure compliance with EN55015B.

4.2 *LYTSwitch-6 Primary-Side Control*

The isolated flyback power supply is controlled by a LYTSwitch-6 IC (LYT6065C). One end 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 DRAIN pin of the LYTSwitch-6 (U1) internal power MOSFET.

A low cost RCD clamp formed by D4, R3, and C7 limits the peak Drain voltage spike due to the effects of transformer leakage inductance.

The VOLTAGE MONITOR (V) pin of the LYTSwitch-6 IC is connected to the positive of the bulk capacitor (C4) to provide input voltage information. The voltage across the bulk capacitor (C4) is sensed and converted into current through V pin resistors R4 and R5 to provide detection of overvoltage. The I_{OV-} determines the input overvoltage threshold.

During the initial power-up, the internal high-voltage current source charges the BPP pin capacitor (C6) initializing the switching via primary side control. The secondary-side assumes the control after a handshake initiating a normal switching operation. During normal operation the primary-side block is powered by the auxiliary winding of the transformer. The output of this is configured as a flyback winding, rectified and filtered by D3 and C5 and fed to the BPP pin via a current limiting resistor R1.

4.3 *LYTSwitch-6 Secondary Side Control*

The transformer secondary is rectified by an ultrafast diode D6 and filtered by the output capacitor C10. RC snubber R7 and C9 reduces voltage stress on D6 and radiated EMI.

The secondary-side of the IC is self-powered from either the secondary bias winding forward voltage or VOUT bias supply. During the on-time of the primary-side power MOSFET the forward voltage that appears across the secondary bias winding is used to charge the BPS capacitor (C12) via FWD pin resistor (R6) and an internal regulator. During CV operation, the secondary bias powers the secondary-side control. The unit enters auto-restart when the VO pin voltage is lower than 3 V.

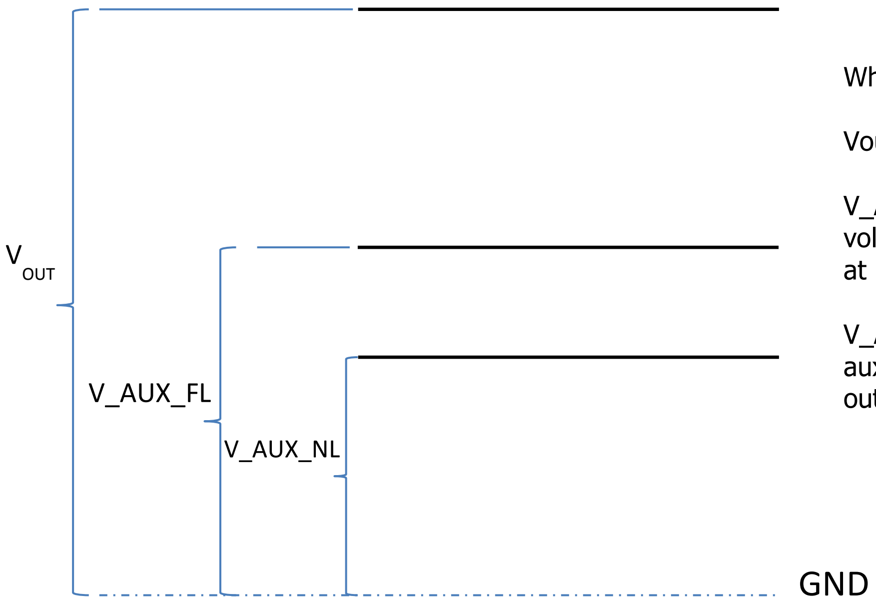
The output voltage is sensed via resistor divider R8 and R9 during CV operation and is compared to a reference voltage of 1.265 V on the FB pin when at the regulated output voltage. Filter capacitor C11 is added across R9 to eliminate unwanted noise that might trigger the OVP or increase ripple voltage.

For high output voltage designs a low voltage secondary bias is needed to ensure that the VO pin rating is not exceeded. The FWD pin is connected to the secondary bias winding and the VO pin to the secondary bias supply. The secondary bias winding voltage is rectified by D8 and C15 and is set at 12 V.

Output current is sensed internally via R10 between the IS and GND pins with a threshold of 35 mV to minimize losses. Diode D7 protects the IS pin from high inrush current during output short-circuit.

It is necessary to use C15 at 680 μF to be able to supply the wireless module for a certain period of time after the mains input is turned OFF. This enables the wireless module to handle the Power-OFF detection functionality. Zener diode VR1 and a resistor R13 are to ensure the auxiliary power supply will not drop significantly when the LED output is turned OFF via the wireless module since the feedback close-loop is tied to the main output. The value of VR1 must be carefully chosen so as not to conduct when the output is loaded; that is, V_Z = (V_{OUT} – V_AUX_NL) and the difference between V_AUX_FL and V_AUX_NL is greater than the tolerance of the Zener diode.

Figure 5 illustrates the voltage levels of the secondary main output and auxiliary output in consideration. V_{OUT} is the main output voltage while V_AUX_FL and V_AUX_NL are the auxiliary output when the main output is at full load and at no-load conditions, respectively. Take note that the secondary auxiliary supply still has to power the BLE module and the gate drivers even when the main output is at no-load condition (which happens when the LED load is turned OFF via the Casambi App). V_AUX_NL should be set at a level enough to supply the BLE module and should not cause the LYTSwitch-6 IC to reset due to low BPS pin voltage; V_AUX_NL ≥ 4.5 V should be good enough for this application.



Where:

Vout – main output voltage

V_AUX_FL – secondary auxiliary voltage when the main output is at Full Load

V_AUX_NL – desired secondary auxiliary voltage when the main output is at No Load

Figure 5 – Secondary Output Voltage Levels.

4.4 *PFC Circuit Operation*

Without the added PFC circuit, the power factor of the flyback power supply is normally around 0.5 to 0.6 at full load condition. Input from the bridge rectifier (BR1) will just directly feed the bulk capacitor (C4) that charges and recharges till the next voltage peak fed to it. The input charging pulse current must be high enough to sustain the load until the next peak. This means that the charging pulse current is around 5-10 times higher than the average current with a high phase angle difference from the voltage waveform; hence, the expected PF from this standard configuration is low and THD is high.

The added PFC circuit is called “Switched Valley-Fill Single Stage PFC” (SVF S^2PFC). Composed of an inductor (T2) and diodes (D1 and D5) connected directly to the DRAIN pin of the LYTSwitch-6 IC. Through this, the LYTSwitch-6 flyback switching action is able to draw a high frequency pulse current from the full wave rectified input. This will reduce the RMS input current and the phase angle difference from the input line voltage will be lower; hence, power factor will increase and will improve THD.

The PFC inductor T2 operates in DCM mode. At turn ON time, current delivered by the rectified input is stored in the PFC inductor which is then delivered via direct energy transfer to the flyback transformer T1. Excess energy from the PFC inductor that is not delivered to the load is being stored to the bulk capacitor. During no-load and light load conditions, the secondary requires less energy from the primary; therefore, more excess energy from the PFC inductor is stored on the bulk capacitor causing the voltage to rise gradually which will be higher than that of the peak input. The line voltage sense of LYTSwitch-6 IC is set to trigger at around 445 V, this is intended to protect during surge. Diodes D1 and D5 are connected in series to withstand voltage stress caused by the resonance ringing during the FET turn off. The variability of the PFC inductor peak current will be compensated by LYTSwitch-6 primary and secondary-side control maintaining the voltage regulation at all conditions.

5 PCB Layout

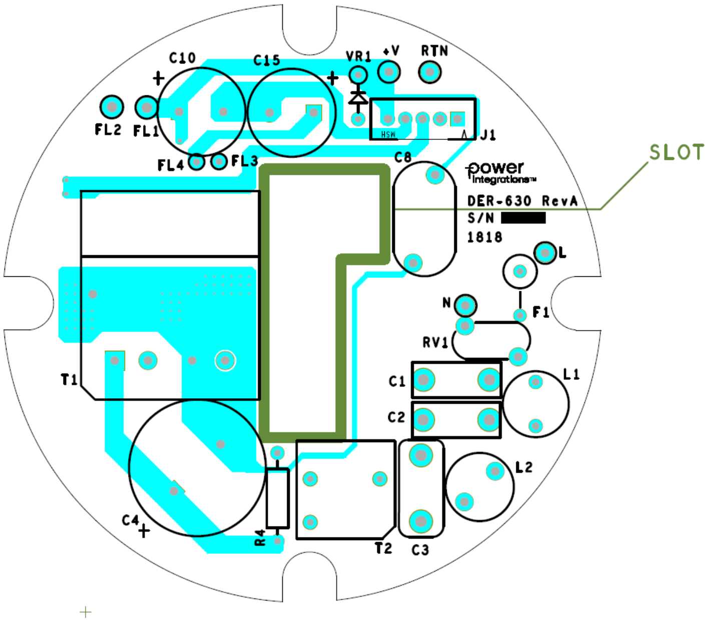


Figure 6 – Top Side.

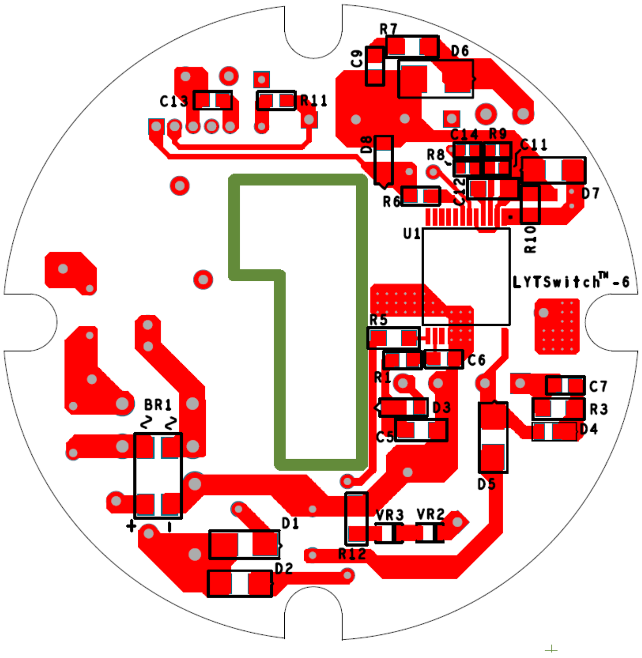


Figure 7 – Bottom Side.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
1	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip
2	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	CAP, 22 μF, ±20%, 450V, Aluminum, Radial, Can, 10000 Hrs @ 105°C, 0.630" Dia (16.00 mm), 0.787" H (20.00 mm), 0.295" LS (7.50 mm), 10000 Hrs @ 105°C	EEU-ED2W220S	Panasonic
6	1	C5	22 μF, 35 V, Ceramic, X5R, 1206	C3216X5R1V226M160AC	TDK
7	1	C6	470 nF, 50 V, Ceramic, X7R, 0805	GRM21BR71H474KA88L	Murata
8	1	C7	1.5 nF, 200 V,10%, Ceramic, X7R, 0805	08052C152KAT2A	AVX
9	1	C8	2.2 nF, Ceramic, Y1	440LD22-R	Vishay
10	1	C9	100 pF, 500 V, Ceramic, NP0, 0805	501R15N101KV4T	Johanson Dielectrics
11	1	C10	470 μF, 35 V, Electrolytic, Very 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	C13	1 μF,50 V, Ceramic, X7R, 0805	C2012X7R1H105M085AC	TDK
15	1	C14	100 nF 50 V, Ceramic, X7R, 0603	C1608X7R1H104K	TDK
16	1	C15	680 μF, 25 V, Electrolytic, Very Low ESR, 32 mΩ, (10 x 16)	EKZH250EC3681MJ16S	Nippon Chemi-Con
17	1	D1	400 V, 1 A, Superfast, 25 ns, DO-214AC, SMA	ES1G-13-F	Diodes, Inc.
18	1	D2	600 V, 1 A, Standard Recovery, SMA	S1J-13-F	Diodes, Inc.
19	1	D3	250 V, 0.2 A, Fast Switching, 50 ns, SOD-123	BAV21W-7-F	Diodes, Inc.
20	1	D4	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
21	1	D5	400 V, 1 A, Superfast, 25 ns, DO-214AC, SMA	ES1G-13-F	Diodes, Inc.
22	1	D6	200 V, 2 A, Ultrafast Recovery, 20 ns, DO-214AA	ES2D	Diodes, Inc.
23	1	D7	Diode Ultrafast, 1 A, 100 V, SMA	US1B-13-F	Diodes, Inc.
24	1	D8	250 V, 0.2 A, Fast Switching, 50 ns, SOD-123	BAV21W-7-F	Diodes, Inc.
25	1	F1	3.15 A, 250 V, Slow, 3.6 mm x 10 mm, Axial	08773.15MXEP	Littlefuse
26	1	L1	1 mH, 0.23 A, Ferrite Core	CTSCH875DF-102K	CT Parts
27	1	L2	1.8 mH, 350 mA	768772182	Wurth
28	1	R1	RES, 10 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1002V	Panasonic
29	1	R3	RES, 1 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ105V	Panasonic
30	1	R4	RES, 2.2 MΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-2M2	Yageo
31	1	R5	RES, 2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
32	1	R6	RES, 47 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ470V	Panasonic
33	1	R7	RES, 15 Ω, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF15R0V	Panasonic
34	1	R8	RES, 102 k, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1023V	Panasonic
35	1	R9	RES, 4.99 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF4991V	Panasonic
36	1	R10	RES, 0.075 Ω, 1%, 1/4 W, Thick Film, 0805	ERJ-L06UF75MV	Panasonic
37	1	R11	RES, 100 Ω, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1000V	Panasonic
38	1	R12	RES, 4.7 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ472V	Panasonic
39	1	RV1	275 VAC, 23 J, 7 mm, RADIAL	V275LA4P	Littlefuse
40	1	T1	Bobbin, RM6_S/I, Vertical, 8 pins w 2 pin clip	CPV-RM6S/I-1S-8PD-TZ	Ferroxcube
41	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
42	1	U1	LYTSwitch-6 Integrated Circuit, InSOP24D	LYT6065C	Power Integrations
43	1	VR1	19 V, 5%, 500 mW, DO-35	1N5249B-T	Diodes, Inc.
44	1	VR2	Diode, ZENER, 200 V, 800 MW, DO219AB	BZD27C200P-E3-08	Vishay
45	1	VR3	Diode, ZENER, 200 V, 800 MW, DO219AB	BZD27C200P-E3-08	Vishay

6.1 *Miscellaneous Parts*

Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
1	1	J1	CONN, Male, Vertical, 5 Pos, Hdr, 0.079" (2.00 mm)	0894000510	Molex, LLC
2	1	L	Test Point, BLUE, Miniature THRU-HOLE MOUNT	5117	Keystone
3	1	N	Test Point, WHT, Miniature THRU-HOLE MOUNT	5002	Keystone
4	1	RTN	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone
5	1	+V	Test Point, RED, Miniature THRU-HOLE MOUNT	5000	Keystone

7 Flyback Transformer Specification (T1)

7.1 *Electrical Diagram*

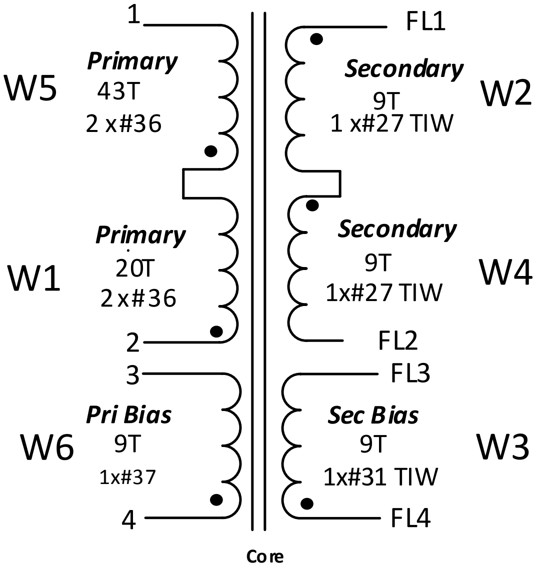


Figure 8 – Transformer Electrical Diagram.

7.2 *Electrical Specifications*

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 1 and pin 2 with all other windings open.	770 μH
Tolerance	Tolerance of Primary Inductance.	±5%

7.3 *Material List*

Item	Description
[1]	Core: RM6 PC95.
[2]	Bobbin, RM6_S/I, Vertical, 8 Pins with 2 Pin Clip: 25-00915-00.
[3]	Magnet Wire: #36 AWG.
[4]	Magnet Wire: #37 AWG.
[5]	TIW: #27 AWG.
[6]	TIW: #31 AWG.
[7]	Polyester Tape: 6.5 mm.
[8]	Mounting Clip: RM6 S/I.

7.4 *Transformer Build Diagram*

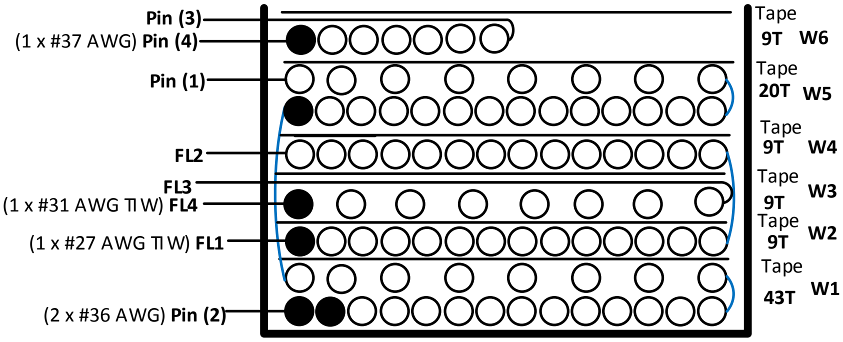
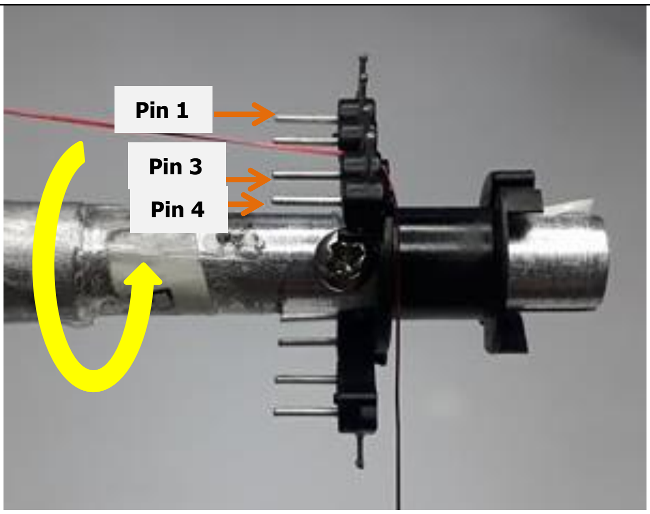
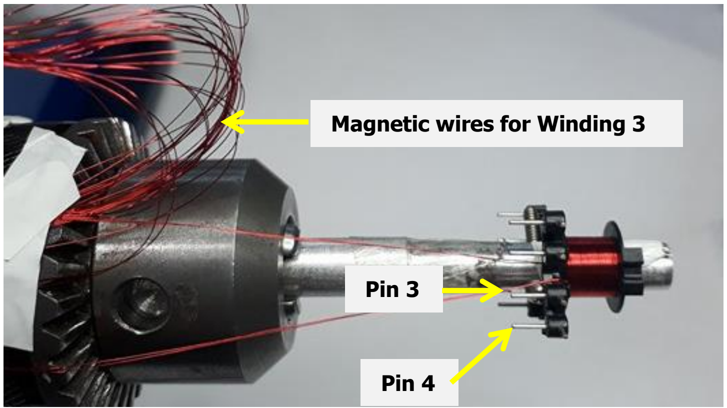
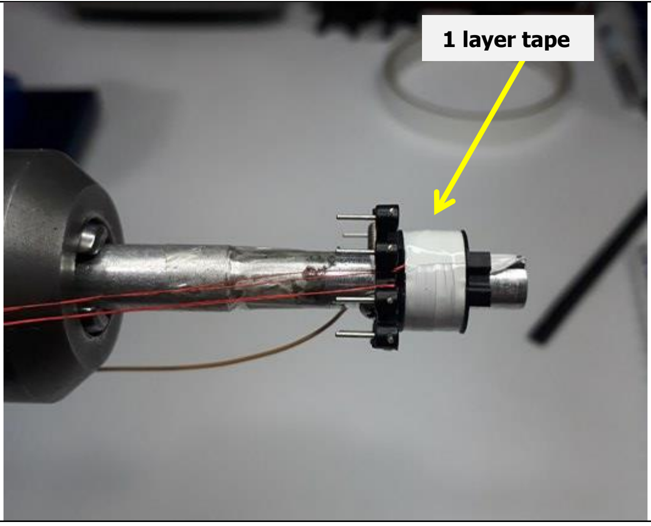


Figure 9 – Transformer Build Diagram.

7.5 *Transformer Construction*

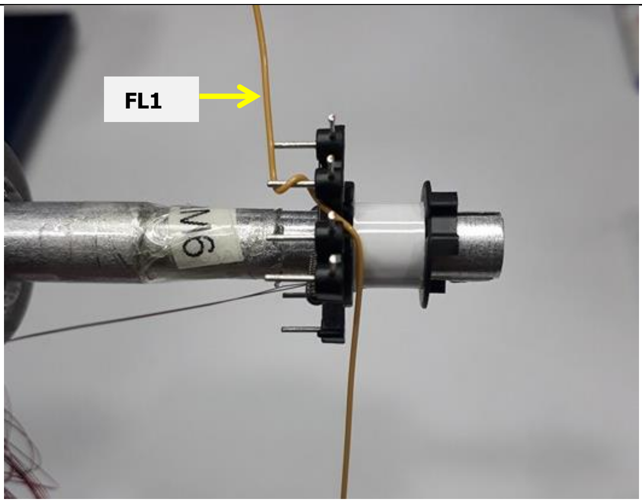
Winding Directions	Bobbin is oriented on winder jig such that terminal pin 1-4 is in the left side. The winding direction is clockwise.
Winding 1	Use magnetic wire Item [3] for bifilar-wound type winding. Prepare an enough length of magnetic wire for primary winding (63 turns). Start the winding 1 at pin 2 and wind 43 turns evenly. Set aside the remaining length of magnetic wire on the left side and reserve it for winding 5. Do not cut the wire and temporally fix it on terminal pin 1 so it will not loosen up during Winding 2.
Insulation	Apply 1 layer of polyester tape, Item [7] for insulation
Winding 2	Use triple insulated wire Item [5]. The terminals for winding 2 are fly wires marked as (FL1) and (FL2). Prepare an enough length of triple insulated wire for the secondary winding (18 turns). Start winding 2 at FL1 and wind 9 turns evenly in a layer. Set aside the remaining length of the triple insulated wire on the left side and reserve it for winding 4. Do not cut the wire and temporally use the bobbin terminals to fix the winding so it will not loosen up during winding 3.
Insulation	Apply 1 layer of polyester tape, Item [7] for insulation.
Winding 3	Use triple insulated wire Item [6]. The terminals for winding 3 are fly wires marked as (FL3) and (FL4). Wind 9 turns evenly in a layer.
Insulation	Apply 1 layer of polyester tape, Item [7] for insulation
Winding 4	Wind the remaining triple insulated wire [5] evenly on a layer for winding 4 ending with FL2.
Insulation	Apply 1 layer of polyester tape, Item [7] for insulation.
Winding 5	Continuing from W1, wind 20 turns evenly in 2 layers. End the winding at pin 2.
Insulation	Apply 1 layer of polyester tape, Item [7] for insulation.
Winding 6	Use magnetic wire item [4]. Starting in pin 4, wind 9 turns and end in pin 3.
Insulation	Apply 2 layers of polyester tape, Item [7] for insulation.
Pins	Cut pin 5-8. Do not cut the mounting clip terminal pin located on the left side near the C7.
Finished	Dip the finished transformer into 2:1 varnish thinner solution.

7.6 *Winding Illustrations*

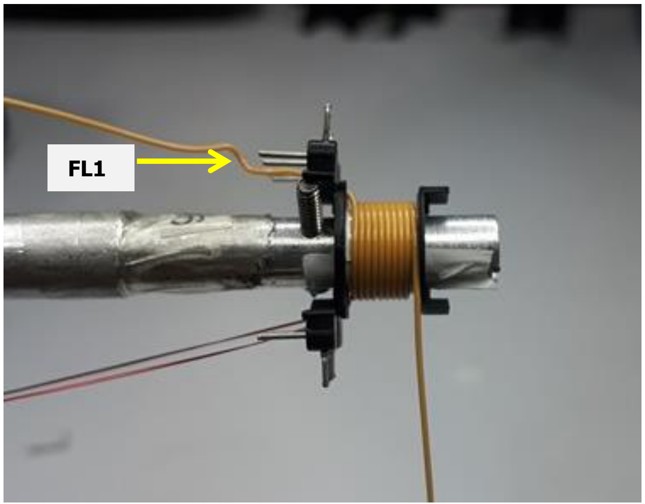
Winding Directions Bobbin is oriented on winder jig such that terminal pin 1-4 is in the left side. The winding direction is clockwise. **Winding 1** Use magnetic wire Item [3] for bifilar-wound type winding. Prepare an enough length of magnetic wire for primary winding (63 turns). Start the winding 1 at pin 2 and wind 43 turns evenly. Set aside the remaining length of magnetic wire on the left side and reserve it for Winding 5. Do not cut the wire and temporally fix it on terminal pin 1 so it will not loosen up during winding 2.	 
Insulation Apply 1 layer of polyester tape, Item [7] for insulation.	

Winding 2

Use triple insulated wire Item [5]. The terminals for winding 2 are fly wires marked as (FL1) and (FL2). Prepare an enough length of triple insulated wire for the secondary winding (18 turns). Start winding 2 at FL1 and wind 9 turns evenly in a layer

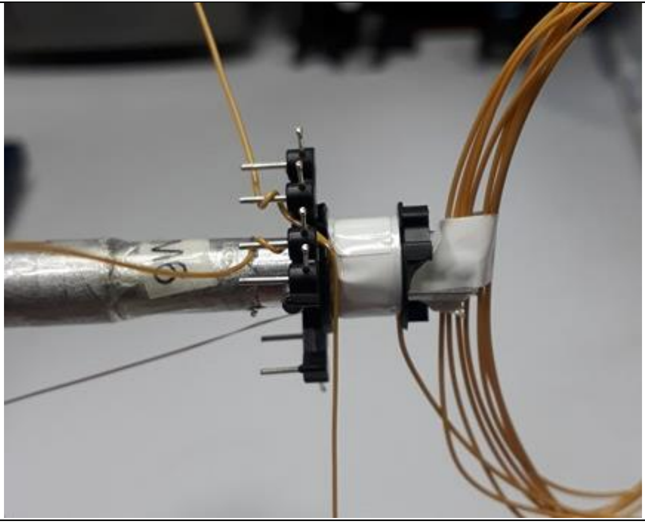


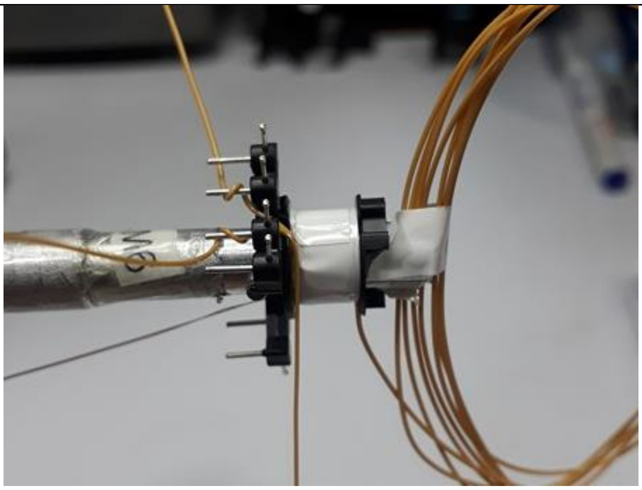
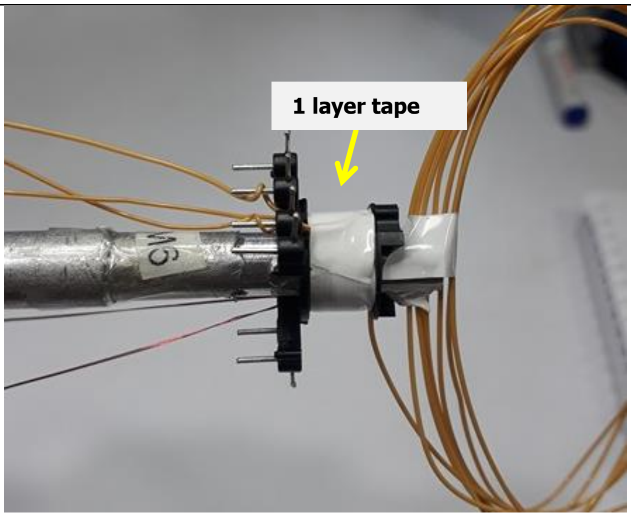
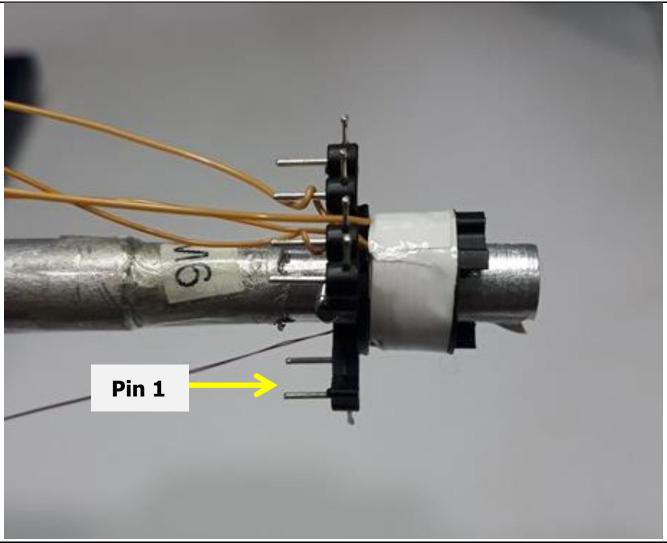
Set aside the remaining length of the triple insulated wire on the left side and reserve it for winding 4. Do not cut the wire and temporally use the bobbin terminals to fix the winding so it will not loosen up during winding 3.

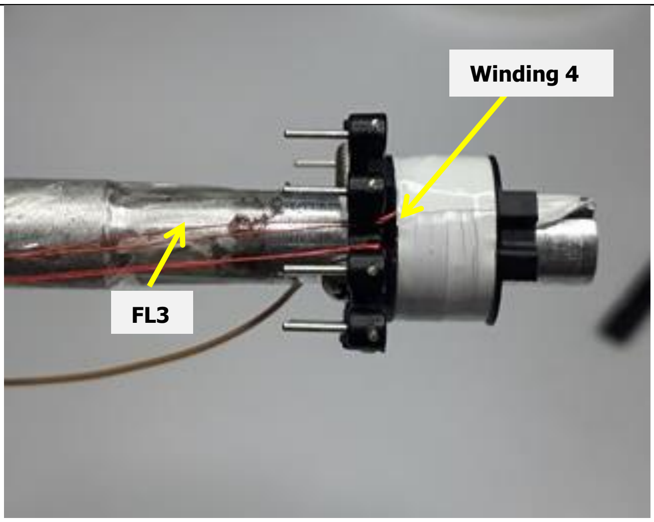


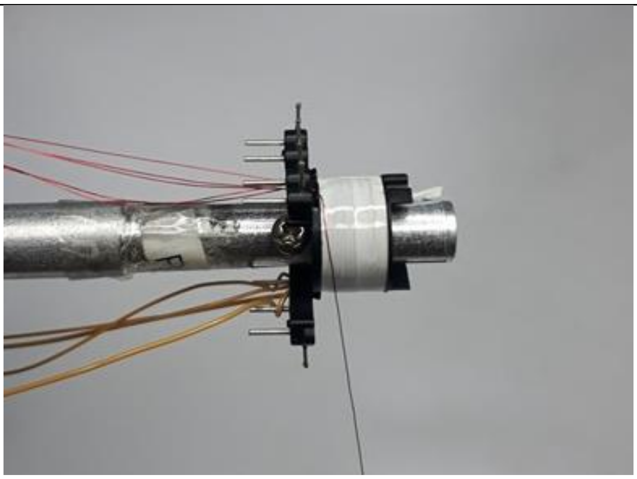
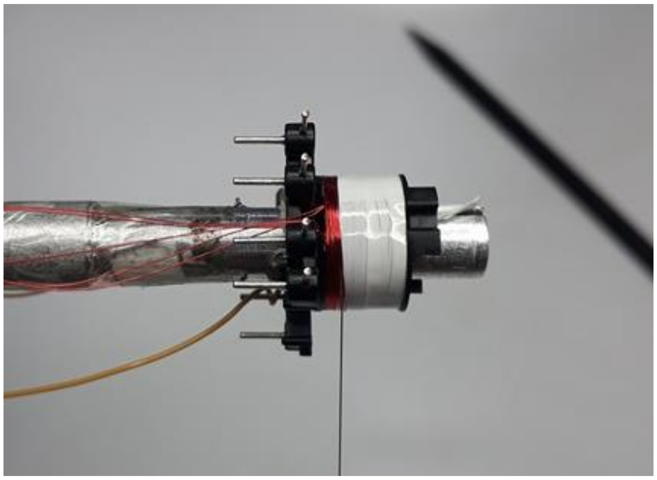
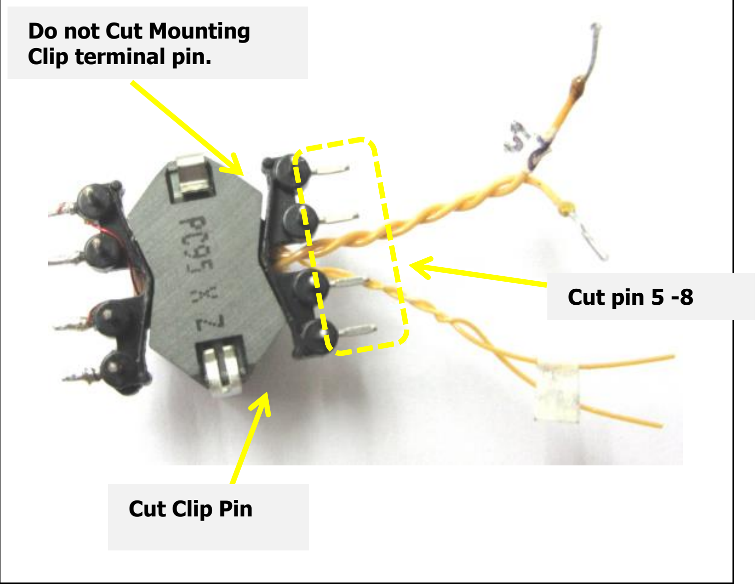
Insulation

Apply 1 layer of polyester tape, Item [7] for insulation



Winding 3 Use triple insulated wire Item [6]. The terminals for winding 3 are fly wires marked as (FL3) and (FL4). Wind 9 turns evenly in a layer.	
Insulation Apply 1 layer of polyester tape, Item [7] for insulation.	
Winding 4 Wind the remaining triple insulated wire [5] evenly on a layer for winding 4 ending with FL2. **Insulation** Apply 1 layer of polyester tape, Item [7] for insulation.	

Winding 5 Continuing from W1, wind 20 turns evenly in 2 layers. End the winding at pin 2. **Insulation** Apply 1 layer of polyester tape, Item [6] for insulation.	

Winding 6 Use magnetic wire item [4]. Starting in pin 4, wind 9 turns and end in pin 3. **Insulation** Apply 2 layer of polyester tape, Item [7] for insulation.	 
TIW Wire Twisting Twist wire FL1/FL2 and FL3/FL4 to minimize the loop that may increase the EMI. **Core Grinding** Grind the center leg of the ferrite core to meet the nominal inductance specification of 1360 µH. **Core Fixing** Assemble the ferrite cores on the bobbin. Apply the mounting clips to fix the cores. **Pins** Cut pin 5-8. **Finished** Dip the finished transformer into 2:1 varnish thinner solution.	

8 PFC Inductor (T2)

8.1 *Electrical Diagram*

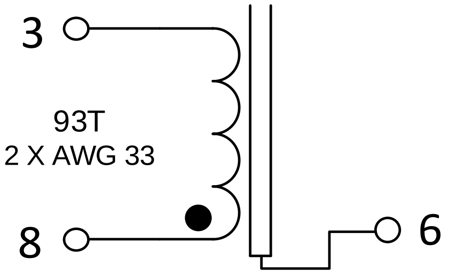


Figure 10 – Transformer Electrical Diagram.

8.2 *Electrical Specification*

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 3 and pin 8, with all other windings open.	580 μH
Tolerance	Tolerance of Primary Inductance.	±5%

8.3 *Material List*

Item	Description
[1]	Core: EE10.
[2]	Bobbin: EE10, Vertical, 8 Pins: Part no. 25-01068-00.
[3]	Magnet Wire: #33 AWG.
[5]	Transformer Tape: 6.5 mm.
[6]	Transformer Tape: 4 mm.

8.4 *Inductor Build Diagram*

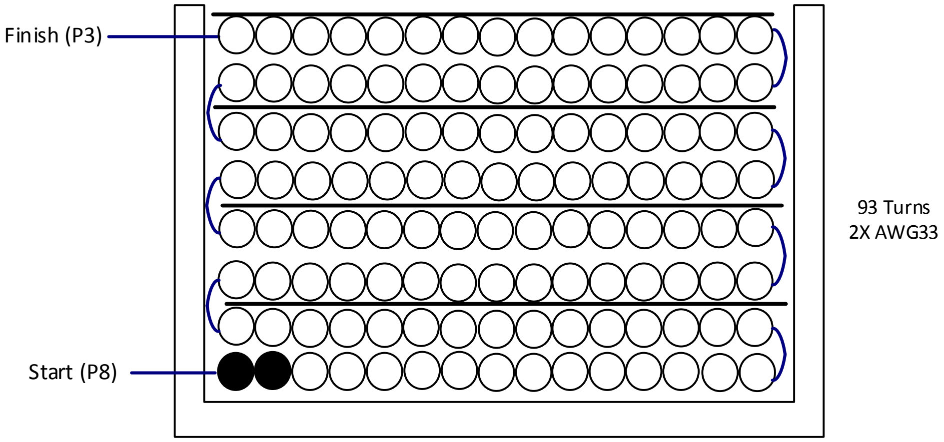


Figure 11 – Transformer Build Diagram.

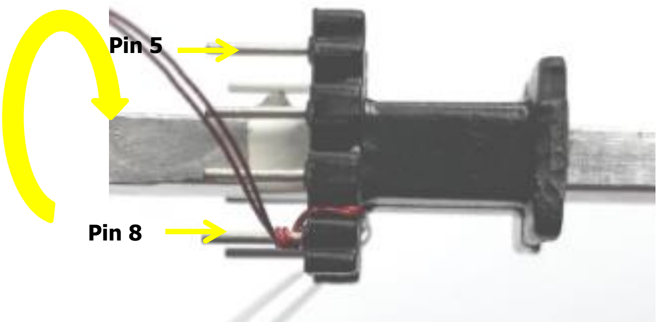
8.5 *Inductor Construction*

Winding Directions	Bobbin is oriented on winder jig such that terminal pin 5-8 is in the left side. The winding direction is clockwise.
Winding 1	Prepare the magnetic wire Item [3] for bifilar-wound type winding. Start at pin 8 and wind 93 turns bifilar in 8 layers. Add 1 layer of tape every 2 layers of magnetic wires. Finish the winding on pin 1.
Insulation	Add 1 layer of tape, Item [4].
Core Grinding	Grind the center leg of the ferrite core evenly until it meets the nominal inductance of 580 μH. Inductance is measured across pin 3 and pin 8.
Assemble Core	Assemble the 2 cores on the bobbin.
Core Termination	Prepare a copper strip with a soldered magnetic wire (AWG #32) at the middle as shown in the picture. Apply copper strip at the bottom part of the core and terminate the magnetic wire on pin 8.
Core Tape	Add 2 layers of tape Item [6] around the core to fix the 2 cores.
Pins	Pull out terminal pin number 1, 2, 4, 5 and pin 7.
Finish	Dip the transformer assembly in 2:1 varnish and thinner solution.

8.6 *Winding Illustrations*

Winding Directions

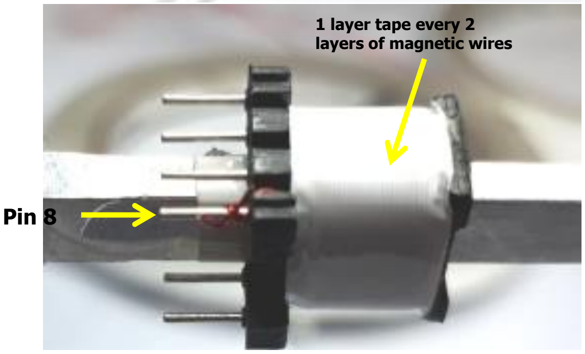
Bobbin is oriented on winder jig such that terminal Pin 5-8 is in the left side. The winding direction is clockwise.



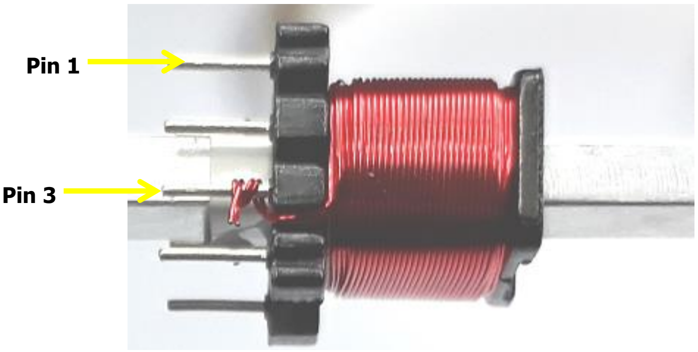
Winding 1

Prepare the magnetic wire item [3] for bifilar-wound type winding. Start at pin 8 and wind 93 turns bifilar in 8 layers.

Add 1 layer of tape every 2 layers of magnetic wires.

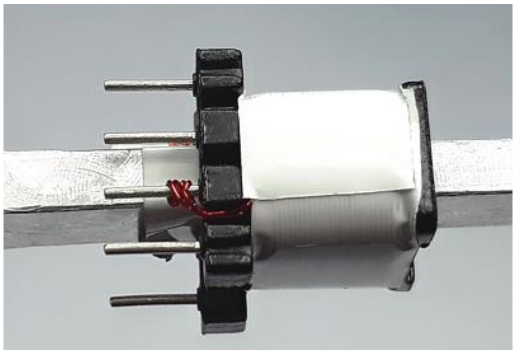


Finish the winding on pin 3.



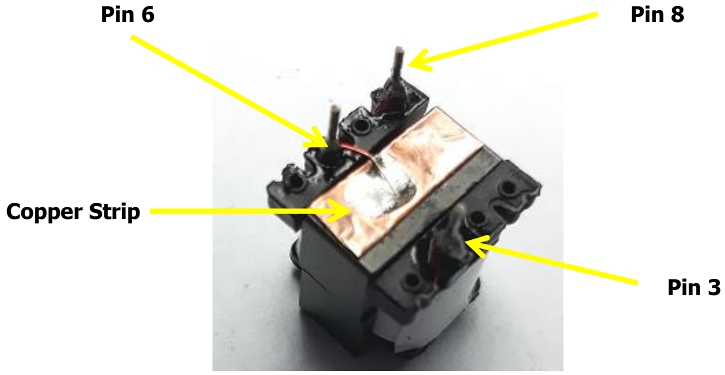
Insulation

Add 1 layer of tape, item [5]



Core Termination

Prepare a copper strip with a soldered magnetic wire (AWG 32) at the middle as shown in the picture. Apply copper strip at the bottom part of the core and terminate the magnetic wire on Pin 8.



Core Tape

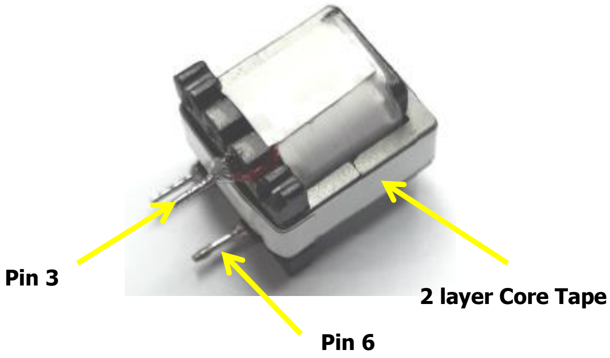
Add 2 Layers of tape Item (6) around the core to fix the 2 cores.

Pins

Pull out Terminal pin number 1, 2, 4, 5 and pin 7.

Finish

Dip the transformer assembly in 2:1 varnish and thinner solution.



9 Transformer Spreadsheet

1	**ACDC_Flyback_PF_ LYTSwitch-6_ 030918; Rev.1.3; Copyright Power Integrations 2018**	**INPUT**	**INFO**	**OUTPUT**	**UNITS**	**Switched Valley-Fill Single Stage PFC (SVF S^2PFC)**
2	**Application Variables**					
3	VACMIN			90	V	Minimum Input AC Voltage
4	VACNOM	115		115	V	Nominal Input AC Voltage
5	VACMAX			265	V	Maximum Input AC Voltage
6	VACRANGE			UNIVERSAL		Input Voltage Range
7	FL			50	Hz	Line Frequency
8	CIN			18.23	µF	Minimum Input Capacitance
9	V_CIN			450	V	Input Capacitance Recommended Voltage Rating
10	VO	27.00		27.00	V	Output Voltage
11	IO	0.45		0.45	A	Output Current
12	PO			12.15	W	Total Output Power
13	N	85.00		85.00	%	Estimated Efficiency
14	Z			0.50		Loss Allocation Factor
15	**Calculations Basis**					
16	PARcalcBASIS	VACNOM		VACNOM		Calculated Results Based on Selected VAC - VACNOM,VACMAX,VACMIN or Worst Case only
17	Flyback_Ind_Basis	Nom		Nom		Calculated Results Based on Selected LP - Min = LP_MIN, Nom = LP_NOM, Max = LP_MAX
18	Boost_Ind_Basis	Nom		Nom		Calculated Results Based on Selected LBOOST - Min = LBOOSTMIN,Nom = LBOOSTNOM,Max = LBOOSTMAX
19	**Primary Controller Section**					
20	DEVICE_MODE	Standard		Standard		Device Current Limit Mode
21	DEVNAME	LYT6065C		LYT6065C		PI Device Name
22	RDSON			3.47	ohms	Device RDSON at 100degC
23	ILIMITMIN			0.864	A	Minimum Current Limit
24	ILIMITTYP			0.950	A	Typical Current Limit
25	ILIMITMAX			1.036	A	Maximum Current Limit
26	BVDSS			650.00	V	Drain-Source Breakdown Voltage
27	VDS			2.00	V	On state Drain to Source Voltage
28	VDRAIN			538.77	V	Peak Drain to Source Voltage during Fet turn off
29	**Calculated Electrical Parameters Based on Specified Basis**					
30	**Boost Converter**					
31	IBOOSTRMS			163.58	mA	Boost RMS current
32	IBOOSTMAX			539.41	mA	Boost PEAK current
33	IBOOSTAVG			84.79	mA	Boost AVG current
34	IINRMS			127.76	mA	Input RMS current
35	PF_est			0.8693		Estimated Power Factor
36	Flyback Converter					
37	FSMIN			47500	Hz	Minimum Switching Frequency in a Line Period
38	FSMAX			99514.91	Hz	Maximum Switching Frequency in a Line Period
39	KPmin			1.7828		Minimum KP in a Line Period for VAC specified by PARcalcBASIS
40	IFETRMS			248.78	mA	Fet RMS current
41	IFETMAX			949.87	mA	Fet PEAK current
42	IPRIRMS			0.1884	A	Primary Winding RMS current
43	IPRIMAX			0.8461	A	Primary Winding PEAK current
44	IPRIAVG			0.0378	A	Primary Winding AVG current

45	IPRIMIN			400.78	mA	Primary Winding Minimum current
46	ISECRMS			0.91	A	Secondary RMS current
47	ISECMAX			3.05	A	Secondary PEAK current
48	**Boost Choke Construction Parameters**					
49	RATIO_LBST_LFB	0.7500		0.7500		Boost Inductance and Flyback Primary Inductance Ratio
50	LBOOSTMIN			549.19	µH	Minimum Boost Inductance
51	LBOOSTNOM			578.10	µH	Nominal Boost Inductance
52	LBOOSTMAX			607.00	µH	Maximum Boost Inductance
53	LBOOSTTOL	5.00		5.00	%	Boost Inductance Tolerance
54	**Boost Core and Bobbin Selection**					
55	CR_TYPE_BOOST	EE10		EE10		Boost Core
56	CR_PN_BOOST			PC40EE10/11-Z		Boost Core Code
57	AE_BOOST			12.10	mm²	Boost Core Cross Sectional Area
58	LE_BOOST			26.10	mm	Boost Core Magnetic Path Length
59	AL_BOOST			850.00	nH/turns²	Boost Core Ungapped Core Effective Inductance
60	VE_BOOST			315.00	mm3	Boost Core Volume
61	BOBBINID_BOOST			BE10-118CPSFR		Bobbin
62	AW_BOOST			12.20	mm²	Window Area of Bobbin
63	BW_BOOST			6.60	mm	Bobbin Width
64	MARGIN_BOOST			0.00	mm	Safety Margin Width
65	BOBFILLFACTOR_Boost			25.95	%	Boost Bobbin Fill Factor
66	**Boost Winding Details**					
67	NBOOST	90.00		90.00		Boost Choke Turns
68	BP_BOOST			3011.52	Gauss	Boost Peak Flux Density
69	ALG_BOOST			71.37	nH/turns²	Boost Core Ungapped Core Effective Inductance
70	LG_BOOST			0.20	mm	Boost Core Gap Length
71	L_BOOST	2.00		2.00		Number of Boost Layers
72	AWG_BOOST			33		Boost Winding Wire AWG
73	OD_BOOST_INSULATED			0.219	mm	Boost Winding Wire Output Diameter with Insulation
74	OD_BOOST_BARE			0.180	mm	Boost Winding Wire Output Diameter without Insulation
75	CMA_BOOST			283.33	Circular Mils/A	Boost Winding Wire CMA
76	**Flyback Transformer Construction Parameters**					
77	VOR	94.00		94.00	V	Secondary Voltage Reflected in the Primary Winding
78	LP_MIN			732.26	µH	Minimum Flyback Inductance
79	LP_NOM			770.80	µH	Nominal Flyback Inductance
80	LP_MAX			809.34	µH	Maximum Flyback Inductance
81	LP_TOL	5.00		5.00	%	Flyback Inductance Tolerance
82	**Flyback Core and Bobbin Selection**					
83	CR_TYPE	RM6S/I		RM6S/I		Flyback Core
84	CR_PN			RM6S/I-3F3		Flyback Core Code
85	AE			37.00	mm²	Flyback Core Cross Sectional Area
86	LE			29.20	mm	Flyback Core Magnetic Path Length
87	AL			2150.00	nH/turns²	Flyback Core Ungapped Core Effective Inductance
88	VE			1090.00	mm3	Flyback Core Volume
89	BOBBINID			Ferroxcube		Flyback Bobbin
90	BB_ORIENTATION	V		V		Flyback Bobbin Orientation H -Horizontal and V -Vertical
91	AW			14.20	mm²	Flyback Window Area of Bobbin
92	BW			6.30	mm	Flyback Bobbin Width
93	MARGIN			0.00	mm	Safety Margin Width
94	BOBFILLFACTOR			97.63	%	Flyback Bobbin Fill Factor

95	**Flyback Winding Details**					
96	NP			63.00		Primary Turns
97	BP			3681.67	Gauss	Flyback Peak Flux Density
98	BM			3589.44	Gauss	Flyback Maximum Flux Density
99	BAC			1398.93	Gauss	Flyback AC Flux Density
100	ALG			194.20	nH/turns²	Flyback Core Ungapped Core Effective Inductance
101	LG			0.22	mm	Flyback Core Gap Length
102	L			2.00		Number of Flyback Layers
103	AWG			33		Primary Winding Wire AWG
104	OD			0.219	mm	Primary Winding Wire Output Diameter with Insulation
105	DIA			0.180	mm	Primary Winding Wire Output Diameter without Insulation
106	CMA			244.54	Circular Mils/A	Primary Winding Wire CMA
107	NB			9.00		Bias Turns
108	L_BIAS			1.00		Number of Flyback Bias Winding Layers
109	AWGpBias			32		Bias Wire AWG
110	NS	18.00		18.00		Secondary Turns
111	AWGS			27		Secondary Winding Wire AWG
112	ODS			0.361	mm	Secondary Winding Wire Output Diameter with Insulation
113	DIAS			0.666	mm	Secondary Winding Wire Output Diameter without Insulation
114	CMAS			221.91	Circular Mils/A	Secondary Winding Wire CMA
115	**Primary Components Selection**					
116	**Line Undervoltage**					
117	BROWN_IN_REQUIRED			72.00	V	Required AC RMS line voltage brown-in threshold
118	RLS			1.78	MOhm	Two Resistors of this Value in Series to the V-pin
119	BROWN_IN_ACTUAL			71.40	V	Actual AC RMS brown-in threshold
120	**Line Overvoltage**					
121	OVERVOLTAGE_LINE			297.50	V	Actual AC RMS line over-voltage threshold
122	**Bias Voltage**					
123	VBIAS			12.00	V	Rectified Bias Voltage
124	VF_BIASDIODE			0.70	V	Bias Winding Diode Forward Drop
125	VRRM_BIASDIODE			65.54	V	Bias diode reverse voltage
126	CBIAS			22.00	µF	Bias winding rectification capacitor
127	CBPP			0.47	µF	BPP pin capacitor
128	**Bulk Capacitor Zener Clamp**					
129	Use Clamp	Yes		Yes		Bulk Capacitor Clamp Needed? Yes, No or N/A
130	VZ1_V			200.00	V	Zener 1 Voltage Rating (In Series with Zener 2)
131	PZ1_W			0.80	W	Zener 1 Minimum Power Rating
132	VZ2_V			200.00	V	Zener 2 Voltage Rating
133	PZ2_W			0.80	W	Zener 2 Minimum Power Rating
134	RZ			4700.00	ohms	Resistor in series with Zener 1 and Zener 2
135	**Secondary Components Selection**					
136	**Feedback Components**					
137	RFB_UPPER			102.00	kOhm	Upper feedback 1% resistor
138	RFB_LOWER			5.00	kOhm	Lower feedback 1% resistor
139	CFB_LOWER			330.00	pF	Lower feedback resistor decoupling at least 5V-rating capacitor
140	CBPS			2.20	µF	BPS pin capacitor
141	**Secondary Auxiliary Section - For VO > 24V ONLY**					
142	**Sec Aux Diode**					
143	VAUX			12.00	V	Rectified auxiliary voltage

144	VF_AUX			0.70	V	Auxiliary winding diode forward drop
145	VRRM_AUXDIODE			65.54	V	Auxiliary diode reverse voltage
146	CAUX			22.00	µF	Auxiliary winding rectification capacitor
147	NAUX_SEC			9.00		Secondary Aux Turns
148	L_AUX			1.00		Number of Flyback Aux Winding Layers
149	AWGSAUX			32		Secondary Aux Winding AWG
150	**Output Parameters**					
151	VOUT_ACTUAL			27.00	V	Actual Output Voltage
152	IOUT_ACTUAL			0.45	A	Actual Output Current
153	ISECRMS			0.91	A	Secondary RMS current for output
154	**Output Components**					
155	VF			0.70	V	Output diode forward drop
156	VRRM			134.08	V	Output diode reverse voltage
157	COUT			140.35	µF	Output Capacitor - Capacitance
158	COUT_VOpercentRip			2.50	%	Output Capacitor Ripple % of VOUT
159	ICOUTrms			0.79	A	Output Capacitor Estimated Ripple Current
160	ESRmax			220.96	mohms	Output Capacitor Maximum Recommended ESR
161	**Errors, Warnings, Information**					
162	Information					Although the design has passed the user should validate functionality on the bench. Please check the variables listed.
163	Design Warnings					Design variables whose values exceed electrical/datasheet specifications.
164	Design Errors					The list of design variables which result in an infeasible design.

10 Performance Data

All measurements were performed at room temperature.

10.1 *System Efficiency*

Set-up: Open frame unit
Load: 450 mA CC load
Ambient Temperature: 25 °C.
Soak Time: 120 seconds per input line

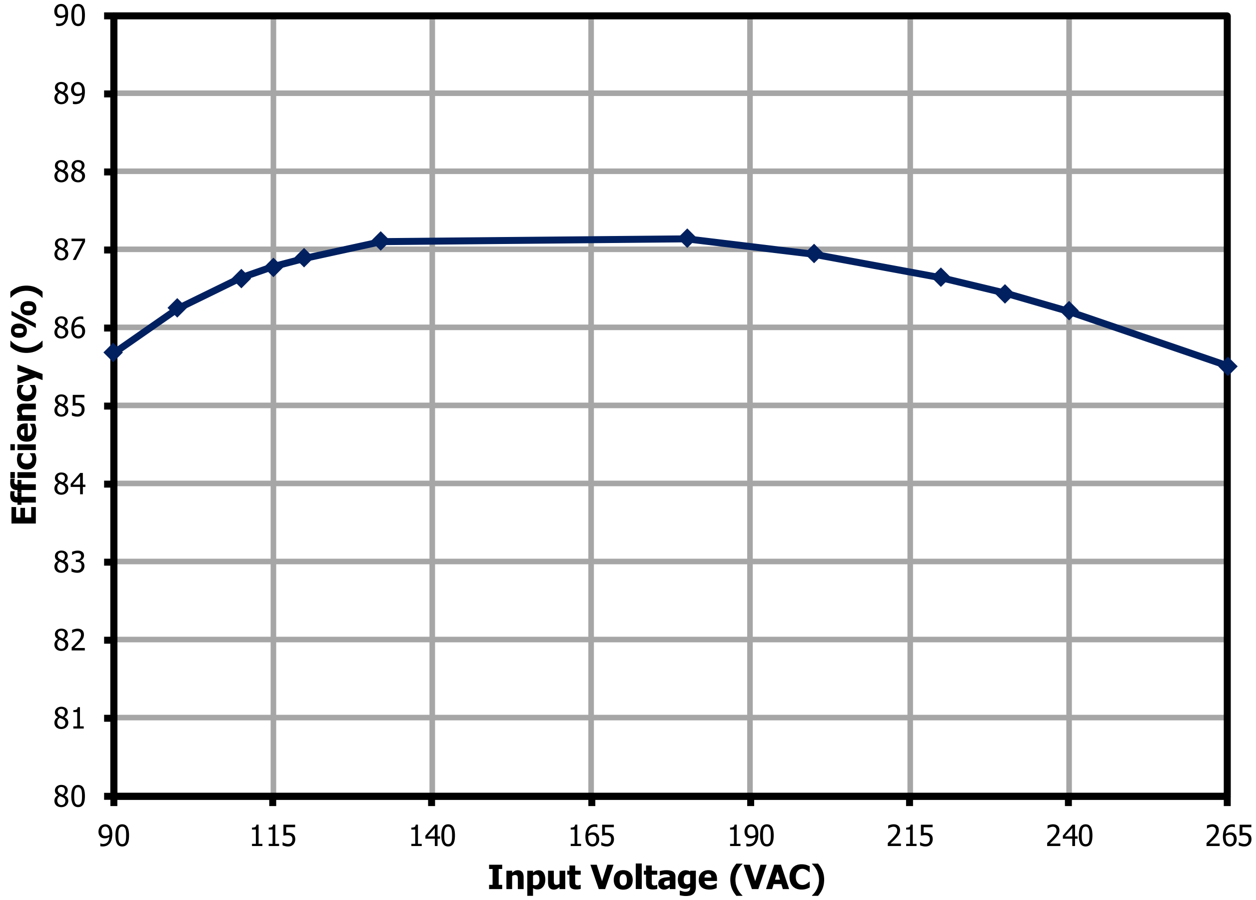


Figure 12 – Efficiency vs. Line.

10.2 *Output Voltage Regulation*

Set-up: Open frame unit
Load: 450 mA CC load
Ambient Temperature: 25 ºC.
Soak Time: 120 seconds per input line

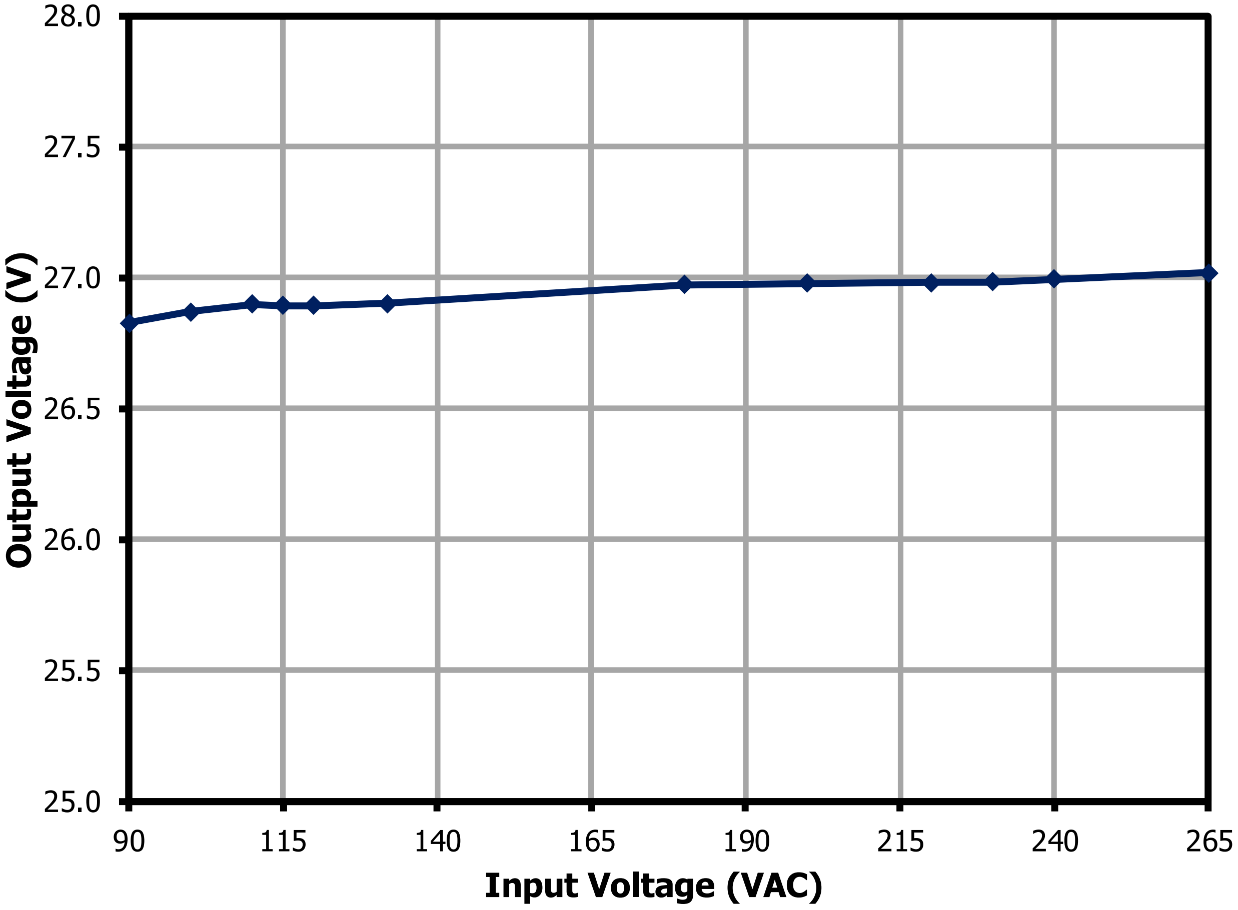


Figure 13 – Output Voltage Regulation vs. Line.

10.3 *Power Factor*

Set-up: Open frame unit
Load: 450 mA CC load
Ambient Temperature: 25 ºC.
Soak Time: 120 seconds per input line

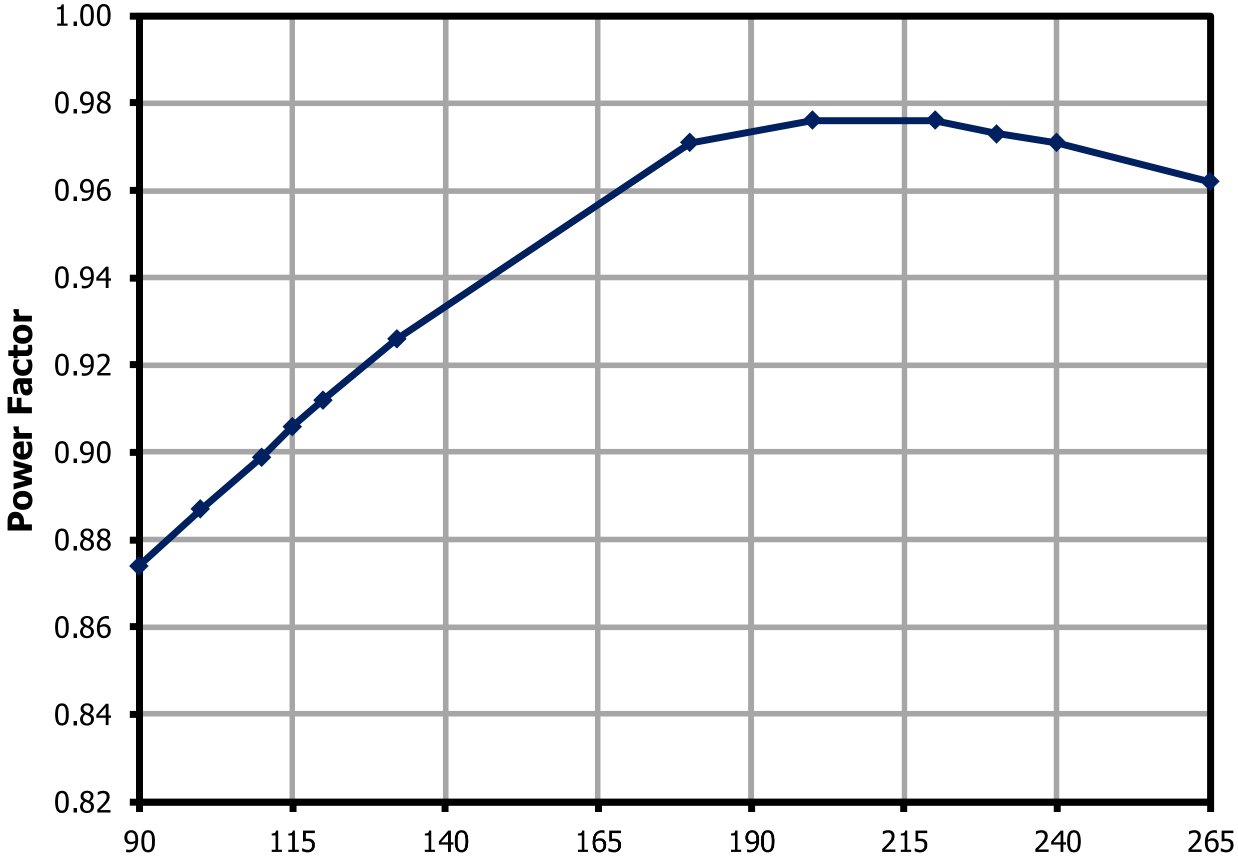


Figure 14 – Power Factor vs. Line.

10.4 *%ATHD*

Set-up: Open frame unit
Load: 450 mA CC load
Ambient Temperature: 25 ºC.
Soak Time: 120 seconds per input line

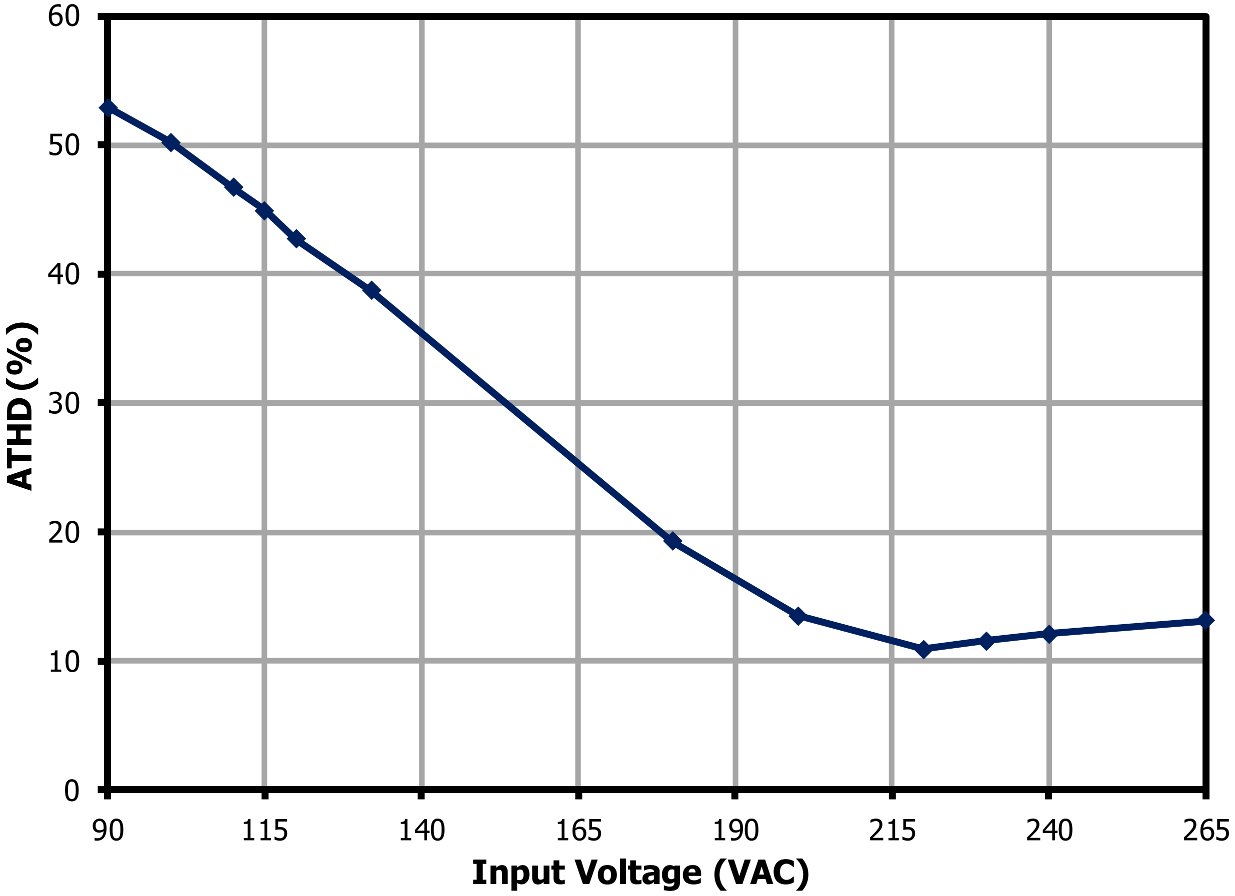


Figure 15 – %ATHD vs. Line.

10.5 *No-Load Input Power*

Set-up: Open frame unit
Load: No-load
Ambient Temperature: 25 ºC.
Soak Time: 120 seconds per line

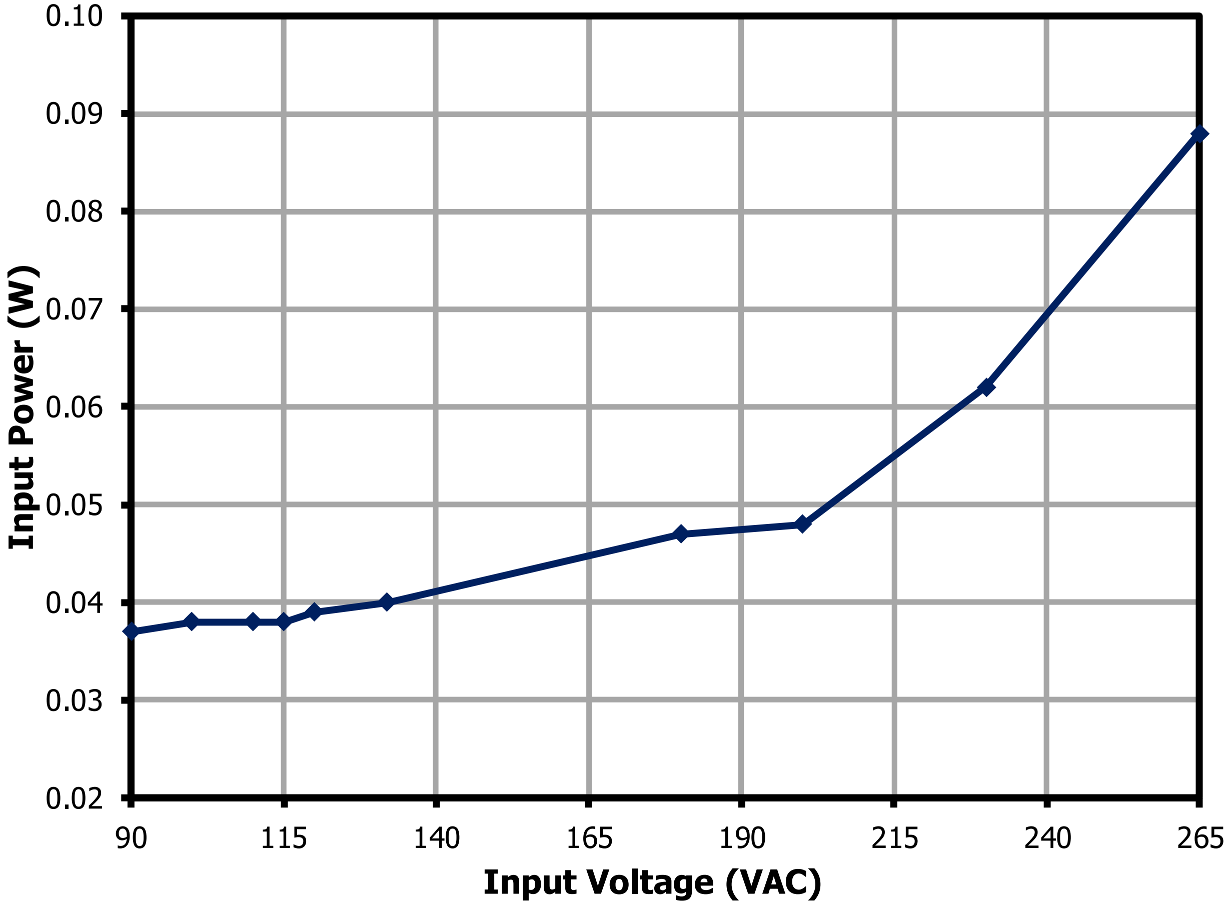


Figure 16 – No Load Input Power vs. Line.

10.6 *No-Load Output Voltage*

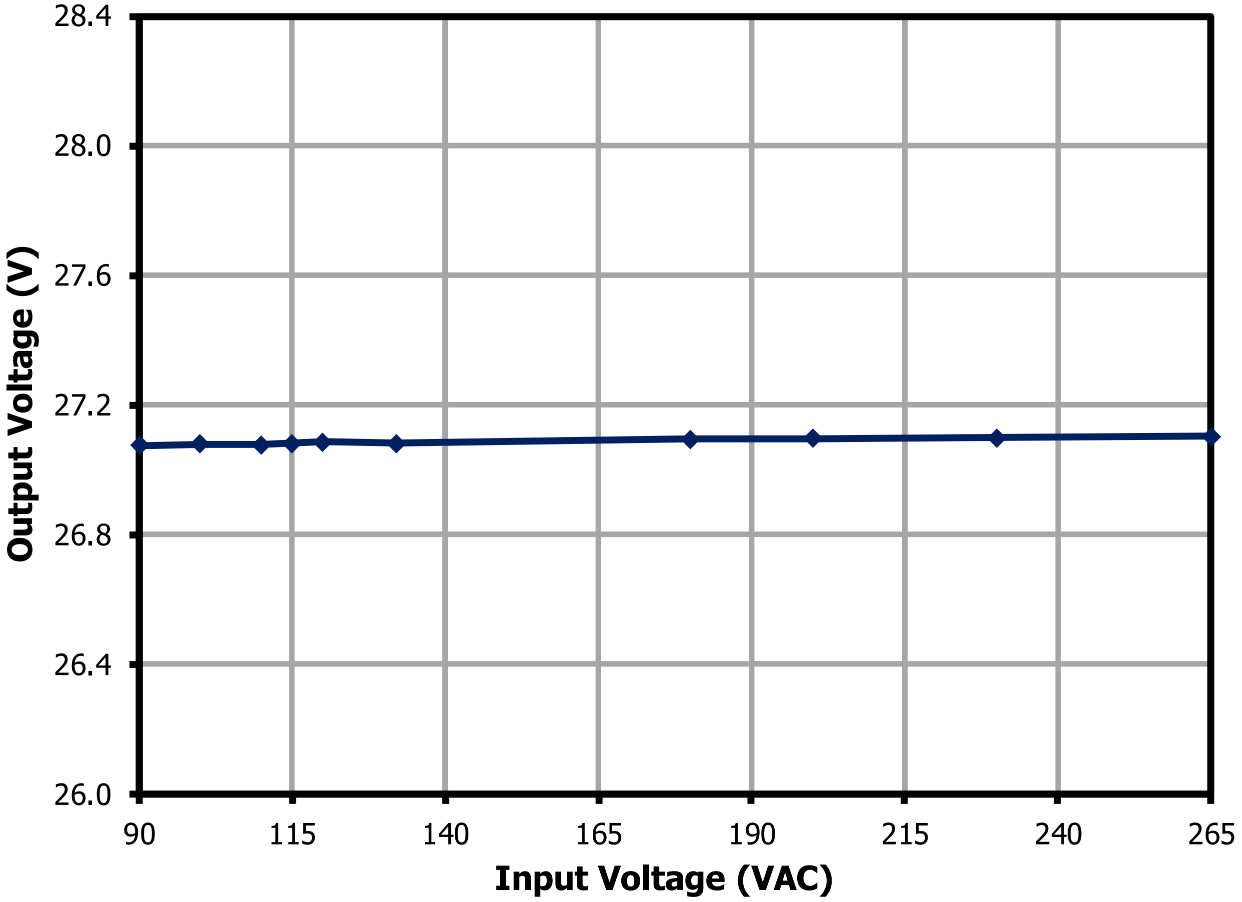


Figure 17 – No Load Voltage vs. Line.

11 Test Data

11.1 *Test Data at Full Load*

Input		Input Measurement					LED Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
90	60	89.84	179.41	14.09	0.874	52.936	26.827	449.99	12.072	85.678
100	60	99.87	158.35	14.019	0.887	50.237	26.869	450	12.091	86.247
110	60	109.9	141.43	13.971	0.899	46.717	26.898	449.98	12.104	86.637
115	60	114.87	134.06	13.946	0.906	44.923	26.895	449.98	12.102	86.778
120	60	119.92	127.35	13.926	0.912	42.719	26.893	449.96	12.101	86.895
132	60	131.92	113.74	13.897	0.926	38.715	26.902	449.99	12.106	87.112
180	50	179.96	79.72	13.927	0.971	19.264	26.973	449.98	12.137	87.147
200	50	199.92	71.54	13.962	0.976	13.473	26.979	449.97	12.14	86.95
220	50	219.95	65.3	14.012	0.976	10.885	26.982	449.98	12.141	86.647
230	50	229.98	62.76	14.047	0.973	11.576	26.984	449.97	12.142	86.438
240	50	240	60.48	14.088	0.971	12.09	26.994	449.95	12.146	86.215

11.2 *Test Data at No-Load*

Input		Input Measurement			V_{OUT} (V_{DC})
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	
90	60	89.95	5.02	0.037	27.08
100	60	99.99	5.04	0.038	27.08
115	60	109.94	5.07	0.038	27.08
120	60	115	5.10	0.038	27.08
132	60	119.98	5.14	0.039	27.09
185	60	131.99	5.27	0.04	27.08
200	60	180.01	5.47	0.047	27.09
220	60	200	5.59	0.048	27.10
230	60	230.03	5.91	0.062	27.1
265	60	265.05	6.58	0.088	27.10

12 Load Regulation Performance

Set-up: Open frame unit
Ambient Temperature: 25 ºC.
Soak Time: 30 seconds per loading point

12.1 *Output Voltage Load Regulation*

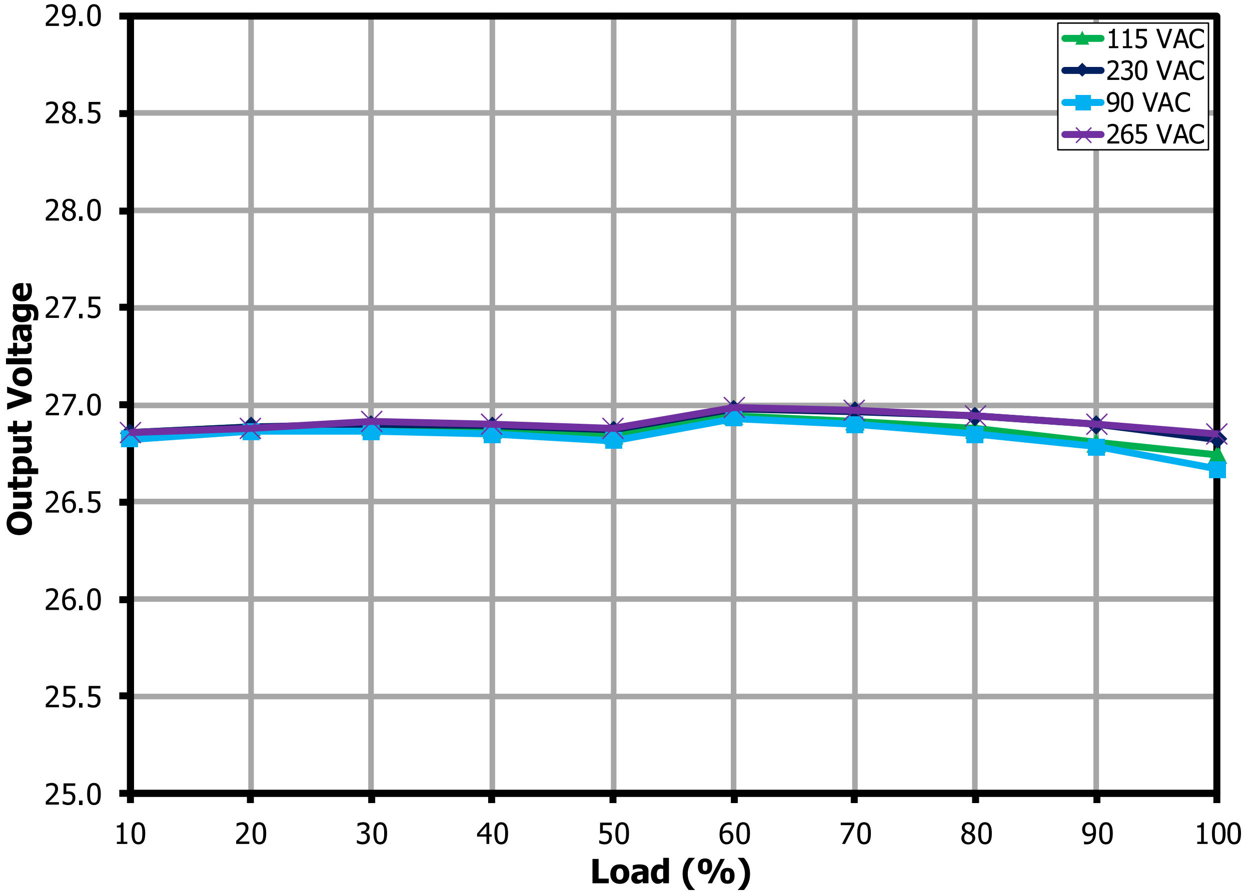


Figure 18 – Output Voltage vs. Load.

12.2 *Efficiency vs. Load*

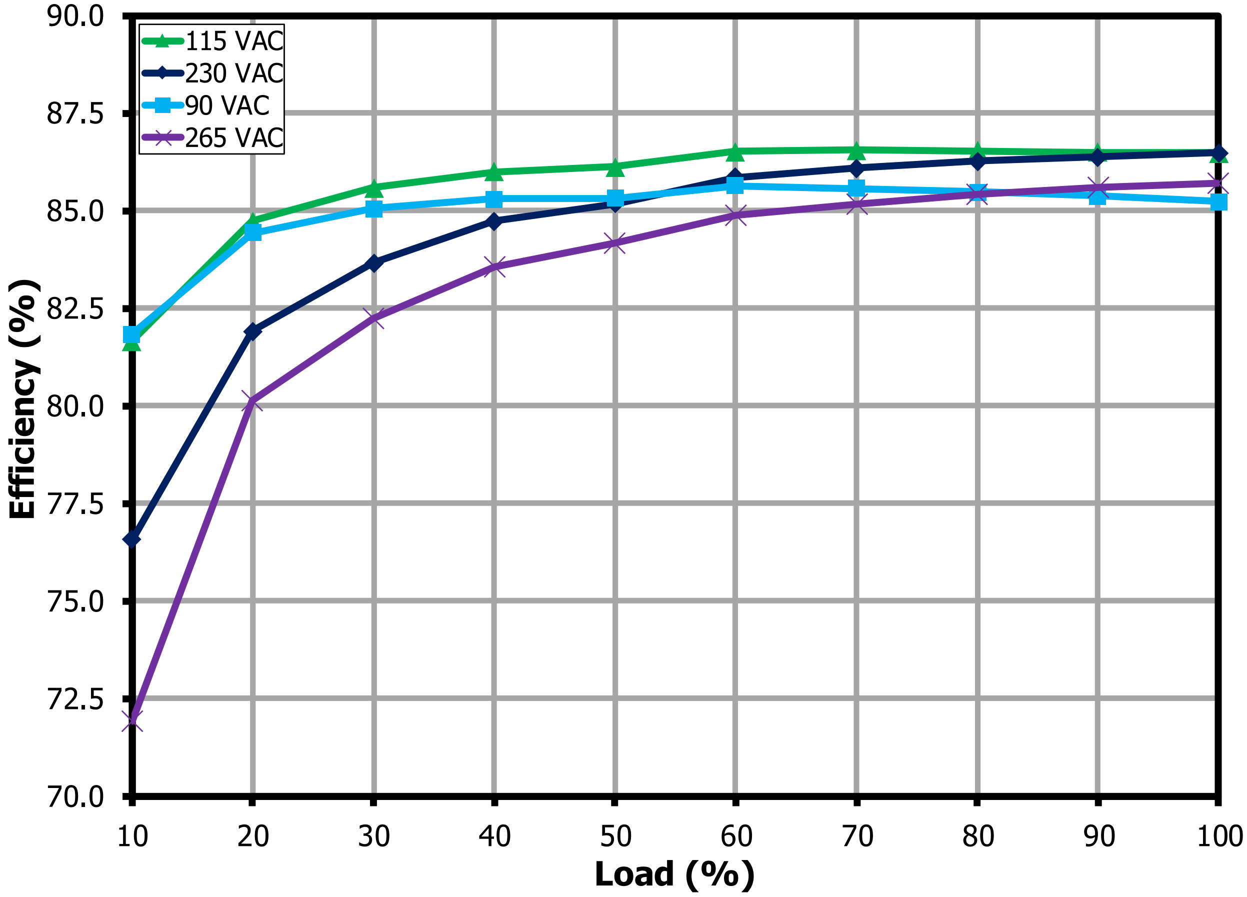


Figure 19 – Efficiency vs Load.

12.3 *Average Efficiency*

12.3.1 Average Efficiency Measurement

% Load	**Efficiency (%)**	
	115 V / 60 Hz	**230V / 50 Hz**
100	84.89	82.88
75	86.03	84.99
50	86.55	86.04
25	86.51	86.35
AVERAGE EFFICIENCY	**85.99**	**85.07**
DOE LEVEL VI Limit	**83.03**	

Note: DOE Level VI Limit for Single-Voltage External AC-DC Power Supply, Basic-Voltage Efficiency Limit ≥ $0.071 \times \ln(P_{OUT}) - 0.0014 \times P_{OUT} + 0.67$

12.4 *Power Factor vs. Load*

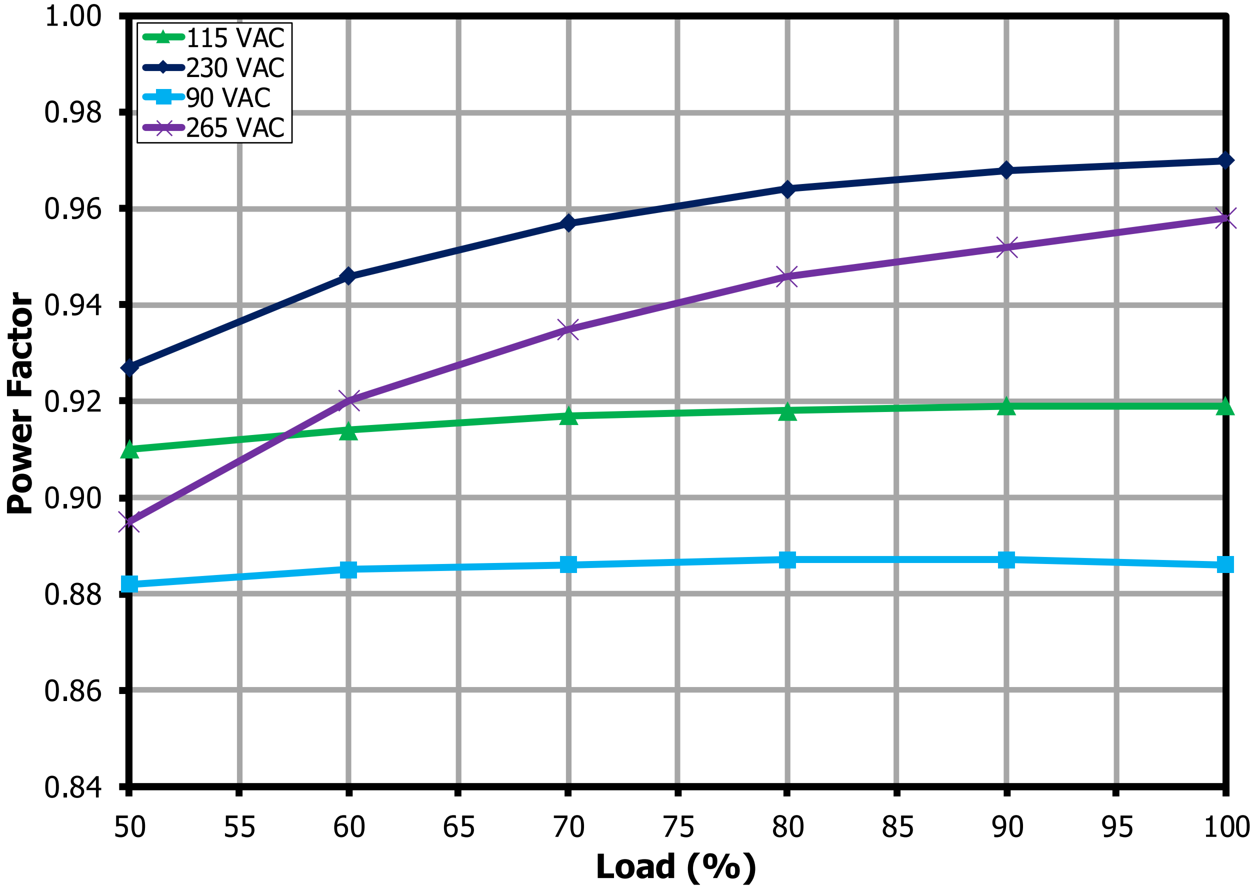


Figure 20 – Power Factor vs Load.

12.5 *%ATHD vs. Load*

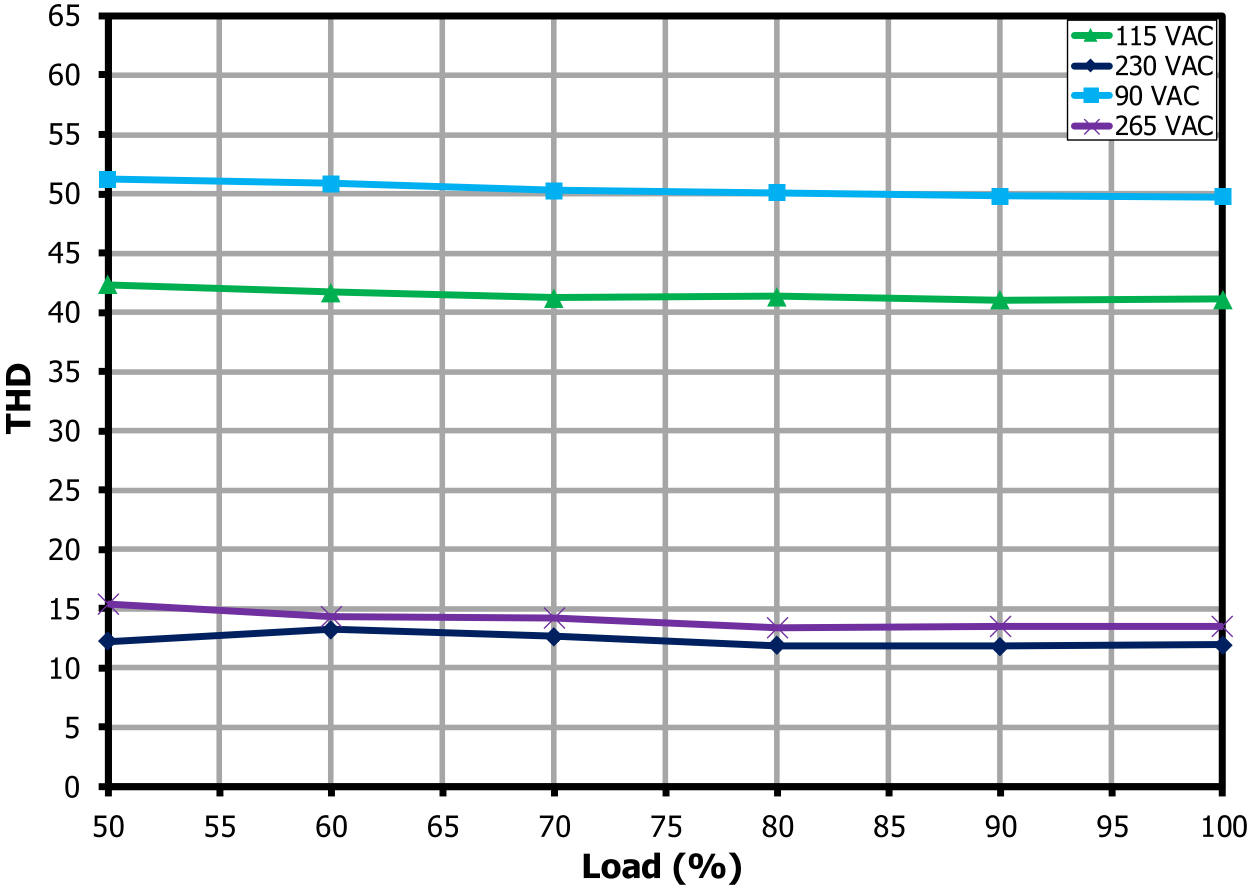


Figure 21 – %ATHD vs Load.

12.6 *CV/CC Curve*

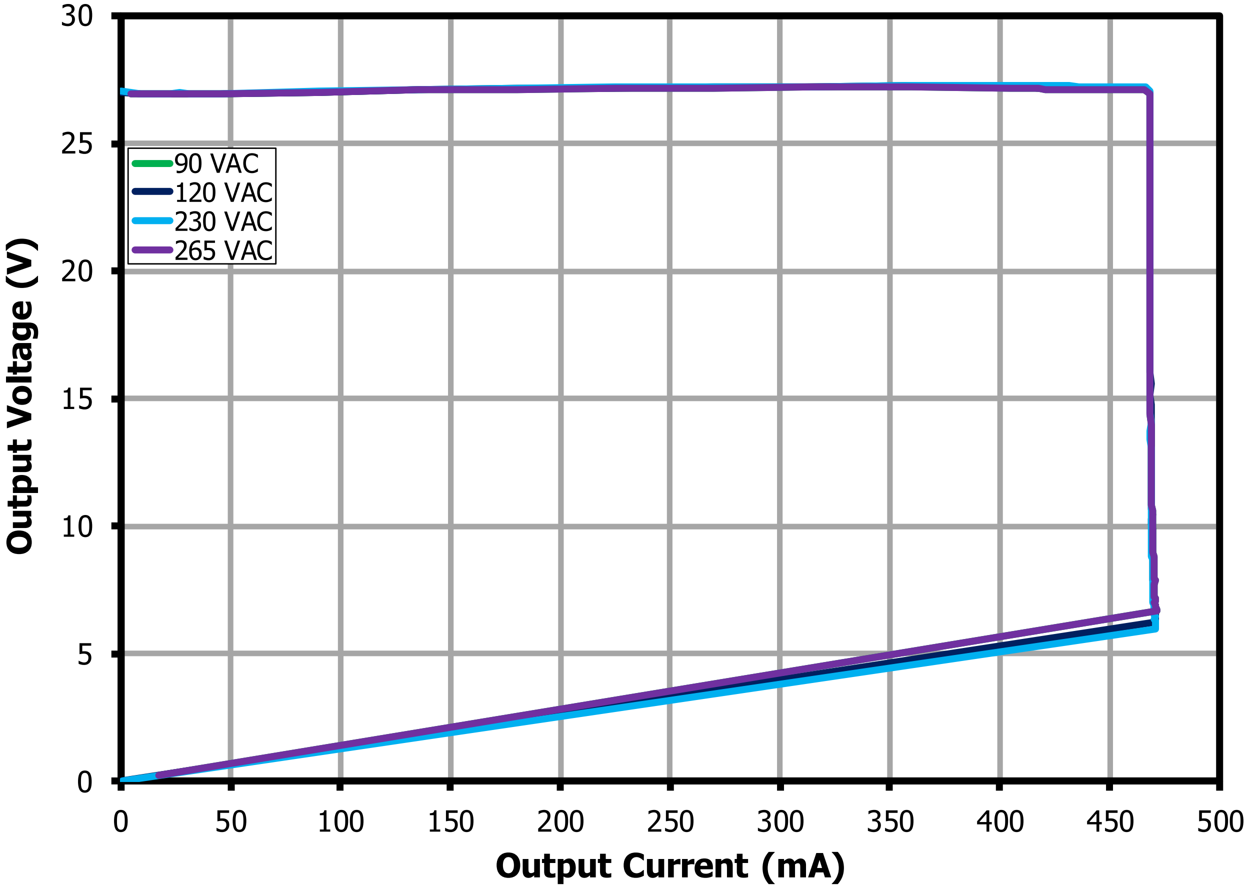


Figure 22 – CV/CC Curve.

13 Thermal Performance

13.1 *Thermal Scan at 25 ºC Ambient*

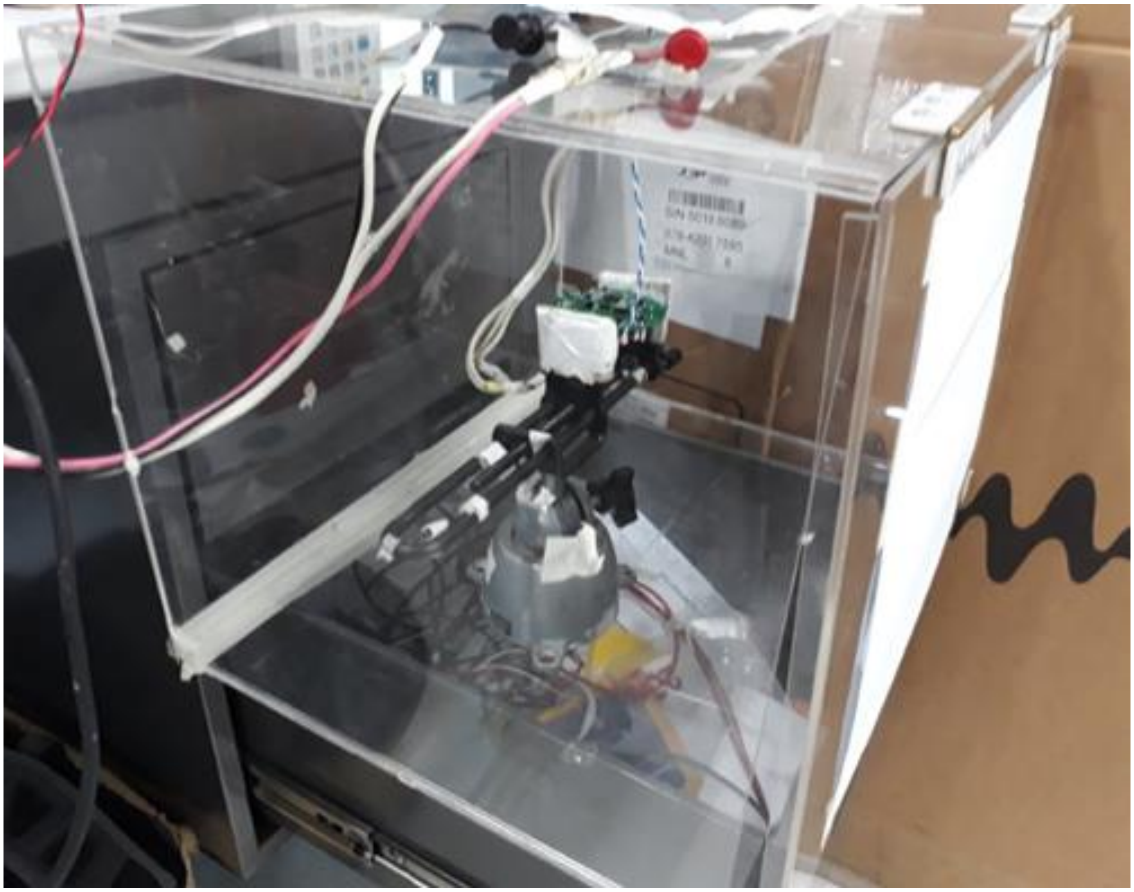


Figure 23 – Test Set-up Picture - Open Frame.

Unit in open frame was placed inside an acrylic enclosure to prevent airflow that might affect the thermal measurements. Temperature was measured using FLIR thermal camera.

13.1.1 Thermal Scan at 90 VAC Full Load

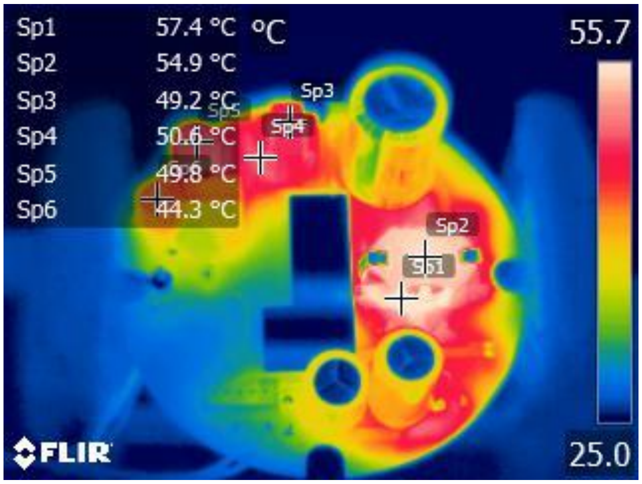


Figure 24 – 90 VAC 60 Hz, Top side.
SP1- Flyback TRF Winding (T1): 57.4 ºC.
SP2- Flyback TRF Core (T1):54.9 ºC.
SP3- PFC TRF Core (T2): 49.2 ºC.
SP4- PFC TRF Winding (T2): 50.6 ºC.
SP5- EMI Inductor (L2): 49.8 ºC.
SP6- EMI Inductor (L1): 44.3 ºC.

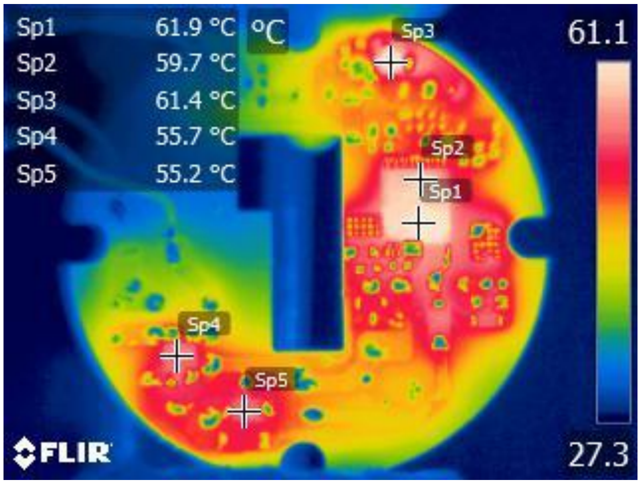


Figure 22 – 90 VAC 60 Hz, Bottom side.
SP1- LYTSwitch-6 FET Side (U1): 61.9 ºC.
SP2- LYTSwitch-6 CTRL Side (U1): 59.7 ºC.
SP3- Secondary Snubber Diode (D6): 61.4 ºC.
SP4- PFC Diode (D1): 55.7 ºC.
SP5- Blocking Diode (D2): 55.2 ºC.

13.1.2 Thermal Scan at 265 VAC Full Load

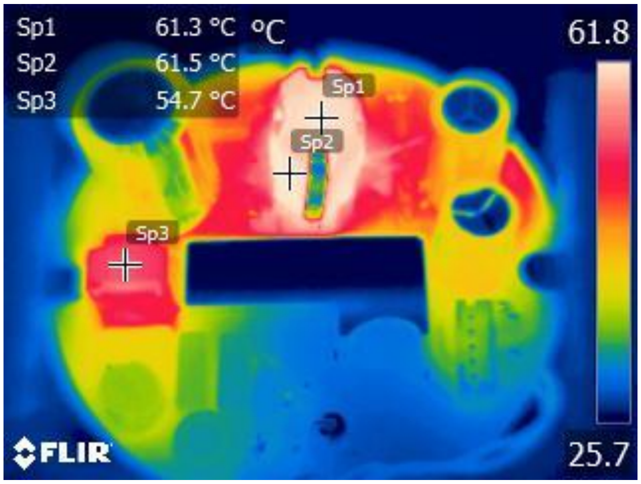


Figure 25 – 265 VAC 60 Hz, Top side.
SP1- Flyback TRF Core (T1): 61.3 ºC.
SP2- Flyback TRF Winding (T1):61.5 ºC.
SP3- PFC TRF Core (T2): 54.7 ºC.

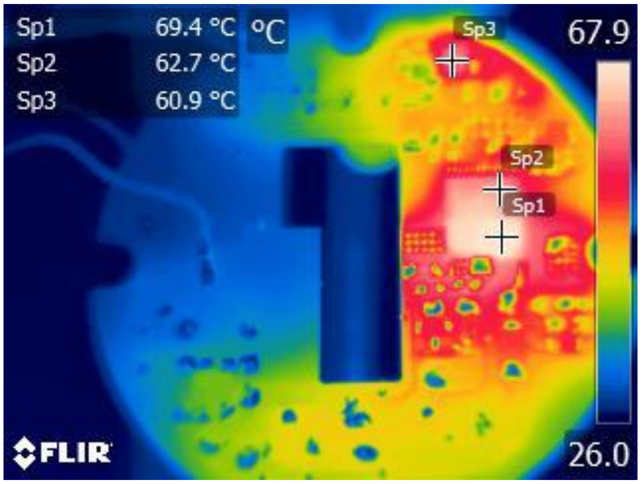


Figure 26 – 265 VAC 60 Hz, Bottom side.
SP1- LYTSwitch-6 FET side (U1): 69.4 ºC.
SP2- LYTSwitch-6 CTRL side (U1): 62.7 ºC.
SP3- Secondary Snubber Diode (D6): 60.9 ºC.

13.2 Thermal Test at 75 ºC Ambient

Set-up:
Unit: DER-630 open frame
Test Chamber: Tenney
Ambient Temperature: 75 ºC (inside enclosure).
Data Logger: Graphtec
Thermocouple: Type T

Figure 27 – Test Set-up Pictures. Unit is Placed Inside an Enclosure to Prevent the Effect of Airflow.

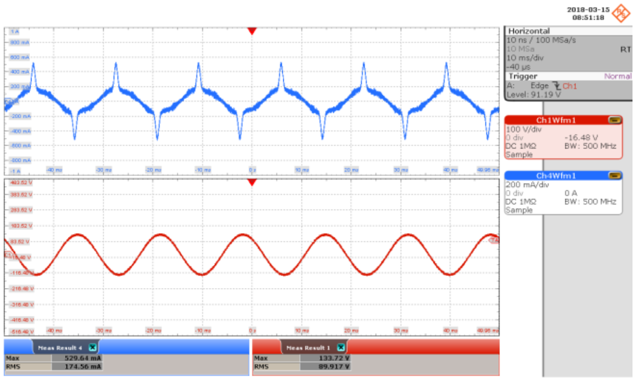
13.3 *Thermal Test Data at 75 ºC Ambient*

Item	**Description**	**Thermal Data (ºC)**	
		90 V	**265 V**
1	Ambient Temperature	75.8	76.2
2	U1 – CTRL Side	103.7	107.3
3	U1 – FET Side	108	114.2
4	D6 – Secondary Snubber Diode	101.2	102.3
5	D1 – PFC Boost Diode	98.7	90.9
6	D5 –PFC Boost Diode	96	96
7	T1 – Flyback Winding	103.6	108.4
8	C10 – Output Capacitor	87.7	88.3
9	C4 – Bulk Capacitor	86.9	87.5
10	D2 – Blocking Diode	95.7	88.9

14 Waveforms

Waveforms were taken at room temperature (25 ºC).

14.1 *Input Voltage and Input Current at Full Load*



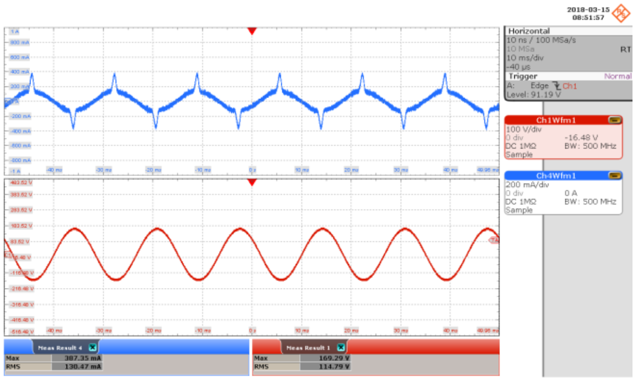
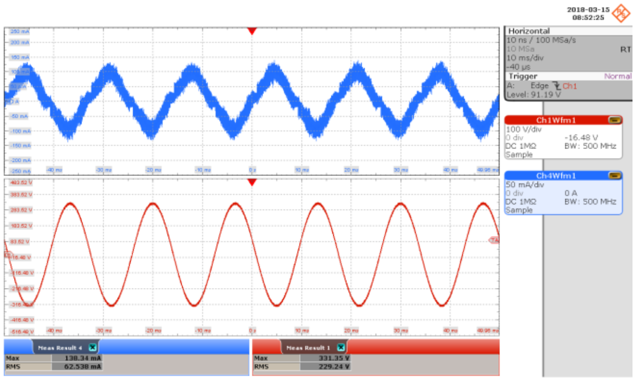


Figure 28 – 90 VAC 60 Hz, Full Load.
Upper: I_{IN}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

Figure 29 – 115 VAC 60 Hz, Full Load.
Upper: I_{IN}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.



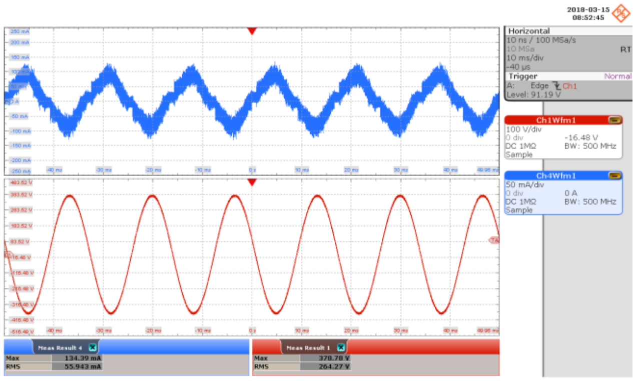


Figure 30 – 230 VAC 50 Hz, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

Figure 31 – 265 VAC 50 Hz, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

14.2 *Start-up Profile at Full Load*

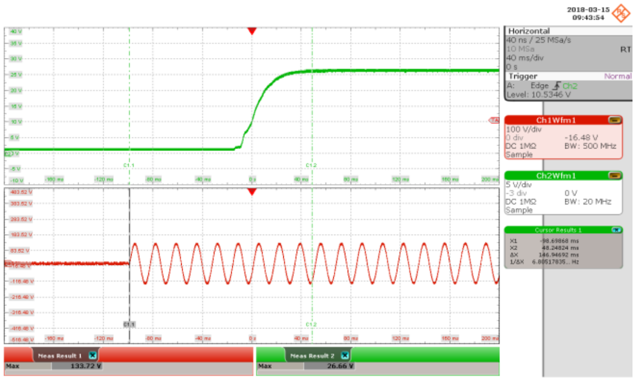


Figure 32 – 90 VAC 60 Hz, Full Load Start-up.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 40 ms / div.
Turn-on Time: 146 ms.

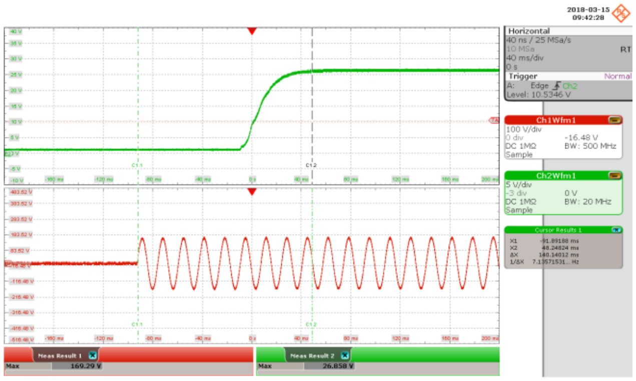


Figure 33 – 115 VAC 60 Hz, Full Load Start-up.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 40 ms / div.
Turn-on Time: 140 ms.

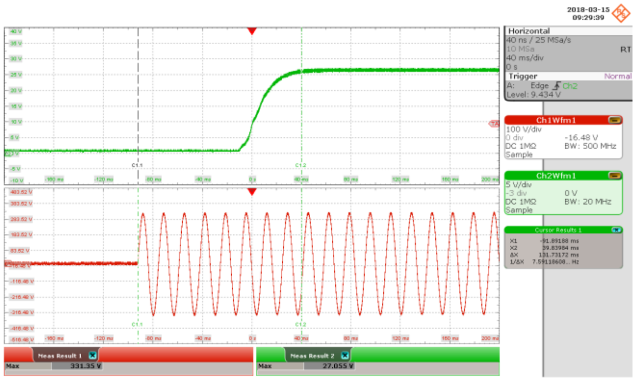


Figure 34 – 230 VAC 50 Hz, Full Load Start-up.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 40 ms / div.
Turn-on Time: 132 ms.

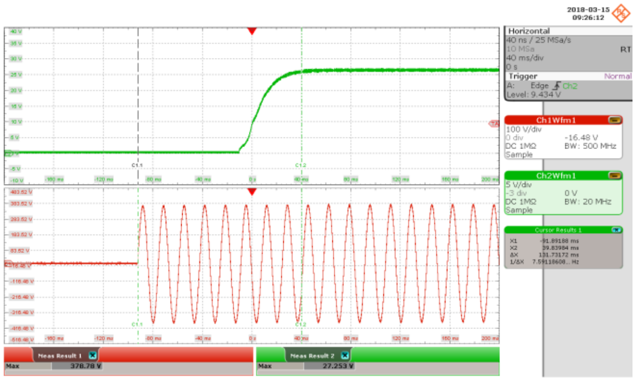
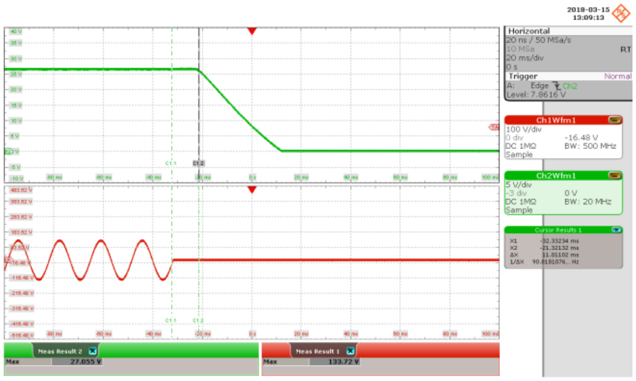


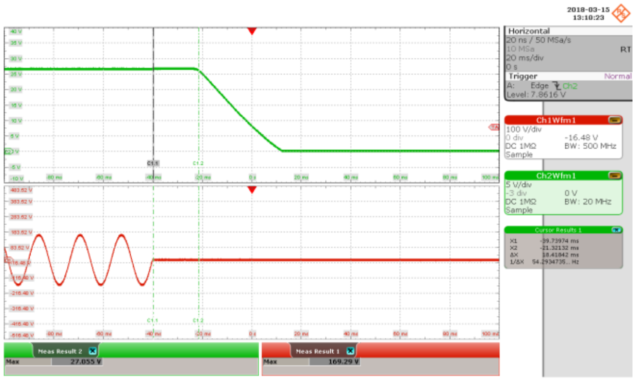
Figure 35 – 265 VAC 50 Hz, Full Load Start-up.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 40 ms / div.
Turn-on Time: 132 ms

14.3 *Output Voltage Fall*



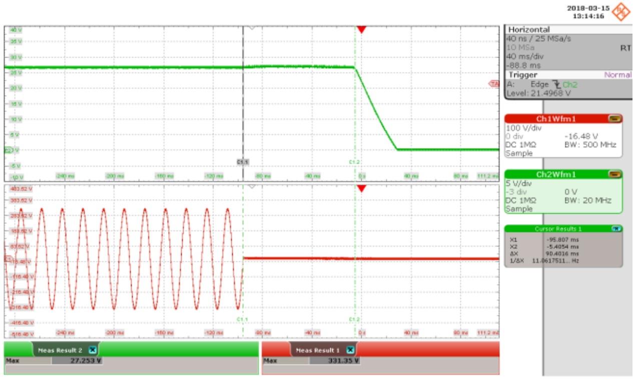
2018-03-15
13:09:13
Horizontal
20 ns / 50 MSa/s
10 MSa RT
20 ms/div
0 s
Trigger Normal
A: Edge Ch2
Level: 7.8616 V
Ch1Wfm1
100 V/div
0 div -16.48 V
DC 1MΩ BW: 500 MHz
Sample
Ch2Wfm1
5 V/div
-3 div 0 V
DC 1MΩ BW: 20 MHz
Sample
Cursor Results 1
X1 -32.33234 ms
X2 -21.32132 ms
ΔX 11.01102 ms
1/ΔX 90.8181076... Hz
Meas Result 2
Max 27.055 V
Meas Result 1
Max 133.72 V

Figure 36 – 90 VAC 60 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 20 ms / div.
Hold-up Time: 11 ms.



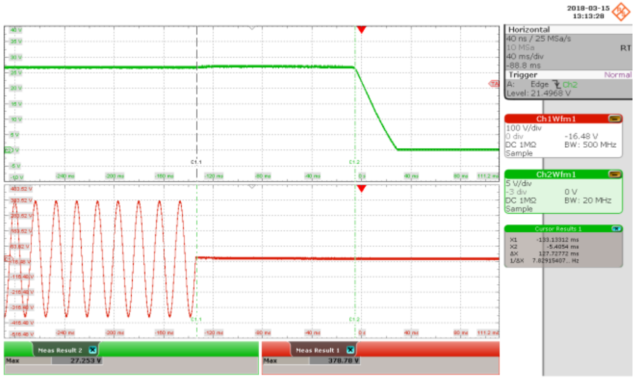
2018-03-15
13:10:23
Horizontal
20 ns / 50 MSa/s
10 MSa RT
20 ms/div
0 s
Trigger Normal
A: Edge Ch2
Level: 7.8616 V
Ch1Wfm1
100 V/div
0 div -16.48 V
DC 1MΩ BW: 500 MHz
Sample
Ch2Wfm1
5 V/div
-3 div 0 V
DC 1MΩ BW: 20 MHz
Sample
Cursor Results 1
X1 -39.73974 ms
X2 -21.32132 ms
ΔX 18.41842 ms
1/ΔX 54.2934735... Hz
Meas Result 2
Max 27.055 V
Meas Result 1
Max 169.29 V

Figure 37 – 115 VAC 60 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 20 ms / div.
Hold-up Time: 18 ms.



2018-03-15
13:14:16
Horizontal
40 ns / 25 MSa/s
10 MSa RT
40 ms/div
-88.8 ms
Trigger Normal
A: Edge Ch2
Level: 21.4968 V
Ch1Wfm1
100 V/div
0 div -16.48 V
DC 1MΩ BW: 500 MHz
Sample
Ch2Wfm1
5 V/div
-3 div 0 V
DC 1MΩ BW: 20 MHz
Sample
Cursor Results 1
X1 -95.807 ms
X2 -5.4054 ms
ΔX 90.4016 ms
1/ΔX 11.0617511... Hz
Meas Result 2
Max 27.253 V
Meas Result 1
Max 331.35 V

Figure 38 – 230 VAC 50 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 40 ms / div.
Hold-up Time: 90 ms.

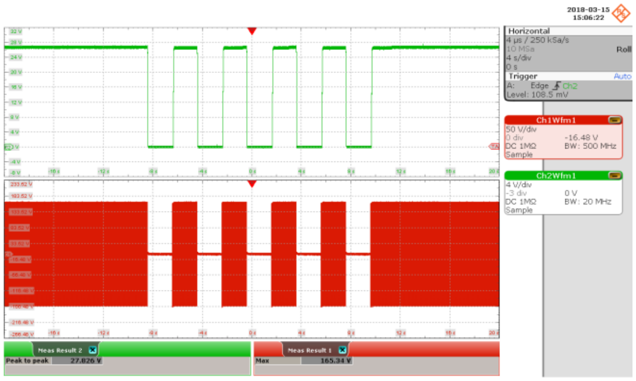


2018-03-15
13:13:28
Horizontal
40 ns / 25 MSa/s
10 MSa RT
40 ms/div
-88.8 ms
Trigger Normal
A: Edge Ch2
Level: 21.4968 V
Ch1Wfm1
100 V/div
0 div -16.48 V
DC 1MΩ BW: 500 MHz
Sample
Ch2Wfm1
5 V/div
-3 div 0 V
DC 1MΩ BW: 20 MHz
Sample
Cursor Results 1
X1 -133.13312 ms
X2 -5.4054 ms
ΔX 127.72772 ms
1/ΔX 7.82915407... Hz
Meas Result 2
Max 27.253 V
Meas Result 1
Max 378.78 V

Figure 39 – 265 VAC 50 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 40 ms / div.
Hold-up Time: 128 ms.

14.4 *Power Cycling*

No high-voltage overshoots during ac power cycling


2018-03-15
15:06:22
Horizontal
4 µs / 250 kSa/s
10 MSa Roll
4 s/div
0 s
Trigger Auto
A: Edge Ch2
Level: 108.5 mV
Ch1Wfm1
50 V/div
0 div -16.48 V
DC 1MΩ BW: 500 MHz
Sample
Ch2Wfm1
4 V/div
-3 div 0 V
DC 1MΩ BW: 20 MHz
Sample
Meas Result 2
Peak to peak 27.826 V
Meas Result 1
Max 165.34 V

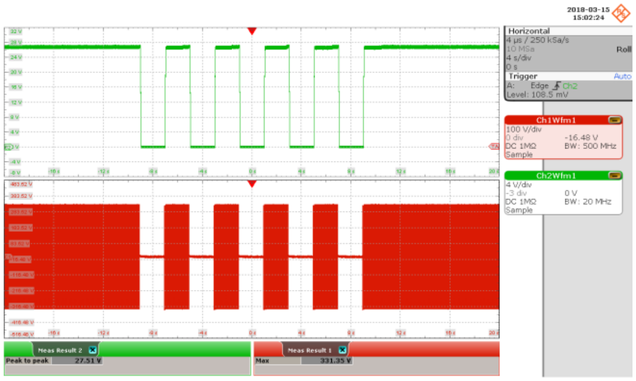
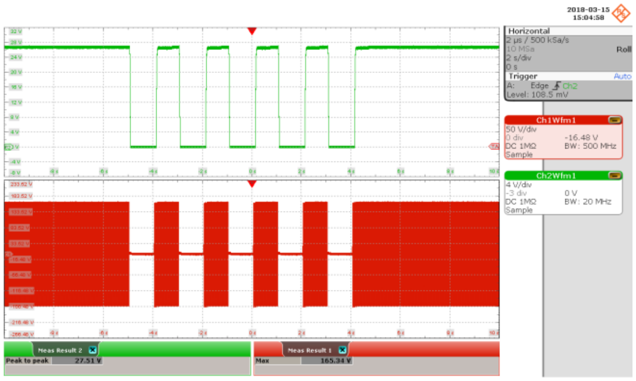

2018-03-15
15:02:24
Horizontal
4 µs / 250 kSa/s
10 MSa Roll
4 s/div
0 s
Trigger Auto
A: Edge Ch2
Level: 108.5 mV
Ch1Wfm1
100 V/div
0 div -16.48 V
DC 1MΩ BW: 500 MHz
Sample
Ch2Wfm1
4 V/div
-3 div 0 V
DC 1MΩ BW: 20 MHz
Sample
Meas Result 2
Peak to peak 27.51 V
Meas Result 1
Max 331.35 V

Figure 40 – 115 VAC 60 Hz, Full Load.
2 s Off, 2 s On.
Upper: V_{OUT}, 4 V / div.
Lower: V_{IN}, 50 V / div., 4 s / div.

Figure 41 – 230 VAC 50 Hz, Full Load.
2 s Off, 2 s On.
Upper: V_{OUT}, 4 V / div.
Lower: V_{IN}, 100 V / div., 4 s / div.


2018-03-15
15:04:58
Horizontal
2 µs / 500 kSa/s
10 MSa Roll
2 s/div
0 s
Trigger Auto
A: Edge Ch2
Level: 108.5 mV
Ch1Wfm1
50 V/div
0 div -16.48 V
DC 1MΩ BW: 500 MHz
Sample
Ch2Wfm1
4 V/div
-3 div 0 V
DC 1MΩ BW: 20 MHz
Sample
Meas Result 2
Peak to peak 27.51 V
Meas Result 1
Max 165.34 V

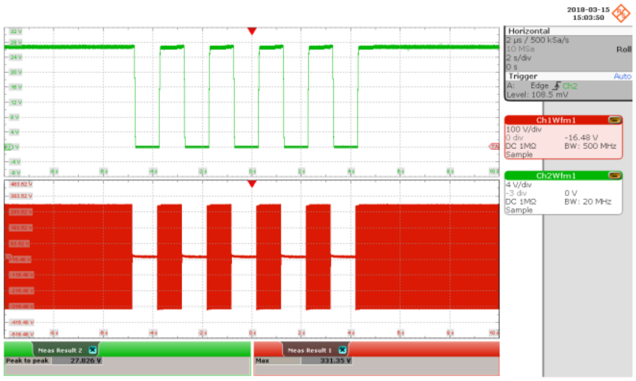
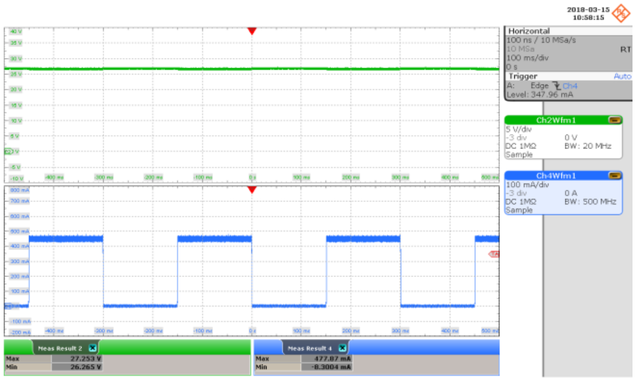

2018-03-15
15:03:50
Horizontal
2 µs / 500 kSa/s
10 MSa Roll
2 s/div
0 s
Trigger Auto
A: Edge Ch2
Level: 108.5 mV
Ch1Wfm1
100 V/div
0 div -16.48 V
DC 1MΩ BW: 500 MHz
Sample
Ch2Wfm1
4 V/div
-3 div 0 V
DC 1MΩ BW: 20 MHz
Sample
Meas Result 2
Peak to peak 27.826 V
Meas Result 1
Max 331.35 V

Figure 42 – 115 VAC 60 Hz, Full Load.
1 s Off, 1 s On.
Upper: V_{OUT}, 4 V / div.
Lower: V_{IN}, 50 V / div., 2 s / div.

Figure 43 – 230 VAC 50 Hz, Full Load.
1 s Off, 1 s On.
Upper: V_{OUT}, 4 V / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

14.5 *Load Transient Response 3 Hz*



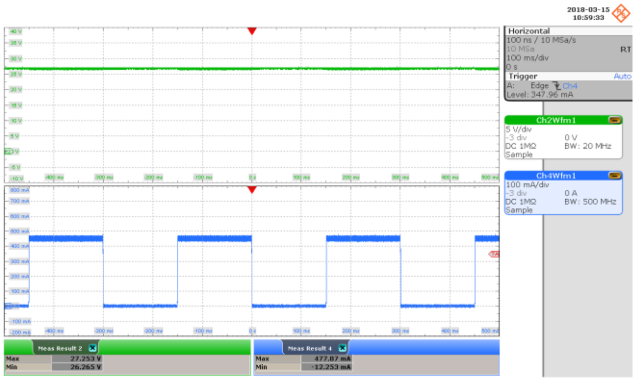
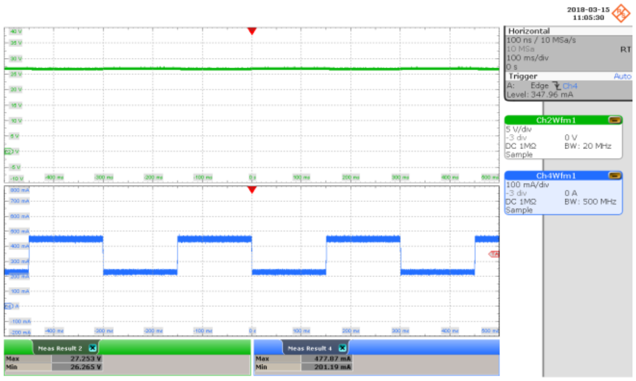


Figure 44 – 115 VAC 60 Hz.
0% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Upper: V_{OUT}, 5 V / div., 100 ms / div.
Lower: I_{OUT}, 100 mA / div.

Figure 45 – 230 VAC 50 Hz.
0% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Upper: V_{OUT}, 5 V / div., 100 ms / div.
Lower: I_{OUT}, 100 mA / div.



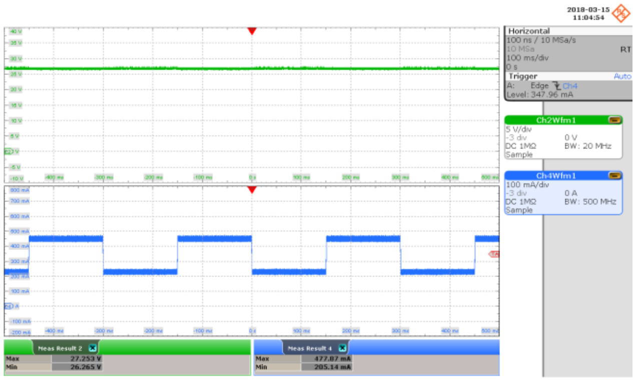
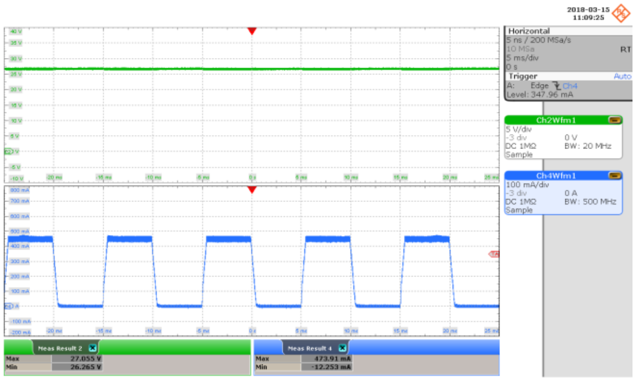


Figure 46 – 115 VAC 60 Hz.
50% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Upper: V_{OUT}, 5 V / div., 100 ms / div.
Lower: I_{OUT}, 100 mA / div.

Figure 47 – 230 VAC 50 Hz.
50% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Upper: V_{OUT}, 5 V / div., 100 ms / div.
Lower: I_{OUT}, 100 mA / div.

14.6 *Load Transient Response 100 Hz*



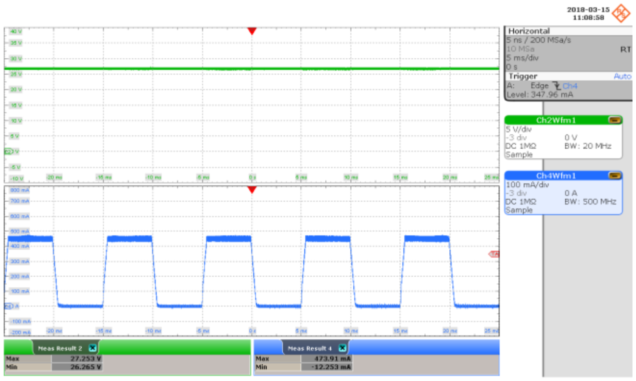
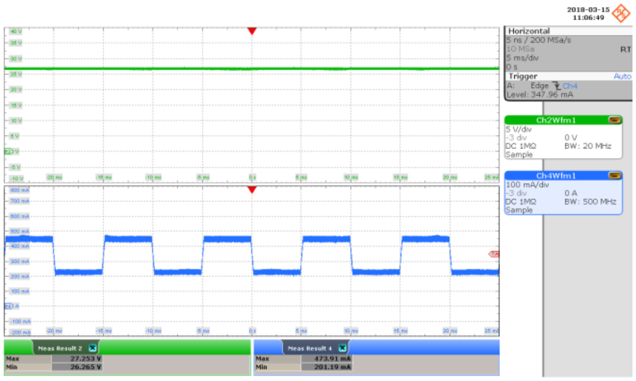


Figure 48 – 115 VAC 60 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Upper: V_{OUT}, 5 V / div., 5 ms / div.
Lower: I_{OUT}, 100 mA / div.

Figure 49 – 230 VAC 50 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Upper: V_{OUT}, 5 V / div., 5 ms / div.
Lower: I_{OUT}, 100 mA / div.



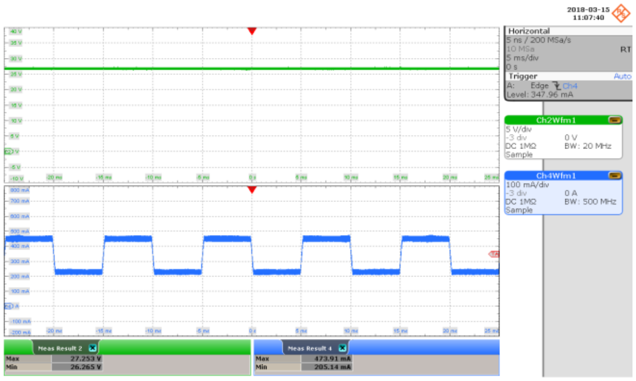


Figure 50 – 115 VAC 60 Hz.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Upper: V_{OUT}, 5 V / div., 5 ms / div.
Lower: I_{OUT}, 100 mA / div.

Figure 51 – 230 VAC 50 Hz, Full Load.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Upper: V_{OUT}, 5 V / div., 5 ms / div.
Lower: I_{OUT}, 100 mA / div.

14.7 *LYTSwitch-6 Drain Voltage and Current Waveforms*

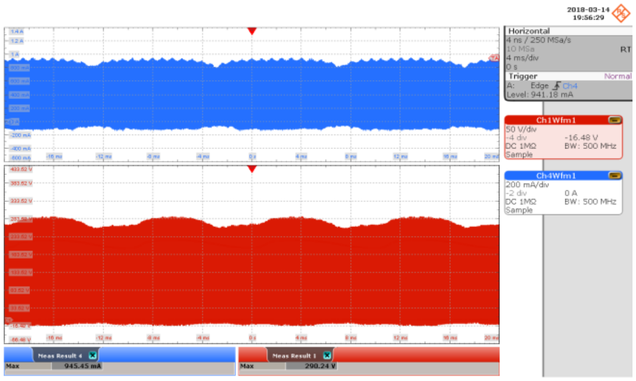


Figure 52 – 90 VAC 60 Hz, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 ms / div.

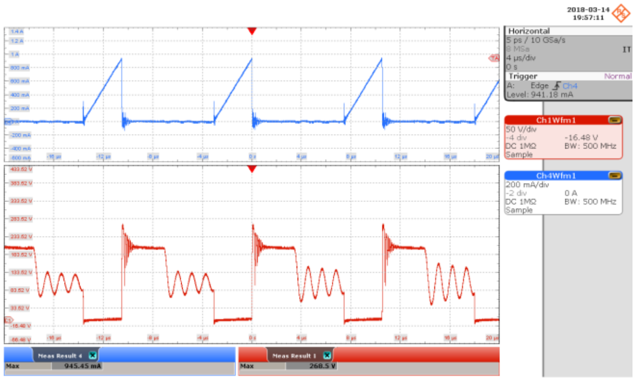


Figure 53 – 90 VAC 60 Hz, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 μs / div.

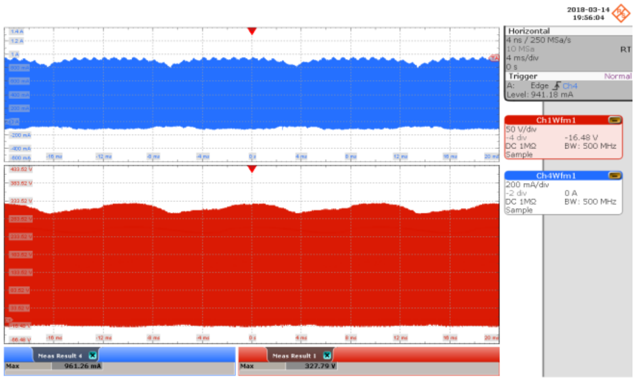


Figure 54 – 115 VAC 60 Hz, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 ms / div.

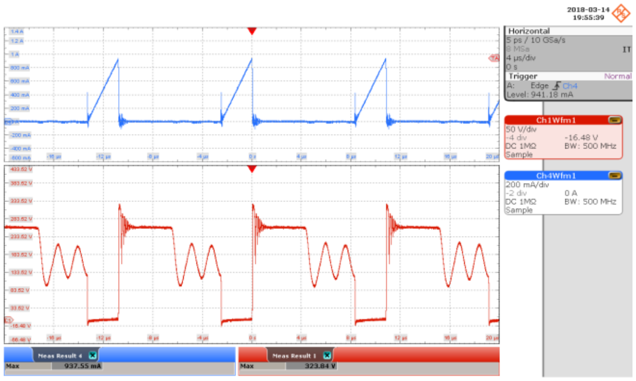
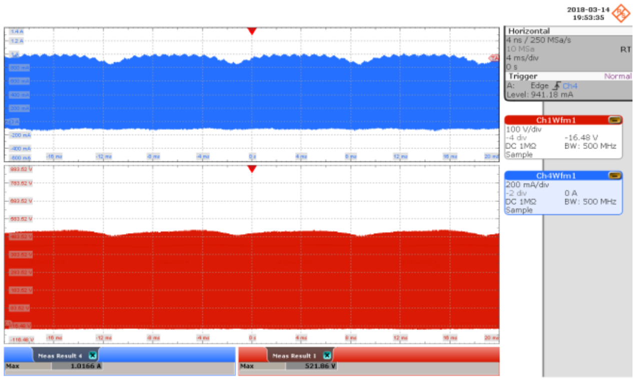


Figure 55 – 115 VAC 60 Hz, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 μs / div.



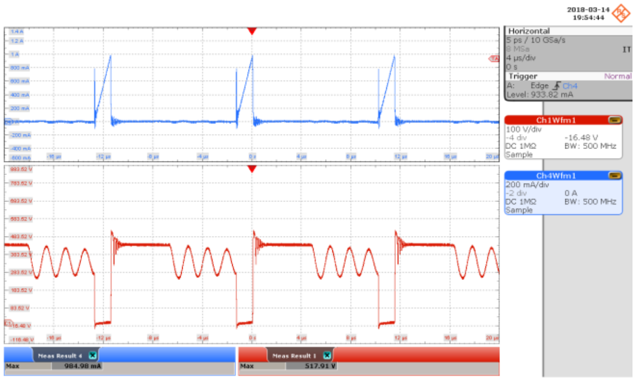
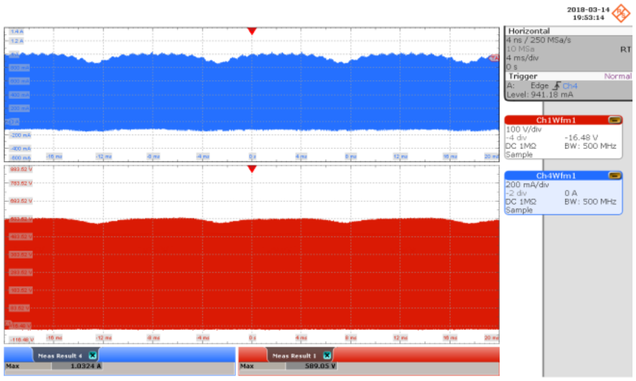


Figure 56 – 230 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

Figure 57 – 230 VAC 50 Hz, Full Load Normal
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 µs / div.



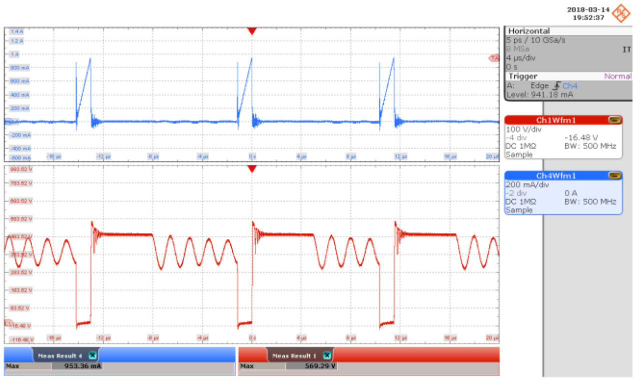


Figure 58 – 265 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

Figure 59 – 265 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 µs / div.

14.8 *LYTSwitch-6 Drain Voltage and Current at Full Start-up*

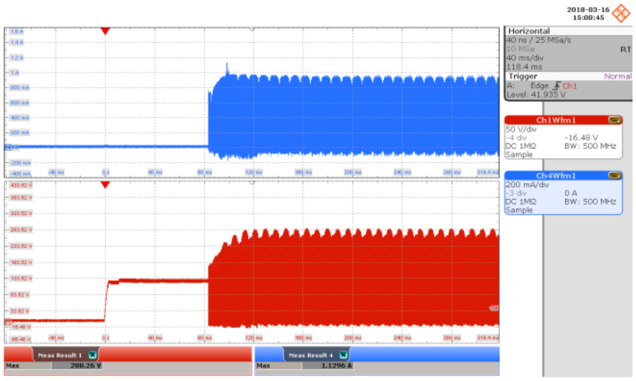


Figure 60 – 90 VAC 60 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 40 ms / div.

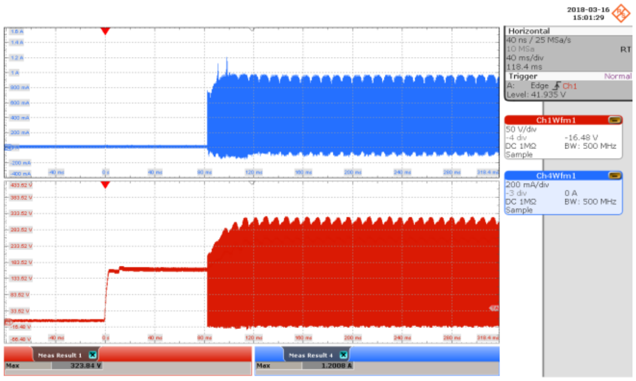


Figure 61 – 115 VAC 60 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 40 ms / div.

Figure 62 – 230 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 40 ms / div.

Figure 63 – 265 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 40 ms / div.

14.9 *LYTSwitch-6 Drain Voltage and Current During Output Short-Circuit*

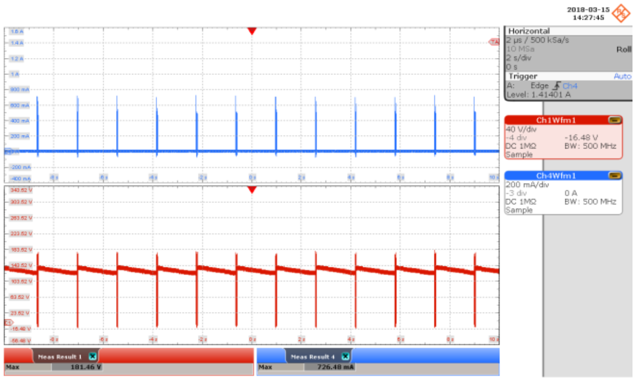


Figure 64 – 90 VAC 60 Hz, Output Shorted.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 40 V / div., 2 s / div.

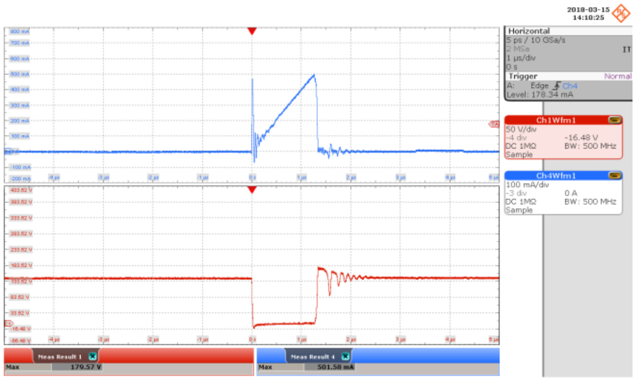


Figure 65 – 90 VAC 60 Hz, Output Shorted.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 50 V / div., 1 μs / div.

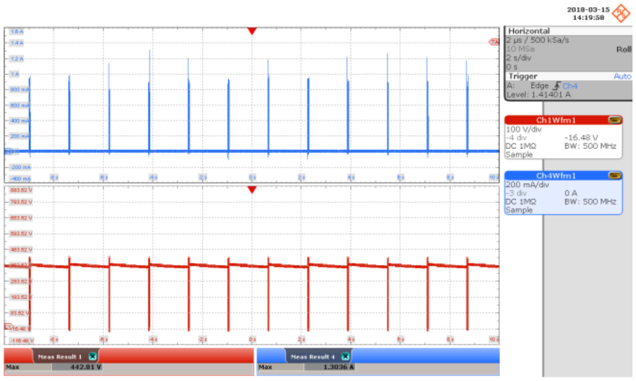


Figure 66 – 265 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 2 s / div.

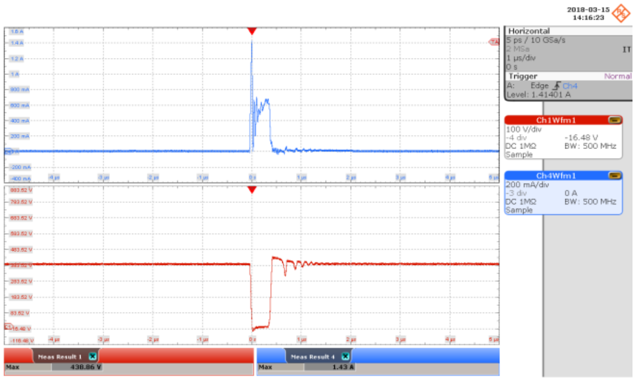
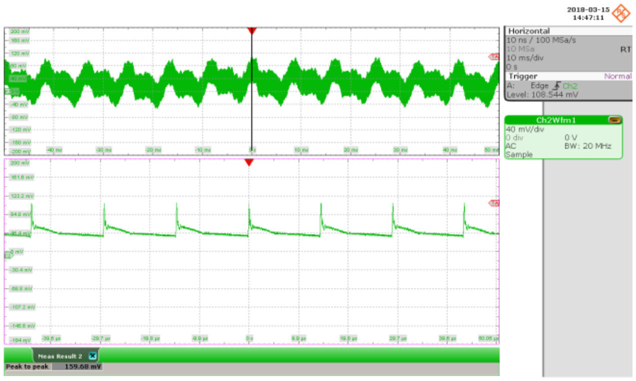


Figure 67 – 265 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 μs / div.

14.10 *Input Power at Short-Circuit*

Input		
VAC (V_{RMS})	Freq (Hz)	P_{IN} (mW)
90	60	86
115	60	98
230	50	200
265	50	230

14.11 *Output Ripple Voltage*


2018-03-15 14:47:11

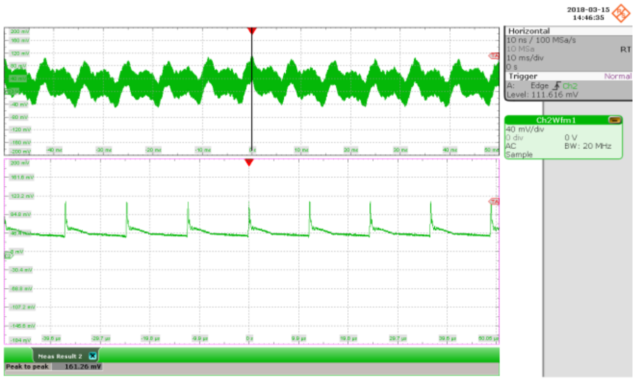
Horizontal
10 ns / 100 MSa/s
10 MSa RT
10 ms/div
0 s

Trigger Normal
A: Edge Ch2
Level: 108.544 mV

Ch2Wfm1
40 mV/div
0 div 0 V
AC BW: 20 MHz
Sample

Meas Result 2
Peak to peak 159.68 mV

Figure 68 – 90 VAC 60 Hz, Full Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 40 mV / div., 10 ms / div.
Ripple Voltage: 159.68 mV_{PK-PK}.


2018-03-15 14:46:35

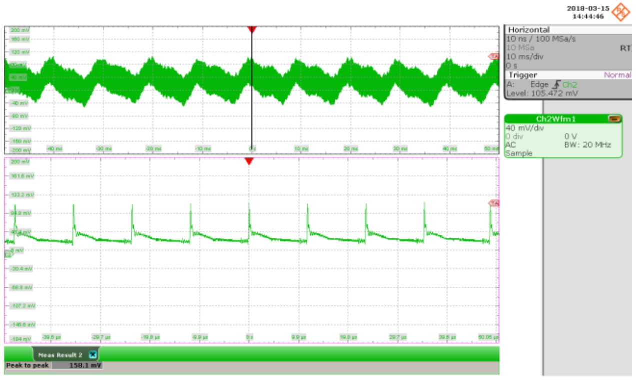
Horizontal
10 ns / 100 MSa/s
10 MSa RT
10 ms/div
0 s

Trigger Normal
A: Edge Ch2
Level: 111.616 mV

Ch2Wfm1
40 mV/div
0 div 0 V
AC BW: 20 MHz
Sample

Meas Result 2
Peak to peak 161.26 mV

Figure 69 – 115 VAC 60 Hz, Full Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 40 mV / div., 10 ms / div.
Ripple Voltage: 161.26 mV_{PK-PK}.


2018-03-15 14:44:46

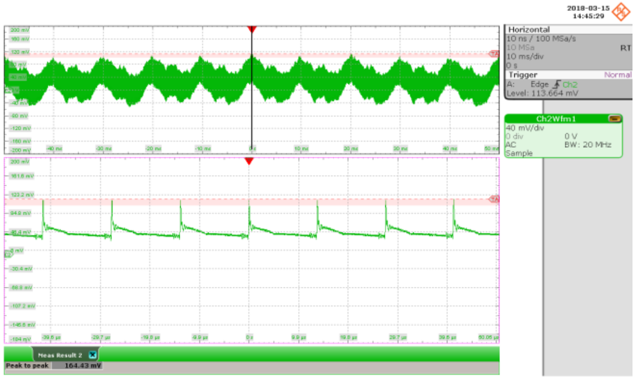
Horizontal
10 ns / 100 MSa/s
10 MSa RT
10 ms/div
0 s

Trigger Normal
A: Edge Ch2
Level: 105.472 mV

Ch2Wfm1
40 mV/div
0 div 0 V
AC BW: 20 MHz
Sample

Meas Result 2
Peak to peak 158.1 mV

Figure 70 – 230 VAC 50 Hz, Full Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 40 mV / div., 10 ms / div.
Ripple Voltage: 158.1 mV_{PK-PK}.


2018-03-15 14:45:29

Horizontal
10 ns / 100 MSa/s
10 MSa RT
10 ms/div
0 s

Trigger Normal
A: Edge Ch2
Level: 113.664 mV

Ch2Wfm1
40 mV/div
0 div 0 V
AC BW: 20 MHz
Sample

Meas Result 2
Peak to peak 164.43 mV

Figure 71 – 265 VAC 50 Hz, Full Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 40 mV / div., 10 ms / div.
Ripple Voltage: 164.43 mV_{PK-PK}.

15 Conducted EMI

15.1 *Test Set-up*

Unit is placed on top of load metal chassis.

15.2 *Equipment and Load Used*

1. Rohde and Schwarz ENV216 two line V-network.
2. Rohde and Schwarz ESRP EMI test receiver.
3. Hioki 3322 power hitester.
4. Chroma measurement test fixture.
5. Full Load with input voltage set at 115 VAC 60 Hz and 230 VAC 60 Hz.

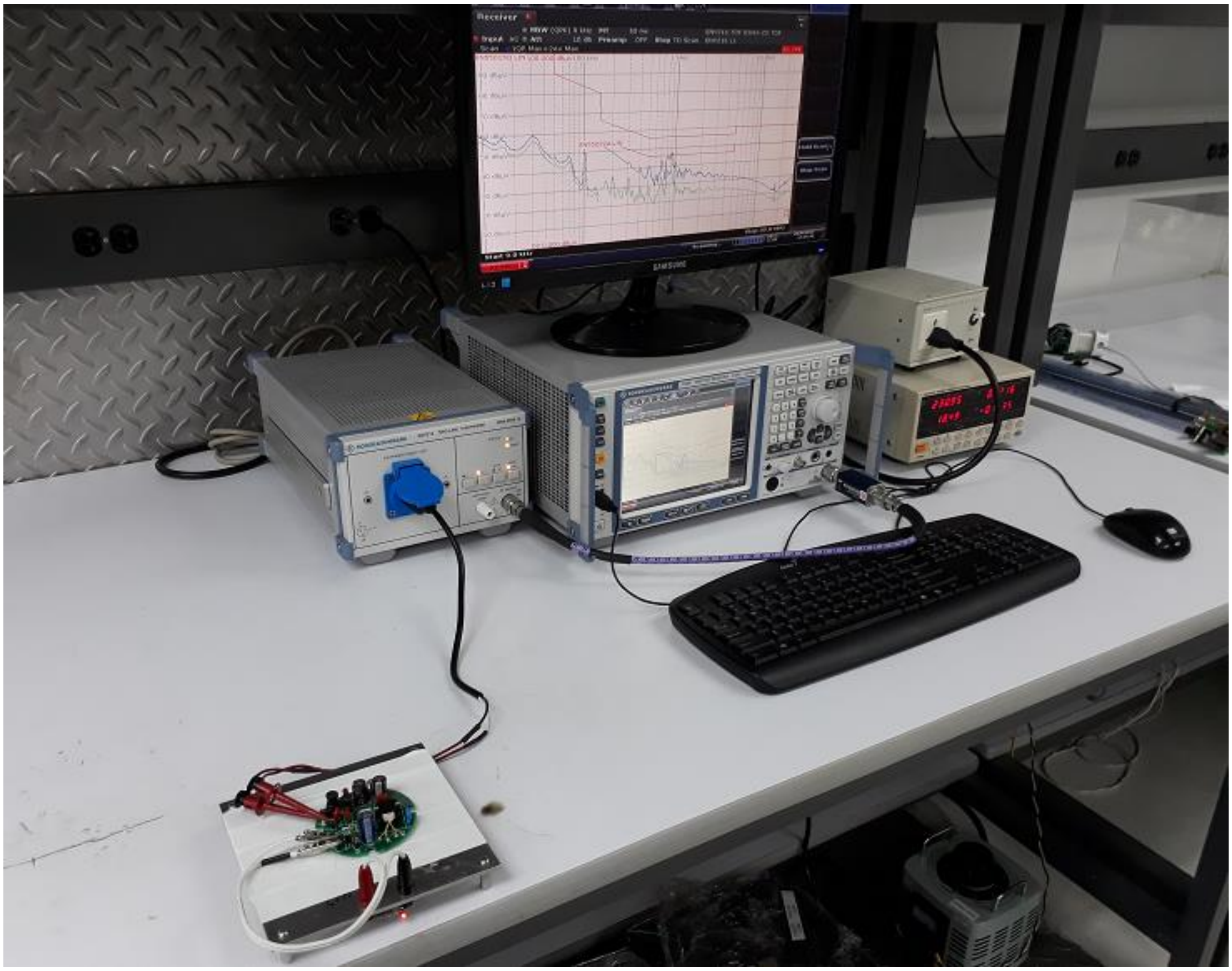
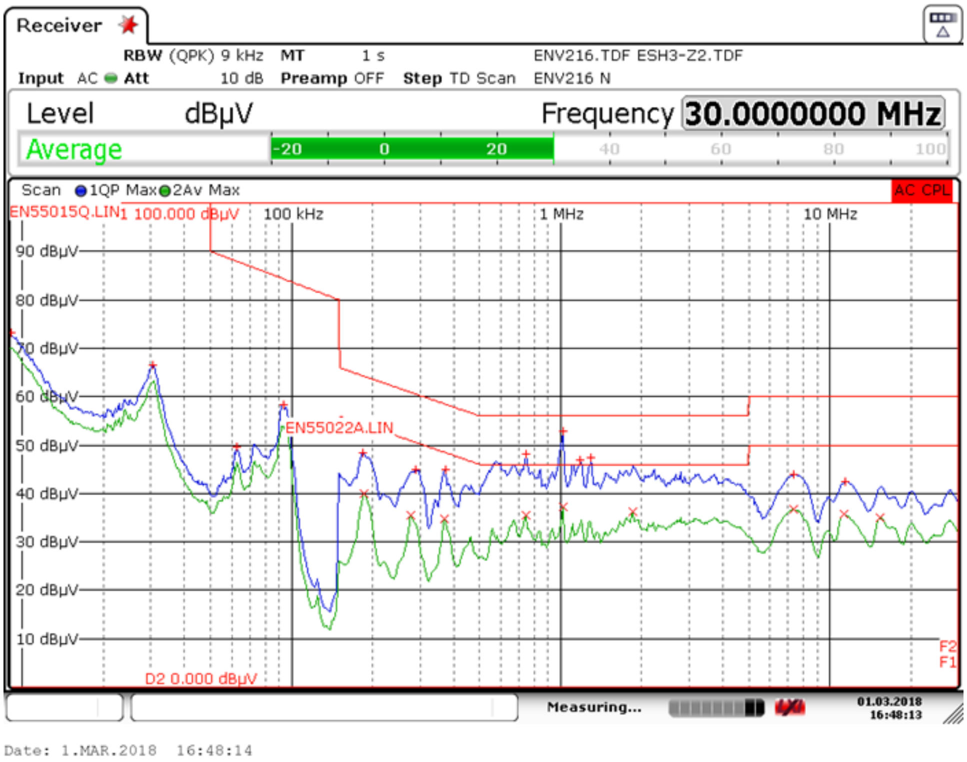


Figure 72 – Conducted EMI Test Set-up.

15.3 *EMI Test Result using R-Load*



Receiver

RBW (QPK) 9 kHz MT 1 s ENV216.TDF ESH3-Z2.TDF

Input AC Att 10 dB Preamp OFF Step TD Scan ENV216 N

Level dBµV Frequency 30.0000000 MHz

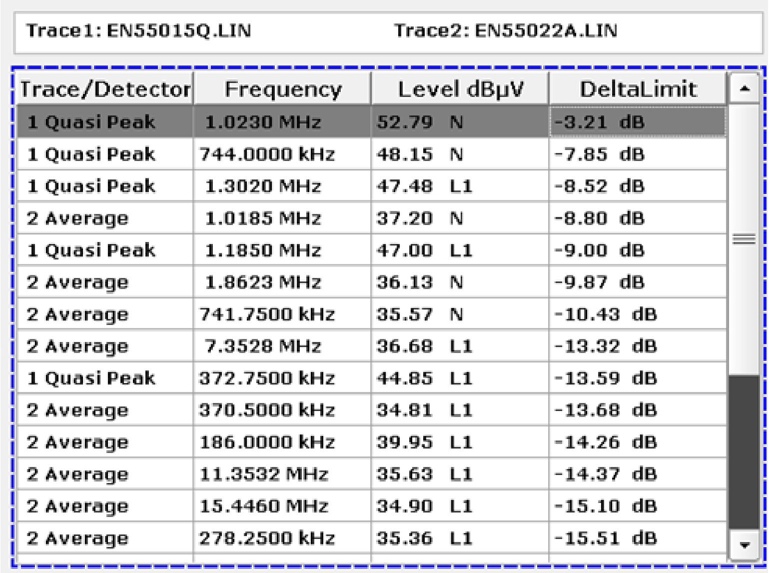
Average

Measuring...

01.03.2018 16:48:13

Date: 1.MAR.2018 16:48:14

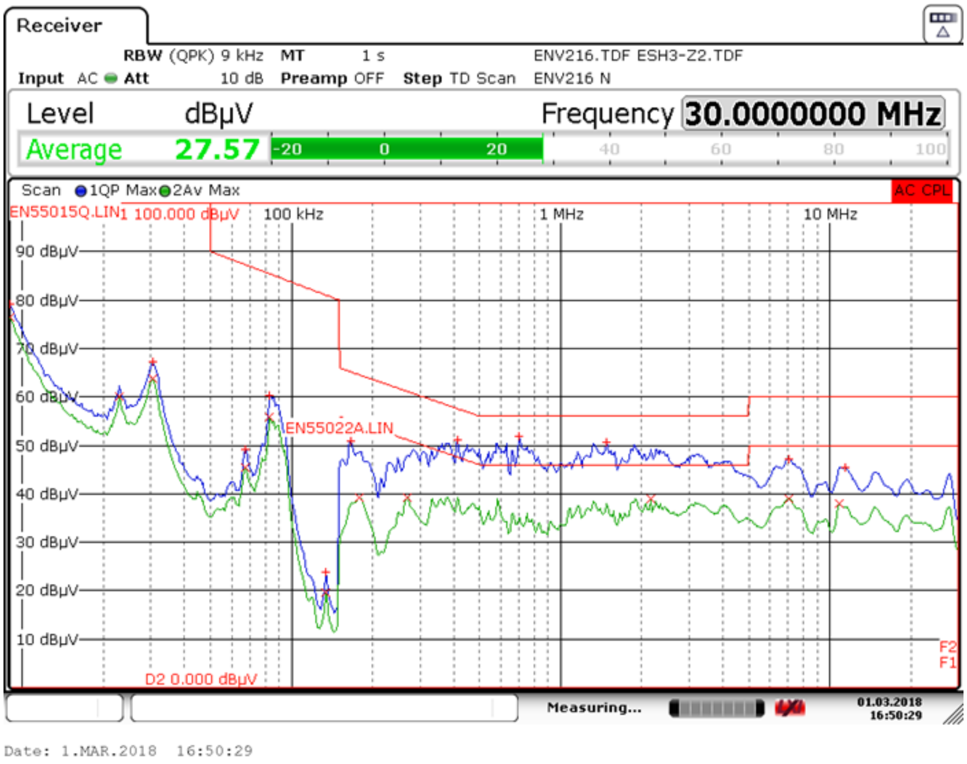
Figure 73 – Conducted EMI QP Scan at Full Load, 115 VAC 60 Hz and EN55015 B Limits.



Trace1: EN55015Q.LIN Trace2: EN55022A.LIN

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	1.0230 MHz	52.79 N	-3.21 dB
1 Quasi Peak	744.0000 kHz	48.15 N	-7.85 dB
1 Quasi Peak	1.3020 MHz	47.48 L1	-8.52 dB
2 Average	1.0185 MHz	37.20 N	-8.80 dB
1 Quasi Peak	1.1850 MHz	47.00 L1	-9.00 dB
2 Average	1.8623 MHz	36.13 N	-9.87 dB
2 Average	741.7500 kHz	35.57 N	-10.43 dB
2 Average	7.3528 MHz	36.68 L1	-13.32 dB
1 Quasi Peak	372.7500 kHz	44.85 L1	-13.59 dB
2 Average	370.5000 kHz	34.81 L1	-13.68 dB
2 Average	186.0000 kHz	39.95 L1	-14.26 dB
2 Average	11.3532 MHz	35.63 L1	-14.37 dB
2 Average	15.4460 MHz	34.90 L1	-15.10 dB
2 Average	278.2500 kHz	35.36 L1	-15.51 dB

Figure 74 – Conducted EMI Data at 115 VAC 60 Hz, Full Load.



Receiver

RBW (QPK) 9 kHz MT 1 s ENV216.TDF ESH3-Z2.TDF

Input AC Att 10 dB Preamp OFF Step TD Scan ENV216 N

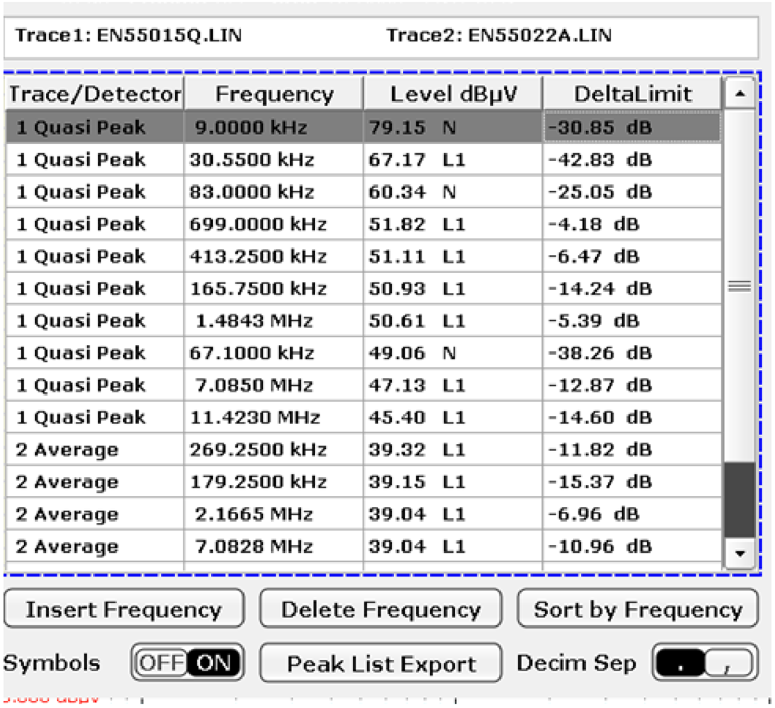
Level dBµV Frequency 30.0000000 MHz

Average 27.57

Measuring...

Date: 1.MAR.2018 16:50:29

Figure 75 – Conducted EMI QP Scan at Full Load, 230 VAC 60 Hz and EN55015 B Limits.

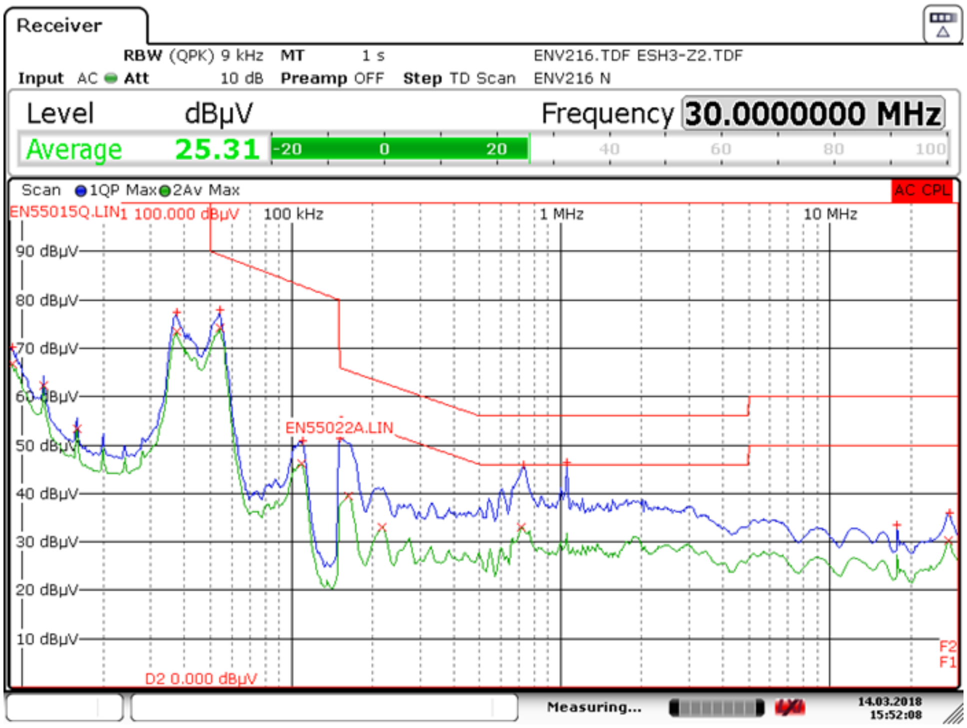


Trace1: EN55015Q.LIN Trace2: EN55022A.LIN

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	9.0000 kHz	79.15 N	-30.85 dB
1 Quasi Peak	30.5500 kHz	67.17 L1	-42.83 dB
1 Quasi Peak	83.0000 kHz	60.34 N	-25.05 dB
1 Quasi Peak	699.0000 kHz	51.82 L1	-4.18 dB
1 Quasi Peak	413.2500 kHz	51.11 L1	-6.47 dB
1 Quasi Peak	165.7500 kHz	50.93 L1	-14.24 dB
1 Quasi Peak	1.4843 MHz	50.61 L1	-5.39 dB
1 Quasi Peak	67.1000 kHz	49.06 N	-38.26 dB
1 Quasi Peak	7.0850 MHz	47.13 L1	-12.87 dB
1 Quasi Peak	11.4230 MHz	45.40 L1	-14.60 dB
2 Average	269.2500 kHz	39.32 L1	-11.82 dB
2 Average	179.2500 kHz	39.15 L1	-15.37 dB
2 Average	2.1665 MHz	39.04 L1	-6.96 dB
2 Average	7.0828 MHz	39.04 L1	-10.96 dB

Figure 76 – Conducted EMI Data at 230 VAC 60 Hz, Full Load.

15.4 *EMI Test Result using Casambi Module*


Receiver

RBW (QPK) 9 kHz MT 1 s ENV216.TDF ESH3-Z2.TDF

Input AC ● Att 10 dB Preamp OFF Step TD Scan ENV216 N

Level dBµV Frequency 30.0000000 MHz

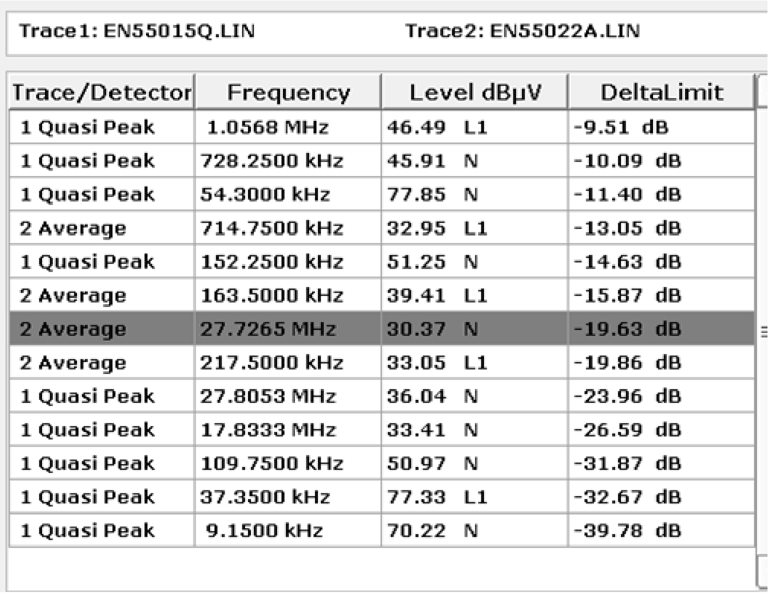
Average 25.31

Measuring...

14.03.2018 15:52:08

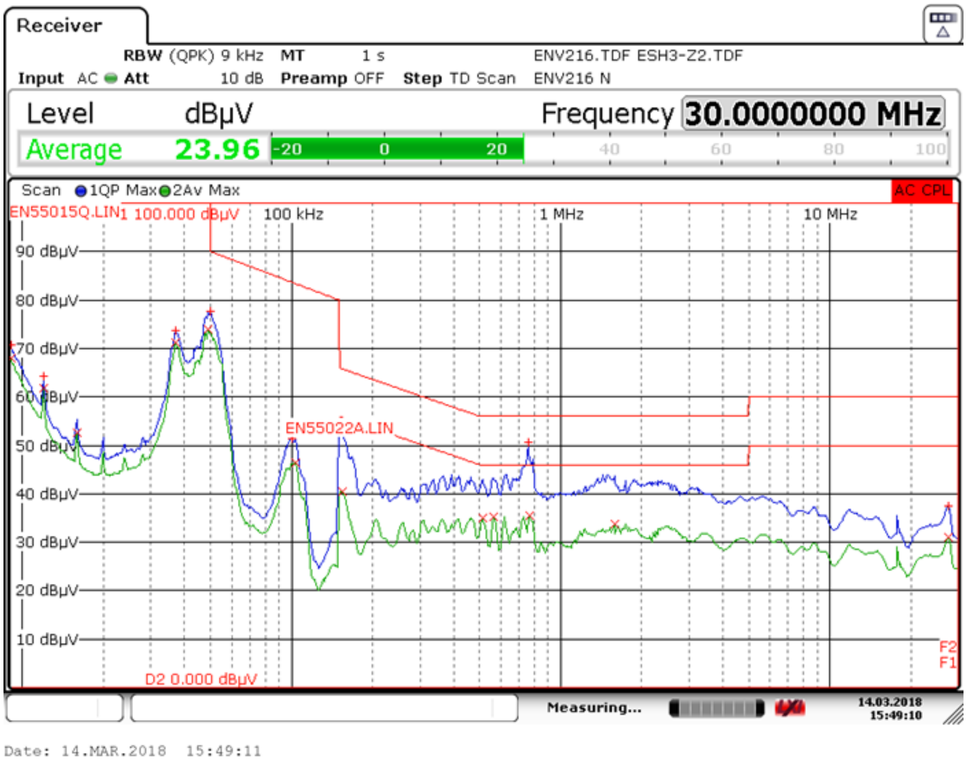
Date: 14.MAR.2018 15:52:08

Figure 77 – Conducted EMI QP Scan at Full Load, 115 VAC 60 Hz and EN55015 B Limits.


Trace1: EN55015Q.LIN Trace2: EN55022A.LIN

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	1.0568 MHz	46.49 L1	-9.51 dB
1 Quasi Peak	728.2500 kHz	45.91 N	-10.09 dB
1 Quasi Peak	54.3000 kHz	77.85 N	-11.40 dB
2 Average	714.7500 kHz	32.95 L1	-13.05 dB
1 Quasi Peak	152.2500 kHz	51.25 N	-14.63 dB
2 Average	163.5000 kHz	39.41 L1	-15.87 dB
2 Average	27.7265 MHz	30.37 N	-19.63 dB
2 Average	217.5000 kHz	33.05 L1	-19.86 dB
1 Quasi Peak	27.8053 MHz	36.04 N	-23.96 dB
1 Quasi Peak	17.8333 MHz	33.41 N	-26.59 dB
1 Quasi Peak	109.7500 kHz	50.97 N	-31.87 dB
1 Quasi Peak	37.3500 kHz	77.33 L1	-32.67 dB
1 Quasi Peak	9.1500 kHz	70.22 N	-39.78 dB

Figure 78 – Conducted EMI Data at 115 VAC 60 Hz, Full Load.

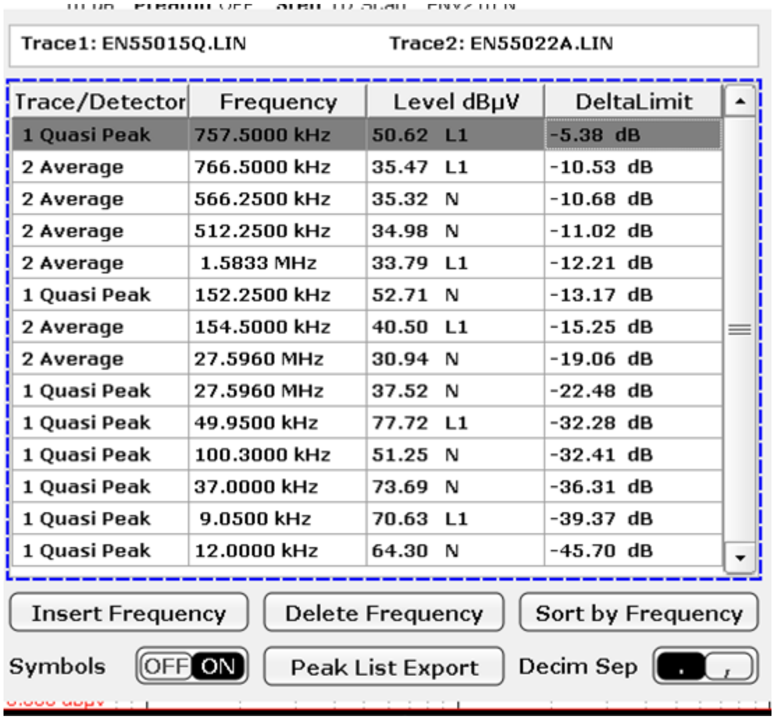

Receiver

RBW (QPK) 9 kHz MT 1 s ENV216.TDF ESH3-Z2.TDF
Input AC Att 10 dB Preamp OFF Step TD Scan ENV216 N

Level dBµV Frequency 30.0000000 MHz
Average 23.96

Date: 14.MAR.2018 15:49:11

Figure 79 – Conducted EMI QP Scan at Full Load, 230 VAC 60 Hz and EN55015 B Limits.


Trace1: EN55015Q.LIN Trace2: EN55022A.LIN

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	757.5000 kHz	50.62 L1	-5.38 dB
2 Average	766.5000 kHz	35.47 L1	-10.53 dB
2 Average	566.2500 kHz	35.32 N	-10.68 dB
2 Average	512.2500 kHz	34.98 N	-11.02 dB
2 Average	1.5833 MHz	33.79 L1	-12.21 dB
1 Quasi Peak	152.2500 kHz	52.71 N	-13.17 dB
2 Average	154.5000 kHz	40.50 L1	-15.25 dB
2 Average	27.5960 MHz	30.94 N	-19.06 dB
1 Quasi Peak	27.5960 MHz	37.52 N	-22.48 dB
1 Quasi Peak	49.9500 kHz	77.72 L1	-32.28 dB
1 Quasi Peak	100.3000 kHz	51.25 N	-32.41 dB
1 Quasi Peak	37.0000 kHz	73.69 N	-36.31 dB
1 Quasi Peak	9.0500 kHz	70.63 L1	-39.37 dB
1 Quasi Peak	12.0000 kHz	64.30 N	-45.70 dB

Figure 80 – Conducted EMI Data at 230 VAC 60 Hz, Full Load.

16 Line Surge

The unit was subjected to ±2500 V, 100 kHz ring wave and ±1000 V differential surge using 10 strikes at each condition. Low line was tested for ring wave surge and VR1 could be placed after the bridge rectifier for high line testing. A test failure was defined as a non-recoverable interruption of output requiring repair or recycling of input voltage.

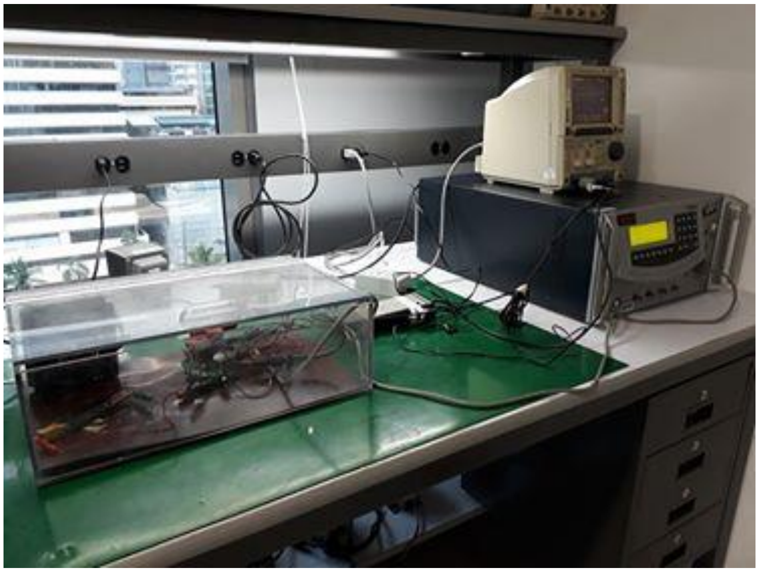


Figure 81 – Surge Set-up.

16.1 *Differential Surge Test Results*

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+1000	115	L to N	0	Pass
-1000		L to N	0	Pass
+1000		L to N	90	Pass
-1000		L to N	90	Pass
+1000		L to N	270	Pass
-1000		L to N	270	Pass
+1000	230	L to N	0	Pass
-1000		L to N	0	Pass
+1000		L to N	90	Pass
-1000		L to N	90	Pass
+1000		L to N	270	Pass
-1000		L to N	270	Pass

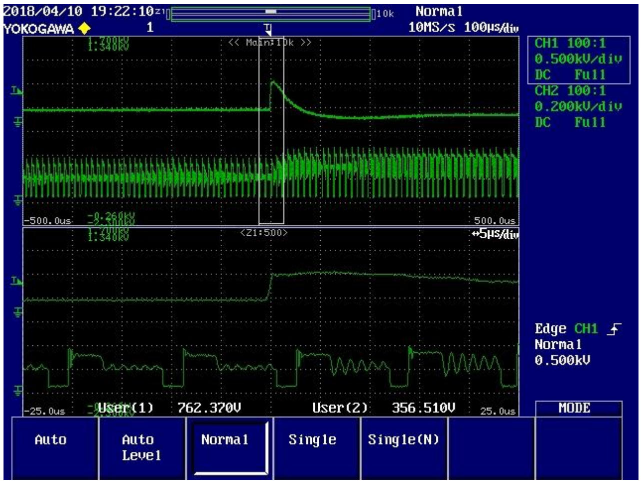


Figure 82 – Differential Mode Surge at Low Line, +1 kV, 90º.

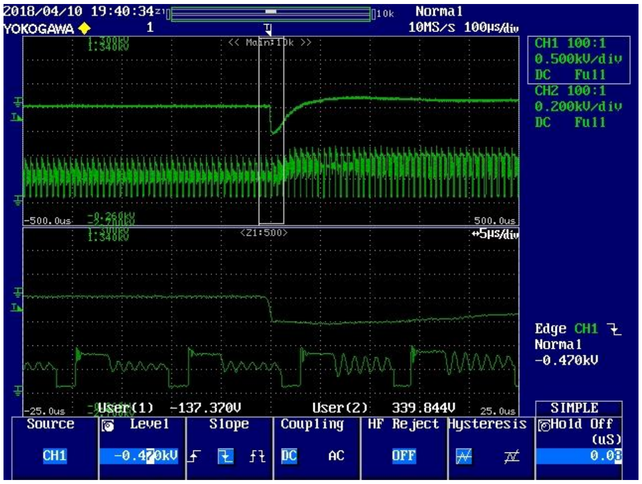


Figure 83 – Differential Mode Surge at Low Line, -1 kV, -270º.

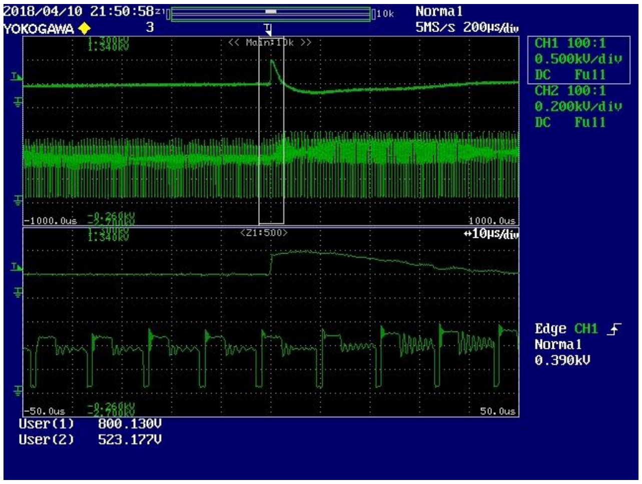


Figure 84 – Differential Mode Surge at High Line, +1 kV, 90º.

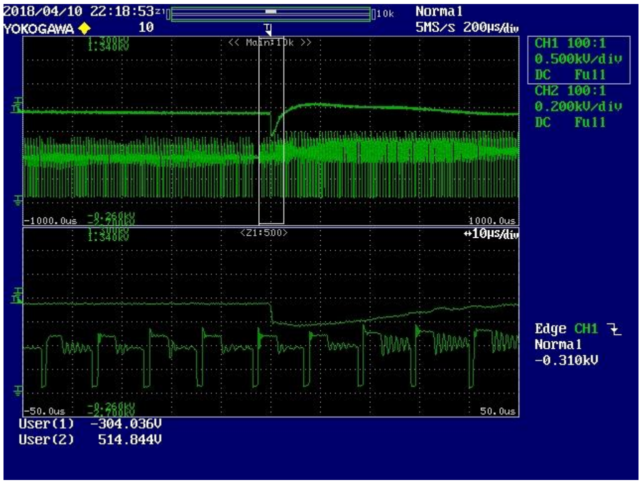
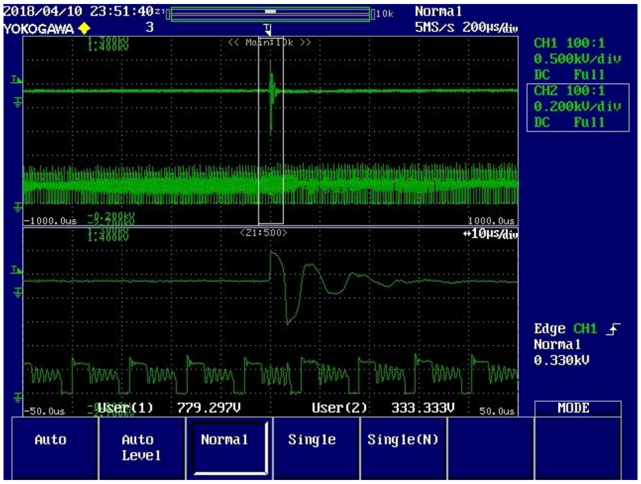


Figure 85 – Differential Mode Surge at High Line, -1 kV, -270º.

16.2 *Ring Wave Test Results*

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2500	115	L to N	0	Pass
-2500		L to N	0	Pass
+2500		L to N	90	Pass
-2500		L to N	90	Pass
+2500		L to N	270	Pass
-2500		L to N	270	Pass



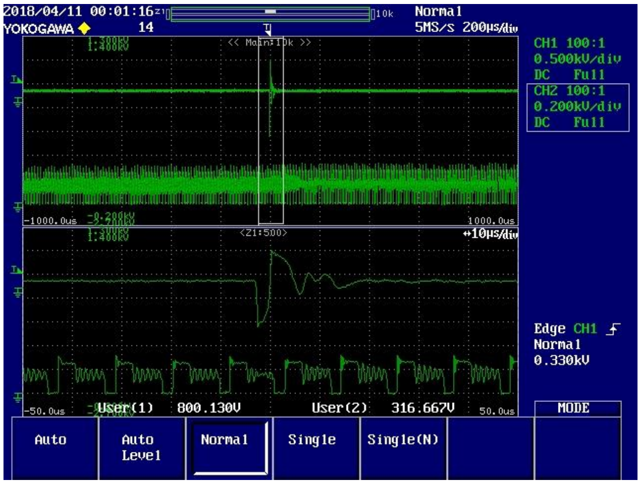
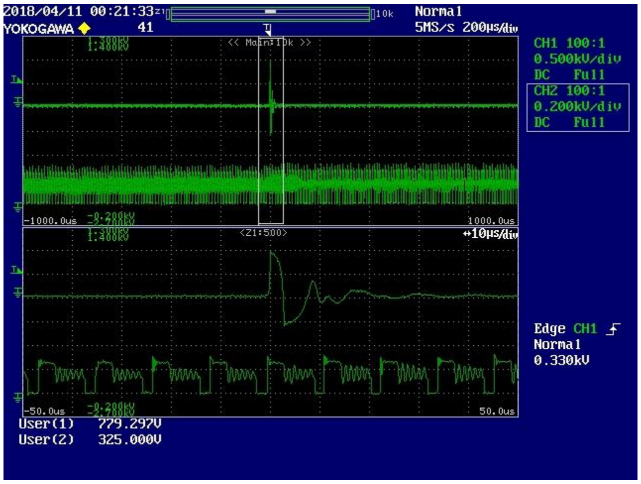


Figure 86 – Ring Wave Surge at Low Line, +2.5 kV, 90º.

Figure 87 – Ring Wave Surge at Low Line, -2.5 kV, 90º.



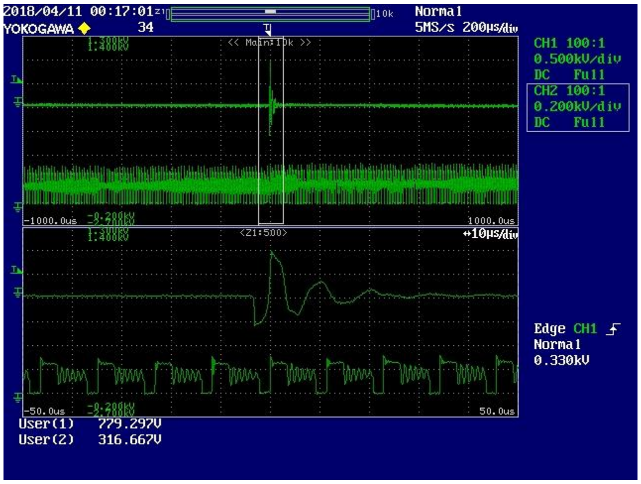
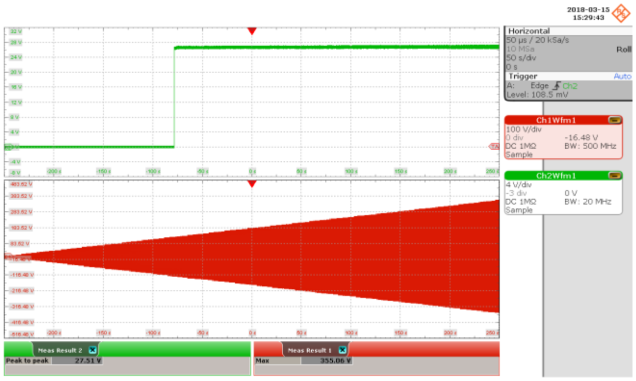


Figure 88 – Ring Wave Surge at Low Line, +2.5 kV, 270º.

Figure 89 – Ring Wave Surge at Low Line, -2.5 kV, 270º.

17 Brown-in/Brown-out Test

No abnormal overheating or voltage overshoot / undershoot was observed during and after 0.5 V / s and 1 V / s brown-in and brown-out test.



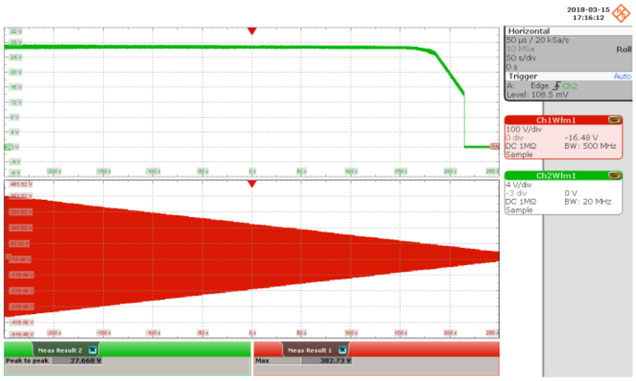


Figure 90 – Brown-in Test at 0.5 V / s.
Ch1: V_{OUT}, 4 V / div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

Figure 91 – Brown-out Test at 0.5 V / s.
Ch1: V_{OUT}, 4 V / div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

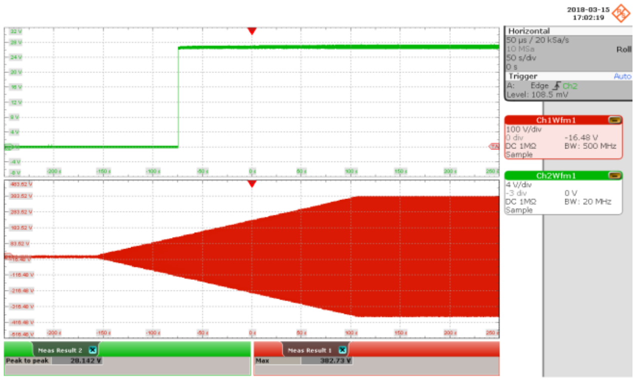


Figure 92 – Brown-in Test at 1 V / s.
Ch1: V_{OUT}, 4 V / div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

Figure 93 – Brown-out Test at 1 V / s.
Ch1: V_{OUT}, 4 V /div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

18 **Appendix**

18.1 ***Application Example***

18.1.1 Smart RGBW Downlight with BLE Control

In this application, DER-630 is used to power a smart RGBW LED downlight controlled via Bluetooth Low Energy (BLE) module. The BLE module used is the Casambi CBM-001.

18.1.2 BLE Interface Circuitry

The BLE Interface Circuitry consists of a 3.3 V linear regulator, the Zero Detect circuit, the Casambi CBM-001 Bluetooth Low Energy (BLE) module, the PWM-driven MOSFETs, and the constant current circuit for each string of the RGBW LED Load. Figure 96 shows the BLE Interface Circuitry. U6 is the 3.3 V linear regulator with input and output bypass capacitors C16 and C17, respectively. The output of the 3.3 V regulator is connected to the VCC pin of the Casambi CBM-001 module (U8). R24, R25, and C18 compose the Power-On Reset (POR) circuitry required for the BLE module. The BLE module also requires a means to detect when the input turns OFF (Zero Detect circuitry). The signal coming from the secondary auxiliary forward winding is rectified by D22 and filtered by C19, then clamped by VR5 for this purpose. C19 must be sized just enough to average the rectified signal and filter noise, as it has to discharge quickly when the input turns OFF. R37 forms an RC filter with C19 that helps minimize the unwanted noise from the forward winding signal. R26 and R27 are current limiters. When the input turns OFF, the C19 voltage will be equal to that of C15 of DER-630; to immediately cut the signal from the set Zero Detect pin of the BLE module (GPIO9, in this case), VR4 voltage is set just above the steady-state voltage of C15. R36 also helps for faster decay of the signal from the Zero Detect pin of the BLE module. *Refer to Casambi CBM-001 data sheet for more details on POR and Zero Detect functionalities*. U13, U14, U15, and U16 are gate drivers with PWM inputs coming from the BLE module, and PWM outputs driving the gates of Q2, Q3, Q4, and Q5 through gate resistors R16, R17, R18, and R19, respectively. There's a constant current circuit for each of the LED string – Q6, U9, and R12 for White LED string; Q7, U10, and R33 for Blue LED string; Q8, U11, and R34 for Green LED string; and Q9, U12, and R35 for Red LED string. The voltages across R12, R33, R34, and R35 are maintained constant by the LMV431 regulators U9, U10, U11, and U12 when the MOSFETs are conducting; hence, the emitter current (as well as the collector current, and therefore, the LED maximum current) is also constant. The LED current for each string is thereby averaged through the set PWM duty; hence, the resulting output color, the brightness, and the color temperature could be set by varying the duty cycle for each of the RGBW LED string. R28, R30, R31, and R32 are base resistors for biasing the BJTs and the LMV431 regulators. The current gain of the BJTs and the desired maximum current for the LED strings should be considered when calculating the value of these base resistors.

Figure 94 – Top Side of BLE Interface Board.

Figure 95 – Bottom Side of BLE Interface Board.

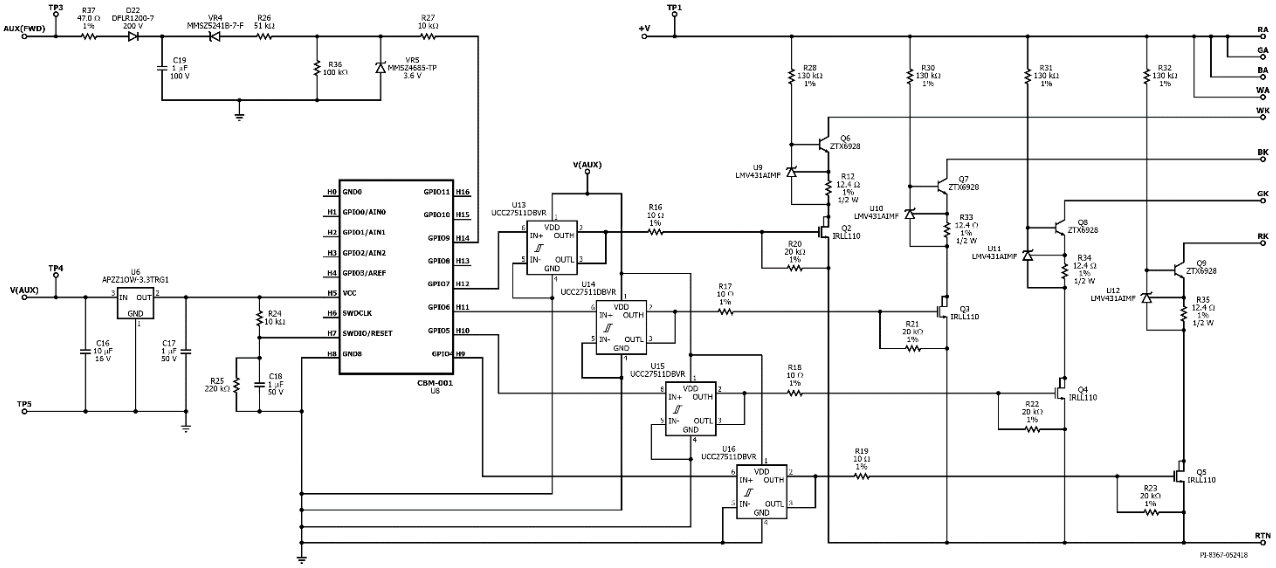


Figure 96 – The BLE Interface Circuitry.

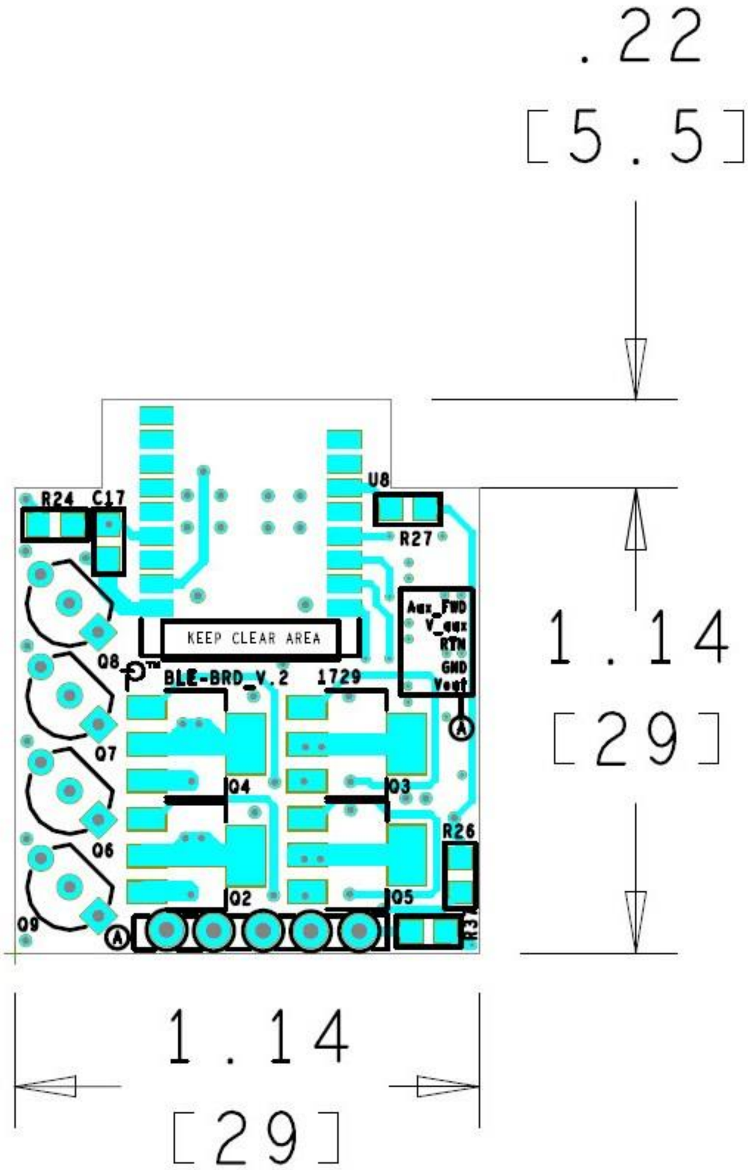


Figure 97 – BLE Interface Board: Component Side.

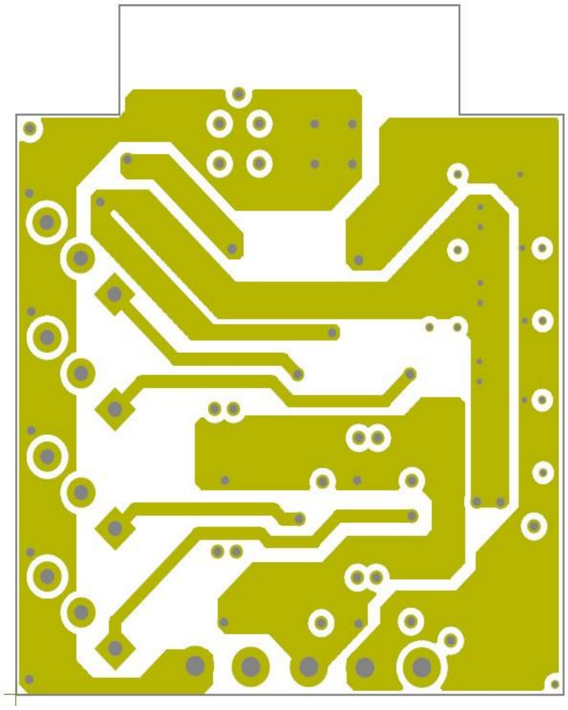


Figure 98 – BLE Interface Board: Second Layer.

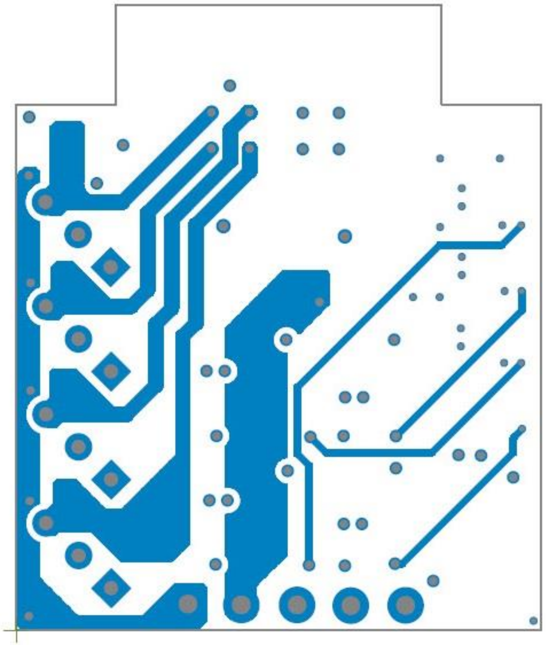


Figure 99 – BLE Interface Board: Third Layer.

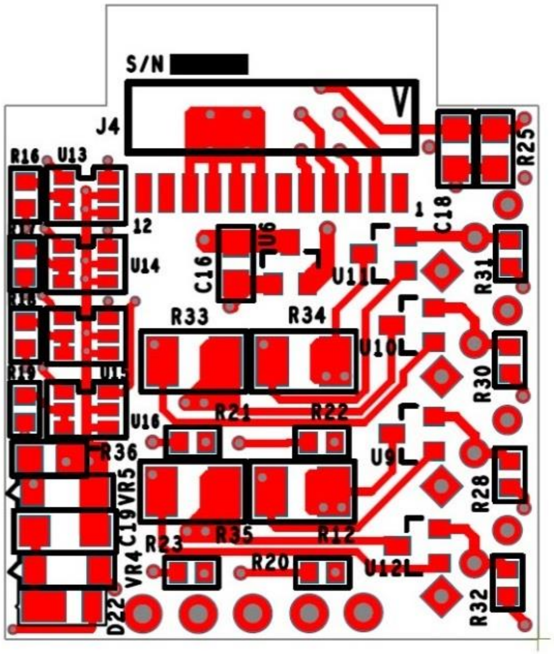


Figure 100 – BLE Interface Board: Solder Side.

18.2 *RGBW LED Load Engine*

The RGBW LED Load circuitry is shown on Figure 103. It is composed of twelve single-package RGBW LEDs, arranged in a way so as to optimize the string voltage of each color; that is, the total voltage of each string must be as close as possible to each other. This is why the Red LED string is comprised of 12 LEDs plus a diode in series; the Green LED string is comprised of 8 LEDs plus diode in series; and the Blue and White LED strings are comprised of 9 LEDs. This optimization is done to minimize the power loss of the BJTs on the constant-current circuit. The arrangement of the LEDs on the PCB board should also be considered so as to achieve a distributed light output and make the blending of colors more effective.

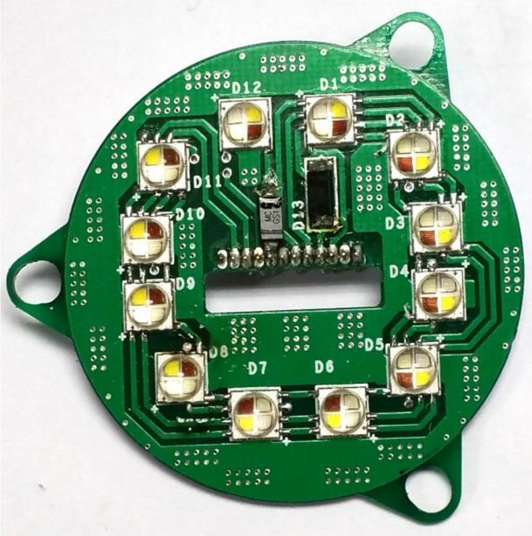


Figure 101 – RGBW LED Engine - Top Side.

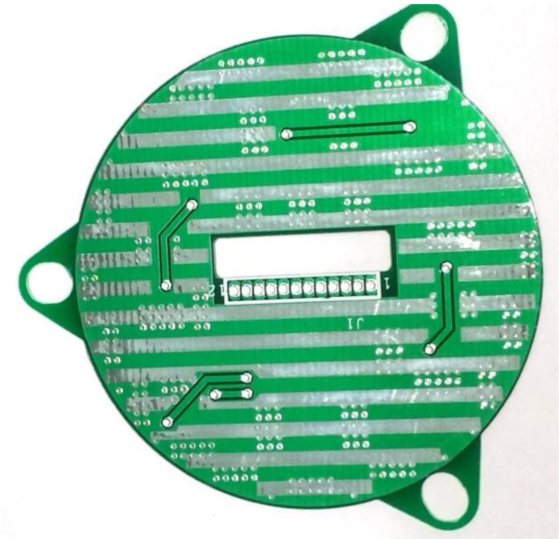


Figure 102 – RGBW LED Engine - Bottom Side.

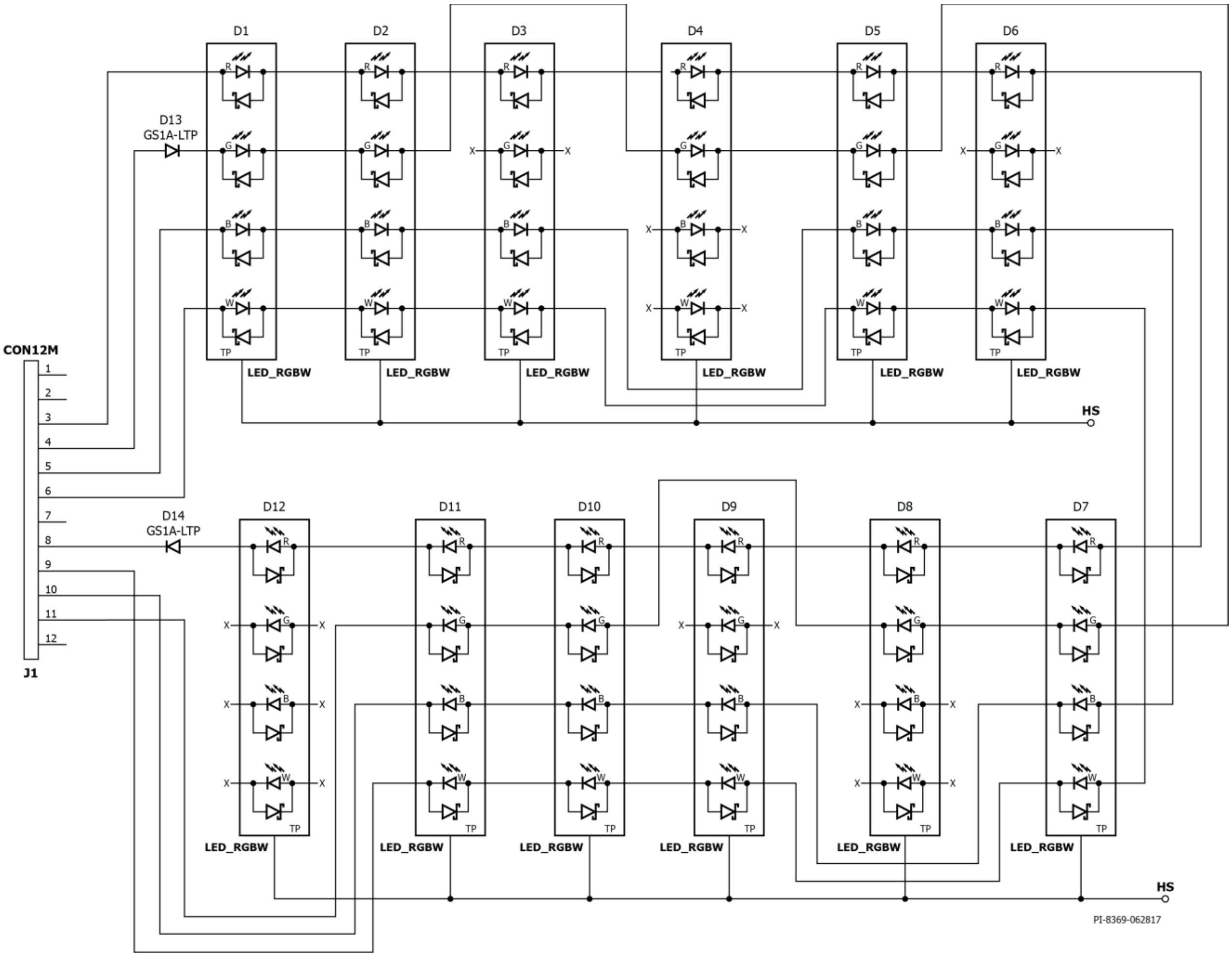


Figure 103 – The RGBW LED Load Engine.

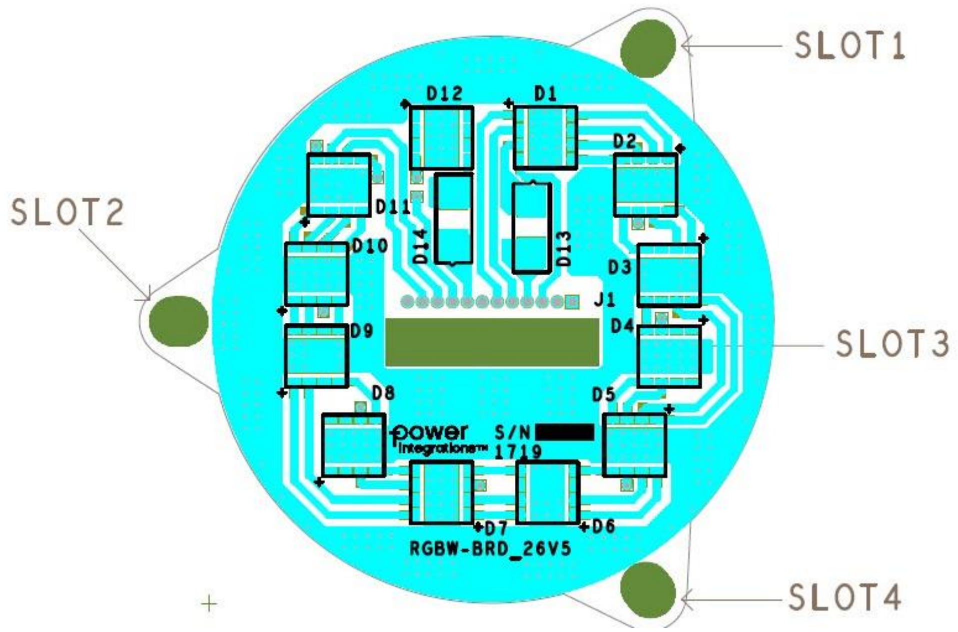


Figure 104 – RGBW LED Board: Component Side.

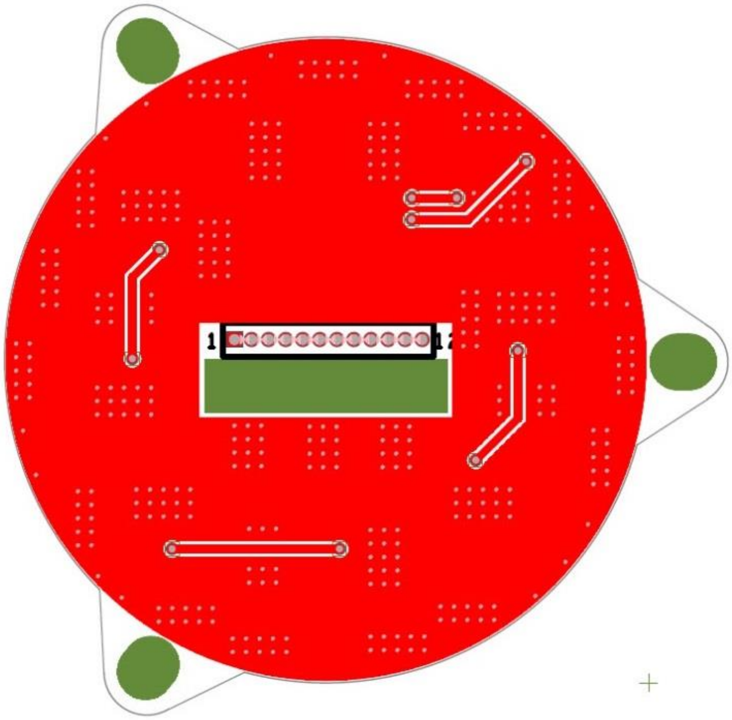


Figure 105 – RGBW LED Board: Solder Side.

18.3 *How to Configure the Casambi CBM-001 Module*

The CBM-001 module is pre-loaded with the Casambi firmware in the default configuration. To view and control the module, power it up (per the reference design) and download the Casambi App to an Android from Google Play or to an iOS device from Apple's App store.

When using the Casambi app on your mobile device in proximity to the module, the module will appear on the "Nearby devices" list inside the Casambi App. Follow the onscreen instructions to create a network and add your module to this network. The module will appear on the Luminaires tab within the Casambi app.

You can interact with the module in at least 4 ways:
- A single tap on the module icon toggles all channels on or off
- Dragging your finger across the module icon from left to right increases the brightness level
- A double tap on the module icon brings up a popup screen providing additional information about the module
- A long press on the module icon brings up a popup screen which allows adjustment of individual channels.

Additional information about using Casambi as well as technical information on the CBM-001 can be found on WWW.Casambi.com

Casambi provides tools to modify the firmware if your design requires it. Modifying the firmware consists of two steps. The first step is using the Casambi web portal to create a downloadable file. This web portal is menu driven. The second step is to use Casambi's Utility app to load the new firmware over the air into the module.

These tools require a user ID and password issued by Casambi. An account can be requested by sending an email to support@casambi.com. Please provide your company name, address and website, your contact information and title and a brief description of your development project. You will then receive an invitation to log into Admin.Casambi.com.

Inside Casambi's admin website, there is a "Downloads" tab where the datasheet, technical guides, and user guides can be found. Please refer to the CBM-001 datasheet, the Technical Guide CBM Module Configuration tool, and the Technical Guide Utility app for information on how to modify the module firmware and then upload that configuration to the module.

An iOS device is required to upload the module configuration into the module as the Casambi Utility App (separate from the Casambi App) only supports iOS devices. It requires iOS 8.2 or later.

18.4 *Complete Assembly of the Application Example*

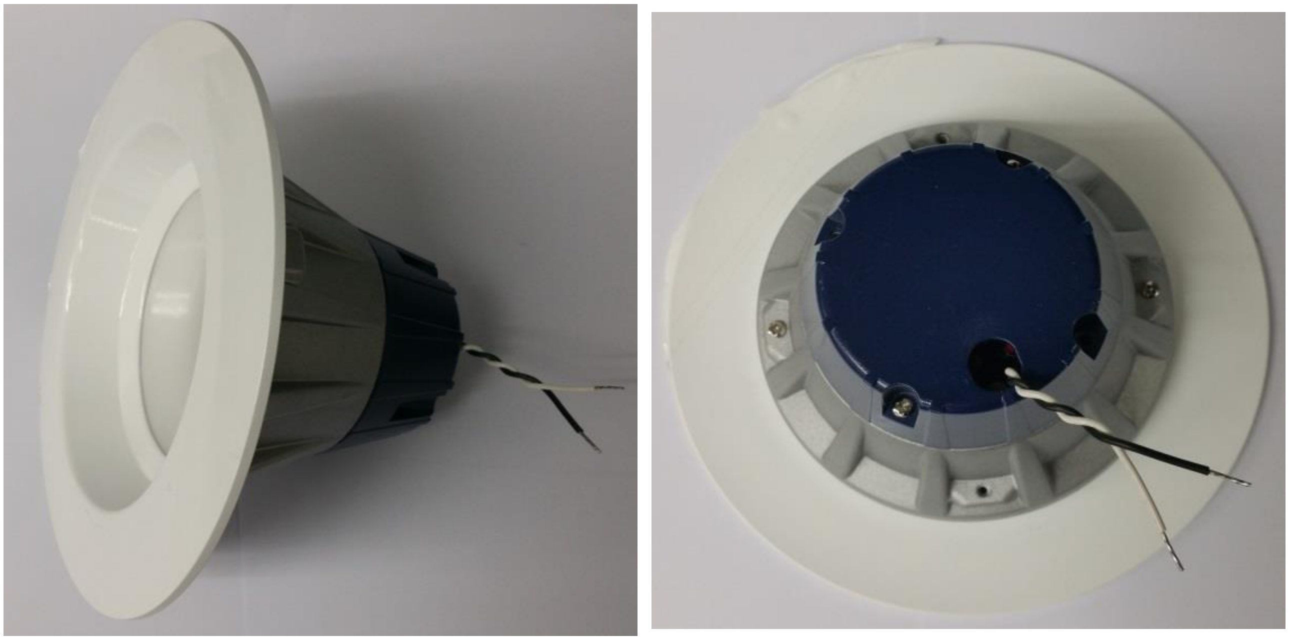


Figure 106 – Completely Assembled Downlight.

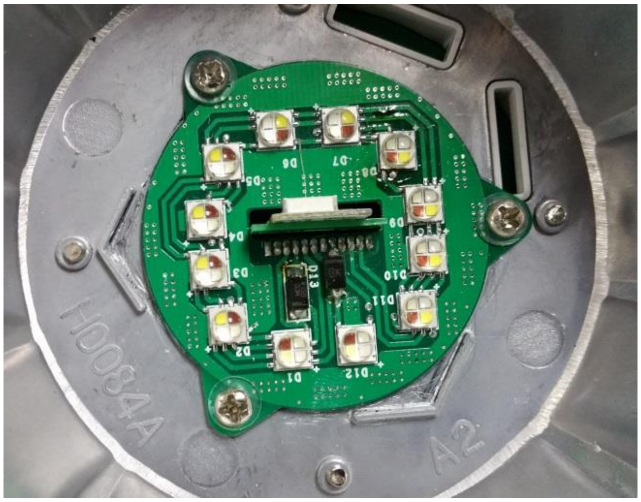


Figure 107 – RGBW Light Engine Mounted on the Downlight Housing / Heat Sink.

Figure 108 – Main Driver and BLE Interface Boards Mounted on the Downlight Housing / Heat Sink.

18.5 *Bill of Materials – BLE Interface Circuitry*

Item	Qty	Ref	Description	Mfg Part Number	Mfg
1	1	C16	10 μF, ±10%, 16 V, X7R, Ceramic, -55 °C ~ 125°C, 0805	CL21B106KOQNNNE	Samsung
2	1	C17	1 μF,50 V, Ceramic, X7R, 0805	C2012X7R1H105M085AC	TDK
3	1	C18	1 μF,50 V, Ceramic, X7R, 0805	C2012X7R1H105M085AC	TDK
4	1	C19	1 μF,100 V, Ceramic, X7R, 1206	HMK316B7105KL-T	Taiyo Yuden
5	1	D22	200 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1200-7	Diodes, Inc.
6	1	J4	12 positions, Horizontal, Female, Header, Connector, 0.050" (1.27mm), SMD, Gold	Y02443-0112CNG1ZUT01	Yinghua
7	1	Q2	MOSFET, N-Channel, 100 V, 1.5 A (Tc), 2 W (Ta), 3.1 W (Tc), 540 mΩ @ 900 mA @ 5 V, -55°C ~ 150°C (TJ), SOT-223	IRLL110TRPBF	Vishay
8	1	Q3	MOSFET, N-Channel, 100 V, 1.5 A (Tc), 2 W (Ta), 3.1 W (Tc), 540 mΩ @ 900 mA @ 5 V, -55°C ~ 150°C (TJ), SOT-223	IRLL110TRPBF	Vishay
9	1	Q4	MOSFET, N-Channel, 100 V, 1.5 A (Tc), 2 W (Ta), 3.1 W (Tc), 540 mΩ @ 900 mA @ 5 V, -55°C ~ 150°C (TJ), SOT-223	IRLL110TRPBF	Vishay
10	1	Q5	MOSFET, N-Channel, 100 V, 1.5 A (Tc), 2 W (Ta), 3.1 W (Tc), 540 mΩ @ 900 mA @ 5 V, -55°C ~ 150°C (TJ), SOT-223	IRLL110TRPBF	Vishay
11	1	Q6	NPN, Power BJT, 70 V, 1 A, TO-92	ZTX692B	Zetex
12	1	Q7	NPN, Power BJT, 70 V, 1 A, TO-92	ZTX692B	Zetex
13	1	Q8	NPN, Power BJT, 70 V, 1 A, TO-92	ZTX692B	Zetex
14	1	Q9	NPN, Power BJT, 70 V, 1 A, TO-92	ZTX692B	Zetex
15	1	R12	RES, 12.4 Ω, ±1%, 0.5 W, ½ W, 1210 (3225 Metric)	ERJ-14NF12R4U	Panasonic
16	1	R16	RES, 10 Ω, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF10R0V	Panasonic
17	1	R17	RES, 10 Ω, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF10R0V	Panasonic
18	1	R18	RES, 10 Ω, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF10R0V	Panasonic
19	1	R19	RES, 10 Ω, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF10R0V	Panasonic
20	1	R20	RES, 20 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2002V	Panasonic
21	1	R21	RES, 20 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2002V	Panasonic
22	1	R22	RES, 20 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2002V	Panasonic
23	1	R23	RES, 20 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2002V	Panasonic
24	1	R24	RES, 10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
25	1	R25	RES, 220 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ224V	Panasonic
26	1	R26	RES, 51 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ513V	Panasonic
27	1	R27	RES, 10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
28	1	R28	RES, 130 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1303V	Panasonic
29	1	R30	RES, 130 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1303V	Panasonic
30	1	R31	RES, 130 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1303V	Panasonic
31	1	R32	RES, 130 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1303V	Panasonic
32	1	R33	RES, 12.4 Ω, ±1%, 0.5W, 1/2W, 1210	ERJ-14NF12R4U	Panasonic
33	1	R34	RES, 12.4 Ω, ±1%, 0.5W, 1/2W, 1210	ERJ-14NF12R4U	Panasonic
34	1	R35	RES, 12.4 Ω, ±1%, 0.5W, 1/2W, 1210	ERJ-14NF12R4U	Panasonic
35	1	R36	RES, 100 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ104V	Panasonic
36	1	R37	RES, 47.0 Ω, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF47R0V	Panasonic
37	1	U6	IC, REG, LDO, 3.3V, 0.3A, SOT23-3	P2210N-3.3TRG1	Diodes, Inc.
38	1	U8	RF TXRX MOD, BLUETOOTH, TRACE ANT	CBM-001	Casambi
39	1	U9	1.24 V Shunt Regulator IC, 1%, -40 to 85 C, SOT23-3	LMV431AIMF	National Semi
40	1	U10	1.24 V Shunt Regulator IC, 1%, -40 to 85 C, SOT23-3	LMV431AIMF	National Semi
41	1	U11	1.24 V Shunt Regulator IC, 1%, -40 to 85 C, SOT23-3	LMV431AIMF	National Semi
42	1	U12	1.24 V Shunt Regulator IC, 1%, -40 to 85 C, SOT23-3	LMV431AIMF	National Semi
43	1	U13	IC, GATE DVR, LOW SIDE, 1CH, SOT23-6	UCC27511DBVR	Texas Instruments
44	1	U14	IC, GATE DVR, LOW SIDE, 1CH, SOT23-6	UCC27511DBVR	Texas Instruments
45	1	U15	IC, GATE DVR, LOW SIDE, 1CH, SOT23-6	UCC27511DBVR	Texas Instruments

46	1	U16	IC, GATE DVR, LOW SIDE, 1CH, SOT23-6	UCC27511DBVR	Texas Instruments
47	1	VR4	DIODE, ZENER 11 V 500 MW SOD123	MMSZ5241B-7-F	Diodes, Inc.
48	1	VR5	DIODE, ZENER, 3.6 V, ±5%, 500 mW, SOD123, 150°C	MMSZ4685-TP	Micro Commercial

18.6 *Bill of Materials – RGBW LED Engine*

Item	Qty	Ref	Description	Mfg Part Number	Mfg
1	1	D1	LED, Lighting, Color, XLamp® XM-L, Red, Green, Blue, White - Cool (RGBW), 625nm Red, 528nm Green, 458nm Blue, 6850K White, 2020 (5050 Metric)	XMLCTW-A0-0000-00C3ABB02	CREE
2	1	D2	LED, Lighting, Color, XLamp® XM-L, Red, Green, Blue, White - Cool (RGBW), 625nm Red, 528nm Green, 458nm Blue, 6850K White, 2020 (5050 Metric)	XMLCTW-A0-0000-00C3ABB02	CREE
3	1	D3	LED, Lighting, Color, XLamp® XM-L, Red, Green, Blue, White - Cool (RGBW), 625nm Red, 528nm Green, 458nm Blue, 6850K White, 2020 (5050 Metric)	XMLCTW-A0-0000-00C3ABB02	CREE
4	1	D4	LED, Lighting, Color, XLamp® XM-L, Red, Green, Blue, White - Cool (RGBW), 625nm Red, 528nm Green, 458nm Blue, 6850K White, 2020 (5050 Metric)	XMLCTW-A0-0000-00C3ABB02	CREE
5	1	D5	LED, Lighting, Color, XLamp® XM-L, Red, Green, Blue, White - Cool (RGBW), 625nm Red, 528nm Green, 458nm Blue, 6850K White, 2020 (5050 Metric)	XMLCTW-A0-0000-00C3ABB02	CREE
6	1	D6	LED, Lighting, Color, XLamp® XM-L, Red, Green, Blue, White - Cool (RGBW), 625nm Red, 528nm Green, 458nm Blue, 6850K White, 2020 (5050 Metric)	XMLCTW-A0-0000-00C3ABB02	CREE
7	1	D7	LED, Lighting, Color, XLamp® XM-L, Red, Green, Blue, White - Cool (RGBW), 625nm Red, 528nm Green, 458nm Blue, 6850K White, 2020 (5050 Metric)	XMLCTW-A0-0000-00C3ABB02	CREE
8	1	D8	LED, Lighting, Color, XLamp® XM-L, Red, Green, Blue, White - Cool (RGBW), 625nm Red, 528nm Green, 458nm Blue, 6850K White, 2020 (5050 Metric)	XMLCTW-A0-0000-00C3ABB02	CREE
9	1	D9	LED, Lighting, Color, XLamp® XM-L, Red, Green, Blue, White - Cool (RGBW), 625nm Red, 528nm Green, 458nm Blue, 6850K White, 2020 (5050 Metric)	XMLCTW-A0-0000-00C3ABB02	CREE
10	1	D10	LED, Lighting, Color, XLamp® XM-L, Red, Green, Blue, White - Cool (RGBW), 625nm Red, 528nm Green, 458nm Blue, 6850K White, 2020 (5050 Metric)	XMLCTW-A0-0000-00C3ABB02	CREE
11	1	D11	LED, Lighting, Color, XLamp® XM-L, Red, Green, Blue, White - Cool (RGBW), 625nm Red, 528nm Green, 458nm Blue, 6850K White, 2020 (5050 Metric)	XMLCTW-A0-0000-00C3ABB02	CREE
12	1	D12	LED, Lighting, Color, XLamp® XM-L, Red, Green, Blue, White - Cool (RGBW), 625nm Red, 528nm Green, 458nm Blue, 6850K White, 2020 (5050 Metric)	XMLCTW-A0-0000-00C3ABB02	CREE
13	1	D13	50 V, 1 A, DO-214AC	GS1A-LTP	Micro Commercial
14	1	D14	50 V, 1 A, DO-214AC	GS1A-LTP	Micro Commercial
15	1	J1	12 positions, Header, Connector, 0.050" (1.27 mm), Through Hole, Gold	GRPB121VWVN-RC	Sullins

19 Revision History

Date	Author	Revision	Description and Changes	Reviewed
21-May-18	MGM and DL	1.0	Initial release	Apps & Mktg

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

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