Design Example Report

Title	***18 W - 25 W Isolated Flyback, Constant Current and Constant Voltage (CC/CV) LED Driver Using LYTSwitch™-4 LYT4325E***
Specification	195 VAC – 265 VAC Input; 24 V, 1.04 A Output
Application	LED Driver
Author	Applications Engineering Department
Document Number	DER-429
Date	May 13, 2015
Revision	1.0

Summary and Features

- Single-stage power factor correction combined with constant current (CC) constant voltage (CV) output
- Integrated protection and reliability features
  - Output short-circuit protected with auto-recovery
  - Auto-recovering thermal shutdown with large hysteresis
  - No damage during brown-out conditions
- PF >0.96 at 230 VAC
- THD <20% at 230 VAC
- Meets ring wave and differential line surge and 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.

1 Introduction

This document describes an isolated, high power factor (PF), low THD LED driver designed to drive a nominal LED string voltage of 24 V at 1 A from an input voltage range of 195 VAC to 265 VAC (50 Hz typical). The LED driver utilizes the LYT4325E from the LYTSwitch-4 family of ICs.

The topology used is a single-stage isolated flyback that provides high power factor, constant current and constant voltage regulation, and low THD.

This document contains the LED driver specification, schematic, PCB details, bill of materials, transformer documentation and typical performance characteristics.

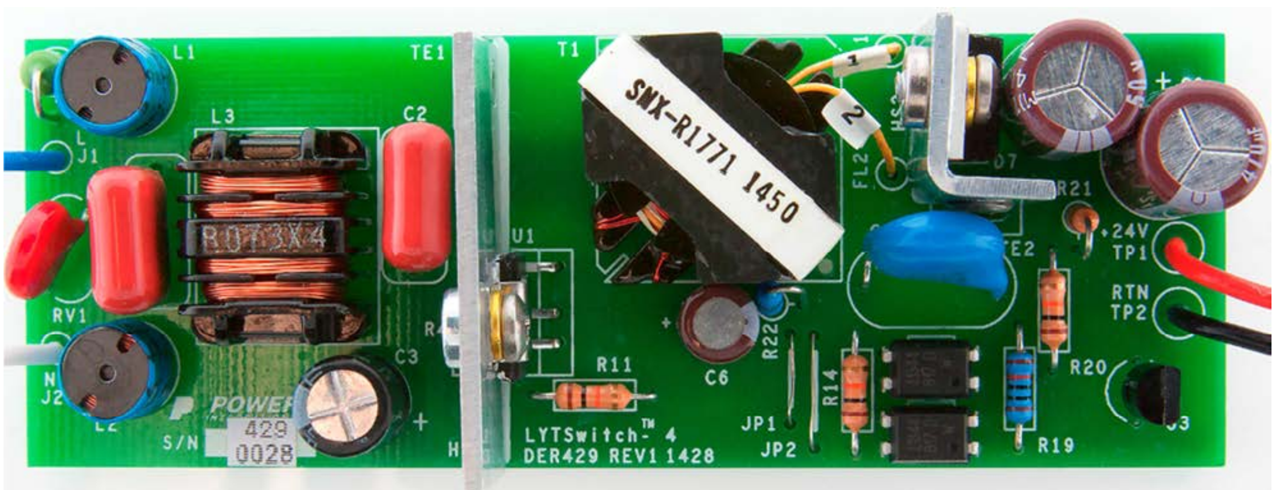

Figure 1 – Populated Circuit Board, Top View.

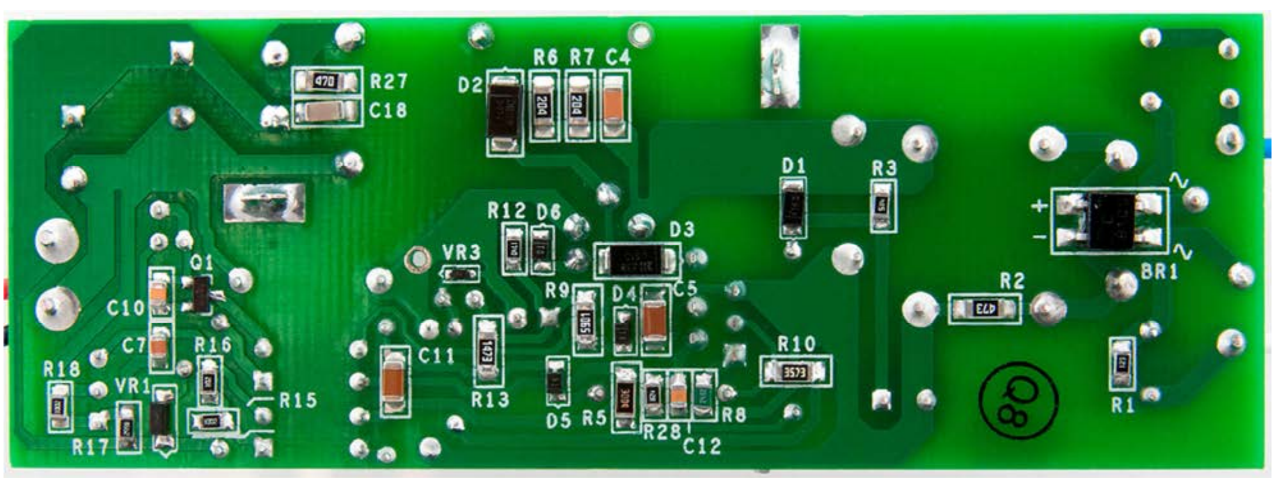

Figure 2 – Populated Circuit Board, Bottom View.

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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}	195	230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}		50/60		Hz	
Output						
Output Voltage	V_{OUT}		24		V	
Output Current	I_{OUT}		1.04		A	
Total Output Power						
Continuous Output Power	P_{OUT}		25		W	
Efficiency						
Full Load	η		85		%	Measured at P_{OUT} 25 °C
Environmental						
Conducted EMI		CISPR 15B / EN55015B				
Safety		Non-Isolated				
Ring Wave (100 kHz)			2.5		kV	
Differential Mode (L1-L2)			1.0		kV	
Power Factor			0.96			Measured at $V_{OUT(TYP)}$, $I_{OUT(TYP)}$ and 230 VAC, 50 Hz
Ambient Temperature	T_{AMB}			40	°C	Free convection, sea level

3 Schematic

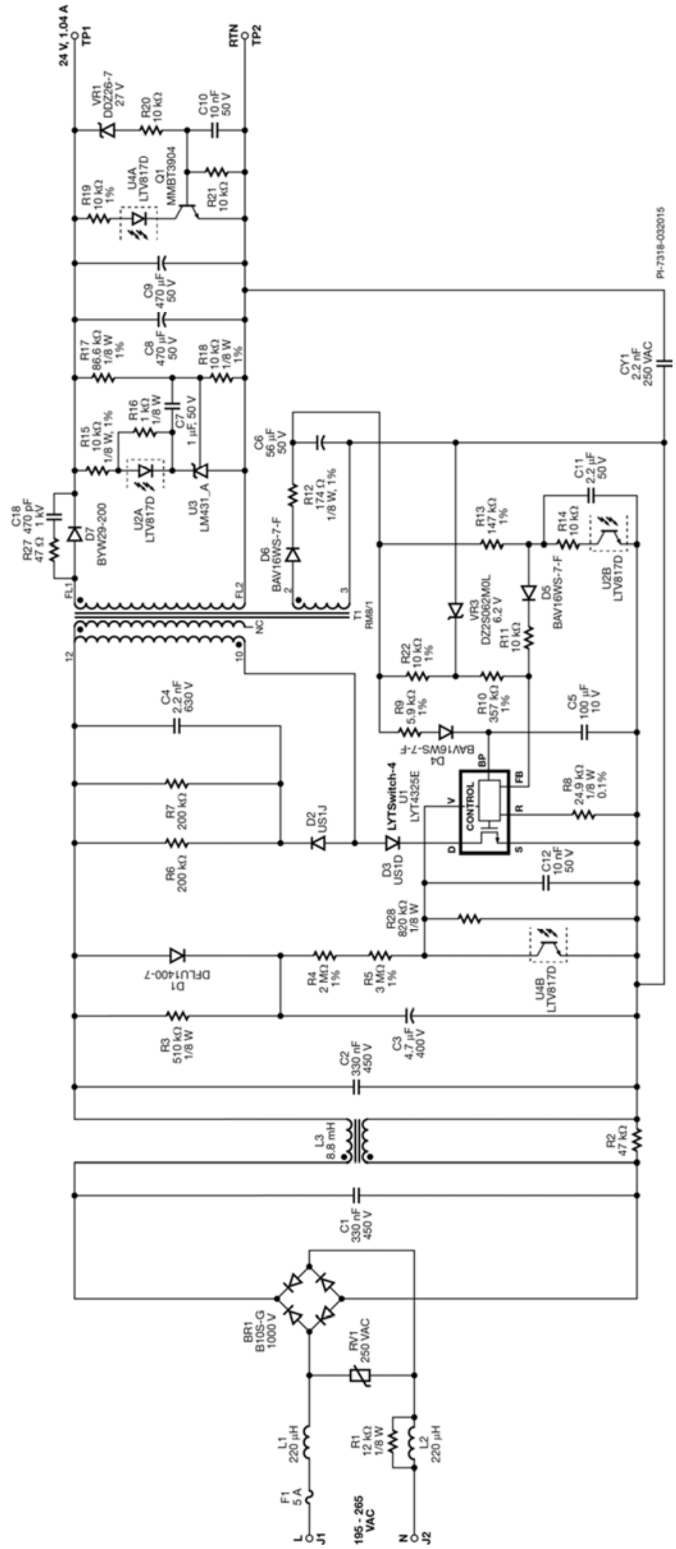

Figure 3 – Schematic.

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4 Circuit Description

The LYTSwitch-4 device (LYT4325E) in this design provides high power factor in a single-stage conversion topology with low THD while regulating the output to provide a constant voltage and current output across a wide input range. The driver also compensates for the output voltage variations that are expected in a typical LED driver environment. The LYT4325E IC is a member of the LYTswitch-4 family and is configured for use in a single-stage flyback topology.

4.1 Input EMI Filtering

Fuse F1 provides protection from component failure and RV1 provides a clamp to limit the maximum voltage during line-surge events. Bridge rectifier BR1 rectifies the AC line voltage and provides a full wave rectified DC across the filter consisting of C1, L3, and C2. Resistor R2 is connected across L3 to lower the Q for better filtering of high frequency EMI.

4.2 Power Circuit

Output diode D7 conducts every time U1 is off and transfers energy to the load. Diode D3 is a blocking diode to prevent reverse current flowing through U1 when the voltage across C2 falls below the output voltage (close to the zero crossing of the input AC voltage). Peak line voltage information needed by U1 for regulation as well as power factor correction is provided by the peak detection circuit consisting of R3, D1, and C3. A current will flow to the VOLTAGE MONITOR (V) pin due to this voltage via R4 and R5. The line overvoltage shutdown function, sensed via the V pin current, extends the rectified line voltage withstand (during surges and line swells) to the 725 BV_{DSS} rating of the internal power MOSFET. Capacitor C5 provides local decoupling for the BP pin of U1 which is the supply pin for the internal controller. During start-up, C5 is charged to ~6 V from an internal high-voltage current source connected to the D pin of U1. The REFERENCE pin of U1 is tied to ground (SOURCE) via 24.9 kΩ value resistor R8.

4.3 Bias Supply and Output Feedback

A bias winding on T1 is used to provide supply and feedback to the IC. The flyback voltage on the bias winding is rectified by diode D6 and filtered by C6. Resistor R12 reduces excess voltage coupled from the leakage inductance energy of the transformer T1. The voltage across the bias circuit results in a current flowing through R13 to the LYT4325E FEEDBACK pin (FB). This information is used by the IC to set the output current of the LED driver.

4.4 Constant Voltage

Constant voltage operation can be achieved through network circuit U2, R15, R17, C7, U3, R18, R14, and C11. Regulator U3 serves as a reference that allows optocoupler U2 to conduct when the output voltage exceeds 24 V. Resistor network R17 and R18 determines the proper voltage divider value that will allow U3 to conduct when its internal reference voltage (approximately 2.5 V) is exceeded. When U2 conducts, current on the FEEDBACK pin is diverted. This means current flows through optocoupler U2 through R2 instead of to the FEEDBACK pin (through R13). In this manner a constant voltage across the output is achieved.

4.5 Overvoltage Circuit

Overvoltage protection is achieved through the VR1, R20, R19, U4, Q1, R21, and C10. In normal operating conditions the output voltage is 24 V. As the output load decreases, (approaching no-load condition), output voltage rises. Zener diode VR1 conducts and injects current into Q1 through R20. This makes the optocoupler U2 conduct. When U2 conducts, current on the VOLTAGE MONITOR pin is diverted. This means that current flows to U2 (primary side) through R4 and R5 and activates the overvoltage protection feature.

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5 PCB Layout

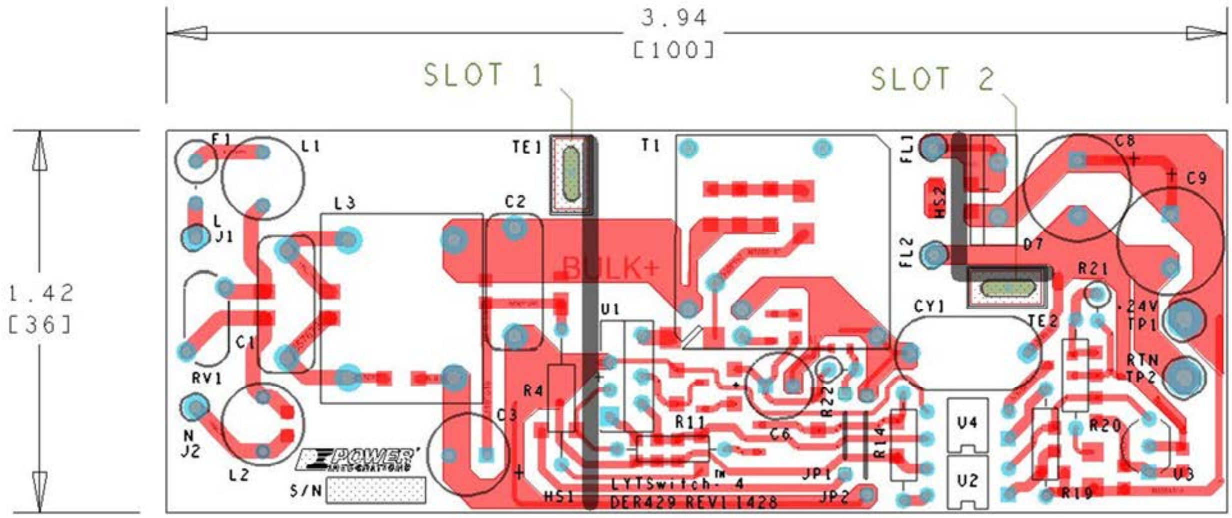

Figure 4 – Top Side.

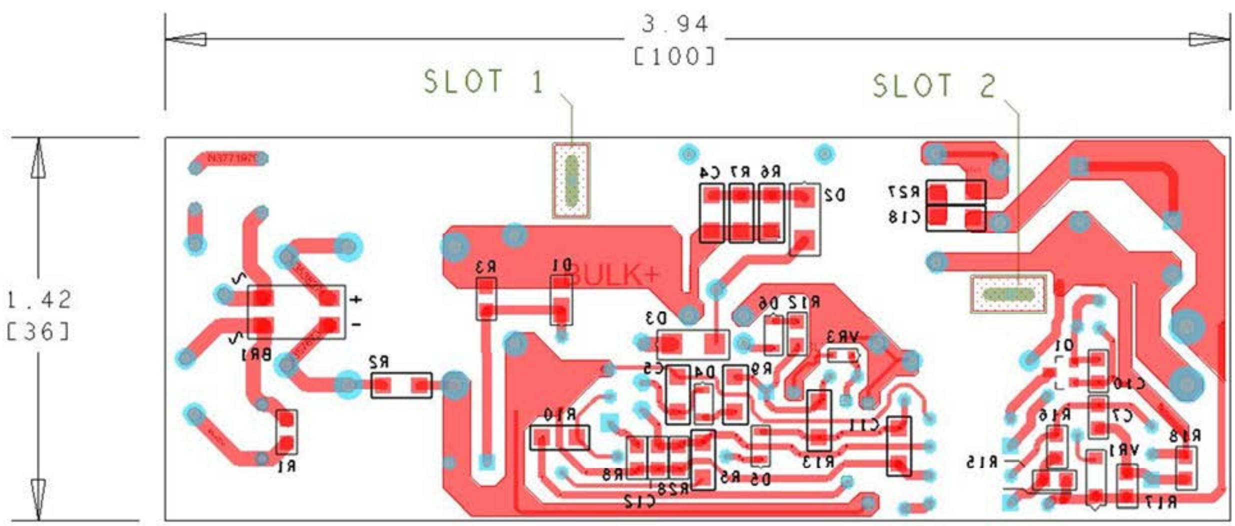

Figure 5 – Bottom Side.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
1	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip Technology
2	1	C1	330 nF, 450 V, Film	ECWF2W334JAQ	Panasonic
3	1	C2	330 nF, 450 V, Film	ECWF2W334JAQ	Panasonic
4	1	C3	4.7 μF, 400 V, Electrolytic, (8 x 11.5)	TAQ2G4R7MK0811MLL3	Taicon
5	1	C4	2.2 nF, 630 V, Ceramic, X7R, 1206	C3216X7R2J222K	TDK
6	1	C5	100 μF, 10 V, Ceramic, X5R, 1206	C3216X5R1A107M	TDK
7	1	C6	56 μF, 50 V, Electrolytic, Very Low ESR, 140 mΩ (6.3 x 11)	EKZE500ELL560MF11D	Nippon Chemi-Con
8	1	C7	1 μF, 50 V, Ceramic, X7R, 0805	C2012X7R1H105M	TDK
9	1	C8	470 μF, 50 V, Electrolytic, (10 x 20)	EKMG500ELL471MJ20S	United Chemi-con
10	1	C9	470 μF, 50 V, Electrolytic, (10 x 20)	EKMG500ELL471MJ20S	United Chemi-con
11	1	C10	10 nF, 50 V, Ceramic, X7R, 0805	C0805C103K5RACTU	Kemet
12	1	C11	2.2 μF, 50 V, Ceramic, Y5V, 1206	UMK316F225ZG-T	Taiyo Yuden
13	1	C12	10 nF, 50 V, Ceramic, X7R, 0805	C0805C103K5RACTU	Kemet
14	1	C18	470 pF, 1000 V, Ceramic, COG, 1206	VJ1206A471JXGAT5Z	Vishay
15	1	CY1	2.2 nF, 250 VAC, Film, X1Y1	CD12-E2GA222MYNS	TDK
16	1	D1	400 V, 1 A, DIODE SUP FAST 1 A PWRDI 123	DFLU1400-7	Diodes, Inc.
17	1	D2	Diode Ultrafast, SW 600 V, 1 A, SMA	US1J-13-F	Diodes, Inc.
18	1	D3	Diode Ultrafast, SW, 200 V, 1 A, SMA	US1D-13-F	Diodes, Inc.
19	1	D4	75 V, 0.15 A, Switching, SOD-323	BAV16WS-7-F	Diodes, Inc.
20	1	D5	75 V, 0.15 A, Switching, SOD-323	BAV16WS-7-F	Diodes, Inc.
21	1	D6	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
22	1	D7	200 V, 8 A, Ultrafast Recovery, 25 ns, TO-220AC	BYW29-200G	ON Semi
23	1	F1	5 A, 250 V, Fast, Microfuse, Axial	0263005.MXL	Littlefuse
24	1	FL1	PCB Terminal Hole, #22 AWG	N/A	N/A
25	1	FL2	PCB Terminal Hole, #22 AWG	N/A	N/A
26	1	J1 / L	Wire, Blue, #20 AWG, 3”		Anixter
27	1	J2 / N	Wire, White, #20 AWG, 3”		Anixter
28	1	L1	220 μH, 0.68 A, 9 x 11.5 mm	SBC3-221-681	Tokin
29	1	L2	220 μH, 0.68 A, 9 x 11.5 mm	SBC3-221-681	Tokin
30	1	L3	8.8 mH, 0.7 mA, AC Filter T/H Common Mode Choke	SU10VFC-R07088	Kemet
31	1	Q1	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3904LT1G	On Semi
32	1	R1	12 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ123V	Panasonic
33	1	R2	47 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ473V	Panasonic
34	1	R3	510 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ514V	Panasonic
35	1	R4	2.00 MΩ, 1%, 1/4 W, Metal Film	RNF14FTD2M00	Stackpole
36	1	R5	3 MΩ, 1%, 1/4 W, Thick Film, 1206	KTR18EZPF3004	Rohm
37	1	R6	200 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ204V	Panasonic
38	1	R7	200 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ204V	Panasonic
39	1	R8	24.9 kΩ, 0.1%, 1/8 W, Thick Film, 0805	TNPW080524K9BEEA	Vishay
40	1	R9	5.9 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF5901V	Panasonic
41	1	R10	357 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF3573V	Panasonic
42	1	R11	10 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-10K	Yageo
43	1	R12	174 Ω, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1740V	Panasonic
44	1	R13	147 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1473V	Panasonic
45	1	R14	10 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-10K	Yageo
46	1	R15	10 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1002V	Panasonic
47	1	R16	1 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ102V	Panasonic

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48	1	R17	86.6 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF8662V	Panasonic
49	1	R18	10 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1002V	Panasonic
50	1	R19	10.0 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-10K0	Yageo
51	1	R20	10 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-10K	Yageo
52	1	R21	10 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-10K	Yageo
53	1	R22	10.0 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-10K0	Yageo
54	1	R27	47 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ470V	Panasonic
55	1	R28	820 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ824V	Panasonic
56	1	RV1	250 V, 21 J, 7 mm, RADIAL LA	V250LA2P	Littlefuse
57	1	T1	Bobbin, RM8, Vertical, 12 pins Transformer	RM8/12/1 SNX-R1771	Schwartzpunkt Santronics
58	1	TE1	Terminal, Eyelet, Tin Plated Brass, Zierick PN 190	190	Zierick
59	1	TE2	Terminal, Eyelet, Tin Plated Brass, Zierick PN 190	190	Zierick
60	1	TP1 / +24V	Wire, Red, #20 AWG, 3”		Anixter
61	1	TP2 / RTN	Wire, Black, #20 AWG, 3”		Anixter
62	1	U1	LYTSwitch-4, eSIP-7C	LYT4325E	Power Integrations
63	1	U2	Optocoupler, 35 V, CTR 300-600%, 4-DIP	LTV-817D	Liteon
64	1	U3	2.495 V Shunt Regulator IC, 2%, 0 to 70C, TO92	LM431ACZ	National Semi
65	1	U4	Optocoupler, 35 V, CTR 300-600%, 4-DIP	LTV-817D	Liteon
66	1	VR1	26 V, 5 mW, SOD-123	DDZ26-7	Diodes, Inc.
67	1	VR3	6.2 V, 5%, 150 mW, SSMINI-2	DZ2S062M0L	Panasonic

7 Inductor Specification

7.1 Electrical Diagram

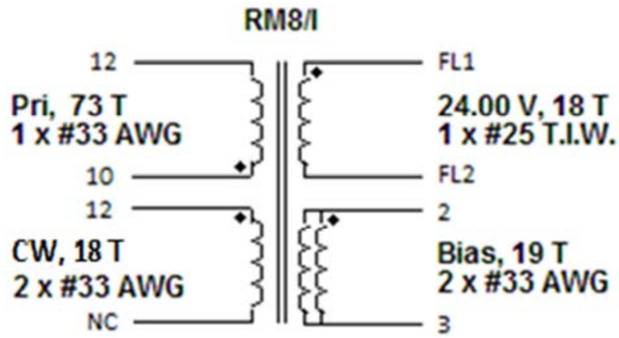

Figure 6 – Inductor Electrical Diagram.

Note:
Pri = Primary Winding
CW = Cancellation Winding
24.00 V = Main Output Winding
Bias = Bias Winding

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.	1043 μH
Tolerance	Tolerance of Primary Inductance	±10%
Primary Leakage Inductance	Measured between pin 10 to pin 12, with all other windings shorted.	30 μH Max.

7.3 Materials

Item	Description
[1]	Core: RM8, PC95 TDK.
[2]	Bobbin: RM8, Vertical, 12 pins (PI P/N: 25-00907-00).
[3]	Barrier Tape: Polyester film [1 mil (25 μm) base thickness], 8.60 mm wide.
[4]	Varnish.
[5]	Magnet Wire: #33 AWG, Solderable Double Coated.
[6]	Triple Insulated Wire: #25 AWG.

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7.4 Inductor Build Diagram

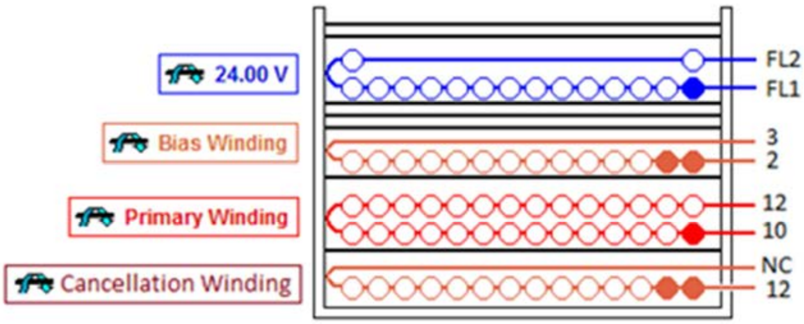

Figure 7 – Inductor Build Diagram.

7.5 Inductor Construction

Cancellation Winding	Start on pin 12, wind 18 turns (x2 filar) of AWG #33 in 1 layer(s) from right to left. Spread the winding evenly across entire bobbin. Finish this winding on pin(s) 12.
Insulation	Add 1 layer of tape, item [3], for insulation.
Primary Winding	Start on pin(s) 10 and wind 73 turns (x1 filar) of AWG #33 in 2 layer(s) from right to left. At the end of 1st layer, continue to wind the next layer from left to right. On the final layer, spread the winding evenly across entire bobbin. Finish this winding on pin(s) 12.
Insulation	Add 1 layer of tape, item [3], for insulation.
Bias Winding	Start on pin(s) 2 and wind 19 turns (x2 filar) of AWG #33. Wind in same rotational direction as primary winding. Spread the winding evenly across entire bobbin. Finish this winding on pin(s) 3.
Insulation	Add 3 layers of tape, item [3], for insulation
Secondary Winding	Start on FL1 (this is a fly lead) and wind 18 turns (x1 filar) of AWG #25 in 2 layer(s) from right to left. At the end of 1st layer, continue to wind the next layer from left to right. Spread the winding evenly across entire bobbin. Finish this winding on FL2 (this is a fly lead).
Insulation	Add 2 layers of tape, item [3], for insulation.
Finish	Grind core to achieve 1043 µH inductance.
Assemble	Assemble and secure core halves with 3 layers of tape.
Pins	Cut pins 1, 4, 5, 6, 7, 9, 11.
Finish	Dip the transformer assembly in varnish.

8 Inductor Design Spreadsheet

ACDC_LYTSwitch-4_HL_102113; Rev.1.1; Copyright Power Integrations 2013	**INPUT**	**INFO**	**OUTPUT**	**UNIT**	**LYTSwitch-4_HL_102113: Flyback Transformer Design Spreadsheet**
ENTER APPLICATION VARIABLES					
Dimming required	**NO**		**NO**		Select 'YES' option if dimming is required. Otherwise select 'NO'.
VACMIN	195.00		195	V	Minimum AC Input Voltage
VACMAX	265.00		265	V	Maximum AC input voltage
fL			50	Hz	AC Mains Frequency
VO	24.00		24	V	Typical output voltage of LED string at full load
VO_MAX	25.20		25.20	V	Maximum expected LED string Voltage.
VO_MIN	22.80		22.80	V	Minimum expected LED string Voltage.
V_OVP	26.00		26.00	V	Over-voltage protection setpoint
IO	1.04		1.04	A	Typical full load LED current
PO			25.0	W	Output Power
n	0.85		0.85		Estimated efficiency of operation
VB	25.00		25	V	Bias Voltage
ENTER LYTSwitch VARIABLES					
LYTSwitch	**LYT4225**		**LYT4225**		Selected LYTSwitch
Current Limit Mode	**FULL**		**FULL**		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN			1.41	A	Minimum current limit
ILIMITMAX			1.63	A	Maximum current limit
fS			132000	Hz	Switching Frequency
fSmin			124000	Hz	Minimum Switching Frequency
fSmax			140000	Hz	Maximum Switching Frequency
IV			80.6	uA	V pin current
RV	4.00		4	M-ohms	Upper V pin resistor
RV2			1000000000000	M-ohms	Lower V pin resistor
IFB	165.00		165.0	uA	FB pin current (85 uA < IFB < 210 uA)
RFB1			133.3	k-ohms	FB pin resistor
VDS	10.00		10	V	LYTSwitch on-state Drain to Source Voltage
VD	0.50		0.50	V	Output Winding Diode Forward Voltage Drop (0.5 V for Schottky and 0.8 V for PN diode)
VDB	0.70		0.70	V	Bias Winding Diode Forward Voltage Drop
Key Design Parameters					
KP	0.65		0.65		Ripple to Peak Current Ratio (For PF > 0.9, 0.4 < KP < 0.9)
LP			1043	uH	Primary Inductance
VOR	100.00		100	V	Reflected Output Voltage.
Expected IO (average)			1.02	A	Expected Average Output Current
KP_VNOM			0.62		Expected ripple current ratio at VACNOM
TON_MIN			1.72	us	Minimum on time at maximum AC input voltage
PCLAMP			0.20	W	Estimated dissipation in primary clamp
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**RM8/I**		**RM8/I**		Select Core Size
Custom Core					Enter Custom core part number (if applicable)
AE	0.63		0.63	cm^2	Core Effective Cross Sectional Area
LE	3.84		3.84	cm	Core Effective Path Length
AL	3000.00		3000	nH/T^2	Ungapped Core Effective Inductance
BW	8.60		8.6	mm	Bobbin Physical Winding Width
M	0.00		0	mm	Safety Margin Width (Half the Primary to

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					Secondary Creepage Distance)
L	2.00		2		Number of Primary Layers
NS	18.00		18		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			276	V	Peak input voltage at VACMIN
VMAX			375	V	Peak input voltage at VACMAX
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.27		Minimum duty cycle at peak of VACMIN
IAVG			0.14	A	Average Primary Current
IP			0.91	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
IRMS			0.26	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			1043	uH	Primary Inductance
LP_TOL	10.00		10		Tolerance of primary inductance
NP			73		Primary Winding Number of Turns
NB			19		Bias Winding Number of Turns
ALG			193	nH/T^2	Gapped Core Effective Inductance
BM			2030	Gauss	Maximum Flux Density at PO, VMIN (BM<3100)
BP			3672	Gauss	Peak Flux Density (BP<3700)
BAC			660	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1455		Relative Permeability of Ungapped Core
LG			0.38	mm	Gap Length (Lg > 0.1 mm)
BWE			17.2	mm	Effective Bobbin Width
OD			0.23	mm	Maximum Primary Wire Diameter including insulation
INS			0.05	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.19	mm	Bare conductor diameter
AWG			33	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			51	Cmils	Bare conductor effective area in circular mils
CMA			194	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 600)
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)					
Lumped parameters					
ISP			3.70	A	Peak Secondary Current
ISRMS			1.59	A	Secondary RMS Current
IRIPPLE			1.23	A	Output Capacitor RMS Ripple Current (based on Expected IO)
CMS			319	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			25	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.46	mm	Secondary Minimum Bare Conductor Diameter
ODS			0.48	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
VOLTAGE STRESS PARAMETERS					
VDRAIN			573	V	Estimated Maximum Drain Voltage assuming maximum LED string voltage (Includes Effect of Leakage Inductance)
PIVS			118	V	Output Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike)
PIVB			123	V	Bias Rectifier Maximum Peak Inverse Voltage

					(calculated at VOVP, excludes leakage inductance spike)
FINE TUNING (Enter measured values from prototype)					
V pin Resistor Fine Tuning					
RV1			4.00	M-ohms	Upper V Pin Resistor Value
RV2			1000000000000	M-ohms	Lower V Pin Resistor Value
VAC1			115.0	V	Test Input Voltage Condition1
VAC2			230.0	V	Test Input Voltage Condition2
IO_VAC1			1.04	A	Measured Output Current at VAC1
IO_VAC2			1.04	A	Measured Output Current at VAC2
RV1 (new)			4.00	M-ohms	New RV1
RV2 (new)			20911.63	M-ohms	New RV2
V_OV			319.6	V	Typical AC input voltage at which OV shutdown will be triggered
V_UV			66.3	V	Typical AC input voltage beyond which power supply can startup
FB pin resistor Fine Tuning					
RFB1	133.00		133	k-ohms	Upper FB Pin Resistor Value
RFB2	200.00		200	k-ohms	Lower FB Pin Resistor Value
VB1	30.00		30.0	V	Test Bias Voltage Condition1
VB2	30.00		30.0	V	Test Bias Voltage Condition2
IO1	1.04		1.04	A	Measured Output Current at Vb1
IO2	0.98		0.98	A	Measured Output Current at Vb2
RFB1 (new)			#DIV/0!	k-ohms	New RFB1
RFB2(new)			0.0000	k-ohms	New RFB2
Input Current Harmonic Analysis					
Harmonic			% of Fund	Limit(%)	
1st Harmonic			120.76	N/A	Fundamental (mA)
3rd Harmonic			19.81	27.00	PASS. Percentage of 3rd Harmonic is lower than the limit
5th Harmonic			8.3	10.00	PASS. Percentage of 5th Harmonic is lower than the limit
7th Harmonic			4.7	7.00	PASS. Percentage of 7th Harmonic is lower than the limit
9th Harmonic			3.17	5.00	PASS. Percentage of 9th Harmonic is lower than the limit
11th Harmonic			2.39	3.00	PASS. Percentage of 11th Harmonic is lower than the limit
13th Harmonic			1.89	3.00	PASS. Percentage of 13th Harmonic is lower than the limit
15th Harmonic			1.52	3.00	PASS. Percentage of 15th Harmonic is lower than the limit
THD			22.0	%	Estimated total Harmonic Distortion (THD)

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9 Heat Sink Assemblies

9.1 eSIP Heat Sink Assembly

9.1.1 eSIP Heat Sink Fabrication Drawing

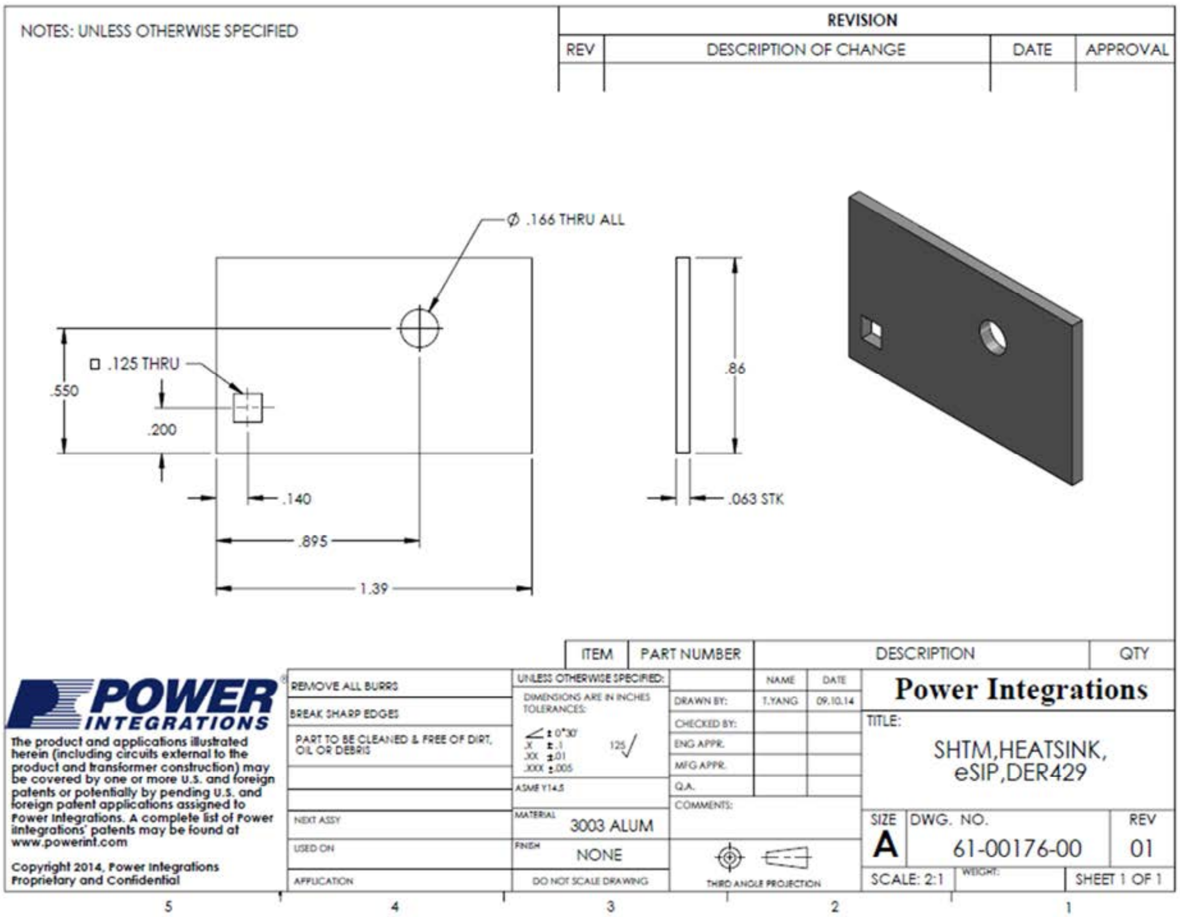

Figure 8 – eSIP Heat Sink Fabrication Drawing.

9.1.2 eSIP Heat Sink Assembly Drawing

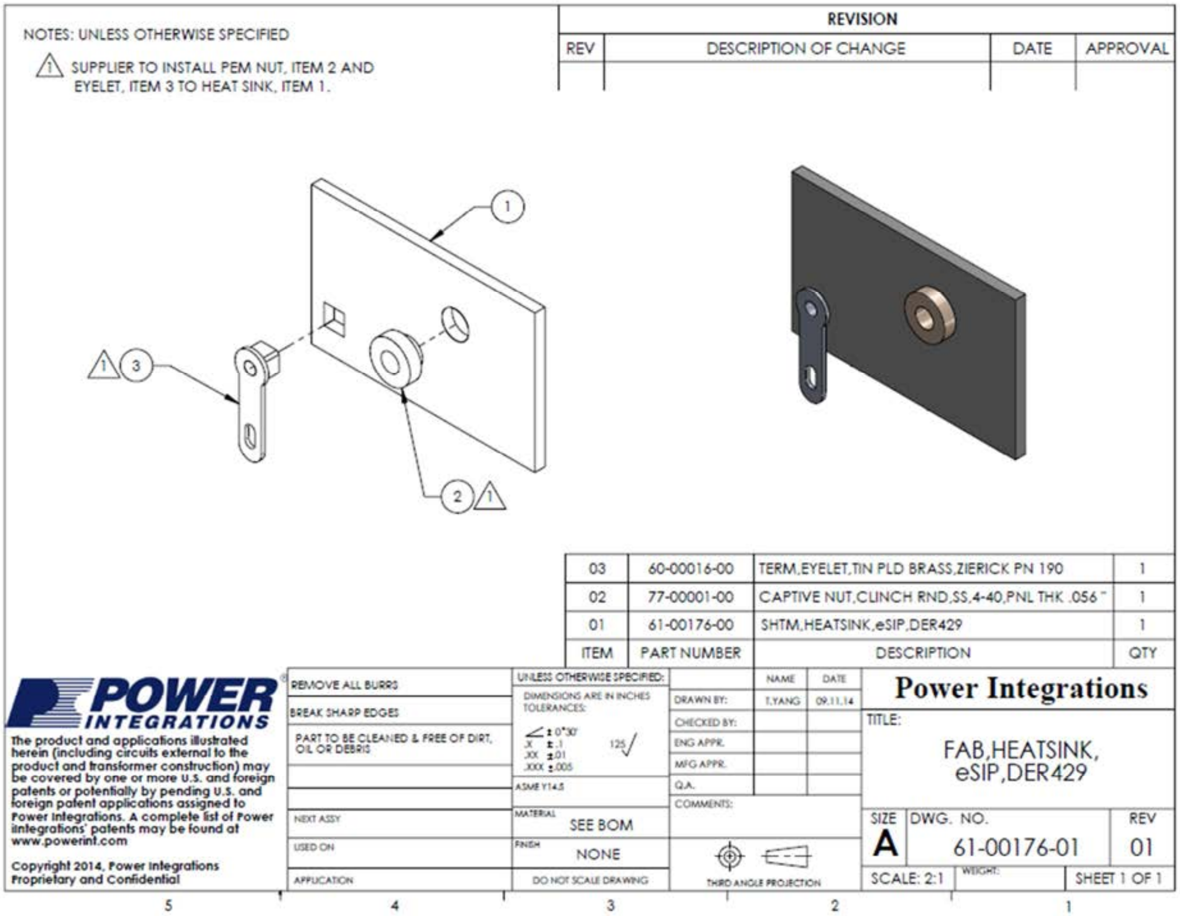

Figure 9 – eSIP Heat Sink Assembly Drawing.

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9.1.3 eSIP and Heat Sink Assembly Drawing

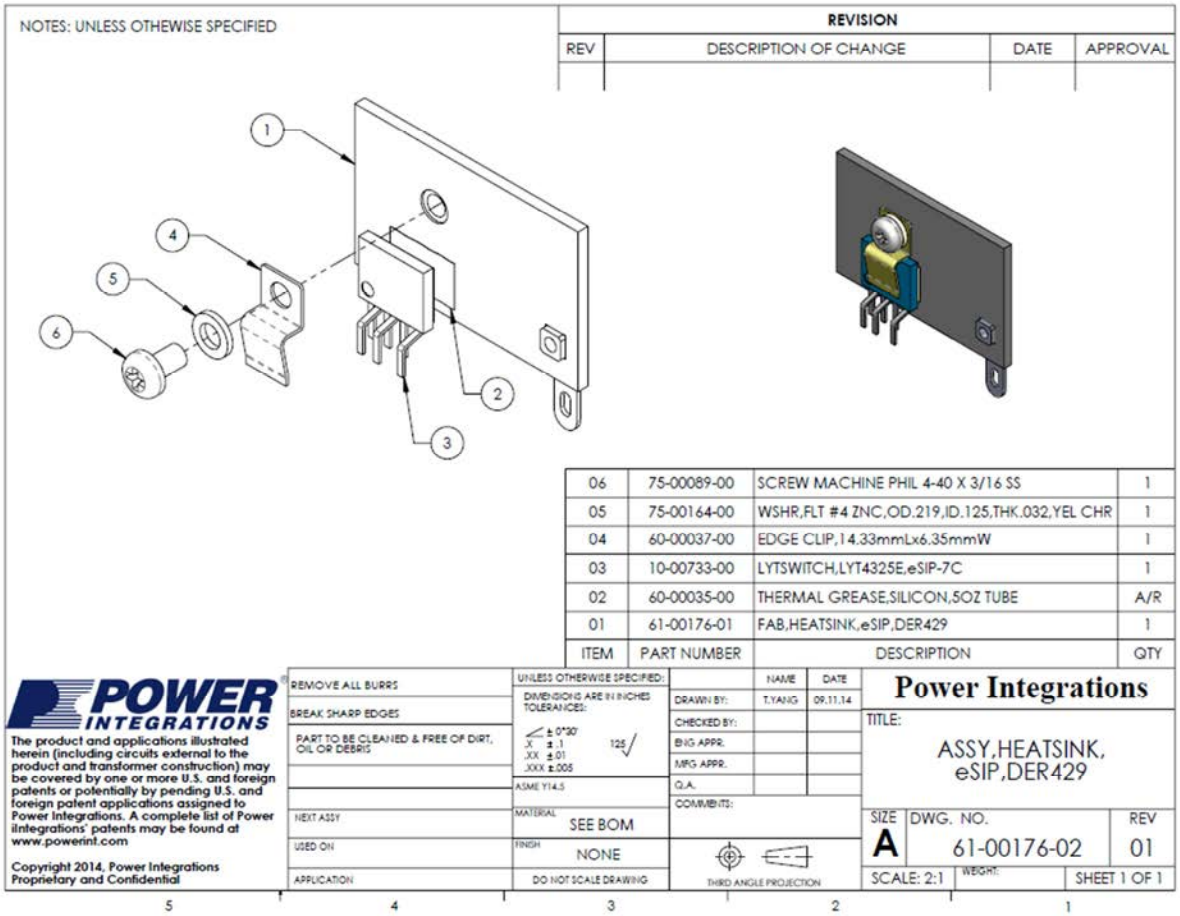

Figure 10 – eSIP and Heat Sink Assembly Drawing.

9.2 Diode Heat Sink Assembly

9.2.1 Diode Heat Sink Fabrication Drawing

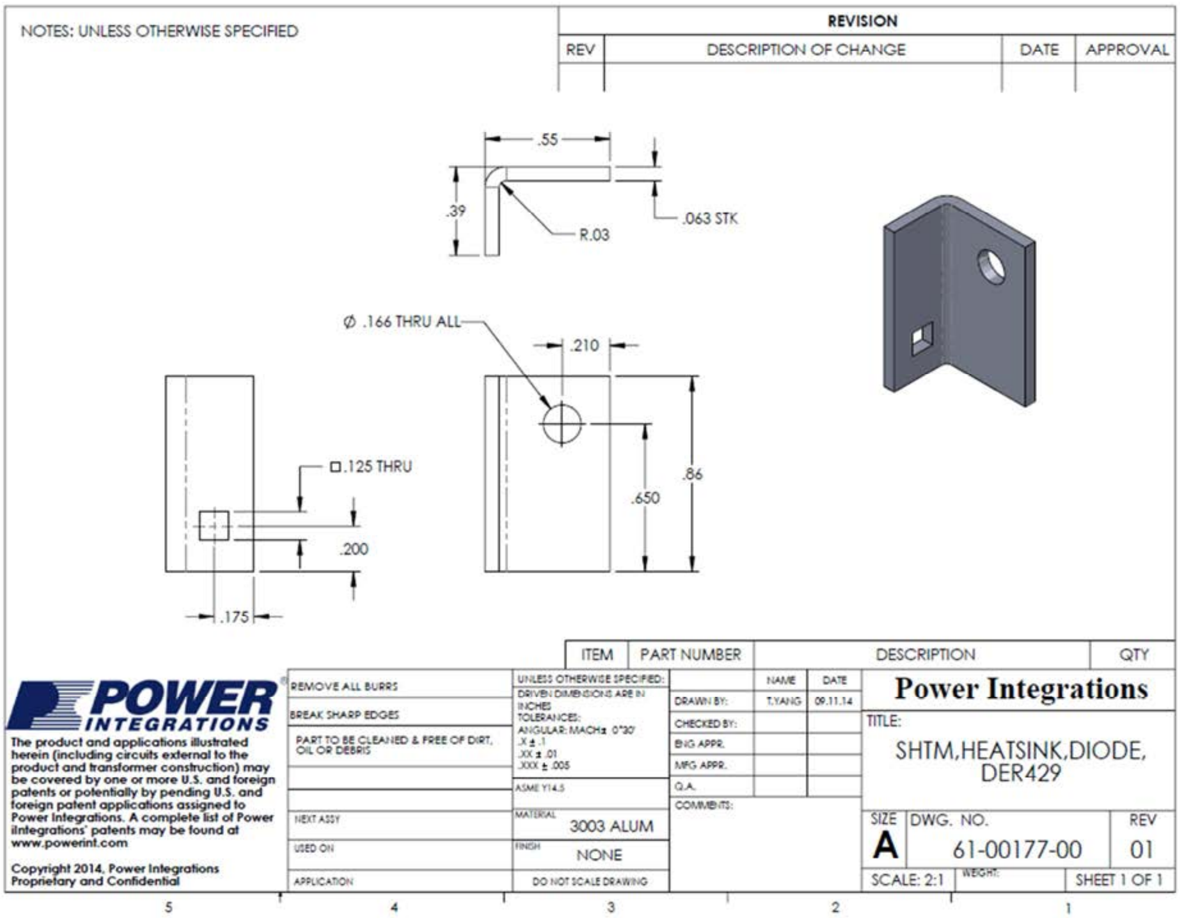

Figure 11 – Diode Heat Sink Fabrication Drawing.

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9.2.2 Diode Heat Sink Assembly Drawing

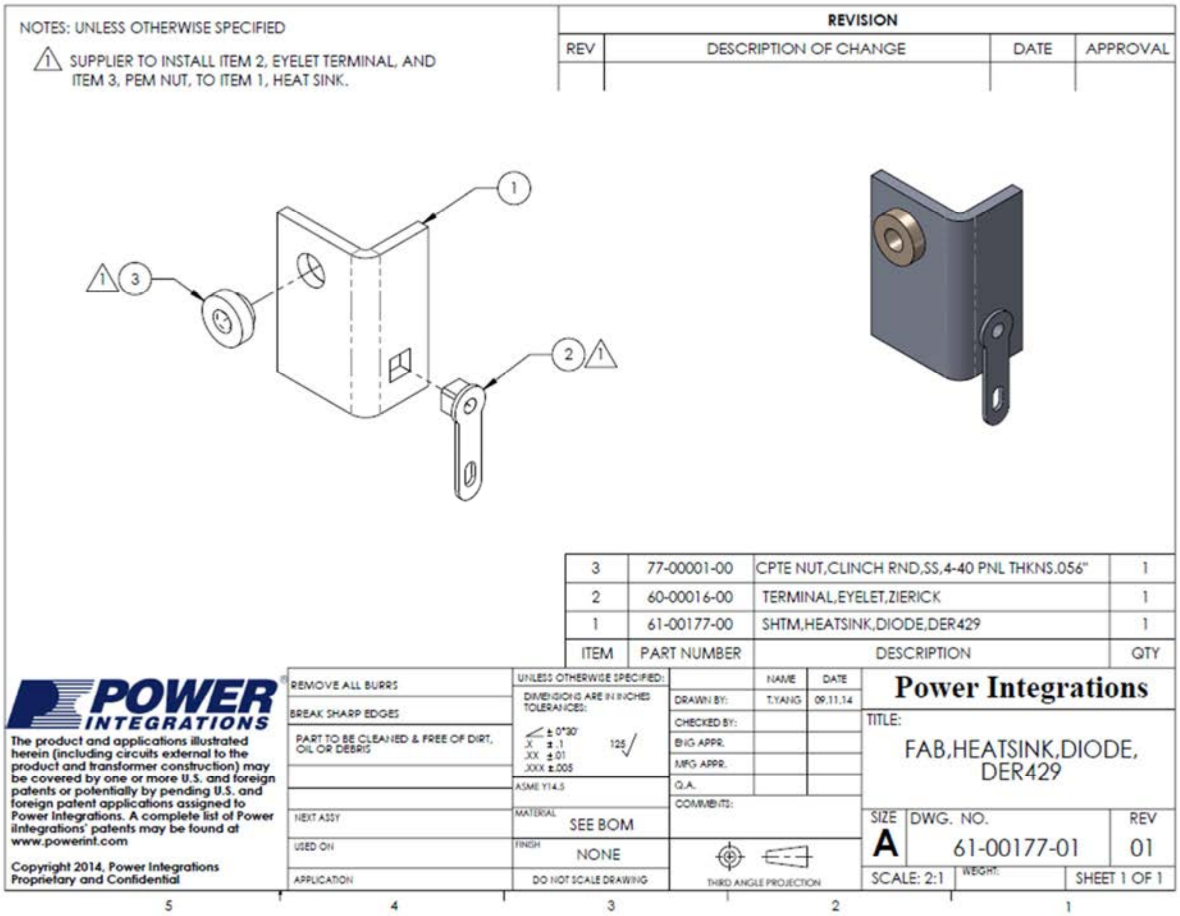
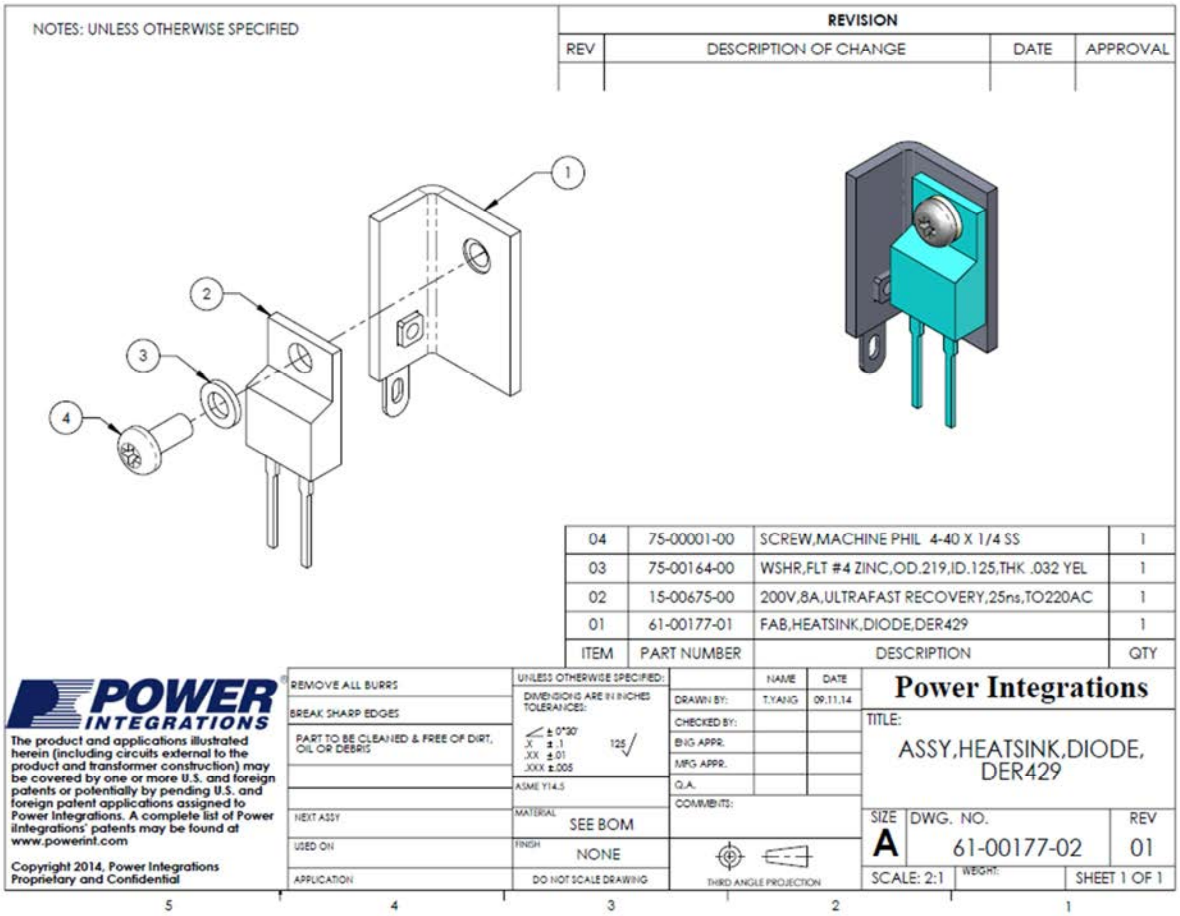


Figure 12 – Diode Heat Sink Assembly Drawing.

9.2.3 Diode and Heat Sink Assembly Drawing



ITEM	PART NUMBER	DESCRIPTION	QTY
04	75-00001-00	SCREW,MACHINE PHIL 4-40 X 1/4 SS	1
03	75-00164-00	WSHR,FLT #4 ZINC,OD.219,ID.125,THK .032 YEL	1
02	15-00675-00	200V,8A,ULTRAFAST RECOVERY,25ns,TO220AC	1
01	61-00177-01	FAB,HEATSINK,DIODE,DER429	1

Figure 13 – Diode and Heat Sink Assembly Drawing.

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10 Performance Data

All measurements were performed at room temperature. Refer to the table below for the complete set of test data and graphs.

10.1 Efficiency at Different Line Condition Using 24 V LED String (Full Load)

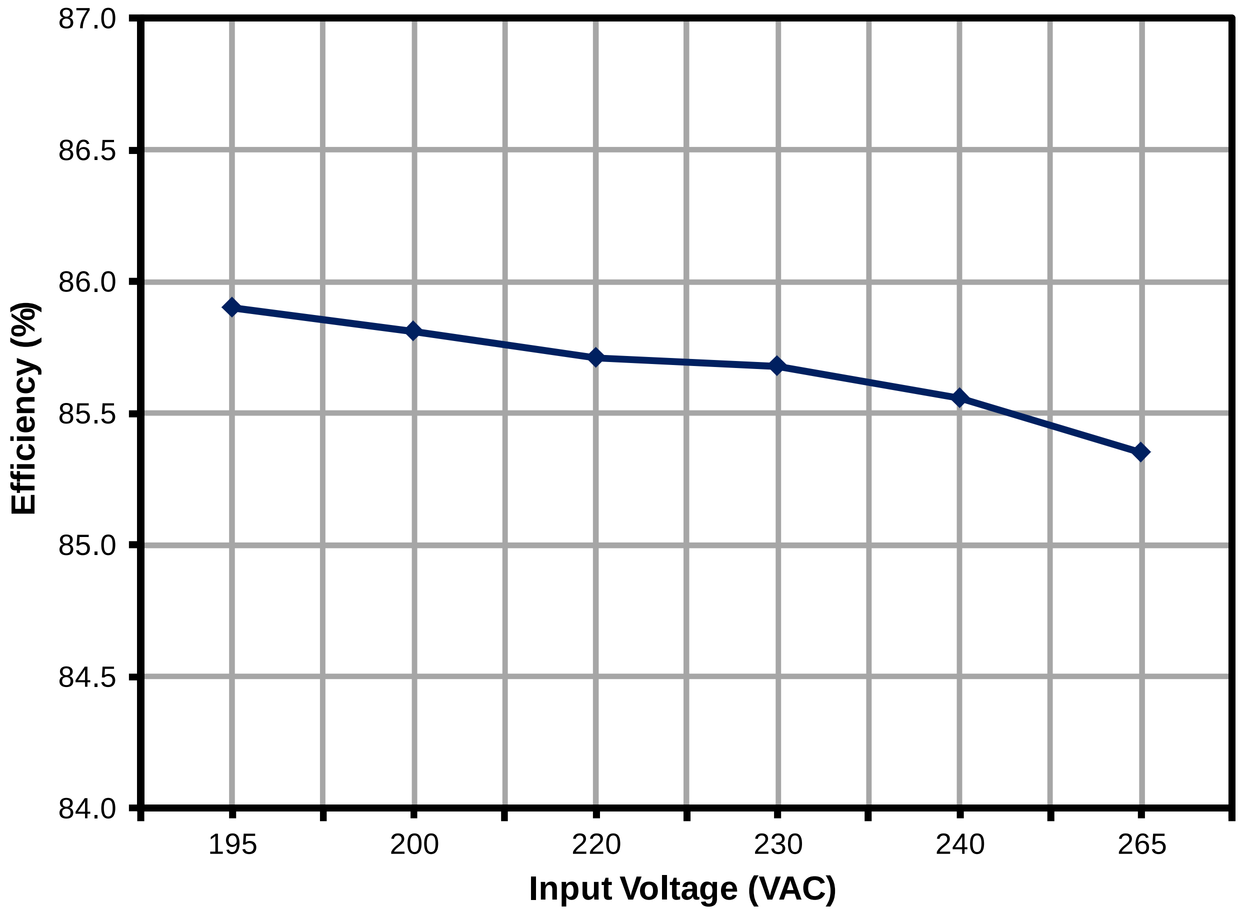

Figure 14 – Efficiency vs. Input Voltage at Using 24 V LED String (Full Load).

Input		Input Measurement					Load Measurement			
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Effeciency (%)
195	50	195.0	139.6	26.3	0.97	20.4	23.1	0.96	22.6	85.9
200	50	200.0	135.3	26.2	0.97	20.2	23.1	0.96	22.4	85.8
220	50	220.0	121.5	25.7	0.96	19.5	23.0	0.94	22.0	85.7
230	50	230.0	116.6	25.7	0.96	19.4	23.0	0.94	22.0	85.7
240	50	240.0	111.5	25.5	0.95	20.1	23.0	0.94	21.8	85.6
265	50	265.1	102.2	25.4	0.94	21.5	22.9	0.93	21.7	85.4

10.2 Efficiency at Different Load Percentage and Line Condition Using E-Load

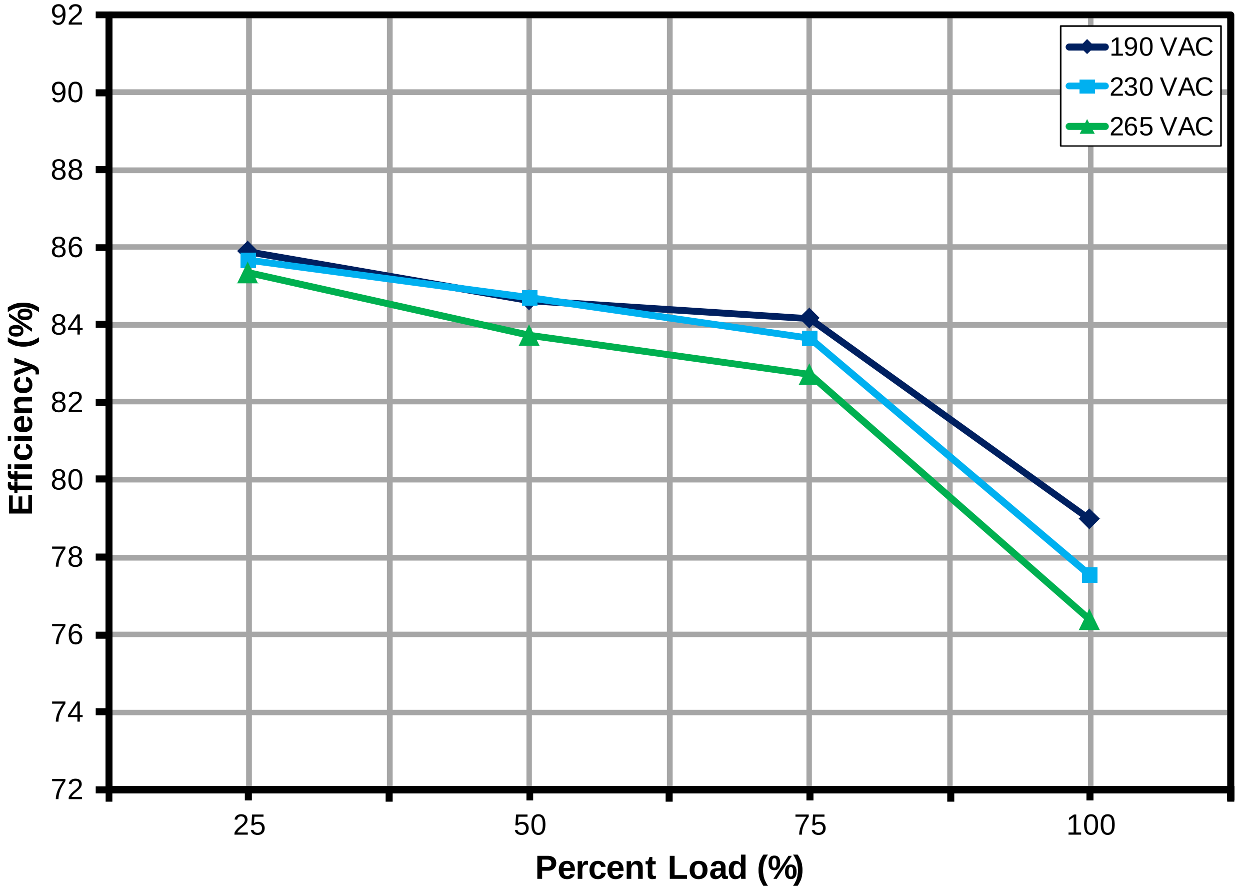

Figure 15 – Efficiency vs. Load Percentage at Different Line Voltage.

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10.2.1 100% Load

VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	V_{OUT} (VDC)	I_{OUT} (ADC)	P_{OUT} (W)	Efficiency (%)
195	50	194.98	139.59	26.32	0.97	23.07	0.96	22.61	85.9
230	50	230.02	116.60	25.69	0.96	22.99	0.94	22.01	85.7
265	50	265.07	102.15	25.40	0.94	22.94	0.93	21.68	85.4

10.2.2 75% Load

VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	V_{OUT} (VDC)	I_{OUT} (ADC)	P_{OUT} (W)	Efficiency (%)
195	50	194.98	0.12	22.03	0.97	23.89	0.78	18.64	84.6
230	50	230.02	0.10	22.11	0.95	24.00	0.78	18.72	84.7
265	63	264.07	0.09	22.26	0.90	23.89	0.78	18.64	83.7

10.2.3 50% Load

VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	V_{OUT} (VDC)	I_{OUT} (ADC)	P_{OUT} (W)	Efficiency (%)
195	50	194.99	0.08	14.83	0.94	24.04	0.52	12.48	84.2
230	50	230.02	0.07	14.91	0.91	24.02	0.52	12.47	83.7
265	63	264.08	0.07	15.01	0.84	23.90	0.52	12.41	82.7

10.2.4 25% Load

VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	V_{OUT} (VDC)	I_{OUT} (ADC)	P_{OUT} (W)	Efficiency (%)
195	50	195.00	0.04	7.52	0.88	23.83	0.25	5.94	79.0
230	50	230.03	0.04	7.67	0.82	23.86	0.25	5.95	77.5
265	63	264.08	0.04	7.79	0.74	23.88	0.25	5.95	76.4

10.3 Average Efficiency at 230 VAC

Load Percentage (%)	Efficiency (%)
100	85.7
75	84.7
50	83.7
25	77.5
AVERAGE EFFICIENCY	82.9

10.4 Current Regulation at Different Line Voltage Using a 24 V LED String

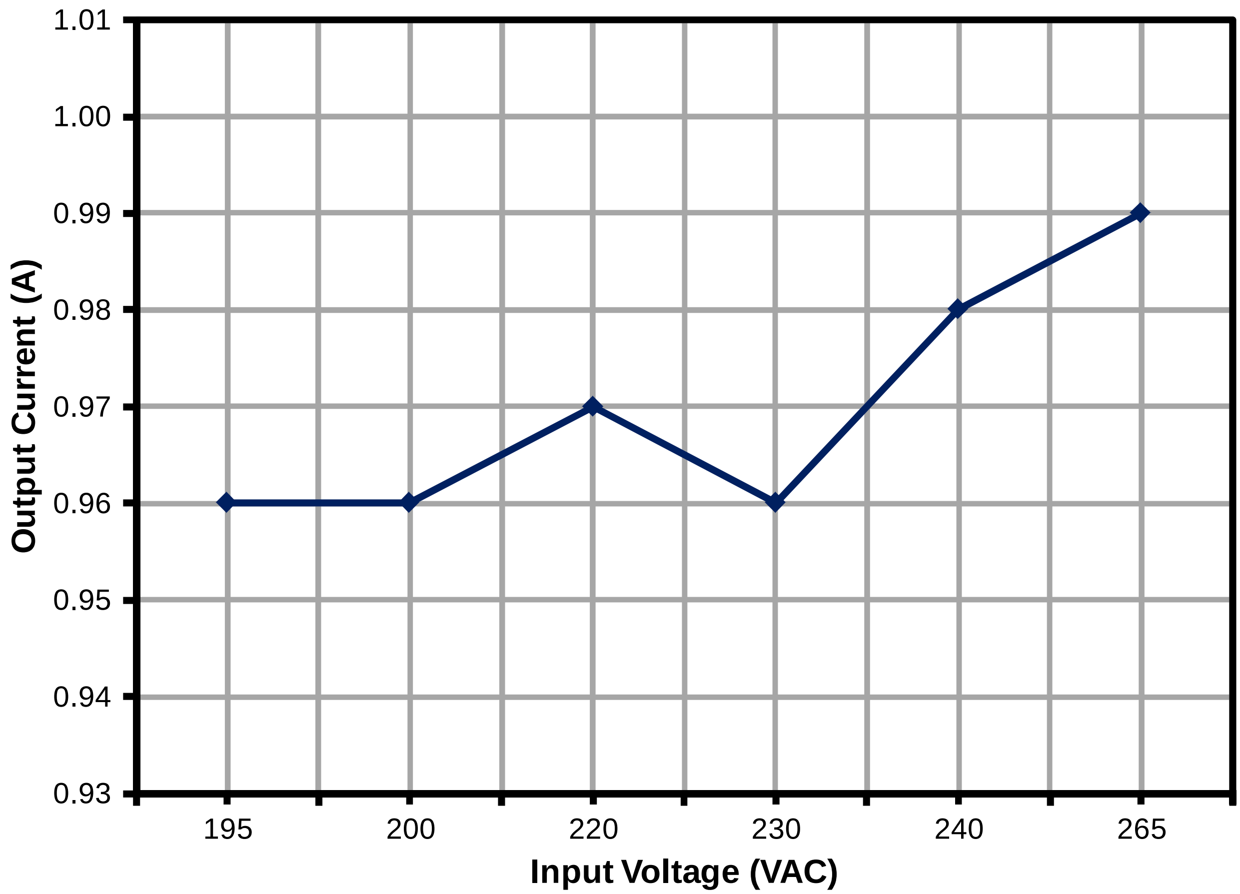

Figure 16 – Current Regulation vs. Line using 24V LED string (Full Load).

Input		Input Measurement					Load Measurement			
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency (%)
195	50	194.98	139.59	26.32	0.97	20.39	23.07	0.96	22.61	85.9
200	50	200.03	135.31	26.15	0.97	20.16	23.05	0.96	22.44	85.8
220	50	219.92	125.53	26.48	0.96	20.02	22.96	0.97	22.65	85.5
230	50	229.95	119.57	26.27	0.96	20.02	22.98	0.96	22.45	85.5
240	50	239.98	117.12	26.81	0.95	19.49	22.96	0.98	22.90	85.4
265	50	265.01	108.80	27.17	0.94	20.44	22.97	0.99	23.14	85.2

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10.5 Constant Voltage / Constant Current Response at Different Line Voltage

10.5.1 Constant Voltage / Constant Current Response at 195 VAC

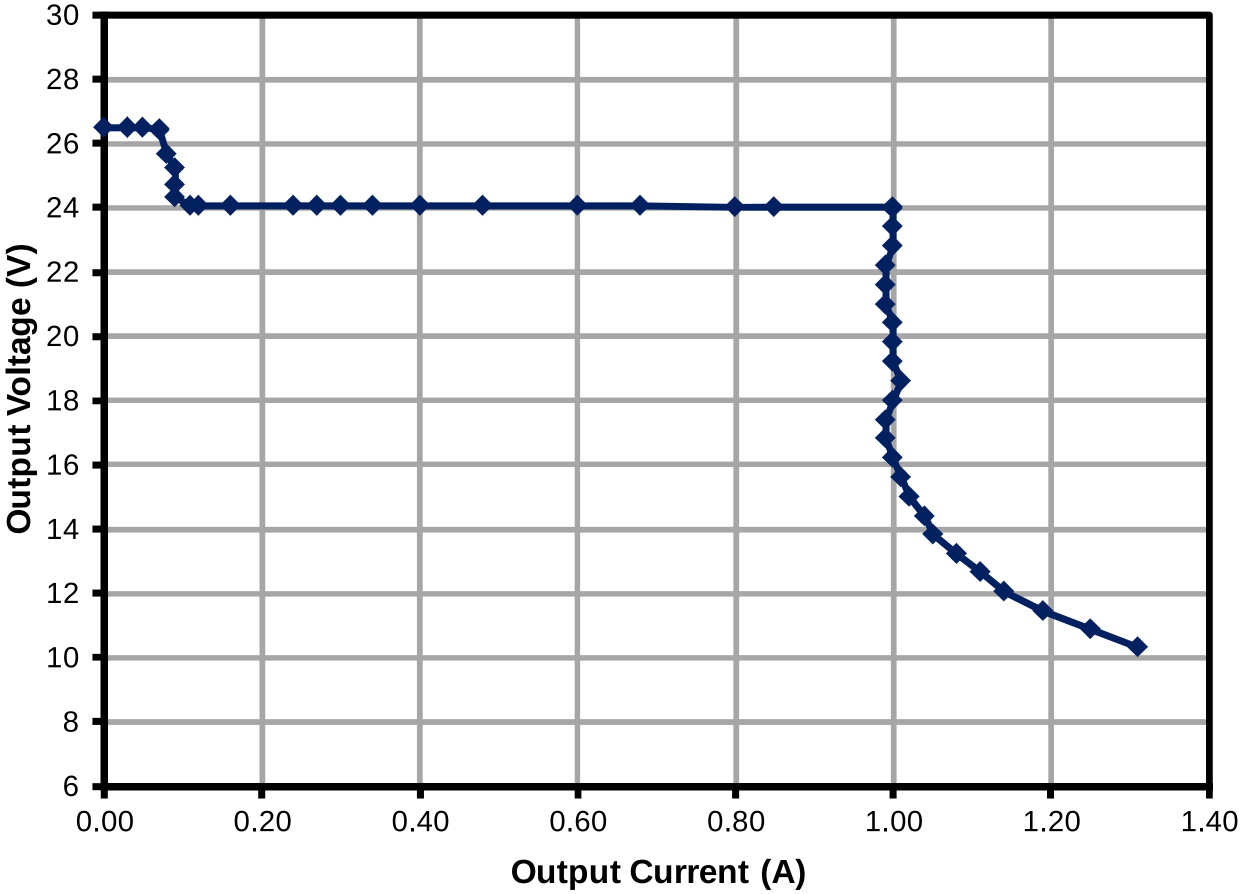

Figure 17 – CV/CC Graph at 195 VAC Input.

10.5.2 Data

Input Voltage V_{IN} (V_{RMS})	Load Resistance R (Ω)	Measured Output Voltage V_{OUT} (V)	Measured Output Current I_{OUT} (A)
195	NO LOAD	26.48	0.00
195	1026.78	26.49	0.03
195	973.79	26.49	0.03
195	919.97	26.50	0.03
195	815.35	26.50	0.03
195	786.78	26.49	0.03
195	500.43	26.49	0.05
195	404.34	26.45	0.07
195	354.13	26.38	0.07
195	303.11	25.67	0.08
195	283.37	25.22	0.09
195	273.15	24.72	0.09
195	262.73	24.33	0.09
195	215.02	24.08	0.11
195	201.47	24.05	0.12
195	151.26	24.05	0.16
195	101.05	24.05	0.24
195	90.41	24.05	0.27
195	80.43	24.05	0.30
195	70.31	24.05	0.34
195	60.42	24.05	0.40
195	50.30	24.04	0.48
195	40.26	24.04	0.60
195	35.25	24.04	0.68
195	30.20	24.03	0.80
195	28.20	24.03	0.85
195	24.02	24.02	1.00
195	23.90	23.99	1.00
195	23.39	23.39	1.00
195	22.89	22.79	1.00
195	22.34	22.19	0.99
195	21.74	21.59	0.99
195	21.13	21.00	0.99
195	20.49	20.40	1.00
195	19.85	19.80	1.00
195	19.16	19.21	1.00
195	18.44	18.60	1.01
195	18.06	18.00	1.00
195	17.61	17.40	0.99
195	16.89	16.80	0.99
195	16.16	16.20	1.00
195	15.42	15.60	1.01

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195	14.67	15.01	1.02
195	13.89	14.41	1.04
195	13.10	13.82	1.05
195	12.30	13.23	1.08
195	11.43	12.64	1.11
195	10.54	12.05	1.14
195	9.64	11.46	1.19
195	8.74	10.88	1.25
195	7.84	10.30	1.31

10.5.3 Constant Voltage / Constant Current Response at 230 VAC

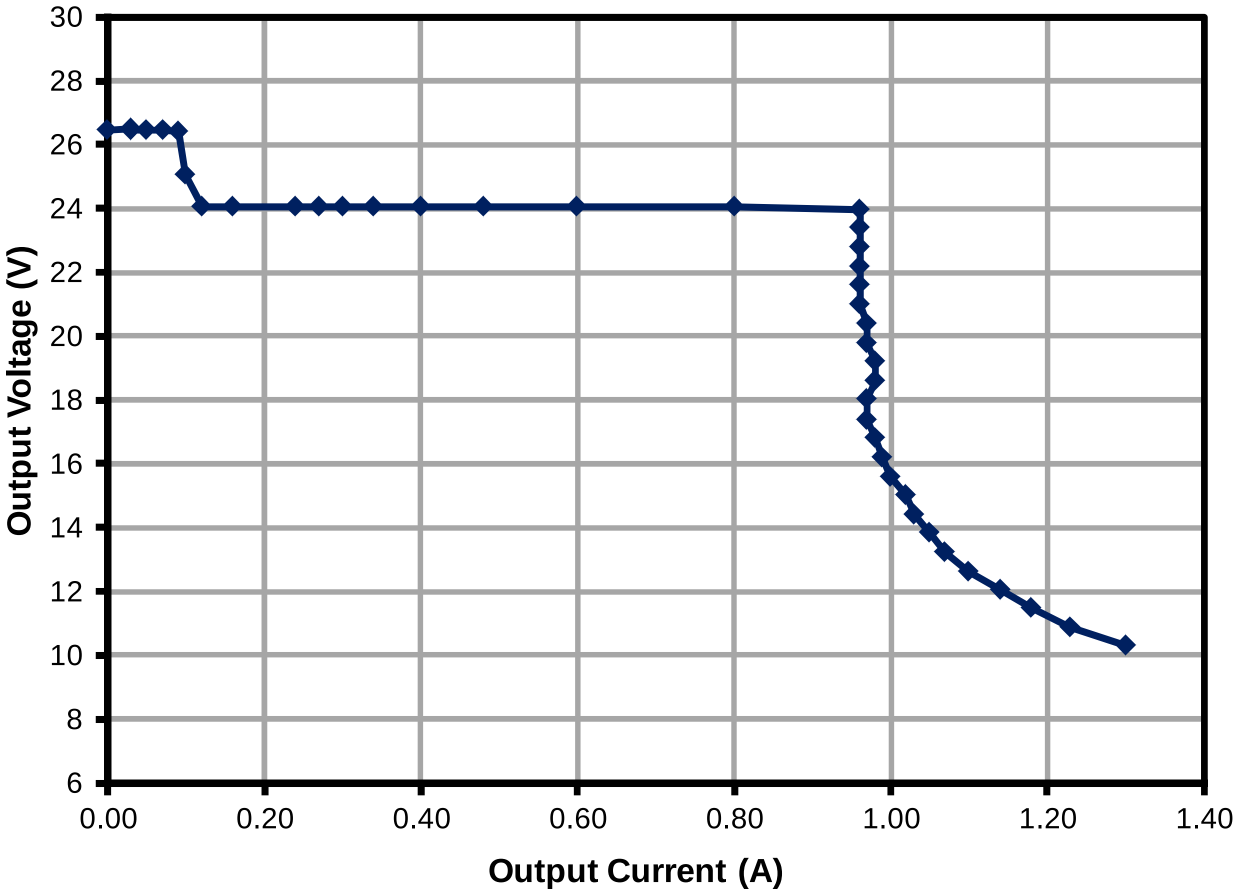

Figure 18 – CV/CC Graph at 230 VAC Input.

10.5.4 Data

Input Voltage V_{IN} (V_{RMS})	**Load Resistance R (Ω)**	**Measured Output Voltage V_{OUT} (V)**	**Measured Output Current I_{OUT} (A)**
230	NO LOAD	26.47	0.00
230	1026.78	26.48	0.03
230	973.79	26.48	0.03
230	919.97	26.47	0.03
230	815.35	26.47	0.03
230	786.78	26.47	0.03
230	500.43	26.46	0.05
230	404.34	26.47	0.07
230	303.11	26.43	0.09
230	215.02	25.05	0.10
230	201.47	24.06	0.12
230	151.26	24.06	0.16
230	101.05	24.05	0.24
230	90.41	24.05	0.27
230	80.43	24.05	0.30
230	70.31	24.05	0.34
230	60.42	24.05	0.40
230	50.30	24.05	0.48
230	40.26	24.04	0.60
230	30.20	24.04	0.80
230	23.90	23.97	0.96
230	22.85	23.38	0.96
230	22.49	22.79	0.96
230	22.43	22.19	0.96
230	21.25	21.59	0.96
230	20.82	21.00	0.96
230	20.36	20.39	0.97
230	20.05	19.79	0.97
230	19.95	19.20	0.98
230	19.66	18.60	0.98
230	19.13	18.01	0.97
230	18.69	17.39	0.97
230	18.15	16.79	0.98
230	17.64	16.20	0.99
230	17.08	15.60	1.00
230	16.53	15.01	1.02
230	15.97	14.41	1.03
230	15.39	13.82	1.05
230	14.87	13.22	1.07
230	14.32	12.63	1.10
230	13.78	12.05	1.14
230	13.23	11.46	1.18

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230	12.66	10.87	1.23
230	12.12	10.29	1.30

10.5.5 Constant Voltage / Constant Current Response at 265 VAC

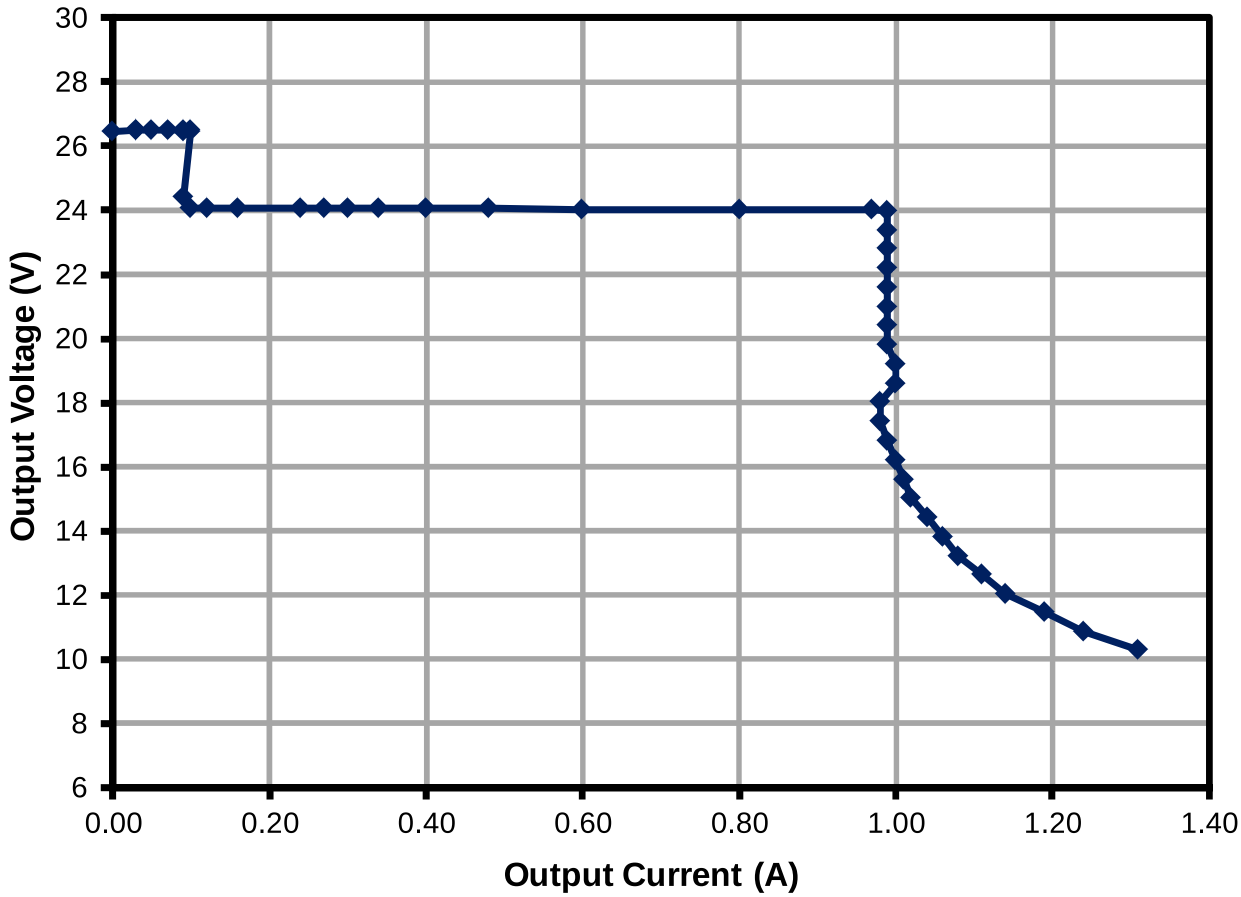

Figure 19 – CV/CC Graph at 265 VAC Input.

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10.5.6 Data

Input Voltage V_{IN} (V_{RMS})	Load Resistance R (Ω)	Measured Output Voltage V_{OUT} (V)	Measured Output Current I_{OUT} (A)
265	NO LOAD	26.46	0.00
265	1026.71	26.49	0.03
265	980.93	26.49	0.03
265	922.06	26.49	0.03
265	827.72	26.49	0.03
265	778.91	26.48	0.03
265	507.24	26.48	0.05
265	404.89	26.48	0.07
265	303.30	26.48	0.09
265	284.41	26.45	0.09
265	272.88	26.47	0.10
265	267.97	26.48	0.10
265	265.72	26.47	0.10
265	262.63	24.43	0.09
265	253.23	24.06	0.10
265	202.14	24.06	0.12
265	151.28	24.05	0.16
265	101.06	24.05	0.24
265	90.77	24.05	0.27
265	80.44	24.05	0.30
265	70.74	24.05	0.34
265	60.42	24.05	0.40
265	50.31	24.05	0.48
265	40.27	24.04	0.60
265	30.23	24.03	0.80
265	24.74	24.02	0.97
265	24.28	23.98	0.99
265	23.70	23.39	0.99
265	23.11	22.80	0.99
265	22.49	22.19	0.99
265	21.86	21.59	0.99
265	21.26	21.00	0.99
265	20.65	20.40	0.99
265	19.94	19.80	0.99
265	19.21	19.20	1.00
265	18.64	18.59	1.00
265	18.39	18.01	0.98
265	17.77	17.40	0.98
265	17.01	16.80	0.99
265	16.24	16.20	1.00
265	15.47	15.60	1.01
265	14.68	15.01	1.02

265	13.89	14.41	1.04
265	13.08	13.82	1.06
265	12.28	13.22	1.08
265	11.43	12.64	1.11
265	10.55	12.05	1.14
265	9.66	11.46	1.19
265	8.75	10.88	1.24
265	7.88	10.29	1.31

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10.6 Current Regulation at Different Line Voltage and Different LED String Voltages

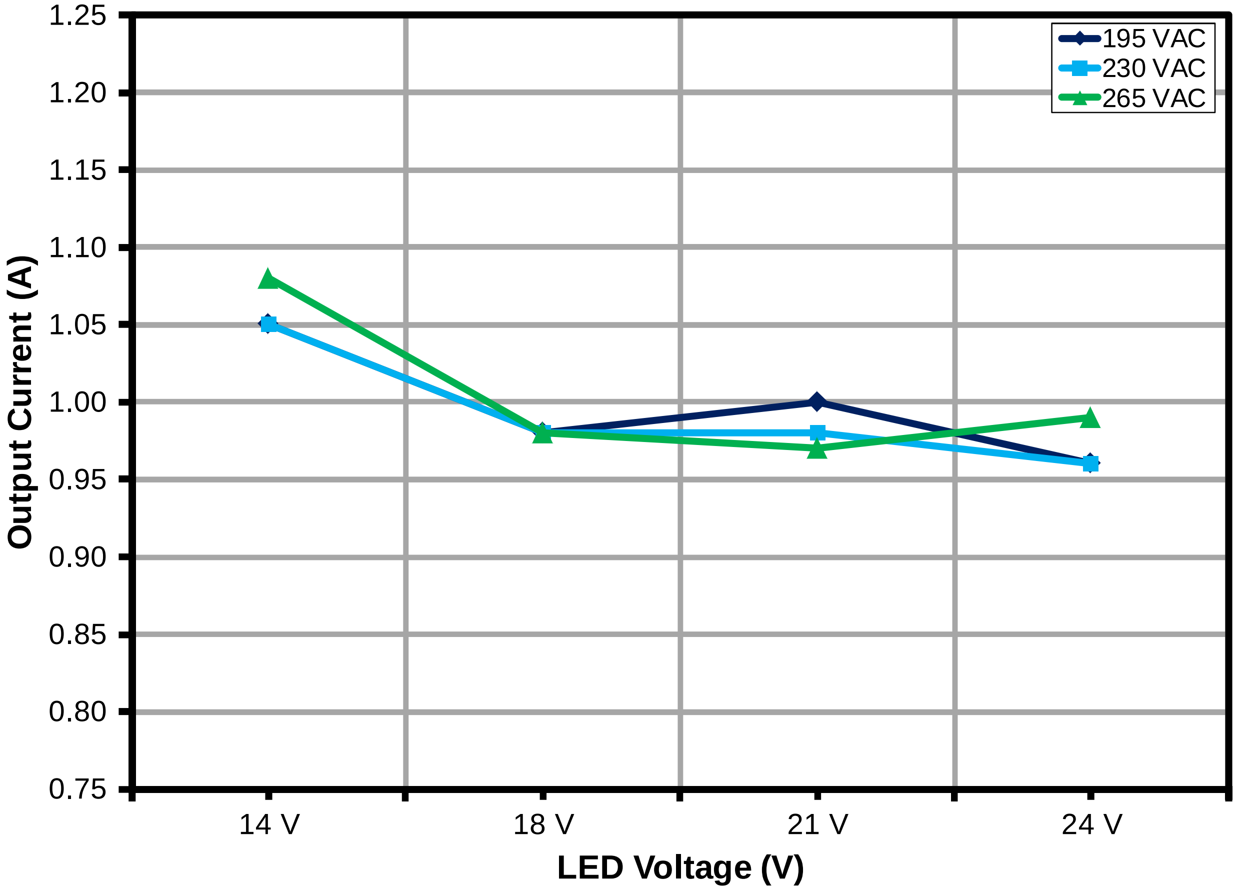

Figure 20 – Output Current vs. LED Voltage at Different Line Condition.

10.6.1 24 V LED

VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency (%)
195	50	194.98	139.59	26.32	0.97	20.39	23.07	0.96	22.61	85.9
230	50	229.95	119.57	26.27	0.96	20.02	22.98	0.96	22.45	85.5
265	50	265.01	108.80	27.17	0.94	20.44	22.97	0.99	23.14	85.2

10.6.2 21 V LED

VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency (%)
195	50	194.98	127.34	24.03	0.97	18.84	20.14	1.00	20.53	85.4
230	50	230.01	107.41	23.60	0.96	18.82	20.08	0.98	20.11	85.2
265	50	265.07	94.13	23.26	0.93	20.87	20.05	0.97	19.72	84.8

10.6.3 18 V LED

VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency (%)
195	50	194.98	108.97	20.43	0.96	19.64	17.21	0.98	17.27	84.5
230	50	230.02	93.29	20.29	0.95	19.54	17.18	0.98	17.08	84.2
265	50	265.08	83.98	20.50	0.92	20.75	17.18	0.98	17.15	83.7

10.6.4 14 V LED

VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency (%)
195	50	194.99	100.19	18.71	0.96	19.83	14.42	1.05	15.57	83.2
230	50	230.02	86.40	18.69	0.94	19.41	14.40	1.05	15.47	82.8
265	50	265.08	79.35	19.29	0.92	19.61	14.41	1.08	15.85	82.2

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10.7 Output Voltage Regulation Under Different Load and Line Conditions

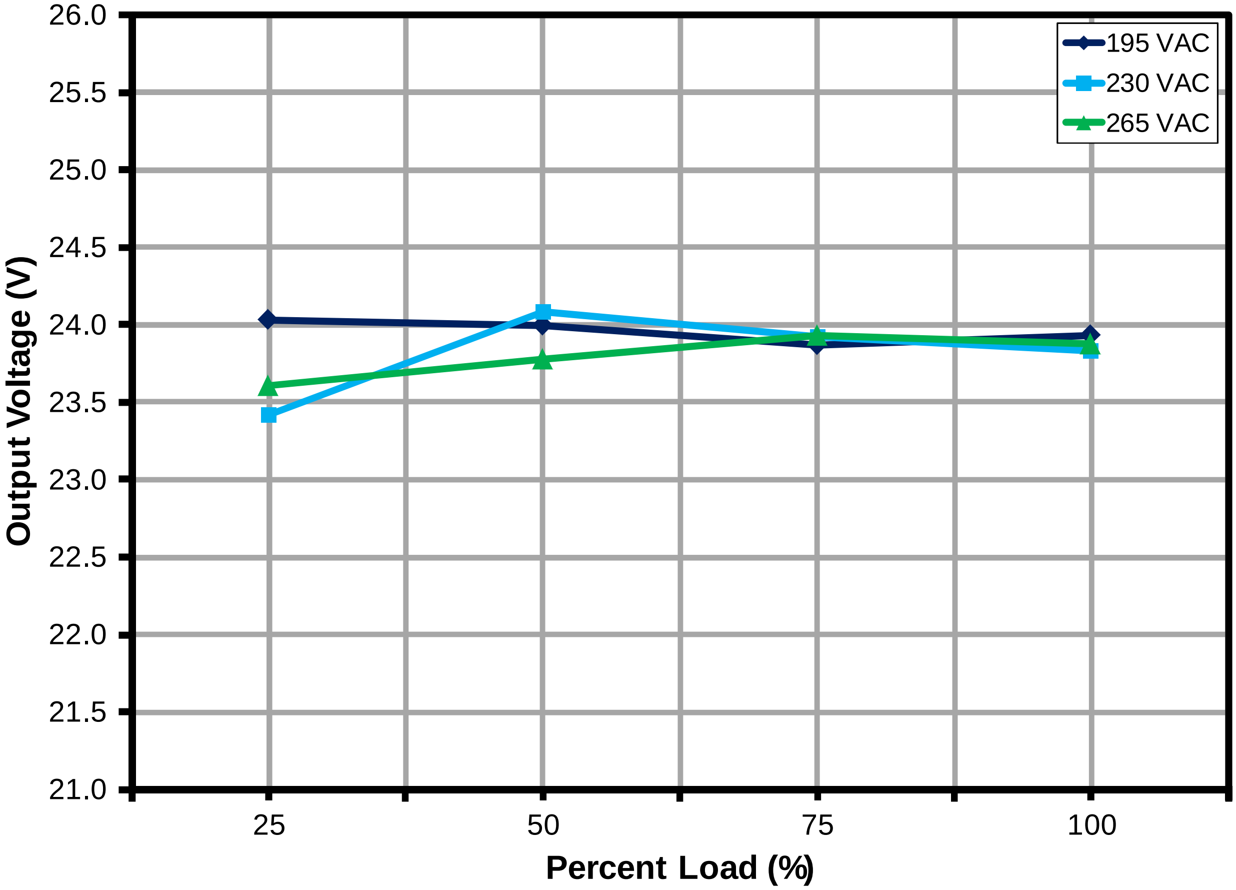

Figure 21 – Graph of Output Voltage vs. Load (25%, 50%, 75%, 100%) at Different Line Condition (195 VAC, 230 VAC, 265 VAC).

10.7.1 Output Voltage Regulation at 100% Load

Input		Input Measurement				Output Measurement
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	V_{OUT} (V_{DC})
195	50	194.97	0.15	28.04	0.97	24.03
230	50	230.01	0.13	27.65	0.96	23.42
265	50	265.08	0.11	27.27	0.94	23.61

10.7.2 Output Voltage Regulation at 75% Load

Input		Input Measurement				Output Measurement
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	V_{OUT} (V_{DC})
195	50	194.99	0.11	21.08	0.96	23.99
230	50	230.03	0.10	21.12	0.94	24.08
265	50	265.08	0.09	21.22	0.92	23.78

10.7.3 Output Voltage Regulation at 50% Load

Input		Input Measurement				Output Measurement
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	V_{OUT} (V_{DC})
195	50	195.00	0.08	14.18	0.94	23.87
230	50	230.03	0.07	14.22	0.91	23.92
265	50	265.09	0.06	14.27	0.87	23.93

10.7.4 Output Voltage Regulation at 25% Load

Input		Input Measurement				Output Measurement
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	V_{OUT} (V_{DC})
195	50	195.00	0.04	7.41	0.88	23.93
230	50	230.04	0.04	7.46	0.83	23.83
265	50	265.09	0.04	7.54	0.78	23.88

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10.8 No-Load Input Power Under Different Line Conditions

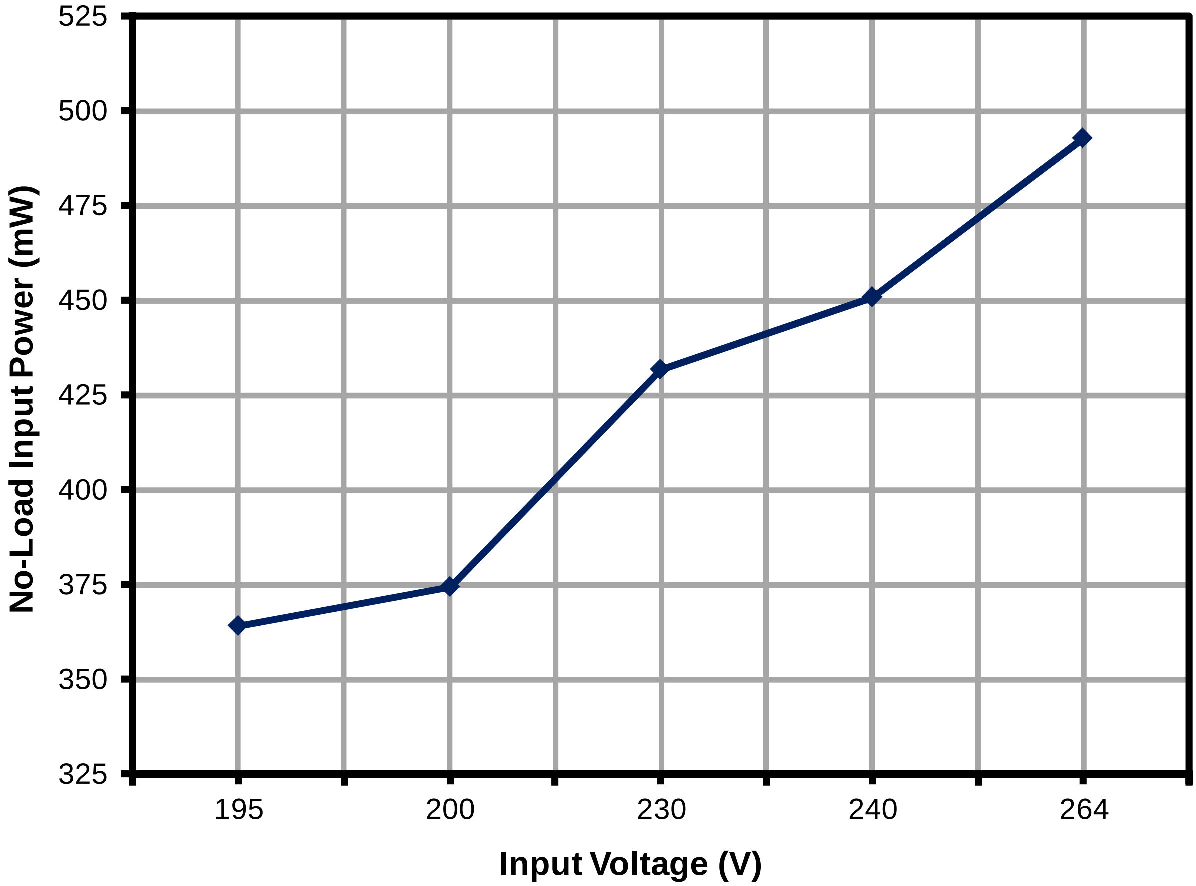

Figure 22 – No-Load Input Power vs. Input Voltage (195 VAC - 265 VAC).

VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (mW)	I (mA_{RMS})	V_{OUT} (V_{DC})
195	50	195.03	4.41	364.13	0	26.46
200	50	200.08	4.45	374.12	0	26.46
230	50	230.06	4.92	431.80	0	26.47
240	50	240.09	5.01	450.67	0	26.46
264	50	264.11	4.75	492.79	0	26.47

10.9 Power Factor

10.9.1 Power Factor vs. Input Line Voltage Using a 24 V LED String

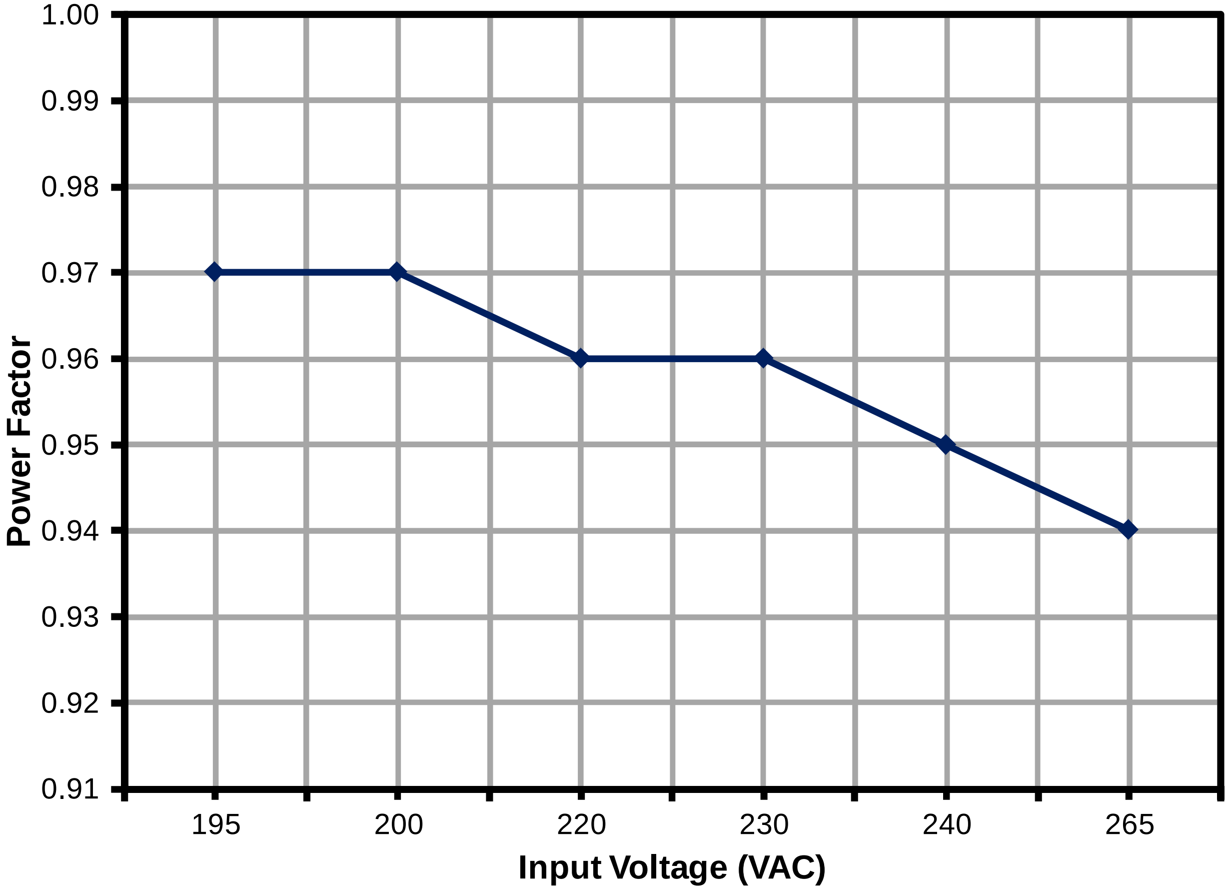

Figure 23 – Power Factor vs. Line.

Input		Input Measurement					Load Measurement			
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency (%)
195	50	195.0	139.6	26.3	0.97	20.4	23.1	0.96	22.6	85.9
200	50	200.0	135.3	26.2	0.97	20.2	23.15	0.96	22.4	85.8
220	50	220.0	121.5	25.7	0.96	19.5	23.0	0.94	22.0	85.7
230	50	230.0	116.6	25.7	0.96	19.4	23.0	0.94	22.0	85.7
240	50	240.0	111.5	25.5	0.95	20.1	23.0	0.94	21.8	85.6
265	50	265.1	102.2	25.4	0.94	21.55	22.9	0.93	21.7	85.4

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10.9.2 Power Factor Under Different Line and Load Conditions

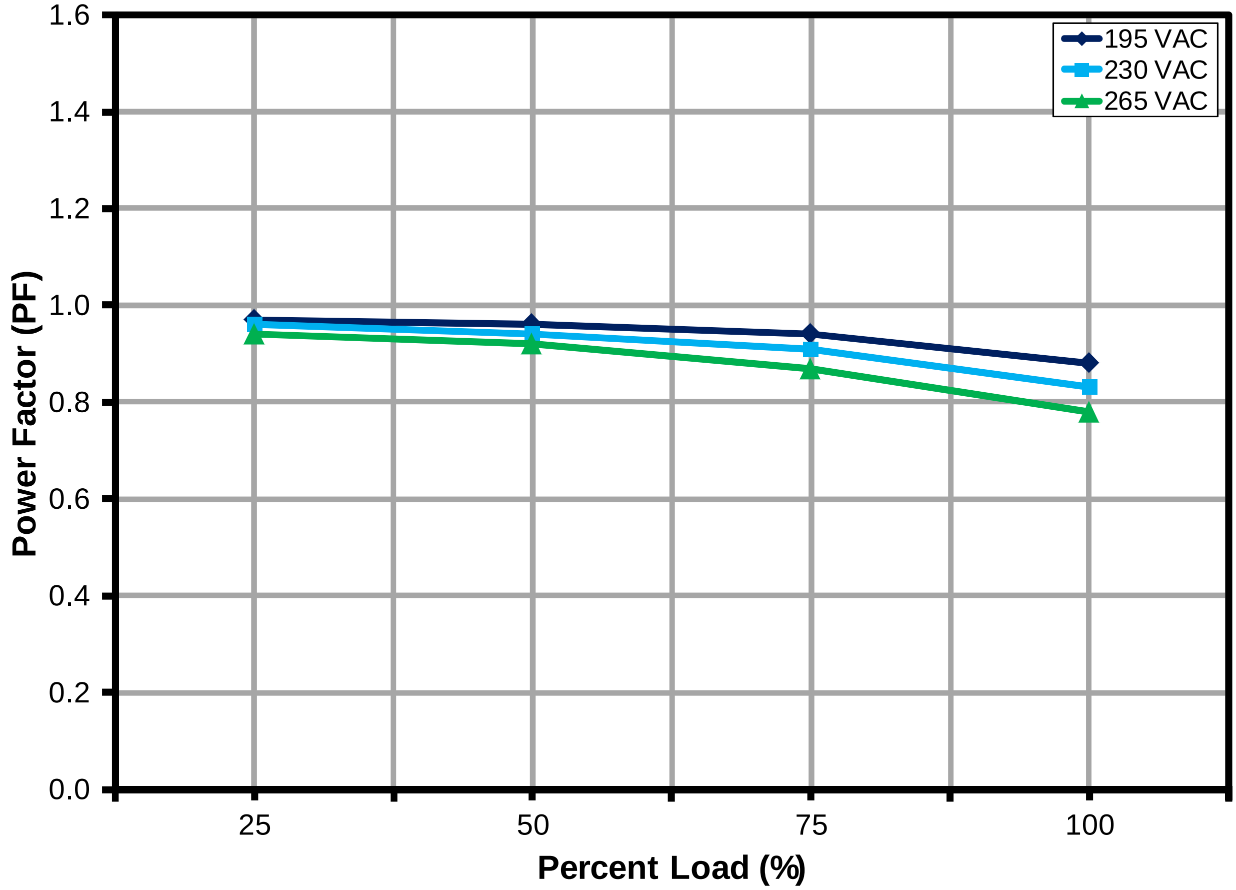

Figure 24 – Power Factor vs. Load (25%, 50%, 75%, 100% Load) at Different Line Conditions (195 VAC, 230 VAC, 265 VAC).

10.9.2.1 PF at 100% Load and Different Line Conditions

Input		Load Measurement			
VAC (V_{RMS})	Freq (Hz)	V_{OUT} (V_{RMS})	I_{OUT} (A_{RMS})	P_{OUT} (W)	PF
195	50	195.0	0.15	28.0	0.97
230	50	230.0	0.13	27.7	0.96
264	50	265.1	0.11	27.3	0.94

10.9.2.2 PF at 75% Load and Different Line Conditions

Input		Load Measurement			
VAC (V_{RMS})	Freq (Hz)	V_{OUT} (V_{RMS})	I_{OUT} (A_{RMS})	P_{OUT} (W)	PF
195	50	195.0	0.11	21.1	0.96
230	50	230.0	0.10	21.1	0.94
264	50	265.1	0.09	21.2	0.92

10.9.2.3 PF at 50% Load and Different Line Conditions

Input		Load Measurement			
VAC (V_{RMS})	Freq (Hz)	VAC (V_{RMS})	Freq (Hz)	VAC (V_{RMS})	Freq (Hz)
195	50	195.0	0.08	14.2	0.94
230	50	230.0	0.07	14.2	0.91
264	50	265.1	0.06	14.3	0.87

10.9.2.4 PF at 25% Load and Different Line Conditions

Input		Load Measurement			
VAC (V_{RMS})	Freq (Hz)	VAC (V_{RMS})	Freq (Hz)	VAC (V_{RMS})	Freq (Hz)
195	50	195.0	0.04	7.4	0.88
230	50	230.0	0.04	7.5	0.83
264	50	265.1	0.04	7.5	0.78

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10.10 % ATHD

10.10.1 % ATHD Under Different Line Conditions and 100% Load, Using E-Load

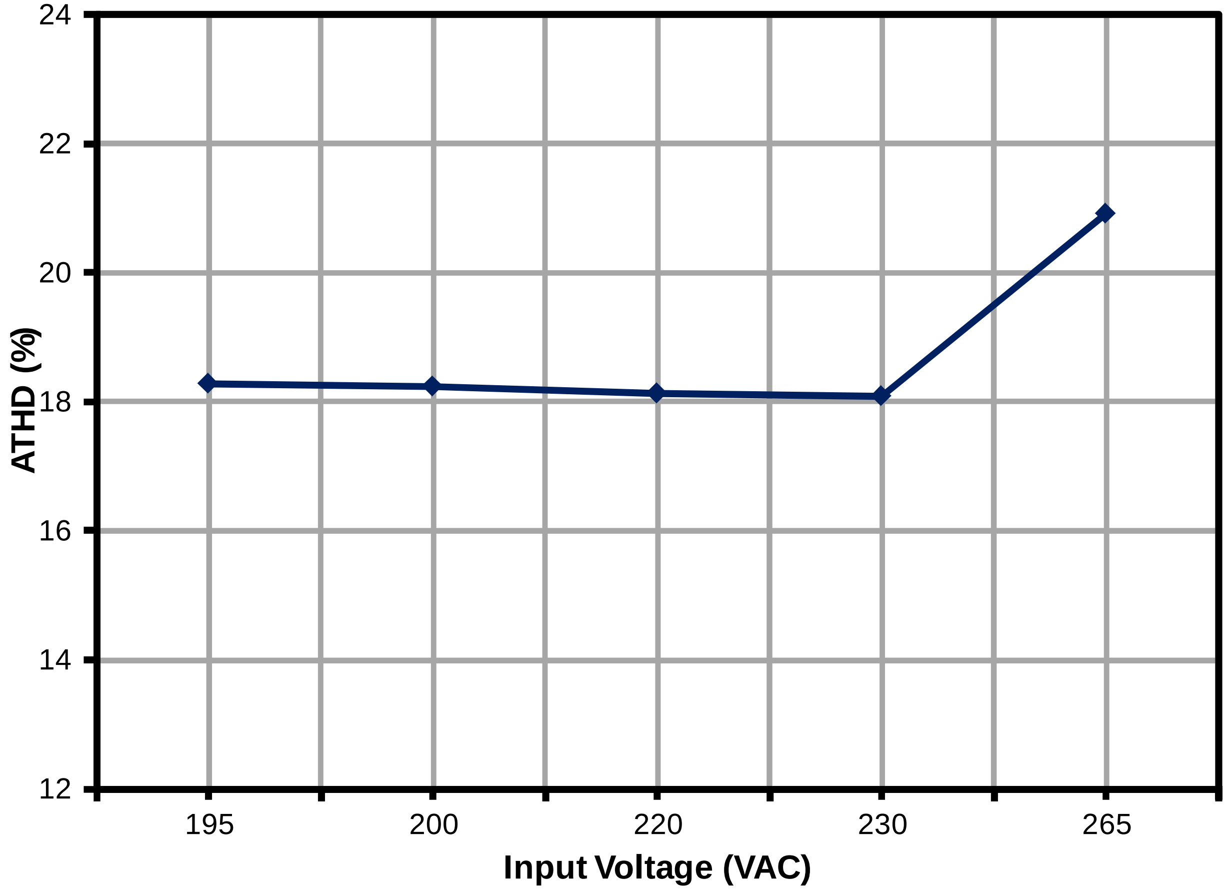

Figure 25 – % A-THD vs. Line.

Input		Input Measurement				
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	PF	%ATHD
195	50	195.0	0.15	28.0	0.97	18.3
200	50	200.0	0.14	28.0	0.97	18.2
220	50	220.0	0.13	27.8	0.96	18.1
230	50	230.0	0.13	27.7	0.96	18.1
265	50	265.1	0.11	27.3	0.94	20.9

10.10.2 % ATHD Under Different Line Conditions and Different LED String Voltages

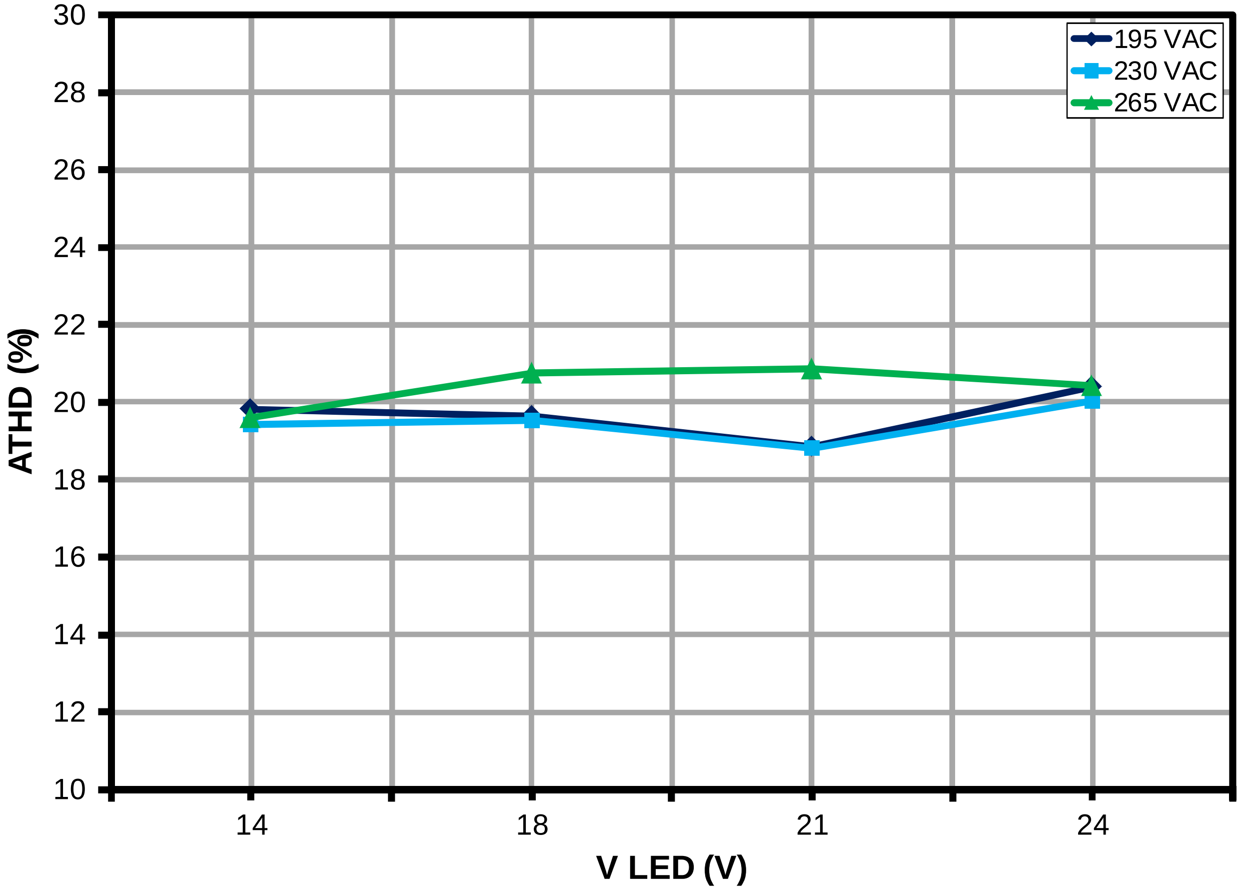

Figure 26 – % A-THD vs. VLED (14 V, 18 V, 21 V, 24 V) at Different Line Condition (195 VAC, 230 VAC, 265 VAC).

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10.10.2.1 24 V LED STRING

Input		Input Measurement				
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD
195	50	195.0	139.6	26.3	0.97	20.4
230	50	230.0	119.6	26.3	0.96	20.0
265	50	265.0	108.8	27.2	0.94	20.4

10.10.2.2 21 V LED STRING

Input		Input Measurement				
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD
195	50	195.0	127.3	24.0	0.97	18.8
230	50	230.0	107.4	23.6	0.96	18.8
265	50	265.1	94.1	23.3	0.93	20.9

10.10.2.3 18 V LED STRING

Input		Input Measurement				
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD
195	50	195.0	109.0	20.4	0.96	19.6
230	50	230.0	93.3	20.3	0.95	19.5
265	50	265.1	84.0	20.5	0.92	20.8

10.10.2.4 14 V LED STRING

Input		Input Measurement				
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD
195	50	195.0	100.2	18.7	0.96	19.8
230	50	230.0	86.4	18.7	0.94	19.4
265	50	265.1	79.4	19.3	0.92	19.6

10.11 Input Current Harmonics for Different Line Conditions Using 24 V LED Load

10.11.1 Input Current Harmonics at 195 VAC Using a 24 V LED String

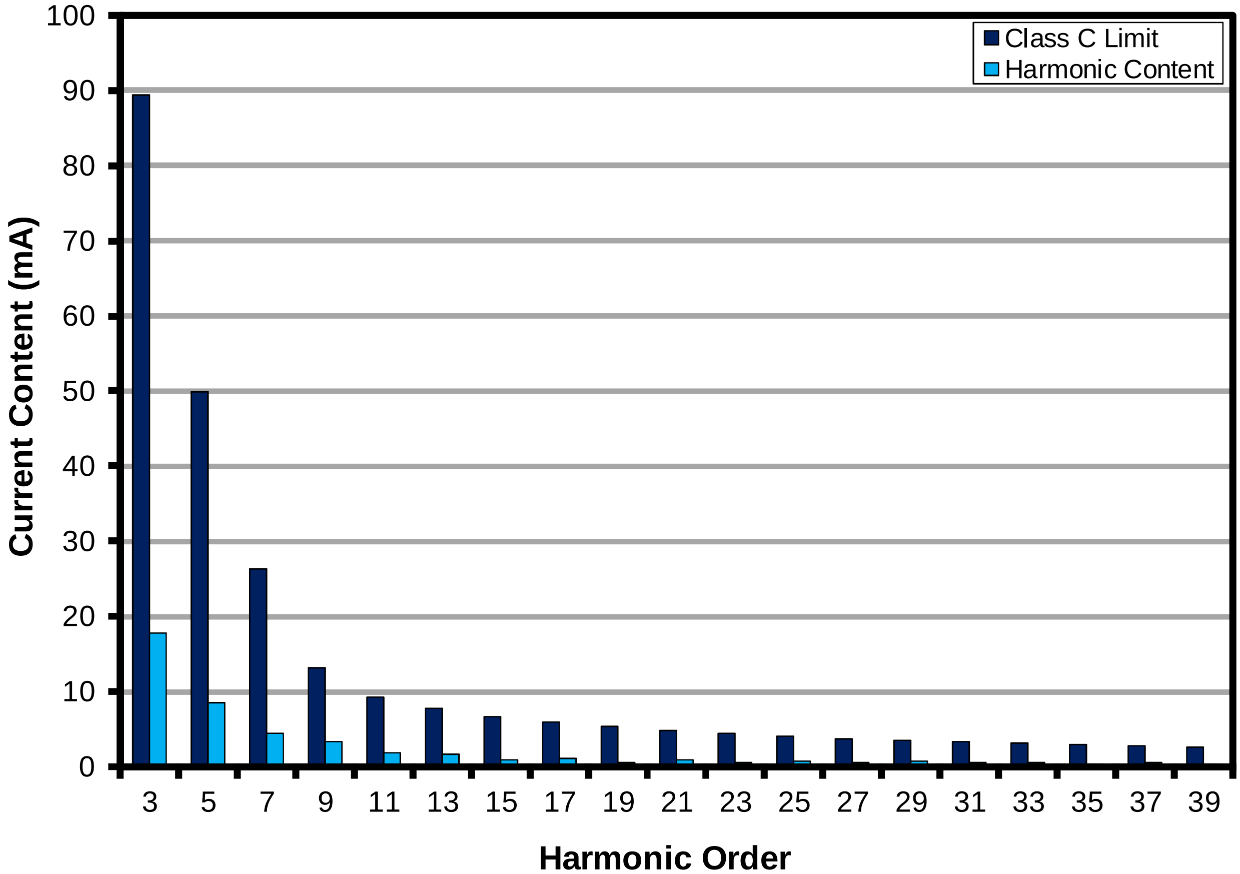

Figure 27 – 24 V LED Input Current Harmonics at 195 VAC.

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10.11.2 Input Current Harmonics at 230 VAC Using a 24 V LED String

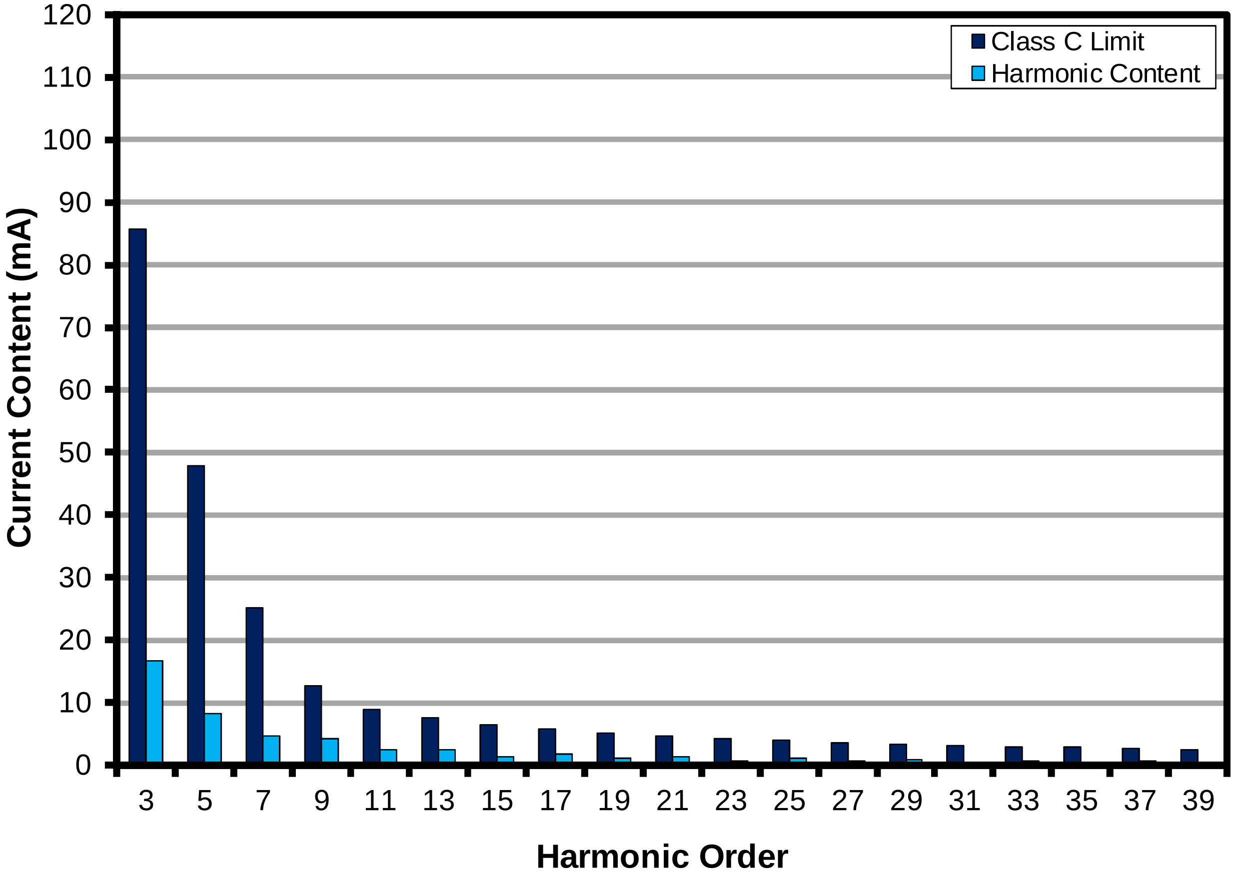

Figure 28 – 24 V LED Input Current Harmonics at 230 VAC.

10.11.3 Input Current Harmonics at 240 VAC Using a 24 V LED String

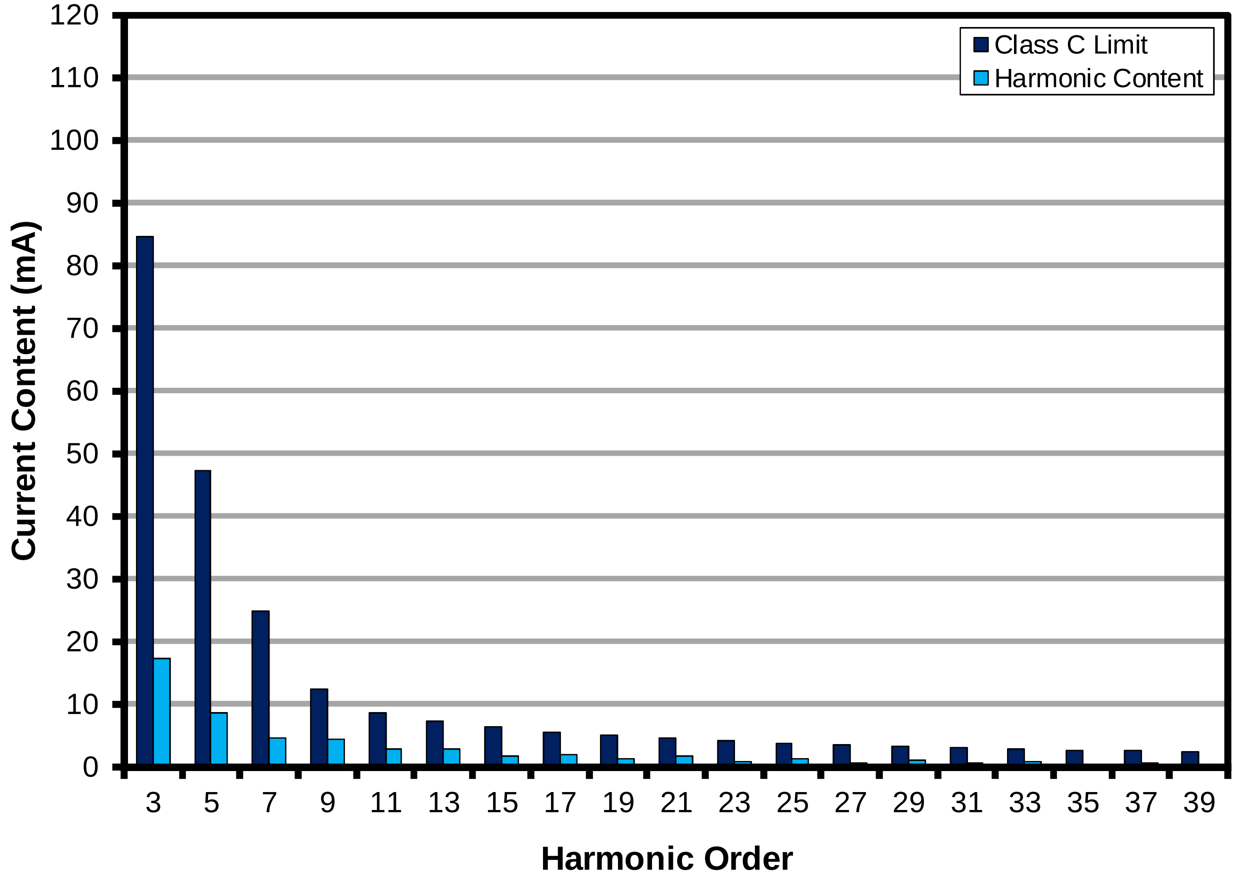

Figure 29 – 24 V LED Input Current Harmonics at 240 VAC.

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10.11.4 Input Current Harmonics at 265 VAC Using a 24 V LED String

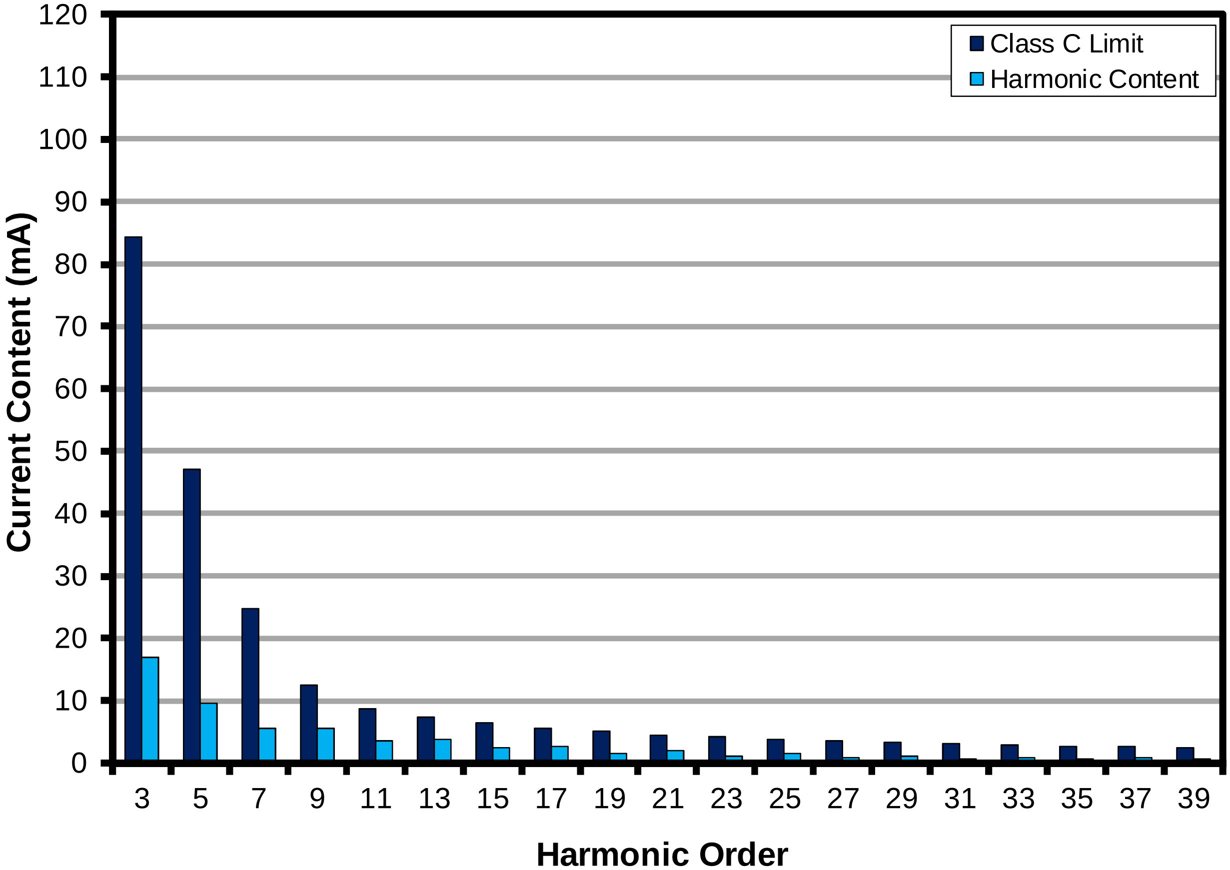

Figure 30 – 24 V LED Input Current Harmonics at 265 VAC.

10.12 Test Data

All measurements were taken with the board in open frame, 25 ºC ambient, 50 Hz line frequency.

10.12.1 24 V LED Load Harmonics at 195 VAC

nth Order	mA Content	% Content	mA Limit <25 W	% Limit >25 W	Remarks
3	24.27	17.82%	89.34	29.02%	Pass
5	11.63	8.54%	49.92	10.00%	Pass
7	6.06	4.45%	26.28	7.00%	Pass
9	4.45	3.27%	13.14	5.00%	Pass
11	2.40	1.76%	9.20	3.00%	Pass
13	2.34	1.72%	7.78	3.00%	Pass
15	1.27	0.93%	6.74	3.00%	Pass
17	1.57	1.15%	5.95	3.00%	Pass
19	0.84	0.62%	5.32	3.00%	Pass
21	1.30	0.95%	4.82	3.00%	Pass
23	0.76	0.56%	4.40	3.00%	Pass
25	1.09	0.80%	4.05	3.00%	Pass
27	0.68	0.50%	3.75	3.00%	Pass
29	0.94	0.69%	3.49	3.00%	Pass
31	0.63	0.46%	3.26	3.00%	Pass
33	0.83	0.61%	3.07	3.00%	Pass
35	0.56	0.41%	2.89	3.00%	Pass
37	0.72	0.53%	2.73	3.00%	Pass
39	0.53	0.39%	2.59	3.00%	Pass

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10.12.2 24 V LED Load Harmonics at 230 VAC

nth Order	mA Content	% Content	mA Limit <25 W	% Limit >25 W	Remarks
3	18.82	16.78%	85.78	28.70%	Pass
5	9.31	8.30%	47.94	10.00%	Pass
7	5.15	4.59%	25.23	7.00%	Pass
9	4.66	4.15%	12.62	5.00%	Pass
11	2.73	2.43%	8.83	3.00%	Pass
13	2.73	2.43%	7.47	3.00%	Pass
15	1.57	1.40%	6.48	3.00%	Pass
17	1.94	1.73%	5.71	3.00%	Pass
19	1.14	1.02%	5.11	3.00%	Pass
21	1.51	1.35%	4.63	3.00%	Pass
23	0.82	0.73%	4.22	3.00%	Pass
25	1.20	1.07%	3.89	3.00%	Pass
27	0.71	0.63%	3.60	3.00%	Pass
29	1.00	0.89%	3.35	3.00%	Pass
31	0.57	0.51%	3.13	3.00%	Pass
33	0.78	0.70%	2.94	3.00%	Pass
35	0.48	0.43%	2.78	3.00%	Pass
37	0.67	0.60%	2.63	3.00%	Pass
39	0.44	0.39%	2.49	3.00%	Pass

10.12.3 24 V LED Load Harmonics at 240 VAC

nth Order	mA Content	% Content	mA Limit <25 W	% Limit >25 W	Remarks
3	18.38	17.26%	84.54	28.51%	Pass
5	9.21	8.65%	47.24	10.00%	Pass
7	4.93	4.63%	24.86	7.00%	Pass
9	4.70	4.41%	12.43	5.00%	Pass
11	3.00	2.82%	8.70	3.00%	Pass
13	3.16	2.97%	7.36	3.00%	Pass
15	1.91	1.79%	6.38	3.00%	Pass
17	2.23	2.09%	5.63	3.00%	Pass
19	1.32	1.24%	5.04	3.00%	Pass
21	1.76	1.65%	4.56	3.00%	Pass
23	1.01	0.95%	4.16	3.00%	Pass
25	1.37	1.29%	3.83	3.00%	Pass
27	0.78	0.73%	3.55	3.00%	Pass
29	1.08	1.01%	3.30	3.00%	Pass
31	0.62	0.58%	3.09	3.00%	Pass
33	0.82	0.77%	2.90	3.00%	Pass
35	0.55	0.52%	2.74	3.00%	Pass
37	0.68	0.64%	2.59	3.00%	Pass
39	0.52	0.49%	2.45	3.00%	Pass

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10.12.4 24 V LED Load Harmonics at 265 VAC

nth Order	mA Content	% Content	mA Limit <25 W	% Limit >25 W	Remarks
3	16.61	17.05%	84.31	28.07%	Pass
5	9.30	9.55%	47.12	10.00%	Pass
7	5.41	5.55%	24.80	7.00%	Pass
9	5.35	5.49%	12.40	5.00%	Pass
11	3.48	3.57%	8.68	3.00%	Pass
13	3.74	3.84%	7.34	3.00%	Pass
15	2.33	2.39%	6.36	3.00%	Pass
17	2.68	2.75%	5.62	3.00%	Pass
19	1.59	1.63%	5.02	3.00%	Pass
21	1.92	1.97%	4.55	3.00%	Pass
23	1.08	1.11%	4.15	3.00%	Pass
25	1.44	1.48%	3.82	3.00%	Pass
27	0.81	0.83%	3.54	3.00%	Pass
29	1.12	1.15%	3.29	3.00%	Pass
31	0.71	0.73%	3.08	3.00%	Pass
33	0.95	0.98%	2.89	3.00%	Pass
35	0.65	0.67%	2.73	3.00%	Pass
37	0.80	0.82%	2.58	3.00%	Pass
39	0.59	0.61%	2.45	3.00%	Pass

11 Thermal Performance

Thermal measurements were made at 25 ºC ambient with a 24 V LED string. Settling time was >1 hour.

11.1 Thermal Performance at 190 VAC with a 24 V LED String

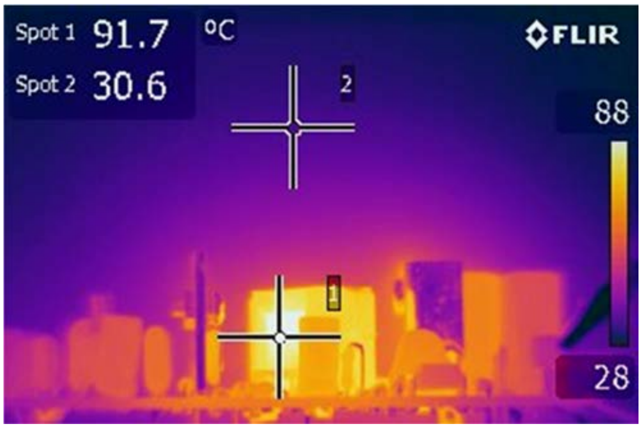

Figure 31 – 195 VAC, Full Load.
Spot 1: Transformer Winding.
Spot 2: Ambient.

Figure 32 – 195 VAC, Full Load.
Spot 1: Transformer Core.
Spot 2: Ambient.

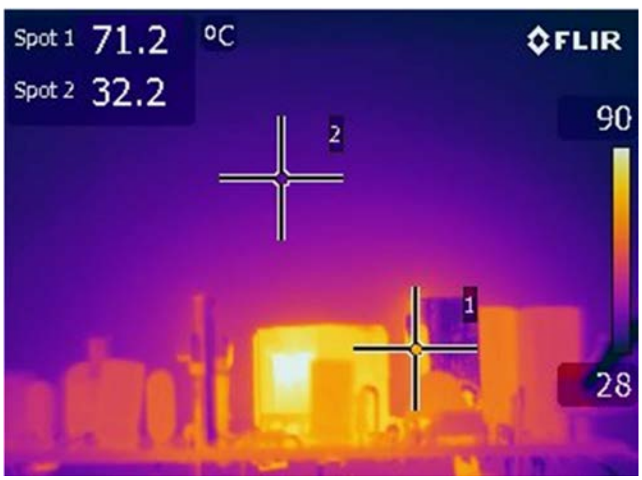

Figure 33 – 195 VAC, Full Load.
Spot 1: LYT4325E.
Spot 2: Ambient.

Figure 34 – 195 VAC, Full Load.
Spot 1: Output Diode.
Spot 2: Ambient.

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11.2 Thermal Performance at 230 VAC with a 24 V LED String

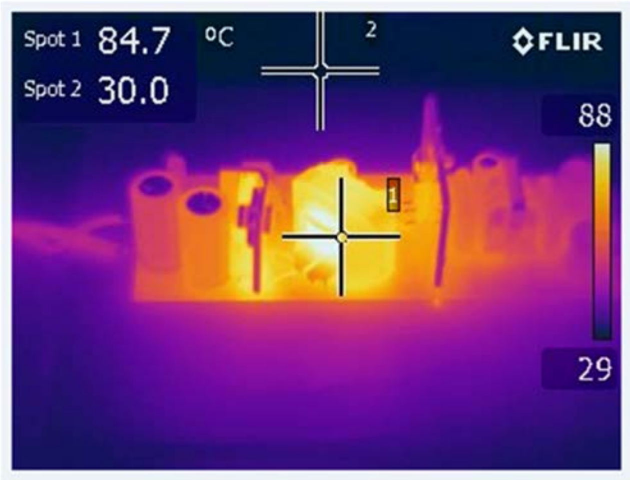

Figure 35 – 230 VAC, Full Load.
Spot 1: Transformer Winding.
Spot 2: Ambient.

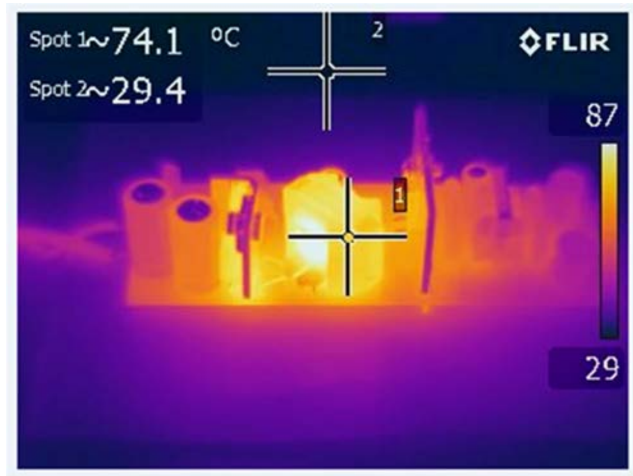

Figure 36 – 230 VAC, Full Load.
Spot 1: Transformer Core.
Spot 2: Ambient.

Figure 37 – 230 VAC, Full Load.
Spot 1: LYT4325E.
Spot 2: Ambient.

Figure 38 – 230 VAC, Full Load.
Spot 1: Output Diode.
Spot 2: Ambient.

11.3 Thermal Performance at 265 VAC with a 24 V LED String

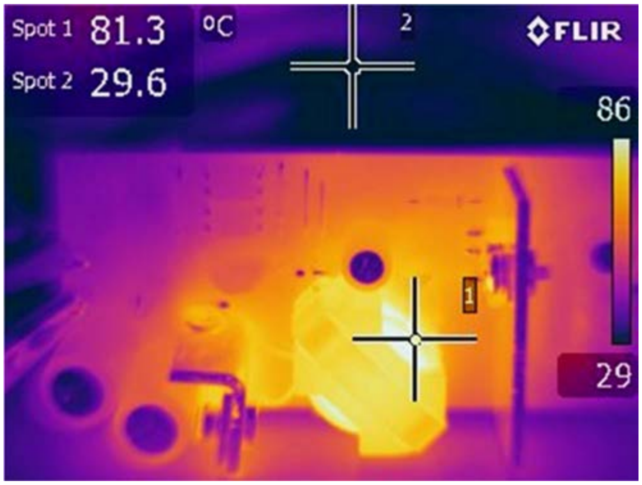

Figure 39 – 265 VAC, Full Load.
Spot 1: Transformer Winding.
Spot 2: Ambient.

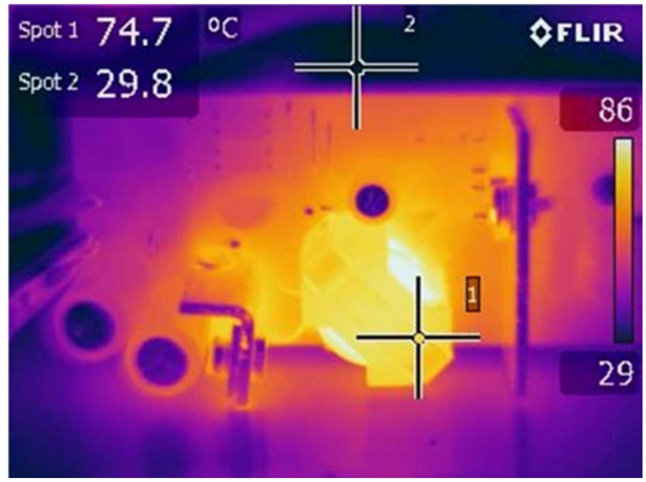

Figure 40 – 265 VAC, Full Load.
Spot 1: Transformer Core.
Spot 2: Ambient.

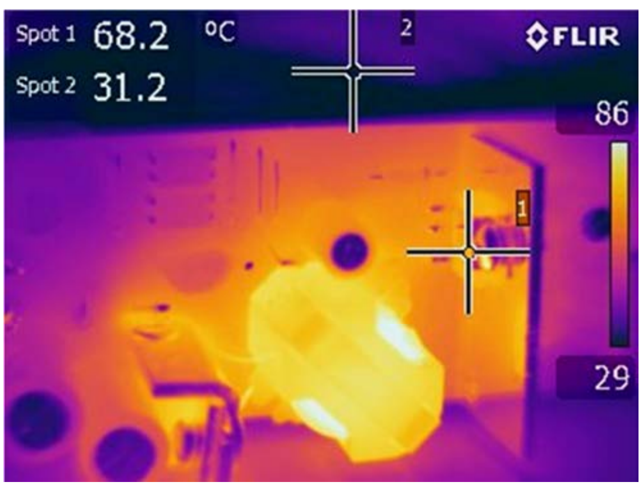

Figure 41 – 265 VAC, Full Load.
Spot 1: LYT4325E.
Spot 2: Ambient.

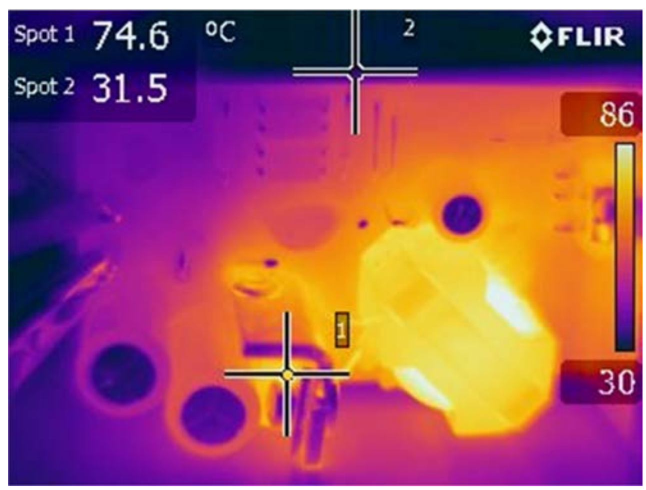

Figure 42 – 265 VAC, Full Load.
Spot 1: Output Diode.
Spot 2: Ambient.

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12 Waveforms

12.1 Input Voltage and Input Current Waveforms

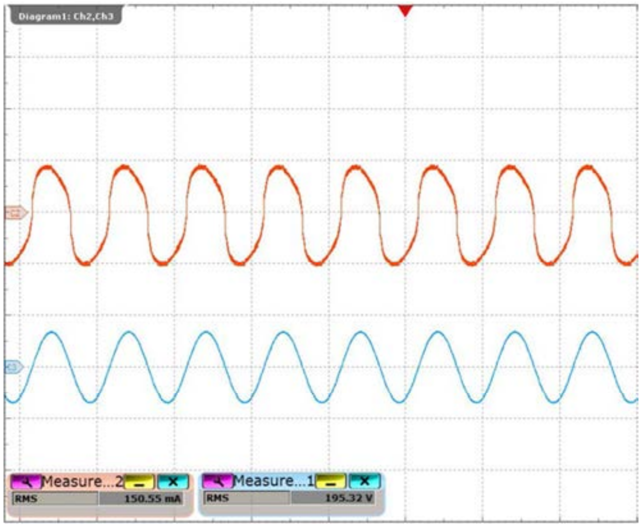

Figure 43 – 195 VAC, Full Load.
Upper: I_{IN}, 500 mA / div.
Lower: V_{IN}, 400 V / div., 20 ms / div.
Measured I_{IN}: 150.55 mA.
Measured V_{IN}: 195.32 V.

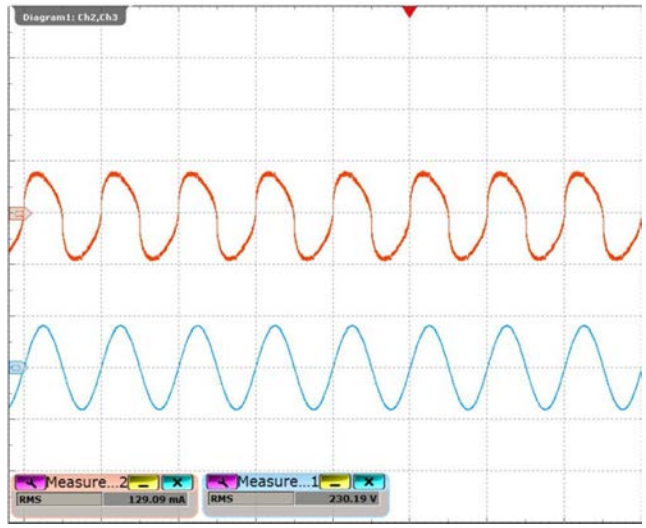

Figure 44 – 230 VAC, Full Load.
Upper: I_{IN}, 500 mA / div.
Lower: V_{IN}, 400 V / div., 20 ms / div.
Measured I_{IN}: 129 mA.
Measured V_{IN}: 230.19 V.

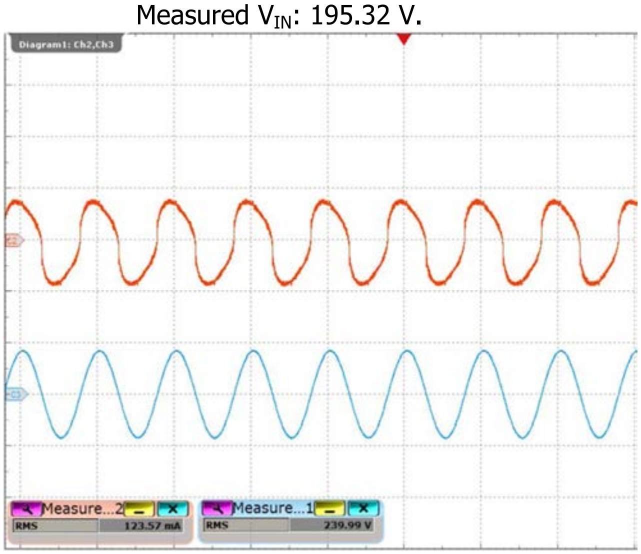

Figure 45 – 240 VAC, Full Load.
Upper: I_{IN}, 500 mA / div.
Lower: V_{IN}, 400 V / div., 20 ms / div.
Measured I_{IN}: 123.57 mA.
Measured V_{IN}: 239.99 V.

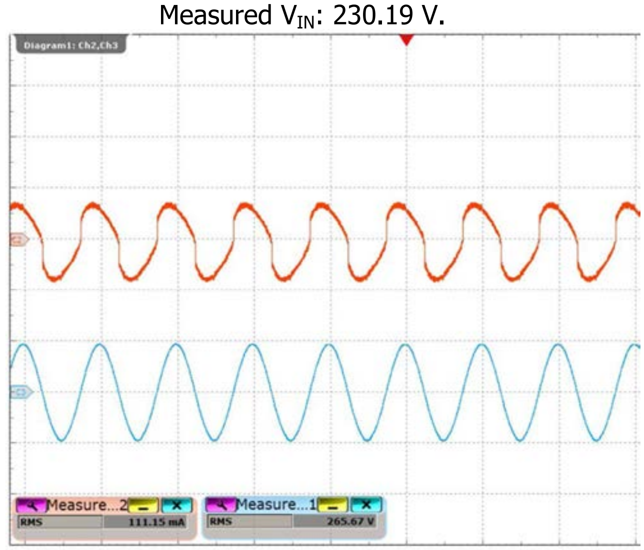

Figure 46 – 265 VAC, Full Load.
Upper: I_{IN}, 500 mA / div.
Lower: V_{IN}, 400 V / div., 20 ms / div.
Measured I_{IN}: 111 mA.
Measured V_{IN}: 265.67 V.

12.2 Output Current and Output Voltage at Normal Operation

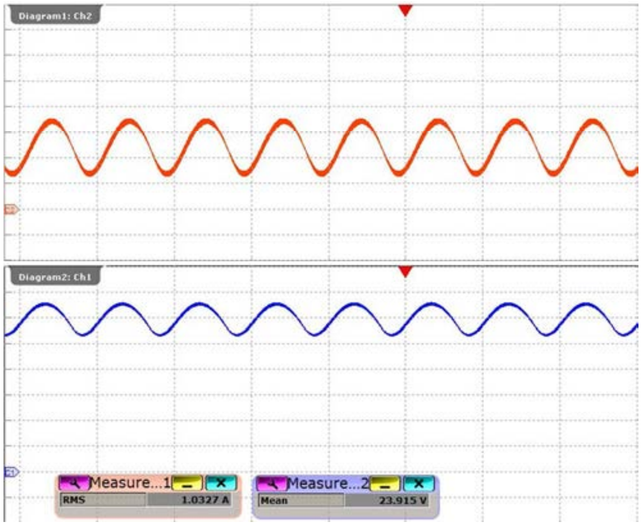

Figure 47 – 195 VAC, Full Load.
Upper: I_{IN}, 400 mA / div.
Lower: V_{IN}, 4 V / div., 10 ms / div.
Measured I_{OUT}: 1.03 A.
Measured V_{OUT}: 23.92 V.

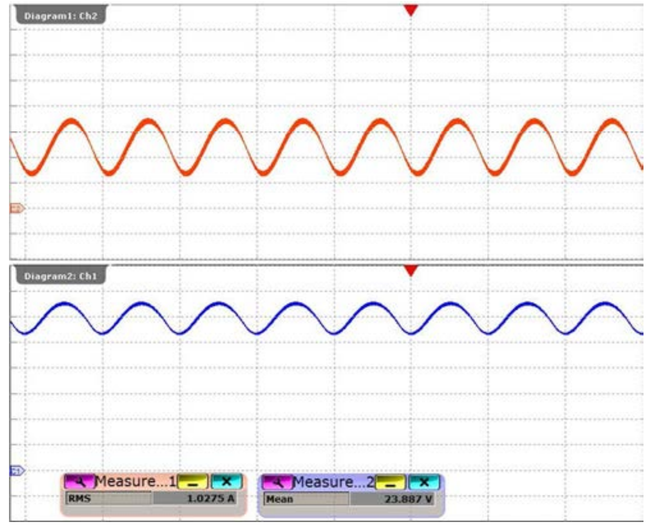

Figure 48 – 230 VAC, 50 Hz Full Load.
Upper: I_{IN}, 400 mA / div.
Lower: V_{IN}, 4 V / div., 10 ms / div.
Measured I_{OUT}: 1.03 A.
Measured V_{OUT}: 23.89 V.

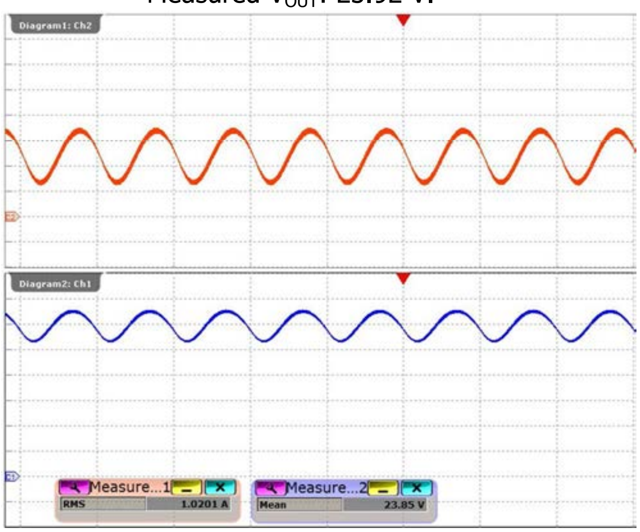

Figure 49 – 240 VAC, 50 Hz Full Load.
Upper: I_{IN}, 400 mA / div.
Lower: V_{IN}, 4 V / div., 10 ms / div.
Measured I_{OUT}: 1 A.
Measured V_{OUT}: 23.85 V.

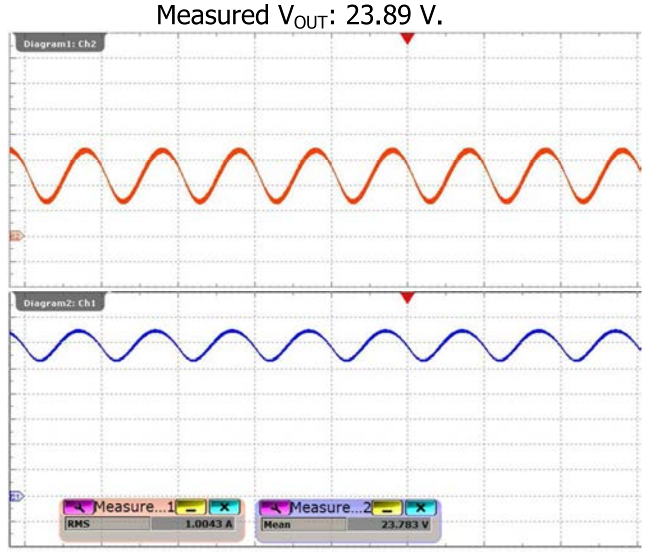

Figure 50 – 265 VAC, 50 Hz Full Load.
Upper: I_{IN}, 400 mA / div.
Lower: V_{IN}, 4 V / div., 10 ms / div.
Measured I_{OUT}: 1 A.
Measured V_{OUT}: 23.78 V.

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12.3 Output Voltage and Output Current Start-Up Characteristic

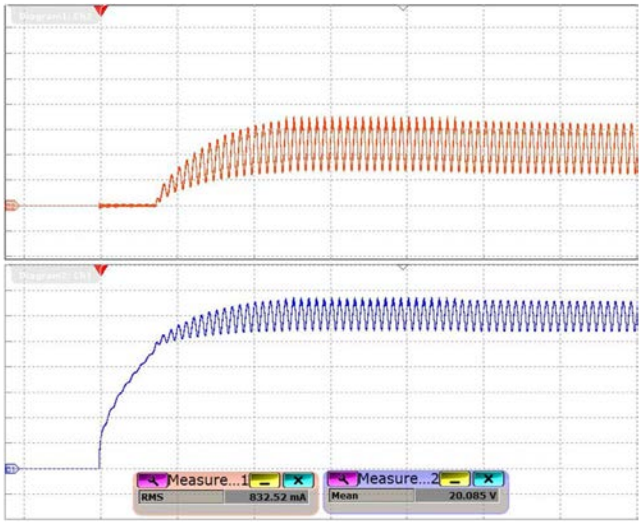

Figure 51 – 195 VAC Output Rise at Full Load.
Upper: I_{OUT}, 400 mA / div.
Lower: V_{OUT}, 4 V / div., 100 ms / div.
Measured Rise Time: 250 ms.

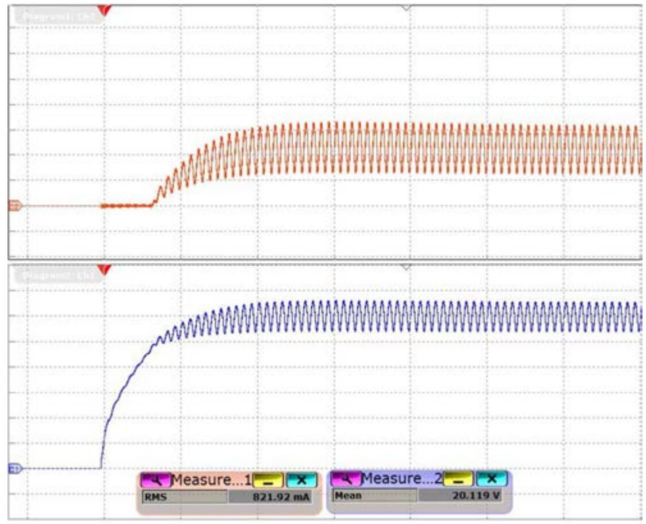

Figure 52 – 230 VAC Output Rise at Full Load.
Upper: I_{OUT}, 400 mA / div.
Lower: V_{OUT}, 4 V / div., 100 ms / div.
Measured Rise Time: 250 ms.

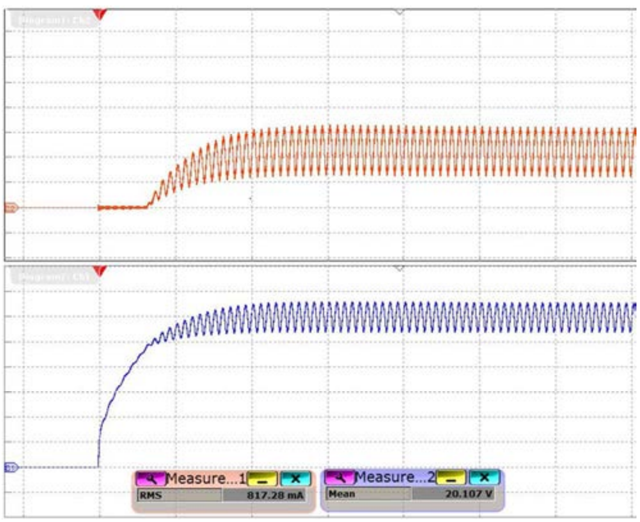

Figure 53 – 240 VAC Output Rise at Full Load.
Upper: I_{OUT}, 400 mA / div.
Lower: V_{OUT}, 4 V / div., 100 ms / div.
Measured Rise Time: 250 ms.

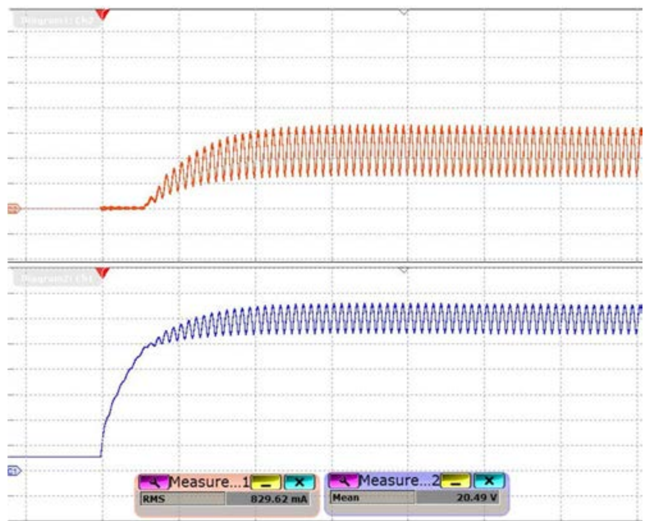

Figure 54 – 265 VAC Output Rise at Full Load.
Upper: I_{OUT}, 400 mA / div.
Lower: V_{OUT}, 4 V / div., 100 ms / div.
Measured Rise Time: 250 ms.

12.4 Drain Voltage and Current at Normal Operation

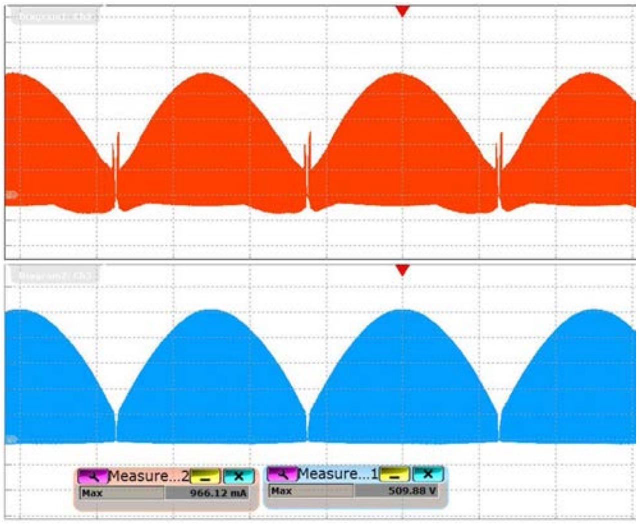

Figure 55 – 195 VAC, 50 Hz.
Upper: I_{DRAIN}, 200 mA / div., 4 ms / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Measured V_{PK} at Normal Operation:
509.88 V_{PK}.
Measured I_{PK} at Normal Operation:
966 mA_{PK}.

Figure 56 – 195 VAC, 50 Hz (Zoomed Version).
Upper: I_{DRAIN}, 200 mA / div., 4 µs / div.
Lower: V_{DRAIN}, 100 V / div., 4 µs / div.
Measured V_{PK} at Normal Operation:
519 V_{PK}.
Measured I_{PK} at Normal Operation:
966 mA_{PK}.

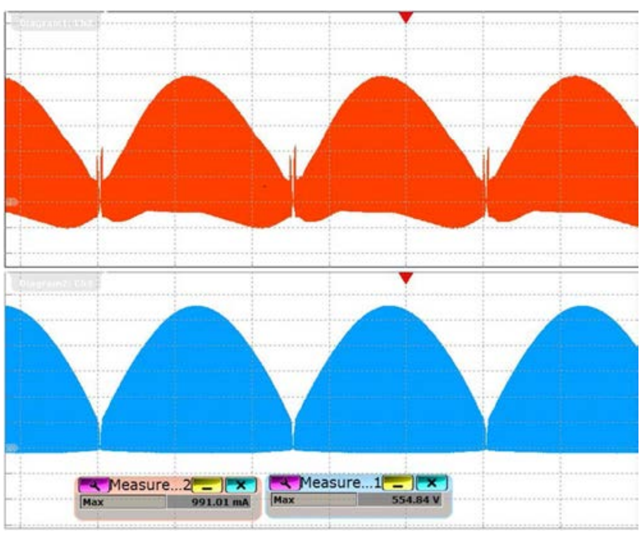

Figure 57 – 230 VAC, 50 Hz.
Upper: I_{DRAIN}, 200 mA / div., 4 ms / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Measured V_{PK} at Normal Operation:
554.84 V_{PK}.
Measured I_{PK} at Normal Operation:
991 mA_{PK}.

Figure 58 – 230 VAC, 50 Hz (zoomed version).
Upper: I_{DRAIN}, 200 mA / div., 4 ms / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Measured V_{PK} at Normal Operation:
562.49 V_{PK}.
Measured I_{PK} at Normal Operation:
982 mA_{PK}.

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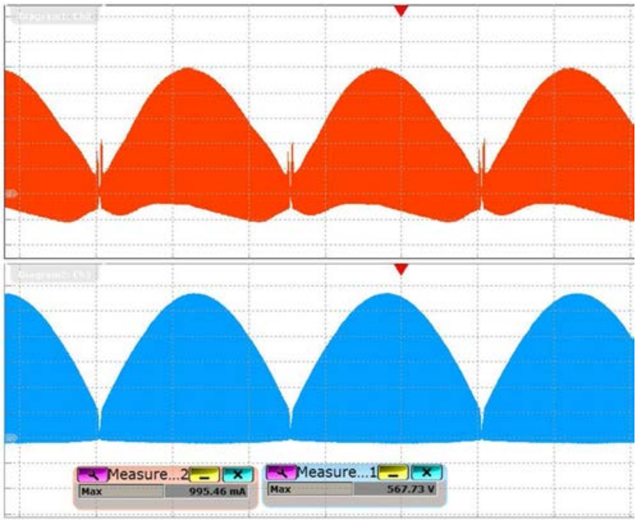

Figure 59 – 240 VAC, 50 Hz.
Upper: I_{DRAIN}, 200 mA / div., 4 ms / div
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Measured V_{PK} at Normal Operation:
567.73 V_{PK}.
Measured I_{PK} at Normal Operation:
995 mA_{PK}.

Figure 60 – 240 VAC, 50 Hz (Zoomed Version).
Upper: I_{DRAIN}, 200 mA / div., 4 ms / div
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Measured V_{PK} at Normal Operation:
574.35 V_{PK}.
Measured I_{PK} at Normal Operation:
974 mA_{PK}.

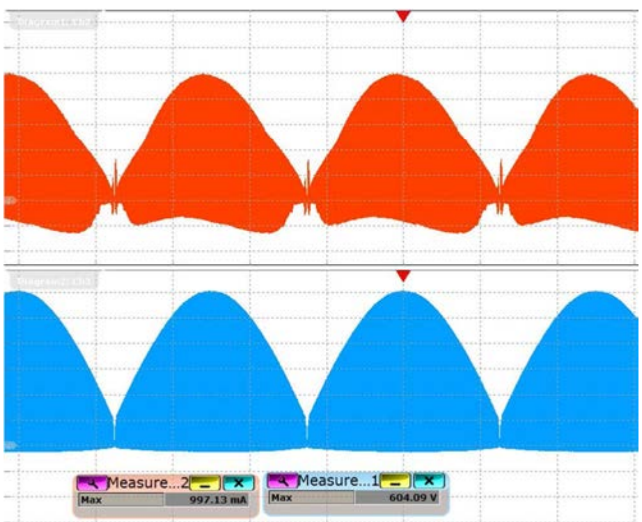

Figure 61 – 265 VAC, 50 Hz.
Upper: I_{DRAIN}, 200 mA / div., 4 ms / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Measured V_{PK} at Normal Operation:
604 V_{PK}.
Measured I_{PK} at Normal Operation:
997 mA_{PK}.

Figure 62 – 265 VAC, 50 Hz (Zoomed Version).
Upper: I_{DRAIN}, 200 mA / div., 4 ms / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Measured V_{PK} at Normal Operation:
602 V_{PK}.
Measured I_{PK} at Normal Operation:
1 A_{PK}.

12.5 Output Diode Voltage Stress

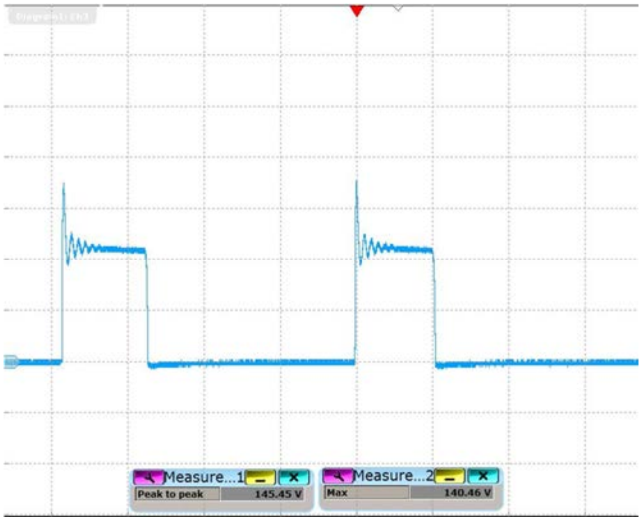

Figure 63 – 195 VAC, 50 Hz.
V_{DIODE}, 40 V / div, 2 µs / div.
Measured Diode V_{PK}: 140.46 V_{PK}.

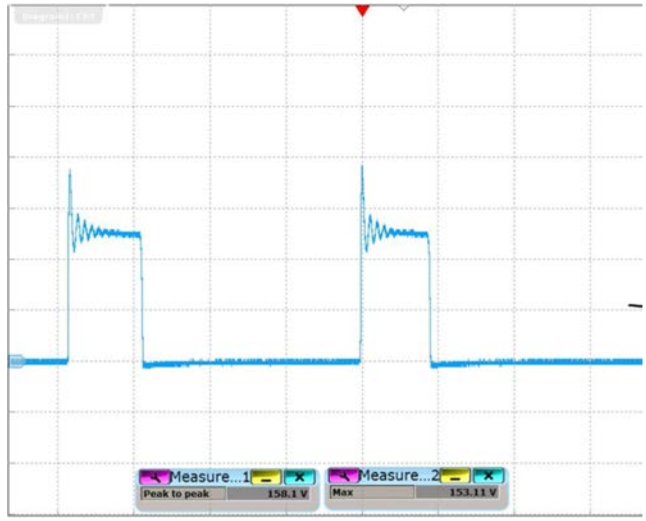

Figure 64 – 230 VAC, 50 Hz.
V_{DIODE}, 40 V / div, 2 µs / div.
Measured Diode V_{PK}: 153.11 V_{PK}.

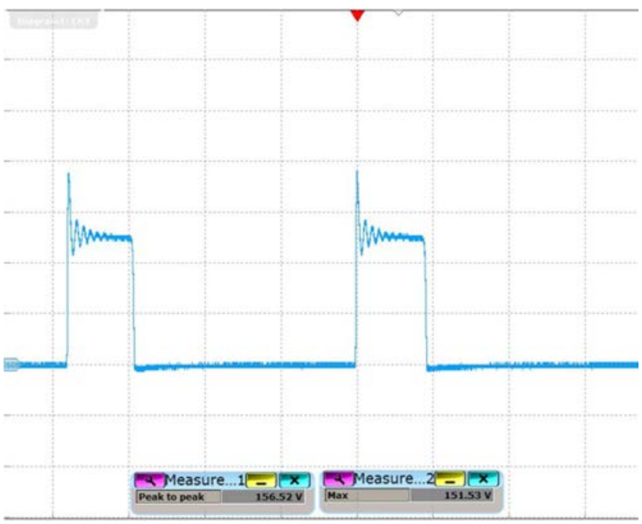

Figure 65 – 240 VAC, 50 Hz.
V_{DIODE}, 40 V / div, 2 µs / div.
Measured Diode V_{PK}: 151.53 V_{PK}.

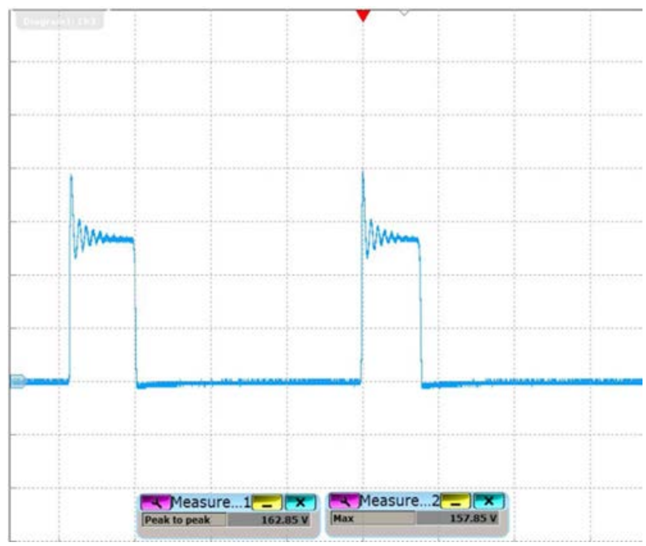

Figure 66 – 265 VAC, 50 Hz.
V_{DIODE}, 40 V / div, 2 µs / div.
Measured Diode V_{PK}: 157.85 V_{PK}.

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12.6 Drain Voltage and Current during Start-Up

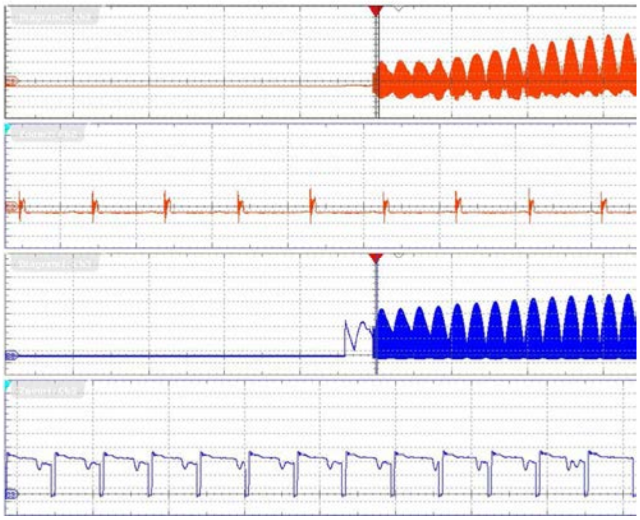

Figure 67 – 190 VAC, 50 Hz.
Upper: I_{DRAIN}, 200 mA / div.
Upper: I_{DRAIN}, 200 mA / div. (Zoomed Version)
Lower: V_{DRAIN}, 100 V, 40 ms / div.
Lower: V_{DRAIN}, 100 V, 40 ms / div. (Zoomed Version)

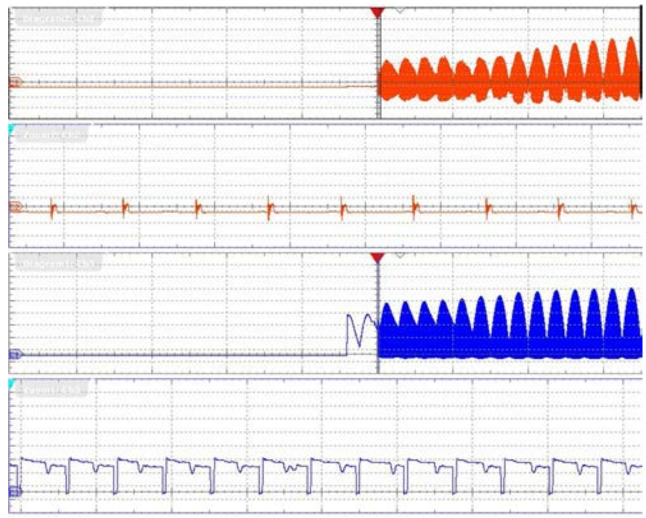

Figure 68 – 230 VAC, 50 Hz.
Upper: I_{DRAIN}, 200 mA / div.
Upper: I_{DRAIN}, 200 mA / div. (Zoomed Version)
Lower: V_{DRAIN}, 100 V, 40 ms / div.
Lower: V_{DRAIN}, 100 V, 40 ms / div. (Zoomed Version)

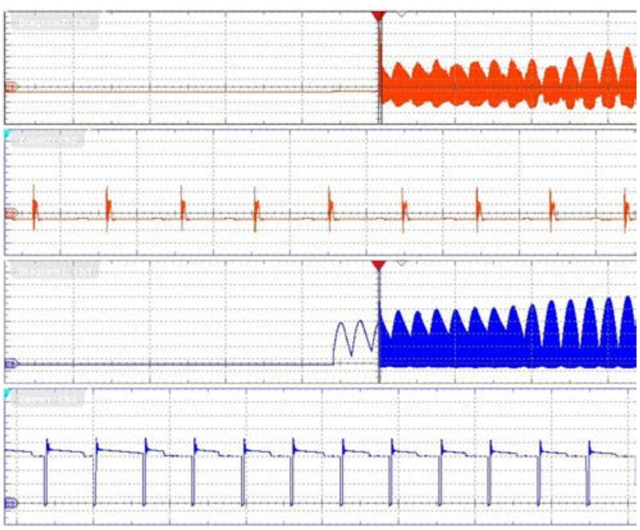

Figure 69 – 240 VAC, 50 Hz.
Upper: I_{DRAIN}, 200 mA / div.
Upper: I_{DRAIN}, 200 mA / div. (Zoomed Version)
Lower: V_{DRAIN}, 100 V, 40 ms / div.
Lower: V_{DRAIN}, 100 V, 40 ms / div. (Zoomed Version)

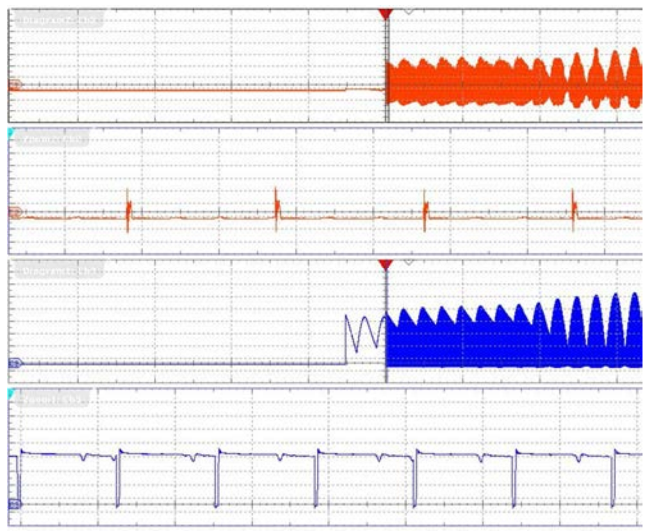

Figure 70 – 265 VAC, 50 Hz.
Upper: I_{DRAIN}, 200 mA / div.
Upper: I_{DRAIN}, 200 mA / div. (Zoomed Version)
Lower: V_{DRAIN}, 100 V, 40 ms / div.
Lower: V_{DRAIN}, 100 V, 40 ms / div. (Zoomed Version)

12.7 Drain Current and Drain Voltage During Output Short Condition (SOA Mode)

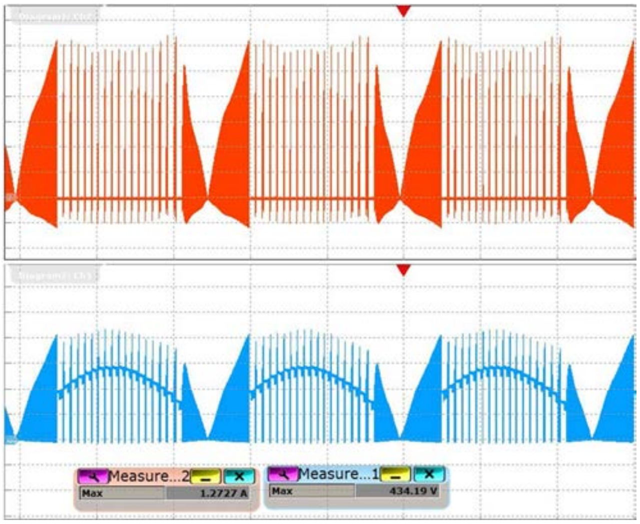

Figure 71 – 195 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 10 ms / div.
Measured V_{PK} at Short-Circuit Condition: 434.19 V_{PK}.
Measured I_{PK} at Short-Circuit Condition: 1.27 A_{PK}.

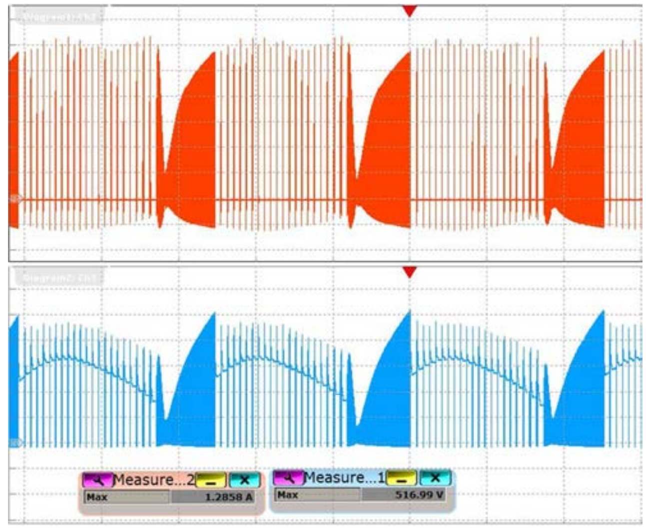

Figure 72 – 230 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 10 ms / div.
Measured V_{PK} at Short-Circuit Condition: 516.99 V_{PK}.
Measured I_{PK} at Short-Circuit Condition: 1.28 A_{PK}.

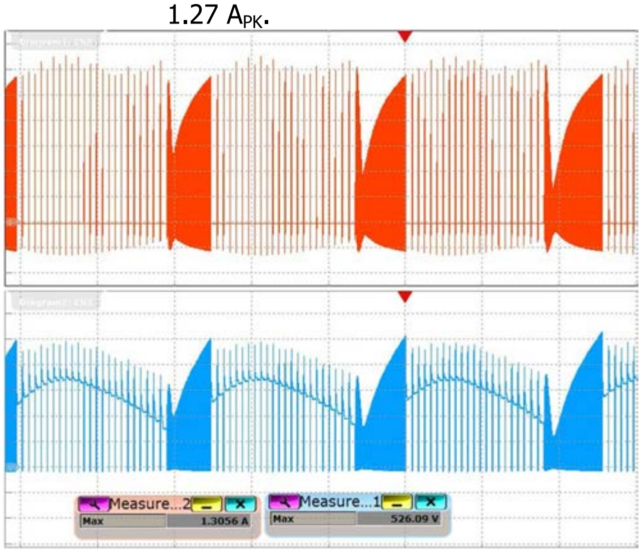

Figure 73 – 240 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 10 ms / div.
Measured V_{PK} at Short-Circuit Condition: 526 V_{PK}.
Measured I_{PK} at Short-Circuit Condition: 1.30 A_{PK}.

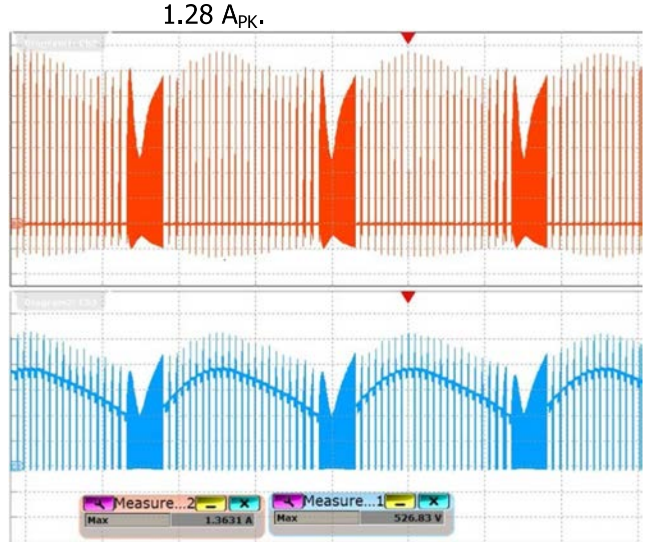

Figure 74 – 265 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 10 ms / div.
Measured V_{PK} at Short-Circuit Condition: 526.83 V_{PK}.
Measured I_{PK} at Short-Circuit Condition: 1.36 A_{PK}.

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12.8 Short-Circuit Input Power at Different Line Conditions (SOA Mode)

LINE VOLTAGE (VAC)	MEASURED INPUT POWER AT SHORT CIRCUIT CONDITION (W)
190	4.21
230	4.38
265	4.45

12.9 PCB and Critical Component Temperature in Short-Circuit Condition (SOA Mode)

LINE VOLTAGE (VAC)	COMPONENT	TEMPERATURE READING (ºC)
190	PCB Bottom Side	65.9
	PCB Top Side	61.6
	Output Diode	82.6
265	PCB Bottom Side	75.8
	PCB Top Side	65.8
	Output Diode	86.7

Test Conditions:

1. Unit was tested in an enclosed environment to prevent any airflow.
2. 1 hour soak time prior to taking temperature readings.
3. Ambient Temperature was 30 ºC

12.10 Open Load Characteristic

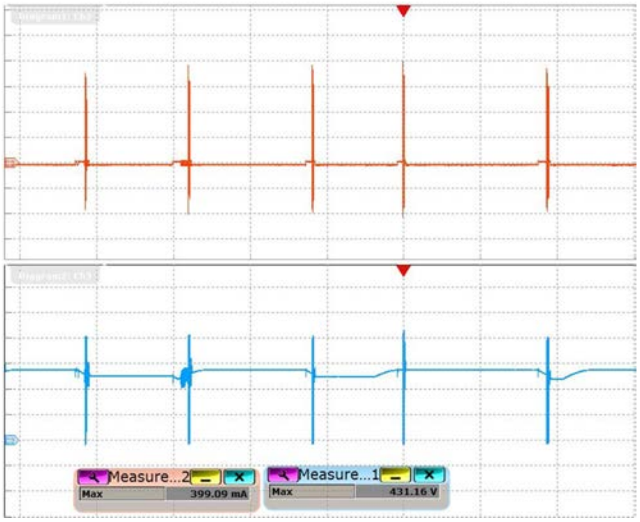

Figure 75 – 195 VAC, 50 Hz Running Open Load.
Middle: $I_{DRAIN,}$ 100 mA / div., 4 ms / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Measured V_{PK} at Open Load Condition: 431.16 V_{PK}.
Measured I_{PK} at Open Load Condition: 399 mA_{PK}.

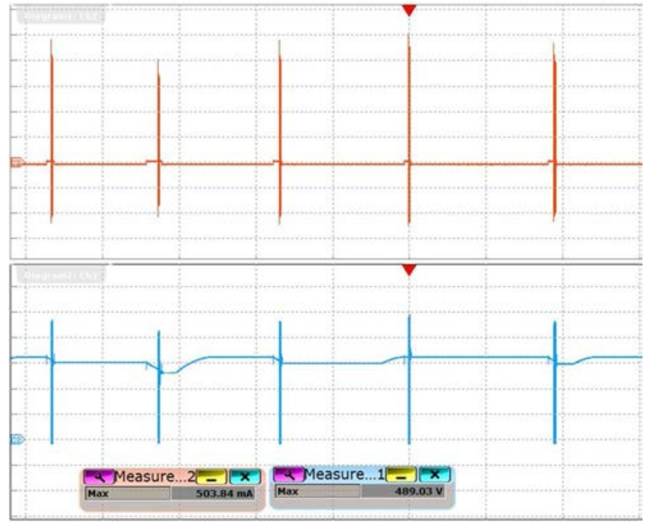

Figure 76 – 230 VAC, 50 Hz Running Open Load.
Middle: $I_{DRAIN,}$ 100 mA / div., 4 ms / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Measured V_{PK} at Open Load Condition: 489 V_{PK}.
Measured I_{PK} at Open Load Condition: 503 mA_{PK}.

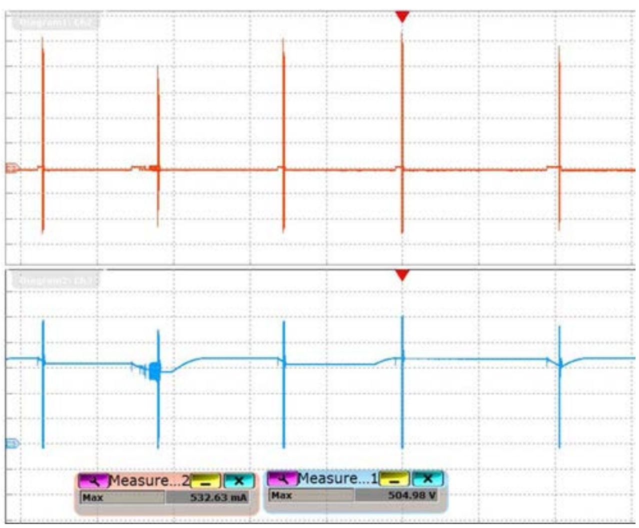

Figure 77 – 240 VAC, 50 Hz Running Open Load.
Middle: $I_{DRAIN,}$ 100 mA / div., 4 ms / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Measured V_{PK} at Open Load Condition: 504.98 V_{PK}.
Measured I_{PK} at Open Load Condition: 532 mA_{PK}.

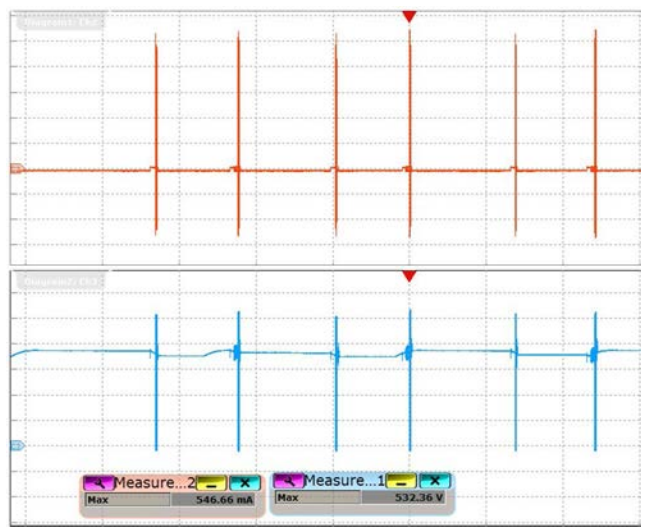

Figure 78 – 265 VAC, 50 Hz Running Open Load.
Middle: $I_{DRAIN,}$ 100 mA / div., 4 ms / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.
Measured V_{PK} at Open Load Condition: 532.36 V_{PK}.
Measured I_{PK} at Open Load Condition: 546 mA_{PK}.

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12.11 Output No-Load Characteristic

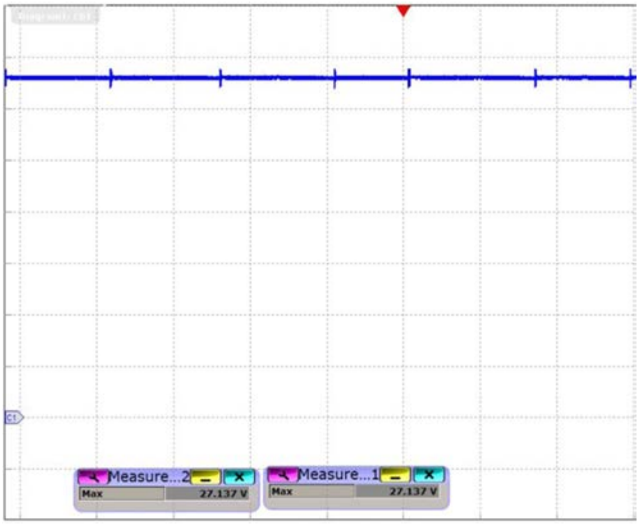

Figure 79 – 195 VAC, 50 Hz Running No-Load.
V_{OUT} at No-Load, 4 V / div., 5 ms / div.
Measured $V_{OUT(PK)}$ at No-Load: 27.13 V_{PK}.

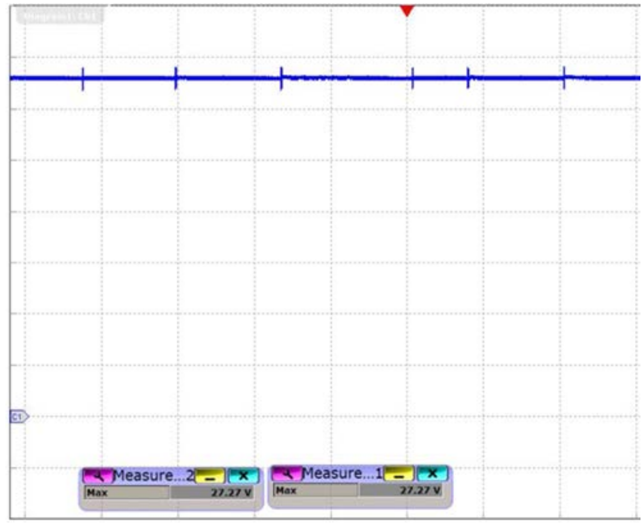

Figure 80 – 230 VAC, 50 Hz Running No-Load.
V_{OUT} at No-Load, 4 V / div., 5 ms / div.
Measured $V_{OUT(PK)}$ at No-Load: 27.27 V_{PK}.

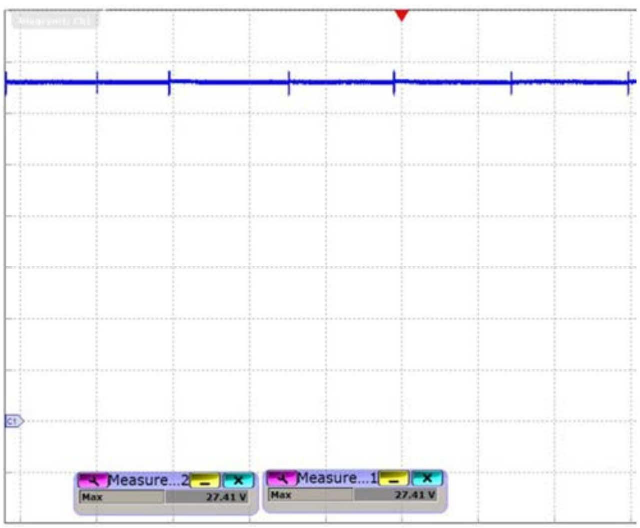

Figure 81 – 240 VAC, 50 Hz Running No-Load.
V_{OUT} at No-Load, 4 V / div., 5 ms / div.
Measured $V_{OUT(PK)}$ at No-Load: 27.41 V_{PK}.

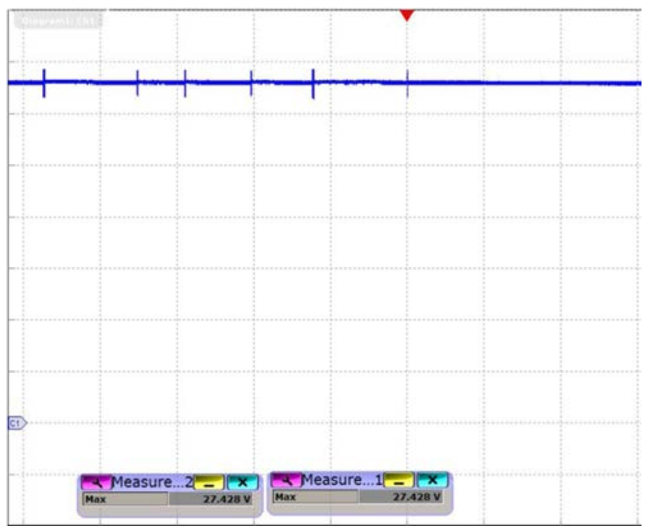

Figure 82 – 265 VAC, 50 Hz Running No-Load.
V_{OUT} at No-Load, 4 V / div., 5 ms / div.
Measured $V_{OUT(PK)}$ at No-Load: 27.42 V_{PK}.

12.12 Output Voltage Ripple Using a 24 V LED String

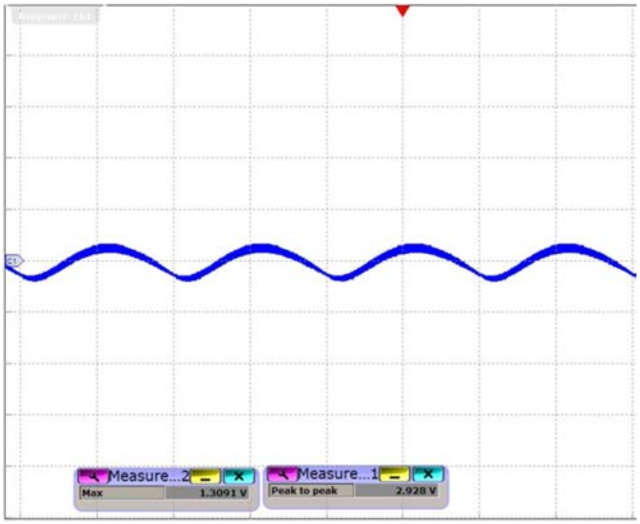

Figure 83 – 195 VAC, 50 Hz.
$V_{OUTRIPPLE}$, 4 V / div., 5 ms / div.
Measured V_{OUT} Ripple: 2.93 V_{PK-PK}.

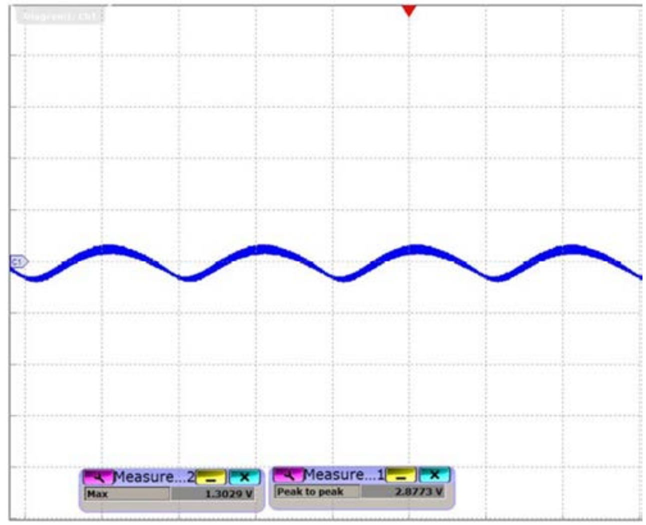

Figure 84 – 230 VAC, 50 Hz.
$V_{OUTRIPPLE}$, 4 V / div., 5 ms / div.
Measured V_{OUT} Ripple: 2.88 V_{PK-PK}.

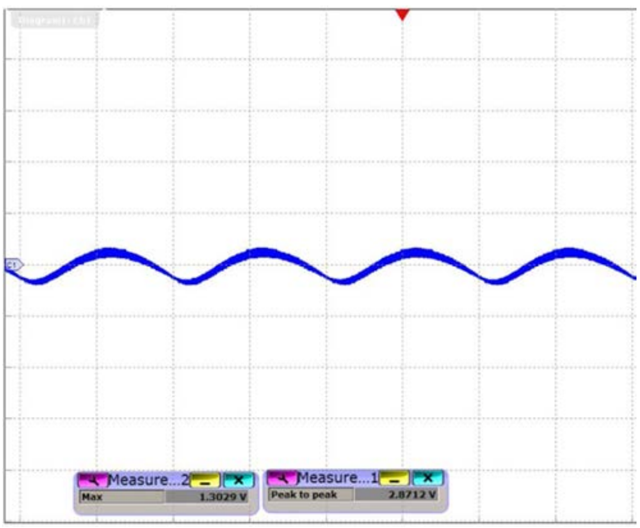

Figure 85 – 240 VAC, 50 Hz.
$V_{OUTRIPPLE}$, 4 V / div., 5 ms / div.
Measured V_{OUT} Ripple: 2.87 V_{PK-PK}.

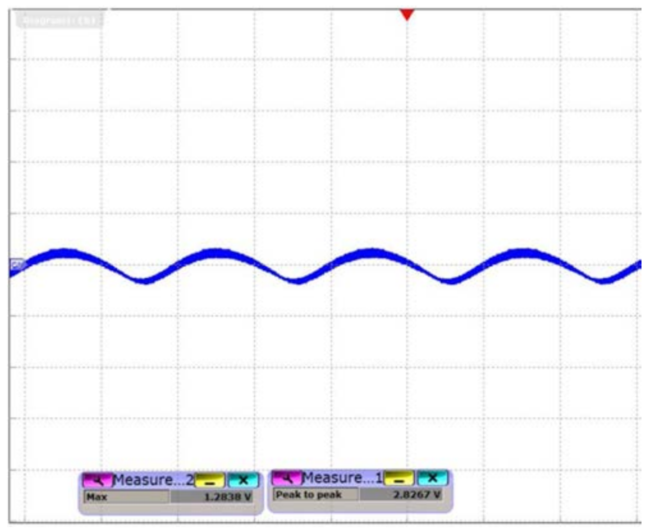

Figure 86 – 265 VAC, 50 Hz.
$V_{OUTRIPPLE}$, 4 V / div., 5 ms / div.
Measured V_{OUT} Ripple: 2.83 V_{PK-PK}.

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13 Conducted EMI

13.1 Test Set-up

Equipment and load used:

1. Rhode and Schwarz ENV216 two line V-network
2. Rhode and Schwarz ESRP EMI test receiver
3. Hioki 3322 power hi tester
4. CHROMA measurement test fixture
5. 24 V LED string load with input voltage set at 230 VAC.

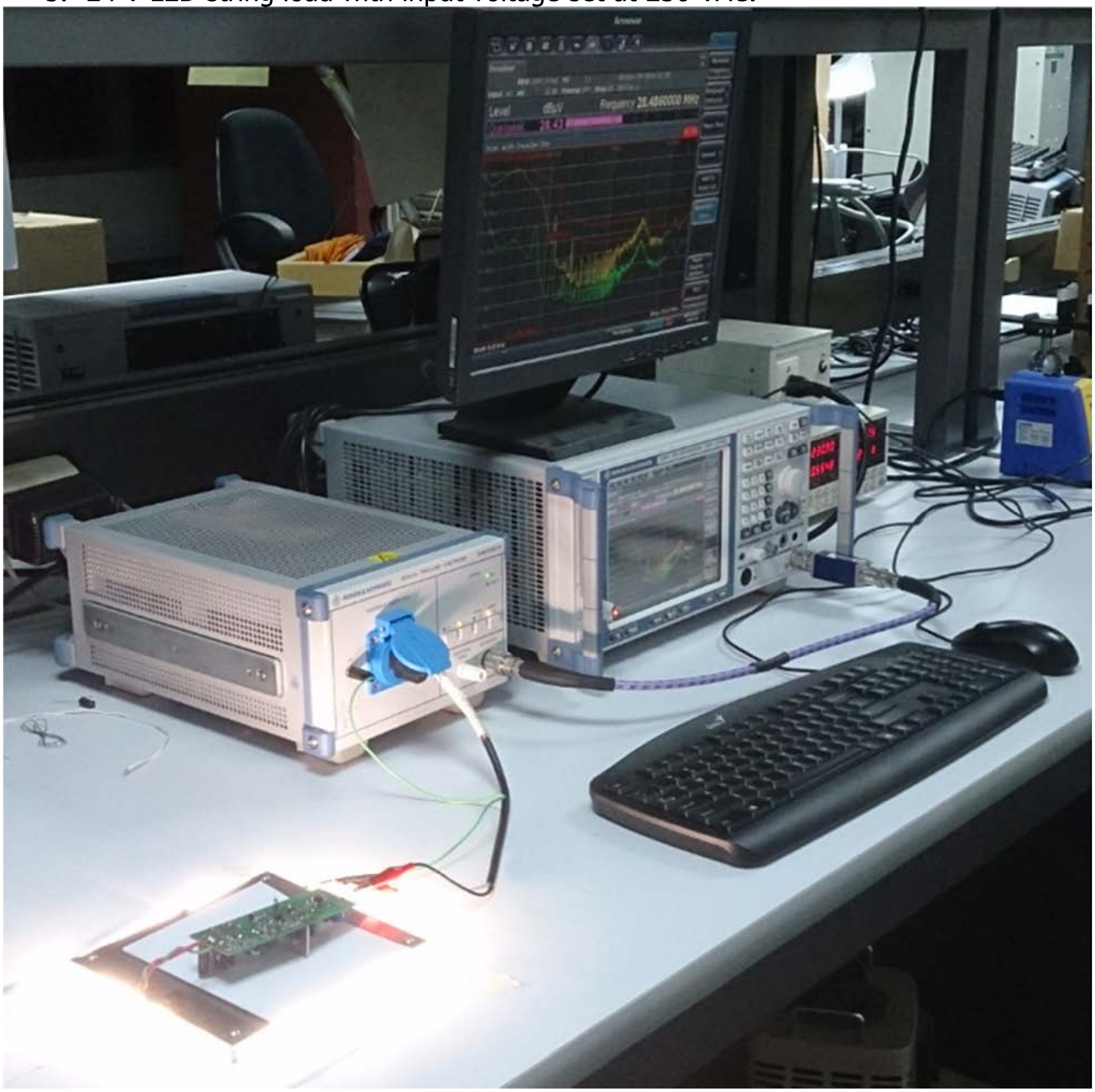

Figure 87 – Conducted EMI Test Set-up.

13.2 230 VAC Test Result

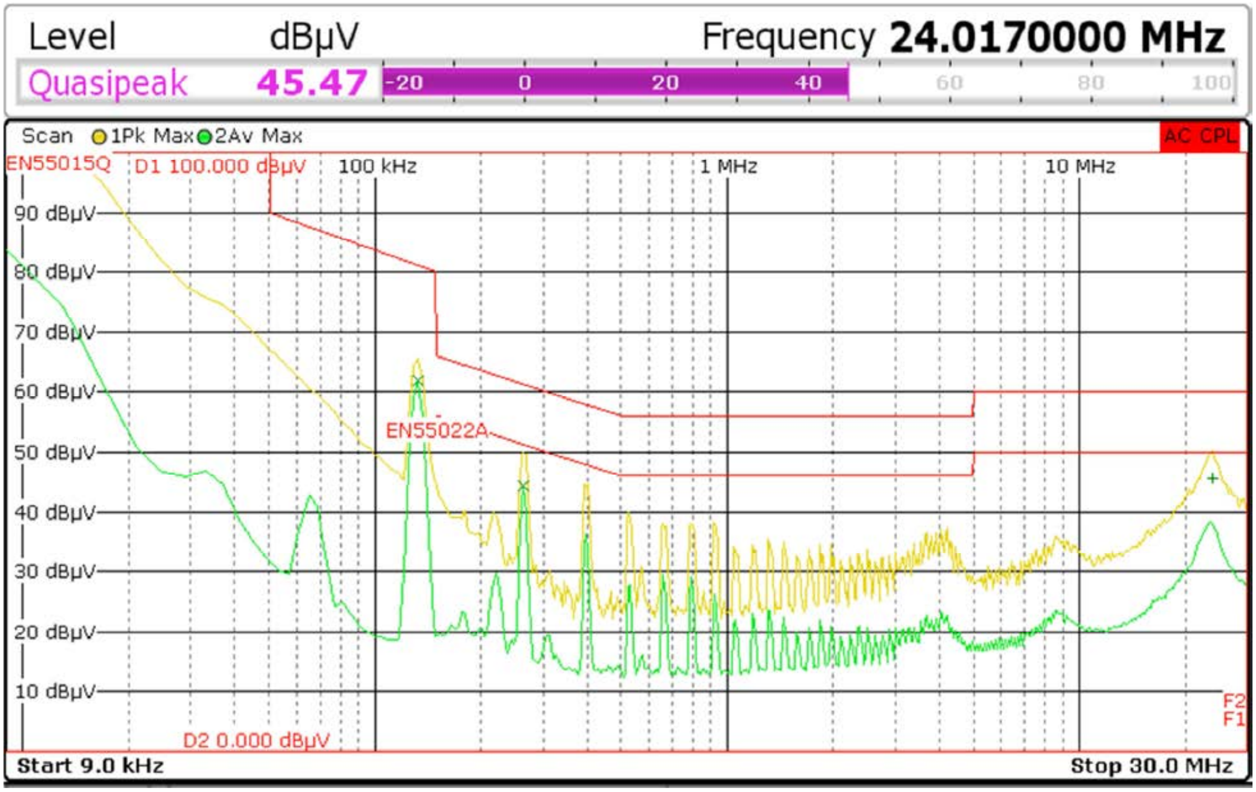

Figure 88 – Conducted EMI, ~24 V LED Load, 230 VAC, 60 Hz, and EN55015 B Limits.

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Trace1: EN55015Q Trace2: EN55022A

Trace/Detector	Frequency	Level dBµV	DeltaLimit
2 Average	133.0000 kHz	61.95 L1	
2 Average	265.0000 kHz	44.25 N	-7.02 dB
1 Quasi Peak	24.0170 MHz	45.47 N	-14.53 dB

Figure 89 – Conducted EMI, Final Measurement Results.

14 Line Surge

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

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

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

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14.1 Differential Surge Test Result and Waveform

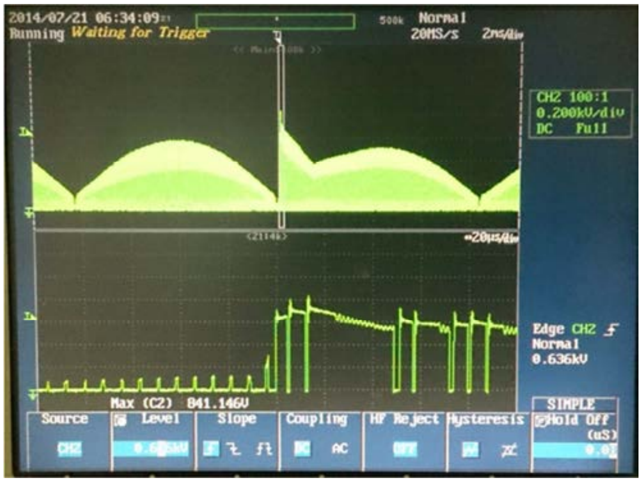

Figure 90 – 230 VAC, 50 Hz, +1000, 0º.
Upper: V_{DRAIN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div. (Zoomed).
Measured Peak Voltage: 841.146 V_{PK}.

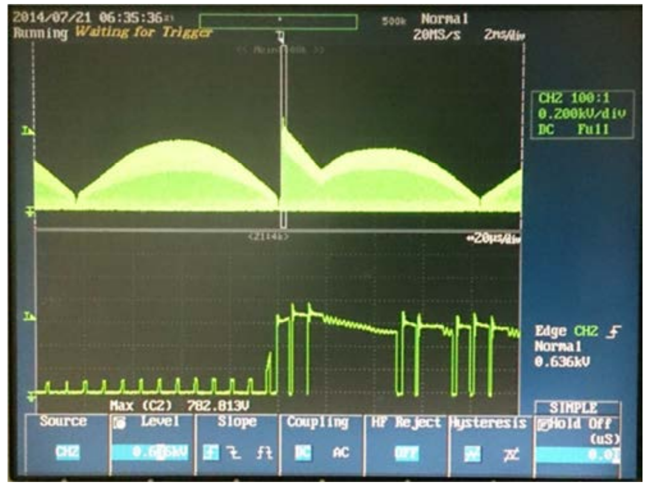

Figure 91 – 230 VAC, 50 Hz, -1000, 0º.
Upper: V_{DRAIN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div. (Zoomed).
Measured Peak Voltage: 782.813 V_{PK}.

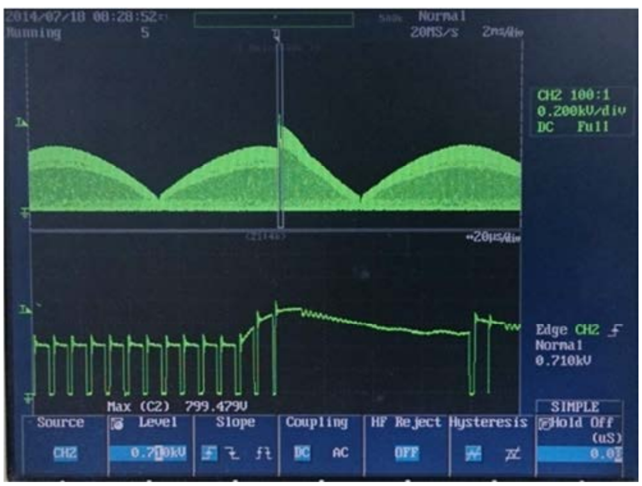

Figure 92 – 230 VAC, 50 Hz, +1000, 90º.
Upper: V_{DRAIN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div. (Zoomed).
Measured Peak Voltage: 799.479 V_{PK}.

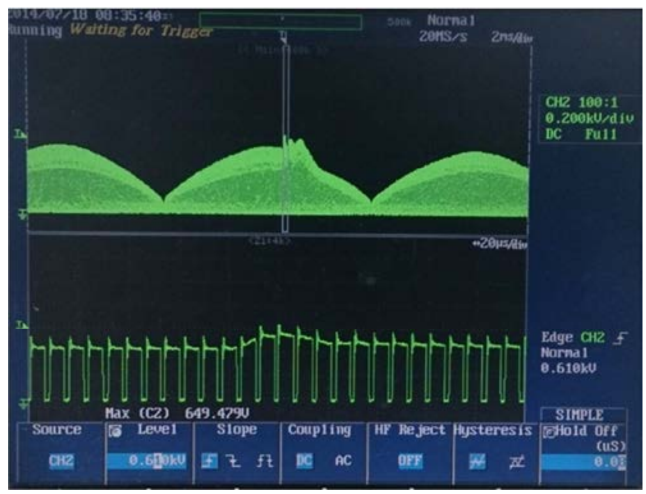

Figure 93 – 230 VAC, 50 Hz, -1000, 90º.
Upper: V_{DRAIN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div. (Zoomed).
Measured Peak Voltage: 649.479 V_{PK}.

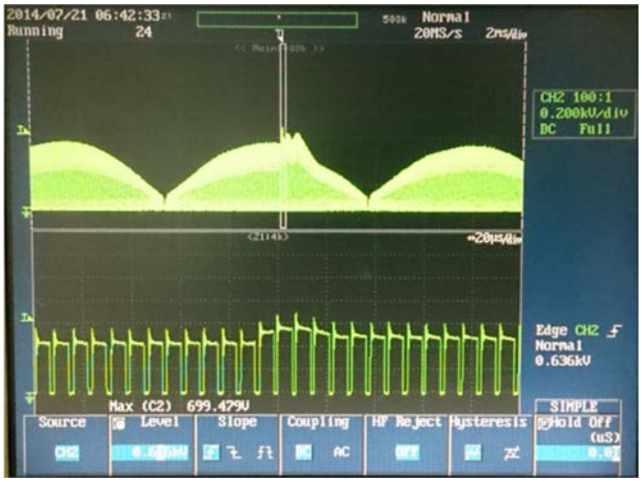

Figure 94 – 230 VAC, 50 Hz, +1000, 270º.
Upper: V_{DRAIN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div. (Zoomed).
Measured Peak Voltage: 699.479 V_{PK}.

Figure 95 – 230 VAC, 50 Hz, -1000, 270º.
Upper: V_{DRAIN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div. (Zoomed).
Measured Peak Voltage: 866.146 V_{PK}.

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14.2 Ring Wave Test Result and Waveform

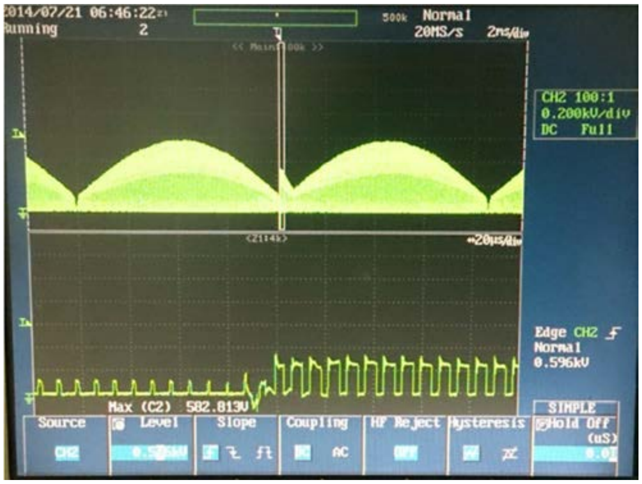

Figure 96 – 230 VAC, 50 Hz, +2500, 0º.
Upper: V_{DRAIN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div. (Zoomed).
Measured Peak Voltage: 582.813 V_{PK}.

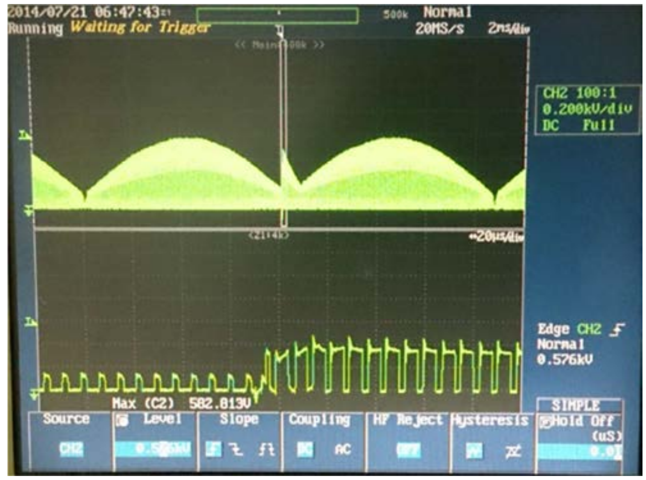

Figure 97 – 230 VAC, 50 Hz, -2500, 0º.
Upper: V_{DRAIN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div. (Zoomed).
Measured Peak Voltage: 582.813 V_{PK}.

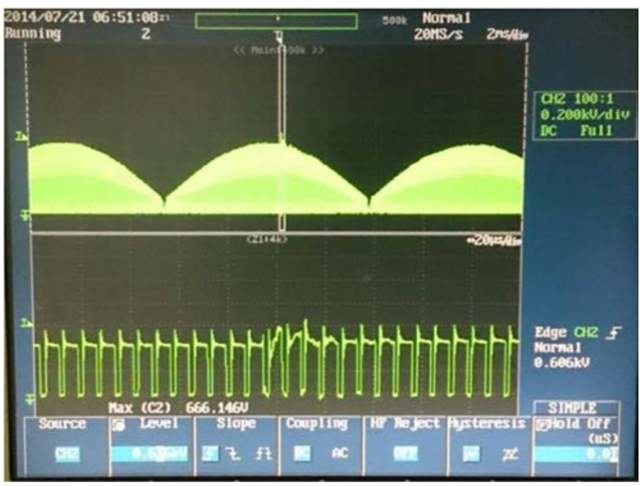

Figure 98 – 230 VAC, 50 Hz, +2500, 90º.
Upper: V_{DRAIN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div. (Zoomed).
Measured Peak Voltage: 666.146 V_{PK}.

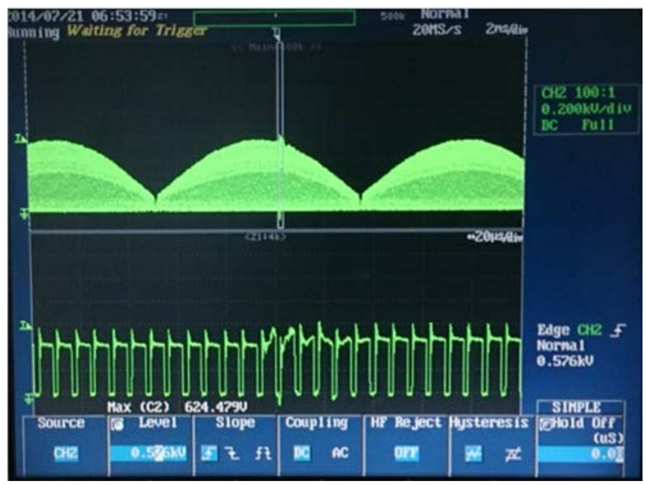

Figure 99 – 230 VAC, 50 Hz, -2500, 90º.
Upper: V_{DRAIN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div. (Zoomed).
Measured Peak Voltage: 624.479 V_{PK}.

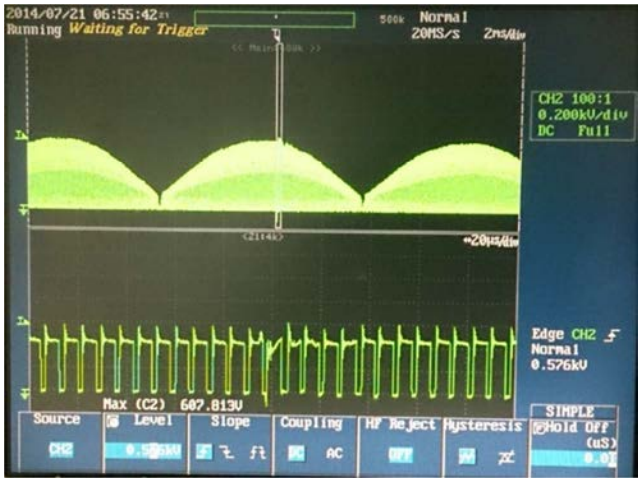

Figure 100 – 230 VAC, 50 Hz, +2500, 270º.
Upper: V_{DRAIN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div. (Zoomed).
Measured Peak Voltage: 607.813 V_{PK}.

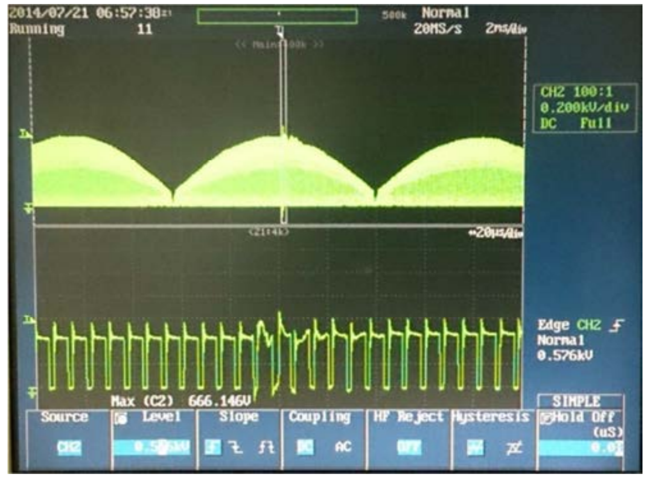

Figure 101 – 230 VAC, 50 Hz, -2500, 270º.
Upper: V_{DRAIN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div. (Zoomed).
Measured Peak Voltage: 666.146 V_{PK}.

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14.3 Additional Surge Testing (At Different Peak Detect Capacitor Value, C3)

When compensating the current needed for the V pin of LYTSwitch-4 (U1) by adjusting pull down resistor R28 the no-load input power, constant current (CC) regulation, and overall efficiency must be taken into consideration. A high pull down resistor value will result in a lower peak voltage detection and a low pull down resistor will result in a higher peak voltage detection but better CC regulation. If a lower pull down resistor is desired, peak voltage detection capacitor C3 must be adjusted accordingly. Below are the results for different capacitance value.

14.3.1 Using 10 μF Peak Detect Capacitor Value

Figure 102 – Measured Peak Voltage: 828 $V_{PK.}$

Test Condition:
Phase Angle = 90º (Worst Case Condition)
Input Voltage = 230 VAC
Surge Voltage = ±1000 V

14.3.2 Using 15 μF Peak Detect Capacitor Value

Figure 103 – Measured Peak Voltage: 788 $V_{PK.}$

Test Condition:
Phase Angle = 90º (Worst Case Condition)
Input Voltage = 230 VAC
Surge Voltage = ±1000 V

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14.3.3 Using 22 μF Peak Detect Capacitor Value

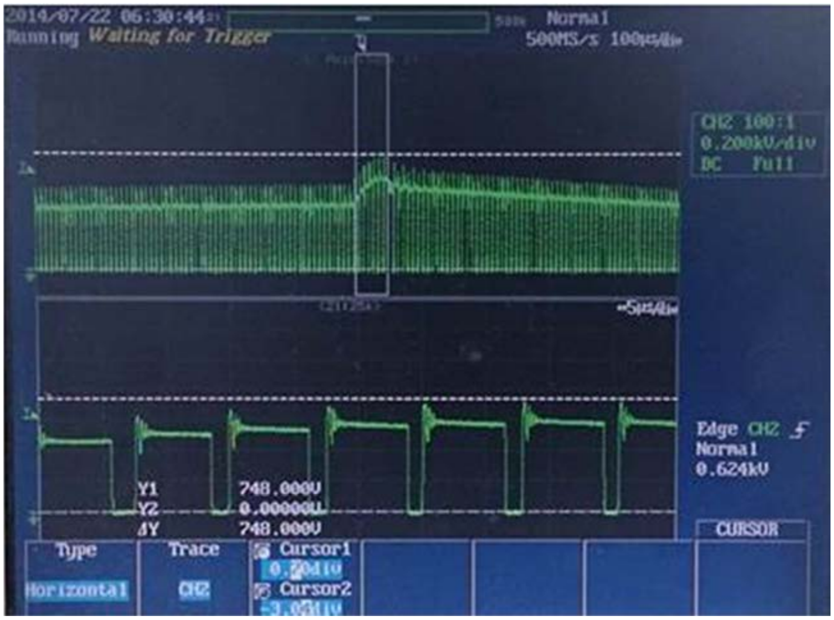

Figure 104 – Measured Peak Voltage: 748 V_{PK}.

Test Condition:
Phase Angle = 90º (Worst Case Condition)
Input Voltage = 230 VAC
Surge Voltage = ±1000 V

14.4 Test Summary

TEST CONDITION	MEASURED PEAK VOLTAGE
90º phase angle, 230 VAC, ±1000 V, 10 μF peak detect capacitance	828 V_{PK}
90º phase angle, 230 VAC, ±1000 V, 15 μF peak detect capacitance	788 V_{PK}
90º phase angle, 230 VAC, ±1000 V, 22 μF peak detect capacitance	748 V_{PK}

15 Revision History

Date	Author	Revision	Description and Changes	Reviewed
13-May-15	JMQC	1.0	Initial Release	Apps & Mktg

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