Design Example Report

Title	***45 W High Power Factor Isolated Flyback with Switched Valley Fill PFC Power Supply Using LYTSwitch™-6 LYT6068C***
Specification	90 VAC – 265 VAC Input; 80 V, 580 mA Output
Application	LED Lighting
Author	Applications Engineering Department
Document Number	DER-657
Date	April 26, 2018
Revision	1.3

Summary and Features

- Accurate constant current and voltage regulation
- Industry first AC/DC controller with isolated, safety rated feedback without an optocoupler
- High power factor, >0.9 at 185 VAC to 265 VAC
- Ultrafast transient response
- Highly energy efficient, >87%
- Integrated protection and reliability features
  - Output short-circuit protection
  - Line and output OVP
  - Thermal foldback and over-temperature shutdown with hysteretic automatic power recovery
- CCM + quasi-resonant switching for precision CC/CV operation without need for loop compensation
- 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 45 W isolated flyback power supply with a single stage power factor correction circuit for LED lighting application. The power supply is designed to provide an 80V constant voltage across 0A to 580mA output current load. It is also capable of providing 580mA constant current output for LED Lighting applications. The board is optimized to operate from an input voltage range of 90 VAC to 265 VAC.

DER-657 is a universal input flyback converter design with an added switched valley-fill PFC circuit. Through the PFC circuit, the unit meets the high power factor requirement in LED lighting application while reducing loss by directly transferring energy to the output. The key design goals were excellent regulation, high efficiency, and high power factor across the input voltage range.

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

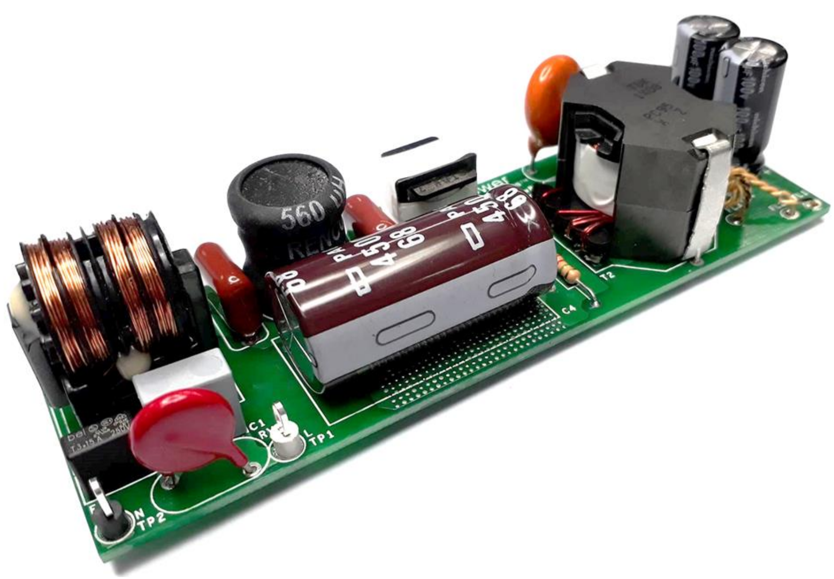

Figure 1 – Populated Circuit Board

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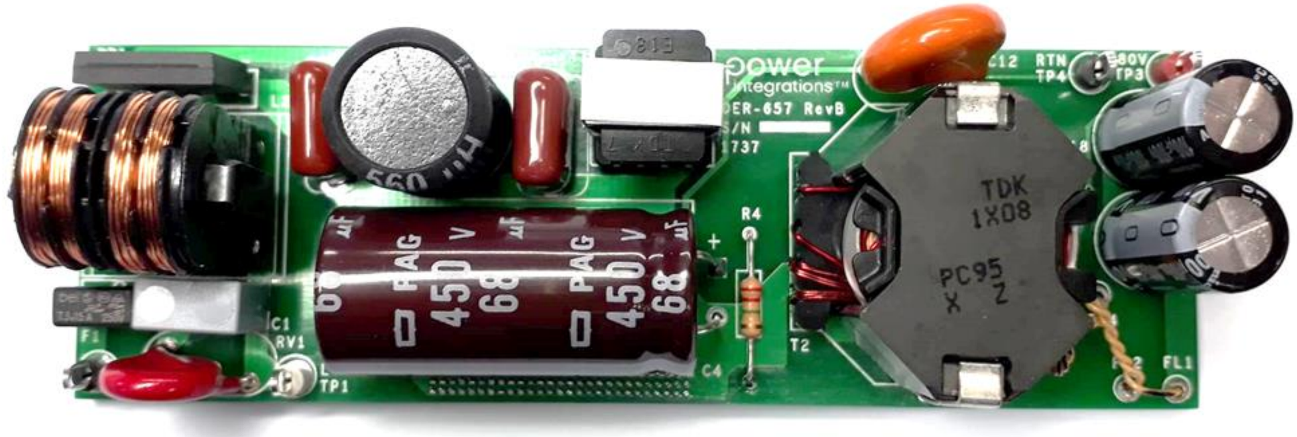

Figure 2 – Populated Circuit Board, Top View.

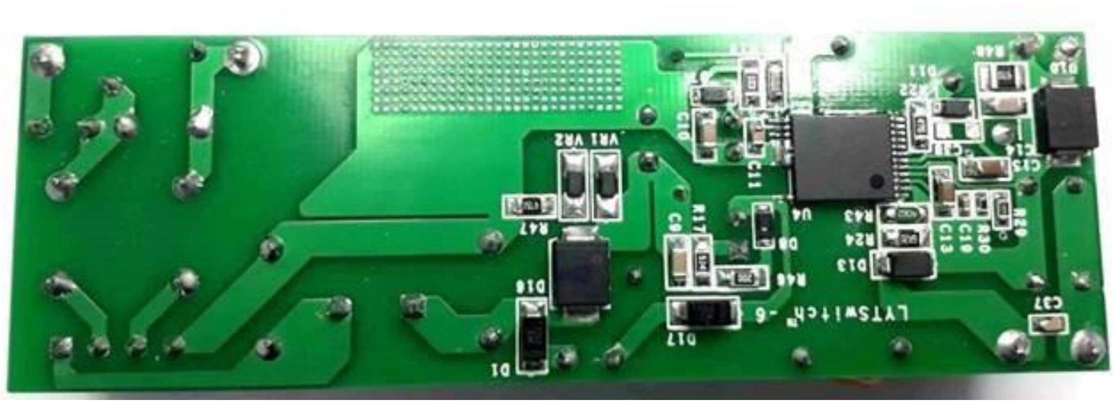

Figure 3 – Populated Circuit Board, Bottom View.

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						
Voltage	V_{IN}	90	120/230	265	Vac/Hz	2 Wire – no P.E.
Frequency	f_{LINE}		50/60			
Output						
Output Voltage	V_{OUT}		80		V	CC Threshold: 580 mA.
Output Current	I_{OUT}	0		580	mA	
Total Output Power						
Continuous Output Power	P_{OUT}		45		W	
Efficiency						
Full Load	η		89		%	At 230 VAC / 50 Hz. 25 ºC Ambient Temperature.
Average Efficiency			>87		%	Meets DOE Level VI.
Environmental						
Conducted EMI		CISPR 15B / EN55015B				
Safety		Isolated				
Ring Wave (100 kHz)			2.5		kV	
Differential Mode (L1-L2)			1		kV	
Power Factor			0.9			Measured at 185 VAC / 50 Hz. and 265 VAC / 50 Hz.
Ambient Temperature	T_{AMB}			60	ºC	Free Air Convection, Sea Level. At <120 VAC Input.

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3 Schematic

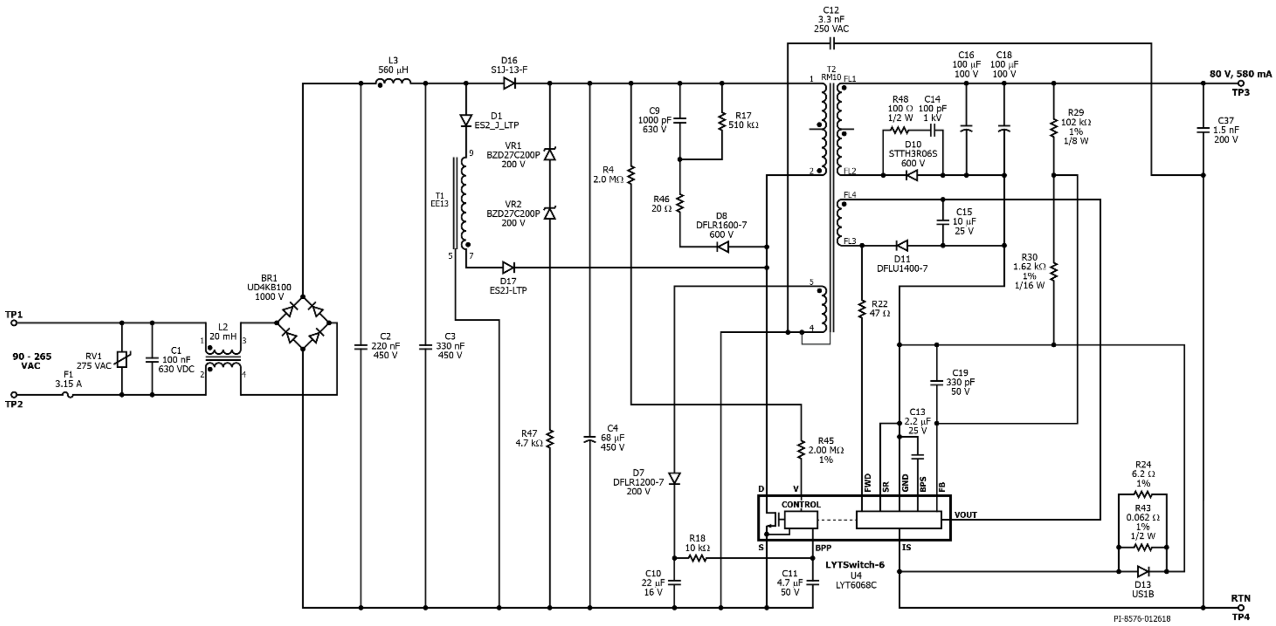

Figure 4 – Schematic Diagram.

4 Circuit Description

The LYTSwitch-6 device (LYT6068C) combines a 650 V power MOSFET, sense elements, a safety-rated feedback mechanism, along with both primary-side and secondary-side controllers in one device. Since LYTSwitch-6 uses an integrated communication link, FluxLink™, accurate control of the primary-side switch by the secondary controller is possible and close component proximity is utilized. The LYTSwitch-6 IC is designed to deliver a 45 W flyback power supply with a switched valley-fill PFC providing a high power factor with 80 V constant voltage supply throughout the input range of 90 VAC to 265 VAC.

4.1 *Input Circuit Description*

Fuse F1 isolates the circuit and provides protection from component failures. Varistor RV1 acts as a voltage clamp at the input in case of voltage spikes from transient line surge. BR1 rectifies the AC line voltage and provide a full wave rectified DC across the input capacitors C2 and C3. Capacitor C1, L2, C2, L3, and C3 forms a 2-stage LC EMI filter to suppress differential and common mode noise caused by the PFC and flyback switching action.

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.

Rectifier diode (D16) delivers the charging current to C4 from the input rectified voltage. During FET off time, D16 blocks current from PFC supply so that flyback DC supply is isolated.

4.2 *Primary Circuit*

One end of transformer (T2) primary is connected to the positive output terminal of the bulk capacitor (C4) while the other side is connected to the drain of the integrated 650 V power MOSFET inside the LYTSwitch-6 IC (U4).

A low cost RCD snubber clamp formed by D8, R17, R46, and C9 limits the peak Drain voltage spike across U4 at the instant turn-off of the MOSFET. The clamp helps dissipate the energy stored in the leakage reactance of transformer T2.

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 R45 to provide detection of overvoltage. The I_{OV-} determines the input overvoltage threshold.

The IC is kick-started by an internal high-voltage current source that charges the BPP pin capacitor C11 when AC is first applied. Primary-side will listen for secondary request signals for around 82 ms. After initial power up, primary-side assumes control first and

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requires a handshake to pass the control to the secondary-side. During normal operation the primary-side block is powered from an auxiliary winding on the transformer. The output of this is configured as a flyback winding which is rectified and filtered using diode D7 and capacitor C10. Resistor R18 limits the current being supplied to the BPP pin of the LYTSwitch-6 (U4).

The thermal shutdown circuitry senses the primary MOSFET die temperature. The threshold (T_{SD}) is typically set to 142 °C with 70 °C hysteresis $T_{SD(H)}$. When the die temperature rises above this threshold the power MOSFET is disabled and remains disabled until the die temperature falls by $T_{SD(H)}$ at which point it is re-enabled. A large hysteresis of 70 °C is provided to prevent over-heating of the PCB due to continuous fault condition.

4.3 *LYTSwitch-6 Secondary Side Control*

The secondary side control of the LYTSwitch-6 IC provides output voltage, output current sensing and drive a non-sync FET providing synchronous rectification. The secondary of the transformer is rectified by D10 and filtered by the output capacitors C16 and C18. Adding an RC snubber (R48 and C14) across the output diode reduces voltage stress across it.
The secondary-side of the IC is powered from an auxiliary winding FL3 and FL4.

During constant voltage mode operation, output voltage regulation is achieved by sensing the output voltage via divider resistors R29 and R30. The voltage across R30 is fed into the FB pin with an internal reference voltage threshold of 1.265 V. Filter capacitor C19 is added across R30 to eliminate unwanted noise that might trigger the OVP function or increase the output ripple voltage.

During constant current operation, the output current is set by the sense resistors R43 and R24 across the IS pin and the GND pin. The internal reference threshold for the IS pin is 35.8 mV. Diode D13 in parallel with the current sense resistor serves as protection during output short-circuit conditions.

The thermal foldback is activated when the secondary controller die temperature reaches 124 °C, the output power is reduced by reducing the constant current reference threshold.

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 (T1) and diodes (D1 and D17) connected directly to the DRAIN pin of the LYTSwitch-6 IC. Through this, the LYTSwitch-6 IC 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 T1 operates in DCM mode. At turn ON, current delivered by the rectified input is stored in the PFC inductor which is then delivered via direct energy transfer to the flyback transformer T2. 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 (i.e, less than 250 mA output load current), 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. For this a Zener-resistor clamp (VR1, VR2, R47) was added in parallel with the bulk capacitor to limit the rise in voltage. The expected voltage stress across the bulk capacitor C4 will be higher than the peak input voltage. The Zener voltage is set at 400 V; when the bulk voltage goes beyond this, the Zener diodes conduct and bleed current from the bulk capacitor through resistor R47. This prevents the bulk capacitor voltage to rise above 450 V. The power dissipation of this Zener-resistor clamp should be considered at the worst-case creeping of the bulk voltage which happens usually at light load condition. Diodes D1 and D17 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 IC's primary and secondary-side control maintaining the voltage regulation at all conditions.

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5 PCB Layout

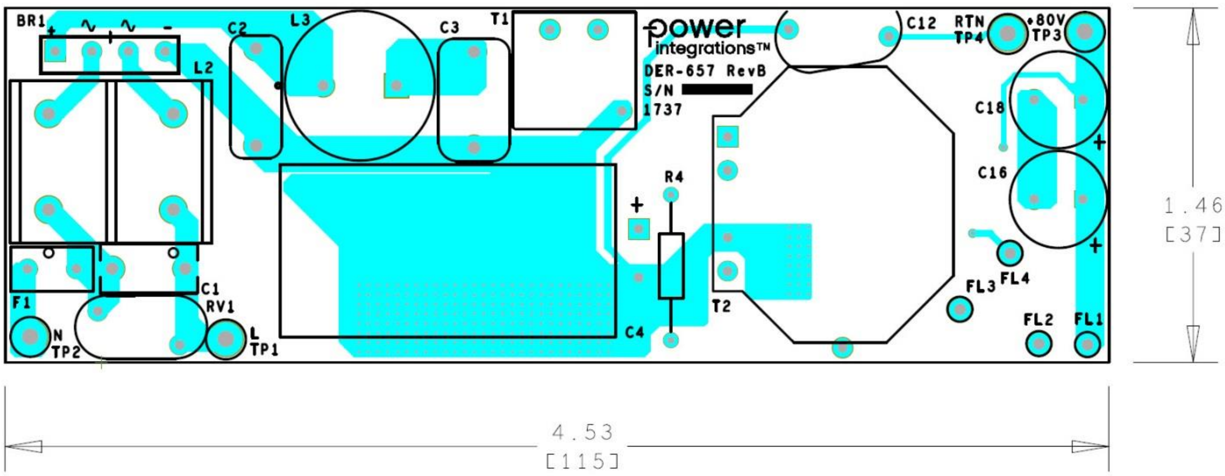

Figure 5 – Top Side.

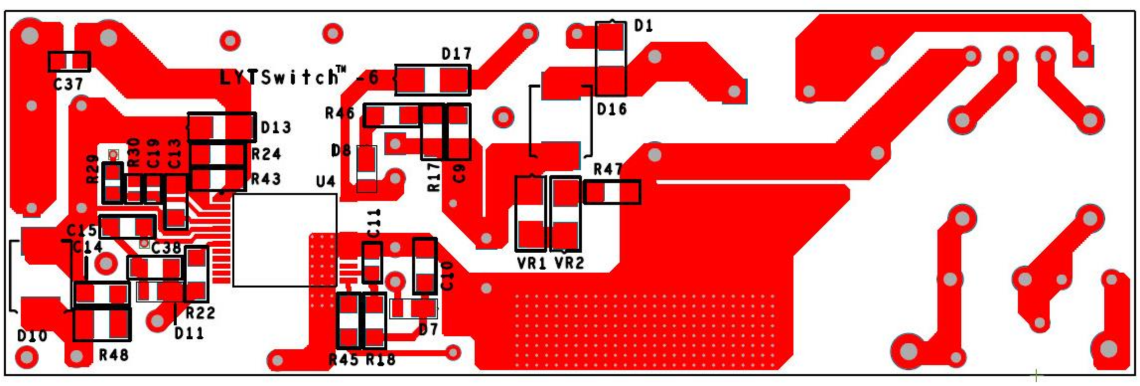

Figure 6 – Bottom Side.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	Bridge Rectifier, 1000 V, 4 A, 4-ESIP, D3K, -55°C ~ 150°C (TJ), Vf=1V @ 7.5A	UD4KB100-BP	Micro Commercial
2	1	C1	0.1 μF, ±20%, Film Capacitor,X2 Safety Rated, 310 VAC, 630 VDC, Polypropylene (PP), Metallized Radial	BFC233920104	Vishay
3	1	C2	220 nF, 450 V, Film	MEXXF32204JJ	Duratech
4	1	C3	330 nF, 450 V, METALPOLYPRO	ECW-F2W334JAQ	Panasonic
5	1	C4	68 μF, 450 V, Electrolytic, Low ESR, (16 x 35.5)	EKXJ451ELL680MLP1S	Nippon Chemi-Con
6	1	C9	1000 pF, 630 V, Ceramic, X7R, 1206	C1206C102KBRACTU	Kemet
7	1	C10	22 μF, 16 V, Ceramic, X5R, 1206	EMK316BJ226ML-T	Taiyo Yuden
8	1	C11	4.7 μF, 16 V, Ceramic, X7R, 0805	GRM21BR71C475KA73L	Murata
9	1	C12	3.3 nF, Ceramic, Y1	440LD33-R	Vishay
10	1	C13	2.2 μF, 25 V, Ceramic, X7R, 1206	TMK316B7225KL-T	Taiyo Yuden
11	1	C14	100 pF, 1000 V, Ceramic, NP0, 1206	102R18N101JV4E	Johanson Dielectrics
12	1	C15	10 μF, 25 V, Ceramic, X7R, 1206	C3216X7R1E106M	TDK
13	1	C16	100 μF, 100 V, Electrolytic, Gen. Purpose, (10 x 20)	UVZ2A101MPD	Nichicon
14	1	C18	100 μF, 100 V, Electrolytic, Gen. Purpose, (10 x 20)	UVZ2A101MPD	Nichicon
15	1	C19	330 pF 50 V, Ceramic, X7R, 0603	CC0603KRX7R9BB331	Yageo
16	1	C37	1.5 nF, 200 V,10%, Ceramic, X7R, 0805	08052C152KAT2A	AVX
17	1	D1	600 V, 2 A, Superfast, 35 ns, DO-214AC, SMA	ES2J-LTP	Micro Commercial
18	1	D7	200 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1200-7	Diodes, Inc.
19	1	D8	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
20	1	D10	600 V, 3 A, SMC, DO-214AB	STTH3R06S	ST Micro
21	1	D11	400 V, 1 A, Diode Superfast 1 A PWRDI 123	DFLU1400-7	Diodes, Inc.
22	1	D13	Diode Ultrafast, 1 A, 100 V, SMA	US1B-13-F	Diodes, Inc.
23	1	D16	600 V, 1 A, Standard Recovery, SMA	S1J-13-F	Diodes, Inc.
24	1	D17	600 V, 2 A, Superfast, 35 ns, DO-214AC, SMA	ES2J-LTP	Micro Commercial
25	1	F1	3.15 A, 300 V, Slow, Long Time Lag, RST	36913150000	Littlefuse
26	1	FL1	Flying Lead, Hole size 50mils	N/A	N/A
27	1	FL2	Flying Lead, Hole size 50mils	N/A	N/A
28	1	FL3	Flying Lead, Hole size 50mils	N/A	N/A
29	1	FL4	Flying Lead, Hole size 50mils	N/A	N/A
30	1	L2	20 mH, 0.8 A, Common Mode Choke	SS21V-R080200	KEMET
31	1	L3	560 μH, 1.60 A, 20%	RL-5480-5-560	Renco
32	1	R4	RES, 2.0 MΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-2M0	Yageo
33	1	R17	RES, 510 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ514V	Panasonic
34	1	R18	RES, 10 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ103V	Panasonic
35	1	R22	RES, 47 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ470V	Panasonic
36	1	R24	RES, 6.2 Ω, ±1%, 1/4 W, 1206, Moisture Resistant, Thick Film	RC1206FR-076R2L	Yageo
37	1	R29	RES, 102 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1023V	Panasonic
38	1	R30	RES, 1.62 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1621V	Panasonic
39	1	R43	RES, 0.062 Ω,±300ppm/°C, ±1%, ½ W, 1206 (3216 Metric), Current Sense, Thick Film	RLP73N2BR062FTDF	TE Connectivity
40	1	R45	RES, 2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
41	1	R46	RES, 20 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ200V	Panasonic
42	1	R47	RES, 4.7 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ472V	Panasonic
43	1	R48	RES, 100 Ω, 5%, 1/2 W, Thick Film, 1210	ERJ-14YJ101U	Panasonic
44	1	RV1	320 VAC, 23 J, 10 mm, RADIAL	V320LA10P	Littlefuse
45	1	T1	Bobbin, EE13, Vertical, 10 pins	P-1302-2	Pin Shine
46	1	T2	Bobbin, RM10, Vertical, 5 pins	P-1031	Pin Shine

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47	1	TP1	Test Point, BLK, THRU-HOLE MOUNT	5011	Keystone
48	1	TP2	Test Point, WHT, THRU-HOLE MOUNT	5012	Keystone
49	1	TP3	Test Point, BLK, THRU-HOLE MOUNT	5011	Keystone
50	1	TP4	Test Point, BLK, THRU-HOLE MOUNT	5011	Keystone
51	1	U4	LYTSwitch-6, InSOP24D	LYT6068C	Power Integrations
52	1	VR1	DIODE, ZENER, 200 V, 800 MW, DO219AB	BZD27C200P-E3-08	Vishay
53	1	VR2	DIODE, ZENER, 200 V, 800 MW, DO219AB	BZD27C200P-E3-08	Vishay

7 Flyback Transformer (T2) Specification

7.1 *Electrical Diagram*

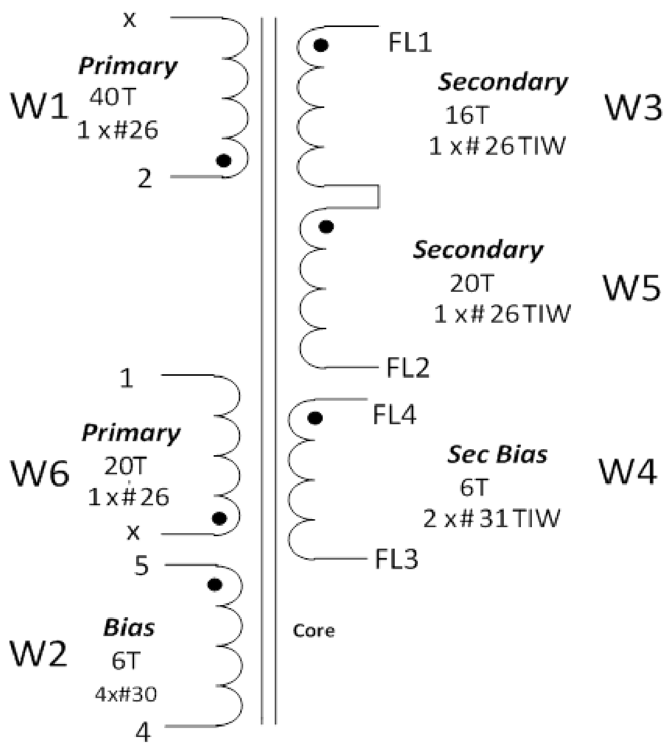

Figure 7 – Transformer Electrical Diagram.

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.	1100 μH
Tolerance	Tolerance of Primary Inductance.	±5%
Leakage Inductance	Measured across primary winding with all other windings shorted	<10 μH

7.3 *Material List*

Item	Description
[1]	Core: RM10 PC95 or Equivalent.
[2]	Bobbin: Bobbin, RM10, Vertical, 5 Pins.
[3]	Magnet Wire: #26 AWG.
[4]	Magnet Wire: #30 AWG.
[5]	TIW: #26 AWG.
[6]	TIW: # 31 AWG.
[7]	Polyester Tape: 9 mm.
[8]	RM10 Core Clip with Terminal.

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7.4 *Transformer Build Diagram*

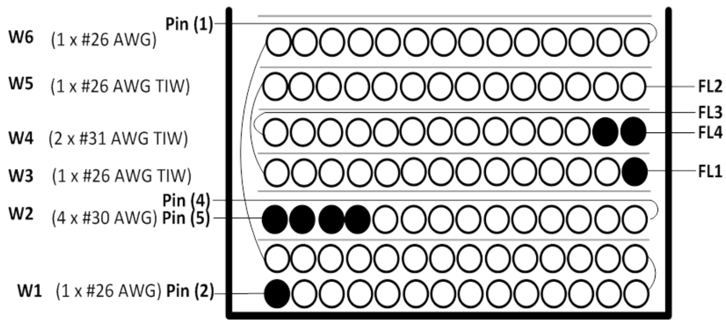
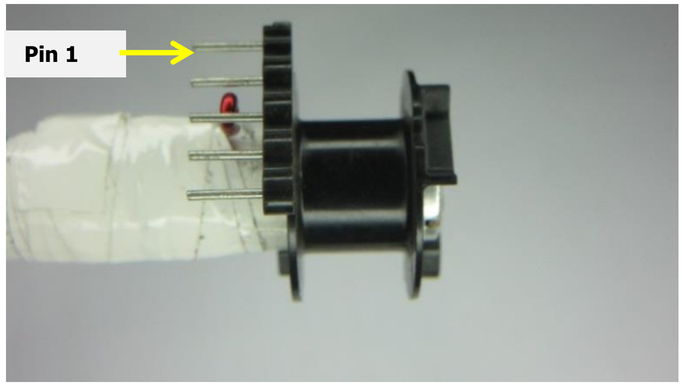
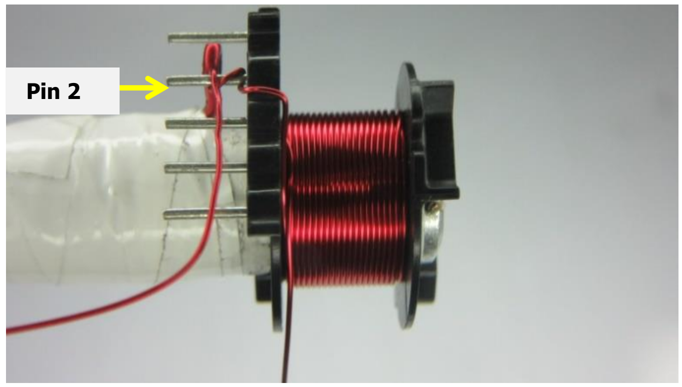
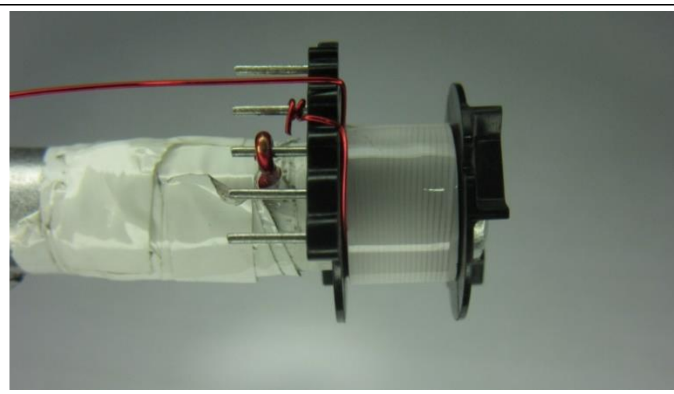
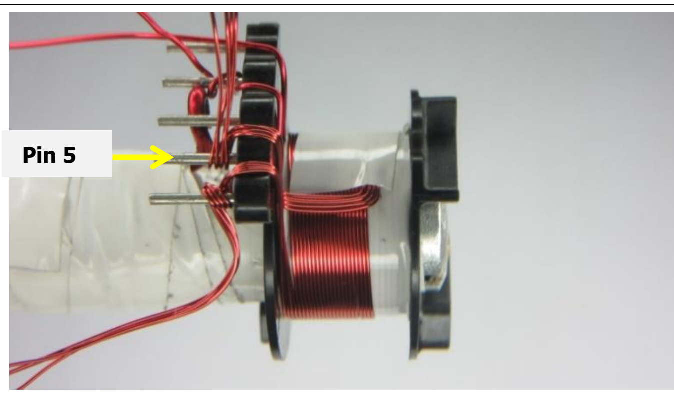


Figure 8 – Transformer Build Diagram.

7.5 *Transformer Construction*

Winding Directions	Bobbin is oriented on winder jig such that terminal pin 1-6 is on the left side. The winding direction is clockwise.
Winding 1	Use magnetic wire Item [3]. Start at pin 2 and wind 40 turns evenly in 2 layers. Do not terminate winding, leave the winding floating.
Insulation	Apply 1 layer of polyester tape, Item [7] for insulation
Winding 2	Use quadrifilar magnetic wire on Item [4]. Start at pin (5) and end at pin (4).
Insulation	Apply 1 layer of polyester tape, Item [7] for insulation.
Winding 3	Start on the other side of the bobbin. Use a triple insulated wire on item [5]. Starting with a fly lead (FL1), wind 16 turns evenly in 1 layer. Do not terminate winding yet.
Insulation	Apply 1 layer of polyester tape, Item [7] for insulation**.**
Winding 4	Start on the side of FL1. Use a bifilar triple insulated wire, Item [6]. Start as a fly lead (FL4), wind 6 turns evenly in 1 layer and finish as a fly lead (FL3).
Insulation	Apply 1 layer of polyester tape, Item [7] for insulation.
Winding 5	Continuing from winding 3, wind 20 turns and finish with a fly lead. (FL2)
Insulation	Apply 1 layer of polyester tape, Item [7] for insulation.
Winding 6	Continuing from W1, wind 20 turns evenly and finish at pin (1).
Insulation	Apply 2 layers of polyester tape, Item [7] for insulation.
Core Grinding	Grind the center leg of the ferrite core to meet the nominal inductance specification of 1100 μH.
Assemble Core	Use RM10 core clips with terminals, Item [8] to fix the 2 cores into the bobbin. Cut the terminal of the clip on the left side of the bobbin, looking at the bottom side facing the fly leads of the secondary winding.
Pins	Cut any excess pins of the bobbin (pins without wire terminations).
Finish	Dip the transformer in a 2:1 varnish and thinner solution.

7.6 *Transformer Winding Illustrations*

Winding Directions Bobbin is oriented on winder jig such that terminal Pin 1-5 is on the left side. The winding direction is clockwise.	
Winding 1 Use magnetic wire Item [3]. Start at pin 2 and wind 40 turns evenly in 2 layers. Do not terminate winding, Leave the winding floating.	
Insulation Apply 1 layer of polyester tape, Item [7] for insulation.	
Winding 2 Use quadrifilar magnetic wire on Item [4]. Start at pin (5) and end at pin (4).	

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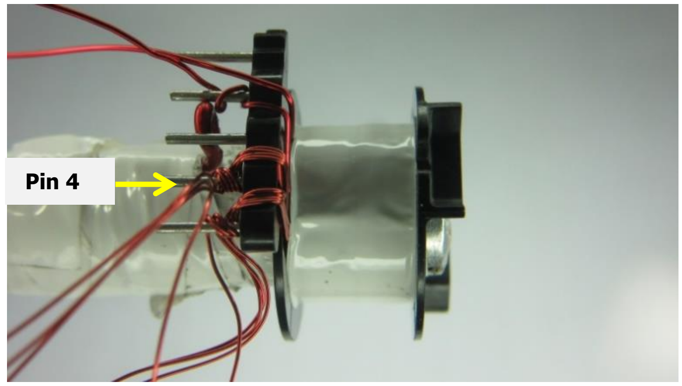
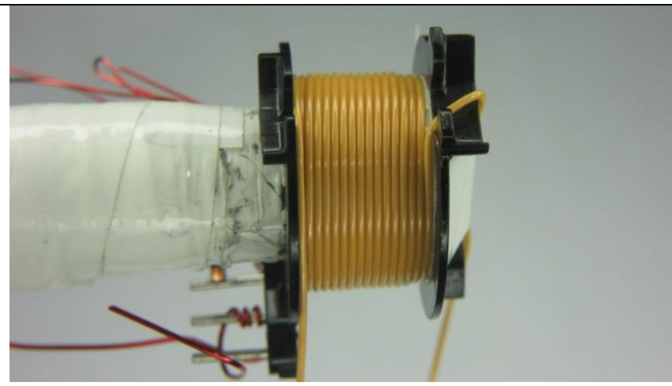
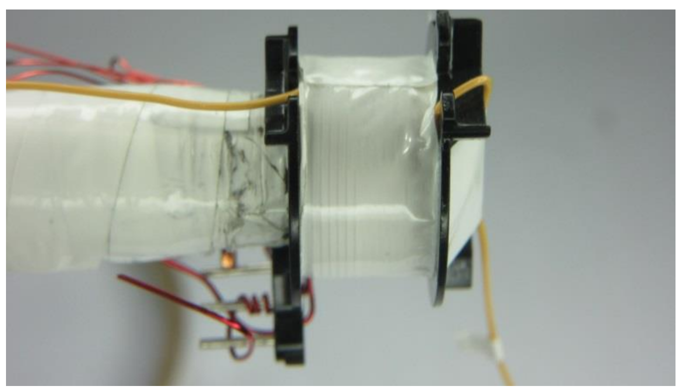
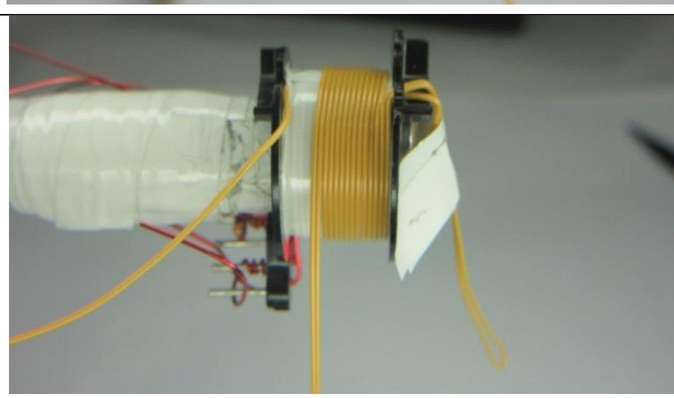
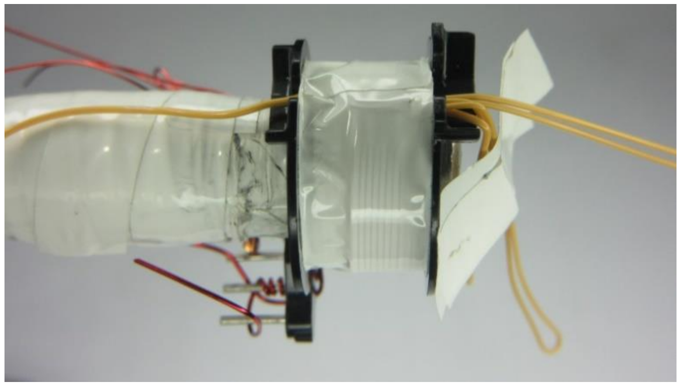
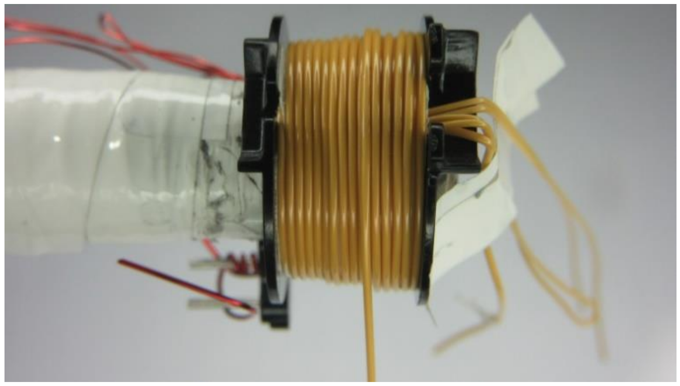
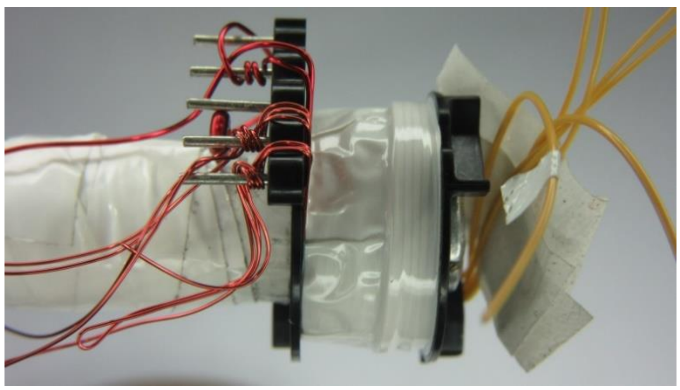
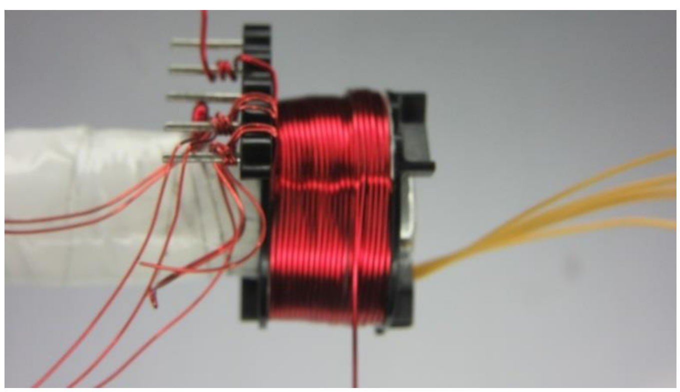
Insulation Apply 1 layer of polyester tape, Item [7] for insulation.	
Winding 3 Start on the other side of the bobbin. Use a triple insulated wire on item [5]. Starting with a fly lead (FL1), wind 16 turns evenly in 1 layer. Do not terminate winding yet.	
Insulation Apply 1 layer of polyester tape, Item [7] for insulation.	
Winding 4 Start on the side of FL1. Use a bifilar triple insulated wire, Item [6]. Start as a fly lead (FL4), wind 6 turns evenly in 1 layer and finish as a fly lead (FL3).	

Insulation Apply 1 layers of polyester tape, Item [7] for insulation.	
Winding 5 Continuing from winding 3, wind 20 turns evenly and finish with a fly lead. (FL2)	
Insulation Apply 1 layer of polyester tape, Item [7] for insulation.	
Winding 6 Continuing from W1, wind 20 turns evenly and finish at pin (1).	

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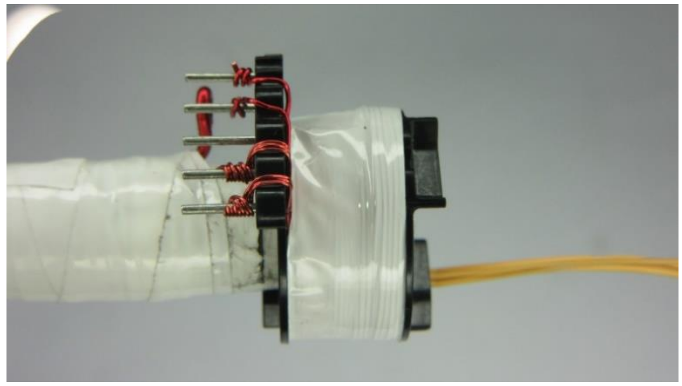
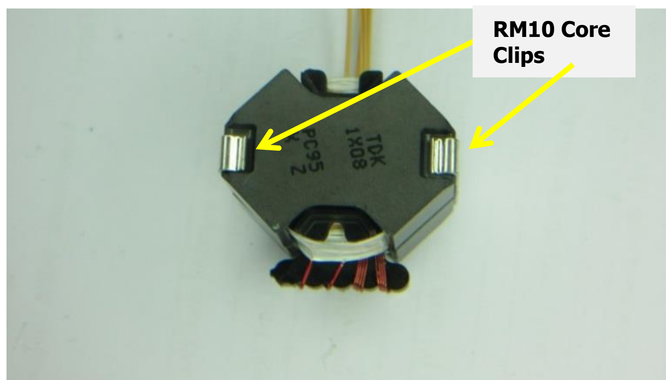
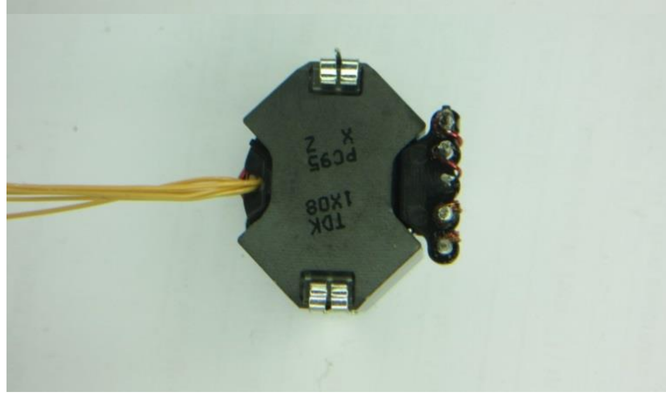
Insulation Apply 2 layers of polyester tape, Item [7] for insulation.	
Core Termination Use two PC95 RM10 cores, item [1] and assemble them with the wound bobbin. **Core Clips** Use RM10 Core Clips with Terminals, Item [8] to fix the 2 cores into the bobbin. Cut the terminal of the clip on the left side of the bobbin, looking at the bottom side facing the fly leads of the secondary winding. **Varnishing** Dip the transformer in a 2:1 varnish and thinner solution	 

8 PFC Inductor (T2) Specification

8.1 *Electrical Diagram*

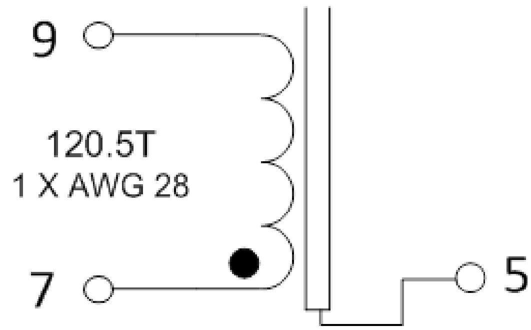


Figure 9 – Inductor Electrical Diagram.

8.2 *Electrical Specifications*

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 9 and pin 7.	750 μH
Tolerance	Tolerance of Primary Inductance.	±5%

8.3 *Material List*

Item	Description
[1]	Core: EE13.
[2]	Bobbin: Bobbin, EE13, Vertical, 10 pins; Part no. 25-01023-00.
[3]	Magnet Wire: #28 AWG.
[4]	Transformer Tape: 6.5 mm.
[5]	Transformer Tape: 4 mm.
[6]	Copper Wire.

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8.4 *Inductor Build Diagram*

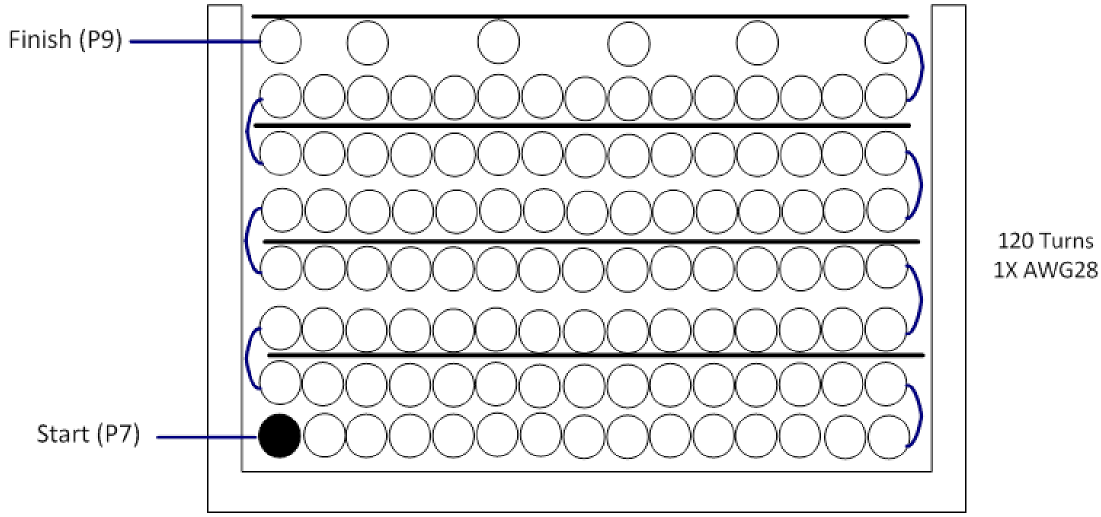


Figure 10 – Transformer Build Diagram.

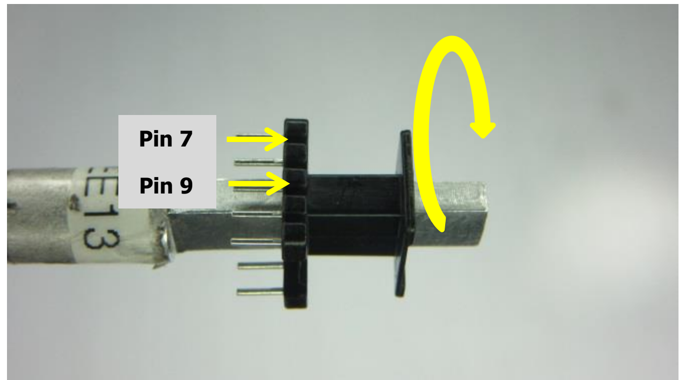
8.5 *Inductor Construction*

Winding Directions	Bobbin is oriented on winder jig such that terminal pin 6 – 10 is in the left side. The winding direction is clockwise.
Winding 1	Prepare the magnetic wire Item [3] for winding. Start at pin 9 and wind 120.5 turns bifilar in 8 layers.
Insulation	Add 1 layer of tape, Item [4] for every 2 layers of winding 1.
Winding 1	Finish the winding on pin 7.
Insulation	Add 2 layers of tape, Item [4] for insulation.
Core Grinding	Grind the center leg of the ferrite core evenly until it meets the nominal inductance of 750 μH. Inductance is measured across pin 9 and pin 7.
Assemble Core	Assemble the 2 cores on the bobbin.
Core Termination	Prepare a copper strip with a soldered magnetic wire, Item [6], 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 5.
Core Tape	Add 2 Layers of tape, Item [5], around the core to fix the 2 cores into the bobbin.
Pins	Pull out or cut terminal pin no. 1, 2, 3, 4, 6, 8, and pin 10.
Finish	Dip the transformer assembly in 2:1 varnish and thinner solution.

8.6 *Inductor Winding Illustrations*

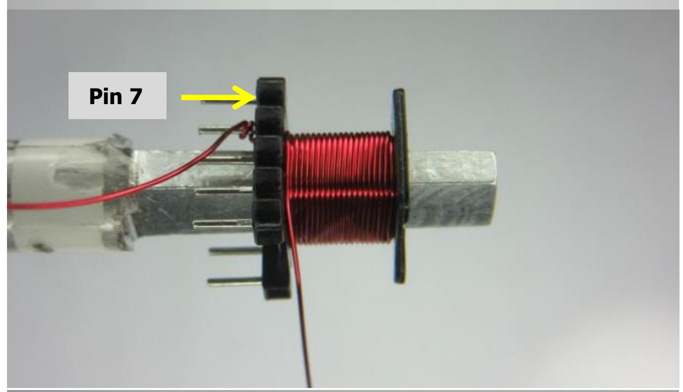
Winding Directions

Bobbin is oriented on winder jig such that terminal pin 6 – 10 is in the left side. The winding direction is clockwise.



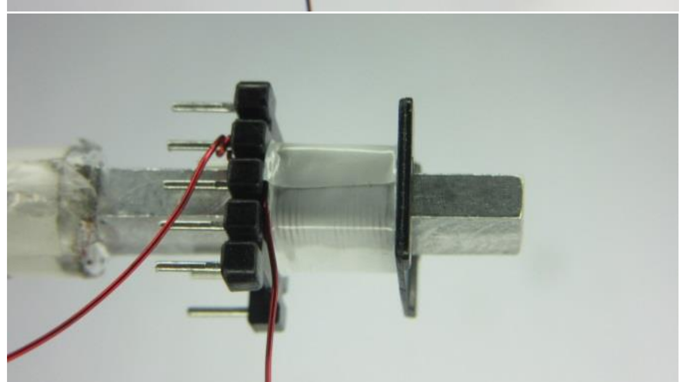
Winding 1

Prepare the magnetic wire Item [3] for bifilar-wound type winding. Start at pin 7 and wind 120.5 turns in 8 layers.



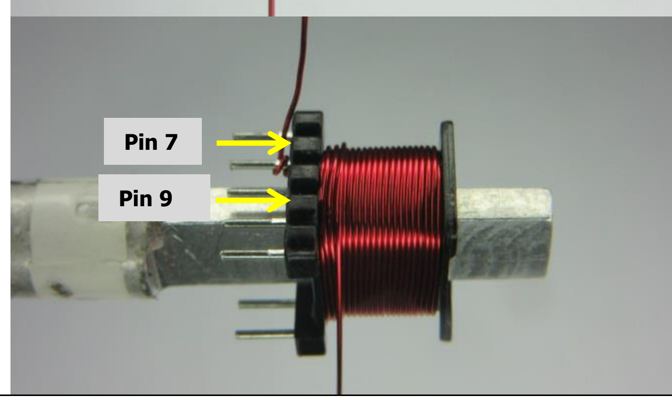
Insulation

Add 1 layer of tape, Item [4] for every 2 layers of winding 1



Winding 1

Finish at pin 9.



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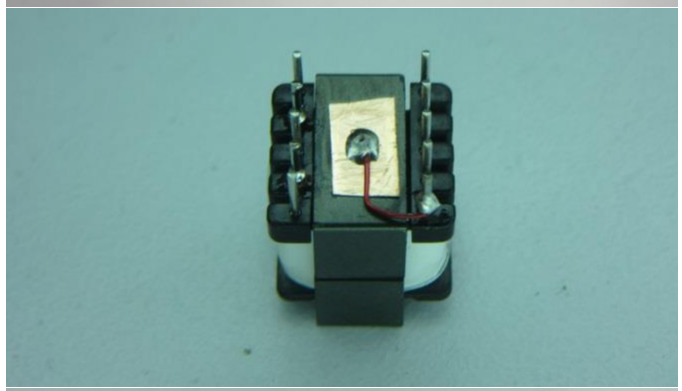
Insulation

Add 2 layers of tape, Item [4] for insulation

Core Termination

Prepare a copper strip with a soldered magnetic wire, Item [6], 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 5.



Core Tape

Add 2 Layers of tape Item [5] around the core to fix the 2 cores into the bobbin.

Pins

Pull out or cut terminal pin no. 1, 2, 3, 4, 6, 8, and pin 10.

Finish

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

9 Design Spreadsheet

1	ACDC_Flyback_PF_LYTSwitch-6_020318; Rev.1.2; 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			230	V	Nominal AC Voltage (For universal designs low line nominal voltage is displayed)
5	VACMAX			265	V	Maximum Input AC Voltage
6	VACRANGE			UNIVERSAL		Input Voltage Range
7	FL			50	Hz	Line Frequency
8	CIN	68.0000		68.0000	µF	Minimum Input Capacitance
9	V_CIN			450	V	Input Capacitance Recommended Voltage Rating
10	VO	80.00		80.00	V	Output Voltage
11	IO	0.58		0.58	A	Output Current
12	PO			46.40	W	Total Output Power
13	N	85.00		85.00		Estimated Efficiency
14	Z			0.50		Loss Allocation Factor
15	**Parametric Calculations Basis**					
16	ILIMcalcBASIS	Nom		Nom		ILIM Calculations Basis - NOM,MAX or MIN only
17	PARcalcBASIS	VACNOM		VACNOM		Calculated Results Based on Selected VAC - VACNOM,VACMAX,VACMIN or Worst Case only
18	**Primary Controller Section**					
19	DEVICE_MODE	Increased		Increased		Device Current Limit Mode
20	DEVNAME	Auto		LYT6068C		PI Device Name
21	RDSON			1.53	ohms	Device RDSON at 100degC
22	ILIMITMIN			1.683	A	Minimum Current Limit
23	ILIMITTYP			1.850	A	Typical Current Limit
24	ILIMITMAX			2.017	A	Maximum Current Limit
25	BVDSS			650	V	Drain-Source Breakdown Voltage
26	VDS			2.00	V	On state Drain to Source Voltage
27	VDRAIN			576.77	V	Peak Drain to Source Voltage during Fet turn off
28	**Worst Case Electrical Parameters**					
29	**Boost Converter**					
30	IBOOSTRMS			343.76	mA	Boost RMS current
31	IBOOSTMAX			1050.63	mA	Boost PEAK current
32	IBOOSTAVG			190.11	mA	Boost AVG current
33	IINRMS			214.57	mA	Input RMS current
34	PF_est			0.9993		Estimated Power Factor
35	**Flyback Converter**					
36	FSMIN	38000		38000	Hz	Minimum Switching Frequency in a Line Period
37	FSMAX			81993.13	Hz	Maximum Switching Frequency in a Line Period
38	KPmin			1.1869		Minimum KP in a Line Period for VAC specified by PARcalcBASIS
39	IFETRMS			476.65	mA	Fet RMS current
40	IFETMAX			1811.74	mA	Fet PEAK current
41	IPRIRMS			0.3782	A	Primary Winding RMS current
42	IPRIMAX			1.5577	A	Primary Winding PEAK current
43	IPRIAVG			0.0054	A	Primary Winding AVG current
44	IPRIMIN			737.91	mA	Primary Winding Minimum current
45	ISECRMS			0.96	A	Secondary RMS current
46	ISECMAX			2.77	A	Secondary PEAK current
47	**Boost Choke Construction Parameters**					
48	RATIO_LBST_LFB	0.6820		0.6820		Boost Inductance and Flyback Primary Inductance Ratio

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49	LBOOSTMIN			705.87	µH	Minimum Boost Inductance
50	LBOOSTNOM			743.02	µH	Nominal Boost Inductance
51	LBOOSTMAX			780.17	µH	Maximum Boost Inductance
52	LBOOSTTOL	5.00		5.00	%	Boost Inductance Tolerance
53	**Boost Core and Bobbin Selection**					
54	CR_TYPE_BOOST	EE13		EE13		Boost Core
55	CR_PN_BOOST			PC40EE13-Z		Boost Core Code
56	AE_BOOST			17.10	mm²	Boost Core Cross Sectional Area
57	LE_BOOST			30.20	mm	Boost Core Magnetic Path Length
58	AL_BOOST			1130.00	nH/turns²	Boost Core Ungapped Core Effective Inductance
59	VE_BOOST			517.00	mm3	Boost Core Volume
60	BOBBINID_BOOST			548		Bobbin
61	AW_BOOST			22.20	mm²	Window Area of Bobbin
62	BW_BOOST			7.40	mm	Bobbin Width
63	MARGIN_BOOST			0.00	mm	Safety Margin Width
64	BOBFILLFACTOR_Boost			101.35	%	Boost Bobbin Fill Factor
65	**Boost Winding Details**					
66	NBOOST	120.50		120.50		Boost Choke Turns
67	BP_BOOST			4029.96	Gauss	Boost Peak Flux Density
68	ALG_BOOST			51.17	nH/turns²	Boost Core Ungapped Core Effective Inductance
69	LG_BOOST			0.40	mm	Boost Core Gap Length
70	L_BOOST	8.00		8.00		Number of Boost Layers
71	AWG_BOOST			28.00		Boost Winding Wire AWG
72	OD_BOOST_INSULATED			0.38	mm	Boost Winding Wire Output Diameter with Insulation
73	OD_BOOST_BARE			0.32	mm	Boost Winding Wire Output Diameter without Insulation
74	CMA_BOOST			340.33	Circular Mils/A	Boost Winding Wire CMA
75	**Flyback Transformer Construction Parameters**					
76	VOR	132		132	V	Secondary Voltage Reflected in the Primary Winding
77	LP_MIN			1035.00	µH	Minimum Flyback Inductance
78	LP_NOM			1089.47	µH	Nominal Flyback Inductance
79	LP_MAX			1143.94	µH	Maximum Flyback Inductance
80	LP_TOL	5.00		5.00	%	Flyback Inductance Tolerance
81	**Flyback Core and Bobbin Selection**					
82	CR_TYPE	RM10/ILP		RM10/ILP		Flyback Core
83	CR_PN			RM10/ILP-3F3		Flyback Core Code
84	AE			99.10	mm²	Flyback Core Cross Sectional Area
85	LE			33.90	mm	Flyback Core Magnetic Path Length
86	AL			5200.00	nH/turns²	Flyback Core Ungapped Core Effective Inductance
87	VE			3360.00	mm3	Flyback Core Volume
88	BOBBINID			BRM10-7112SDFR		Flyback Bobbin
89	BB_ORIENTATION			H		Flyback Bobbin Orientation H - Horizontal and V -Vertical
90	AW			21.00	mm²	Flyback Window Area of Bobbin
91	BW			4.35	mm	Flyback Bobbin Width
92	MARGIN			0.00	mm	Safety Margin Width
93	**Flyback Winding Details**					
94	NP			60.00		Primary Turns
95	BP			3971.76	Gauss	Flyback Peak Flux Density
96	BM			3761.59	Gauss	Flyback Maximum Flux Density
97	BAC			1427.02	Gauss	Flyback AC Flux Density
98	ALG			302.63	nH/turns²	Flyback Core Ungapped Core Effective Inductance
99	LG			0.39	mm	Flyback Core Gap Length

100	L	5.00		5.00		Number of Flyback Layers
101	AWG			28.00		Primary Winding Wire AWG
102	OD			0.38	mm	Primary Winding Wire Output Diameter with Insulation
103	DIA			0.32	mm	Primary Winding Wire Output Diameter without Insulation
104	CMA			277.16	Circular Mils/A	Primary Winding Wire CMA
105	NB			6.00		Bias Turns
106	L_BIAS			1.00		Number of Flyback Bias Winding Layers
107	AWGpBias			40.00		Bias Wire AWG
108	NS	36		36		Secondary Turns
109	AWGS			27.00		Secondary Winding Wire AWG
110	ODS			0.36	mm	Secondary Winding Wire Output Diameter with Insulation
111	DIAS			0.67	mm	Secondary Winding Wire Output Diameter without Insulation
112	CMAS			206.72	Circular Mils/A	Secondary Winding Wire CMA
113	**Primary Components Selection**					
114	**Line Undervoltage**					
115	BROWN_IN_REQUIRED	80.00		80.00	V	Required AC RMS line voltage brown-in threshold
116	RLS			2.00	MOhm	Two Resistors of this Value in Series to the V-pin
117	BROWN_IN_ACTUAL			80.16	V	Actual AC RMS brown-in threshold
118	**Line Overvoltage**					
119	OVERVOLTAGE_LINE			334.21	V	Actual AC RMS line over-voltage threshold
120	**Bias Voltage**					
121	VBIAS			12.0	V	Rectified Bias Voltage
122	VF_BIASDIODE			0.70	V	Bias Winding Diode Forward Drop
123	VRRM_BIASDIODE			49.48	V	Bias diode reverse voltage
124	CBIAS			22.0	µF	Bias winding rectification capacitor
125	CBPP			4.70	µF	BPP pin capacitor
126	**Bulk Capacitor Zener Clamp**					
127	Use_Clamp			Yes		Bulk Capacitor Clamp Needed? Yes, No or N/A
128	VZ1_V			200.00	V	Zener 1 Voltage Rating (In Series with Zener 2)
129	PZ1_W			1.25	W	Zener 1 Minimum Power Rating
130	VZ2_V			200.00	V	Zener 2 Voltage Rating
131	PZ2_W			1.25	W	Zener 2 Minimum Power Rating
132	RZ			4700.00	ohms	Resistor in series with Zener 1 and Zener 2
133	**Secondary Components Selection**					
134	**Feedback Components**					
135	RFB_UPPER			102.00	kOhm	Upper feedback 1% resistor
136	RFB_LOWER			1.65	kOhm	Lower feedback 1% resistor
137	CFB_LOWER			330.0	pF	Lower feedback resistor decoupling at least 5V-rating capacitor
138	CBPS			2.2	µF	BPS pin capacitor
139	**Secondary Auxiliary Section - For VO > 24V ONLY**					
140	**Sec Aux Diode**					
141	VAUX			12.00	V	Rectified auxiliary voltage
142	VF_AUX			0.70	V	Auxiliary winding diode forward drop
143	VRRM_AUXDIODE			49.48	V	Auxiliary diode reverse voltage
144	CAUX			22.00	µF	Auxiliary winding rectification capacitor

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145	NAUX_SEC			6.00		Secondary Aux Turns
146	L_AUX			1.00		Number of Flyback Aux Winding Layers
147	AWGSAUX			38		Secondary Aux Winding AWG
148	**Output Parameters**					
149	VOUT_ACTUAL			80.00	V	Actual Output Voltage
150	IOUT_ACTUAL			0.58	A	Actual Output Current
151	ISECRMS			0.96	A	Secondary RMS current for output
152	**Output Components**					
153	VF			0.70	V	Output diode forward drop
154	VRRM			304.86	V	Output diode reverse voltage
155	COUT			76.32	µF	Output Capacitor - Capacitance
156	COUT_VOpercentRip			2.50	%	Output Capacitor Ripple % of VOUT
157	ICOUTrms			0.77	A	Output Capacitor Estimated Ripple Current
158	ESRmax			720.97	mohms	Output Capacitor Maximum Recommended ESR
159	**Errors, Warnings, Information**					
160	Information					Although the design has passed the user should validate functionality on the bench. Please check the variables listed.
161	Design Warnings			OVERVOLTAGE_LINE		Design variables whose values exceed electrical/datasheet specifications.
162	Design Errors					The list of design variables which result in an infeasible design.

Notes: Row 161 – Actual line overvoltage protection is triggered below the absolute maximum V_{DS} rating of the LYTSwitch-6 IC.

10 Performance Data

All measurements were performed at room temperature.

10.1 *Output Current Regulation*

Set-up: Open frame unit
Load: 580 mA, varying voltage LED load
Ambient Temperature: 25 ºC
Soak Time: 60 seconds

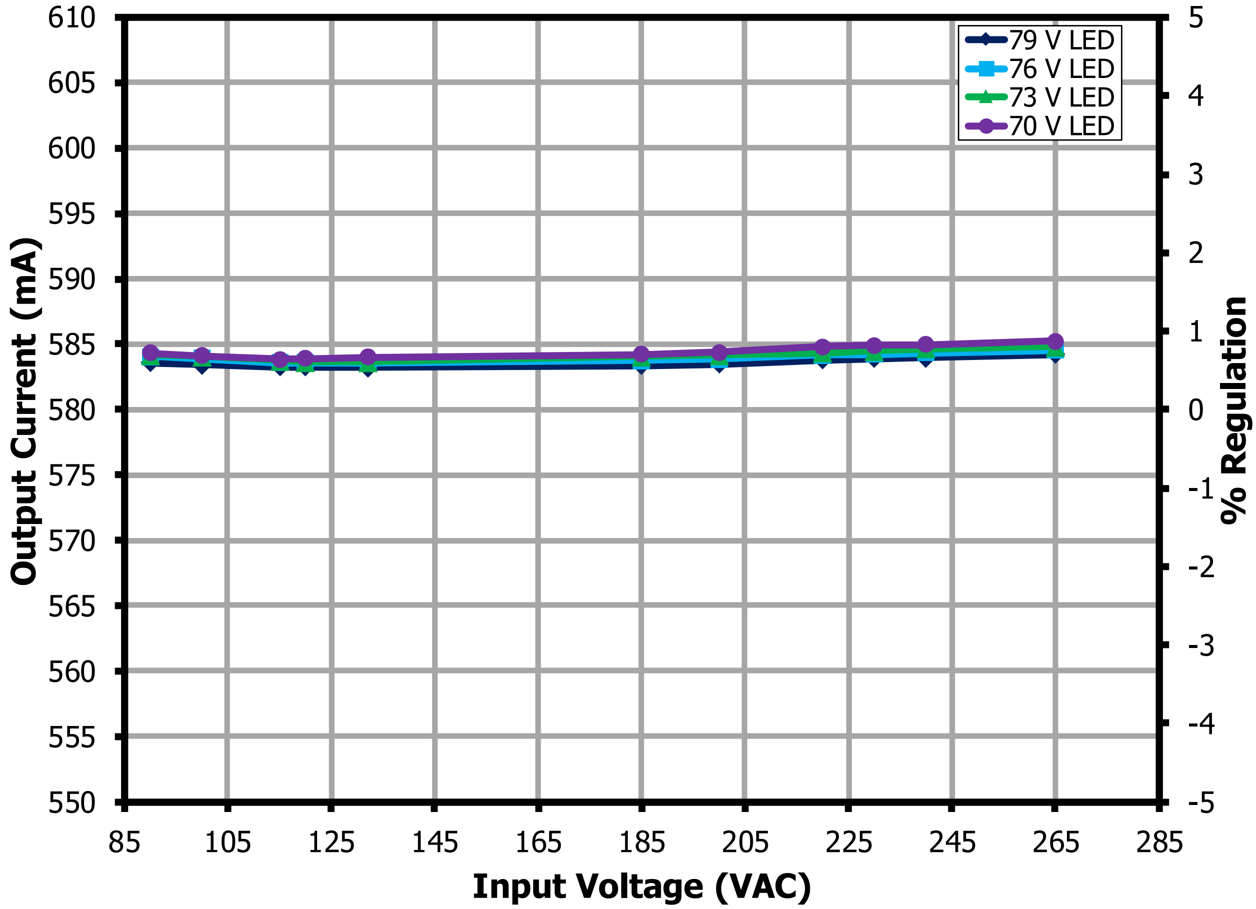

Figure 11 – Output Current Regulation vs. Input Line Voltage.

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10.2 *System Efficiency*

Set-up: Open frame unit
Load: 580 mA, varying voltage LED load
Ambient Temperature: 25 ºC
Soak Time: 60 seconds

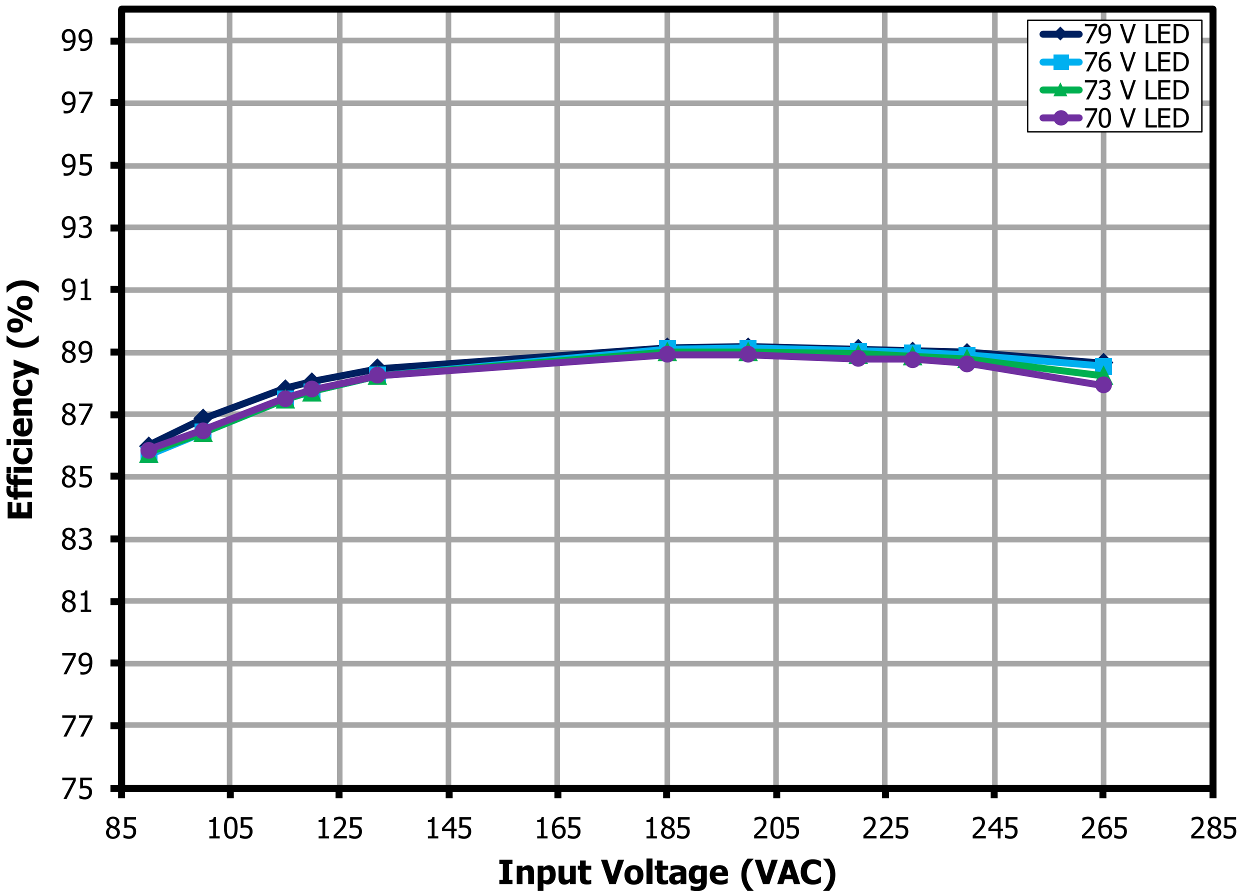

Figure 12 – Efficiency vs. Input Line Voltage.

10.3 *Power Factor*

Set-up: Open frame unit
Load: 580mA, varying voltage LED load
Ambient Temperature: 25 ºC
Soak Time: 60 seconds

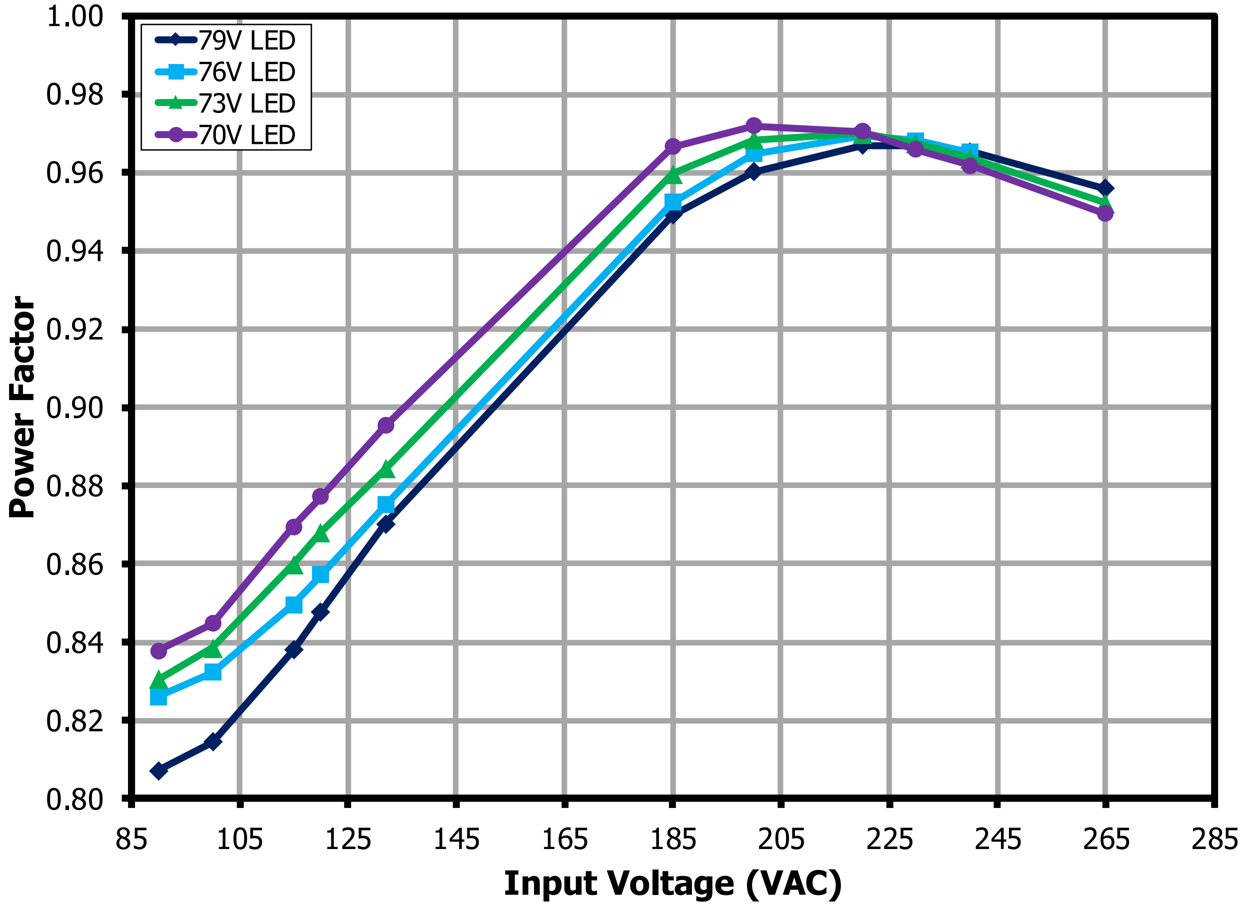

Figure 13 – Power Factor vs. Input Line Voltage.

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10.4 *%ATHD*

Set-up: Open frame unit
Load: 580 mA, varying voltage LED load
Ambient Temperature: 25 ºC
Soak Time: 60 seconds

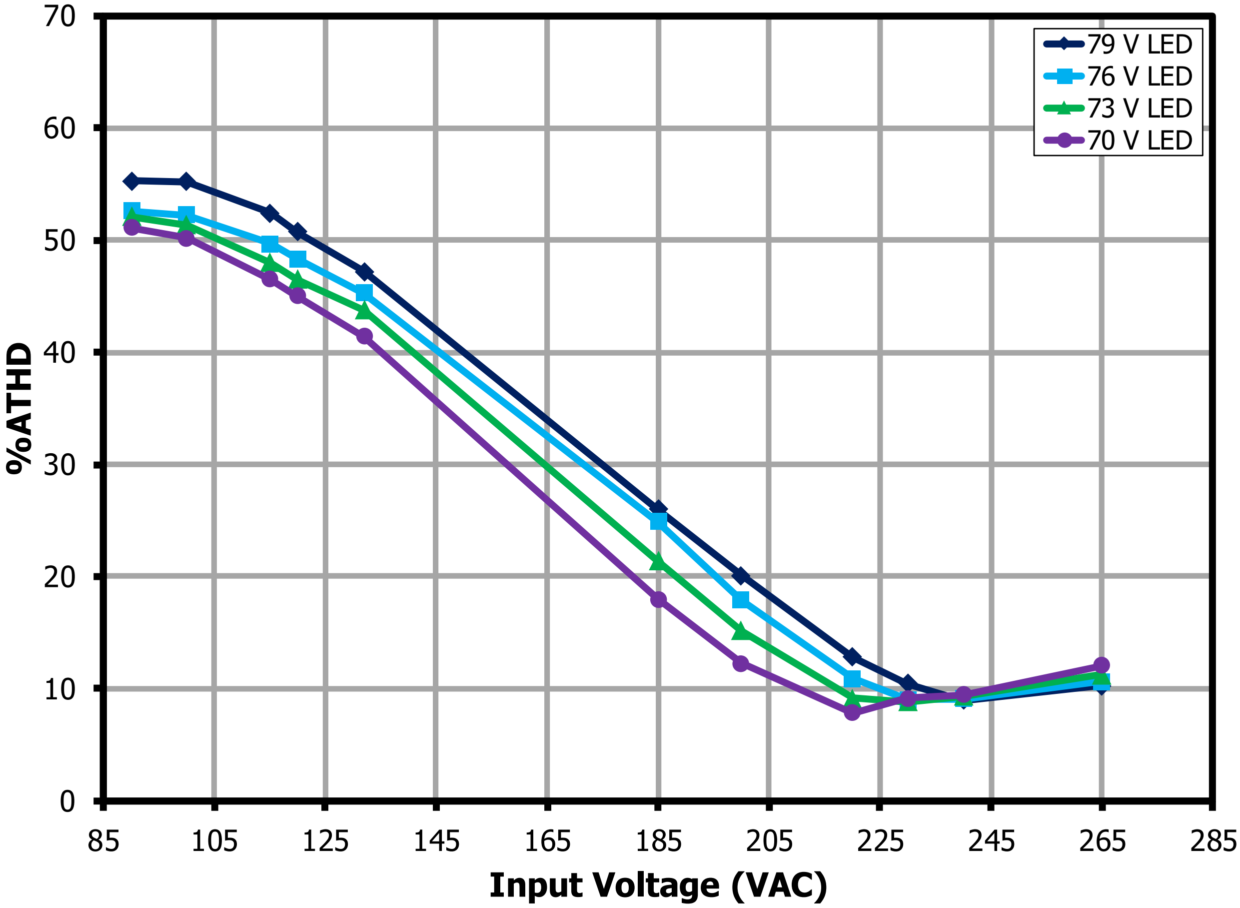

Figure 14 – %ATHD vs. Input Line Voltage.

10.5 *Individual Harmonics Content at Full Load*

Set-up: Open frame unit
Load: 80 V 580 mA LED load
VIN: 230 V 50 Hz
Ambient Temperature: 25 ºC
Soak Time: 60 seconds

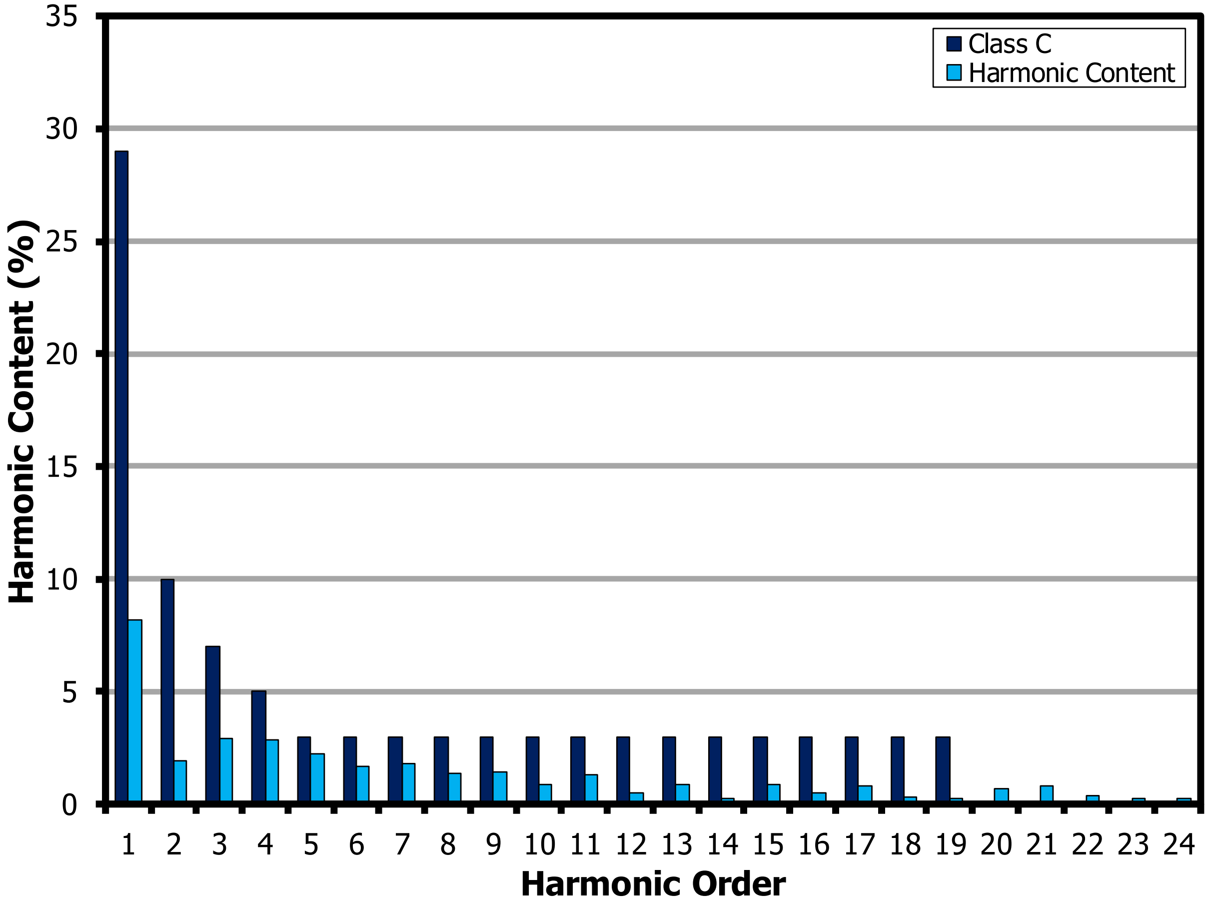

Figure 15 – Full Load Input Current Harmonics at 230 VAC 50 Hz.

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10.6 ***No-Load Input Power***

Set-up: Open frame unit
Load: Open load
Ambient Temperature: 25 ºC
Soak Time: 60 seconds

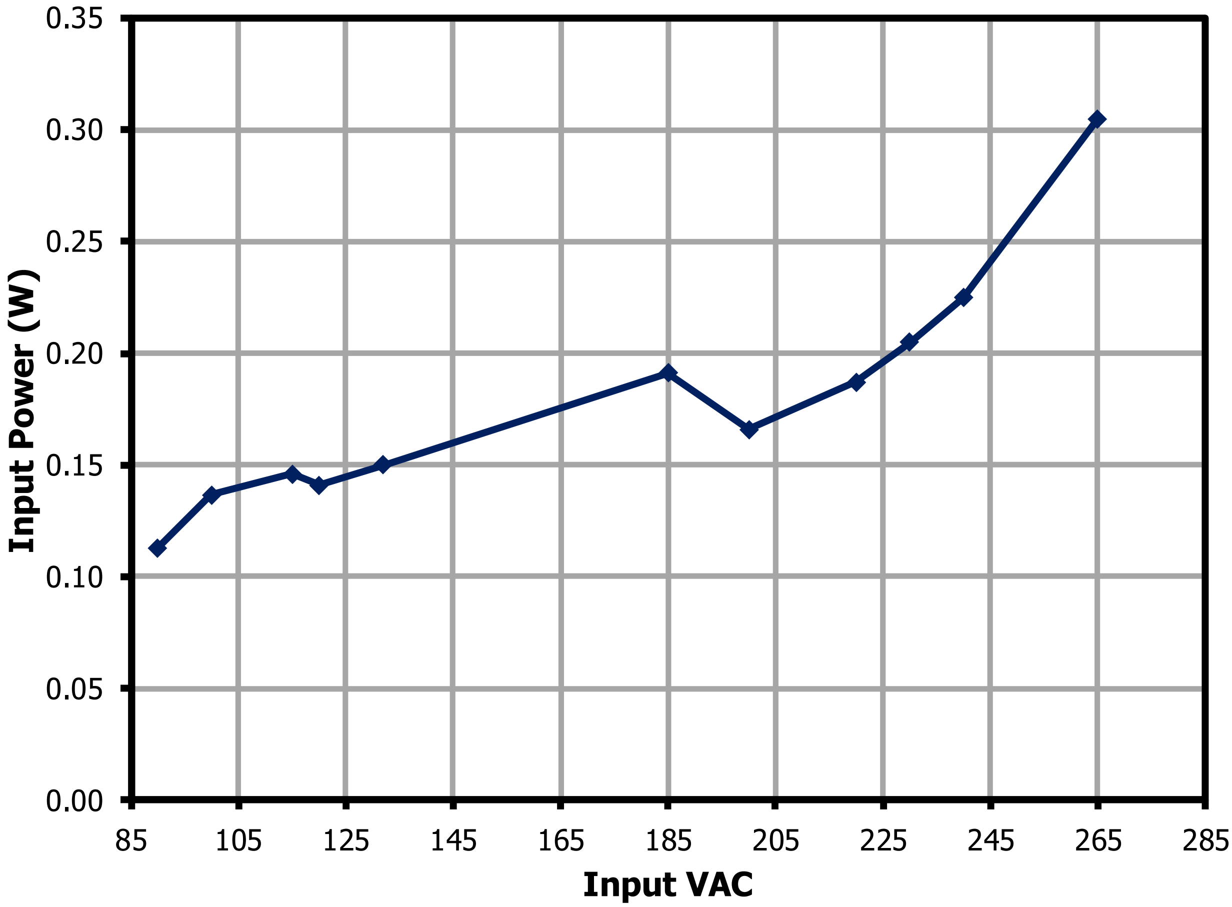

Figure 16 – No-Load Input Power vs. Input Line Voltage.

10.7 *CV/CC Curve*

Set-up: Open frame unit
Load: E-load in CR mode
Ambient Temperature: 25 ºC

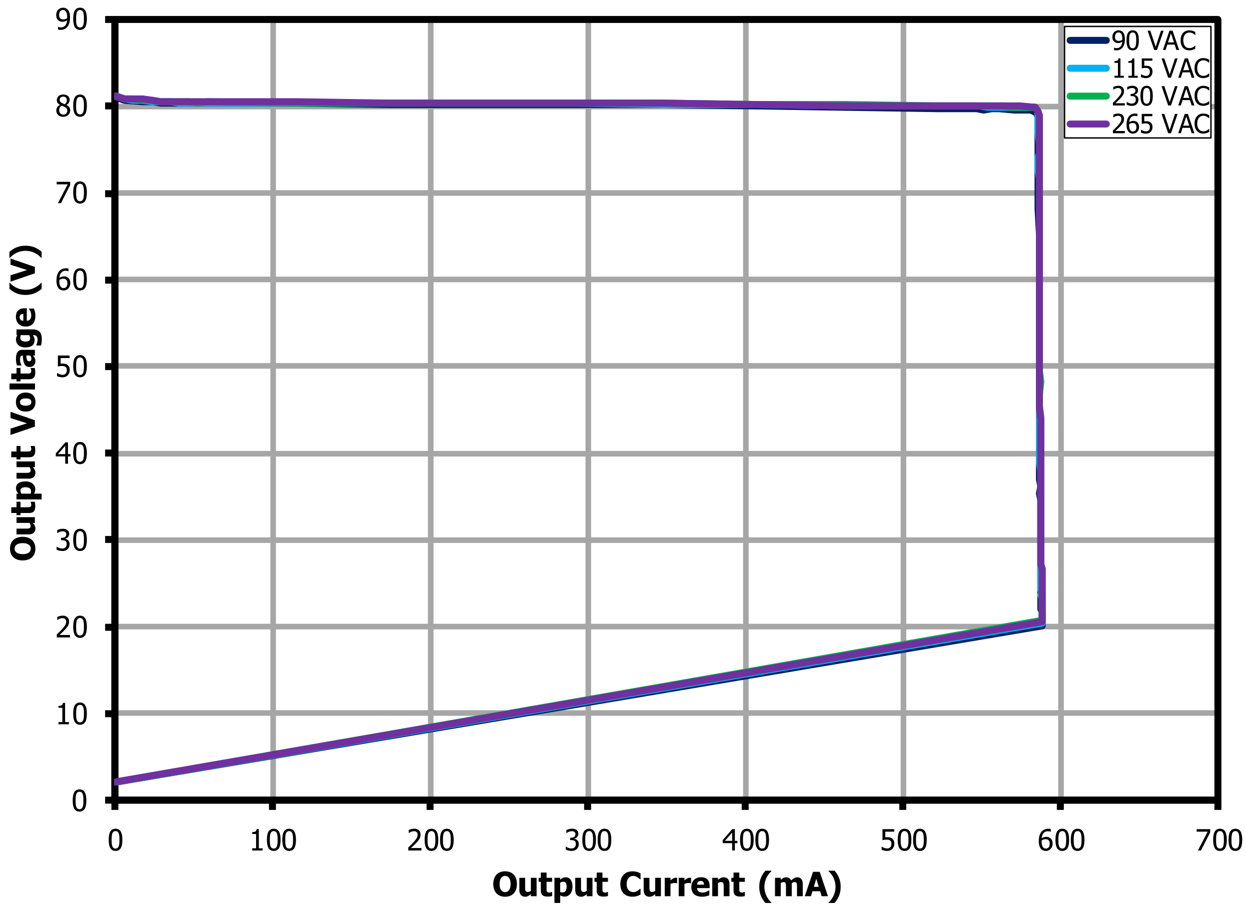

Figure 17 – CV/CC Curve.

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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	89.90	737.70	53.54	0.807	55.33	78.89	583.61	46.04	85.99
100	60	99.96	650.30	52.95	0.815	55.22	78.84	583.40	45.99	86.86
115	60	114.97	543.10	52.33	0.838	52.40	78.80	583.24	45.95	87.82
120	60	119.94	513.10	52.16	0.848	50.76	78.75	583.27	45.93	88.06
132	60	131.96	451.70	51.88	0.870	47.19	78.71	583.22	45.90	88.48
185	50	184.97	293.20	51.48	0.949	26.00	78.67	583.37	45.89	89.15
200	50	199.98	267.90	51.45	0.960	20.05	78.63	583.50	45.88	89.18
220	50	219.97	242.10	51.49	0.967	12.78	78.59	583.78	45.88	89.11
230	50	230.00	231.60	51.52	0.967	10.42	78.56	583.92	45.87	89.04
240	50	239.96	222.50	51.54	0.965	8.96	78.53	583.97	45.86	88.98
265	50	265.02	204.20	51.74	0.956	10.22	78.51	584.25	45.86	88.65

11.2 *Test Data at No-Load*

Input		Input Measurement				
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD
90	60	89.95	15.45	0.11	0.085	57.04
100	60	99.99	15.55	0.14	0.095	67.51
115	60	115.00	15.16	0.15	0.090	55.94
120	60	119.98	14.84	0.14	0.080	62.54
132	60	131.98	14.69	0.15	0.080	46.32
185	50	184.99	13.97	0.21	0.084	52.45
200	50	200.00	13.97	0.19	0.068	46.26
220	50	219.99	14.63	0.21	0.064	40.27
230	50	230.02	15.08	0.22	0.064	33.05
240	50	239.98	15.53	0.25	0.066	38.65
265	50	265.04	16.64	0.33	0.075	35.16

11.3 *Individual Harmonic Content at 230 VAC 50 Hz and Full Load*

V	Freq	I (mA)	P	PF	%THD
230	50.00	231.60	51.52	0.9670	10.43
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**
1	227.90				
2	0.30	0.13%		2.00%	Pass
3	18.70	8.21%	175.1680	29.01%	Pass
5	4.30	1.89%	97.8880	10.00%	Pass
7	6.70	2.94%	51.5200	7.00%	Pass
9	6.50	2.85%	25.7600	5.00%	Pass
11	5.10	2.24%	18.0320	3.00%	Pass
13	3.80	1.67%	15.2578	3.00%	Pass
15	4.10	1.80%	13.2235	3.00%	Pass
17	3.10	1.36%	11.6678	3.00%	Pass
19	3.30	1.45%	10.4396	3.00%	Pass
21	1.90	0.83%	9.4453	3.00%	Pass
23	2.90	1.27%	8.6240	3.00%	Pass
25	1.10	0.48%	7.9341	3.00%	Pass
27	2.00	0.88%	7.3464	3.00%	Pass
29	0.60	0.26%	6.8397	3.00%	Pass
31	2.00	0.88%	6.3985	3.00%	Pass
33	1.10	0.48%	6.0107	3.00%	Pass
35	1.80	0.79%	5.6672	3.00%	Pass
37	0.70	0.31%	5.3609	3.00%	Pass
39	0.60	0.26%	5.0859	3.00%	Pass
41	1.50	0.66%			
43	1.80	0.79%			
45	0.90	0.39%			
47	0.50	0.22%			
49	0.50	0.22%			

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12 Load Regulation Performance

Set-up: Open frame unit
Load: CC load
Ambient Temperature: 25 ºC (room temp)

12.1 ***Output Voltage Load Regulation***

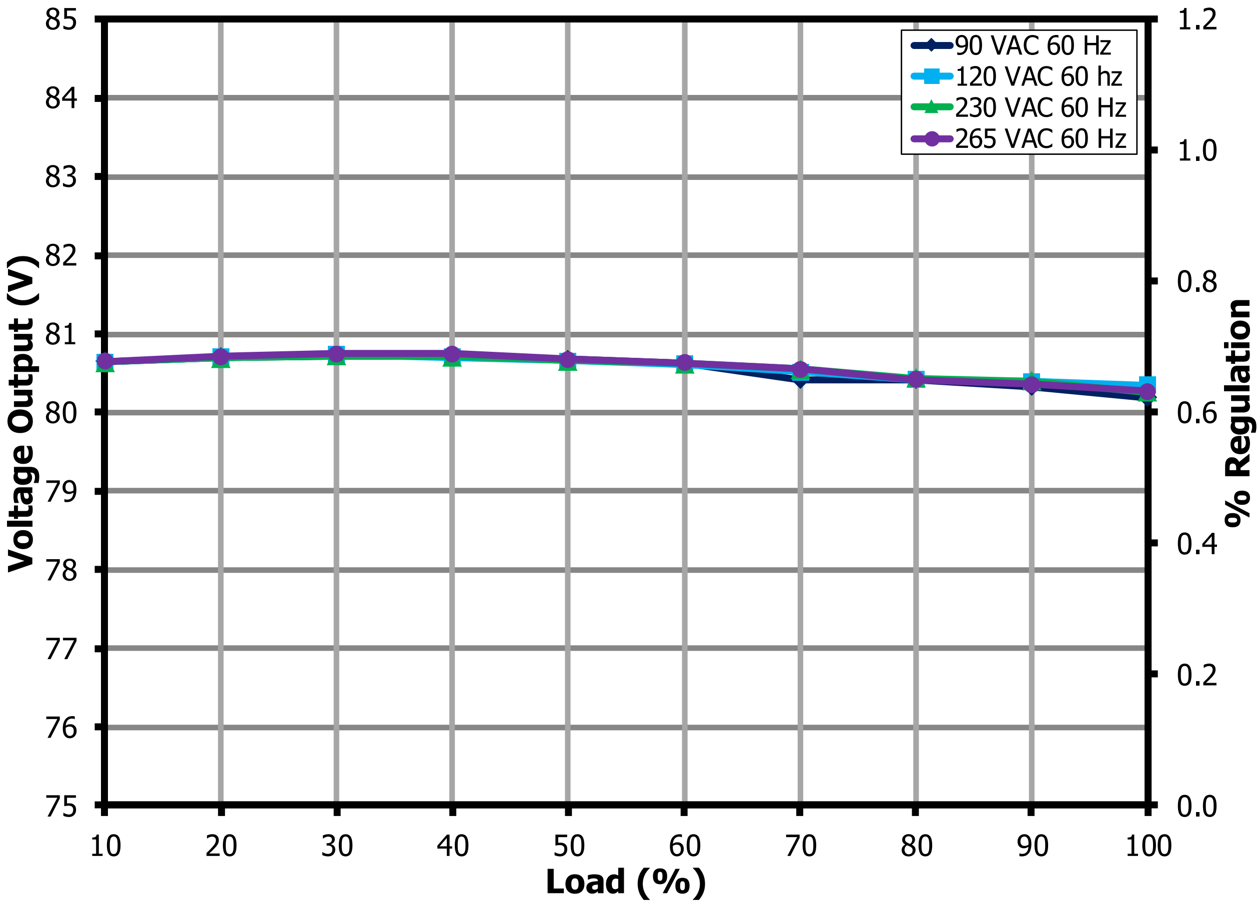

Figure 18 – Output Voltage vs. Load.

12.2 *Efficiency vs. Load*

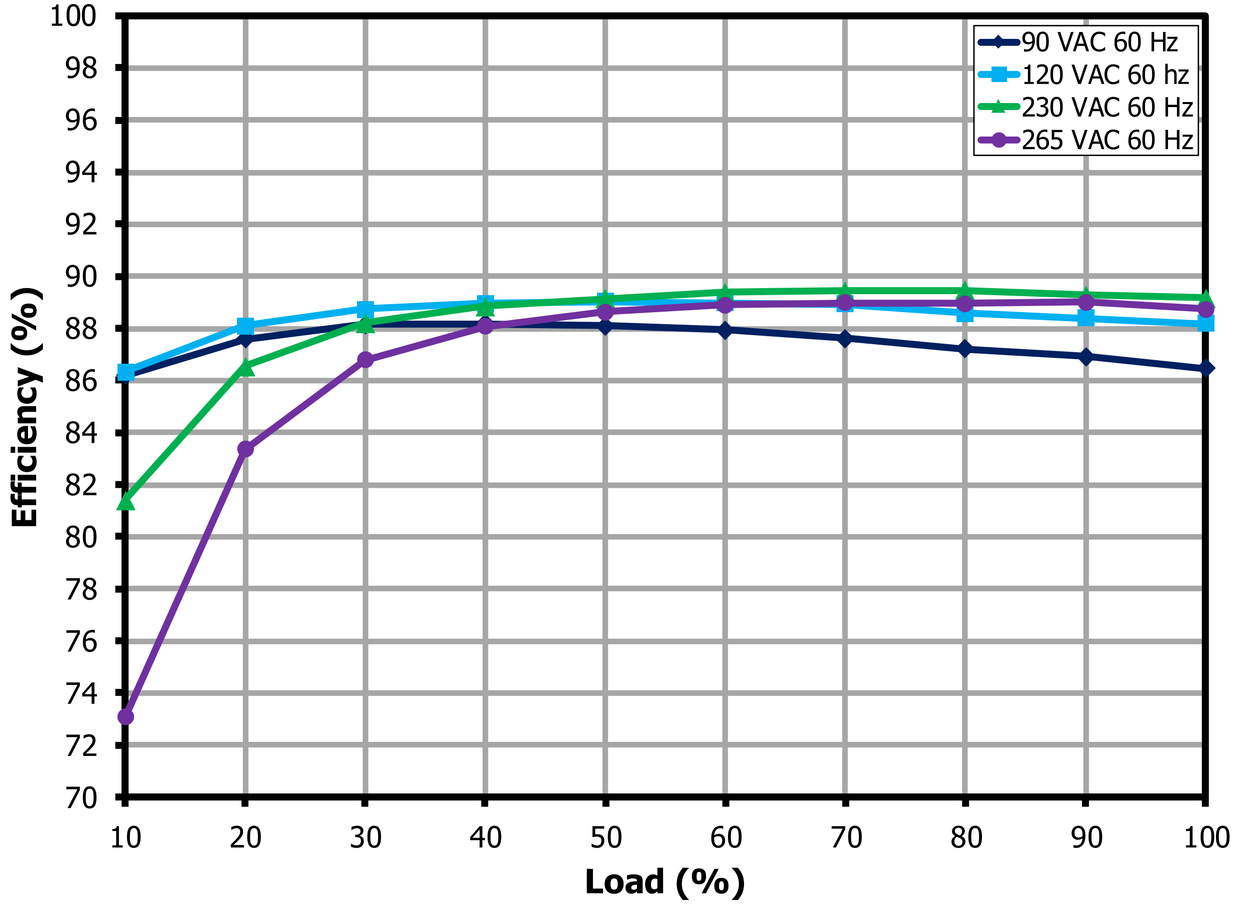

Figure 19 – Efficiency vs Load.

12.3 *Average Efficiency*

12.3.1 Average Efficiency Measurement

%Load	Efficiency (%)	
	115 V / 60 Hz	230 V / 60 Hz
100	88.17	89.21
75	88.70	89.52
50	88.99	89.28
25	88.42	87.69
Average Efficiency	88.92	88.57
DOE Level VI Limit	**80.93**	

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12.4 ***Power Factor vs. Load***

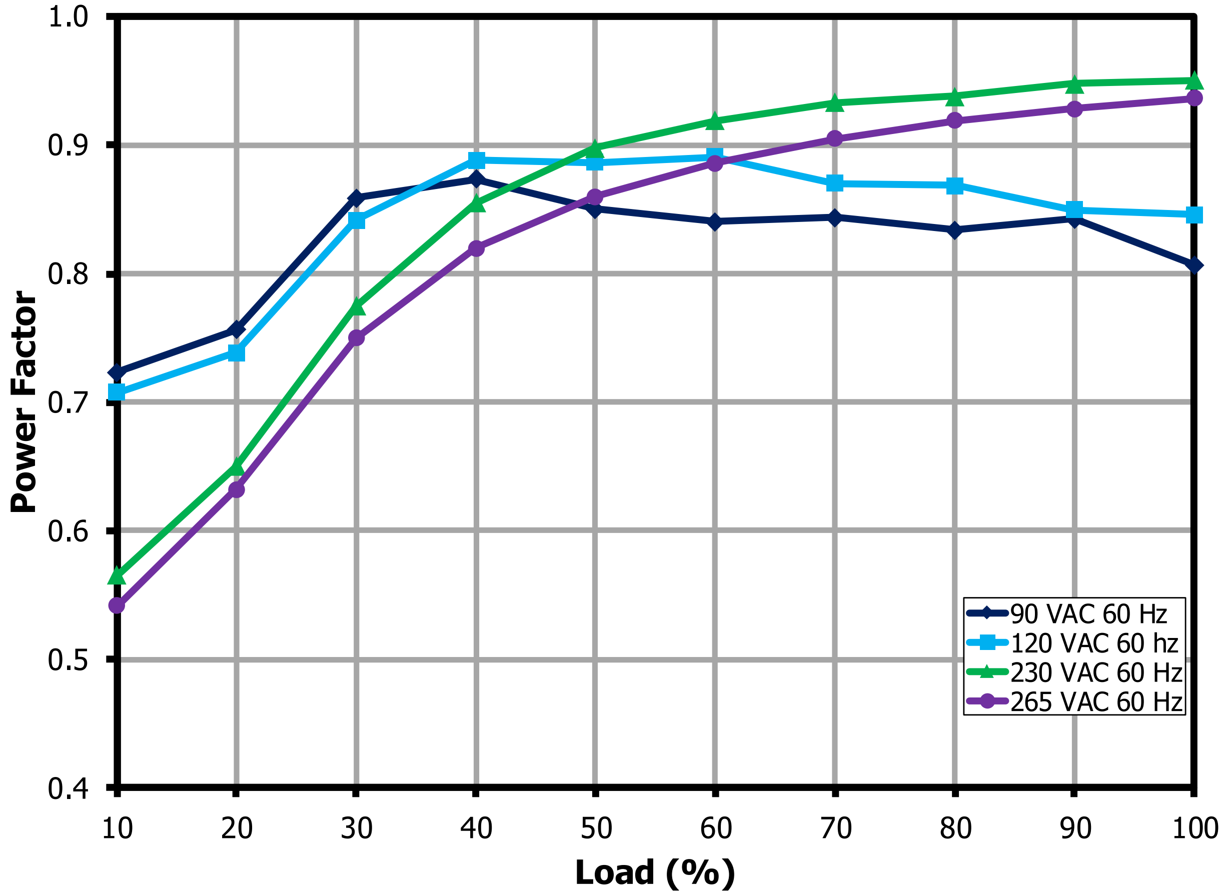

Figure 20 – Power Factor vs. Load.

12.5 *% ATHD vs. Load*

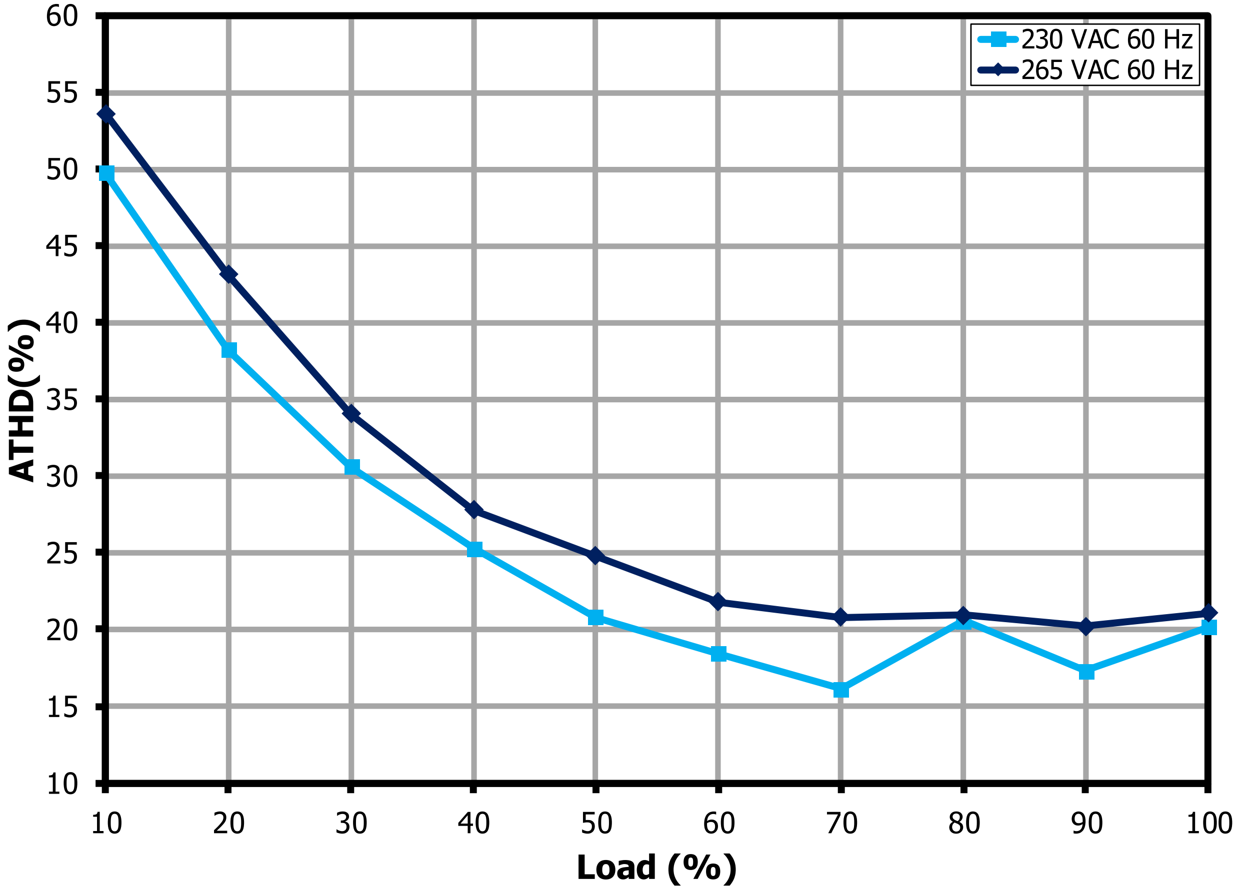

Figure 21 – Power Factor vs. Load.

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13 Thermal Performance

13.1 *Thermal Measurements at Room Temp Ambient*

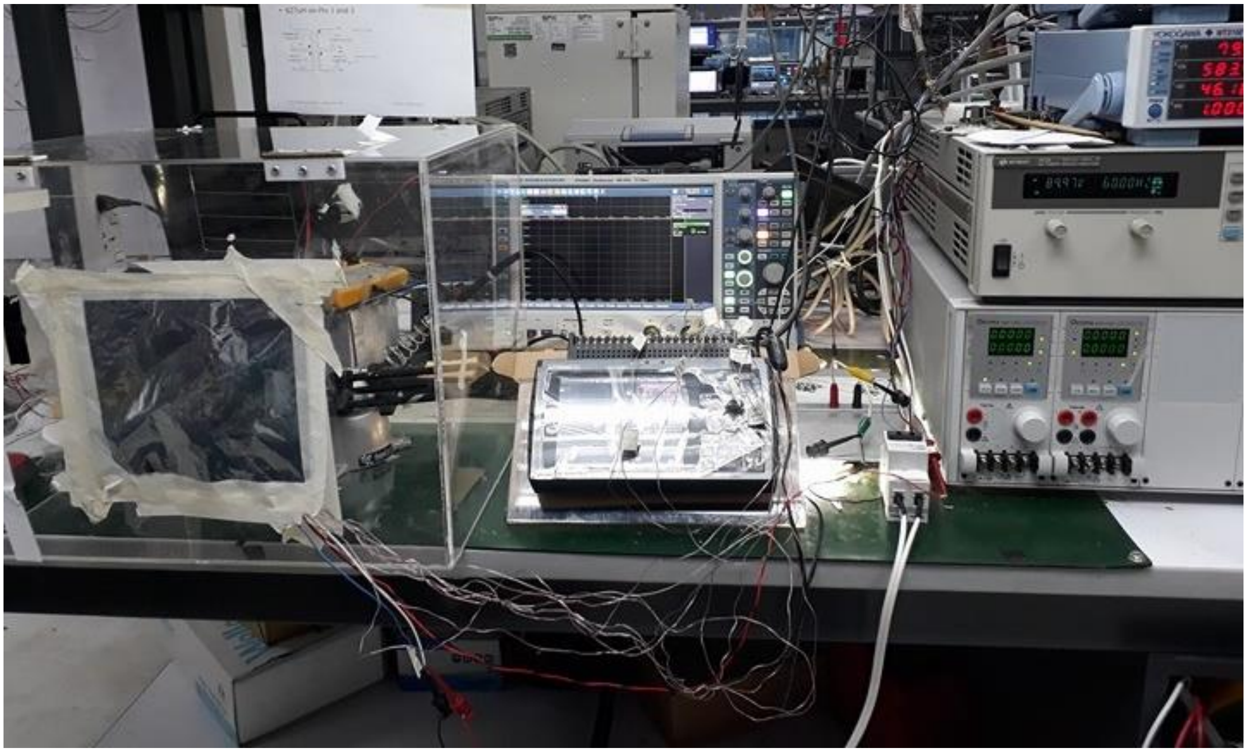

Figure 22 – Test Set-up Picture - Open Frame.

Unit in open frame was placed inside the acrylic enclosure to prevent airflow that might affect the thermal measurements. Temperature was measured using T-type thermocouple.

Equipment used:

1. KEYSIGHT 6812B AC Power Source/Analyzer
2. Chroma 6314A DC Electronic Load Mainframe and Chroma 63110A DC Electronic Load
3. Graphtec GL820 Data Logger
4. Yokogawa WT310E Digital Power Meter
5. CADWILL Step-up Transformer (for Inputs >300 VAC)

Ref Des	Description	Thermal Reading at Room Temperature	
		120 VAC	230 VAC
U4	LYTSwitch-6 IC	94.2	89.6
D8	Primary Snubber Diode	44.5	44.2
T1	PFC Inductor	61.6	64.2
T2	DCDC TRF Primary	74	71.3
D1	PFC Diode	60.1	55.9
D17	PFC Diode	64.4	59.6
D10	Output Diode	81.5	74.2
R48	Secondary Snubber Resistor	78.4	73.1
AMBIENT		25.9	22.5

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13.2 *Thermal Performance at High Temperature Ambient*

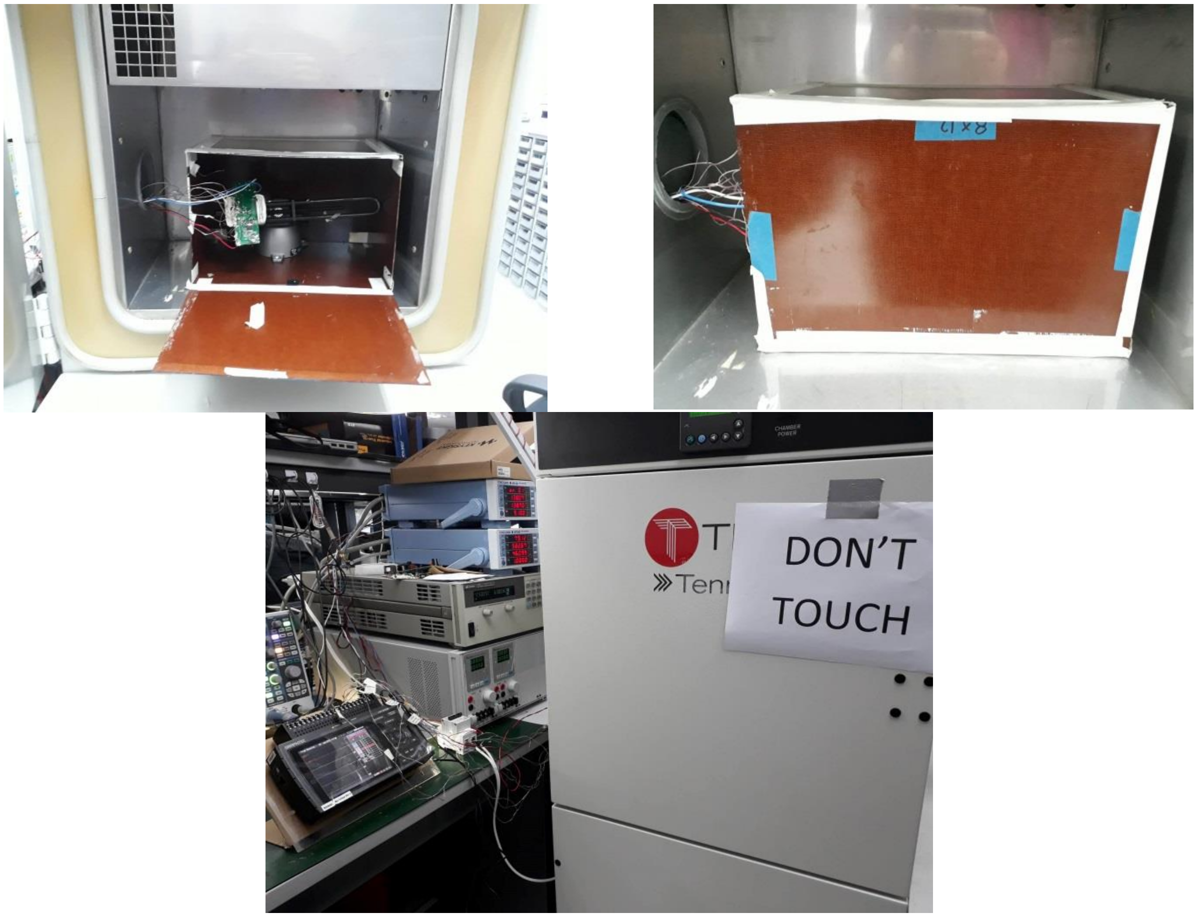

Figure 23 – Test Set-up Picture Thermal at 60 ºC Ambient - Open Frame.

Open frame unit was placed inside the enclosure to prevent airflow that may affect the thermal measurements. Ambient temperature inside enclosure is set at 60 ºC. Temperature was measured using T-type thermocouple. Soak time at full load is more than 1 hour.

Equipment used:

1. KEYSIGHT 6812B AC Power Source/Analyzer
2. Chroma 6314A DC Electronic Load Mainframe and Chroma 63110A DC Electronic Load
3. Graphtec GL820 Data Logger
4. Yokogawa WT310E Digital Power Meter
5. SPX Tenney TUJR Thermal Chamber
6. CADWILL Step-up Transformer (for Inputs >300 VAC)

Ckt. Code	Description	Thermal Reading at High Temp	
		120 VAC	230 VAC
U4	LYTSwitch-6 IC	132.4	127.9
D8	Primary Snubber Diode	63	56.5
T1	PFC Inductor	91.4	98.5
T2	DCDC TRF Primary	104.5	102.7
D1	PFC Diode	88.8	88.4
D17	PFC Diode	95.3	90.9
D10	Output Diode	114	103.8
R48	Secondary Snubber Resistor	110.9	103.5
AMBIENT		60.2	57.9

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14 **Waveforms**

Waveforms were taken at room temperature (25 ºC).

14.1 ***Input Voltage and Input Current at Full Load***

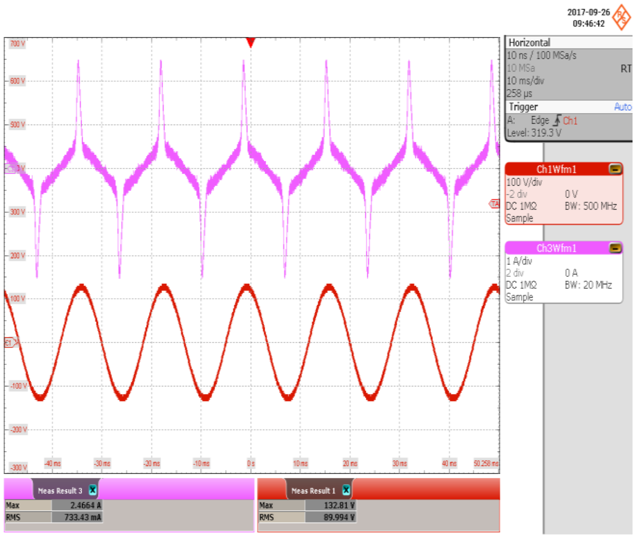

Figure 24 – 90 VAC 50 Hz, Full Load.
Upper: I_{IN}, 1 A / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

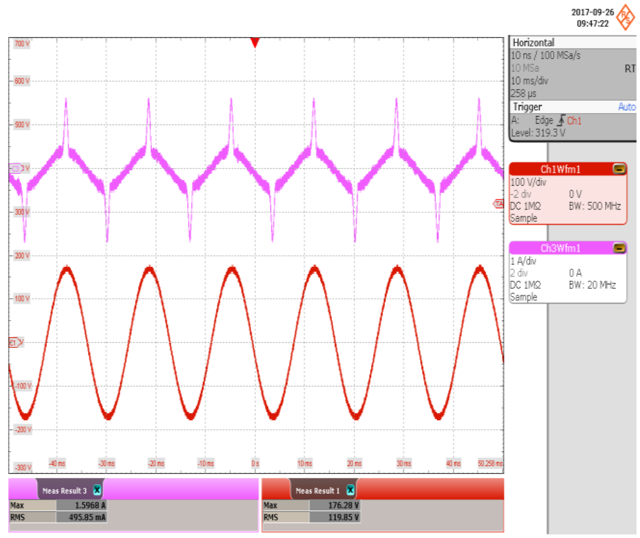

Figure 25 – 120 VAC 50 Hz, Full Load.
Upper: I_{IN}, 1 A / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

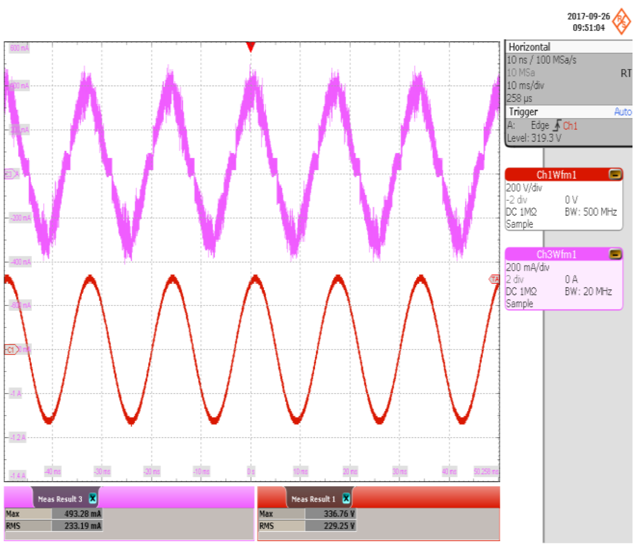

Figure 26 – 230 VAC 50 Hz, Full Load.
Upper: I_{IN}, 200 mA / div.
Lower: V_{IN}, 200 V / div., 10 ms / div.

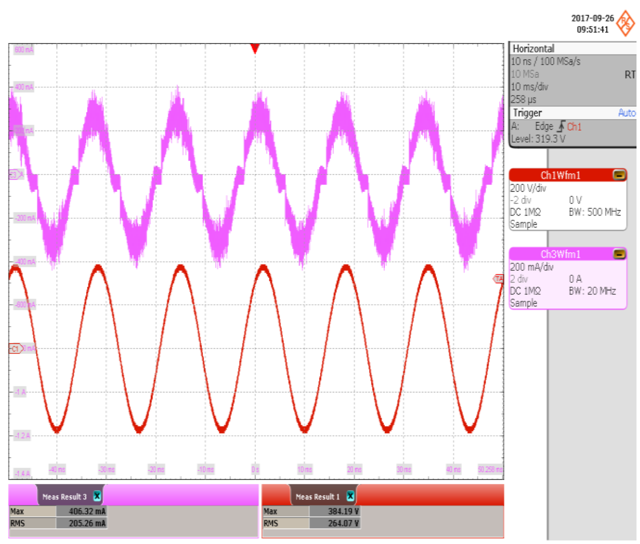

Figure 27 – 265 VAC 50 Hz, Full Load.
Upper: I_{IN}, 200 mA / div.
Lower: V_{IN}, 200 V / div., 10 ms / div.

14.2 *Start-up Profile at Full Load*

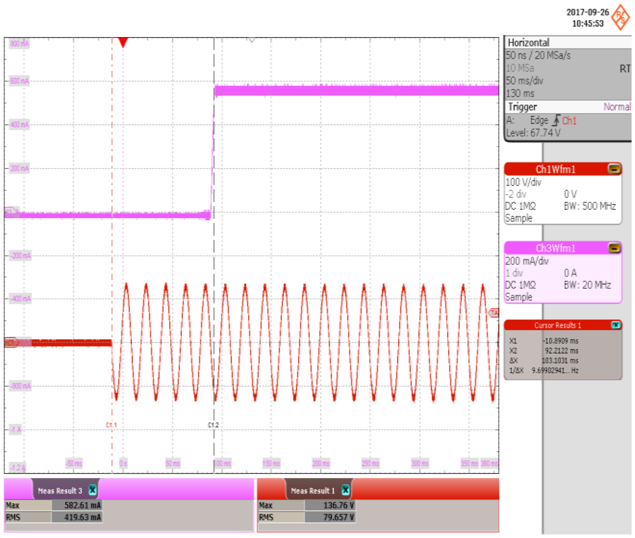

Figure 28 – 90 VAC 50 Hz, Full Load Start-up.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Turn-on Time: 103 ms.

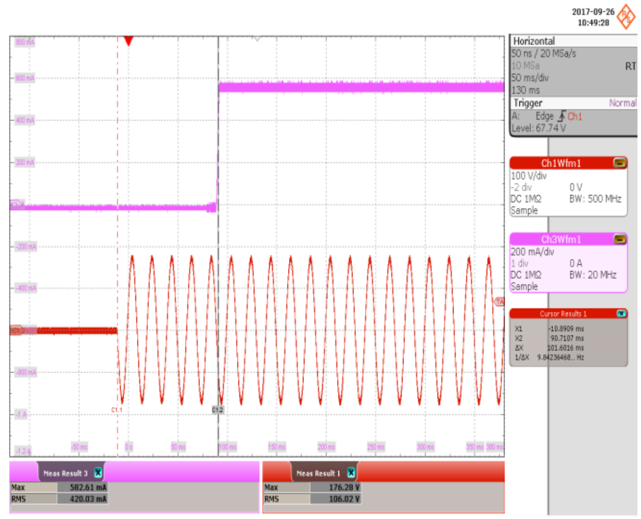

Figure 29 – 120 VAC 50 Hz, Full Load Start-up.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Turn-on Time: 101 ms.

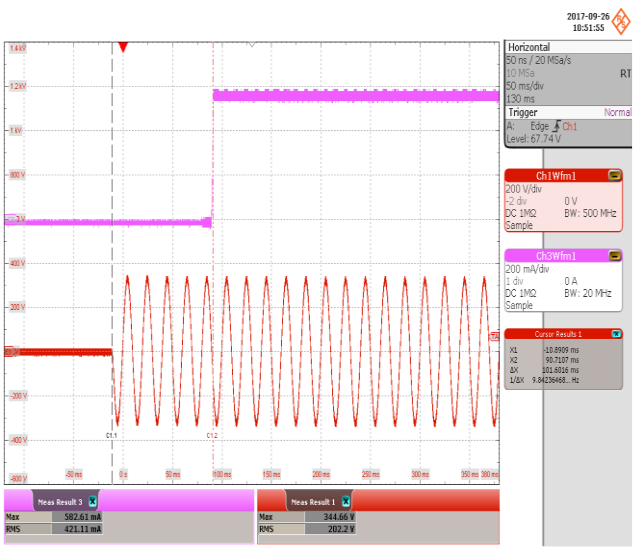

Figure 30 – 230 VAC 50 Hz, Full Load Start-up.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 200 V / div., 50 ms / div.
Turn-on Time: 101 ms.

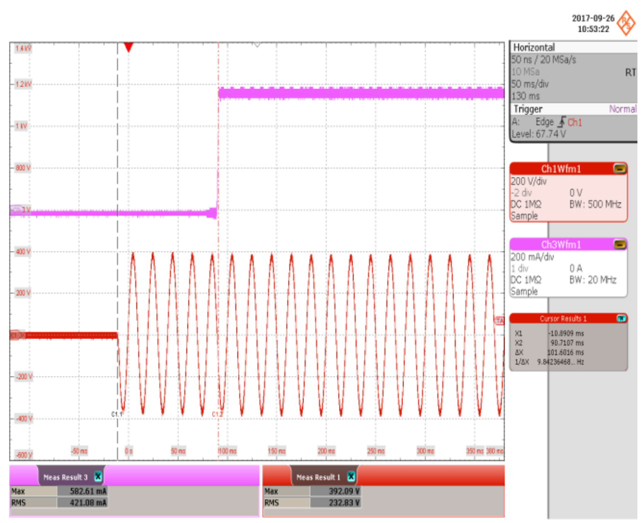

Figure 31 – 265 VAC 50 Hz, Full Load Start-up.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Turn-on Time: 101 ms.

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14.3 *Output Current Fall*

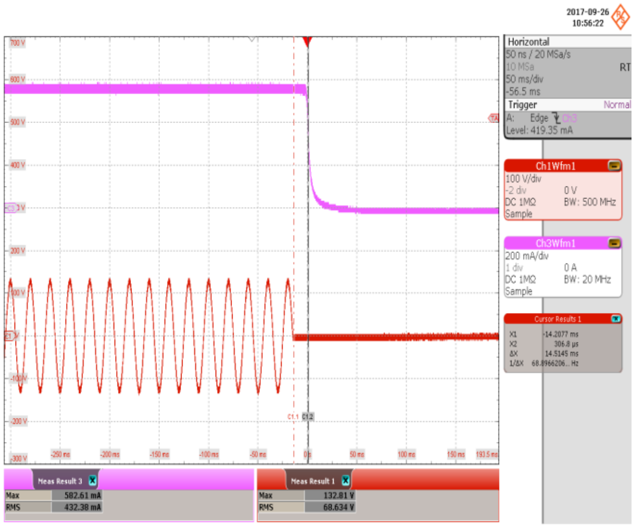

Figure 32 – 90 VAC 50 Hz, Full Load, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold-Up Time: 14 ms.

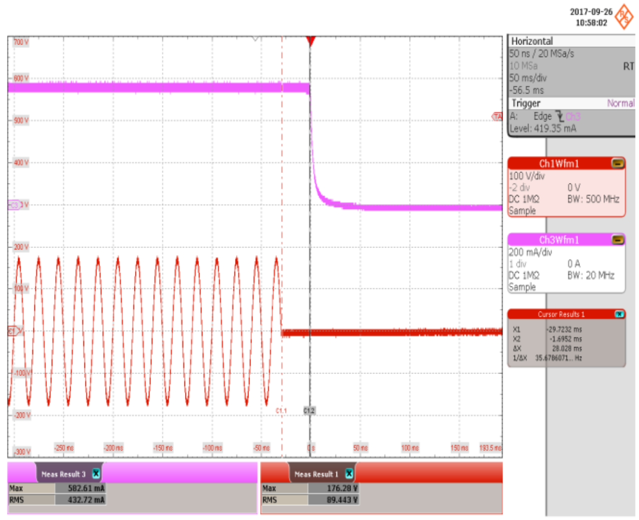

Figure 33 – 120 VAC 50 Hz, Full Load, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold-Up Time: 28 ms.

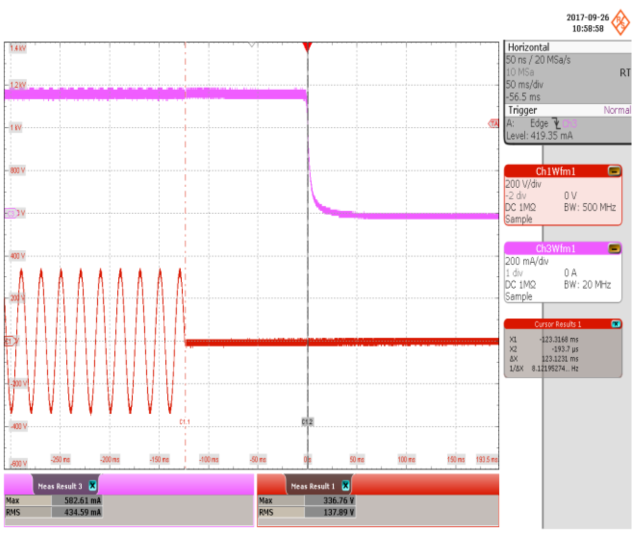

Figure 34 – 230 VAC 50 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 200 mA / div.
Lower: V_{IN}, 200 V / div., 50 ms / div.
Hold-Up Time: 123 ms.

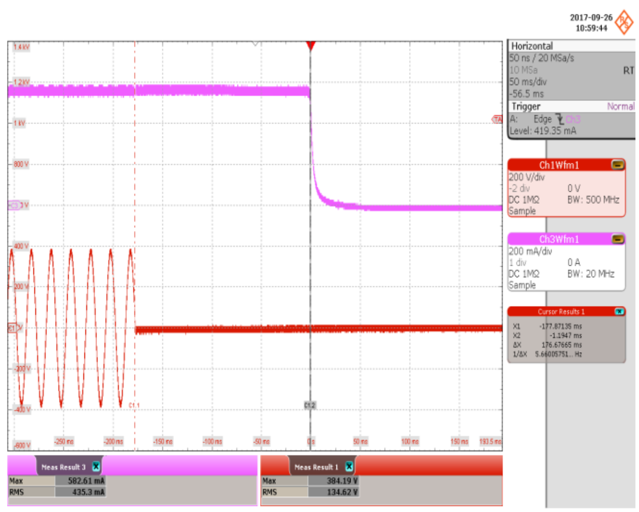

Figure 35 – 265 VAC 50 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold-Up Time: 196.5 ms.

14.4 *Load Transient Response 100 Hz*

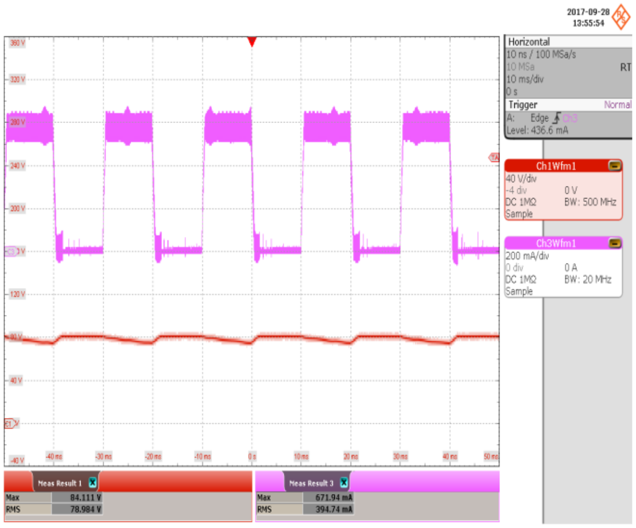

Figure 36 – 90 VAC 50 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 40 V / div., 10 ms / div.

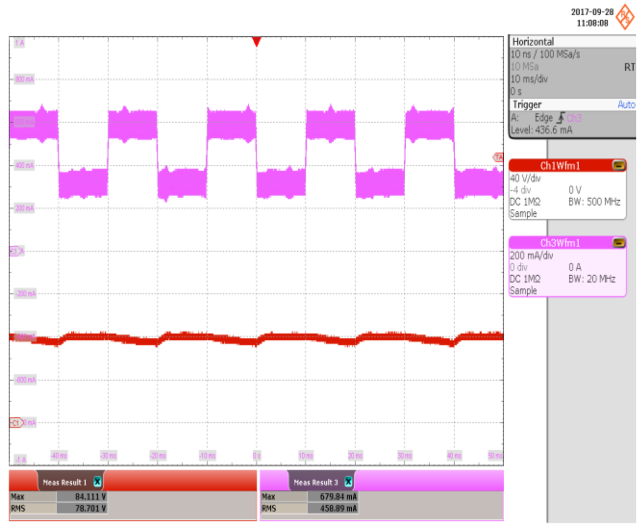

Figure 37 – 90 VAC 50 Hz.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 40 V / div., 10 ms / div.

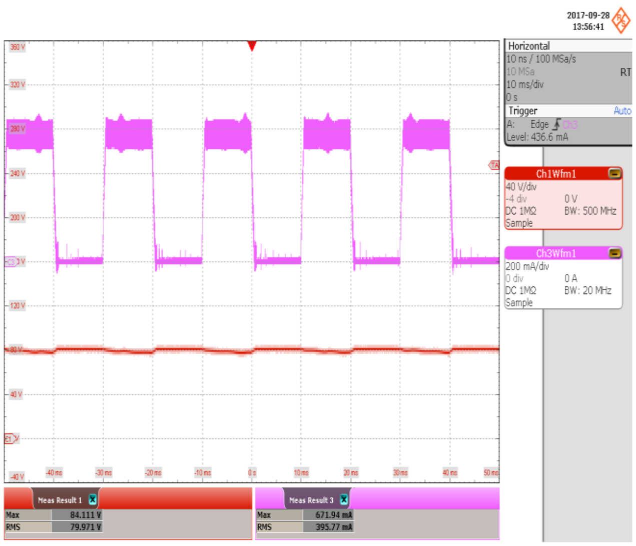

Figure 38 – 120 VAC 50 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 40 V / div., 10 ms / div.

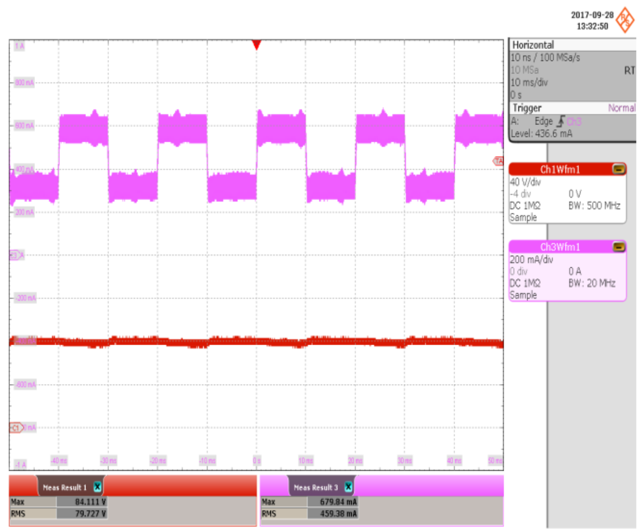

Figure 39 – 120 VAC 50 Hz.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 40 V / div., 10 ms / div.

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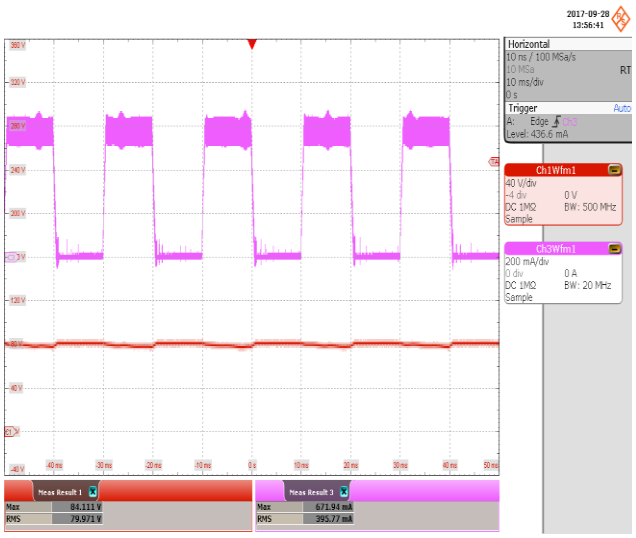

Figure 40 – 230 VAC 50 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 40 V / div., 10 ms / div.

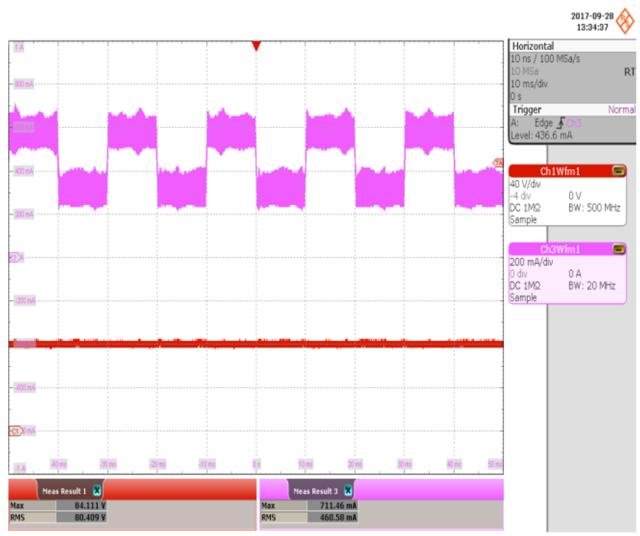

Figure 41 – 230 VAC 50 Hz.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 40 V / div., 10 ms / div.

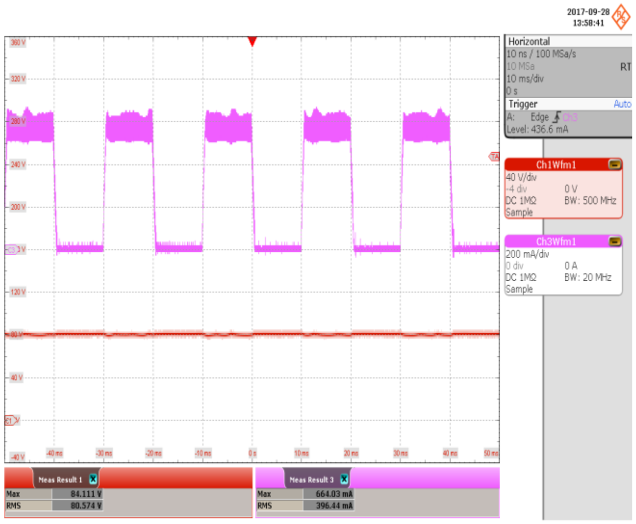

Figure 42 – 265 VAC 50 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / μs.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 40 V / div., 10 ms / div.

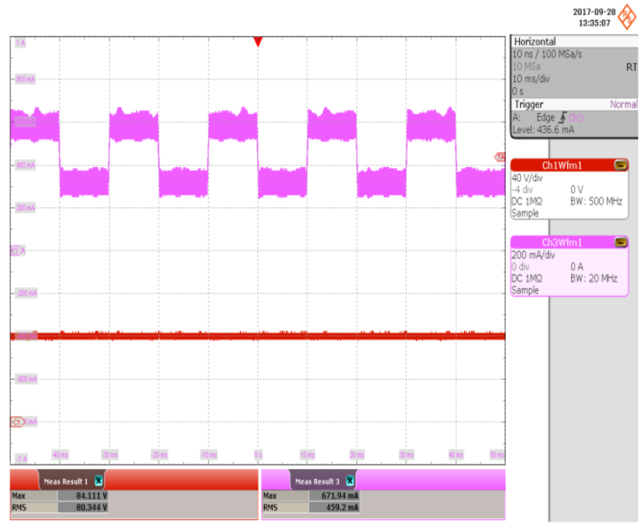

Figure 43 – 265 VAC 50 Hz.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / μs.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 40 V / div., 10 ms / div.

14.5 *LYTSwitch-6 Drain Voltage and Current Waveforms at Normal Operation*

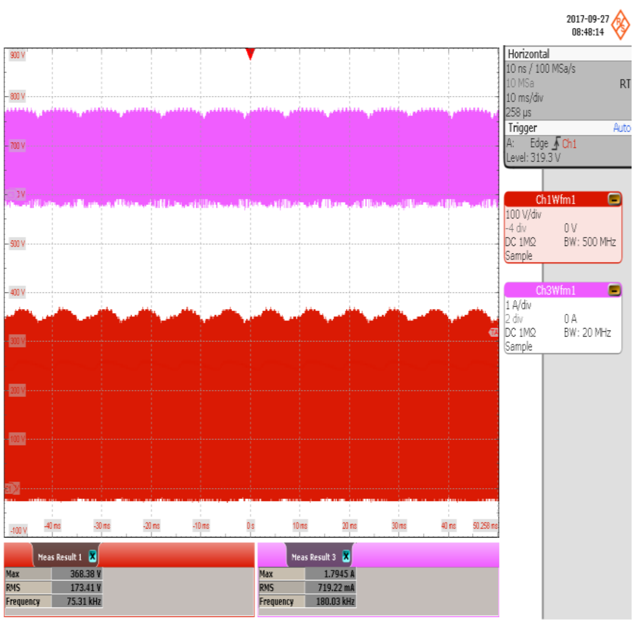

Figure 44 – 90 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 ms / div.

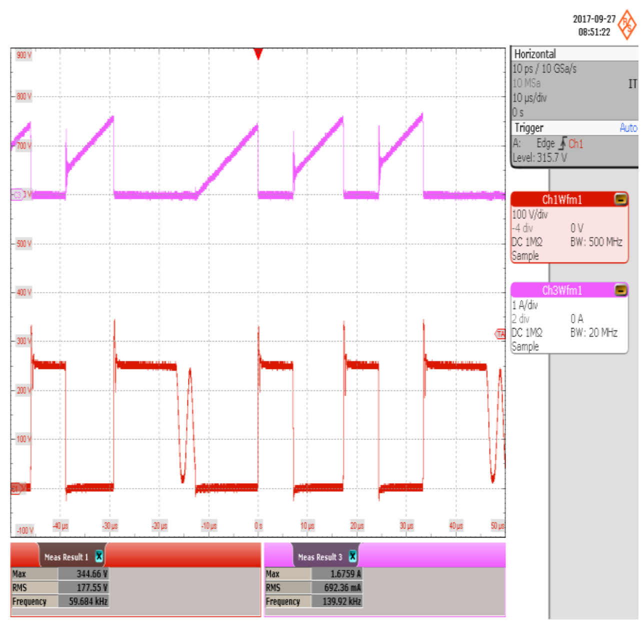

Figure 45 – 90 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.

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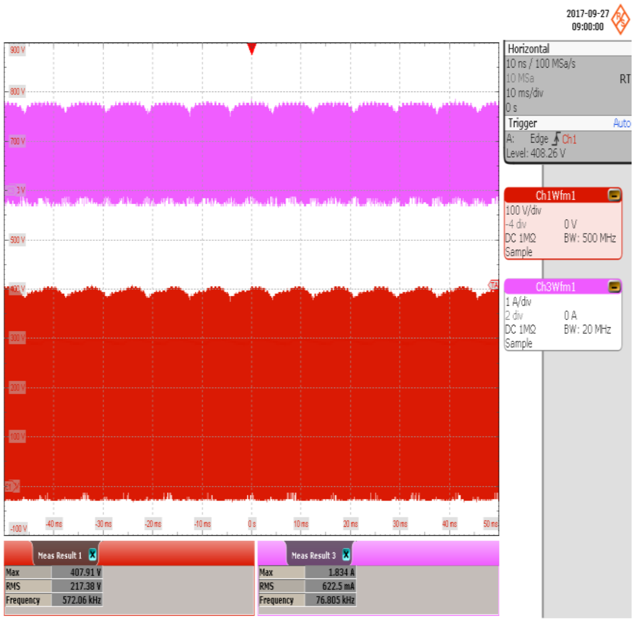

Figure 46 – 120 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 ms / div.

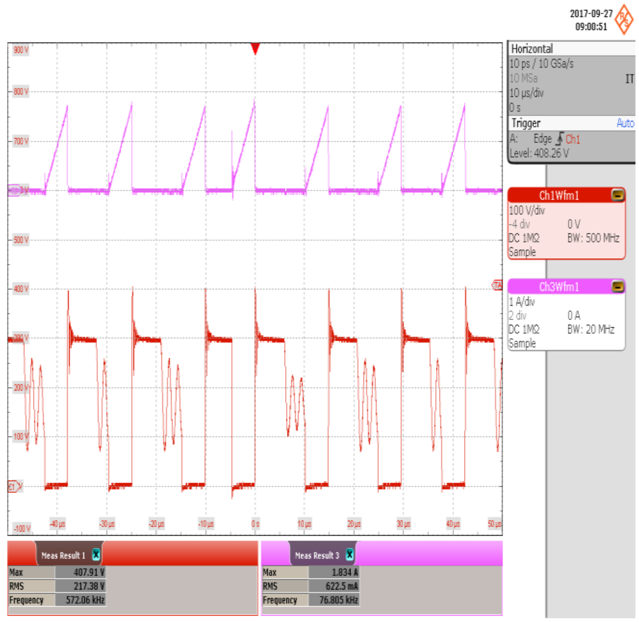

Figure 47 – 120 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 µs / div.

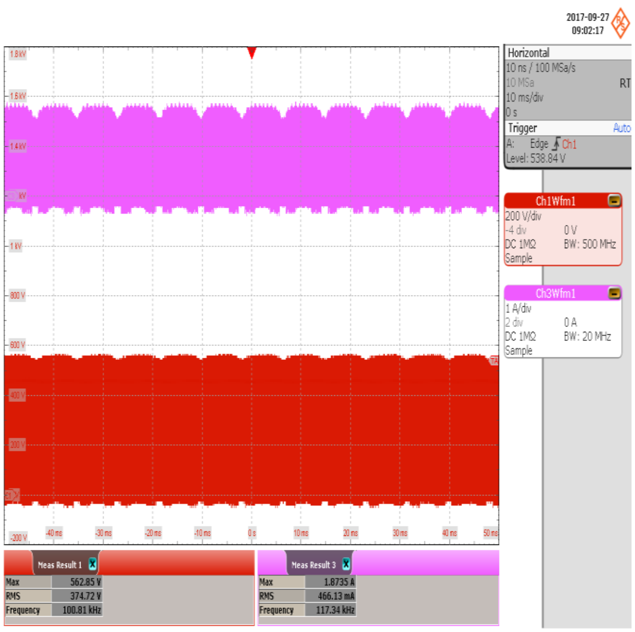

Figure 48 – 230 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 ms / div.

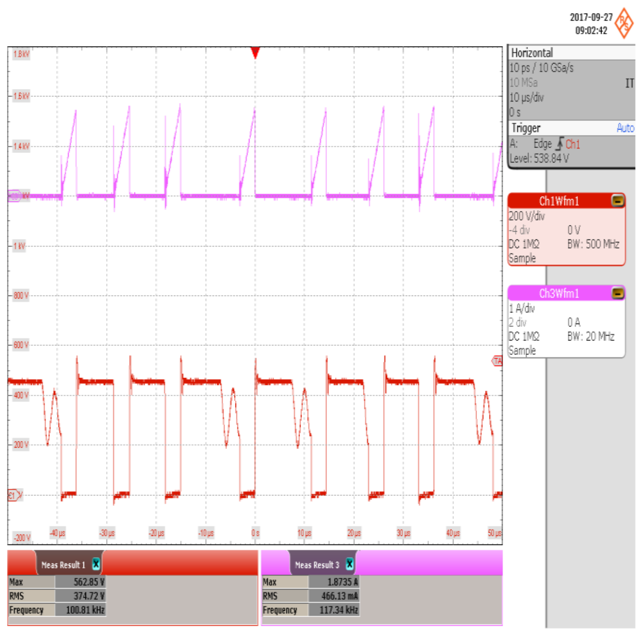

Figure 49 – 230 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 µs / div.

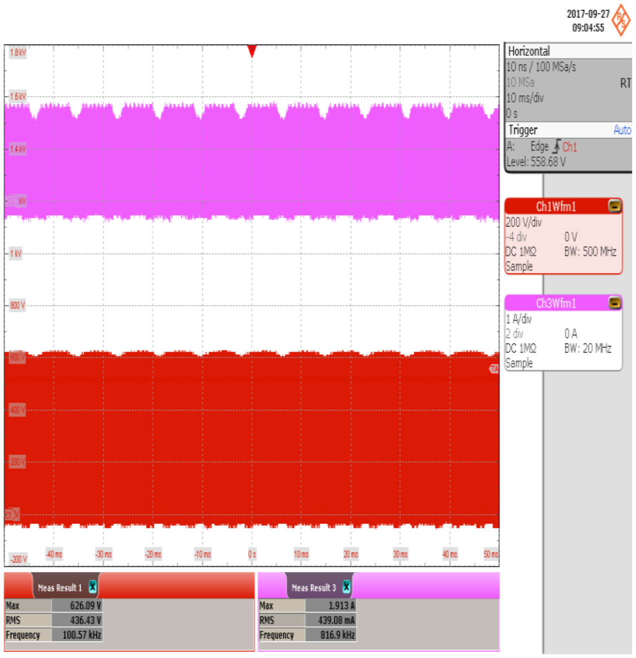

Figure 50 – 265 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 ms / div.

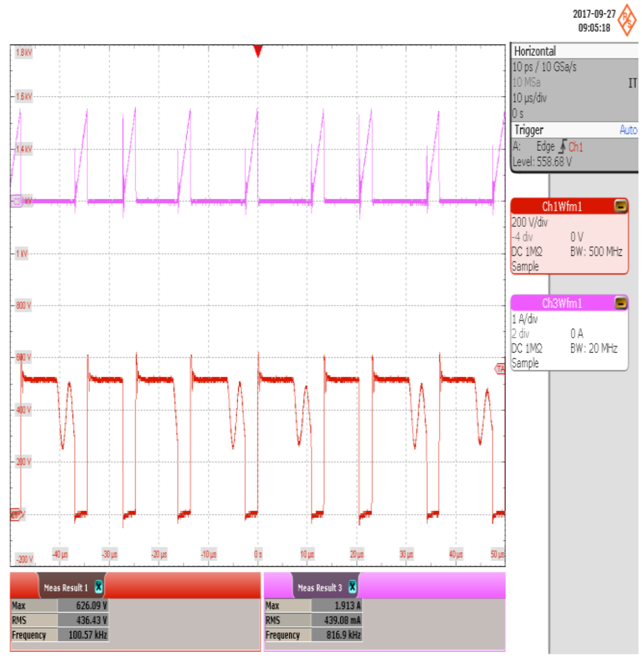

Figure 51 – 265 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.

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

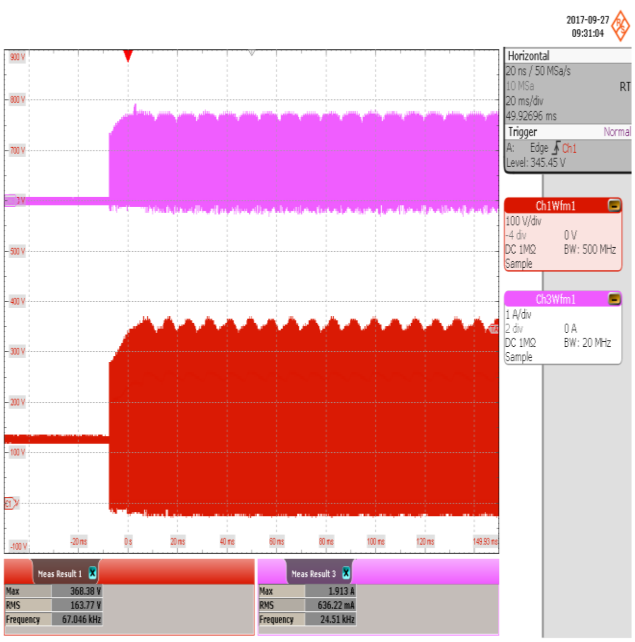

Figure 52 – 90 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 20 ms / div.

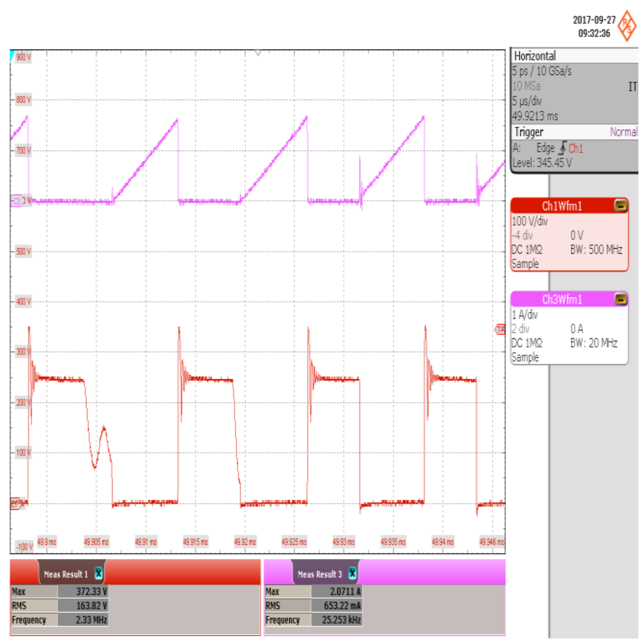

Figure 53 – 90 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

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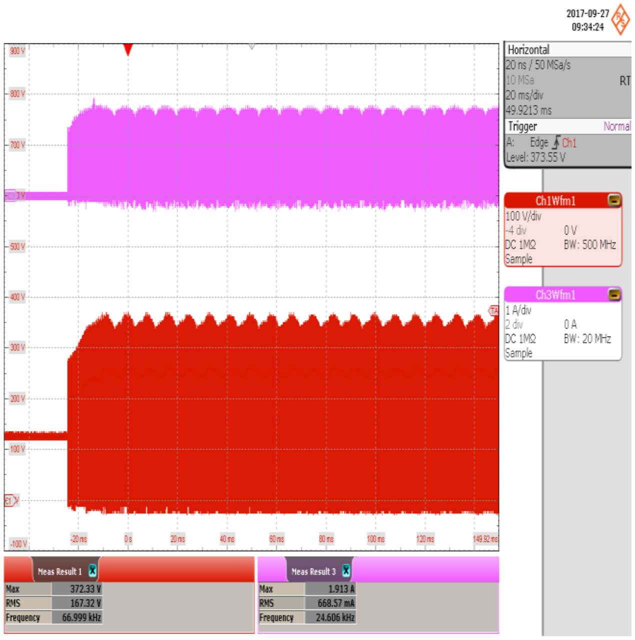

Figure 54 – 120 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 20 ms / div.

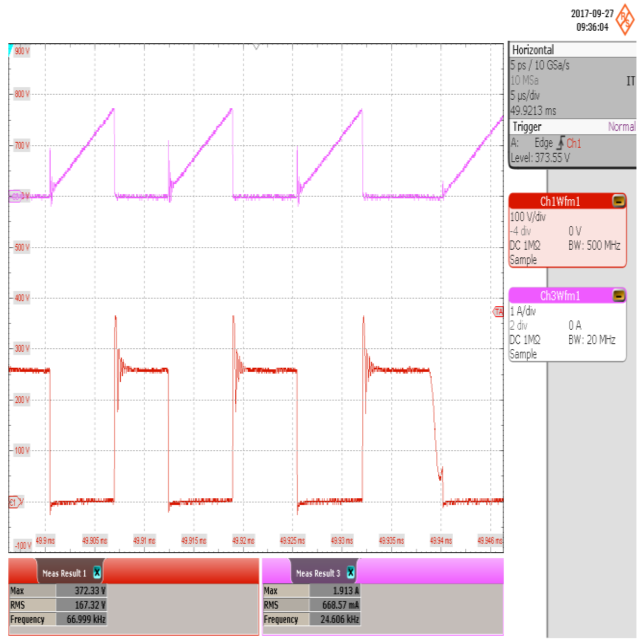

Figure 55 – 120 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 5 µs / div.

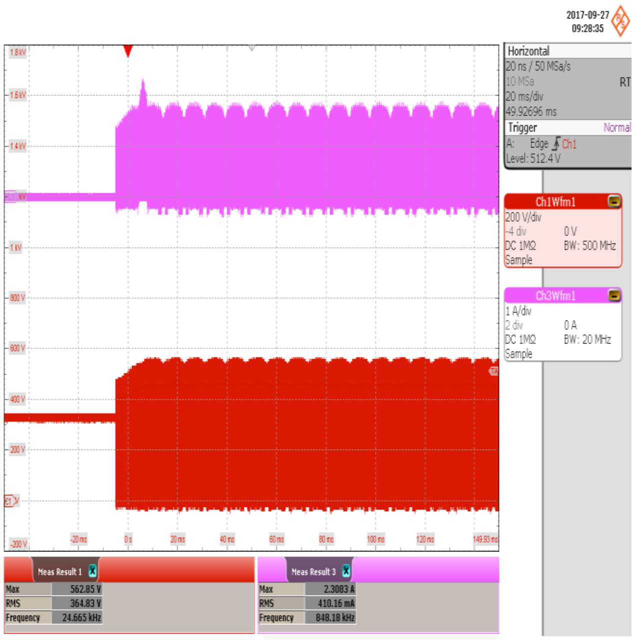

Figure 56 – 230 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 20 ms / div.

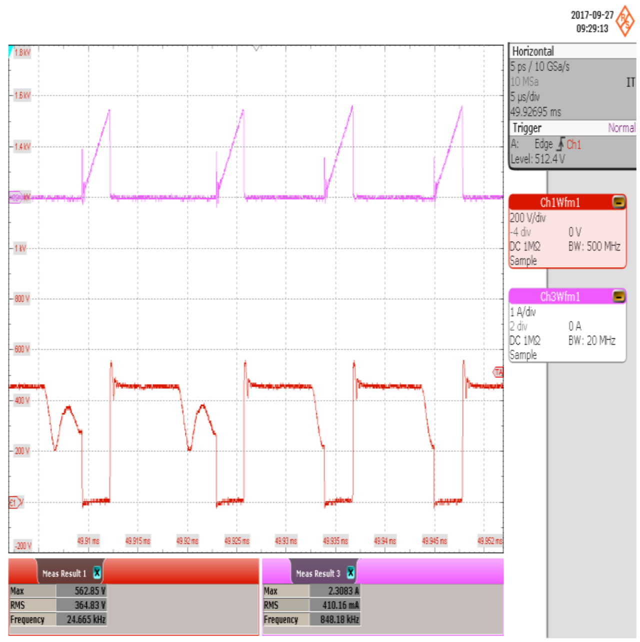

Figure 57 – 230 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 5 µs / div.

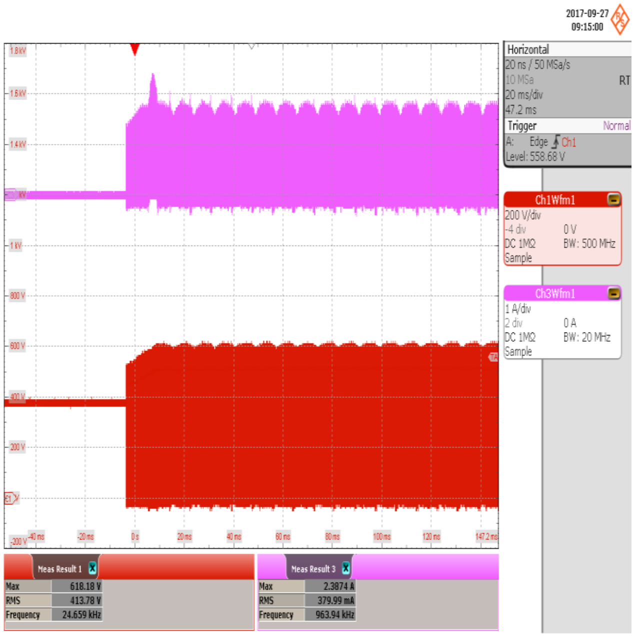

Figure 58 – 265 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 20 ms / div.

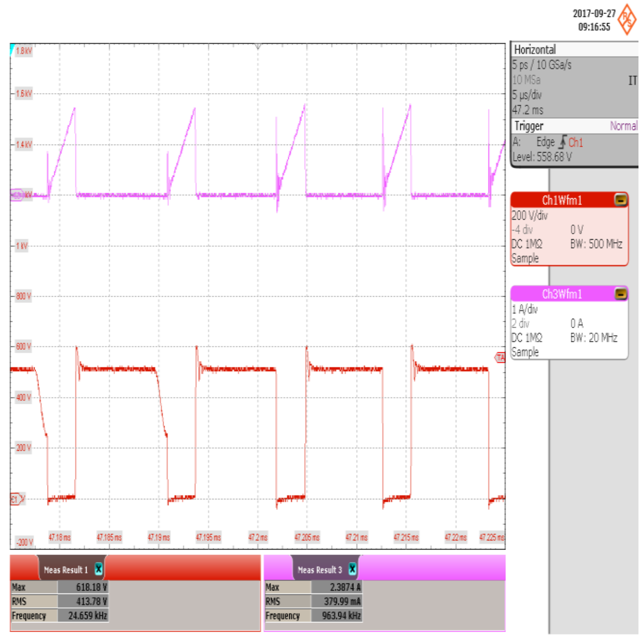

Figure 59 – 265 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

14.7 *LYTSwitch-6 Drain Voltage and Current during Output Short-Circuit*

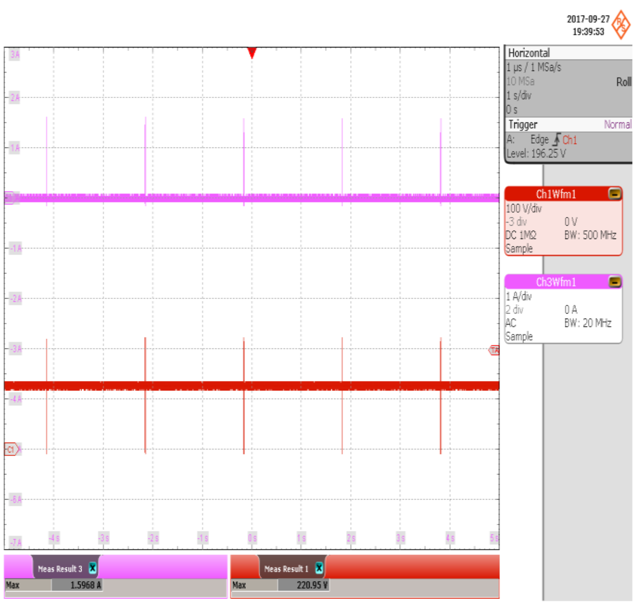

Figure 60 – 90 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.
P_{IN} Average: 63 mW.

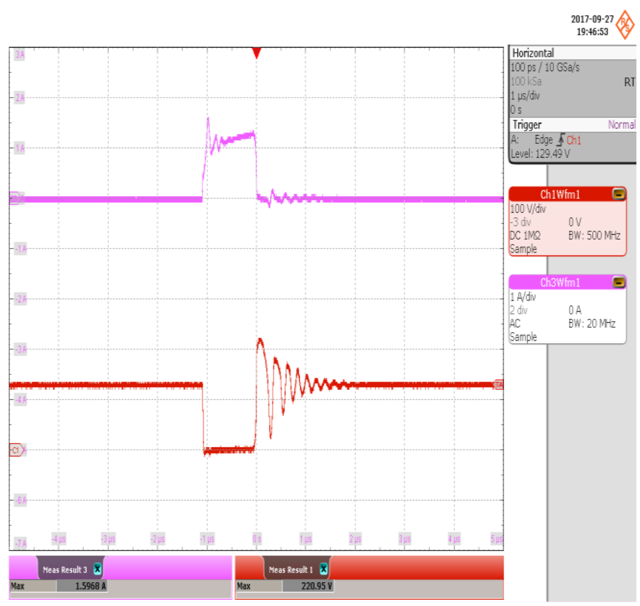

Figure 61 – 90 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 μs / div.

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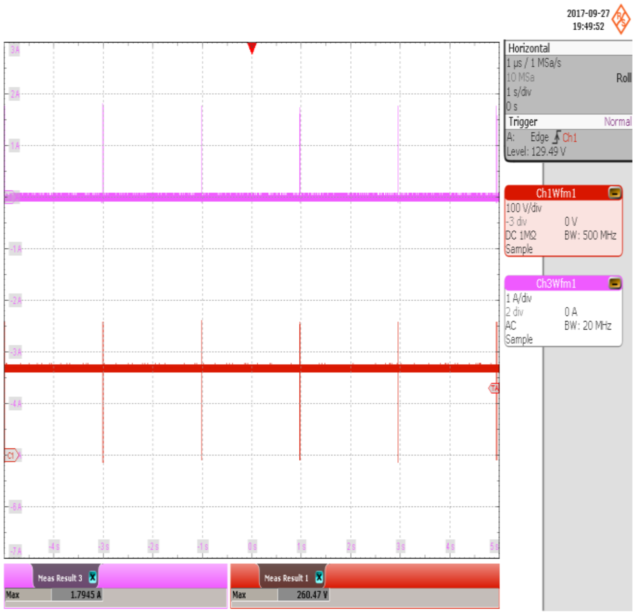

Figure 62 – 120 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.
P_{IN} Average: 67 mW.

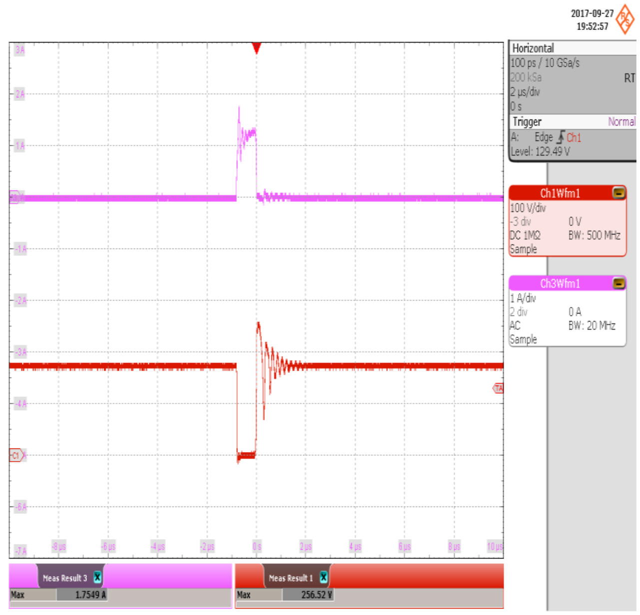

Figure 63 – 23120 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 2 μs / div.

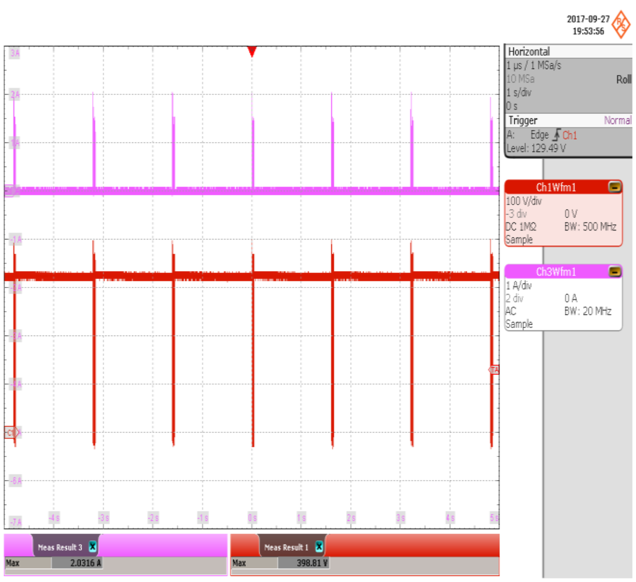

Figure 64 – 230 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.
P_{IN} Average: 91 mW.

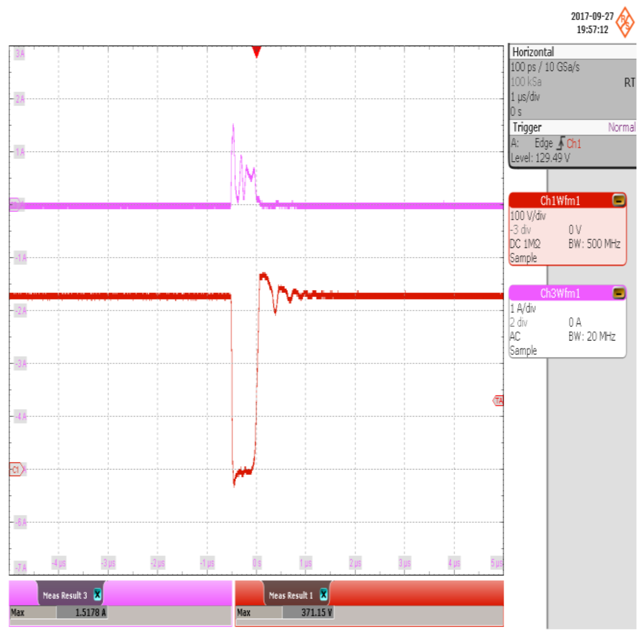

Figure 65 – 230 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 1 μs / div.

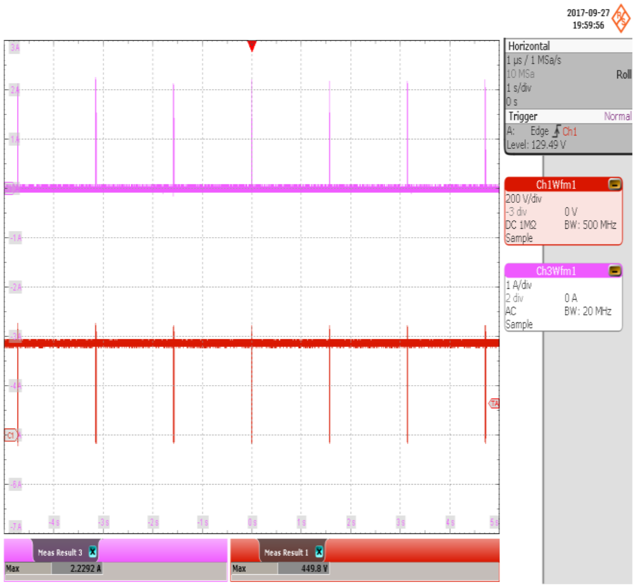

Figure 66 – 265 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.
P_{IN} Average: 170 mW.

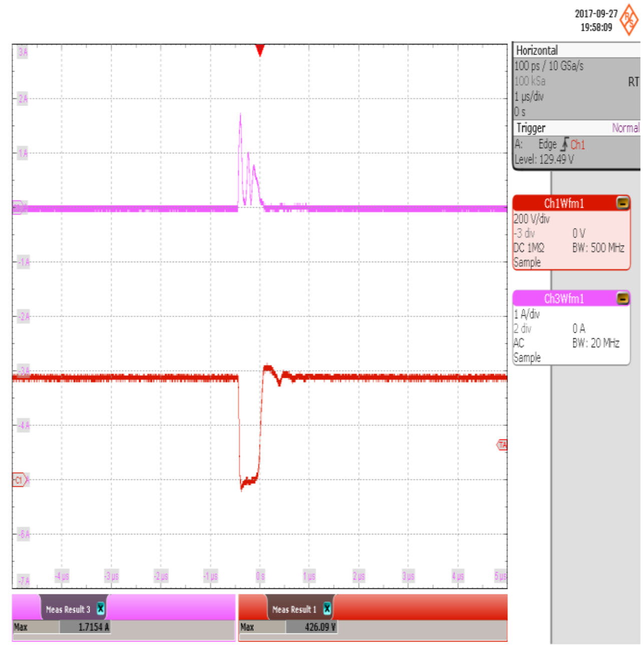

Figure 67 – 265 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 1 μs / div.

14.8 *PFC Diode Voltage and Current at Normal Operation*

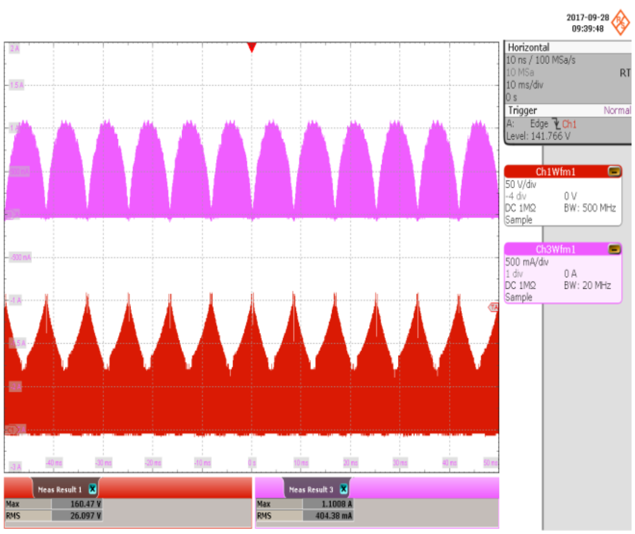

Figure 68 – 90 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

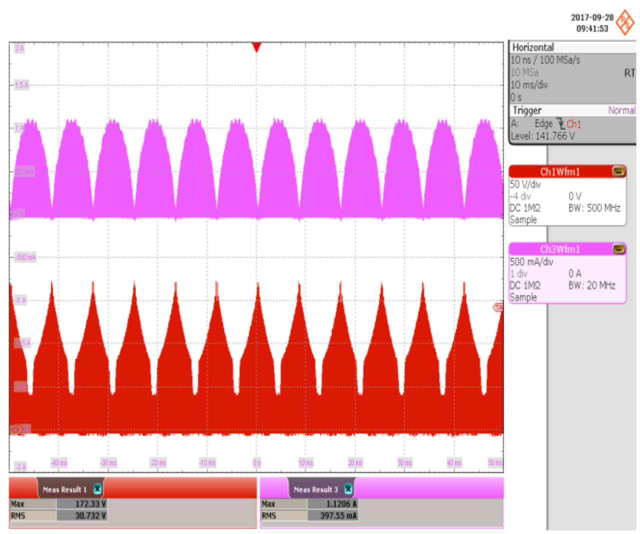

Figure 69 – 120 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

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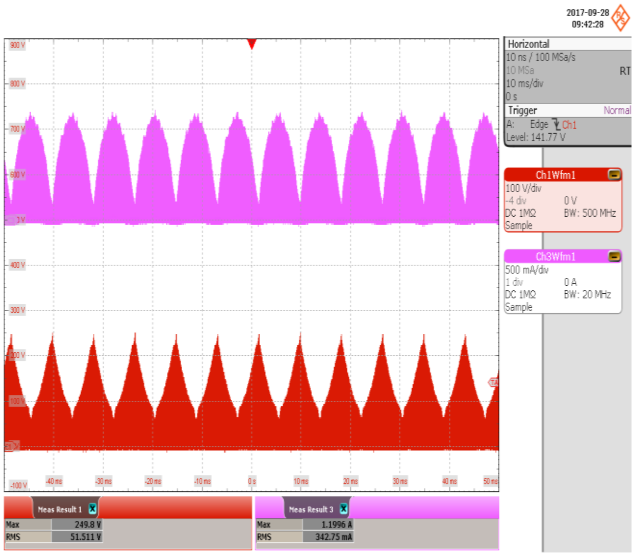

Figure 70 – 230 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

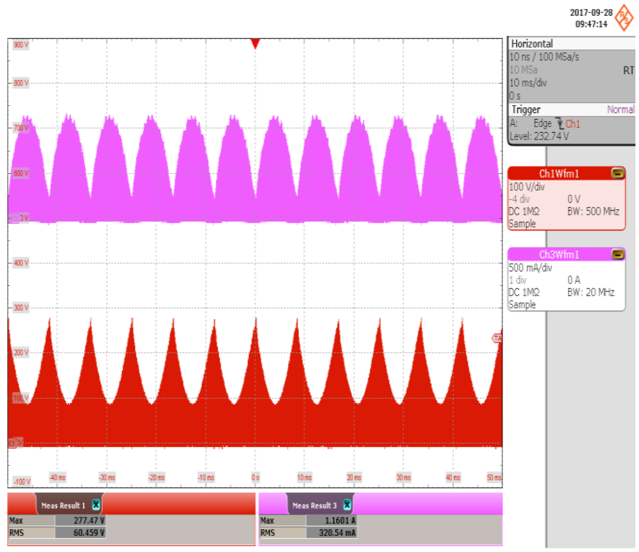

Figure 71 – 265 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

14.9 *PFC Diode Voltage and Current at Start-up Full Load*

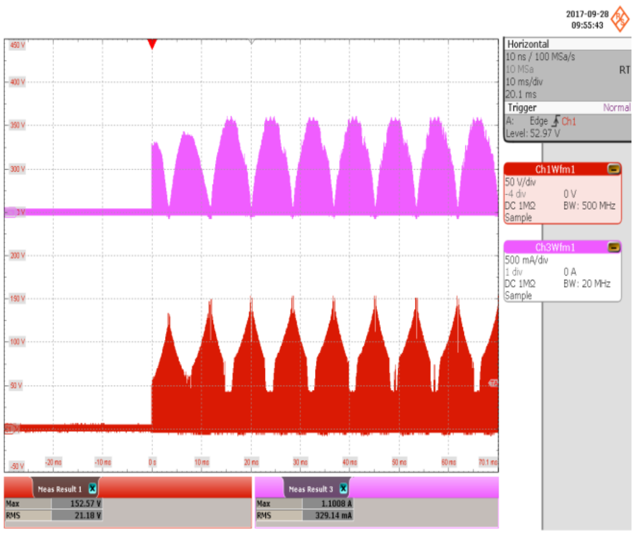

Figure 72 – 90 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

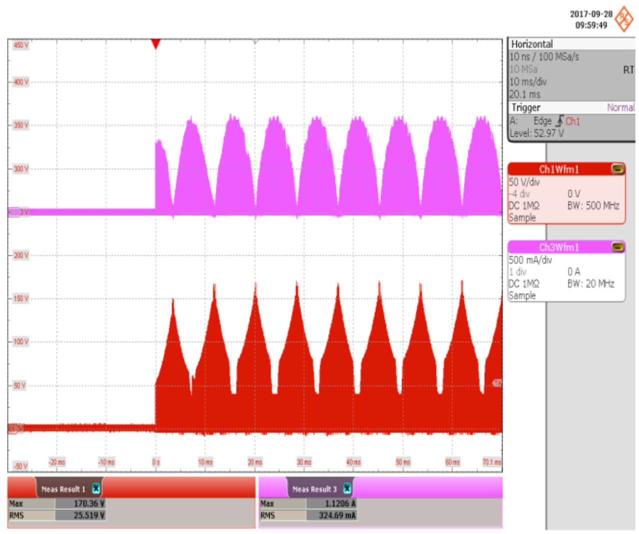

Figure 73 – 120 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

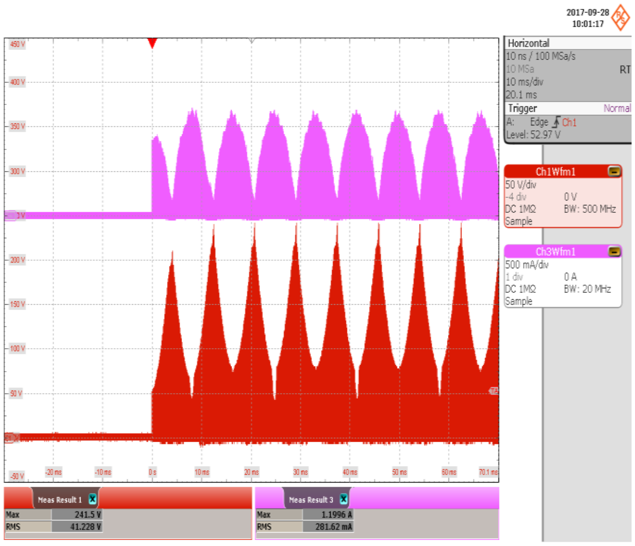

Figure 74 – 230 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

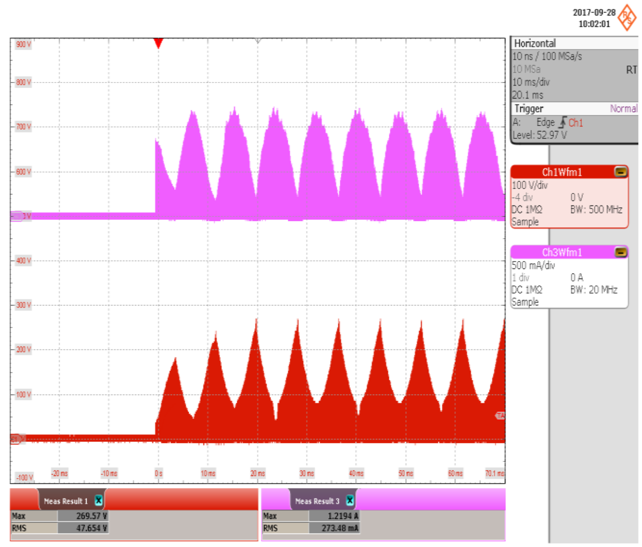

Figure 75 – 265 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

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14.10 ***Output Voltage Ripple***

14.10.1 Ripple Measurement Set-up

Figure 76 – Probe Set-up for Output Voltage Ripple Test.

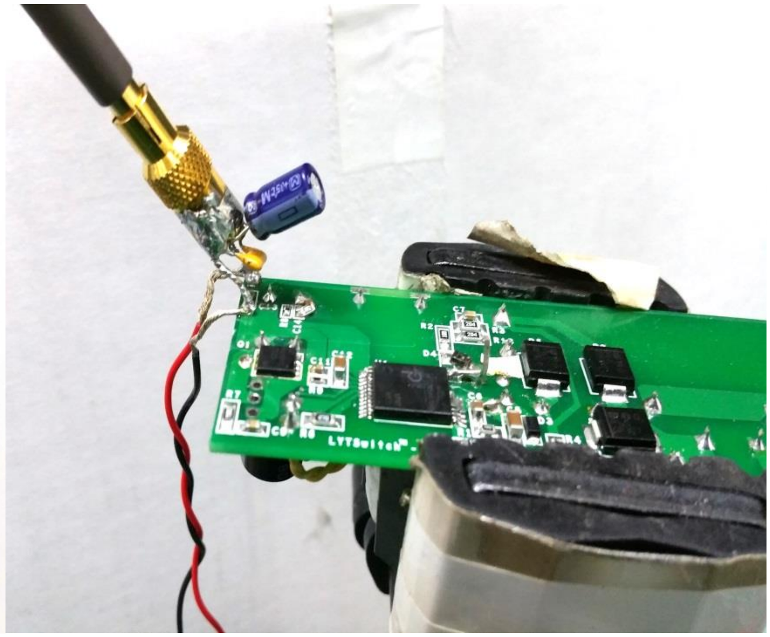

Figure 77 – Unit Set-up for Output Voltage Ripple Test.

Ripple voltage was taken using a X1 probe with 1 μF electrolytic capacitor and 0.1 μF ceramic capacitor connected in parallel across the probe.

14.10.2 Ripple Measurements

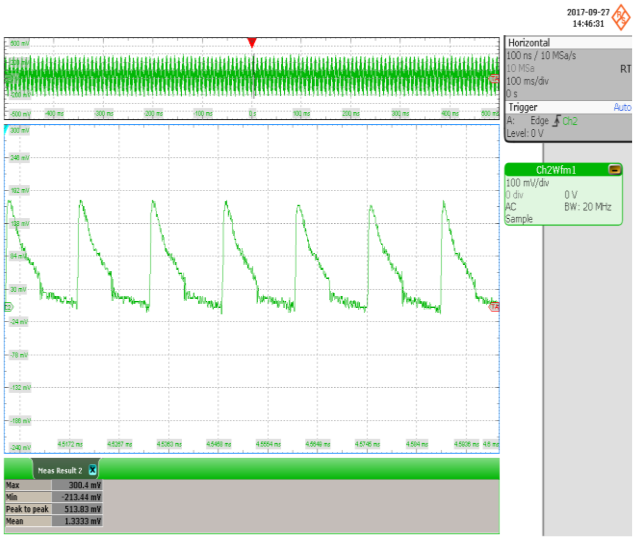

Figure 78 – 90 VAC 50 Hz, 580 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 100 mV / div., 100 ms / div.
Ripple Voltage: 513.83 mV_{PK-PK}.

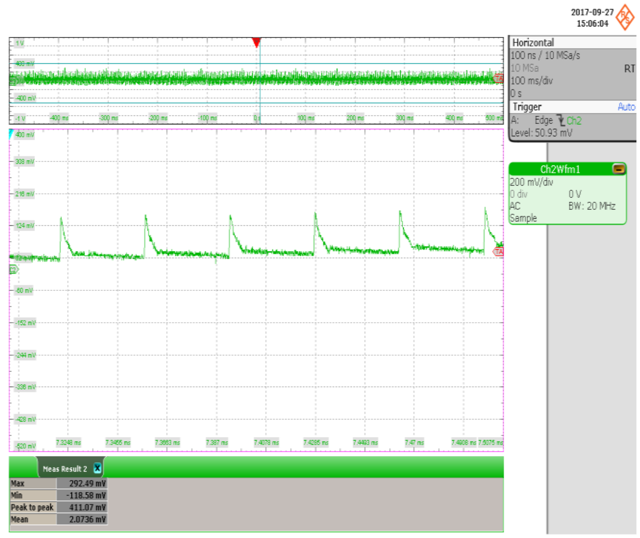

Figure 79 – 90 VAC 50 Hz, 58 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 200 mV / div., 100 ms / div.
Ripple Voltage: 411.07 mV_{PK-PK}.

Figure 80 – 120 VAC 50 Hz, 580 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 200 mV / div., 100 ms / div.
Ripple Voltage: 561.26 mV_{PK-PK}.

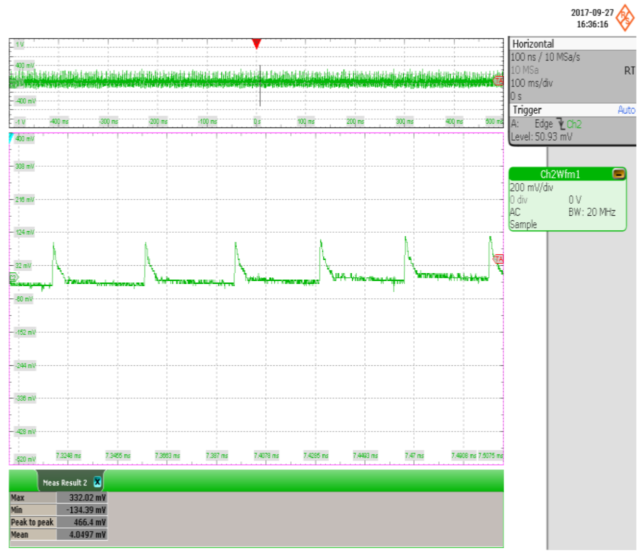

Figure 81 – 120 VAC 50 Hz, 58 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 200 mV / div., 100 ms / div.
Ripple Voltage: 466.4 mV_{PK-PK}.

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Figure 82 – 230 VAC 50 Hz, 580 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 200 mV / div., 100 ms / div.
Ripple Voltage: 814.23 mV_{PK-PK}.

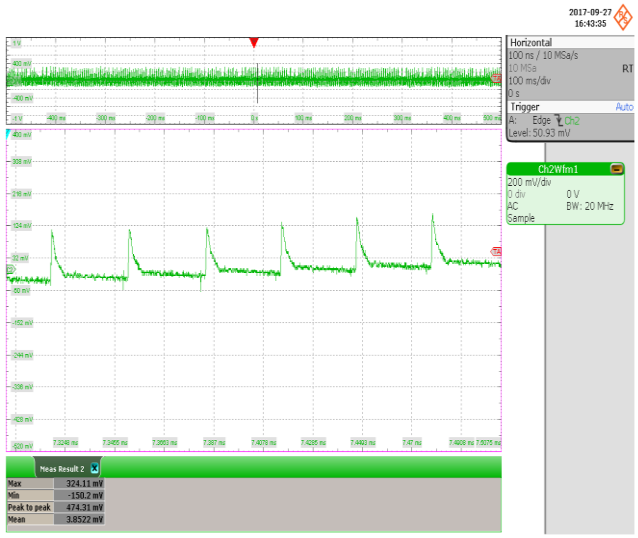

Figure 83 – 230 VAC 50 Hz, 58 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 200 mV / div., 100 ms / div.
Ripple Voltage: 466.4 mV_{PK-PK}.

Figure 84 – 265 VAC 50 Hz, 580 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 200 mV / div., 100 ms / div.
Ripple Voltage: 909.9 mV_{PK-PK}.

Figure 85 – 265 VAC 50 Hz, 58 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
V_{OUT}, 200 mV / div., 100 ms / div.
Ripple Voltage: 490.12 mV_{PK-PK}.

14.11 *Output Current Ripple*

14.11.1 Equipment Used

1. Rohde & Schwarz RTO1004 Oscilloscope
2. Rohde & Schwarz RT-ZC20B Current Probe
3. 80 V LED Load

14.12 *Ripple Ratio and Flicker % Measurement*

V_{IN}	$I_{O(MAX)}$ (mA)	$I_{O(MIN)}$ (mA)	I_{MEAN} (mA)	Ripple Ratio (I_{RP}-$_P$/I_{MEAN})	% Flicker 100 x (I_{RP}-$_P$ / $I_{O(MAX)}$+$I_{O(MIN)}$)
90 VAC	600.79	553.36	573.95	0.08	4.11
120 VAC	616.6	529.64	573.18	0.08	7.59
230 VAC	600.79	553.36	47.43	0.08	4.11
265 VAC	600.79	545.45	574.68	0.08	4.83

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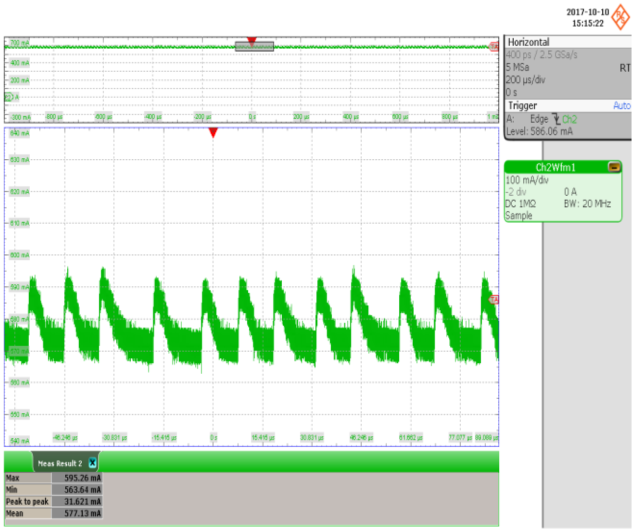

Figure 86 – 90 VAC 50 Hz, 580 mA LED Load.
20 MHz Bandwidth.
I_{OUT}, 20 mA / div., 20 ms / div.
Ripple Current: 31.621 mA_{PK-PK}.

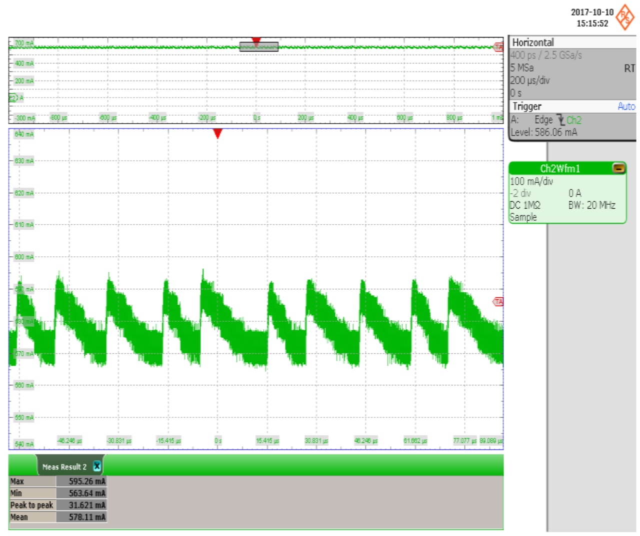

Figure 87 – 120 VAC 50 Hz, 580 mA LED Load.
20 MHz Bandwidth.
I_{OUT}, 20 mA / div., 20 ms / div.
Ripple Current: 31.621 mA_{PK-PK}.

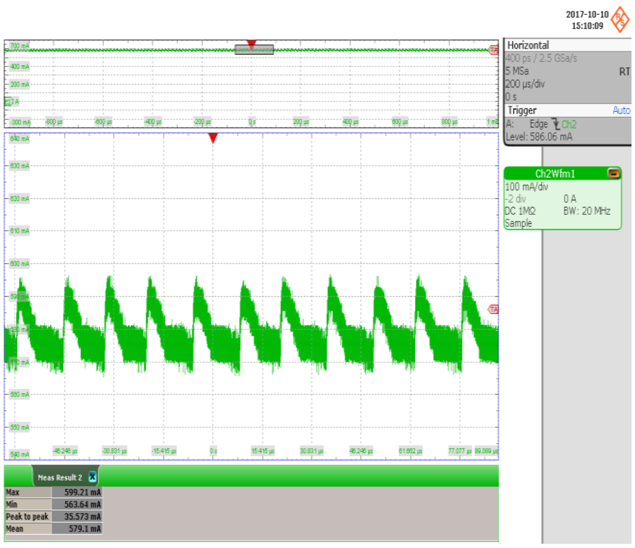

Figure 88 – 230 VAC 50 Hz, 580 mA LED Load.
20 MHz Bandwidth.
I_{OUT}, 20 mA / div., 20 ms / div.
Ripple Current: 35.573 mA_{PK-PK}.

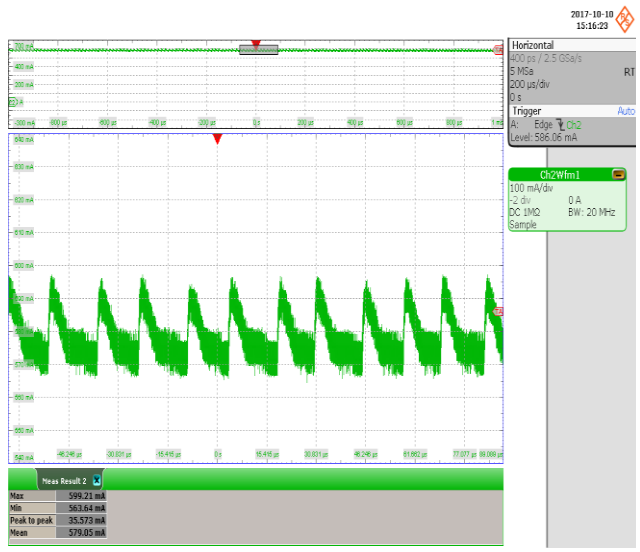

Figure 89 – 265 VAC 50 Hz, 580 mA LED Load.
20 MHz Bandwidth.
I_{OUT}, 20 mA / div., 20 ms / div.
Ripple Voltage: 35.573 mA_{PK-PK}.

15 Conducted EMI

15.1 *Test Set-up*

15.1.1 Equipment and Load Used

1. Rohde and Schwarz ENV216 two line V-network
2. Rohde and Schwarz ESRP EMI test receiver
3. Hioki 3332 power hitester
4. Chroma Measurement Test Fixture model A662003
5. 80V LED Load
6. HOSSONI TDGC2 VARIAC set at 230 VAC 60 Hz

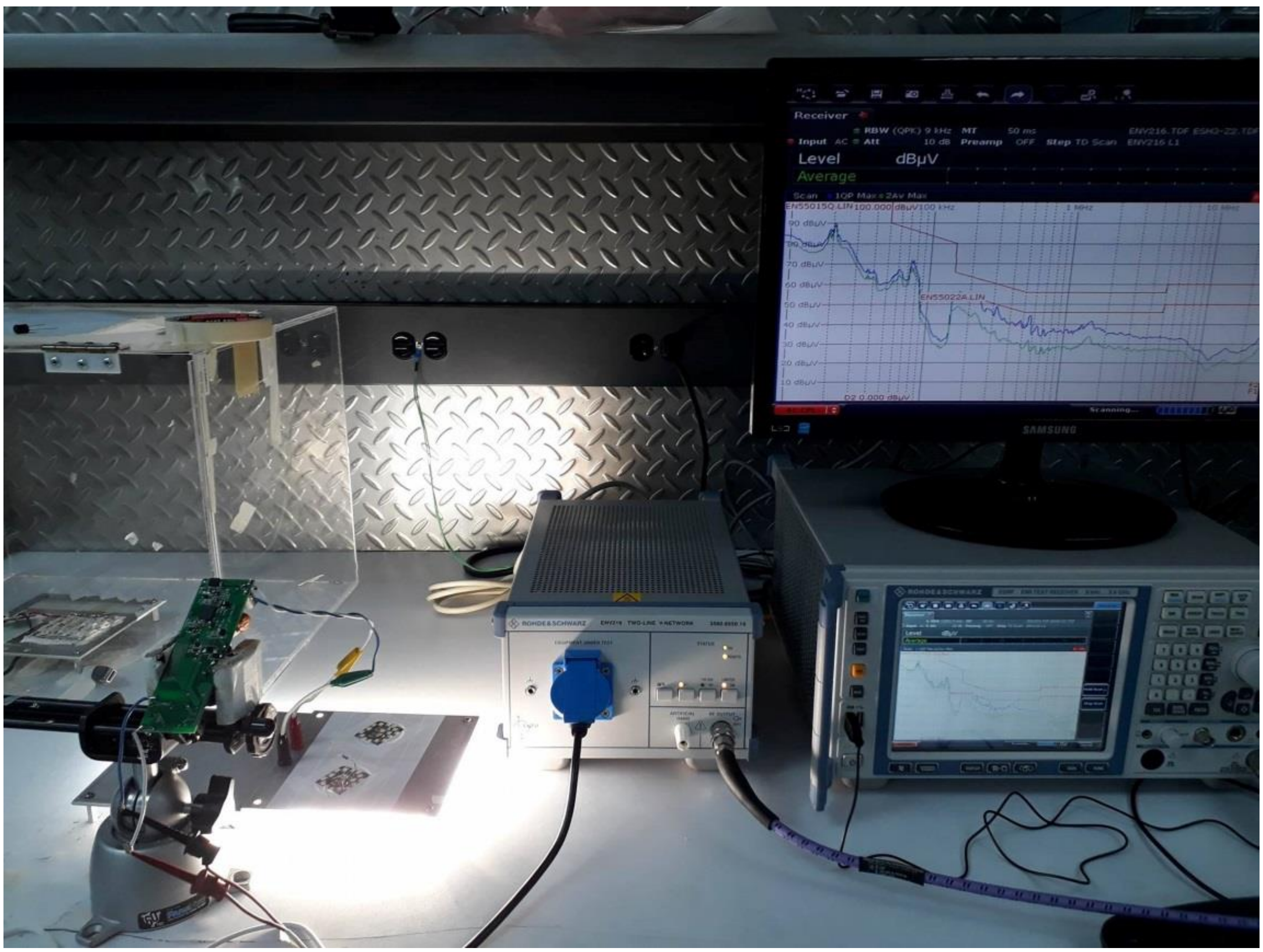

Figure 90 – Conducted EMI Test Set-up.

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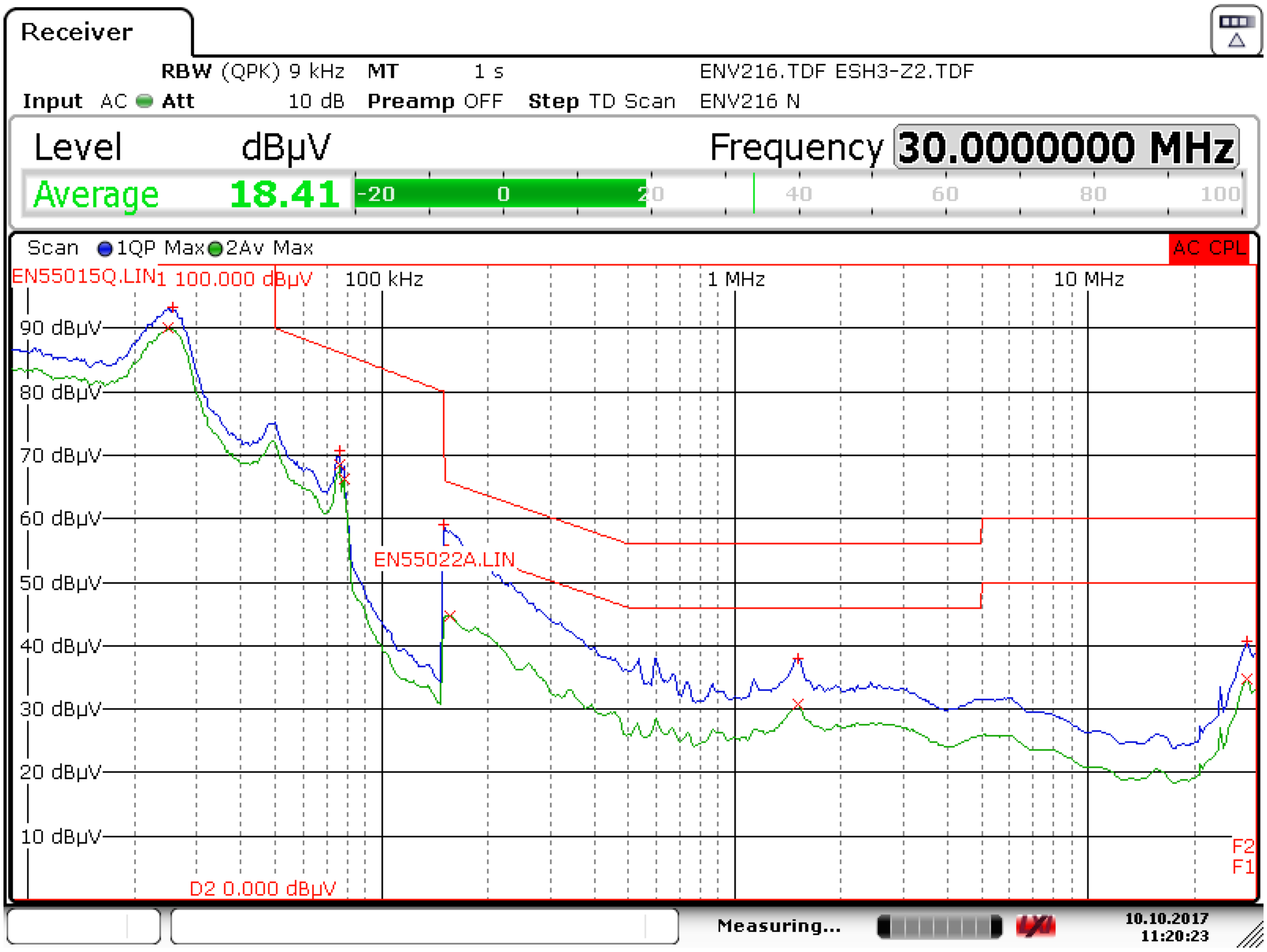
15.2 *EMI Test Result*



Date: 10.OCT.2017 11:20:23

Figure 91 – Conducted EMI QP Scan at Full Load, 115 VAC 60 Hz and EN55015 B Limits.

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	25.7500 kHz	93.18 L1	-16.82 dB
2 Average	24.8000 kHz	90.06 L1	
1 Quasi Peak	76.1500 kHz	70.79 N	-15.38 dB
2 Average	76.1500 kHz	68.50 N	
2 Average	78.6500 kHz	66.35 N	
1 Quasi Peak	150.0000 kHz	58.94 N	-7.06 dB
2 Average	156.7500 kHz	44.69 L1	-10.94 dB
1 Quasi Peak	28.2148 MHz	40.66 N	-19.34 dB
1 Quasi Peak	1.5113 MHz	38.01 N	-17.99 dB
2 Average	28.2170 MHz	34.83 N	-15.17 dB
2 Average	1.5045 MHz	30.76 L1	-15.24 dB

Insert Frequency | Delete Frequency | Sort by Frequency

Symbols OFF ON | Peak List Export | Decim Sep . ,

Figure 92 – Conducted EMI Data at 115 VAC 60 Hz, Full Load.

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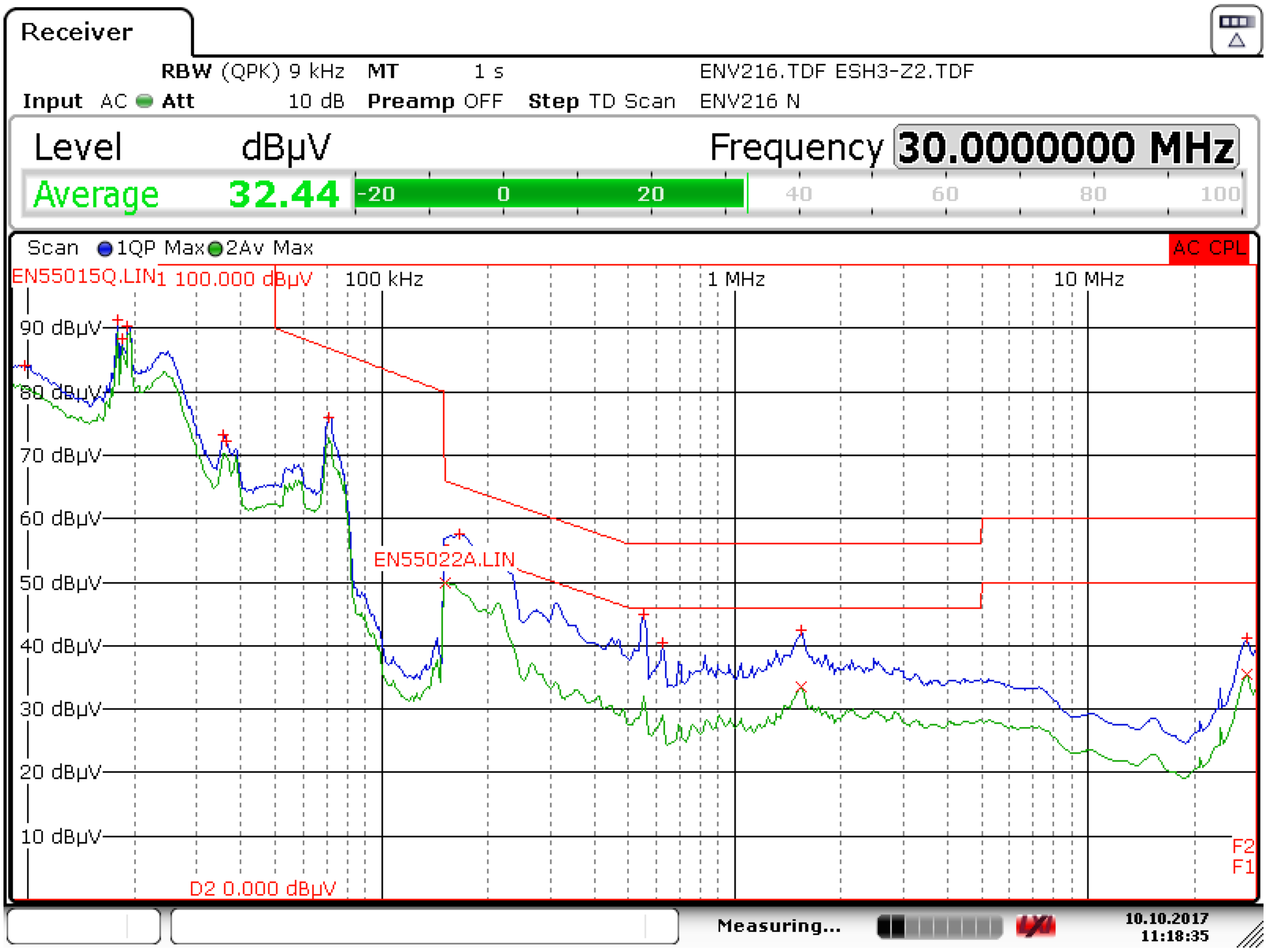

Date: 10.OCT.2017 11:18:36

Figure 93 – Conducted EMI QP Scan at Full Load, 230 VAC 60 Hz and EN55015 B Limits.

Trace/Detector	Frequency	Level dBµV		DeltaLimit
2 Average	152.2500 kHz	49.91	L1	-5.97 dB
1 Quasi Peak	165.7500 kHz	57.62	L1	-7.55 dB
1 Quasi Peak	70.8500 kHz	76.01	L1	-10.82 dB
1 Quasi Peak	552.7500 kHz	44.88	L1	-11.12 dB
2 Average	1.5450 MHz	33.40	N	-12.60 dB
1 Quasi Peak	1.5473 MHz	42.35	N	-13.65 dB
2 Average	28.1968 MHz	35.40	N	-14.60 dB
1 Quasi Peak	622.5000 kHz	40.39	N	-15.61 dB
1 Quasi Peak	17.9500 kHz	91.20	N	-18.80 dB
1 Quasi Peak	28.2868 MHz	41.07	N	-18.93 dB
1 Quasi Peak	19.1000 kHz	90.35	N	-19.65 dB
1 Quasi Peak	18.5000 kHz	88.41	N	-21.59 dB
1 Quasi Peak	9.8000 kHz	84.21	L1	-25.79 dB
1 Quasi Peak	35.8000 kHz	73.24	N	-36.76 dB

Insert Frequency Delete Frequency Sort by Frequency

Symbols OFF ON Peak List Export Decim Sep . ,

Figure 94 – Conducted EMI Data at 230 VAC 60 Hz, Full Load.

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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. A test failure was defined as a non-recoverable interruption of output requiring repair or recycling of input voltage.

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	115	L to N	0	Pass
+1000	115	L to N	90	Pass
-1000	115	L to N	90	Pass
+1000	115	L to N	270	Pass
-1000	115	L to N	270	Pass
+1000	230	L to N	0	Pass
-1000	230	L to N	0	Pass
+1000	230	L to N	90	Pass
-1000	230	L to N	90	Pass
+1000	230	L to N	270	Pass
-1000	230	L to N	270	Pass

16.2 *Ring Wave Surge Test Results*

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2500	115	L to N	0	Pass
-2500	115	L to N	0	Pass
+2500	115	L to N	90	Pass
-2500	115	L to N	90	Pass
+2500	115	L to N	270	Pass
-2500	115	L to N	270	Pass
+2500	230	L to N	0	Pass
-2500	230	L to N	0	Pass
+2500	230	L to N	90	Pass
-2500	230	L to N	90	Pass
+2500	230	L to N	270	Pass
-2500	230	L to N	270	Pass

16.3 ***1 kV Differential Surge Test***

The Drain voltage of U1-LYTSwitch-6 was measured during 1 kV differential surge test.

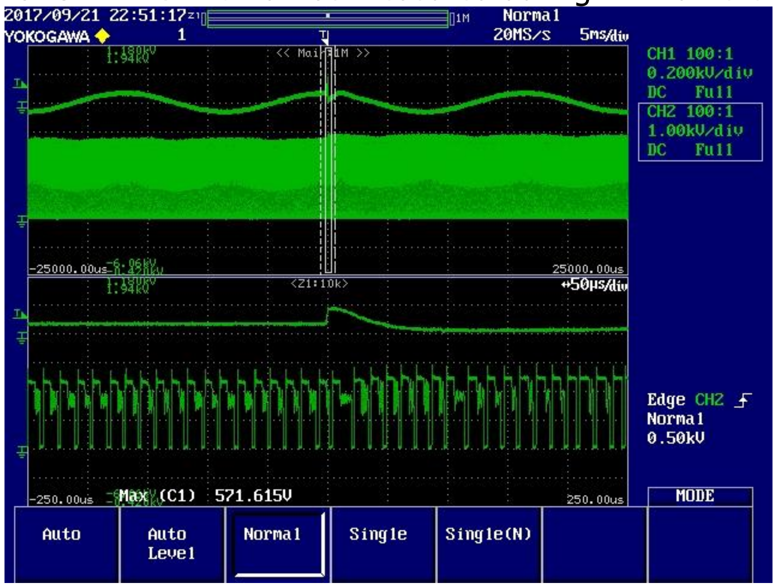

Figure 95 – (+)1 kV Differential Surge.
90º Phase Angle, Input: 230 VAC.
V_{DRAIN}, 200 V / div., 20 ms / div.
Peak V_{DRAIN}: 571.615 V.

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16.4 *2.5 kV Ring Wave Surge Test*

The Drain voltage of U1-LYTSwitch-6 was measured during 2 kV ring wave surge test.

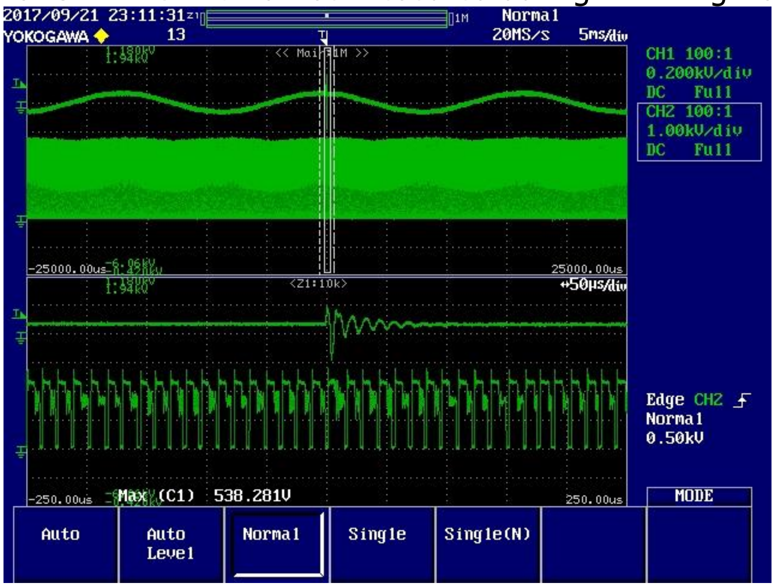

Figure 96 – (+) 2.5 kV Ring Wave Surge.
90º Phase Angle, Input: 230 VAC.
V_{DRAIN}, 200 V / div., 20 ms / div.
Peak V_{DRAIN}: 558.333 V.

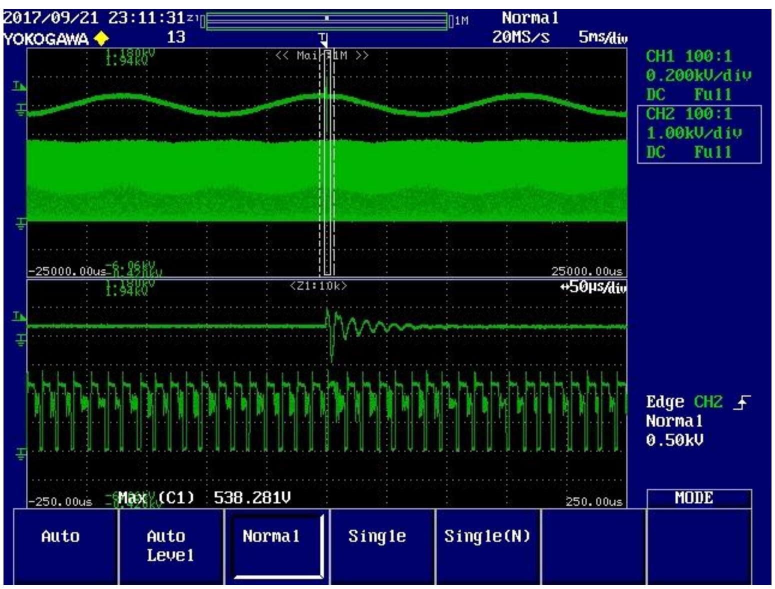

Figure 97 – (+) 2.5 kV Ring Wave Surge.
90º Phase Angle, Input: 230 VAC.
V_{DRAIN}, 200 V / div., 20 ms /div.
Peak V_{DRAIN}: 558.333 V.

17 Revision History

Date	Author	Revision	Description and Changes	Reviewed
23-Jan-18	IB and DL	1.0	Initial Release.	Apps & Mktg
16-Feb-18	IB and DL	1.1	Minor Text Edits.	
20-Feb-18	IB and DL	1.2	Updated PIXls.	
26-Apr-18	IB and DL	1.3	Updated Magnetics.	

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