



Design Example Report

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|------------------------|--|
| Title | <i>4.8 W Non-Isolated Buck Converter Using 900 V LinkSwitch™-TN2 LNK3296G/P</i> |
| 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

PATENT INFORMATION

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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 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.

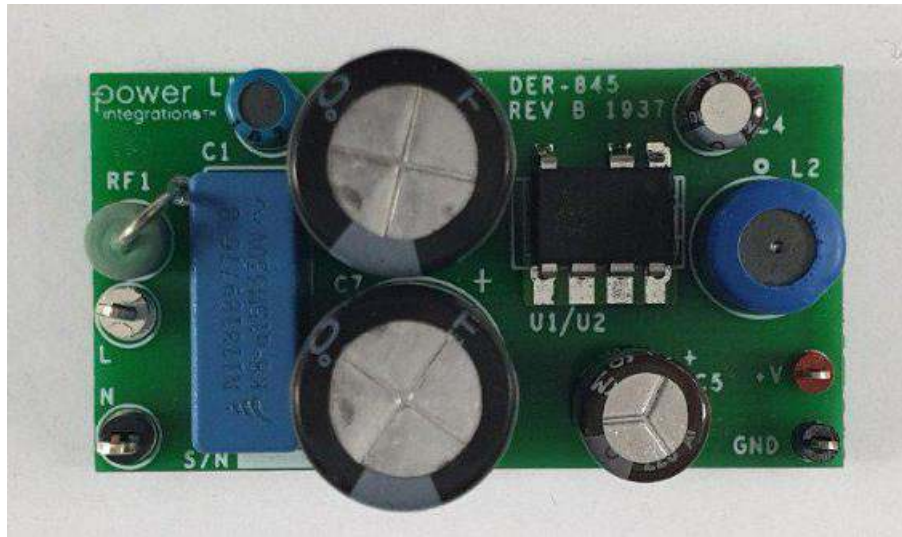


Figure 1– Populated Circuit Board Photograph, Top.

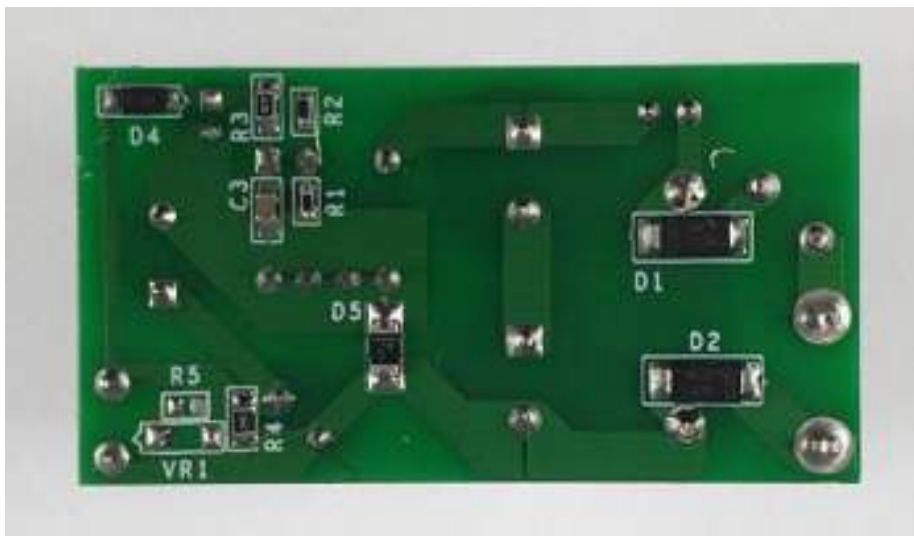


Figure 2 – Populated Circuit Board Photograph, Bottom.

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%. 20 MHz Bandwidth. |
| Output Ripple Voltage | V_{RIPPLE} | | | 150 | mV | |
| 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 °C. |
| Environmental | | | | | | |
| Conducted EMI | | Meets CISPR22B / EN55022B | | | | 1.2/50 μ s surge, IEC 61000-4-5, Series Impedance: Differential Mode: 2 Ω . |
| Line Surge Differential Mode (L1-L2) | | | 1 | | kV | |
| Ambient Temperature | T_{AMB} | 0 | | 40 | °C | Free Convection, Sea Level. |

3 Schematic

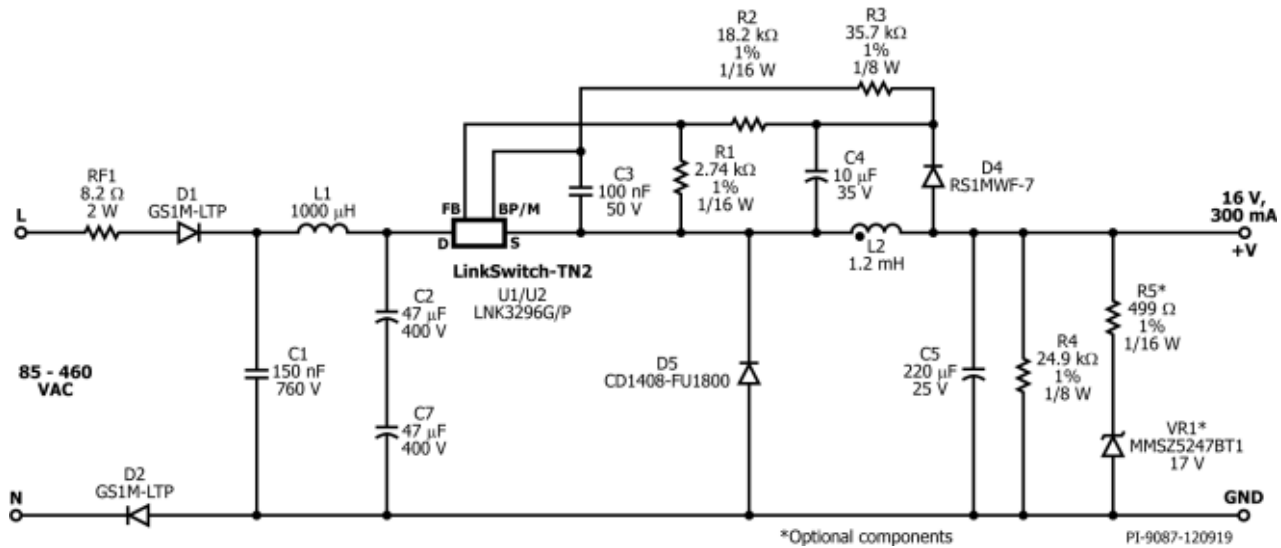


Figure 3 – Schematic.

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 μ A will inhibit the switching of the internal MOSFET, while current below this allows switching cycles to occur.

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 μ A with a tolerance of $\pm 1.3\%$ over a temperature range of -40 to 125 $^{\circ}$ C. This allows this simple feedback to meet the required overall output tolerance of $\pm 5\%$ 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

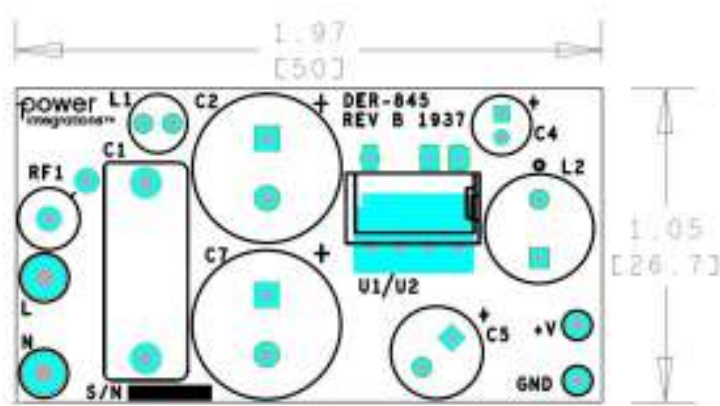


Figure 4 – Printed Circuit Layout, Top (1.97" [50 mm] L x 1.05" [26.7 mm] W).

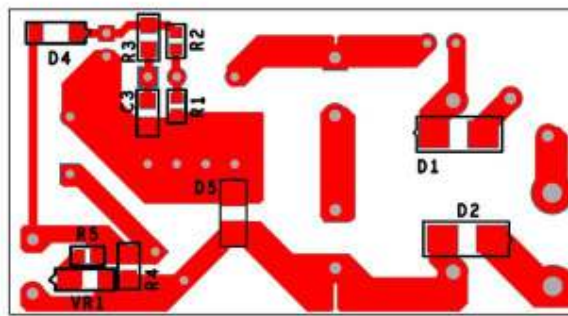


Figure 5 – Printed Circuit Layout, Bottom.

6 Bill of Materials

| Item | Qty | Ref Des | Description | Mfg Part Number | Mfg |
|------|-----|---------|---|--------------------|--------------------|
| 1 | 2 | C2 C7 | 47 μ F, 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 μ F, 35 V, Electrolytic, Gen Purpose, (5 x 7) | UPW1V100MDD6 | Nichicon |
| 5 | 1 | C5 | 220 μ F, 25 V, Electrolytic, Very Low ESR, 72 m Ω , (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 μ H, 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 k Ω , 1%, 1/16 W, Thick Film, 0603 | ERJ-3EKF2741V | Panasonic |
| 12 | 1 | R2 | RES, 18.2 k Ω , 1%, 1/16 W, Thick Film, 0603 | ERJ-3EKF1822V | Panasonic |
| 13 | 1 | R3 | RES, 35.7 k Ω , 1%, 1/8 W, Thick Film, 0805 | ERJ-6ENF3572V | Panasonic |
| 14 | 1 | R4 | RES, 24.9 k Ω , 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, \pm 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 'Full wave rectification or 'Half wave rectification |
| VOOUT | | | 16.00 | V | Output voltage |
| IOOUT | 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 |
| RDSOIN | | | 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 |



| 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

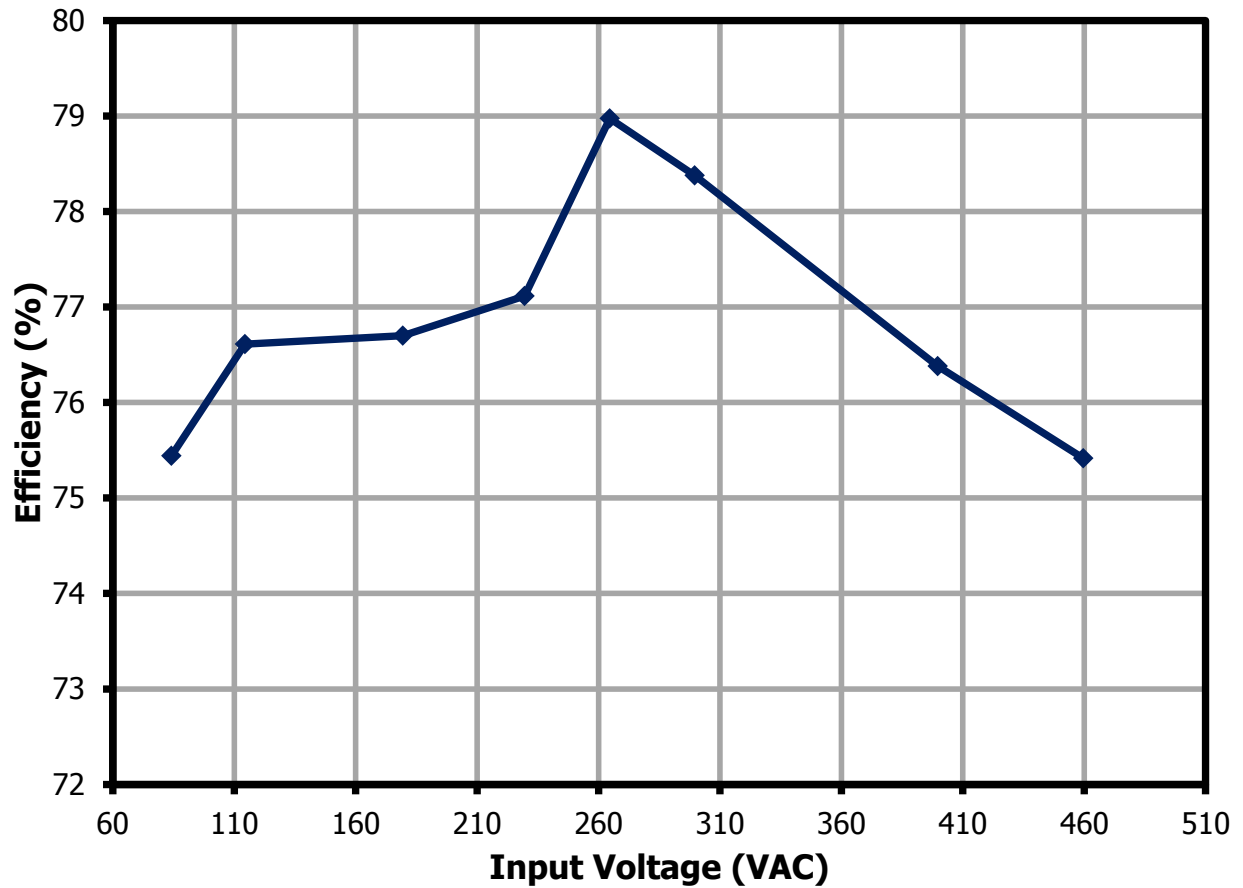


Figure 6 – Full Load (300 mA) Efficiency vs. Line Voltage, Room Temperature.

8.2 Efficiency vs. Load

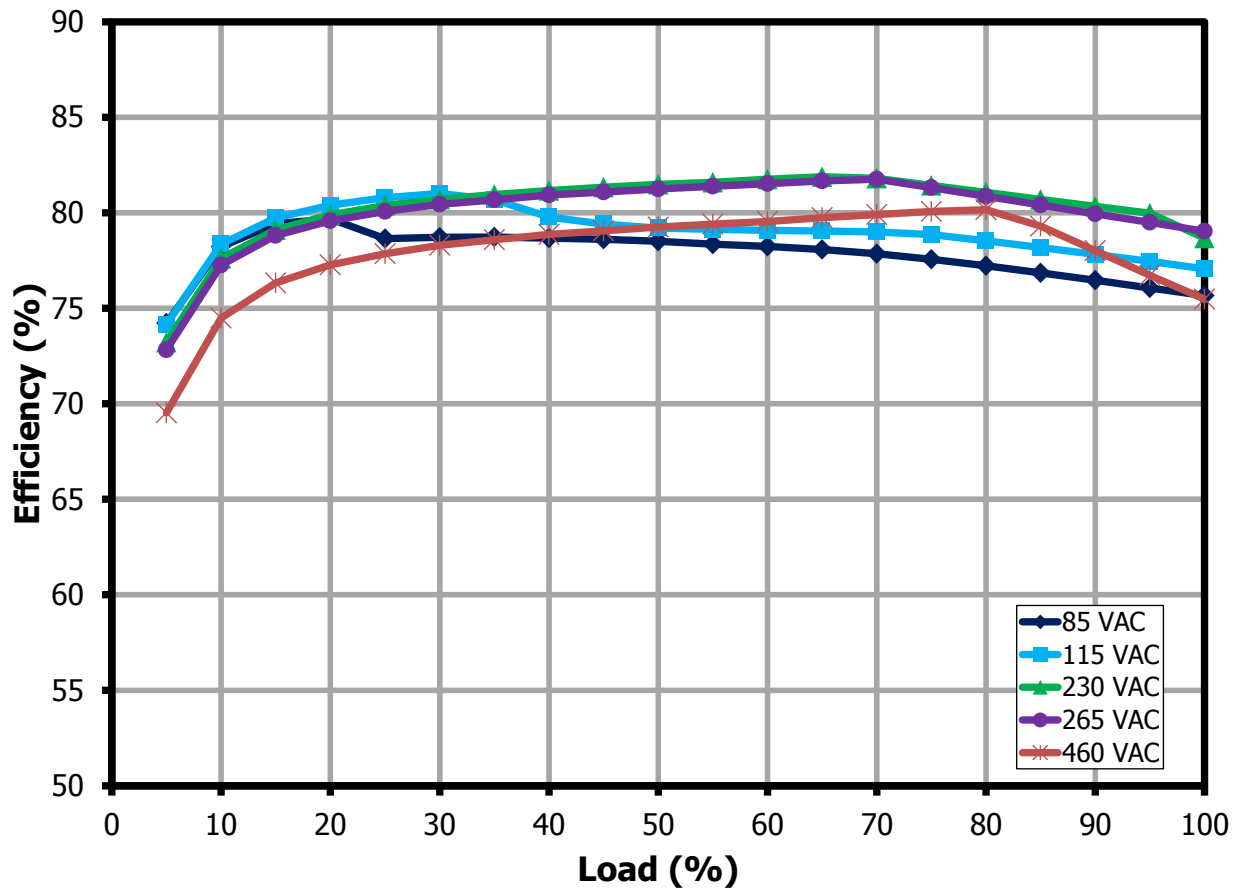


Figure 7 – Efficiency vs. Load, Room Temperature.

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 |

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.

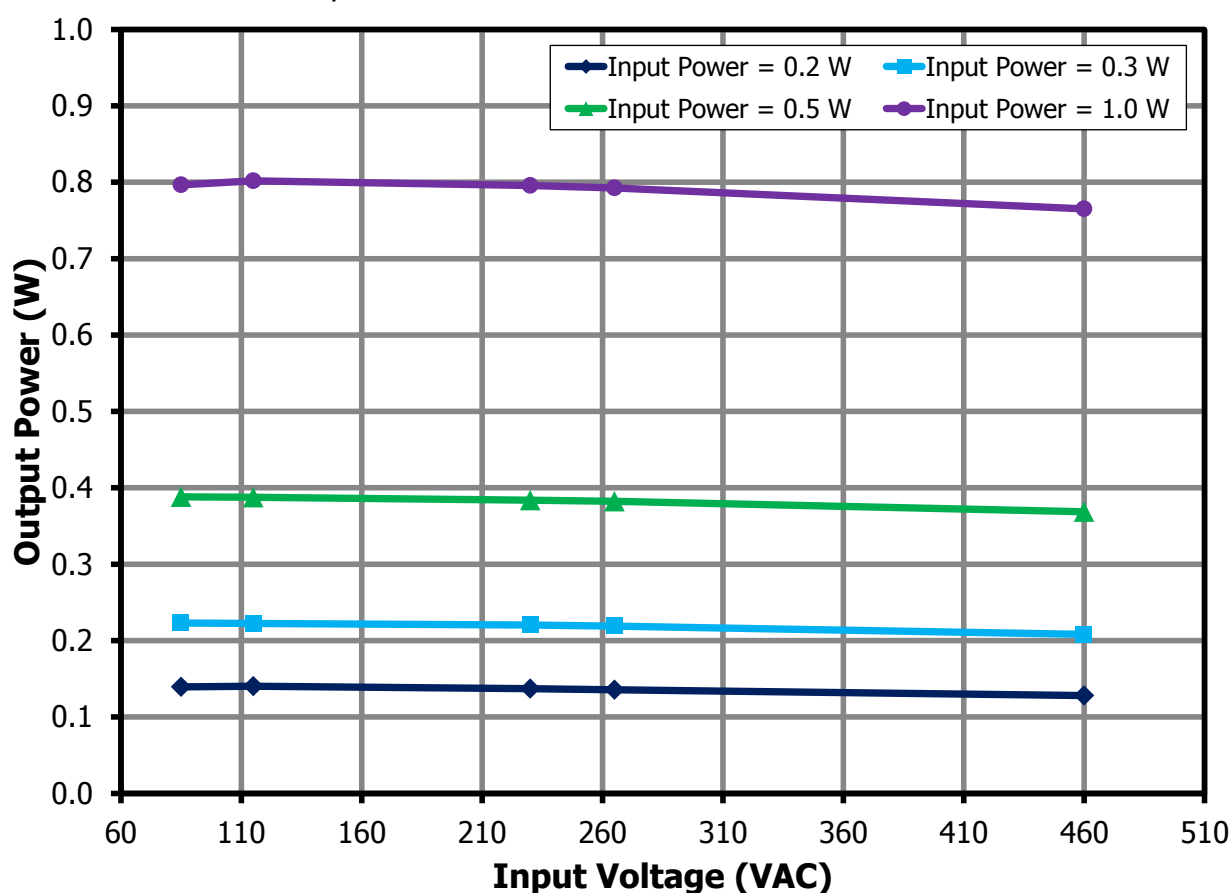


Figure 8 – Available Output Power per Input Power.

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 |

8.5 *No-Load Input Power*

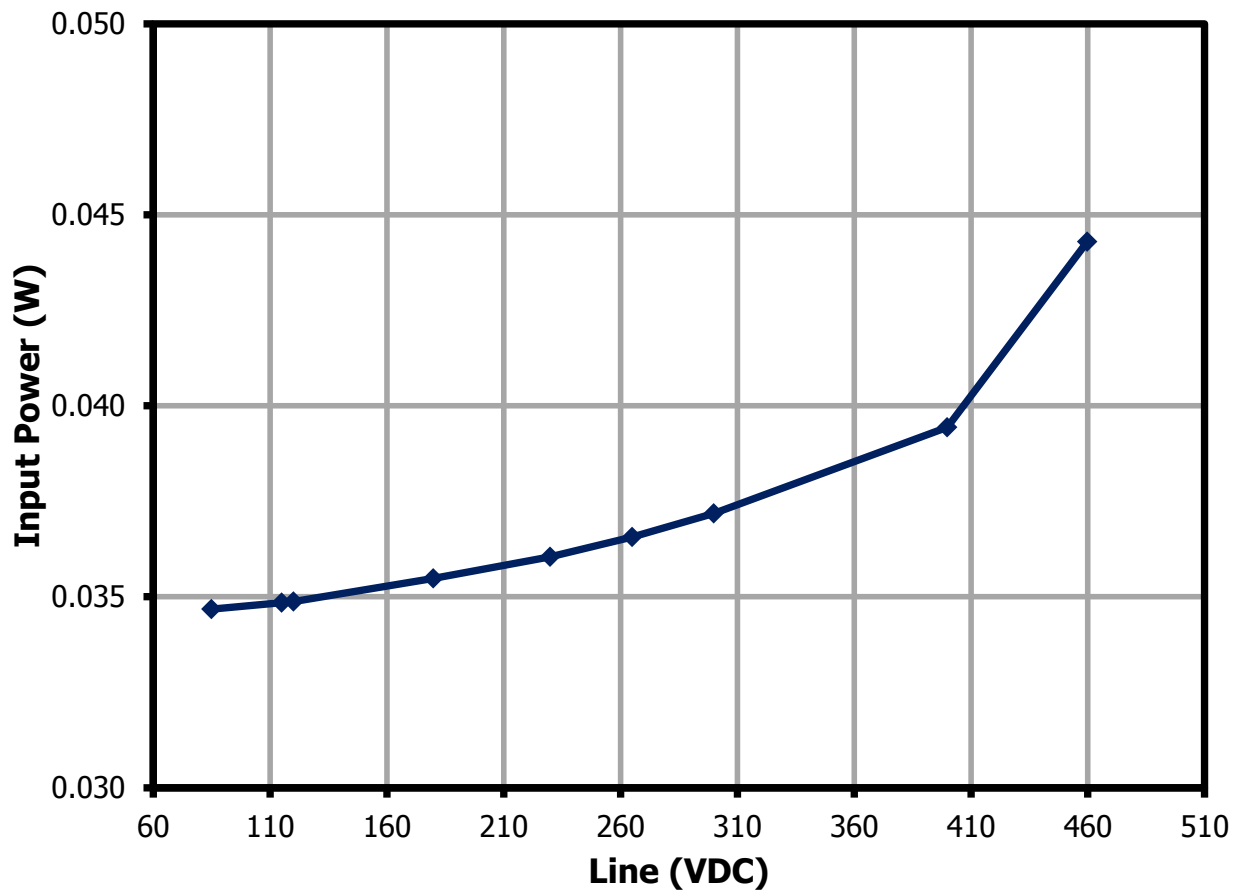


Figure 9 – No-Load Input Power vs. Input Line Voltage, Room Temperature.

8.6 Load Regulation

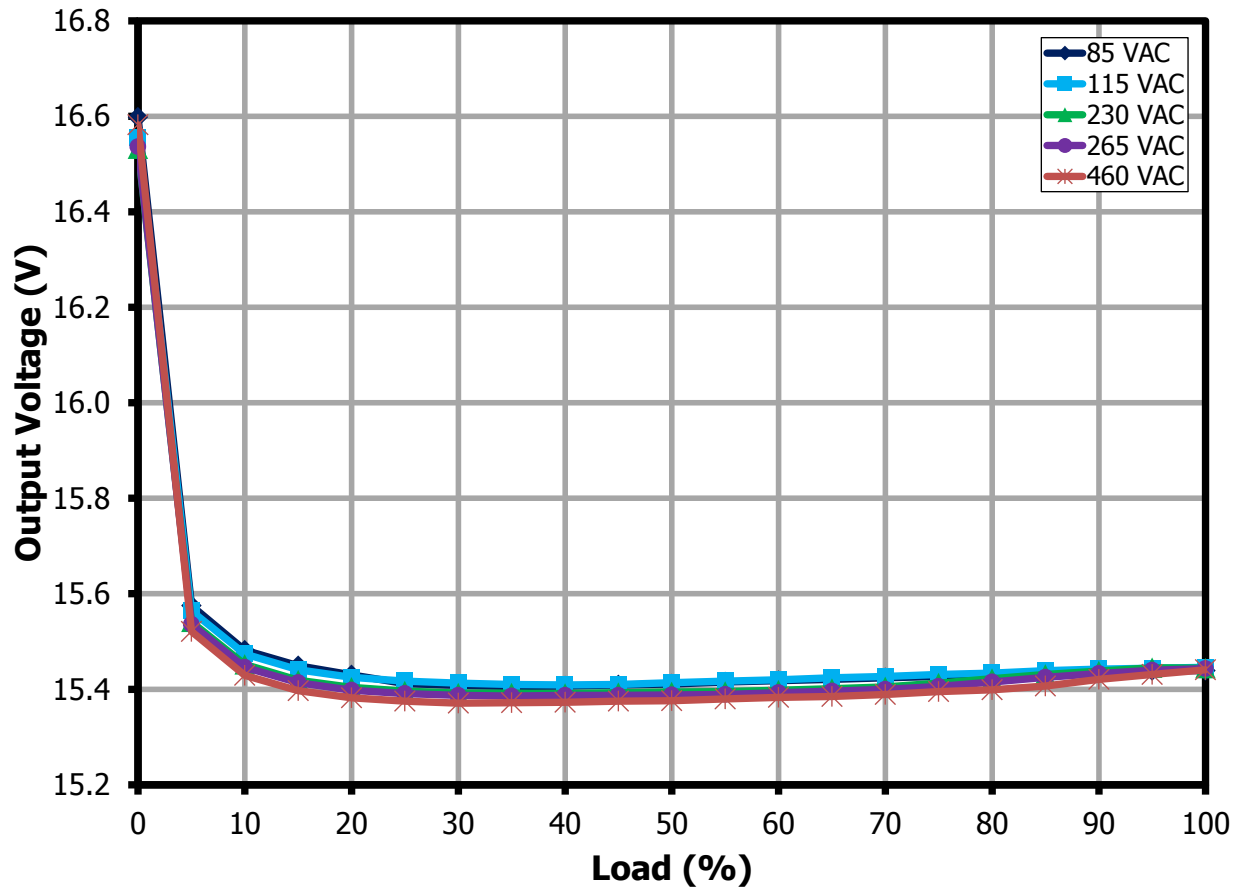


Figure 10 – Output Voltage vs. Output Current, Room Temperature.

8.7 *Line Regulation at Full Load*

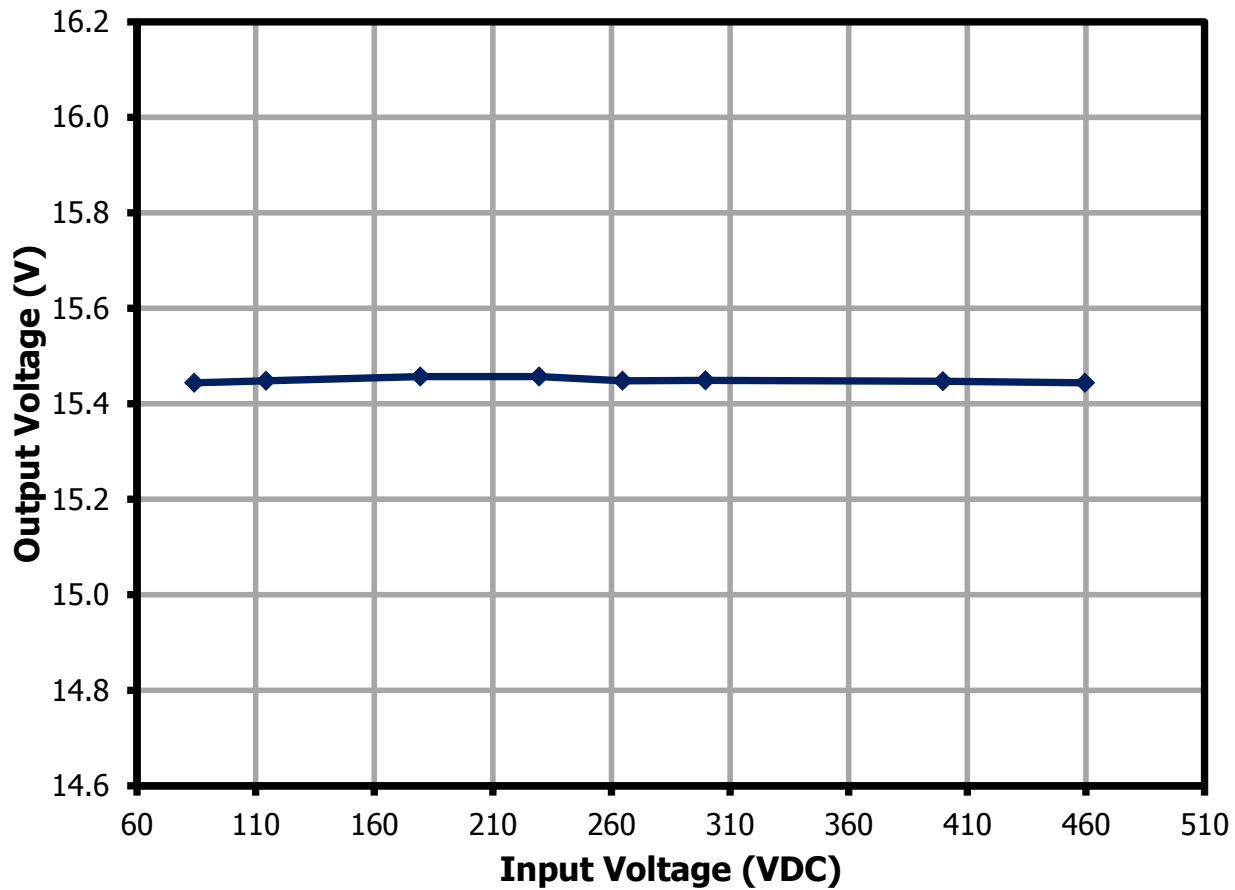


Figure 11 – Output Voltage vs. Input Voltage, Room Temperature.

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.

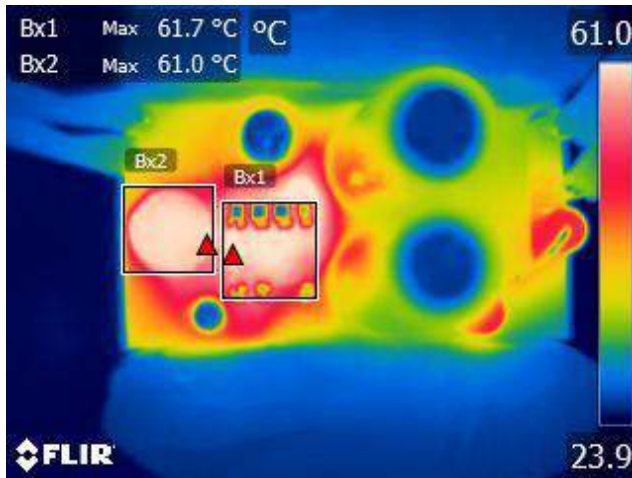


Figure 12 – 85 VAC, 300 mA Load.
LNK3296P Maximum = 61.7 °C.
L2 Maximum = 61 °C.
Ambient = 23.9 °C.

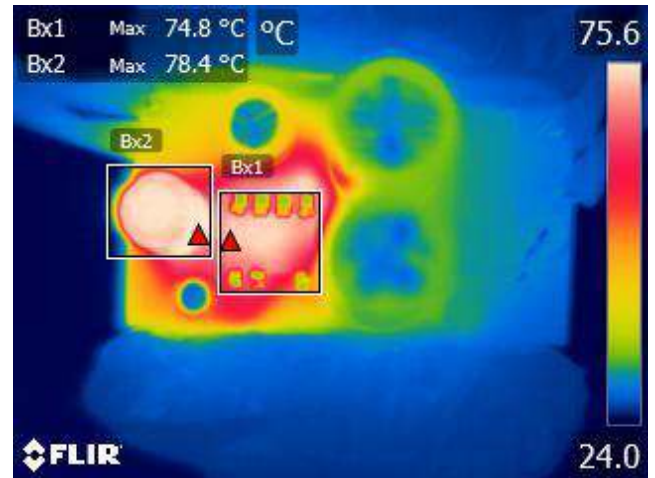


Figure 13 – 460 VAC, 300 mA Load.
LNK3296P Maximum = 74.8°C.
L2 Maximum = 78.4 °C.
Ambient = 24 °C.

10 Waveforms

10.1 Switching Waveforms

10.1.1 LNK3296P Waveforms

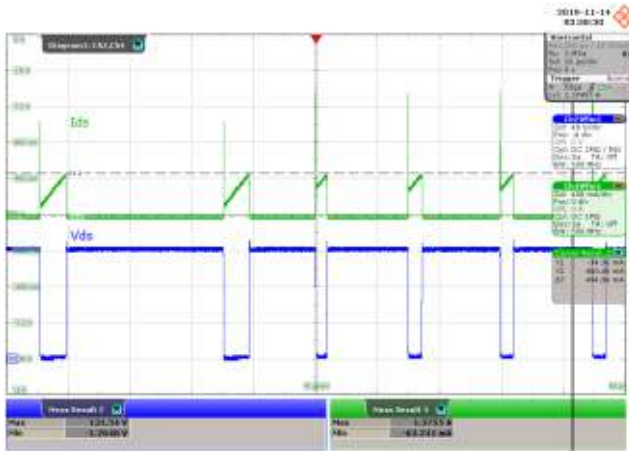


Figure 14 – Drain Voltage and Current Waveforms.
85 VAC, 300 mA Output.
Upper: I_{DRAIN} , 400 mA / div.
Lower: V_{DRAIN} , 40 V, 10 μ s / div.
 $I_{MAX} = 1.376$ A, $V_{MAX} = 131.54$ V.

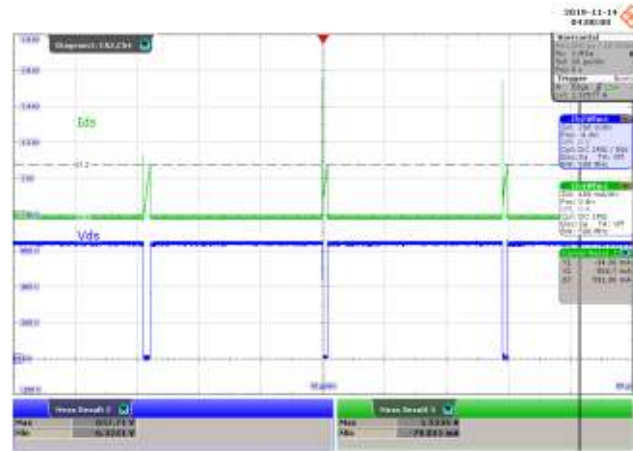


Figure 15 – Drain Voltage and Current Waveforms.
460 VAC, 300 mA Output.
Upper: I_{DRAIN} , 400 mA / div.
Lower: V_{DRAIN} , 200 V, 10 μ s / div.
 $I_{MAX} = 1.5336$ A, $V_{MAX} = 657.71$ V.

10.1.2 LNK3296P Drain Voltage and Current Waveforms During Start-Up

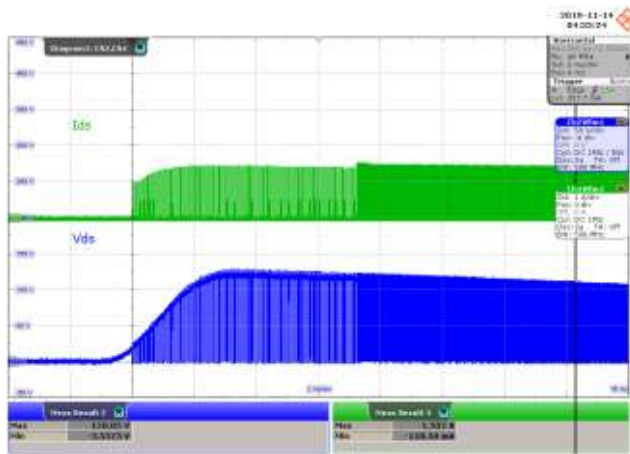


Figure 16 – Drain Voltage and Current Waveforms.
85 VAC, 300 mA Output.
Upper: I_{DRAIN} , 1 A / div.
Lower: V_{DRAIN} , 50 V, 2 ms / div.
 $I_{MAX} = 1.502$ A, $V_{MAX} = 128.85$ V

Note: The peaks are within the SOA limits.



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

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.

10.1.4 Freewheeling Diode Waveforms

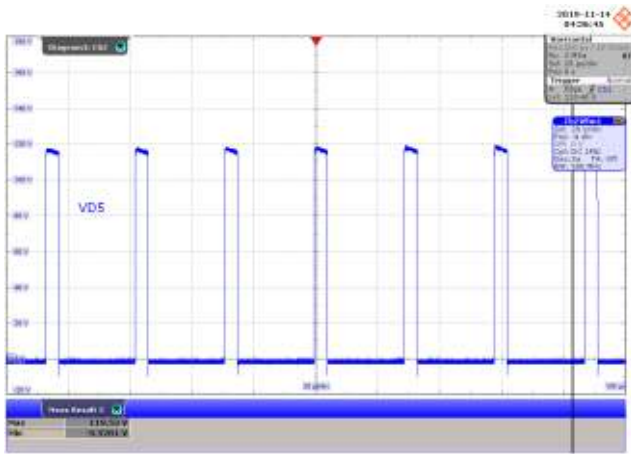


Figure 20 – Freewheeling Diode Voltage Waveforms.
85 VAC, 300 mA Output.
20 V, 20 μ s / div.
 V_{MAX} : 119.53 V.

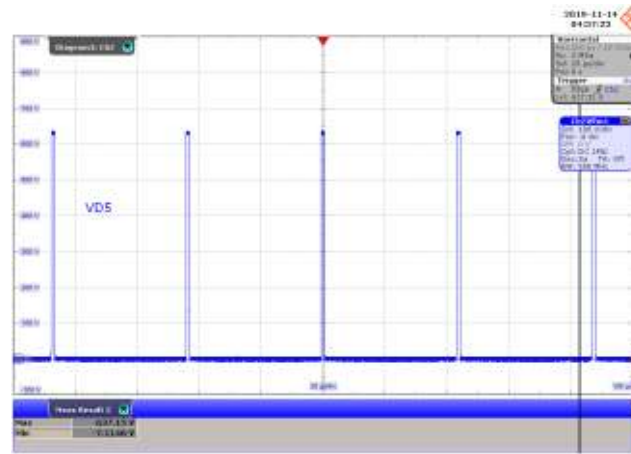


Figure 21 – Freewheeling Diode Voltage Waveforms.
460 VAC, 300 mA Output.
100 V, 20 μ s / div.
 V_{MAX} : 637.15 V.

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

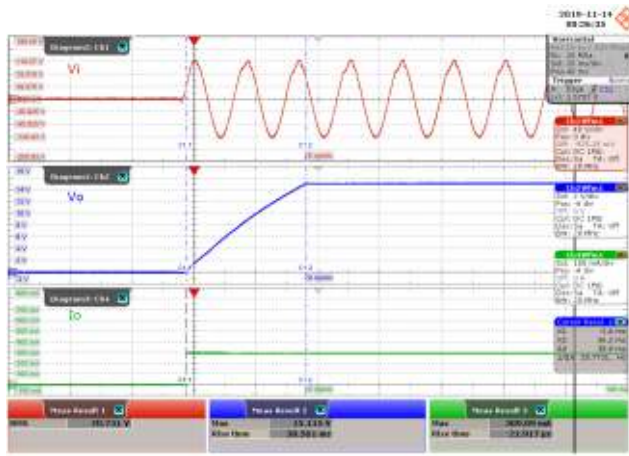


Figure 22 – Output Voltage and Current Waveforms.
85 VAC, 300 mA Output.
Upper: V_{IN} , 40 V, 20 ms / div.
Middle: V_{OUT} , 2 V / div.
Lower: I_{OUT} , 100 mA / div.
Rise Time = 38.8 ms.

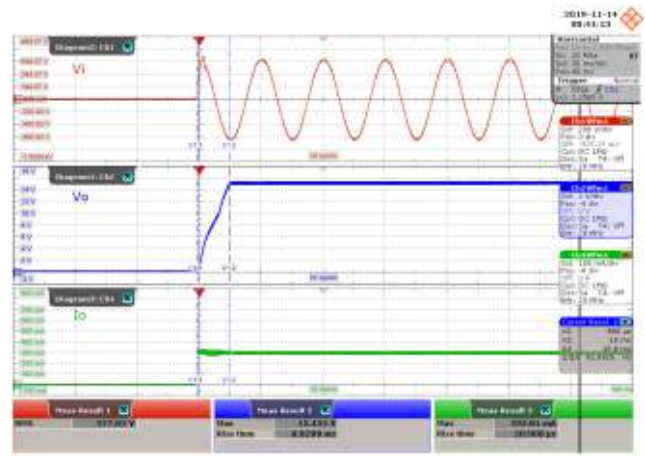


Figure 23 – Output Voltage and Current Waveforms.
460 VAC, 300 mA Output.
Upper: V_{IN} , 200 V, 20 ms / div.
Middle: V_{OUT} , 2 V / div.
Lower: I_{OUT} , 100 mA / div.
Rise Time = 10.8 ms.

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

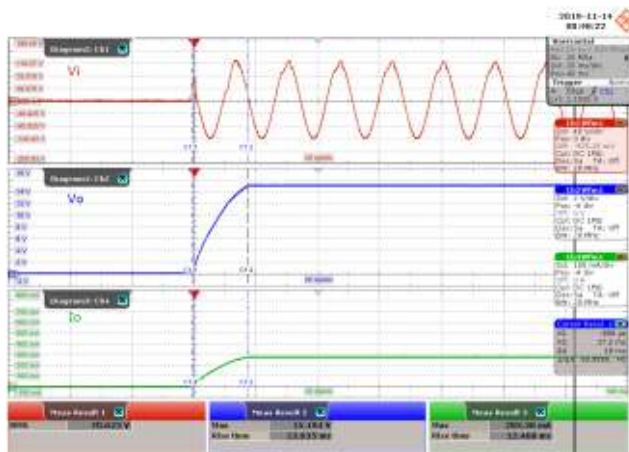


Figure 24 – Output Voltage and Current Waveforms.
85 VAC, 300 mA Output.
Upper: V_{IN} , 40 V, 20 ms / div.
Middle: V_{OUT} , 2 V / div.
Lower: I_{OUT} , 100 mA / div.
Rise Time = 18 ms.

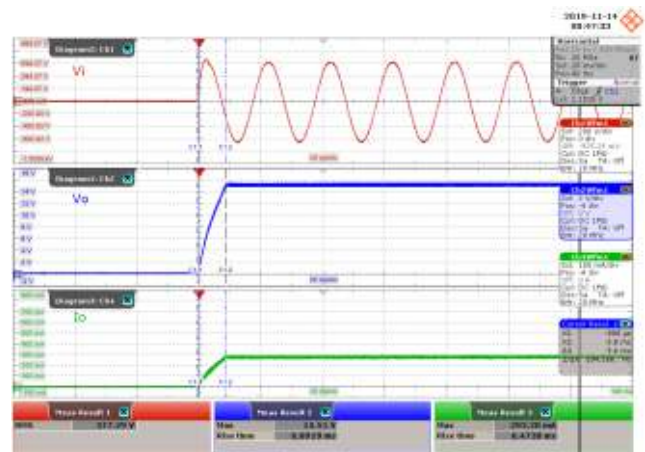


Figure 25 – Output Voltage and Current Waveforms.
460 VAC, 300 mA Output.
Upper: V_{IN} , 200 V, 20 ms / div.
Middle: V_{OUT} , 2 V / div.
Lower: I_{OUT} , 100 mA / div.
Rise Time = 9.6 ms.

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).

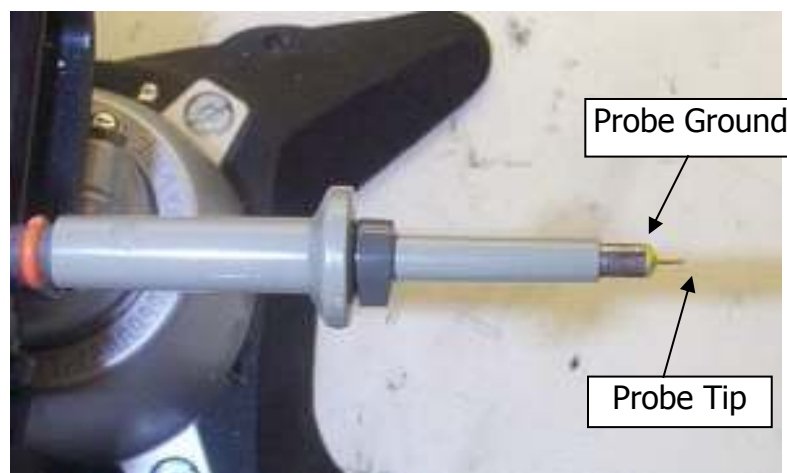
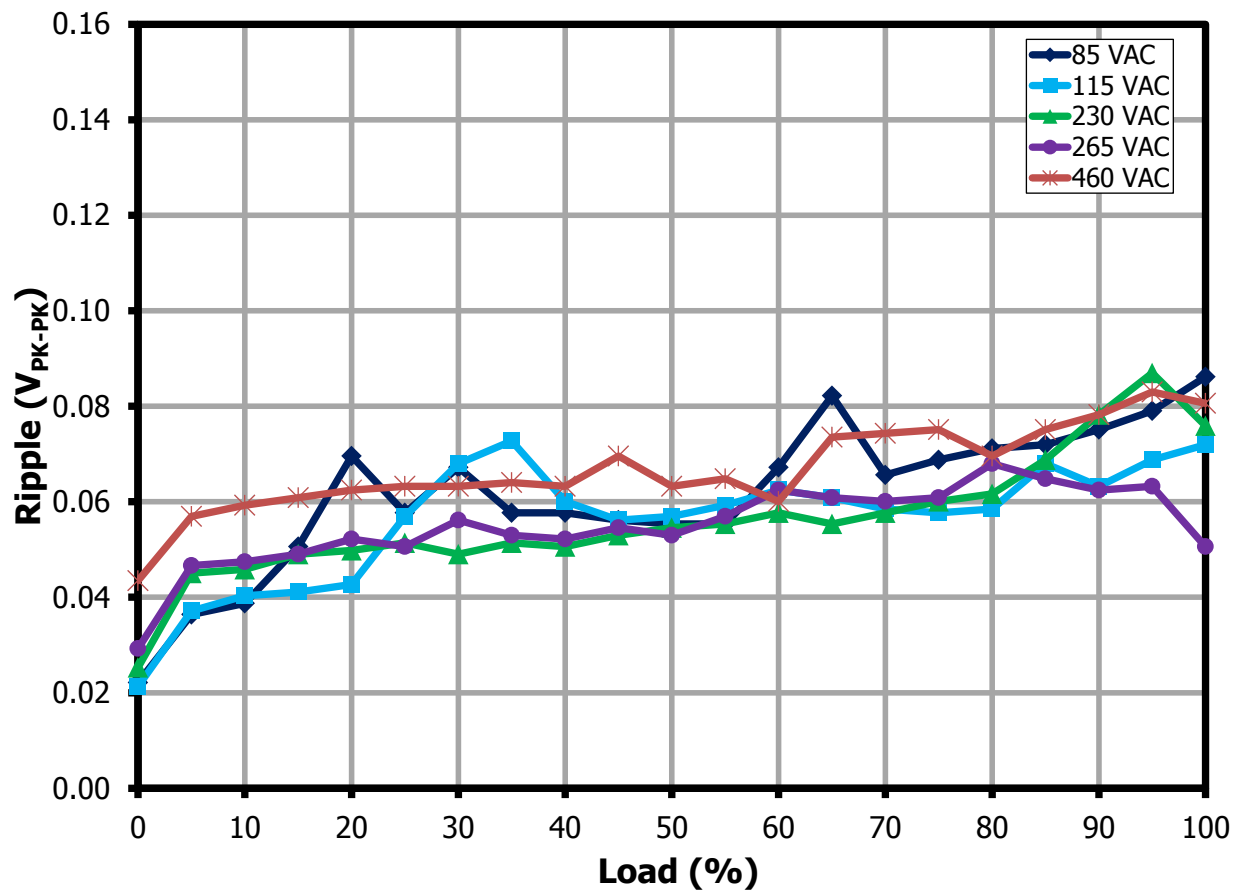


Figure 24 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed.)



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.

10.2.3 Ripple Voltage Waveforms

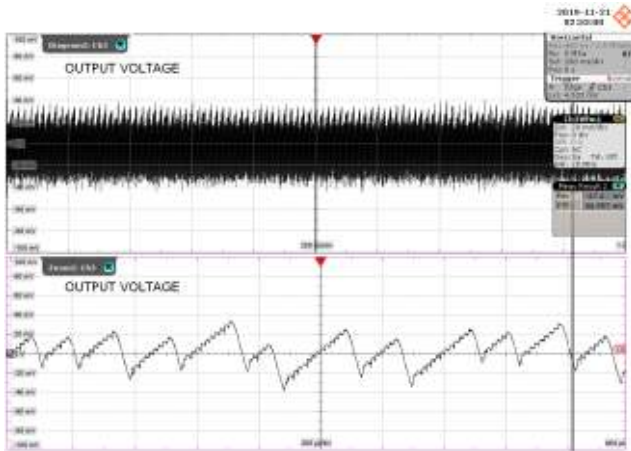


Figure 27 – Output Voltage Ripple Waveforms.
85 VAC, 300 mA Output.
20 mV / div, 200 ms / div.; 200 μ s / div.
 V_{PK-PK} : 86.96 mV.

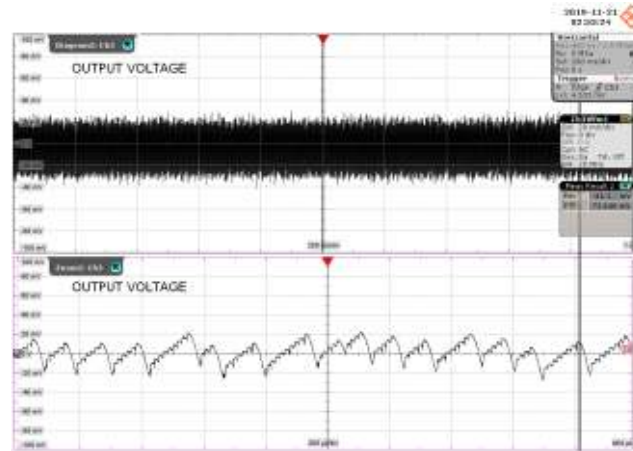


Figure 28 – Output Voltage Ripple Waveforms.
115 VAC, 300 mA Output.
20 mV / div, 200 ms / div.; 200 μ s / div.
 V_{PK-PK} : 71.146 mV.

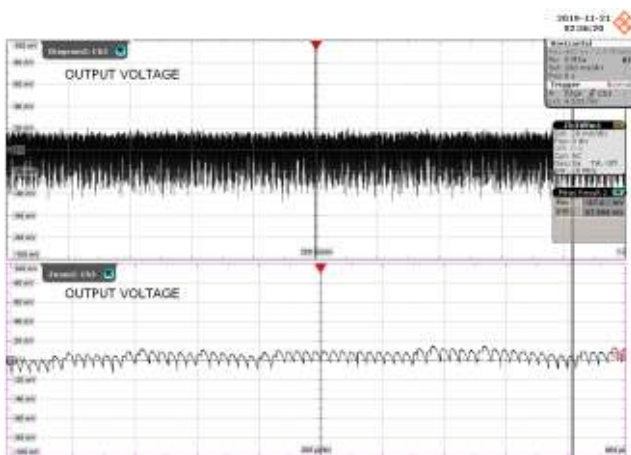


Figure 29 – Output Voltage Ripple Waveforms.
230 VAC, 300 mA Output.
20 mV / div, 200 ms / div.; 200 μ s / div.
 V_{PK-PK} : 67.984 mV.

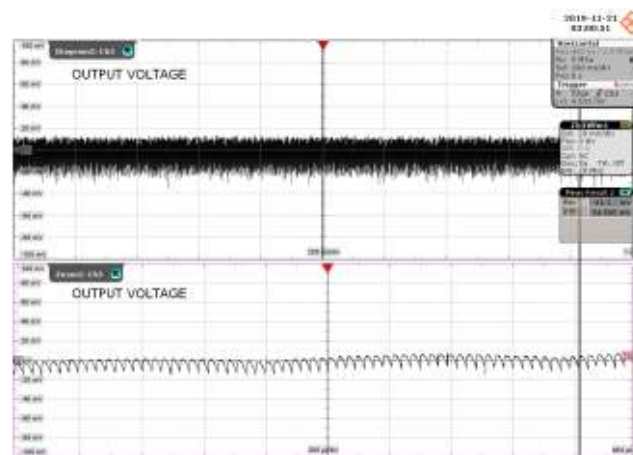


Figure 30 – Output Voltage Ripple Waveforms.
265 VAC, 300 mA Output.
20 mV / div, 200 ms / div.; 200 μ s / div.
 V_{PK-PK} : 54.545 mV.

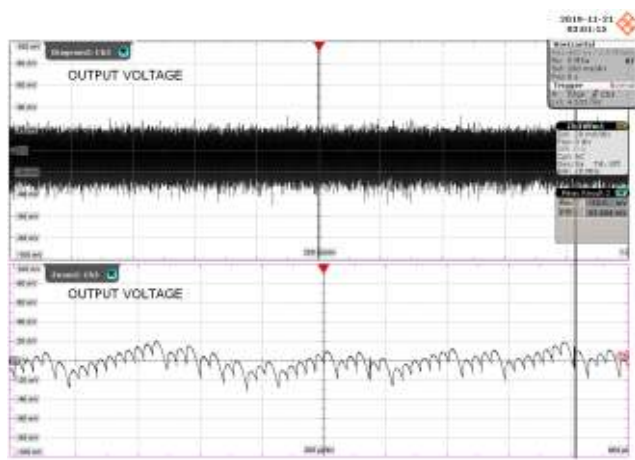


Figure 31 – Output Voltage Ripple Waveforms.
460 VAC, 300 mA Output.
20 mV / div, 200 ms / div.; 200 μ s / div.
 V_{PK-PK} : 83 mV.

11 Conductive EMI

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

11.1 115 VAC, Floating

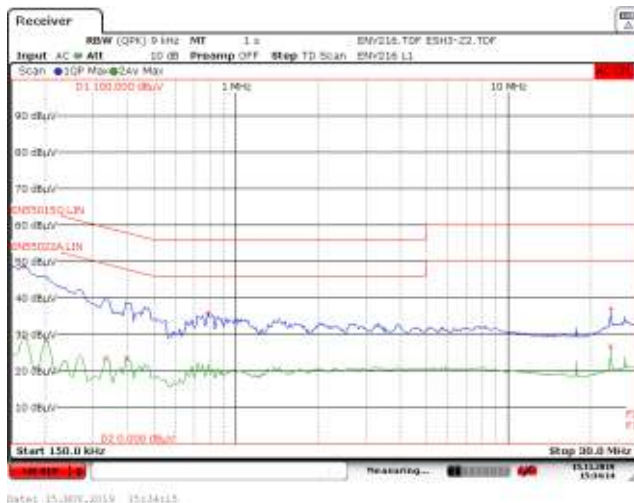


Figure 31 – Line.

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

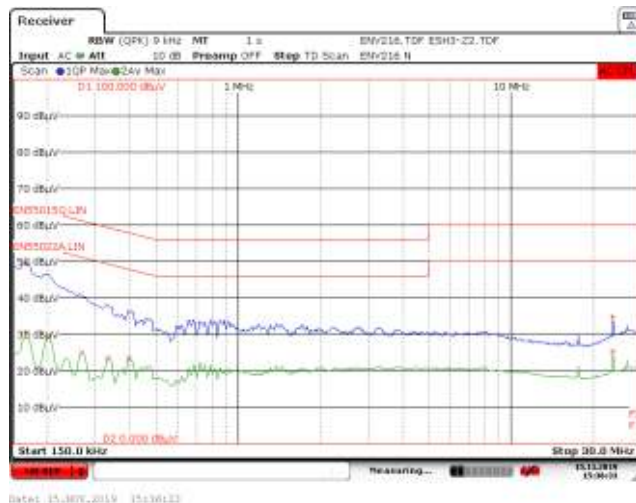


Figure 32 – Neutral.

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

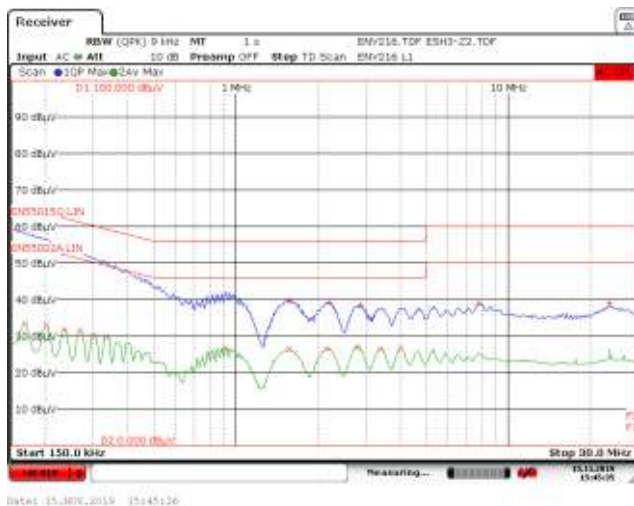


Figure 33 – Line.

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

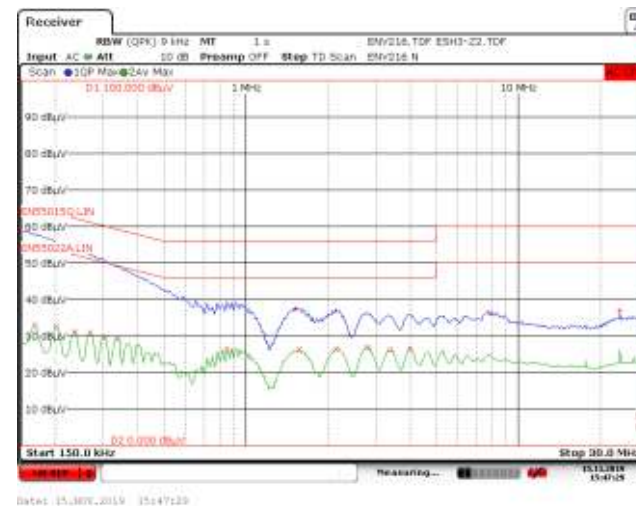


Figure 34 – Neutral.

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 90° Differential Mode Surge

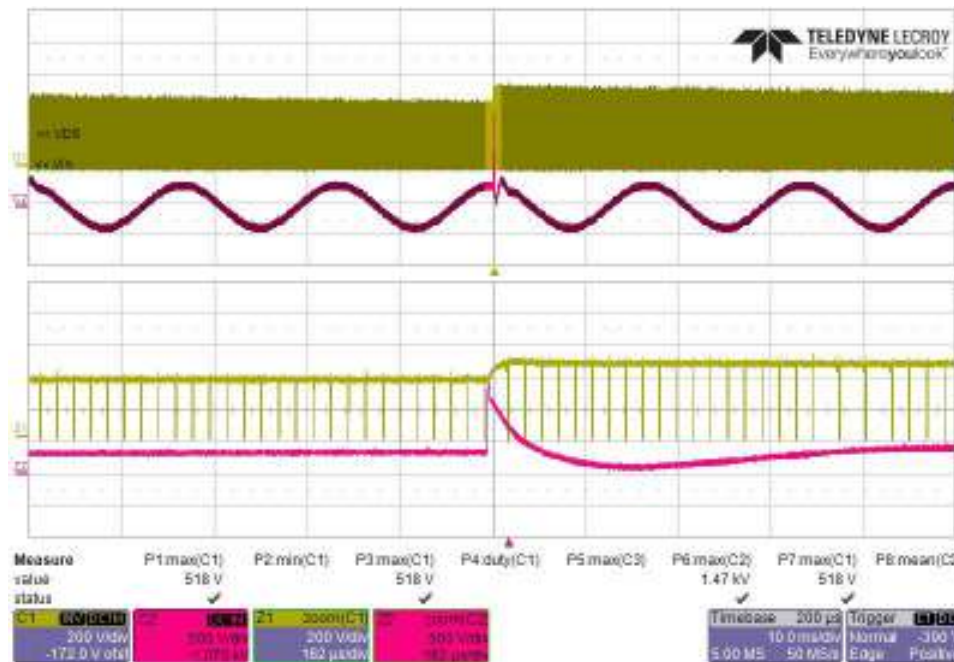


Figure 36 – Drain Voltage, 230 VAC, 300 mA.

12.1.2 -1000 V 270° Differential Mode Surge

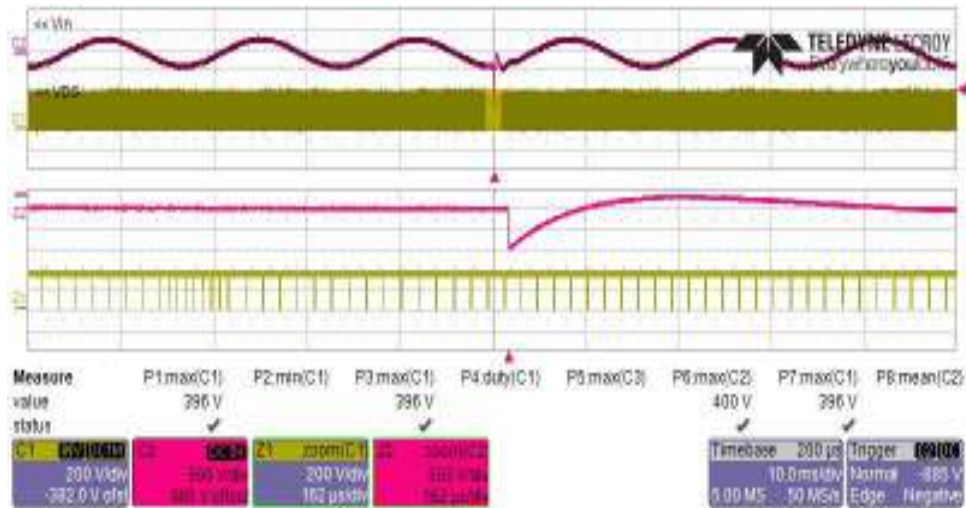


Figure 37 – Drain Voltage, 230 VAC, 300 mA.

13 Revision History

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



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