Design Example Report

Title	***12 W High Efficiency, High Power Factor, Isolated Flyback Power Supply Using InnoSwitch™-CH INN2003K***
Specification	90 VAC – 265 VAC Input; 30 V, 400 mA Output
Application	Smart Lighting with Casambi CBM-001
Author	Applications Engineering Department
Document Number	DER-612
Date	December 14, 2017
Revision	1.1

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, 2 kV differential surge
- Meets EN55015 conducted EMI

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

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1 Introduction

This engineering report describes a constant voltage (CV) output 12 W isolated flyback power supply with a valley-fill passive power factor correction circuit for smart lighting applications. The power supply is designed to provide a 30 V constant voltage output across 0 mA to 400 mA output current load and throughout the input voltage from 90 VAC to 265 VAC.

The power supply IC controller device, InnoSwitch-CH combines primary, secondary and feedback circuits in a single surface-mounted off-line flyback switcher IC. It incorporates the primary FET, 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.

The added valley-fill passive power factor correction circuit is a simple and low cost solution to meet power factor requirements for lighting applications.

DER-612 using InnoSwitch-CH offers a highly efficient constant voltage supply with a fast transient load response. The design achieves high power factor (0.9) at low line. The key design goals were high efficiency, optimized power factor and low components count.

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

Figure 1 – Populated Circuit Board.

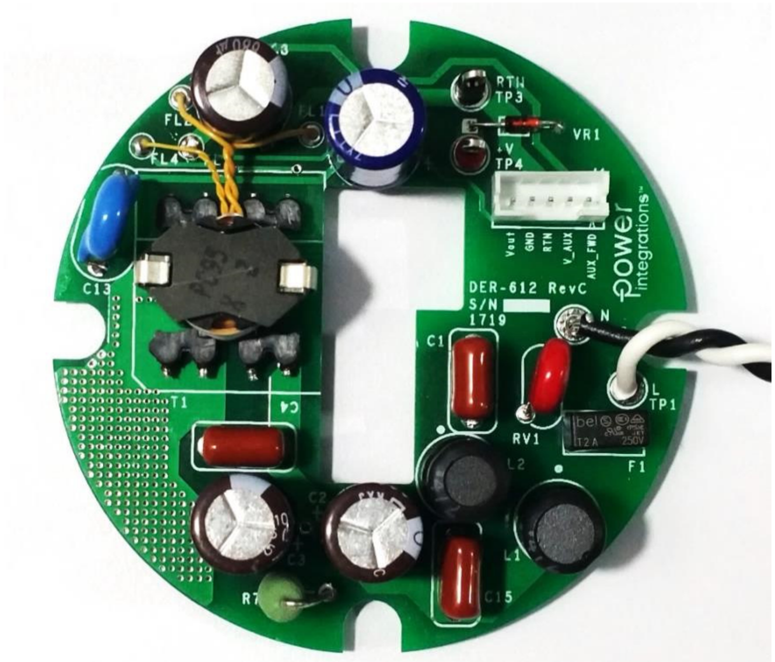

Figure 2 – Populated Circuit Board, Top View.

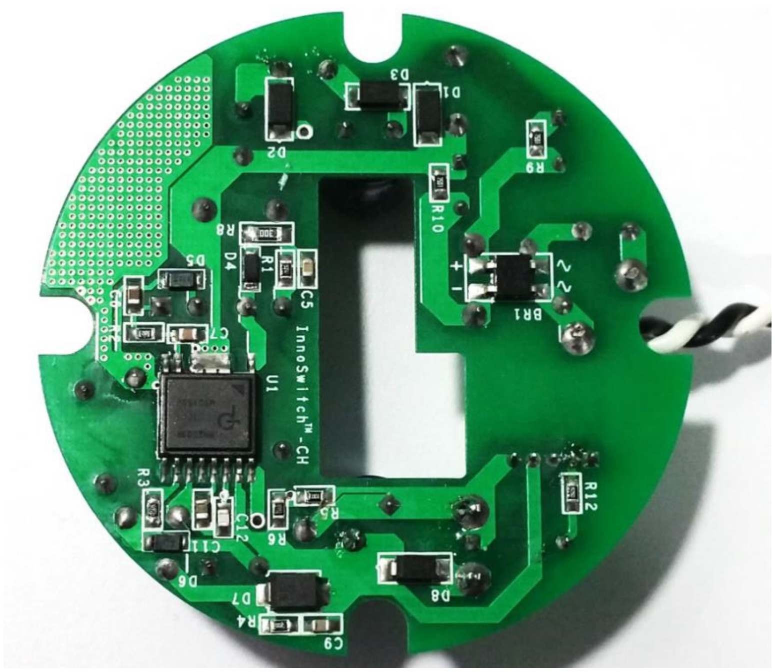

Figure 3 – Populated Circuit Board, Bottom View.

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2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input Voltage Frequency	 V_{IN} f_{LINE}	 90	115/60 230/50	 265	 Vac/Hz	 2 Wire – no P.E.
Output Output Voltage Output Current (Full Load) **Output Power** Continuous Output Power	 V_{OUT} I_{OUT} P_{OUT}	 26.5	 400 12	 30	 V mA W	
Full Efficiency	η		84 89		%	At 115 V / 60 Hz. At 230 V / 50 Hz.
Average Efficiency	η		83		%	DOE Level VI.
Environmental Conducted EMI Safety Ring Wave (100 kHz) Differential Mode Surge (L1-L2)			 CISPR 15B / EN55015B Isolated 2.5 1.0		 kV kV	
Power Factor			0.9			Measured at 115 V / 60 Hz.
Ambient Temperature	T_{AMB}			70	ºC	Free Air Convection, Sea Level.

3 Schematic

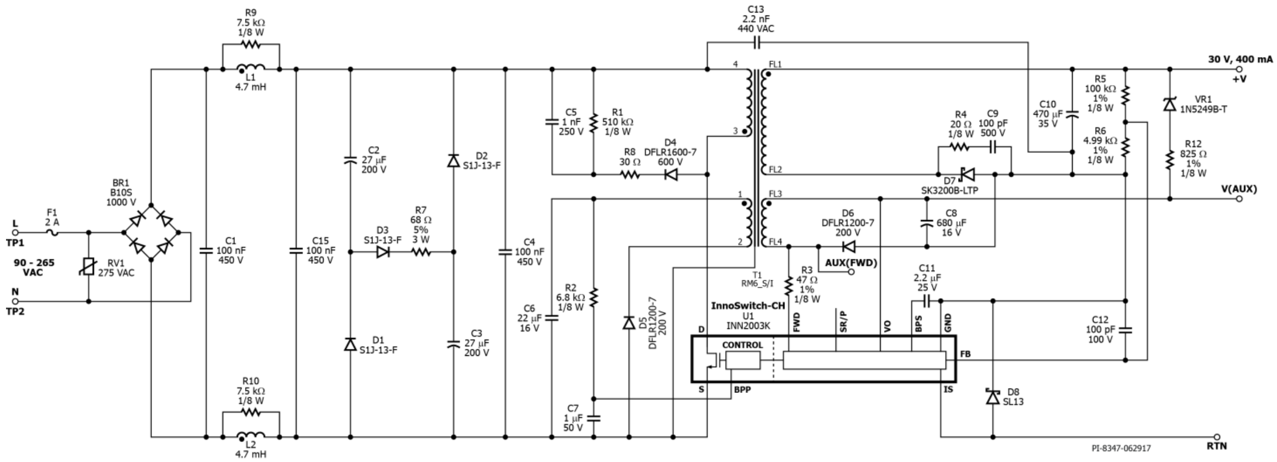

Figure 4 – Schematic.

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4 Circuit Description

InnoSwitch-CH (INN2003K) incorporates the primary FET, 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. InnoSwitch-CH is configured to drive a 12 W flyback power supply with added valley-fill passive PFC circuit providing a high power factor 30 V constant voltage supply throughout the input range of 90 VAV to 265 VAC.

4.1 Input EMI Filter and Rectifier

The input fuse F1 provides safety protection from component failures. Varistor RV1 acts as a voltage clamp that limits the voltage spike on the primary during line 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 C2 and C3 provides input line ripple voltage filtering for a stable flyback DC supply voltage.

Capacitor C1, L1, L2, C4 and C15 provide EMI filtering to suppress differential mode noise caused by the PFC and flyback switching action. Common mode noise is suppressed by Y-capacitor C13. These together with the InnoSwitch-CH frequency jitter and electronically quiet source pins ensure compliance with EN55015B.

4.2 Valley-Fill PFC Circuit

Off-line flyback power supplies without PFC usually consist of an input bridge rectifier followed by a storage bulk capacitor. The input line current is drawn in high amplitude narrow pulses near the peaks of the voltage waveform introducing high input RMS current and high harmonic distortion. The valley-fill PFC is a simple low cost solution to improve power factor.

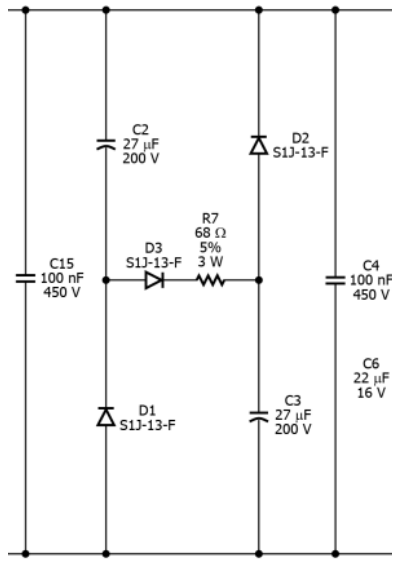

Figure 5 – Valley-Fill PFC.

Capacitor C2 and C3 are charged through diode D3 while the input rectified AC voltage approaches $V_{PEAK}/2$ increasing the input current conduction angle. Resistor R7 reduces peak current that will increase RMS current and harmonic distortion. When the input rectified AC voltage is greater than $V_{PEAK}/2$ the flyback converter switches with its supply current drawn directly from the input DC bus supply. Capacitor C4 and C15 filter the switching voltage spikes that appear on the DC bus supply. Diode D1 and D2 block current from charging C2 and C3 when the input rectified voltage is less than half of the V_{PEAK}. Capacitor C2 and C3 supply current through D1 and D2 while the input rectified voltage is below $V_{PEAK}/2$. At this time C2 and C3 are basically in parallel.

4.3 InnoSwitch-CH Primary Side Control

The isolated flyback power supply is controlled by InnoSwitch-CH (INN2003K). One side of the transformer (T1) primary is connected to the positive DC bus terminal while the other side is connected to the drain pin of the InnoSwitch-CH (U1) internal power MOSFET.

A low cost RCD clamp formed by D4, R8, C5 and R1 limits the peak drain voltage spike due to the effects of transformer leakage inductance.

During the initial power-up, the internal high-voltage current source charges the (BPP) pin capacitor (C7) 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 D5 and C6 and fed to the BPP pin via a current limiting resistor R2.

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Output regulation is achieved using On/Off control, the number of enabled switching cycles are adjusted based on the output load. At high load most switching cycles are enabled, and at light load or no-load most cycled are disabled or skipped. Once a cycle is enabled, the power MOSFET remains on until the primary current ramps to the device current limit for the specific operating state. There are four operating states (current limits) arranged such that the frequency content of the primary current switching pattern remains out of the audible range until light load where the transformer flux density and therefore audible noise generation is at a very low level.

4.4 InnoSwitch-CH Secondary Side Control

The transformer secondary is rectified by a low V_F Schottky diode D7 and filtered by the output capacitor C10. R-C snubber R4 and C9 reduces voltage stress on D7 and radiated EMI.

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 D6 and C8 and is set at 10 V.

The secondary side of the IC is self-powered from either the secondary bias winding forward voltage or 10 V bias supply. During the on-time of the primary side MOSFET the forward voltage that appears across the secondary bias winding is used to charge the BPS capacitor (C11) via FWD pin resistor (R3) and an internal regulator. During CV operation, the 10 V 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 R5 and R6 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 C12 is added across R6 to eliminate unwanted noise that might trigger the OVP or increase ripple voltage.

Output current is sensed internally between the IS and GND pins with a threshold of 35 mV to minimize losses. Once the internal current sense threshold is exceeded, the device adjusts the number of enabled switching cycles to maintain a fixed output current. Diode D8 protects the IS pin from high inrush current during output short-circuit.

It is necessary to use C8 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 R12 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 6 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 InnoSwitch-CH IC to reset due to low BPS pin voltage; V_AUX_NL ≥ 4.5 V should be good enough for this application.

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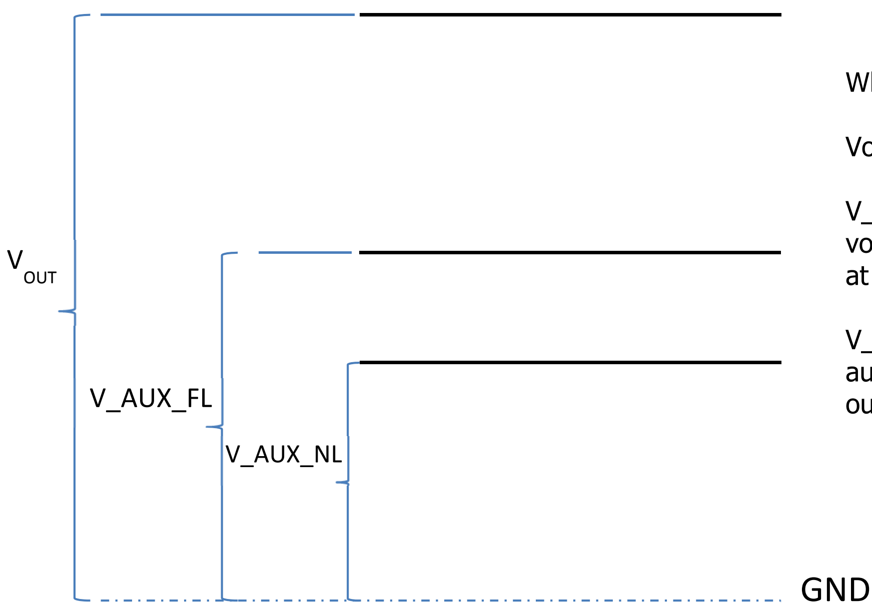

Where:

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 6 – Secondary Output Voltage Levels.

5 PCB Layout

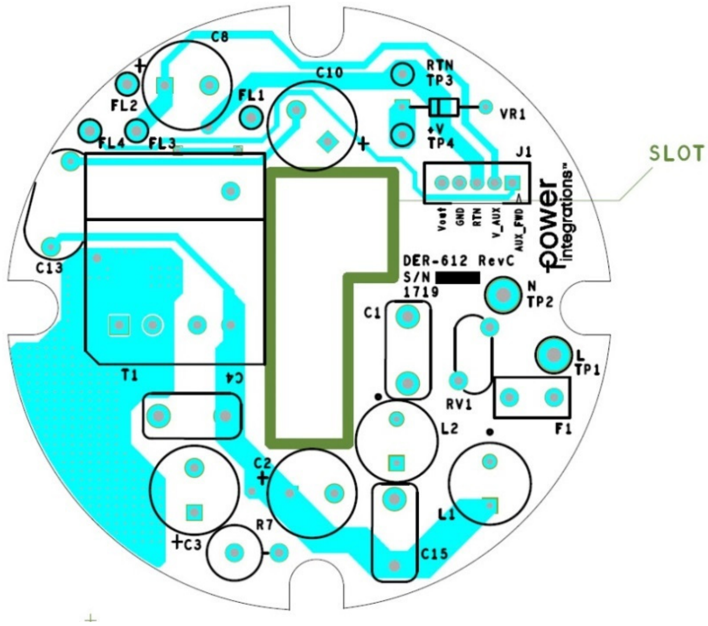

Figure 7a – Top Side.

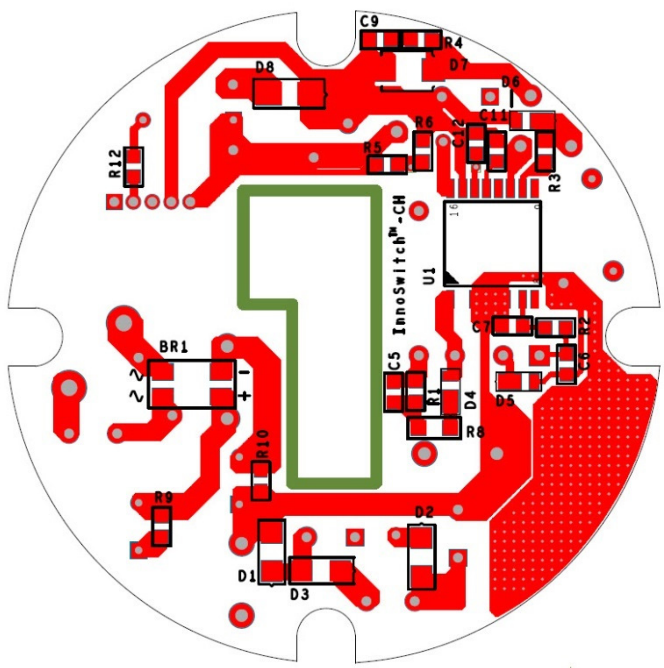

Figure 7b – Bottom Side.

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6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip
2	1	C1	100 nF, 450 V, Film	MEXXD31004JJ1	Duratech
3	1	C2	27 μF, 200 V, Electrolytic, (10 x 16),	EKXJ201ELL270MJ16S	Nippon Chemi-Con
4	1	C3	27 μF, 200 V, Electrolytic, (10 x 16),	EKXJ201ELL270MJ16S	Nippon Chemi-Con
5	1	C4	100 nF, 450 V, Film	MEXXD31004JJ1	Duratech
6	1	C5	1 nF, 250 V, Ceramic, X7R, 0805	GRM21AR72E102KW01D	Murata
7	1	C6	22 μF, 16 V, Ceramic, X5R, 0805	C2012X5R1C226K	TDK
8	1	C7	1 μF,50 V, Ceramic, X7R, 0805	C2012X7R1H105M085AC	TDK
9	1	C8	680 μF, 16 V, Electrolytic, (10 x 12.5)	KMG16WV680UF10X12.5	Sam Young
10	1	C9	100 pF, 500 V, Ceramic, NPO, 0805	501R15N101KV4T	Johanson Dielectrics
11	1	C10	470 μF, 35 V, Electrolytic, Low ESR, 23 mΩ, (10 x 20)	UHD35470MPD	Nichicon
12	1	C11	2.2 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
13	1	C12	100 pF 100V 10 % X7R 0805	08051C101JAT2A	AVX
14	1	C13	2.2 nF, Ceramic, Y1	CD90ZU2GA222MYNKA	TDK
15	1	C15	100 nF, 450 V, Film	MEXXD31004JJ1	Duratech
16	1	D1	600 V, 1 A, Standard Recovery, SMA	S1J-13-F	Diodes, Inc.
17	1	D2	600 V, 1 A, Standard Recovery, SMA	S1J-13-F	Diodes, Inc.
18	1	D3	600 V, 1 A, Standard Recovery, SMA	S1J-13-F	Diodes, Inc.
19	1	D4	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
20	1	D5	200 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1200-7	Diodes, Inc.
21	1	D6	200 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1200-7	Diodes, Inc.
22	1	D7	200 V, 3 A, DIODE SCHOTTKY 1 A 200 V, SMB	SK3200B-LTP	Micro Commercial
23	1	D8	30 V, 1.5 A, Schottky, Low Vf, DO-214AC	SL13-E3/61T	Vishay
24	1	F1	2 A, 250V, Slow, Long Time Lag, RST	RST 2	Belfuse
25	1	J1	CONN, Male, Vertical, 5 Positions, Header, 0.079" (2.00 mm), TH, Tin	0894000510	Molex
26	1	L1	4.7 mH, 240 mA, 9 x 12.2 mm H	RLB9012-472KL PM-R30472	Bourns Premier Magnetics
27	1	L2	4.7 mH, 240 mA, 9 x 12.2 mm H	RLB9012-472KL PM-R30472	Bourns Premier Magnetics
28	1	R1	RES, 510 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ514V	Panasonic
29	1	R2	RES, 6.8 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ682V	Panasonic
30	1	R3	RES, 47.0 Ω, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF47R0V	Panasonic
31	1	R4	RES, 20 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ200V	Panasonic
32	1	R5	RES, 100 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1003V	Panasonic
33	1	R6	RES, 4.99 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF4991V	Panasonic
34	1	R7	RES, 68 Ω, 5%, 3 W, Wirewound, Axial, Flame Retardant Coating, Fusible	AC03000006809JACCS	Vishay
35	1	R8	RES, 30 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ300V	Panasonic
36	1	R9	RES, 7.5 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ752V	Panasonic
37	1	R10	RES, 7.5 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ752V	Panasonic
38	1	R12	RES, 825 Ω, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF8250V	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. Transformer	CPV-RM6S/I-1S-8PD POL-INN026	Ferroxcube Premier Magnetics
41	1	U1	InnoSwitch-CH, Off-Line CV/CC Flyback Switcher, ReSOP-16B	INN2003K	Power Integrations
42	1	VR1	19 V, 5%, 500 mW, DO-35	1N5249B-T	Diodes, Inc.

6.1 Miscellaneous Parts

Item	Qty	Ref	Description	Mfg Part Number	Mfg
1	4	FL1, FL2, FL3, FL4	Flying Lead, Hole size 50mils	N/A	N/A
2	1	TP1	Test Point, WHT, THRU-HOLE MOUNT	5012	Keystone
3	1	TP2	Test Point, BLK, THRU-HOLE MOUNT	5011	Keystone
4	1	TP3	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone
5	1	TP4	Test Point, RED, Miniature THRU-HOLE MOUNT	5000	Keystone

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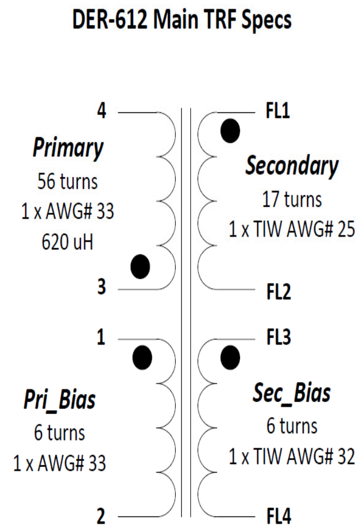
7 Flyback Transformer Specification (T1)

7.1 Electrical Diagram



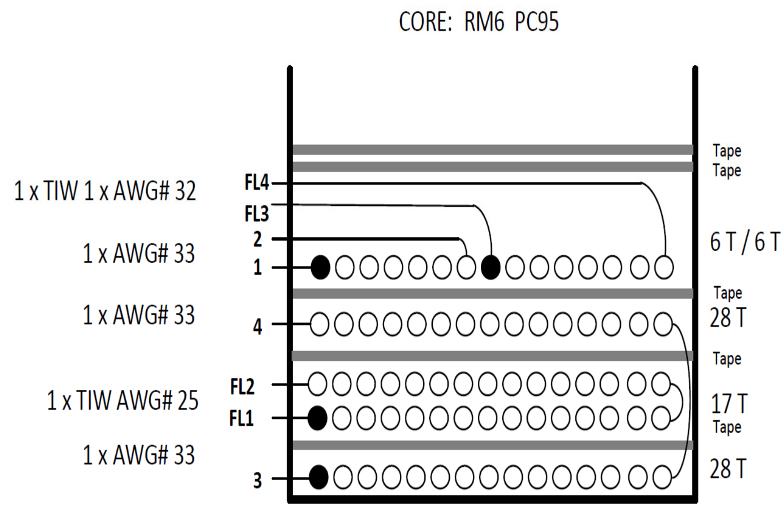


Figure 8 – Transformer Electrical Diagram. **Figure 9 –** Transformer Mechanical Diagram.

7.2 Electrical Specifications

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 3 and pin 4 with all other windings open.	630 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 w 2 pin clip: 25-00915-00.
[3]	Magnet Wire: #33 AWG.
[4]	TIW: #25 AWG.
[5]	TIW: #32 AWG.
[6]	Polyester Tape: 6.5 mm.
[7]	Mounting Clip: RM6 S/I.

7.4 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]. Prepare an enough length of magnetic wire for primary winding (56 turns). Start the winding 1 at pin 3 and wind 28 turns evenly. Set aside the remaining length of magnetic wire on the left side and reserve it for Winding 3. Do not cut the wire and temporally fix it on terminal pin 4 so it will not loosen up during Winding 2.
Insulation	Apply 1 layer of polyester tape, Item [6] for insulation
Winding 2	Use triple insulated wire Item [4]. The terminals for Winding 2 are fly wires marked as (FL1) and (FL2). Start the Winding 2 at FL1 and wind 17 turns evenly in 2 layers. Finish the winding on FL2. Temporally use the bobbin terminals to fix the FL1 and FL2 so it will not loosen up.
Insulation	Apply 1 layer of polyester tape, Item [6] for insulation.
Winding 3	Use the remaining magnetic wires from Winding 1 reserved for winding 3 on the left side. Start the winding on the left side as shown in the figure and 28 turns evenly. Finish the winding on pin 4.
Insulation	Apply 1 layer of polyester tape, Item [6] for insulation
Winding 4	Use magnetic wire Item [3]. Start at pin 1 and wind 6 turns tightly. Finish the winding on pin 2.
Winding 5	Use triple insulated wire item [5]. The terminals for Winding 5 are fly wires marked as (FL3) and (FL4). Start Winding 5 at FL3 and wind 6 turns evenly beside Winding 4. Finish the winding on FL4. Temporally use the bobbin terminals to fix fly wire terminals (FL3) and (FL4) so it will not loosen up.
Insulation	Apply 1 layer of polyester tape, Item [6] 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 620 μH.
Core Fixing	Assemble the ferrite cores on the bobbin. Apply the mounting clips to fix the cores.
Pins	Cut pin 6 -8. Cut Pin 5 horizontal Pin. Do not cut the mounting clip terminal pin located on the left side near the C13.
Finished	Dip the finished transformer into 2:1 varnish thinner solution.

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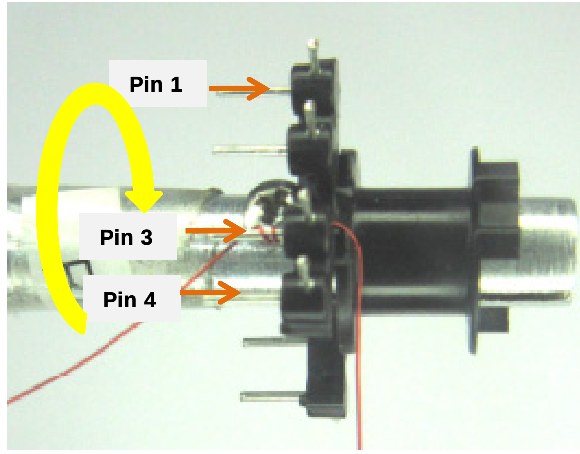
7.5 Winding Illustrations

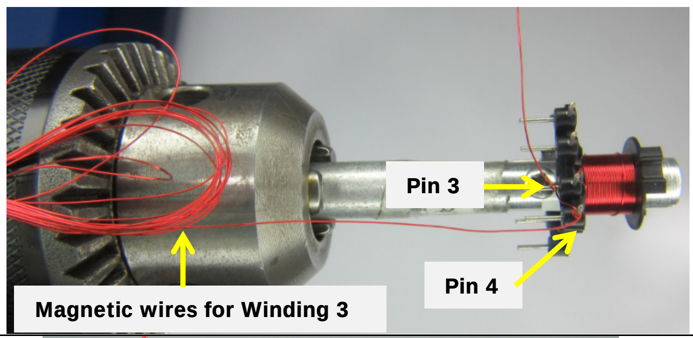
<table>
<tr><td>Winding Directions

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. Prepare an enough length of magnetic wire for primary winding (56 turns). Start the winding 1 at pin 3 and wind 28 turns evenly.

Set aside the remaining length of magnetic wire on the left side and reserve it for Winding 3. Do not cut the wire and temporally fix it on terminal pin 4 so it will not loosen up during Winding 2.</td><td>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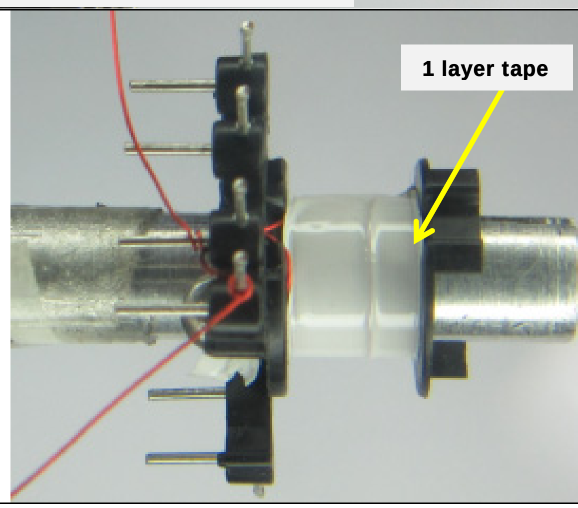
<tr><td>Insulation

Apply 1 layer of polyester tape, Item [6] for insulation.</td><td>
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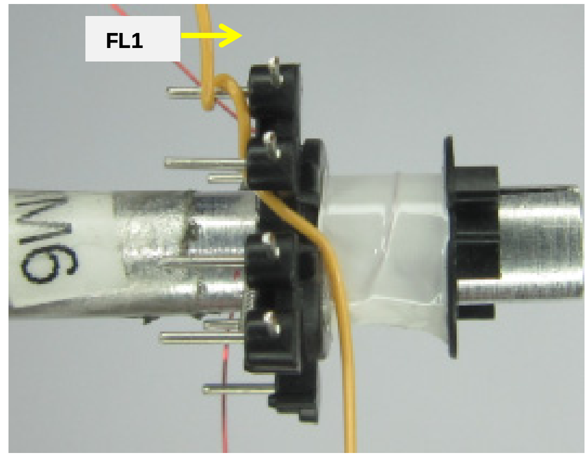
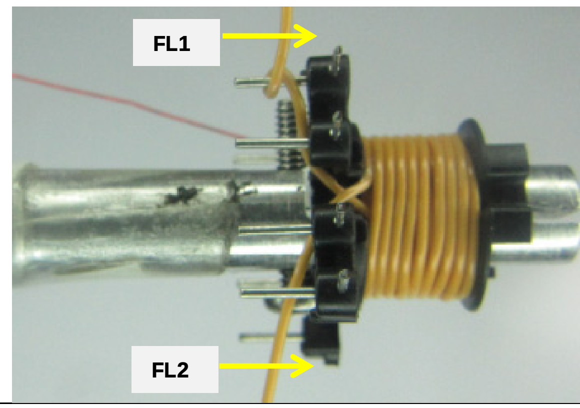
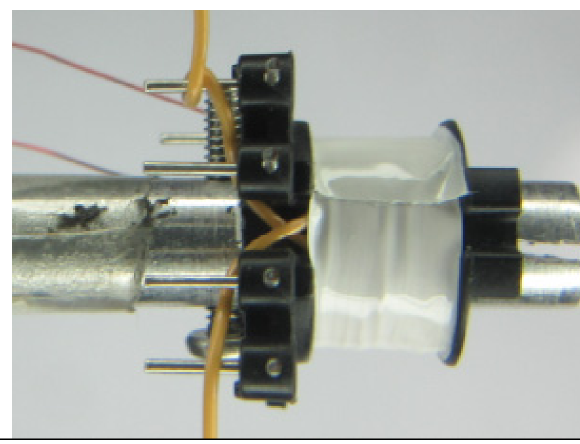
Winding 2 Use triple insulated wire item [4]. The terminals for Winding 2 are fly wires marked as (FL1) and (FL2). Start the Winding 2 at FL1 and wind 17 turns evenly in 2 layers. Finish the winding on FL2. Temporally use the bobbin terminals to fix the FL1 and FL2 so it will not loosen up.	 
Insulation Apply 1 layer of polyester tape, Item [6] for insulation	

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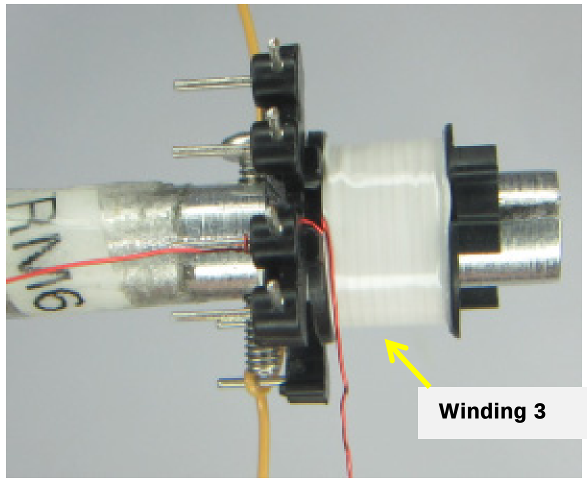
<table>
<tr><td>Winding 3

Use the remaining magnetic wires from Winding 1 reserved for winding 3 on the left side. Start the winding on the left side as shown in the figure and 28 turns evenly.</td><td>
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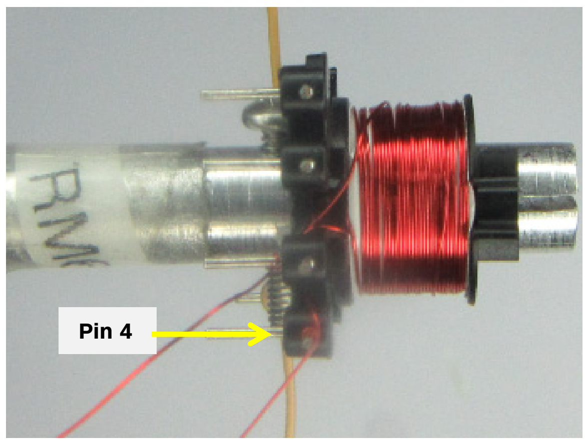
<tr><td>Finished the winding on pin 4.</td><td>
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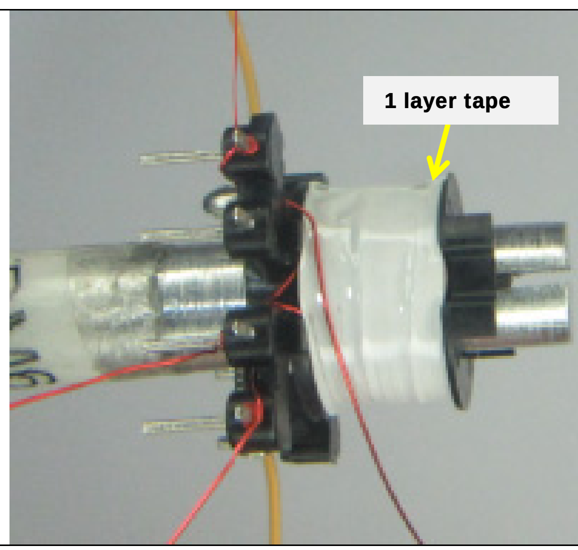
Apply 1 layer of polyester tape, Item [6] for insulation.</td><td>
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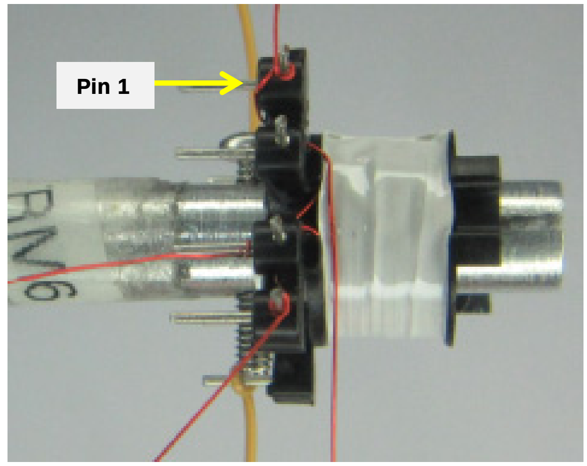
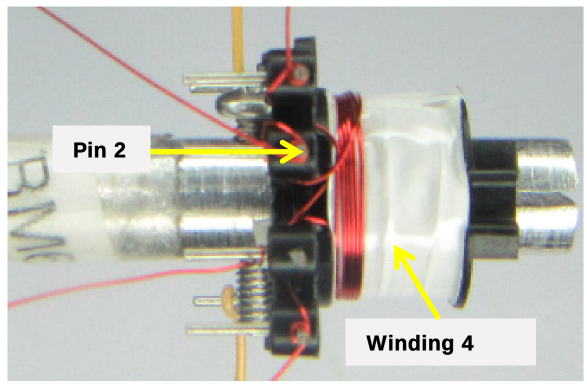
</table>

Winding 4 Use magnetic wire Item (3). Start at pin 1 and wind 6 turns tightly.	
Finish the winding on pin 2.	

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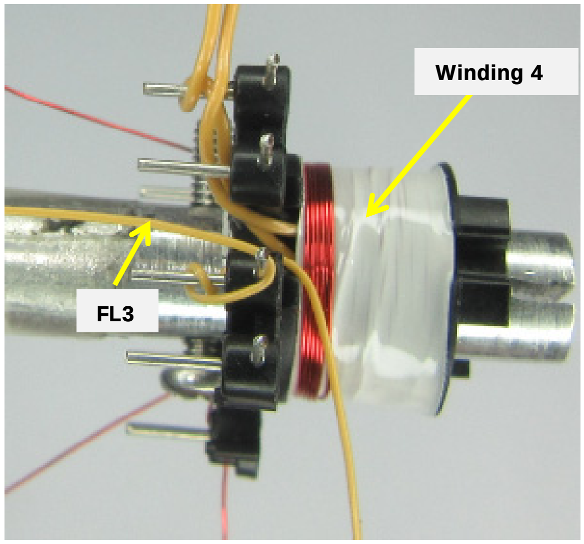
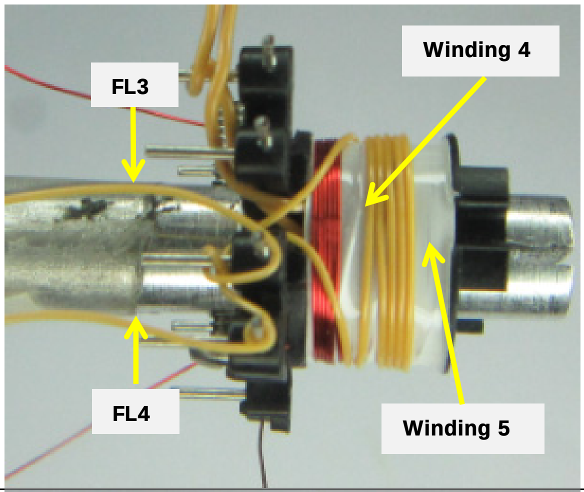
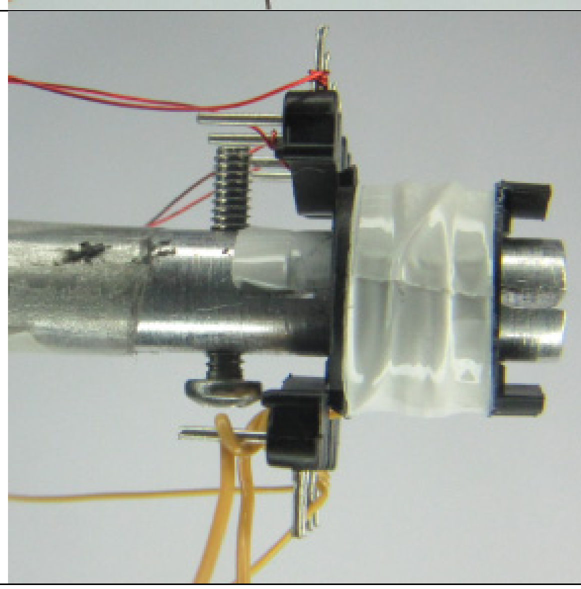
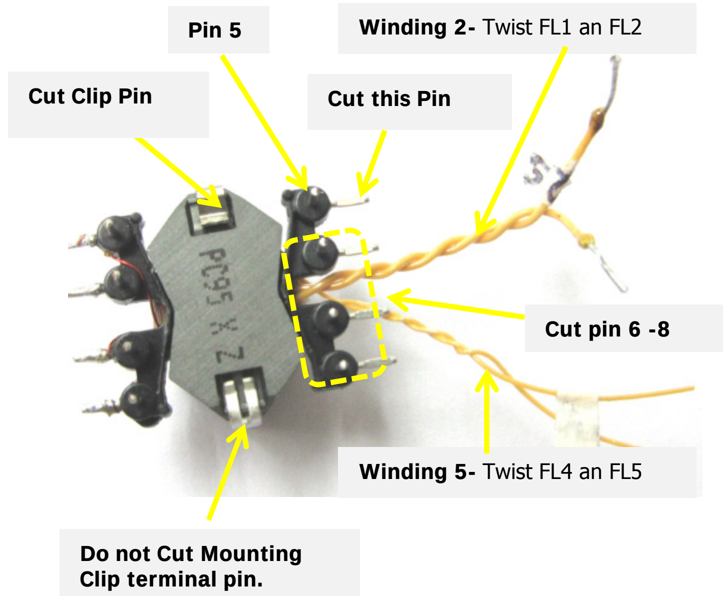
Winding 5 Use triple insulated wire Item [5]. The terminals for Winding 5 are fly wires marked as (FL3) and (FL4). Start Winding 5 at FL3 and wind 6 turns evenly beside Winding 4. Finish the winding on FL4. Temporally use the bobbin terminals to fix fly wire terminals (FL3) and (FL4) so it will not loosen up.	 
Insulation Apply 1 layer of polyester tape, Item [6] 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 620 μH. **Core Fixing** Assemble the ferrite cores on the bobbin. Apply the mounting clips to fix the cores. **Pins** Cut pin 6-8. Cut pin 5 horizontal pin. **Finished** Dip the finished transformer into 2:1 varnish thinner solution.	

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8 Transformer Spreadsheet

ACDC_InnoSwitch-CH_031816; Rev.2.2; Copyright Power Integrations 2016	INPUT	INFO	OUTPUT	UNIT	ACDC_InnoSwitch-CH_031816_Rev2-2; InnoSwitch-CH Continuous/Discontinuous Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					
VACMIN	90		90	V	Minimum AC Input Voltage
VACMAX	265		265	V	Maximum AC Input Voltage
fL	60		60	Hz	AC Mains Frequency
VO	30.00		30.00	V	Output Voltage (continuous power at the end of the cable)
IO	0.40		0.40	A	Power Supply Output Current (corresponding to peak power)
Power			12	W	Continuous Output Power, including cable drop compensation
N	0.80		0.80		Efficiency Estimate at output terminals. Use 0.8 if no better data available
Z	0.50		0.50		Z Factor. Ratio of secondary side losses to the total losses in the power supply. Use 0.5 if no better data available
tC			3.00	mSeconds	Bridge Rectifier Conduction Time Estimate
CIN	22.00		22.00	uFarad	Input capacitance
ENTER InnoSwitch-CH VARIABLES					
InnoSwitch-CH	**Auto**		**INN20x3**		Recommended InnoSwitch-CH
Cable drop compensation	**0%**		**0%**		Select Cable Drop Compensation option
Complete Part Number			**INN2003K**		Final part number including package
Chose Configuration	**INC**		**Increased Current Limit**		Enter "RED" for reduced current limit (sealed adapters), "STD" for standard current limit or "INC" for increased current limit (peak or higher power applications)
ILIMITMIN			0.682	A	Minimum Current Limit
ILIMITTYP			0.750	A	Typical Current Limit
ILIMITMAX			0.818	A	Maximum Current Limit
fSmin			93000	Hz	Minimum Device Switching Frequency
I^2fmin			47.25	A^2kHz	Worst case I2F parameter across the temperature range
VOR	100		100	V	Reflected Output Voltage (VOR <= 100 V Recommended)
VDS			5.00	V	InnoSwitch on-state Drain to Source Voltage
KP			1.41		Ripple to Peak Current Ratio at Vmin, assuming ILIMITMIN, and I2FMIN (KP < 6)
KP_TRANSIENT			0.68		Worst case transient Ripple to Peak Current Ratio. Ensure KP_TRANSIENT > 0.25
ENTER BIAS WINDING VARIABLES					
VB			10.00	V	Bias Winding Voltage
VDB			0.70	V	Bias Winding Diode Forward Voltage Drop
NB			5.65	V	Bias Winding Number of Turns
PIVB			64.92	V	Bias winding peak reverse voltage at VACmax and assuming VB*1.2

ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**RM6**		**RM6**		Enter Transformer Core
Core			PC47RM6Z-12		Enter core part number, if necessary
Bobbin			BRM6-716SPFR		Enter bobbin part number, if necessary
AE			0.366	cm^2	Core Effective Cross Sectional Area
LE			2.86	cm	Core Effective Path Length
AL			1837	nH/T^2	Ungapped Core Effective Inductance
BW			6.35	mm	Bobbin Physical Winding Width
M			0.00	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L			3		Number of Primary Layers
NS			17		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			94	V	Minimum DC Input Voltage
VMAX			375	V	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.53		Duty Ratio at full load, minimum primary inductance and minimum input voltage
IAVG			0.15	A	Average Primary Current
IP			0.682	A	Peak Primary Current assuming ILIMITMIN
IR			0.682	A	Primary Ripple Current assuming ILIMITMIN, and LPMIN
IRMS			0.26	A	Primary RMS Current, assuming ILIMITMIN, and LPMIN
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			635	uHenry	Typical Primary Inductance. +/- 10% to ensure a minimum primary inductance of 571 uH
LP_TOLERANCE	10.0		10.0	%	Primary inductance tolerance
NP			56		Primary Winding Number of Turns
ALG			202	nH/T^2	Gapped Core Effective Inductance
BM			2962	Gauss	Maximum Operating Flux Density, BM<3000 is recommended
BAC			1481	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
Ur			1142		Relative Permeability of Ungapped Core
LG			0.20	mm	Gap Length (Lg > 0.1 mm)
BWE			19.05	mm	Effective Bobbin Width
OD			0.34	mm	Maximum Primary Wire Diameter including insulation
INS			0.06	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.28	mm	Bare conductor diameter
AWG			30	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			102	Cmils	Bare conductor effective area in circular mils
CMA			388	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
TRANSFORMER SECONDARY DESIGN PARAMETERS					
Lumped parameters					
ISP			2.25	A	Peak Secondary Current, assuming ILIMITMIN
ISRMS			0.82	A	Secondary RMS Current
IRIPPLE			0.71	A	Output Capacitor RMS Ripple Current
CMS			163	Cmils	Secondary Bare Conductor minimum circular mils

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VOLTAGE STRESS PARAMETERS					
VDRAIN			525	V	Maximum Drain Voltage Estimate
PIVS			191	V	Output Rectifier Maximum Peak Inverse Voltage, assuming the primary has a Voltage spike 40% above VMAX and VO*1.05
TRANSFORMER SECONDARY DESIGN PARAMETERS					
1st output					
VO1			30.00	V	Main Output Voltage directly after output rectifier
IO1			0.40	A	Output DC Current
PO1			12.00	W	Output Power
VD1			0.10	V	Output Synchronous Rectification FET Forward Voltage Drop
NS1			17.00	Turns	Output Winding Number of Turns
ISRMS1			0.82	A	Output Winding RMS Current
IRIPPLE1			0.71	A	Output Capacitor RMS Ripple Current
PIVS1			191	V	Output Rectifier Maximum Peak Inverse Voltage, assuming the primary has a Voltage spike 40% above VMAX and VO*1.05
Recommended MOSFET			**Si7456**		Recommended SR FET for this output
RDSON_HOT			0.042	Ohm	RDSon at 100C
VRATED			100	V	Rated voltage of selected SR FET
CMS1			163	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS1			27	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS1			0.36	mm	Minimum Bare Conductor Diameter
ODS1			0.37	mm	Maximum Outside Diameter for Triple Insulated Wire

9 Performance Data

All measurements were performed at room temperature.

9.1 System Efficiency

Set-up: Open frame unit
Load: 400 mA CC load
Ambient Temperature: 25 ^{o}C
Soak time: 60 seconds per input line

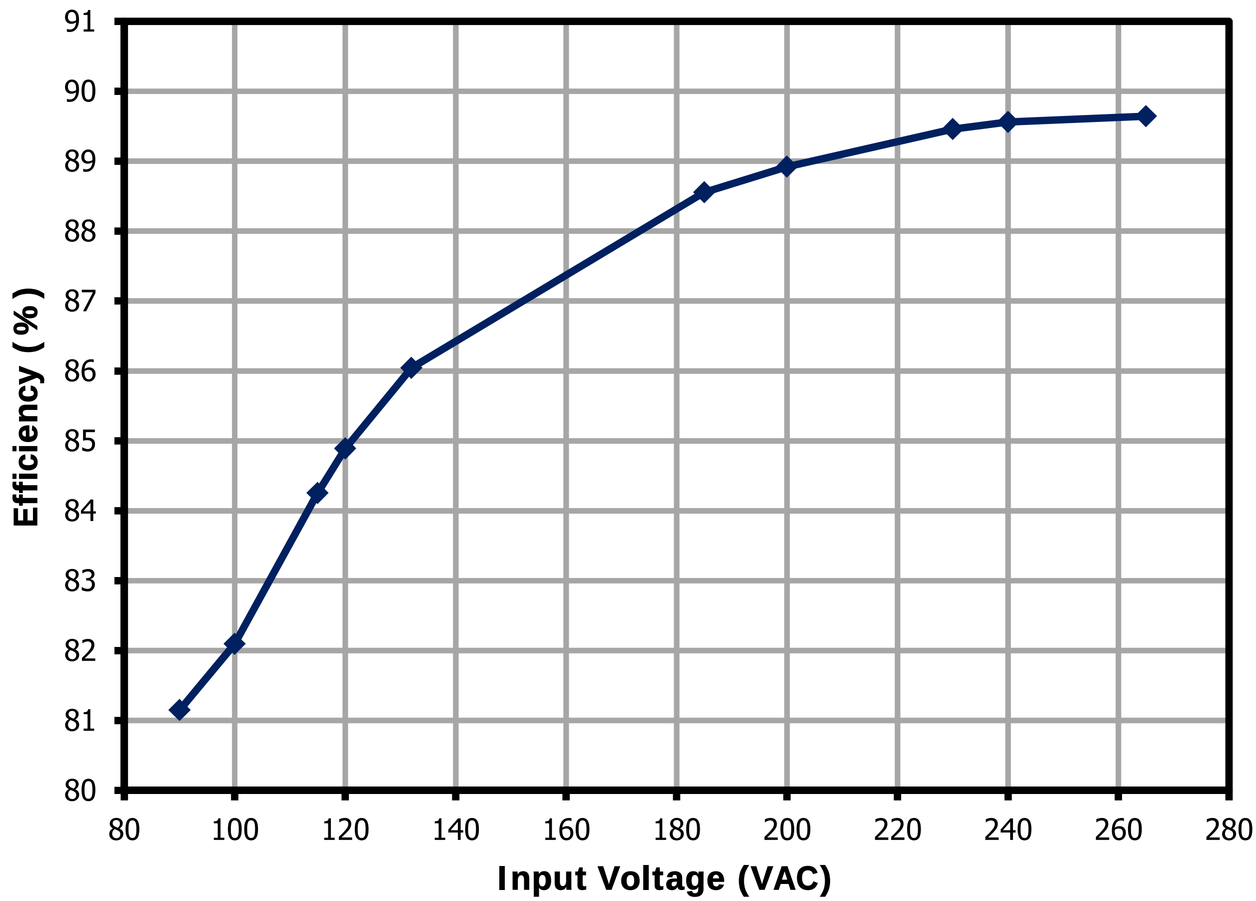

Figure 10 – Efficiency vs. Line.

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9.2 Output Voltage Regulation

Set-up: Open frame unit
Load: 400 mA CC load
Ambient Temperature: 25 ºC
Soak time: 60 seconds per input line

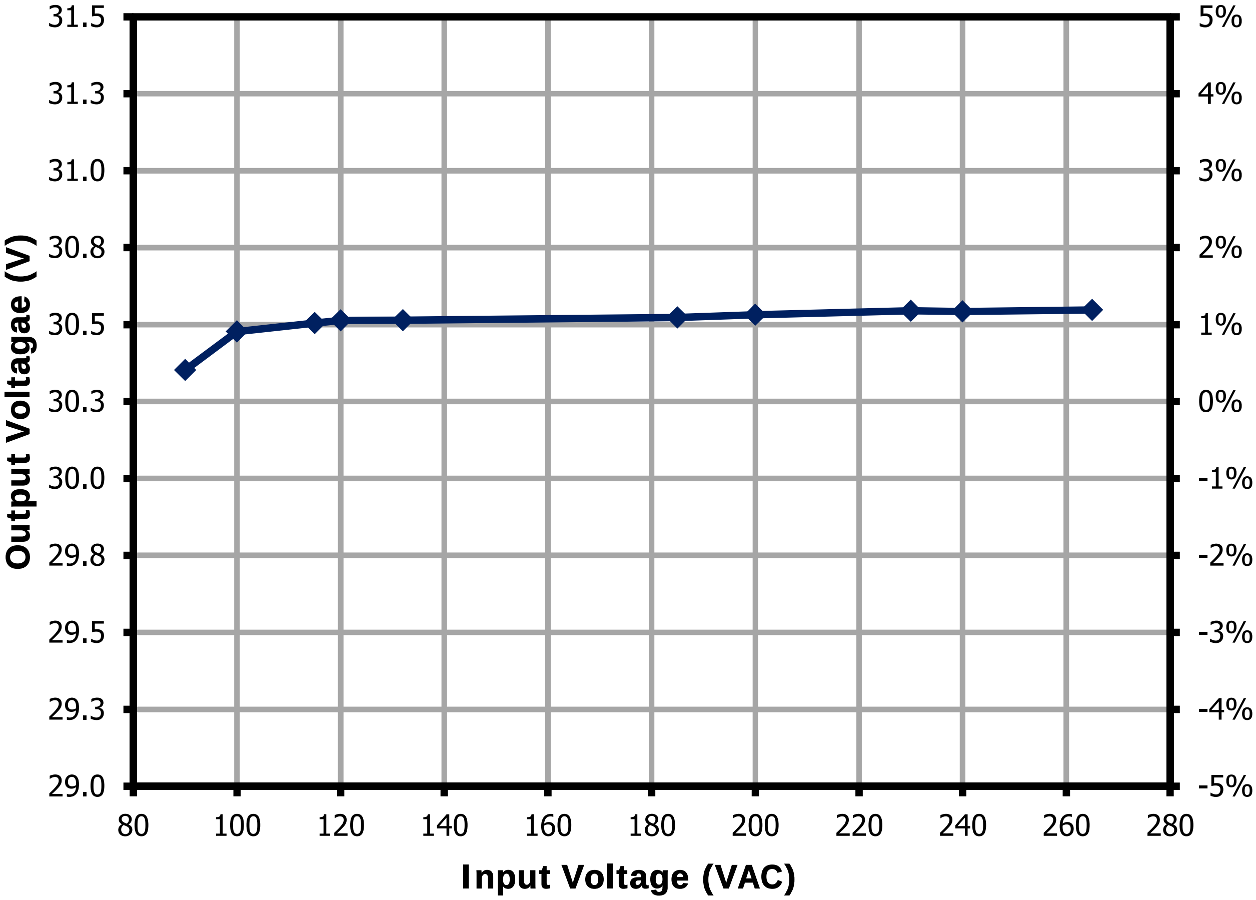

Figure 11 – Output Voltage Regulation vs. Line.

9.3 Power Factor

Set-up: Open frame unit
Load: 400 mA CC load
Ambient Temperature: 25 ºC
Soak time: 60 seconds per input line

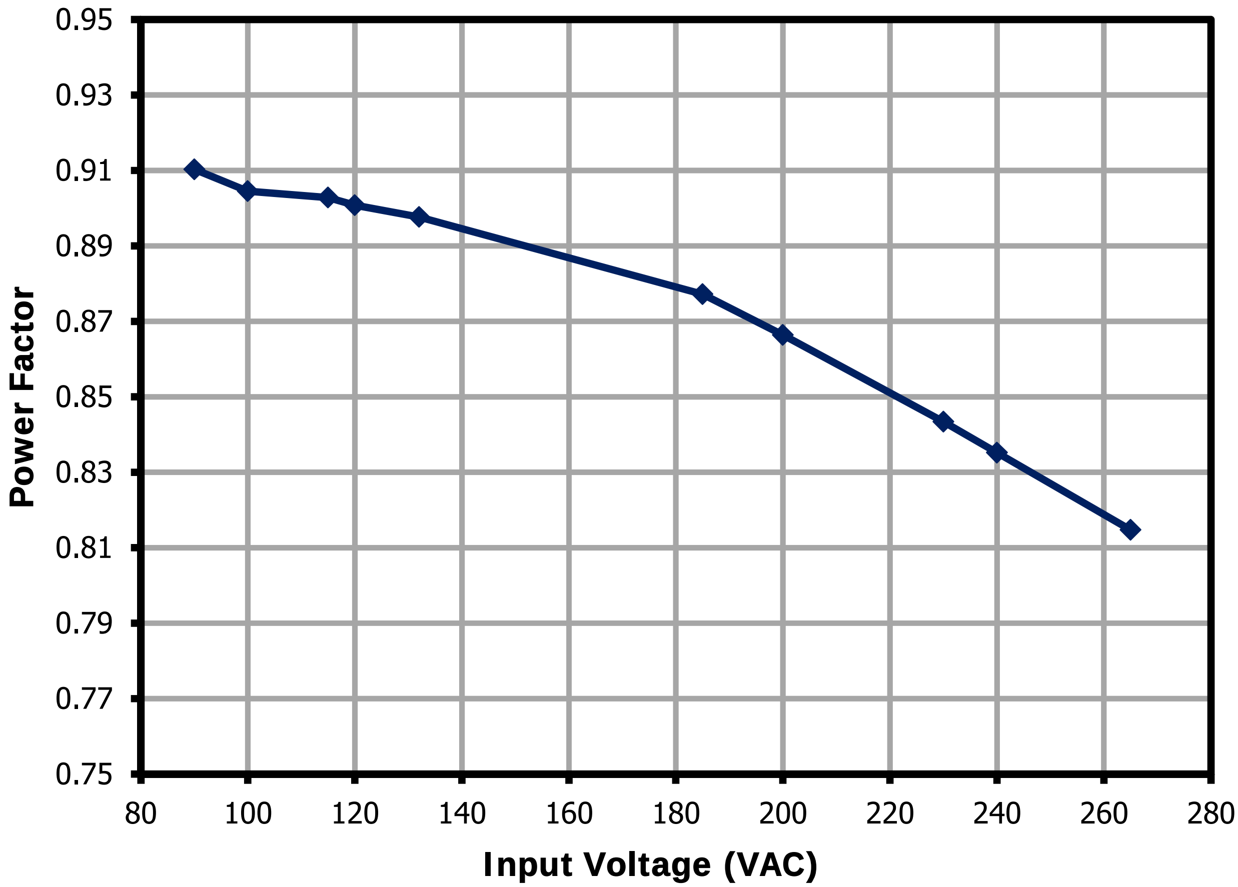

Figure 12 – Power Factor vs. Line.

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9.4 %ATHD

Set-up: Open frame unit
Load: 400 mA CC load
Ambient Temperature: 25 ºC
Soak time: 60 seconds per input line

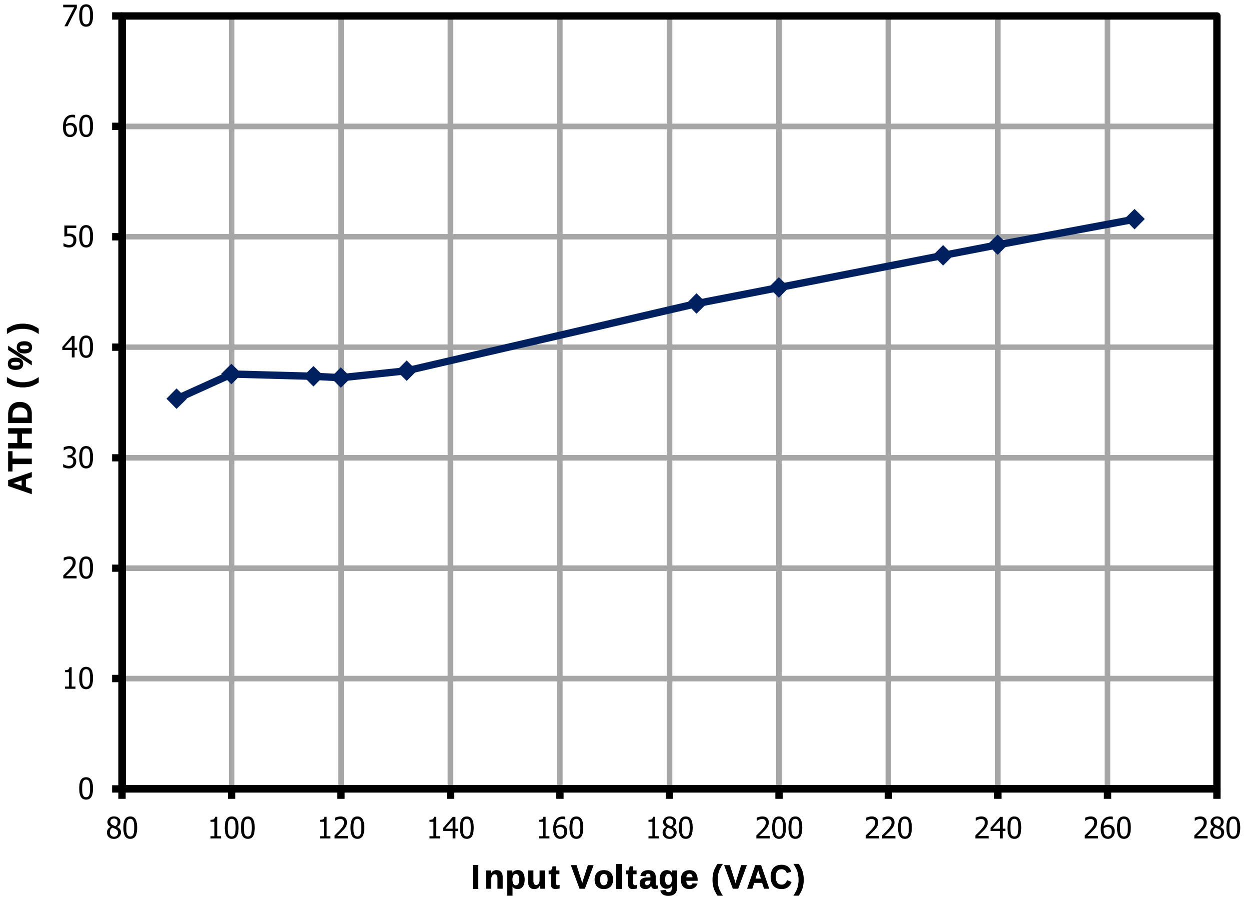

Figure 13 – %ATHD vs. Line.

9.5 No-Load Input Power

Set-up: Open frame unit
Load: No-load
Ambient Temperature: 25 ºC
Soak time: 60 seconds per line

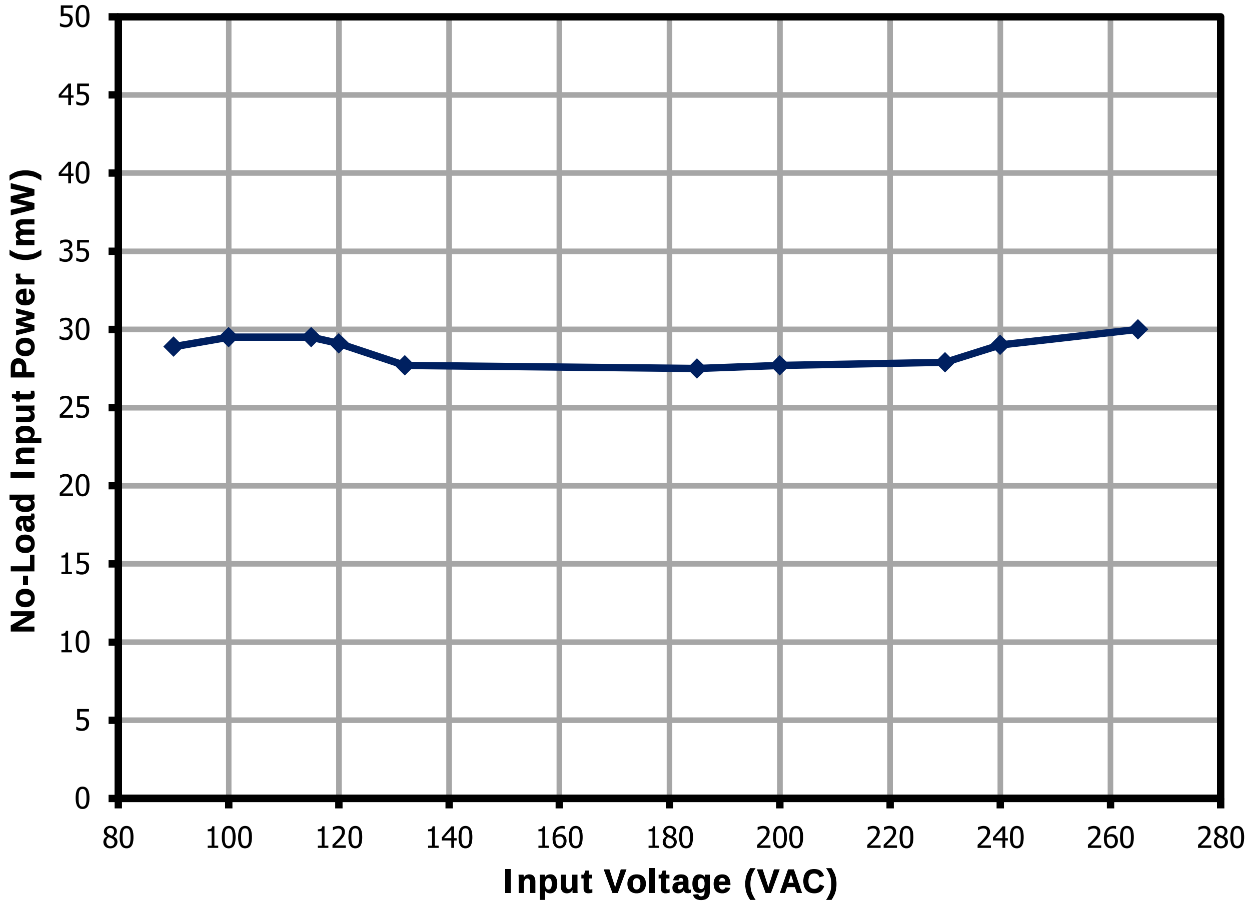

Figure 14 – No Load Input Power vs. Line.

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9.6 No-Load Output Voltage

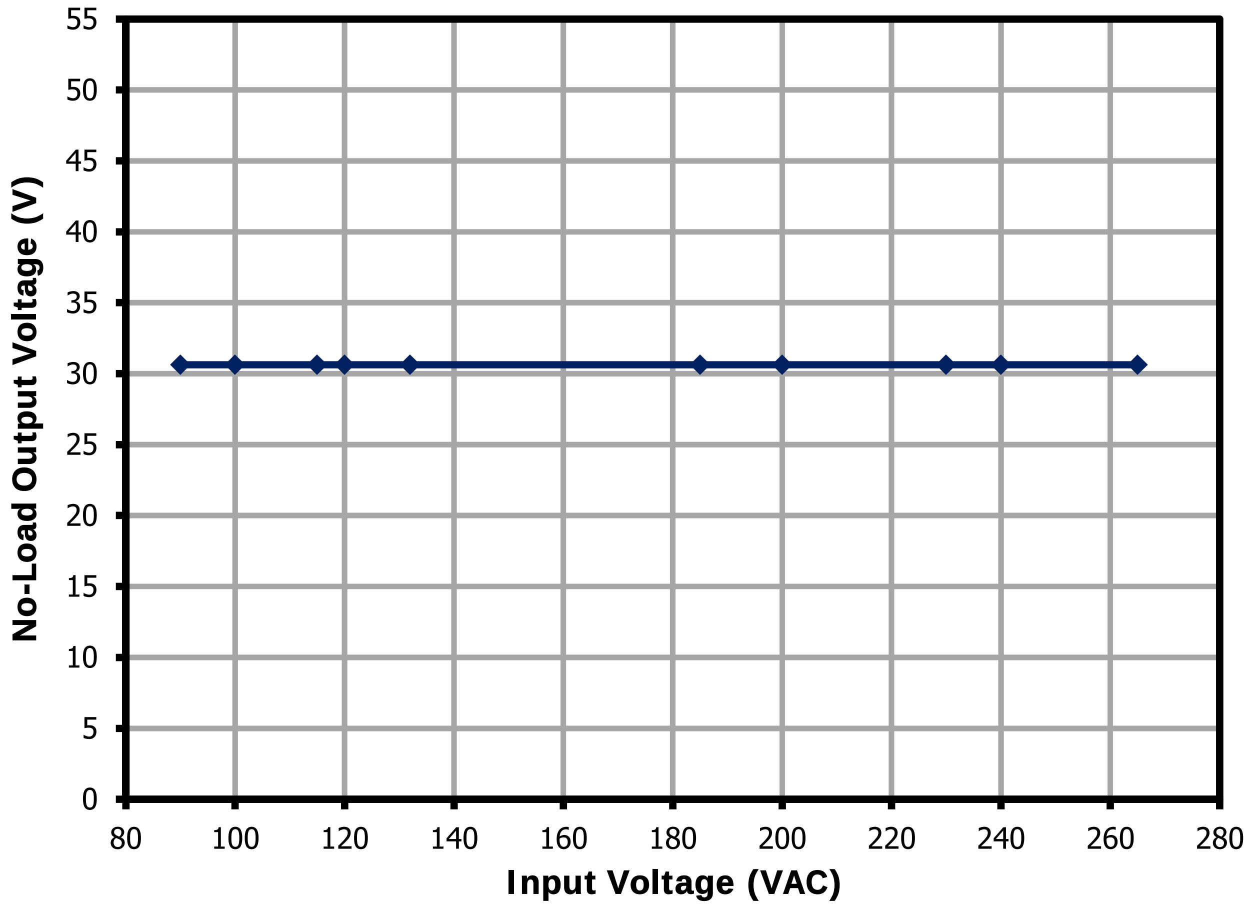

Figure 15 – No Load Voltage vs. Line.

10 Test Data

10.1 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	89.97	0.18	14.94	0.910	35.34	30.35	0.40	12.12	81.15
100	60	99.93	0.16	14.83	0.905	37.57	30.48	0.40	12.17	82.10
115	60	114.95	0.14	14.46	0.903	37.36	30.50	0.40	12.18	84.25
120	60	119.92	0.13	14.36	0.901	37.25	30.51	0.40	12.19	84.89
132	60	131.93	0.12	14.16	0.898	37.87	30.51	0.40	12.19	86.04
185	50	184.93	0.08	13.77	0.877	43.95	30.52	0.40	12.19	88.56
200	50	199.94	0.08	13.71	0.866	45.41	30.53	0.40	12.19	88.92
230	50	229.95	0.07	13.63	0.843	48.31	30.54	0.40	12.19	89.46
240	50	239.99	0.07	13.62	0.835	49.28	30.54	0.40	12.20	89.56
265	50	264.97	0.06	13.61	0.815	51.59	30.55	0.40	12.20	89.64

10.2 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	90.01	1.88	28.90	30.62
100	60	99.95	1.80	29.50	30.62
115	60	114.97	1.62	29.50	30.63
120	60	119.94	1.54	29.10	30.63
132	60	131.95	1.41	27.70	30.63
185	50	184.93	1.05	27.50	30.63
200	50	199.94	1.05	27.70	30.63
230	50	229.96	0.94	27.90	30.63
240	50	240.00	0.96	29.00	30.62
265	50	264.97	0.91	30.00	30.63

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11 Load Regulation Performance

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

11.1 Output Voltage Load Regulation

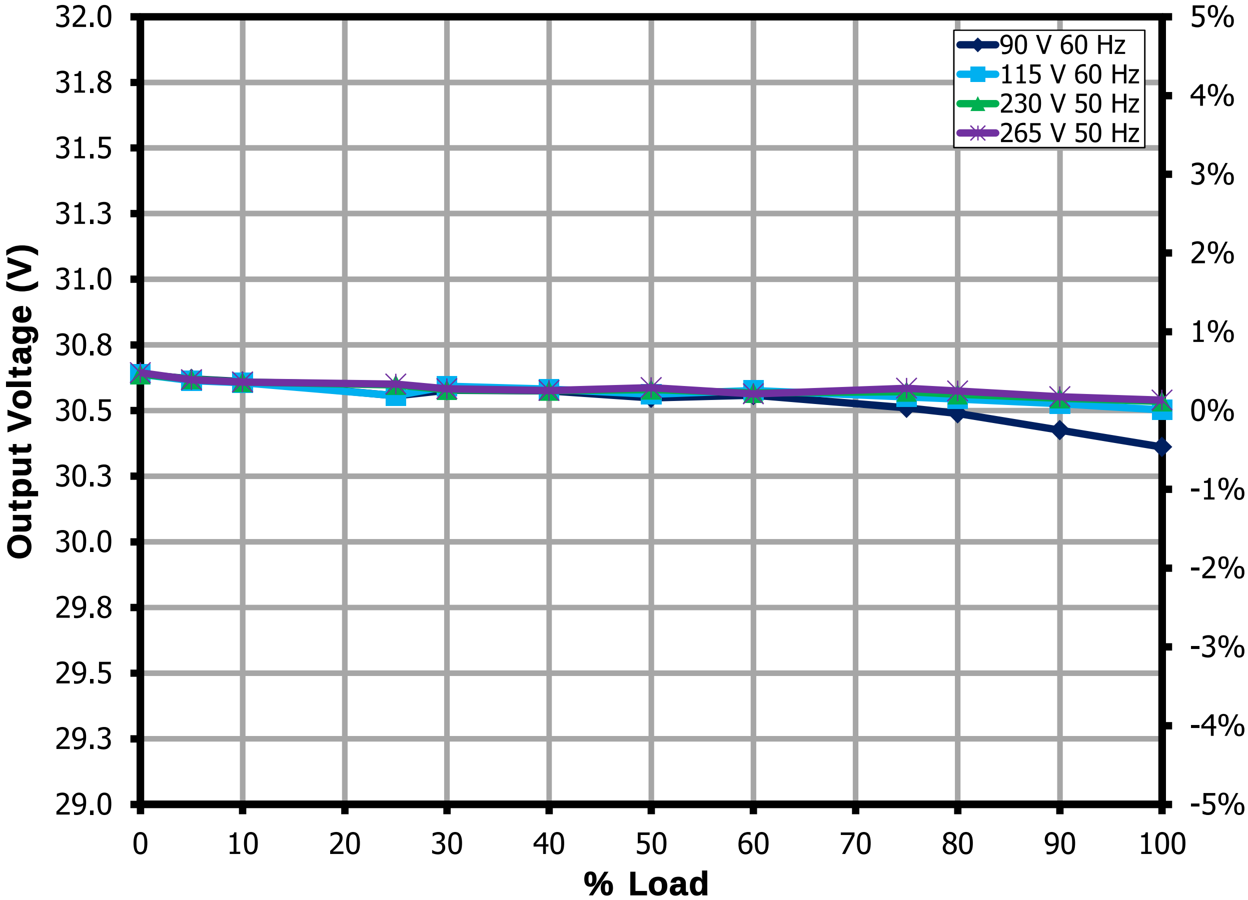

Figure 16 – Output Voltage vs. Load.

11.2 Efficiency vs. Load

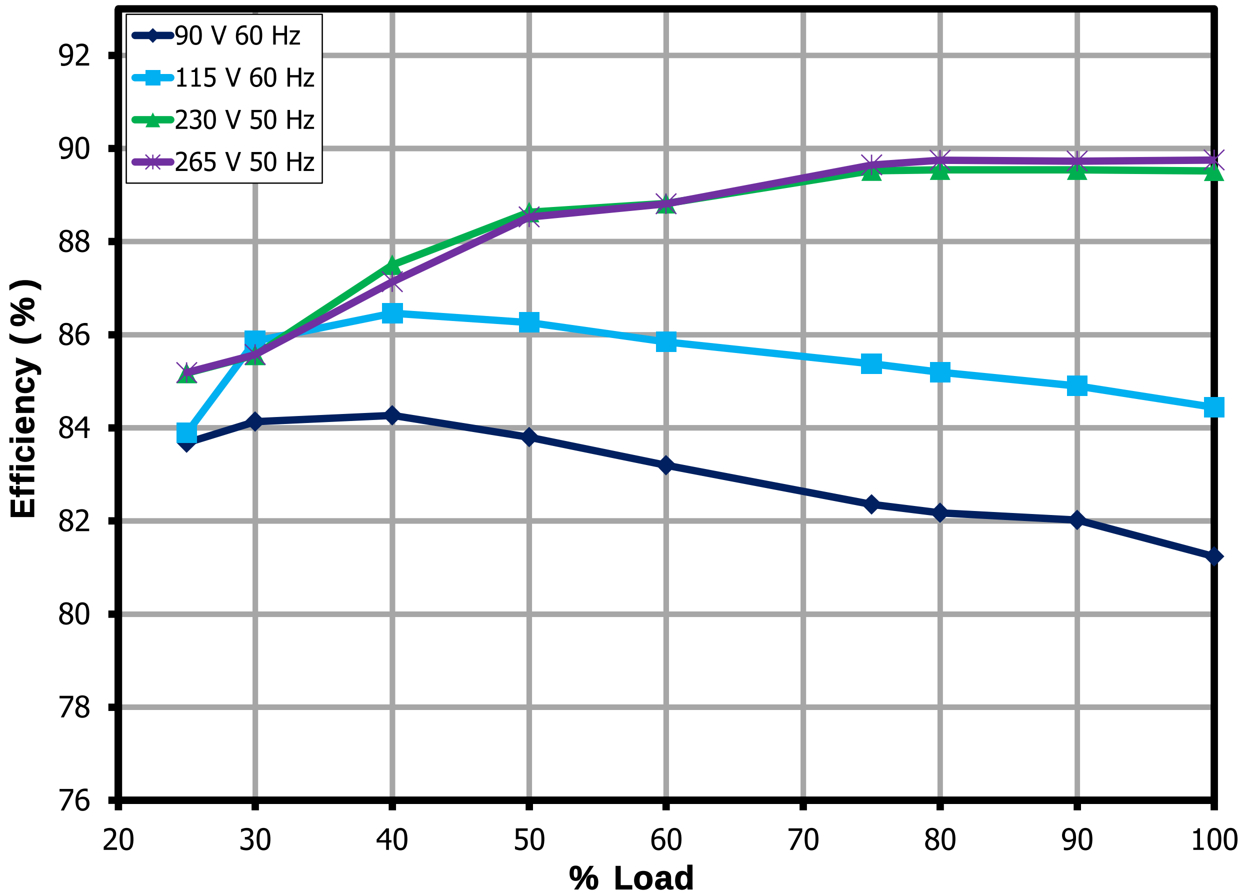

Figure 17 – Efficiency vs Load.

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11.3 Average Efficiency

11.3.1 Average Efficiency Measurement

% Load	Efficiency (%)	
	115 V / 60 Hz	230V / 50 Hz
100	84.44	89.52
75	85.38	89.52
50	86.26	88.63
25	83.89	85.18
AVERAGE EFFICIENCY	**84.99**	**88.21**
DOE LEVEL VI Limit	**82.96 %**	

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

11.4 Power Factor vs. Load

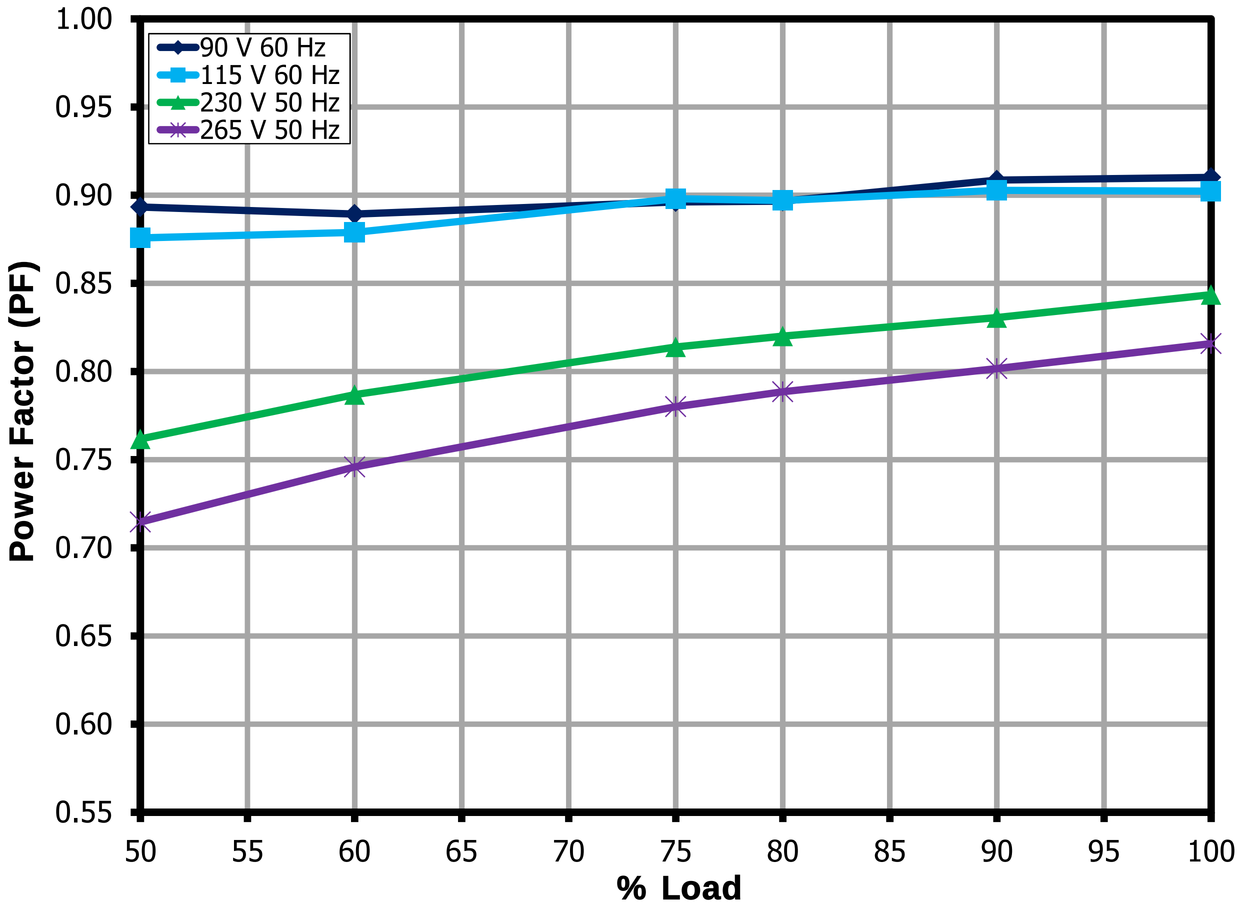

Figure 18 – Power Factor vs Load.

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11.5 %ATHD vs. Load

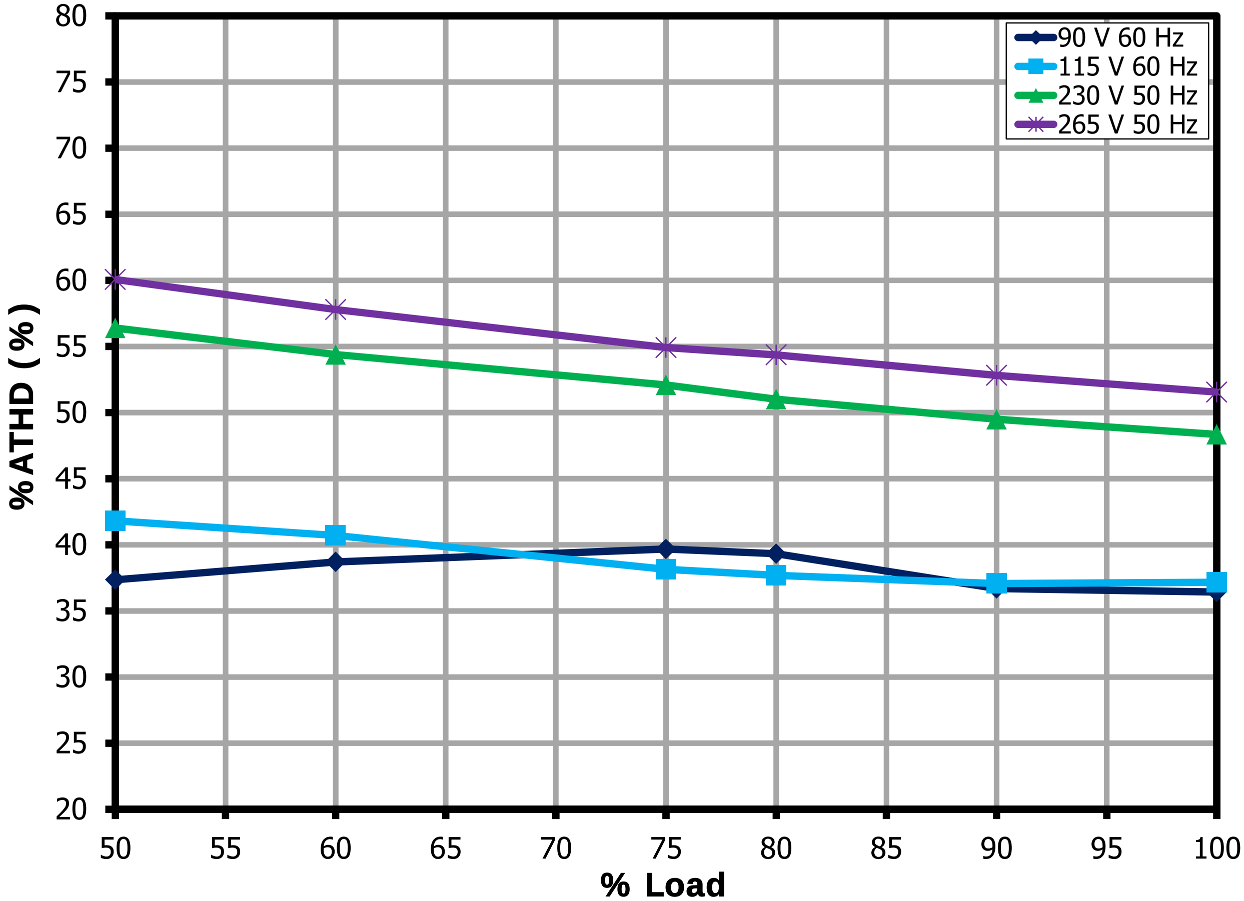

Figure 19 – %ATHD vs Load.

12 Thermal Performance

12.1 Thermal Scan at 25 °C Ambient

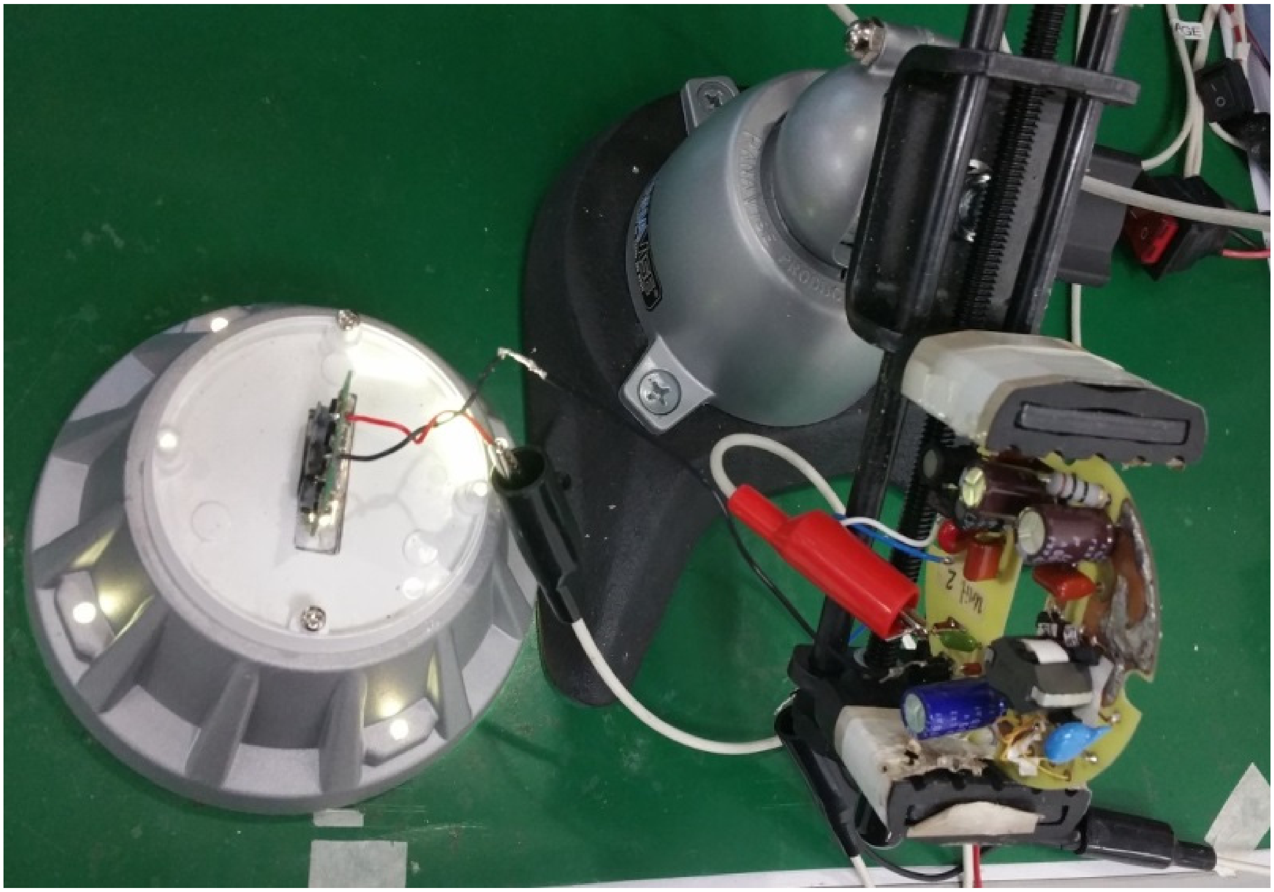

Figure 20 – Test Set-up Picture - Open Frame

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.

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12.1.1 Thermal Scan at 90 VAC Full Load

Figure 21 – 90 VAC 60 Hz, Full Load.
InnoSwitch-CH (U1): 49.7 ºC.

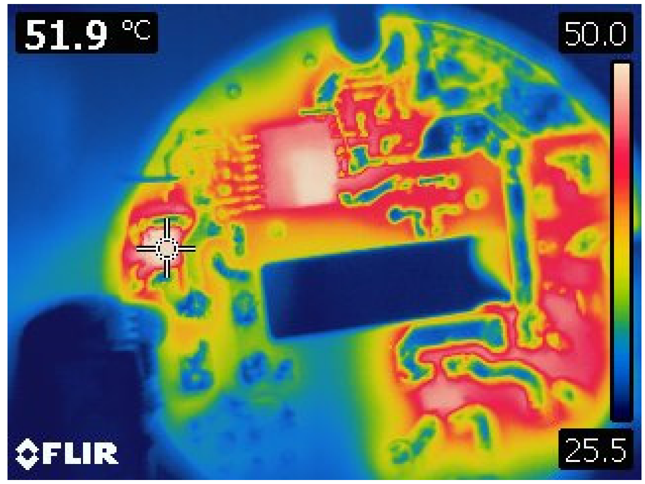

Figure 22 – 90 VAC 60 Hz, Full Load.
Output Diode (D7): 51.9 ºC.

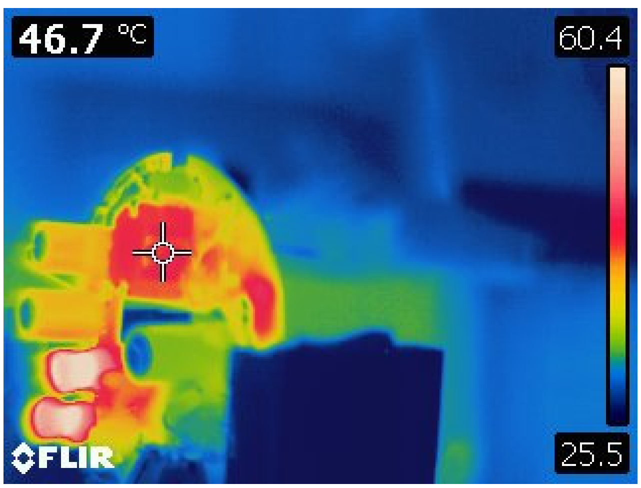

Figure 23 – 90 VAC 60 Hz, Full Load.
Power Transformer (T1): 46.7 ºC.

Figure 24 – 90 VAC 60 Hz, Full Load.
Inductor (L2): 63.1 ºC.

12.1.2 Thermal Scan at 115 VAC Full Load

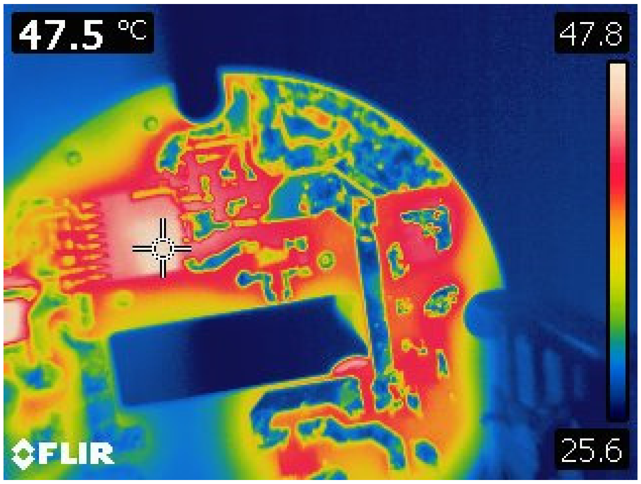

Figure 25 – 115 VAC 60 Hz, Full Load.
InnoSwitch-CH (U1): 47.5 ºC

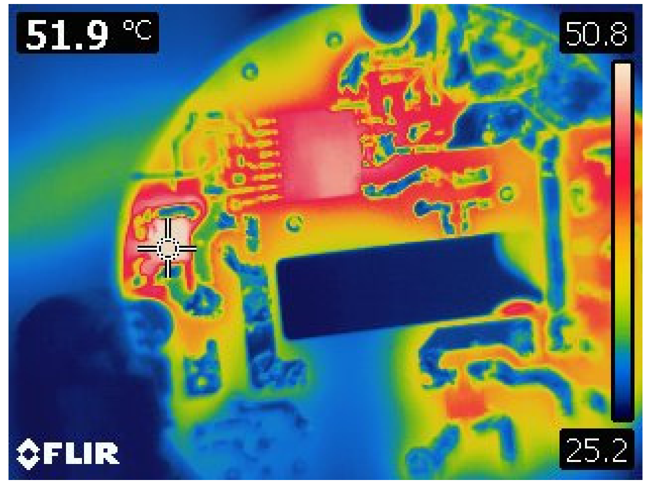

Figure 26 – 115 VAC 60 Hz, Full Load.
Output Diode (D7): 51.9 ºC.

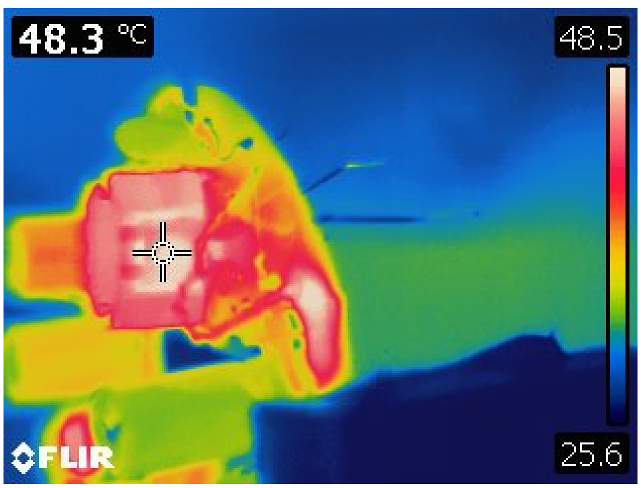

Figure 27 – 115 VAC 60 Hz, Full Load.
Power Transformer (T1): 48.3 ºC.

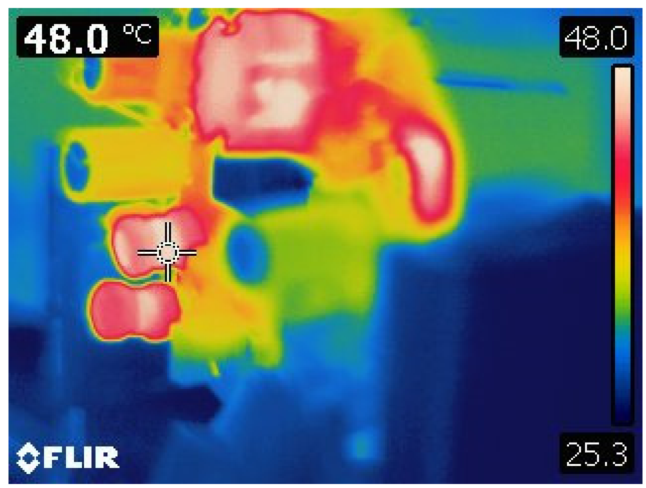

Figure 28 – 115 VAC 60 Hz, Full Load.
Inductor (L2): 48 ºC.

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12.1.3 Thermal Scan at 230 VAC Full Load

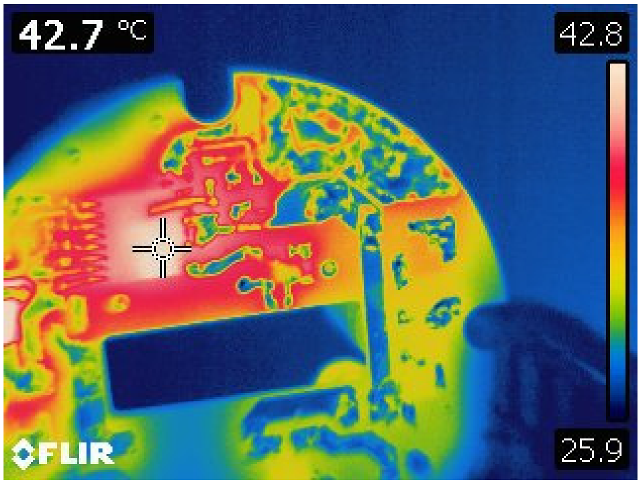

Figure 29 – 230 VAC 50 Hz, Full Load.
InnoSwitch-CH (U1): 42.7 ºC.

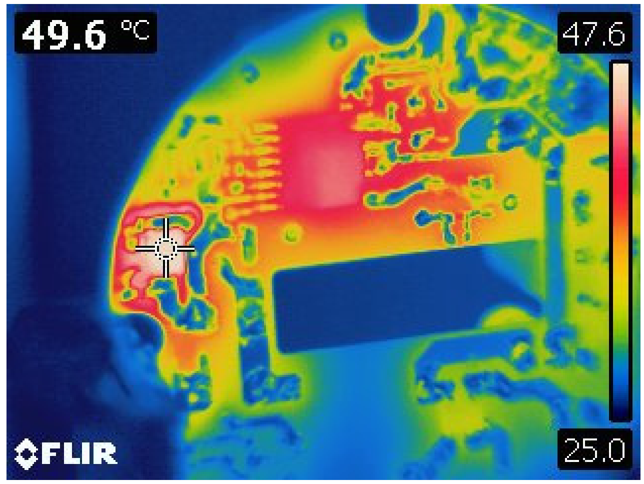

Figure 30 – 230 VAC 50 Hz, Full Load.
Output Diode (D7): 49.6 ºC.

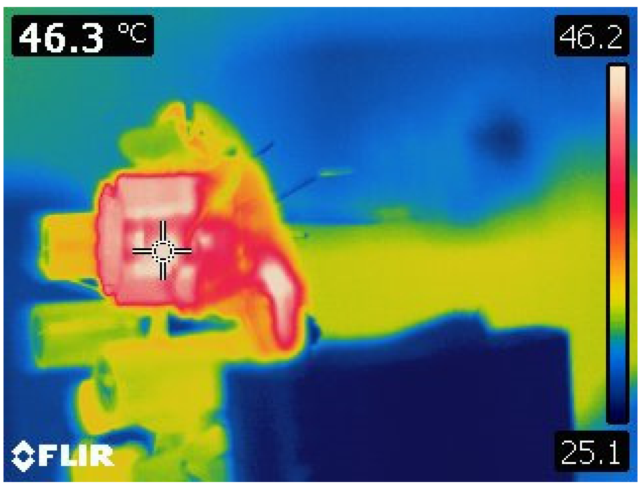

Figure 31 – 230 VAC 50 Hz, Full Load.
Power Transformer (T1): 46.3 ºC.

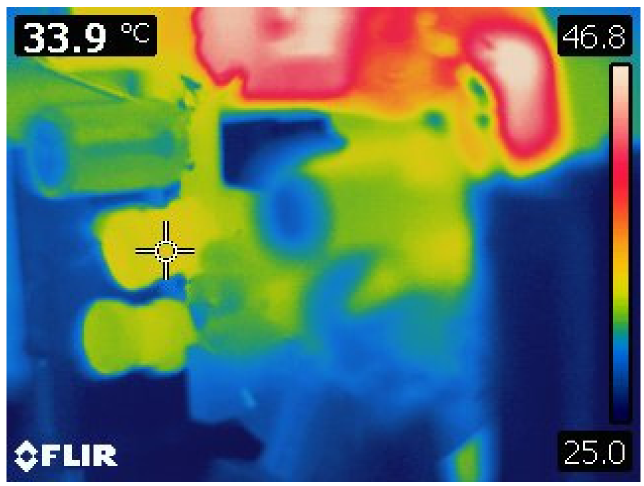

Figure 32 – 230 VAC 50 Hz, Full Load.
Inductor (L2): 33.9 ºC.

12.1.4 Thermal Scan at 265 VAC Full Load

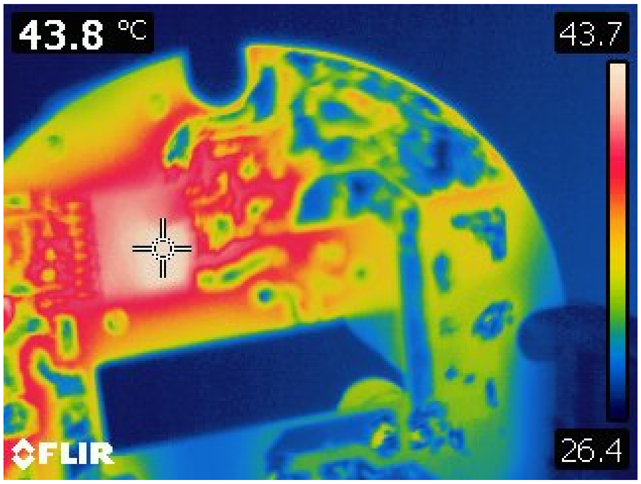

Figure 33 – 265 VAC 50 Hz, Full Load.
InnoSwitch-CH (U1): 43.8 ºC.

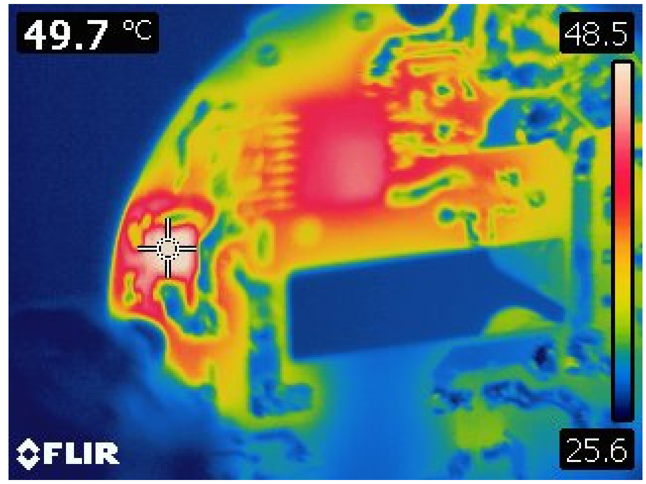

Figure 34 – 265 VAC 50 Hz, Full Load.
Output Diode (D7): 49.7 ºC.

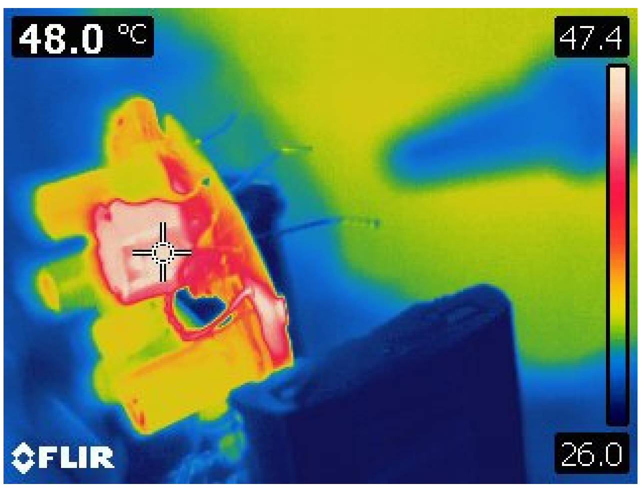

Figure 35 – 265 VAC 50 Hz, Full Load.
Power Transformer (T1): 48 ºC.

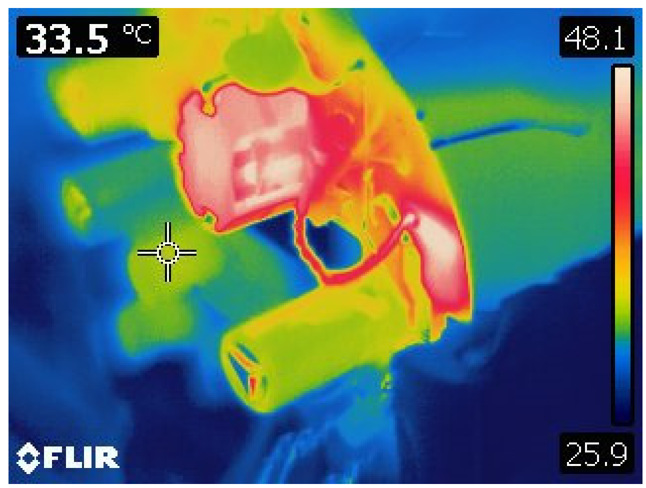

Figure 36 – 265 VAC 50 Hz, Full Load.
Inductor (L2): 33.5 ºC.

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12.2 Thermal Test at 75 ^{0}C Ambient

Set-up:
Unit: DER-612 open frame
Test Chamber: Tenney
Ambient Temperature: 75 ^{o}C (inside enclosure)
Data Logger: Yokogawa
Thermocouple: Type T

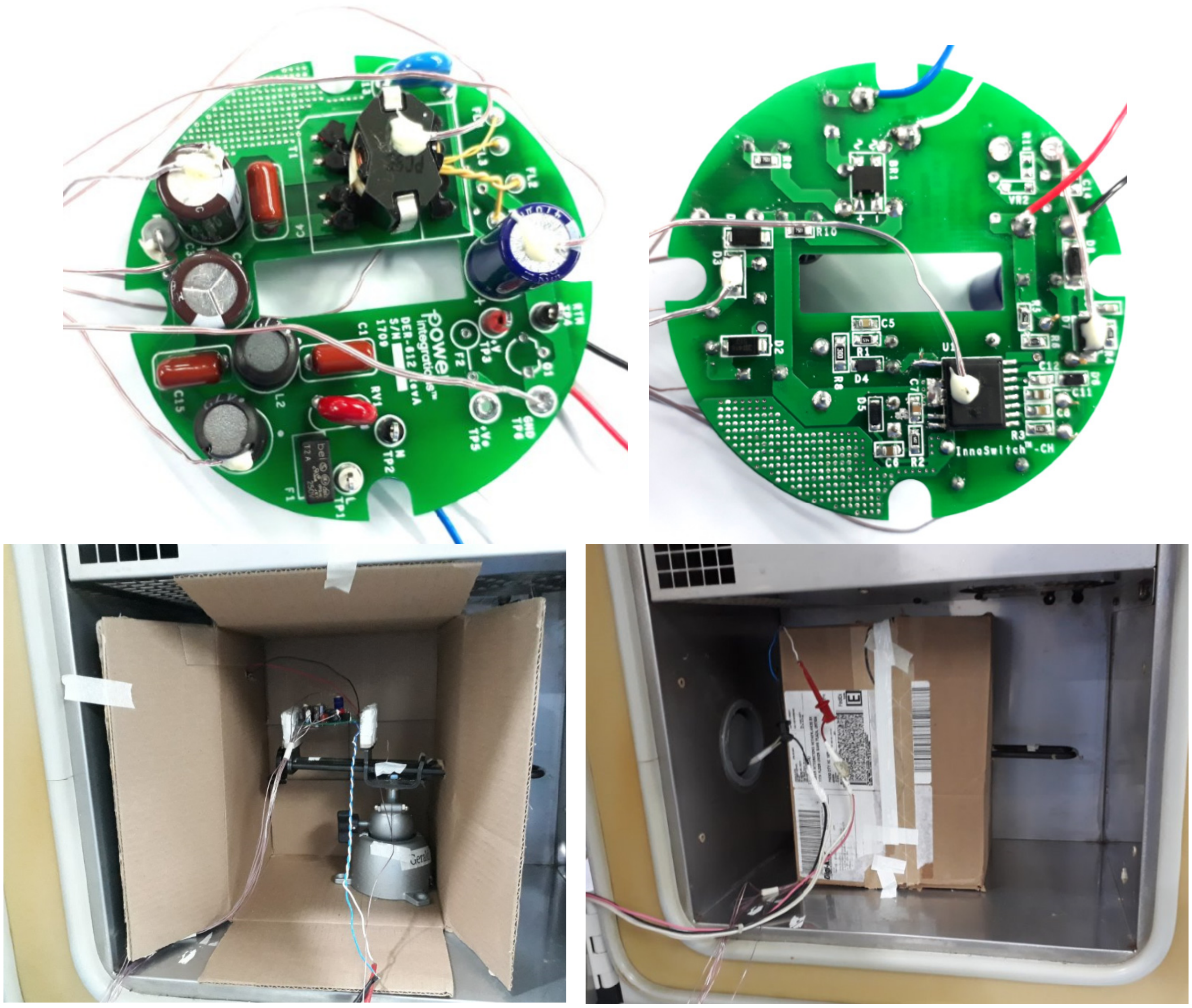

Figure 37 – Test Set-up Pictures. Unit is placed inside an enclosure to prevent the effect of airflow.

12.3 Thermal Test Data at 75 ºC Ambient

Item	Description	Thermal Data (ºC)			
		90 V	115 V	230 V	265 V
1	Ambient	75.7	76.3	75.3	75.4
2	U1 - InnoSwitch-CH	107	105.2	95	95.2
3	C3 - BulK Capacitor	89.4	90.5	82.8	81.9
4	T1 - Transformer	99.7	99.9	96.5	95.9
5	L1 - Differential Choke	120	105.8	84	82.8
6	R7 - Current Limiting Resistor	96.4	100.9	85.8	84.7
7	D7 - Output Diode	101.1	101.2	97.9	97.6
8	C10 - Output Capacitor	86.2	86.4	84.3	84.4
9	D3 - Charging Diode	93.2	93	82.8	82.1

12.4 Electrical Test Data at 75 ºC Ambient

Input		Input Measurement					Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	% ATHD	V_{OUT} (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	
90	60	89.90	0.18	14.96	0.929	31.22	30.13	0.40	12.03	80.42
100	60	99.86	0.17	15.05	0.904	34.72	30.43	0.40	12.15	80.74
115	60	114.89	0.14	14.78	0.902	37.10	30.54	0.40	12.20	82.56
120	60	119.87	0.14	14.63	0.900	38.06	30.54	0.40	12.20	83.36
132	60	131.88	0.12	14.39	0.897	38.56	30.56	0.40	12.20	84.79
185	50	184.89	0.09	13.89	0.883	43.37	30.56	0.40	12.20	87.84
200	50	199.91	0.08	13.82	0.871	45.17	30.57	0.40	12.21	88.32
230	50	229.92	0.07	13.73	0.849	47.97	30.59	0.40	12.21	88.91
240	50	239.96	0.07	13.71	0.840	48.82	30.59	0.40	12.21	89.07
265	50	264.94	0.06	13.70	0.820	51.40	30.59	0.40	12.22	89.21

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13 Waveforms

Waveforms were taken at room temperature (25 ºC)

13.1 Input Voltage and Input Current at Full Load

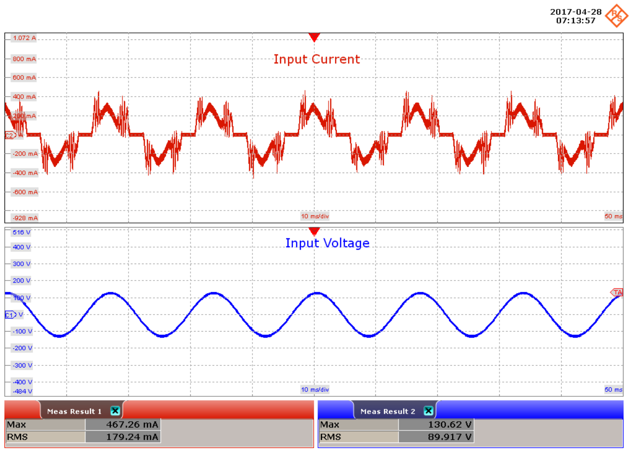

Figure 38 –90 VAC 60 Hz, Full Load.
Upper: I_{IN}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

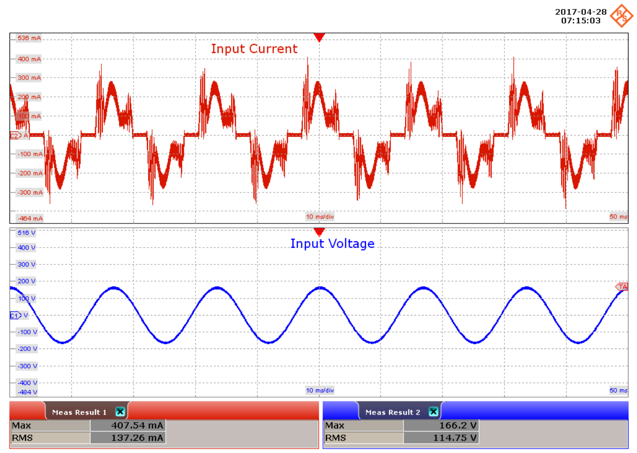

Figure 39 – 115 VAC 60 Hz, Full Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

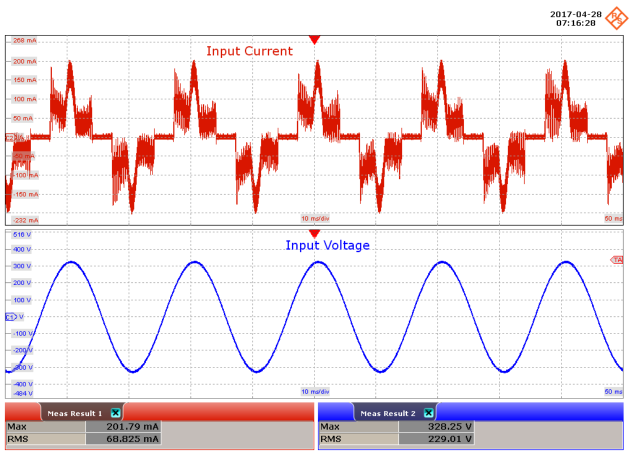

Figure 40 – 230 VAC 50 Hz, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

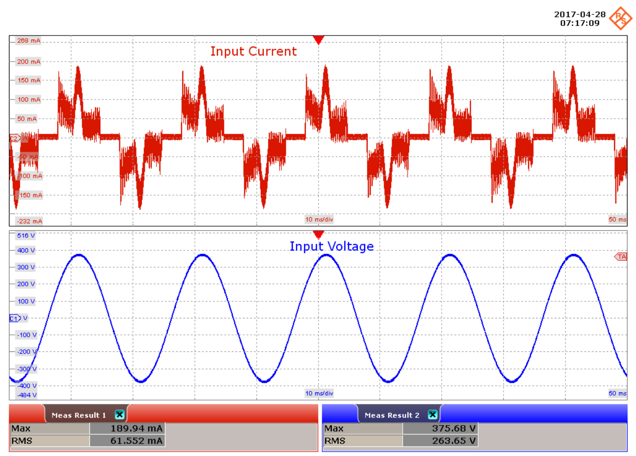

Figure 41 – 265 VAC 50 Hz, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

13.2 Start-up Profile at Full Load

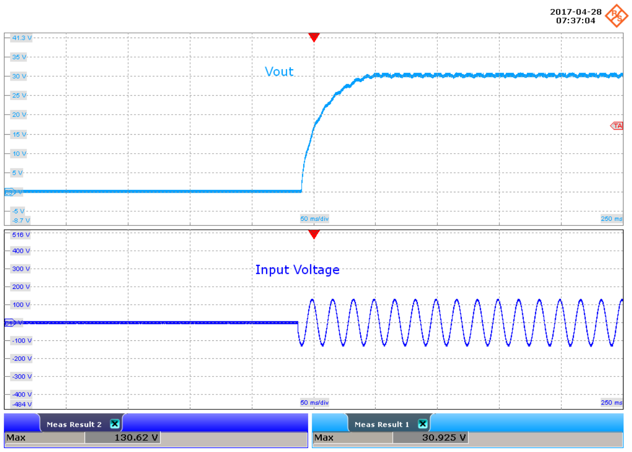

Figure 42 – 90 VAC 60 Hz, Full Load Start-up.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Turn-on Time: 46 ms.

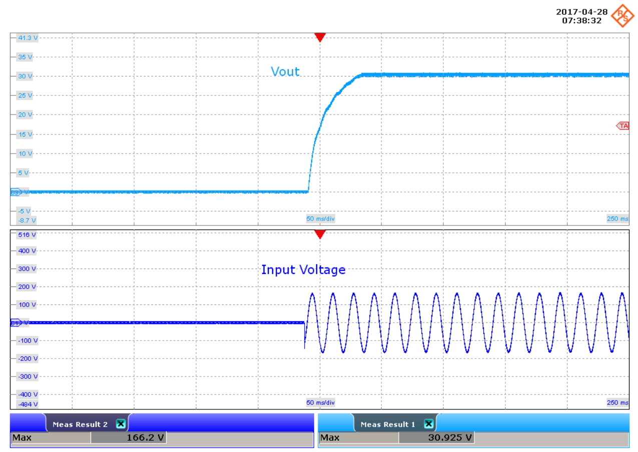

Figure 43 – 115 VAC 60 Hz, Full Load Start-up.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Turn-on Time: 40 ms.

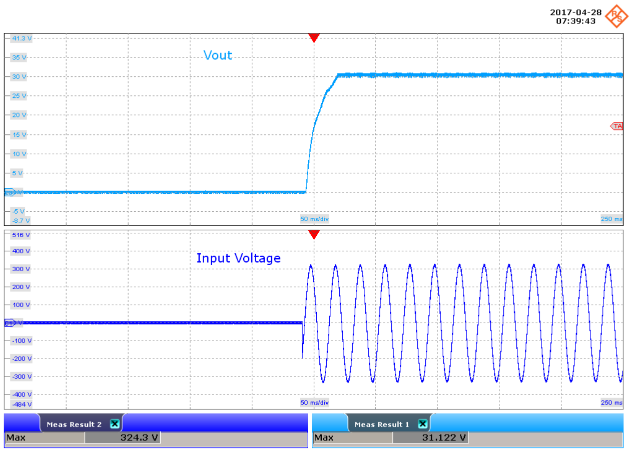

Figure 44 – 230 VAC 50 Hz, Full Load Start-up.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Turn-on Time: 26 ms.

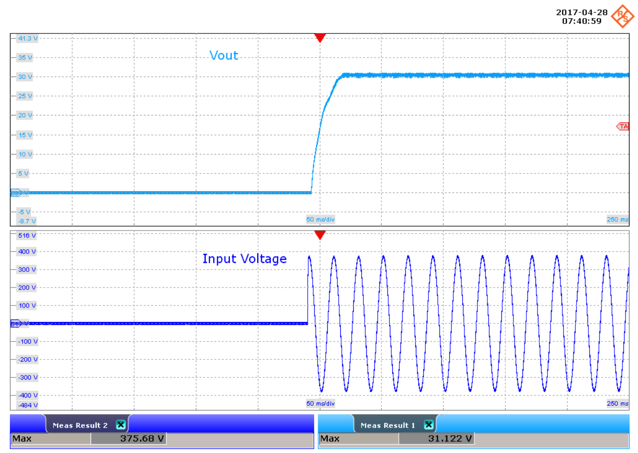

Figure 45 – 265 VAC 50 Hz, Full Load Start-up.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Turn-on Time: 25 ms

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13.3 Output Voltage Fall

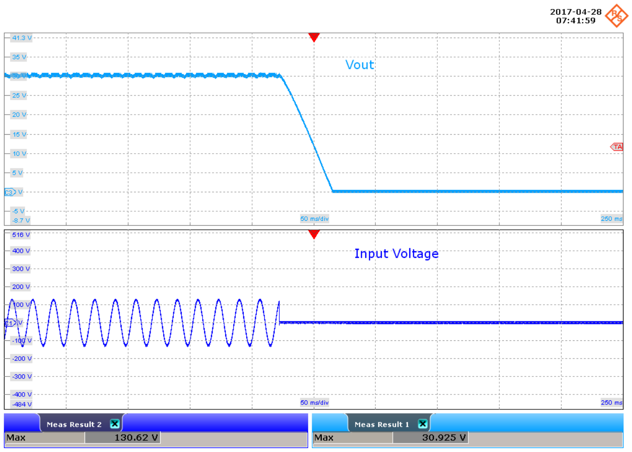

Figure 46 – 90 VAC 60 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.

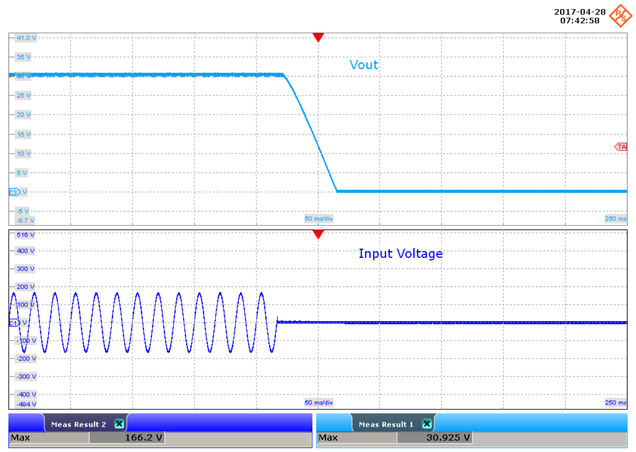

Figure 47 – 115 VAC 60 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.

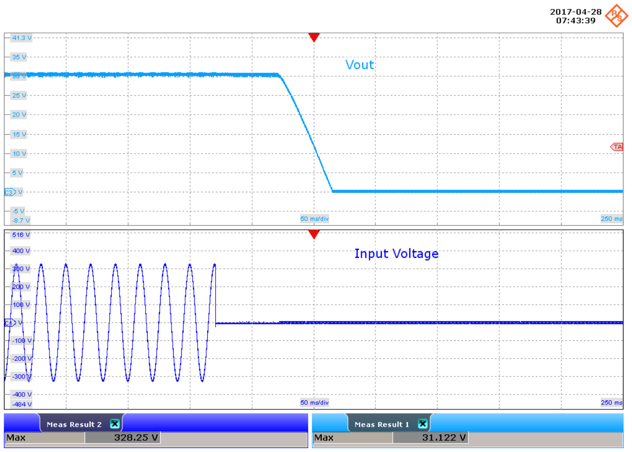

Figure 48 – 230 VAC 50 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold-up Time: 53 ms.

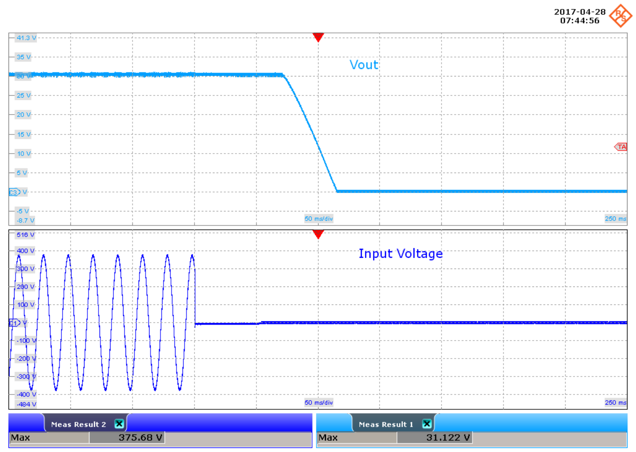

Figure 49 – 265 VAC 50 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold-up Time: 74 ms.

13.4 Power Cycling

No high-voltage overshoots during ac power cycling

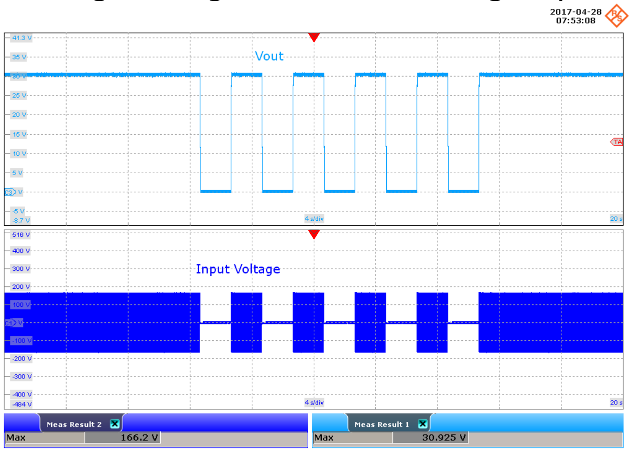

Figure 50 – 115 VAC 60 Hz, Full Load.
2 s Off, 2 sec On.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 4 s / div.

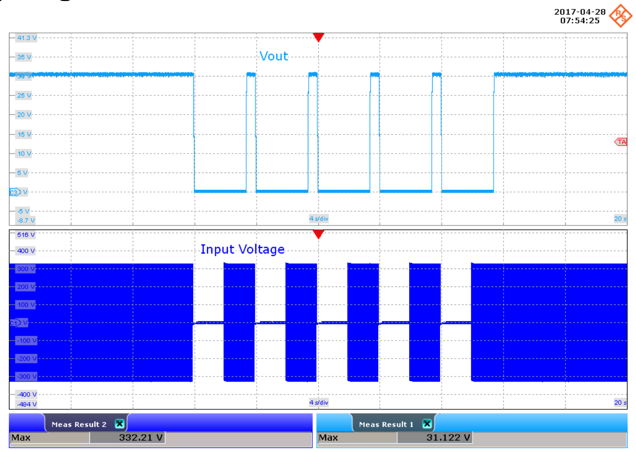

Figure 51 – 230 VAC 50 Hz, Full Load.
2 s Off, 2 sec On.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 4 s / div.

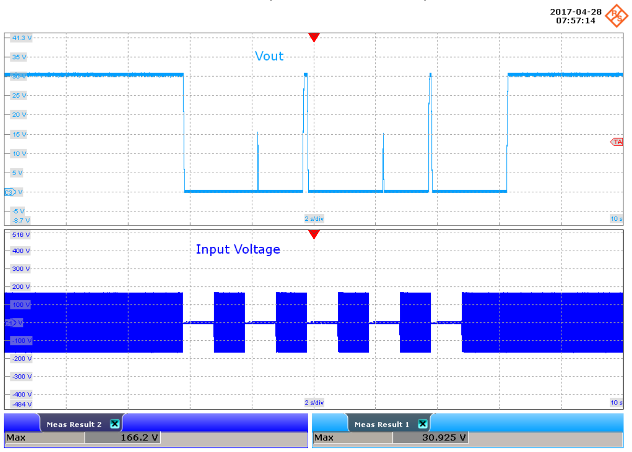

Figure 52 – 115 VAC 60 Hz, Full Load.
1 s Off, 1 sec On.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 1 s / div.

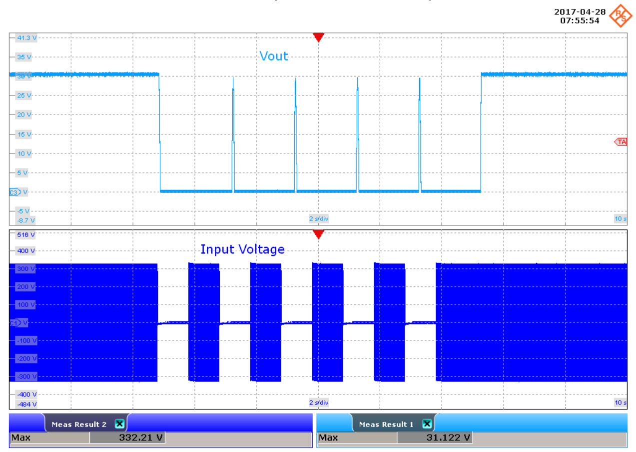

Figure 53 – 230 VAC 50 Hz, Full Load.
1 s Off, 1 sec On.
Upper: V_{OUT}, 5 V / div.
Lower: V_{IN}, 100 V / div., 2 s / div.

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13.5 Load Transient Response 3 Hz

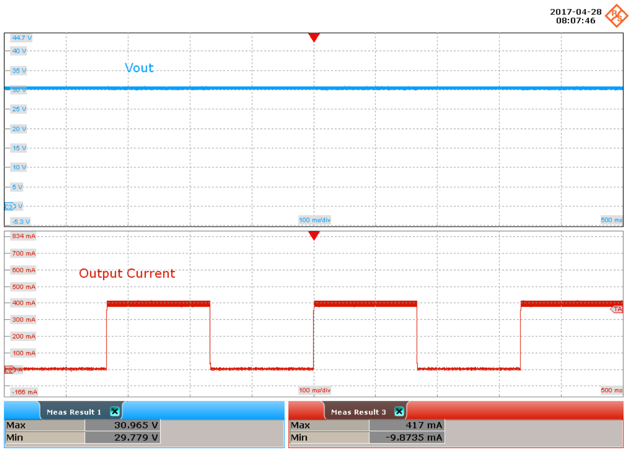

Figure 54 – 115 VAC 60 Hz.
0% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µS.
Upper: V_{OUT}, 5 V / div., 100 ms / div.
Lower: I_{OUT}, 100 mA / div.

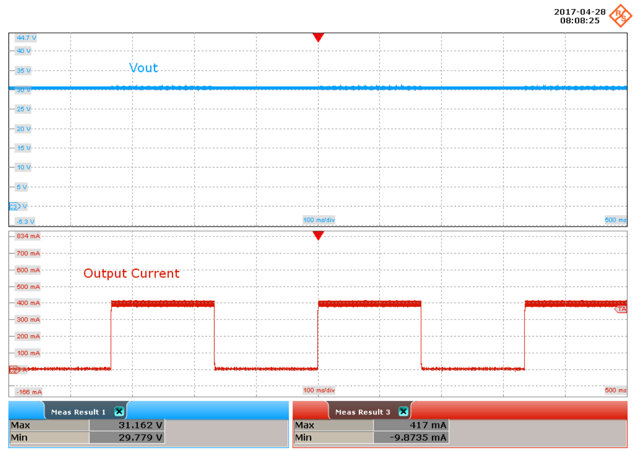

Figure 55 – 230 VAC 50 Hz.
0% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µS.
Upper: V_{OUT}, 5 V / div., 100 ms / div.
Lower: I_{out}, 100 mA / div.

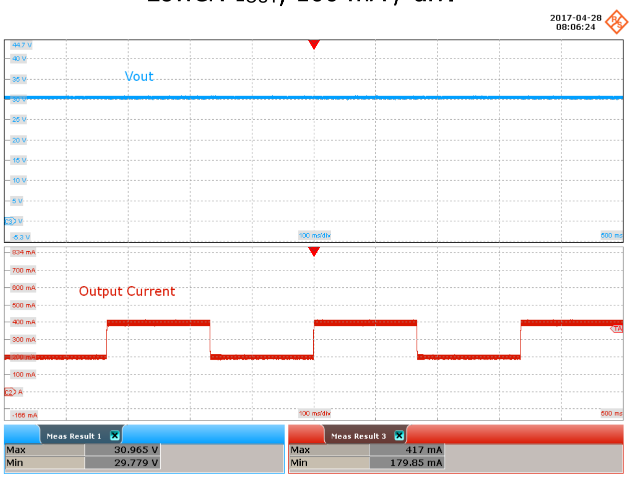

Figure 56 – 115 VAC 60 Hz.
50% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µS.
Upper: V_{OUT}, 5 V / div., 100 ms / div.
Lower: I_{OUT}, 100 mA / div.

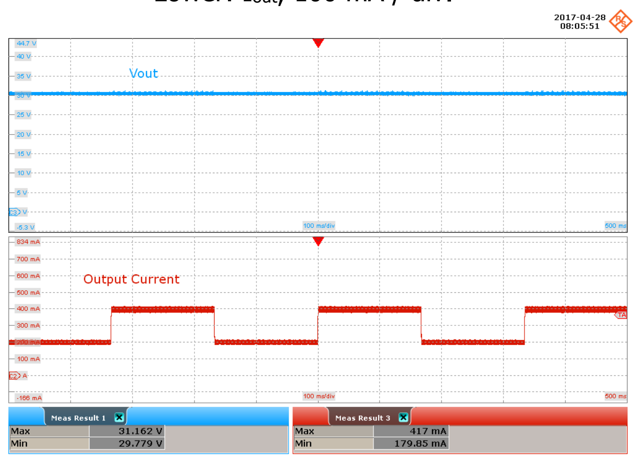

Figure 57 – 230 VAC 50 Hz.
50% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µS.
Upper: V_{OUT}, 5 V / div., 100 ms / div.
Lower: I_{OUT}, 100 mA / div.

13.6 Load Transient Response 100 Hz

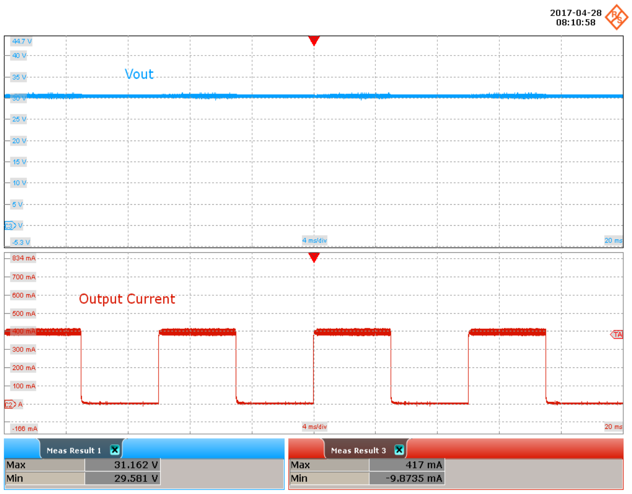

Figure 58 – 115 VAC 60 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µS.
Upper: V_{OUT}, 5 V / div., 4 ms / div.
Lower: I_{OUT}, 100 mA / div.

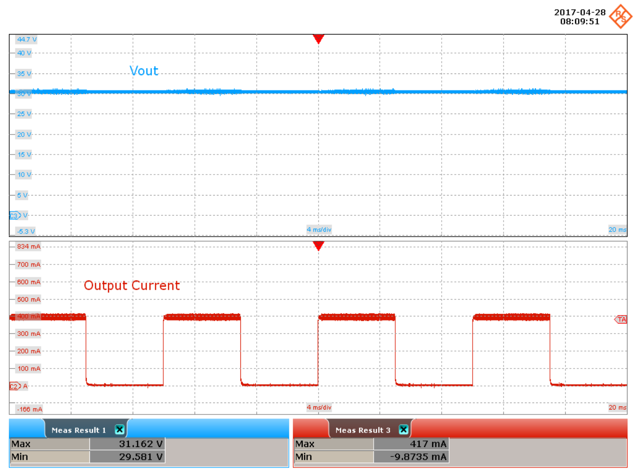

Figure 59 – 230 VAC 50 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µS.
Upper: V_{OUT}, 5 V / div., 4 ms / div.
Lower: I_{OUT}, 100 mA / div.

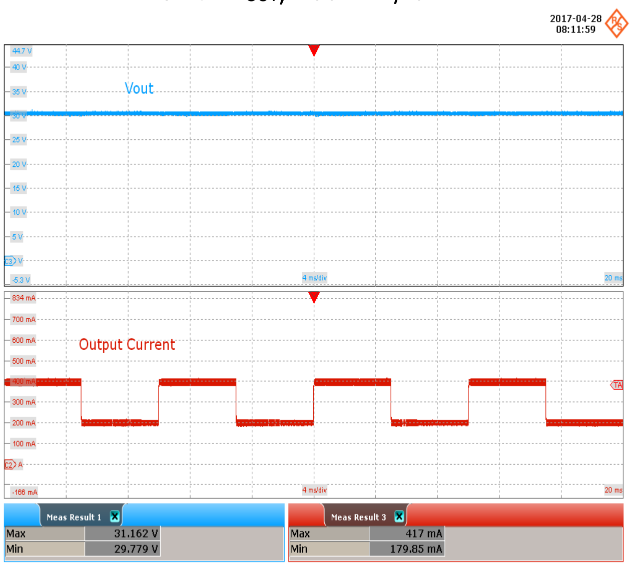

Figure 60 – 115 VAC 60 Hz.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µS.
Upper: V_{OUT}, 5 V / div., 4 ms / div.
Lower: I_{OUT}, 100 mA / div.

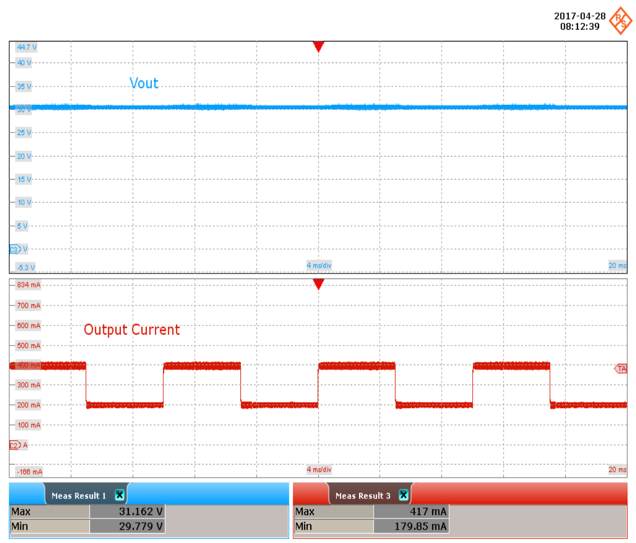

Figure 61 – 230 VAC 50 Hz, Full Load.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µS.
Upper: V_{OUT}, 5 V / div., 4 ms / div.
Lower: I_{OUT}, 100 mA / div.

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13.7 InnoSwitch-CH Drain Voltage and Current Waveforms

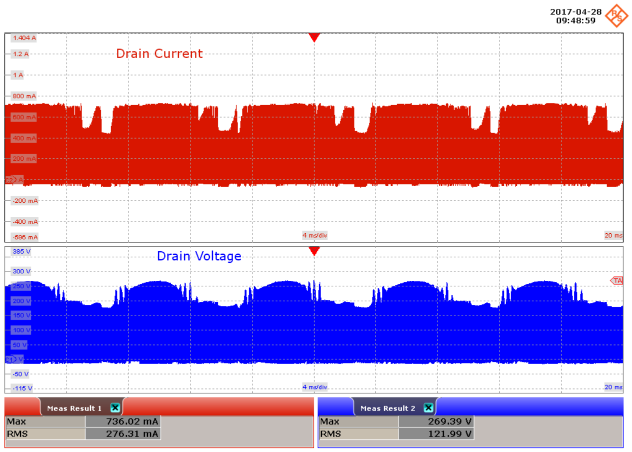

Figure 62 – 90 VAC 60 Hz, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 ms / div.

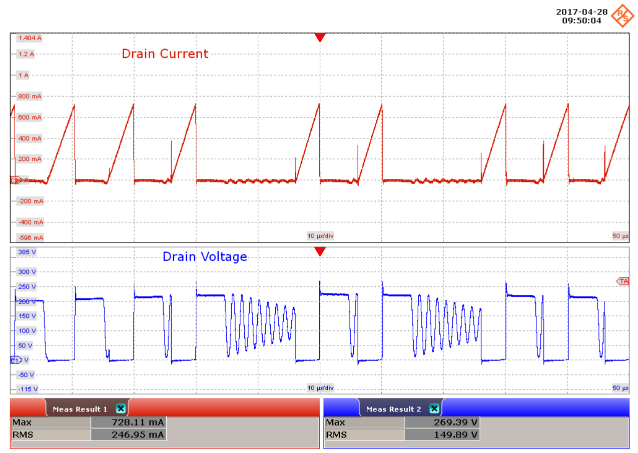

Figure 63 – 90 VAC 60 Hz, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 10 μs / div.

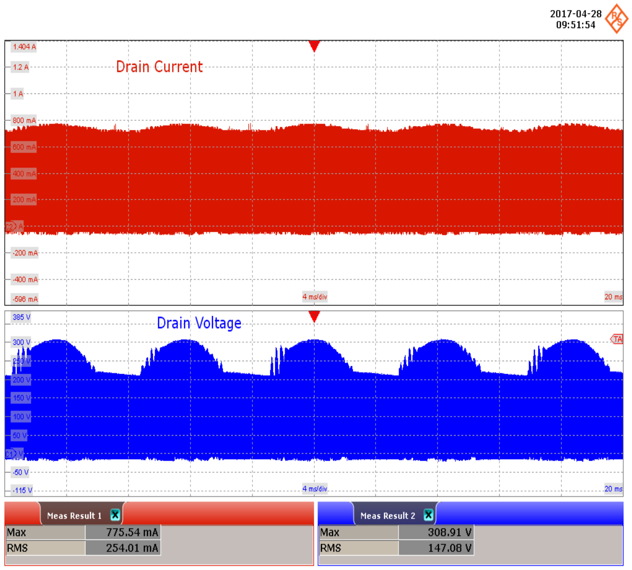

Figure 64 – 115 VAC 60 Hz, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 ms / div.

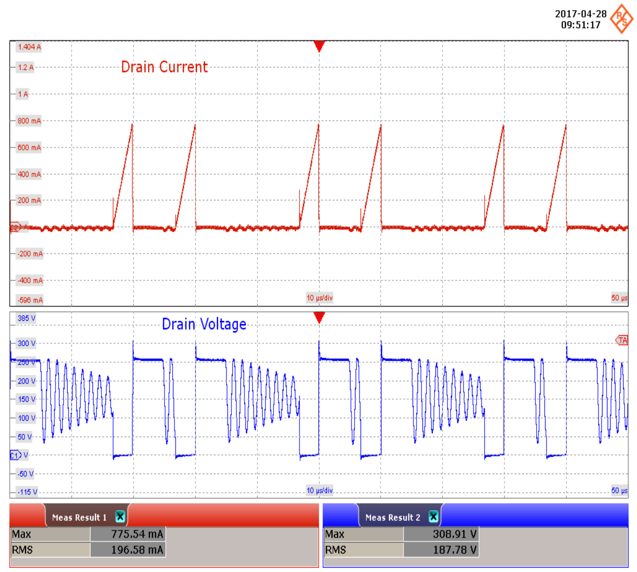

Figure 65 – 115 VAC 60 Hz, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 10 μs / div.

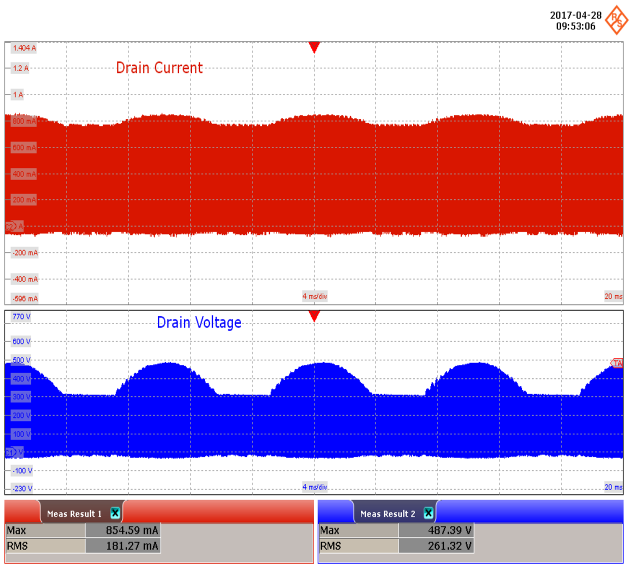

Figure 66 – 230 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

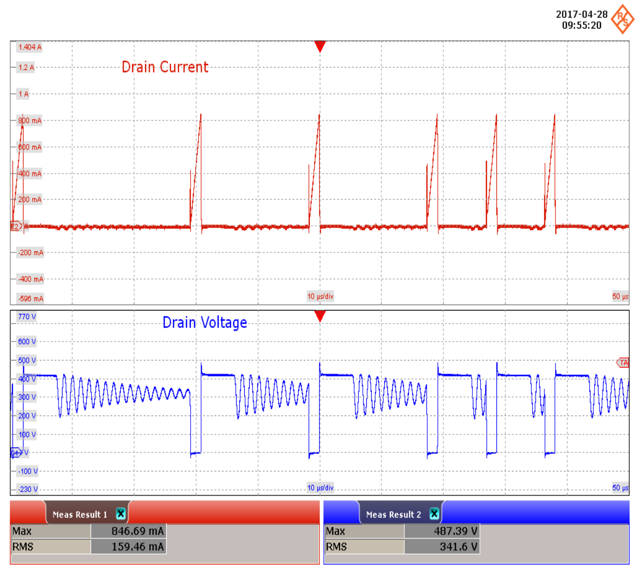

Figure 67 – 230 VAC 50 Hz, Full Load Normal
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.

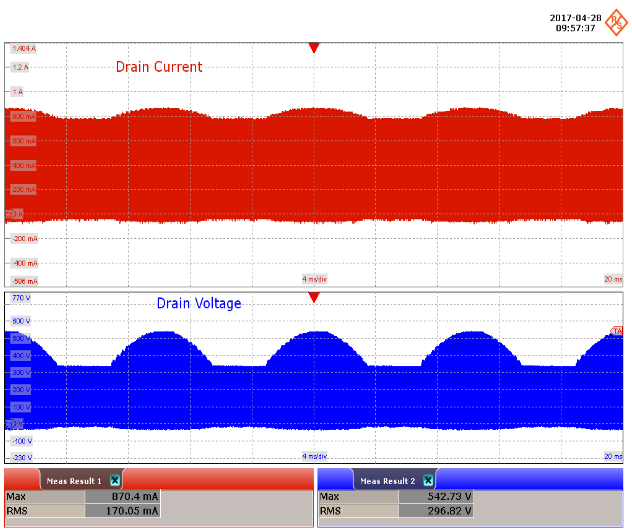

Figure 68 – 265 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

Figure 69 – 265 VAC, Full Load Normal.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.

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13.8 InnoSwitch-CH Drain Voltage and Current at Full Start-up

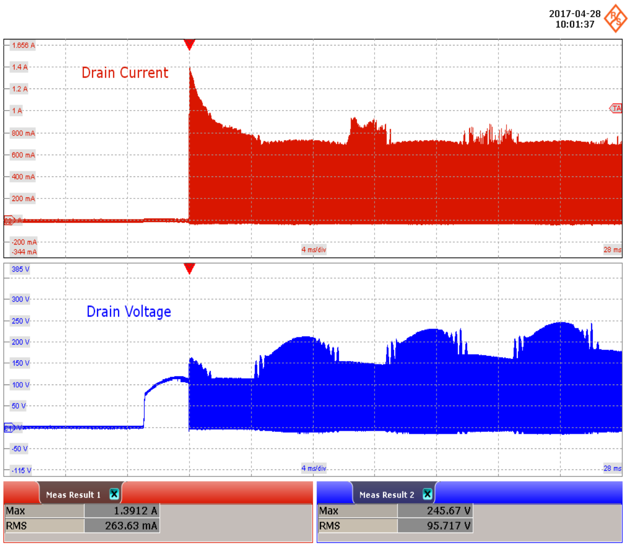

Figure 70 – 90 VAC 60 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 ms / div.

Figure 71 – 90 VAC 60 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 5 µs / div.

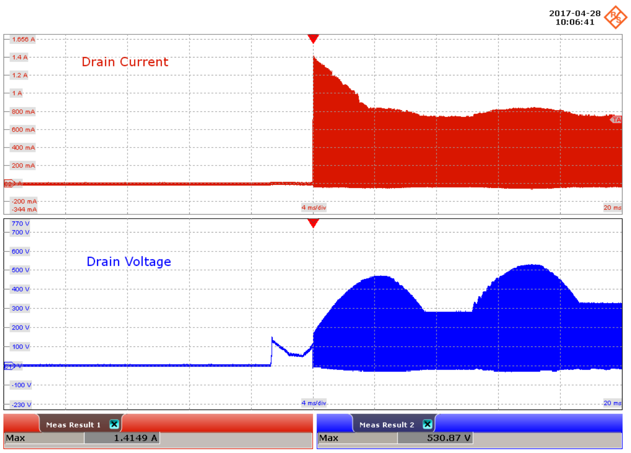

Figure 72 – 265 VAC, Full Load Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

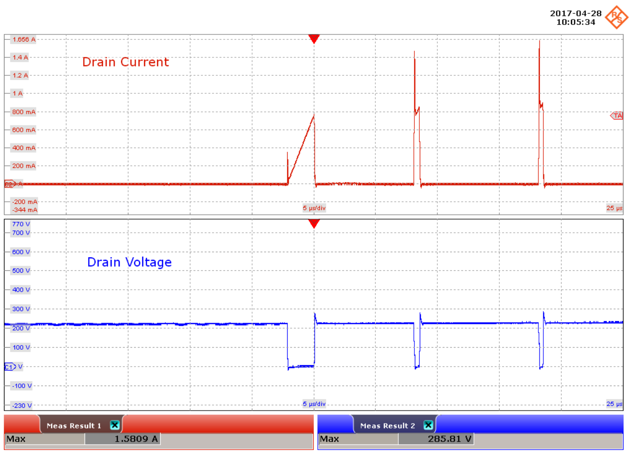

Figure 73 – 265 VAC, Full Load Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 µs /div.

13.9 InnoSwitch-CH Drain Voltage and Current During Output Short-Circuit

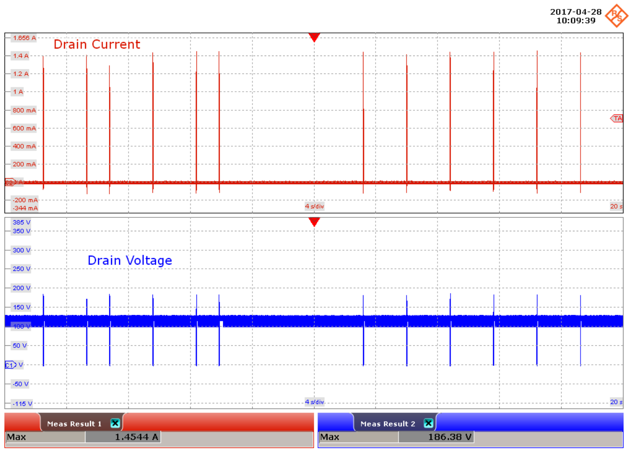

Figure 74 – 90 VAC 60 Hz, Output Shorted.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 4 s /div.

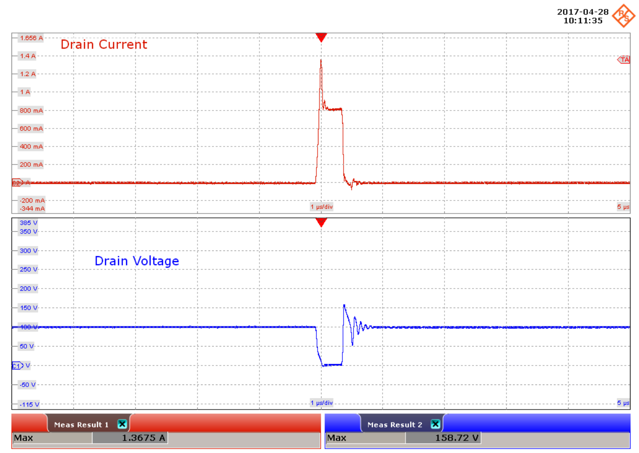

Figure 75 – 90 VAC 60 Hz, Output Shorted.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 50 V / div., 1 μs /div.

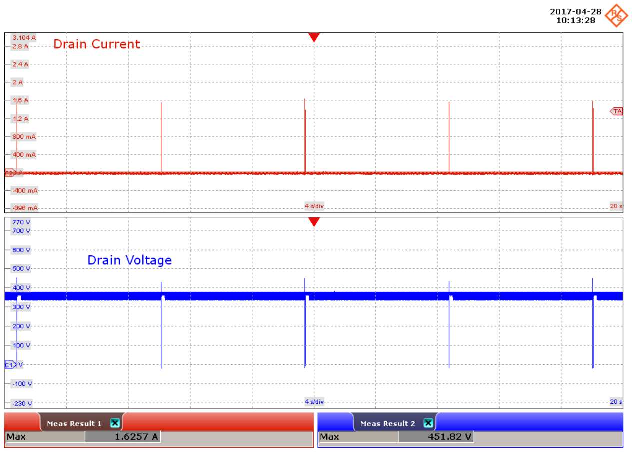

Figure 76 – 265 VAC, Output Shorted.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 s /div.

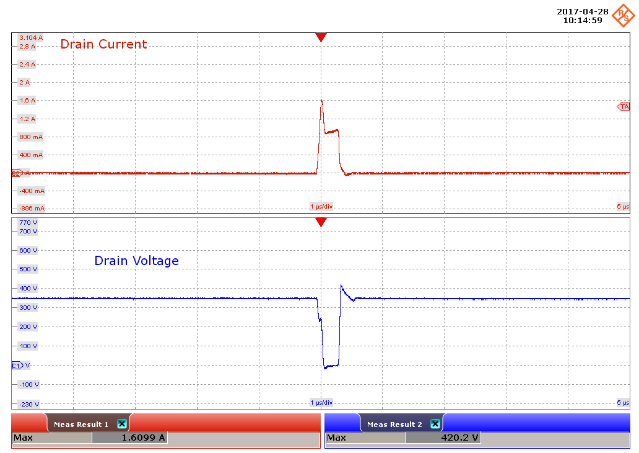

Figure 77 – 265 VAC, Output Shorted.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 μs /div.

13.10 Input Power at Short-Circuit

Input		Input Measurement		
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (mW)
90	60	90.01	4.21	125.40
115	60	114.97	4.13	163.40
132	60	131.95	4.07	189.80
185	50	184.94	3.91	272.50
230	50	229.96	4.10	346.20
265	50	264.97	4.23	404.20

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13.11 Output Ripple Voltage

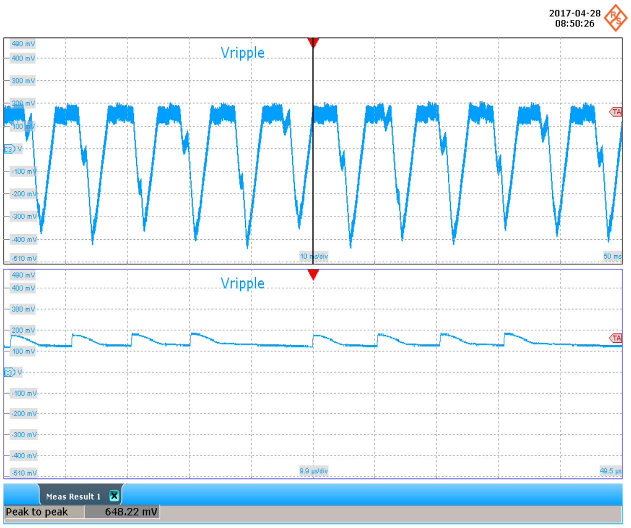

Figure 78 – 90 VAC 60 Hz, Full Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 100 mV / div., 10 ms / div.
Ripple Voltage: 648.2 mV_{P-P}.

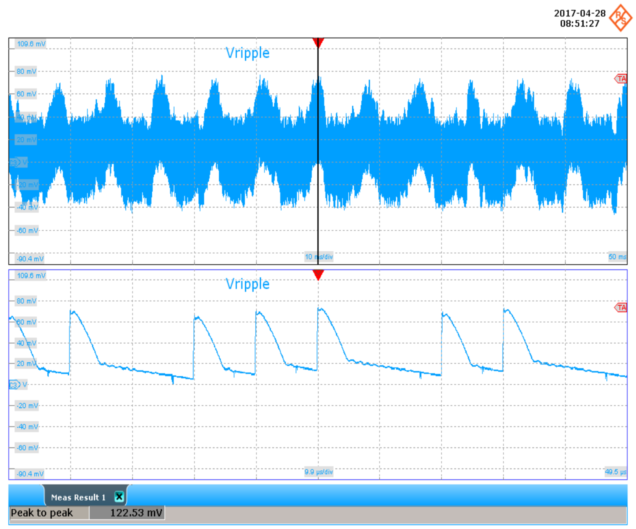

Figure 79 – 115 VAC 60 Hz, Full Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 20 mV / div., 10 ms / div.
Ripple Voltage: 122.53 mV_{P-P}.

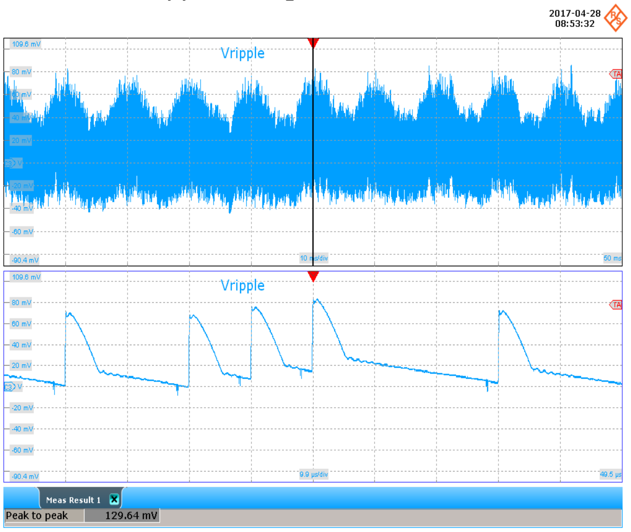

Figure 80 – 230 VAC 50 Hz, Full Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 20 mV / div., 10 ms / div.
Ripple Voltage: 122.53 mV_{P-P}.

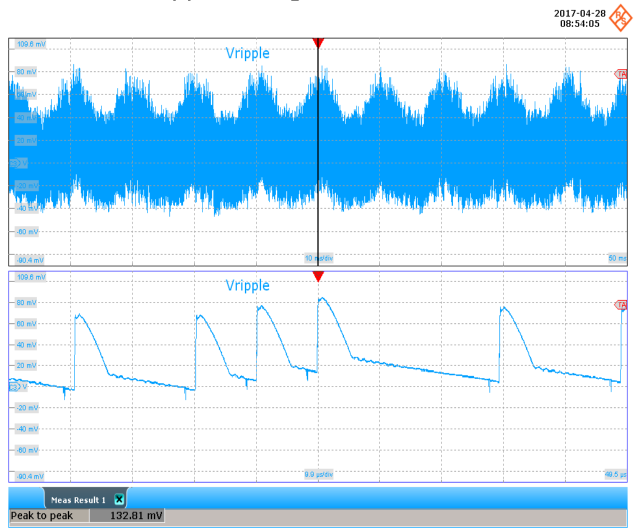

Figure 81 – 265 VAC 50 Hz, Full Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 20 mV / div., 10 ms / div.
Ripple Voltage: 132.8 mV_{P-P}.

14 Conducted EMI

14.1 Test Set-up

Unit is placed on top of load metal chassis.

14.2 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.

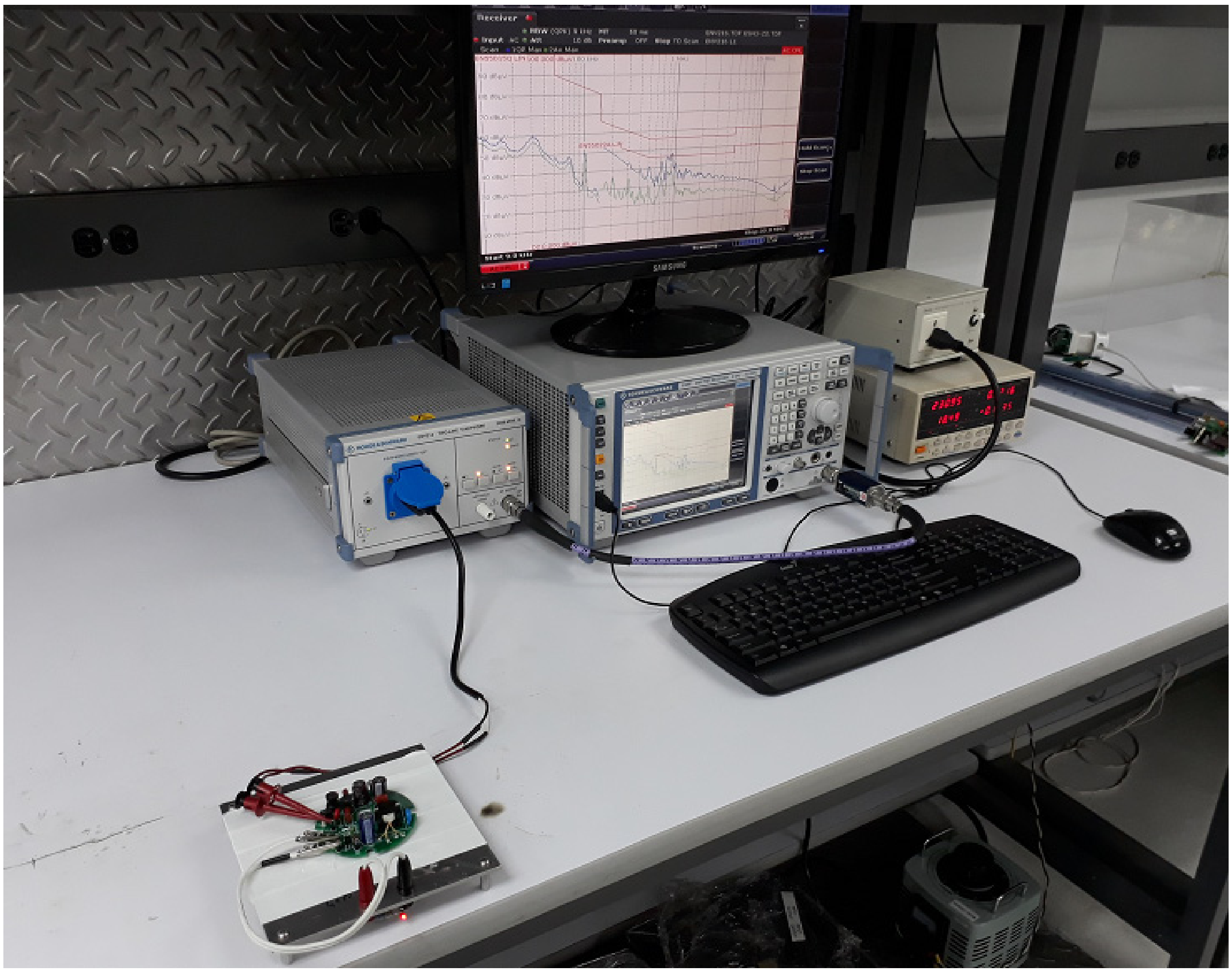

Figure 82 – Conducted EMI Test Set-up.

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14.3 EMI Test Result

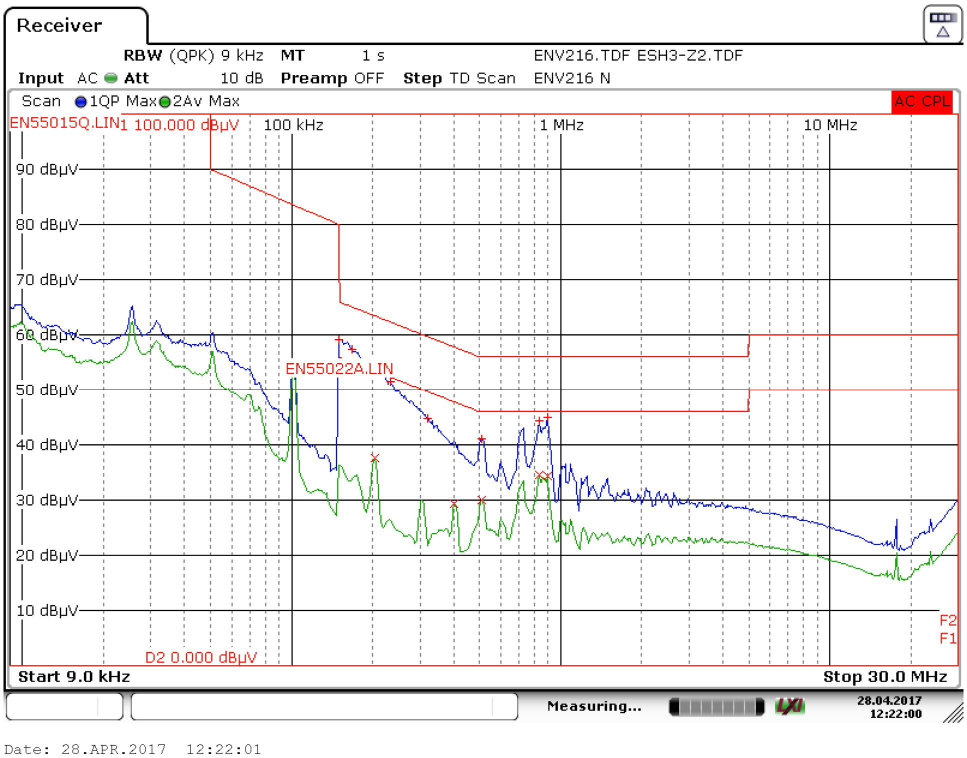

Figure 83 – Conducted EMI QP Scan at Full Load, 115 VAC 60 Hz and EN55015 B Limits.

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	150.0000 kHz	59.23 N	-6.77 dB
1 Quasi Peak	168.0000 kHz	57.37 L1	-7.69 dB
2 Average	204.0000 kHz	37.60 N	-15.85 dB
1 Quasi Peak	233.2500 kHz	51.45 N	-10.88 dB
1 Quasi Peak	321.0000 kHz	44.78 L1	-14.90 dB
2 Average	402.0000 kHz	29.33 L1	-18.48 dB
1 Quasi Peak	507.7500 kHz	41.06 L1	-14.94 dB
2 Average	510.0000 kHz	30.02 N	-15.98 dB
2 Average	831.7500 kHz	34.52 N	-11.48 dB
1 Quasi Peak	834.0000 kHz	44.32 N	-11.68 dB
1 Quasi Peak	892.5000 kHz	45.01 L1	-10.99 dB
2 Average	894.7500 kHz	34.30 L1	-11.70 dB

Figure 84 – Conducted EMI Data at 115 VAC 60 Hz, Full Load.

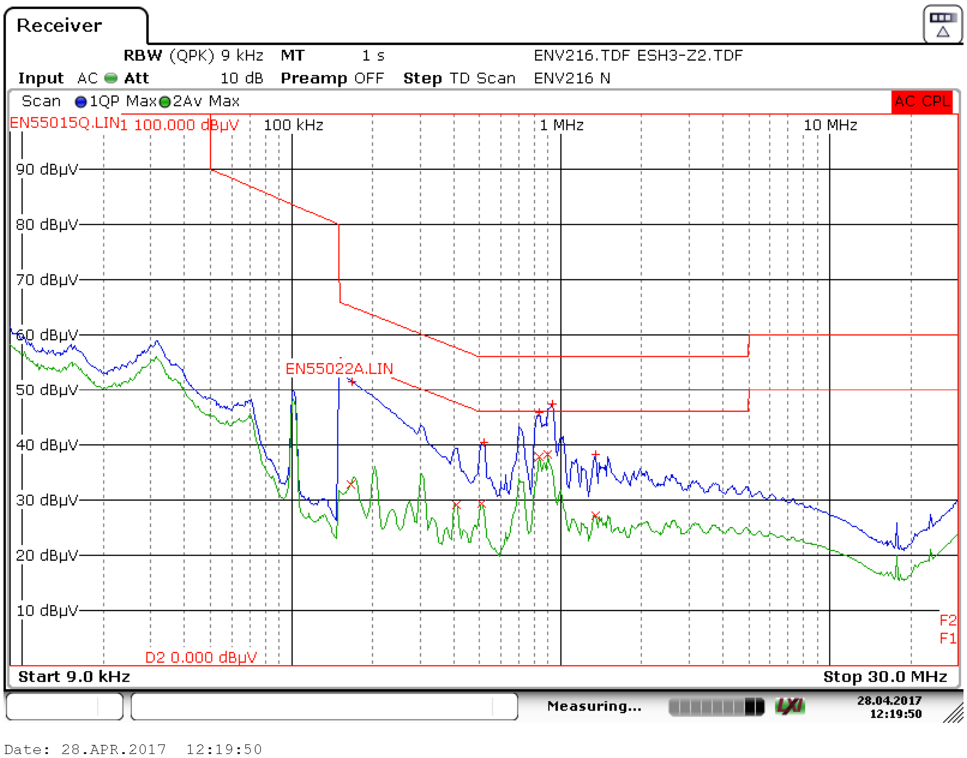

Figure 85 – Conducted EMI QP Scan at Full Load, 230 VAC 60 Hz and EN55015 B Limits.

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	150.0000 kHz	52.96 L1	-13.04 dB
2 Average	165.7500 kHz	32.89 L1	-22.28 dB
1 Quasi Peak	168.0000 kHz	51.58 L1	-13.48 dB
2 Average	408.7500 kHz	29.12 N	-18.55 dB
2 Average	510.0000 kHz	29.30 L1	-16.70 dB
1 Quasi Peak	521.2500 kHz	40.46 N	-15.54 dB
1 Quasi Peak	834.0000 kHz	45.91 L1	-10.09 dB
2 Average	834.0000 kHz	37.74 N	-8.26 dB
2 Average	899.2500 kHz	38.25 N	-7.75 dB
1 Quasi Peak	928.5000 kHz	47.35 N	-8.65 dB
1 Quasi Peak	1.3538 MHz	38.22 L1	-17.78 dB
2 Average	1.3560 MHz	27.15 N	-18.85 dB

Figure 86 – Conducted EMI Data at 230 VAC 60 Hz, Full Load.

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15 Line Surge

The unit was subjected to ±2500 V, 100 kHz ring wave and ±1000 V differential surge using 10 strikes at each condition. A test failure was defined as a non-recoverable interruption of output requiring repair or recycling of input voltage.

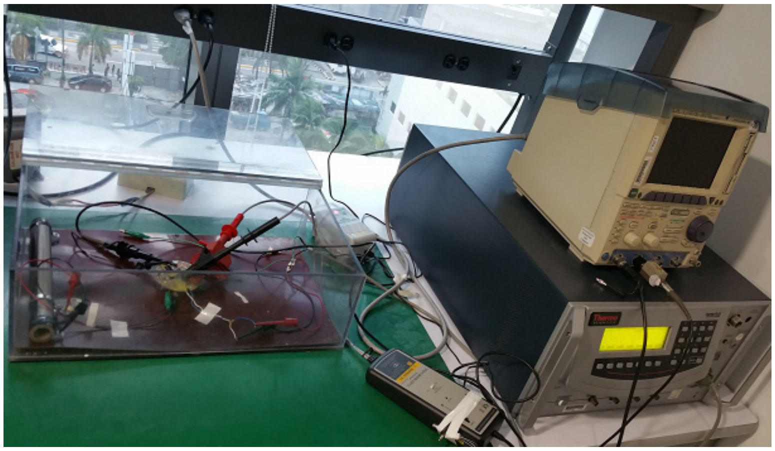

Figure 87 – Surge Set-up.

15.1 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

15.2 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
+2500	230	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

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15.3 Differential Surge (1 KV)

The Drain voltage of InnoSwitch-CH was measured during 1 kV differential surge test.

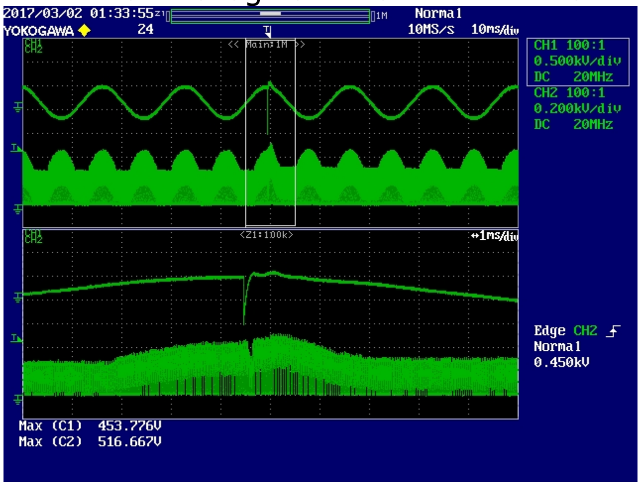

Figure 88 – (-)1 kV Differential Surge.
V_{IN}=230 V, 90º Phase Angle.
Lower: V_{DRAIN}, 200 V / div., 10 ms / div.
Peak V_{DRAIN}: 516.67 V.

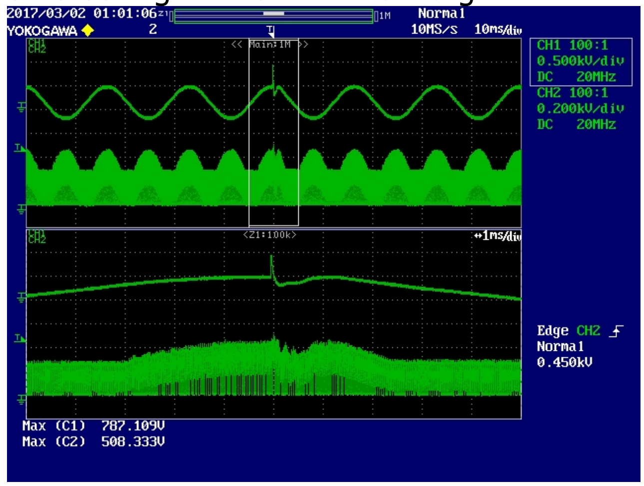

Figure 89 – (+)1 kV Differential Surge.
V_{IN} = 230 V, 90º Phase Angle.
Lower: V_{DRAIN}, 200 V / div., 10 ms / div.
Peak V_{DRAIN}: 508.33 V.

15.4 Ring Wave Test (2.5 kV)

The Drain voltage of InnoSwitch-CH was measured during 2.5 kV ring wave test.

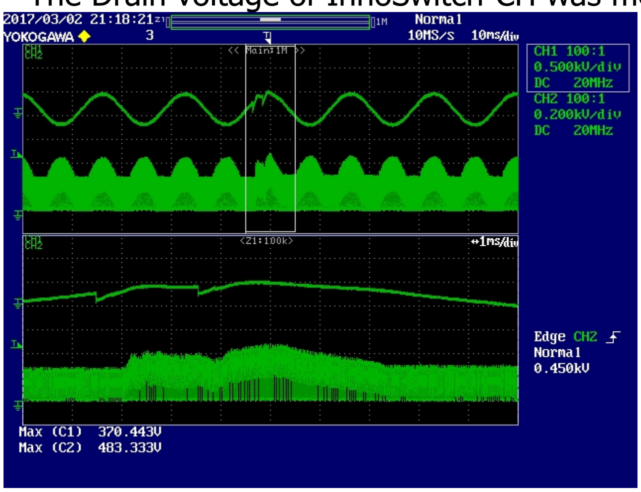

Figure 90 – (+)2.5 kV Ring Wave.
V_{IN} = 230 V, 90º Phase Angle.
Lower: V_{DRAIN}, 200 V / div., 10 ms / div.
Peak V_{DRAIN}: 483.33 V.

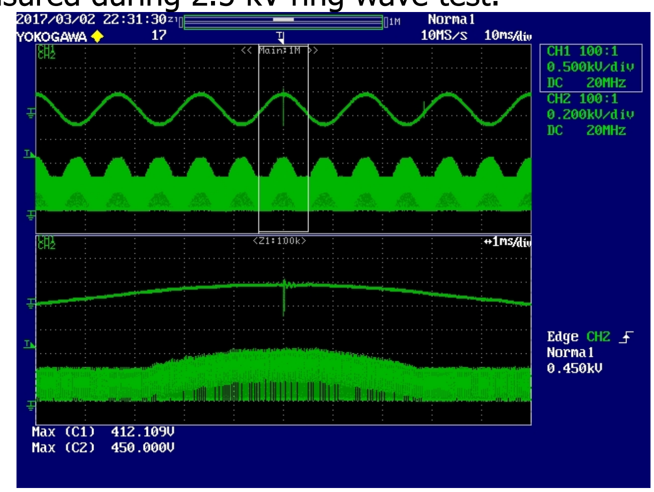

Figure 91 – (-)2.5 kV Ring Wave Surge.
V_{IN} = 230 V, 90º Phase Angle.
Lower: V_{DRAIN}, 200 V / div., 10 ms / div.
Peak V_{DRAIN}: 450 V.

16 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.

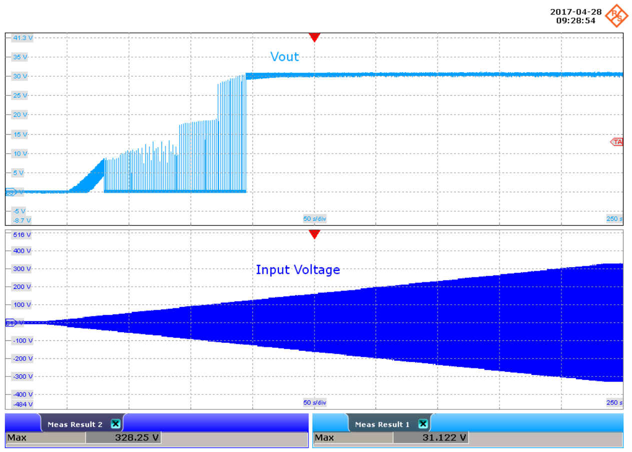

Figure 92 – Brown-in Test at 0.5 V / s.
Ch1: V_{OUT}, 5 V / div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

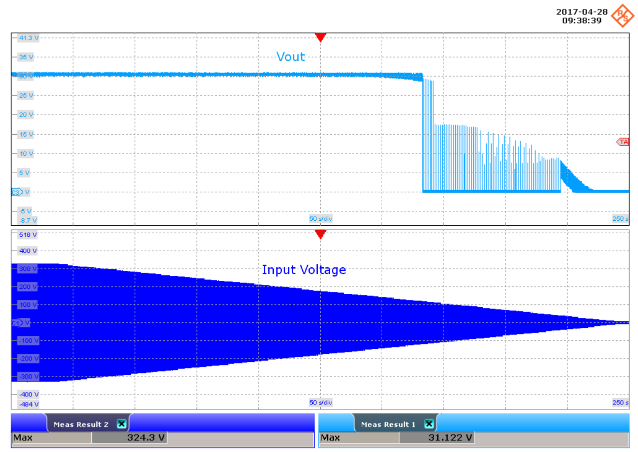

Figure 93 – Brown-out Test at 0.5 V / s.
Ch1: V_{OUT}, 5 V / div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

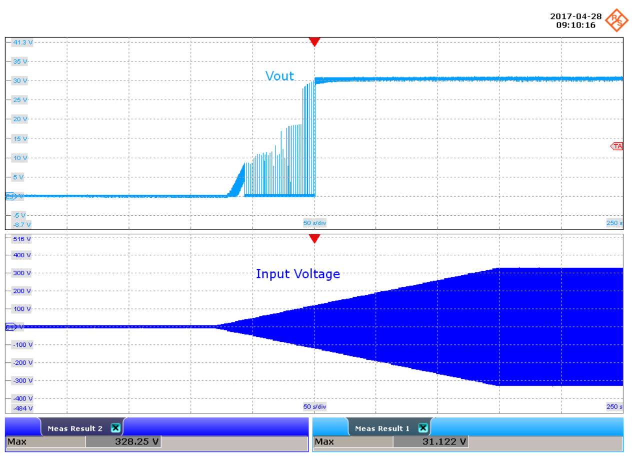

Figure 94 – Brown-in Test at 1 V / s.
Ch1: V_{OUT}, 5 V / div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

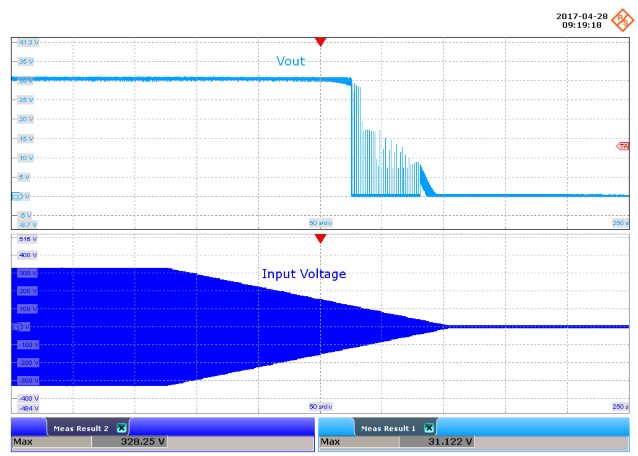

Figure 95 – Brown-out Test at 1 V / s.
Ch1: V_{OUT}, 5 V /div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

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17 Appendix

17.1 Application Example

17.1.1 Smart RGBW Downlight with BLE Control

In this application, DER-612 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.

17.1.2 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 C8 of DER-612; 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 C8. R36 also helps for faster decay of the signal from the Zero Detect pin of the BLE module. *Refer to Casambi CBM-001 datasheet 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.

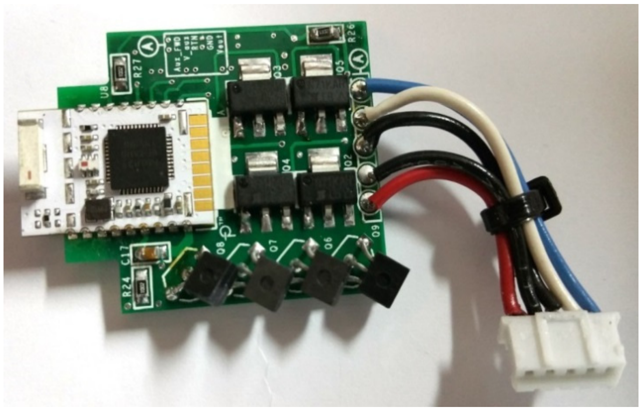

Figure 96 – Top Side of BLE Interface Board.

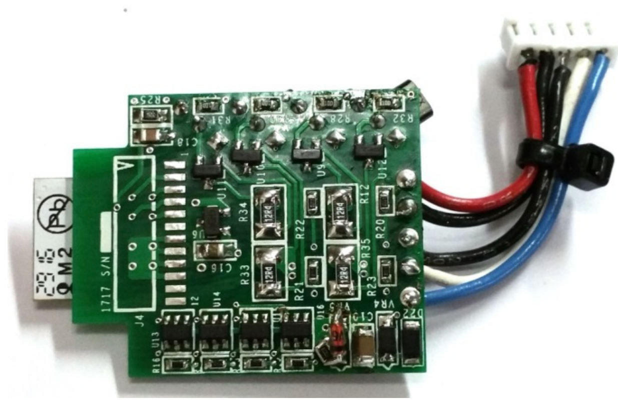

Figure 97 – Bottom Side of BLE Interface Board.

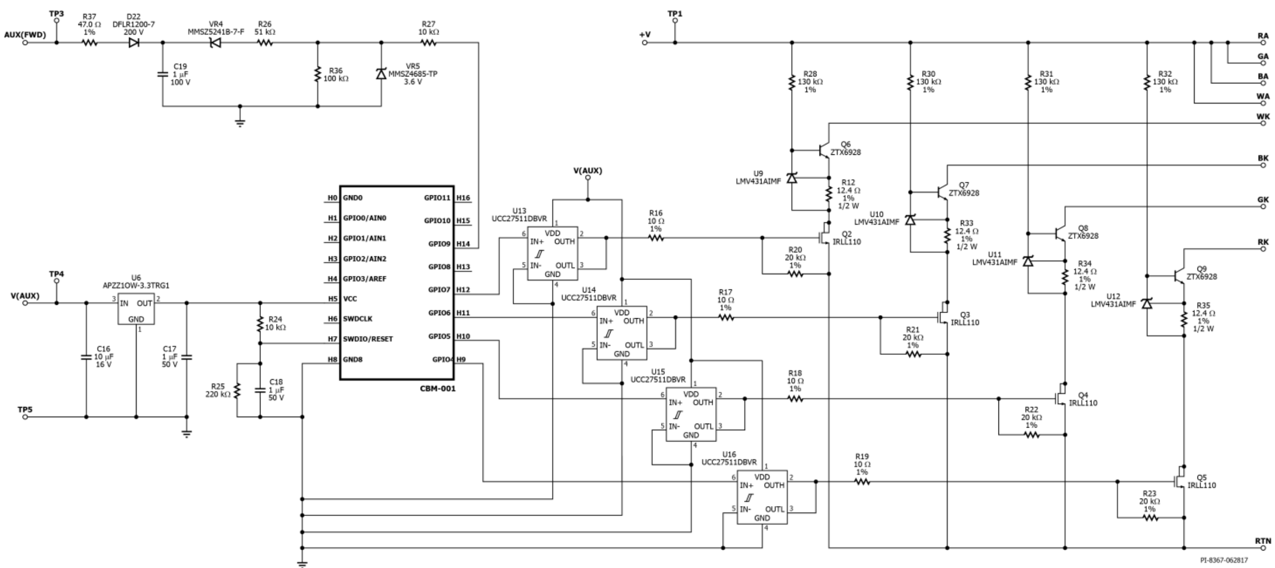

Figure 98– The BLE Interface Circuitry.

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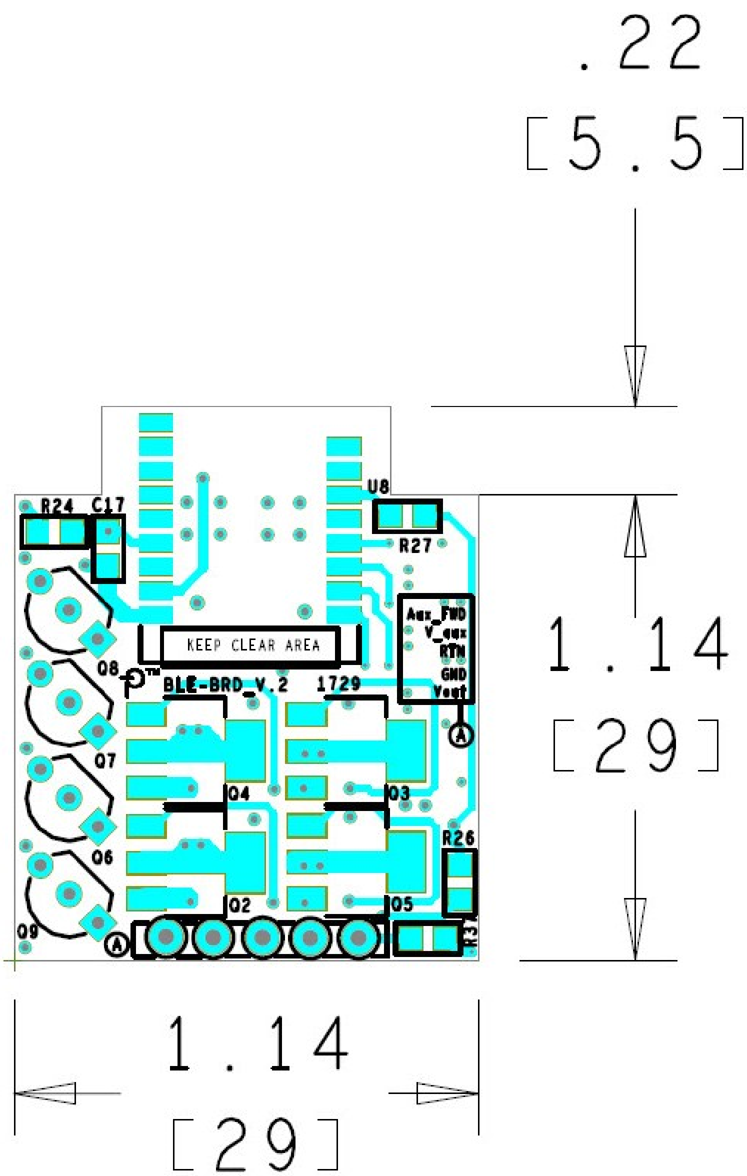

Figure 99 – BLE Interface Board: Component Side.

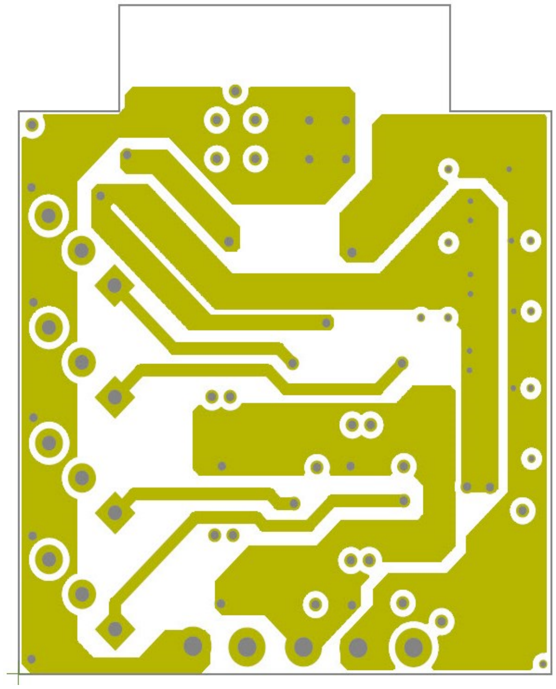

Figure 100 – BLE Interface Board: Second Layer.

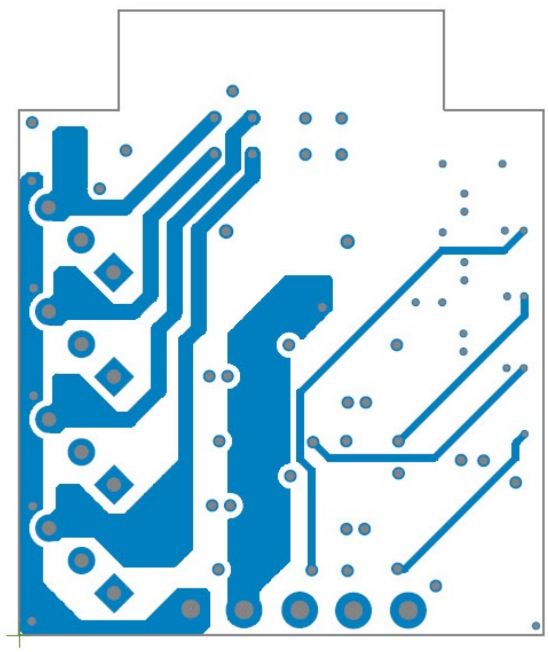

Figure 101 – BLE Interface Board: Third Layer.

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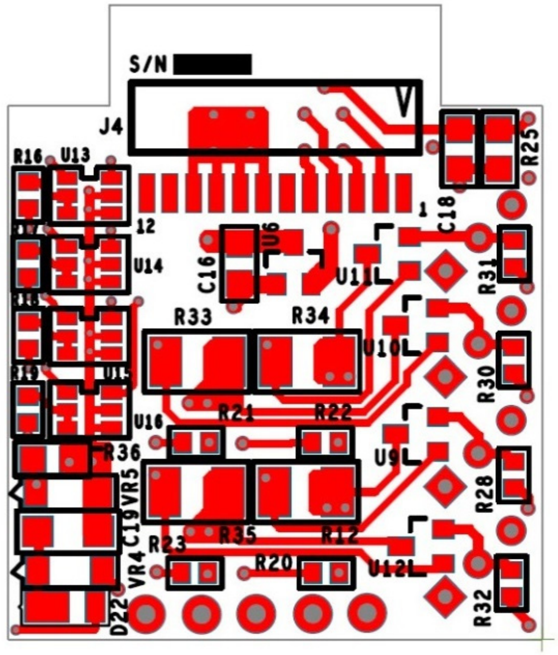

Figure 102 – BLE Interface Board: Solder Side.

17.2 RGBW LED Load Engine

The RGBW LED Load circuitry is shown on Figure 101. It is composed of twelve single-package RGBW LEDs, arrange 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.

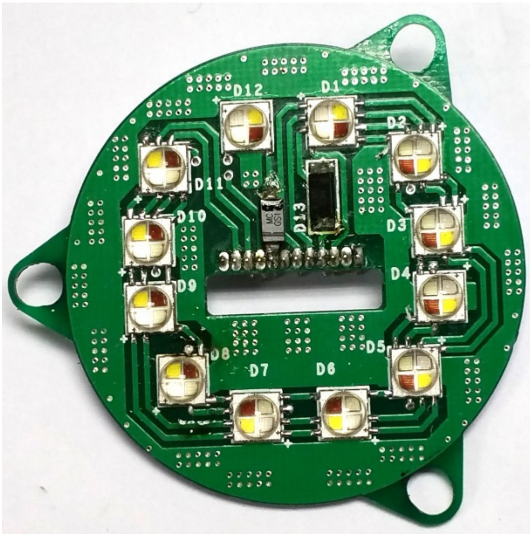

Figure 103 – RGBW LED Engine - Top Side.

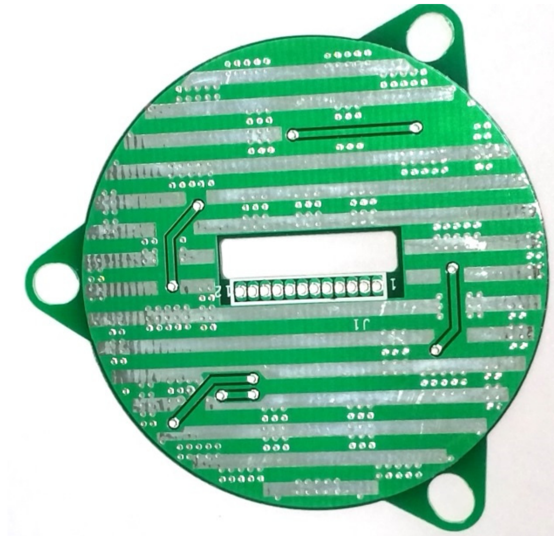

Figure 104 – RGBW LED Engine - Bottom Side.

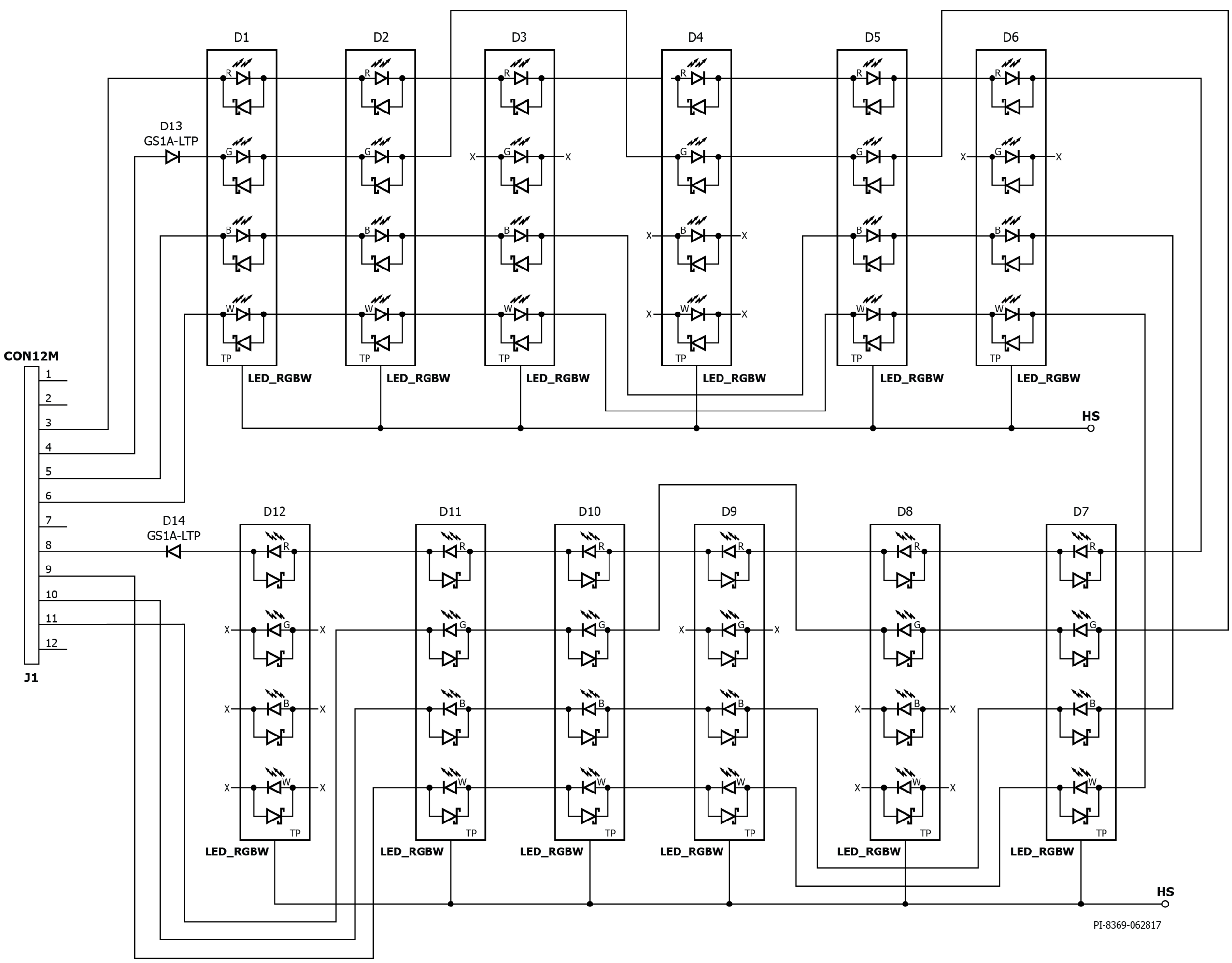

Figure 105 – The RGBW LED Load Engine.

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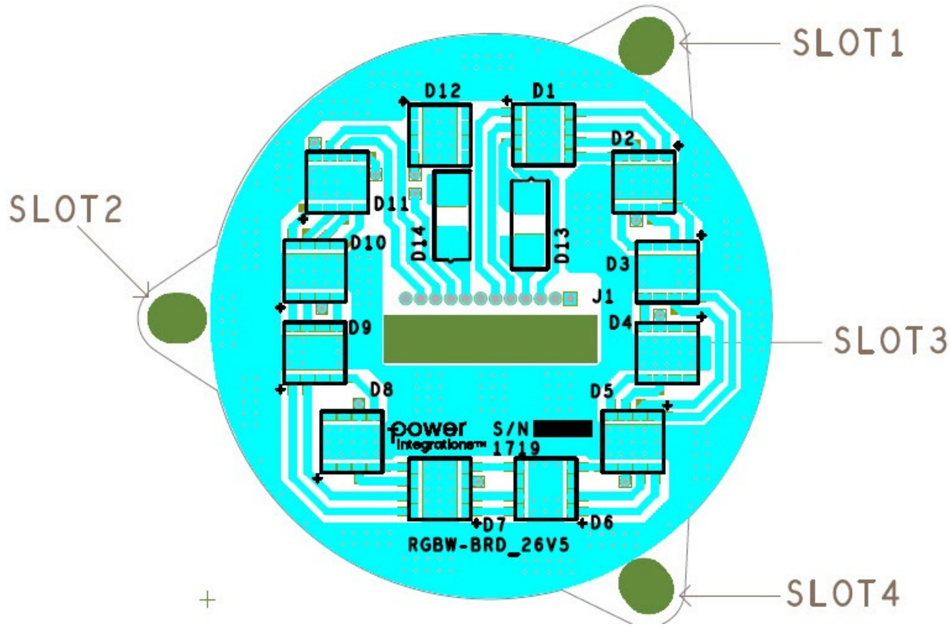

Figure 106 – RGBW LED Board: Component Side.

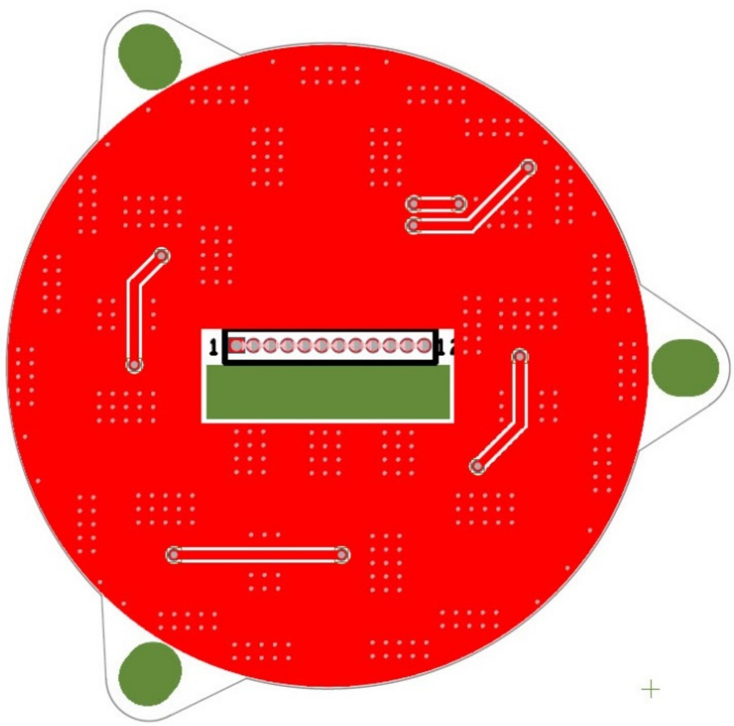

Figure 107 – RGBW LED Board: Solder Side.

17.3 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.

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17.4 Complete Assembly of the Application Example

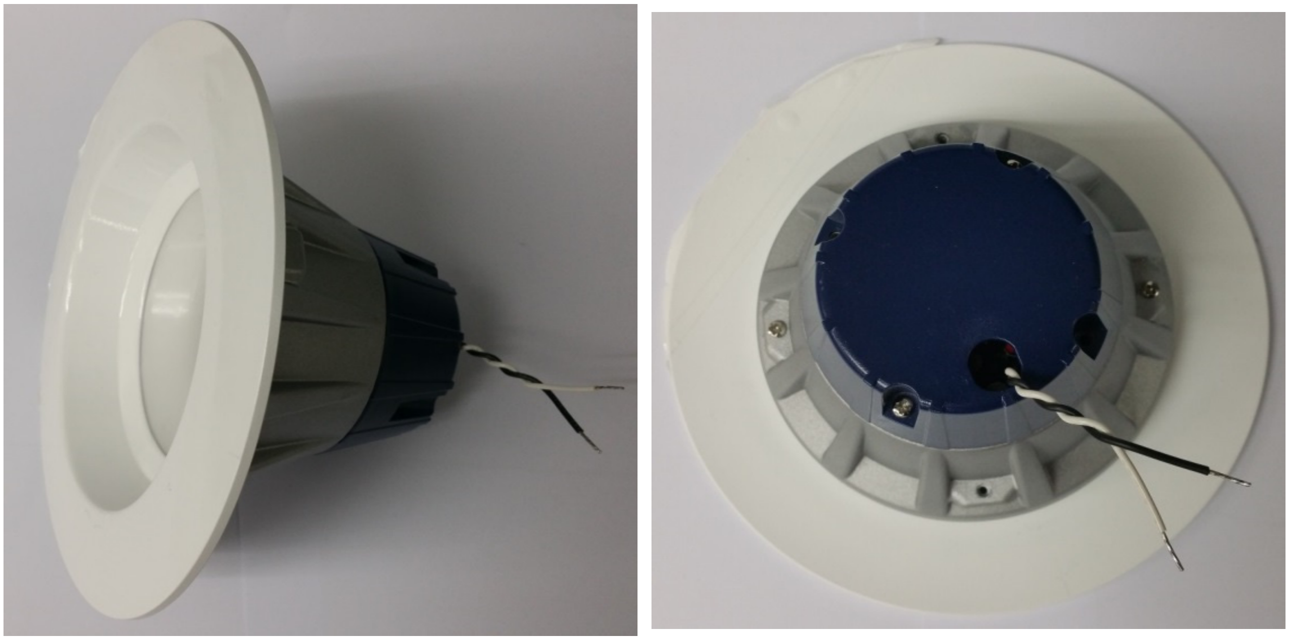

Figure 108 – Completely Assembled Downlight.

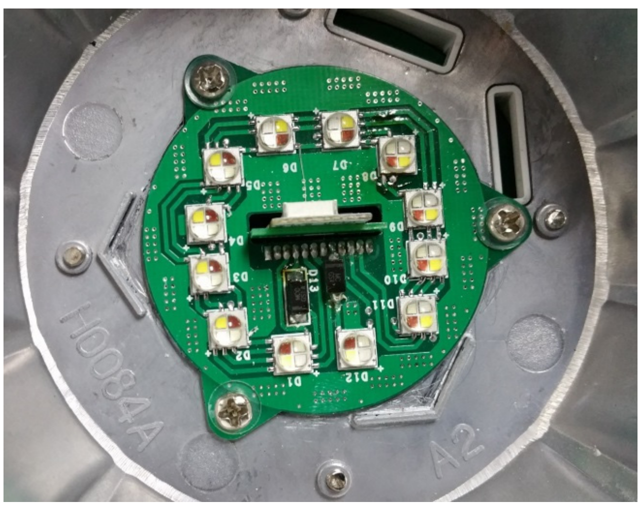

Figure 109 – RGBW Light Engine Mounted on the Downlight Housing / Heat Sink.

Figure 110 – Main Driver and BLE Interface Boards Mounted on the Downlight Housing / Heat Sink.

17.5 Bill of Materials – BLE Interface Circuitry

Item	Qty	Ref	Description	Mfg Part Number	Mfg
1	1	C16	10 μF, ±10%, 16V, X7R, Ceramic Capacitor, -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, 100V, 1.5A (Tc), 2W (Ta), 3.1W (Tc), 540 mOhm @ 900mA @ 5V, -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

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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

17.6 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 Co
14	1	D14	50 V, 1 A, DO-214AC	GS1A-LTP	Micro Commercial Co
15	1	J1	12 positions, Header, Connector, 0.050" (1.27mm), Through Hole, Gold	GRPB121VWVN-RC	Sullins

18 Revision History

Date	Author	Revision	Description and Changes	Reviewed
24-Jul-17	EDdL/MGM	1.0	Initial Release.	Apps & Mktg
14-Dec-17	KM	1.1	Add Magnetics Supplier.	

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