# Design Example Report

| | |
|---|---|
| **Title** | ***45 W High Power Factor Isolated Flyback with Switched Valley Fill PFC Power Supply Using LYTSwitch™-6 LYT6068C*** |
| **Specification** | 90 VAC – 265 VAC Input; 80 V, 580 mA Output |
| **Application** | LED Lighting |
| **Author** | Applications Engineering Department |
| **Document Number** | DER-657 |
| **Date** | February 16, 2018 |
| **Revision** | 1.1 |


**Summary and Features**

- Accurate constant current and voltage regulation
- Industry first AC/DC controller with isolated, safety rated feedback without an optocoupler
- High power factor, >0.9 at 90 VAC to 265 VAC
- Ultrafast transient response
- Highly energy efficient, >87%
- Integrated protection and reliability features
  - Output short-circuit protection
  - Line and output OVP
  - Thermal foldback and over-temperature shutdown with hysteretic automatic power recovery
- CCM + quasi-resonant switching for precision CC/CV operation without need for loop compensation
- Meets IEC 2.5 kV ring wave, 1 kV differential surge
- Meets EN55015 conducted EMI



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# Table of Contents



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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 engineering report describes a 45 W isolated flyback power supply with a single stage power factor correction circuit for LED lighting application. The power supply is designed to provide an 80V constant voltage across 0A to 580mA output current load. It is also capable of providing 580mA constant current output for LED Lighting applications. The board is optimized to operate from an input voltage range of 90 VAC to 265 VAC.

DER-657 is a universal input flyback converter design with an added switched valley-fill PFC circuit. Through the PFC circuit, the unit meets the high power factor requirement in LED lighting application while reducing loss by directly transferring energy to the output. The key design goals were excellent regulation, high efficiency, and high power factor across the input voltage range.

This document contains the power supply specification, schematic diagram, bill of materials, transformer documentation, printed circuit board layout, and performance data.

**Figure 1 –** Populated Circuit Board


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**Figure 2 –** Populated Circuit Board, Top View.

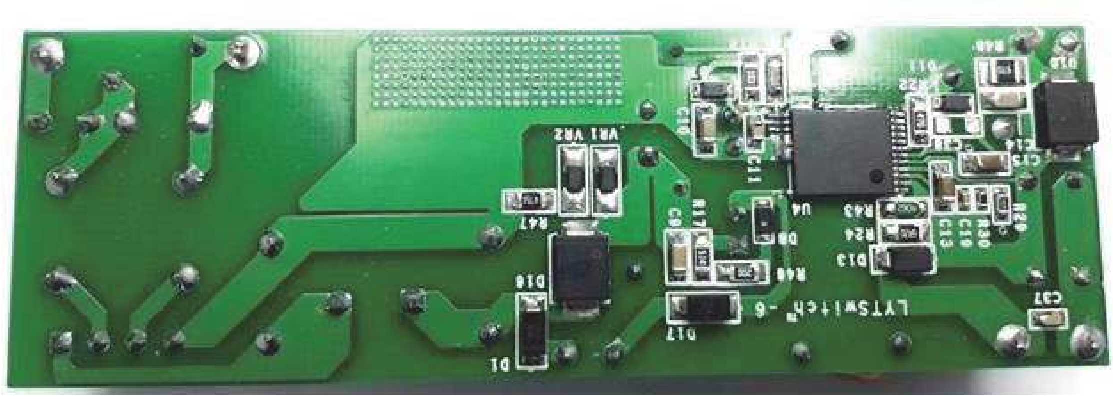

**Figure 3 –** Populated Circuit Board, Bottom View.

# 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 | $V_{IN}$ | 90 | 120/230 | 265 | Vac/Hz | 2 Wire – no P.E. |
| Frequency | $f_{LINE}$ | | 50/60 | | | |
| **Output** | | | | | | |
| Output Voltage | $V_{OUT}$ | | 80 | | V | CC Threshold: 580 mA. |
| Output Current | $I_{OUT}$ | 0 | | 580 | mA | |
| **Total Output Power** | | | | | | |
| Continuous Output Power | $P_{OUT}$ | | 45 | | W | |
| **Efficiency** | | | | | | |
| Full Load | $\eta$ | | 89 | | % | At 230 VAC / 50 Hz. 25 ºC Ambient Temperature. |
| Average Efficiency | | | >87 | | % | Meets DOE Level VI. |
| **Environmental** | | | | | | |
| Conducted EMI | | CISPR 15B / EN55015B | | | | |
| Safety | | Isolated | | | | |
| Ring Wave (100 kHz) | | | 2.5 | | kV | |
| Differential Mode (L1-L2) | | | 1 | | kV | |
| Power Factor | | | 0.9 | | | Measured at 185 VAC / 50 Hz. and 265 VAC / 50 Hz. |
| Ambient Temperature | $T_{AMB}$ | | | 60 | ºC | Free Air Convection, Sea Level. At <120 VAC Input. |


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# 3 Schematic

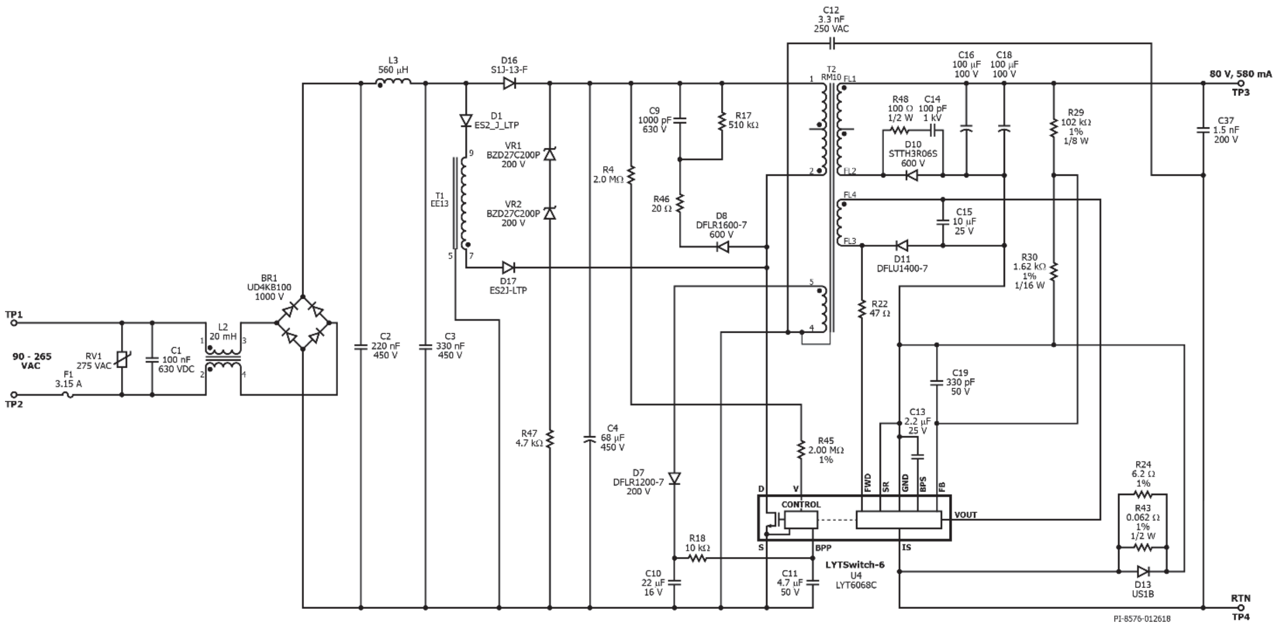


**Figure 4 –** Schematic Diagram.

# 4 Circuit Description

The LYTSwitch-6 device (LYT6068C) combines a 650 V power MOSFET, sense elements, a safety-rated feedback mechanism, along with both primary-side and secondary-side controllers in one device. Since LYTSwitch-6 uses an integrated communication link, FluxLink™, accurate control of the primary-side switch by the secondary controller is possible and close component proximity is utilized. The LYTSwitch-6 IC is designed to deliver a 45 W flyback power supply with a switched valley-fill PFC providing a high power factor with 80 V constant voltage supply throughout the input range of 90 VAC to 265 VAC.

## 4.1 Input Circuit Description

Fuse F1 isolates the circuit and provides protection from component failures. Varistor RV1 acts as a voltage clamp at the input in case of voltage spikes from transient line surge. BR1 rectifies the AC line voltage and provide a full wave rectified DC across the input capacitors C2 and C3. Capacitor C1, L2, C2, L3, and C3 forms a 2-stage LC EMI filter to suppress differential and common mode noise caused by the PFC and flyback switching action.

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

Rectifier diode (D16) delivers the charging current to C4 from the input rectified voltage. During FET off time, D16 blocks current from PFC supply so that flyback DC supply is isolated.

## 4.2 Primary Circuit

One end of transformer (T2) primary is connected to the positive output terminal of the bulk capacitor (C4) while the other side is connected to the drain of the integrated 650 V power MOSFET inside the LYTSwitch-6 IC (U4).

A low cost RCD snubber clamp formed by D8, R17, R46, and C9 limits the peak Drain voltage spike across U4 at the instant turn-off of the MOSFET. The clamp helps dissipate the energy stored in the leakage reactance of transformer T2.

The VOLTAGE MONITOR (V) pin of the LYTSwitch-6 IC is connected to the positive of the bulk capacitor (C4) to provide input voltage information. The voltage across the bulk capacitor (C4) is sensed and converted into current through V pin resistors R4 and R45 to provide detection of overvoltage. The $I_{OV-}$ determines the input overvoltage threshold.

The IC is kick-started by an internal high-voltage current source that charges the BPP pin capacitor C11 when AC is first applied. Primary-side will listen for secondary request signals for around 82 ms. After initial power up, primary-side assumes control first and



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requires a handshake to pass the control to the secondary-side. During normal operation the primary-side block is powered from an auxiliary winding on the transformer. The output of this is configured as a flyback winding which is rectified and filtered using diode D7 and capacitor C10. Resistor R18 limits the current being supplied to the BPP pin of the LYTSwitch-6 (U4).

The thermal shutdown circuitry senses the primary MOSFET die temperature. The threshold ($T_{SD}$) is typically set to 142 °C with 70 °C hysteresis $T_{SD(H)}$. When the die temperature rises above this threshold the power MOSFET is disabled and remains disabled until the die temperature falls by $T_{SD(H)}$ at which point it is re-enabled. A large hysteresis of 70 °C is provided to prevent over-heating of the PCB due to continuous fault condition.

## *4.3 LYTSwitch-6 Secondary Side Control*

The secondary side control of the LYTSwitch-6 IC provides output voltage, output current sensing and drive a non-sync FET providing synchronous rectification. The secondary of the transformer is rectified by D10 and filtered by the output capacitors C16 and C18. Adding an RC snubber (R48 and C14) across the output diode reduces voltage stress across it.
The secondary-side of the IC is powered from an auxiliary winding FL3 and FL4.

During constant voltage mode operation, output voltage regulation is achieved by sensing the output voltage via divider resistors R29 and R30. The voltage across R30 is fed into the FB pin with an internal reference voltage threshold of 1.265 V. Filter capacitor C19 is added across R30 to eliminate unwanted noise that might trigger the OVP function or increase the output ripple voltage.

During constant current operation, the output current is set by the sense resistors R43 and R24 across the IS pin and the GND pin. The internal reference threshold for the IS pin is 35.8 mV. Diode D13 in parallel with the current sense resistor serves as protection during output short-circuit conditions.

The thermal foldback is activated when the secondary controller die temperature reaches 124 °C, the output power is reduced by reducing the constant current reference threshold.

## *4.4 PFC Circuit Operation*

Without the added PFC circuit, the power factor of the flyback power supply is normally around 0.5 to 0.6 at full load condition. Input from the bridge rectifier (BR1) will just directly feed the bulk capacitor (C4) that charges and recharges till the next voltage peak fed to it. The input charging pulse current must be high enough to sustain the load until the next peak. This means that the charging pulse current is around 5-10 times higher than the average current with a high phase angle difference from the voltage waveform; hence, the expected PF from this standard configuration is low and THD is high.

The added PFC circuit is called "Switched Valley-Fill Single Stage PFC" (SVF $S^2$PFC). Composed of an inductor (T1) and diodes (D1 and D17) connected directly to the DRAIN pin of the LYTSwitch-6 IC. Through this, the LYTSwitch-6 IC flyback switching action is able to draw a high frequency pulse current from the full wave rectified input. This will reduce the rms input current and the phase angle difference from the input line voltage will be lower; hence, power factor will increase and will improve THD.

The PFC inductor T1 operates in DCM mode. At turn ON, current delivered by the rectified input is stored in the PFC inductor which is then delivered via direct energy transfer to the flyback transformer T2. Excess energy from the PFC inductor that is not delivered to the load is being stored to the bulk capacitor. During no-load and light load conditions (i.e, less than 250 mA output load current), the secondary requires less energy from the primary; therefore, more excess energy from the PFC inductor is stored on the bulk capacitor causing the voltage to rise gradually which will be higher than that of the peak input. For this a Zener-resistor clamp (VR1, VR2, R47) was added in parallel with the bulk capacitor to limit the rise in voltage. The expected voltage stress across the bulk capacitor C4 will be higher than the peak input voltage. The Zener voltage is set at 400 V; when the bulk voltage goes beyond this, the Zener diodes conduct and bleed current from the bulk capacitor through resistor R47. This prevents the bulk capacitor voltage to rise above 450 V. The power dissipation of this Zener-resistor clamp should be considered at the worst-case creeping of the bulk voltage which happens usually at light load condition. Diodes D1 and D17 are connected in series to withstand voltage stress caused by the resonance ringing during the FET turn off. The variability of the PFC inductor peak current will be compensated by LYTSwitch-6 IC's primary and secondary-side control maintaining the voltage regulation at all conditions.


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# 5 PCB Layout

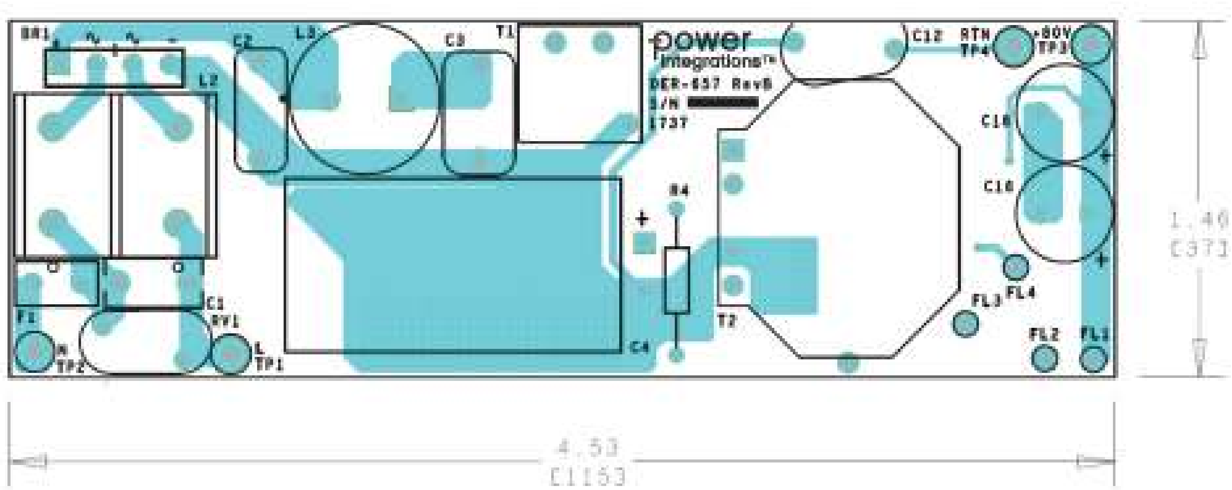

**Figure 5 –** Top Side.

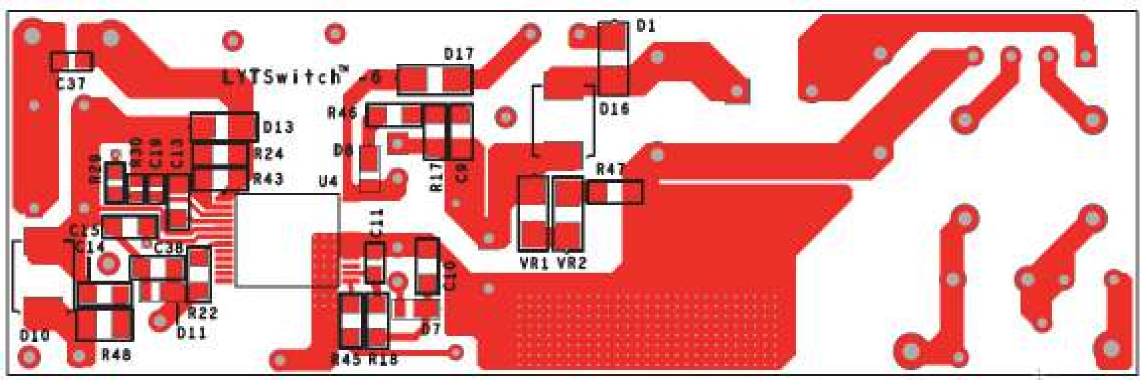

**Figure 6 –** Bottom Side.

# 6 Bill of Materials

| Item | Qty | Ref Des | Description | Mfg Part Number | Mfg |
|---|---|---|---|---|---|
| 1 | 1 | BR1 | Bridge Rectifier, 1000 V, 4 A, 4-ESIP, D3K, -55°C ~ 150°C (TJ), Vf=1V @ 7.5A | UD4KB100-BP | Micro Commercial |
| 2 | 1 | C1 | 0.1 μF, ±20%, Film Capacitor,X2 Safety Rated, 310 VAC, 630 VDC, Polypropylene (PP), Metallized Radial | BFC233920104 | Vishay |
| 3 | 1 | C2 | 220 nF, 450 V, Film | MEXXF32204JJ | Duratech |
| 4 | 1 | C3 | 330 nF, 450 V, METALPOLYPRO | ECW-F2W334JAQ | Panasonic |
| 5 | 1 | C4 | 68 μF, 450 V, Electrolytic, Low ESR, (16 x 35.5) | EKXJ451ELL680MLP1S | Nippon Chemi-Con |
| 6 | 1 | C9 | 1000 pF, 630 V, Ceramic, X7R, 1206 | C1206C102KBRACTU | Kemet |
| 7 | 1 | C10 | 22 μF, 16 V, Ceramic, X5R, 1206 | EMK316BJ226ML-T | Taiyo Yuden |
| 8 | 1 | C11 | 4.7 μF, 16 V, Ceramic, X7R, 0805 | GRM21BR71C475KA73L | Murata |
| 9 | 1 | C12 | 3.3 nF, Ceramic, Y1 | 440LD33-R | Vishay |
| 10 | 1 | C13 | 2.2 μF, 25 V, Ceramic, X7R, 1206 | TMK316B7225KL-T | Taiyo Yuden |
| 11 | 1 | C14 | 100 pF, 1000 V, Ceramic, NP0, 1206 | 102R18N101JV4E | Johanson Dielectrics |
| 12 | 1 | C15 | 10 μF, 25 V, Ceramic, X7R, 1206 | C3216X7R1E106M | TDK |
| 13 | 1 | C16 | 100 μF, 100 V, Electrolytic, Gen. Purpose, (10 x 20) | UVZ2A101MPD | Nichicon |
| 14 | 1 | C18 | 100 μF, 100 V, Electrolytic, Gen. Purpose, (10 x 20) | UVZ2A101MPD | Nichicon |
| 15 | 1 | C19 | 330 pF 50 V, Ceramic, X7R, 0603 | CC0603KRX7R9BB331 | Yageo |
| 16 | 1 | C37 | 1.5 nF, 200 V,10%, Ceramic, X7R, 0805 | 08052C152KAT2A | AVX |
| 17 | 1 | D1 | 600 V, 2 A, Superfast, 35 ns, DO-214AC, SMA | ES2J-LTP | Micro Commercial |
| 18 | 1 | D7 | 200 V, 1 A, Rectifier, Glass Passivated, POWERDI123 | DFLR1200-7 | Diodes, Inc. |
| 19 | 1 | D8 | 600 V, 1 A, Rectifier, Glass Passivated, POWERDI123 | DFLR1600-7 | Diodes, Inc. |
| 20 | 1 | D10 | 600 V, 3 A, SMC, DO-214AB | STTH3R06S | ST Micro |
| 21 | 1 | D11 | 400 V, 1 A, Diode Superfast 1 A PWRDI 123 | DFLU1400-7 | Diodes, Inc. |
| 22 | 1 | D13 | Diode Ultrafast, 1 A, 100 V, SMA | US1B-13-F | Diodes, Inc. |
| 23 | 1 | D16 | 600 V, 1 A, Standard Recovery, SMA | S1J-13-F | Diodes, Inc. |
| 24 | 1 | D17 | 600 V, 2 A, Superfast, 35 ns, DO-214AC, SMA | ES2J-LTP | Micro Commercial |
| 25 | 1 | F1 | 3.15 A, 300 V, Slow, Long Time Lag, RST | 36913150000 | Littlefuse |
| 26 | 1 | FL1 | Flying Lead, Hole size 50mils | N/A | N/A |
| 27 | 1 | FL2 | Flying Lead, Hole size 50mils | N/A | N/A |
| 28 | 1 | FL3 | Flying Lead, Hole size 50mils | N/A | N/A |
| 29 | 1 | FL4 | Flying Lead, Hole size 50mils | N/A | N/A |
| 30 | 1 | L2 | 20 mH, 0.8 A, Common Mode Choke | SS21V-R080200 | KEMET |
| 31 | 1 | L3 | 560 μH, 1.60 A, 20% | RL-5480-5-560 | Renco |
| 32 | 1 | R4 | RES, 2.0 MΩ, 5%, 1/4 W, Carbon Film | CFR-25JB-2M0 | Yageo |
| 33 | 1 | R17 | RES, 510 kΩ, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ514V | Panasonic |
| 34 | 1 | R18 | RES, 10 kΩ, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ103V | Panasonic |
| 35 | 1 | R22 | RES, 47 Ω, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ470V | Panasonic |
| 36 | 1 | R24 | RES, 6.2 Ω, ±1%, 1/4 W, 1206, Moisture Resistant, Thick Film | RC1206FR-076R2L | Yageo |
| 37 | 1 | R29 | RES, 102 kΩ, 1%, 1/8 W, Thick Film, 0805 | ERJ-6ENF1023V | Panasonic |
| 38 | 1 | R30 | RES, 1.62 kΩ, 1%, 1/16 W, Thick Film, 0603 | ERJ-3EKF1621V | Panasonic |
| 39 | 1 | R43 | RES, 0.062 Ω,±300ppm/°C, ±1%, ½ W, 1206 (3216 Metric), Current Sense, Thick Film | RLP73N2BR062FTDF | TE Connectivity |
| 40 | 1 | R45 | RES, 2.00 MΩ, 1%, 1/4 W, Thick Film, 1206 | ERJ-8ENF2004V | Panasonic |
| 41 | 1 | R46 | RES, 20 Ω, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ200V | Panasonic |
| 42 | 1 | R47 | RES, 4.7 kΩ, 5%, 1/4 W, Thick Film, 1206 | ERJ-8GEYJ472V | Panasonic |
| 43 | 1 | R48 | RES, 100 Ω, 5%, 1/2 W, Thick Film, 1210 | ERJ-14YJ101U | Panasonic |
| 44 | 1 | RV1 | 320 VAC, 23 J, 10 mm, RADIAL | V320LA10P | Littlefuse |
| 45 | 1 | T1 | Bobbin, EE13, Vertical, 10 pins | P-1302-2 | Pin Shine |
| 46 | 1 | T2 | Bobbin, RM10, Vertical, 5 pins | P-1031 | Pin Shine |


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| | | | | | |
|---|---|---|---|---|---|
| 47 | 1 | TP1 | Test Point, BLK, THRU-HOLE MOUNT | 5011 | Keystone |
| 48 | 1 | TP2 | Test Point, WHT, THRU-HOLE MOUNT | 5012 | Keystone |
| 49 | 1 | TP3 | Test Point, BLK, THRU-HOLE MOUNT | 5011 | Keystone |
| 50 | 1 | TP4 | Test Point, BLK, THRU-HOLE MOUNT | 5011 | Keystone |
| 51 | 1 | U4 | LYTSwitch-6, InSOP24D | LYT6068C | Power Integrations |
| 52 | 1 | VR1 | DIODE, ZENER, 200 V, 800 MW, DO219AB | BZD27C200P-E3-08 | Vishay |
| 53 | 1 | VR2 | DIODE, ZENER, 200 V, 800 MW, DO219AB | BZD27C200P-E3-08 | Vishay |

# 7 Flyback Transformer (T2) Specification

## 7.1 Electrical Diagram

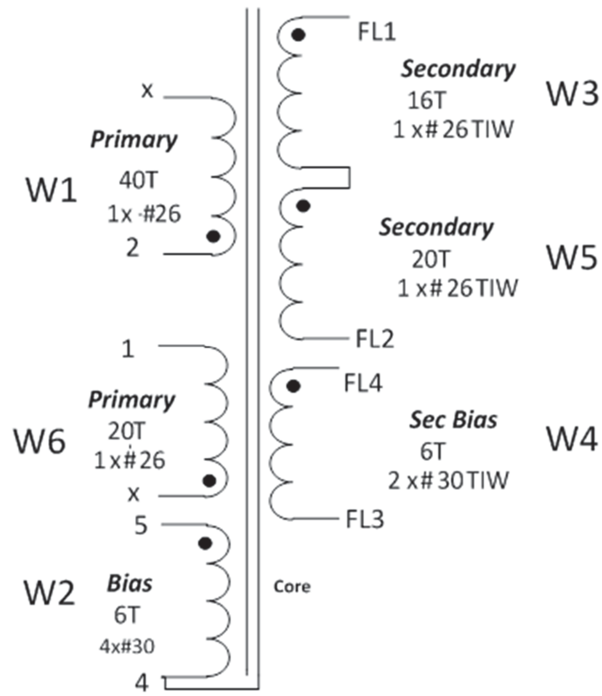


**Figure 7 –** Transformer Electrical Diagram.

## 7.2 Electrical Specifications

| Parameter | Condition | Spec. |
|---|---|---|
| Nominal Primary Inductance | Measured at 1 $V_{PK-PK}$, 100 kHz switching frequency, between pin 1 and pin 2 with all other windings open. | 1100 μH |
| Tolerance | Tolerance of Primary Inductance. | ±5% |
| Leakage Inductance | Measured across primary winding with all other windings shorted | <10 μH |

## 7.3 Material List

| Item | Description |
|---|---|
| **[1]** | Core: RM10 PC95 or Equivalent. |
| **[2]** | Bobbin: Bobbin, RM10, Vertical, 5 Pins. |
| **[3]** | Magnet Wire: #26 AWG. |
| **[4]** | Magnet Wire: #30 AWG. |
| **[5]** | TIW: #26 AWG. |
| **[6]** | TIW: # 31 AWG. |
| **[7]** | Polyester Tape: 9 mm. |
| **[8]** | RM8 Core Clip with Terminal. |


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## 7.4 Transformer Build Diagram

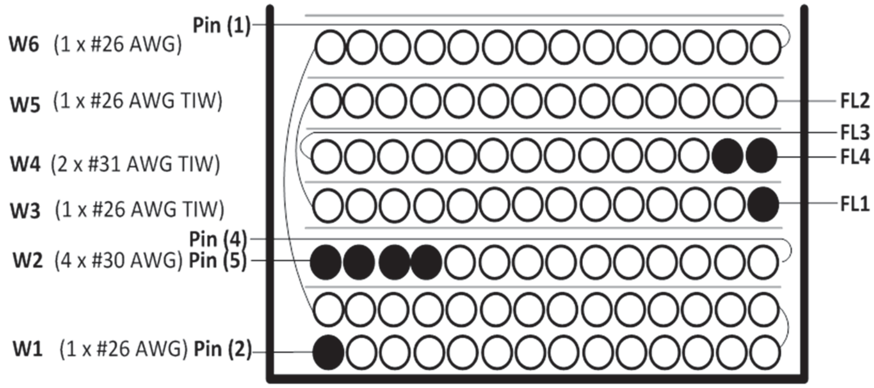
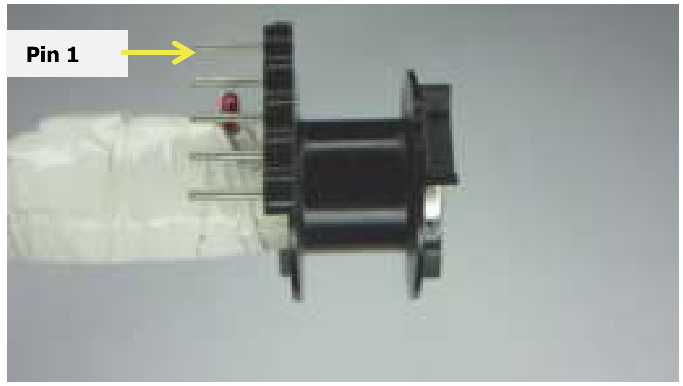
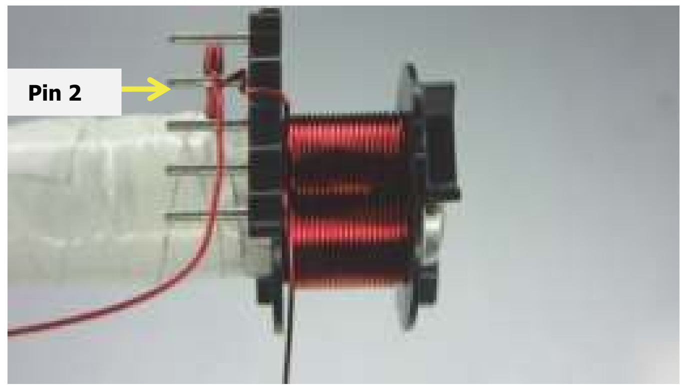
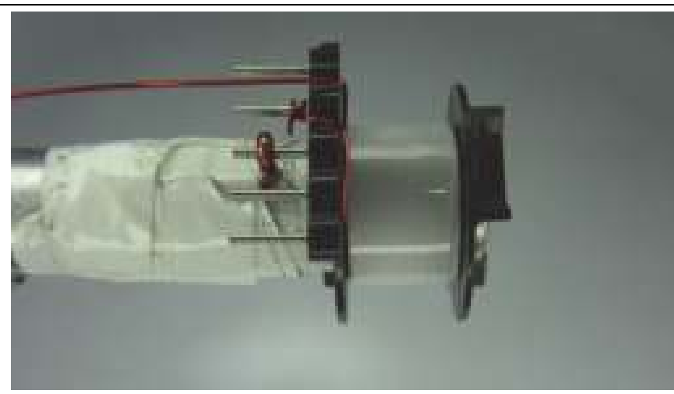
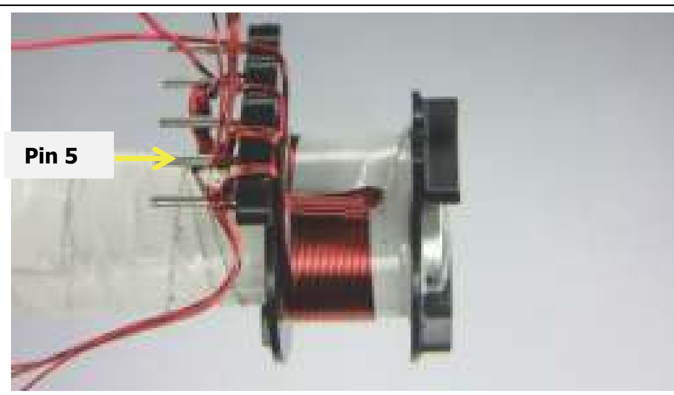



**Figure 8 –** Transformer Build Diagram.

## 7.5 Transformer Construction

| | |
|---|---|
| **Winding Directions** | Bobbin is oriented on winder jig such that terminal pin 1-6 is on the right side. The winding direction is clockwise. |
| **Winding 1** | Use magnetic wire Item [3]. Start at pin 2 and wind 40 turns evenly in 2 layers. Do not terminate winding, leave the winding floating. |
| **Insulation** | Apply 1 layer of polyester tape, Item [7] for insulation |
| **Winding 2** | Use quadrifilar magnetic wire on Item [4]. Start at pin (5) and end at Item (4). |
| **Insulation** | Apply 1 layer of polyester tape, Item [7] for insulation. |
| **Winding 3** | Start on the other side of the bobbin. Use a triple insulated wire on item [5]. Starting with a fly lead (FL1), wind 16 turns evenly in 1 layer. Do not terminate winding yet. |
| **Insulation** | Apply 1 layer of polyester tape, Item [7] for insulation**.** |
| **Winding 4** | Start on the side of FL1. Use a bifilar triple insulated wire, Item [5]. Start as a fly lead (FL4), wind 6 turns evenly in 1 layer and finish as a fly lead (FL3). |
| **Insulation** | Apply 1 layers of polyester tape, Item [7] for insulation. |
| **Winding 5** | Continuing from winding 3, wind 20 turns and finish with a fly lead. (FL2) |
| **Insulation** | Apply 1 layers of polyester tape, Item [7] for insulation. |
| **Winding 6** | Continuing from W1, wind 20 turns evenly and finish at pin (1). |
| **Insulation** | Apply 2 layers of polyester tape, Item [7] for insulation. |
| **Core Grinding** | Grind the center leg of the ferrite core to meet the nominal inductance specification of 1100 μH. |
| **Assemble Core** | Use RM10 core clips with terminals, Item [8] to fix the 2 cores into the bobbin. Cut the terminal of the clip on the left side of the bobbin, looking at the bottom side facing the fly leads of the secondary winding. |
| **Pins** | Cut any excess pins of the bobbin (pins without wire terminations). |
| **Finish** | Dip the transformer in a 2:1 varnish and thinner solution. |

## 7.6 Transformer Winding Illustrations

| | |
|---|---|
| **Winding Directions**<br><br>Bobbin is oriented on winder jig such that terminal Pin 1-6 is on the right side. The winding direction is clockwise. |  |
| **Winding 1**<br><br>Use magnetic wire Item [3]. Start at pin 2 and wind 40 turns evenly in 2 layers. Do not terminate winding, Leave the winding floating. |  |
| **Insulation**<br><br>Apply 1 layer of polyester tape, Item [7] for insulation. |  |
| **Winding 2**<br><br>Use quadrifilar magnetic wire on Item [4]. Start at pin (5) and end at pin (4). |  |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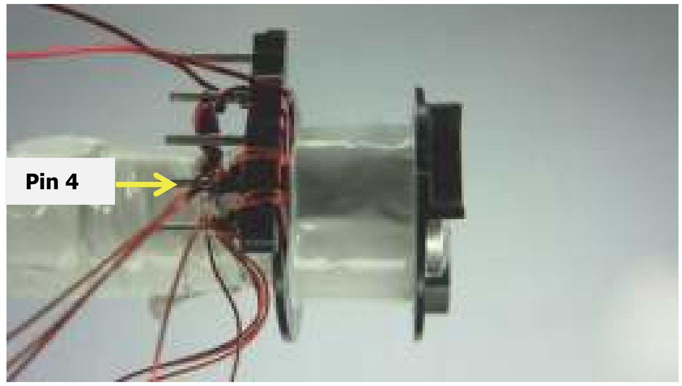
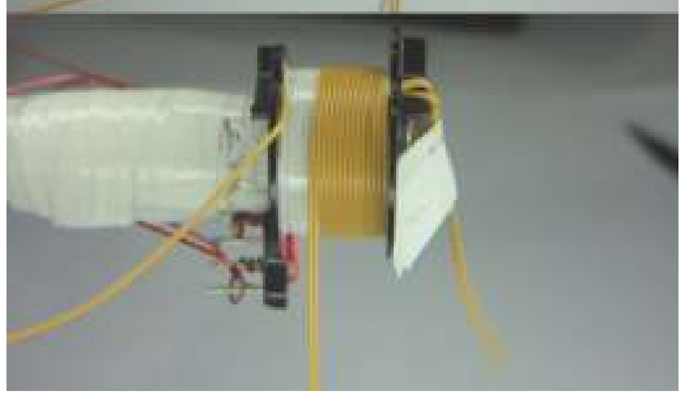
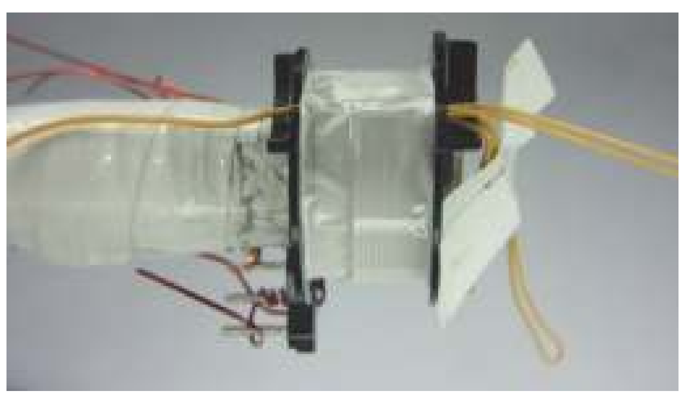
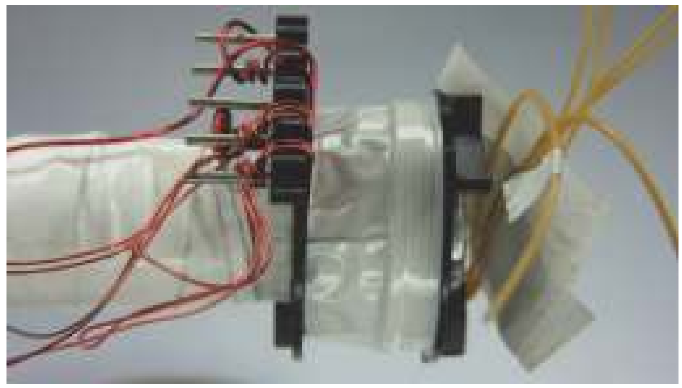
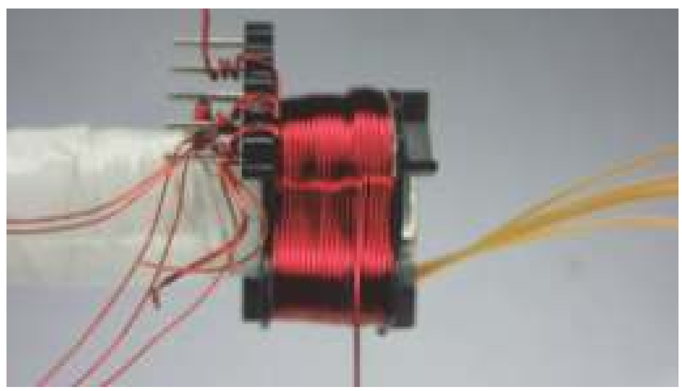
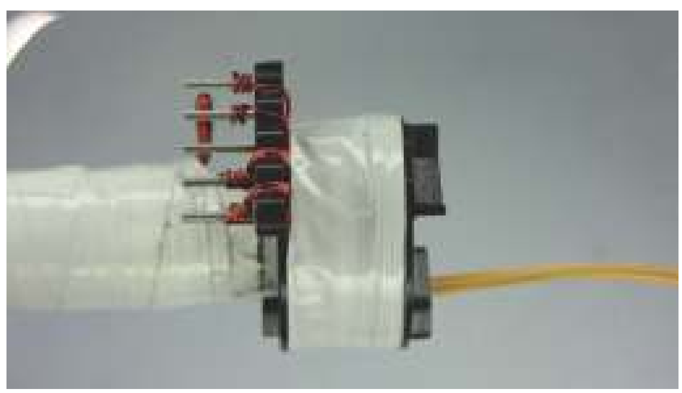
| | |
|---|---|
| **Insulation**<br><br>Apply 1 layer of polyester tape, Item [7] for insulation. |  |
| **Winding 4**<br><br>Start on the side of FL1. Use a bifilar triple insulated wire, Item [5]. Start as a fly lead (FL4), wind 6 turns evenly in 1 layer and finish as a fly lead (FL3). | <br> |
| **Insulation**<br><br>Apply 1 layers of polyester tape, Item [7] for insulation. |  |

| | |
|---|---|
| **Winding 5**<br><br>Continuing from winding 3, wind 20 turns evenly and finish with a fly lead. (FL2) |  |
| **Insulation**<br><br>Apply 1 layer of polyester tape, Item [7] for insulation. |  |
| **Winding 6**<br><br>Continuing from W1, wind 20 turns evenly and finish at pin (1). |  |
| **Insulation**<br><br>Apply 2 layers of polyester tape, Item [7] for insulation. |  |



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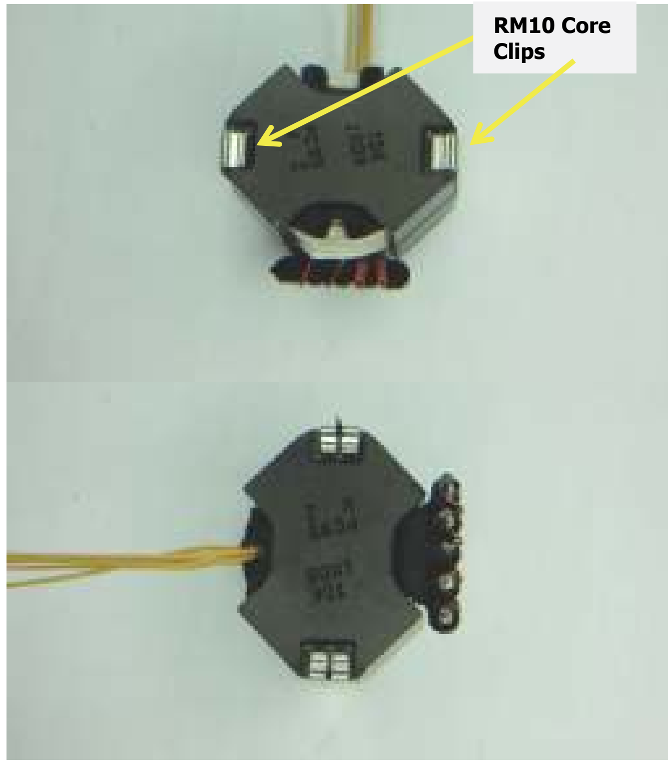
| | |
|---|---|
| **Core Termination**<br><br>Use two PC95 RM10 cores, item [1] and assemble them with the wound bobbin.<br><br>**Core Clips**<br><br>Use RM8 Core Clips with Terminals, Item [6] to fix the 2 cores into the bobbin. Cut the terminal of the clip on the left side of the bobbin, looking at the bottom side facing the fly leads of the secondary winding.<br><br>**Pins**<br><br>Cut any excess pins of the bobbin (pins without wire terminations). Trim pin 11 as short as possible.<br><br>**Varnishing**<br><br>Dip the transformer in a 2:1 varnish and thinner solution |  |

# 8 PFC Inductor (T2) Specification

## 8.1 Electrical Diagram

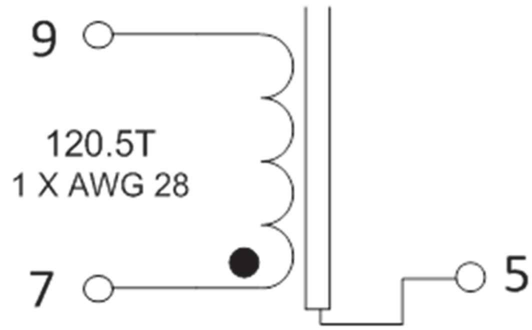



**Figure 9 –** Inductor Electrical Diagram.

## 8.2 Electrical Specifications

| Parameter | Condition | Spec. |
|---|---|---|
| Nominal Primary Inductance | Measured at 1 $V_{PK-PK}$, 100 kHz switching frequency, between pin 9 and pin 7. | 750 μH |
| Tolerance | Tolerance of Primary Inductance. | ±5% |

## 8.3 Material List

| Item | Description |
|---|---|
| **[1]** | Core: EE13. |
| **[2]** | Bobbin: Bobbin, EE13, Vertical, 10 pins; Part no. 25-01023-00. |
| **[3]** | Magnet Wire: #28 AWG. |
| **[4]** | Transformer Tape: 6.5 mm. |
| **[5]** | Transformer Tape: 4 mm. |
| **[6]** | Copper Wire. |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## 8.4 Inductor Build Diagram

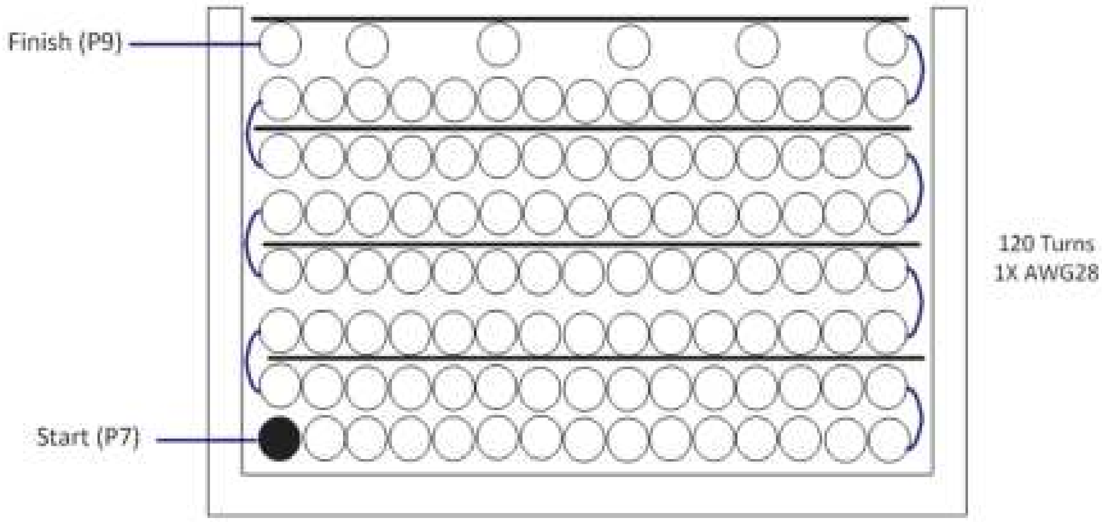



**Figure 10 –** Transformer Build Diagram.

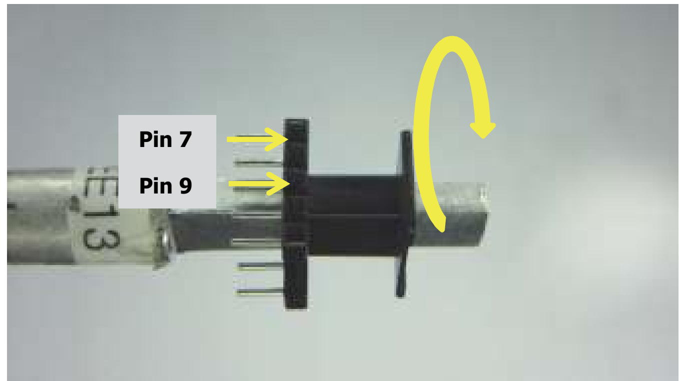
## 8.5 Inductor Construction

| | |
|---|---|
| **Winding Directions** | Bobbin is oriented on winder jig such that terminal pin 6 – 10 is in the left side. The winding direction is clockwise. |
| **Winding 1** | Prepare the magnetic wire Item [3] for winding. Start at pin 9 and wind 120.5 turns bifilar in 8 layers. |
| **Insulation** | Add 1 layer of tape, Item [4] for every 2 layers of winding 1. |
| **Winding 1** | Finish the winding on pin 7. |
| **Insulation** | Add 2 layers of tape, Item [4] for insulation. |
| **Core Grinding** | Grind the center leg of the ferrite core evenly until it meets the nominal inductance of 750 $\mu$H. Inductance is measured across pin 9 and pin 7. |
| **Assemble Core** | Assemble the 2 cores on the bobbin. |
| **Core Termination** | Prepare a copper strip with a soldered magnetic wire, Item [6], at the middle as shown in the picture. Apply copper strip at the bottom part of the core and terminate the magnetic wire on pin 5. |
| **Core Tape** | Add 2 Layers of tape, Item [5], around the core to fix the 2 cores into the bobbin. |
| **Pins** | Pull out or cut terminal pin no. 1, 2, 3, 4, 6, 8, and pin 10. |
| **Finish** | Dip the transformer assembly in 2:1 varnish and thinner solution. |

## *8.6 Inductor Winding Illustrations*

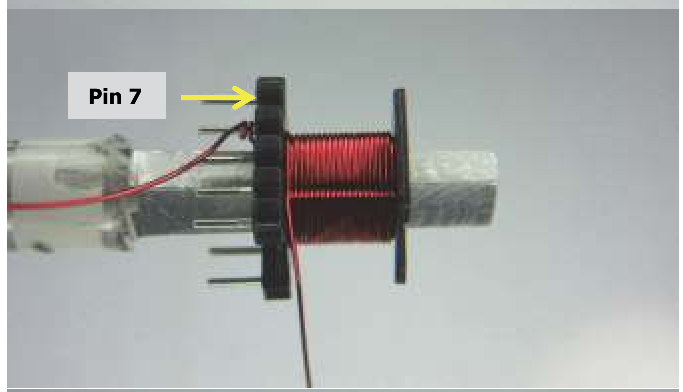
**Winding Directions**

Bobbin is oriented on winder jig such that terminal pin 6 – 10 is in the left side. The winding direction is clockwise.



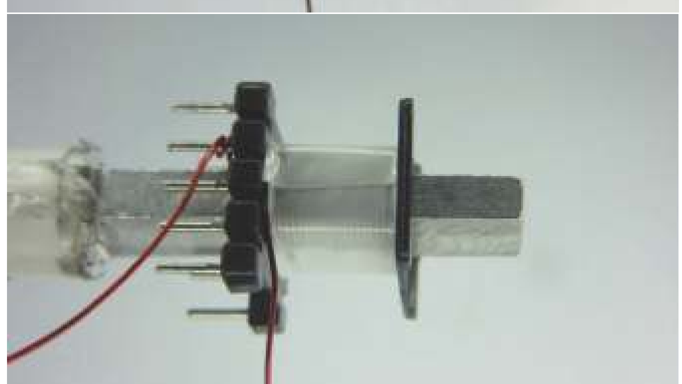

**Winding 1**

Prepare the magnetic wire Item [3] for bifilar-wound type winding. Start at pin 7 and wind 120.5 turns in 8 layers.



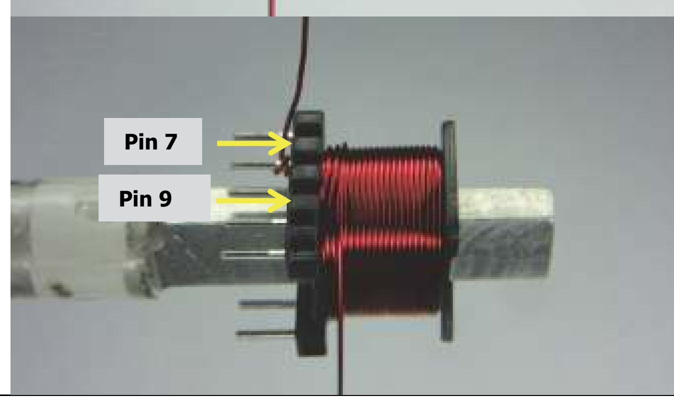

**Insulation**

Add 1 layer of tape, Item [4] for every 2 layers of winding 1



**Winding 1**

Finish at pin 9.





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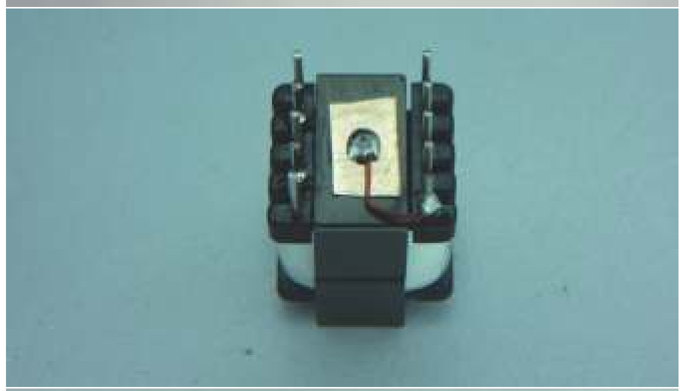
| | |
|---|---|
| **Insulation**<br>Add 2 layers of tape, Item [4] for insulation |  |
| **Core Termination**<br><br>Prepare a copper strip with a soldered magnetic wire, Item [6], at the middle as shown in the picture. Apply copper strip at the bottom part of the core and terminate the magnetic wire on pin 5. |  |
| **Core Tape**<br><br>Add 2 Layers of tape Item [5] around the core to fix the 2 cores into the bobbin.<br><br>**Pins**<br><br>Pull out or cut terminal pin no. 1, 2, 3, 4, 6, 8, and pin 10.<br><br>**Finish**<br><br>Dip the transformer assembly in 2:1 varnish and thinner solution. |  |

# 9 Performance Data

All measurements were performed at room temperature.

## *9.1 Output Current Regulation*

**Set-up:** Open frame unit
**Load:** 580 mA, varying voltage LED load
**Ambient Temperature:** 25 ºC
**Soak Time:** 60 seconds

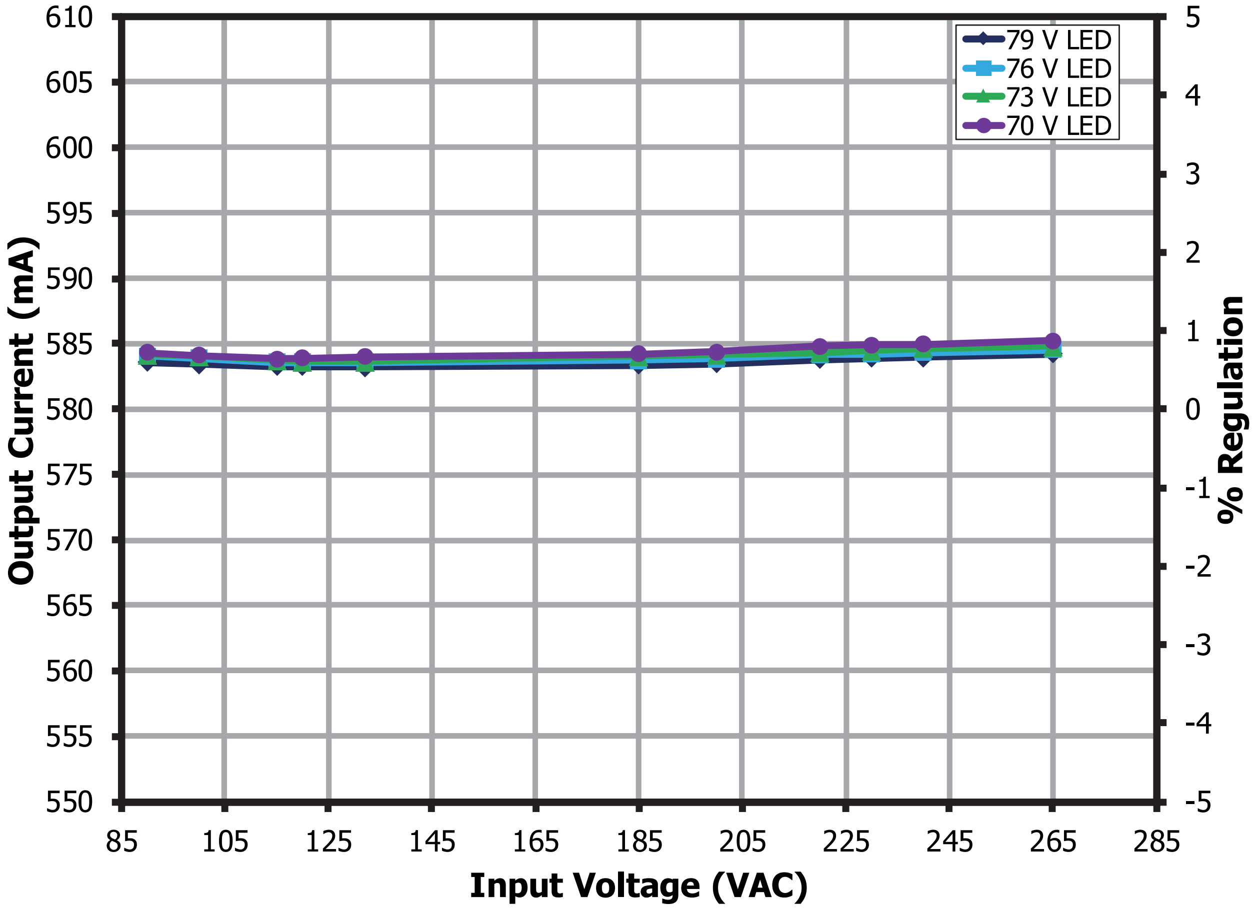



**Figure 11 –** Output Current Regulation vs. Input Line Voltage.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## *9.2 System Efficiency*

**Set-up:** Open frame unit
**Load:** 580 mA, varying voltage LED load
**Ambient Temperature:** 25 ºC
**Soak Time:** 60 seconds

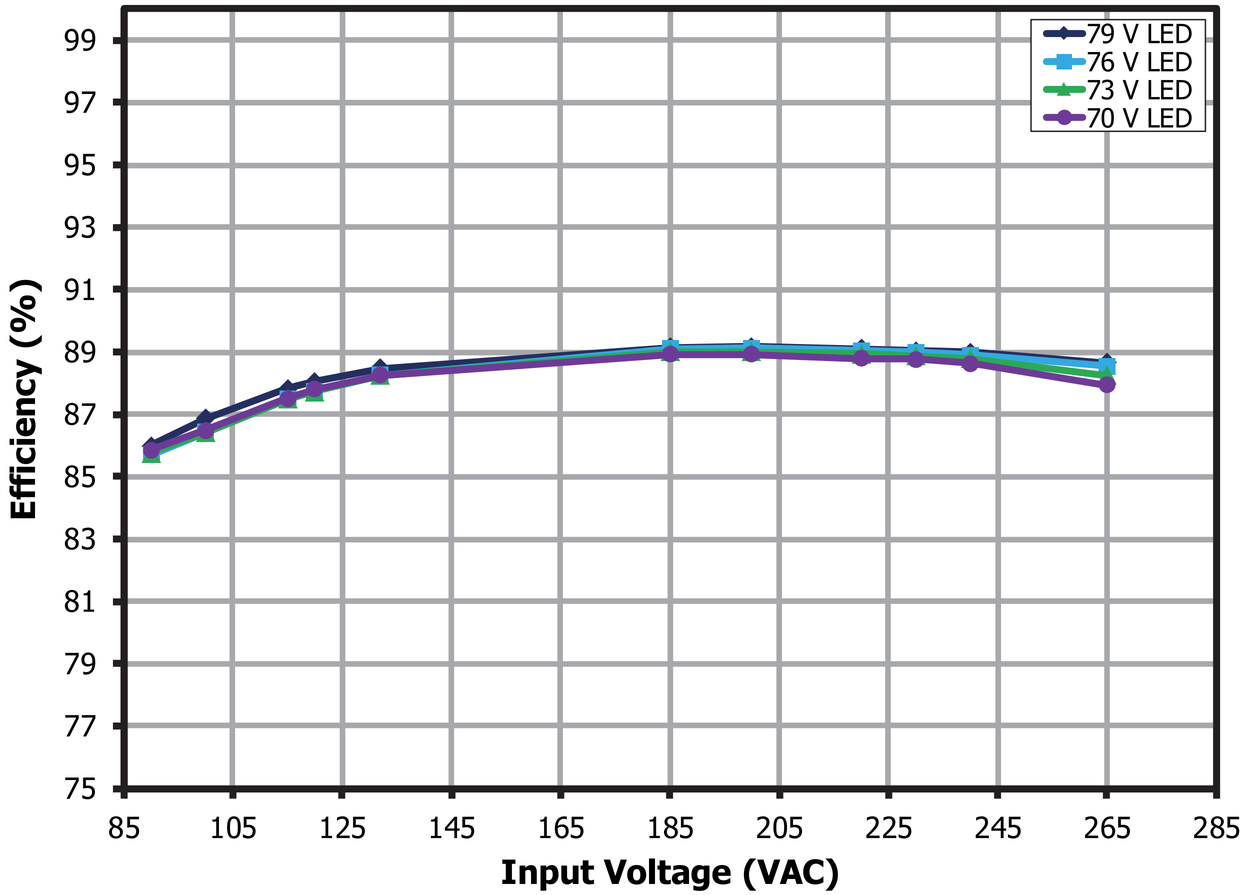


**Figure 12 –** Efficiency vs. Input Line Voltage.

## *9.3 Power Factor*

**Set-up:** Open frame unit
**Load:** 580mA, varying voltage LED load
**Ambient Temperature:** 25 ºC
**Soak Time:** 60 seconds

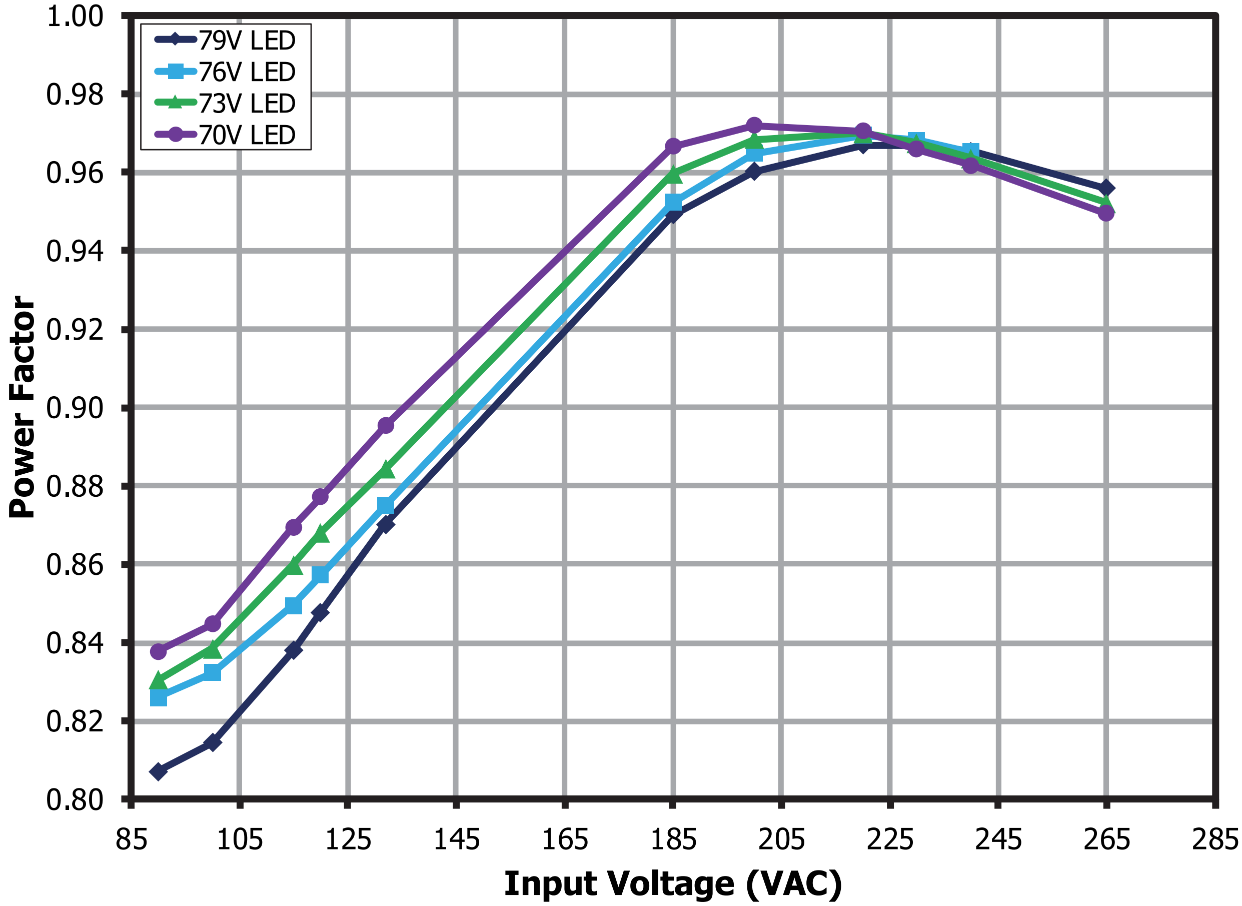


**Figure 13 –** Power Factor vs. Input Line Voltage.


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### *9.4 %ATHD*

**Set-up:** Open frame unit
**Load:** 580 mA, varying voltage LED load
**Ambient Temperature:** 25 ºC
**Soak Time:** 60 seconds

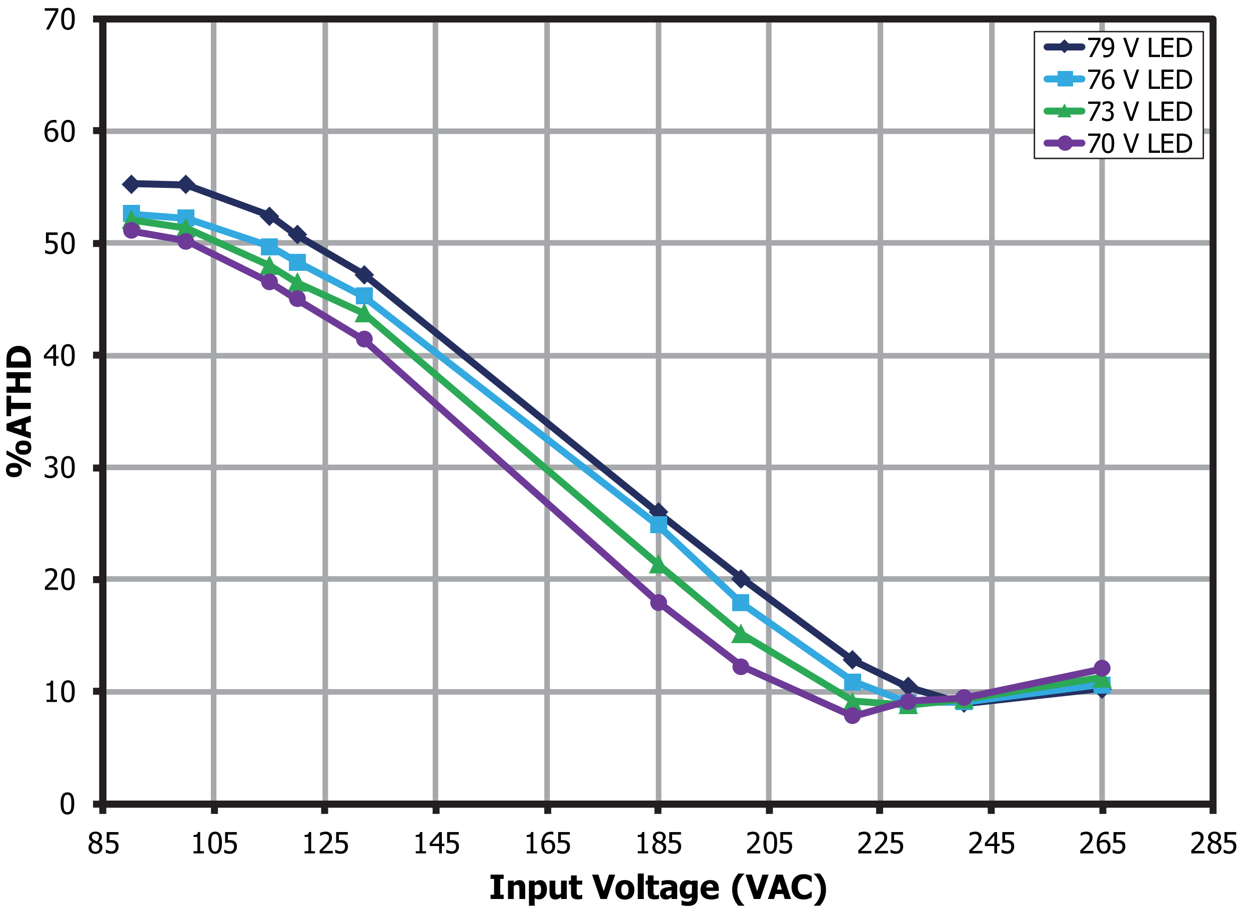


**Figure 14 –** %ATHD vs. Input Line Voltage.

## *9.5 Individual Harmonics Content at Full Load*

| | |
|---|---|
| **Set-up:** | Open frame unit |
| **Load:** | 80 V 580 mA LED load |
| **VIN:** | 230 V 50 Hz |
| **Ambient Temperature:** | 25 ºC |
| **Soak Time:** | 60 seconds |

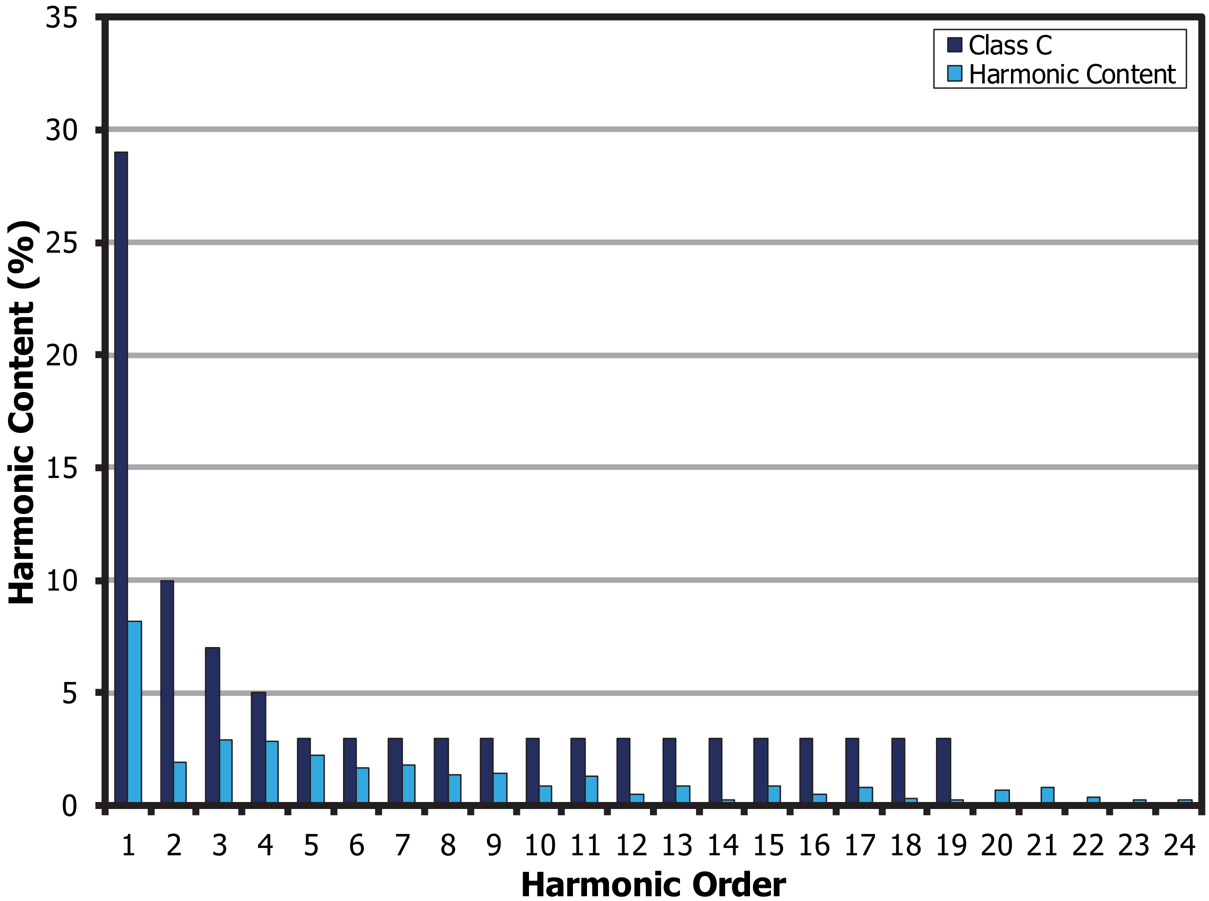


**Figure 15 –** Full Load Input Current Harmonics at 230 VAC 50 Hz.



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## 9.6 No-Load Input Power

**Set-up:** Open frame unit
**Load:** Open load
**Ambient Temperature:** 25 ºC
**Soak Time:** 60 seconds

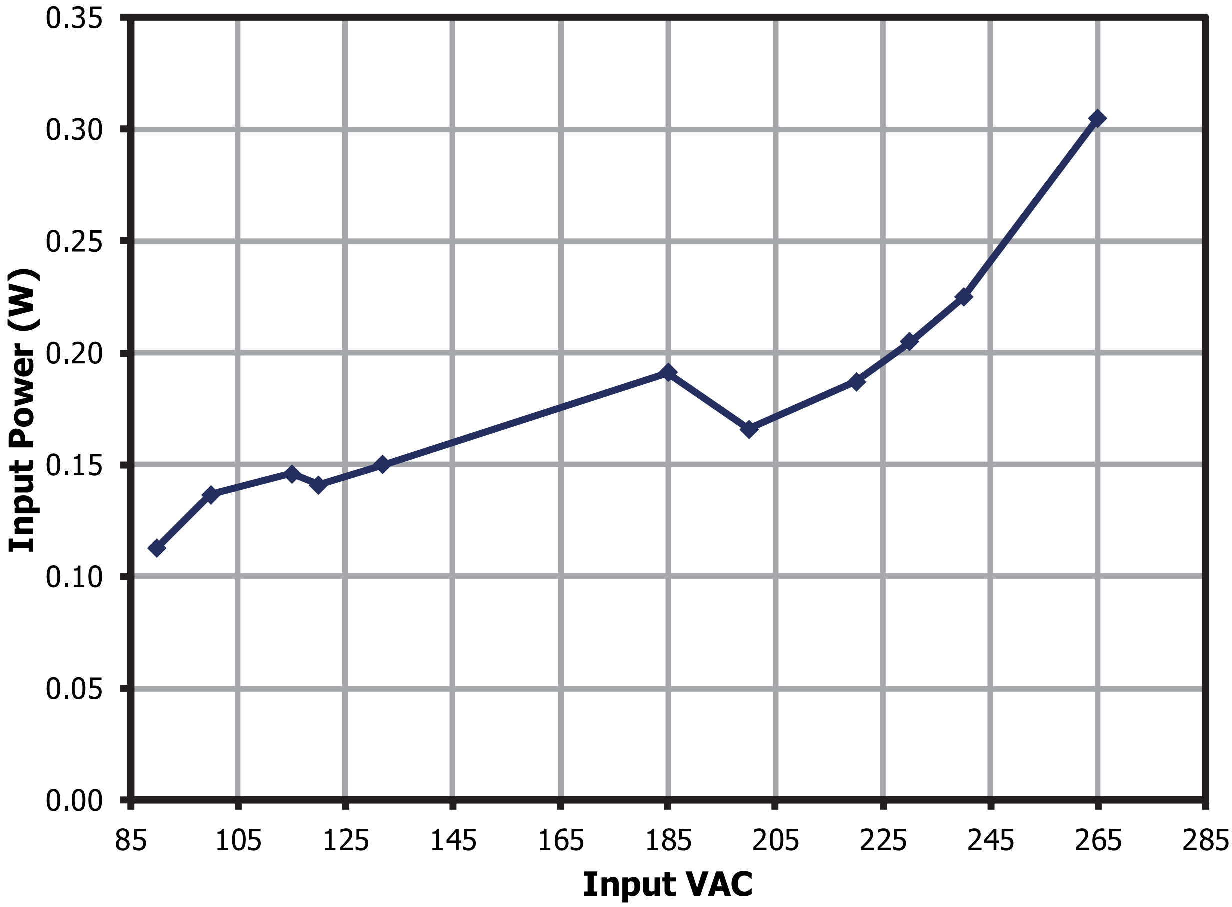


**Figure 16 –** No-Load Input Power vs. Input Line Voltage.

## *9.7 CV/CC Curve*

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

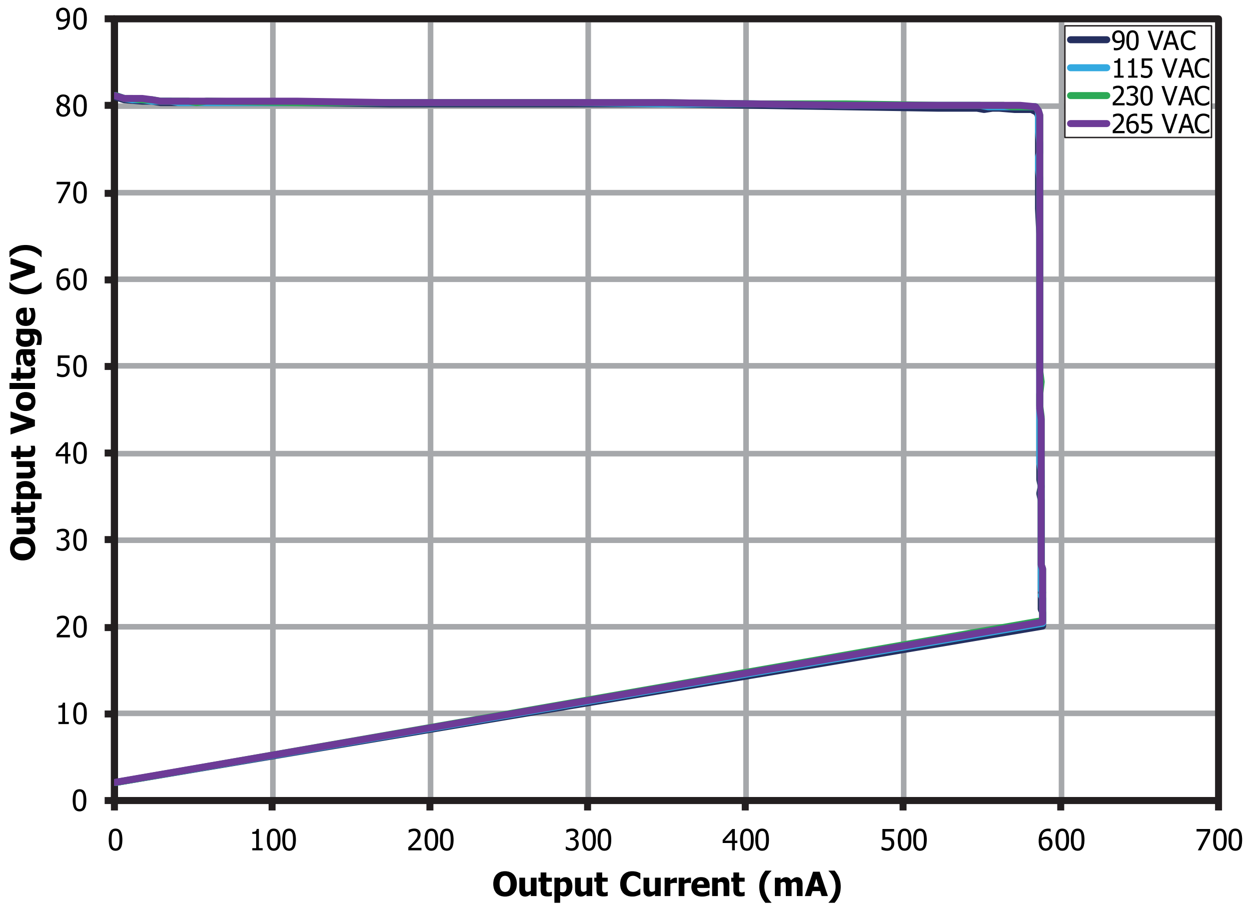


**Figure 17 –** CV/CC Curve.


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# 10 Test Data

## 10.1 Test Data at Full Load

| Input | | Input Measurement | | | | | LED Load Measurement | | | Efficiency (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| VAC ($V_{RMS}$) | Freq (Hz) | $V_{IN}$ ($V_{RMS}$) | $I_{IN}$ ($mA_{RMS}$) | $P_{IN}$ (W) | PF | %ATHD | $V_{OUT}$ ($V_{DC}$) | $I_{OUT}$ ($mA_{DC}$) | $P_{OUT}$ (W) | |
| 90 | 60 | 89.90 | 737.70 | 53.54 | 0.807 | 55.33 | 78.89 | 583.61 | 46.04 | 85.99 |
| 100 | 60 | 99.96 | 650.30 | 52.95 | 0.815 | 55.22 | 78.84 | 583.40 | 45.99 | 86.86 |
| 115 | 60 | 114.97 | 543.10 | 52.33 | 0.838 | 52.40 | 78.80 | 583.24 | 45.95 | 87.82 |
| 120 | 60 | 119.94 | 513.10 | 52.16 | 0.848 | 50.76 | 78.75 | 583.27 | 45.93 | 88.06 |
| 132 | 60 | 131.96 | 451.70 | 51.88 | 0.870 | 47.19 | 78.71 | 583.22 | 45.90 | 88.48 |
| 185 | 50 | 184.97 | 293.20 | 51.48 | 0.949 | 26.00 | 78.67 | 583.37 | 45.89 | 89.15 |
| 200 | 50 | 199.98 | 267.90 | 51.45 | 0.960 | 20.05 | 78.63 | 583.50 | 45.88 | 89.18 |
| 220 | 50 | 219.97 | 242.10 | 51.49 | 0.967 | 12.78 | 78.59 | 583.78 | 45.88 | 89.11 |
| 230 | 50 | 230.00 | 231.60 | 51.52 | 0.967 | 10.42 | 78.56 | 583.92 | 45.87 | 89.04 |
| 240 | 50 | 239.96 | 222.50 | 51.54 | 0.965 | 8.96 | 78.53 | 583.97 | 45.86 | 88.98 |
| 265 | 50 | 265.02 | 204.20 | 51.74 | 0.956 | 10.22 | 78.51 | 584.25 | 45.86 | 88.65 |

## 10.2 Test Data at No-Load

| Input | | Input Measurement | | | | |
|---|---|---|---|---|---|---|
| VAC ($V_{RMS}$) | Freq (Hz) | $V_{IN}$ ($V_{RMS}$) | $I_{IN}$ ($mA_{RMS}$) | $P_{IN}$ (W) | PF | %ATHD |
| 90 | 60 | 89.95 | 15.45 | 0.11 | 0.085 | 57.04 |
| 100 | 60 | 99.99 | 15.55 | 0.14 | 0.095 | 67.51 |
| 115 | 60 | 115.00 | 15.16 | 0.15 | 0.090 | 55.94 |
| 120 | 60 | 119.98 | 14.84 | 0.14 | 0.080 | 62.54 |
| 132 | 60 | 131.98 | 14.69 | 0.15 | 0.080 | 46.32 |
| 185 | 50 | 184.99 | 13.97 | 0.21 | 0.084 | 52.45 |
| 200 | 50 | 200.00 | 13.97 | 0.19 | 0.068 | 46.26 |
| 220 | 50 | 219.99 | 14.63 | 0.21 | 0.064 | 40.27 |
| 230 | 50 | 230.02 | 15.08 | 0.22 | 0.064 | 33.05 |
| 240 | 50 | 239.98 | 15.53 | 0.25 | 0.066 | 38.65 |
| 265 | 50 | 265.04 | 16.64 | 0.33 | 0.075 | 35.16 |

## 10.3 Individual Harmonic Content at 230 VAC 50 Hz and Full Load

| V | Freq | I (mA) | P | PF | %THD |
|---|---|---|---|---|---|
| 230 | 50.00 | 231.60 | 51.5200 | 0.9670 | 10.428 |
| | | | | | |
| **nth Order** | **mA Content** | **% Content** | **Limit <25 W** | **Limit >25 W** | **Remarks** |
| **1** | 227.90 | | | | |
| **2** | 0.30 | 0.13% | | 2.00% | Pass |
| **3** | 18.70 | 8.21% | 175.1680 | 29.01% | Pass |
| **5** | 4.30 | 1.89% | 97.8880 | 10.00% | Pass |
| **7** | 6.70 | 2.94% | 51.5200 | 7.00% | Pass |
| **9** | 6.50 | 2.85% | 25.7600 | 5.00% | Pass |
| **11** | 5.10 | 2.24% | 18.0320 | 3.00% | Pass |
| **13** | 3.80 | 1.67% | 15.2578 | 3.00% | Pass |
| **15** | 4.10 | 1.80% | 13.2235 | 3.00% | Pass |
| **17** | 3.10 | 1.36% | 11.6678 | 3.00% | Pass |
| **19** | 3.30 | 1.45% | 10.4396 | 3.00% | Pass |
| **21** | 1.90 | 0.83% | 9.4453 | 3.00% | Pass |
| **23** | 2.90 | 1.27% | 8.6240 | 3.00% | Pass |
| **25** | 1.10 | 0.48% | 7.9341 | 3.00% | Pass |
| **27** | 2.00 | 0.88% | 7.3464 | 3.00% | Pass |
| **29** | 0.60 | 0.26% | 6.8397 | 3.00% | Pass |
| **31** | 2.00 | 0.88% | 6.3985 | 3.00% | Pass |
| **33** | 1.10 | 0.48% | 6.0107 | 3.00% | Pass |
| **35** | 1.80 | 0.79% | 5.6672 | 3.00% | Pass |
| **37** | 0.70 | 0.31% | 5.3609 | 3.00% | Pass |
| **39** | 0.60 | 0.26% | 5.0859 | 3.00% | Pass |
| **41** | 1.50 | 0.66% | | | |
| **43** | 1.80 | 0.79% | | | |
| **45** | 0.90 | 0.39% | | | |
| **47** | 0.50 | 0.22% | | | |
| **49** | 0.50 | 0.22% | | | |



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# 11 Load Regulation Performance

**Set-up:** Open frame unit
**Load:** CC load
**Ambient Temperature:** 25 ºC (room temp)

## *11.1 Output Voltage Load Regulation*

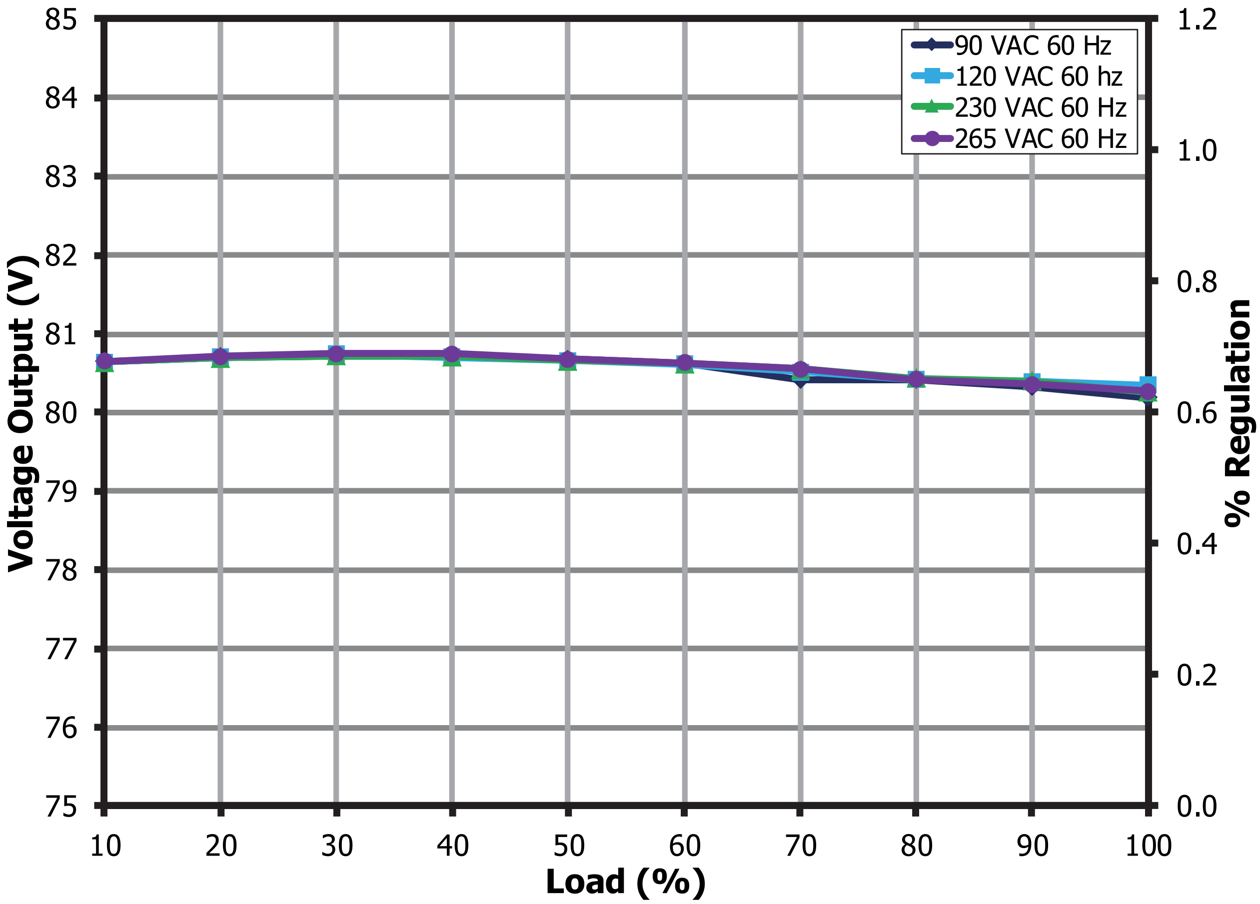


**Figure 18 –** Output Voltage vs. Load.

## *11.2 Efficiency vs. Load*

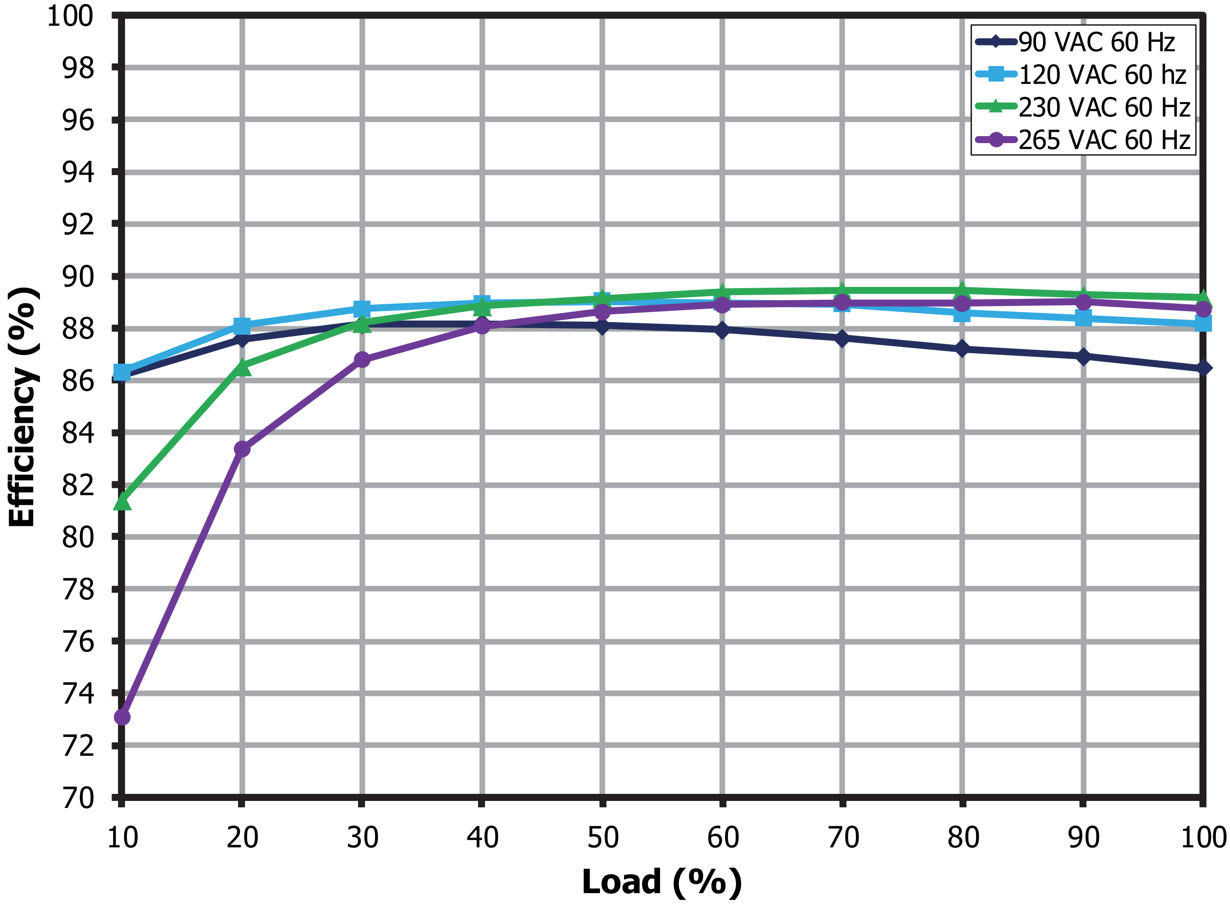


**Figure 19 –** Efficiency vs Load.

## *11.3 Average Efficiency*

### 11.3.1 Average Efficiency Measurement

| %Load | Efficiency (%) | |
|---|---|---|
| | 115 V / 60 Hz | 230 V / 60 Hz |
| **100** | 88.17 | 89.21 |
| **75** | 88.70 | 89.52 |
| **50** | 88.99 | 89.28 |
| **25** | 88.42 | 87.69 |
| **Average Efficiency** | 88.92 | 88.57 |
| **DOE Level VI Limit** | **80.93** | |



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## *11.4 Power Factor vs. Load*

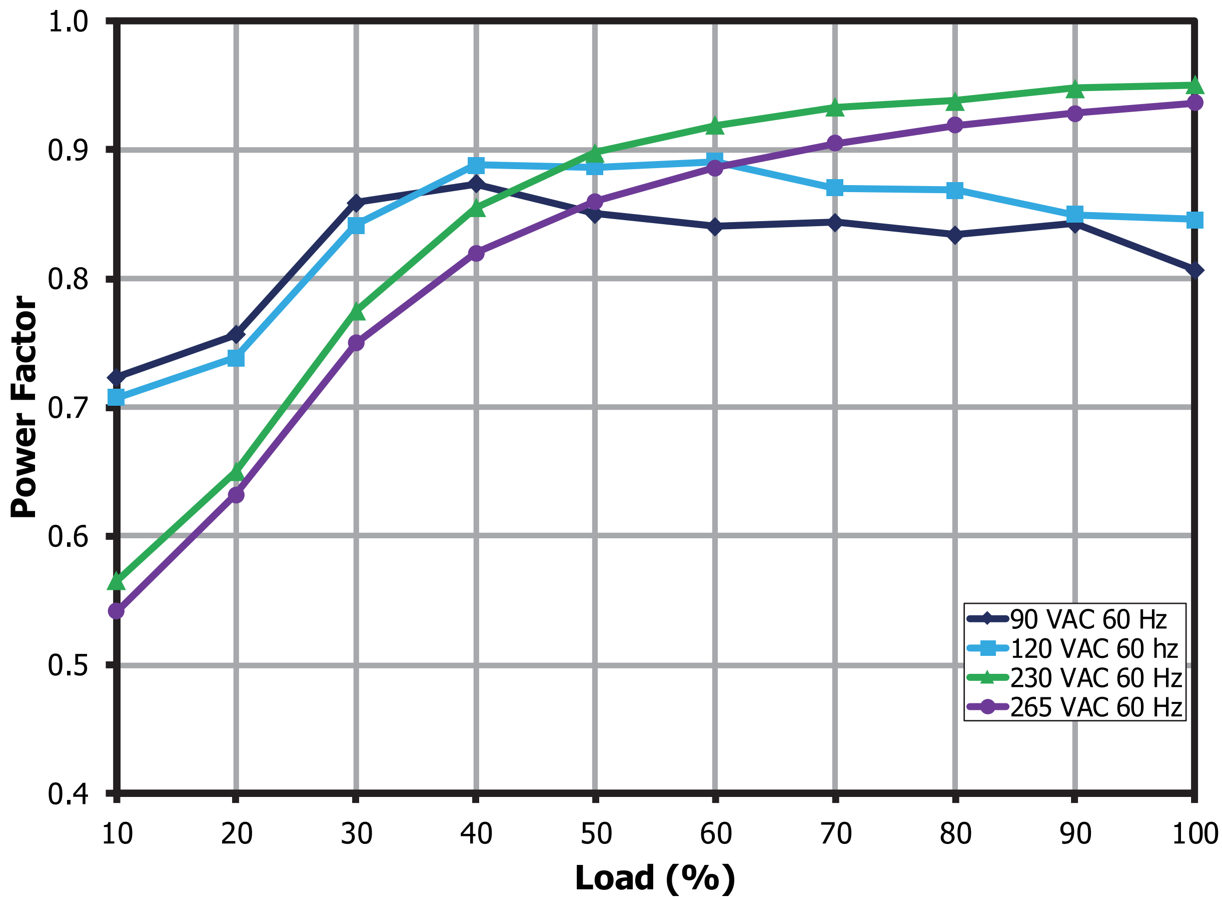


**Figure 20 –** Power Factor vs Load.

### *11.5 % ATHD vs. Load*

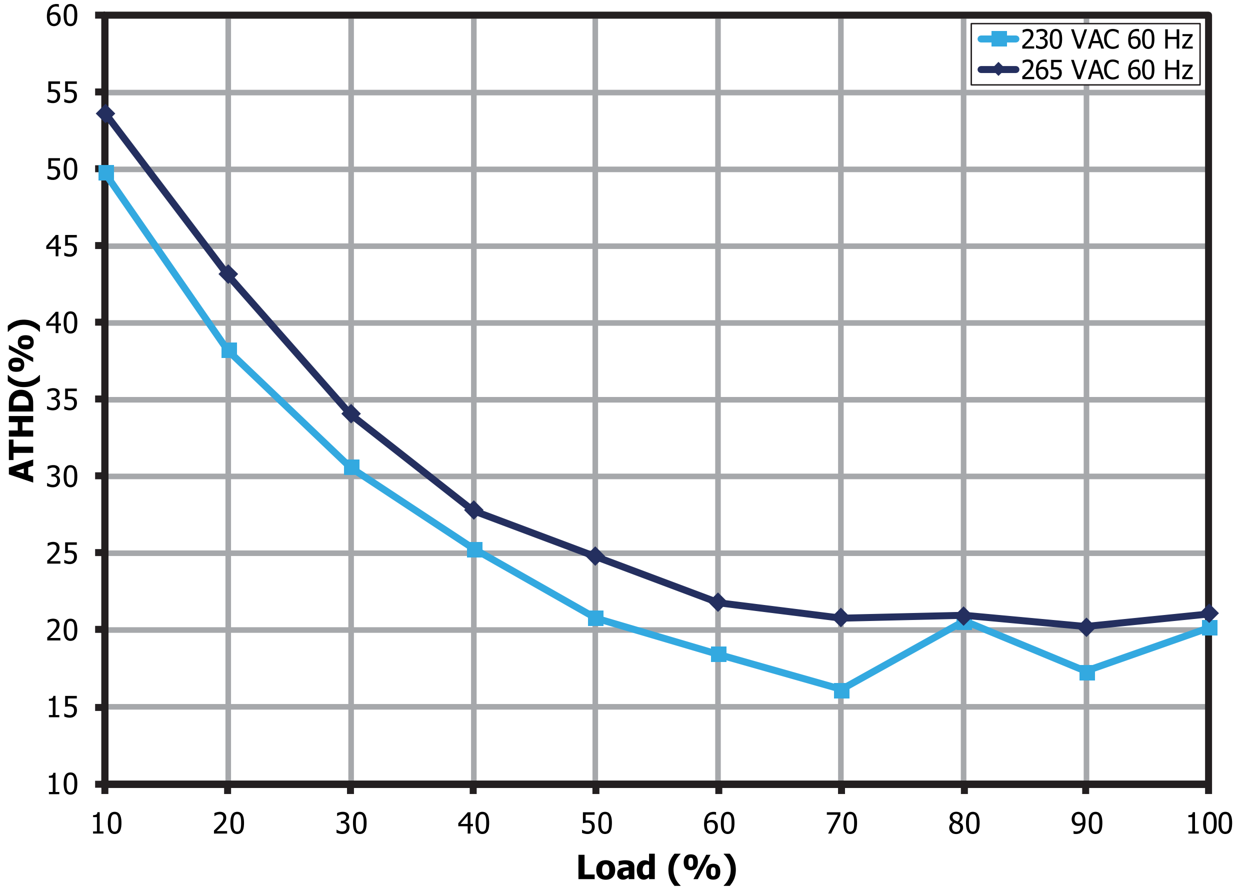


**Figure 21 –** Power Factor vs Load.


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# 12 Thermal Performance

## *12.1 Thermal Measurements at Room Temp Ambient*

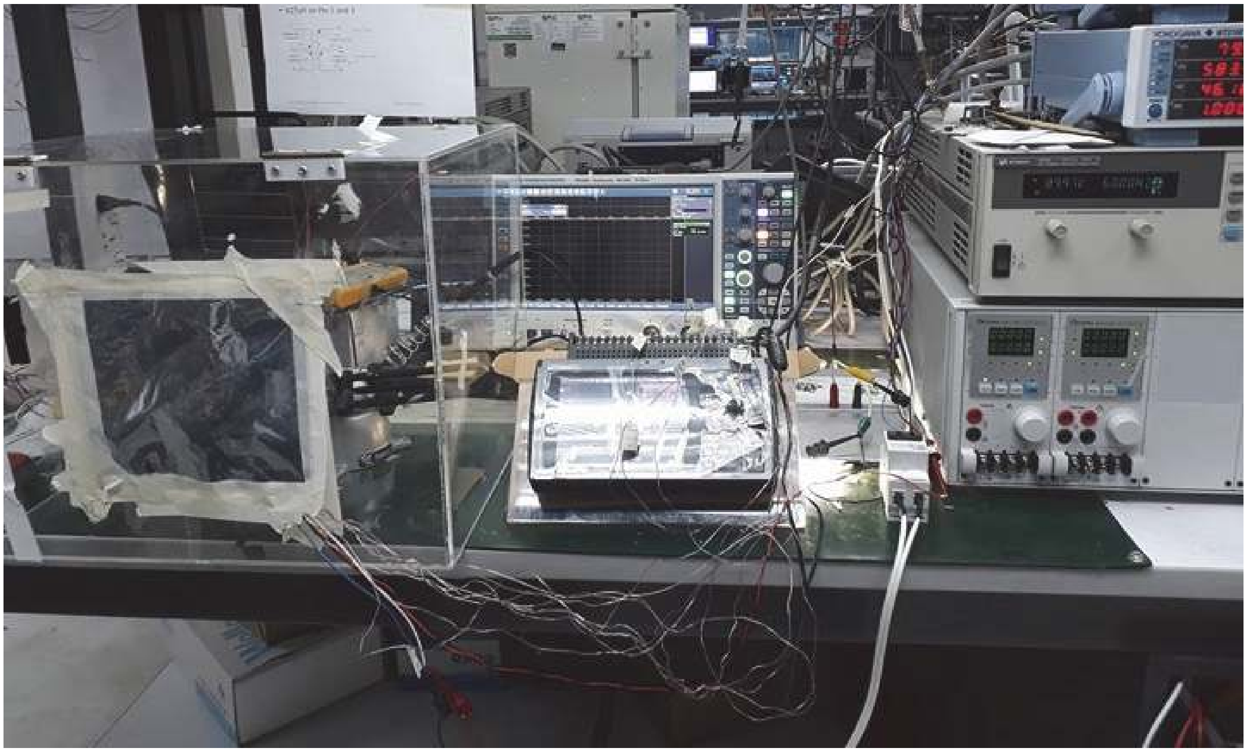

**Figure 22 –** Test Set-up Picture - Open Frame.

Unit in Open Frame was placed inside the acrylic enclosure to prevent airflow that might affect the thermal measurements. Temperature was measured using T-type thermocouple.

Equipment used:
1. KEYSIGHT 6812B AC Power Source/Analyzer
2. Chroma 6314A DC Electronic Load Mainframe and Chroma 63110A DC Electronic Load
3. Graphtec GL820 Data Logger
4. Yokogawa WT310E Digital Power Meter
5. CADWILL Step-up Transformer (for Inputs >300 VAC)

| Ref Des | Description | Thermal Reading at Room Temperature | |
|---|---|---|---|
| | | 120 VAC | 230 VAC |
| **U4** | LYTSwitch-6 IC | 94.2 | 89.6 |
| **D8** | Primary Snubber Diode | 44.5 | 44.2 |
| **T1** | PFC Inductor | 61.6 | 64.2 |
| **T2** | DCDC TRF Primary | 74 | 71.3 |
| **D1** | PFC Diode | 60.1 | 55.9 |
| **D17** | PFC Diode | 64.4 | 59.6 |
| **D10** | Output Diode | 81.5 | 74.2 |
| **R48** | Secondary Snubber Resistor | 78.4 | 73.1 |
| **AMBIENT** | | 25.9 | 22.5 |


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## 12.2 Thermal Performance at High Temp Ambient


**Figure 23 –** Test Set-up Picture Thermal at 60 ºC Ambient - Open Frame.

Open frame unit was placed inside the enclosure to prevent airflow that may affect the thermal measurements. Ambient temperature inside enclosure is set at 60 ºC. Temperature was measured using T-type thermocouple. Soak time at full load is more than 1 hour.

Equipment used:

1. KEYSIGHT 6812B AC Power Source/Analyzer
2. Chroma 6314A DC Electronic Load Mainframe and Chroma 63110A DC Electronic Load
3. Graphtec GL820 Data Logger
4. Yokogawa WT310E Digital Power Meter
5. SPX Tenney TUJR Thermal Chamber
6. CADWILL Step-up Transformer (for Inputs >300 VAC)

| Ckt. Code | Description | Thermal Reading at High Temp | |
|---|---|---|---|
| | | 120 VAC | 230 VAC |
| **U4** | LYTSwitch-6 IC | 132.4 | 127.9 |
| **D8** | Primary Snubber Diode | 63 | 56.5 |
| **T1** | PFC Inductor | 91.4 | 98.5 |
| **T2** | DCDC TRF Primary | 104.5 | 102.7 |
| **D1** | PFC Diode | 88.8 | 88.4 |
| **D17** | PFC Diode | 95.3 | 90.9 |
| **D10** | Output Diode | 114 | 103.8 |
| **R48** | Secondary Snubber Resistor | 110.9 | 103.5 |
| **AMBIENT** | | 60.2 | 57.9 |


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# 13 Waveforms

Waveforms were taken at room temperature (25 ºC).

## *13.1 Input Voltage and Input Current at Full Load*

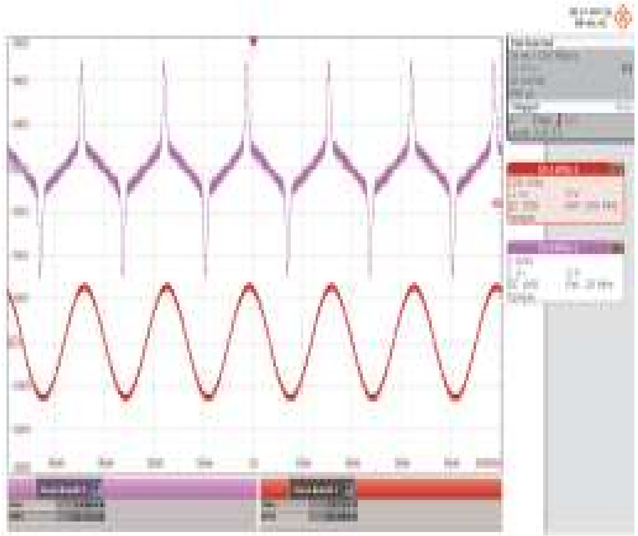

**Figure 24 –** 90 VAC 50 Hz, Full Load.
Upper: $I_{IN}$, 1 A / div.
Lower: $V_{IN}$, 100 V / div., 10 ms / div.

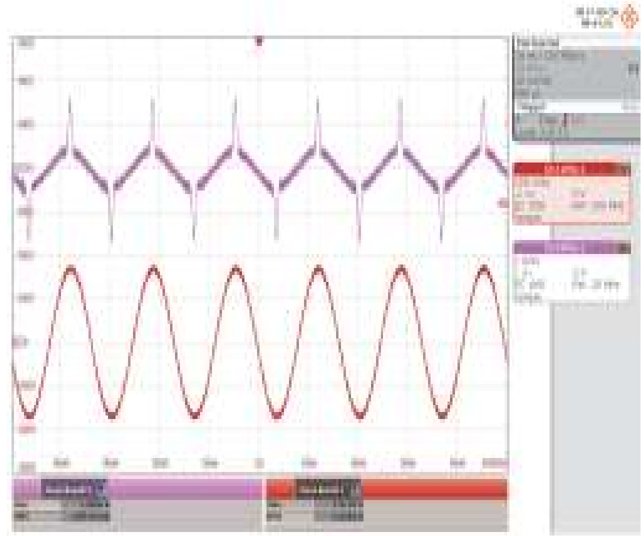

**Figure 25 –** 120 VAC 50 Hz, Full Load.
Upper: $I_{IN}$, 1 A / div.
Lower: $V_{IN}$, 100 V / div., 10 ms / div.

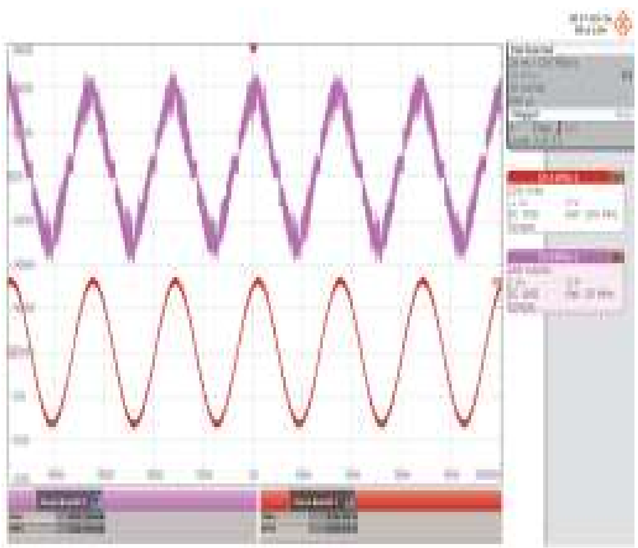

**Figure 26 –** 230 VAC 50 Hz, Full Load.
Upper: $I_{IN}$, 200 mA / div.
Lower: $V_{IN}$, 200 V / div., 10 ms / div.

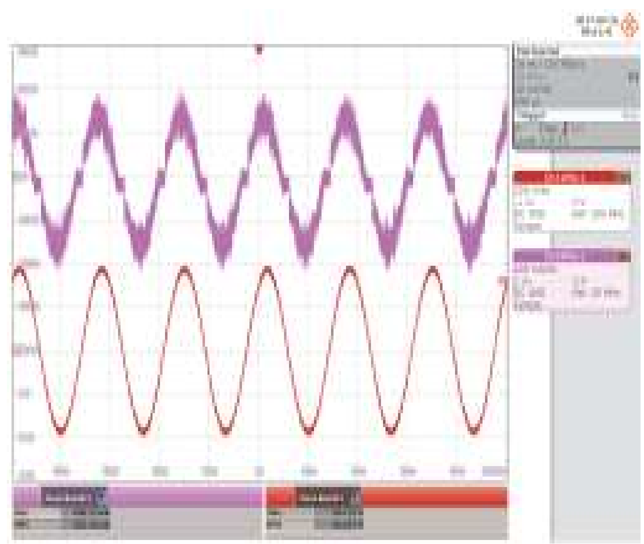

**Figure 27 –** 265 VAC 50 Hz, Full Load.
Upper: $I_{IN}$, 200 mA / div.
Lower: $V_{IN}$, 200 V / div., 10 ms / div.

## 13.2 Start-up Profile at Full Load

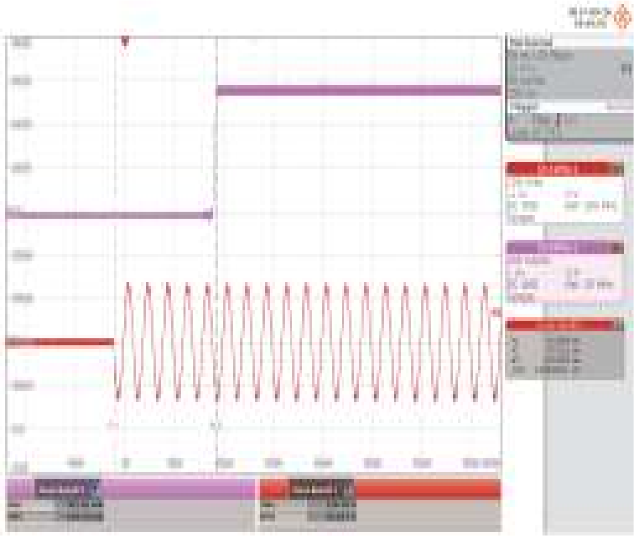

**Figure 28 –** 90 VAC 50 Hz, Full Load Start-up
Upper: $I_{OUT}$, 200 mA / div.
Lower: $V_{IN}$, 100 V / div., 50 ms / div.
Turn-on Time: 103 ms

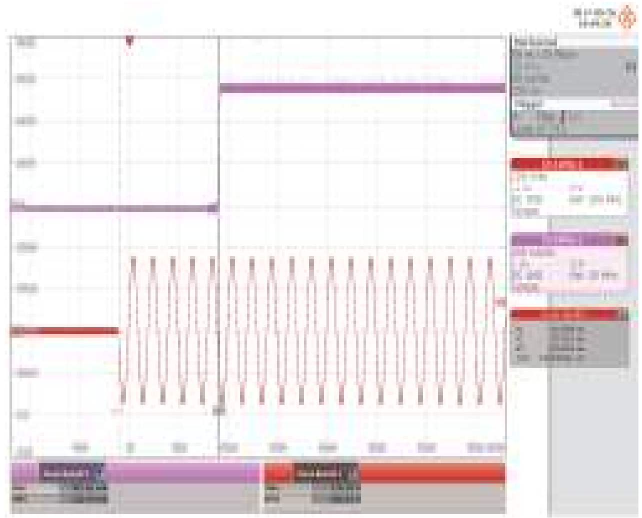

**Figure 29 –** 120 VAC 50 Hz, Full Load Start-up.
Upper: $I_{OUT}$, 200 mA / div.
Lower: $V_{IN}$, 100 V / div., 50 ms / div.
Turn-on Time: 101 ms

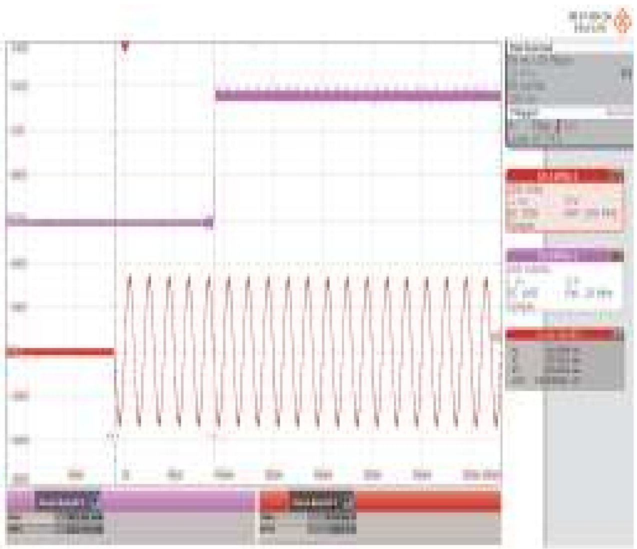

**Figure 30 –** 230 VAC 50 Hz, Full Load Start-up.
Upper: $I_{OUT}$, 200 mA / div.
Lower: $V_{IN}$, 200 V / div., 50 ms / div.
Turn-on Time: 101 ms.

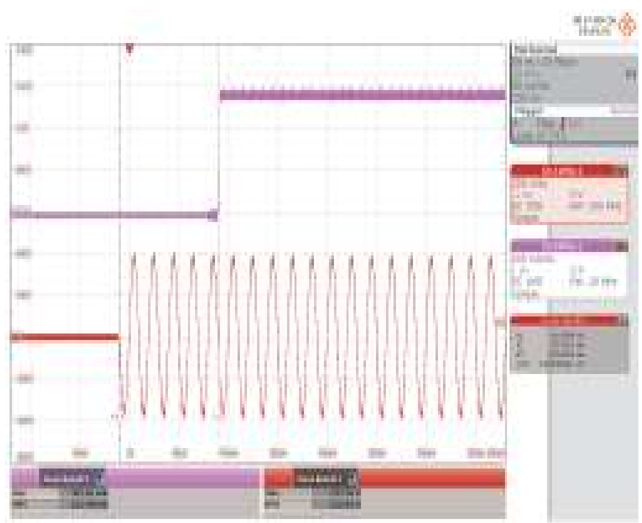

**Figure 31 –** 265 VAC 50 Hz, Full Load Start-up
Upper: $I_{OUT}$, 200 mA / div.
Lower: $V_{IN}$, 100 V / div., 50 ms / div.
Turn-on Time: 101 ms.



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### *13.3 Output Current Fall*

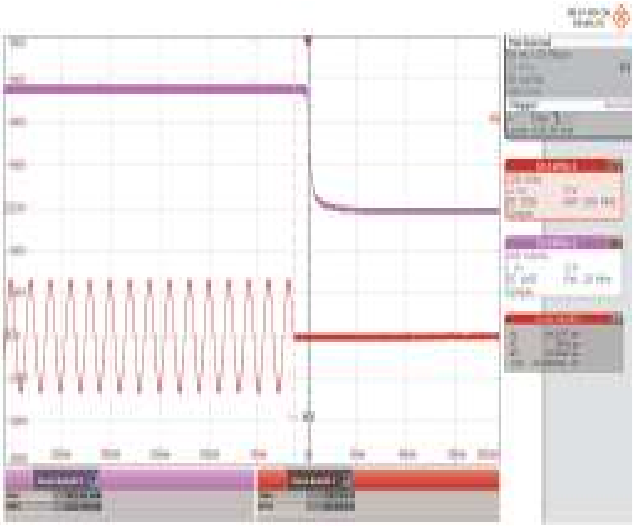

**Figure 32 –** 90 VAC 50 Hz, Full Load, Output Fall.
Upper: $I_{OUT}$, 200 mA / div.
Lower: $V_{IN}$, 100 V / div., 50 ms / div.
Hold-Up Time: 14 ms.

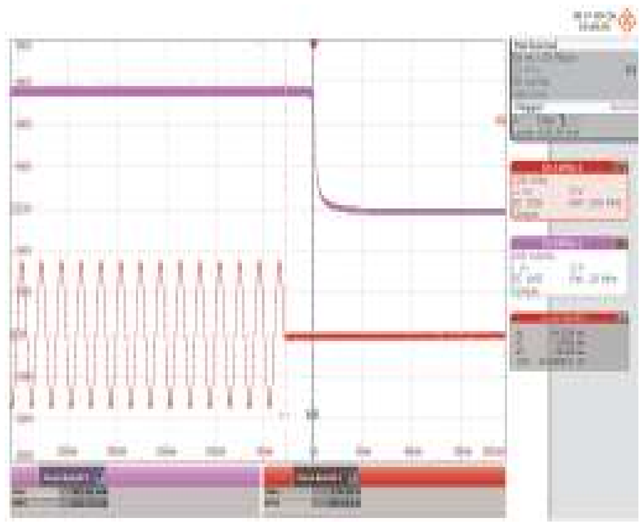

**Figure 33 –** 120 VAC 50 Hz, Full Load, Output Fall.
Upper: $I_{OUT}$, 200 mA / Div
Lower: $V_{IN}$, 100 V / div., 50 ms / div.
Hold-Up Time: 28 ms.

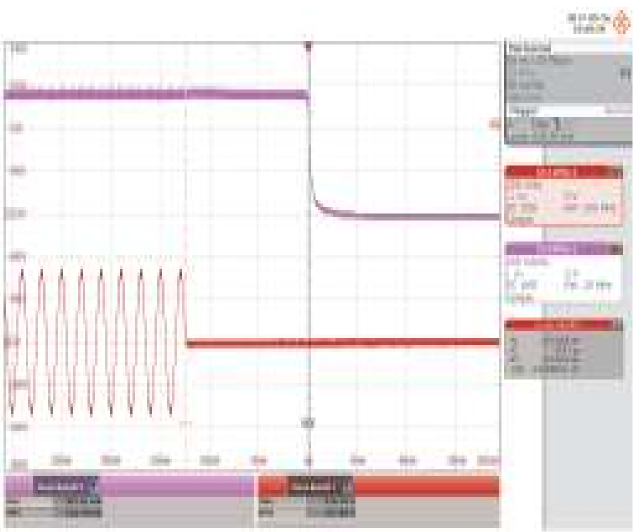

**Figure 34 –** 230 VAC 50 Hz, Full Load, Output Fall.
Upper: $V_{OUT}$, 200 mA / div.
Lower: $V_{IN}$, 200 V / div., 50 ms / div.
Hold-Up Time: 123 ms.

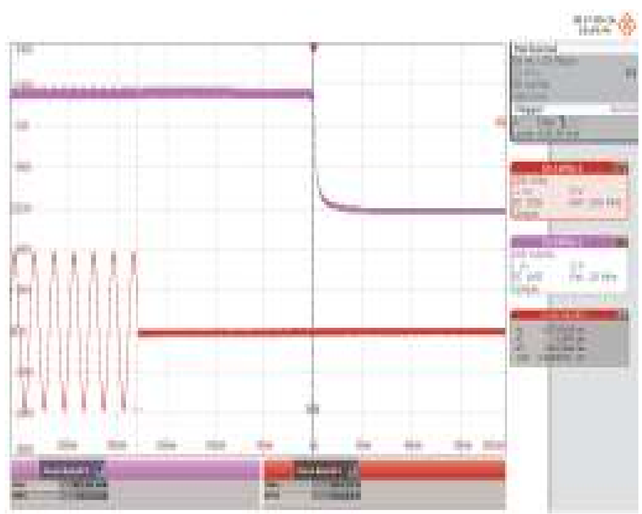

**Figure 35 –** 265 VAC 50 Hz, Full Load, Output Fall.
Upper: $V_{OUT}$, 200 mA / div.
Lower: $V_{IN}$, 100 V / div., 50 ms / div.
Hold-Up Time: 196.5 ms.

## *13.4 Load Transient Response 100 Hz*

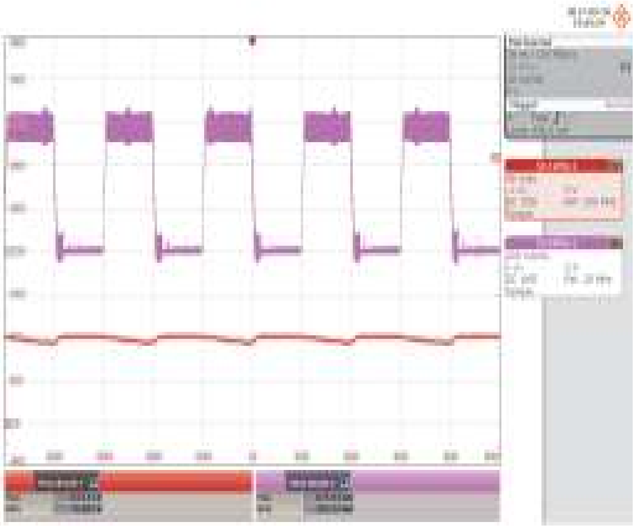

**Figure 36 –** 90 VAC 50 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs.
Upper: $I_{OUT}$, 200 mA / div.
Lower: $V_{OUT}$, 40 V / div., 10 ms / div.

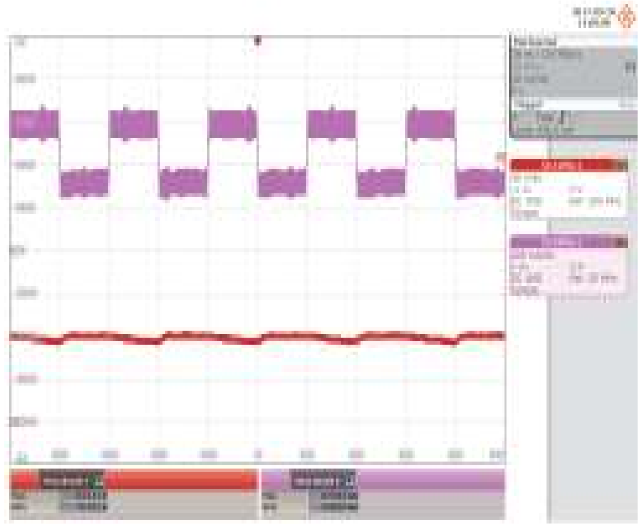

**Figure 37 –** 90 VAC 50 Hz.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs.
Upper: $I_{OUT}$, 200 mA / div.
Lower: $V_{OUT}$, 40 V / div., 10 ms / div.

**Figure 38 –** 120 VAC 50 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs.
Upper: $I_{OUT}$, 200 mA / div.
Lower: $V_{OUT}$, 40 V / div., 10 ms / div.

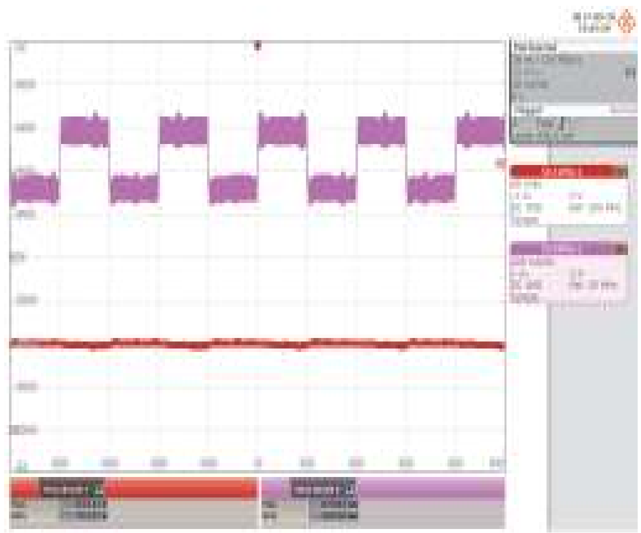

**Figure 39 –** 120 VAC 50 Hz.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs.
Upper: $I_{OUT}$, 200 mA / div.
Lower: $V_{OUT}$, 40 V / div., 10 ms / div.


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**Figure 40 –** 230 VAC 50 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs.
Upper: $I_{OUT}$, 200 mA / div.
Lower: $V_{OUT}$, 40 V / div., 10 ms / div.

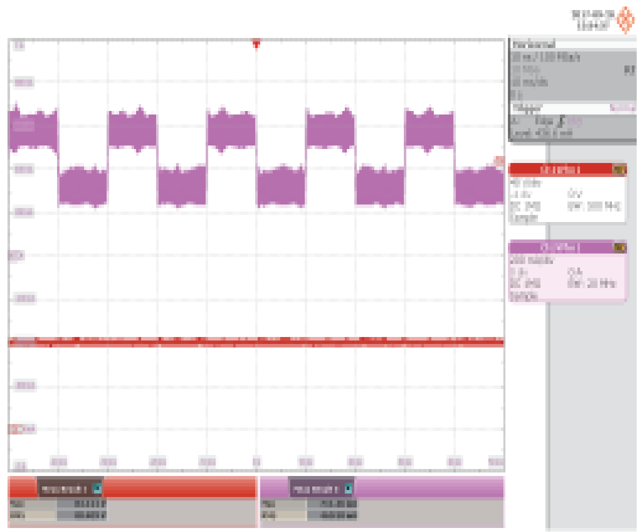

**Figure 41 –** 230 VAC 50 Hz.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs
Upper: $I_{OUT}$, 200 mA / div.
Lower: $V_{OUT}$, 40 V / div., 10 ms / div.

**Figure 42 –** 265 VAC 50 Hz.
0% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs.
Upper: $I_{OUT}$, 200 mA / div.
Lower: $V_{OUT}$, 40 V / div., 10 ms / div.

**Figure 43 –** 265 VAC 50 Hz.
50% to 100% Load Change.
100 Hz, 50% Duty Cycle.
Slew Rate: 3.2 mA / µs.
Upper: $I_{OUT}$, 200 mA / div.
Lower: $V_{OUT}$, 40 V / div., 10 ms / div.

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

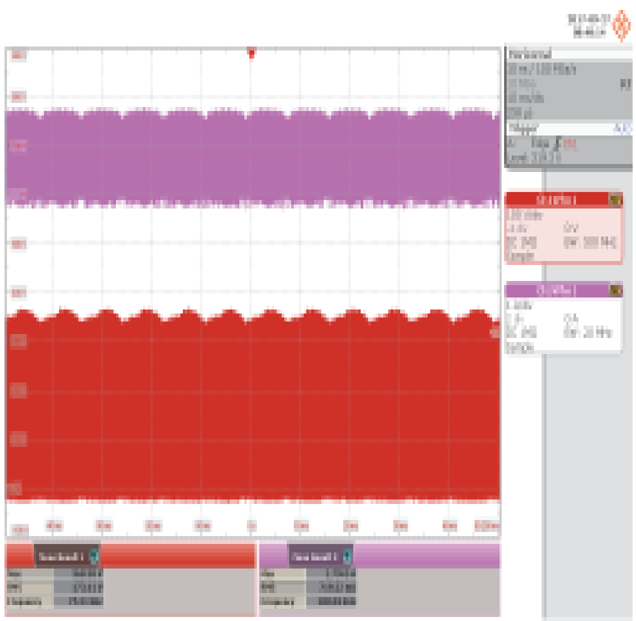

**Figure 44 –** 90 VAC 50 Hz, Full Load Normal.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 10 ms / div.

**Figure 45 –** 90 VAC 50 Hz, Full Load Normal.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 10 µs / div.



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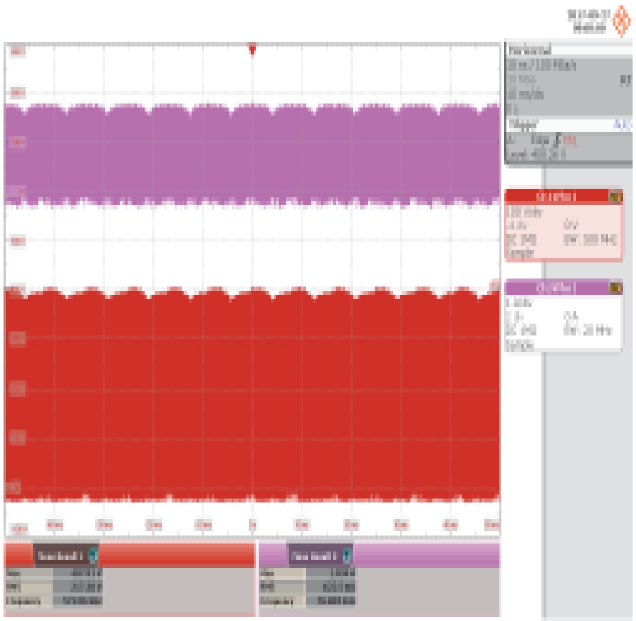

**Figure 46 –** 120 VAC 50 Hz, Full Load Normal.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 10 ms / div.

**Figure 47 –** 120 VAC 50 Hz, Full Load Normal.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 10 μs / div.

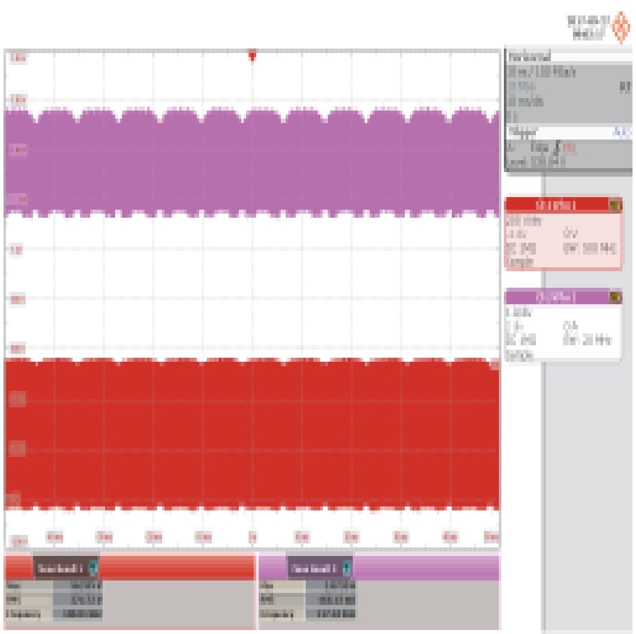

**Figure 48 –** 230 VAC 50 Hz, Full Load Normal.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 10 ms / div.

**Figure 49 –** 230 VAC 50 Hz, Full Load Normal.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 10 μs / div.



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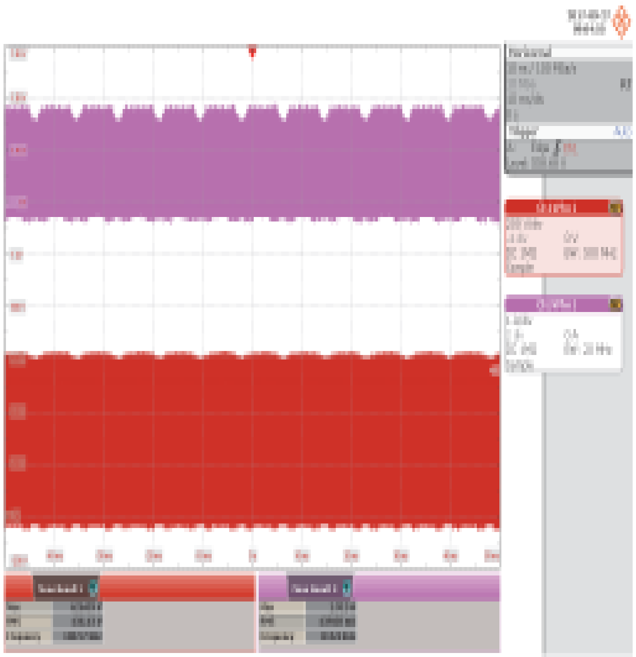

**Figure 50 –** 265 VAC 50 Hz, Full Load Normal.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 10 ms / div.

**Figure 51 –** 265 VAC 50 Hz, Full Load Normal.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 10 μs / div.

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

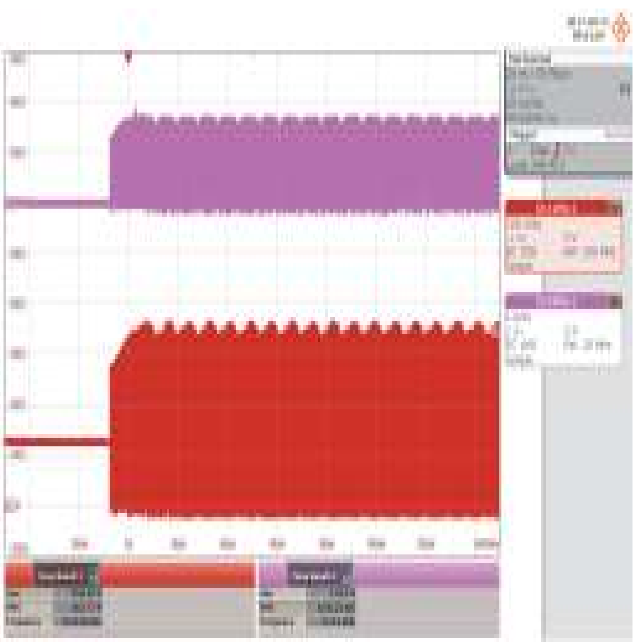

**Figure 52 –** 90 VAC 50 Hz, Full Load Start-up.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 20 ms / div.

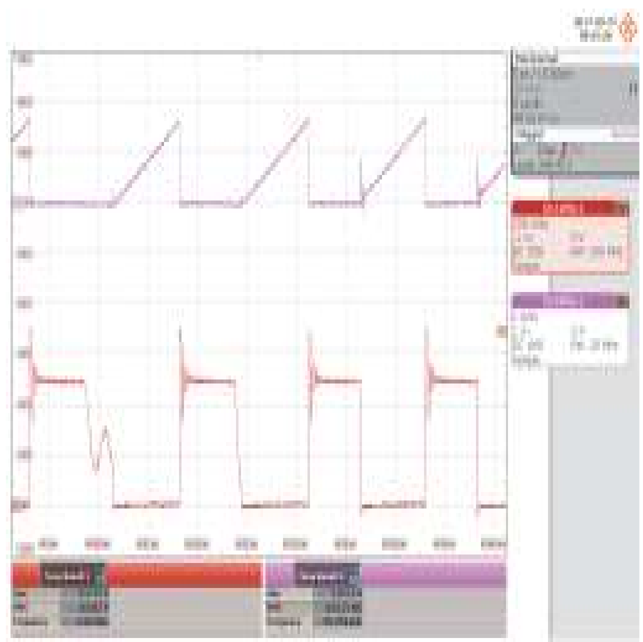

**Figure 53 –** 90 VAC 50 Hz, Full Load Start-up.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 5 μs / div.

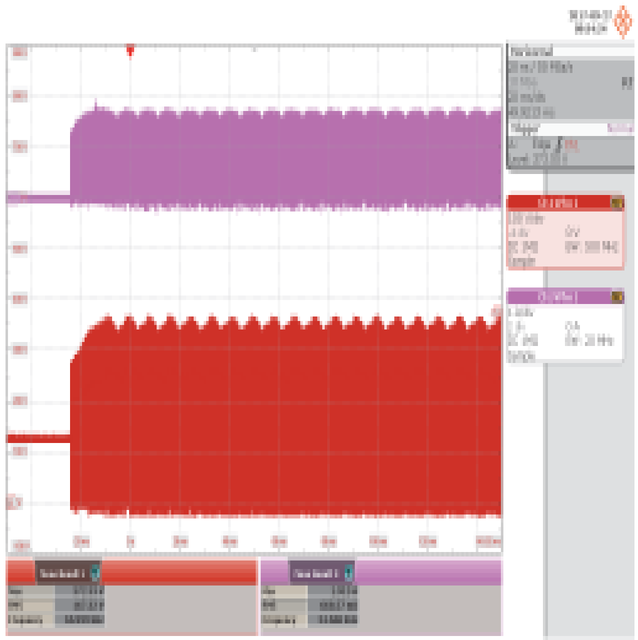

**Figure 54 –** 120 VAC 50 Hz, Full Load Start-up.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 20 ms / div.

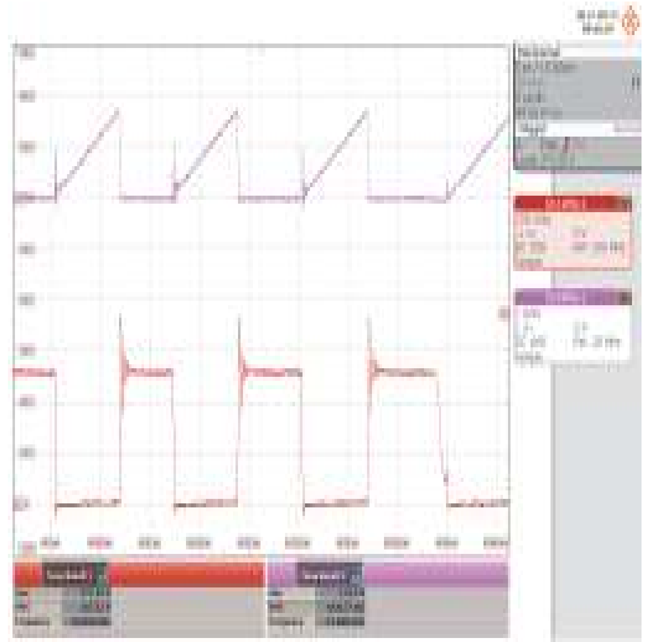

**Figure 55 –** 120 VAC 50 Hz, Full Load Start-up.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 5 µs / div.

**Figure 56 –** 230 VAC 50 Hz, Full Load Start-up.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 20 ms / div.

**Figure 57 –** 230 VAC 50 Hz, Full Load Start-up.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 5 µs / div.



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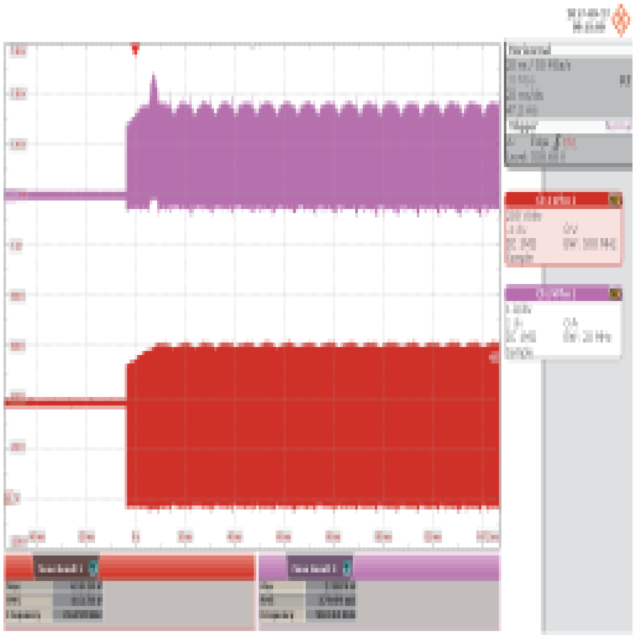

**Figure 58 –** 265 VAC 50 Hz, Full Load Start-up.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 20 ms / div.

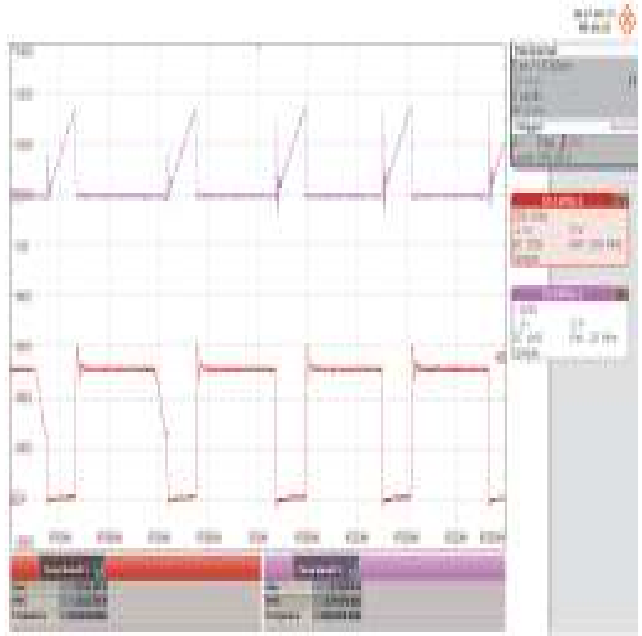

**Figure 59 –** 265 VAC 50 Hz, Full Load Start-up.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 5 μs / div.

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

**Figure 60 –** 90 VAC 50 Hz, Output Shorted.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 1 s / div.
$P_{IN}$ Average: 63 mW.

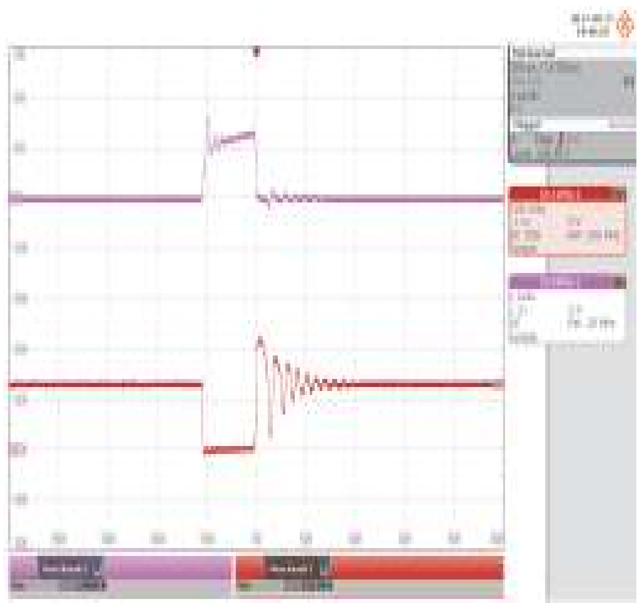

**Figure 61 –** 90 VAC 50 Hz, Output Shorted.
Upper: $I_{DRAIN}$, 500 mA / div.
Lower: $V_{DRAIN}$, 100 V / div., 1 μs / div.

**Figure 62 –** 120 VAC 50 Hz, Output Shorted.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 1 s / div.
$P_{IN}$ Average: 67 mW.

**Figure 63 –** 23120 VAC 50 Hz, Output Shorted.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 2 μs / div.

**Figure 64 –** 230 VAC 50 Hz, Output Shorted.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 1 s / div.
$P_{IN}$ Average: 91 mW.

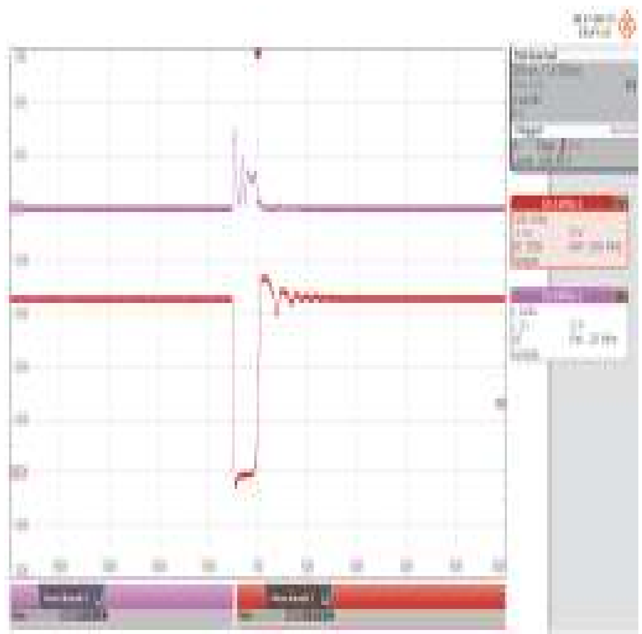

**Figure 65 –** 230 VAC 50 Hz, Output Shorted.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 1 μs / div.


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**Figure 66 –** 265 VAC 50 Hz, Output Shorted.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 1 s / div.
$P_{IN}$ Average: 170 mW.

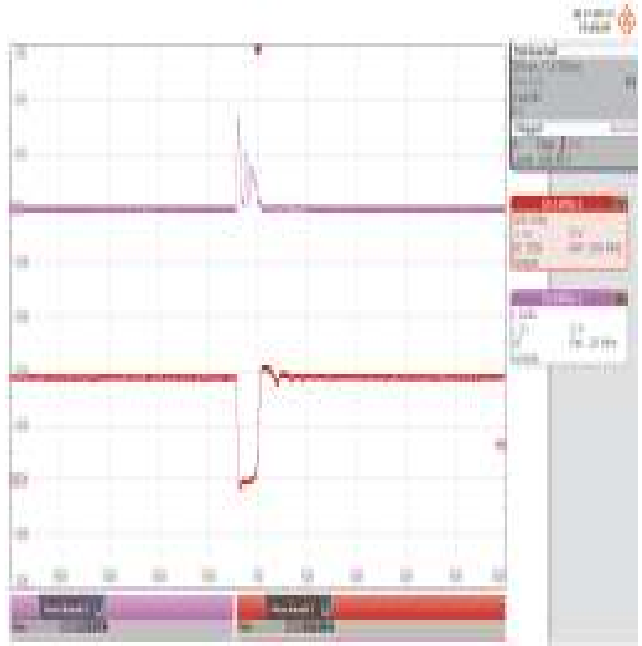

**Figure 67 –** 265 VAC 50 Hz, Output Shorted.
Upper: $I_{DRAIN}$, 1 A / div.
Lower: $V_{DRAIN}$, 100 V / div., 1 μs / div.

## *13.8 PFC Diode Voltage and Current at Normal Operation*

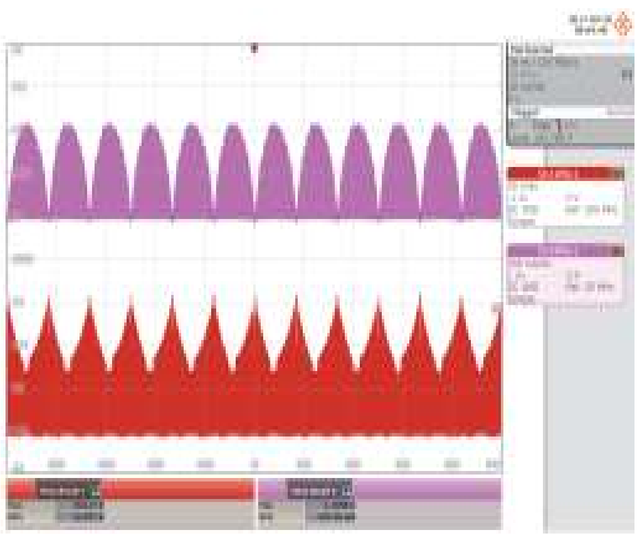

**Figure 68 –** 90 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

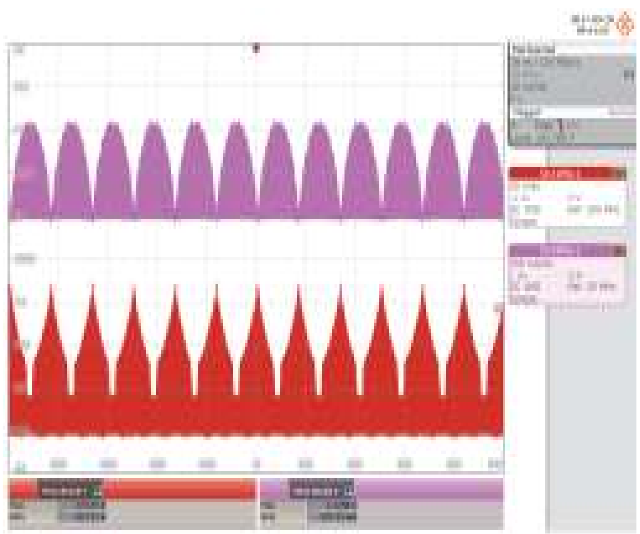

**Figure 69 –** 120 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

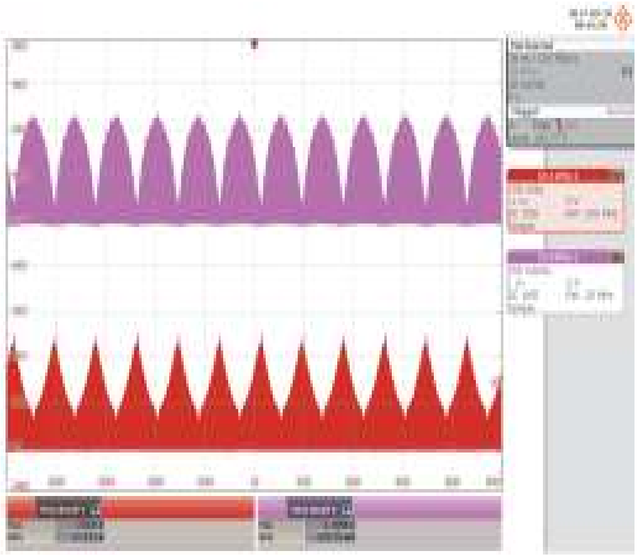

**Figure 70 –** 230 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

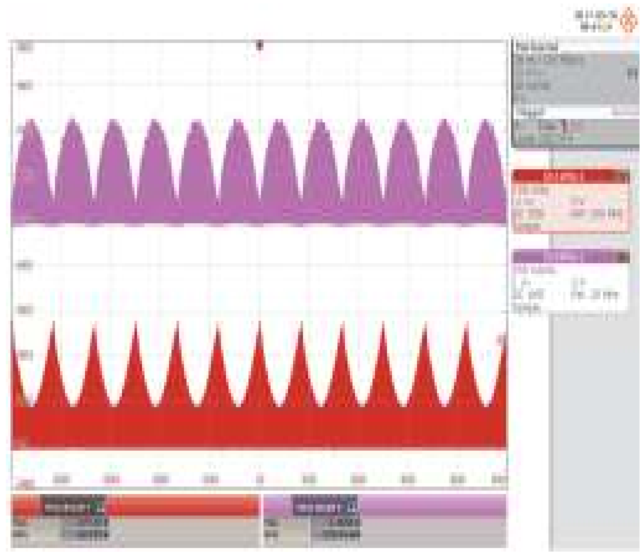

**Figure 71 –** 265 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

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

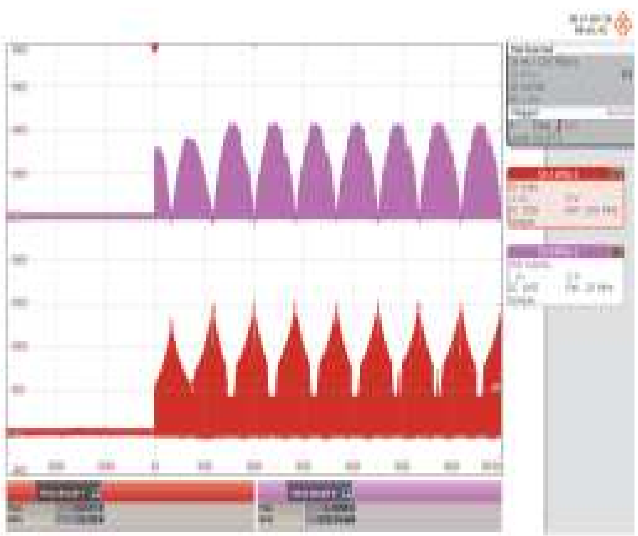

**Figure 72 –** 90 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

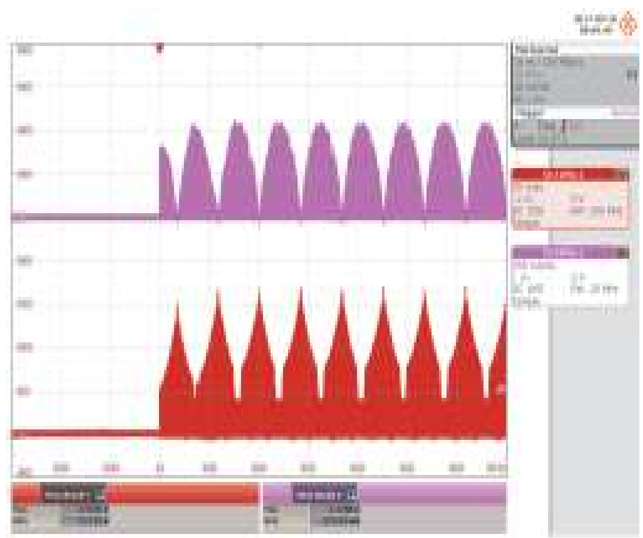

**Figure 73 –** 120 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.


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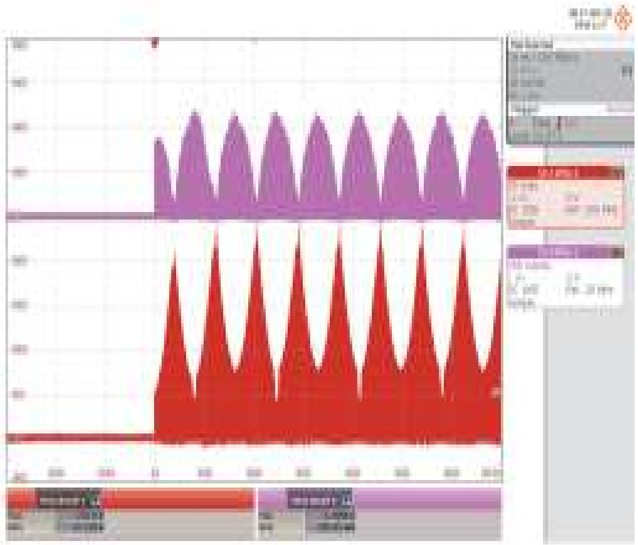

**Figure 74 –** 230 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

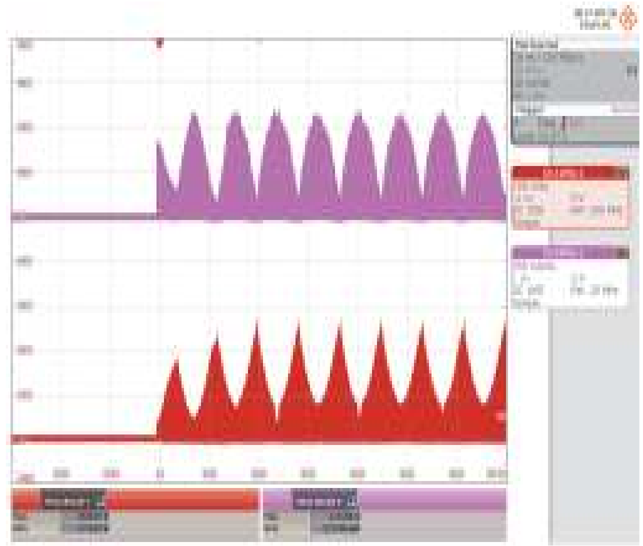

**Figure 75 –** 265 VAC 50 Hz, 580 mA LED Load.
Upper: 500 mA / div.
Lower: 50 V / div.
Horizontal: 10 ms / div.

### *13.10 Output Voltage Ripple*

#### 13.10.1 Ripple Measurement Set-up

**Figure 76 –** Probe Set-up for Output Voltage Ripple Test.

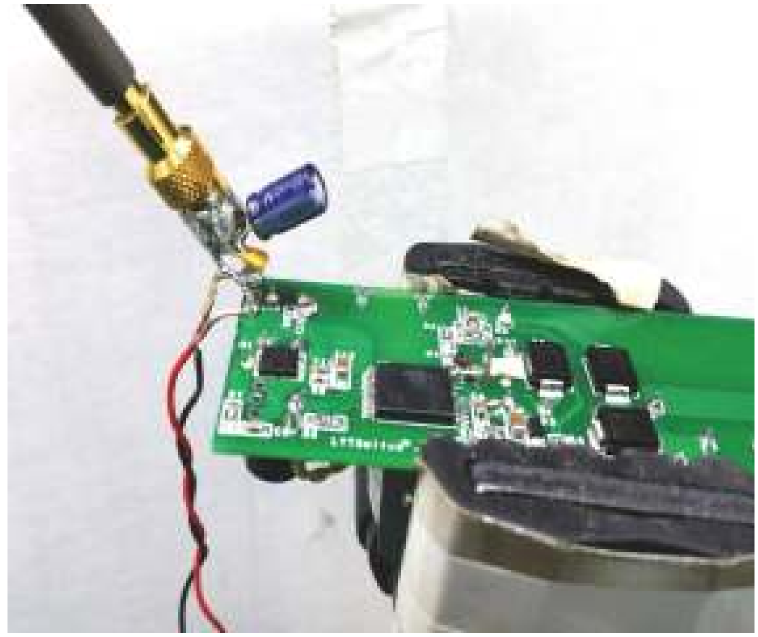

**Figure 77 –** Unit Set-up for Output Voltage Ripple Test.

Ripple voltage was taken using a X1 probe with 1 μF electrolytic capacitor and 0.1 μF ceramic capacitor connected in parallel across the probe.


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### 13.10.2 Ripple Measurements

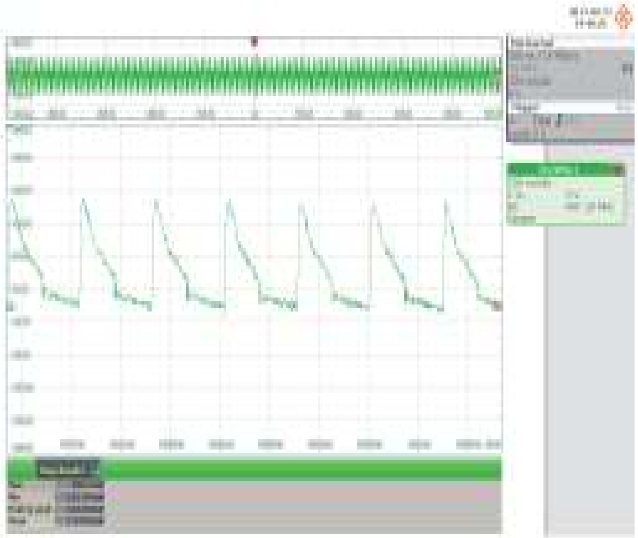

**Figure 78 –** 90 VAC 50 Hz, 580 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
$V_{OUT}$, 100 mV / div., 100 ms / div.
Ripple Voltage: 513.83 $mV_{PK-PK}$.

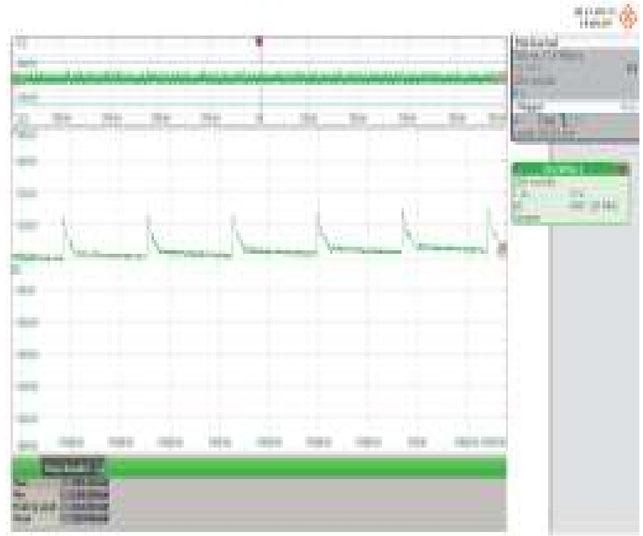

**Figure 79 –** 90 VAC 50 Hz, 58 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
$V_{OUT}$, 200 mV / div., 100 ms / div.
Ripple Voltage: 411.07 $mV_{PK-PK}$.

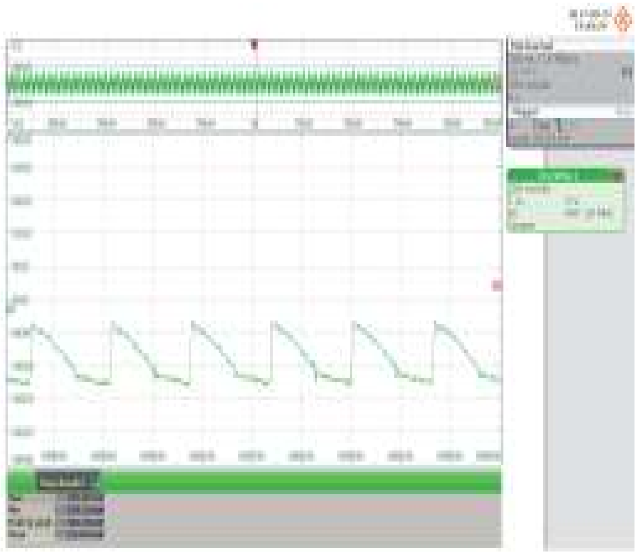

**Figure 80 –** 120 VAC 50 Hz, 580 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
$V_{OUT}$, 200 mV / div., 100 ms / div.
Ripple Voltage: 561.26 $mV_{PK-PK}$.

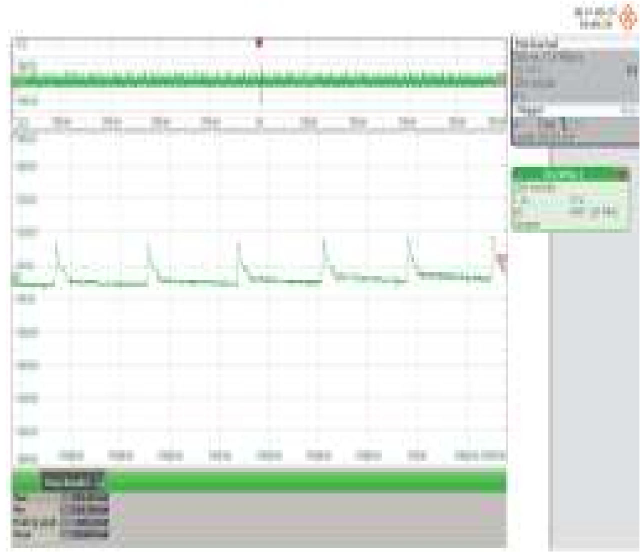

**Figure 81 –** 120 VAC 50 Hz, 580 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
$V_{OUT}$, 200 mV / div., 100 ms / div.
Ripple Voltage: 466.4 $mV_{PK-PK}$.

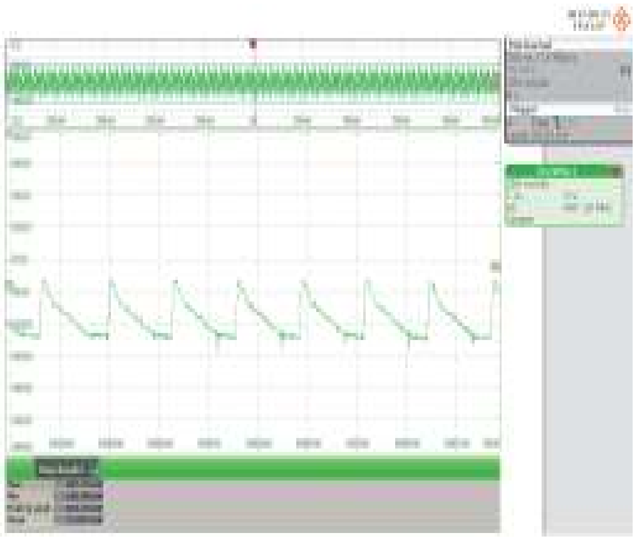

**Figure 82 –** 230 VAC 50 Hz, 580 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
$V_{OUT}$, 200 mV / div., 100 ms / div.
Ripple Voltage: 814.23 $mV_{PK-PK}$.

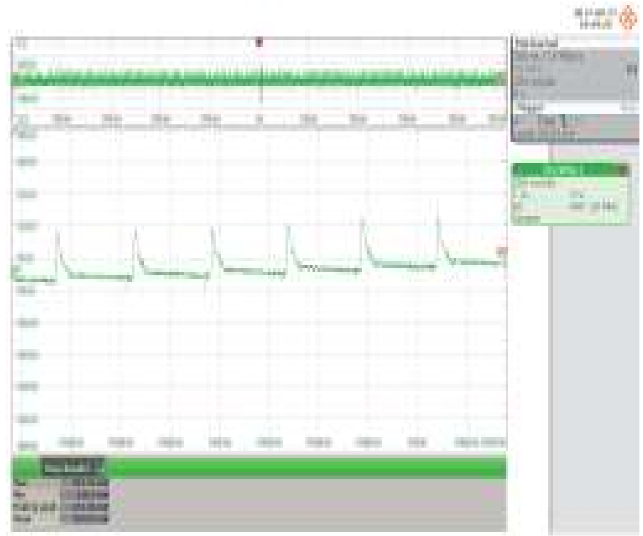

**Figure 83 –** 230 VAC 50 Hz, 580 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
$V_{OUT}$, 200 mV / div., 100 ms / div.
Ripple Voltage: 466.4 $mV_{PK-PK}$.

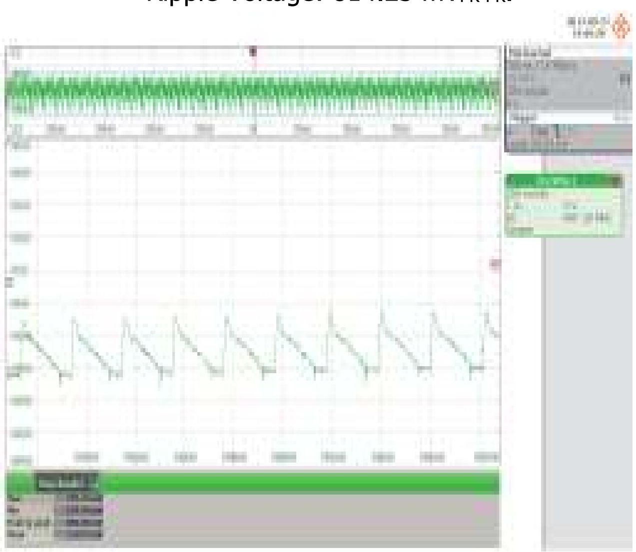

**Figure 84 –** 265 VAC 50 Hz, 580 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
$V_{OUT}$, 200 mV / div., 100 ms / div.
Ripple Voltage: 909.9 $mV_{PK-PK}$.

**Figure 85 –** 265 VAC 50 Hz, 580 mA LED Load.
AC Coupling, 20 MHz Bandwidth.
$V_{OUT}$, 200 mV / div., 100 ms / div.
Ripple Voltage: 490.12 $mV_{PK-PK}$.


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## 13.11 Output Current Ripple

### 13.11.1 Equipment Used

1. Rohde & Schwarz RTO1004 Oscilloscope
2. Rohde & Schwarz RT-ZC20B Current Probe
3. 80 V LED Load

## 13.12 Ripple Ratio and Flicker % Measurement

| $V_{IN}$ | $I_{O(MAX)}$ (mA) | $I_{O(MIN)}$ (mA) | $I_{MEAN}$ (mA) | Ripple Ratio ($I_{RP-P}/I_{MEAN}$) | % Flicker 100 x ($I_{RP-P}$ / $I_{O(MAX)}+I_{O(MIN)}$) |
|---|---|---|---|---|---|
| **90 VAC** | 600.79 | 553.36 | 573.95 | 0.08 | 4.11 |
| **120 VAC** | 616.6 | 529.64 | 573.18 | 0.08 | 7.59 |
| **230 VAC** | 600.79 | 553.36 | 47.43 | 0.08 | 4.11 |
| **265 VAC** | 600.79 | 545.45 | 574.68 | 0.08 | 4.83 |

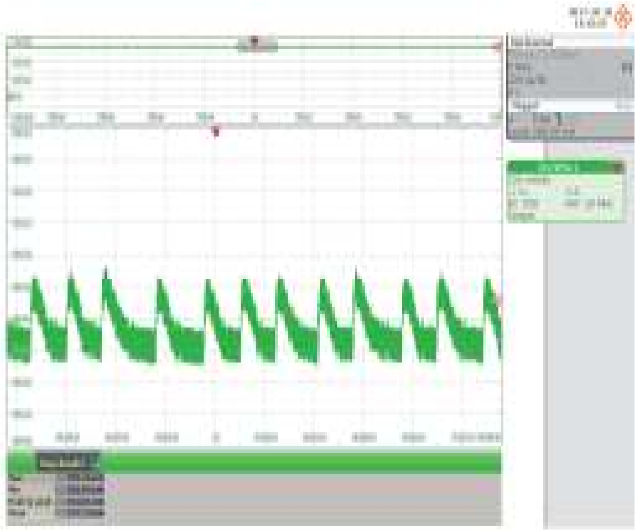

**Figure 86 –** 90 VAC 50 Hz, 580 mA LED Load.
20 MHz Bandwidth.
$I_{OUT}$, 20 mA / div., 20 ms / div.
Ripple Current: 31.621 $mA_{PK-PK}$.

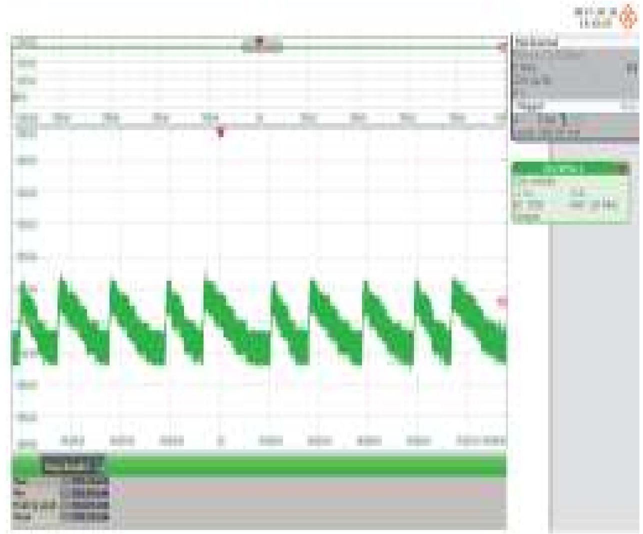

**Figure 87 –** 120 VAC 50 Hz, 580 mA LED Load.
20 MHz Bandwidth.
$I_{OUT}$, 20 mA / div., 20 ms / div.
Ripple Current: 31.621 $mA_{PK-PK}$.

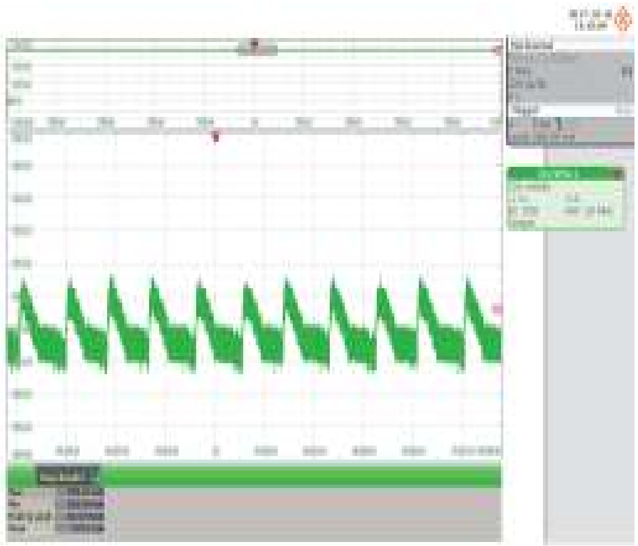

**Figure 88 –** 230 VAC 50 Hz, 580 mA LED Load.
20 MHz Bandwidth.
$I_{OUT}$, 20 mA / div., 20 ms / div.
Ripple Current: 35.573 $mA_{PK-PK}$.

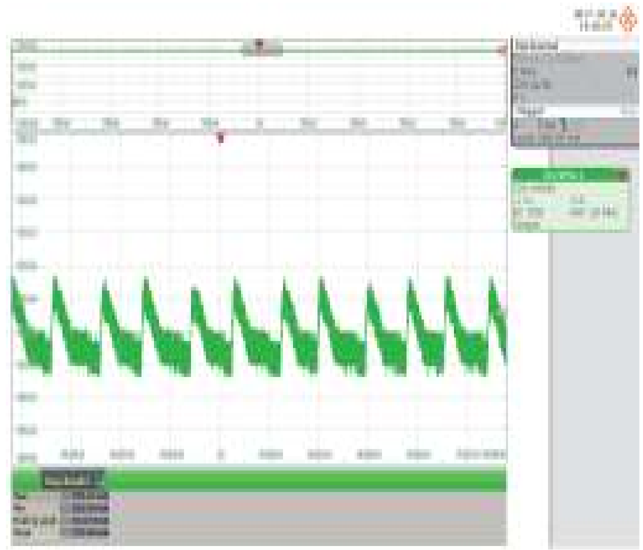

**Figure 89 –** 265 VAC 50 Hz, 580 mA LED Load.
20 MHz Bandwidth.
$I_{OUT}$, 20 mA / div., 20 ms / div.
Ripple Voltage: 35.573 $mA_{PK-PK}$.



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# 14 Conducted EMI

## *14.1 Test Set-up*

### 14.1.1 Equipment and Load Used

1. Rohde and Schwarz ENV216 two line V-network
2. Rohde and Schwarz ESRP EMI test receiver
3. Hioki 3332 power hitester
4. Chroma Measurement Test Fixture model A662003
5. 80V LED Load
6. HOSSONI TDGC2 VARIAC set at 230 VAC 60 Hz

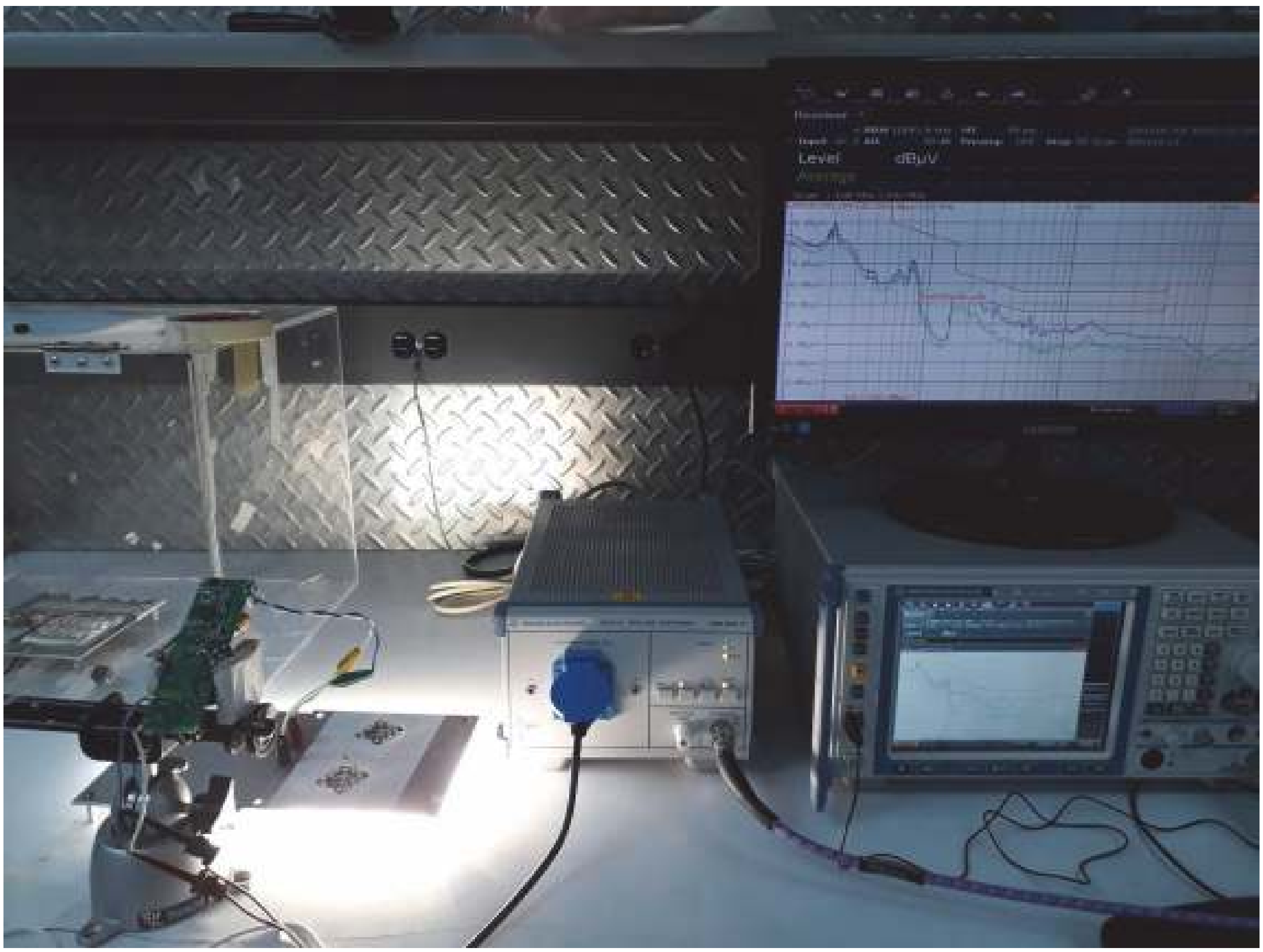

**Figure 90 –** Conducted EMI Test Set-up.

### *14.2 EMI Test Result*


**Figure 91 –** Conducted EMI QP Scan at Full Load, 115 VAC 60 Hz and EN55015 B Limits.



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| Trace/Detector | Frequency | Level dBµV | DeltaLimit |
|---|---|---|---|
| 1 Quasi Peak | 25.7500 kHz | 93.18 L1 | -16.82 dB |
| 2 Average | 24.8000 kHz | 90.06 L1 | |
| 1 Quasi Peak | 76.1500 kHz | 70.79 N | -15.38 dB |
| 2 Average | 76.1500 kHz | 68.50 N | |
| 2 Average | 78.6500 kHz | 66.35 N | |
| 1 Quasi Peak | 150.0000 kHz | 58.94 N | -7.06 dB |
| 2 Average | 156.7500 kHz | 44.69 L1 | -10.94 dB |
| 1 Quasi Peak | 28.2148 MHz | 40.66 N | -19.34 dB |
| 1 Quasi Peak | 1.5113 MHz | 38.01 N | -17.99 dB |
| 2 Average | 28.2170 MHz | 34.83 N | -15.17 dB |
| 2 Average | 1.5045 MHz | 30.76 L1 | -15.24 dB |

Insert Frequency | Delete Frequency | Sort by Frequency

Symbols OFF ON | Peak List Export | Decim Sep . ,

**Figure 92 –** Conducted EMI Data at 115 VAC 60 Hz, Full Load.


**Figure 93 –** Conducted EMI QP Scan at Full Load, 230 VAC 60 Hz and EN55015 B Limits.



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| Trace/Detector | Frequency | Level dBµV | DeltaLimit |
|---|---|---|---|
| 2 Average | 152.2500 kHz | 49.91 L1 | -5.97 dB |
| 1 Quasi Peak | 165.7500 kHz | 57.62 L1 | -7.55 dB |
| 1 Quasi Peak | 70.8500 kHz | 76.01 L1 | -10.82 dB |
| 1 Quasi Peak | 552.7500 kHz | 44.88 L1 | -11.12 dB |
| 2 Average | 1.5450 MHz | 33.40 N | -12.60 dB |
| 1 Quasi Peak | 1.5473 MHz | 42.35 N | -13.65 dB |
| 2 Average | 28.1968 MHz | 35.40 N | -14.60 dB |
| 1 Quasi Peak | 622.5000 kHz | 40.39 N | -15.61 dB |
| 1 Quasi Peak | 17.9500 kHz | 91.20 N | -18.80 dB |
| 1 Quasi Peak | 28.2868 MHz | 41.07 N | -18.93 dB |
| 1 Quasi Peak | 19.1000 kHz | 90.35 N | -19.65 dB |
| 1 Quasi Peak | 18.5000 kHz | 88.41 N | -21.59 dB |
| 1 Quasi Peak | 9.8000 kHz | 84.21 L1 | -25.79 dB |
| 1 Quasi Peak | 35.8000 kHz | 73.24 N | -36.76 dB |

Insert Frequency Delete Frequency Sort by Frequency

Symbols OFF ON Peak List Export Decim Sep . ,

**Figure 94 –** Conducted EMI Data at 230 VAC 60 Hz, Full Load.

# 15 Line Surge

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

## *15.1 Differential Surge Test Results*

| Surge Level (V) | Input Voltage (VAC) | Injection Location | Injection Phase (°) | Test Result (Pass/Fail) |
|---|---|---|---|---|
| +1000 | 115 | L to N | 0 | Pass |
| -1000 | 115 | L to N | 0 | Pass |
| +1000 | 115 | L to N | 90 | Pass |
| -1000 | 115 | L to N | 90 | Pass |
| +1000 | 115 | L to N | 270 | Pass |
| -1000 | 115 | L to N | 270 | Pass |
| +1000 | 230 | L to N | 0 | Pass |
| -1000 | 230 | L to N | 0 | Pass |
| +1000 | 230 | L to N | 90 | Pass |
| -1000 | 230 | L to N | 90 | Pass |
| +1000 | 230 | L to N | 270 | Pass |
| -1000 | 230 | L to N | 270 | Pass |

## *15.2 Ring Wave Surge Test Results*

| Surge Level (V) | Input Voltage (VAC) | Injection Location | Injection Phase (°) | Test Result (Pass/Fail) |
|---|---|---|---|---|
| +2500 | 115 | L to N | 0 | Pass |
| -2500 | 115 | L to N | 0 | Pass |
| +2500 | 115 | L to N | 90 | Pass |
| -2500 | 115 | L to N | 90 | Pass |
| +2500 | 115 | L to N | 270 | Pass |
| -2500 | 115 | L to N | 270 | Pass |
| +2500 | 230 | L to N | 0 | Pass |
| -2500 | 230 | L to N | 0 | Pass |
| +2500 | 230 | L to N | 90 | Pass |
| -2500 | 230 | L to N | 90 | Pass |
| +2500 | 230 | L to N | 270 | Pass |
| -2500 | 230 | L to N | 270 | Pass |


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## 15.3 1 kV Differential Surge Test

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

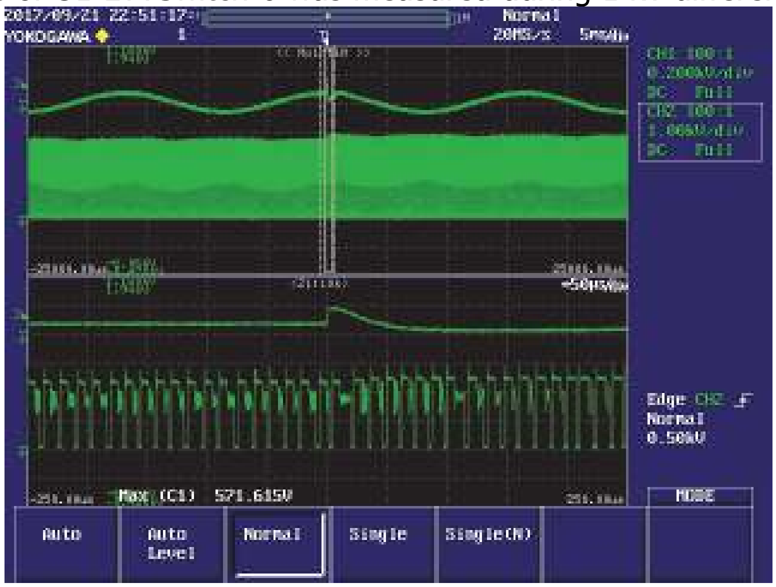


**Figure 95 –** (+)1 kV Differential Surge.
90º Phase Angle, Input: 230 VAC.
$V_{DRAIN}$, 200 V / div., 20 ms / div.
Peak $V_{DRAIN}$: 571.615 V.

## 15.4 2.5 kV Ring Wave Surge Test

The Drain voltage of U1-LYTSwitch-6 was measured during 2 kV ring wave surge test.

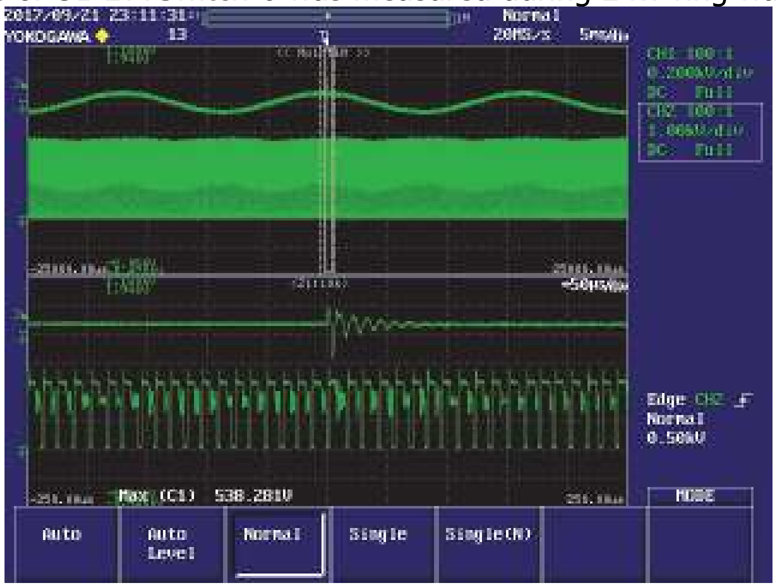


**Figure 96 –** (+) 2.5 kV Ring Wave Surge.
90º Phase Angle, Input: 230 VAC.
$V_{DRAIN}$, 200 V / div., 20 ms / div.
Peak $V_{DRAIN}$: 558.333 V.

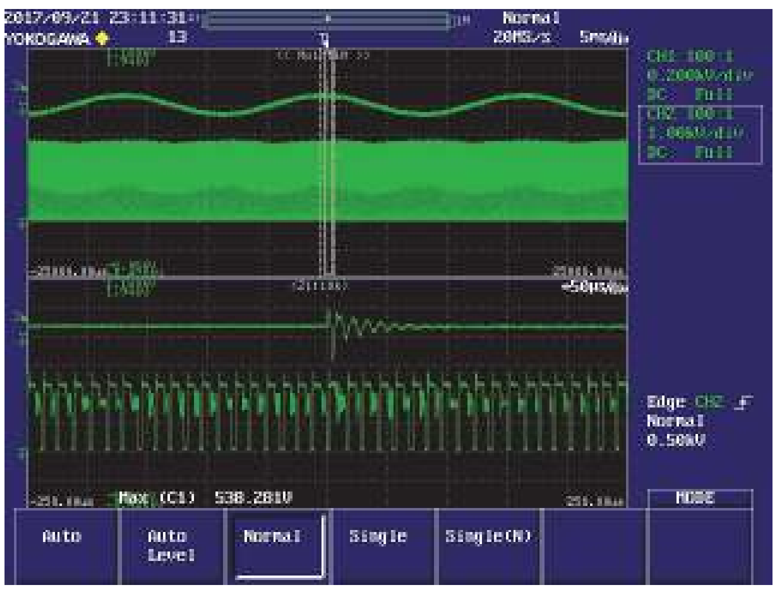


**Figure 97 –** (+) 2.5 kV Ring Wave Surge.
90º Phase Angle, Input: 230 VAC.
$V_{DRAIN}$, 200 V / div., 20 ms /div.
Peak $V_{DRAIN}$: 558.333 V.


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# 16 Revision History

| Date | Author | Revision | Description and Changes | Reviewed |
|---|---|---|---|---|
| 23-Jan-18 | IB and DL | 1.0 | Initial Release. | Apps & Mktg |
| 16-Feb-18 | IB and DL | 1.1 | Minor Text Edits. | |
| | | | | |
| | | | | |

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