Design Example Report

Title	***4.8 W Non-Isolated Buck Converter Using 900 V LinkSwitch™-TN2 LNK3296G/P***
Specification	85 VAC – 460 VAC Input; 16 V, 300 mA Output
Application	Small Appliance
Author	Applications Engineering Department
Document Number	DER-845
Date	December 03, 2019
Revision	1.0

Summary and Features

- 900 V maximum drain voltage
- Highly integrated solution
- Lowest possible component count
- No optocoupler required for regulation
- Thermal overload protection with automatic recovery
- <50 mW no-load consumption
- >74% efficiency at full load
- <±5% load regulation

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Table of Contents

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 is an engineering prototype report describing a non-isolated 16 V, 300 mA power supply utilizing a LNK3296G/P from Power Integrations. The document contains the power supply specification, schematic, bill-of-materials, printed circuit layout, and performance data.

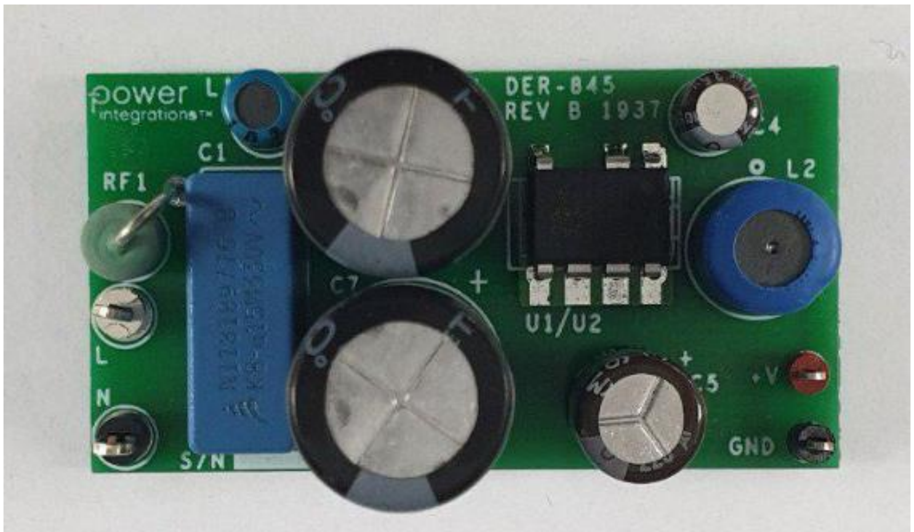

Figure 1– Populated Circuit Board Photograph, Top.

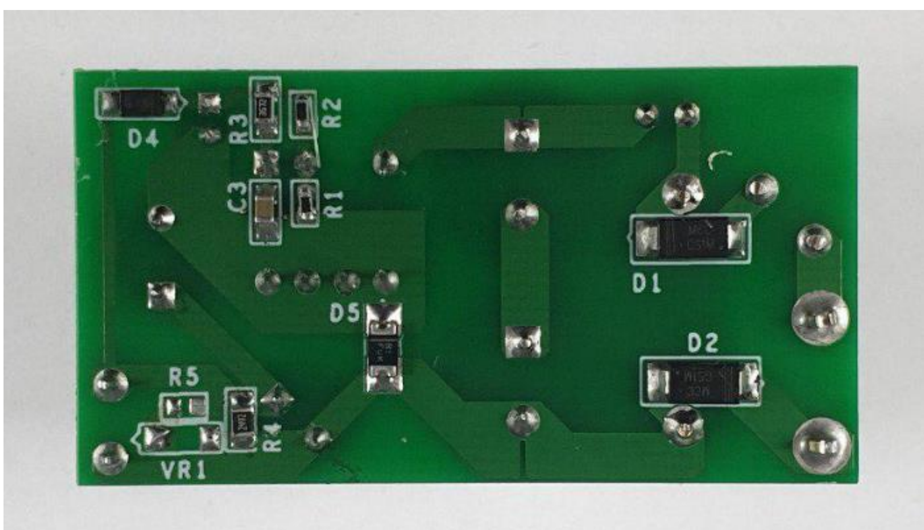

Figure 2 – Populated Circuit Board Photograph, Bottom.

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}	85		460	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (230 VAC)				<50	mW	
Output						
Output Voltage	V_{OUT}		16		V	±5%.
Output Ripple Voltage	V_{RIPPLE}			150	mV	20 MHz Bandwidth.
Output Current	I_{OUT}		0.3		A	
Total Output Power						
Continuous Output Power	P_{OUT}		4.8		W	
Peak Output Power	P_{OUT_PEAK}				W	
Efficiency						
Full Load (460Vac)	η	74			%	Measured at the End of PCB. 25 ºC.
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Line Surge Differential Mode (L1-L2)			1		kV	1.2/50 µs surge, IEC 61000-4-5, Series Impedance: Differential Mode: 2 Ω.
Ambient Temperature	T_{AMB}	0		40	ºC	Free Convection, Sea Level.

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3 Schematic

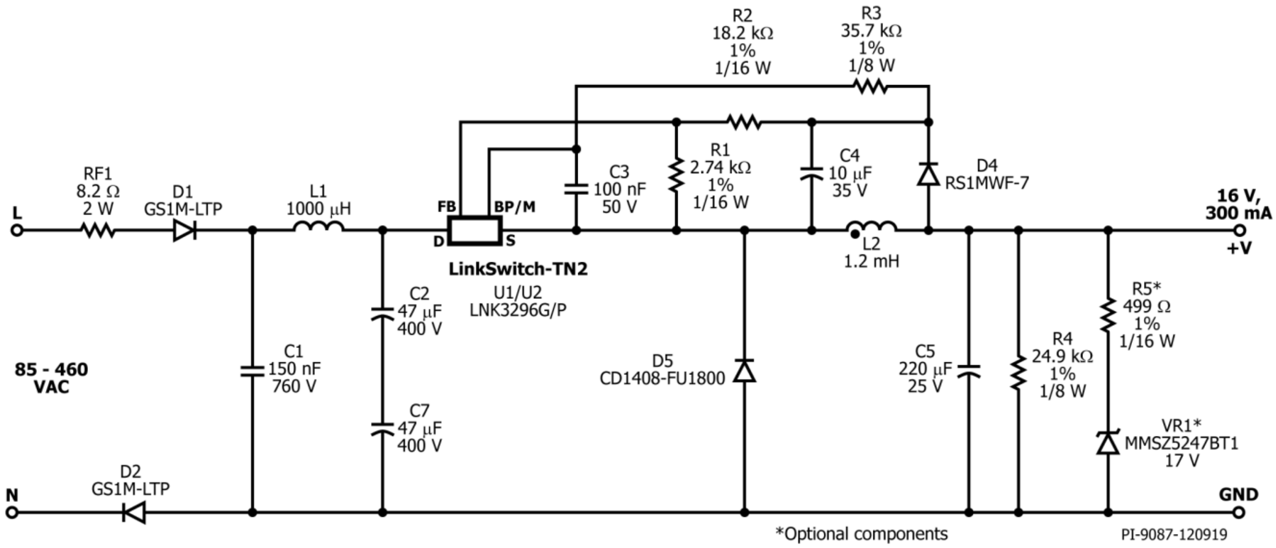

Figure 3 – Schematic.

Note:
1. U1 can be implemented as LNK3296G or U2 for LNK3296P.
2. *VR1 and *R5 are optional components. Please see circuit description.

4 Circuit Description

The schematic in Figure 3 shows a buck converter using LNK3296G/P. The circuit provides a non-isolated 16 V, 300 mA continuous output. In applications this is used to supply the control circuits and micro controller. The 900 V LinkSwitch-TN2 integrates a 900 V MOSFET and control circuitry into a single low cost IC. Regulation is achieved using a low cost resistor divider feedback network. The switching frequency jitter feature of the LinkSwitch-TN2 family and the 66 kHz switching frequency of operation helps reduce EMI.

4.1 *Input EMI Filtering*

The input stage is comprised of fusible resistor RF1, diode D1 and D2, capacitors C1, C2 and C7, and inductor L1. Resistor RF1 is a flameproof, fusible, wire-wound resistor. It accomplishes several functions: (a) limits inrush current to safe levels for rectifiers D1, D2 (b) provides differential mode noise attenuation and (c) acts as an input fuse in the event any other component fails short-circuit. As this component is used as a fuse, it should fail safely open-circuit without emitting smoke, fire or incandescent material to meet typical safety requirements. To withstand the instantaneous inrush power dissipation, wire wound types are recommended. Metal film resistors are not recommended in place of RF1.

4.2 *900 V LinkSwitch-TN2*

The 900 V LinkSwitch-TN2 integrates a 900 V power MOSFET and control circuitry into a single low cost IC. The device is self-starting from the DRAIN (D) pin with local supply decoupling provided by a small 100 nF capacitor C3 connected to the BYPASS (BP/M) pin when AC is first applied. During normal operation the device is powered from output via a current limiting resistor R3. Here, the device LNK3296P is used in a buck converter. The supply is designed to operate in mostly continuous conduction mode (MCM), with the peak L2 inductor current set by the LNK3296P internal current limit. The control scheme used is similar to the ON/OFF control used in TinySwitch™. The on-time for each switching cycle is set by the inductance value of L2, 900 V LinkSwitch-TN2 current limit and the high-voltage DC input bus across C2 and C7. Output regulation is accomplished by skipping switching cycles in response to an ON/OFF feedback signal applied to the FEEDBACK (FB) pin. This differs significantly from traditional PWM schemes that control the duty factor (duty cycle) of each switching cycle. Unlike TinySwitch, the logic of the FB pin has been inverted in LinkSwitch-TN. This allows a very simple feedback scheme to be used when the device is used in the buck converter configuration. Current into the FB pin greater than 49 μA will inhibit the switching of the internal MOSFET, while current below this allows switching cycles to occur.

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4.3 *Output Rectification*

During the ON time of U1, current ramps in L2 and is simultaneously delivered to the load. During the OFF time the inductor current ramps down via free-wheeling diode D5 into C5 and is delivered to the load. Diode D5 should be selected as an ultrafast diode (t_{RR} of 35 ns or better is recommended). Capacitor C5 should be selected to have an adequate ripple current rating (low ESR type). Please see the spreadsheet output capacitor section.

4.4 *Output Feedback*

The voltage across L2 is rectified and smoothed by D4 and C4 during the off-time of U1. To provide a feedback signal, the voltage developed across C4 is divided by R1 and R2 and connected to U1's FB pin. The values of R1 and R2 are selected such that at the nominal output voltage, the voltage on the FB pin is 2 V. R1 and R2 can be optimized for better output voltage regulation and efficiency. This voltage is specified for U1 at an FB pin current of 49 μA with a tolerance of ±1.3% over a temperature range of -40 to 125 ºC. This allows this simple feedback to meet the required overall output tolerance of ±5% at rated output current.

4.5 *Optional Components*

Zener diode VR1 and R5 are optional components and are used to limit the desired output voltage during brown in.

5 PCB Layout

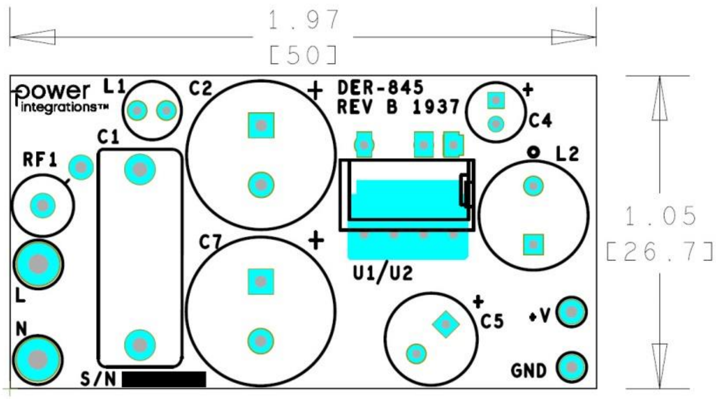

Figure 4 – Printed Circuit Layout, Top (1.97” [50 mm] L x 1.05” [26.7 mm] W).

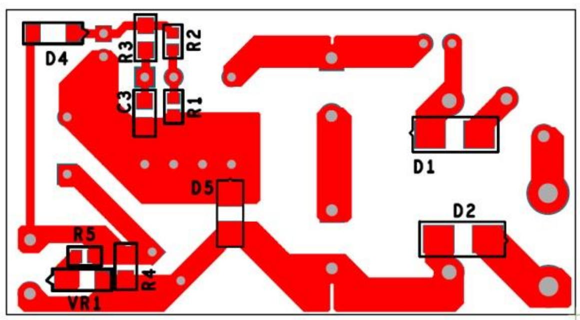

Figure 5 – Printed Circuit Layout, Bottom.

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6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	2	C2 C7	47 μF, 400 V, Electrolytic, (12.5 x 30)	TYB2CM470J300	Ltec
2	1	C1	150 nF, 760 V, Polypropylene Film	B32912B3154M	Epcos
3	1	C3	100 nF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB104	Yageo
4	1	C4	10 μF, 35 V, Electrolytic, Gen Purpose, (5 x 7)	UPW1V100MDD6	Nichicon
5	1	C5	220 μF, 25 V, Electrolytic, Very Low ESR, 72 mΩ, (8 x 11.5)	EKZE250ELL221MHB5D	Nippon Chemi-Con
6	2	D1 D2	1000 V, 1 A, DO-214AC	GS1M-LTP	Micro Commercial
7	1	D5	Diode, Std Recovery, 800V, 1A, Surface Mount 1408	CD1408-FU1800	Bourns
8	1	D4	1000 V, 1 A, General Purpose, Fast Recovery =< 500 ns, trr = 500 ns, SOD123F	RS1MWF-7	Diodes, Inc.
9	1	L1	1000 μH, 0.21 A, 5.5 x 10.5 mm	SBC1-102-211	Tokin
10	1	L2	1.2 mH, 0.490 A, 10%	RL-5480HC-3-1200	Renco
11	1	R1	RES, 2.74 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2741V	Panasonic
12	1	R2	RES, 18.2 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1822V	Panasonic
13	1	R3	RES, 35.7 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF3572V	Panasonic
14	1	R4	RES, 24.9 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF2492V	Panasonic
15*	1	R5	RES, 499 Ω, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF4990V	Panasonic
16	1	RF1	RES, 8.2 Ω, 2 W, Fusible/Flame Proof Wire Wound	FKN200JR-73-8R2	Yageo
17*	1	VR1	DIODE, ZENER, 17 V, ±5%, 500 mW, SOD123	MMSZ5247BT1GOSCT	ON Semi
18	1	U1/U2	900 V LinkSwitch-TN2 IC	LNK3296G/P	Power Integrations

Miscellaneous Parts

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	L	Test Point, WHT, THRU-HOLE MOUNT	5012	Keystone
2	1	N	Test Point, BLK, THRU-HOLE MOUNT	5011	Keystone
3	1	+V	Test Point, RED, Miniature THRU-HOLE MOUNT	5000	Keystone
4	1	GND	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone

7 Design Spreadsheet

ACDC_LinkSwitchTN2_900V_Buck_011919; Rev.1.1; Copyright Power Integrations 2019	INPUT	INFO	OUTPUT	UNIT	ACDC LinkSwitchTN2 900V Buck
APPLICATION VARIABLES					
LINE VOLTAGE RANGE			Custom		AC line voltage range
VACMIN	85.00		85.00	V	Minimum AC line voltage
VACTYP			115.00	V	Typical AC line voltage
VACMAX	460.00		460.00	V	Maximum AC line voltage
fL	50.00		50.00	Hz	AC mains frequency
LINE RECTIFICATION TYPE	H		H		Select 'F'ull wave rectification or 'H'alf wave rectification
VOUT			16.00	V	Output voltage
IOUT	0.300		0.300	A	Average output current
EFFICIENCY_ESTIMATED			0.80		Efficiency estimate at output terminals
EFFICIENCY_CALCULATED			0.69		Calculated efficiency based on real components and operating point
POUT			4.8	W	Continuous Output Power
CIN	23.50		23.50	uF	Input capacitor
VMIN			84.2	V	Valley of the rectified input voltage
VMAX			650.5	V	Peak of the rectified maximum input AC voltage
T_AMBIENT			50	degC	Operating ambient temperature in degrees celcius
INPUT STAGE RESISTANCE			10	Ohms	Input stage resistance (includes fuse, thermistor, filtering components)
PLOSS_INPUTSTAGE			0.050	W	Input stage losses estimate
CONTROLLER SELECTION					
OPERATION MODE			MCM		Mostly continuous mode of operation
CURRENT LIMIT MODE	STD		STD		Choose 'RED' for reduced current limit or 'STD' for standard current limit
PACKAGE	PDIP-8C		PDIP-8C		Select the device package
DEVICE SERIES	LNK3296		LNK3296		Generic device selection
DEVICE CODE			LNK3296P		Device code
ILIMITMIN			0.450	A	Minimum current limit of the device
ILIMITTYP			0.482	A	Typical current limit of the device
ILIMITMAX			0.515	A	Maximum current limit of the device
RDSON			9.70	ohms	Switch on-time drain to source resistance at 100degC
FSMIN			62000	Hz	Minimum switching frequency
FSTYP			68000	Hz	Typical switching frequency
FSMAX			72000	Hz	Maximum switching frequency
BVDSS			900	V	Primary switch breakdown voltage
SWITCH PARAMETERS					
VDSON			2.00	V	Switch on-time drain to source voltage estimate
DUTY			0.22		Maximum duty cycle
TIME_ON			3.522	us	Switch conduction time at the minimum line voltage
TIME_ON_MIN			0.869	us	Switch conduction time at the maximum line voltage
KP_TRANSIENT			0.136		KP under conditions of a transient
IRMS_MOSFET			0.146	A	Switch RMS current
PLOSS_MOSFET			0.658	W	Primary switch loss estimate
BUCK INDUCTOR PARAMETERS					
INDUCTANCE_MIN			1080	uH	Minimum design inductance required for power delivery
INDUCTANCE_TYP	1200		1200	uH	Typical design inductance required for power delivery
INDUCTANCE_MAX			1320	uH	Maximum design inductance required for power delivery
TOLERANCE_INDUCTANCE			10	%	Tolerance of the design inductance
DC RESISTANCE OF INDUCTOR			2.0	ohms	DC resistance of the buck inductor
FACTOR_LOSS			0.900		Factor that accounts for "off-state" power loss to be supplied by inductor
IRMS_INDUCTOR			0.312	A	Inductor RMS current
PLOSS_INDUCTOR			0.195	W	Inductor losses

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FREEWHEELING DIODE PARAMETERS					
VF_FREEWHEELING	2.5		2.5	V	Forward voltage drop of the freewheeling diode
PIV_CALCULATED			813	V	Peak inverse voltage of the freewheeling diode
IRMS_DIODE			0.276	A	Diode RMS current
TRR			75	ns	Reverse recovery time of the recommended diode
PLOSS_DIODE			1.209	W	Freewheeling diode(s) total losses
RECOMMENDED DIODE				STTH110	Recommended freewheeling diode
BIAS/FEEDBACK PARAMETERS					
VF_BIAS			0.70	V	Forward voltage drop of the bias diode
RBIAS			2490	Ohms	Bias resistor
RBP			0.1	uF	BP pin capacitor
RFB			18700	Ohms	Feedback resistor (Trim this value to meet specific application)
CFB			10	uF	Feedback capacitor
C_SOFTSTART			1-10	uF	If the output voltage is greater than 12 V or total output and system capacitance is greater than 100 uF, a soft start capacitor between 1uF and 10 uF is recommended
PLOSS_FEEDBACK			0.012	W	Feedback section losses
OUTPUT CAPACITOR					
OUTPUT VOLTAGE RIPPLE			0.320	V	Desired output voltage ripple
IRIPPLE_COUT			0.300	A	Output capacitor ripple current
ESR_COUT			1.067	Ohms	Maximum ESR of the output capacitor

8 Performance Data

All measurements performed at room temperature.

8.1 *Efficiency vs. Line*

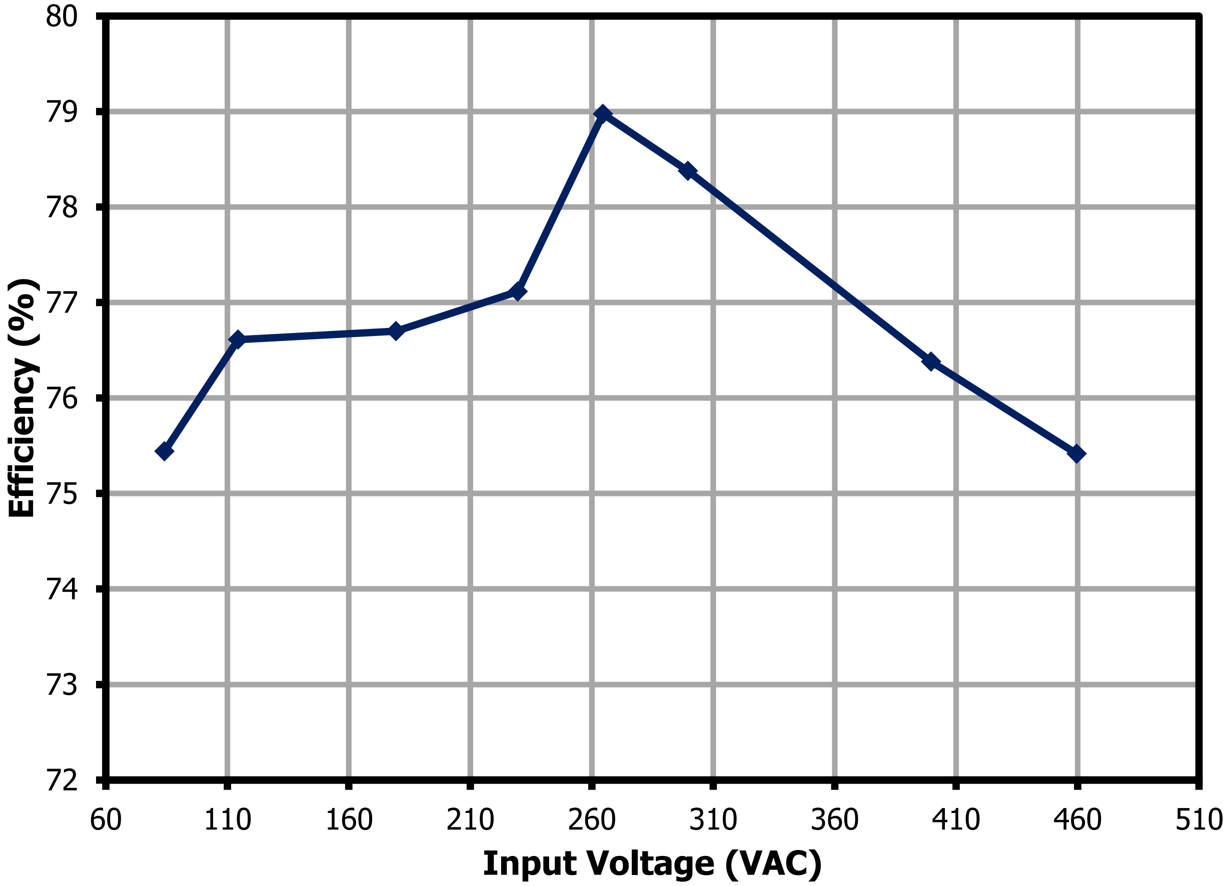

Figure 6 – Full Load (300 mA) Efficiency vs. Line Voltage, Room Temperature.

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8.2 *Efficiency vs. Load*

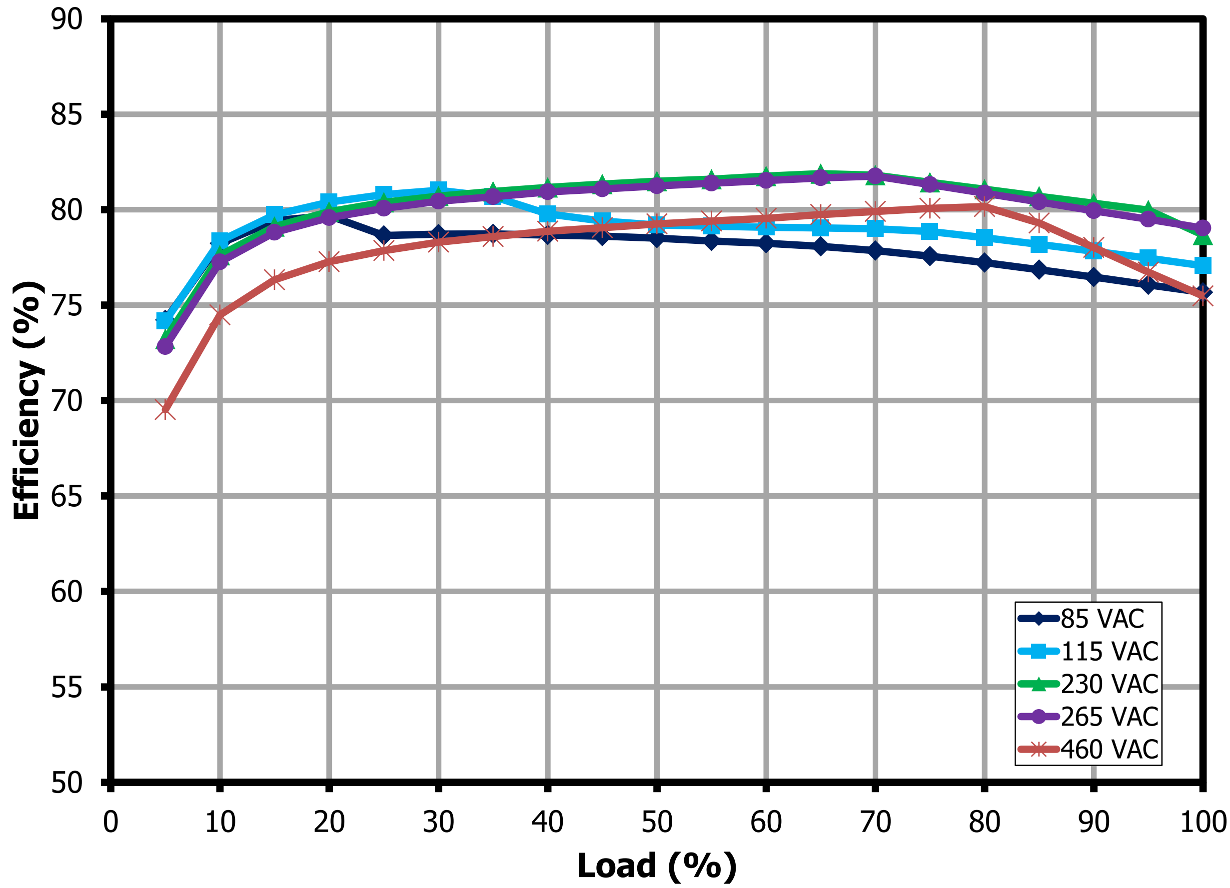

Figure 7 – Efficiency vs. Load, Room Temperature.

8.3 *Average Efficiency*

8.3.1 85 VAC / 60 Hz

Load (%)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	V_{OUT} at PCB (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency at PCB (%)
100	85	151.9	6.11	15.4	299	4.62	75.7
75	85	113.1	4.46	15.4	224	3.46	77.6
50	85	77.1	2.93	15.4	149	2.30	78.5
25	85	41.2	1.46	15.4	74	1.14	78.7
						Average	**77.6**

8.3.2 115 VAC / 60 Hz

Load (%)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	V_{OUT} at PCB (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency at PCB (%)
100	115	115.6	6.00	15.5	299	4.62	77.1
75	115	87.2	4.39	15.4	224	3.46	78.9
50	115	60.3	2.91	15.4	149	2.30	79.2
25	115	31.9	1.42	15.4	74	1.14	80.8
						Average	**79.0**

8.3.3 230 VAC / 50 Hz

Load (%)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	V_{OUT} at PCB (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency at PCB (%)
100	230	67.4	5.87	15.44	299	4.62	78.7
75	230	50.6	4.24	15.41	224	3.46	81.4
50	230	35.3	2.82	15.39	149	2.30	81.5
25	230	19.3	1.42	15.40	74	1.14	80.4
						Average	**80.5**

8.3.4 265 VAC / 50 Hz

Load (%)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	V_{OUT} at PCB (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency at PCB (%)
100	265	60.2	5.85	15.4	299	4.62	79.0
75	265	45.4	4.25	15.4	224	3.45	81.3
50	265	31.7	2.83	15.4	149	2.30	81.2
25	265	17.4	1.43	15.4	74	1.14	80.1
						Average	**80.4**

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8.3.5 460 VAC / 50 Hz

Load (%)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	V_{OUT} at PCB (V_{DC})	I_{OUT} (A_{DC})	P_{OUT} (W)	Efficiency at PCB (%)
100	460	41.2	6.12	15.4	299	4.62	75.5
75	460	30.3	4.31	15.4	224	3.45	80.1
50	460	21.4	2.90	15.4	149	2.30	79.3
25	460	11.8	1.47	15.4	74	1.14	77.9
						Average	**78.2**

8.4 *Standby Mode Efficiency*

Test Condition: Soak at full load for 5 minutes and decrease load to standby mode for 5 minutes for each line step.

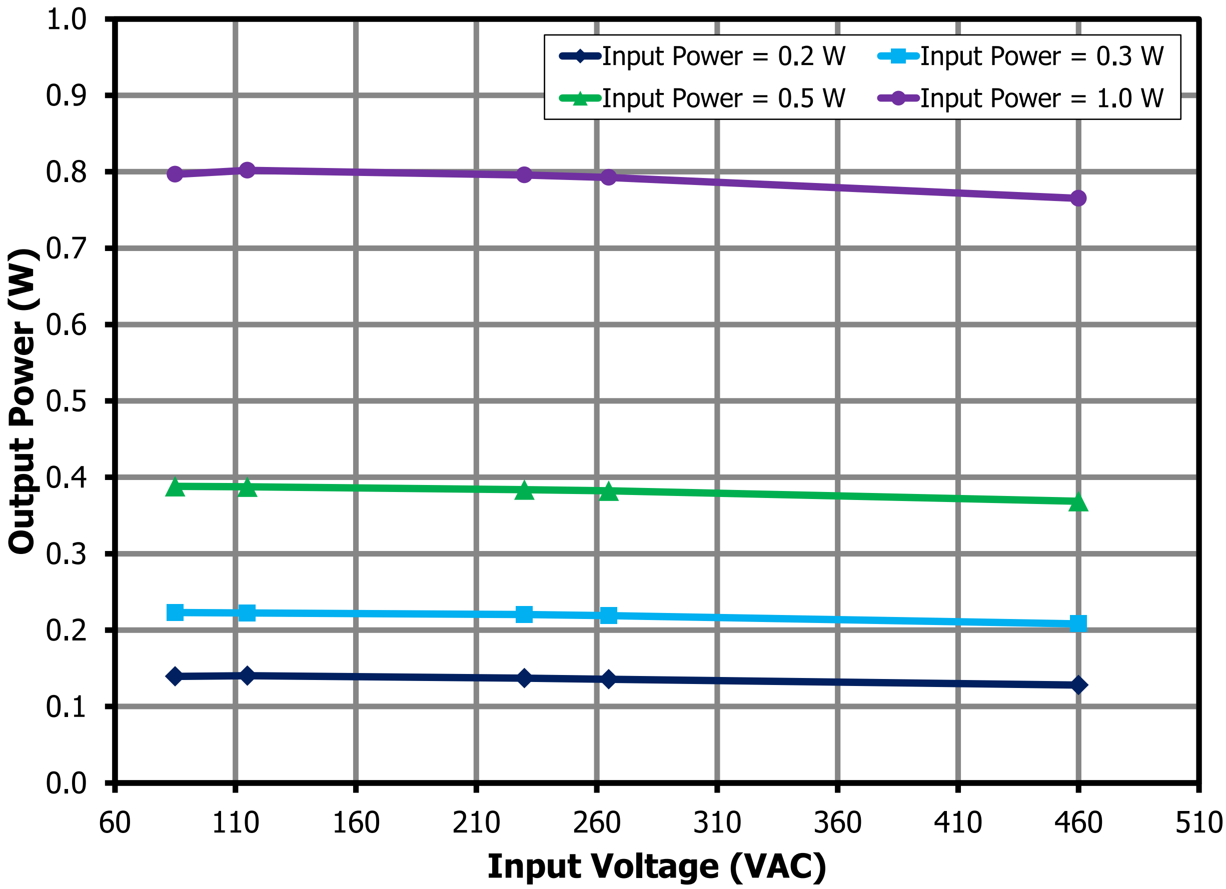

Figure 8 – Available Output Power per Input Power.

8.4.1 0.2 W Input Power

Input Measurement			Output 1 Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
85	7.2	0.1995	15.6	9	0.14	69.9
115	5.8	0.201	15.6	9	0.14	69.8
230	3.4	0.2001	15.6	9	0.14	68.6
265	3.1	0.1994	15.6	9	0.14	68.0
460	2.1	0.1997	15.6	8	0.13	64.1

8.4.2 0.3 W Input Power

Input Measurement			Output 1 Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
85	10.4	0.3003	15.5	14	0.22	74.2
115	8.3	0.2998	15.5	14	0.22	74.2
230	4.9	0.3009	15.5	14	0.22	73.2
265	4.4	0.3006	15.5	14	0.22	72.8
460	2.9	0.2999	15.5	13	0.22	69.4

8.4.3 0.5 W Input Power

Input Measurement			Output 1 Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
85	16.3	0.5004	15.5	25	0.39	77.6
115	12.9	0.4992	15.5	25	0.39	77.7
230	7.7	0.4996	15.4	25	0.38	76.8
265	6.9	0.5001	15.4	25	0.38	76.4
460	4.6	0.5	15.4	24	0.37	73.7

8.4.4 1.0 W Input Power

Input Measurement			Output 1 Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
85	30.2	0.999	15.4	52	0.80	79.8
115	23.9	1.001	15.4	52	0.80	80.1
230	14.2	1.001	15.4	52	0.80	79.5
265	12.7	1	15.4	52	0.79	79.3
460	8.4	0.995	15.4	50	0.77	76.9

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8.5 *No-Load Input Power*

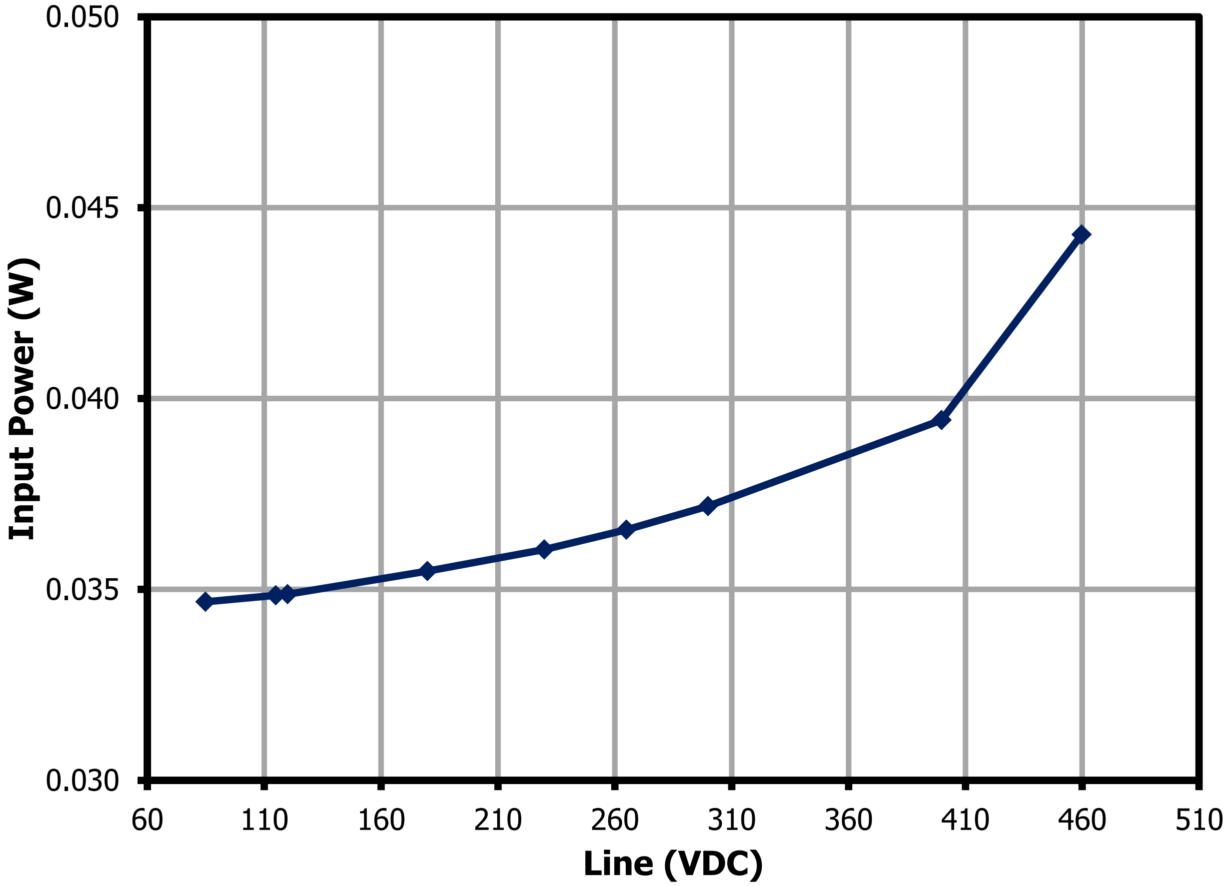

Figure 9 – No-Load Input Power vs. Input Line Voltage, Room Temperature.

8.6 *Load Regulation*

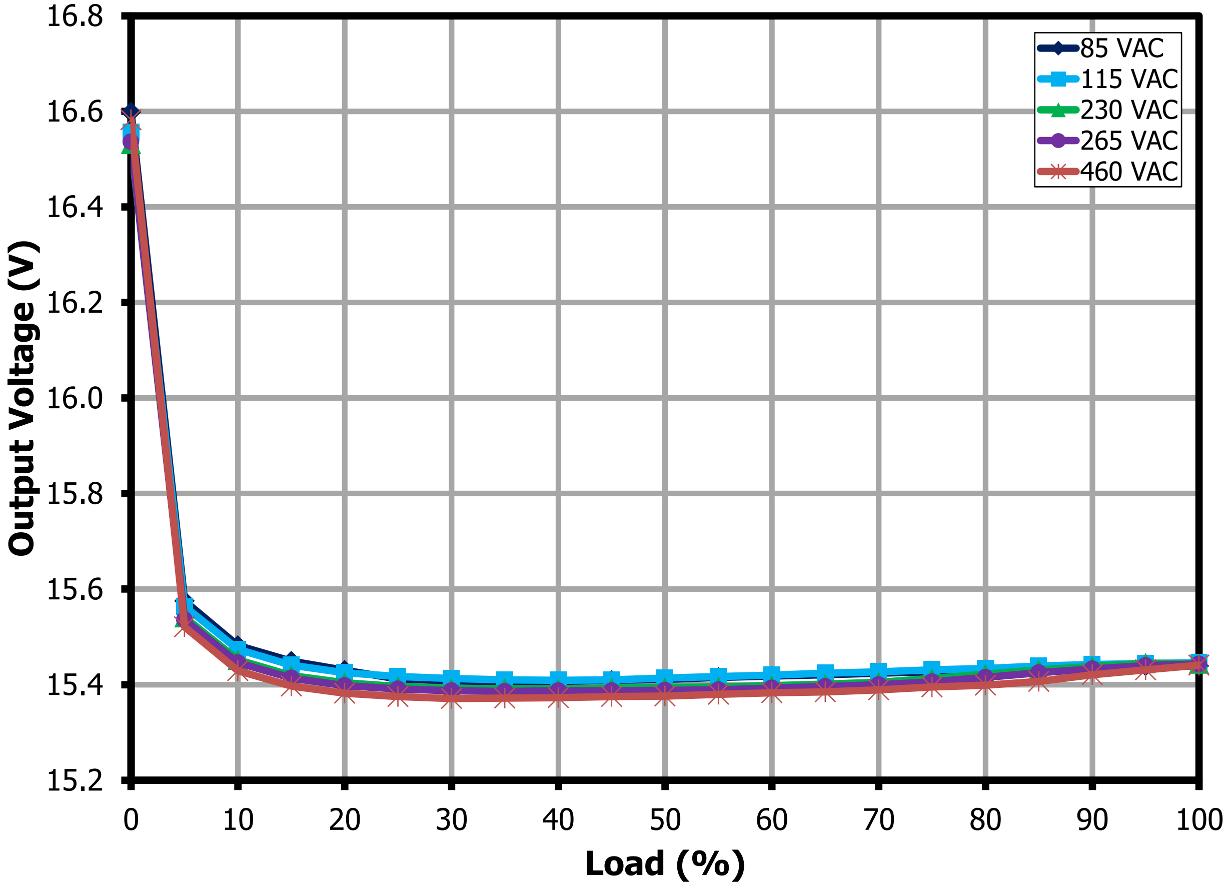

Figure 10 – Output Voltage vs. Output Current, Room Temperature.

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8.7 *Line Regulation at Full Load*

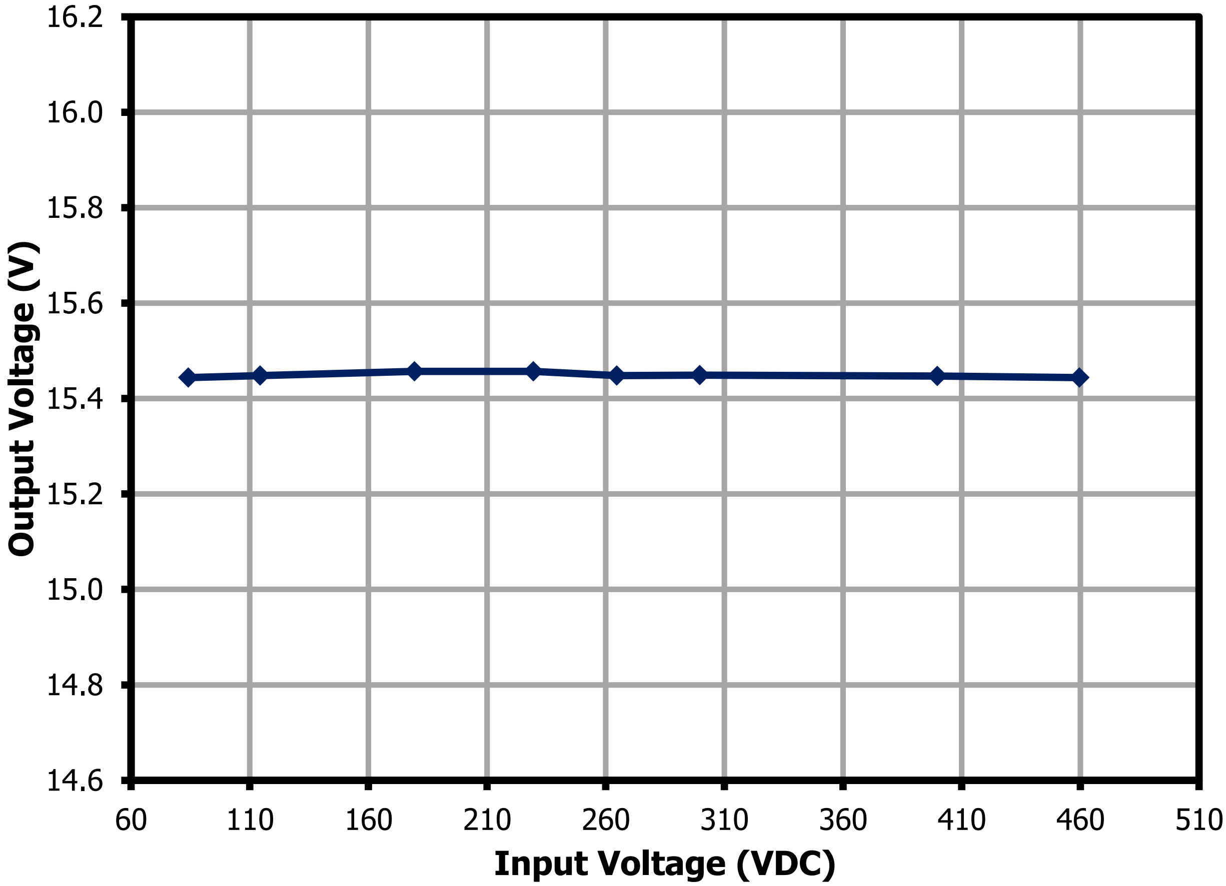

Figure 11 – Output Voltage vs. Input Voltage, Room Temperature.

9 Open Case Thermal Performance

IC temperature check was performed inside an acrylic box. Output load condition was set to the maximum output current of the device at 300 mA.

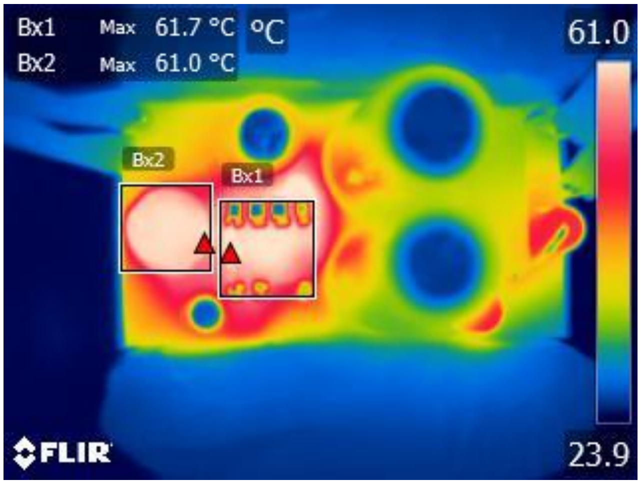

Figure 12 – 85 VAC, 300 mA Load.
LNK3296P Maximum = 61.7 ºC.
L2 Maximum = 61 ºC.
Ambient = 23.9 ºC.

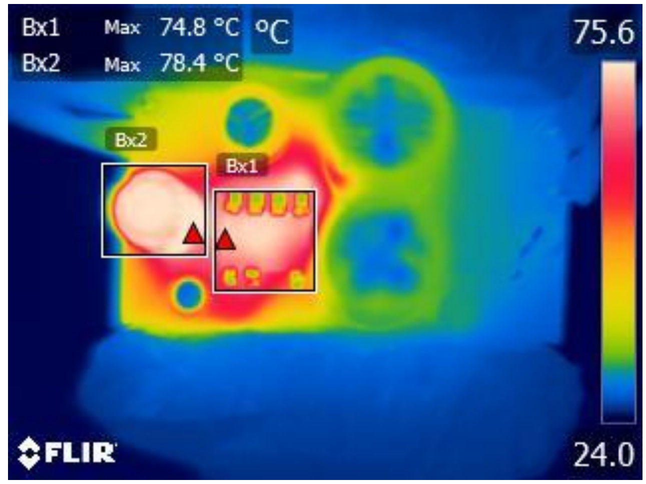

Figure 13 – 460 VAC, 300 mA Load.
LNK3296P Maximum = 74.8ºC.
L2 Maximum = 78.4 ºC.
Ambient = 24 ºC.

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10 **Waveforms**

10.1 ***Switching Waveforms***

10.1.1 LNK3296P Waveforms

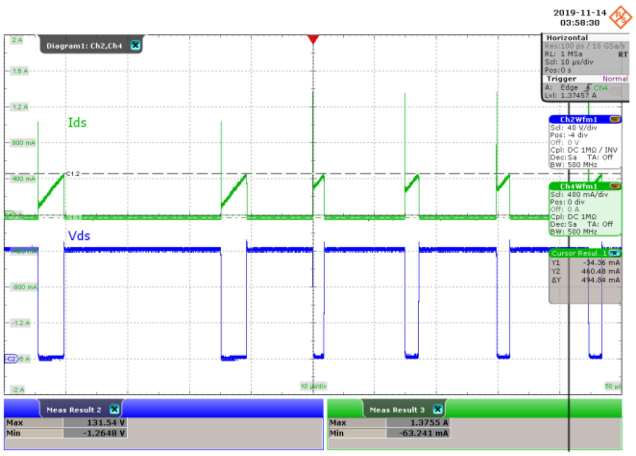

Figure 14 – Drain Voltage and Current Waveforms.
85 VAC, 300 mA Output.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 40 V, 10 µs / div.
I_{MAX} = 1.376 A, V_{MAX} = 131.54 V.

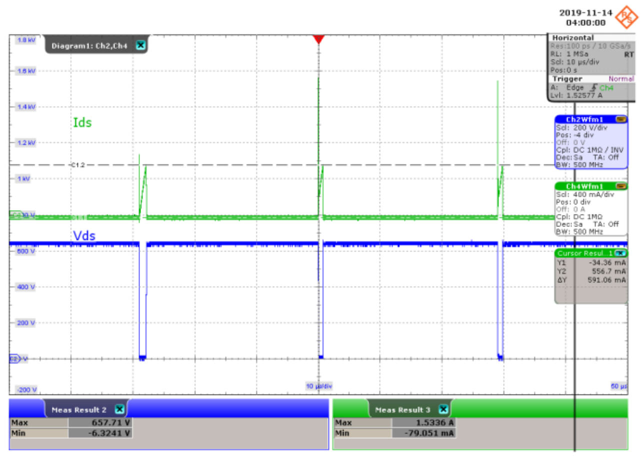

Figure 15 – Drain Voltage and Current Waveforms.
460 VAC, 300 mA Output.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 200 V, 10 µs / div.
I_{MAX} = 1.5336 A, V_{MAX} = 657.71 V.

10.1.2 LNK3296P Drain Voltage and Current Waveforms During Start-Up

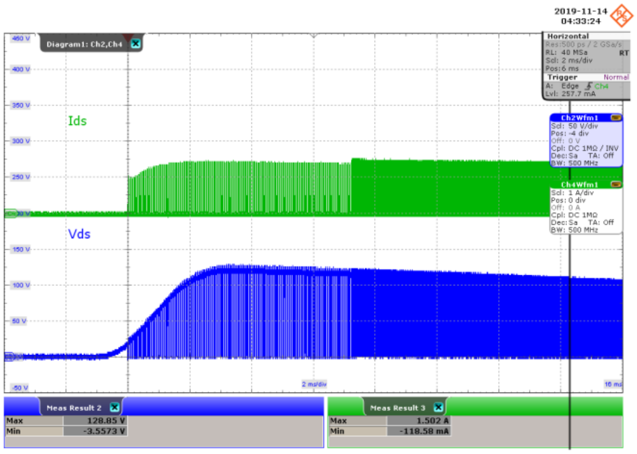

Figure 16 – Drain Voltage and Current Waveforms.
85 VAC, 300 mA Output.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 50 V, 2 ms / div.
I_{MAX} = 1.502 A, V_{MAX} = 128.85 V

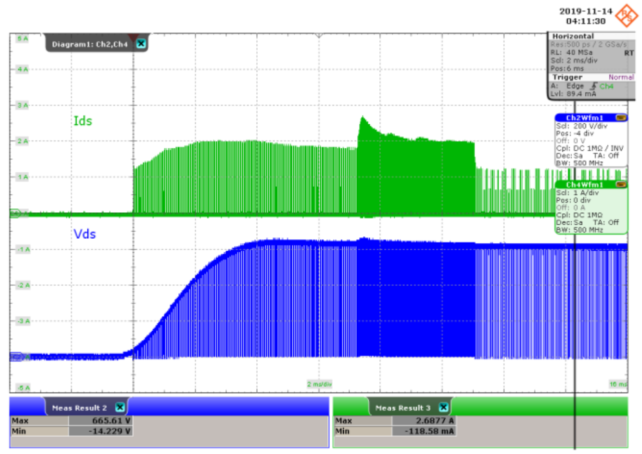

Figure 17 – Drain Voltage and Current Waveforms.
460 VAC, 300 mA Output.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 200 V, 2 ms / div.
I_{MAX} = 2.6877 A, V_{MAX} = 665.61 V

Note: The peaks are within the SOA limits.

10.1.3 Drain Current and Output Waveform During Output Short

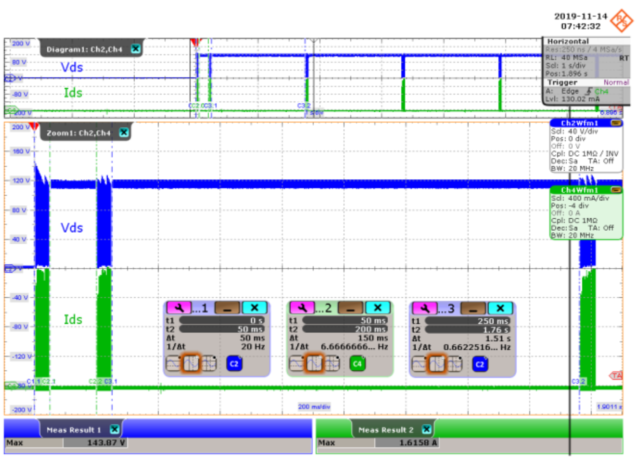

Figure 18 – Drain Current and Output Waveforms.
85 VAC Input.
V_{DS}, 40 V / div.
I_{DS}, 400 mA / div.

Figure 19 – Drain Voltage and Output Waveforms.
460 VAC Input.
V_{DS}, 200 V / div.
I_{DS}, 1 A / div.

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10.1.4 Freewheeling Diode Waveforms

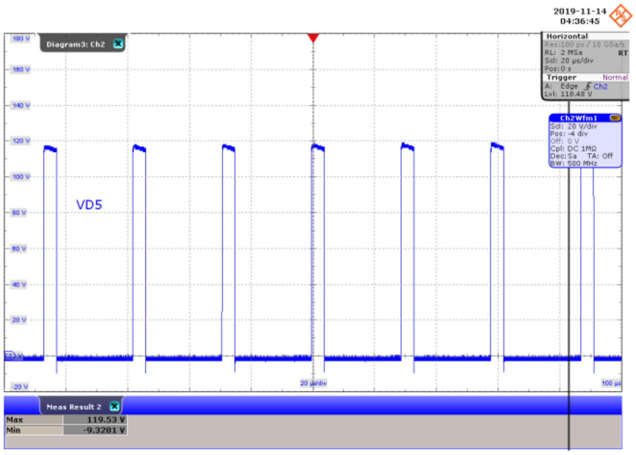

Figure 20 – Freewheeling Diode Voltage Waveforms.
85 VAC, 300 mA Output.
20 V, 20 µs / div.
V_{MAX}: 119.53 V.

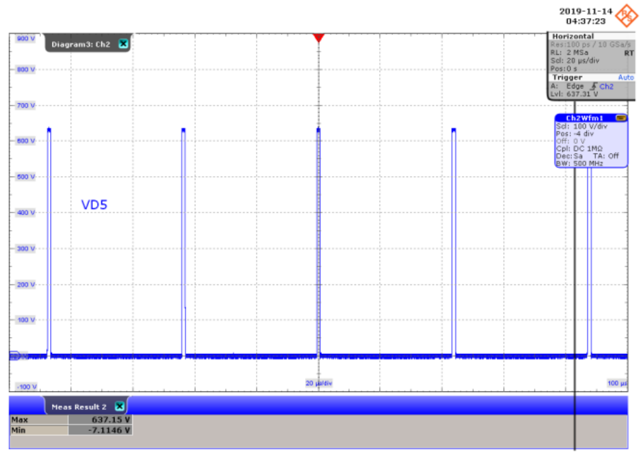

Figure 21 – Freewheeling Diode Voltage Waveforms.
460 VAC, 300 mA Output.
100 V, 20 µs / div.
V_{MAX}: 637.15 V.

10.1.5 Output Voltage and Current Waveforms During Start-Up (CC mode)

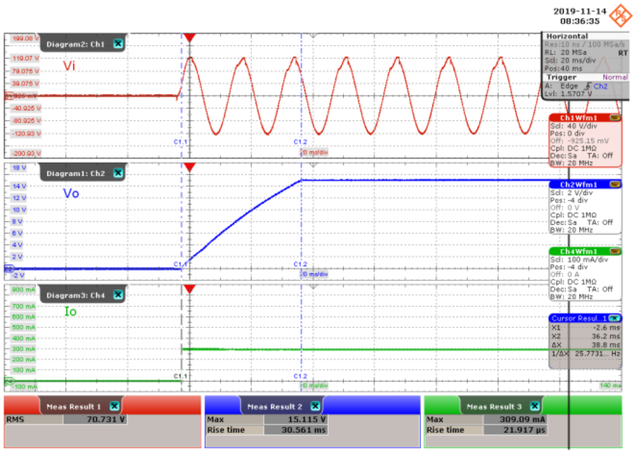

Figure 22 – Output Voltage and Current Waveforms.
85 VAC, 300 mA Output.
Upper: V_{IN}, 40 V, 20 ms / div.
Middle: V_{OUT}, 2 V / div.
Lower: I_{OUT}, 100 mA / div.
Rise Time = 38.8 ms.

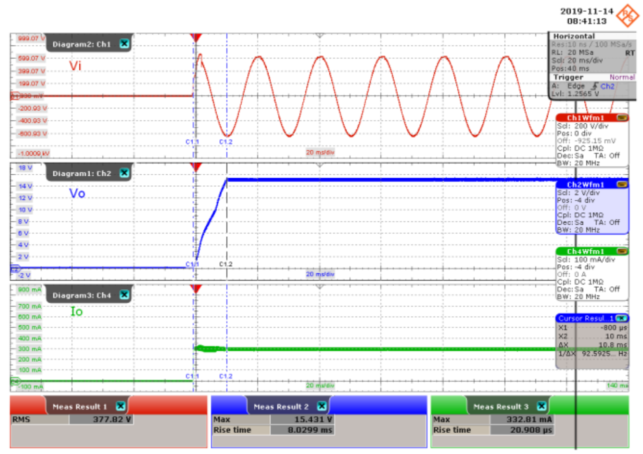

Figure 23 – Output Voltage and Current Waveforms.
460 VAC, 300 mA Output.
Upper: V_{IN}, 200 V, 20 ms / div.
Middle: V_{OUT}, 2 V / div.
Lower: I_{OUT}, 100 mA / div.
Rise Time = 10.8 ms.

10.1.6 Output Voltage and Current Waveforms During Start-Up (CR mode)

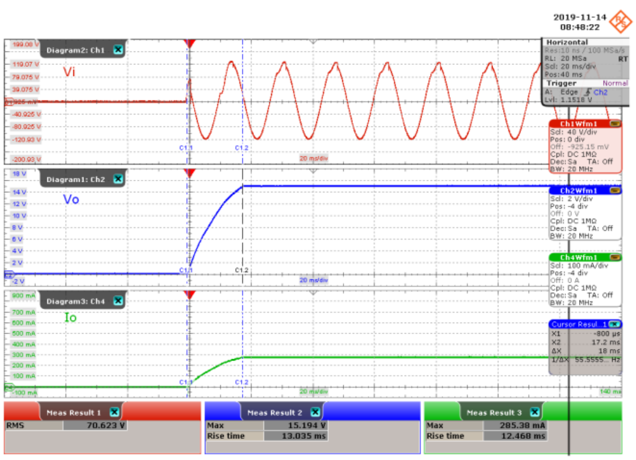

Figure 24 – Output Voltage and Current Waveforms.
85 VAC, 300 mA Output.
Upper: V_{IN}, 40 V, 20 ms / div.
Middle: V_{OUT}, 2 V / div.
Lower: I_{OUT}, 100 mA / div.
Rise Time = 18 ms.

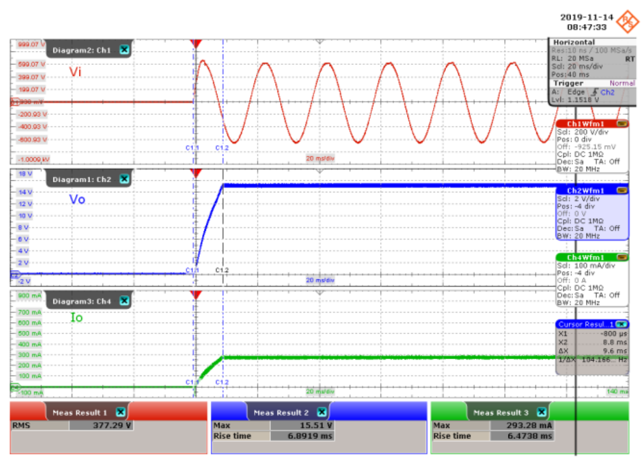

Figure 25 – Output Voltage and Current Waveforms.
460 VAC, 300 mA Output.
Upper: V_{IN}, 200 V, 20 ms / div.
Middle: V_{OUT}, 2 V / div.
Lower: I_{OUT}, 100 mA / div.
Rise Time = 9.6 ms.

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10.2 ***Output Ripple Measurements***

10.2.1 Ripple Measurement Technique

For DC output ripple measurements, a modified oscilloscope test probe must be utilized in order to reduce spurious signals due to pick-up. Details of the probe modification are provided in the Figures below.

The 4987BA probe adapter is affixed with two capacitors tied in parallel across the probe tip. The capacitors include one (1) 0.1 μF/50 V ceramic type and one (1) 1 μF/50 V aluminum electrolytic. The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).

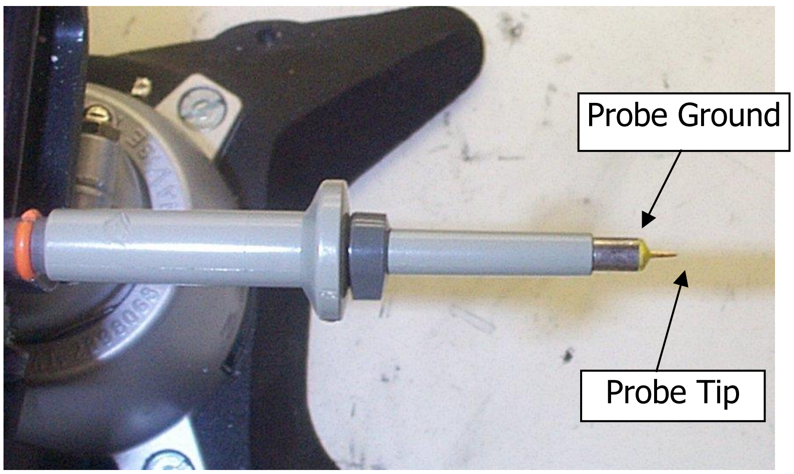

Figure 24 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed.)

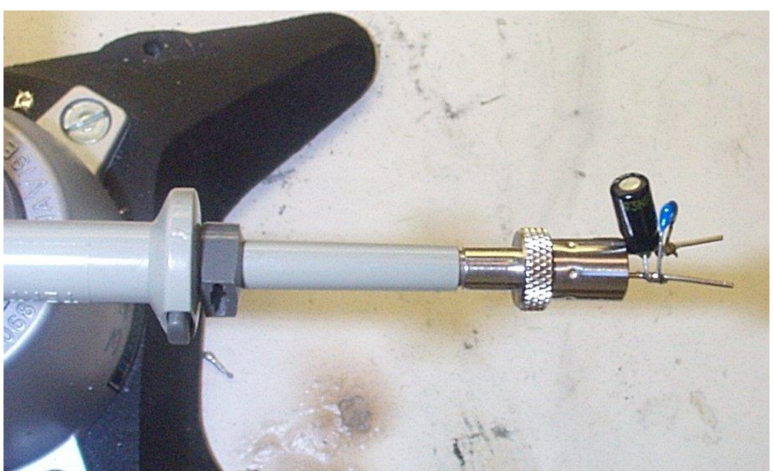

Figure 25 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added.)

10.2.2 Measurement Results

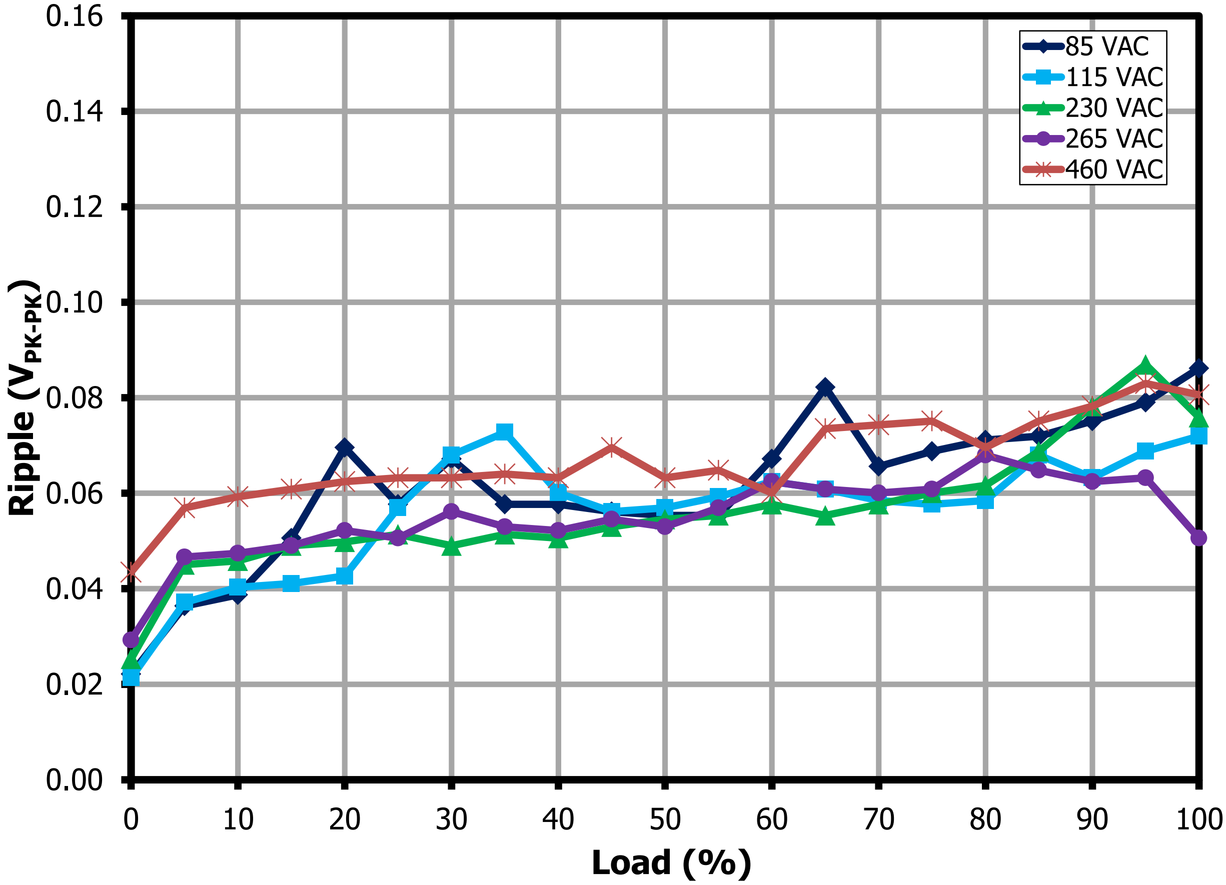

Figure 26 – Output Ripple Voltage.

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10.2.3 Ripple Voltage Waveforms

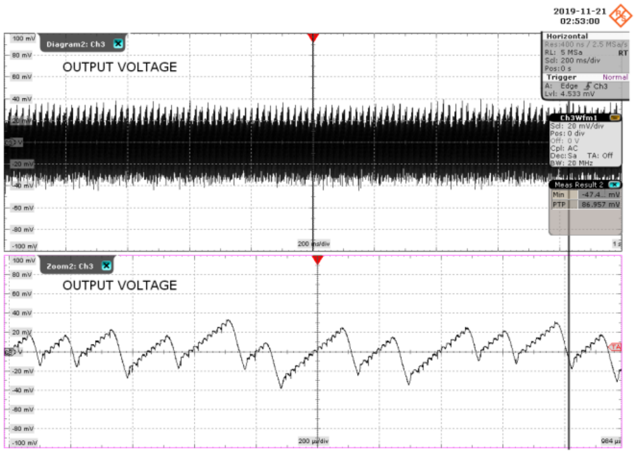

Figure 27 – Output Voltage Ripple Waveforms.
85 VAC, 300 mA Output.
20 mV / div, 200 ms / div.; 200 µs / div.
V_{PK-PK}: 86.96 mV.

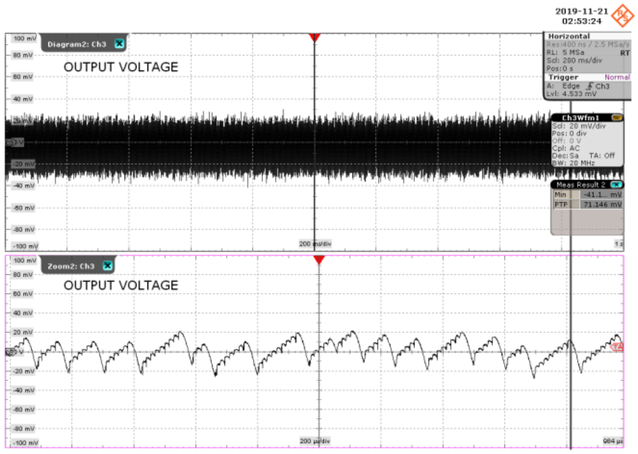

Figure 28 – Output Voltage Ripple Waveforms.
115 VAC, 300 mA Output.
20 mV / div, 200 ms / div.; 200 µs / div.
V_{PK-PK}: 71.146 mV.

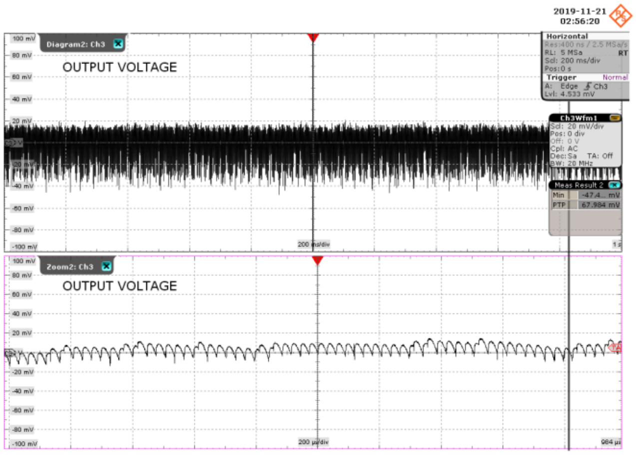

Figure 29 – Output Voltage Ripple Waveforms.
230 VAC, 300 mA Output.
20 mV / div, 200 ms / div.; 200 µs / div.
V_{PK-PK}: 67.984 mV.

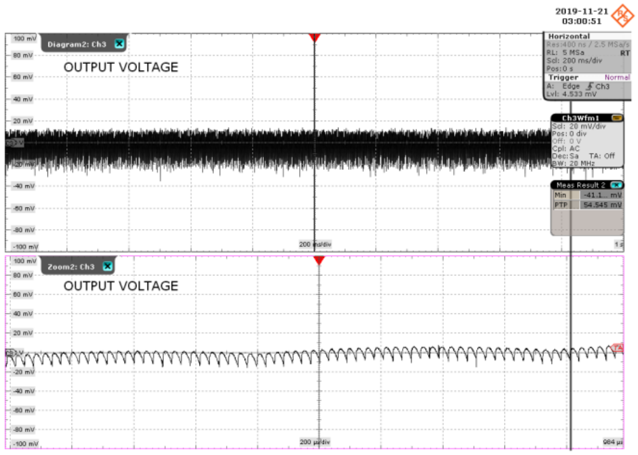

Figure 30 – Output Voltage Ripple Waveforms.
265 VAC, 300 mA Output.
20 mV / div, 200 ms / div.; 200 µs / div.
V_{PK-PK}: 54.545 mV.

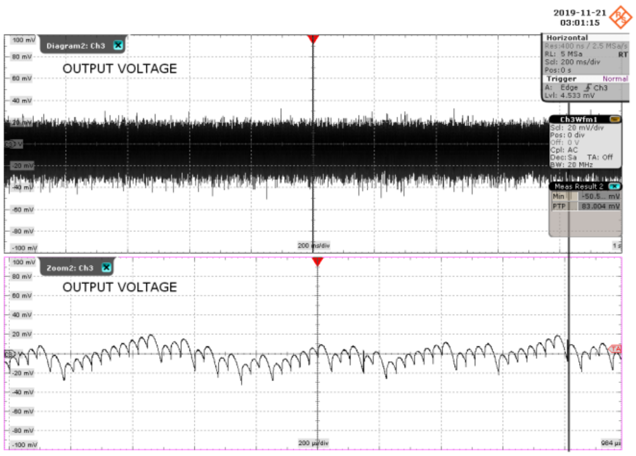

Figure 31 – Output Voltage Ripple Waveforms.
460 VAC, 300 mA Output.
20 mV / div, 200 ms / div.; 200 μs / div.
V_{PK-PK}: 83 mV.

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11 Conductive EMI

300 mA Resistive Load, Floating Output (QPK / AV) After running for 5 minutes.

11.1 *115 VAC, Floating*

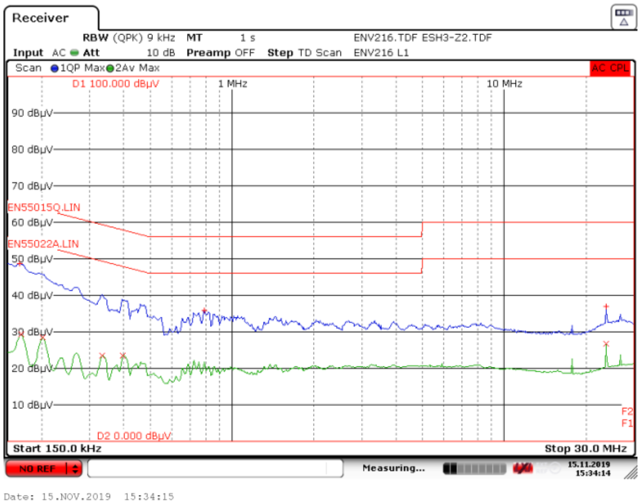

Figure 31 – Line.
Lowest Peak Delta Limit: -16.44 dB, 165.75 kHz.
Lowest Average Delta Limit: -23.24 dB, 23.7188 MHz.

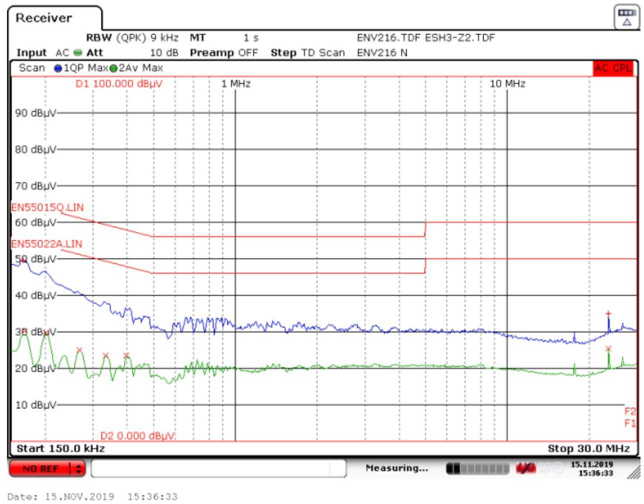

Figure 32 – Neutral.
Lowest Peak Delta Limit: -15.51 dB, 165.75 kHz.
Lowest Average Delta Limit: -23.75 dB, 201.75 kHz.

11.2 *230 VAC, Floating*

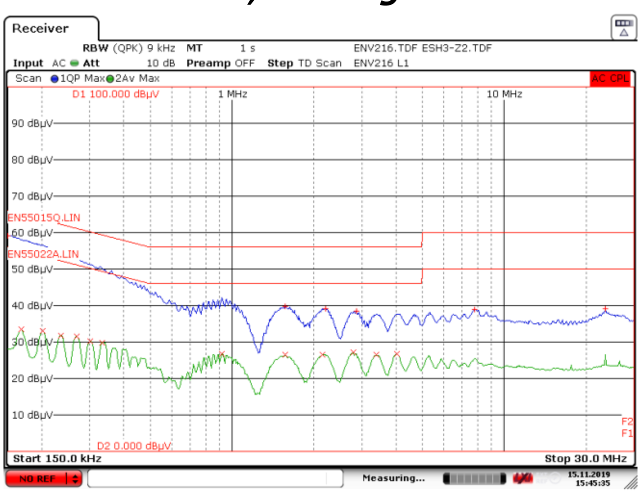

Figure 33 – Line.
Lowest Peak Delta Limit: -6.8 dB, 150 kHz.
Lowest Average Delta Limit: -18.84 dB, 2.8005 MHz.

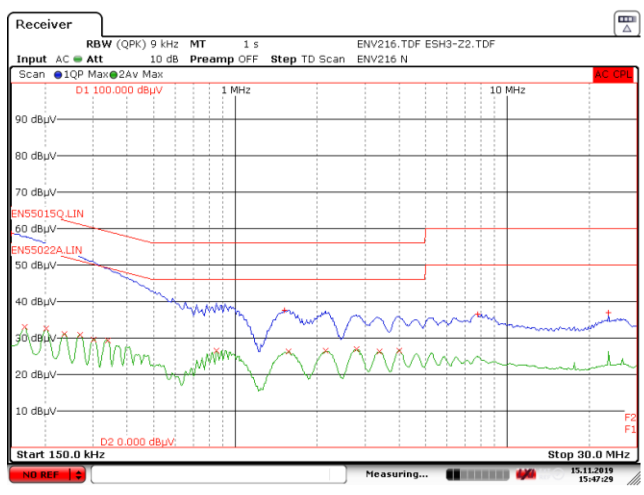

Figure 34 – Neutral.
Lowest Peak Delta Limit: -7.2 dB, 150 kHz.
Lowest Average Delta Limit: -19.02 dB, 2.7982 MHz.

12 Lighting Surge

12.1 *Differential Mode Test*

Passed ±1 kV surge test.

Surge Voltage (kV)	Phase Angle	IEC Coupling	Generator Impedance (Ω)	Number Strikes	Result	Remarks
+1	0	L1/L2	2	10	PASS	No Auto-restart
-1	0	L1/L2	2	10	PASS	No Auto-restart
+1	90	L1/L2	2	10	PASS	No Auto-restart
-1	90	L1/L2	2	10	PASS	No Auto-restart
+1	180	L1/L2	2	10	PASS	No Auto-restart
-1	180	L1/L2	2	10	PASS	No Auto-restart
+1	270	L1/L2	2	10	PASS	No Auto-restart
-1	270	L1/L2	2	10	PASS	No Auto-restart

12.1.1 1000 V 90º Differential Mode Surge

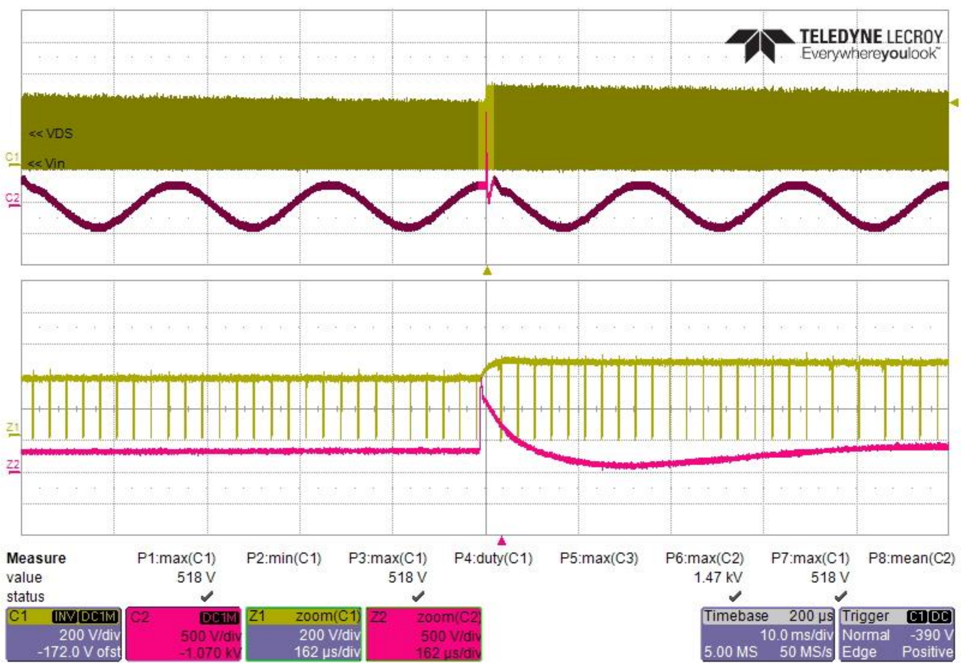

Figure 36 – Drain Voltage, 230 VAC, 300 mA.

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12.1.2 -1000 V 270º Differential Mode Surge

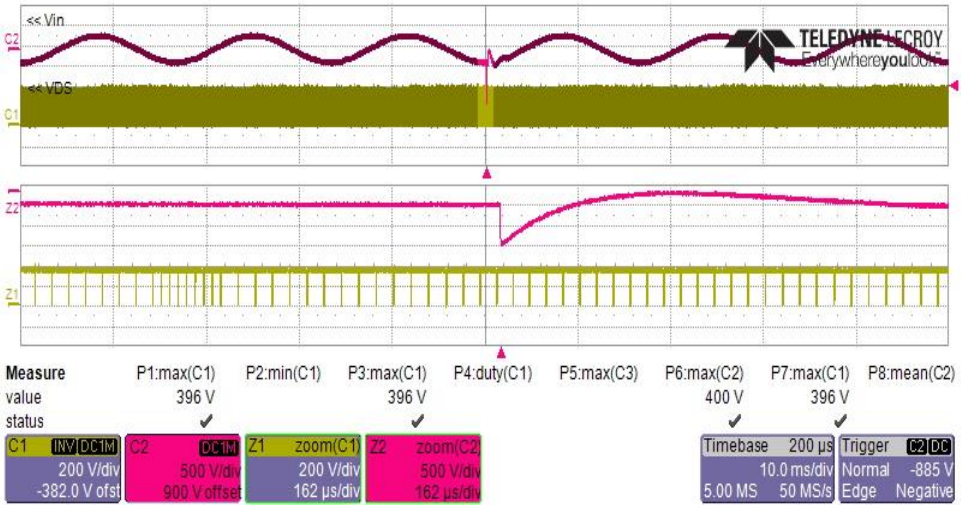

Figure 37 – Drain Voltage, 230 VAC, 300 mA.

13 Revision History

Date	Author	Revision	Description & Changes	Reviewed
03-Dec-19	MAGM	1.0	Initial Release	Apps & Mktg

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