Design Example Report

Title	***35 W High Power Factor Isolated Flyback with Switched Valley Fill PFC Power Supply Using LYTSwitch™-6 LYT6068C***
Specification	140 VAC – 320 VAC Input; 12 V, 2.92 A Output
Application	Emergency Light with Battery Charging
Author	Applications Engineering Department
Document Number	DER-637
Date	April 23, 2018
Revision	1.4

Summary and Features

- Accurate constant voltage regulation
- High power factor, >0.9 at 230 V and 277 V inputs
- Fast transient load response
- Highly energy efficient, >88 % at 230 V and 277 V inputs
- Integrated protection and reliability features
    - Output short-circuit protection
    - Line and output OVP
    - Thermal foldback and over-temperature shutdown with hysteretic automatic power recovery
- No damage during line brown-out or brown-in conditions
- Meets IEC 2.5 kV ring wave, 1 kV differential surge
- Meets EN55015 conducted EMI

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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 35 W isolated flyback power supply with a single-stage power factor correction circuit for LED lighting application. The power supply is designed to provide a 12 V constant voltage across 0 A to 2.92 A output current load. It’s also capable of providing 2.98 A constant current output for LED lighting applications. The board is optimized to operate from an input voltage range of 140 VAC to 320 VAC.

The LYTSwitch-6 IC 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.

A switched valley-fill PFC circuit is added to meet the high PF requirement in lighting applications. The energy stored across the PFC inductor is delivered to the load via direct energy transfer reducing the power loss.

DER-637, using a LYTSwitch-6 IC, offers an accurate, fast transient response, constant voltage supply with a high power factor throughout the input range. The key design goals were high efficiency and high power factor throughout 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.

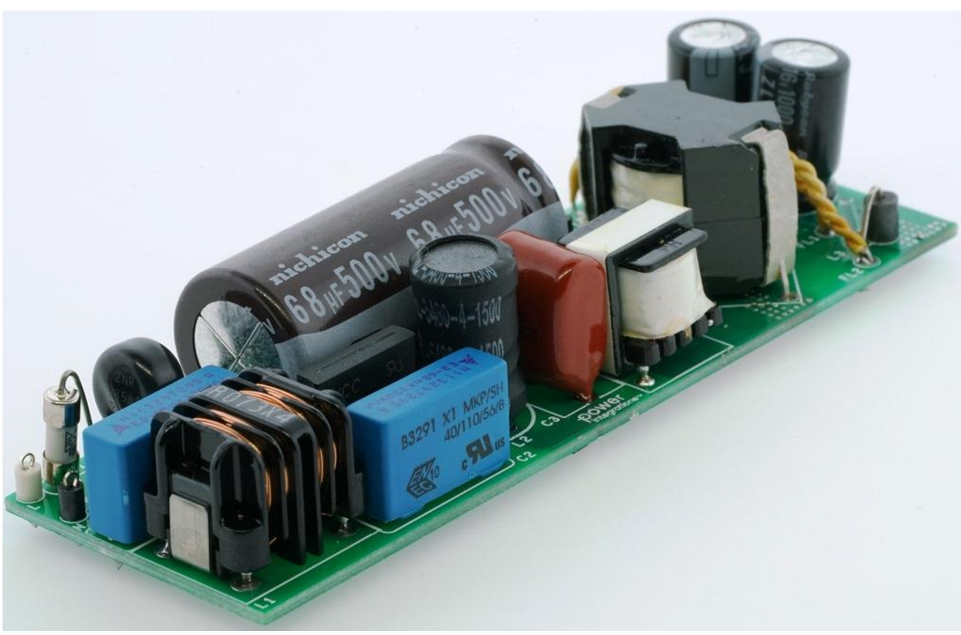

Figure 1 – Populated Circuit Board.

Figure 2 – Populated Circuit Board, Top View.

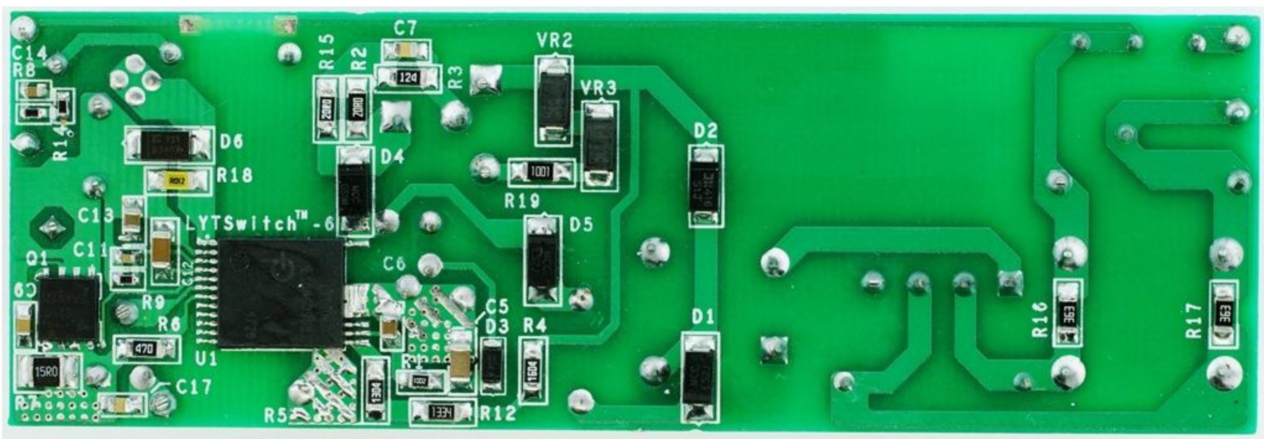

Figure 3 – Populated Circuit Board, Bottom View.

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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	V_{IN}	140	230/277	320	Vac/Hz	2 Wire – no P.E.
Frequency	f_{LINE}		50			
Output						
Output Voltage	V_{OUT}		12		V	CC Threshold: 2.98 A.
Output Current	I_{OUT}	0		2.92	A	
Total Output Power						
Continuous Output Power	P_{OUT}		35		W	
Efficiency						
Full Load	η		88		%	At 230 VAC / 50 Hz and 277 VAC / 50 Hz. 25 ºC Ambient Temperature.
Average Efficiency 25%, 50%, 75%, and 100% Load		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 230 VAC / 50 Hz and 277 VAC / 50 Hz.
Ambient Temperature	T_{AMB}			60	ºC	Free Air Convection, Sea Level.

3 Schematic

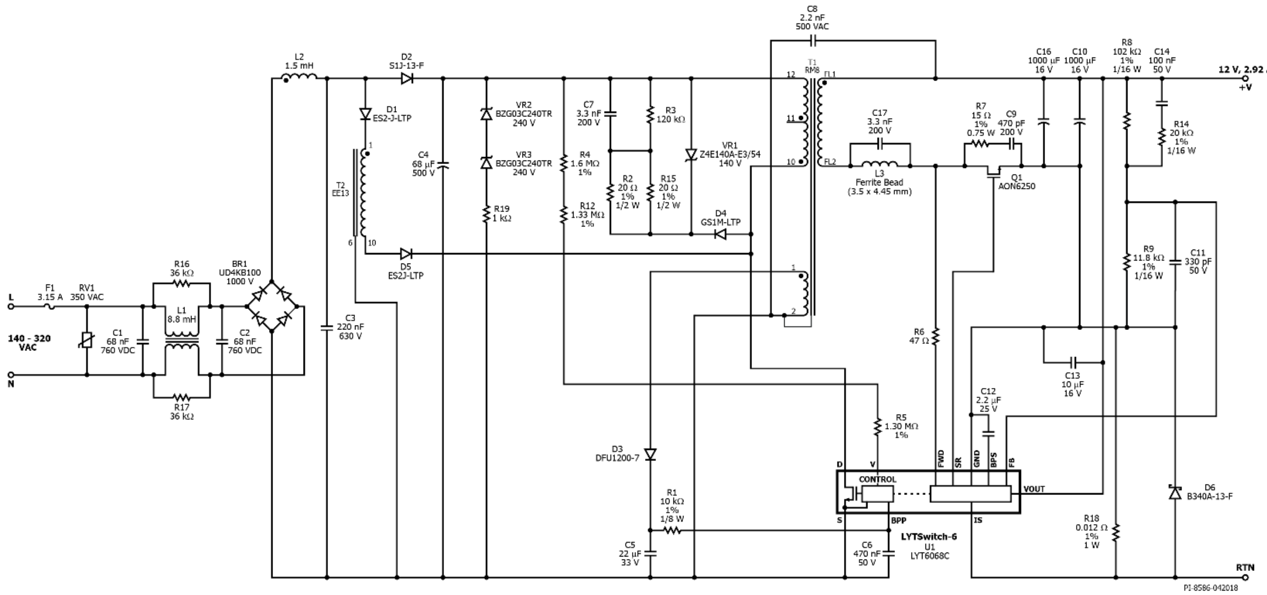

Figure 4 – Schematic Diagram.

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4 Circuit Description

The LYTSwitch-6 device (LYT6068C) incorporates the primary MOSFET, the primary-side controller and a secondary-side synchronous rectification controller in a single inSOP-24D package. This IC also includes an innovative new technology, FluxLink™, which safely bridges the isolation barrier and eliminates the need for an optocoupler. The LYTSwitch-6 IC is configured to drive a 35 W flyback power supply with a switched valley fill PFC providing a high power factor 12 V constant voltage supply throughout the input range of 140 VAC to 320 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 350 V rated part was selected, being slightly above the maximum specified operating input voltage (320 V). The AC input voltage is full wave rectified by BR1 to achieve good power factor and low THD.

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

Capacitor C1, L1, C2, L2, and C3 forms a 2 stage LC EMI filter to suppress differential mode noise caused by the PFC and flyback switching action. Common mode noise is suppressed by Y capacitor C8.

Rectifier diode (D2) provides a bypass charging current to the bulk capacitor (C4) from the input rectified voltage. Diode D2 also serves as a blocking diode during the power MOSFET turn OFF to isolate the flyback DC supply from the PFC supply maintaining the functionality of the added PFC circuit.

4.2 *LYTSwitch-6 Primary Side Control*

The isolated flyback power supply is controlled by the LYTSwitch-6 IC LYT6068C. One side of the transformer (T1) primary is connected to the positive output terminal of the bulk capacitor (C4) while the other side is connected to the drain of the integrated 650 V power MOSFET inside the LYTSwitch-6 IC (U1). A low cost RCDZ snubber clamp formed by D4, R2, R15, C7, R3, and VR1 limits the peak Drain voltage spike due to the effects of transformer leakage inductance.

The VOLTAGE MONITOR (V) pin of the LYTSwitch-6 IC is connected to the positive of the bulk capacitor (C4) to provide input voltage information. The voltage across the bulk capacitor (C4) is sensed and converted into current through V pin resistors R4, R12, and R5 to provide detection of overvoltage. The I_{OV-} determines the input overvoltage threshold.

During the initial power-up, the internal high-voltage current source charges the BPP pin capacitor (C6). Before switching, the primary will pause for around 80 ms to listen for secondary request signals. When the primary starts switching after initial power-up, it will initially assume control and require a handshake to pass the control to the secondary side. The LYTSwitch-6 IC is at normal operation when switching with the secondary in control. 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 (D3 and C5) and fed to the BPP pin via a current limiting resistor R1. The value of the BPP pin capacitor C6 sets the current limit of the LYTSwitch-6 IC. The 0.47 μF capacitance value for C6 corresponds to STANDARD current limit mode.

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 and output current sensing. The secondary of the transformer is rectified by a synchronous rectifier MOSFET (Q1), driven by the Synchronous Rectifier Drive (SR) pin of LYTSwitch-6 IC. This is then filtered by the output capacitors C10 and C16. Adding an RC snubber (R7 and C9) across the SR FET reduces voltage stress across its drain-to-source. An LC filter (L3 and C17) in series with the secondary winding of the transformer helps to further reduce the voltage spike across the drain-to-source of the SR FET, if a simple RC snubber is not enough, with little to no effect on system efficiency. Component L3 is a single-turn ferrite bead that, in conjunction with a parallel ceramic capacitor C17, suppresses high frequency spike present on the secondary of the transformer especially during start-up.

The secondary side of the IC is self-powered from either the secondary bias winding forward voltage or the 12 V regulated output. During normal operation the regulated output voltage powers the device, through the OUTPUT VOLTAGE (VOUT) pin. During start-up operation, when the output voltage is still building-up, the device will power itself from the secondary winding directly. During the ON-time of the primary-side MOSFET the forward voltage that appears across the secondary winding is used to charge the (BPS) capacitor C12 via the FORWARD (FWD) pin through resistor R6 and an internal regulator.

During constant voltage mode operation, output voltage regulation is achieved through sensing the output voltage via divider resistors R8 and R9. The voltage across R9 is fed into the FB pin with an internal reference voltage threshold of 1.265 V. Filter capacitor

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C11 is added across R9 to eliminate unwanted noise that might trigger the OVP function or increase the output ripple voltage. The feedforward network composed of C14 and R14 across R8 helps reduce output voltage ripple and achieve better output voltage regulation. Capacitor C13 filters out any unwanted noise that may enter the VOUT pin, and also helps reduce output voltage ripple. During constant current operation, the output current is set by the sense resistor (R18) across the IS pin and the GND pin. The internal reference threshold for the IS pin is 35.8 mV. Diode D6 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. The input of the flyback power supply circuit usually consists of the full wave bridge rectifier (BR1) followed by a storage bulk capacitor (C4) capable of maintaining a voltage approximately equal to the peak voltage of the input sine wave until the next peak comes to recharge the capacitor. 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). It is comprised of an inductor (T2) and diodes (D1 and D5) connected directly to the DRAIN pin of the LYTSwitch-6 IC. The LYTSwitch-6 flyback switching action is able to draw a high frequency pulse current from the full wave rectified input. This will reduce the rms input current and the phase angle difference from the input line voltage will be lower; hence, power factor will increase and will improve THD.

The PFC inductor T2 operates in DCM mode. During the LYTSwitch-6 turn ON time, current drawn from the rectified input ramps through the PFC inductor (T2) storing energy. The stored energy on T2 is then delivered to the load via direct energy transfer between the primary and secondary winding of the flyback transformer T1. Any 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. The expected voltage stress across the bulk capacitor C4 will be higher than the peak input voltage. To limit the bulk voltage below the bulk capacitor rating, especially at high input voltage, a Zener-resistor clamp circuit is used (VR2, VR3, and

R19). The Zener voltage is set at 480 V; when the bulk voltage goes beyond this, the Zener diodes conduct and bleed current from the bulk capacitor through resistor R19. This prevents the bulk capacitor voltage to rise above 480 V. The power dissipation of this Zener-resistor clamp should be considered at the worst-case creeping of the bulk voltage – happens usually at light load condition. Diodes D1 and D5 are connected in series to withstand voltage stress caused by the resonance ringing during the FET turn off. The variability of the PFC inductor peak current will be compensated by LYTSwitch-6 primary and secondary side control maintaining the voltage regulation at all conditions.

A low cost RCD clamp circuit across the Drain-to-Source pins of the LYTSwitch-6 IC will also limit the bulk voltage from rising at light load, but the additional dissipation will cause a decrease in overall system efficiency and increase no-load input power consumption.

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5 **PCB Layout**

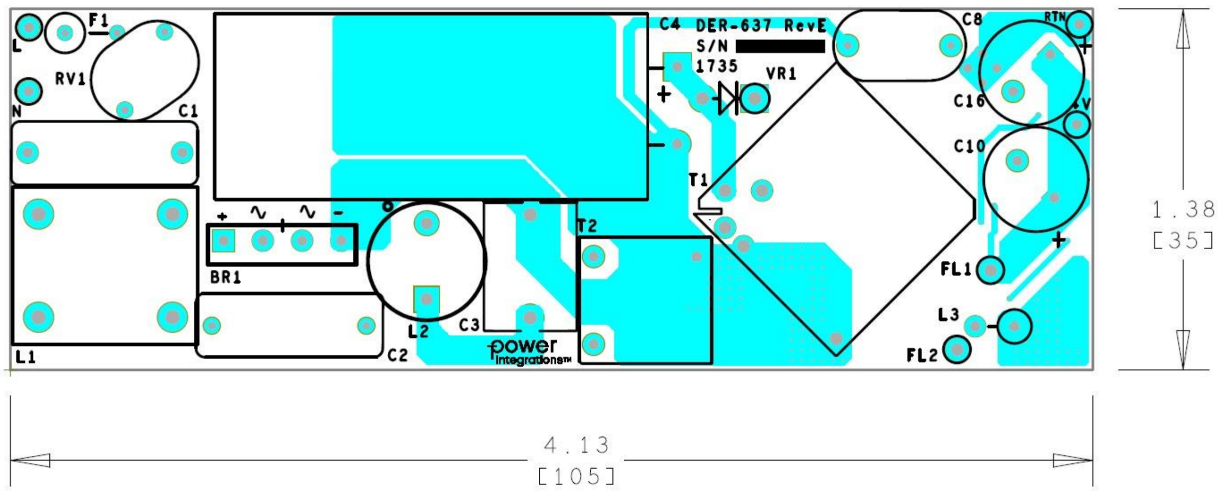

Figure 5 – Top Side.

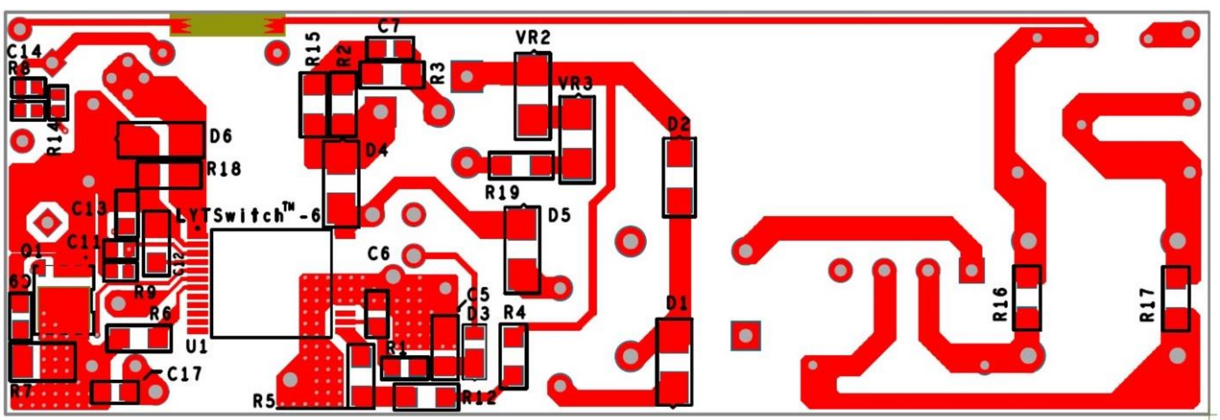

Figure 6 – Bottom Side.

6 Bill of Materials

6.1 *Main Bill of Material*

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=1 V @ 7.5 A	UD4KB100-BP	Micro Commercial
2	1	C1	68 nF, ±10%, 330 VAC, 760 VDC, X1 Safety Rated, Metallized Polypropylene Film, RAD	B32912A3683K000	Epcos
3	1	C2	68 nF, ±10%, 330 VAC, 760 VDC, X1 Safety Rated, Metallized Polypropylene Film, RAD	B32912A3683K000	Epcos
4	1	C3	220 nF, ±5%,630 VDC, 250 VAC, Film, 12.5 mm L x 15.8 mm H x 9.0 mm T, 10 mm LS	MEXPF3220JJ	Duratech
5	1	C4	68 uF, 500 V, Electrolytic ,(18 x 41.5), LS 0.295" (7.50 mm)	UCY2H680MHD	Nichicon
6	1	C5	22 μF, 35 V, Ceramic, X5R, 1206	C3216X5R1V226M160AC	TDK
7	1	C6	470 nF, 50 V, Ceramic, X7R, 0805	GRM21BR71H474KA88L	Murata
8	1	C7	3.3 nF, 200 V, Ceramic, X7R, 0805	08052C332KAT2A	AVX
9	1	C8	CAP Ceramic 2.2nF 500 VAC	VY1222M47Y5UQ63V0	Vishay
10	1	C9	470 pF, 200 V, Ceramic, X7R, 0805	C0805C471K2RACTU	Kemet
11	1	C10	1000 μF, 16 V, Electrolytic, Gen. Purpose, (10 x 17.5)	16ZLJ1000M10X16	Rubycon
12	1	C11	330 pF 50 V, Ceramic, X7R, 0603	CC0603KRX7R9BB331	Yageo
13	1	C12	2.2 μF, 25 V, Ceramic, X7R, 1206	TMK316B7225KL-T	Taiyo Yuden
14	1	C13	10 μF, ±10%, 16V, X7R, Ceramic Capacitor, -55°C ~ 125°C, Surface Mount, MLCC 0805	CL21B106KOQNNNE	Samsung
15	1	C14	100 nF 50 V, Ceramic, X7R, 0603	C1608X7R1H104K	TDK
16	1	C16	1000 μF, 16 V, Electrolytic, Gen. Purpose, (10 x 17.5)	16ZLJ1000M10X16	Rubycon
17	1	C17	3.3 nF, 200 V, Ceramic, X7R, 0805	08052C332KAT2A	AVX
18	1	D1	600 V, 2 A, Superfast, 35 ns, DO-214AC, SMA	ES2J-LTP	Micro Commercial
19	1	D2	600 V, 1 A, Standard Recovery, SMA	S1J-13-F	Diodes, Inc.
20	1	D3	Diode, Ultrafast, 200 V, 1 A, POWERDI123	DFLU1200-7	Diodes, Inc.
21	1	D4	1000 V, 1 A, DO-214AC	GS1M-LTP	Micro Commercial
22	1	D5	600 V, 2 A, Superfast, 35 ns, DO-214AC, SMA	ES2J-LTP	Micro Commercial
23	1	D6	Diode, SCHOTTKY, 40 V, 3 A, SMA, DO-214AA	B340A-13-F	Diodes, Inc.
24	1	F1	3.15 A, 250 V, Slow, 3.6 mm x 10 mm, Axial	08773.15MXEP	Littlefuse
25	1	L1	8.8 mH, 0.7 mA, AC Filter T/H Common Mode Choke	SU10VFC-R07088	Kemet
26	1	L2	1.5 mH, 0.8 A, 20%	RL-5480-4-1500	Renco
27	1	L3	3.5 mm x 4.45 mm, 56 Ω at 100 MHz, 22 AWG hole, Ferrite Bead	2761001112	Fair-Rite
28	1	Q1	MOSFET, N-CH, 150 V, 52 A, 8DFN	AON6250	Alpha & Omega Semi
29	1	R1	RES, 10 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1002V	Panasonic
30	1	R2	RES, 20 Ω, 1%, 1/2 W, Thin Film, 1206	RNCP1206FTD20R0	Stackpole
31	1	R3	RES, 120 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ124V	Panasonic
32	1	R4	RES, 1.60 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1604V	Panasonic
33	1	R5	RES, 1.30 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1304V	Panasonic
34	1	R6	RES, 47 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ470V	Panasonic
35	1	R7	RES, 15 Ω, ±1%, 0.75W, 3/4W, 1210, Thick Film	CRCW121015R0FKEAHP	Vishay Dale
36	1	R8	RES, 102 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1023V	Panasonic
37	1	R9	RES, 11.8 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1182V	Panasonic
38	1	R12	RES, 1.33 MΩ, 1%, 1/4 W, Thick Film, 1206	RC1206FR-071M33L	Yageo
39	1	R14	RES, 20 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2002V	Panasonic
40	1	R15	RES, 20 Ω, 1%, 1/2 W, Thin Film, 1206	RNCP1206FTD20R0	Stackpole
41	1	R16	RES, 36 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ363V	Panasonic
42	1	R17	RES, 36 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ363V	Panasonic
43	1	R18	0.012 Ω, ±1%, ±100ppm/°C, 1 W, 1206 (3216 Metric), Current Sense, Thick Film	RUK3216FR012CS	Samsung

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44	1	R19	RES, 1 k, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ102V	Panasonic
45	1	RV1	Varistor, 350 VAC, 3.5K A, 10.5 mm, Bulk ZNR, ERZ-E, Surge Absorber	ERZ-E08A561	Panasonic
46	1	T1	Bobbin, RM8, Vertical, 12 pins	BRM08-1112CP-W-P5.0	MH&W
47	1	T2	Bobbin, EE13, Vertical, 10 pins	P-1302-2	Pin Shine
48	1	VR1	DIODE, ZENER, 140 V, ±5%,1.5 W, DO204AL, DO-204AL (DO-41)	Z4KE140A-E3/54	Vishay
49	1	VR2	240 V, 1.25 W, 600 W (Peak, non-repetitive),5%, DO214AC (SMA)	BZG03C240TR	Vishay
50	1	VR3	240 V, 1.25 W, 600 W (Peak, non-repetitive),5%, DO214AC (SMA)	BZG03C240TR	Vishay
51	1	U1	LYTSwitch-6, InSOP24D	LYT6068C	Power Integrations

6.2 ***Miscellaneous Parts***

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	+V	Test Point, RED, Miniature THRU-HOLE MOUNT	5000	Keystone
2	1	RTN	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone
3	1	L	Test Point, WHT, Miniature THRU-HOLE MOUNT	5002	Keystone
4	1	N	Test Point, BLK, THRU-HOLE MOUNT	5011	Keystone
5	1	FL1	Flying Lead, Hole size 50mils	N/A	N/A
6	1	FL2	Flying Lead, Hole size 50mils	N/A	N/A

7 Flyback Transformer (T1) Specification

7.1 *Electrical Diagram*

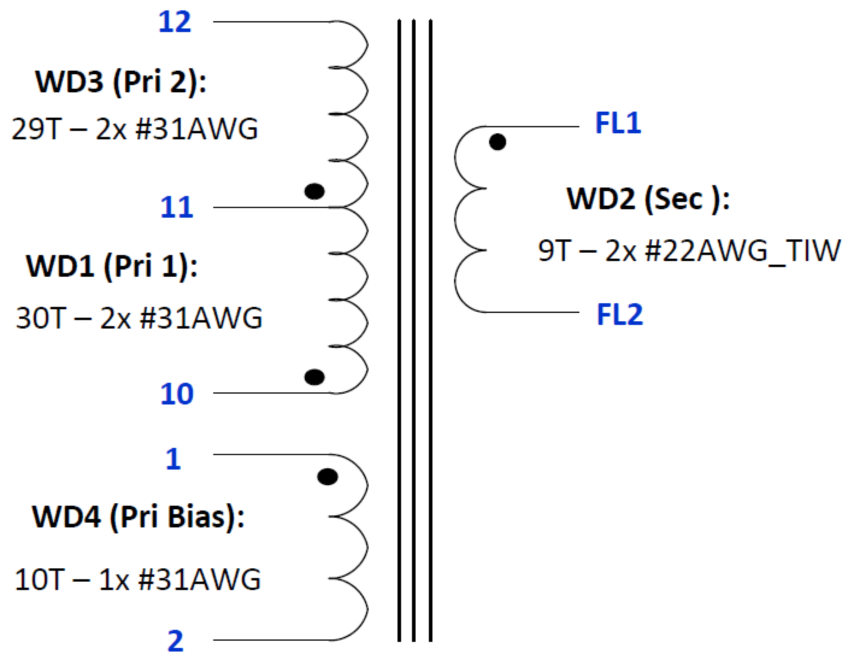

Figure 7 – Transformer Electrical Diagram.

7.2 *Electrical Specifications*

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 10 and pin 12 with all other windings open.	720 μH
Tolerance	Tolerance of Primary Inductance.	±5%
Leakage Inductance	Measured across primary winding with all other windings shorted.	<6 μH

7.3 *Material List*

Item	Description
[1]	Core: RM8 PC95.
[2]	Bobbin: Bobbin, RM8, Vertical, 12 pins; Part No. : 25-01084-00.
[3]	Magnet Wire: #31 AWG.
[4]	TIW: # 22 AWG.
[5]	Polyester Tape: 9 mm.
[6]	RM8 Core Clip with Terminal.

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7.4 *Transformer Build Diagram*

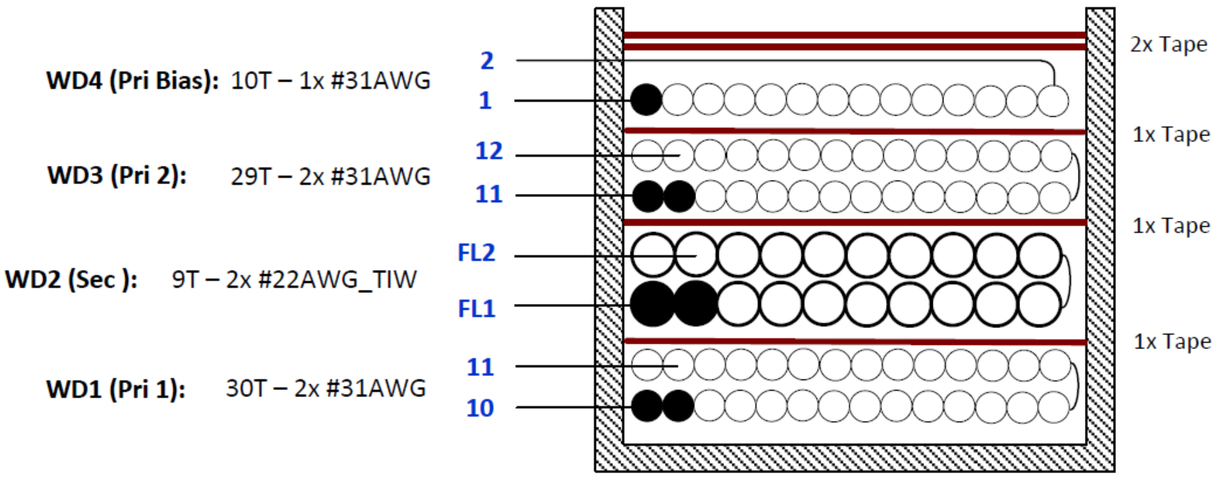
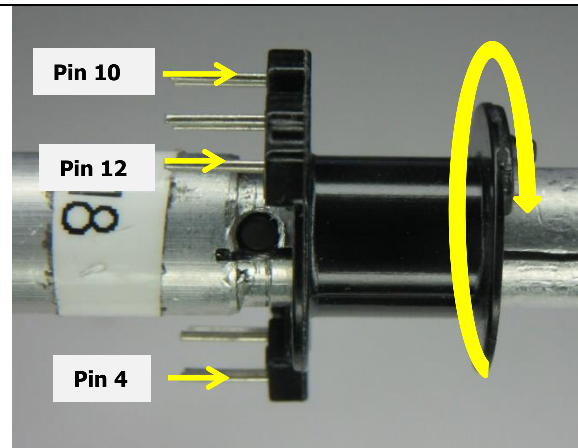
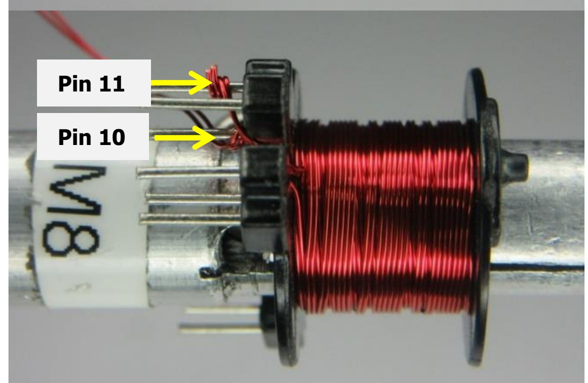
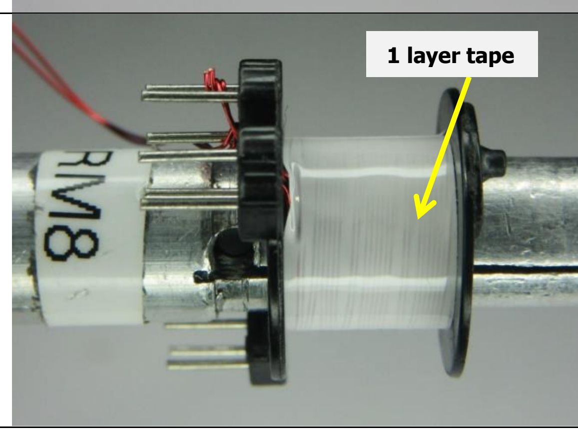


Figure 8 – Transformer Build Diagram.

7.5 *Transformer Construction*

Winding Directions	Bobbin is oriented on winder jig such that terminal pin 10-12 is in the right side. The winding direction is clockwise.
Winding 1	Use bifilar magnetic wire, Item [3]. Start at pin 10 and wind 30 turns evenly in 2 layers. Finish the winding on pin 11.
Insulation	Apply 1 layer of polyester tape, Item [5] for insulation
Winding 2	Use bifilar triple insulated wire, Item [4]. Start at the other side of the bobbin (pin 4 – pin 9 side) and wind 9 turns evenly in 2 layers. Finished the winding on the same side of the bobbin. Do not terminate the winding on any pin of the bobbin; Just leave them as fly-leads.
Insulation	Apply 1 layer of polyester tape, Item [5] for insulation.
Winding 3	Use bifilar magnetic wire, Item [3]. Start at pin 11 and wind 29 turns evenly in 2 layers. Finished the winding on pin 12.
Insulation	Apply 1 layer of polyester tape, Item [5] for insulation**.**
Winding 4	Use magnetic wire, Item [3]. Start at pin 1 and wind 10 turns. Finish the winding on pin 2.
Insulation	Apply 2 layers of polyester tape, Item [5] for insulation.
Core Grinding	Grind the center leg of the ferrite core to meet the nominal inductance specification of 720 μH.
Assemble Core	Use RM8 core clips with terminals, Item [6] 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). Trim pin 11 as short as possible.
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 10-12 is in the right side. The winding direction is clockwise.	
Winding 1 Use bifilar magnetic wire, Item [3]. Start at pin 10 and wind 30 turns evenly in 2 layers. Finish the winding on pin 11.	
Insulation Apply 1 layer of polyester tape, Item [5] for insulation.	

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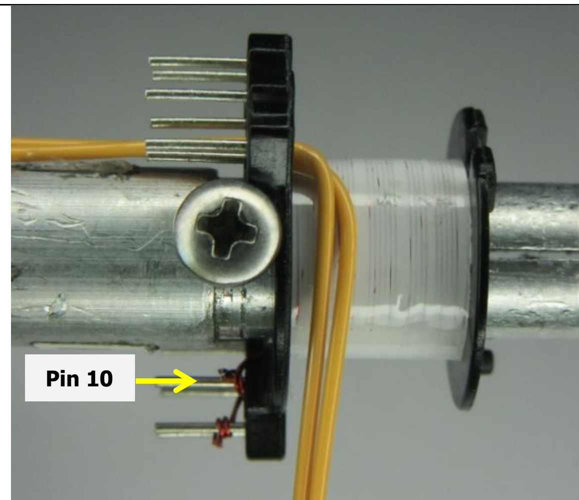
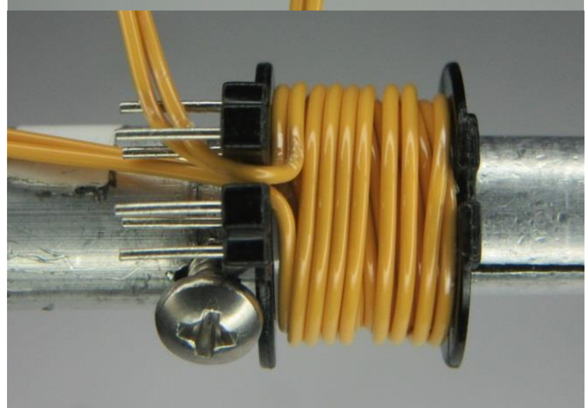
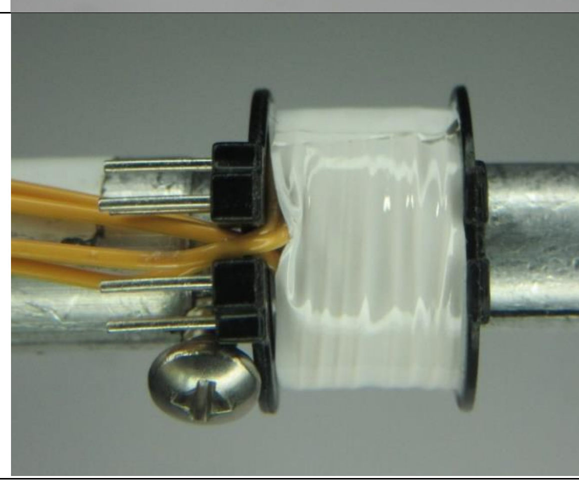
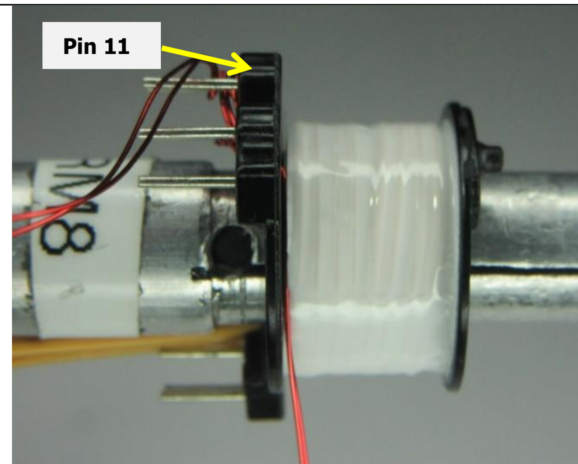
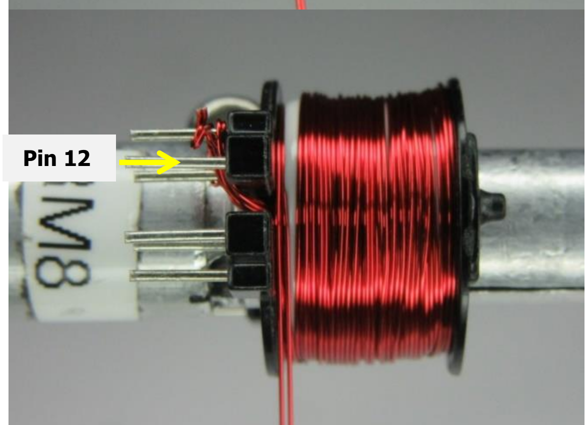
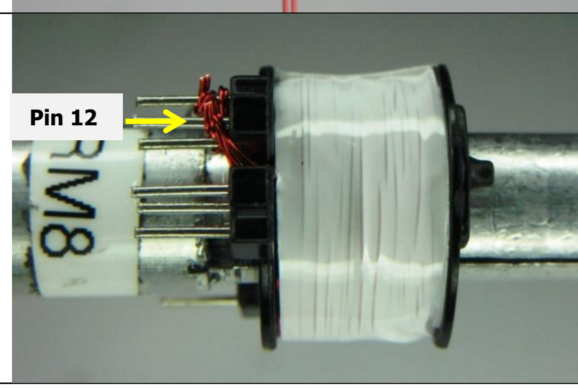
Winding 2 Use bifilar triple insulated wire, Item [4]. Start at the other side of the bobbin (pin 4 – pin 9 side) and wind 9 turns evenly in 2 layers.	
Finished the winding on the same side of the bobbin. Do not terminate the winding on any pin of the bobbin; Just leave them as fly-leads.	
Insulation Apply 1 layer of polyester tape, Item [5] for insulation.	

Winding 3 Use bifilar magnetic wire, Item [3]. Start at pin 11 and wind 29 turns evenly in 2 layers. Finished the winding on pin 12.	 
Insulation Apply 1 layer of polyester tape, Item [5] for insulation.	

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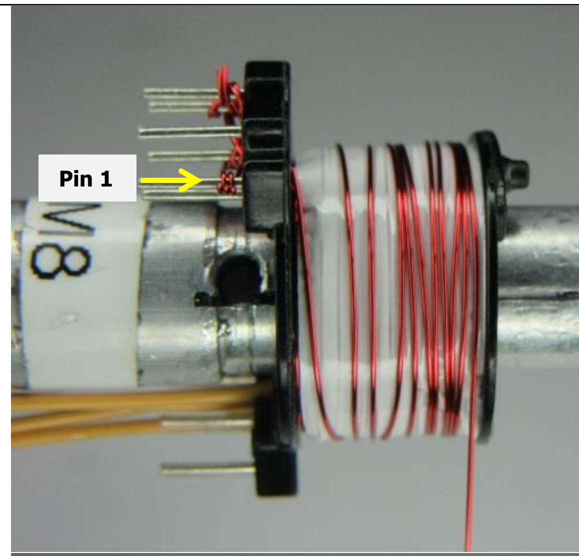
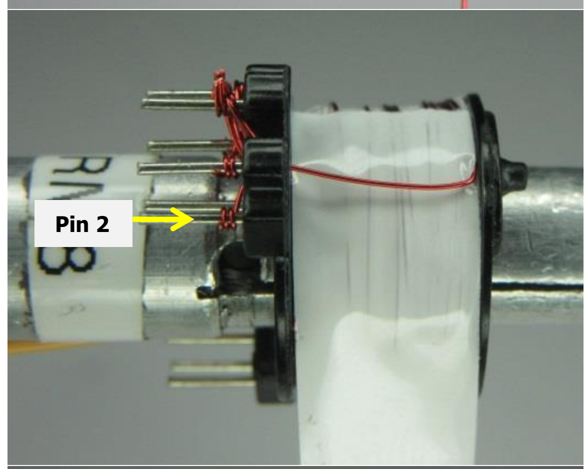
Winding 4

Use magnetic wire, Item [3]. Start at pin 1 and wind 10 turns.

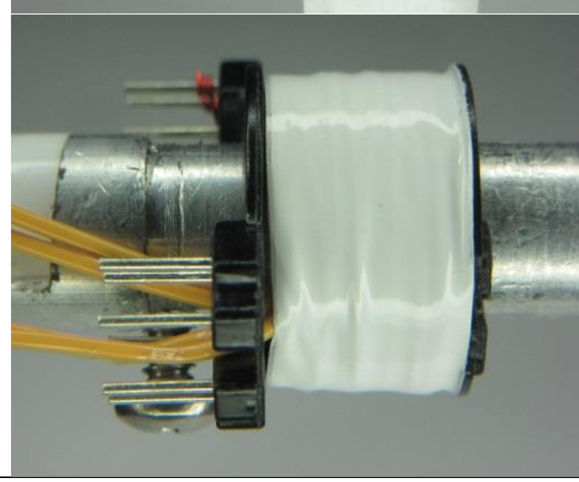


Finish the winding on pin 2.



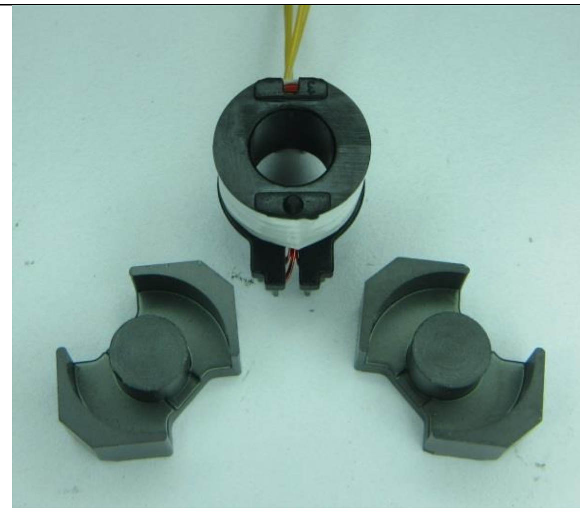
Insulation

Apply 2 layers of polyester tape, Item [5] for insulation.



Core Termination

Use two PC95 RM8 cores, Item [1] and assemble them with the wounded bobbin.

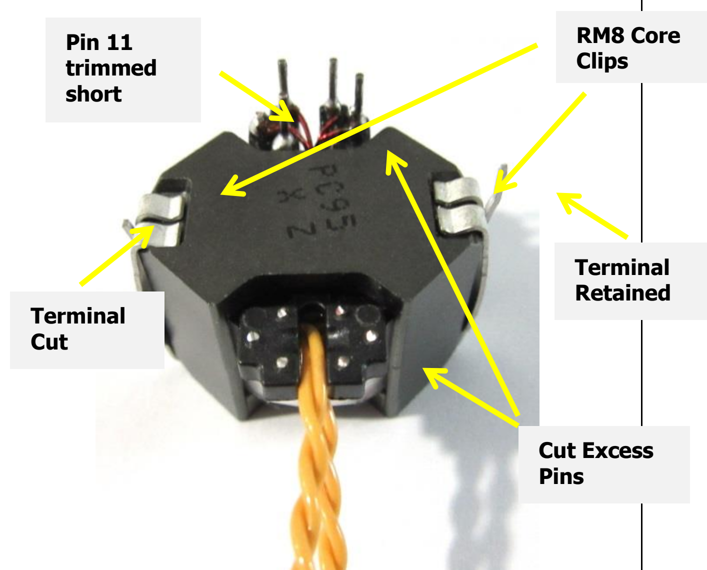


Core Clips

Use RM8 Core Clips with Terminals, Item [6] 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). Trim pin 11 as short as possible.

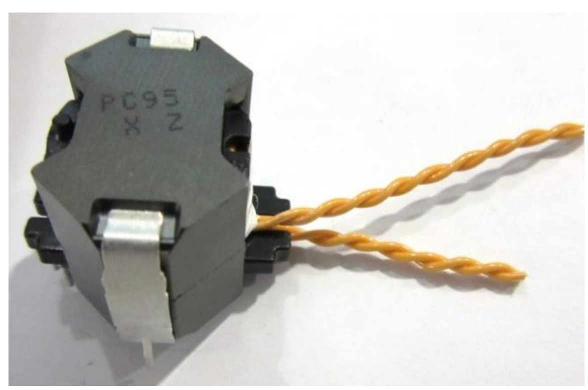


Fly Leads

Twist the fly leads for easier termination on the PCB.

Varnishing

Dip the transformer in a 2:1 varnish and thinner solution



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8 PFC Inductor (T2) Specifications

8.1 *Electrical Diagram*

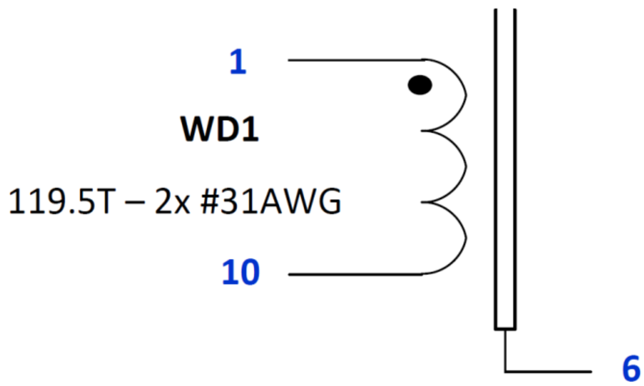

Figure 9 – Inductor Electrical Diagram.

8.2 *Electrical Specifications*

Parameter	Condition	Spec.
Nominal Primary Inductance	**Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 1 and pin 10.**	**760 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: #31 AWG.
[4]	Transformer tape: 7.7 mm.
[5]	Transformer tape: 6 mm.

8.4 *Inductor Build Diagram*

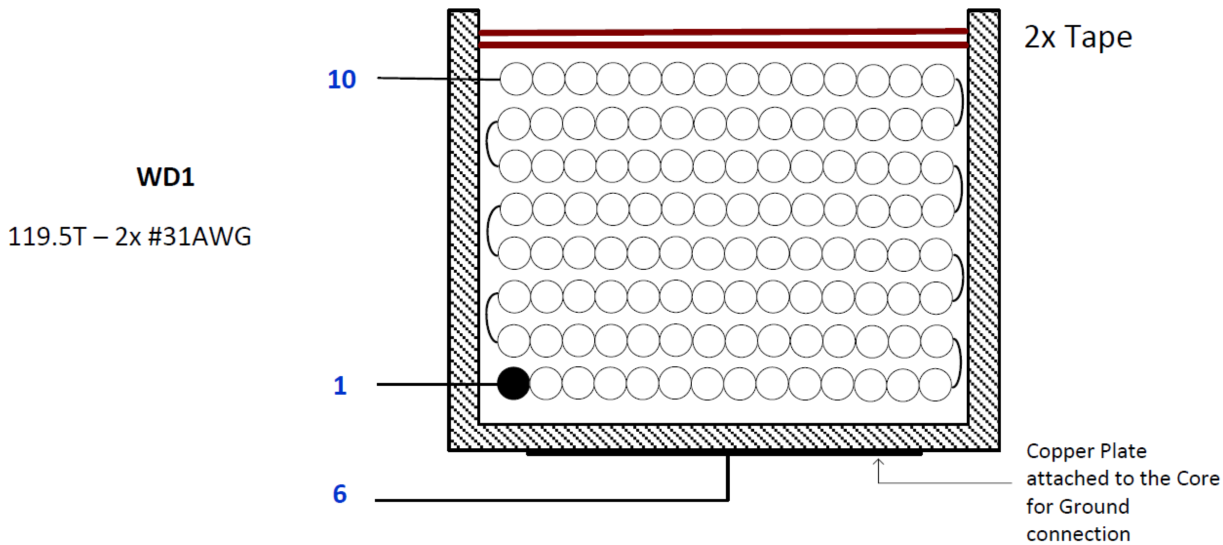

Figure 10 – Transformer Build Diagram.

8.5 *Inductor Construction*

Winding Directions	Bobbin is oriented on winder jig such that terminal pin 1 – 5 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 1 and wind 119.5 turns bifilar in 9 layers. Finish the winding on pin 10.
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 760 μH. Inductance is measured across pin 1 and pin 10.
Assemble Core	Assemble the 2 cores on the bobbin.
Core Termination	Prepare a copper strip with a soldered magnetic wire, Item [3], 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 6.
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. 2, 3, 4, 5, 7, 8, and pin 9.
Finish	Dip the transformer assembly in 2:1 varnish and thinner solution.

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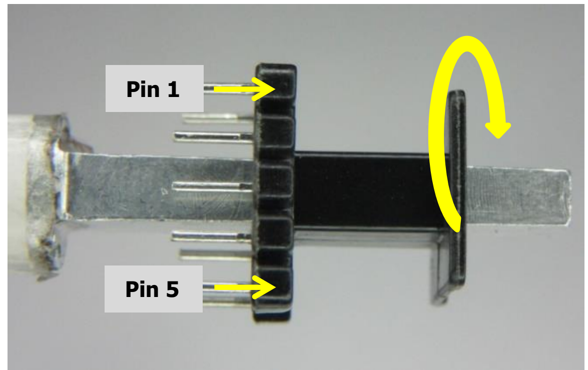
8.6 *Inductor Winding Illustrations*

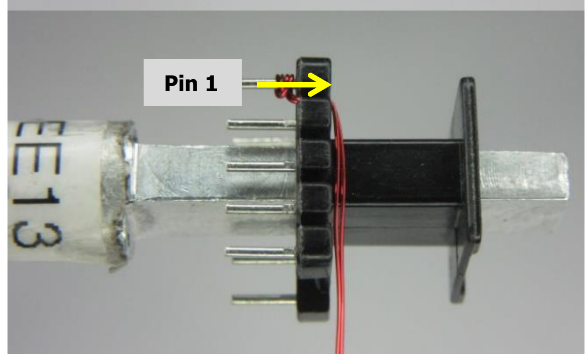
Winding Directions

Bobbin is oriented on winder jig such that terminal pin 1 – 5 is in the left side. The winding direction is clockwise.

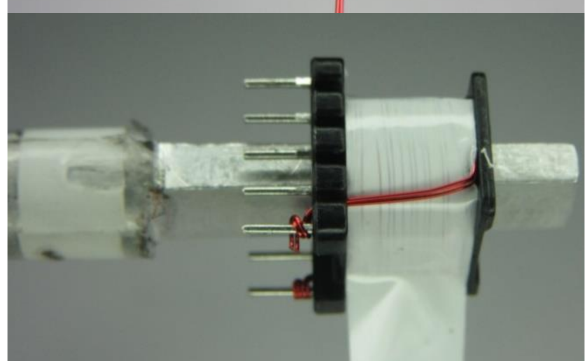


Winding 1

Prepare the magnetic wire Item [3] for bifilar-wound type winding. Start at pin 1 and wind 119.5 turns bifilar in 9 layers.

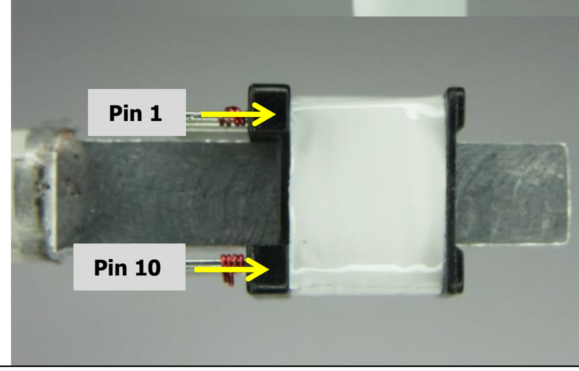


Finish the winding on pin 10.



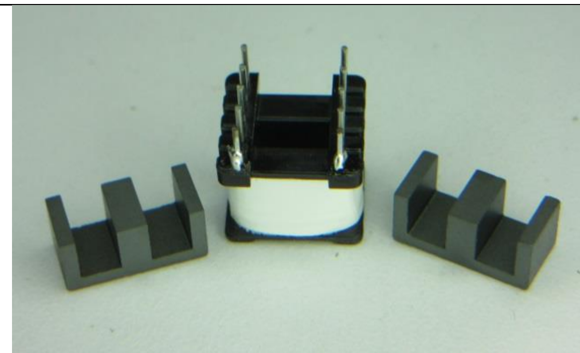
Insulation

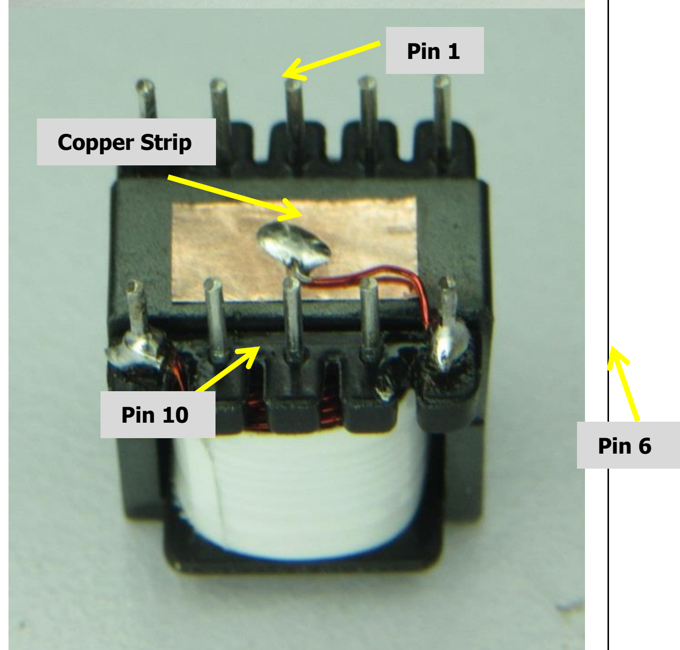
Add 2 layers of tape, Item [4] for insulation



Core Termination

Prepare a copper strip with a soldered magnetic wire, Item [3], 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 6.





Core Tape

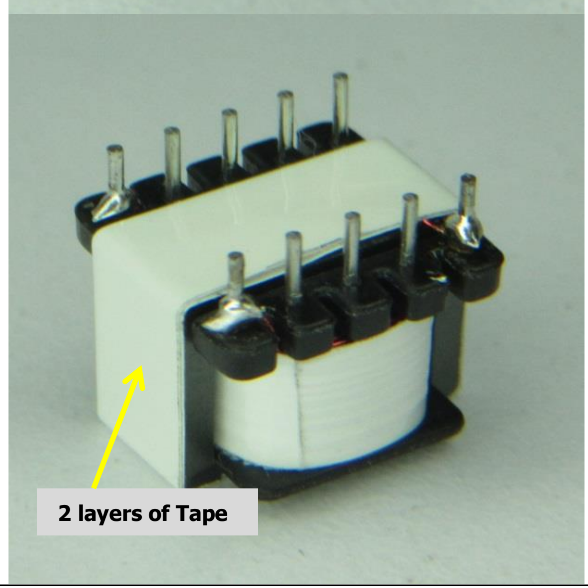
Add 2 layers of tape Item [5] around the core to fix the 2 cores into the bobbin.

PINS

Pull out or cut Terminal pin no. 2,3, 4, 5, 7, 8, and pin 9

Finish

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



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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	140		140	V	Minimum Input AC Voltage
4	VACNOM	230		230	V	Nominal AC Voltage (For universal designs low line nominal voltage is displayed)
5	VACMAX	320		320	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			500	V	Input Capacitance Recommended Voltage Rating
10	VO	12.00		12.00	V	Output Voltage
11	IO	2.92		2.92	A	Output Current
12	PO			35.04	W	Total Output Power
13	N			88.00		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	Worst_Case		Worst_Case		Calculated Results Based on Selected VAC - VACNOM,VACMAX,VACMIN or Worst Case only
18	**Primary Controller Section**					
19	DEVICE_MODE	Standard		Standard		Device Current Limit Mode
20	DEVNAME	LYT6068C		LYT6068C		PI Device Name
21	RDSON			1.53	ohms	Device RDSON at 100degC
22	ILIMITMIN			1.534	A	Minimum Current Limit
23	ILIMITTYP			1.650	A	Typical Current Limit
24	ILIMITMAX			1.766	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			600.55	V	Peak Drain to Source Voltage during Fet turn off
28	**Worst Case Electrical Parameters**					
29	**Boost Converter**					
30	IBOOSTRMS			296.90	mA	Boost RMS current
31	IBOOSTMAX			788.21	mA	Boost PEAK current
32	IBOOSTAVG			190.53	mA	Boost AVG current
33	IINRMS			313.49	mA	Input RMS current
34	PF_est			0.8258		Estimated Power Factor
35	**Flyback Converter**					
36	FSMIN	47700		47700	Hz	Minimum Switching Frequency in a Line Period
37	FSMAX			97880.19	Hz	Maximum Switching Frequency in a Line Period
38	KPmin			0.8528		Minimum KP in a Line Period for VAC specified by PARcalcBASIS
39	IFETRMS			498.46	mA	Fet RMS current
40	IFETMAX			1647.13	mA	Fet PEAK current
41	IPRIRMS			0.4040	A	Primary Winding RMS current
42	IPRIMAX			1.4870	A	Primary Winding PEAK current
43	IPRIAVG			0.0704	A	Primary Winding AVG current
44	IPRIMIN			885.63	mA	Primary Winding Minimum current
45	ISECRMS			4.19	A	Secondary RMS current

46	ISECMAX			10.11	A	Secondary PEAK current
47	**Boost Choke Construction Parameters**					
48	RATIO_LBST_LFB	1.0555		1.0555		Boost Inductance and Flyback Primary Inductance Ratio
49	LBOOSTMIN			720.89	µH	Minimum Boost Inductance
50	LBOOSTNOM			758.83	µH	Nominal Boost Inductance
51	LBOOSTMAX			796.77	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			40.32	%	Boost Bobbin Fill Factor
65	**Boost Winding Details**					
66	NBOOST	119.50		119.50		Boost Choke Turns
67	BP_BOOST			3057.81	Gauss	Boost Peak Flux Density
68	ALG_BOOST			53.14	nH/turns²	Boost Core Ungapped Core Effective Inductance
69	LG_BOOST			0.39	mm	Boost Core Gap Length
70	L_BOOST	4.00		4.00		Number of Boost Layers
71	AWG_BOOST			31.00		Boost Winding Wire AWG
72	OD_BOOST_INSULATED			0.27	mm	Boost Winding Wire Output Diameter with Insulation
73	OD_BOOST_BARE			0.23	mm	Boost Winding Wire Output Diameter without Insulation
74	CMA_BOOST			269.68	Circular Mils/A	Boost Winding Wire CMA
75	**Flyback Transformer Construction Parameters**					
76	VOR	78		78	V	Secondary Voltage Reflected in the Primary Winding
77	LP_MIN			682.98	µH	Minimum Flyback Inductance
78	LP_NOM			718.93	µH	Nominal Flyback Inductance
79	LP_MAX			754.88	µH	Maximum Flyback Inductance
80	LP_TOL	5.00		5.00	%	Flyback Inductance Tolerance
81	**Flyback Core and Bobbin Selection**					
82	CR_TYPE	RM8/I		RM8/I		Flyback Core
83	CR_PN			RM8/I-3F3		Flyback Core Code
84	AE			63.00	mm²	Flyback Core Cross Sectional Area
85	LE			38.40	mm	Flyback Core Magnetic Path Length
86	AL			3000.00	nH/turns²	Flyback Core Ungapped Core Effective Inductance
87	VE			2440.00	mm3	Flyback Core Volume
88	BOBBINID			Ferroxcube		Flyback Bobbin
89	BB_ORIENTATION			H		Flyback Bobbin Orientation H - Horizontal and V -Vertical
90	AW			30.90	mm²	Flyback Window Area of Bobbin
91	BW			8.60	mm	Flyback Bobbin Width
92	MARGIN			0.00	mm	Safety Margin Width
93	**Flyback Winding Details**					
94	NP			59.00		Primary Turns
95	BP			3670.89	Gauss	Flyback Peak Flux Density
96	BM			3533.33	Gauss	Flyback Maximum Flux Density
97	BAC			1487.83	Gauss	Flyback AC Flux Density
98	ALG			206.53	nH/turns²	Flyback Core Ungapped Core Effective

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						Inductance
99	LG			0.36	mm	Flyback Core Gap Length
100	L			2.00		Number of Flyback Layers
101	AWG			30.00		Primary Winding Wire AWG
102	OD			0.30	mm	Primary Winding Wire Output Diameter with Insulation
103	DIA			0.26	mm	Primary Winding Wire Output Diameter without Insulation
104	CMA			249.81	Circular Mils/A	Primary Winding Wire CMA
105	NB			10.00		Bias Turns
106	L_BIAS			1.00		Number of Flyback Bias Winding Layers
107	AWGpBias			36.00		Bias Wire AWG
108	NS	9		9		Secondary Turns
109	AWGS			20.00		Secondary Winding Wire AWG
110	ODS			0.81	mm	Secondary Winding Wire Output Diameter with Insulation
111	DIAS			1.12	mm	Secondary Winding Wire Output Diameter without Insulation
112	CMAS			244.62	Circular Mils/A	Secondary Winding Wire CMA
113	**Primary Components Selection**					
114	**Line Undervoltage**					
115	BROWN_IN_REQUIRED	85.00		85.00	V	Required AC RMS line voltage brown-in threshold
116	RLS			2.10	MOhm	Two Resistors of this Value in Series to the V-pin
117	BROWN_IN_ACTUAL			84.15	V	Actual AC RMS brown-in threshold
118	**Line Overvoltage**					
119	OVERVOLTAGE_LINE			350.90	V	Actual AC RMS line over-voltage threshold
120	**Bias Voltage**					
121	VBIAS	13.0		13.0	V	Rectified Bias Voltage
122	VF_BIASDIODE			0.70	V	Bias Winding Diode Forward Drop
123	VRRM_BIASDIODE			89.70	V	Bias diode reverse voltage
124	CBIAS			22.0	µF	Bias winding rectification capacitor
125	CBPP			0.47	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			240.00	V	Zener 1 Voltage Rating (In Series with Zener 2)
129	PZ1_W			1.25	W	Zener 1 Minimum Power Rating
130	VZ2_V			240.00	V	Zener 2 Voltage Rating
131	PZ2_W			1.25	W	Zener 2 Minimum Power Rating
132	RZ			1000.00	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			12.10	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			82.03	V	Auxiliary diode reverse voltage
144	CAUX			22.00	µF	Auxiliary winding rectification capacitor
145	NAUX_SEC			9.00		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			12.00	V	Actual Output Voltage
150	IOUT_ACTUAL			2.92	A	Actual Output Current
151	ISECRMS			4.19	A	Secondary RMS current for output
152	**Output Components**					
153	VF			0.70	V	Output diode forward drop
154	VRRM			81.03	V	Output diode reverse voltage
155	COUT			2040.53	µF	Output Capacitor - Capacitance
156	COUT_VOpercentRip			2.50	%	Output Capacitor Ripple % of VOUT
157	ICOUTrms			3.00	A	Output Capacitor Estimated Ripple Current
158	ESRmax			29.69	mohms	Output Capacitor Maximum Recommended ESR
159	**Errors, Warnings, Information**					
160	Information			VDRAIN,OVERVOLTAGE_LINE		Although the design has passed the user should validate functionality on the bench. Please check the variables listed.
161	Design Warnings					Design variables whose values exceed electrical/datasheet specifications.
162	Design Errors					The list of design variables which result in an infeasible design.

Notes: Row 160 – Actual drain voltage stress does not exceed the absolute maximum V_{DS} rating of LYTSwitch-6 IC. Actual line overvoltage protection is below the absolute maximum V_{DS} rating of LYTSwitch-6 IC.

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10 Performance Data

All measurements were performed at room temperature.

10.1 *Output Voltage Regulation*

Set-up:	Open frame unit
Load:	2.92 A CC load
Ambient Temperature:	25 ºC
Soak time:	180 seconds

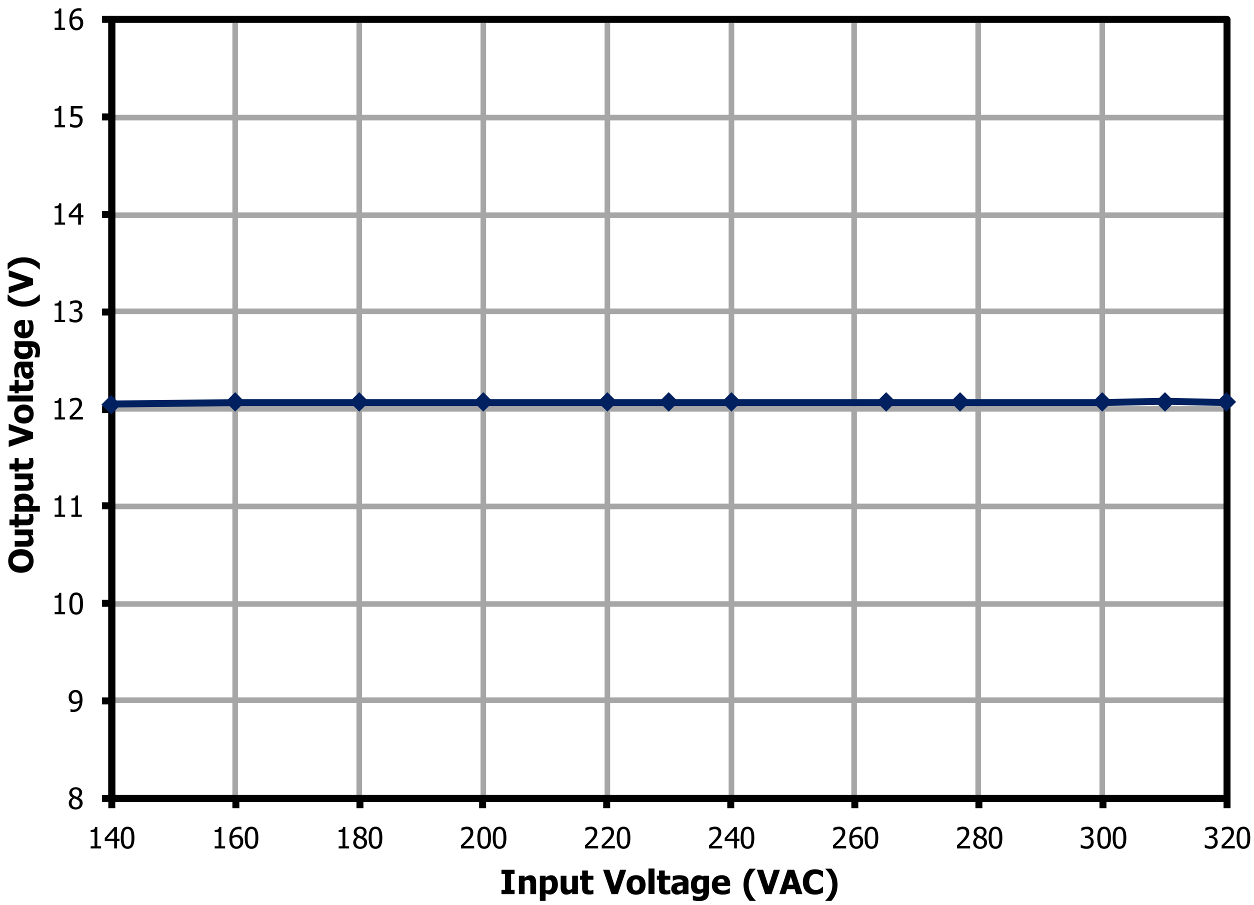

Figure 11 – Output Voltage Regulation vs. Input Line Voltage.

10.2 *System Efficiency*

Set-up: Open frame unit
Load: 2.92 A CC load
Ambient Temperature: 25 ºC
Soak time: 180 seconds

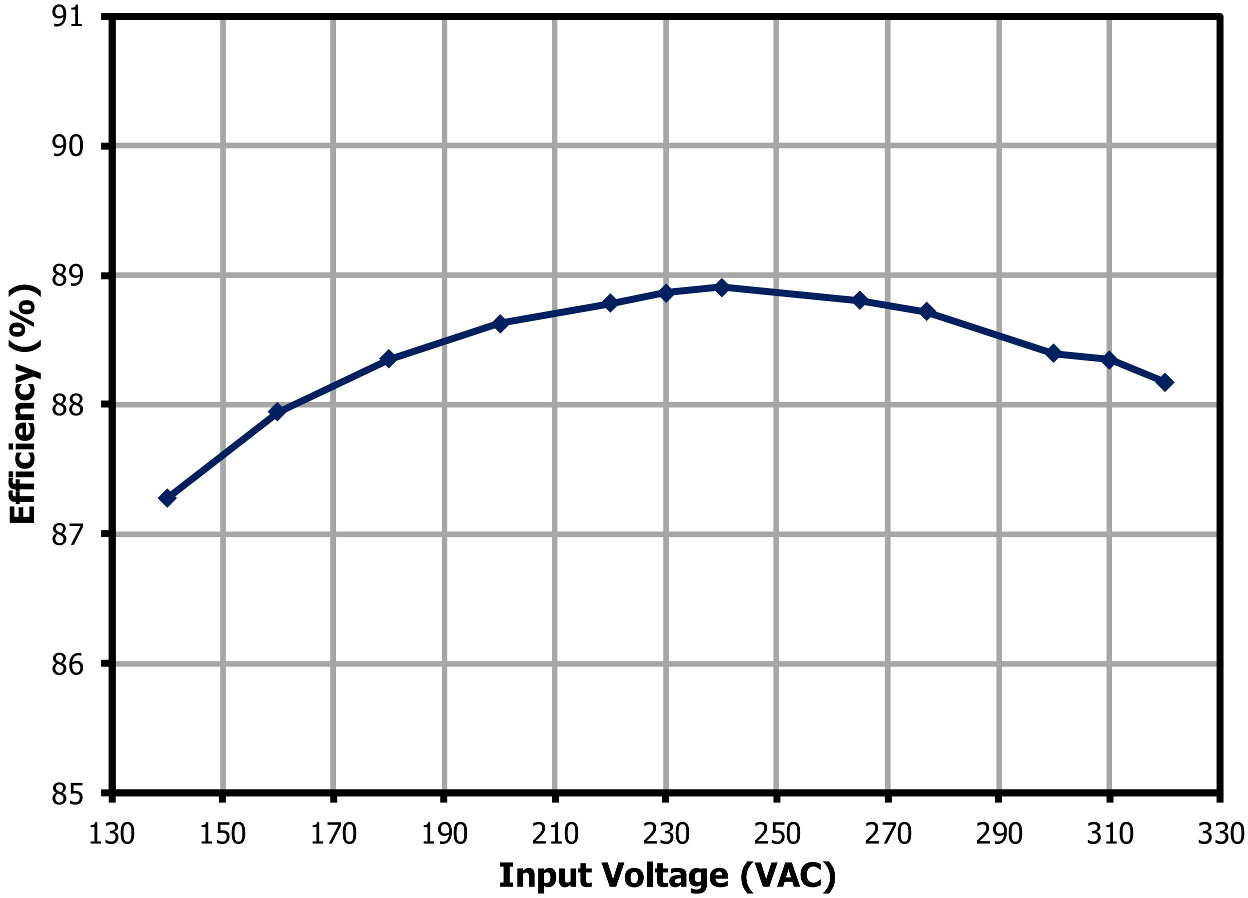

Figure 12 – Efficiency vs. Input Line Voltage.

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10.3 *Power Factor*

Set-up: Open frame unit
Load: 2.92 A CC load
Ambient Temperature: 25 ºC
Soak time: 180 seconds

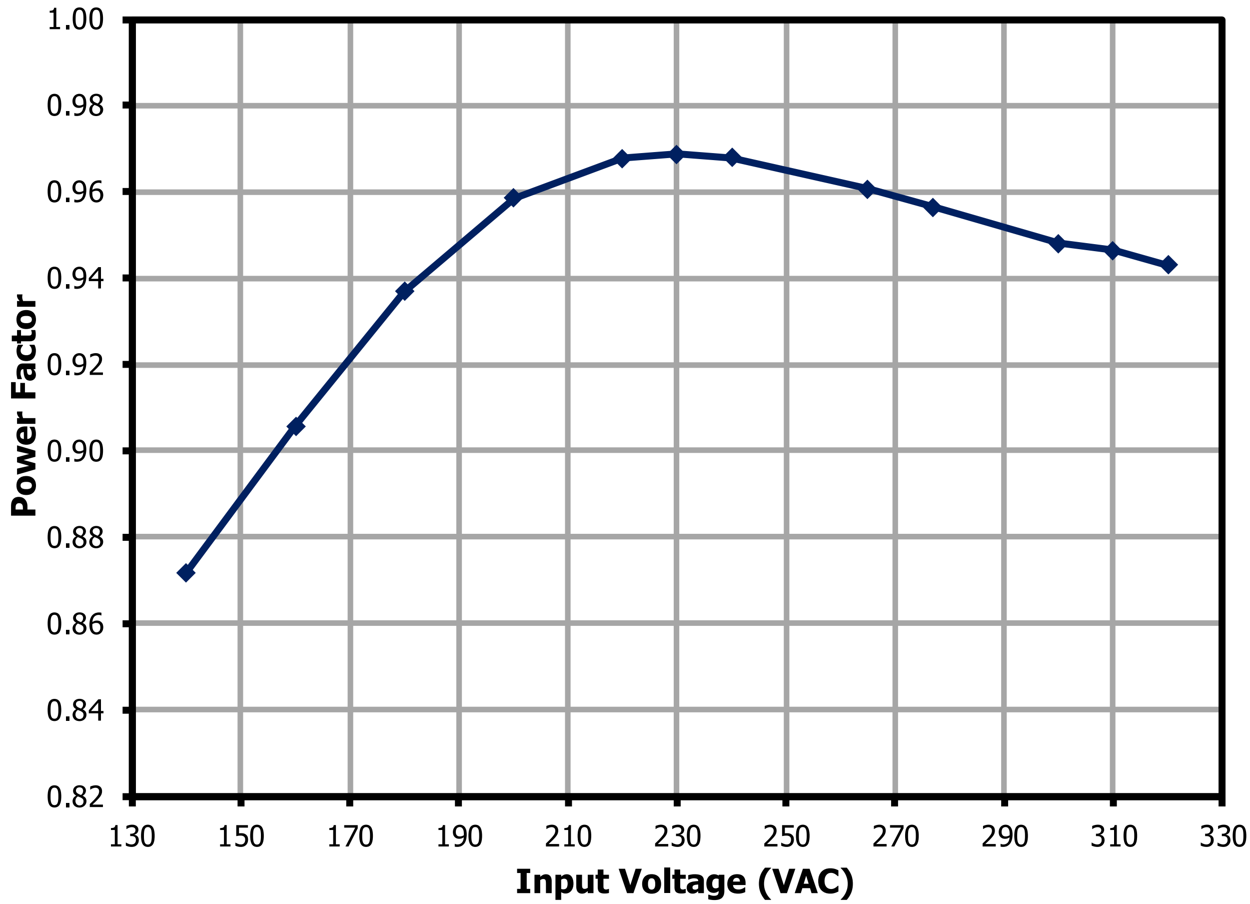

Figure 13 – Power Factor vs. Input Line Voltage.

10.4 *%ATHD*

Set-up: Open frame unit
Load: 2.92 A CC load
Ambient Temperature: 25 ºC
Soak time: 180 seconds

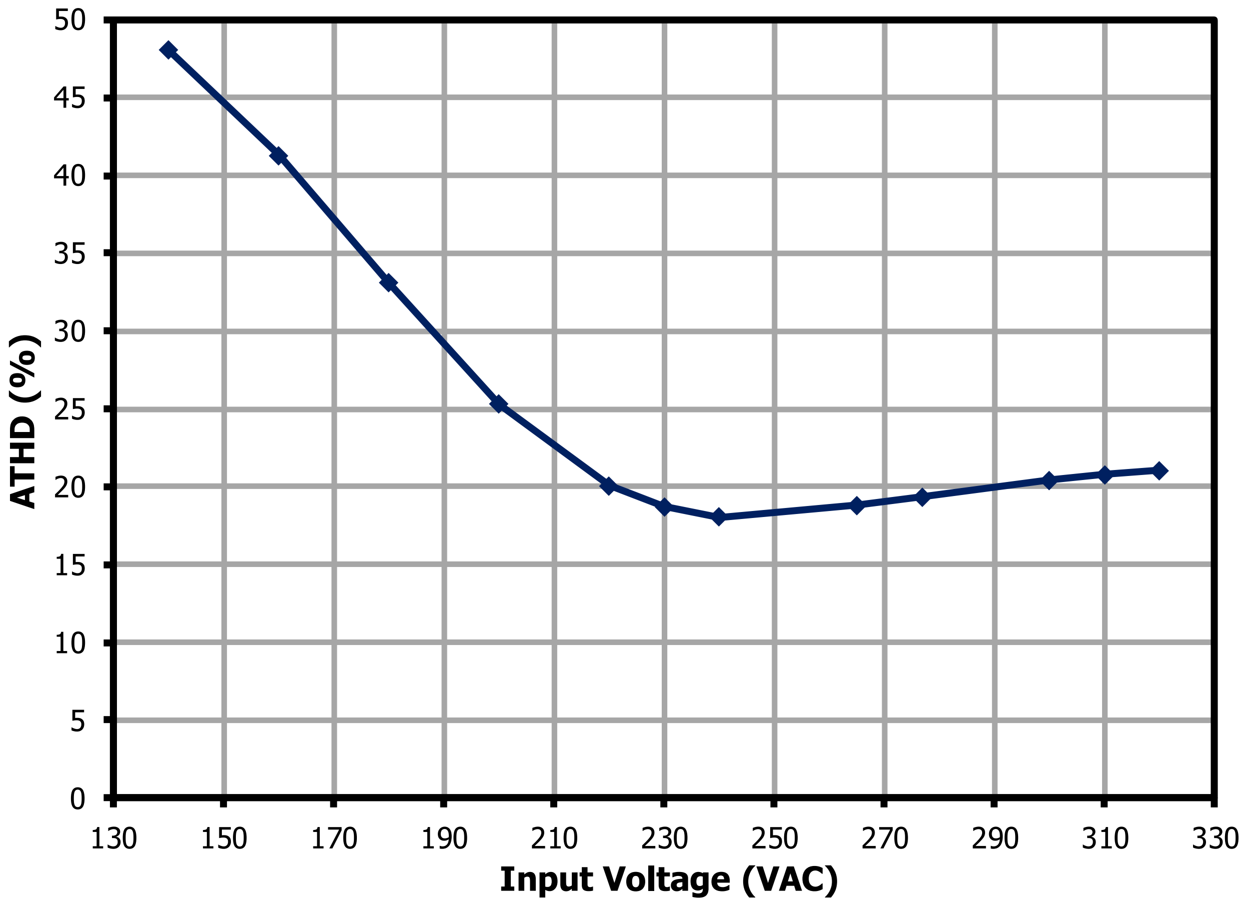

Figure 14 – %ATHD vs. Input Line Voltage.

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10.5 *Individual Harmonics Content at Full Load*

Set-up: Open frame unit
Load: 2.92 A CC load
V_{IN}: 230 V 50 Hz
Ambient Temperature: 25 ºC
Soak time: 180 seconds

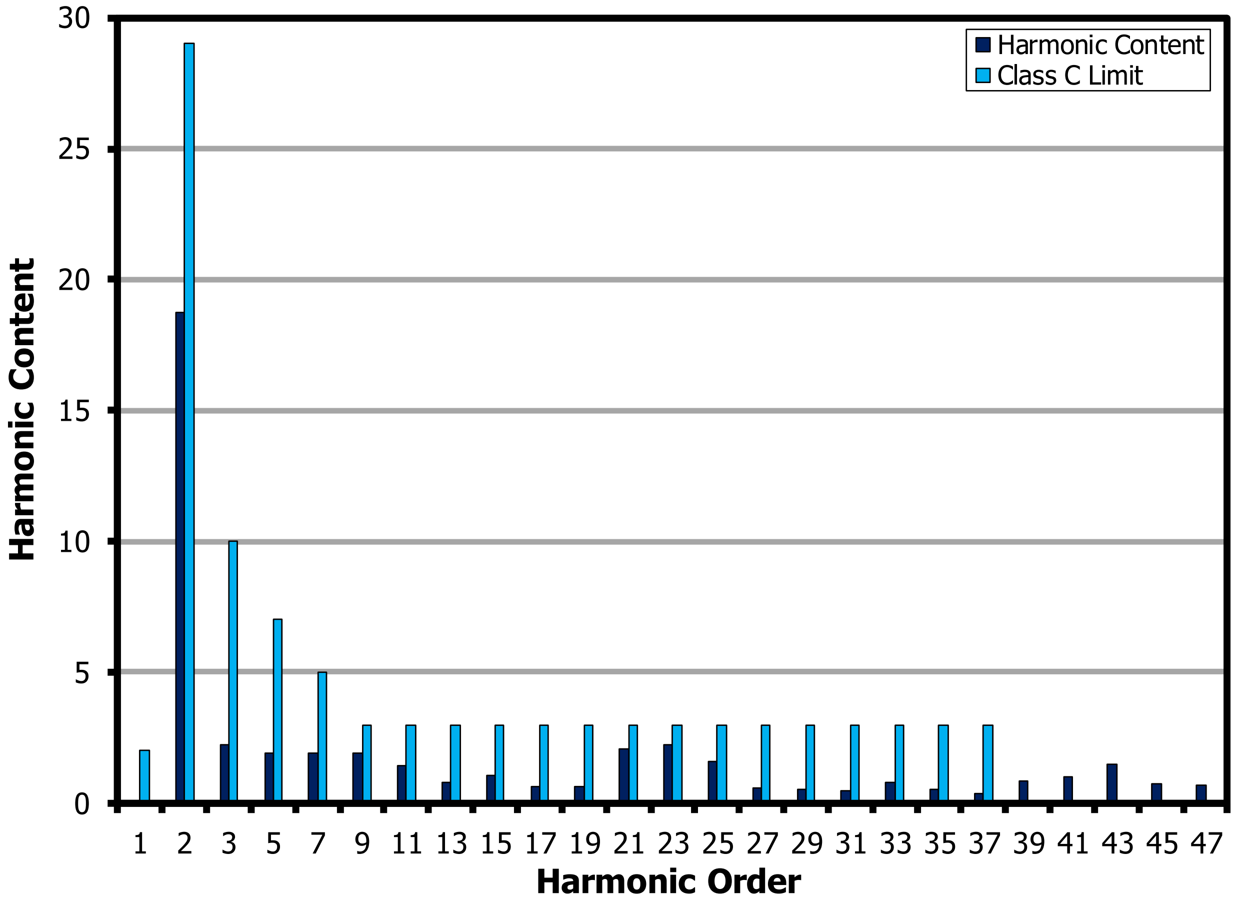

Figure 15 – Full Load Input Current Harmonics at 230 VAC 50 Hz.

Set-up: Open frame unit
Load: 2.92 A CC Load
V_{IN}: 277 V 50 Hz
Ambient Temperature: 25 ºC
Soak time: 180 seconds

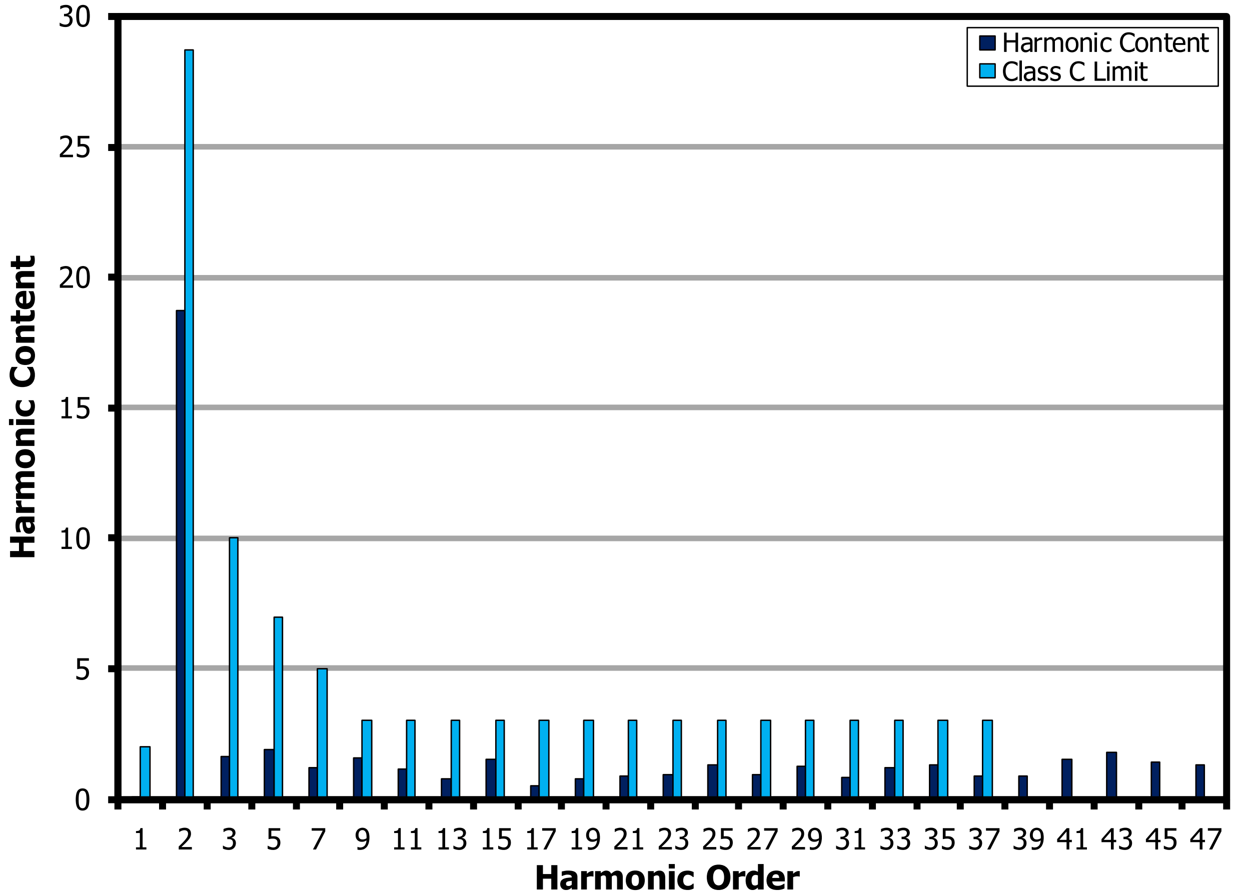

Figure 16 – Full Load Input Current Harmonics at 277 VAC 50 Hz.

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10.6 *No-Load Input Power*

Set-up: Open frame unit
Load: Open load
Ambient Temperature: 25 ºC
Soak time: 180 seconds

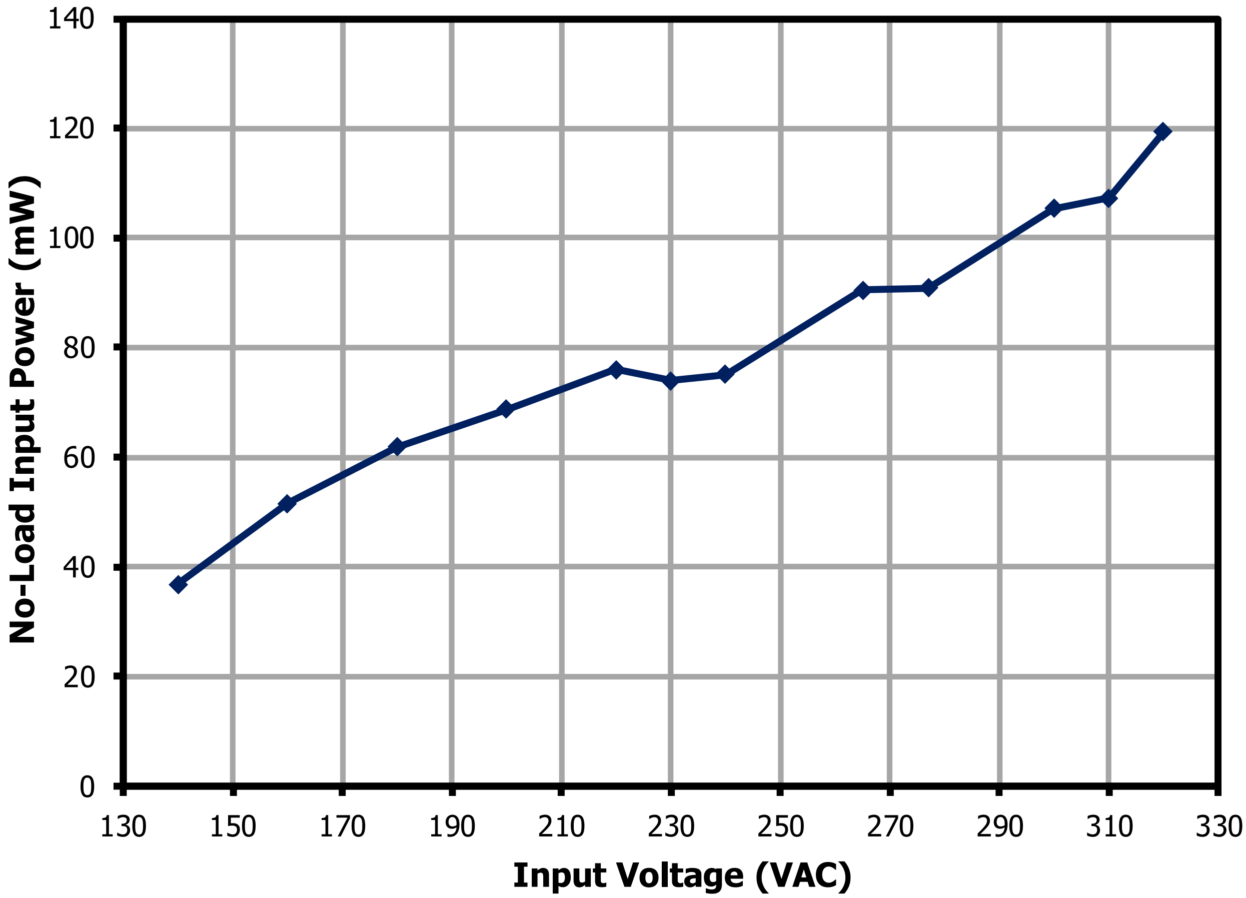

Figure 17 – No-Load Input Power vs. Input Line Voltage.

10.7 *CV/CC Curve*

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

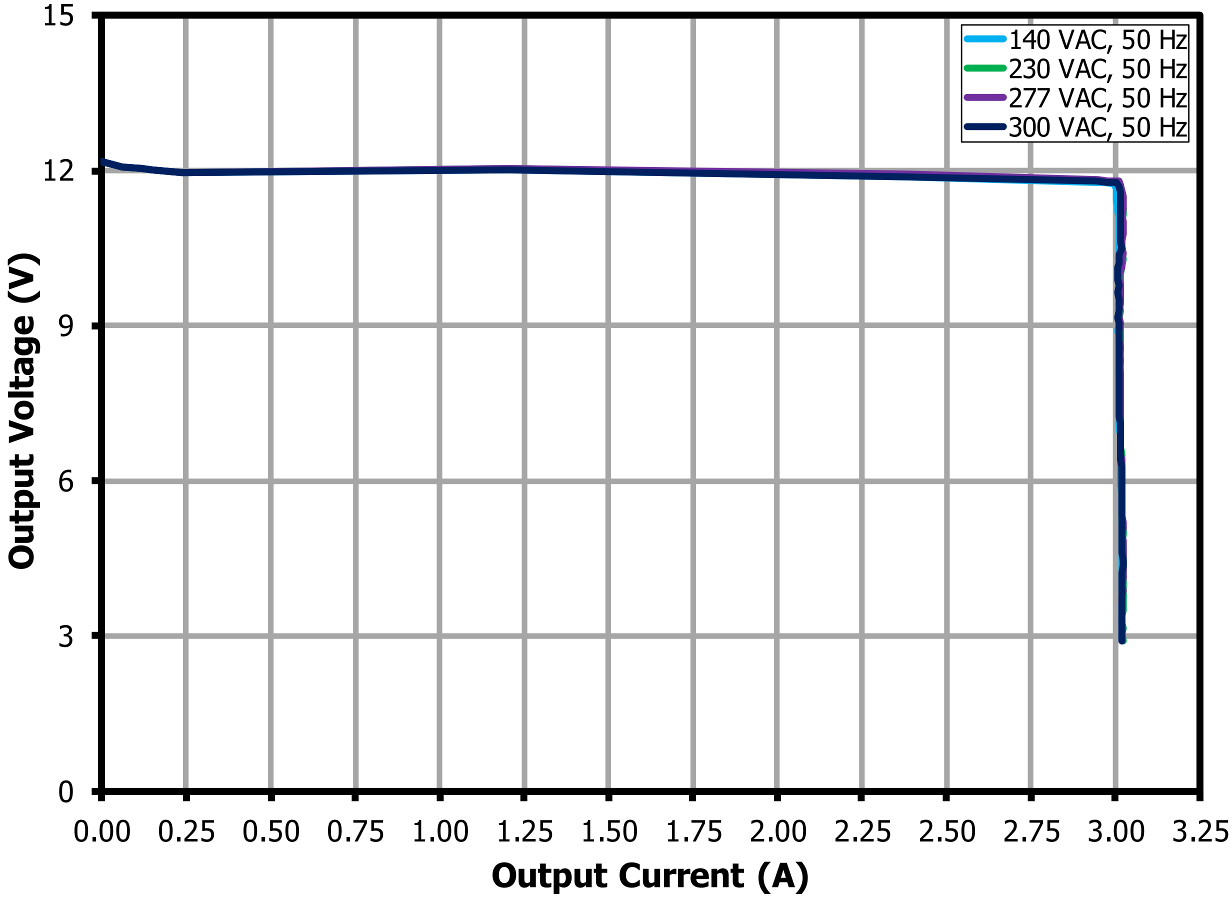

Figure 18 – CV/CC Curve.

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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)	
140	50	139.96	330.37	40.31	0.872	48.04	12.05	2919.80	35.18	87.27
160	50	159.92	276.59	40.06	0.906	41.28	12.07	2919.80	35.23	87.95
180	50	179.97	236.51	39.88	0.937	33.09	12.07	2919.80	35.23	88.35
200	50	199.92	207.49	39.76	0.959	25.31	12.07	2919.80	35.24	88.63
220	50	219.96	186.47	39.69	0.968	20.08	12.07	2919.80	35.24	88.78
230	50	229.99	177.99	39.65	0.969	18.74	12.07	2919.70	35.23	88.86
240	50	240.01	170.58	39.63	0.968	18.05	12.07	2919.70	35.23	88.90
265	50	265.03	155.84	39.68	0.961	18.83	12.07	2919.70	35.24	88.80
277	50	277.02	149.89	39.72	0.957	19.35	12.07	2919.80	35.24	88.72
300	50	300.07	140.13	39.86	0.948	20.42	12.07	2919.70	35.23	88.39
310	50	309.84	136.14	39.92	0.947	20.79	12.08	2919.80	35.27	88.35
320	50	319.75	132.56	39.97	0.943	21.04	12.07	2919.70	35.24	88.17

11.2 *Test Data at No-Load*

Input		Input Measurement					Output Measurement
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})
140	50	140.03	10.29	0.037	0.026	48.28	12.19
160	50	159.98	10.51	0.052	0.031	14.79	12.19
180	50	180.02	10.82	0.062	0.032	34.03	12.19
200	50	199.97	11.30	0.069	0.030	28.46	12.19
220	50	220.00	12.03	0.076	0.029	11.69	12.19
230	50	230.02	12.46	0.074	0.026	21.99	12.19
240	50	240.04	12.92	0.075	0.024	20.81	12.19
265	50	265.07	14.01	0.091	0.024	20.94	12.19
277	50	277.06	14.45	0.091	0.023	8.78	12.19
300	50	300.10	15.13	0.105	0.023	20.94	12.19
310	50	310.32	12.57	0.107	0.028	5.44	12.19
320	50	320.22	12.98	0.119	0.029	6.13	12.19

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

V	Freq	I_{IN} (mA_{RMS})	P	PF	%THD
230	50.00	179.08	39.870	0.968	19.466
nth Order	**mA Content**	**% Content**	**mA Limit <25 W**	**% Limit >25 W**	**Remarks**
1	175.32				
2	0.09	0.05%		2.00%	Pass
3	32.83	18.73%	135.56	29.04%	Pass
5	3.91	2.23%	75.75	10.00%	Pass
7	3.35	1.91%	39.87	7.00%	Pass
9	3.33	1.90%	19.94	5.00%	Pass
11	3.34	1.91%	13.95	3.00%	Pass
13	2.52	1.44%	11.81	3.00%	Pass
15	1.41	0.80%	10.23	3.00%	Pass
17	1.81	1.03%	9.03	3.00%	Pass
19	1.10	0.63%	8.08	3.00%	Pass
21	1.11	0.63%	7.31	3.00%	Pass
23	3.66	2.09%	6.67	3.00%	Pass
25	3.86	2.20%	6.14	3.00%	Pass
27	2.77	1.58%	5.69	3.00%	Pass
29	1.05	0.60%	5.29	3.00%	Pass
31	0.93	0.53%	4.95	3.00%	Pass
33	0.81	0.46%	4.65	3.00%	Pass
35	1.36	0.78%	4.39	3.00%	Pass
37	0.93	0.53%	4.15	3.00%	Pass
39	0.65	0.37%	3.94	3.00%	Pass
41	1.47	0.84%			
43	1.74	0.99%			
45	2.56	1.46%			
47	1.27	0.72%			
49	1.15	0.66%			

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11.4 *Individual Harmonic Content at 277 VAC 50 Hz and Full Load*

V	Freq	I_{IN} (mA_{RMS})	P	PF	%THD
277	50.00	150.53	39.920	0.957	19.508
nth Order	**mA Content**	**% Content**	**mA Limit <25 W**	**% Limit >25 W**	**Remarks**
1	146.61				
2	0.15	0.10%		2.00%	Pass
3	27.44	18.72%	135.66	28.72%	Pass
5	2.37	1.62%	75.81	10.00%	Pass
7	2.78	1.90%	39.90	7.00%	Pass
9	1.74	1.19%	19.95	5.00%	Pass
11	2.30	1.57%	13.97	3.00%	Pass
13	1.65	1.13%	11.82	3.00%	Pass
15	1.17	0.80%	10.24	3.00%	Pass
17	2.26	1.54%	9.04	3.00%	Pass
19	0.73	0.50%	8.09	3.00%	Pass
21	1.13	0.77%	7.32	3.00%	Pass
23	1.28	0.87%	6.68	3.00%	Pass
25	1.39	0.95%	6.14	3.00%	Pass
27	1.96	1.34%	5.69	3.00%	Pass
29	1.41	0.96%	5.30	3.00%	Pass
31	1.84	1.26%	4.96	3.00%	Pass
33	1.23	0.84%	4.66	3.00%	Pass
35	1.75	1.19%	4.39	3.00%	Pass
37	1.96	1.34%	4.15	3.00%	Pass
39	1.28	0.87%	3.94	3.00%	Pass
41	1.27	0.87%			
43	2.22	1.51%			
45	2.60	1.77%			
47	2.10	1.43%			
49	1.94	1.32%			

12 Load Regulation Performance

Set-up: Open frame unit
Ambient Temperature: 25 ºC (Room Temp)

12.1 *Output Voltage Load Regulation*

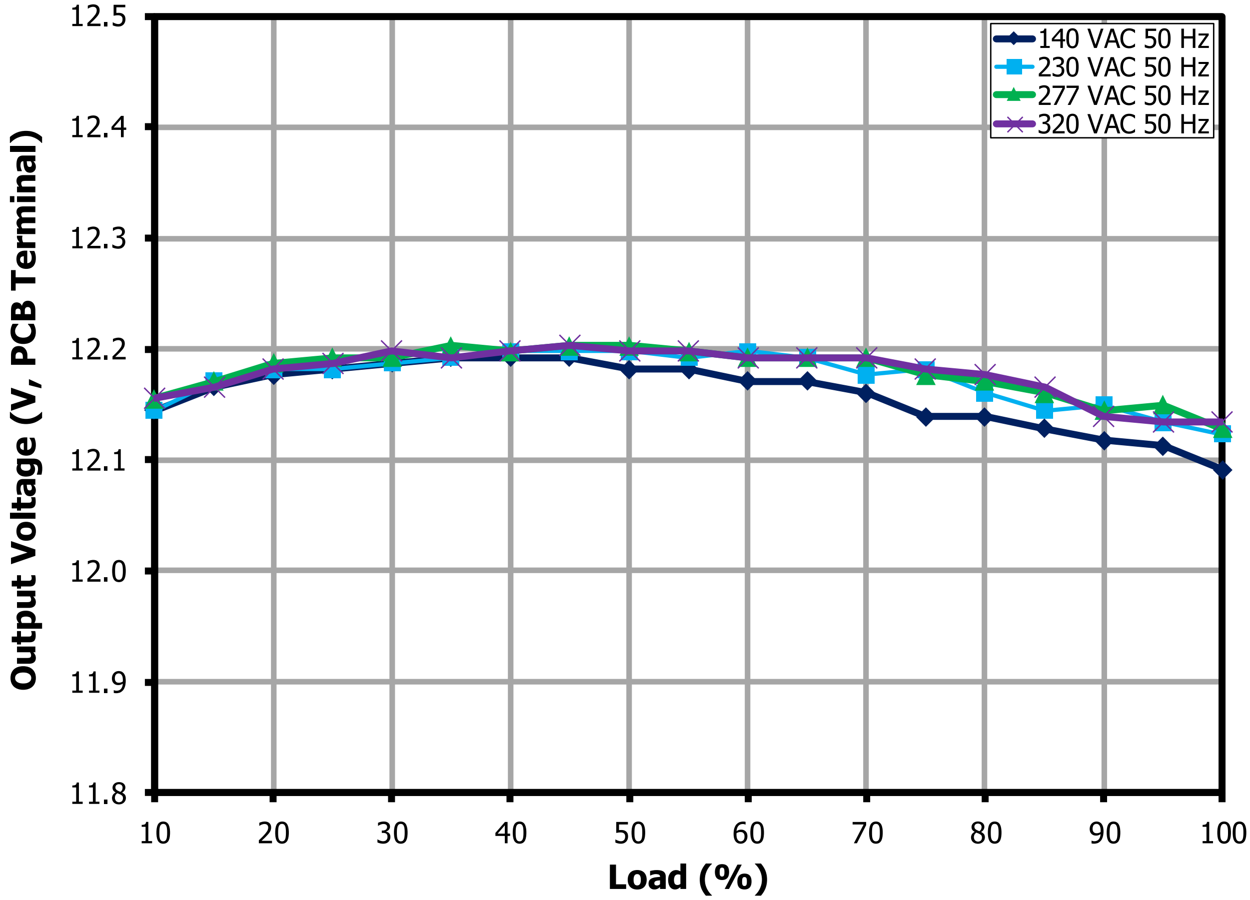

Figure 19 – Output Voltage vs. Load.

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12.2 *Efficiency vs. Load*

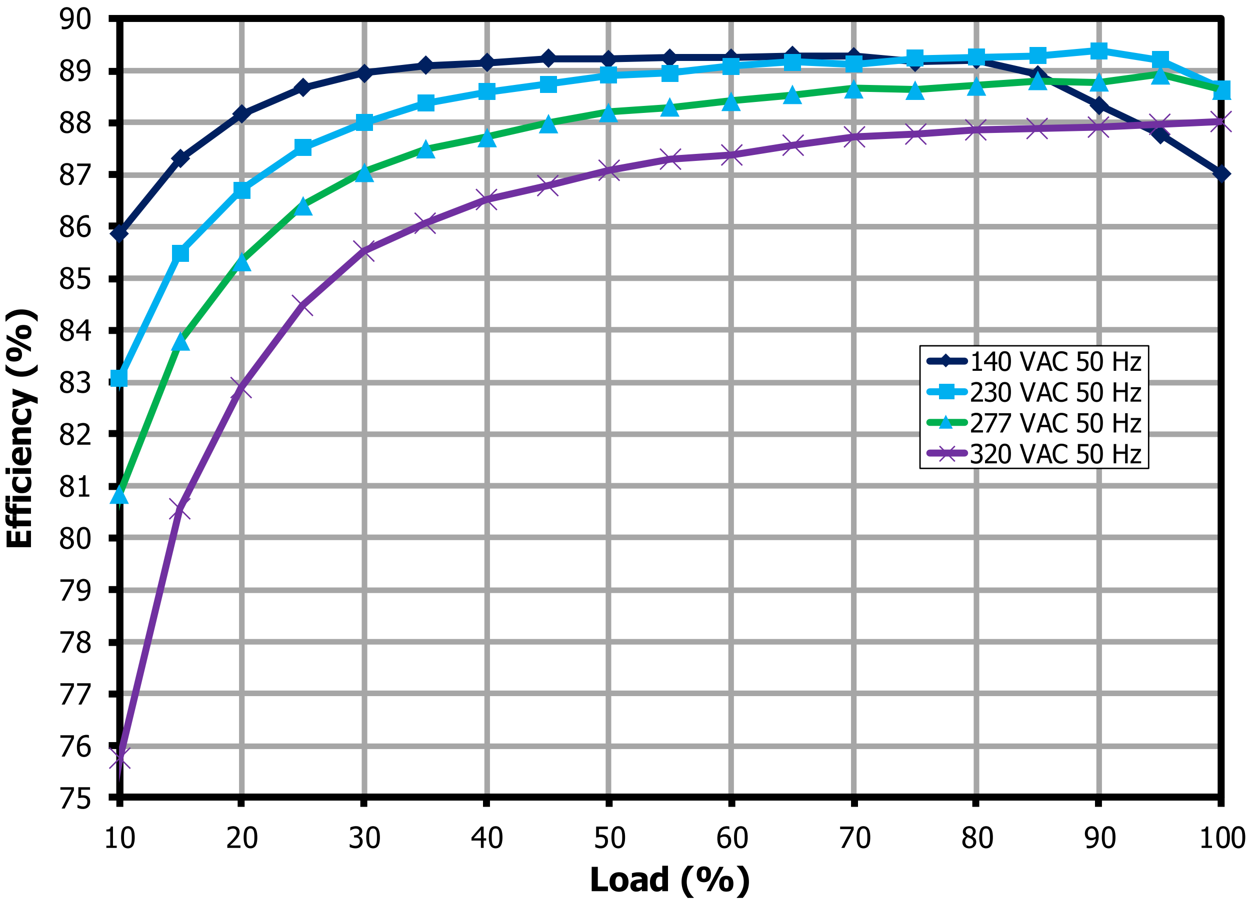

Figure 20 – Efficiency vs Load.

12.3 *Average Efficiency*

12.3.1 Average Efficiency Measurement

%Load	Efficiency (%)	
	230 V / 50 Hz	277 V / 50 Hz
100%	88.66	88.64
75%	89.24	88.64
50%	88.91	88.20
25%	87.53	86.41
Average Efficiency	88.59	87.97
DOE Level VI Limit	**80.93**	

12.4 *Power Factor vs. Load*

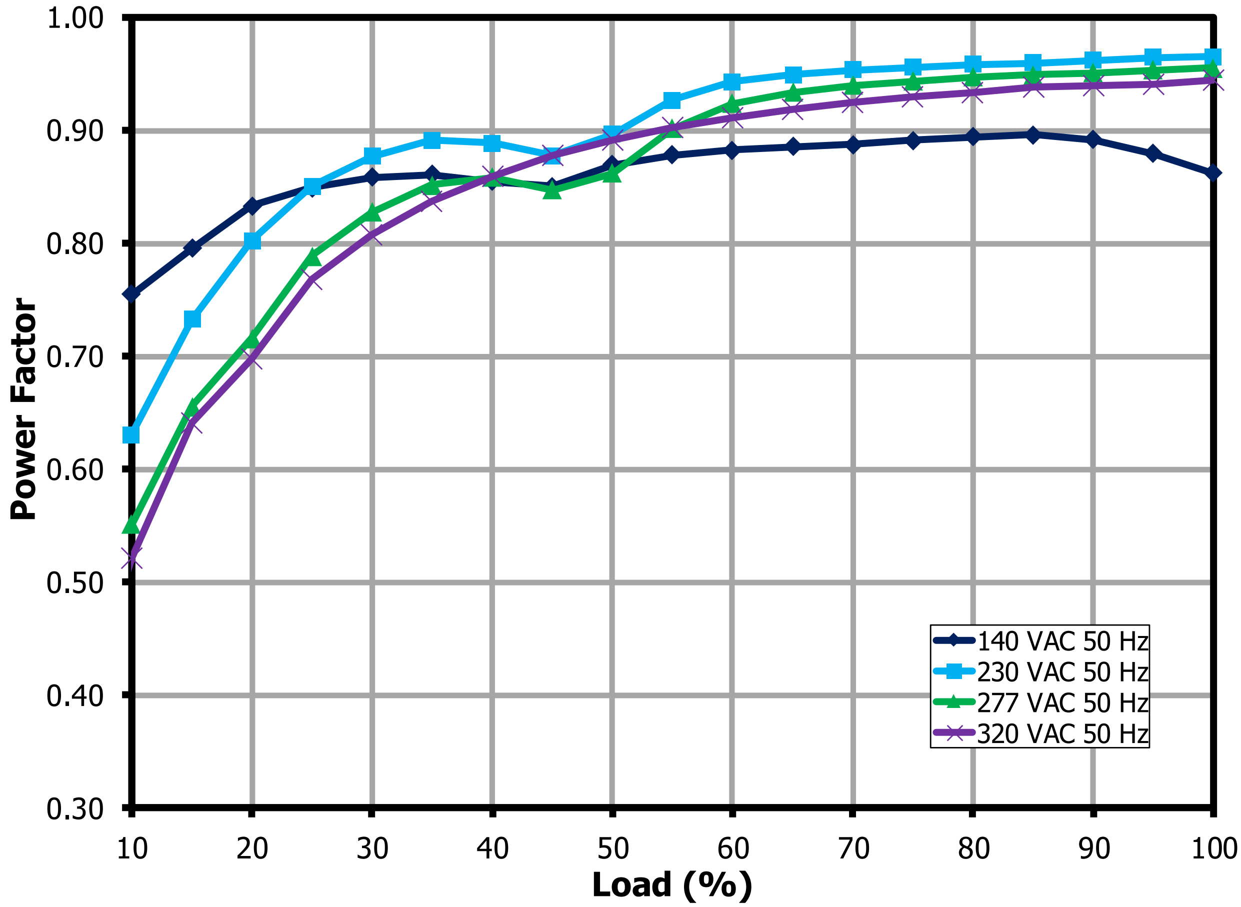

Figure 21 – Power Factor vs Load.

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12.5 *%ATHD vs. Load*

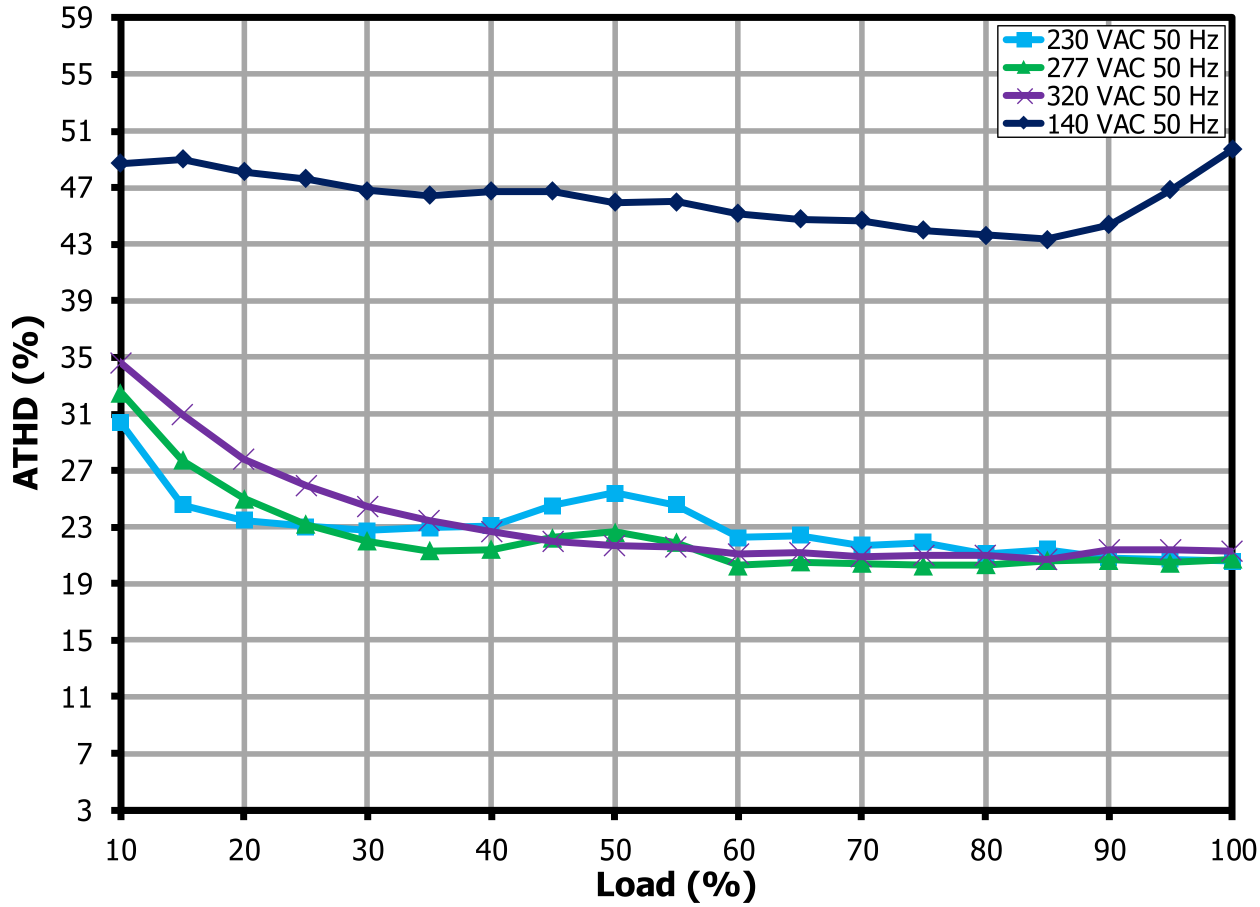

Figure 22 – %ATHD vs Load.

13 Thermal Performance

13.1 Thermal Measurements at Room Temp Ambient

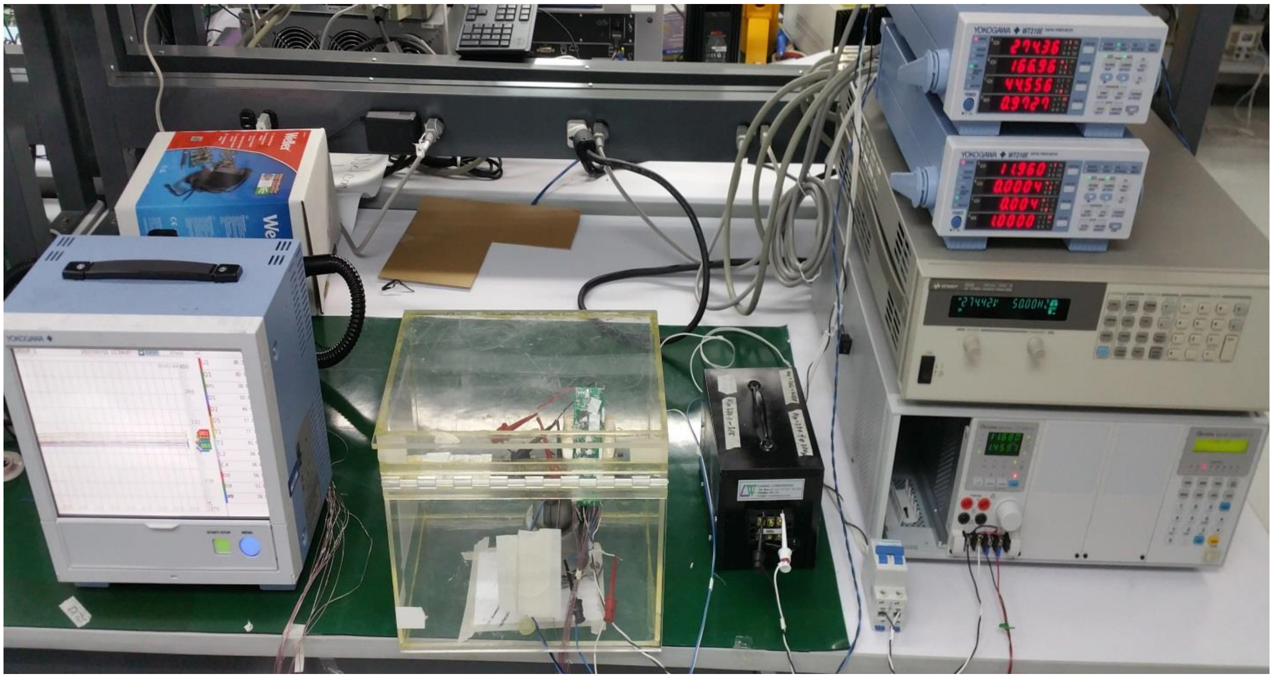

Figure 23 – Test Set-up Picture - Open Frame.

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. Yokogawa GP20 Data Logger
4. Yokogawa WT310E Digital Power Meter
5. CADWILL Step-up Transformer (for Inputs >300Vac)

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Ckt. Code	Description	Thermal Reading at Room Temperature			
		140 VAC	230 VAC	277 VAC	320 VAC
U1	LYTSwitch-6 IC	83.1	80	84.4	89.9
D4	Primary Snubber Diode	86.9	78.9	80.8	82.9
VR1	Primary Snubber Zener	78.1	69.6	70.8	72.5
Q1	SR FET	79.6	77.9	79.8	82.6
T2	PFC Inductor	63.1	63.4	65.9	67.6
T1	DCDC TRF Primary	82.1	81.3	84.3	86.5
L3	Bead on Secondary	78.5	76.1	78.2	81.4
D1	PFC Diode	54.2	50.5	50.2	49.5
D5	PFC Diode	60.4	56.3	56.8	56.8
BR1	Bridge Diode	52.4	43.9	42.5	41.8
R2 / R15	Primary Snubber Series Resistor	78.8	72	73.1	75
R7	Secondary Snubber Resistor	77.5	76.4	78.7	80.9
C4	Bulk Capacitor	48.2	43.8	44.2	44.2
C10	Output Capacitor	62.3	62.3	63.6	65.3
AMBIENT		27.2	28.6	28.7	28.4

13.2 *Thermal Performance at High Temp Ambient*

Figure 24 – 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. Yokogawa GP20 Data Logger
4. Yokogawa WT310E Digital Power Meter
5. SPX Tenney TUJR Thermal Chamber
6. CADWILL Step-up Transformer (for Inputs >300Vac)

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Ckt. Code	Description	Thermal Reading at High Temperature			
		140 VAC	230 VAC	277 VAC	320 VAC
U1	LYTSwitch-6 IC	116.6	112.2	116.9	123.4
D4	Primary Snubber Diode	117.1	110	111.5	114.5
VR1	Primary Snubber Zener	106.2	98.8	99.6	101.4
Q1	SR FET	112.3	110.4	112.6	114.6
T2	PFC Inductor	94.2	93.7	96.1	98.6
T1	DCDC TRF Primary	114.1	113.1	115.2	118.7
L3	Bead on Secondary	110.5	108.1	110.4	112.7
D1	PFC Diode	86.7	81.1	80.8	80.9
D5	PFC Diode	91.7	87.4	87.1	88.4
BR1	Bridge Diode	83.8	75.7	74.4	73.8
R2 / R15	Primary Snubber Series Resistor	108.7	102.2	103.5	105.5
R7	Secondary Snubber Resistor	110	108.5	110.5	113
C4	Bulk Capacitor	79.6	75.6	75.5	75.9
C10	Output Capacitor	95	93.7	95.2	96.7
AMBIENT		62.4	61.9	62.1	62.1

14 Waveforms

Waveforms were taken at room temperature (25 ºC).

14.1 *Input Voltage and Input Current at Full Load*

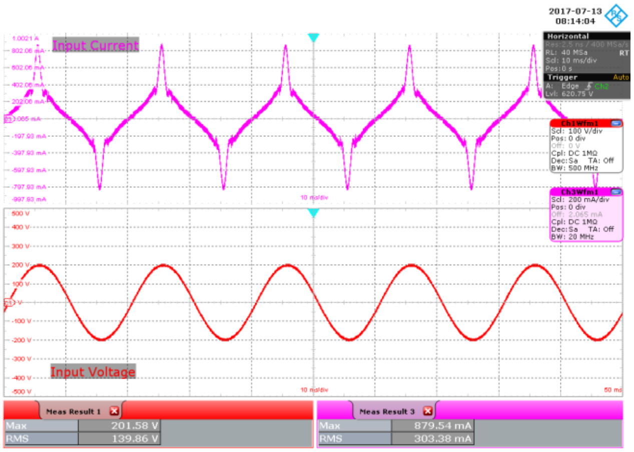

Figure 25 – 140 VAC 50 Hz, Full Load.
Upper: I_{IN}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

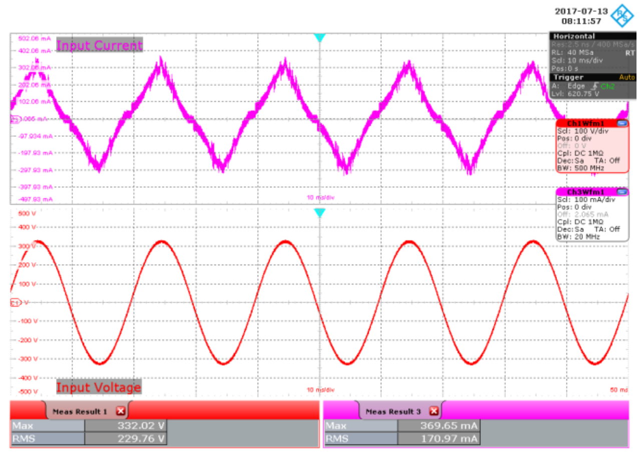

Figure 26 – 230 VAC 50 Hz, Full Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

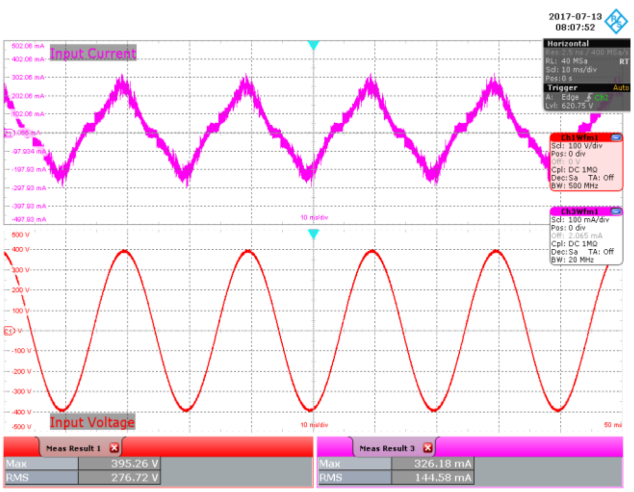

Figure 27 – 277 VAC 50 Hz, Full Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

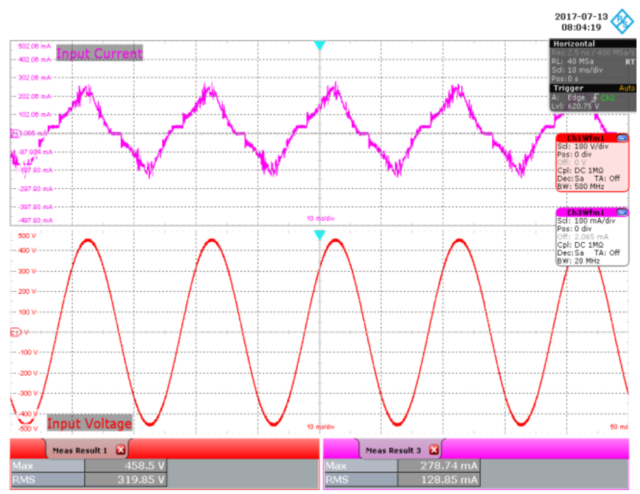

Figure 28 – 320 VAC 50 Hz, Full Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

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14.2 *Start-up Profile at Full Load*

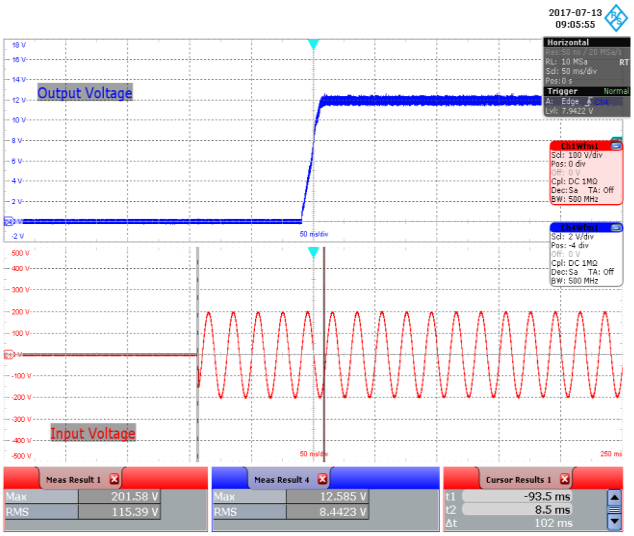

Figure 29 – 140 VAC 50 Hz, Full Load Start-up.
Upper: V_{OUT}, 2 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Turn on Time: 102 ms.

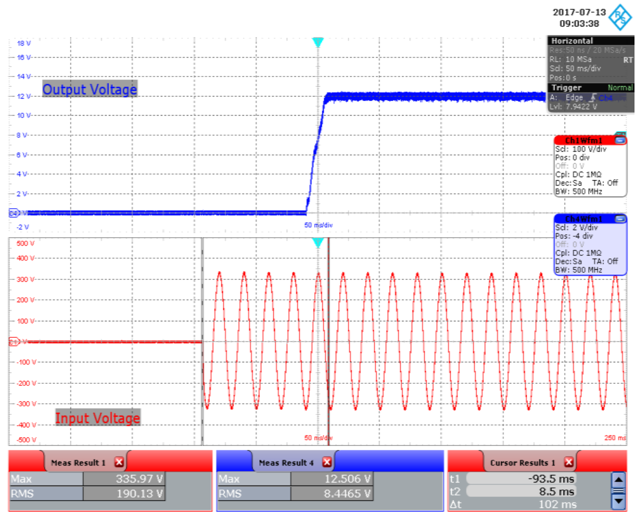

Figure 30 – 230 VAC 50 Hz, Full Load Start-up.
Upper: V_{OUT}, 2 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Turn on Time: 102 ms.

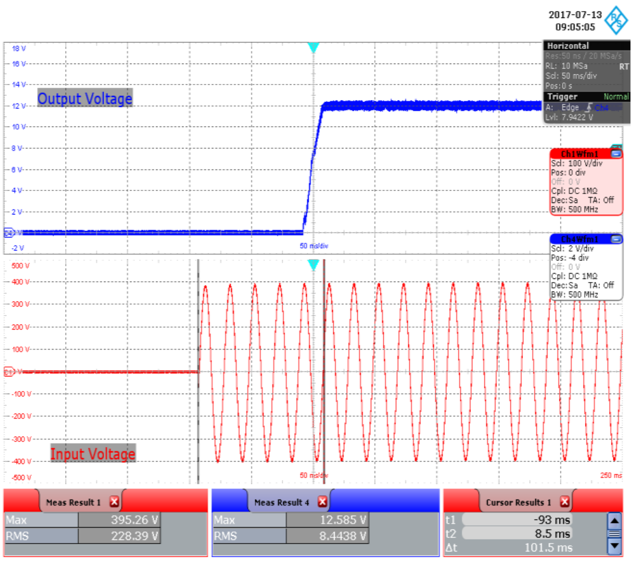

Figure 31 – 277 VAC 50 Hz, Full Load Start-up.
Upper: V_{OUT}, 2 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Turn on Time: 101.5 ms.

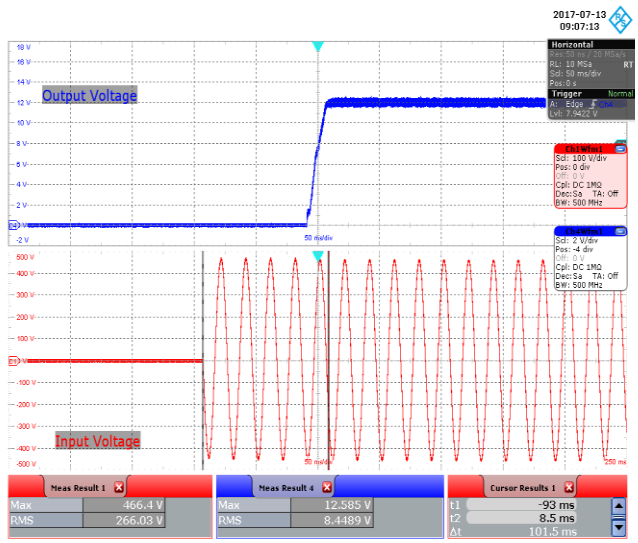

Figure 32 – 320 VAC 50 Hz, Full Load Start-up.
Upper: V_{OUT}, 2 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Turn on Time: 101.5 ms.

14.3 *Output Voltage Fall*

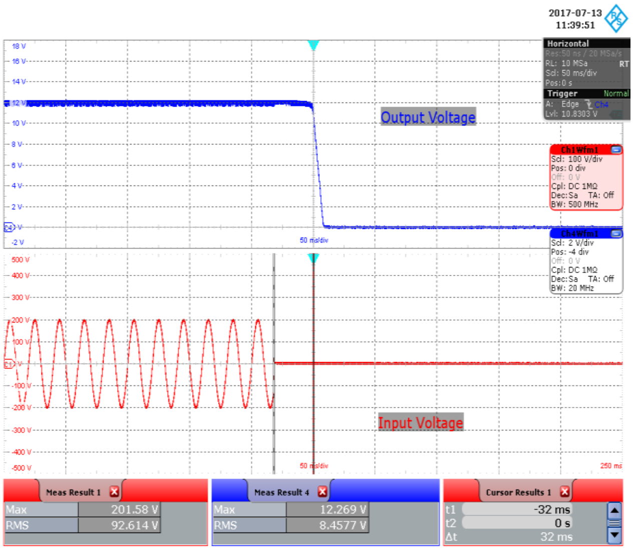

Figure 33 – 140 VAC 50 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 2 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold Up Time: 32 ms.

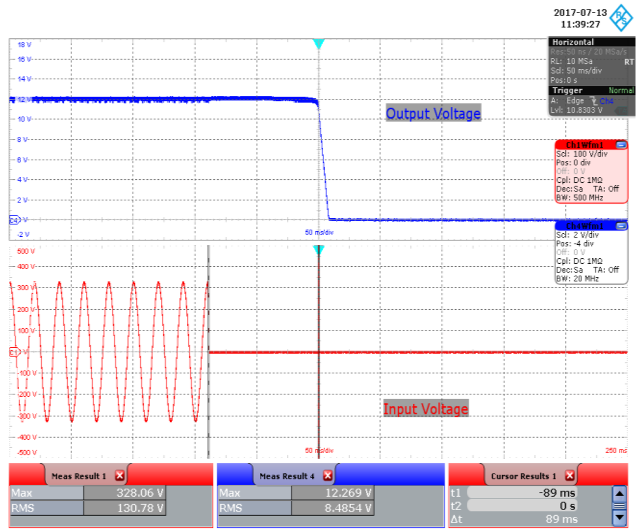

Figure 34 – 230 VAC 50 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 2 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold Up Time: 89 ms.

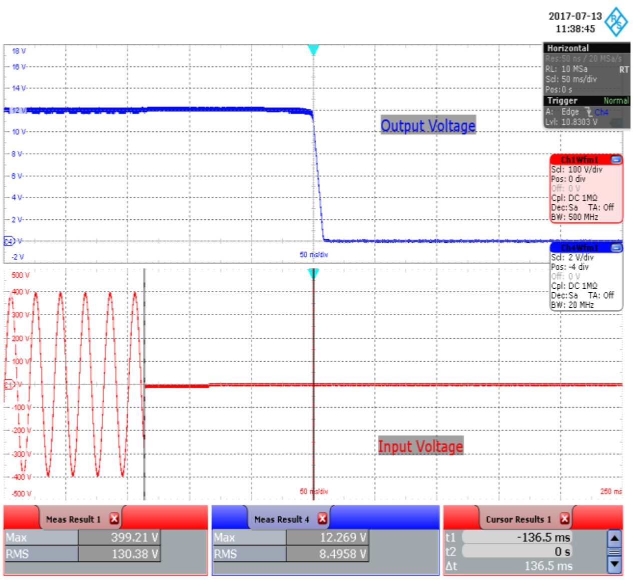

Figure 35 – 277 VAC 50 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 2 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold Up Time: 136.5 ms.

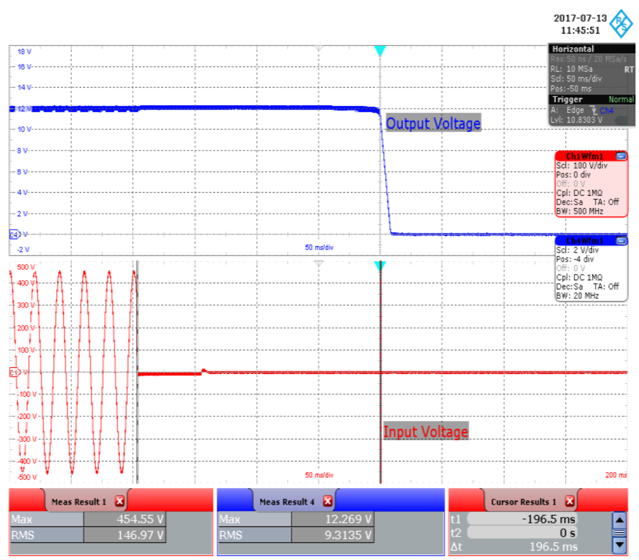

Figure 36 – 320 VAC 50 Hz, Full Load, Output Fall.
Upper: V_{OUT}, 2 V / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold Up Time: 196.5 ms.

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14.4 *Power Cycling*

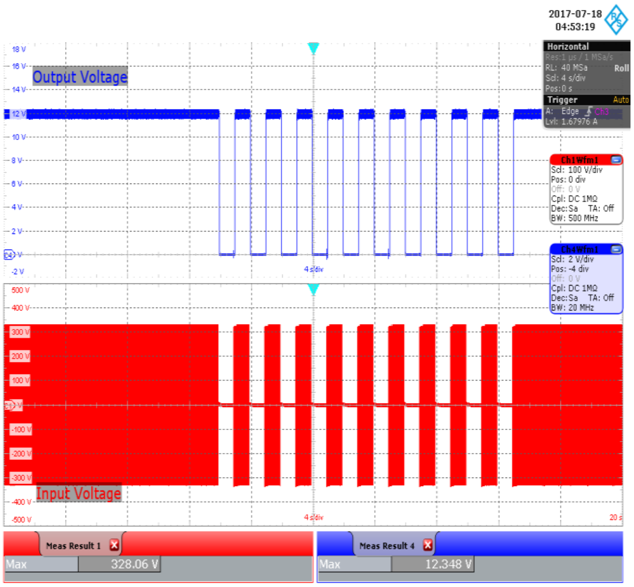

Figure 37 – 230 VAC 50 Hz, Full Load.
1 s Off, 1 s On.
Upper: V_{OUT}, 2 V / div.
Lower: V_{IN}, 100 V / div., 4 s / div.

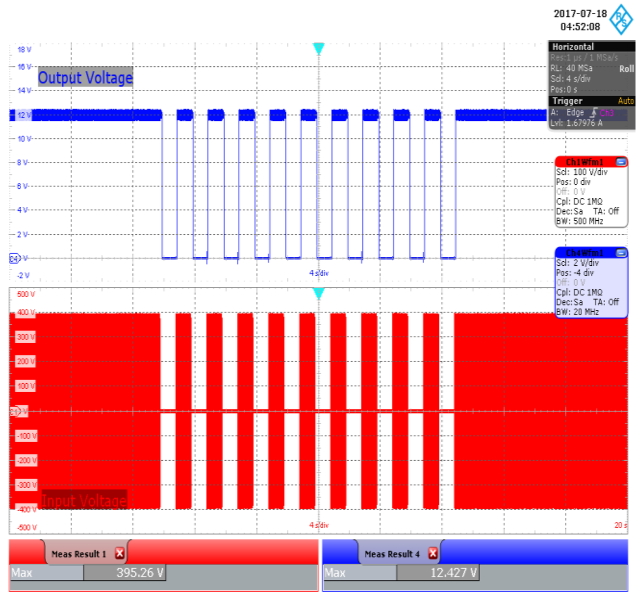

Figure 38 – 277 VAC 50 Hz, Full Load.
1 s Off, 1 s On.
Upper: V_{OUT}, 2 V / div.
Lower: V_{IN}, 100 V / div., 4 s / div.

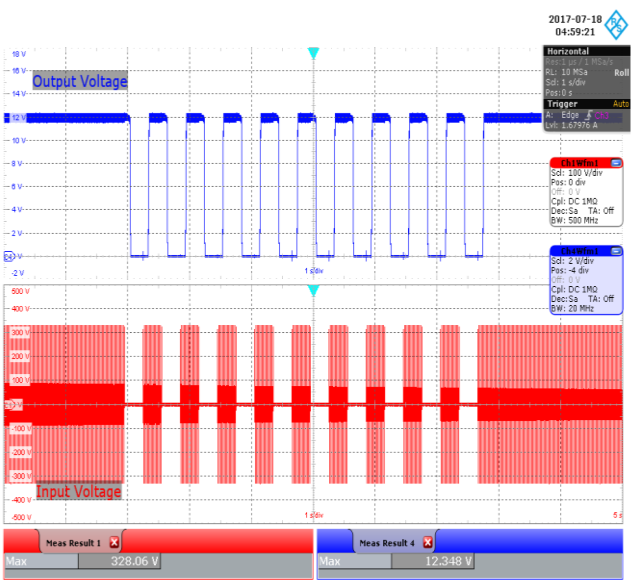

Figure 39 – 230 VAC 50 Hz, Full Load.
0.3 s Off, 0.3 s On.
Upper: V_{OUT}, 2 V / div.
Lower: V_{IN}, 100 V / div., 1 s / div.

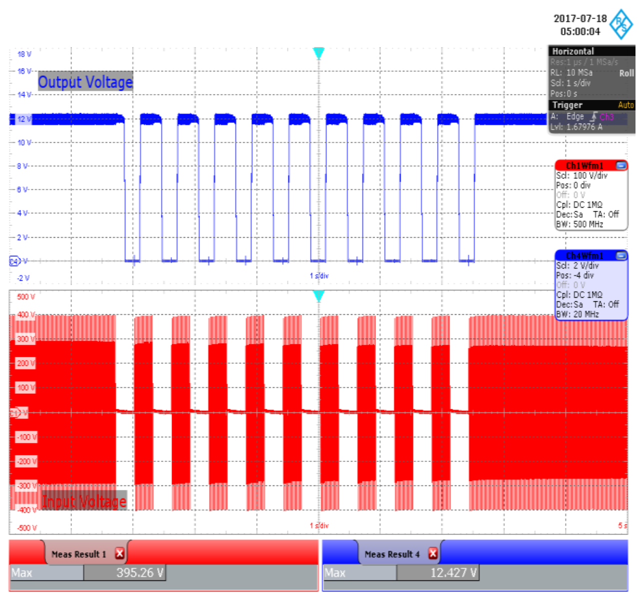

Figure 40 – 277 VAC 50 Hz, Full Load.
0.3 s Off, 0.3 s On.
Upper: V_{OUT}, 2 V / div.
Lower: V_{IN}, 100 V / div., 1 s / div.

14.5 *Load Transient Response 3 Hz*

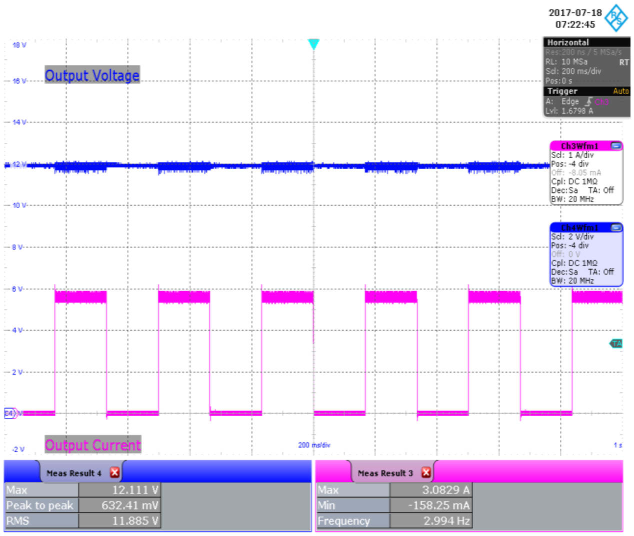

Figure 41 – 230 VAC 50 Hz.
0% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 200 ms / div.
Lower: I_{OUT}, 1 A / div.

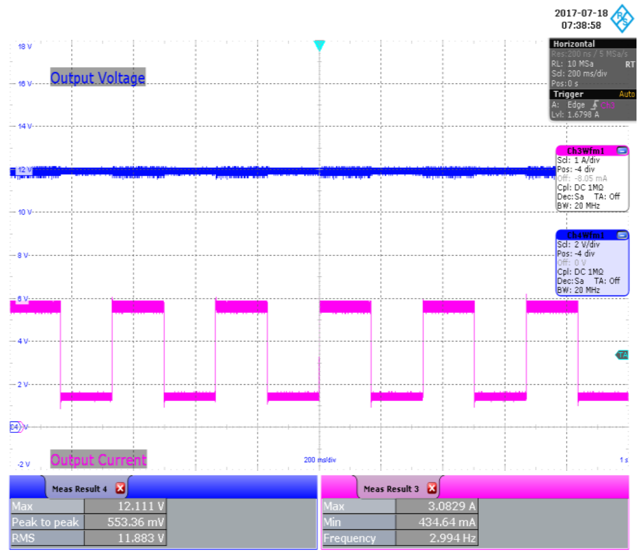

Figure 42 – 230 VAC 50 Hz.
25% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 200 ms / div.
Lower: I_{OUT}, 1 A / div.

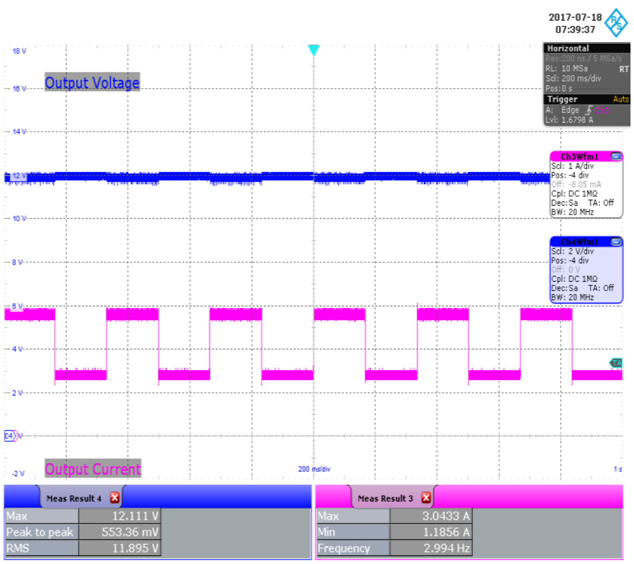

Figure 43 – 230 VAC 50 Hz.
50% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 200 ms / div.
Lower: I_{OUT}, 1 A / div.

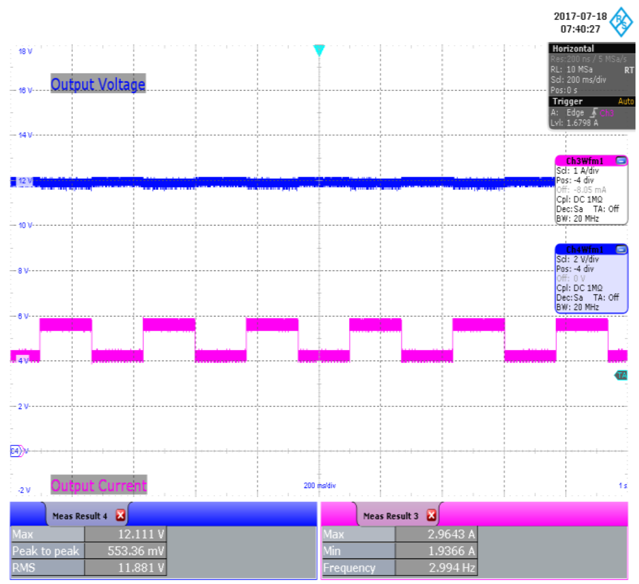

Figure 44 – 230 VAC 50 Hz.
75% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 200 ms / div.
Lower: I_{OUT}, 1 A / div.

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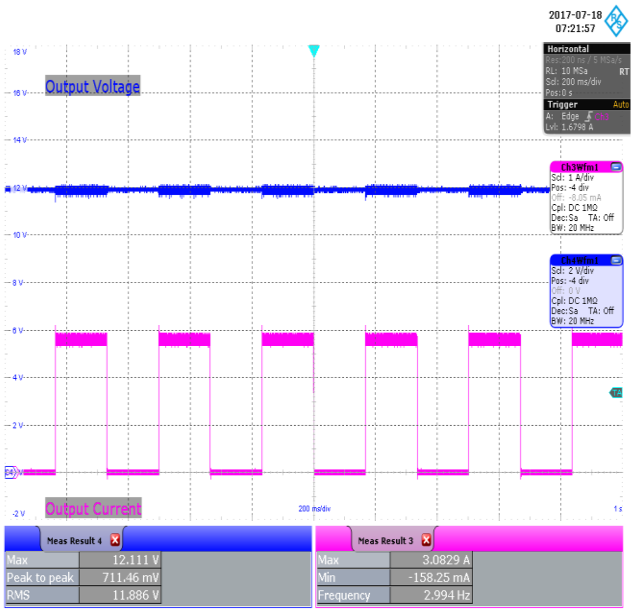

Figure 45 – 277 VAC 50 Hz.
0% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 200 ms / div.
Lower: I_{OUT}, 1 A / div.

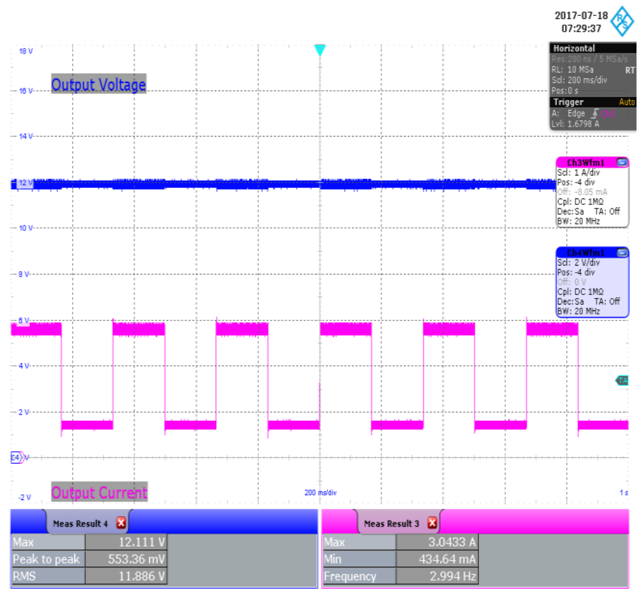

Figure 46 – 277 VAC 50 Hz.
25% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 200 ms / div.
Lower: I_{OUT}, 1 A / div.

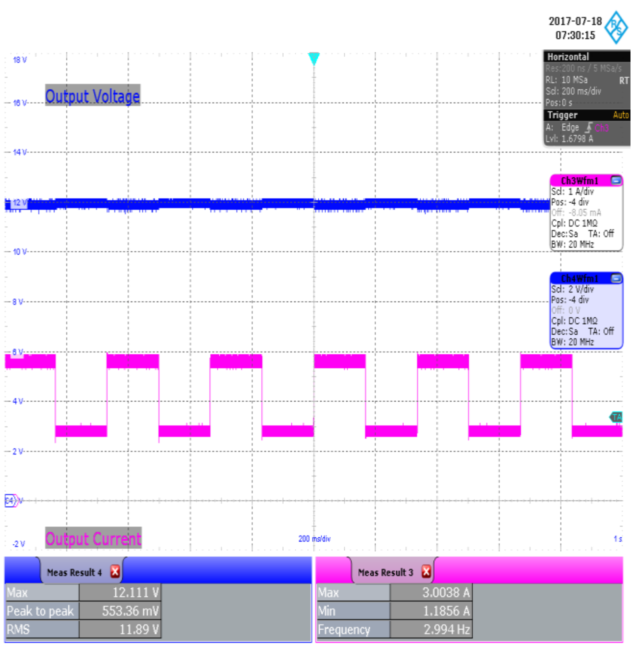

Figure 47 – 277 VAC 50 Hz.
50% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 200 ms / div.
Lower: I_{OUT}, 1 A / div.

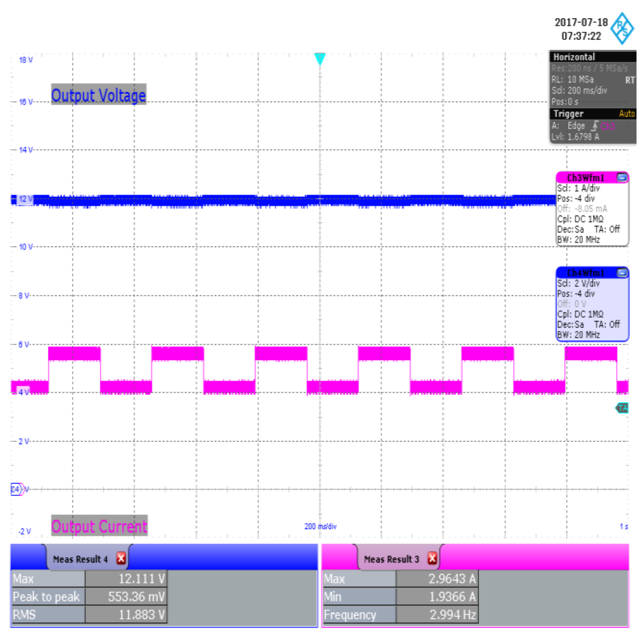

Figure 48 – 277 VAC 50 Hz.
75% to 100% Load Change.
3 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 200 ms / div.
Lower: I_{OUT}, 1 A / div.

14.6 *Load Transient Response 100 Hz*

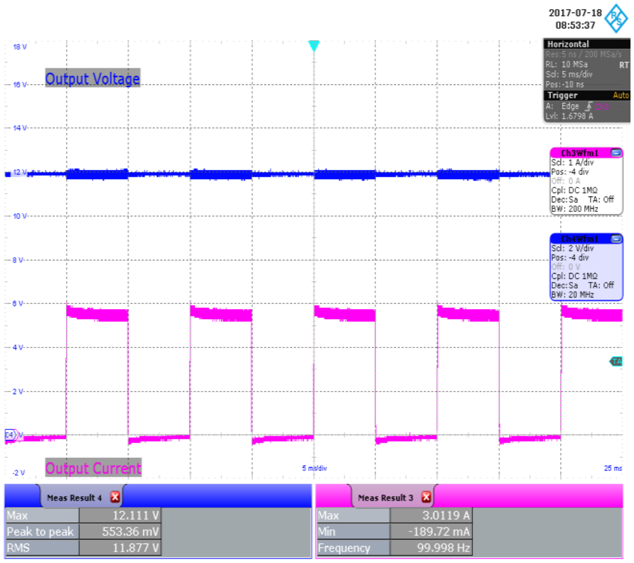

Figure 49 – 230 VAC 50 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 5 ms / div.
Lower: I_{OUT}, 1 A / div.

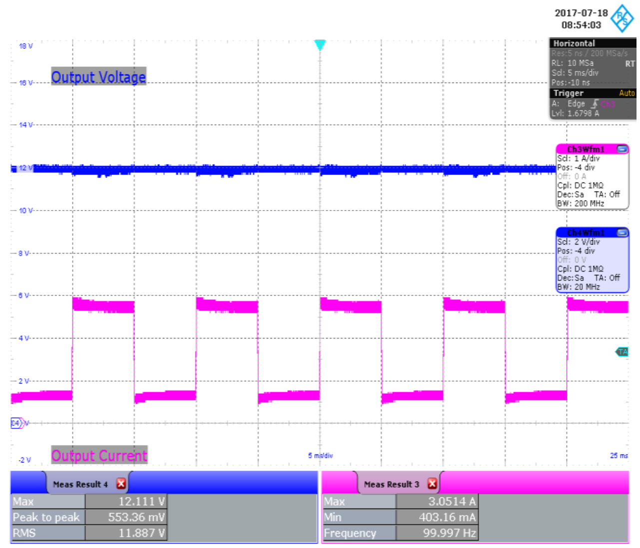

Figure 50 – 230 VAC 50 Hz.
25% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2V / div., 5 ms / div.
Lower: I_{OUT}, 1A / div.

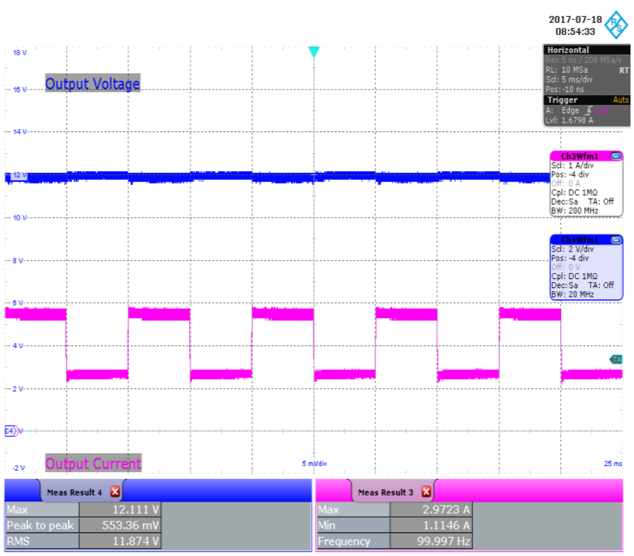

Figure 51 – 230 VAC 50 Hz.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 5 ms / div.
Lower: I_{OUT}, 1 A / div.

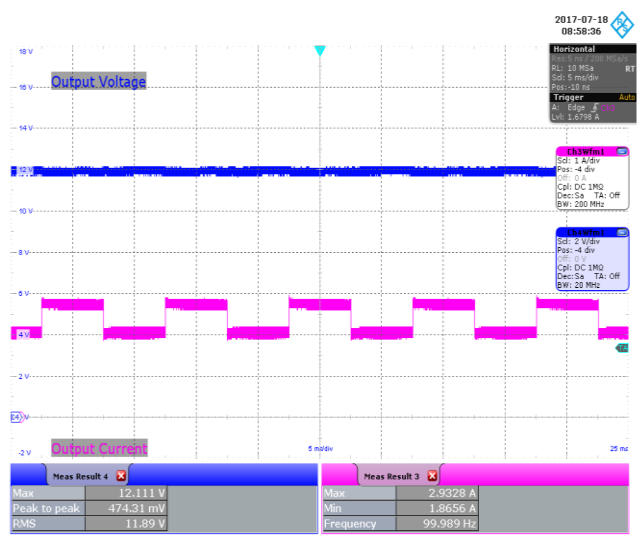

Figure 52 – 230 VAC 50 Hz.
75% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 5 ms / div.
Lower: I_{OUT}, 1 A / div.

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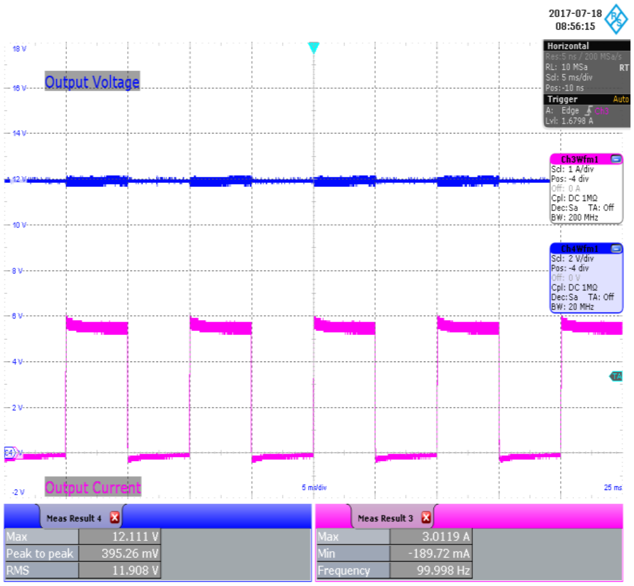

Figure 53 – 277 VAC 50 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 5 ms / div.
Lower: I_{OUT}, 1 A / div.

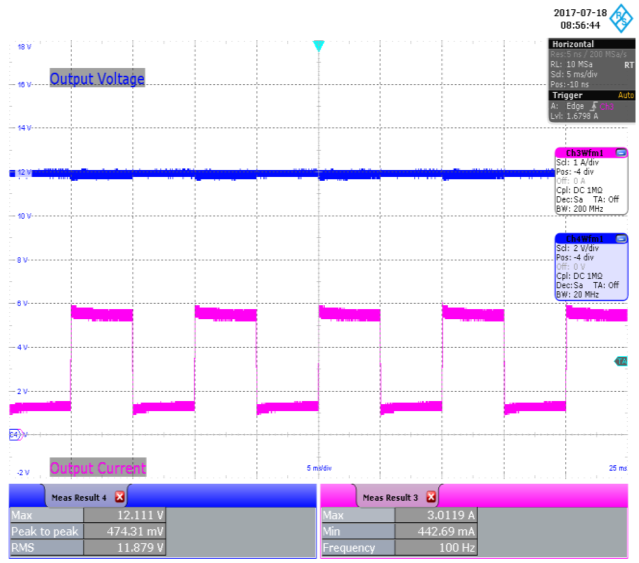

Figure 54 – 277 VAC 50 Hz.
25% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 5 ms / div.
Lower: I_{OUT}, 1 A / div.

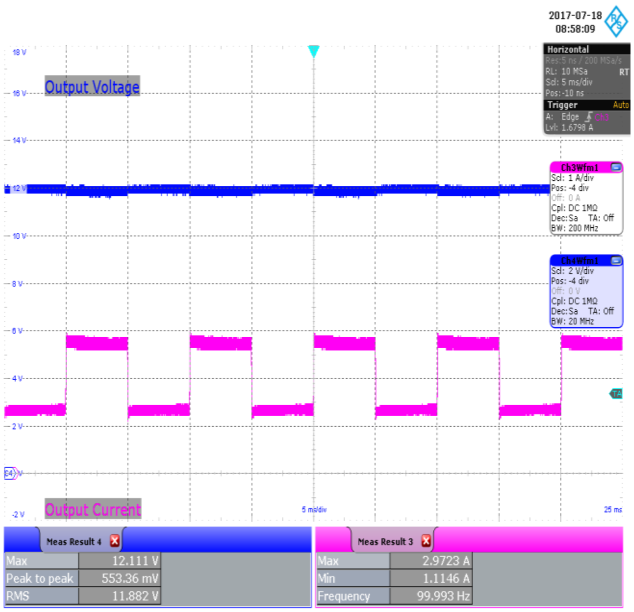

Figure 55 – 277 VAC 50 Hz.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 5 ms / div.
Lower: I_{OUT}, 1 A / div.

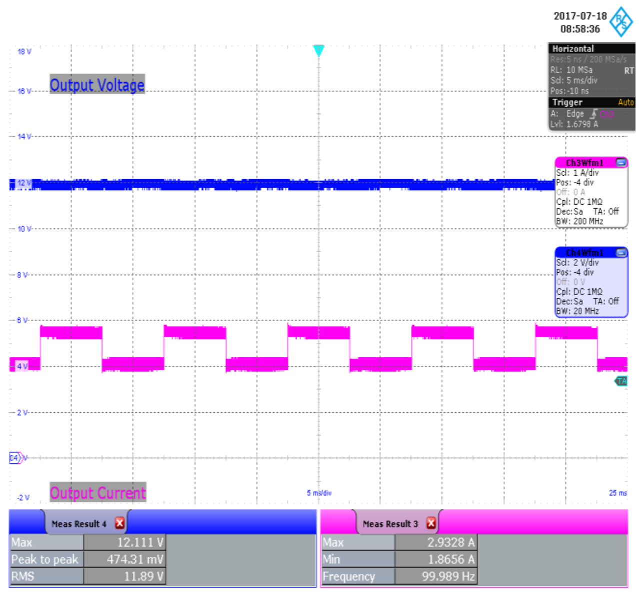

Figure 56 – 277 VAC 50 Hz.
75% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 800 mA / µs.
Upper: V_{OUT}, 2 V / div., 5 ms / div.
Lower: I_{OUT}, 1 A / div.

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

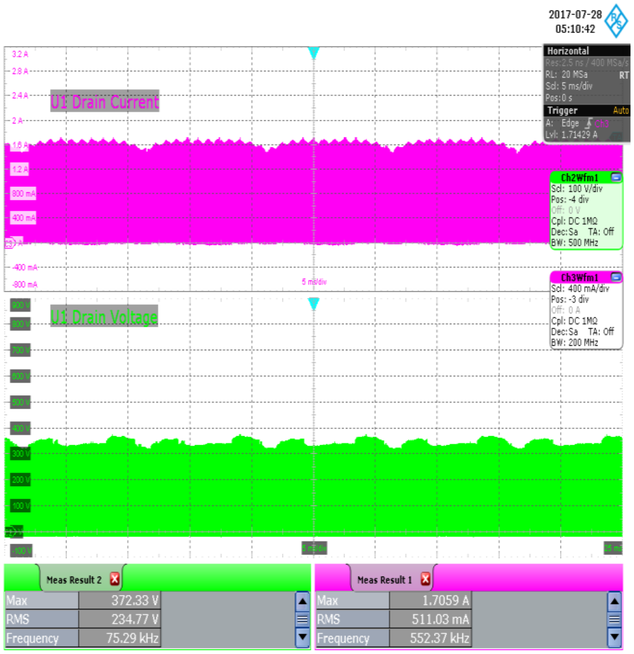

Figure 57 – 140 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 ms / div.

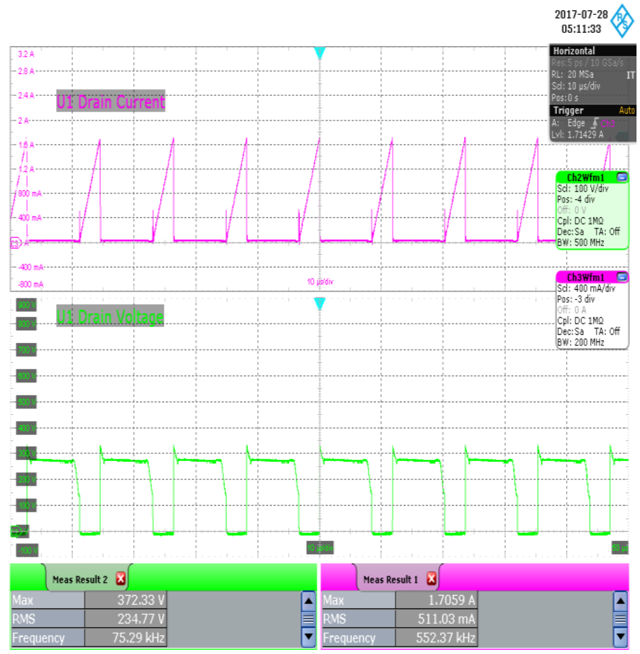

Figure 58 – 140 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.

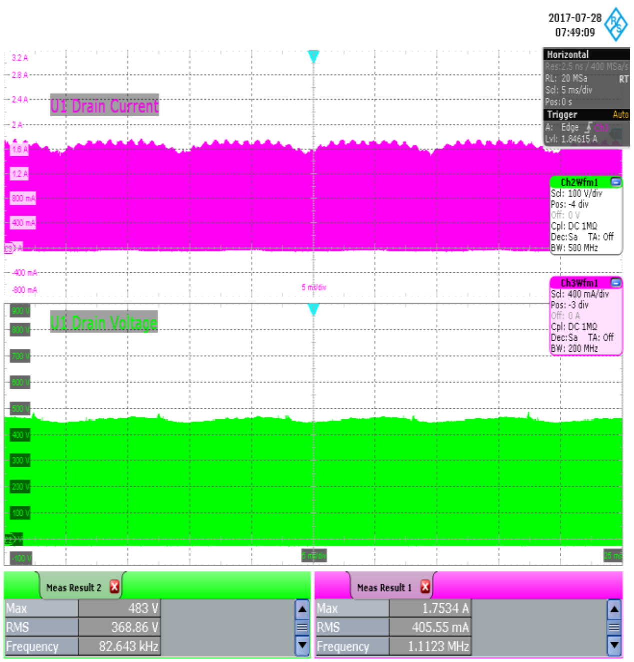

Figure 59 – 230 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 ms / div.

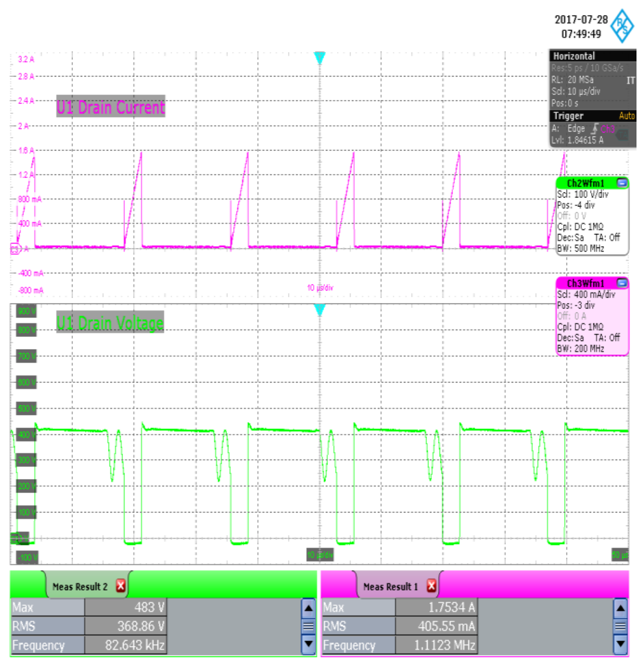

Figure 60 – 230 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.

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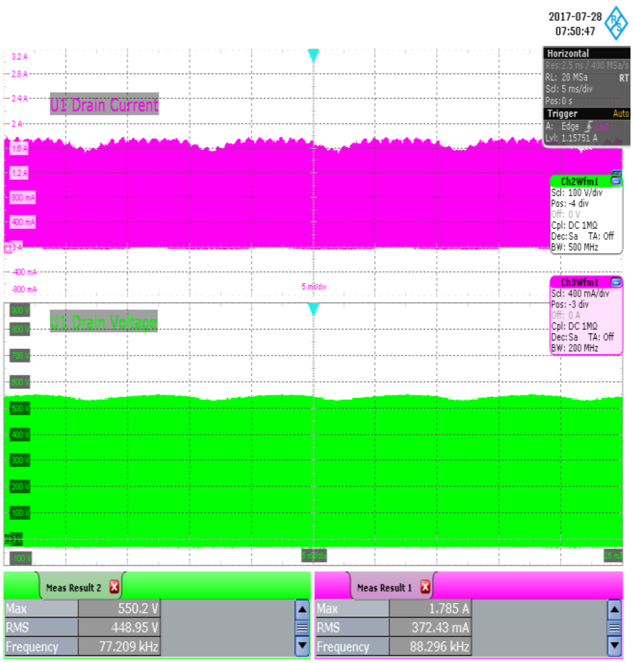

Figure 61 – 277 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 ms / div.

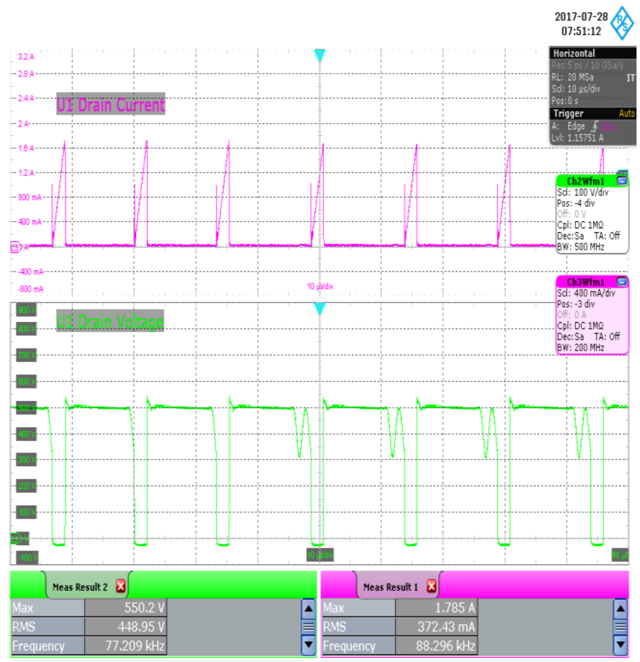

Figure 62 – 277 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.

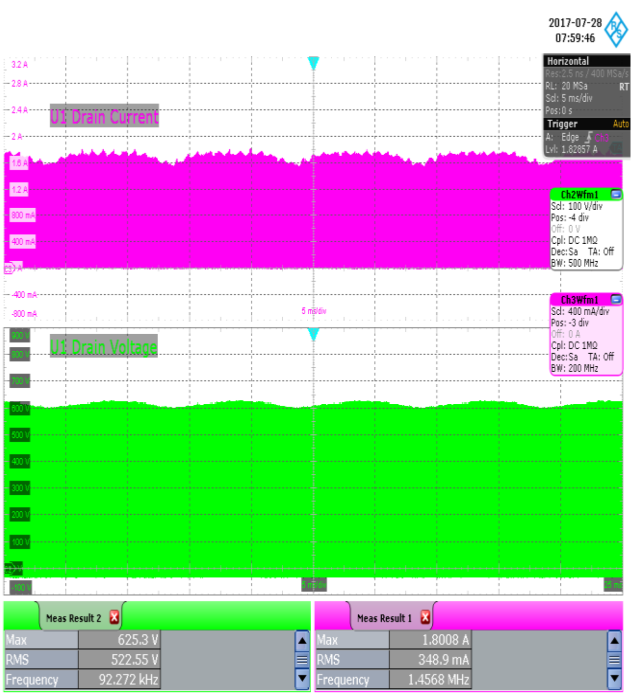

Figure 63 – 320 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 ms / div.

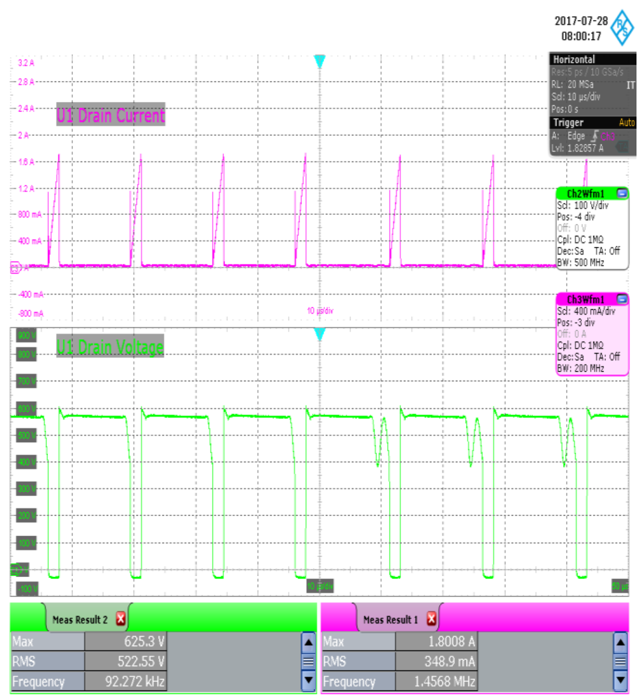

Figure 64 – 320 VAC 50 Hz, Full Load Normal.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.

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

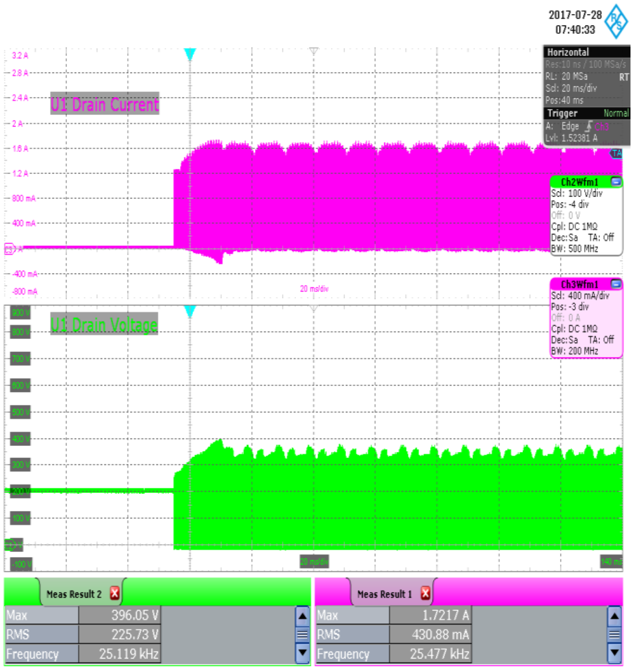

Figure 65 – 140 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 ms / div.

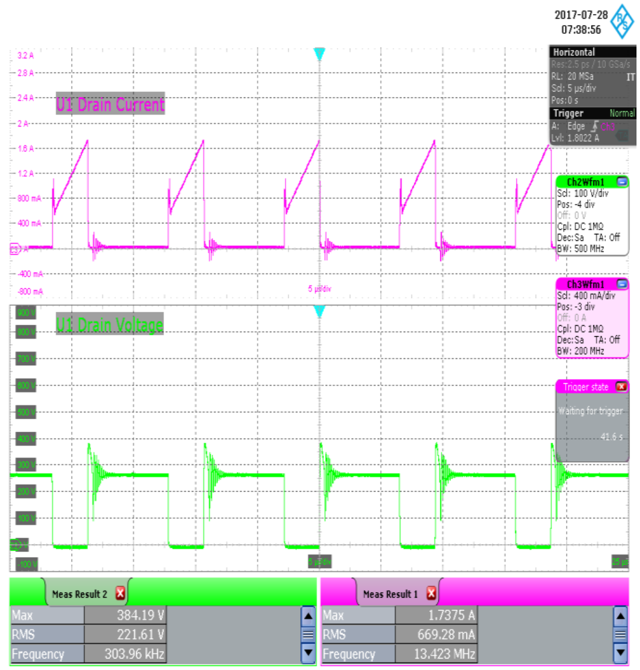

Figure 66 – 140 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

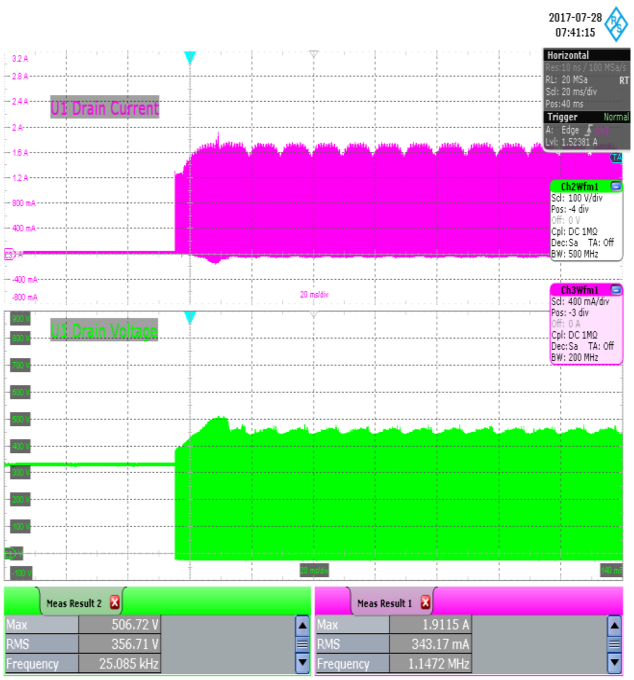

Figure 67 – 230 VAC, Full Load Start-up.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 ms / div.

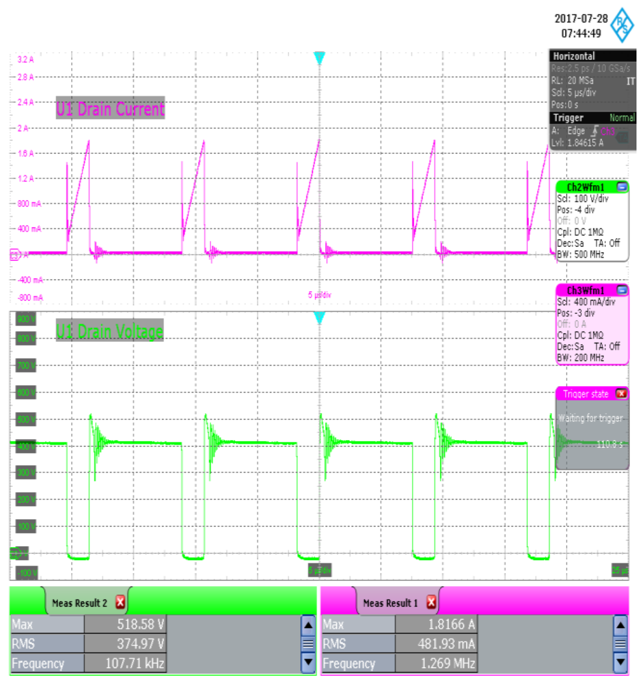

Figure 68 – 230 VAC, Full Load Start-up.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

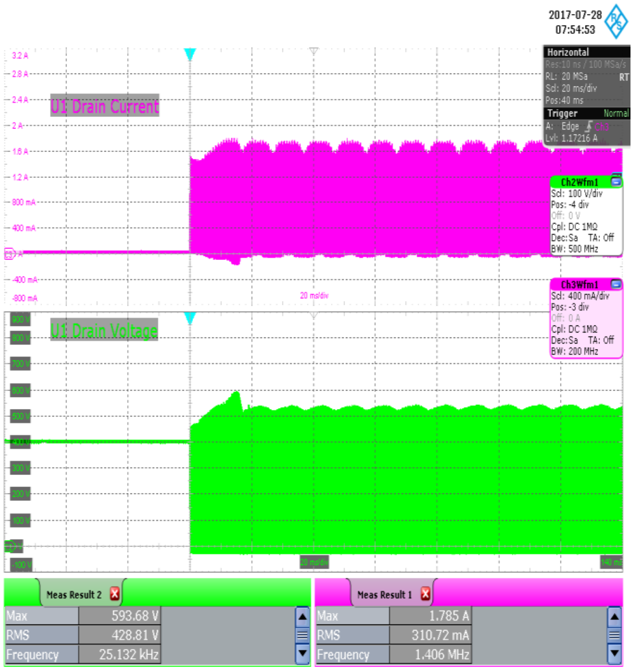

Figure 69 – 277 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 ms / div.

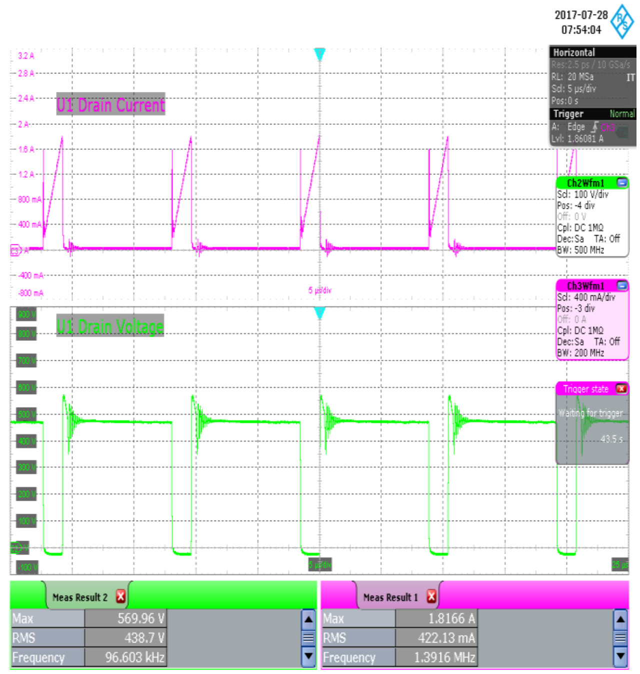

Figure 70 – 277 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 µs / div.

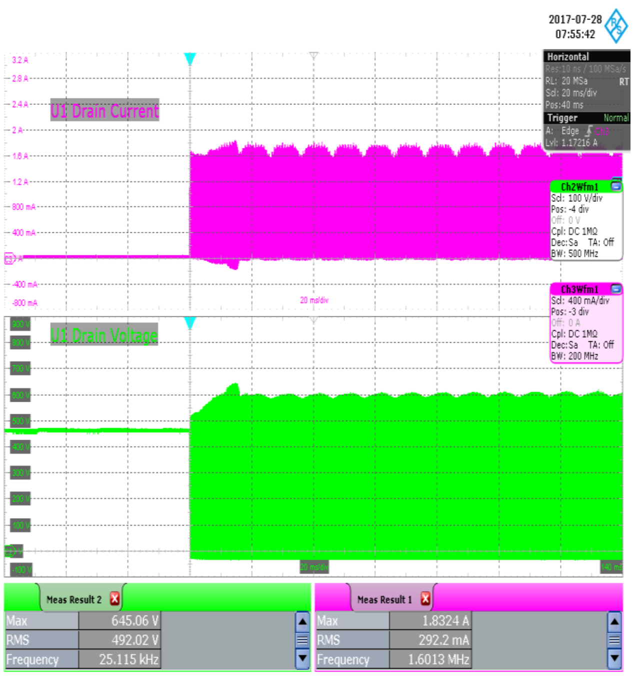

Figure 71 – 320 VAC, Full Load Start-up.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 ms / div.

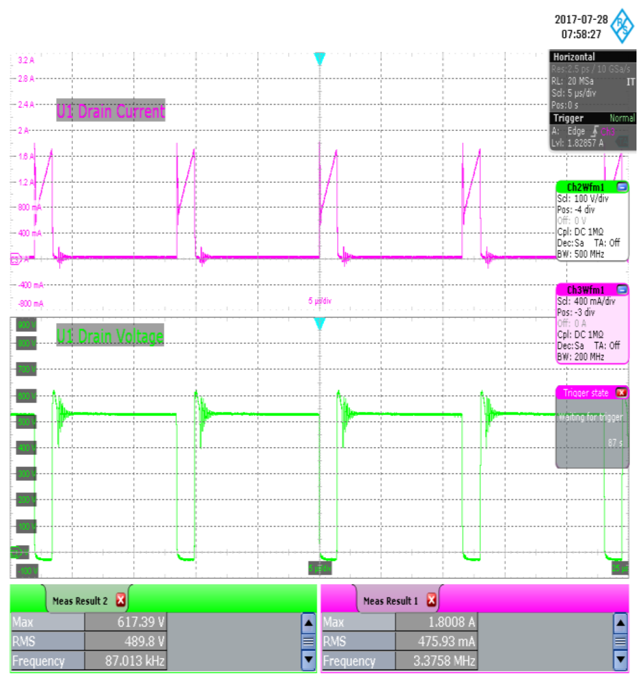

Figure 72 – 320 VAC, Full Load Start-up.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 µs / div.

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

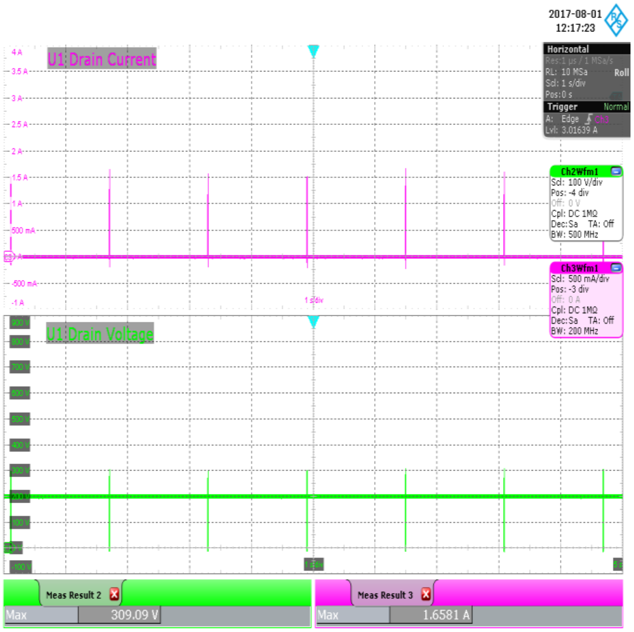

Figure 73 – 140 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.
P_{IN} Average: 155.4 mW.

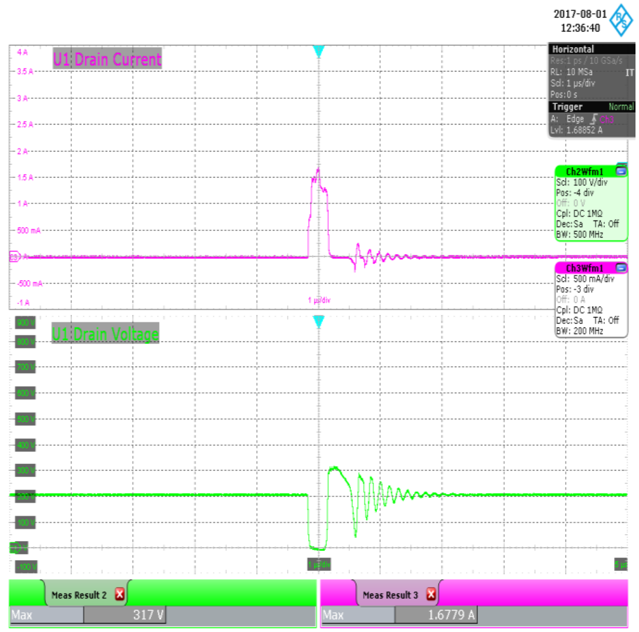

Figure 74 – 140 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 μs / div.

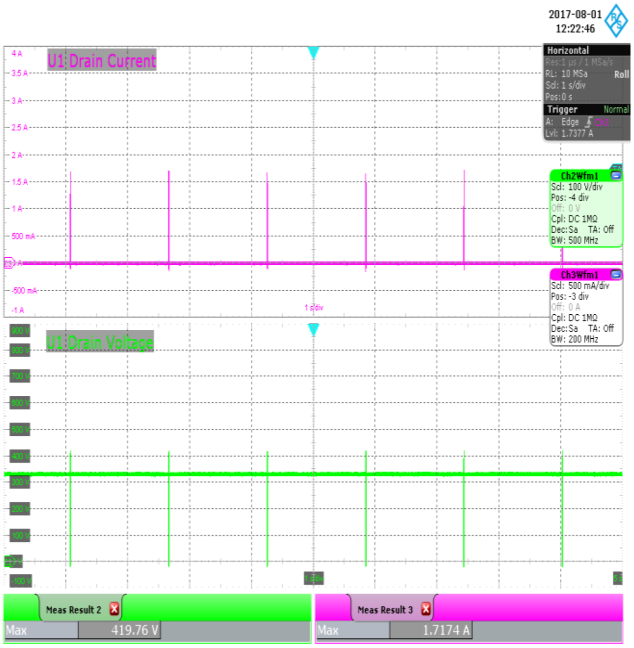

Figure 75 – 230 VAC, Output Shorted.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.
P_{IN} Average: 259.7 mW.

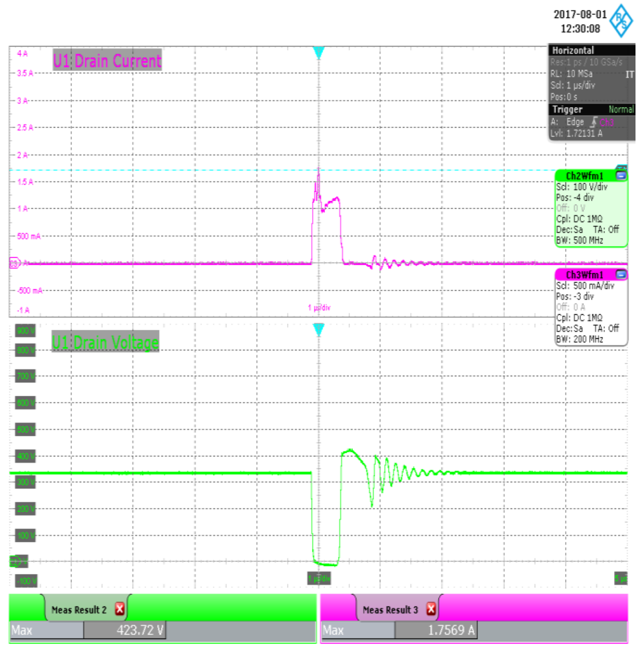

Figure 76 – 230 VAC, Output Shorted.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 μs / div.

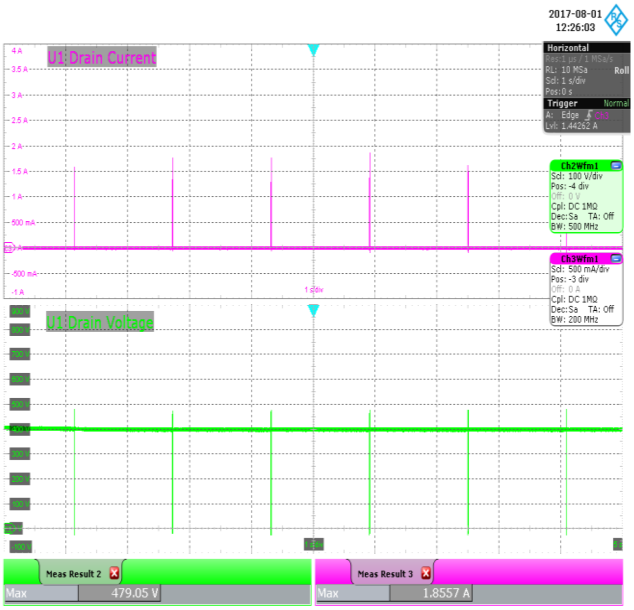

Figure 77 – 277 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.
Pin Average: 242.51 mW.

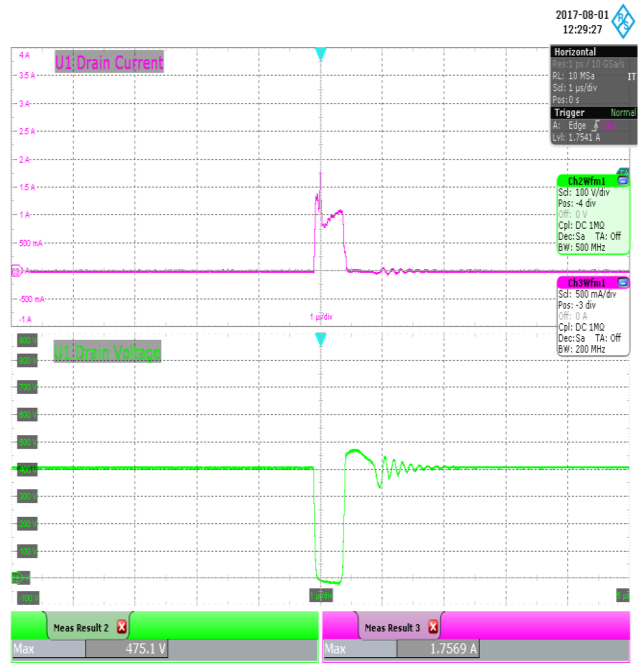

Figure 78 – 277 VAC 50 Hz, Output Shorted.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 µs / div.

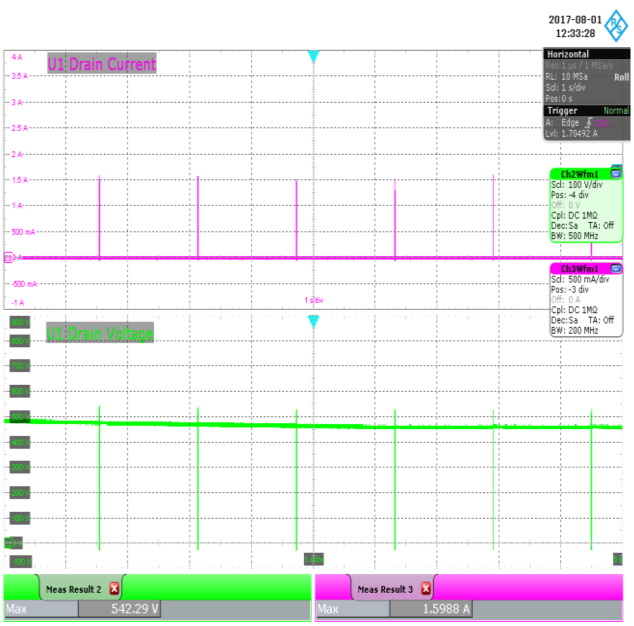

Figure 79 – 320 VAC, Output Shorted.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.
P_{IN} Average: 411.41 mW.

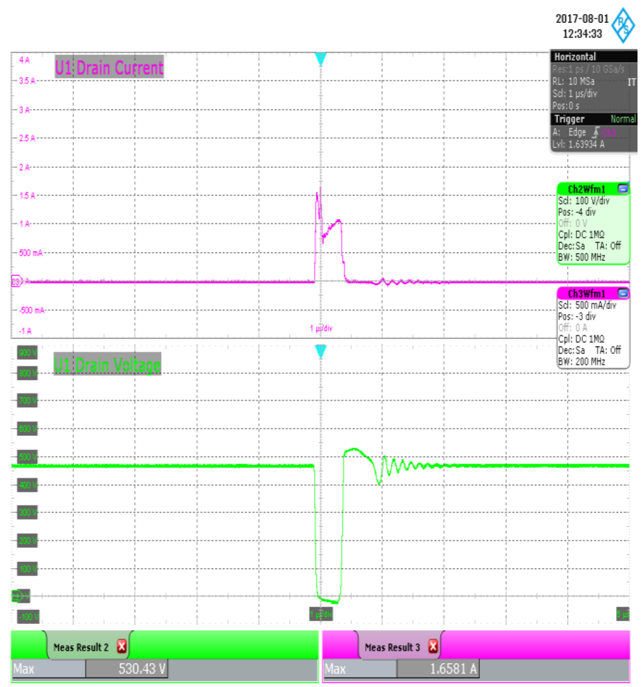

Figure 80 – 320 VAC, Output Shorted.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 µs / div.

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14.10 *PFC Diode Voltage and Current at Normal Operation*

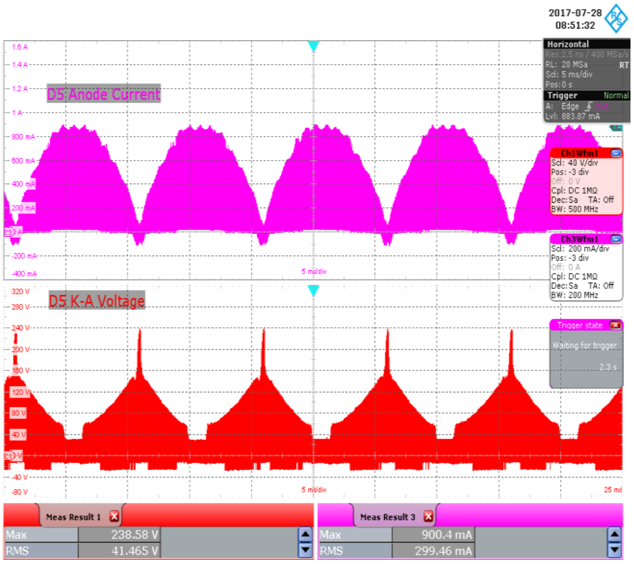

Figure 81 – 140 VAC 50 Hz, 2.92 A CC Load.
Upper: 200 mA / div.
Lower: 40 V / div.
Horizontal: 5 ms / div.

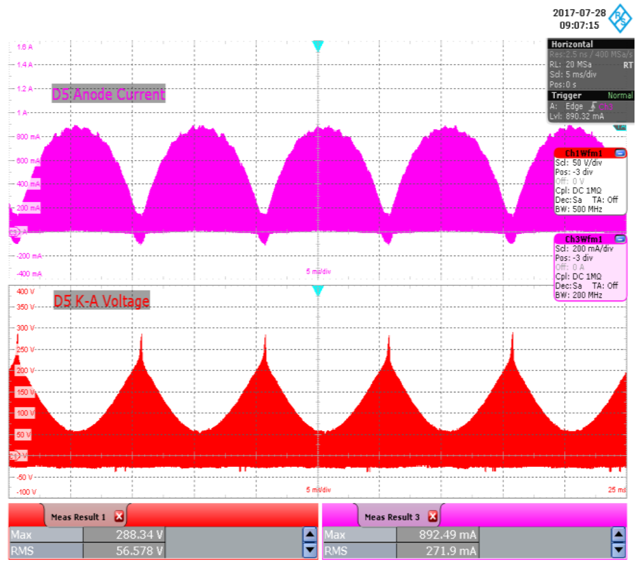

Figure 82 – 230 VAC 50 Hz, 2.92 A CC Load.
Upper: 200 mA / div.
Lower: 50 V / div.
Horizontal: 5 ms / div.

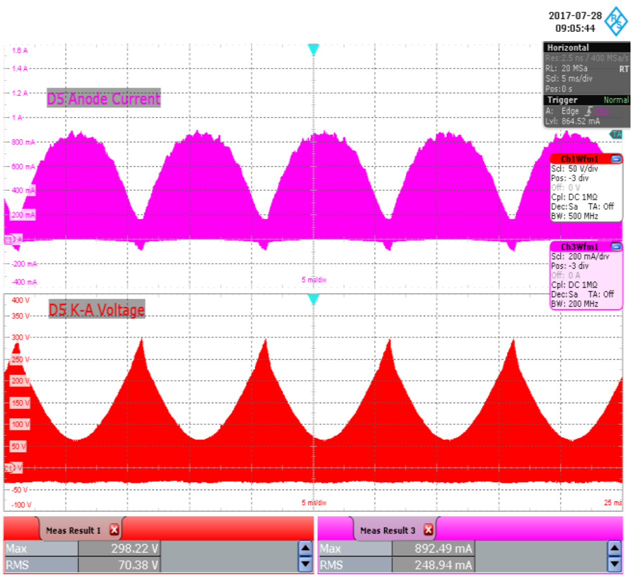

Figure 83 – 277 VAC 50 Hz, 2.92 A CC Load.
Upper: 200 mA / div.
Lower: 50 V / div.
Horizontal: 5 ms / div.

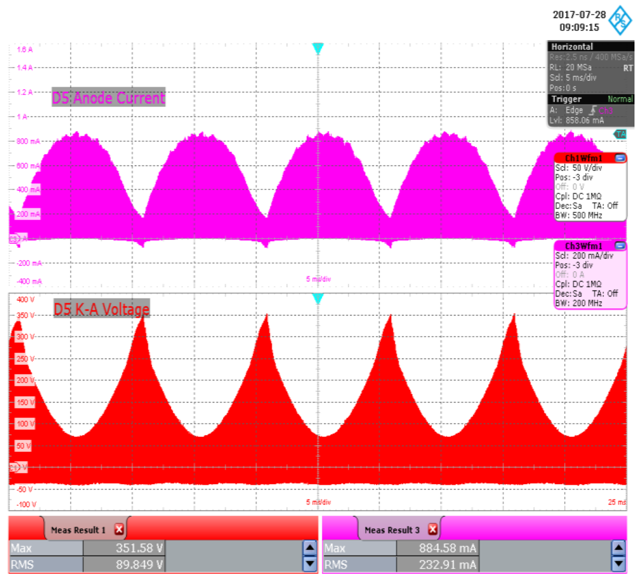

Figure 84 – 320 VAC 50 Hz, 2.92 A CC Load.
Upper: 200 mA / div.
Lower: 50 V / div.
Horizontal: 5 ms / div.

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

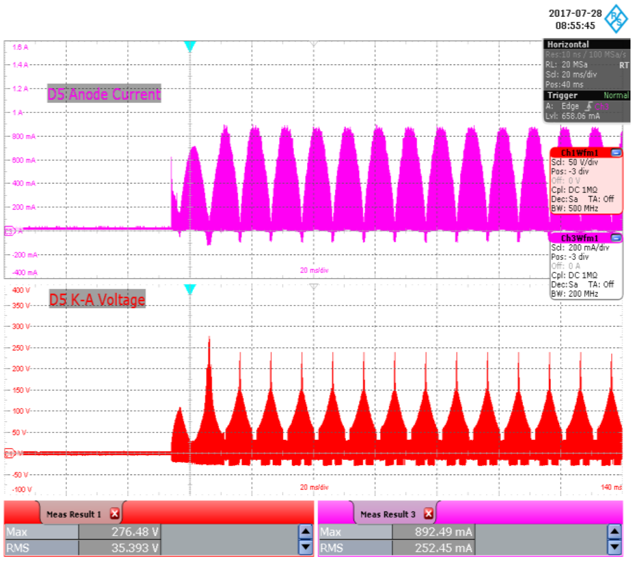

Figure 85 – 140 VAC 50 Hz, 2.92 A CC Load.
Upper: 200 mA / div.
Lower: 50 V / div.
Horizontal: 20 ms / div.

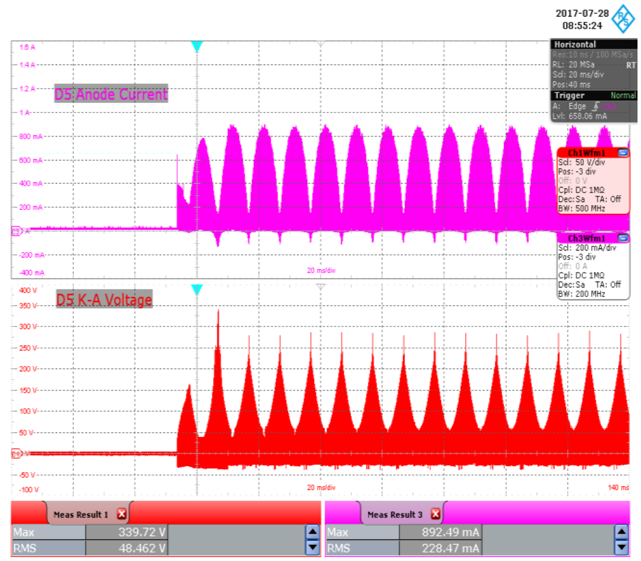

Figure 86 – 230 VAC 50 Hz, 2.92 A CC Load.
Upper: 200 mA / div.
Lower: 50 V / div.
Horizontal: 20 ms / div.

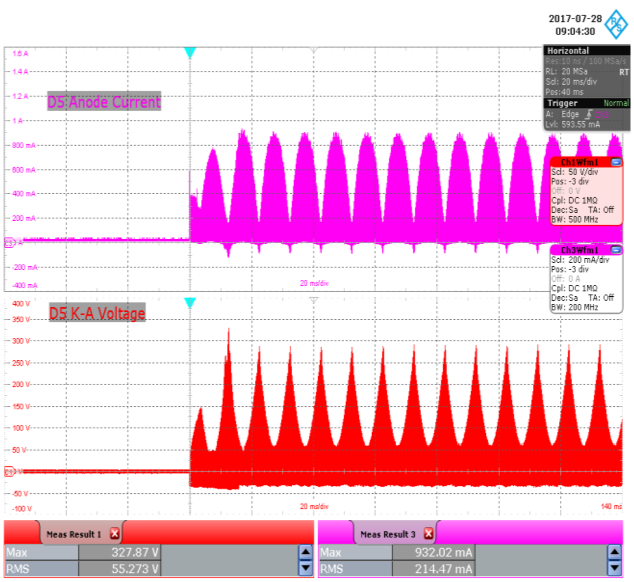

Figure 87 – 277 VAC 50 Hz, 2.92 A CC Load.
Upper: 200 mA / div.
Lower: 50 V / div.
Horizontal: 20 ms / div.

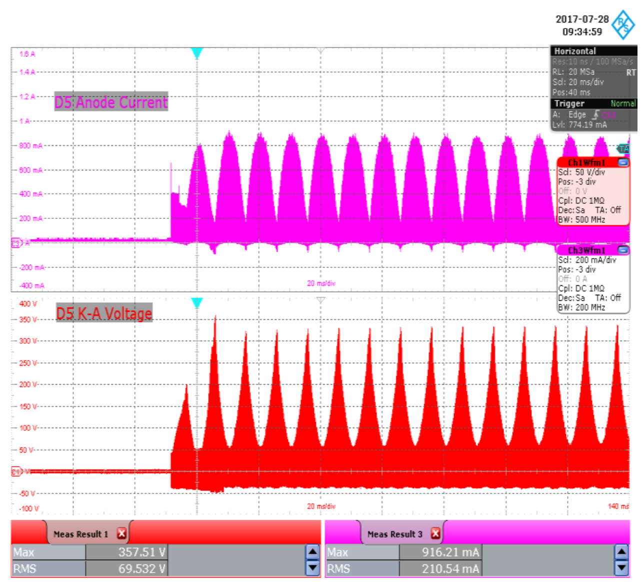

Figure 88 – 320 VAC 50 Hz, 2.92 A CC Load.
Upper: 200 mA / div.
Lower: 50 V / div.
Horizontal: 20 ms / div.

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14.12 ***SR FET Drain Voltage and Current at Normal Operation***

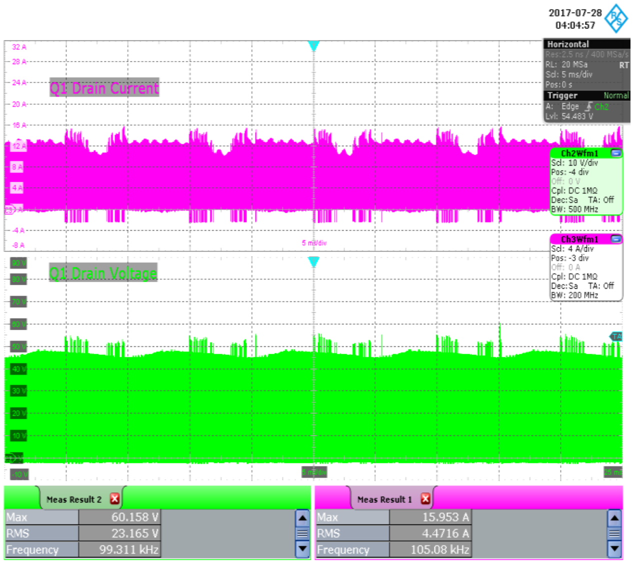

Figure 89 – 140 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 10 V / div.
Horizontal: 5 ms / div.

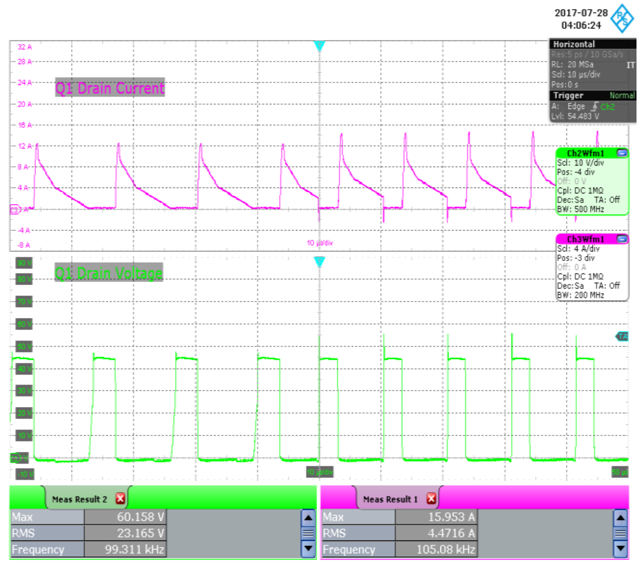

Figure 90 – 140 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 10 V / div.
Horizontal: 10 μs / div.

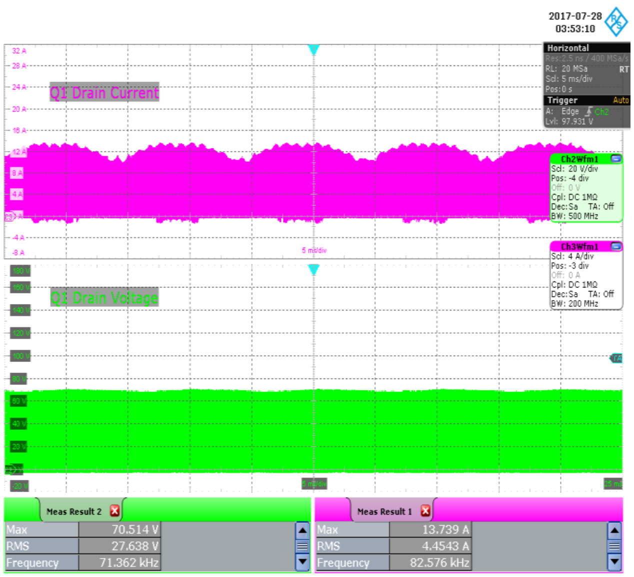

Figure 91 – 230 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 20 V / div.
Horizontal: 5 ms / div.

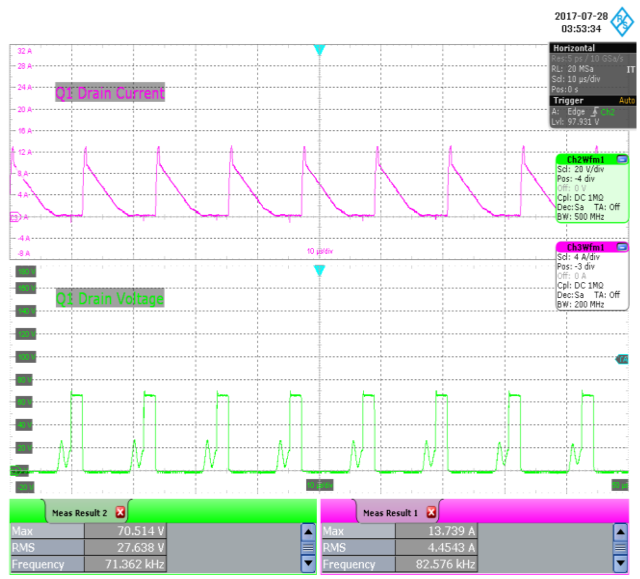

Figure 92 – 230 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 20 V / div.
Horizontal: 10 μs / div.

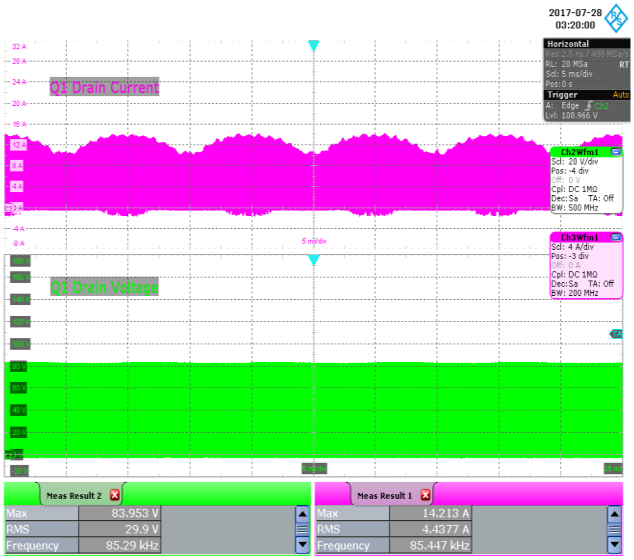

Figure 93 – 277 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 20 V / div.
Horizontal: 5 ms / div.

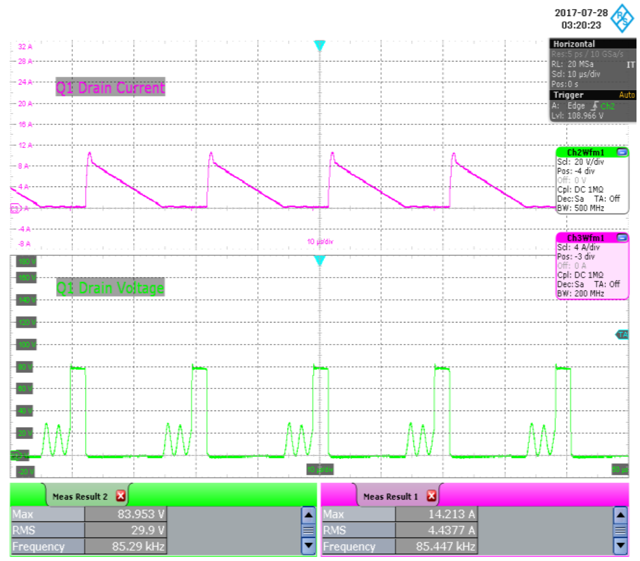

Figure 94 – 277 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 20 V / div.
Horizontal: 10 μs / div.

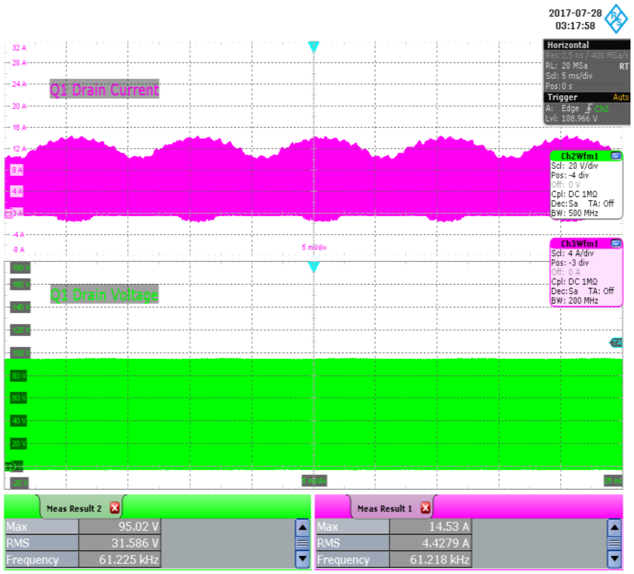

Figure 95 – 320 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A/ div.
Lower: 20 V / div.
Horizontal: 5 ms / div.

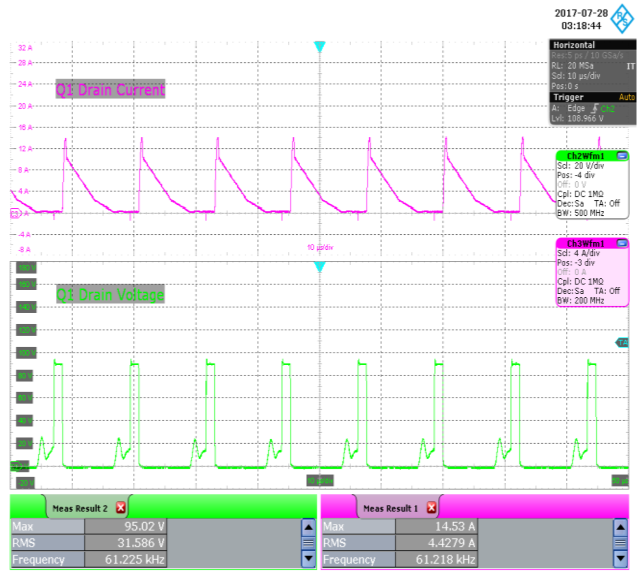

Figure 96 – 320 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A/ div.
Lower: 20 V / div.
Horizontal: 10 μs / div.

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14.13 *SR FET Drain Voltage and Current at Full Load Start-up*

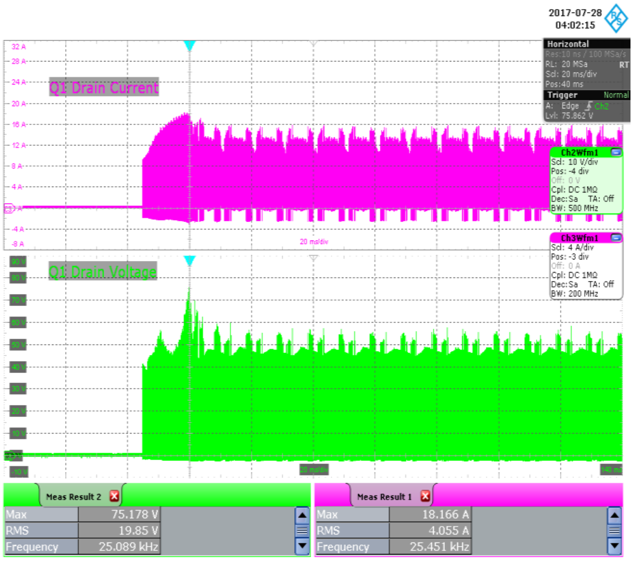

Figure 97 – 140 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 10 V / div.
Horizontal: 20 ms / div.

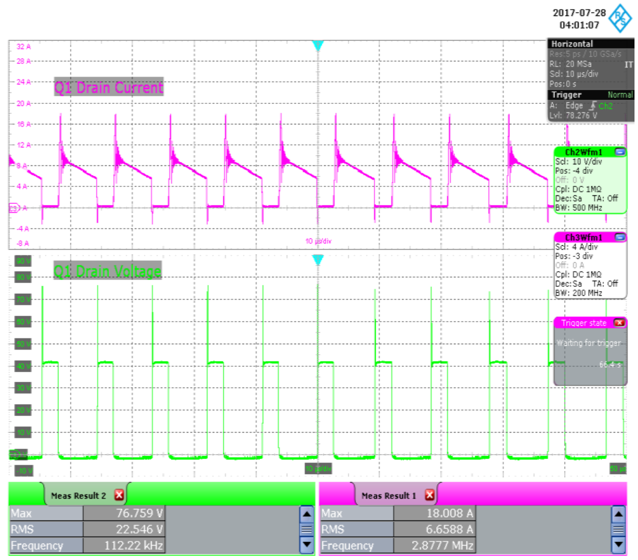

Figure 98 – 140 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 10 V / div.
Horizontal: 10 µs / div.

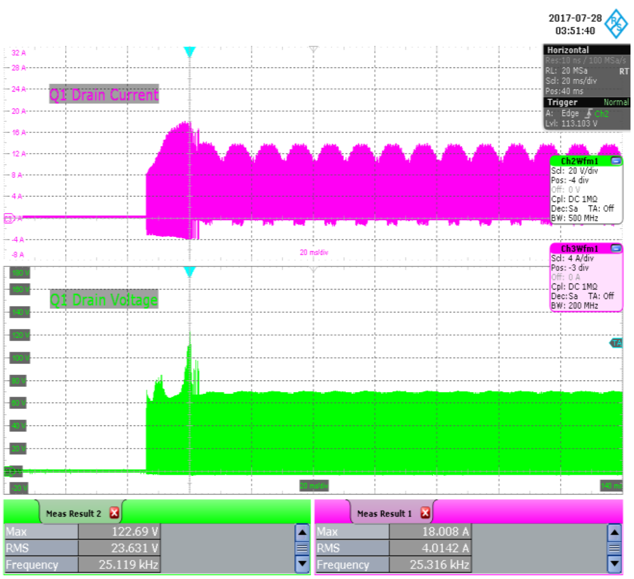

Figure 99 – 230 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 20 V / div.
Horizontal: 20 ms / div.

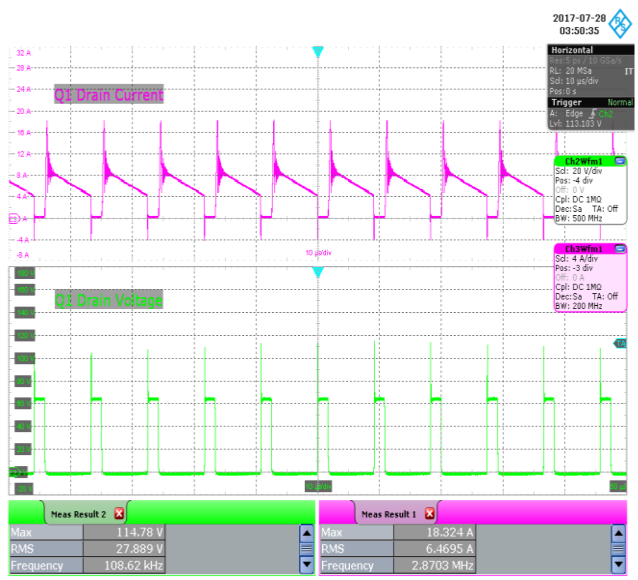

Figure 100 – 230 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 20 V / div.
Horizontal: 10 µs / div.

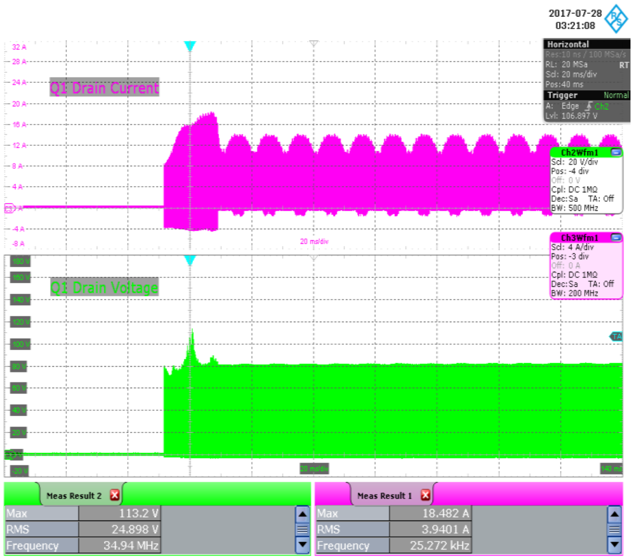

Figure 101 – 277 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 20 V / div.
Horizontal: 20 ms / div.

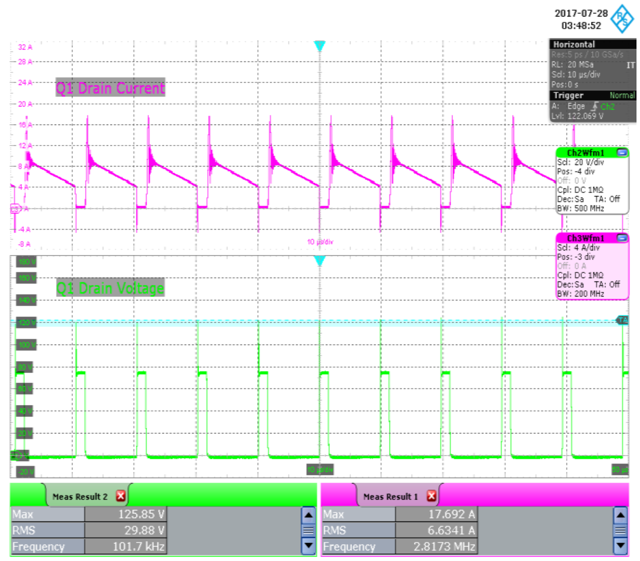

Figure 102 – 140 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 20 V / div.
Horizontal: 10 μs / div.

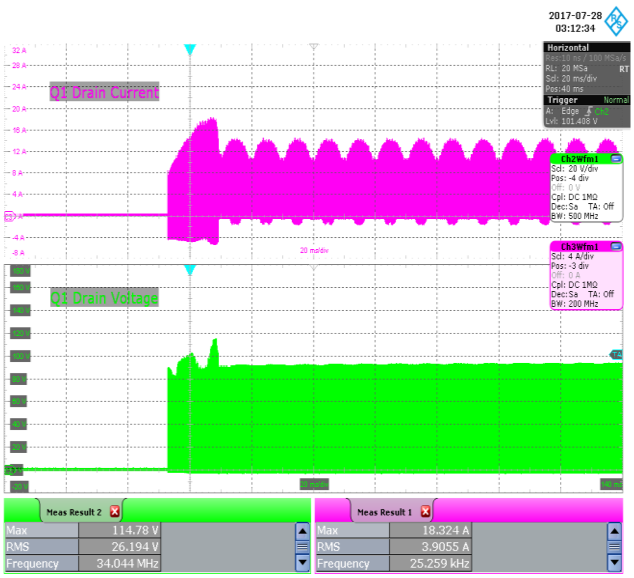

Figure 103 – 320 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 20 V / div.
Horizontal: 20 ms / div.

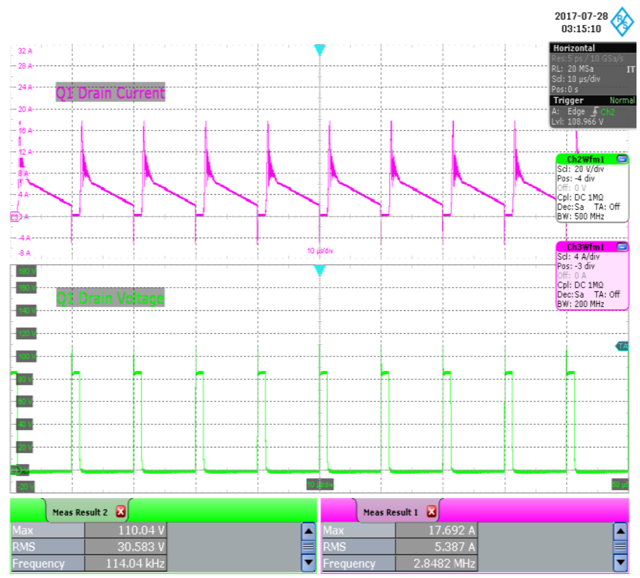

Figure 104 – 320 VAC 50 Hz, 2.92 A CC Load.
Upper: 4 A / div.
Lower: 20 V / div.
Horizontal: 10 μs / div.

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14.14 ***Output Voltage Ripple***

Figure 105 – Probe Set-up for Output Voltage Ripple Test.

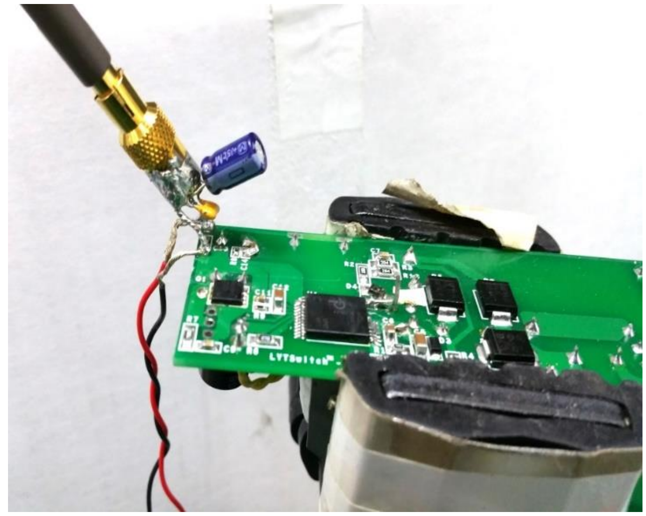

Figure 106 – Unit Set-up for Output Voltage Ripple Test.

Ripple voltage was taken using a X1 probe with 47 μF electrolytic capacitor and 0.1 μF ceramic capacitor connected in parallel across the probe.

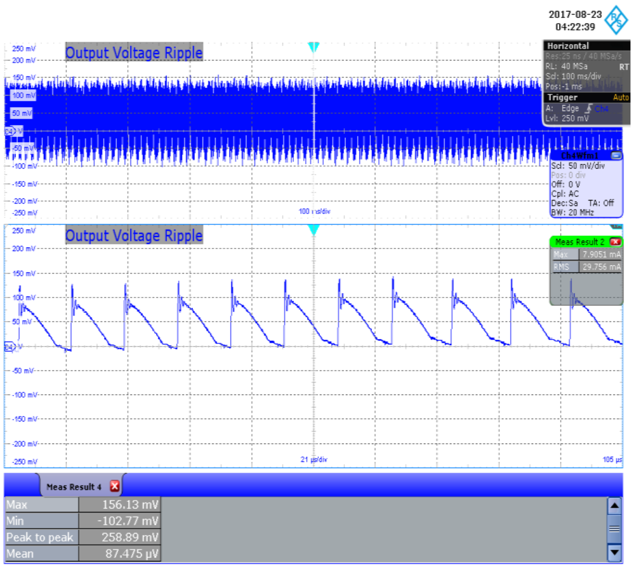

Figure 107 – 140 VAC 50 Hz, 2.92 A CC Load.
AC Coupling, 20 MHz Bandwidth
V_{OUT}, 50 mV / div., 100 ms / div.
Ripple Voltage: 258.89 mV_{PK-PK}.

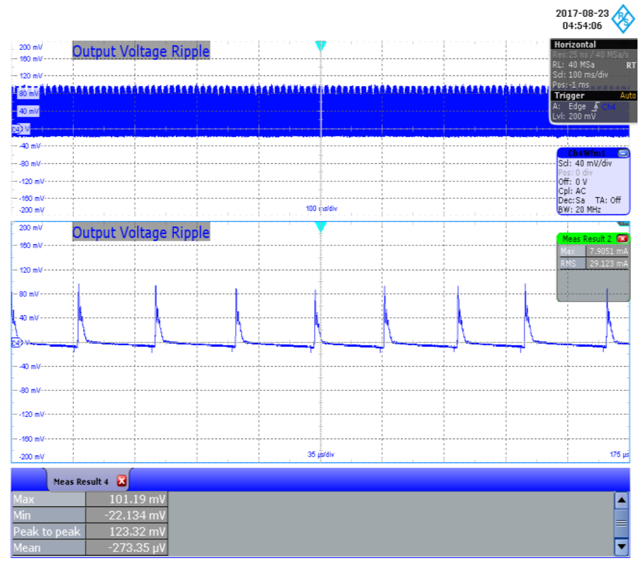

Figure 108 – 140 VAC 50 Hz, 300 mA CC Load.
AC Coupling, 20 MHz Bandwidth
V_{OUT}, 40 mV / div., 100 ms / div.
Ripple Voltage: 123.32 mV_{PK-PK}.

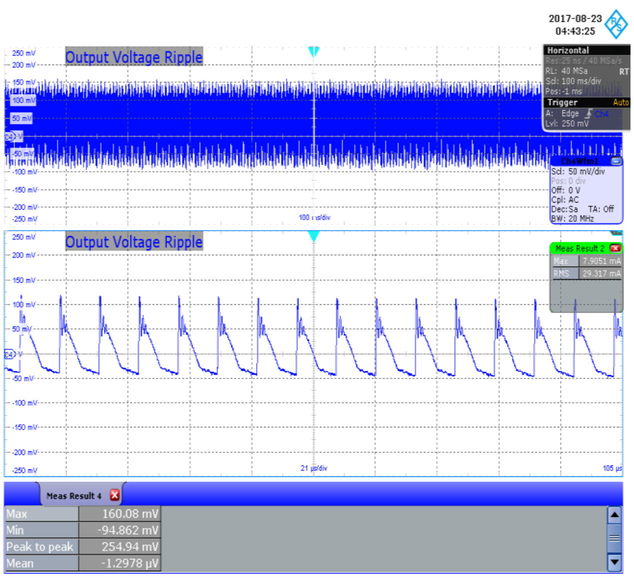

Figure 109 – 230 VAC 50 Hz, 2.92 A CC Load.
AC Coupling, 20 MHz Bandwidth
V_{OUT}, 50 mV / div., 100 ms / div.
Ripple Voltage: 254.94 mV_{PK-PK}.

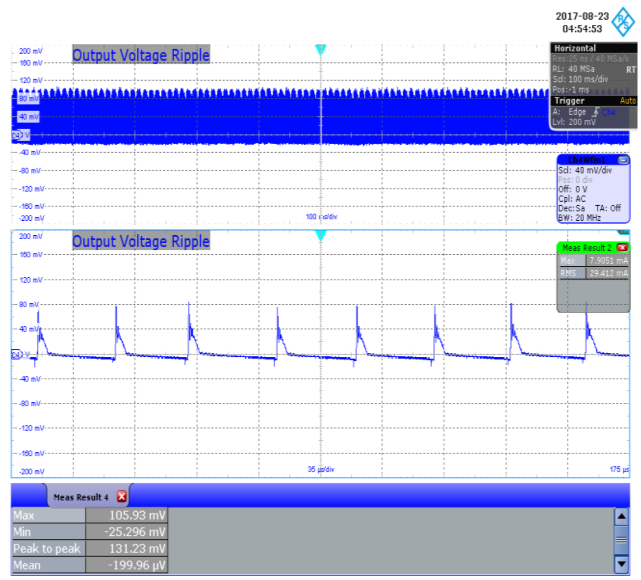

Figure 110 – 230 VAC 50 Hz, 300 mA CC Load.
AC Coupling, 20 MHz Bandwidth
V_{OUT}, 40 mV / div., 100 ms / div.
Ripple Voltage: 131.23 mV_{PK-PK}.

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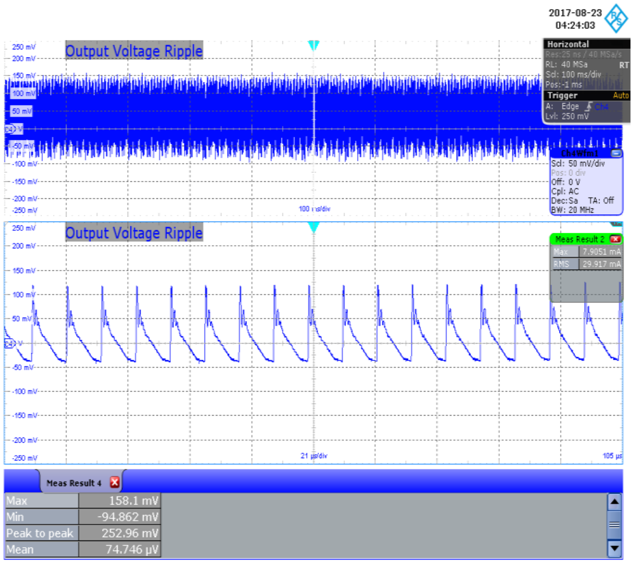

Figure 111 – 277 VAC 50 Hz, 2.92 A CC Load.
AC Coupling, 20 MHz Bandwidth
V_{OUT}, 50 mV / div., 100 ms / div.
Ripple Voltage: 252.96 mV_{PK-PK}.

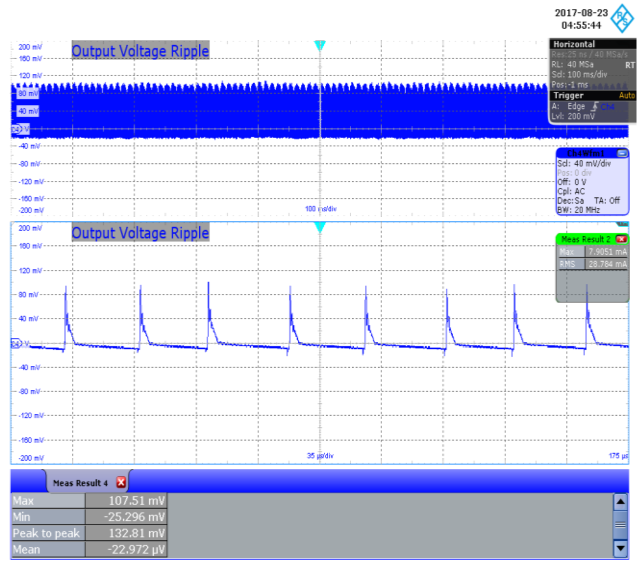

Figure 112 – 140 VAC 50 Hz, 300 mA CC Load.
AC Coupling, 20 MHz Bandwidth
V_{OUT}, 40 mV / div., 100 ms / div.
Ripple Voltage: 132.81 mV_{PK-PK}.

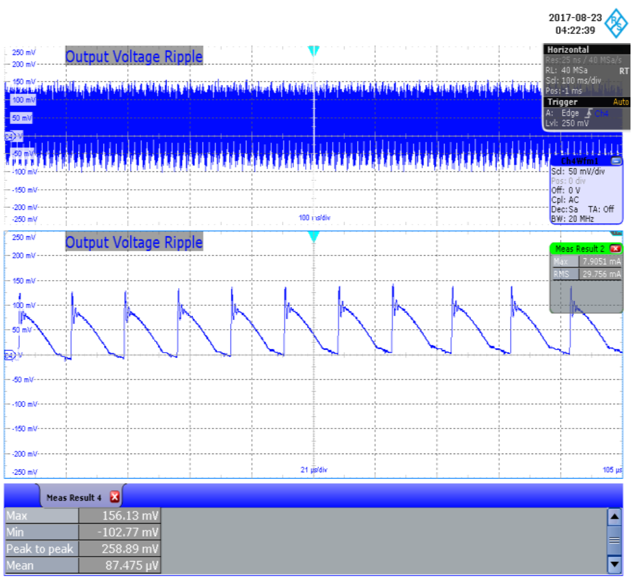

Figure 113 – 320 VAC 50 Hz, 2.92 A CC Load.
AC Coupling, 20 MHz Bandwidth
V_{OUT}, 50 mV / div., 100 ms / div.
Ripple Voltage: 258.89 mV_{PK-PK}.

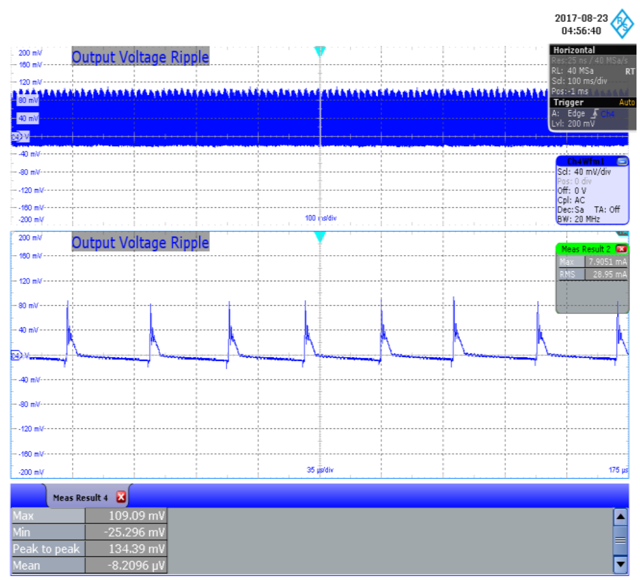

Figure 114 – 320 VAC 50 Hz, 300 mA CC Load.
AC Coupling, 20 MHz Bandwidth
V_{OUT}, 40 mV / div., 100 ms / div.
Ripple Voltage: 134.39 mV_{PK-PK}.

14.15 ***Output Current Ripple***

14.15.1 Equipment Used

1. Rohde & Schwarz RTO1004 Oscilloscope
2. Rohde & Schwarz RT-ZC20 Current Probe
3. Keysight 6812B AC Power Source / Analyzer
4. 12 V LED Load

14.15.2 Ripple Ratio and Flicker % Measurement

V_{IN} (VAC)	$I_{OUT(MAX)}$ (mA)	$I_{OUT(MIN)}$ (mA)	I_{MEAN} (mA)	Ripple Ratio (I_{RP-P}/I_{MEAN})	% Flicker 100 x (I_{RP-P} / $I_{O(MAX)}+I_{O(MIN)}$)
140	3030.8	2801.6	2923.9	0.08	3.93
230	3026.9	2793.7	2927	0.08	4.01
277	3030.8	2793.7	2928.8	0.08	4.07
320	3038.7	2789.7	2932.7	0.08	4.27

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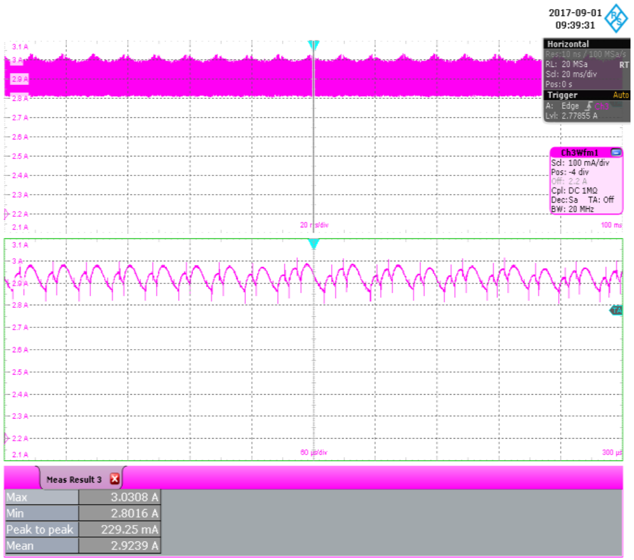

Figure 115 – 140 VAC 50 Hz, 2.98 A LED Load.
20 MHz Bandwidth
I_{OUT}, 100 mA / div., 20 ms / div.
Ripple Current: 229.25 mA_{PK-PK}.

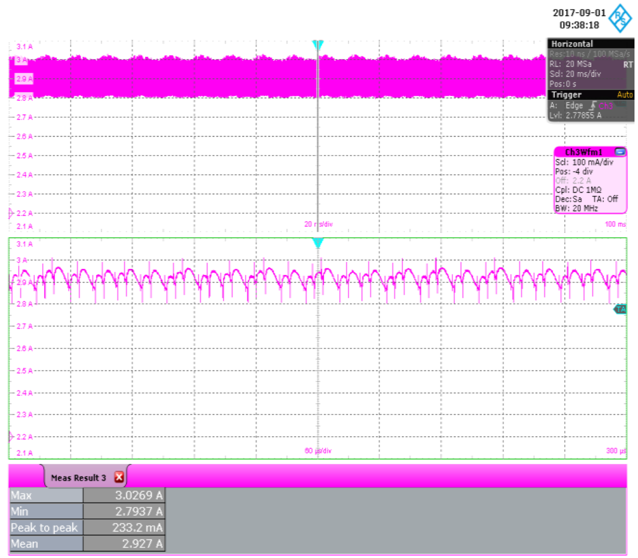

Figure 116 – 230 VAC 50 Hz, 2.98 A LED Load.
20 MHz Bandwidth
I_{OUT}, 100 mA / div., 20 ms / div.
Ripple Current: 233.2 mA_{PK-PK}.

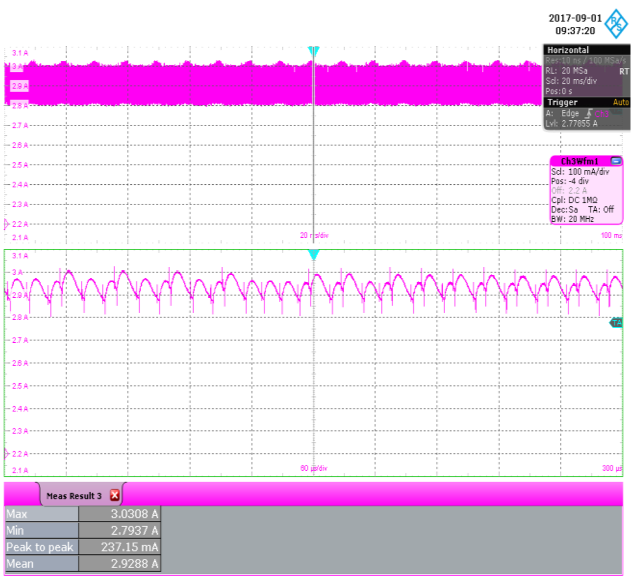

Figure 117 – 277 VAC 50 Hz, 2.98 A LED Load.
20 MHz Bandwidth
I_{OUT}, 100 mA / div., 20 ms / div.
Ripple Current: 237.15 mA_{PK-PK}.

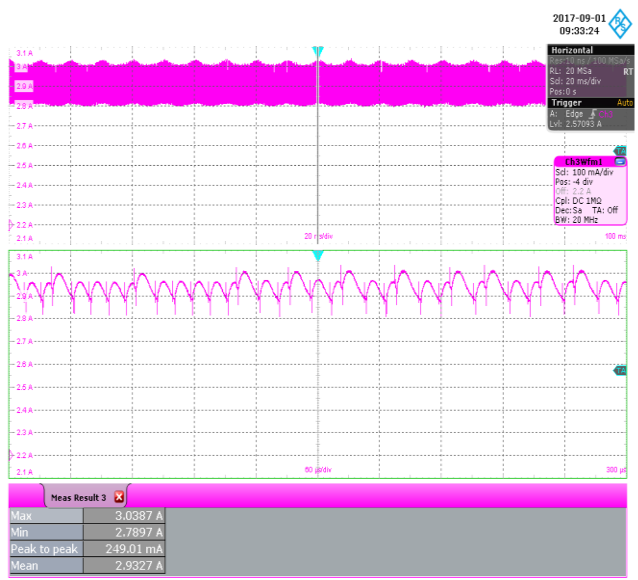

Figure 118 – 320 VAC 50 Hz, 2.98 A LED Load.
20 MHz Bandwidth
I_{OUT}, 100 mA / div., 20 ms / div.
Ripple Voltage: 249.01 mA_{PK-PK}.

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. Resistive Load (set at Full Load)
6. HOSSONI TDGC2 VARIAC set at 230 VAC 60 Hz

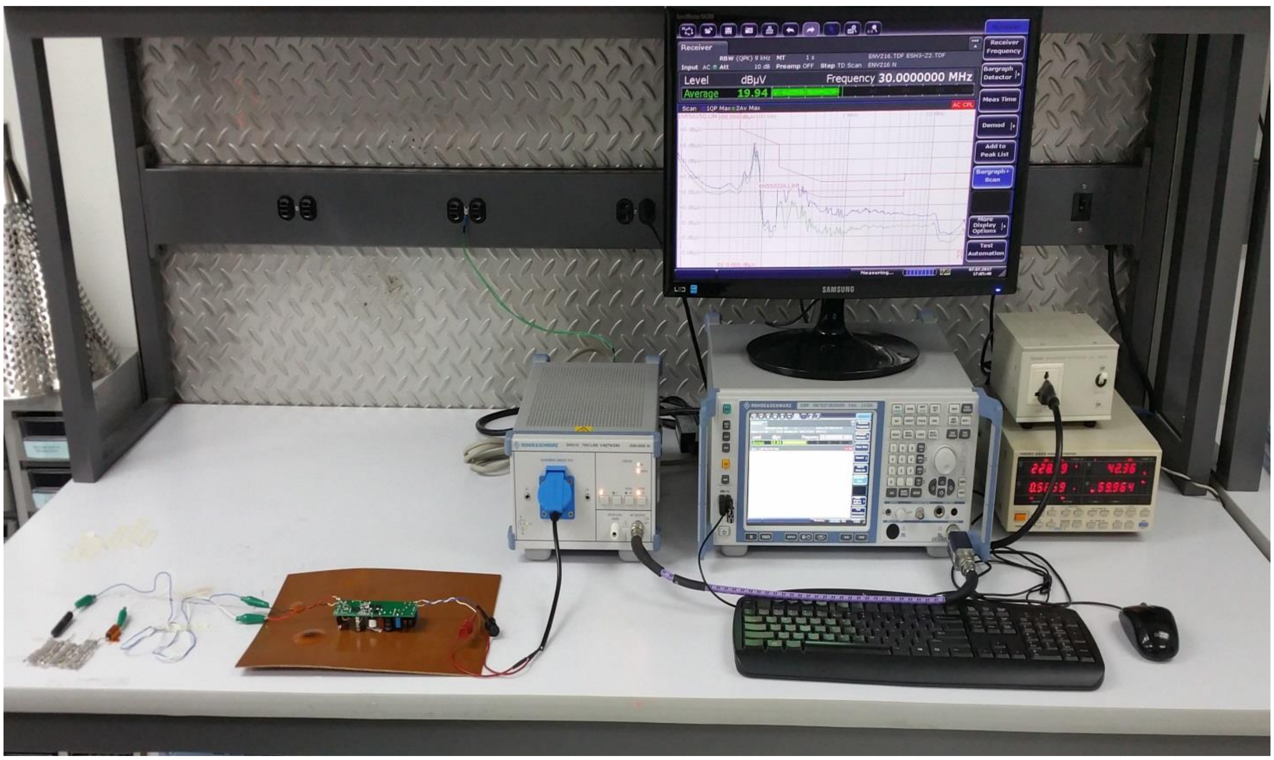

Figure 119 – Conducted EMI Test Set-up.

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15.2 *EMI Test Result*

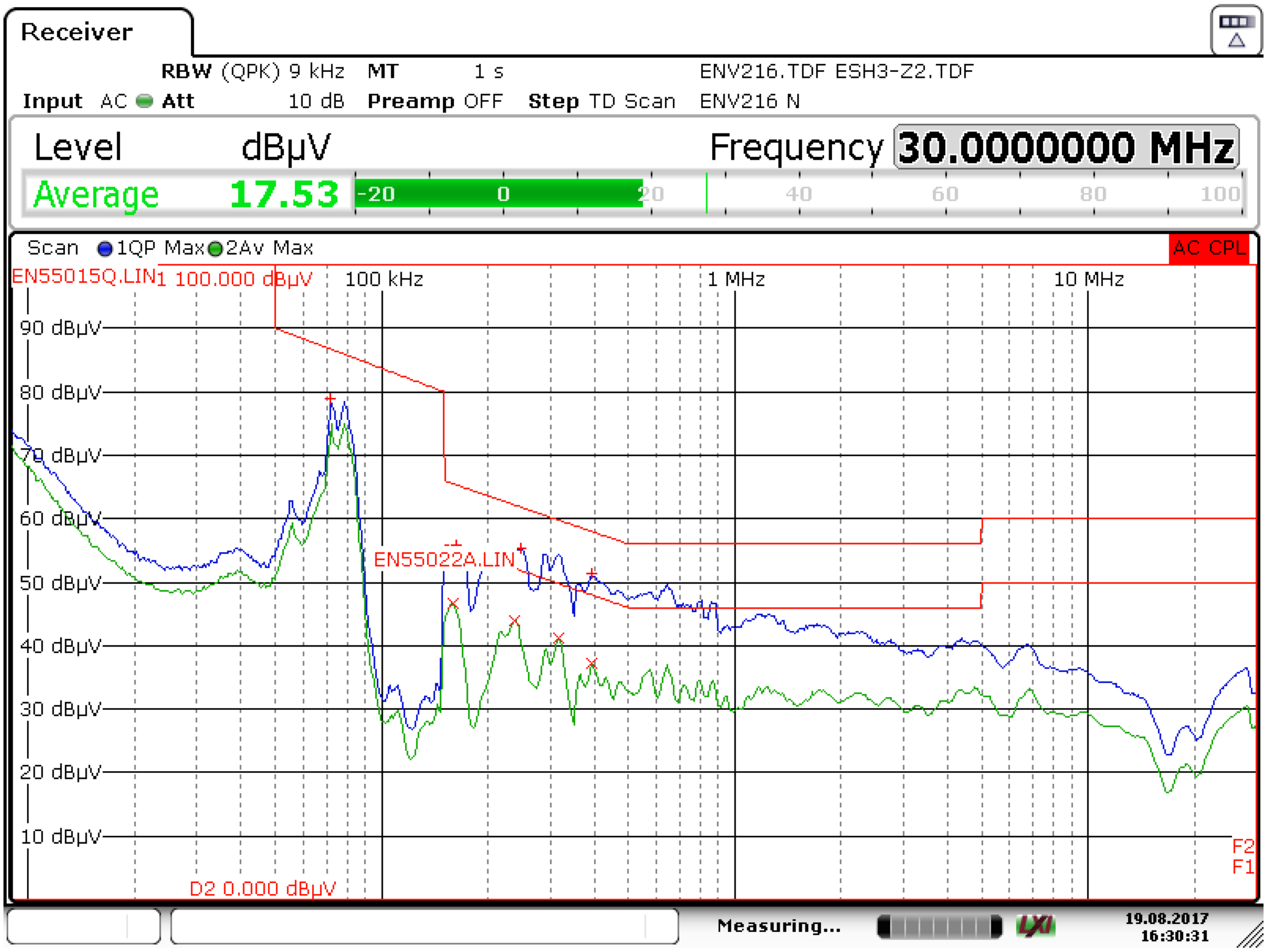

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Figure 120 – Conducted EMI QP Scan at Full Load, 230 VAC 60 Hz and EN55015 B Limits.

Trace1: EN55015Q.LIN Trace2: EN55022A.LIN

Trace/Detector	Frequency	Level dBμV	DeltaLimit
1 Quasi Peak	249.0000 kHz	55.35 L1	-6.44 dB
1 Quasi Peak	395.2500 kHz	51.29 L1	-6.66 dB
1 Quasi Peak	71.9500 kHz	78.85 L1	-7.84 dB
2 Average	237.7500 kHz	43.93 N	-8.24 dB
2 Average	316.5000 kHz	41.24 N	-8.56 dB
2 Average	159.0000 kHz	46.61 L1	-8.91 dB
1 Quasi Peak	163.5000 kHz	55.79 L1	-9.49 dB
2 Average	395.2500 kHz	37.19 N	-10.76 dB

Figure 121 – 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.

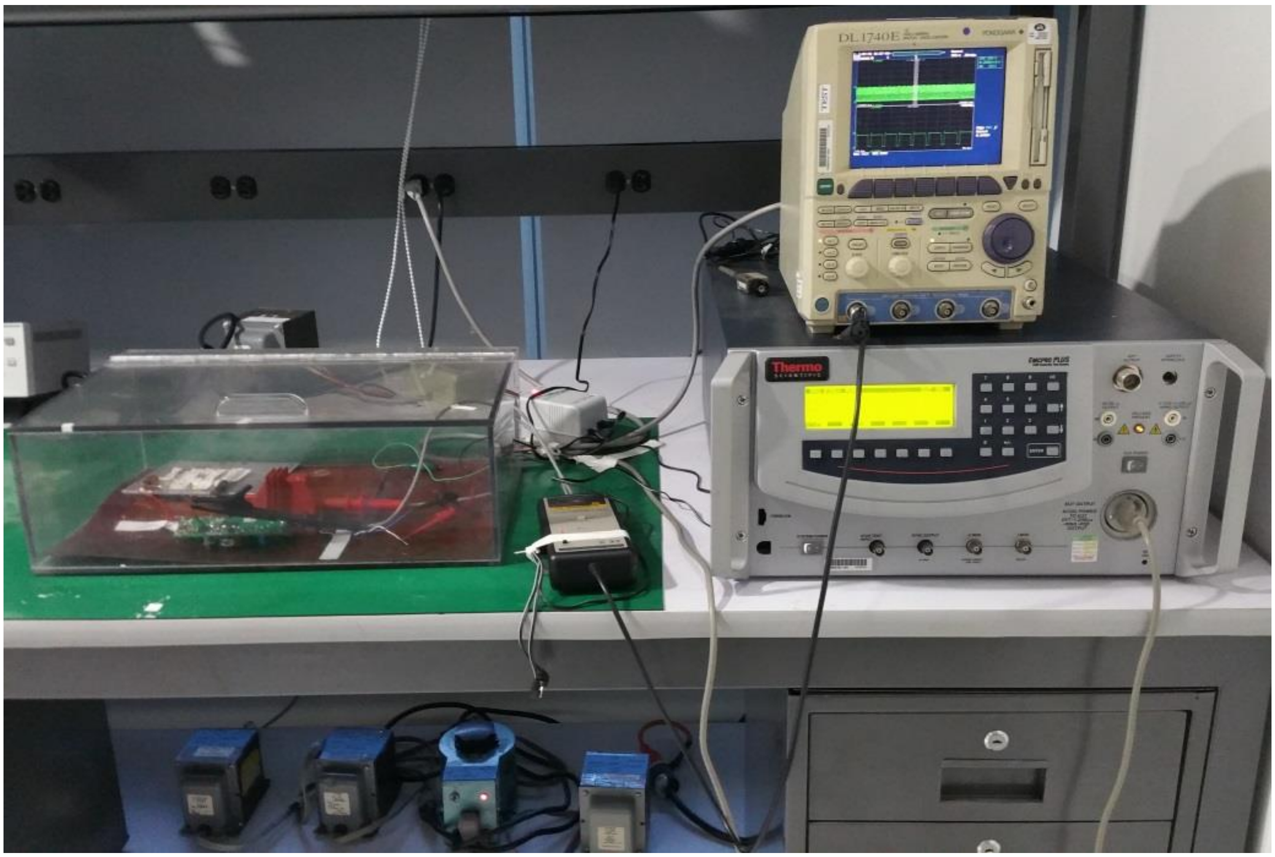

Figure 122 – Test Set-up for Line Surge Test.

16.1 *Differential Surge Test Results*

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+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
+1000	277	L to N	0	Pass
-1000	277	L to N	0	Pass
+1000	277	L to N	90	Pass
-1000	277	L to N	90	Pass
+1000	277	L to N	270	Pass
-1000	277	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	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
+2500	277	L to N	0	Pass
-2500	277	L to N	0	Pass
+2500	277	L to N	90	Pass
-2500	277	L to N	90	Pass
+2500	277	L to N	270	Pass
-2500	277	L to N	270	Pass

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

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

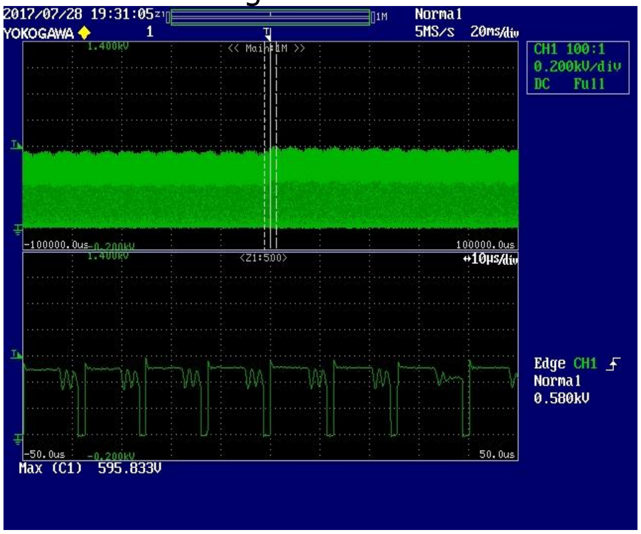

Figure 123 – (+)1 kV Differential Surge.
90º Phase Angle, Input: 277 VAC.
V_{DRAIN}, 200 V / div., 20 ms / div.
Peak V_{DRAIN}: 595.833 V.

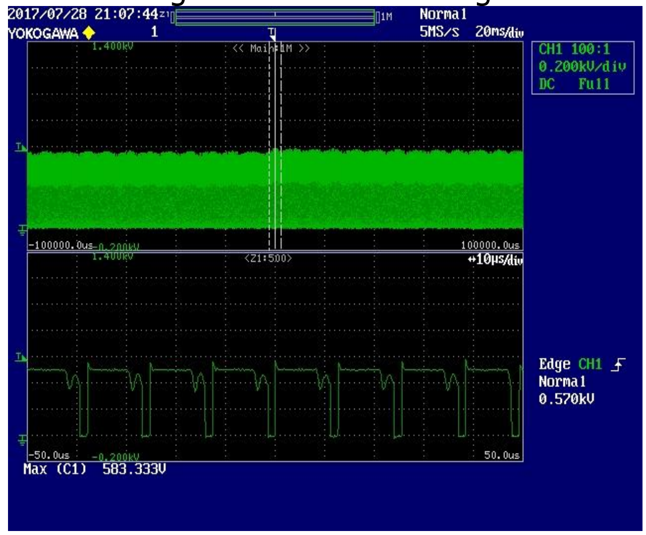

Figure 124 – (-)1 kV Differential Surge.
90º Phase Angle, Input: 277 VAC.
V_{DRAIN}, 200 V / div., 20 ms / div.
Peak V_{DRAIN}: 583.333 V.

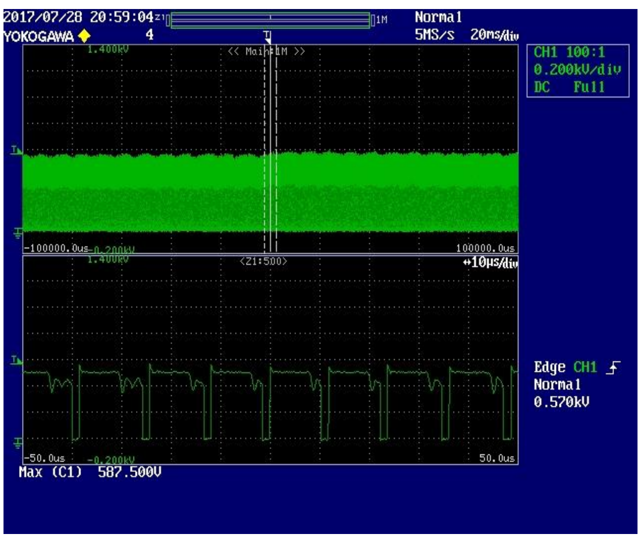

Figure 125 – (+)1 kV Differential Surge.
270º Phase Angle, Input: 277 VAC.
V_{DRAIN}, 200 V / div., 20 ms / div.
Peak V_{DRAIN}: 587.5 V.

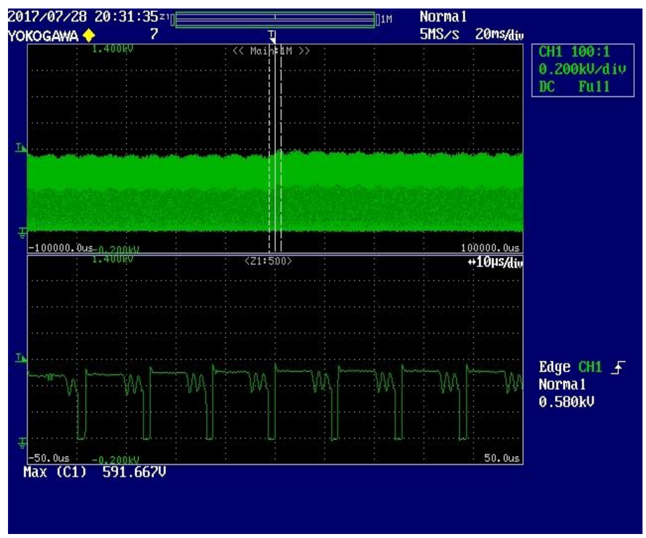

Figure 126 – (-)1 kV Differential Surge.
270º Phase Angle, Input: 277 VAC.
V_{DRAIN}, 200 V / div., 20 ms / div.
Peak V_{DRAIN}: 591.667 V.

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.

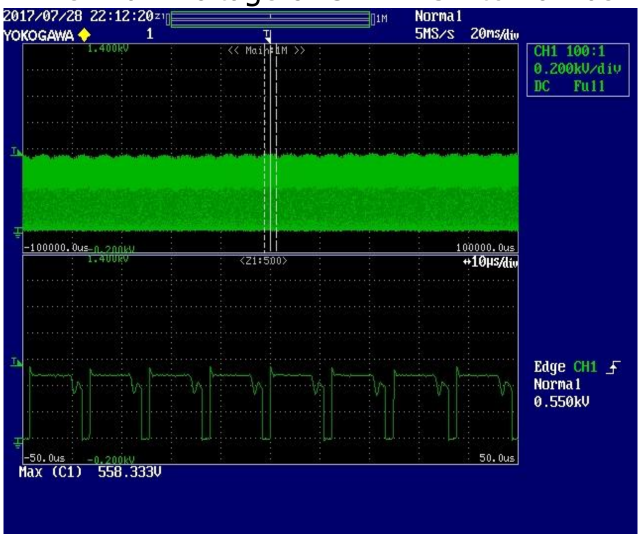

Figure 127 – (+) 2.5 kV Ring Wave Surge.
90º Phase Angle, Input: 277 VAC.
V_{DRAIN}, 200 V / div., 20 ms / div.
Peak V_{DRAIN}: 558.333 V.

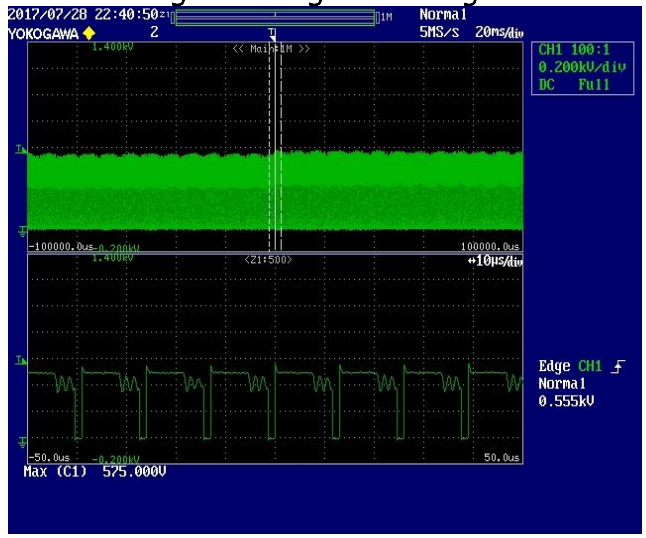

Figure 128 – (-) 2.5 kV Ring Wave Surge.
90º Phase Angle, Input: 277 VAC.
V_{DRAIN}, 200 V / div., 20 ms / div.
Peak V_{DRAIN}: 575.0 V.

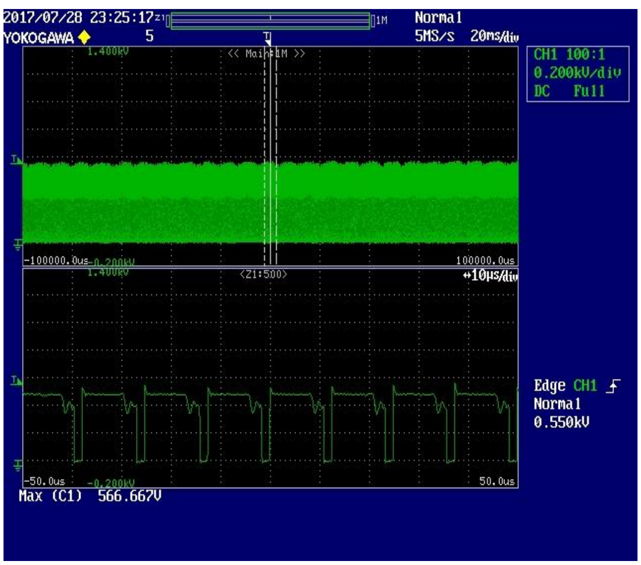

Figure 129 – (+) 2.5 kV Ring Wave Surge.
270º Phase Angle, Input: 277 VAC.
V_{DRAIN}, 200 V / div., 20 ms / div.
Peak V_{DRAIN}: 566.667 V.

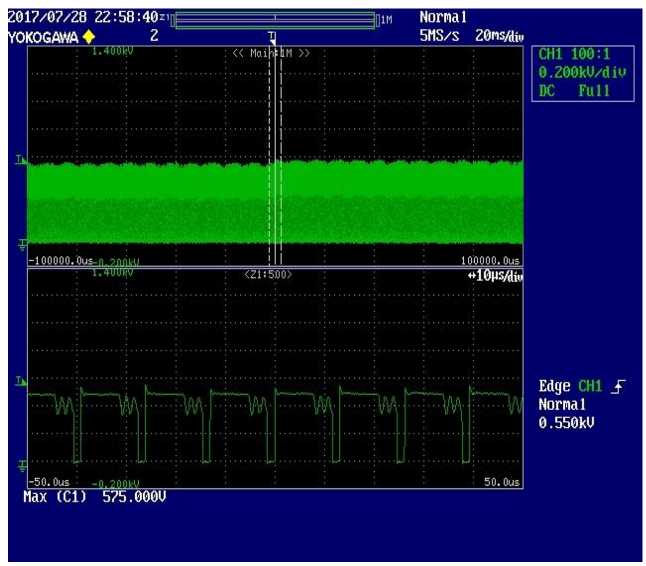

Figure 130 – (-) 2.5 kV Ring Wave Surge.
270º Phase Angle, Input: 277 VAC.
Lower: V_{DRAIN}, 200 V / div., 20 ms / div.
Peak V_{DRAIN}: 575.0 V.

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17 Brown-in / Brown-out Test

No abnormal overheating and nor voltage overshoot / undershoot was observed during and after 0.5 V / s brown-in and brown-out test.

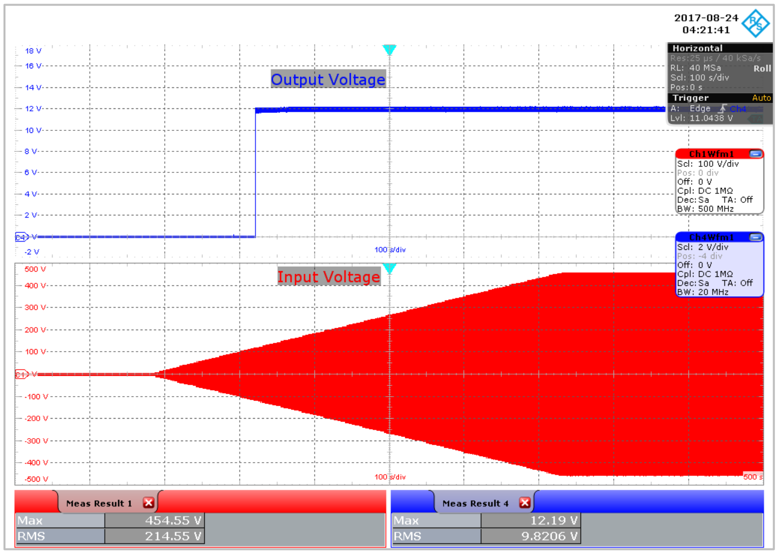

Figure 131 – Brown-in Test at 0.5 V / s.
Time Scale: 100 s / div.
Ch1: V_{OUT}, 2 V / div.
Ch2: V_{IN}, 100 V / div.

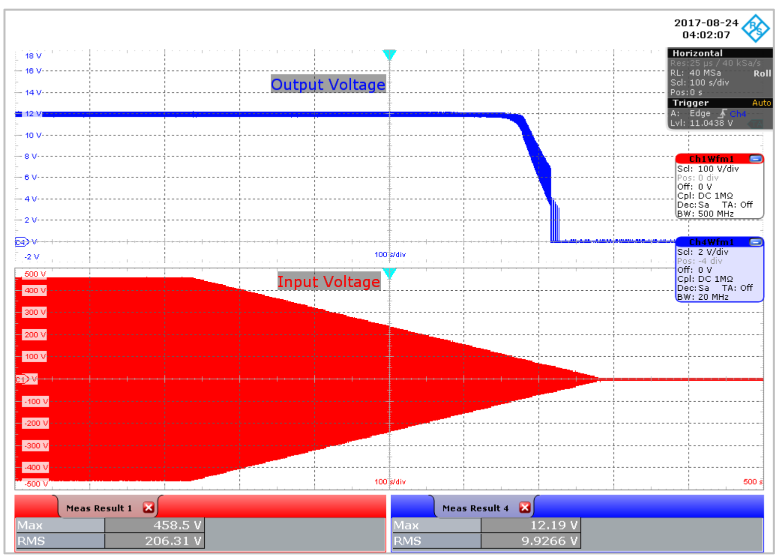

Figure 132 – Brown-in Test at 0.5 V / s.
Time Scale: 100 s / div.
Ch1: V_{OUT}, 2 V / div.
Ch2: V_{IN}, 100 V / div.

18 Revision History

Date	Author	Revision	Description and Changes	Reviewed
23-Jan-18	EDdL	1.0	Initial Release.	Apps & Mktg
16-Feb-18	EDdL	1.1	Minor Text Updates. PCB Images Updated.	
21-Feb-18	EDdl	1.2	Added PIXls Spreadsheet.	
26-Mar-18	EDdl	1.3	Updated Power Supply Specification, Section 2.0.	
23-Apr-18	KCM	1.4	Updated Figure 4 Schematic.	

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