Design Example Report

Title	***16.2 W Low THD High Efficiency Non-Isolated Tapped Buck, Universal Input LED Driver Using LYTSwitch™-4 LYT4214E***
Specification	95 VAC – 265 VAC Input; 36 V_{TYP}, 450 mA Output
Application	LED Tube Driver
Author	Applications Engineering Department
Document Number	DER-431
Date	March 31, 2015
Revision	1.0

Summary and Features

- Combined single-stage power factor correction and constant current (CC) output
- Universal input voltage
- Integrated protection features
  - Output short-circuit protection with auto-recovery
  - Input and output overvoltage protection
  - Open LED string protection
  - Auto-recovering thermal shutdown with large hysteresis
  - No damage during brown-out conditions
- PF >0.9 at 115 VAC and 230 VAC
- THD <15% at 115 VAC and 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.

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1 Introduction

This document describes a non-isolated, tapped buck, universal input 16 W LED power supply configured for use as tube driver. The design makes use of the LYT4214E IC, from the LYTSwitch-4 family, which allows the design to achieve high efficiency, high power factor (PF), low THD and accurate regulation.

The driver was designed to deliver a nominal LED string voltage of 36 V at 450 mA from an input voltage range of 95 VAC to 265 VAC (50 Hz typical).

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

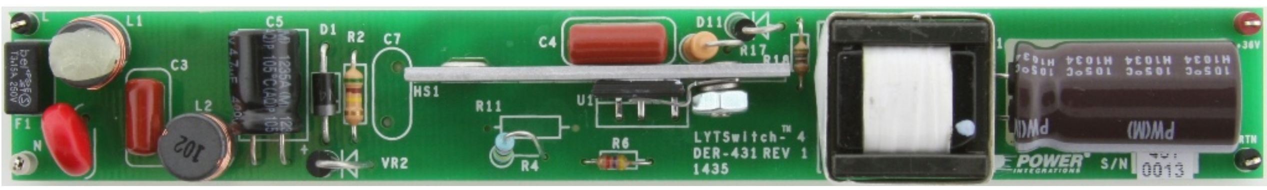

Figure 1 – Populated Circuit Board, Top View.

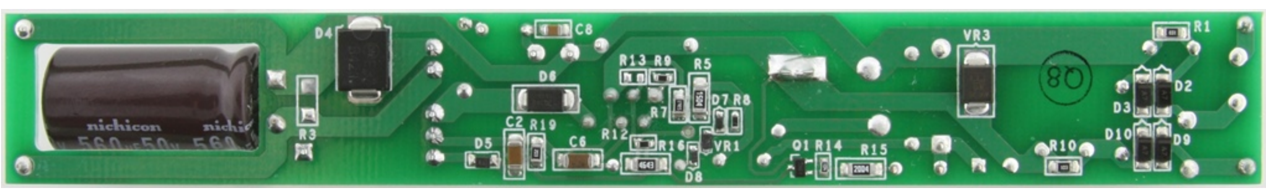

Figure 2 – Populated Circuit Board, Bottom View.

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}	95	115/230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}		50/60		Hz	
Output						
Output Voltage	V_{OUT}		36		V	
Output Current	I_{OUT}		450		mA	
Total Output Power						
Continuous Output Power	P_{OUT}		16.2		W	
Efficiency						
Full Load, 115 VAC	η				%	Measured at P_{OUT} 25 °C
Full Load, 230 VAC	η				%	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		0.92				Measured at $V_{OUT(TYP)}$, $I_{OUT(TYP)}$ and 120 VAC, 50 Hz
Ambient Temperature	T_{AMB}		30		°C	Free convection, sea level

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3 Schematic

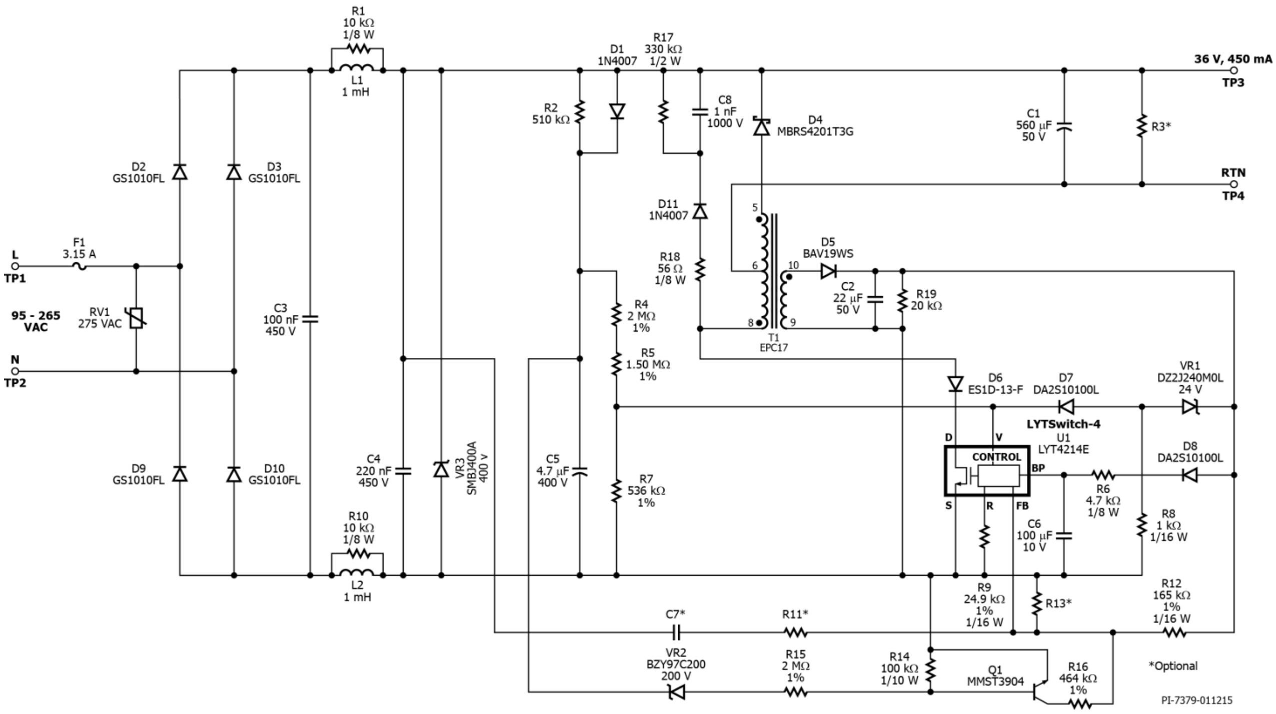

Figure 3 – Schematic.

Note: R3, R11, R13 and C3 are optional components.

4 Circuit Description

The LYTSwitch-4 family are devices that combine a single-stage, power factor corrected controller with a monolithically integrated 725 V power MOSFET for use in LED driver applications. This design uses the LYT4214E IC and is configured for use in a non-isolated, single-stage tapped-buck topology. It provides a regulated constant current output while maintaining high efficiency, high power factor and low THD across a universal AC mains supply.

4.1 Input EMI Filtering

The AC input voltage is rectified to a pulsating DC by diodes D2, D3, D9 and D10. A pi (π) filter consisting of C3, C4, L1 and L2 serves as an EMI filter. Resistors R1 and R10 are connected across L1 and L2 to damp any LC resonance. Fuse F1 provides protection from any component failure and RV1 clamps the maximum voltage at the input during differential line surge events. Diode VR3 is an optional component which may be used to increase the surge withstand voltage.

4.2 Power Circuit

A low-side tapped-buck topology was used to provide high efficiency while maintaining a very low %iTHD across the universal input range. This topology allows the use of smaller magnetic component size, reduces current stress on the LYT4214E and reduces voltage stress on the freewheeling diode D4. A turns ratio of 4:1 was chosen to minimize the maximum reverse voltage on the freewheeling diode while keeping the maximum Drain voltage across LYT4214E below its limit.

During the LYT4214E on-time, current flows to the output through the primary and secondary sides of T1. Upon switch turn-off, energy stored in the primary side of the T1 inductance will be coupled to the secondary side of the inductor. Current will then flow through the freewheeling diode D4 to the output. Output capacitor C1 serves to reduce output ripple.

Diode D6 is a blocking diode and prevents reverse current from flowing through the LYT4214E when the voltage across C4 falls below the output voltage (close to the zero crossing of the input AC voltage).

A voltage clamp is formed by R17, C8 and D11 to limit the voltage across the LYT4214E caused by the leakage inductance of T1.

Peak line voltage information is provided by the peak detect circuit consisting of R2, D1, and C5. A current will flow to the VOLTAGE MONITOR (V) pin through R4 and R5 due to this voltage. This information is then used by the LYT4214E IC for regulation as well as power factor correction. Resistor R7 was used to fine tune the output current regulation across the input voltage range. A value of 4.7 μF was chosen for C5 to provide enough capacitance to absorb energy during an input voltage surge.

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The line overvoltage shutdown function, sensed via the V pin current, extends the rectified line voltage withstand (during surges and line swells) to the BV_{DSS} rating of the internal power MOSFET.

Capacitor C6 provides local decoupling for the BP pin of U1 which is the supply pin for the internal controller. During start-up, C6 is charged to ~6 V from an internal high-voltage current source connected to the D pin of U1. Capacitor C6 is also chosen to be 100 μF to enable the device to operate in reduced-power (high efficiency) mode.

The REFERENCE pin of U1 is tied to ground (SOURCE) via 24.9 kΩ resistor R9.

4.3 Output Feedback

The LYTSwitch-4 IC is a primary side regulated controller, and as such makes use of the bias winding as feedback. The network consisting of D5, C2 and R19 produces a voltage which together with R12 provides a current which is fed to the LYT4214E's FEEDBACK pin. This sets the output current to the LEDs. Resistor R13 is an optional component which when used serves as a fine-tuning resistor to center the output current.

4.4 Bias Voltage and Open LED Protection

The voltage across C2 serves as an external bias supply connected in parallel to C6 through R6 and D8 to increase LED driver efficiency.

Zener diode VR1 and D7 provides open LED-string protection. Voltage across the bias winding will increase due to an open LED-string which increases current flow to the VOLTAGE MONITOR (V) pin of LYT4214E. Once I_{OV} threshold is exceeded, the device will to the enter skip-cycle operation. Resistor R8 serves as a bleeder, which is used to prevent any miss-trigger of VR1 caused by leakage current through the device.

4.5 Feedback Offset Circuit

The feedback-current offset circuit consisting of Zener diode VR2, resistors R15, R14, R16 and transistor Q1 serves to shift the level of the feedback current during high-line operation. Once the voltage across C4 exceeds VR2 threshold, Zener diode VR2 will drive Q1, which then draws current from the FB pin. The offset circuit ensures that the output current stays within regulation during high-line operation.

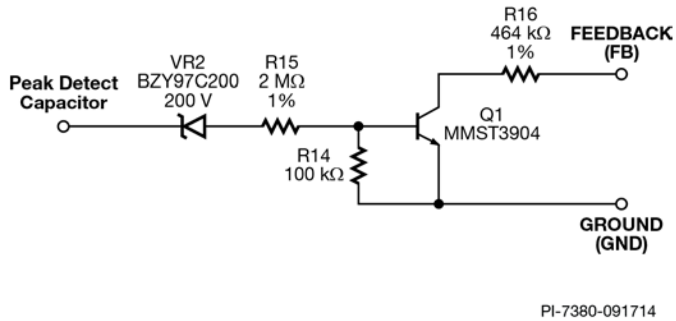

Figure 4 – FB Current Offset Circuit Schematic

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5 PCB Layout

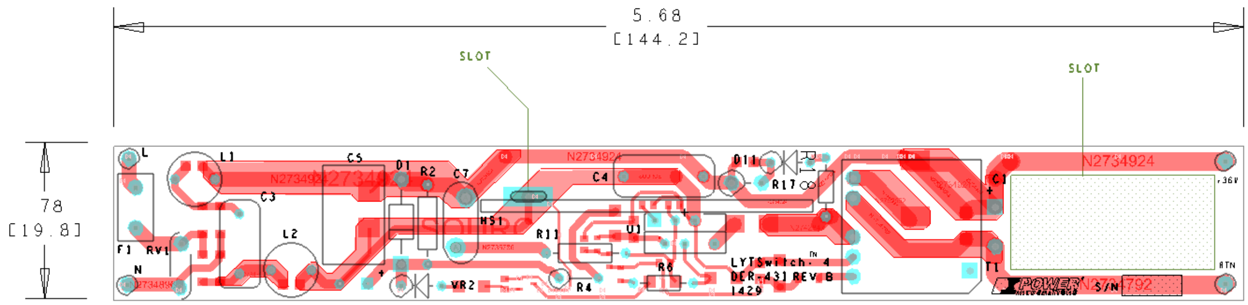

Figure 5 – Top Side.

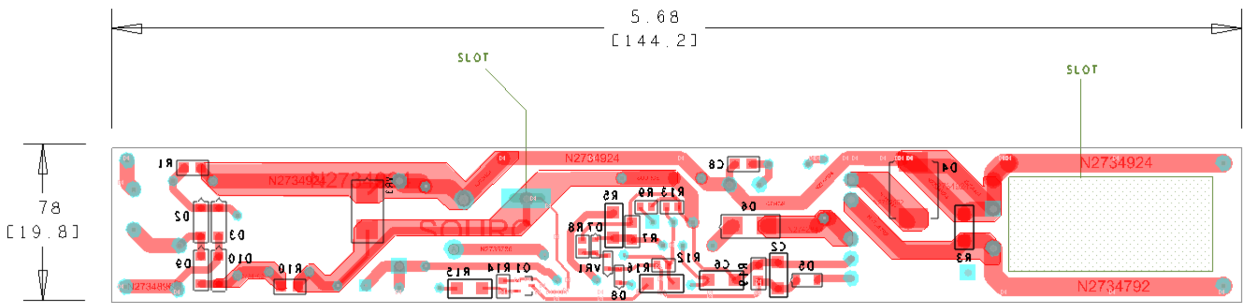

Figure 6 – Bottom Side.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	C1	560 μF, 50 V, Electrolytic, Gen. Purpose, (12.5 x 25)	UPW1H561MHD	Nichicon
2	1	C2	2.2 μF, 50 V, Ceramic, Y5V, 1206	UMK316F225ZG-T	Taiyo Yuden
3	1	C3	100 nF, 450 V, Film	MEXXD31004JJ1	Duratech
4	1	C4	220 nF, 450 V, Film	MEXXF32204JJ	Duratech
5	1	C5	4.7 μF, 400 V, Electrolytic, (8 x 11.5)	TAQ2G4R7MK0811MLL3	Taicon
6	1	C6	100 μF, 10 V, X5R, 1206	C3216X5R1A107M	TDK
7	1	C8	1 nF, 1000 V, Ceramic, X7R, 0805	C0805C102KDRACTU	Kemet
8	2	D1 D11	1000 V, 1 A, Rectifier, DO-41	1N4007-E3/54	Vishay
9	4	D2 D3 D9 D10	1000 V, 1 A, Standard Recovery, SOD-123FL	GS1010FL	PANJIT Micro Commercial
10	1	D4	200 V, 4 A, Schottky, SMC, DO-214AB	MBRS4201T3G	ON Semi
11	1	D5	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diodes, Inc.
12	1	D6	200 V, 1 A, Ultrafast Recovery, 25 ns, DO-214AC	ES1D-13-F	Diodes, Inc.
13	2	D7 D8	DIODE SML SIG 80 V 100 MA SSMINI2	DA2S10100L	Panasonic
14	1	F1	3.15 A, 250V, Slow, RST	507-1181	Belfuse
15	1	HS1	Heat Sink, Custom, Al, 3003, 0.062" Thk		Custom
16	2	L1 L2	1 mH, 0.30 A, Ferrite Core	CTCH895F-102K	CT Parts
17	1	Q1	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-323	MMST3904-7-F	Diodes, Inc.
18	2	R1 R10	10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
19	1	R2	510 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-510K	Yageo
20	1	R4	2.00 MΩ, 1%, 1/4 W, Metal Film	RNF14FTD2M00	Stackpole
21	1	R5	1.50 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1504V	Panasonic
22	1	R6	4.7 kΩ, 5%, 1/8 W, Carbon Film	CF18JT4K70	Stackpole
23	1	R7	536 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF5363V	Panasonic
24	1	R8	1 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1001V	Panasonic
25	1	R9	24.9 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2492V	Panasonic
26	1	R12	165 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1653V	Panasonic
27	1	R14	100 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ104V	Panasonic
28	1	R15	2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
29	1	R16	464 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF4643V	Panasonic
30	1	R17	330 kΩ, 5%, 1/2 W, Carbon Film	CFR-50JB-330K	Yageo
31	1	R18	56 Ω, 5%, 1/8 W, Carbon Film	CF18JT56R0	Stackpole
32	1	R19	20 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ203V	Panasonic
33	1	RV1	275 V, 23 J, 7 mm, RADIAL	V275LA4P	Littlefuse
34	1	T1	Bobbin, EPC17, Horizontal, 10 pins Transformer	BEPC-17-1110CPHFR SNX-R1773	TDK Santronics
35	2	TP4/RTN, TP1/L	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone
36	1	TP2/N	Test Point, WHT, Miniature THRU-HOLE MOUNT	5002	Keystone
37	1	TP3/+36V	Test Point, RED, Miniature THRU-HOLE MOUNT	5000	Keystone
38	1	U1	LYTSwitch-4, eSIP-7C	LYT4214E	Power Integrations
39	1	VR1	Diode, Zener, 24 V, 200 MW, SMINI2	DZ2J240M0L	Panasonic
40	1	VR2	200 V, 1.5 W, DO-41	BZY97C200-TR	Vishay
41	1	VR3	400 V, 600 W, 5%, DO214AC (SMB)	SMBJ400A	Littlefuse

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7 Inductor Specification

7.1 Electrical Diagram

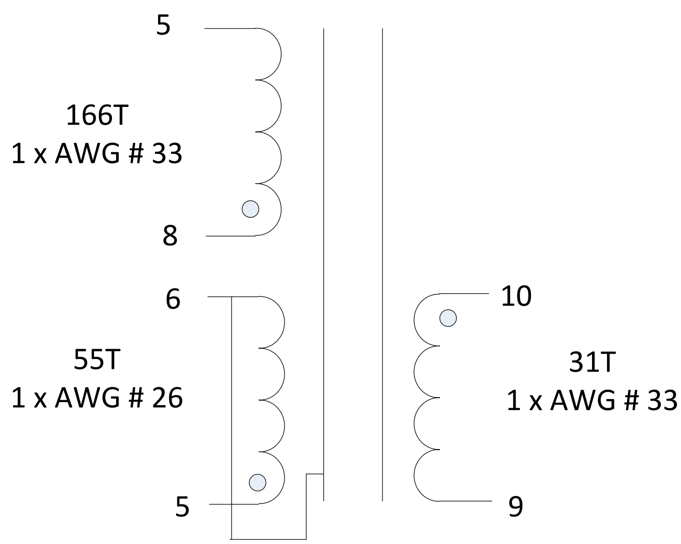

Figure 7 – Inductor Electrical Diagram.

7.2 Electrical Specifications

Primary Inductance	Pins 6-8, all other windings open, measured at 100 kHz, 0.4 RMS.	1.9 mH ±5%
Resonant Frequency	Pins 6-8, all other windings open.	1 MHz (Min.)

7.3 Materials

Item	Description
[1]	Core: EPC-17.
[2]	Bobbin: BEPC-17-1110-CPHFR. PI p/n 25-00976-00.
[3]	Magnet Wire: #33 AWG.
[4]	Magnet Wire: #26 AWG.
[5]	Non-insulated Wire: #31 AWG.
[6]	Tape: 3M 1298 Polyester Film, 9.9 mm wide.
[7]	Tape: 3M 1298 Polyester Film, 6 mm wide.

7.4 Inductor Build Diagram

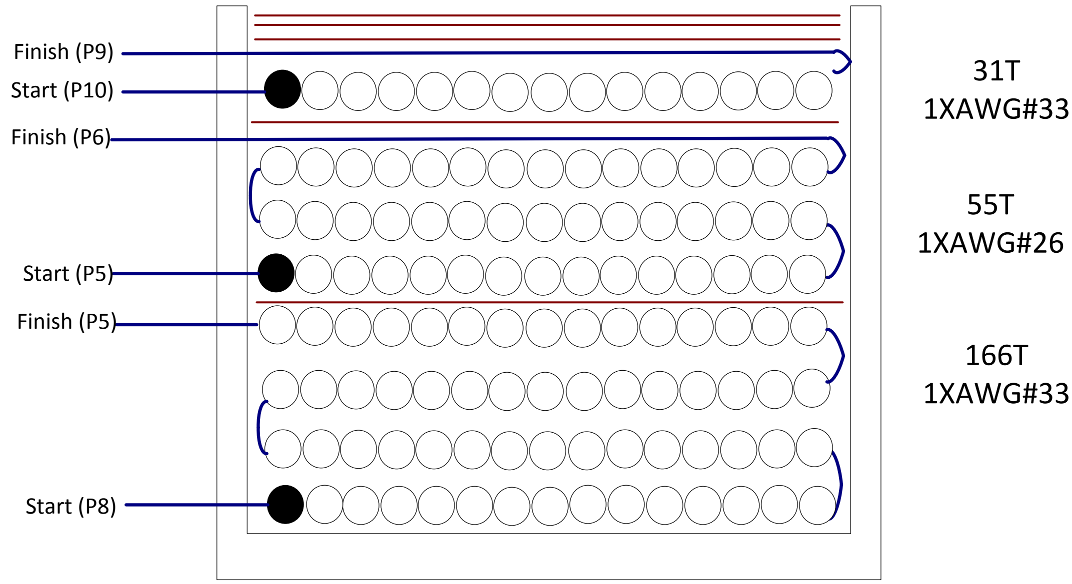

Figure 8 – Inductor Build Diagram.

7.5 Inductor Construction

Bobbin Preparation	Place the bobbin item [2] on the mandrel with pins 5-10 on the left.
Winding 1	Use wire item [3], start at pin 8 and wind 166 turns in clockwise direction. Terminate end of wire at pin 5.
Insulation	Fix with 1 layer tape item [6] for insulation.
Winding 2	Use wire item [4], start at pin 5 wind 55 turns in clockwise direction. Terminate wire at pin 6.
Insulation	Fix with 1 layer tape item [6] for insulation.
Winding 3	Use wire item [3], start at pin 10 wind 31 turns in clockwise direction. Terminate wire at pin 9.
Finish	Grind core to achieve 1.9 mH inductance.
Assemble	Assemble and secure core halves with 3 layers of tape item [7]
Flux Wire Band	Wrap two turns of item [6] around core halves with tight tension. Short wires and terminate to pin 6.
Pins	Cut pins 2, 3, 4 and 7.
Finish	Dip varnish transformer assembly.

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8 Inductor Design Spreadsheet

ACDC_LYTSwitch-4_TappedBuck_102413; Rev.1.0; Copyright Power Integrations 2013	INPUT	INFO	OUTPUT	UNIT	ACDC_LYTSwitch_102413: LYTSwitch-4 Buck / Tapped Buck Design Spreadsheet
ENTER APPLICATION VARIABLES					
Topology Selection			**Tapped-Buck**		
Dimming required	**NO**		**NO**		Select "YES" option if dimming is required. Otherwise select "NO".
VACMIN	90.00		90	V	Minimum AC Input Voltage
VACNOM			230	V	Nominal AC Input Voltage
VACMAX	265.00	Info	265	V	!!!The specified input voltage range may degrade line regulation
fL			60	Hz	AC Mains Frequency
VO	36.00		36	V	Typical output voltage of LED string at full load
VO_MAX			39	V	Maximum LED string Voltage
VO_MIN			33	V	Minimum LED string Voltage
IO	0.45		0.45	A	Typical full load LED current
PO			16.2	Watts	Output Power
n	0.87		0.87		Estimated efficiency of operation
Feedback System	BIAS		BIAS		BIAS Supply
Bias Voltage			20	V	Bias Voltage
ENTER LYTSwitch VARIABLES					
LYTSwitch	**LYT4xx4**		LYT4224		Selected LYTSwitch device.
Current Limit Mode	**RED**		RED		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN			0.950	A	Minimum current limit
ILIMITMAX			1.110	A	Maximum current limit
fS			132000	Hz	Switching Frequency
fSmin			124000	Hz	Minimum Switching Frequency
fSmax			140000	Hz	Maximum Switching Frequency
IV			89.52	uA	V pin current
Rv	3.60		3.6	M-ohms	Voltage sense resistor
Rref			24.9	k-ohms	Reference Resistor Value
IFB			196	uA	FB pin current (90 uA < IFB < 210 uA)
RFB			86	k-ohms	IFB setting resistor
VDS			10	V	LYTSwitch on-state Drain to Source Voltage
VD			0.5	V	Output Winding Diode Forward Voltage Drop
VDB			0.7	V	Bias Winding Diode Forward Voltage Drop
CBP			47	uF	BP pin capacitor. Use 47uF for electrolytic cap and 100uF for ceramic cap.
Key Design Parameters					
L_TOTAL	1900.00		1900	uH	Total Inductance
N_RATIO	4.00		4.00		Turns Ratio (Np/Ns). For Buck Topology, N_RATIO=1
KP_VNOM			0.78		Ripple to Peak Current Ratio VACMIN peak)
KP_VMIN			0.52		Ripple to Peak Current Ratio VACMIN peak)

T_ON_MIN			2.31	us	Minimum T_ON at Maximum Input Voltage
Duty_Expected			0.64		Minimum duty cycle at peak of VACMIN
Expected IO (average)			0.45	A	Expected Average Output Current
IFB_VO_MAX		Info	217	uA	IFB at VO_MAX exceeds IFB(SKIP) and may affect regulation. Set VO_MAX lower
IFB_VO_MIN			178	uA	FB pin current at VO_MIN
STRESS PARAMETERS					
VDRAIN			591.77		Peak voltage at the Drain of LYTSwitch (assuming 100V leakage spike)
VDIODE			147.94		Peak voltage across freewheeling diode
IP			0.40	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
ISP			1.60	A	Peak Secondary Current (calculated at minimum input voltage VACMIN)
PIVB			68.30	V	Bias Rectifier Maximum Peak Inverse Voltage (calculated at VO_MAX, excludes leakage inductance spike)
INPUT CURRENT PARAMETERS					
IAVG			0.10	A	Average Primary Current at VACMIN
IRMS			0.16	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
DC INPUT VOLTAGE PARAMETERS					
VMIN			127	V	Peak input voltage at VACMIN
VMAX			375	V	Peak input voltage at VACMAX
VIN_OVP			446	V	Typical Line Overvoltage Protection Threshold
TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**EPC17**		EPC17		Selected Core for inductor
Core		EPC17		P/N:	PC44EPC17-Z
Bobbin		EPC17_BOBBIN		P/N:	BEPC-17-1110CPH
AE			0.228	cm^2	Core Effective Cross Sectional Area
LE			4.02	cm	Core Effective Path Length
AL			1150	nH/T^2	Ungapped Core Effective Inductance
BW			9.55	mm	Bobbin Physical Winding Width
M			0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
NLAYER_PRI	4.00		4		Number of Primary Layers
NLAYER_SEC	3.00		3		Number of Secondary Layers
TRANSFORMER PRIMARY DESIGN PARAMETERS					
L_TOTAL			1900	uH	Total Inductance
N_RATIO			4		Turns Ratio (Np/Ns). For Buck Topology, N_RATIO=1
N_TOTAL			221		Total Number of Turns (primary + secondary)
NS			55		Secondary winding turns
NB			31		Bias number of turns
ALG			39	nH/T^2	Gapped Core Effective Inductance
BM			1871	Gauss	Maximum Flux Density at PO, VMIN (BM<3000)
BP			4186	Gauss	Peak Flux Density (BP<4200)
BAC			484	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1614		Relative Permeability of Ungapped

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					Core
LG			0.71	mm	Gap Length (Lg > 0.1 mm)
BWE			38.2	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			0.18	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			325	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
TRANSFORMER SECONDARY DESIGN PARAMETERS					
Lumped parameters					
ISP			1.60	A	Peak Secondary Current
ISRMS			0.70	A	Secondary RMS Current
BWES			28.65	mm	Effective Bobbin Width
ODS			0.52	mm	Secondary Maximum Outside Diameter
INSS			0.07	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIAS			0.45	mm	Secondary Minimum Bare Conductor Diameter
AWGS			26.00	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
CMS			256.00	Cmils	Secondary Bare Conductor minimum circular mils
CMAS			356.06	Cmils/Amp	Secondary Winding Current Capacity (200 < CMAS < 500)
Estimated Input Current Harmonic Analysis					
Harmonic			Max Current (mA)	Limit (mA)	
1st Harmonic			78.62	N/A	Fundamental (mA)
3rd Harmonic			8.32	63.31	PASS. 3rd Harmonic current content is lower than the limit
5th Harmonic			0.70	35.38	PASS. 5th Harmonic current content is lower than the limit
7th Harmonic			1.14	18.62	PASS. 7th Harmonic current content is lower than the limit
9th Harmonic			1.91	9.31	PASS. 9th Harmonic current content is lower than the limit
11th Harmonic			2.25	6.52	PASS. 11th Harmonic current content is lower than the limit
13th Harmonic			2.21	5.51	PASS. 13th Harmonic current content is lower than the limit
15th Harmonic			1.85	4.78	PASS. 15th Harmonic current content is lower than the limit
THD			12.1	%	Estimated total Harmonic Distortion (THD)
FB Fine Tuning					
RFB_initial				kohms	Preliminary RFB used
IO_actual				A	Measured Output Current at VACNOM
RFB_new				kohms	New RFB

Notes:

- The addition of a resistor from the V pin to SOURCE pin (R7) provides tighter line regulation.

- Through iterative fine tuning, the FB pin resistor (RFB) needed to provide the nominal output current was found to be 165 kΩ. This value also ensures that the power supply will not go into skip-cycle mode at maximum output voltage (refer to note on IFB_VO_MAX).
- A low-line device should be used for universal input operation

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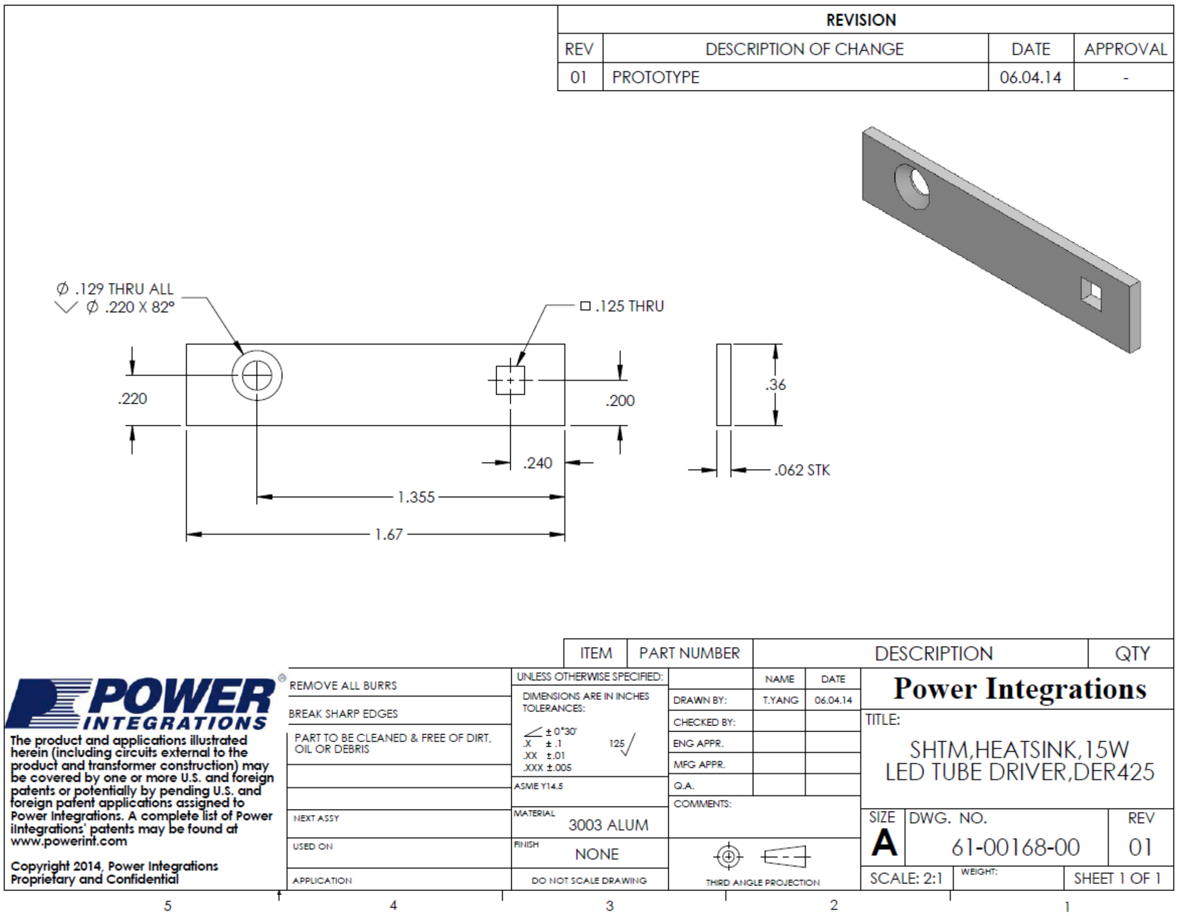
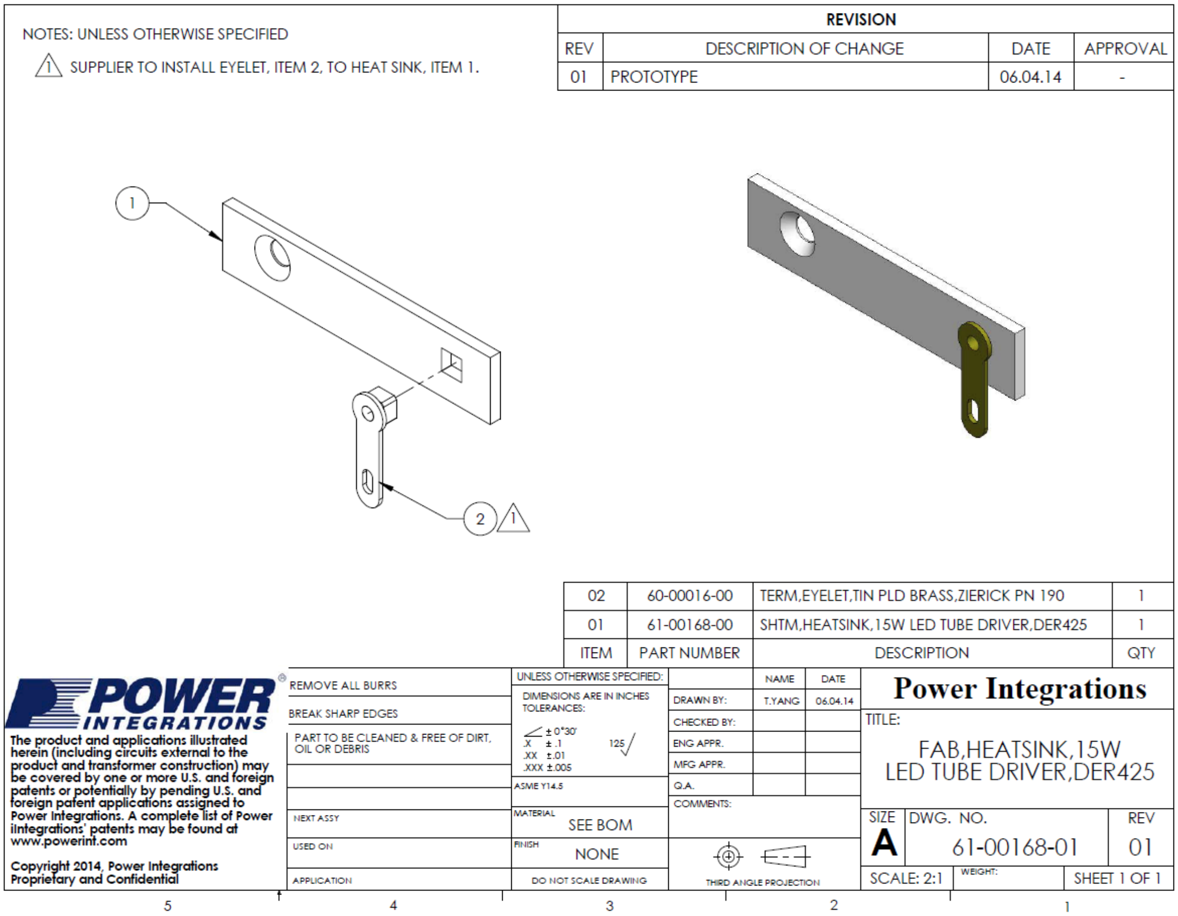
9 Heat Sink Assembly

9.1 Heat Sink Fabrication Drawing



9.2 Heat Sink Assembly Drawing



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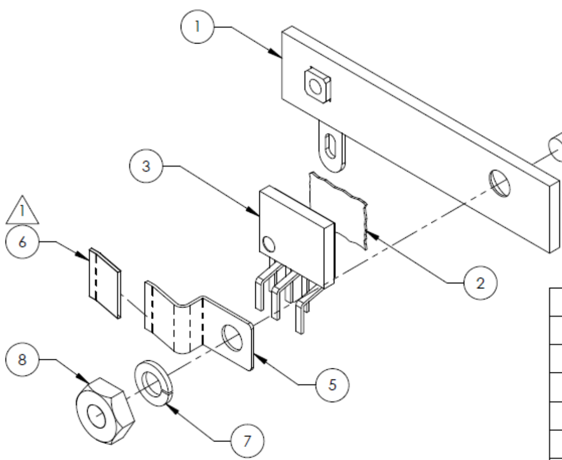
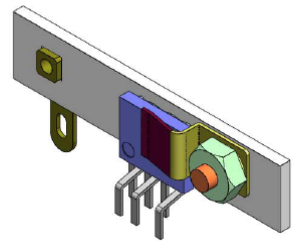
9.3 Heat Sink and U1 Assembly Drawing

NOTES: UNLESS OTHERWISE SPECIFIED

1. CUT SHRINK TUBING, ITEM 6, TO .20" IN LENGTH AND INSTALL INTO CLIP'S EDGE, ITEM 5, AS SHOWN.

REVISION			
REV	DESCRIPTION OF CHANGE	DATE	APPROVAL





ITEM	PART NUMBER	DESCRIPTION	QTY
8	75-00024-00	NUT,HEX 4-40,SS	1
7	75-00153-00	WASHER,LK,#4	1
6	62-00003-00	HEATSHRINK 3/16"X4FT BLACK	A/R
5	60-00037-00	EDGE-CLIP-14.33mmL x 6.35mmW	1
4	75-00136-00	SCR PHIL FLT HD,UNDERCUT 4-40 X .250 SST	1
3	10-00616-00	LYTSWITCH, LYT4213E, eSIP-7C	1
2	66-00084-00	THERMALLY CONDUCTIVE SILICONE GREASE	A/R
1	61-00168-01	FAB,HEATSINK,15W LED TUBE DRIVER,DER425	1

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The product and applications illustrated herein (including circuits external to the product and transformer construction) may be covered by one or more U.S. and foreign patents or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations' patents may be found at www.powerint.com

REMOVE ALL BURRS
BREAK SHARP EDGES
PART TO BE CLEANED & FREE OF DIRT, OIL OR DEBRIS
NEXT ASSY
USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
∠ ±0°30'
.X ±.1
.XX ±.01
.XXX ±.005
125 √
ASME Y14.5
MATERIAL: SEE BOM
FINISH: NONE
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN BY:	T.YANG	06.05.14
CHECKED BY:		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:
THIRD ANGLE PROJECTION

Power Integrations

TITLE: ASSY,HEATSINK,15W LED TUBE DRIVER,DER425

SIZE: A | DWG. NO. 61-00168-02 | REV 01
SCALE: 2:1 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1

10 Performance Data

All measurements were performed at room temperature using an LED load. The following data were measured using the LED load set to ~36 V. Refer to the table in Section 9.6 for measurement values.

10.1 Efficiency

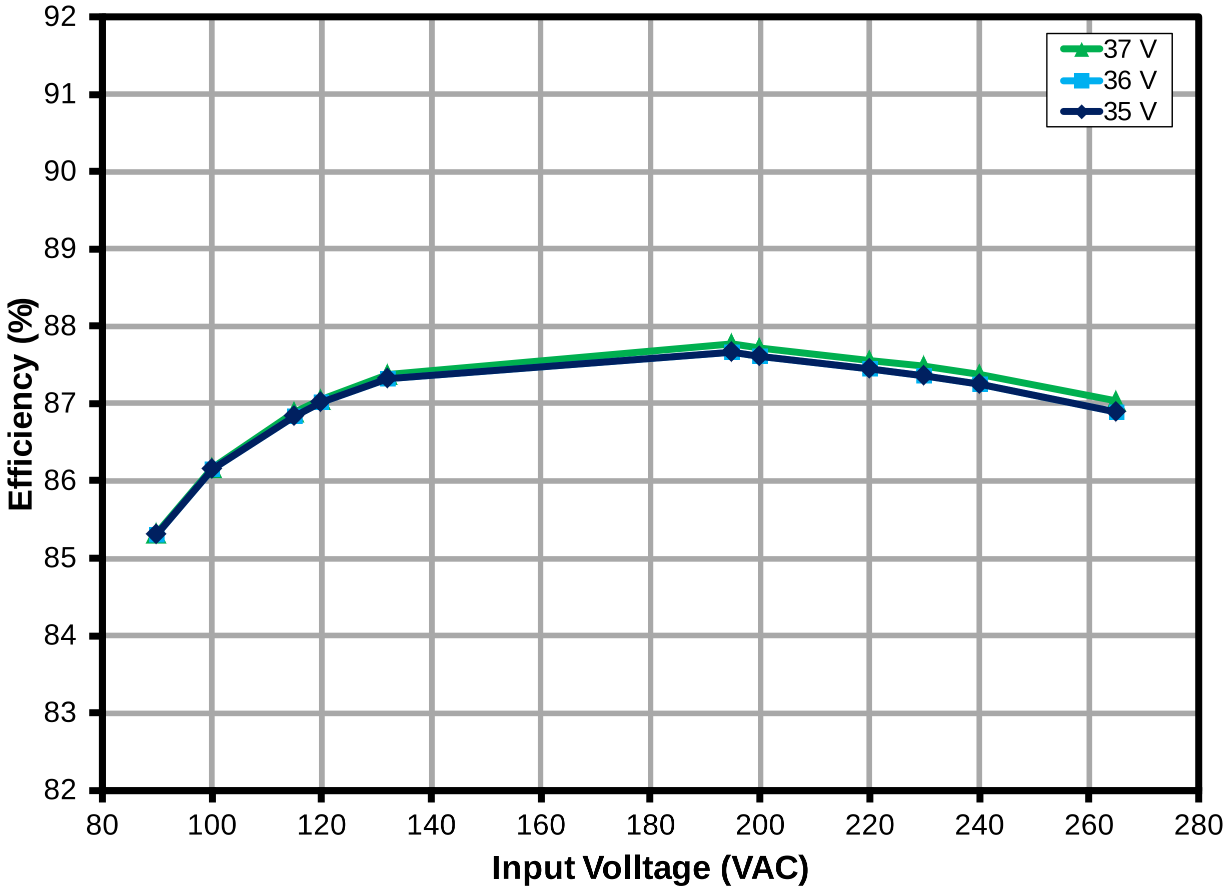

Figure 9 – Efficiency vs. Input Voltage.

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10.2 Line / Load Regulation

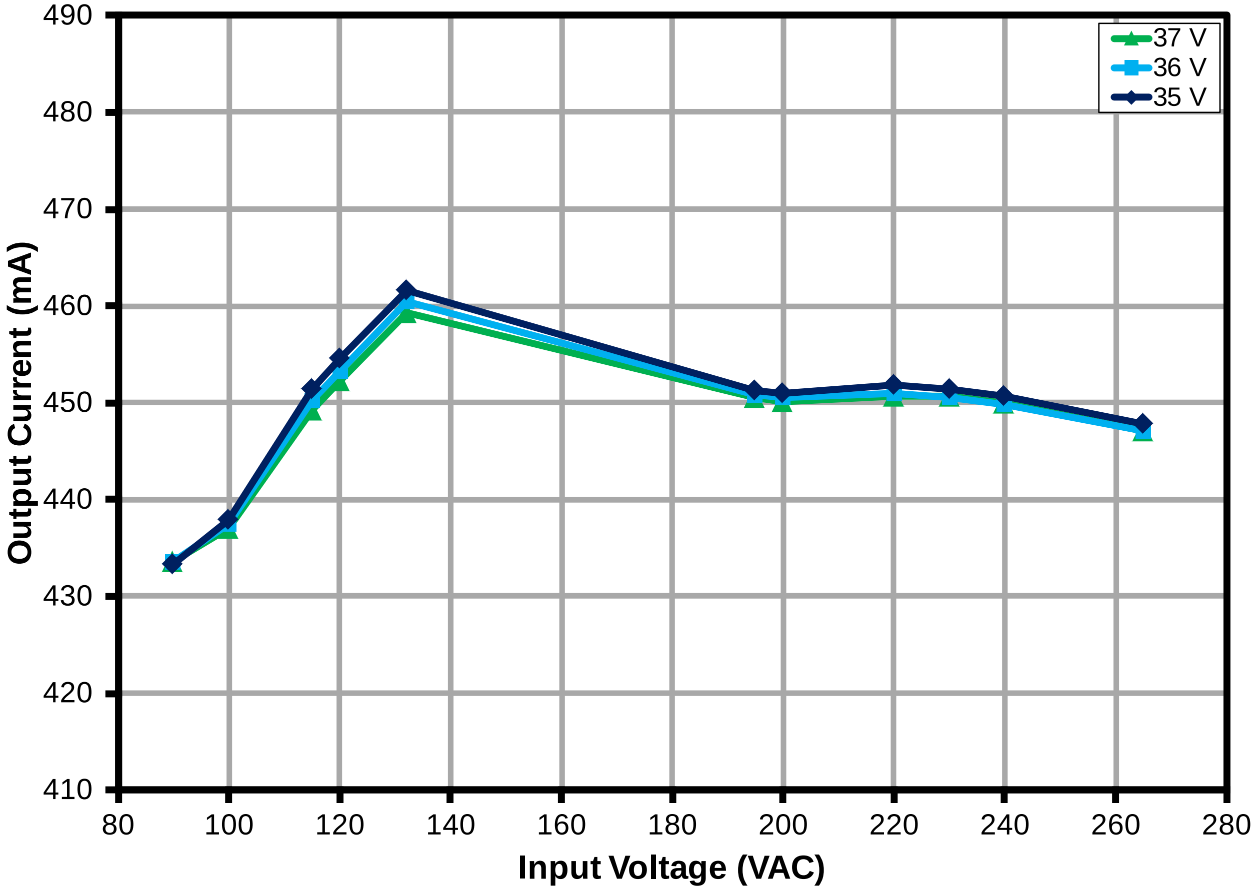

Figure 10 – Regulation vs. Line and Load.

10.3 Power Factor

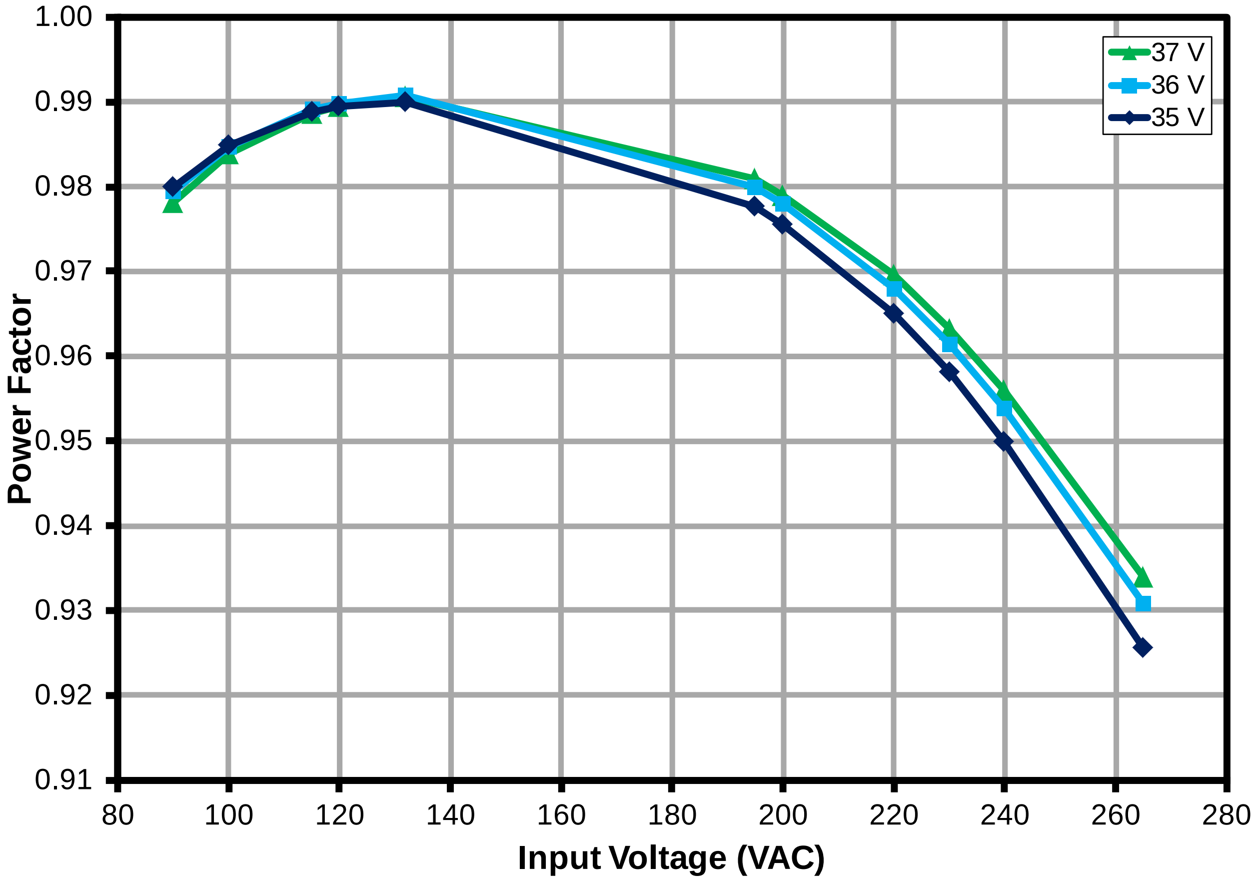

Figure 11 – Power Factor vs. Line.

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10.4 % ATHD

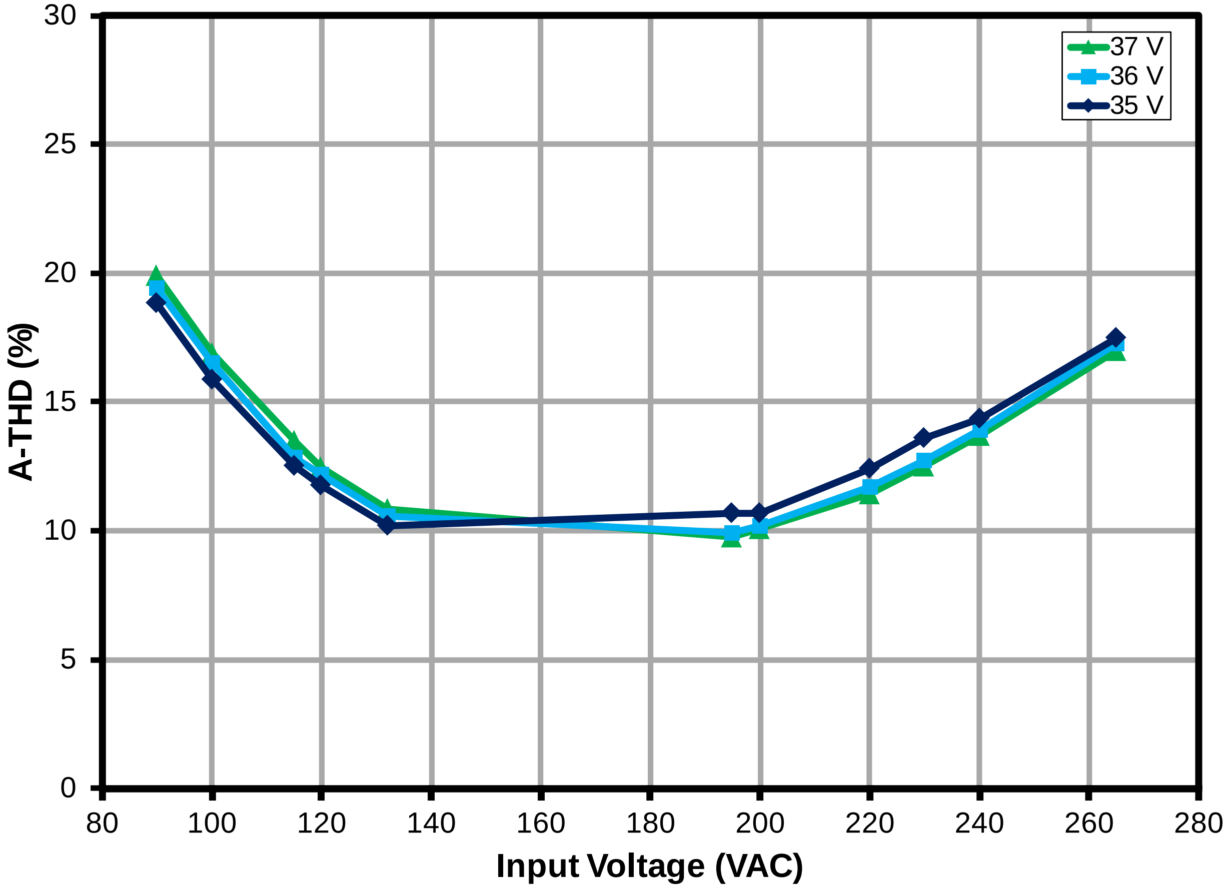

Figure 12 – % A-THD vs. Line.

10.5 Input Current Harmonics

10.5.1 115 VAC, LED Load Set to 37 V

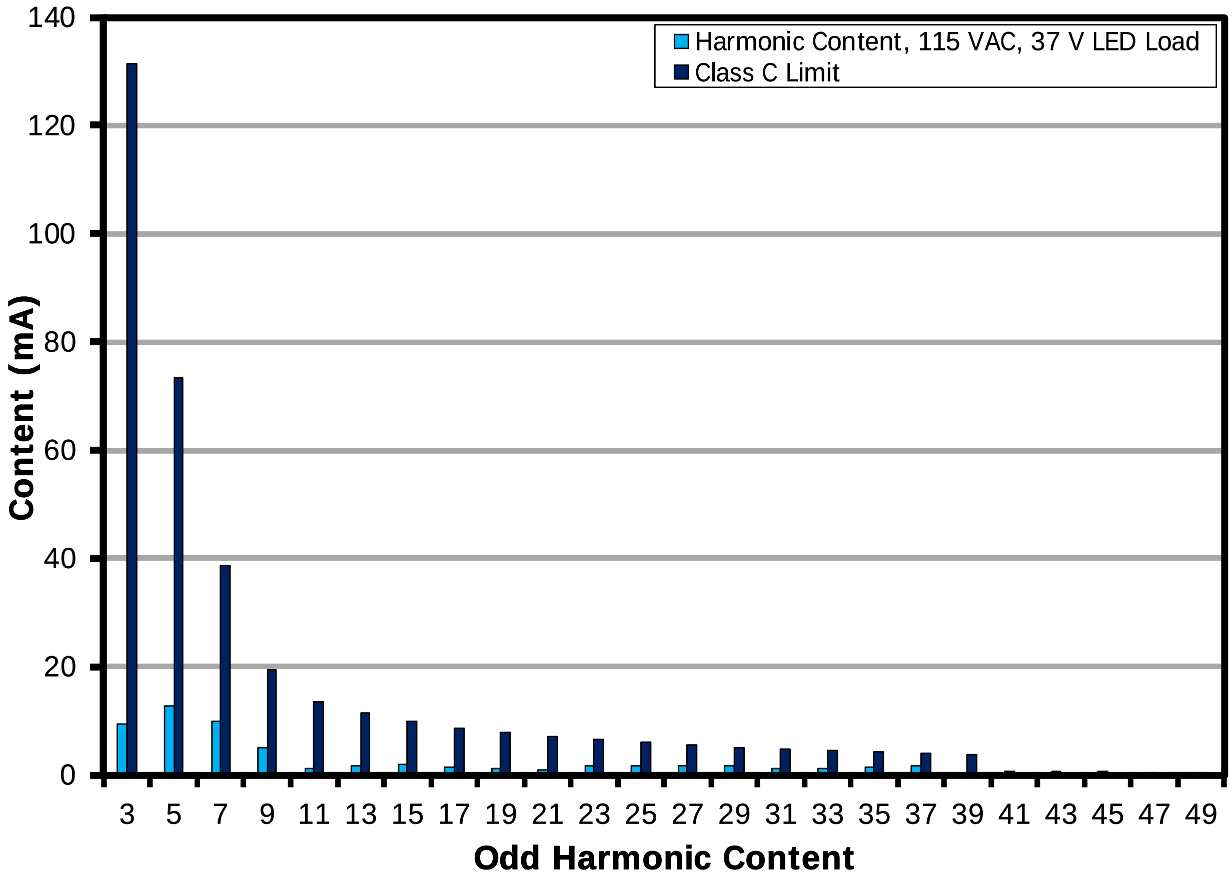

Figure 13 – Input Current Harmonics at 115 VAC. 37 V LED Load.

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10.5.2 230 VAC, LED Load Set to 37 V

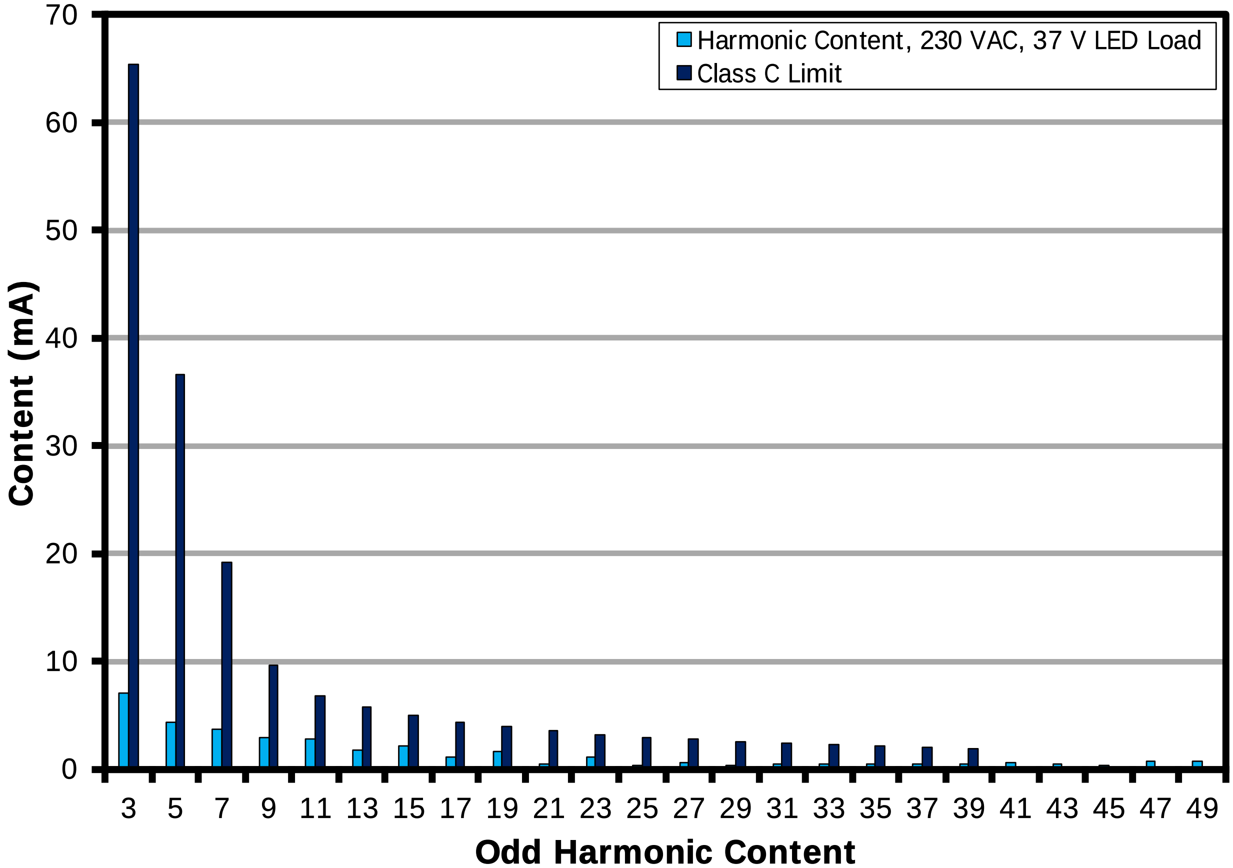

Figure 14 – Input Current Harmonics at 230 VAC. 37 V LED Load.

10.5.3 115 VAC, LED Load Set to 36 V

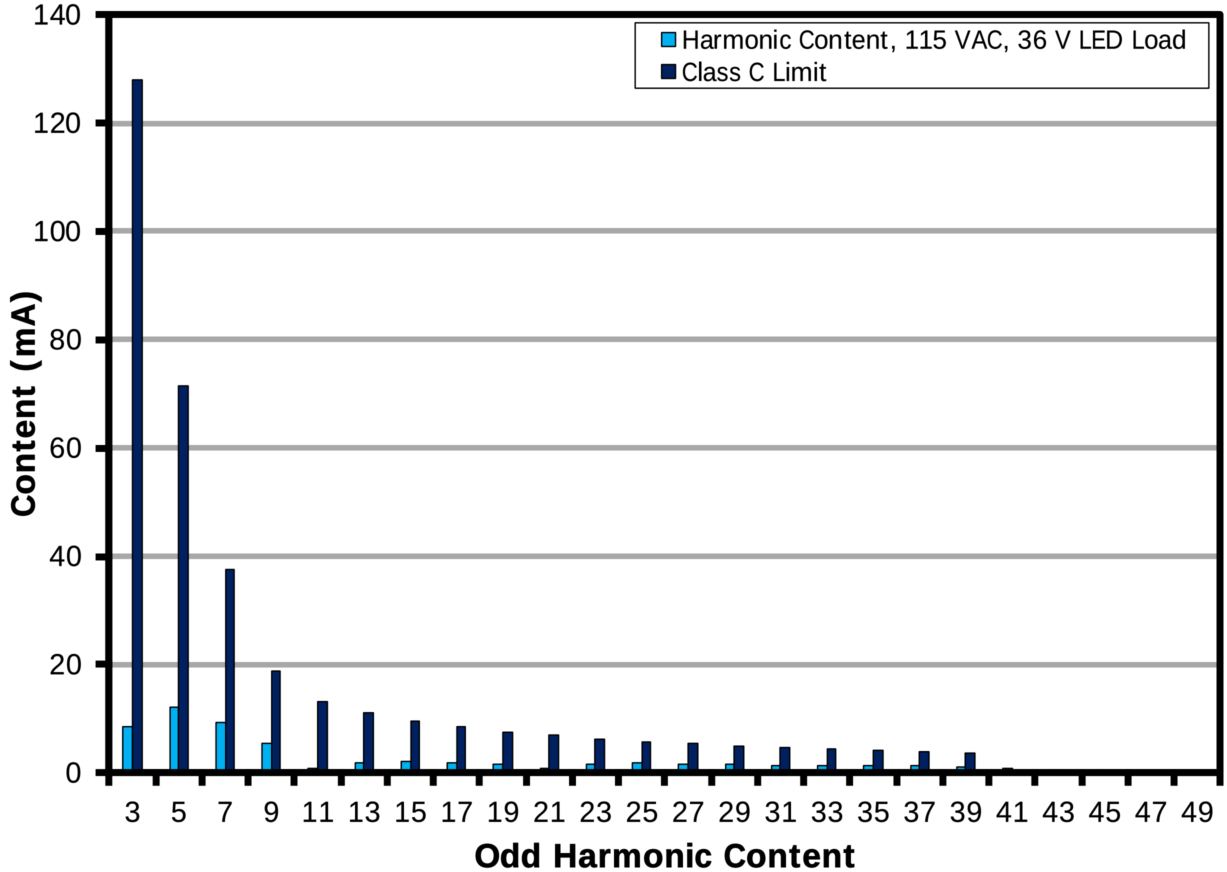

Figure 15 – Input Current Harmonics at 115 VAC. 36 V LED Load.

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10.5.4 230 VAC, LED Load Set to 36 V

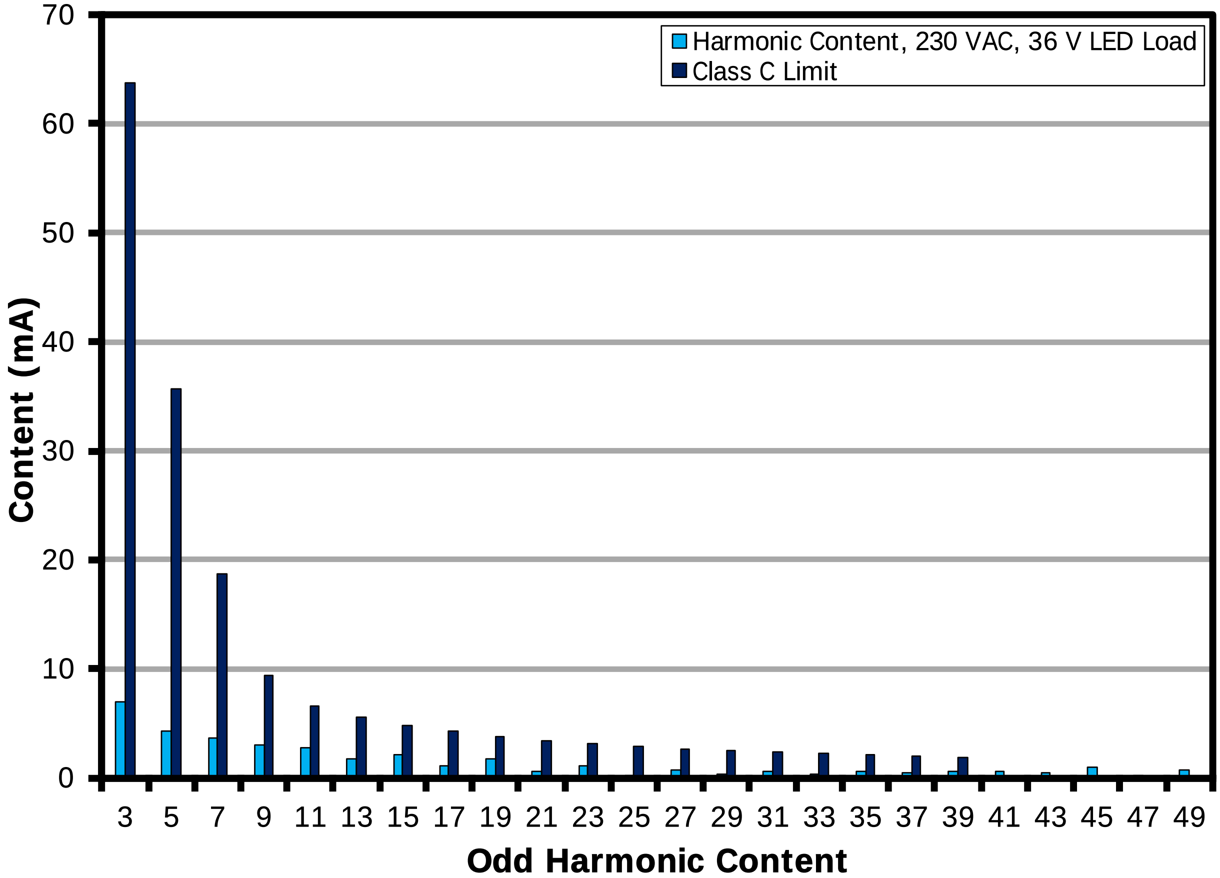

Figure 16 – Input Current Harmonics at 230 VAC. 36 V LED Load.

10.5.5 115 VAC, LED Load Set to 35 V

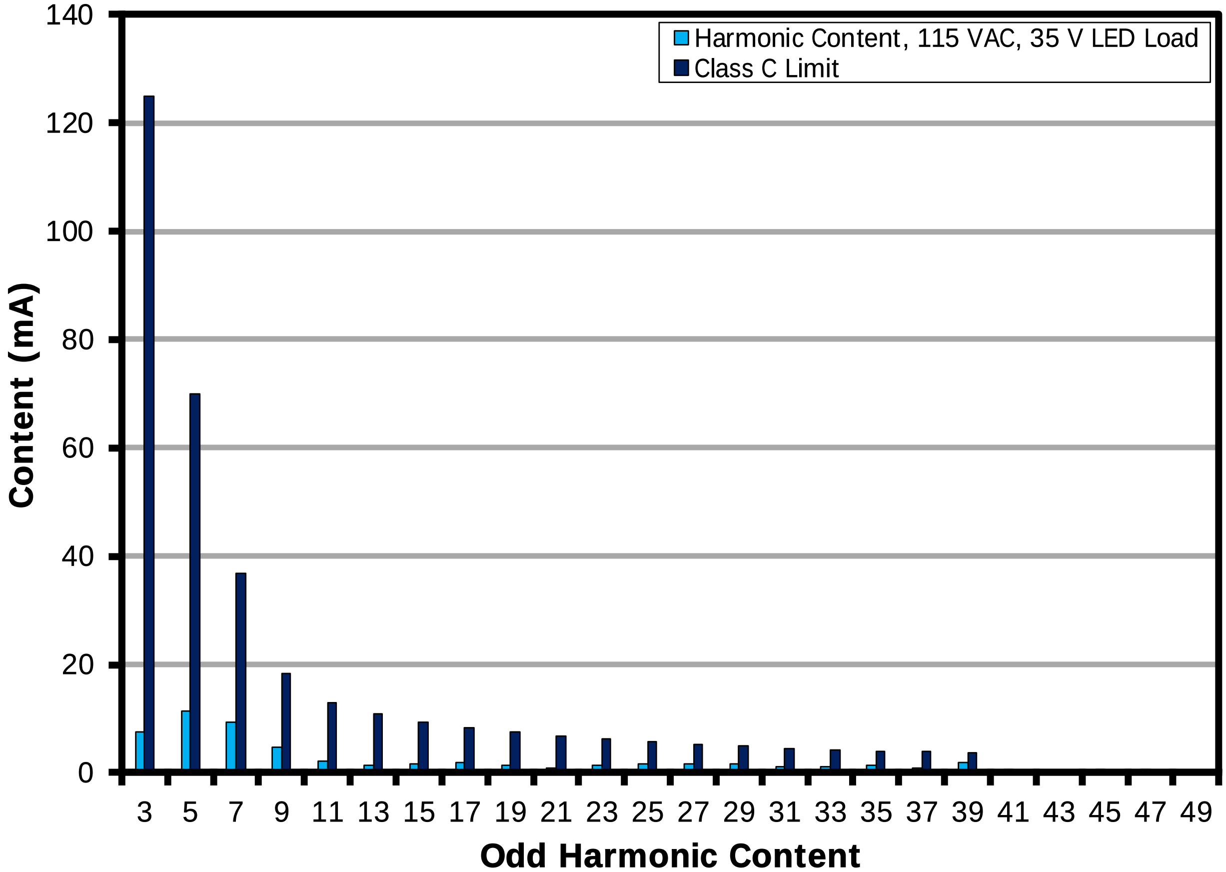

Figure 17 – Input Current Harmonics at 115 VAC. 35 V LED Load.

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10.5.6 230 VAC, LED Load Set to 35 V

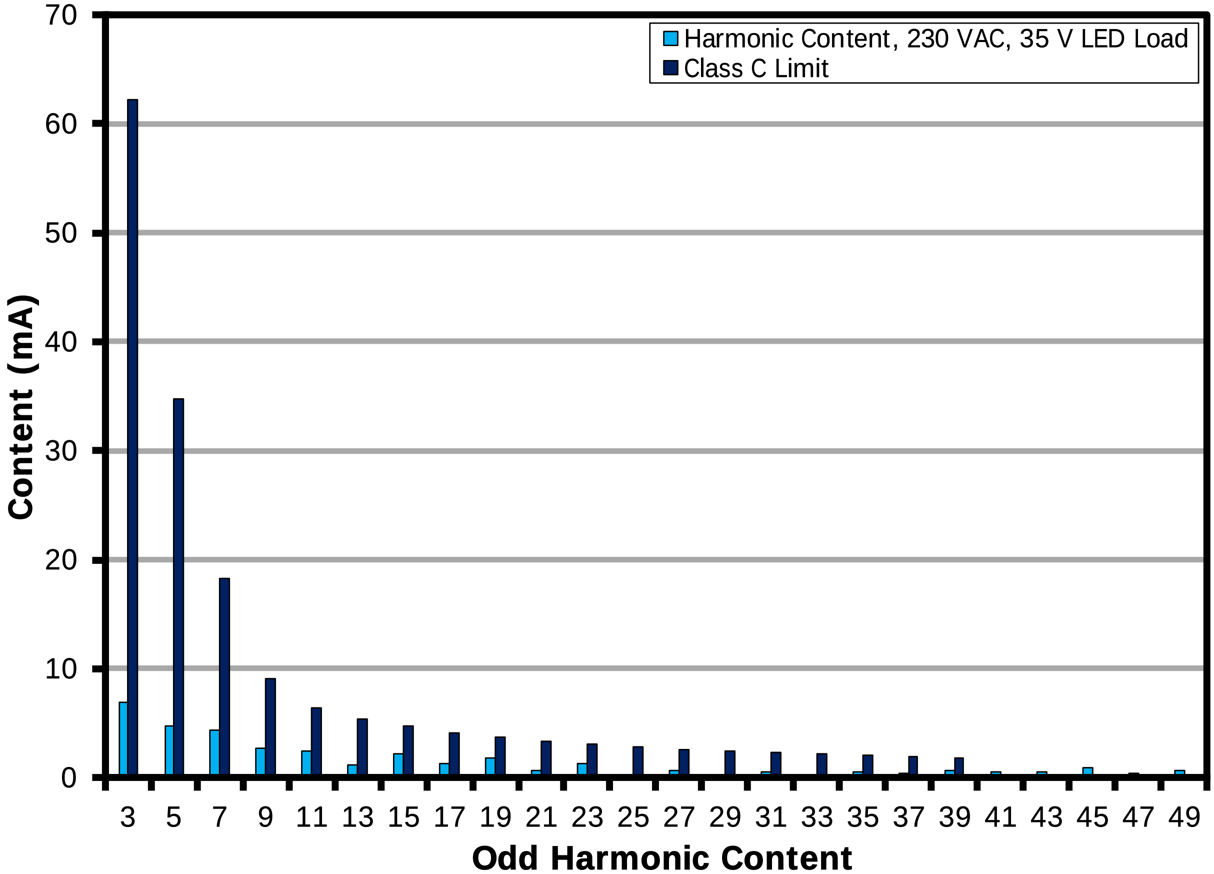

Figure 18 – Input Current Harmonics at 230 VAC. 35 V LED Load.

10.6 Test Data

All measurements were taken open frame, 25 ºC ambient, 50 Hz line frequency.

10.6.1 37 V LED Load Test Data

Input		Input Measurement					LED Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
90	60	89.99	214.83	18.91	0.98	19.89	37.04	433.64	16.14	85.33
100	60	100.00	191.91	18.88	0.98	16.90	37.07	437.04	16.27	86.17
115	60	114.99	169.87	19.31	0.99	13.49	37.20	449.23	16.78	86.89
120	60	119.95	163.61	19.42	0.99	12.48	37.24	452.27	16.91	87.06
132	60	132.01	150.49	19.68	0.99	10.82	37.31	459.24	17.20	87.38
195	50	195.00	100.29	19.18	0.98	9.78	37.21	450.49	16.84	87.78
200	50	199.97	97.96	19.18	0.98	10.05	37.20	450.11	16.82	87.71
220	50	219.99	90.17	19.23	0.97	11.42	37.21	450.62	16.84	87.55
230	50	230.01	86.89	19.25	0.96	12.49	37.21	450.65	16.84	87.48
240	50	240.02	83.83	19.23	0.96	13.72	37.20	449.91	16.81	87.37
265	50	265.03	77.45	19.17	0.93	17.01	37.18	447.15	16.69	87.04

10.6.2 36 V LED Load Test Data

Input		Input Measurement					LED Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
90	60	89.99	208.61	18.39	0.98	19.42	36.00	433.60	15.69	85.31
100	60	100.01	186.71	18.39	0.98	16.52	36.05	437.50	15.84	86.16
115	60	114.99	165.59	18.83	0.99	12.83	36.18	450.20	16.35	86.84
120	60	119.95	159.55	18.94	0.99	12.19	36.21	453.30	16.48	87.01
132	60	132.02	146.89	19.21	0.99	10.59	36.29	460.40	16.78	87.32
195	50	195.00	97.88	18.70	0.98	9.90	36.20	450.90	16.40	87.66
200	50	199.97	95.64	18.70	0.98	10.19	36.20	450.60	16.39	87.61
220	50	219.99	88.09	18.76	0.97	11.68	36.21	451.00	16.40	87.45
230	50	230.01	84.83	18.76	0.96	12.72	36.21	450.60	16.39	87.36
240	50	240.02	81.87	18.74	0.95	13.91	36.20	449.80	16.35	87.24
265	50	265.04	75.71	18.68	0.93	17.24	36.16	447.10	16.23	86.89

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10.6.3 35 V LED Load Test Data

Input		Input Measurement					LED Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
90	60	89.99	202.46	17.85	0.98	18.84	35.03	433.29	15.25	85.42
100	60	100.00	181.74	17.90	0.98	15.88	35.09	437.97	15.44	86.23
115	60	114.99	161.67	18.38	0.99	12.53	35.23	451.34	15.97	86.87
120	60	119.95	155.72	18.48	0.99	11.74	35.24	454.58	16.09	87.04
132	60	132.02	143.40	18.74	0.99	10.17	35.31	461.55	16.37	87.33
195	50	195.00	95.53	18.21	0.98	10.68	35.21	451.22	15.96	87.66
200	50	199.97	93.37	18.21	0.98	10.70	35.20	451.00	15.95	87.60
220	50	219.99	86.13	18.28	0.96	12.39	35.21	451.79	15.98	87.42
230	50	230.01	82.99	18.29	0.96	13.57	35.21	451.46	15.97	87.29
240	50	240.02	80.15	18.27	0.95	14.34	35.21	450.68	15.94	87.22
265	50	265.04	74.25	18.21	0.93	17.45	35.18	447.82	15.82	86.86

10.6.4 37 V LED Load Harmonic Data

V	Freq	I (mA)	P	PF	%THD		V	Freq	I (mA)	P	PF	%THD
115	60.00	169.87	19.31	0.99	13.49		230	50.00	86.89	19.25	0.96	12.49
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**		**nth Order**	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**
3	9.32	5.76%	131.31	29.66%	Pass		**3**	7.01	8.19%	65.45	28.90%	Pass
5	12.78	7.89%	73.38	10.00%	Pass		**5**	4.38	5.12%	36.58	10.00%	Pass
7	9.96	6.15%	38.62	7.00%	Pass		**7**	3.74	4.37%	19.25	7.00%	Pass
9	4.98	3.08%	19.31	5.00%	Pass		**9**	2.97	3.47%	9.63	5.00%	Pass
11	1.22	0.75%	13.52	3.00%	Pass		**11**	2.82	3.30%	6.74	3.00%	Pass
13	1.76	1.09%	11.44	3.00%	Pass		**13**	1.72	2.01%	5.70	3.00%	Pass
15	1.90	1.17%	9.91	3.00%	Pass		**15**	2.18	2.55%	4.94	3.00%	Pass
17	1.51	0.93%	8.75	3.00%	Pass		**17**	1.05	1.23%	4.36	3.00%	Pass
19	1.27	0.78%	7.83	3.00%	Pass		**19**	1.57	1.83%	3.90	3.00%	Pass
21	0.99	0.61%	7.08	3.00%	Pass		**21**	0.45	0.53%	3.53	3.00%	Pass
23	1.58	0.98%	6.46	3.00%	Pass		**23**	1.10	1.29%	3.22	3.00%	Pass
25	1.82	1.12%	5.95	3.00%	Pass		**25**	0.31	0.36%	2.96	3.00%	Pass
27	1.61	0.99%	5.51	3.00%	Pass		**27**	0.54	0.63%	2.74	3.00%	Pass
29	1.66	1.03%	5.13	3.00%	Pass		**29**	0.32	0.37%	2.56	3.00%	Pass
31	1.30	0.80%	4.80	3.00%	Pass		**31**	0.48	0.56%	2.39	3.00%	Pass
33	1.27	0.78%	4.51	3.00%	Pass		**33**	0.43	0.50%	2.25	3.00%	Pass
35	1.41	0.87%	4.25	3.00%	Pass		**35**	0.51	0.60%	2.12	3.00%	Pass
37	1.73	1.07%	4.02	3.00%	Pass		**37**	0.53	0.62%	2.00	3.00%	Pass
39	0.48	0.30%	3.81	3.00%	Pass		**39**	0.53	0.62%	1.90	3.00%	Pass
41	0.79	0.49%					**41**	0.64	0.75%			
43	0.54	0.33%					**43**	0.48	0.56%			
45	0.65	0.40%					**45**	0.39	0.46%			
47	0.50	0.31%					**47**	0.75	0.88%			
49	0.34	0.21%					**49**	0.73	0.85%			

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10.6.5 36 V LED Load Harmonic Data

V	Freq	I (mA)	P	PF	%THD		V	Freq	I (mA)	P	PF	%THD
115	60.00	165.59	18.83	0.99	12.83		230	50.00	84.83	18.76	0.96	12.72
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**		**nth Order**	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**
3	8.54	5.41%	128.06	29.67%	Pass		**3**	6.99	8.37%	63.78	28.84%	Pass
5	12.07	7.65%	71.56	10.00%	Pass		**5**	4.34	5.20%	35.64	10.00%	Pass
7	9.35	5.93%	37.66	7.00%	Pass		**7**	3.64	4.36%	18.76	7.00%	Pass
9	5.54	3.51%	18.83	5.00%	Pass		**9**	2.95	3.53%	9.38	5.00%	Pass
11	0.86	0.55%	13.18	3.00%	Pass		**11**	2.75	3.29%	6.57	3.00%	Pass
13	1.82	1.15%	11.15	3.00%	Pass		**13**	1.76	2.11%	5.56	3.00%	Pass
15	2.19	1.39%	9.67	3.00%	Pass		**15**	2.11	2.53%	4.81	3.00%	Pass
17	1.87	1.19%	8.53	3.00%	Pass		**17**	1.04	1.25%	4.25	3.00%	Pass
19	1.55	0.98%	7.63	3.00%	Pass		**19**	1.72	2.06%	3.80	3.00%	Pass
21	0.85	0.54%	6.91	3.00%	Pass		**21**	0.56	0.67%	3.44	3.00%	Pass
23	1.60	1.01%	6.30	3.00%	Pass		**23**	1.08	1.29%	3.14	3.00%	Pass
25	1.96	1.24%	5.80	3.00%	Pass		**25**	0.23	0.28%	2.89	3.00%	Pass
27	1.57	1.00%	5.37	3.00%	Pass		**27**	0.73	0.87%	2.67	3.00%	Pass
29	1.66	1.05%	5.00	3.00%	Pass		**29**	0.39	0.47%	2.49	3.00%	Pass
31	1.33	0.84%	4.68	3.00%	Pass		**31**	0.61	0.73%	2.33	3.00%	Pass
33	1.29	0.82%	4.39	3.00%	Pass		**33**	0.27	0.32%	2.19	3.00%	Pass
35	1.40	0.89%	4.14	3.00%	Pass		**35**	0.56	0.67%	2.06	3.00%	Pass
37	1.42	0.90%	3.92	3.00%	Pass		**37**	0.41	0.49%	1.95	3.00%	Pass
39	1.07	0.68%	3.72	3.00%	Pass		**39**	0.58	0.69%	1.85	3.00%	Pass
41	0.73	0.46%					**41**	0.58	0.69%			
43	0.46	0.29%					**43**	0.42	0.50%			
45	0.56	0.36%					**45**	0.99	1.19%			
47	0.43	0.27%					**47**	0.19	0.23%			
49	0.34	0.22%					**49**	0.68	0.81%			

10.6.6 35 V LED Load Harmonic Data

V	Freq	I (mA)	P	PF	%THD		V	Freq	I (mA)	P	PF	%THD
115	60.00	161.67	18.38	0.99	12.53		230	50.00	82.99	18.29	0.96	13.57
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**		**nth Order**	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**
3	7.47	4.8%	124.99	29.7%	Pass		**3**	6.96	8.5%	62.19	28.7%	Pass
5	11.46	7.4%	69.85	10.0%	Pass		**5**	4.70	5.8%	34.75	10.0%	Pass
7	9.22	6.0%	36.76	7.0%	Pass		**7**	4.32	5.3%	18.29	7.0%	Pass
9	4.77	3.1%	18.38	5.0%	Pass		**9**	2.67	3.3%	9.15	5.0%	Pass
11	2.27	1.5%	12.87	3.0%	Pass		**11**	2.50	3.1%	6.40	3.0%	Pass
13	1.43	0.9%	10.89	3.0%	Pass		**13**	1.23	1.5%	5.42	3.0%	Pass
15	1.61	1.0%	9.44	3.0%	Pass		**15**	2.23	2.7%	4.69	3.0%	Pass
17	1.80	1.2%	8.33	3.0%	Pass		**17**	1.24	1.5%	4.14	3.0%	Pass
19	1.41	0.9%	7.45	3.0%	Pass		**19**	1.85	2.3%	3.71	3.0%	Pass
21	0.95	0.6%	6.74	3.0%	Pass		**21**	0.66	0.8%	3.35	3.0%	Pass
23	1.42	0.9%	6.15	3.0%	Pass		**23**	1.26	1.5%	3.06	3.0%	Pass
25	1.66	1.1%	5.66	3.0%	Pass		**25**	0.22	0.3%	2.82	3.0%	Pass
27	1.60	1.0%	5.24	3.0%	Pass		**27**	0.61	0.7%	2.61	3.0%	Pass
29	1.67	1.1%	4.88	3.0%	Pass		**29**	0.24	0.3%	2.43	3.0%	Pass
31	1.22	0.8%	4.57	3.0%	Pass		**31**	0.52	0.6%	2.27	3.0%	Pass
33	1.17	0.8%	4.29	3.0%	Pass		**33**	0.30	0.4%	2.13	3.0%	Pass
35	1.28	0.8%	4.04	3.0%	Pass		**35**	0.57	0.7%	2.01	3.0%	Pass
37	0.92	0.6%	3.83	3.0%	Pass		**37**	0.37	0.5%	1.90	3.0%	Pass
39	1.93	1.3%	3.63	3.0%	Pass		**39**	0.65	0.8%	1.81	3.0%	Pass
41	0.53	0.34%					**41**	0.54	0.66%			
43	0.44	0.29%					**43**	0.54	0.66%			
45	0.58	0.38%					**45**	0.97	1.19%			
47	0.50	0.32%					**47**	0.37	0.45%			
49	0.39	0.25%					**49**	0.68	0.83%			

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11 Thermal Performance

Thermal measurements were taken at an ambient temperature of 25 ºC with a 36 V LED load.

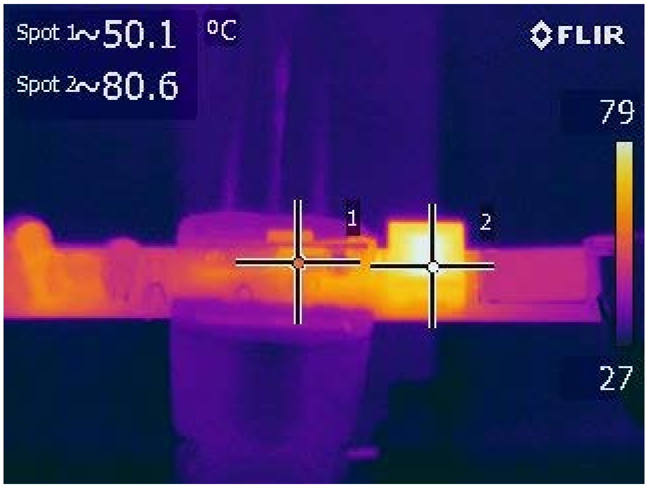

Figure 19 – 90 VAC, Full Load.
Spot 1: LYT4214E.
Spot 2: Tansformer.

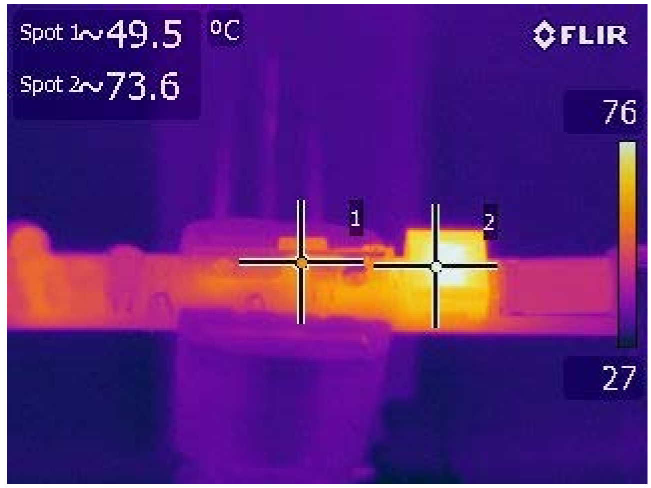

Figure 20 – 115 VAC, Full Load.
Spot 1: LYT4214E.
Spot 2: Transformer.

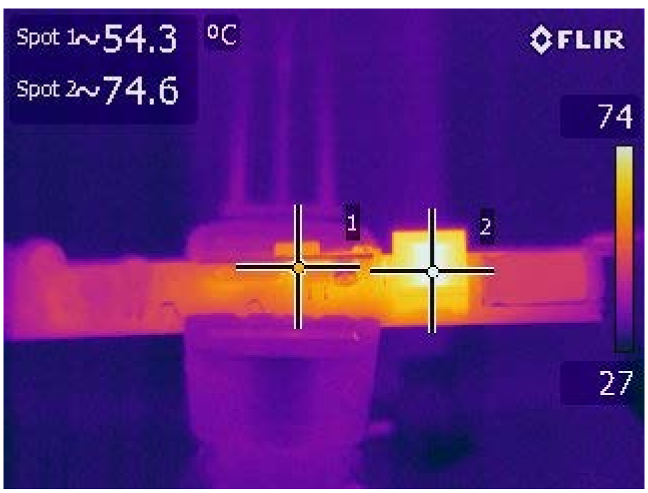

Figure 21 – 230 VAC, Full Load.
Spot 1: LYT4214E.
Spot 2: Transformer.

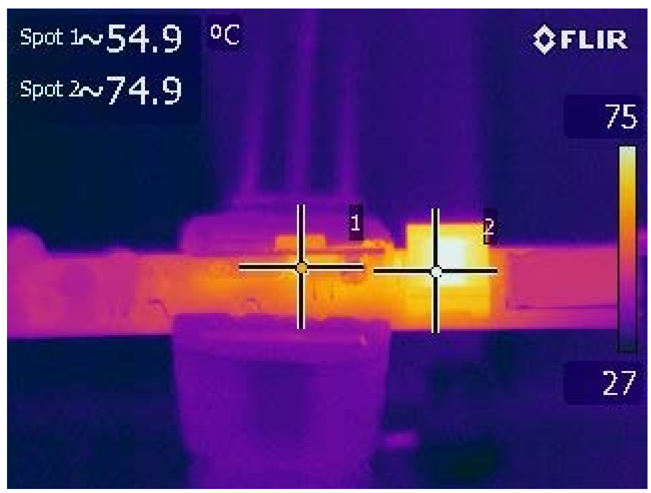

Figure 22 – 265 VAC, Full Load.
Spot 1: LYT4214E.
Spot 2: Transformer.

12 Waveforms

12.1 Input Voltage and Input Current Waveforms

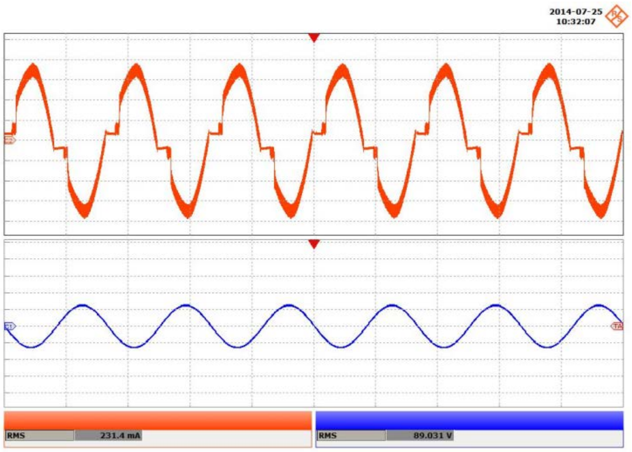

Figure 23 – 90 VAC, Full Load.
Upper: I_{IN}, 20 mA / div.
Lower: V_{IN}, 100 V, 10 ms / div.

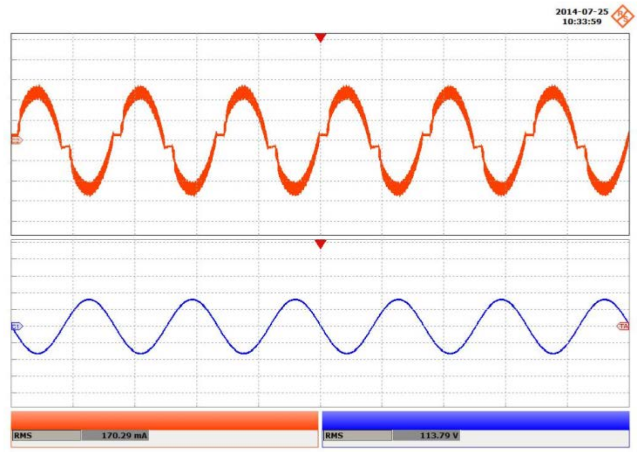

Figure 24 – 115 VAC, Full Load.
Upper: I_{IN}, 20 mA / div.
Lower: V_{IN}, 100 V, 10 ms / div.

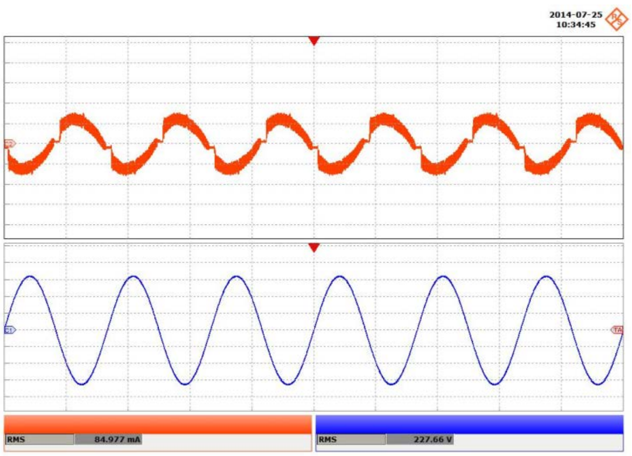

Figure 25 – 230 VAC, Full Load.
Upper: I_{IN}, 20 mA / div.
Lower: V_{IN}, 100 V, 10 ms / div.

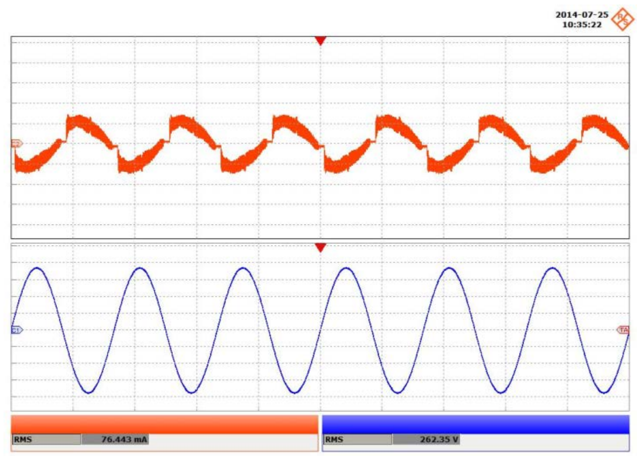

Figure 26 – 265 VAC, Full Load.
Upper: I_{IN}, 20 mA / div.
Lower: V_{IN}, 100 V, 10 ms / div.

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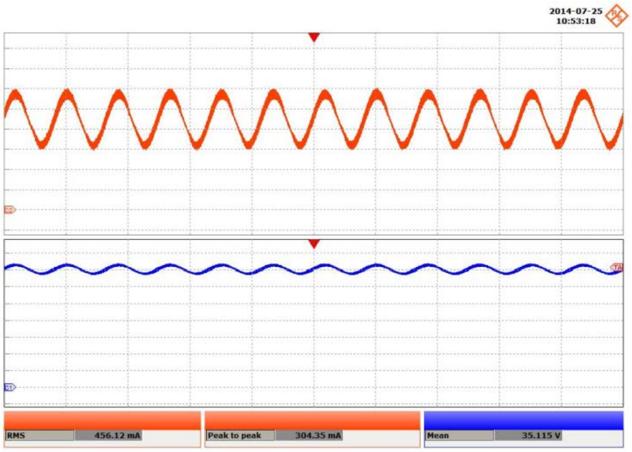
12.2 Output Current and Output Voltage in Normal Operation



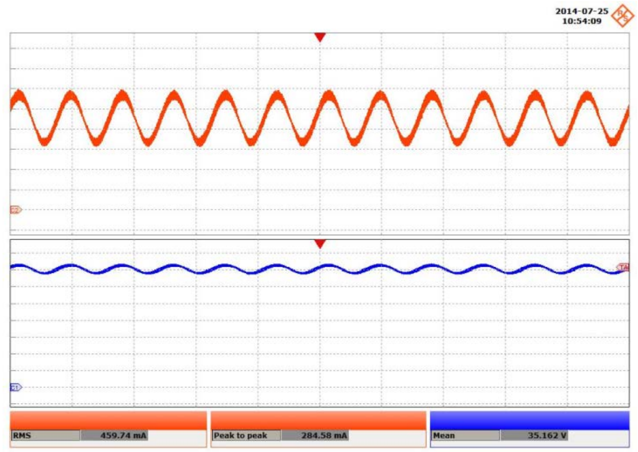
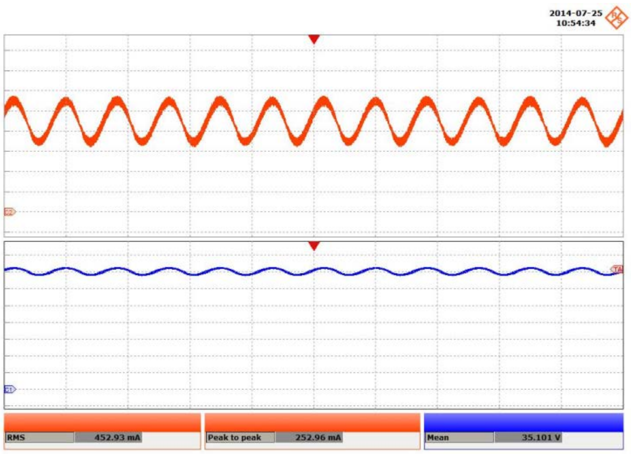


Figure 27 – 90 VAC, 50 Hz Full Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 5 V, 10 ms / div.

Figure 28 – 115 VAC, 50 Hz Full Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 5 V, 10 ms / div.



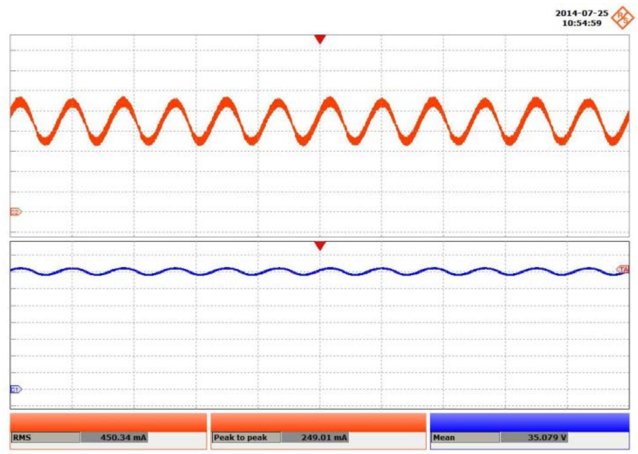


Figure 29 – 230 VAC, 50 Hz Full Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 5 V, 10 ms / div.

Figure 30 – 265 VAC, 50 Hz Full Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 5 V, 10 ms / div.

12.3 Output Rise Time

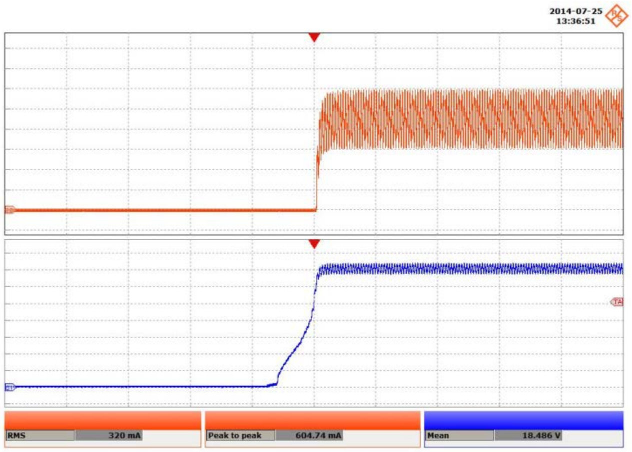


Figure 31 – 90 VAC Output Rise.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT} 5 V, 200 ms / div.

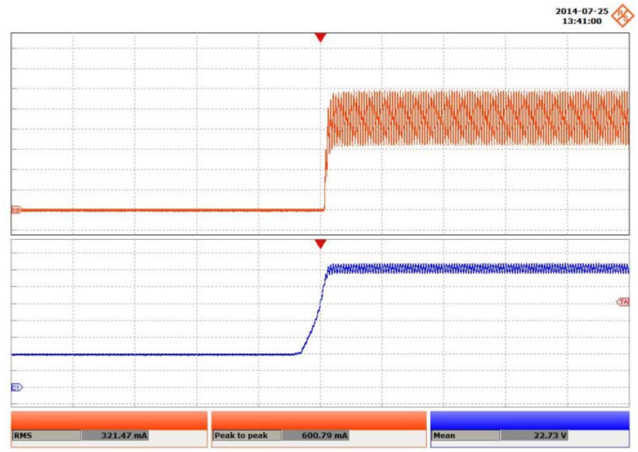


Figure 32 – 115 VAC Output Rise.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 5 V, 200 ms / div.

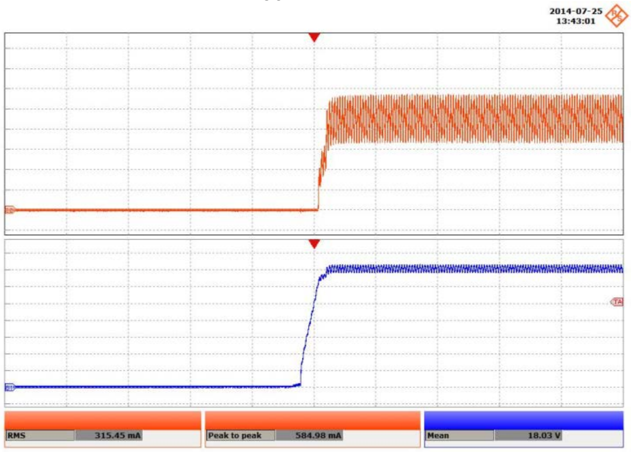


Figure 33 – 230 VAC Output Rise.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 5 V, 200 ms / div.

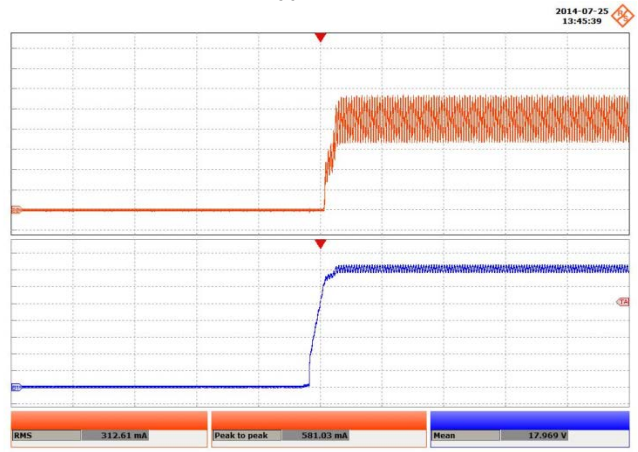


Figure 34 – 265 VAC Output Rise.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 5 V, 200 ms / div.

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12.4 Drain Voltage and Current in Normal Operation

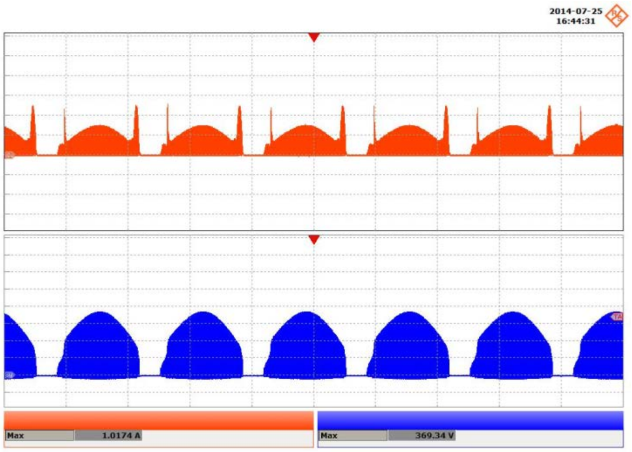

Figure 35 – 90 VAC, 50 Hz.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.
Max V_{DRAIN}: 369.4 V.
Max I_{DRAIN}: 1.0174 A.

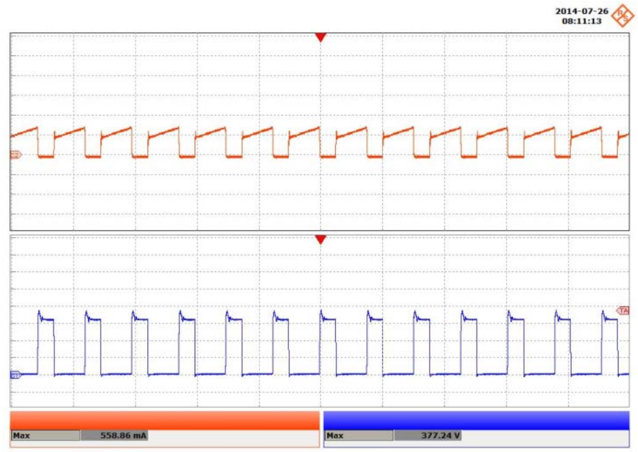

Figure 36 – 90 VAC, 50 Hz.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.
Max V_{DRAIN}: 377.24 V.
Max I_{DRAIN}: 558.86 mA.

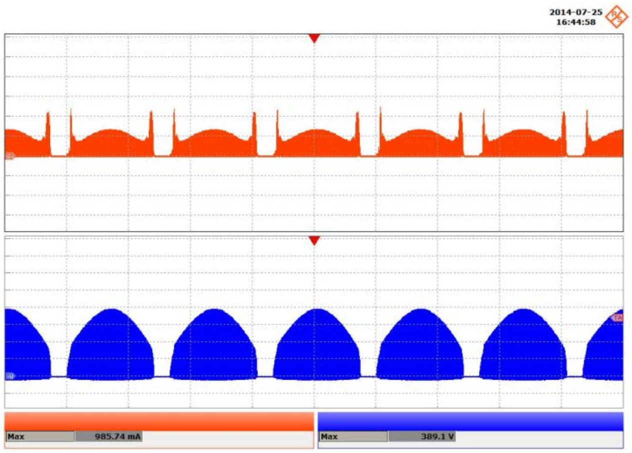

Figure 37 – 115 VAC, 50 Hz.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.
Max V_{DRAIN}: 389.1 V.
Max I_{DRAIN}: 985.74 mA.

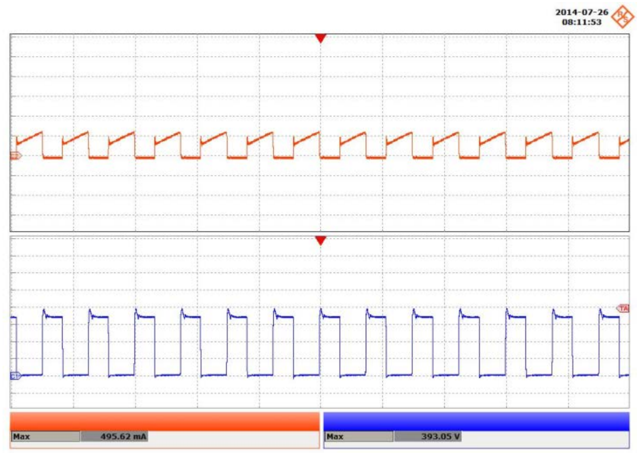

Figure 38 – 115 VAC, 50 Hz.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.
Max V_{DRAIN}: 393.05 V.
Max I_{DRAIN}: 495.62 mA.

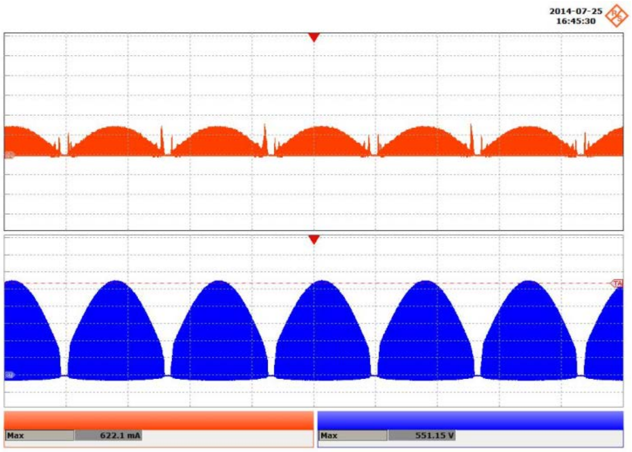

Figure 39 – 230 VAC, 50 Hz.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.

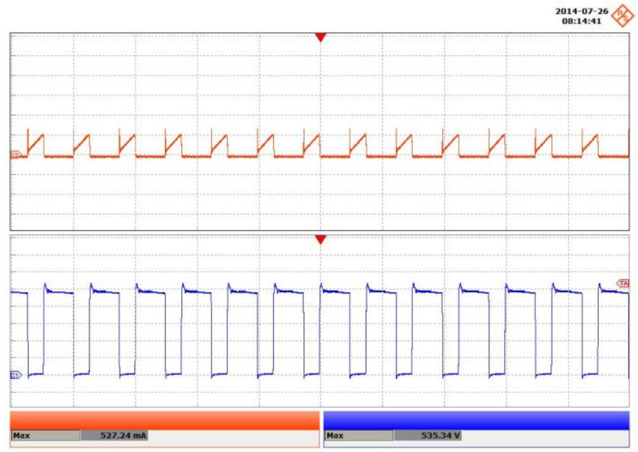

Figure 40 – 230 VAC, 50 Hz.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.

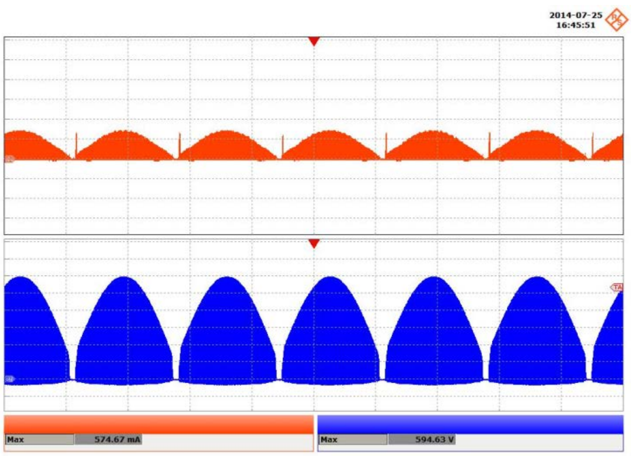

Figure 41 – 265 VAC, 50 Hz.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.
Max V_{DRAIN}: 594.63 V.
Max I_{DRAIN}: 574.67 mA.

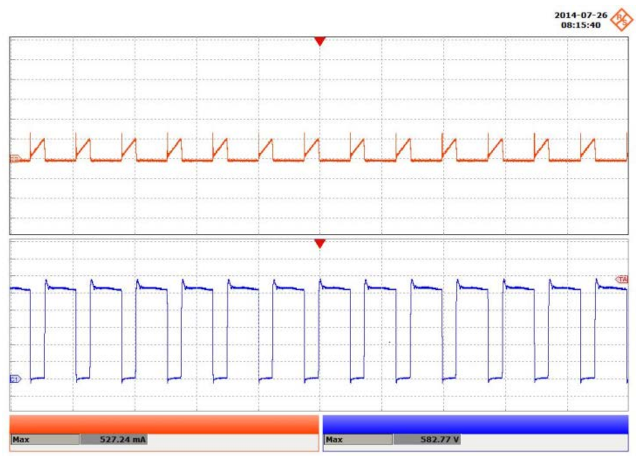

Figure 42 – 265 VAC, 50 Hz.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.
Max V_{DRAIN}: 582.77 V.
Max I_{DRAIN}: 527.24 mA.

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12.5 Start-up Drain Voltage and Current

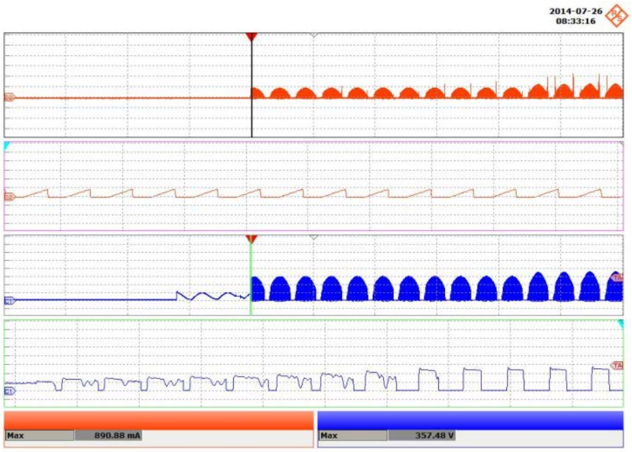

Figure 43 – 90 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V, 20 ms / div.
Max V_{DRAIN}: 357.48 V.
Max I_{DRAIN}: 890.88 mA.

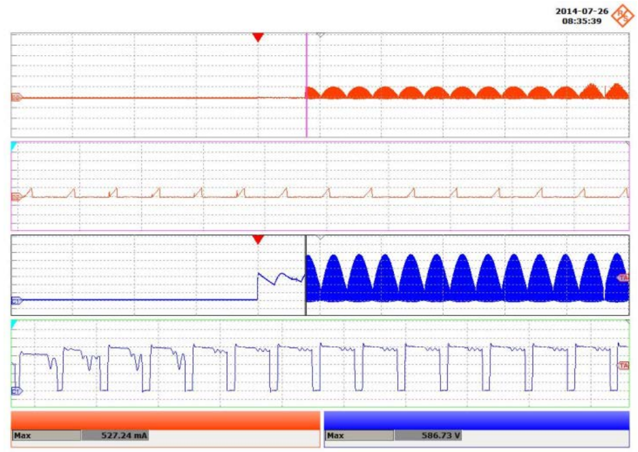

Figure 44 – 265 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 0.2 A / div.
Lower: V_{DRAIN}, 100 V, 20 ms / div.
Max V_{DRAIN}: 586.73 V.
Max I_{DRAIN}: 527.24 mA.

12.6 Drain Current and Drain Voltage During Output Short Condition

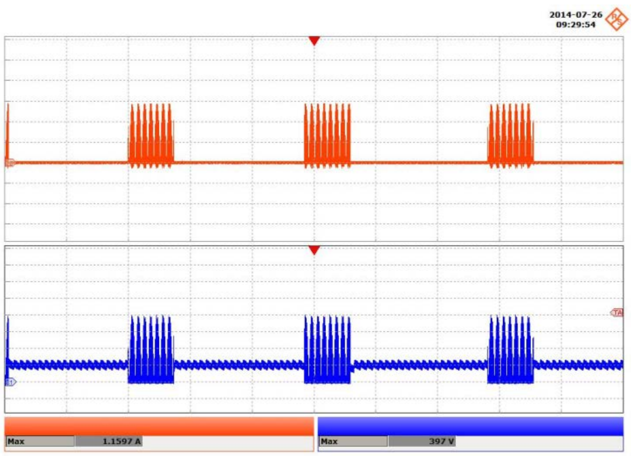

Figure 45 – 90 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V, 100 ms / div.
Max V_{DRAIN}: 397 V.
Max I_{DRAIN}: 1.1597 A.

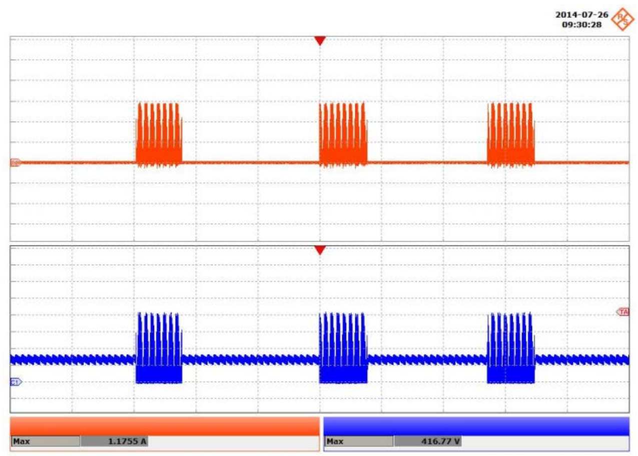

Figure 46 – 115 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V, 100 ms / div.
Max V_{DRAIN}: 416.77 V.
Max I_{DRAIN}: 1.1755 A.

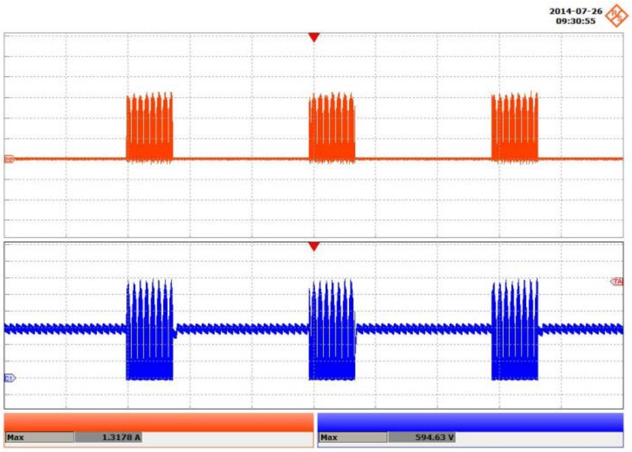

Figure 47 – 230 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 400 mA / div.
Lower: $V_{DRAIN,}$ 100 V, 100 ms / div.
Max V_{DRAIN}: 594.63 V.
Max I_{DRAIN}: 1.3178 A.

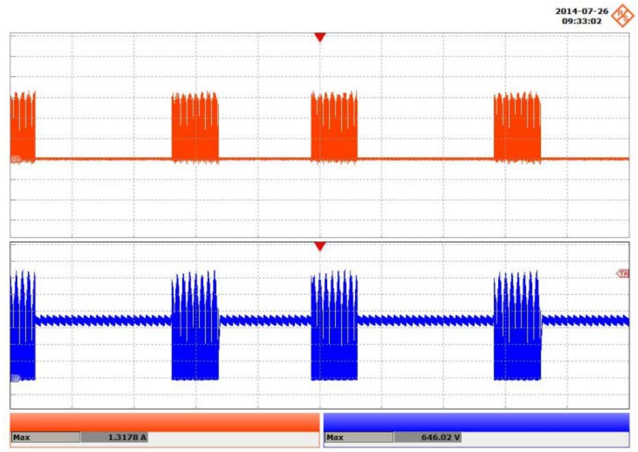

Figure 48 – 265 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 400 mA / div.
Lower: $V_{DRAIN,}$ 100 V, 100 ms / div.
Max V_{DRAIN}: 646.02 V.
Max I_{DRAIN}: 1.3178 mA.

12.7 Open Load Characteristic

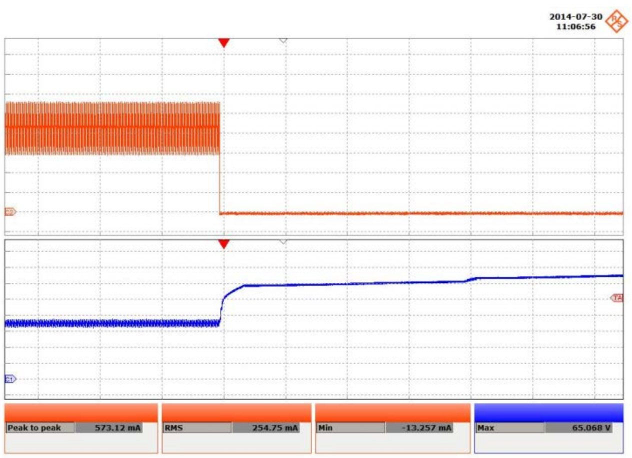

Figure 49 – 90 VAC, 50 Hz Running Open Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V / div., 400 ms / div.

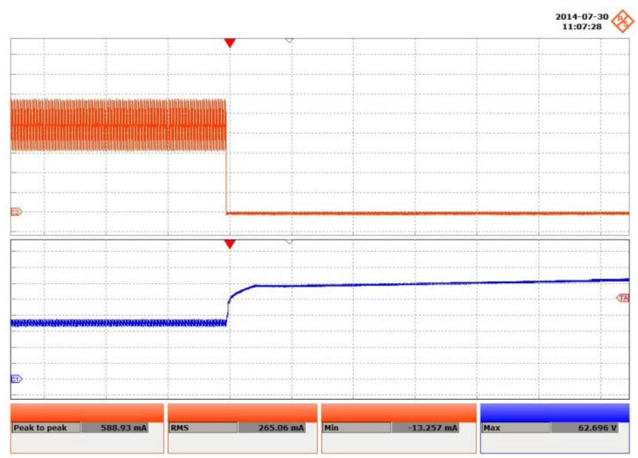

Figure 50 – 115 VAC, 50 Hz Running Open Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V / div., 400 ms / div.

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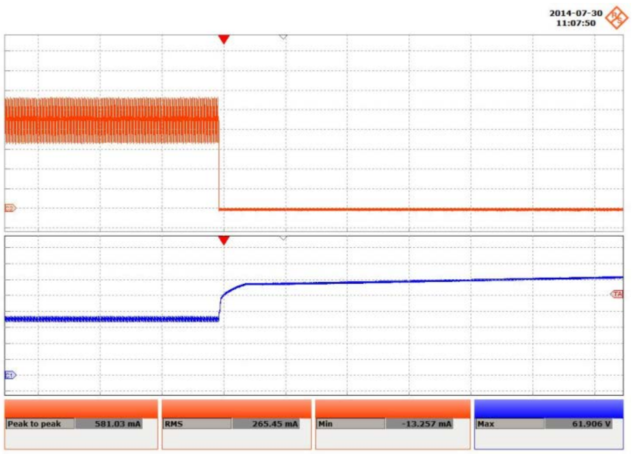

Figure 51 – 230 VAC, 50 Hz Running Open Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V / div., 400 ms / div.

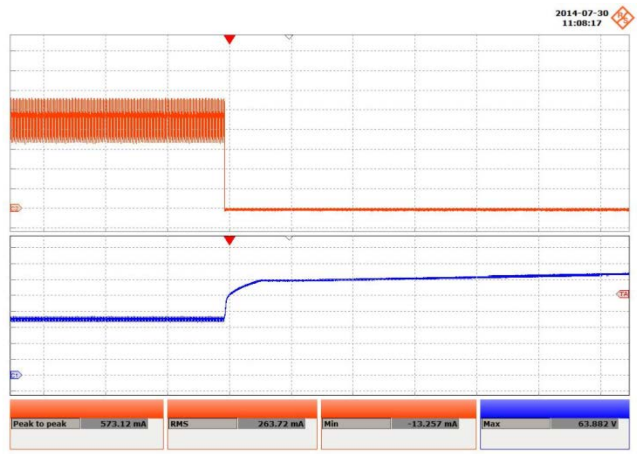

Figure 52 – 265 VAC, 50 Hz Running Open Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V / div., 400 ms / div.

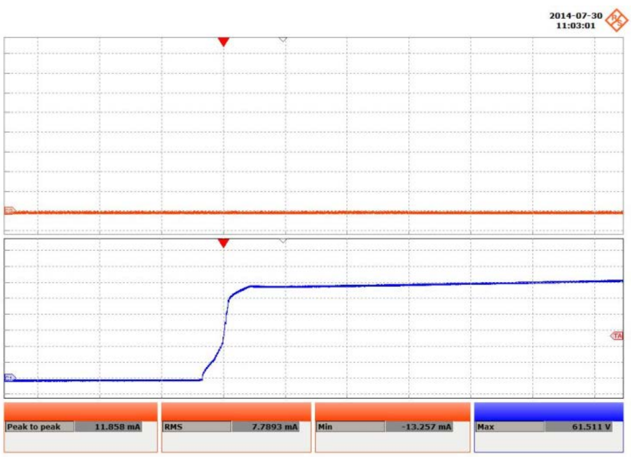

Figure 53 – 90 VAC, 50 Hz Open Load Start-Up.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V / div., 400 ms / div.

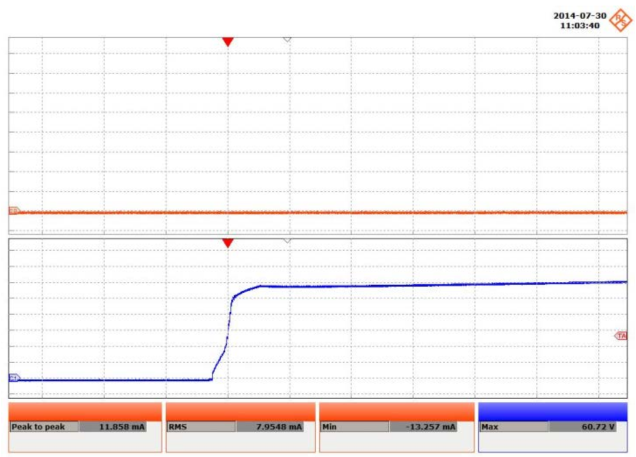

Figure 54 – 115 VAC, 50 Hz Open Load Start-Up.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V / div., 400 ms / div.

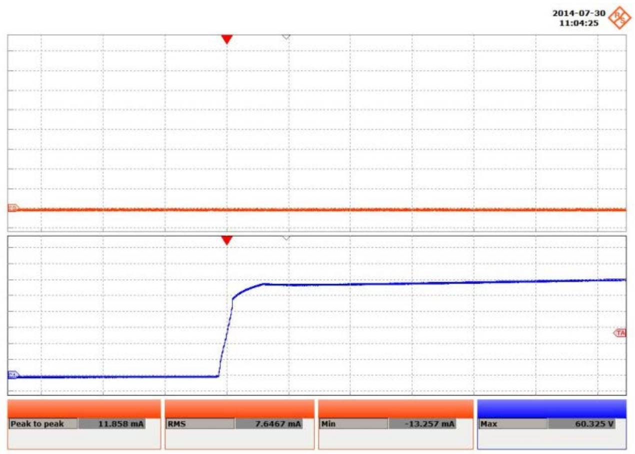

Figure 55 – 230 VAC, 50 Hz Open Load Start-Up.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V / div., 400 ms / div.

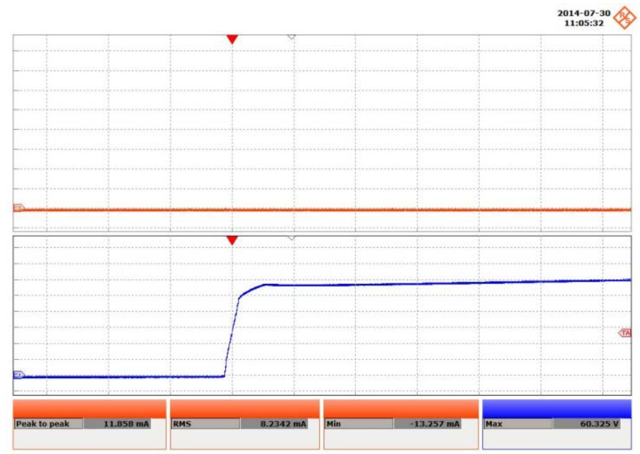

Figure 56 – 265 VAC, 50 Hz Open Load Start-Up.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V / div., 400 ms / div.

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12.8 Brown-out / Brown-in

No failure of any component was found during brown-out and brown-in testing.

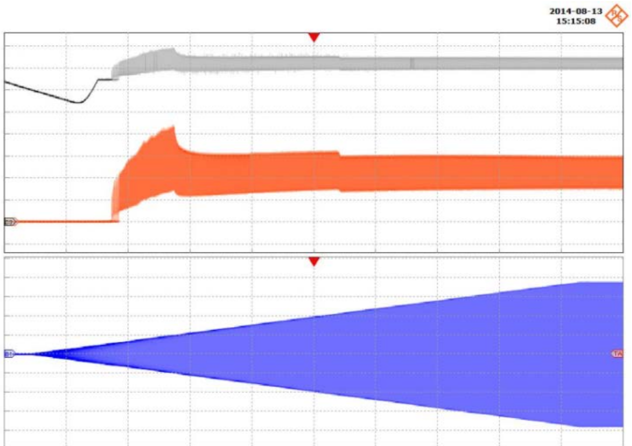

Figure 57 – Brown-in.
Upper: V_{OUT}, 5 V / div.
Middle: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 100 V / div., 30 s / div.

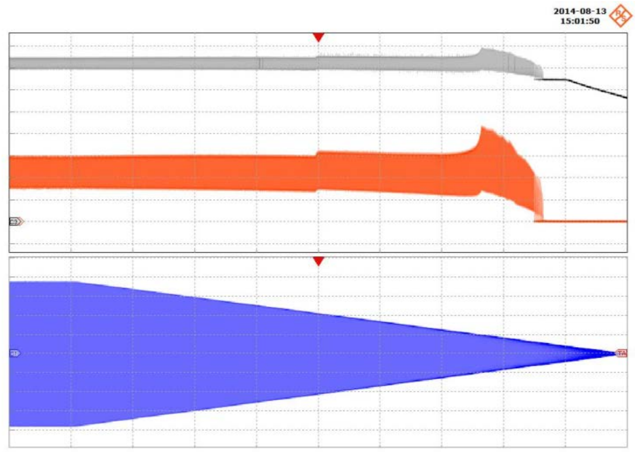

Figure 58 – Brown-out.
Upper: V_{OUT}, 5 V / div.
Middle: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 100 V / div., 30 s / div.

13 Conducted EMI

13.1 Test Set-up

EMI Receiver: Rohde & Schwarz ESRP
Line Impedance Stabilization Network: ENV216
Pulse Limiter: ESH3-Z2

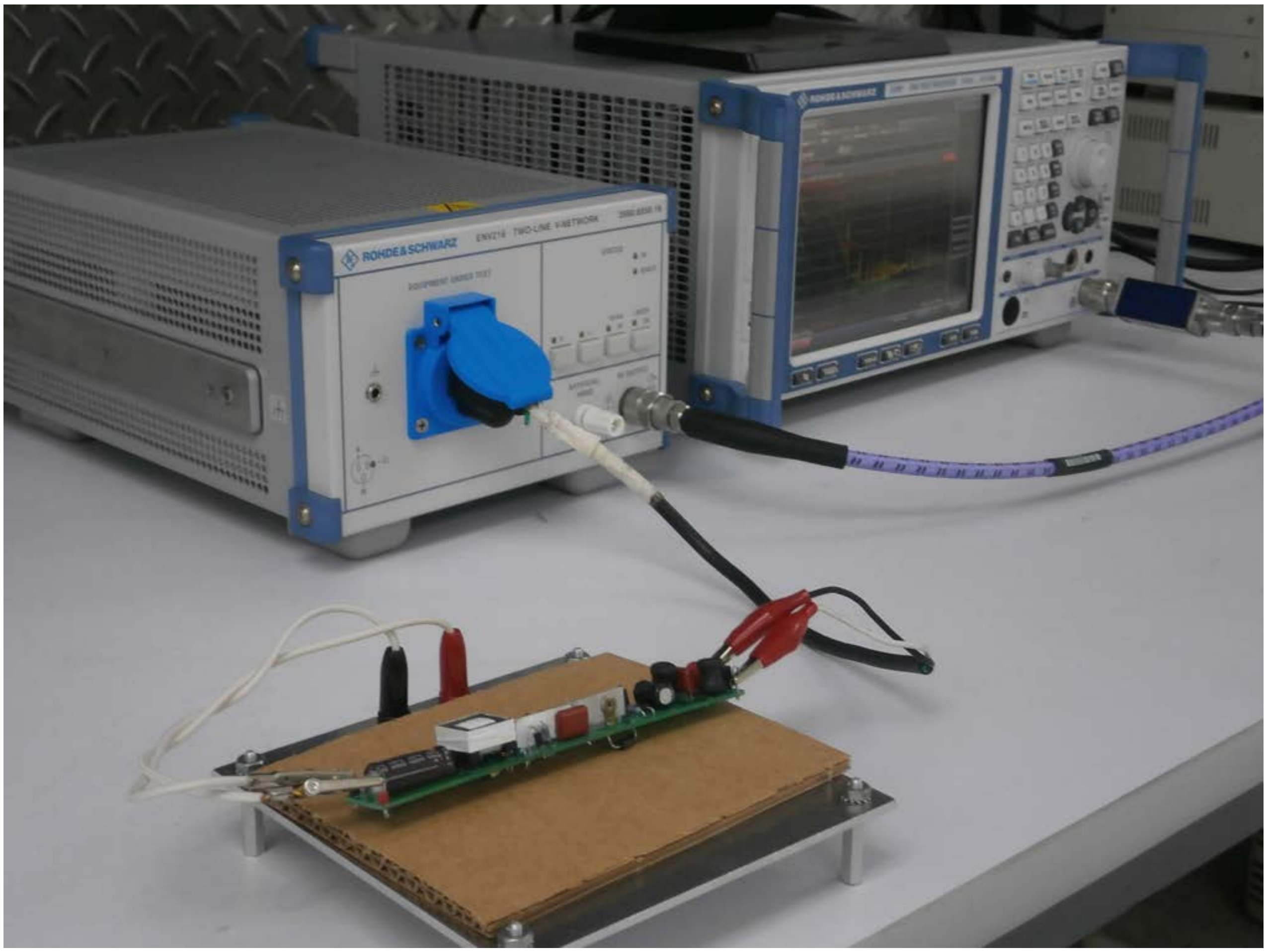

Figure 59 – Conducted EMI Test Set-up.

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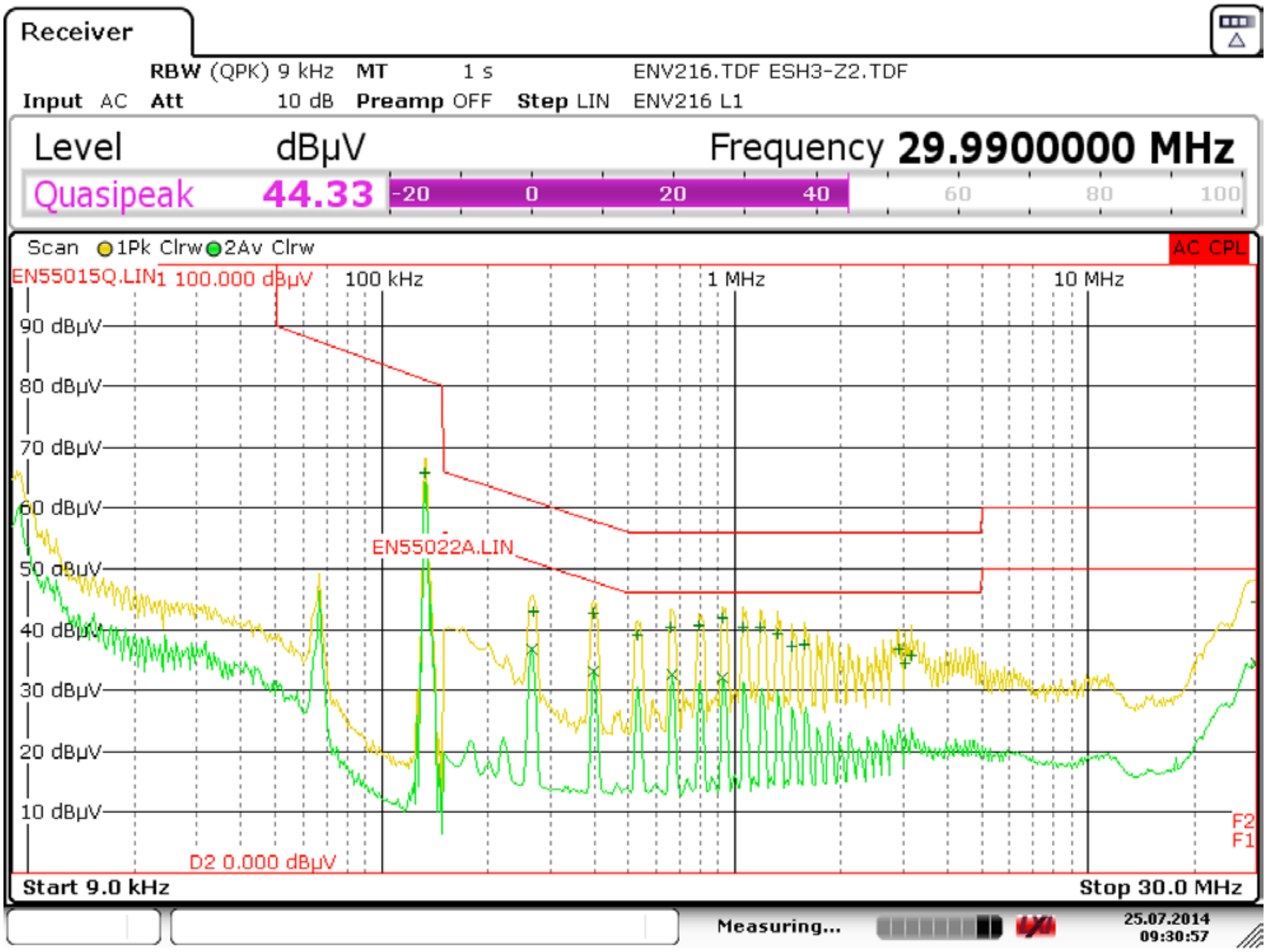
13.2 115 VAC Test Result



Date: 25.JUL.2014 09:30:57

Figure 60 – Conducted EMI, ~36 V LED Load, 115 VAC, 60 Hz, and EN55015 B Limits.

Trace/Detector	Frequency	Level dBµV	DeltaLimit
2 Average	662.0000 kHz	32.60 L1	-13.40 dB
2 Average	926.0000 kHz	32.03 N	-13.97 dB
1 Quasi Peak	926.0000 kHz	41.98 L1	-14.02 dB
2 Average	266.0000 kHz	36.76 L1	-14.48 dB
2 Average	398.0000 kHz	33.23 N	-14.67 dB
1 Quasi Peak	398.0000 kHz	42.83 L1	-15.07 dB
1 Quasi Peak	133.2400 kHz	65.78 N	-15.30 dB
1 Quasi Peak	794.0000 kHz	40.58 L1	-15.42 dB
1 Quasi Peak	1.0540 MHz	40.52 N	-15.48 dB
1 Quasi Peak	658.0000 kHz	40.48 L1	-15.52 dB
1 Quasi Peak	29.9900 MHz	44.44 L1	-15.56 dB
2 Average	29.8620 MHz	34.41 N	-15.59 dB
1 Quasi Peak	1.1860 MHz	40.33 L1	-15.67 dB
1 Quasi Peak	1.3180 MHz	39.45 N	-16.55 dB

Figure 61 – Conducted EMI, Final Measurements.

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13.3 230 VAC Test Result

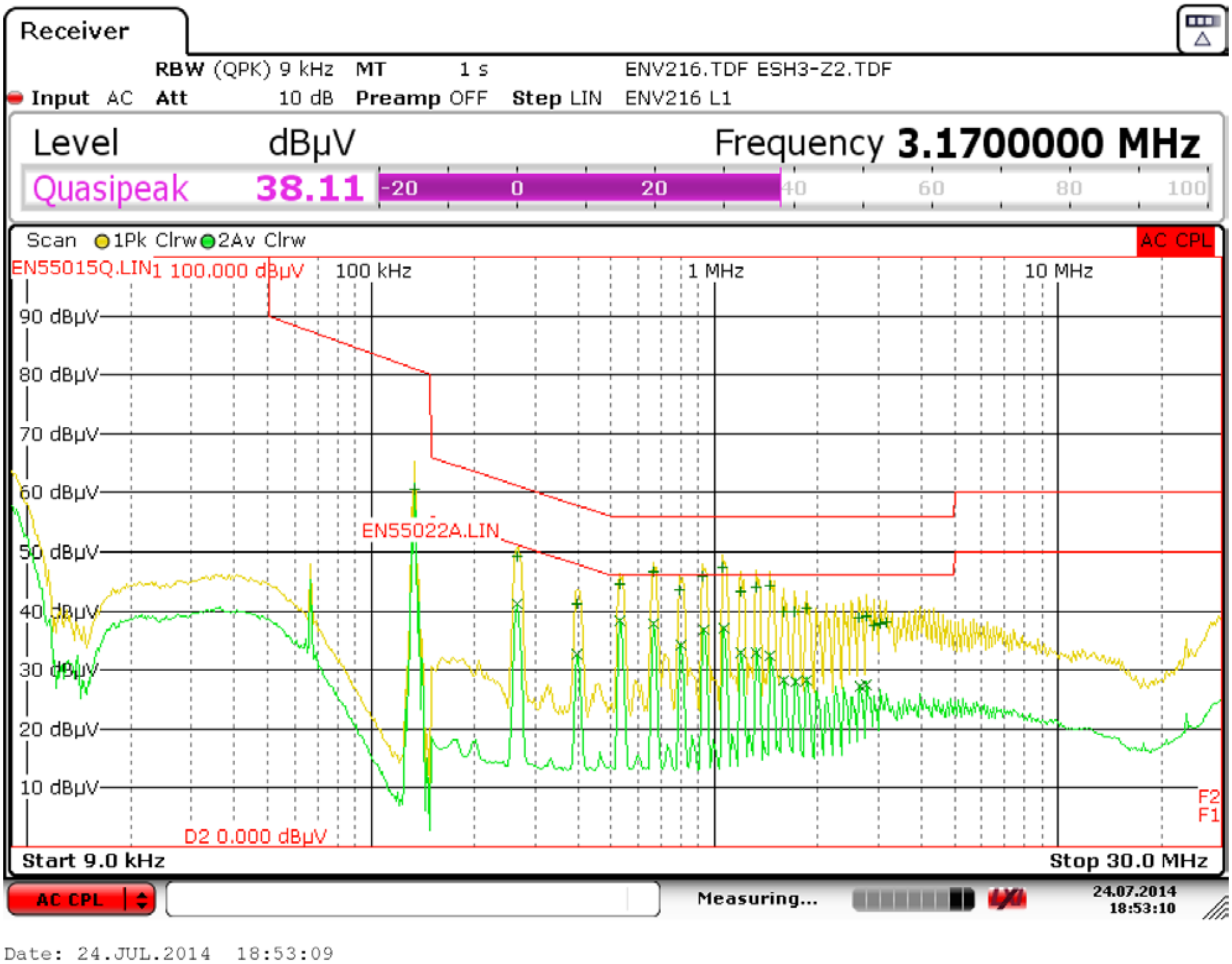

Figure 62 – Conducted EMI, ~36 V LED Load, 230 VAC, 60 Hz, and EN55015 B Limits.

Trace/Detector	Frequency	Level dBµV	DeltaLimit
2 Average	530.0000 kHz	38.39 L1	-7.61 dB
2 Average	666.0000 kHz	37.90 L1	-8.10 dB
1 Quasi Peak	1.0580 MHz	47.52 L1	-8.48 dB
2 Average	1.0620 MHz	36.95 N	-9.05 dB
2 Average	930.0000 kHz	36.81 L1	-9.19 dB
1 Quasi Peak	662.0000 kHz	46.67 L1	-9.33 dB
1 Quasi Peak	926.0000 kHz	45.97 L1	-10.03 dB
2 Average	266.0000 kHz	41.12 L1	-10.12 dB
1 Quasi Peak	530.0000 kHz	44.52 L1	-11.48 dB
1 Quasi Peak	1.4540 MHz	44.38 N	-11.62 dB
1 Quasi Peak	1.3220 MHz	44.12 N	-11.88 dB
2 Average	798.0000 kHz	34.07 N	-11.93 dB
1 Quasi Peak	266.0000 kHz	49.15 L1	-12.09 dB
1 Quasi Peak	794.0000 kHz	43.41 L1	-12.59 dB

Figure 63 – Conducted EMI, Final Measurements.

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14 Line Surge

The unit was subjected to ±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.

14.1 Test Results

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

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

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

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

14.2 Surge Drain Waveforms

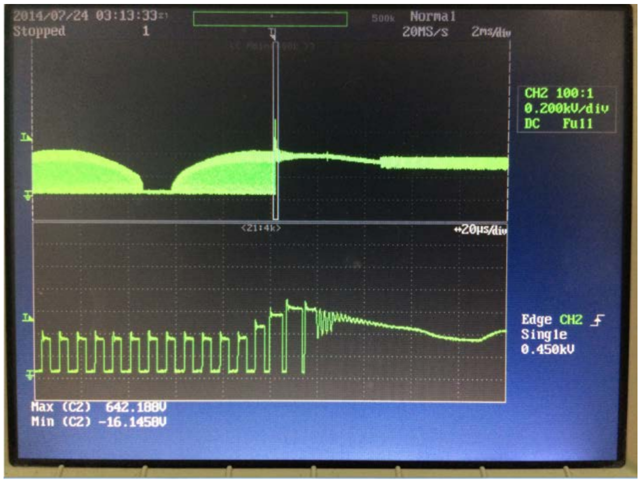

Figure 64 – 115 VAC, +1 kV Differential Surge, 90°
V_{DRAIN}, 200 V / div., 2 ms / div.

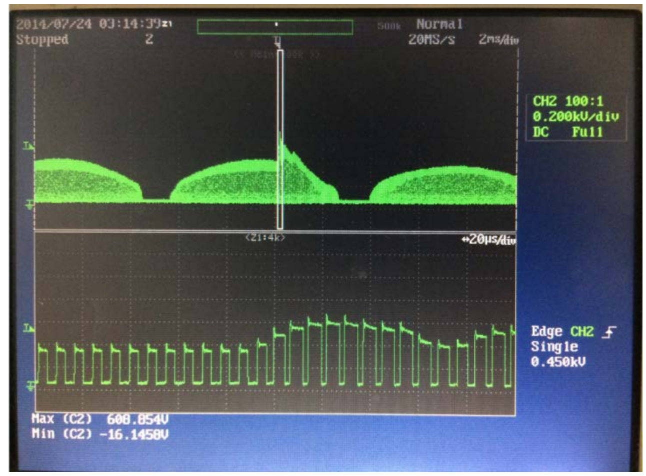

Figure 65 – 115 VAC, -1 kV Differential Surge, 90°
V_{DRAIN}, 200 V / div., 2 ms / div.

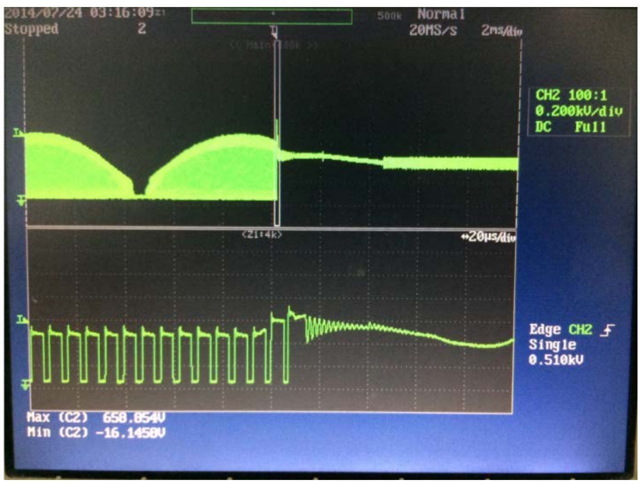

Figure 66 – 230 VAC, +1 kV Differential Surge, 90°
V_{DRAIN}, 200 V / div., 2 ms / div.

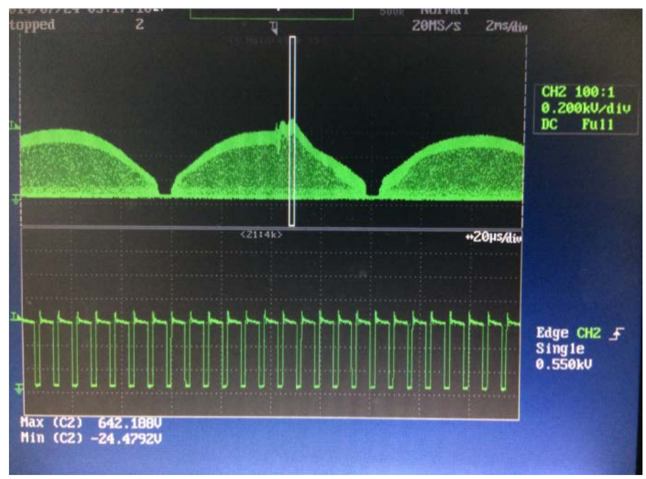

Figure 67 – 230 VAC, -1 kV Differential Surge, 90°
V_{DRAIN}, 200 V / div., 2 ms / div.

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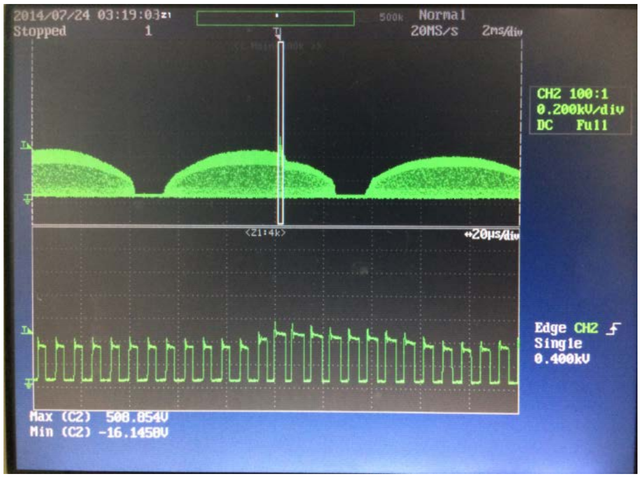

Figure 68 – 115 VAC, +2.5 kV Ring Wave Surge, 90°
V_{DRAIN}, 200 V / div., 2 ms / div.

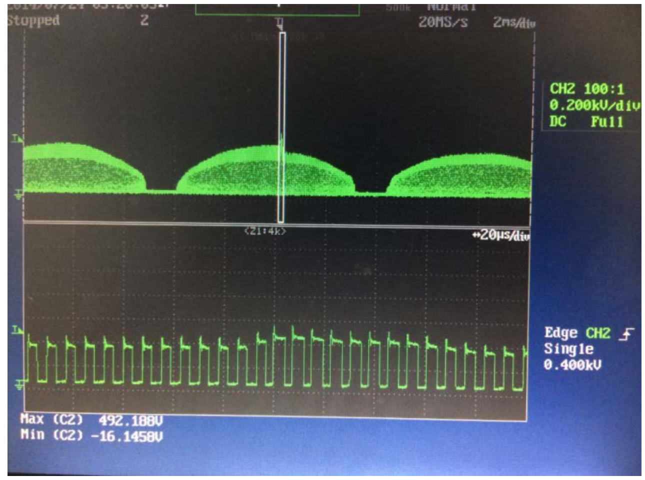

Figure 69 – 115 VAC, -2.5 kV Ring Wave Surge, 90°
V_{DRAIN}, 200 V / div., 2 ms / div.

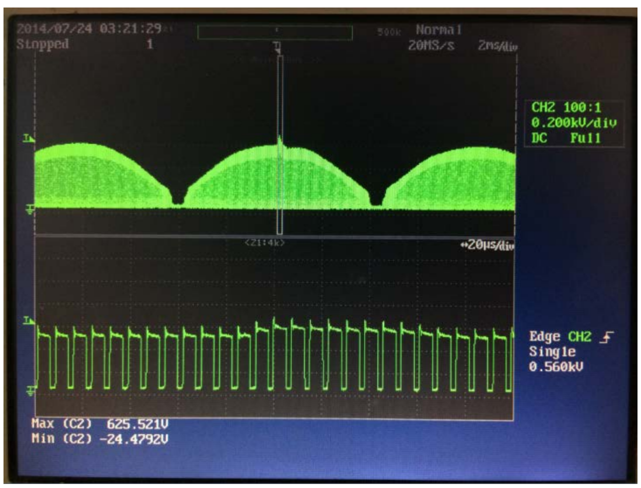

Figure 70 – 230 VAC, +2.5 kV Ring Wave Surge, 90°
V_{DRAIN}, 200 V / div., 2 ms / div.

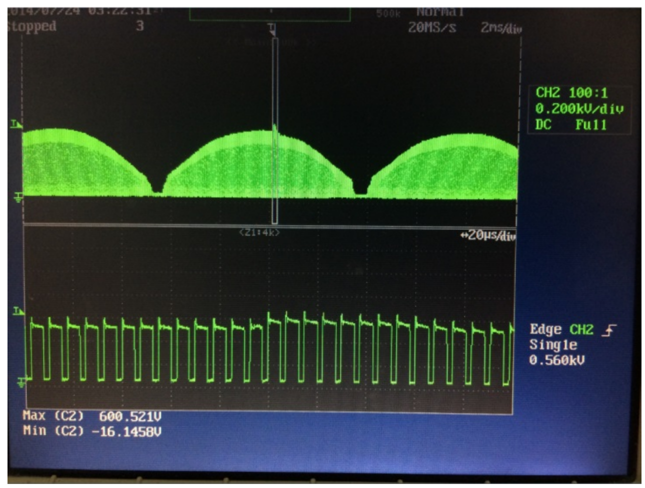

Figure 71 – 230 VAC, -2.5 kV Ring Wave Surge, 90°
V_{DRAIN}, 200 V / div., 2 ms / div.

15 Appendix: Using LYTSwitch-4 Low Line Device for Universal Input in Tapped-Buck Configuration

The LYTSwitch-4 low line family of devices are intended for single line input operation however, the family may be used for universal input. The following guidelines are provided for a universal input design.

Step by Step Procedure for Setting Output Current

Step 1: Use LYTSwitch-4 Tapped-buck PIXIs. Enter desired values for VACMAX [7], IO [12], VO [9], n [14], and L_TOTAL [41] for desired KP.

1	ACDC_LYTSwitch-4_TappedBuck_081214; Rev.1.1; Copyright Power Integrations 2014	INPUT	INFO	OUTPUT	UNIT	ACDC_LYTSwitch_081214: LYTSwitch-4 Buck / Tapped Buck Design Spreadsheet
2	ENTER APPLICATION VARIABLES					Design Title
3	Topology Selection			Tapped-Buck		
4	Dimming required	NO ▼		NO		Select "YES" option if dimming is required. Otherwise select "NO".
5	VACMIN	90		90	V	Minimum AC Input Voltage
6	VACNOM	230		230	V	Nominal AC Input Voltage
7	VACMAX	265	Info	265	V	!!!The specified input voltage range may degrade line regulation
8	fL			60.00	Hz	AC Mains Frequency
9	VO	36.00		36.00	V	Typical output voltage of LED string at full load
10	VO_MAX			39.00	V	Maximum LED string Voltage
11	VO_MIN			33.00	V	Minimum LED string Voltage
12	IO	0.450		0.450	A	Typical full load LED current
13	PO			16.20	Watts	Output Power
14	n	0.86		0.86		Estimated efficiency of operation
15	Feedback System	BIAS		BIAS		BIAS Supply
16	Bias Voltage	20.00		20.00	V	Bias Voltage
17						

Figure 72 – PIXls Spreadsheet Showing Input Cells.

40	Key Design Parameters					
41	L_TOTAL	1900.00		1900.00	uH	Total Inductance
42	N_RATIO			4.00		Turns Ratio (Np/Ns). For Buck Topology, N_RATIO=1
43	KP_VNOM			0.78		Ripple to Peak Current Ratio VACMIN peak)
44	KP_VMIN			0.51		Ripple to Peak Current Ratio VACMIN peak)
45	T_ON_MIN			2.31	us	Minimum T_ON at Maximum Input Voltage
46	Duty_Expected			0.64		Minimum duty cycle at peak of VACMIN

Figure 73 – PIXls Spreadsheet Showing L_TOTAL and KP Values.

Step 2: Use 3.6 MΩ resistor as initial value for upper RV [28] V-pin resistor, this is the recommended value for high line application and use the FB feedback pin resistor value in RFB [31] as calculated by PIXls. This first assumption will provide output current close to the desired output. However, expect output current to be much higher at high line input. This will be corrected in later steps. Choose Auto or desired device for LYTSwitch-4 [20] device selection cell and REDuce for Current Limit Mode [21]. Set IFB [30] until Expected IO (average) [47] becomes almost equal to the specified IO [12] output current. Use Goal Seek for faster results.

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19	**ENTER LYTSwitch VARIABLES**					
20	**LYTSwitch**	LYT4xx4 ▼		LYT4224		Selected LYTSwitch device.
21	Current Limit Mode	RED ▼		RED		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
22	ILIMITMIN			0.95	A	Minimum current limit
23	ILIMITMAX			1.11	A	Maximum current limit
24	fS			132000	Hz	Switching Frequency
25	fSmin			124000	Hz	Minimum Switching Frequency
26	fSmax			140000	Hz	Maximum Switching Frequency
27	IV			89.52	uA	V pin current
28	Rv	3.60		3.60	M-ohms	Voltage sense resistor
29	Rref			24.9	k-ohms	Reference Resistor Value
30	IFB			197.89	uA	FB pin current (90 uA < IFB < 210 uA)
31	RFB			85	k-ohms	IFB setting resistor
32	VDS			10.00	V	LYTSwitch on-state Drain to Source Voltage
33	VD			0.50	V	Output Winding Diode Forward Voltage Drop
34	VDB			0.70	V	Bias Winding Diode Forward Voltage Drop
35	CBP			47	uF	BP pin capacitor. Use 47uF for electrolytic cap and 100uF for ceramic cap.

Figure 74 – PIXls Spreadsheet Showing RV and RFB Values to be Used on the First Prototype Pass.

47	Expected IO (average)			0.445	A	Expected Average Output Current
48	IFB_VO_MAX		Info	220	uA	IFB at VO_MAX exceeds IFB(SKIP) and may affect regulation. Set VO_MAX lower
49	IFB_VO_MIN			180	uA	FB pin current at VO_MIN
50						

Figure 75 – PIXls Spreadsheet Showing Expected IO (Average) Cell.

Step 3: Fine tune the feedback resistor to provide correct output current at low line input and set nominal output current at nominal input voltage. Using data from Step 2 enter actual measurements in the cells under FB pin resistor Fine Tuning section, that is RFB_Initial [132] and IO_actual [133], then use values from RFB_new [134], repeat until desired target is achieved. Again, output current maybe much higher at high line input but this will be corrected in the next step.

131	**FB Fine Tuning**					
132	RFB_initial	165.00		165.00	kohms	Preliminary RFB used
133	IO_actual	0.450		0.450	A	Measured Output Current at VACNOM
134	RFB_new			165.00	kohms	New RFB

Figure 76 – PIXls Spreadsheet Showing Input Cells for FB Pin Resistor Fine Tuning.

Step 4: Employ FB Offset Circuit shown in Figure 4 in Section 4.4 by connecting R16 to FB pin of LYTSwitch-4, find the value of R16, start at 500 kΩ then reduce the value until the output current at 230 VAC is almost equal to the 115 VAC as initially set in Step 3.

Step 5: The objective in this step is not to get exactly the desired output current but to make the line regulation flat across the entire input range as possible. Use Fine Tuning section for upper (RV1) and (RV2) lower V-pin resistors to optimize regulation across the entire input range. Enter 3.6 MΩ resistor to RV1 [108] as originally used in Step 2 and enter 1.1 MΩ value for RV2 [109] V-pin resistor. Enter measured output currents at VAC1 [110] and VAC2 [111] in IO_VAC1 [112] and IO_VAC2 [113] respectively. Replace mounted V pin resistors with new V pin resistors RV1(new) [114] and RV2(new) [115] as calculated by PIXls and re-measure output. Repeat the process until measured output currents at VAC1 [110] and VAC2 [111] are almost equal then repeat Step 3 to get desired output current set at IO [12] in step 1.

1	ACDC_LYTSwitch-4_010614; Rev.1.4; Copyright Power Integrations 2014	INPUT	INFO	OUTPUT	UNIT	LYTSwitch-4_010614: Flyback Transformer Design Spreadsheet
106	**FINE TUNING (Enter measured values from prototype)**					
107	**V pin Resistor Fine Tuning**					
108	RV1	3.60		3.60	M-ohms	Upper V Pin Resistor Value
109	RV2	1.10		1.1	M-ohms	Lower V Pin Resistor Value
110	VAC1			115.0	V	Test Input Voltage Condition1
111	VAC2			230.0	V	Test Input Voltage Condition2
112	IO_VAC1	0.0750		0.0750	A	Measured Output Current at VAC1
113	IO_VAC2	0.0750		0.0750	A	Measured Output Current at VAC2
114	RV1 (new)			3.60	M-ohms	New RV1
115	RV2 (new)			1.10	M-ohms	New RV2
116	V_OV			294.8	V	Typical AC input voltage at which OV shutdown will be triggered
117	V_UV			66.9	V	Typical AC input voltage beyond which power supply can startup
118						

Figure 77 – PIXls Spreadsheet Showing Input Cells for V Pin Resistor Fine Tuning.

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16 Revision History

Date	Author	Revision	Description and Changes	Reviewed
31-Mar-15	AM	1.0	Initial Release	Apps & Mktg

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