

|                        |                                                                                                        |
|------------------------|--------------------------------------------------------------------------------------------------------|
| <b>Title</b>           | <b><i>Reference Design Report for a 8.4 W Open Frame Power Supply Using LinkSwitch™-3 LNK6407D</i></b> |
| <b>Specification</b>   | 90 VAC – 265 VAC Input; 12 V, 0.7 A Output                                                             |
| <b>Application</b>     | Open Frame Power Supply for Appliances                                                                 |
| <b>Author</b>          | Applications Engineering Department                                                                    |
| <b>Document Number</b> | RDR-734                                                                                                |
| <b>Date</b>            | January 31, 2019                                                                                       |
| <b>Revision</b>        | 1.2                                                                                                    |

### **Summary and Features**

- Primary-side control eliminates secondary-side control and optocoupler
- >83% efficiency at full load
- Easily meet ErP regulation with >70% efficiency at 500 mW output
- Provides  $\pm 5\%$  constant voltage (CV) and  $\pm 10\%$  constant current
- Max power output guarantee <15 W to easily meet UL simplified qualification requirement
- Accurate over-temperature protection with hysteretic recovery
- Auto-restart output short-circuit and open loop protection

### **PATENT INFORMATION**

The products and applications illustrated herein (including transformer construction and circuits external to the products) may be covered by one or more U.S. and foreign patents, or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations' patents may be found at [www.power.com](http://www.power.com). Power Integrations grants its customers a license under certain patent rights as set forth at <https://www.power.com/company/intellectual-property-licensing/>.

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## Table of Contents

|        |                                                                |    |
|--------|----------------------------------------------------------------|----|
| 1      | Introduction .....                                             | 5  |
| 2      | Power Supply Specification .....                               | 6  |
| 3      | Schematic Diagram .....                                        | 7  |
| 4      | Circuit Description .....                                      | 8  |
| 4.1    | Input EMI Filtering.....                                       | 8  |
| 4.2    | LNK6407D Primary.....                                          | 8  |
| 4.3    | Output Rectification and Filtering.....                        | 8  |
| 4.4    | Output Regulation .....                                        | 8  |
| 4.5    | Design Key Points.....                                         | 9  |
| 5      | PCB Layout .....                                               | 10 |
| 6      | Bill of Materials .....                                        | 11 |
| 6.1    | Main BOM .....                                                 | 11 |
| 6.2    | Miscellaneous Parts.....                                       | 11 |
| 7      | Transformer Specification .....                                | 12 |
| 7.1    | Electrical Diagram.....                                        | 12 |
| 7.2    | Electrical Specification.....                                  | 12 |
| 7.3    | Material List .....                                            | 12 |
| 7.4    | Transformer Build Diagram .....                                | 13 |
| 7.5    | Transformer Instructions.....                                  | 13 |
| 7.6    | Winding Illustrations .....                                    | 14 |
| 8      | Transformer Design Spreadsheet .....                           | 19 |
| 9      | Performance Data .....                                         | 22 |
| 9.1    | Average Efficiency .....                                       | 22 |
| 9.1.1  | Efficiency Requirements .....                                  | 22 |
| 9.1.2  | Average Efficiency Measured (Across PCB Connector) .....       | 22 |
| 9.1.3  | Average Efficiency Measured (at the End of 100 mΩ Cable).....  | 22 |
| 9.2    | Efficiency vs. Line .....                                      | 23 |
| 9.2.1  | Measured at 0.7 A Full Load. ....                              | 23 |
| 9.3    | Efficiency vs. Load .....                                      | 24 |
| 9.3.1  | Measured across PCB connector.....                             | 24 |
| 9.3.2  | Measured at the End 100 mΩ Cable .....                         | 25 |
| 10     | CV/CC Regulation.....                                          | 26 |
| 10.1   | CV/CC Regulation at 25 °C Measured Across PCB Connector .....  | 26 |
| 10.2   | CV/CC Regulation at 25 °C Measured on End of 100 mΩ Cable..... | 27 |
| 10.3   | CV/CC Regulation at Hot and Cold Temperature .....             | 28 |
| 10.3.1 | 90 VAC.....                                                    | 29 |
| 10.3.2 | 115 VAC.....                                                   | 30 |
| 10.3.3 | 230 VAC.....                                                   | 31 |
| 10.3.4 | 265 VAC.....                                                   | 32 |
| 11     | No-Load Input Power .....                                      | 33 |
| 12     | Line Regulation .....                                          | 34 |
| 13     | Load Regulation .....                                          | 35 |



|        |                                                               |    |
|--------|---------------------------------------------------------------|----|
| 13.1.1 | Measured across PCB connector.....                            | 35 |
| 13.1.2 | Measured at the End of 100 mΩ Cable .....                     | 36 |
| 14     | Thermal Performance.....                                      | 37 |
| 14.1   | Thermal Scan at Room Temperature.....                         | 37 |
| 14.1.1 | 90 VAC.....                                                   | 38 |
| 14.1.2 | 115 VAC.....                                                  | 39 |
| 14.1.3 | 230 VAC.....                                                  | 40 |
| 14.1.4 | 265 VAC.....                                                  | 41 |
| 15     | Thermal Performance at 70 °C.....                             | 42 |
| 15.1   | 90 VAC.....                                                   | 43 |
| 15.2   | 265 VAC.....                                                  | 44 |
| 16     | Over Temperature Protection.....                              | 45 |
| 16.1   | 90 VAC.....                                                   | 45 |
| 16.2   | 265 VAC.....                                                  | 47 |
| 17     | Test Waveforms.....                                           | 48 |
| 17.1   | Load Transient Response .....                                 | 48 |
| 17.1.1 | 0% - 100% Load Condition .....                                | 48 |
| 17.1.2 | 50% - 100% Load Condition.....                                | 49 |
| 17.2   | Output Voltage at Start-up .....                              | 50 |
| 17.2.1 | Measured at the End of 1.2m #22 Cable .....                   | 50 |
| 17.2.2 | CC mode .....                                                 | 50 |
| 17.2.3 | CR mode .....                                                 | 52 |
| 17.3   | Switching Waveforms.....                                      | 54 |
| 17.3.1 | Drain-to-Source Voltage and Current at Normal Operation.....  | 54 |
| 17.3.2 | Drain-to-Source Voltage and Current at Startup Operation..... | 57 |
| 17.3.3 | Output Diode Voltage at Normal Operation .....                | 59 |
| 17.3.4 | Output Diode Voltage at Startup Operation.....                | 61 |
| 17.4   | Brown-in / Brown-out Test .....                               | 63 |
| 17.5   | Output Short Circuit Auto-restart Test.....                   | 64 |
| 17.6   | Output Ripple Measurements.....                               | 65 |
| 17.6.1 | Ripple Measurement Technique .....                            | 65 |
| 17.6.2 | Measurement Results .....                                     | 66 |
| 17.6.3 | Ripple at Hot and Cold Temperatures .....                     | 71 |
| 18     | Conducted EMI .....                                           | 75 |
| 18.1   | Test Set-up .....                                             | 75 |
|        | Equipment and Load Used .....                                 | 75 |
| 18.2   | 8.4 W Resistive Load, Floating Output.....                    | 76 |
| 18.2.1 | 115 VAC, Line .....                                           | 76 |
| 18.2.2 | 115 VAC, Neutral .....                                        | 77 |
| 18.2.3 | 230 VAC, Line.....                                            | 78 |
| 18.2.4 | 230 VAC, Neutral .....                                        | 79 |
| 18.3   | 8.4 W Resistive Load, Artificial Hand .....                   | 80 |
| 18.3.1 | 115 VAC, Line.....                                            | 80 |

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|        |                        |    |
|--------|------------------------|----|
| 18.3.2 | 115 VAC, Neutral ..... | 81 |
| 18.3.3 | 230 VAC, Line .....    | 82 |
| 18.3.4 | 230 VAC, Neutral ..... | 83 |
| 19     | ESD Test .....         | 84 |
| 19.1   | ESD Test.....          | 84 |
| 20     | Revision History ..... | 85 |

**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 report describing a 12 V, 0.7 A adapter utilizing a device from the LinkSwitch-3 family of ICs. This design is intended to show the high power density and efficiency that is possible due to the high level of integration while still providing exceptional performance.

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

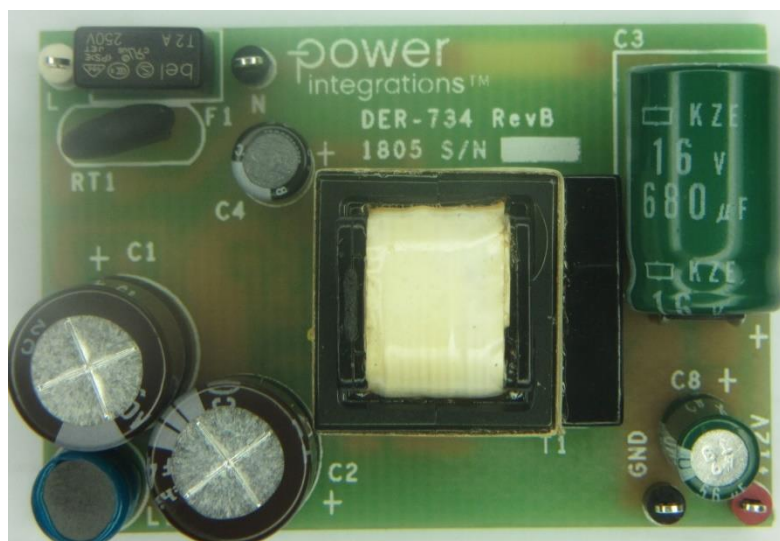


**Figure 1** – Populated Circuit Board Photograph, Top.

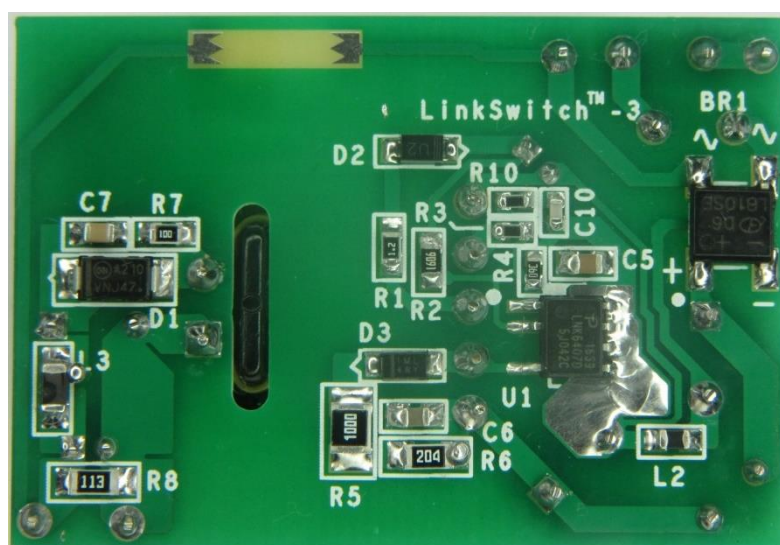


**Figure 2** – Populated Circuit Board Photograph, Bottom.

## 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                                         |
|------------------------------|-------------------|-------|-------|-----|-------|-------------------------------------------------|
| <b>Input</b>                 |                   |       |       |     |       |                                                 |
| Voltage                      | $V_{IN}$          | 90    |       | 265 | VAC   | 2 Wire – no P.E.                                |
| Frequency                    | $f_{LINE}$        | 47    | 50/60 | 63  | Hz    |                                                 |
| No-load Input Power          |                   |       |       | 75  | mW    | 265 VAC Input                                   |
| <b>Output</b>                |                   |       |       |     |       |                                                 |
| Output Voltage               | $V_{OUT}$         |       | 12.00 |     | V     | ±5% PCB connector side                          |
| Output Ripple Voltage        | $V_{RIPPLE}$      |       |       | 200 | mVpp  | Measured at the PCB connector                   |
| Output Current               | $I_{OUT}$         | 0.7   |       |     | A     |                                                 |
| Continuous Output Power      | $P_{OUT}$         |       | 8.4   |     | W     |                                                 |
| <b>Efficiency</b>            |                   |       |       |     |       |                                                 |
| Average                      |                   |       |       |     |       |                                                 |
| 25%, 50%, 75%, and 100%      | $\eta_{AVE[BRD]}$ | 80.93 |       |     | %     | DoE Level VI, Basic Voltage                     |
| <b>Environmental</b>         |                   |       |       |     |       |                                                 |
| Conducted EMI                |                   |       |       |     |       | Resistive Load, 6 dB Margin.                    |
| Safety                       |                   |       |       |     |       | Designed to Meet.                               |
| Differential Line Surge      |                   | 1     |       |     | kV    |                                                 |
| Common Mode Surge (L1/L2-PE) |                   | 2     |       |     | kV    | Ring Wave, Common Mode: 12 $\Omega$ .           |
| ESD                          |                   | ±16   |       |     | kV    | Air Discharge                                   |
|                              |                   | ±8    |       |     | kV    | Contact Discharge                               |
| Ambient Temperature          | $T_{AMB}$         | 0     |       | 40  | °C    | Free Convection, Sea Level in Sealed Enclosure. |

### 3 Schematic Diagram

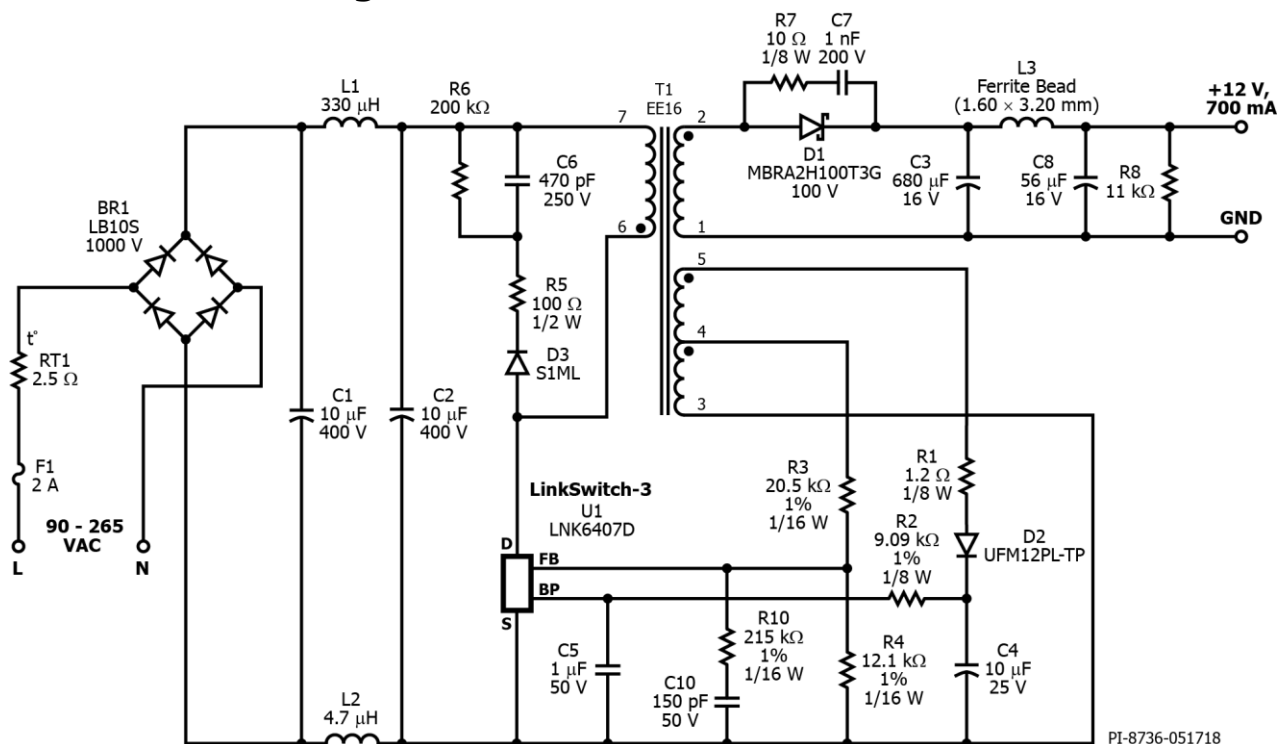


Figure 3 – Schematic Diagram.

## 4 Circuit Description

### 4.1 *Input EMI Filtering*

Fuse F1 provides protection against catastrophic failure of components on the primary-side.

Thermistor RT1 limits the inrush current when the power supply is connected to the input AC supply due to the low impedance of the input capacitor C1 and C2.

Bridge rectifier BR1 rectifies the AC line voltage and provides a full wave rectified DC across the input capacitors, C1 and C2.

Capacitors C1 and C2 provide filtering of the rectified AC Input and together with L1 and L2 form a  $\pi$  (pi) filter to attenuate differential mode EMI.

### 4.2 *LNK6407D Primary*

The LNK6407D device (U1) incorporates the power switching device, oscillator, CV/CC control engine, and start-up and protection function on a single IC. The integrated 725 V power MOSFET allows sufficient voltage margins across universal AC input applications. The device is powered from the BYPASS pin with the decoupling capacitor C5 via the bias circuit R1, R2, D2, C4, with bias winding of transformer T1. The resistor R1 helps dampen the ringing on the bias winding voltage. The resistor R2 limits the BYPASS pin current.

The rectified and filtered input voltage is applied to one end of the transformer T1 primary winding. The other side of the T1 primary winding is driven by the internal MOSFET of U1. A low cost RCD clamp formed by D3, R5, R6 and C6 limits the peak drain voltage due to the effects of transformer leakage reactance and output trace inductance.

### 4.3 *Output Rectification and Filtering*

Transformer T1 secondary voltage is rectified by a Schottky barrier-type diode D1 and filtered by the low ESR output capacitor C3. A post-filter using L3 and C8 were added to improve the voltage peak-to-peak ripple at the output connector.

### 4.4 *Output Regulation*

The LNK6407D regulates the output using ON/OFF control for CV regulation and frequency control for CC regulation. The output voltage is sensed by a feedback winding on transformer T1. The feedback resistors R3 and R4 were selected using standard 1% tolerance resistor values to center both the nominal output voltage and constant current regulation thresholds. Resistor R10 and capacitor C10 across the feedback pin improve transient response and output voltage ripple measurements. Resistor R8 provides a

minimum load to maintain the output regulation when no-load is connected across the output.

#### 4.5 ***Design Key Points***

The design targets to meet the standard basic voltage DoE Level VI and COC5 Tier 2 regulatory requirements. Efficiency was optimized with the transformer design, active devices, primary clamp and filter components, and bias voltage. For the transformer design, maximizing the wire gauge of the primary and secondary windings to fit the bobbin width helps decrease copper loss with the increased conducted effective area.

To minimize power losses, the primary clamp or RCD snubber circuit were selected such that the peak MOSFET drain voltage is maintained to <680 V while still meeting efficiency and thermal performance of these components. Also, since LinkSwitch-3 uses primary side regulation (PSR), the resulting peak MOSFET drain voltage will affect the feedback voltage sensing and should settle at 1% within 1.2  $\mu$ s from the turn-off of the primary MOSFET for best output regulation. The use of slow recovery type (typical  $t_{rr} > 1 \mu$ s) reduces the feedback voltage ringing and further improve regulation.

An external bias supply through the bias winding of the transformer also increases efficiency, especially at light load, and lowers the no-load input power consumption by disabling the internal high-voltage supply for LNK6407D.

Proper selection of the secondary side components (output diode, output filter capacitor, and preload) likewise helps meet efficiency specifications. A low forward voltage and low leakage current Schottky-barrier type diode was used with a voltage rating enough to have around 20% margin from actual diode voltage stress to the peak inverse voltage (PIV) rating of the diode. Take into consideration the diode's self-heating to meet thermal and efficiency margins. For the output filter capacitor, a very-low ESR type with a high ripple current rating can be used to meet output voltage ripple specification and improves efficiency. And since the preload is a fixed loss to the power supply, it should be sized such that the output voltage at no-load is within the target regulation.

The design also aims to have a good margin for conducted EMI performance and simplify the input filter stage by eliminating the need for a common mode choke or Y-class capacitor. The transformer uses E-Shield technique to minimize the noise coupling by having a cancellation shield as the first layer of the transformer filling the bobbin width followed by the primary winding. To decrease the loss incurred by parasitic capacitance between the shield and the primary winding, the 4 layers of tape were added. Succeeding windings are for the bias, feedback and the secondary. The secondary was wound in counter-clockwise direction with respect to the other windings with the physical start connected to the GND and terminating the winding to the anode of the output diode. To further decrease noise coupling, the core was connected to B- (negative side of the input bulk capacitor).

## 5 PCB Layout

PCB copper thickness is 1 oz (2.8 mils / 70  $\mu\text{m}$ ) unless otherwise stated.

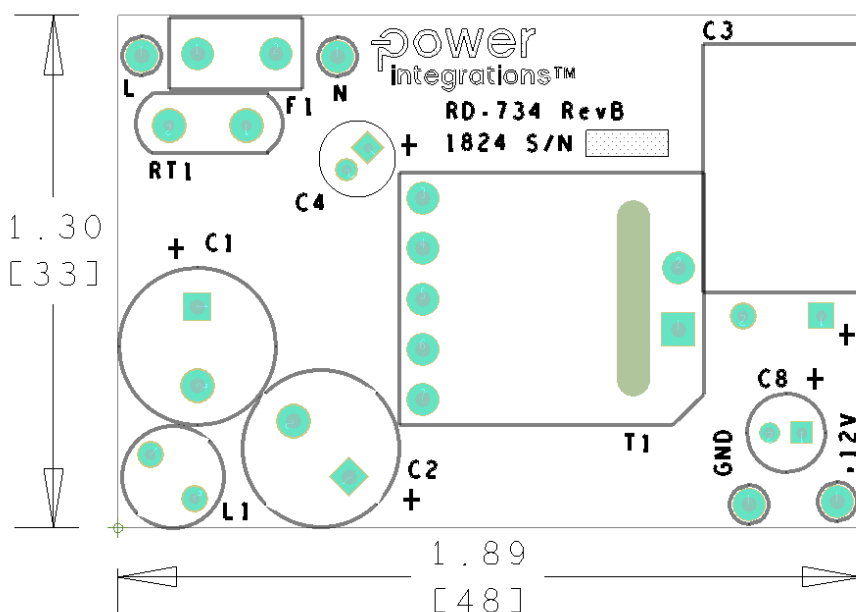


**Figure 4** – Printed Circuit Layout, Top.

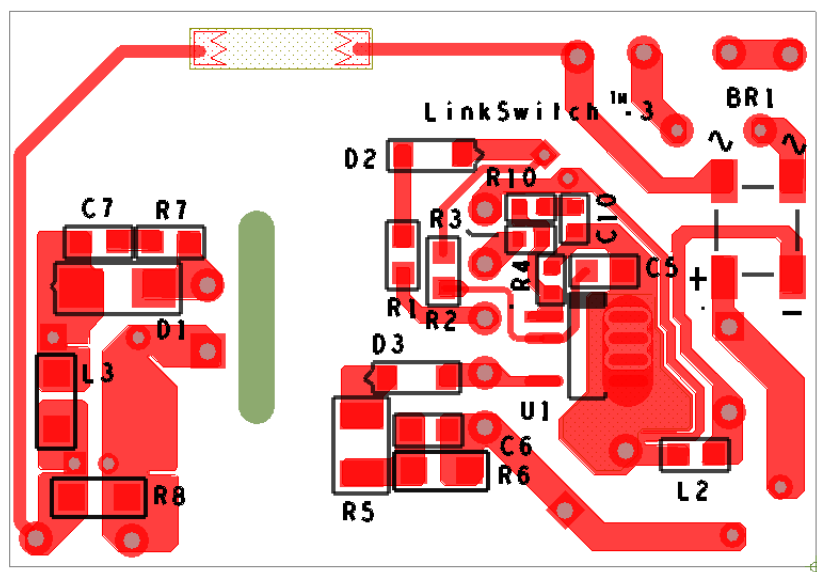


**Figure 5** – Printed Circuit Layout, Bottom.

## 6 Bill of Materials

### 6.1 Main BOM

| Item | Qty | Ref Des | Description                                                                                          | Mfg Part Number    | Manufacturer           |
|------|-----|---------|------------------------------------------------------------------------------------------------------|--------------------|------------------------|
| 1    | 1   | BR1     | 1000 V, 0.8 A, Bridge Rectifier, SMD, SOPA-4                                                         | LB10S              | Good Ark               |
| 2    | 2   | C1, C2  | 10 $\mu$ F, $\pm$ 20%, 400 V, Electrolytic, (10 x 14.5)                                              | UVC2G100MPD        | Nichicon               |
| 3    | 1   | C3      | 680 $\mu$ F, 16 V, Electrolytic, Very Low ESR, 38 m $\Omega$ , (10 x 16)                             | EKZE160ELL681MJ16S | Nippon Chemi-Con       |
| 4    | 1   | C4      | 10 $\mu$ F, 20%, 25 V, Electrolytic, -55°C ~ 105°C, 1000 Hrs @ 105°C, Gen Purpose, (5 x 6)           | UMT1E100MDD1TP     | Nichicon               |
| 5    | 1   | C5      | 1 $\mu$ F, 16 V, Ceramic, X7R, 0805                                                                  | GRM21BR71C105KA01L | Murata                 |
| 6    | 1   | C6      | 470 pF, 250 V, Ceramic, GCM, 0805                                                                    | GCM21A7U2E471JX01D | Murata                 |
| 7    | 1   | C7      | 1 nF, 200 V, Ceramic, X7R, 0805                                                                      | 08052C102KAT2A     | AVX                    |
| 8    | 1   | C8      | 56 $\mu$ F, 16 V, Electrolytic, Very Low ESR, 22 m $\Omega$ , (10 x 25)                              | EKZE160ELL560ME11D | Nippon Chemi-Con       |
| 9    | 1   | C10     | CAP, CER, 150pF, $\pm$ 5%, 50V, -55°C ~ 125°C, C0G/NPO, 0603 (1608 Metric)                           | GRM1885C1H151JA01D | Murata                 |
| 10   | 1   | D1      | Diode, Schottky, 100 V, 2 A, Fast Recovery =< 500 ns, > 200 mA (Io), Tj -65°C ~ 175°C, DO-214AC, SMA | MBRA2H100T3G       | ON Semi                |
| 11   | 1   | D2      | 100V, 1 A, Ultrafast Recovery, SOD-123FL                                                             | UFM12PL-TP         | Micro Commercial       |
| 12   | 1   | D3      | 1 kV, 1 A, Standard Recovery, SMA                                                                    | S1ML               | Taiwan Semi            |
| 13   | 1   | F1      | 2 A, 250 V, Slow, Long Time Lag, RST                                                                 | RST 2              | Belfuse                |
| 14   | 1   | L1      | 330 $\mu$ H, 0.34 A, 7 x 10.5 mm                                                                     | SBC2-331-341       | Tokin                  |
| 15   | 1   | L2      | 4.7 $\mu$ H, 600 mA SMD INDUCTOR, MULTILAYER                                                         | MLZ2012N4R7LT000   | TDK                    |
| 16   | 1   | L3      | Ferrite Bead, 60 $\Omega$ , 4 A, 1206 SMD                                                            | FBMJ3216HM600-T    | Taiyo Yuden            |
| 17   | 1   | R1      | RES, 1.2 $\Omega$ , 5%, 1/8 W, Thick Film, 0805                                                      | ERJ-6GEYJ1R2V      | Panasonic              |
| 18   | 1   | R2      | RES, 9.09 k $\Omega$ , 1%, 1/8 W, Thick Film, 0805                                                   | ERJ-6ENF9091V      | Panasonic              |
| 19   | 1   | R3      | RES, 20.5 k $\Omega$ , 1%, 1/16 W, Thick Film, 0603                                                  | ERJ-3EKF2052V      | Panasonic              |
| 20   | 1   | R4      | RES, 12.1 k $\Omega$ , 1%, 1/16 W, Thick Film, 0603                                                  | ERJ-3EKF1212V      | Panasonic              |
| 21   | 1   | R5      | RES, 100 $\Omega$ , 5%, 1/2 W, Thick Film, 1210                                                      | ERJ-14YJ101U       | Panasonic              |
| 22   | 1   | R6      | RES, 200 k $\Omega$ , 5%, 1/4 W, Thick Film, 1206                                                    | ERJ-8GEYJ204V      | Panasonic              |
| 23   | 1   | R7      | RES, 10 $\Omega$ , 5%, 1/8 W, Thick Film, 0805                                                       | ERJ-6GEYJ100V      | Panasonic              |
| 24   | 1   | R8      | RES, 11 k $\Omega$ , 5%, 1/4 W, Thick Film, 1206                                                     | ERJ-8GEYJ113V      | Panasonic              |
| 25   | 1   | R10     | RES, 215 k $\Omega$ , 1%, 1/16 W, Thick Film, 0603                                                   | ERJ-3EKF2153V      | Panasonic              |
| 26   | 1   | RT1     | NTC Thermistor, 2.5 $\Omega$ , 3 A                                                                   | SL08 2R503         | Ametherm               |
| 27   | 1   | T1      | Bobbin, EE16, Horizontal, 7 pins (5primary,2secondary)                                               | RH-EE-1606-1       | Shenzhen Rui Qi Danend |
| 28   | 1   | U1      | LinkSwitch-III, LNK6407D, 1%, SO-8-D                                                                 | LNK6407D           | Power Integrations     |

### 6.2 Miscellaneous Parts

| Item | Qty | Ref Des | Description                                | Mfg Part Number | Manufacturer |
|------|-----|---------|--------------------------------------------|-----------------|--------------|
| 1    | 1   | L       | Test Point, WHT, Miniature THRU-HOLE MOUNT | 5002            | Keystone     |
| 2    | 2   | N, GND  | Test Point, BLK, Miniature THRU-HOLE MOUNT | 5001            | Keystone     |
| 3    | 1   | +12V    | Test Point, RED, Miniature THRU-HOLE MOUNT | 5000            | Keystone     |

## 7 Transformer Specification

### 7.1 Electrical Diagram

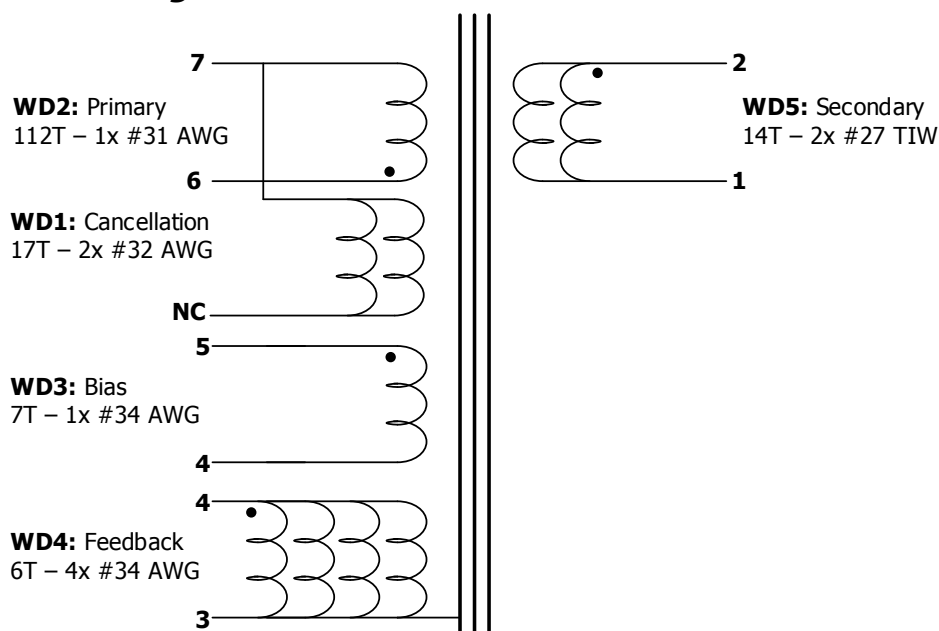


**Figure 6–** Transformer Electrical Diagram.

### 7.2 Electrical Specification

|                                   |                                                                              |                        |
|-----------------------------------|------------------------------------------------------------------------------|------------------------|
| <b>Electrical Strength</b>        | 1 sec, 60 Hz, from pins 3-7 to pins 1-2                                      | 3000 VAC               |
| <b>Primary Inductance</b>         | Pins 6-7, all other windings open, measured at 100 kHz, 1 V <sub>RMS</sub> . | 1270 $\mu$ H $\pm$ 10% |
| <b>Primary Leakage Inductance</b> | Pins 6-7, with pins 1-2 shorted, measured at 100 kHz, 0.4 V <sub>RMS</sub> . | 60 $\mu$ H (Max.)      |

### 7.3 Material List

| Item | Description                                                             |
|------|-------------------------------------------------------------------------|
| [1]  | Core: EE16, Ferrite Core PC40, gapped for ALG of 101nH/T <sup>2</sup> . |
| [2]  | Bobbin: EE-1606-1 Horizontal.                                           |
| [3]  | Magnet Wire: #32 AWG, Double Coated.                                    |
| [4]  | Magnet Wire: #31 AWG, Double Coated.                                    |
| [5]  | Magnet Wire: #34 AWG, Double Coated.                                    |
| [6]  | Triple Insulated Wire: #27 AWG                                          |
| [7]  | Tape: 3M 1298 Polyester Film, 1 mil thick, 8.43 mm Wide.                |
| [8]  | Bus Wire: #30 AWG, Belden Electronics Div; or Equivalent.               |
| [9]  | Varnish: Dolph BC-359.                                                  |
| [10] | Tape: 3M 1298 Polyester Film 1 mil thick, 4.5 mm Wide.                  |

## 7.4 Transformer Build Diagram

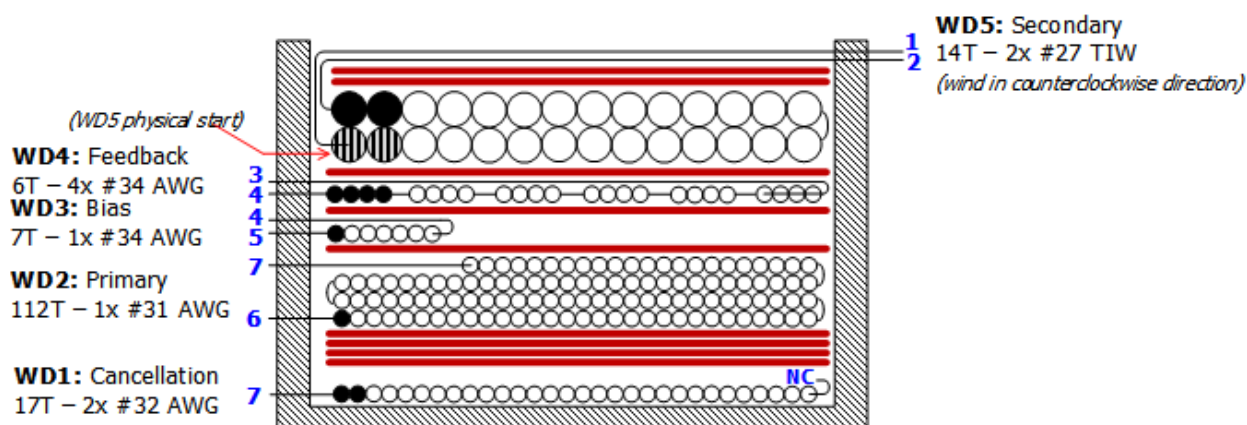
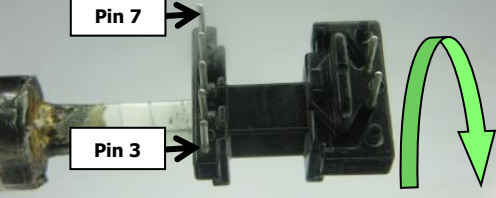
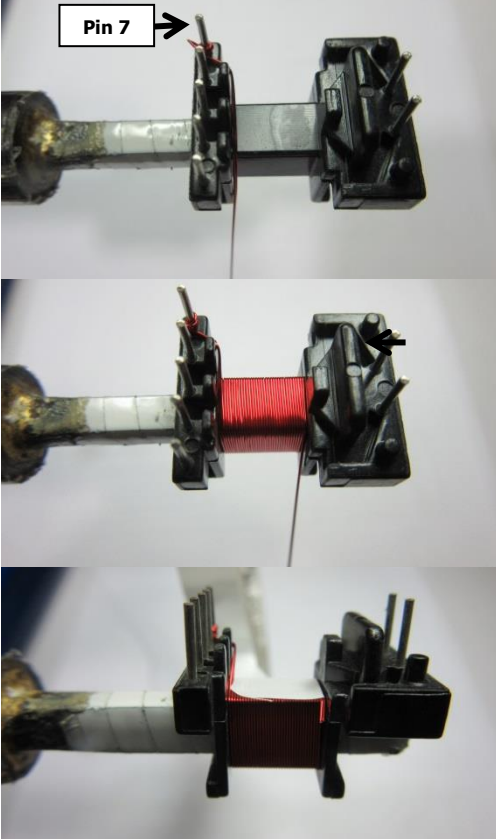
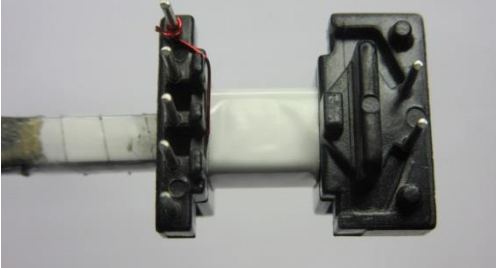


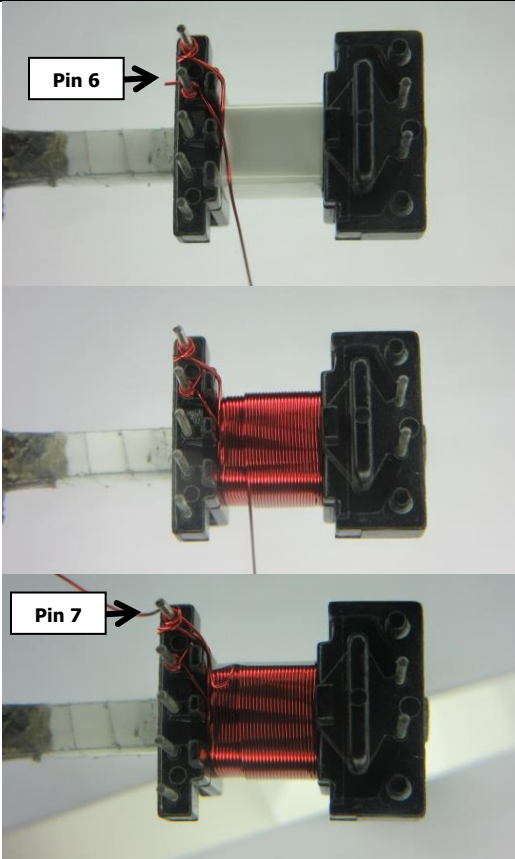
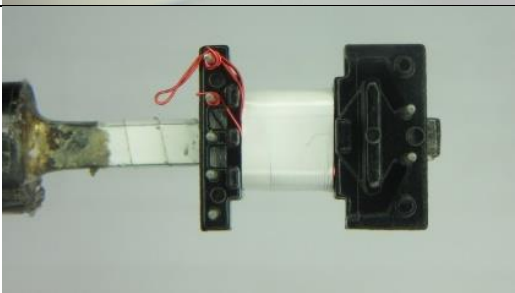
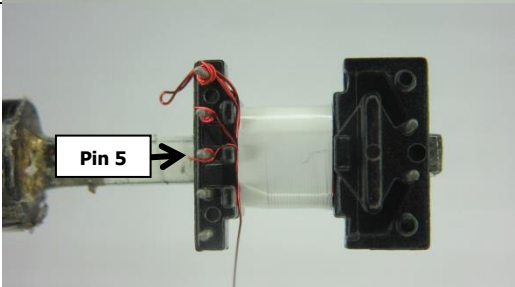
Figure 7– Transformer Build Diagram.

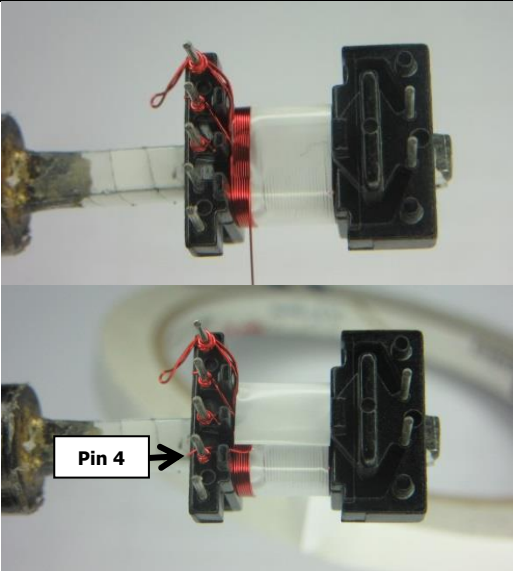
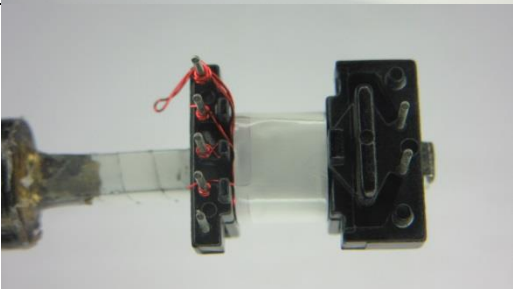
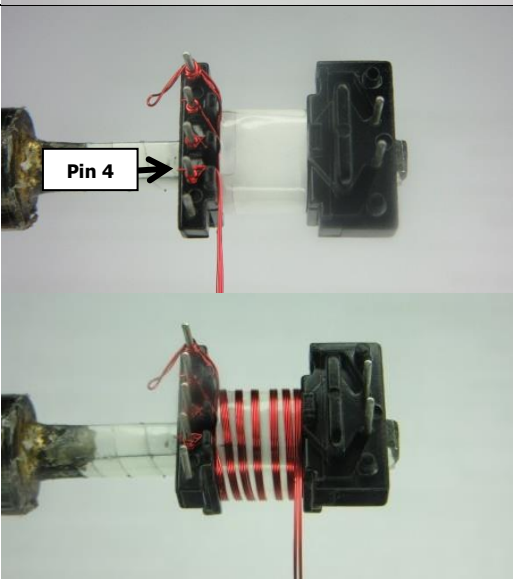
## 7.5 Transformer Instructions

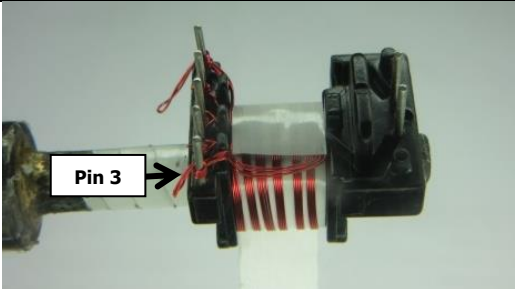
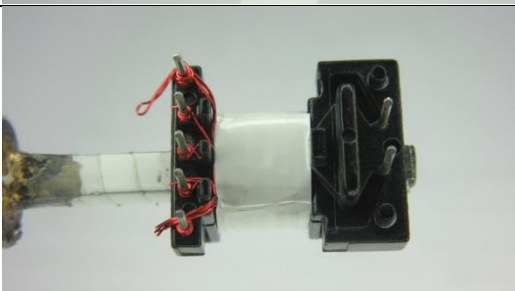
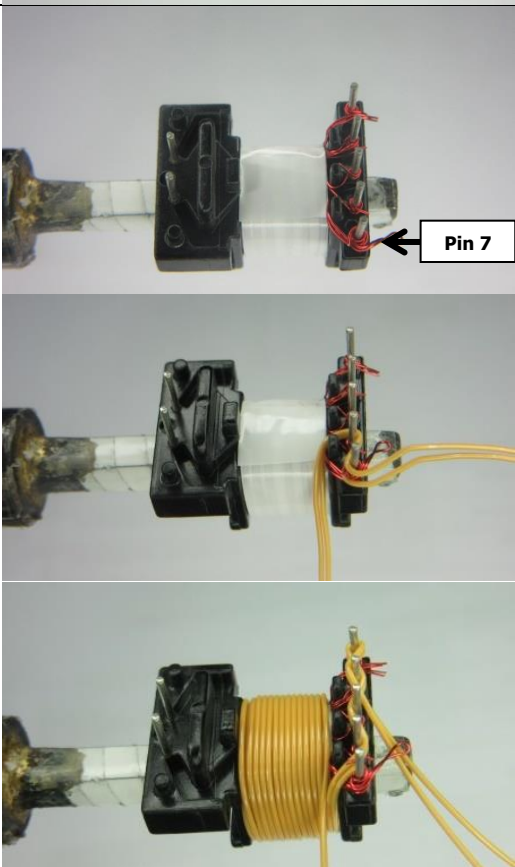
|                            |                                                                                                                                                                                                                                                                                                                                               |
|----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Winding Preparation</b> | For the purpose of these instructions, bobbin is oriented on winder such that primary side (5-pin) is on the left side with pin 3 at the bottom. Winding direction is clockwise direction.                                                                                                                                                    |
| <b>WD1 Cancellation</b>    | Start at pin 7, wind 17 turns (x2 filar) of wire Item [3] in one layer. Last turn will be left floating (not connected).                                                                                                                                                                                                                      |
| <b>Insulation</b>          | 4 layers of tape Item [7] for insulation.                                                                                                                                                                                                                                                                                                     |
| <b>WD2 Primary</b>         | Start at pin 6, wind 112 turns (x1 filar) of wire Item [4] in 4 layers with tight tension (Layer 1 – 30T, Layer 2 – 30T, Layer 3 – 30T, Layer 4 – 22T). At the last turn, bring the wire back to the left and terminate at pin 7.                                                                                                             |
| <b>Insulation</b>          | 1 layer of tape Item [7] for insulation.                                                                                                                                                                                                                                                                                                      |
| <b>WD3 Bias</b>            | Start at pin 5, wind 7 turns (x1 filar) of wire Item [5]. Terminate winding at pin 4.                                                                                                                                                                                                                                                         |
| <b>Insulation</b>          | 1 layer of tape Item [7] for insulation.                                                                                                                                                                                                                                                                                                      |
| <b>WD4 Feedback</b>        | Start at pin 4, wind 6 turns (x4 filar) of wire Item [5]. Spread the turns across the bobbin width. Terminate at pin 3.                                                                                                                                                                                                                       |
| <b>Insulation</b>          | 1 layer of tape Item [7] for insulation.                                                                                                                                                                                                                                                                                                      |
| <b>WD5 Secondary</b>       | Reverse position of the bobbin on winder such that the primary side (5-pin) is on the right side with pin 7 at the bottom. Winding in clockwise direction. Start winding at the right side of the bobbin with 14 turns (x2 filar) of wire Item [6]. Connect the start winding on pin 1 and terminate on pin 2 on the left side of the bobbin. |
| <b>Insulation</b>          | 2 layers of tape Item [7] to secure the windings.                                                                                                                                                                                                                                                                                             |
| <b>Finish</b>              | Gap core halves for 1270 $\mu$ H inductance. Use 2" of bus wire Item [8] solder to pin 3. Wrap core halves and bus wire above which lean along the core with tape Item [10]. Coat with Varnish Item [9].                                                                                                                                      |

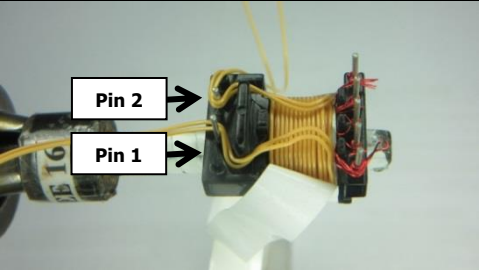
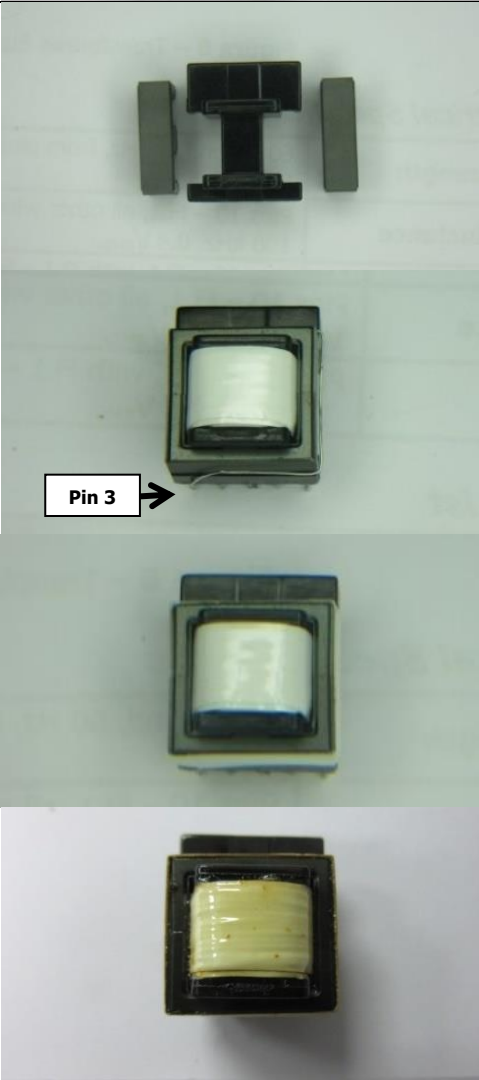
7.6 **Winding Illustrations**

|                            |                                                                                     |                                                                                                                                                                                                   |
|----------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Winding Preparation</b> |    | <p>For the purpose of these instructions, bobbin is oriented on winder such that primary side (5-pin) is on the left side with Pin 3 at the bottom. Winding direction is clockwise direction.</p> |
| <b>WD1 Cancellation</b>    |   | <p>Start at pin 7, wind 17 turns (x2 filar) of wire Item [3] in one layer.</p> <p>Last turn will be left floating (not connected).</p>                                                            |
| <b>Insulation</b>          |  | <p>4 layers of tape Item [7] for insulation.</p>                                                                                                                                                  |

|                               |                                                                                                               |                                                                                                                                                                                                                                                |
|-------------------------------|---------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>WD2<br/>Primary</b></p> |  <p>Pin 6</p> <p>Pin 7</p> | <p>Start at pin 6, wind 112 turns (x1 filar) of wire Item [4] in 4 layers with tight tension (Layer 1 –30T, Layer 2 – 30T, Layer 3 – 30T, Layer 4 – 22T).</p> <p>At the last turn, bring the wire back to the left and terminate at pin 7.</p> |
| <p><b>Insulation</b></p>      |                           | <p>1 layer of tape Item [7] for insulation.</p>                                                                                                                                                                                                |
| <p><b>WD3<br/>Bias</b></p>    |  <p>Pin 5</p>             | <p>Start at pin 5, wind 7 turns (x1 filar) of wire Item [5].</p>                                                                                                                                                                               |

|                         |                                                                                     |                                                                                                                       |
|-------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| <b>WD3<br/>Bias</b>     |    | Terminate winding at pin 4.                                                                                           |
| <b>Insulation</b>       |   | 1 layer of tape Item [7] for insulation.                                                                              |
| <b>WD4<br/>Feedback</b> |  | <p>Start at pin 4, wind 6 turns (x4 filar) of wire Item [5].</p> <p>Distribute the turns across the bobbin width.</p> |

|                          |                                                                                     |                                                                                                                                                                                                                                                                   |
|--------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>WD4<br/>Feedback</b>  |   | Terminate at pin 3.                                                                                                                                                                                                                                               |
| <b>Insulation</b>        |   | 1 layer of tape Item [7] for insulation.                                                                                                                                                                                                                          |
| <b>WD5<br/>Secondary</b> |  | <p>Reverse position of the bobbin on winder such that the primary side (5-pin) is on the right side with Pin 7 at the bottom. Winding in clockwise direction.</p> <p>Start winding at the right side of the bobbin with 14 turns (x2 filar) of wire Item [6].</p> |

|                          |                                                                                    |                                                                                                                                                                                                                                                |
|--------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>WD5<br/>Secondary</b> |   | Connect the start winding on Pin 1 and terminate on Pin 2 on the left side of the bobbin.                                                                                                                                                      |
| <b>Insulation</b>        |   | 2 layers of tape Item [7] to secure the windings.                                                                                                                                                                                              |
| <b>Finish</b>            |  | <p>Gap core halves for 1270 <math>\mu</math>H inductance.</p> <p>Use 2" of bus wire Item [8] solder to pin 3.</p> <p>Wrap core halves and bus wire above which lean along the core with tape Item [10].</p> <p>Coat with varnish Item [9].</p> |

## 8 Transformer Design Spreadsheet

| 1  | ACDC_LinkSwitch-3_080516;<br>Rev.2.3; Copyright<br>Power<br>Integrations 2016 | INPUT     | INFO | OUTPUT    | UNIT  | LinkSwitch-3 Discontinuous Flyback<br>Transformer Design Spreadsheet                                                  |
|----|-------------------------------------------------------------------------------|-----------|------|-----------|-------|-----------------------------------------------------------------------------------------------------------------------|
| 2  | <b>ENTER APPLICATION VARIABLES</b>                                            |           |      |           |       |                                                                                                                       |
| 3  | VACMIN                                                                        | 90        |      | 90        | V     | Minimum AC Input Voltage                                                                                              |
| 4  | VACMAX                                                                        | 265       |      | 265       | V     | Maximum AC Input Voltage                                                                                              |
| 5  | fL                                                                            | 50        |      | 50        | Hz    | AC Mains Frequency                                                                                                    |
| 6  | Application Type                                                              | Adapter   |      | Adapter   |       | Choose application type                                                                                               |
| 7  | VO                                                                            | 12.00     |      | 12.00     | V     | Output Voltage (at continuous power)                                                                                  |
| 8  | IO                                                                            | 0.70      |      | 0.70      | A     | Minimum required output current                                                                                       |
| 9  | Power                                                                         | .         | Info | 8.40      | W     | !!! Continuous output power may be too high. Verify thermal performance                                               |
| 10 | n                                                                             | 0.84      |      | 0.84      |       | Efficiency Estimate at output terminals.                                                                              |
| 11 | Z                                                                             |           |      | 0.50      |       | Z Factor. Ratio of secondary side losses to the total losses in the power supply. Use 0.5 if no better data available |
| 12 | tC                                                                            |           |      | 3.00      | ms    | Bridge Rectifier Conduction Time Estimate                                                                             |
| 13 | CIN                                                                           | 20.00     |      | 20.00     | uF    | Input Capacitance                                                                                                     |
| 15 | <b>ENTER LinkSwitch-3 VARIABLES</b>                                           |           |      |           |       |                                                                                                                       |
| 16 | Chosen Device                                                                 | LNK64x7D  |      | LNK64x7D  |       | Chosen LinkSwitch-3 device and package. E.g. - LNK64x4D or LNK64x8K                                                   |
| 17 | Cable drop compensation option                                                | 1%        |      | 1%        |       | Select level of cable drop compensation                                                                               |
| 18 | Complete Part Number                                                          |           |      | LNK6407D  |       | Full Part Number                                                                                                      |
| 19 | ILIMITMIN                                                                     |           |      | 0.41      | A     | Minimum Current Limit                                                                                                 |
| 20 | ILIMITTYP                                                                     |           |      | 0.44      | A     | Typical Current Limit                                                                                                 |
| 21 | ILIMITMAX                                                                     |           |      | 0.47      | A     | Maximum Current Limit                                                                                                 |
| 22 | FS                                                                            | 77.50     |      | 77.50     | kHz   | Typical Device Switching Frequency at maximum power                                                                   |
| 23 | VOR                                                                           |           |      | 100.00    | V     | Reflected Output Voltage (VOR < 135 V Recommended)                                                                    |
| 24 | VDS                                                                           |           |      | 10.00     | V     | LinkSwitch-3 on-state Drain to Source Voltage                                                                         |
| 25 | VD                                                                            | 0.50      |      | 0.50      | V     | Output Winding Diode Forward Voltage Drop                                                                             |
| 26 | KP                                                                            |           |      | 1.18      |       | KP assuming minimum LP, VMIN, and Maximum Switching Frequency, but not including frequency jitter.                    |
| 29 | <b>FEEDBACK WINDING PARAMETERS</b>                                            |           |      |           |       |                                                                                                                       |
| 30 | NFB                                                                           | 6.00      |      | 6.00      |       | Feedback winding turns                                                                                                |
| 31 | VFLY                                                                          |           |      | 5.36      | V     | Flyback Voltage - Voltage on Feedback Winding during switch off time                                                  |
| 32 | VFOR                                                                          |           |      | 5.14      | V     | Forward voltage - Voltage on Feedback Winding during switch on time                                                   |
| 34 | <b>BIAS WINDING PARAMETERS</b>                                                |           |      |           |       |                                                                                                                       |
| 35 | BIAS                                                                          | Ext. Bias |      | Ext. Bias |       | Select between self bias or external bias to supply the IC. Note that this will affect ILIMIT                         |
| 36 | VB                                                                            | 11.00     |      | 11.00     | V     | Bias Winding Voltage. Ensure that VB > VFLY. Bias winding is assumed to be AC-STACKED on top of Feedback winding      |
| 37 | NB                                                                            |           |      | 7.00      |       | Bias Winding number of turns                                                                                          |
| 38 | REXT                                                                          |           |      | 7.50      | k-ohm | Suggested value of BYPASS pin resistor (use standard 5% resistor)                                                     |
| 39 | <b>DESIGN PARAMETERS</b>                                                      |           |      |           |       |                                                                                                                       |
| 40 | DCON                                                                          |           |      | 4.60      | us    | Desired output diode conduction time                                                                                  |
| 41 | DCON_FINAL                                                                    |           |      | 4.68      | us    | Final output conduction diode, assuming integer values for NP and NS, and VMIN                                        |
| 42 | TON                                                                           |           |      | 4.88      | us    | LinkSwitch-3 On-time (calculated at LPMIN, VMIN                                                                       |

|           |                                                      |       |      |             |                      |                                                                                             |
|-----------|------------------------------------------------------|-------|------|-------------|----------------------|---------------------------------------------------------------------------------------------|
|           |                                                      |       |      |             |                      | and ILIMITMIN)                                                                              |
| 43        | RUPPER                                               |       |      | 19.86       | k-ohm                | Upper resistor in Feedback resistor divider                                                 |
| 44        | RLOWER                                               |       |      | 11.27       | k-ohm                | Lower resistor in resistor divider                                                          |
| <b>46</b> | <b>ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES</b> |       |      |             |                      |                                                                                             |
| <b>47</b> | <b>Core Type</b>                                     |       |      |             |                      |                                                                                             |
| 48        | Core                                                 | EE16  |      | EE16        |                      | Enter Transformer Core.                                                                     |
| 49        | Custom_Core                                          |       |      |             |                      | Enter Core name if selection on drop down menu is "Custom"                                  |
| 50        | Bobbin                                               |       |      | BE-16-116CP |                      | Bobbin part number                                                                          |
| 51        | AE                                                   |       |      | 19.20       | mm <sup>2</sup>      | Core Effective Cross Sectional Area                                                         |
| 52        | LE                                                   |       |      | 35.00       | mm                   | Core Effective Path Length                                                                  |
| 53        | AL                                                   |       |      | 1140.00     | nH/turn <sup>2</sup> | Ungapped Core Effective Inductance                                                          |
| 54        | BW                                                   | 8.00  |      | 8.00        | mm                   | Bobbin Physical Winding Width                                                               |
| 55        | M                                                    |       |      | 0.00        | mm                   | Safety Margin Width (Half the Primary to Secondary Creepage Distance)                       |
| 56        | L                                                    | 4.00  |      | 3.00        |                      | Number of Primary Layers                                                                    |
| 57        | NS                                                   |       |      | 14.00       | turns                | Number of Secondary Turns. To adjust Secondary number of turns change DCON                  |
| <b>59</b> | <b>DC INPUT VOLTAGE PARAMETERS</b>                   |       |      |             |                      |                                                                                             |
| 60        | VMIN                                                 |       |      | 95.92       | V                    | Minimum DC bus voltage                                                                      |
| 61        | VMAX                                                 |       |      | 374.77      | V                    | Maximum DC bus voltage                                                                      |
| <b>63</b> | <b>CURRENT WAVEFORM SHAPE PARAMETERS</b>             |       |      |             |                      |                                                                                             |
| 64        | DMAX                                                 |       |      | 0.47        |                      | Maximum duty cycle measured at VMIN                                                         |
| 65        | IAVG                                                 |       |      | 0.12        | A                    | Input Average current, at VMIN                                                              |
| 66        | IP                                                   |       |      | 0.41        | A                    | Peak primary current                                                                        |
| 67        | IR                                                   |       |      | 0.41        | A                    | Primary ripple current                                                                      |
| 68        | IRMS                                                 |       |      | 0.19        | A                    | Primary RMS current                                                                         |
| <b>70</b> | <b>TRANSFORMER PRIMARY DESIGN PARAMETERS</b>         |       |      |             |                      |                                                                                             |
| 71        | LPMIN                                                |       |      | 1142.65     | uH                   | Minimum Primary Inductance                                                                  |
| 72        | LPTYP                                                |       |      | 1269.62     | uH                   | Typical Primary inductance                                                                  |
| 73        | LP_TOLERANCE                                         | 10.00 |      | 10.00       | %                    | Tolerance in primary inductance                                                             |
| 74        | NP                                                   |       |      | 112.00      |                      | Primary number of turns. To adjust Primary number of turns change BM_TARGET                 |
| 75        | ALG                                                  |       |      | 101.21      | nH/turn <sup>2</sup> | Gapped Core Effective Inductance                                                            |
| 76        | BM_TARGET                                            |       |      | 2600.00     | Gauss                | Target Flux Density                                                                         |
| 77        | BM                                                   |       | Info | 2603.70     | Gauss                | Maximum Operating Flux Density (calculated with LPTYP, ILIMITTYP), BM < 2600 is recommended |
| 78        | BP                                                   |       |      | 3061.83     | Gauss                | Peak Operating Flux Density (calculated with LPMAX, ILIMITMAX), BP < 3100 is recommended    |
| 79        | BAC                                                  |       |      | 1301.85     | Gauss                | AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)                                   |
| 80        | ur                                                   |       |      | 165.37      |                      | Relative Permeability of Ungapped Core                                                      |
| 81        | LG                                                   |       |      | 0.24        | mm                   | Gap Length (LG > 0.1 mm)                                                                    |
| 82        | BWE                                                  |       |      | 32.00       | mm                   | Effective Bobbin Width                                                                      |
| 83        | OD                                                   | 0.28  |      | 0.28        | mm                   | Maximum Primary Wire Diameter including insulation                                          |
| 84        | INS                                                  |       |      | 0.05        | mm                   | Estimated Total Insulation Thickness (= 2 * film thickness)                                 |
| 85        | DIA                                                  |       |      | 0.23        | mm                   | Bare conductor diameter                                                                     |
| 86        | AWG                                                  |       |      | 31          | AWG                  | Primary Wire Gauge (Rounded to next smaller standard AWG value)                             |
| 87        | CM                                                   |       |      | 80.63       | Cmils                | Bare conductor effective area in circular mils                                              |
| 88        | CMA                                                  |       |      | 432.83      | Cmils/A              | Primary Winding Current Capacity (200 < CMA < 500)                                          |
| 89        |                                                      |       |      |             |                      |                                                                                             |
| <b>90</b> | <b>TRANSFORMER SECONDARY DESIGN PARAMETERS</b>       |       |      |             |                      |                                                                                             |
| 91        |                                                      |       |      |             |                      |                                                                                             |
| 92        | ISP                                                  |       |      | 3.28        | A                    | Peak Secondary Current assuming Ilimitmin                                                   |
| 93        | ISRMS                                                |       |      | 1.46        | A                    | Secondary RMS Current assuming Ilimitmax and Dmax                                           |
| 94        | IRIPPLE                                              |       |      | 1.28        | A                    | Output Capacitor RMS Ripple Current                                                         |



|            |                                        |       |  |        |       |                                                                                                                     |
|------------|----------------------------------------|-------|--|--------|-------|---------------------------------------------------------------------------------------------------------------------|
| 95         | CMS                                    |       |  | 291.93 | Cmils | Secondary Bare Conductor minimum circular mils                                                                      |
| 96         | AWGS                                   |       |  | 25.00  |       | Secondary Wire Gauge (Rounded up to next larger standard AWG value)                                                 |
| <b>98</b>  | <b>VOLTAGE STRESS PARAMETERS</b>       |       |  |        |       |                                                                                                                     |
| 99         | VDRAIN                                 |       |  | 604.77 | V     | Maximum Drain Voltage Estimate (Assumes 20% clamping voltage tolerance and an additional 10% temperature tolerance) |
| 100        | PIVS                                   |       |  | 78.18  | V     | Output Rectifier Maximum Peak Inverse Voltage                                                                       |
| <b>102</b> | <b>FINE TUNING</b>                     |       |  |        |       |                                                                                                                     |
| 103        | RUPPER_ACTUAL                          | 20.50 |  | 20.50  | k-ohm | Actual Value of upper resistor (RUPPER) used on PCB                                                                 |
| 104        | RLOWER_ACTUAL                          | 12.10 |  | 12.10  | k-ohm | Actual Value of lower resistor (RLOWER) used on PCB                                                                 |
| 105        | Actual (Measured) Output Voltage (VDC) |       |  | 12.00  | V     | Measured Output voltage from first prototype                                                                        |
| 106        | Actual (Measured) Output Current (ADC) |       |  | 0.70   | Amps  | Measured Output current from first prototype                                                                        |
| 107        | RUPPER_FINE                            |       |  | 20.50  | k-ohm | New value of Upper resistor (RUPPER) in Feedback resistor divider. Nearest standard value is 20.5 k-ohms            |
| 108        | RLOWER_FINE                            |       |  | 12.10  | k-ohm | New value of Lower resistor (RLOWER) in Feedback resistor divider. Nearest standard value is 12.1 k-ohms            |

## 9 Performance Data

All measurements performed with external room ambient temperature and 60 Hz input for 115 VAC range and 50 Hz for 230 VAC input range.

### 9.1 Average Efficiency

#### 9.1.1 Efficiency Requirements

| Test      | Average       | Average       | Average       | Average       | 10% Load      | 10% Load      |
|-----------|---------------|---------------|---------------|---------------|---------------|---------------|
| Model     | Standard      | Basic Voltage | Basic Voltage | Basic Voltage | Basic Voltage | Basic Voltage |
| Effective | Now           | 2016          | Now           | 2016          | Now           | 2016          |
| Power [W] | Energy Star 2 | DoE Level VI  | CoC v5 Tier 1 | CoC v5 Tier 2 | CoC v5 Tier 1 | CoC v5 Tier 2 |
| 8.4       | 75.52%        | 80.93%        | 77.92%        | 81.14%        | 67.92%        | 71.14%        |

#### 9.1.2 Average Efficiency Measured (Across PCB Connector)

| Load (%) | 115 VAC (%) | 230 VAC (%) |
|----------|-------------|-------------|
| 100      | 83.48       | 83.62       |
| 75       | 83.14       | 83.10       |
| 50       | 82.76       | 80.16       |
| 25       | 81.00       | 78.74       |
| 10       | 77.89       | 76.52       |
| Average  | 82.59       | 81.41       |

#### 9.1.3 Average Efficiency Measured (at the End of 100 mΩ Cable)

| Load (%) | 115 VAC (%) | 230 VAC (%) |
|----------|-------------|-------------|
| 100      | 82.90       | 83.16       |
| 75       | 82.74       | 82.69       |
| 50       | 82.44       | 79.87       |
| 25       | 80.68       | 78.44       |
| 10       | 77.07       | 75.21       |
| Average  | 82.19       | 81.04       |

## 9.2 ***Efficiency vs. Line***

Soak for 20 minutes and 5 minutes for each line/step.

### 9.2.1 Measured at 0.7 A Full Load.

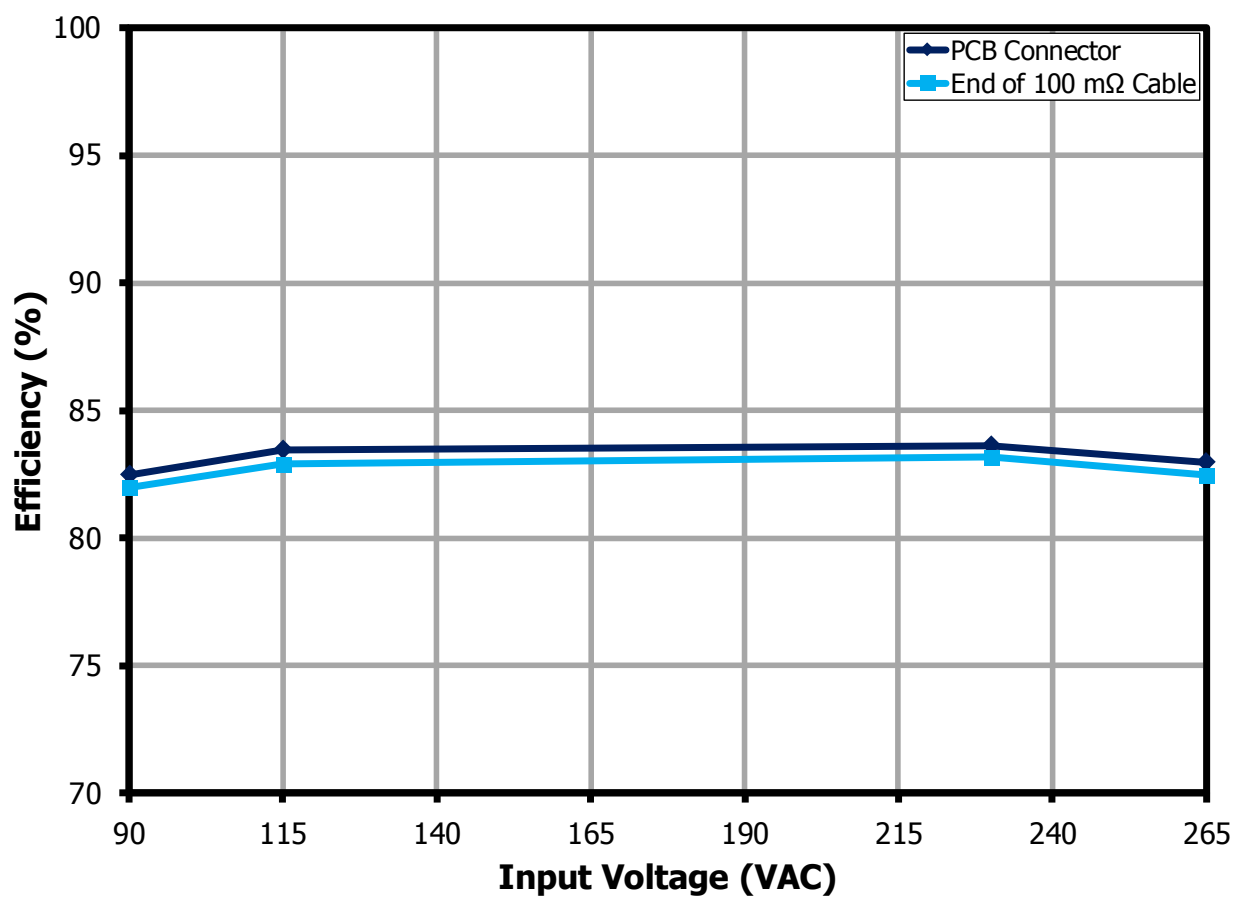


**Figure 8** – Efficiency vs. Line.

### 9.3 *Efficiency vs. Load*

Soak for 5 minutes and 30 seconds for each load step.

#### 9.3.1 Measured across PCB connector

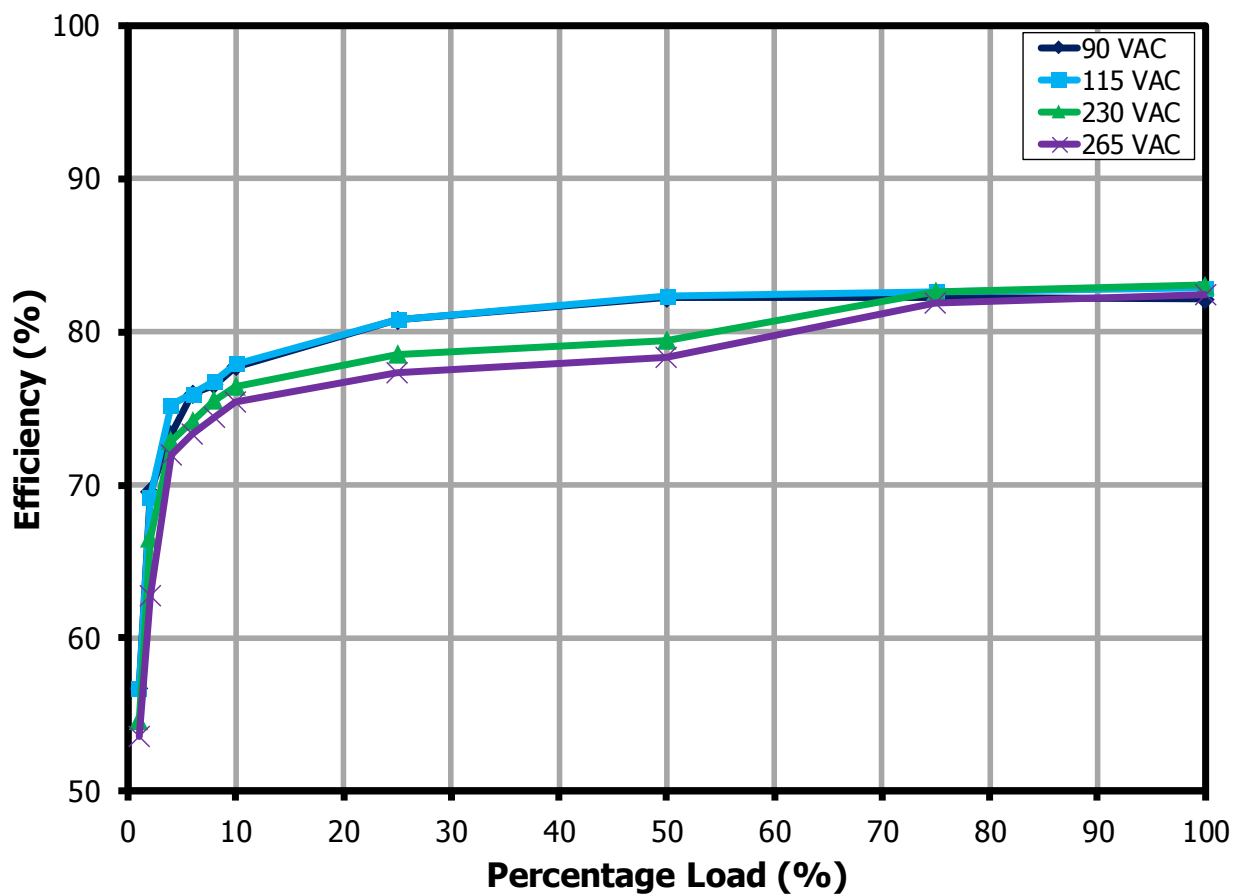


**Figure 9** – Efficiency vs. Load (Measured Across PCB Connector).

## 9.3.2 Measured at the End 100 mΩ Cable

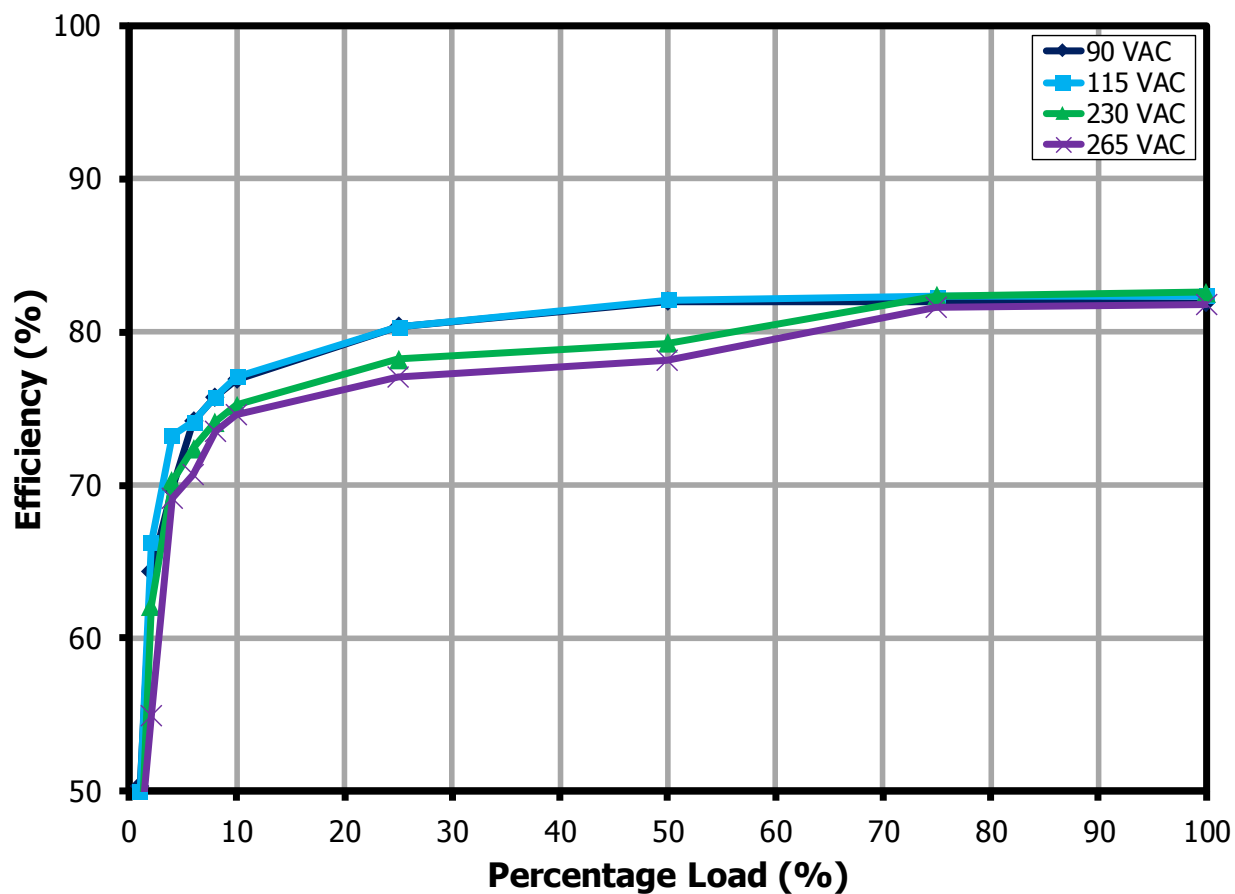


**Figure 10** – Efficiency vs Load (Measured at the End of 1.2m #22 Cable).

## 10 CV/CC Regulation

### 10.1 CV/CC Regulation at 25 °C Measured Across PCB Connector

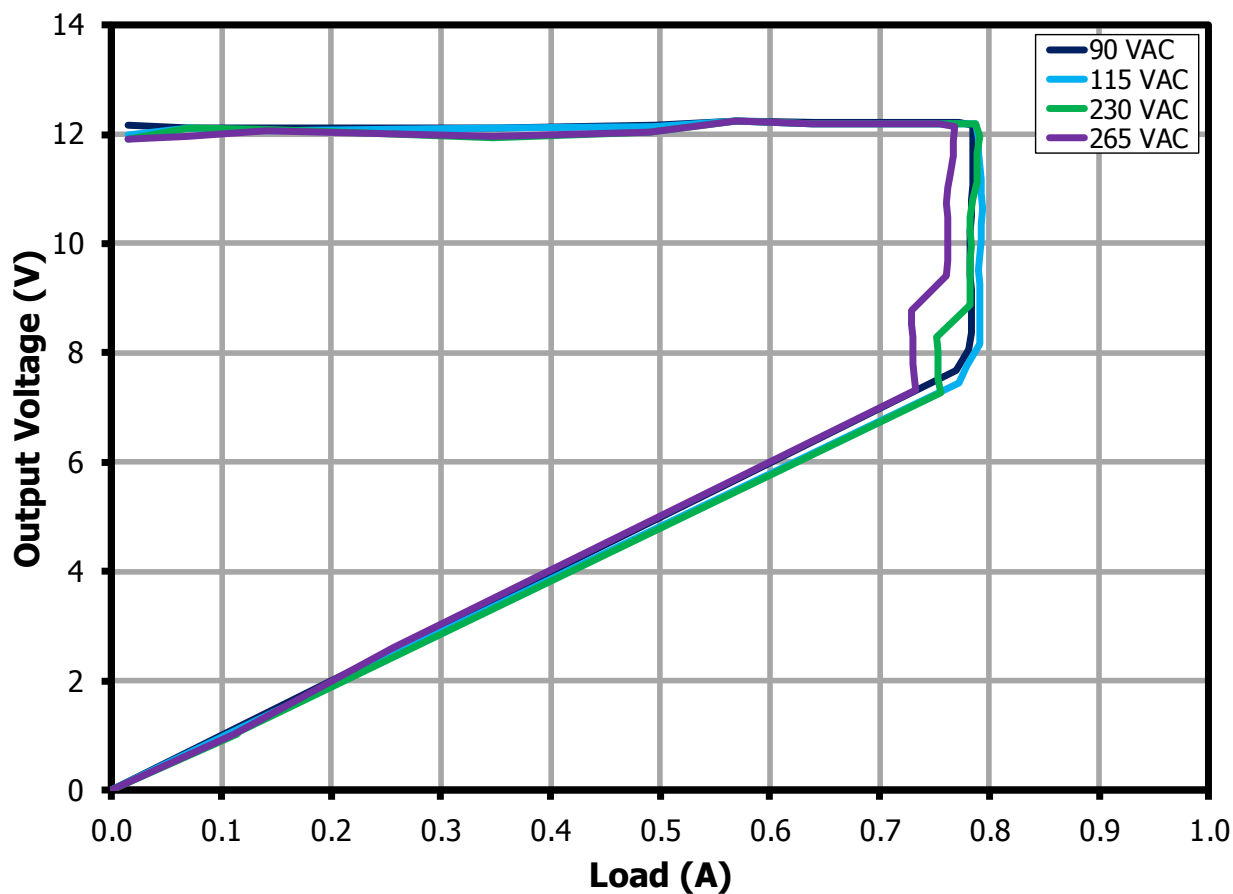
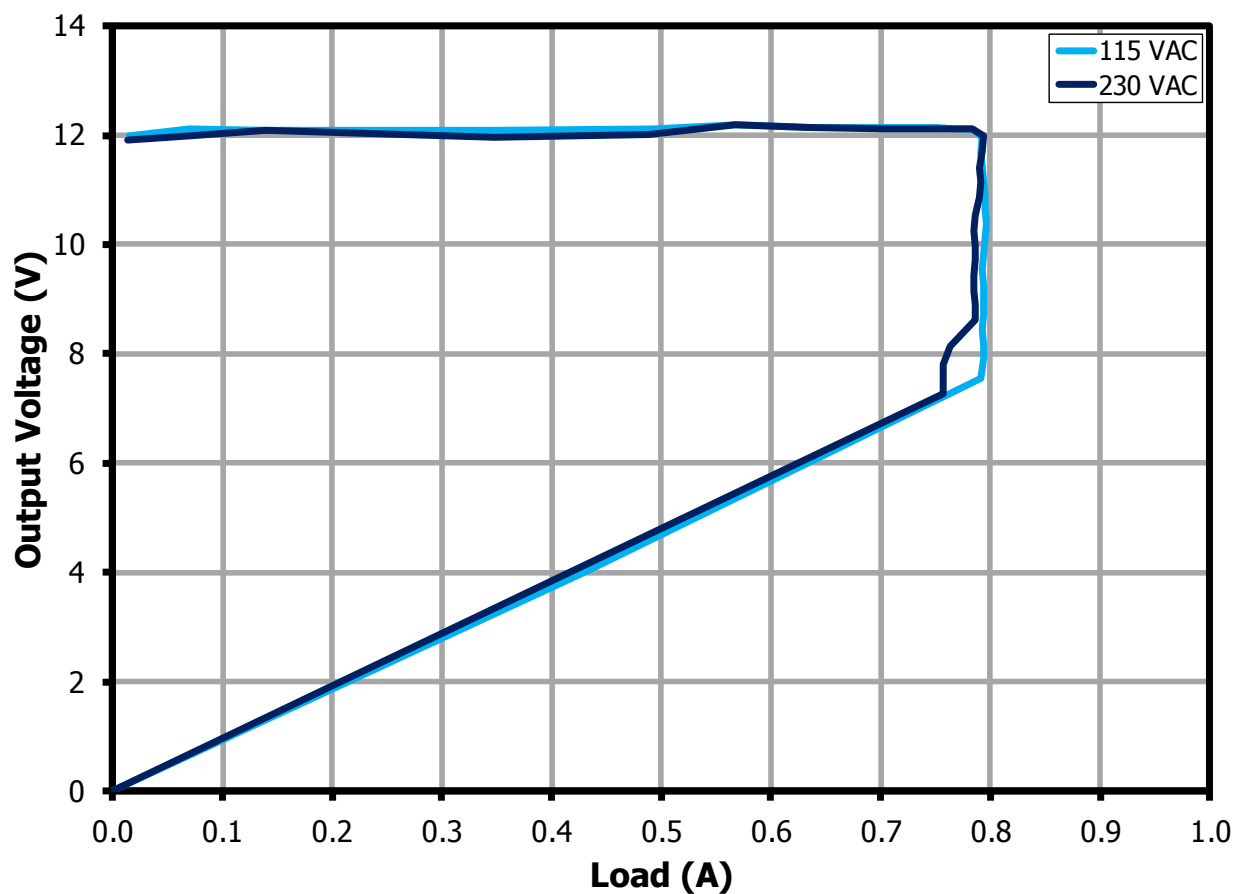


**Figure 11** – CV/CC across PCB connector. Room Temperature.

10.2 **CV/CC Regulation at 25 °C Measured on End of 100 mΩ Cable****Figure 12** – CV/CC Measured at the End of 100 mΩ Cable. Room Temperature.

### 10.3 *CV/CC Regulation at Hot and Cold Temperature*

Open frame unit was placed inside the enclosure to prevent airflow that may affect the thermal measurements. Ambient temperature inside was measured using type T thermocouple.



**Figure 13** – Test Set-up.

## 10.3.1 90 VAC

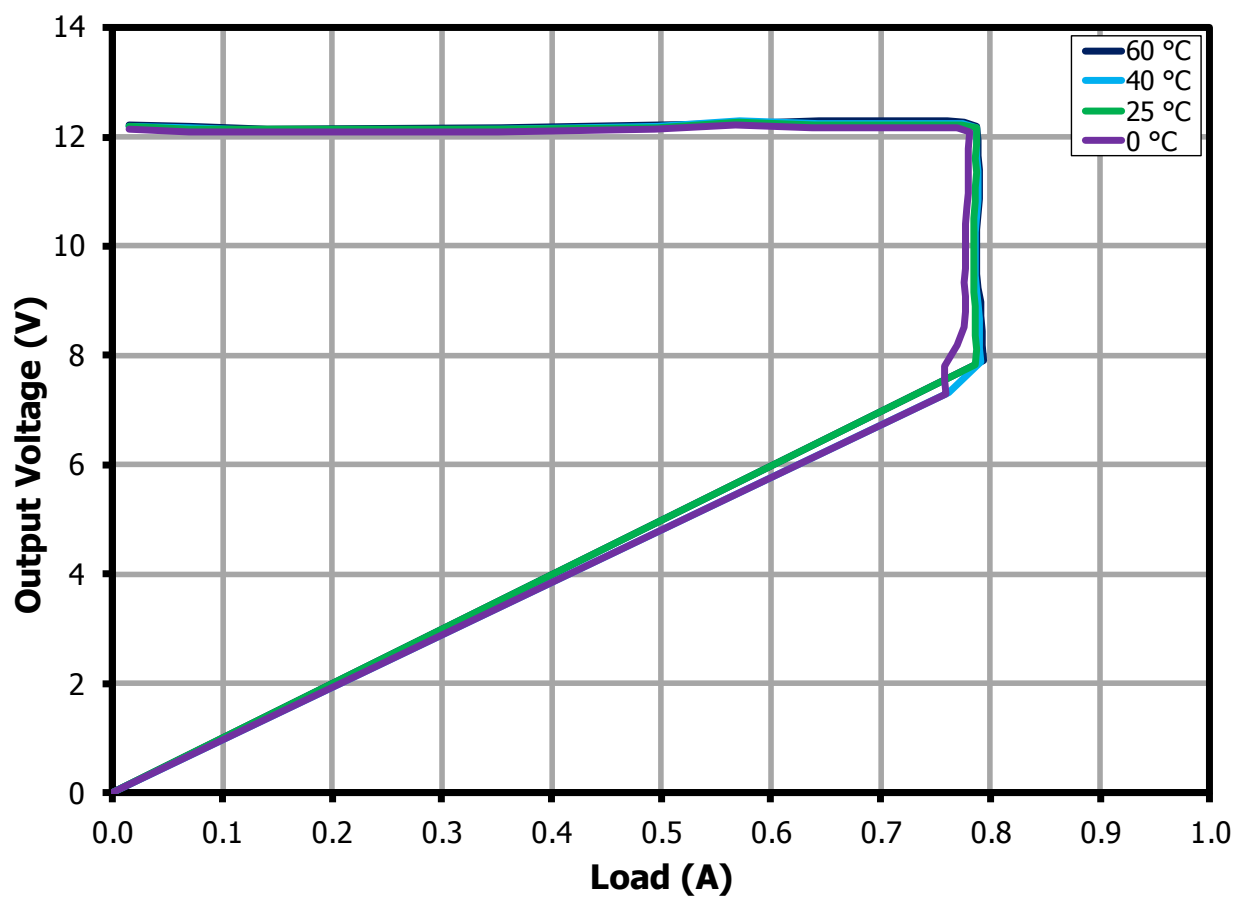


**Figure 14** – 90 VAC CV/CC Measured at the End of 100 mΩ Cable.

## 10.3.2 115 VAC

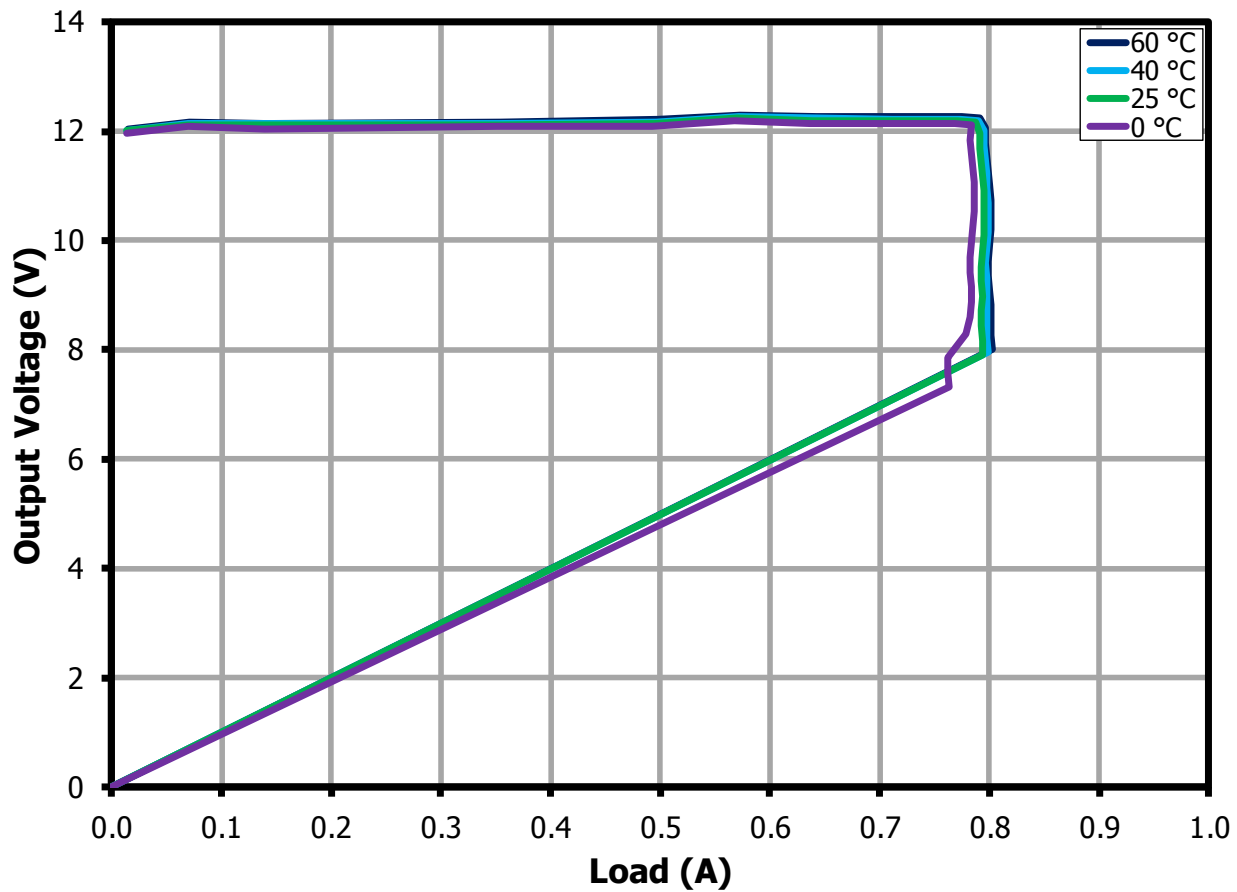


**Figure 15** – 115 VAC CV/CC Measured at the End of 100 mΩ Cable.

## 10.3.3 230 VAC

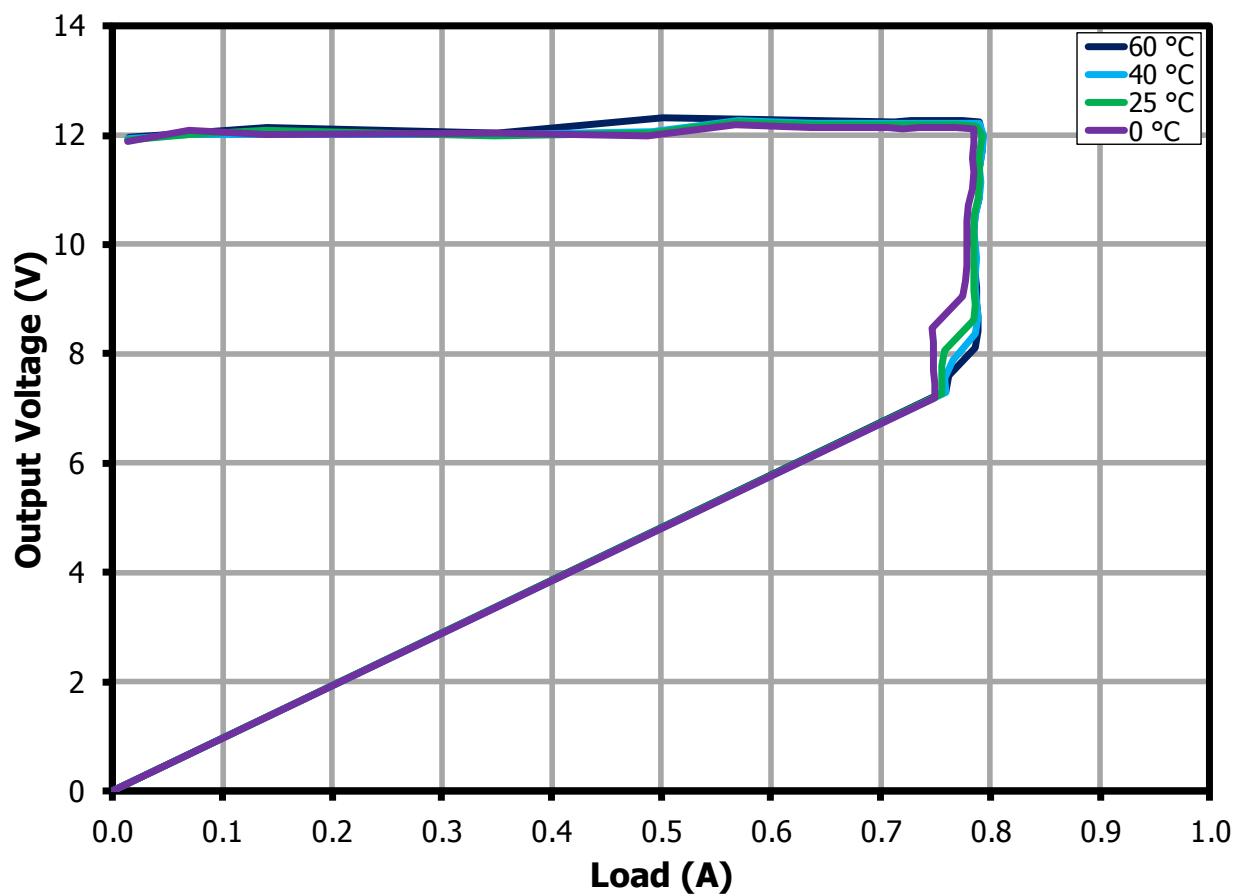


**Figure 16** – 230 VAC CV/CC Measured at the End of 100 mΩ Cable.

## 10.3.4 265 VAC

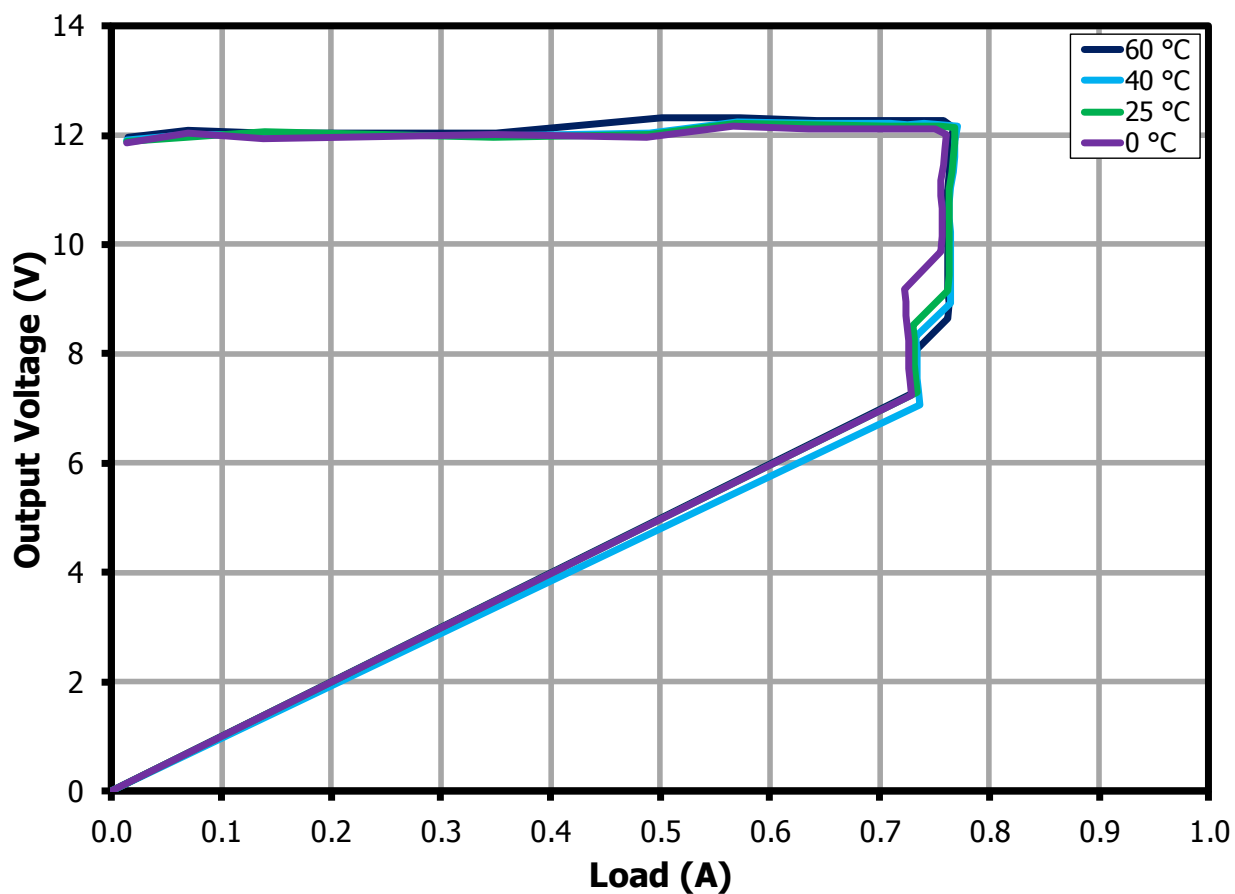


**Figure 17** – 265 VAC CV/CC Measured at the End of 100 mΩ Cable.

## 11 No-Load Input Power

Soak for 15 minutes and 3 minutes integration time for each line/step.

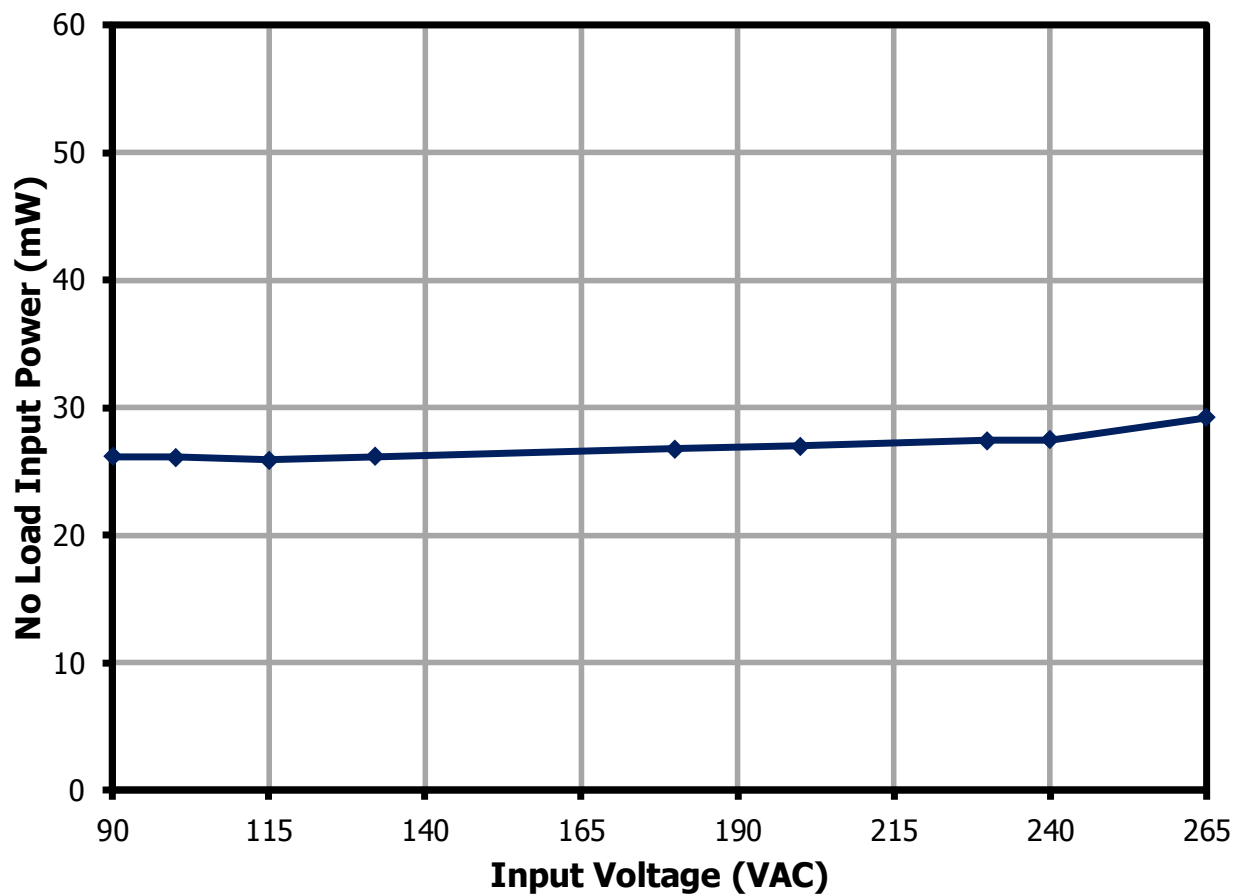


**Figure 18** – No-Load Input Power vs. Input Line Voltage, Room Temperature.

## 12 Line Regulation

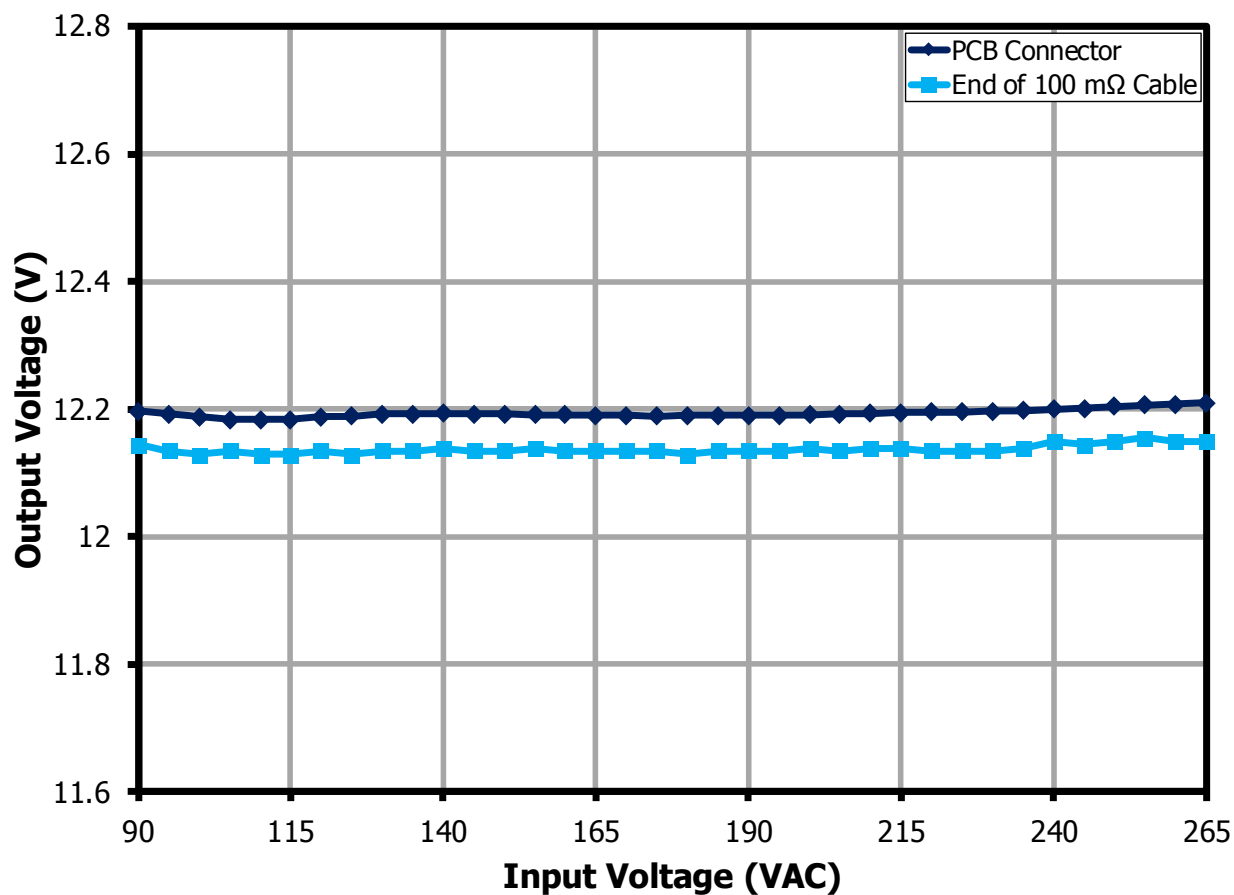


Figure 19 – Line Regulation.

## 13 Load Regulation

### 13.1.1 Measured across PCB connector

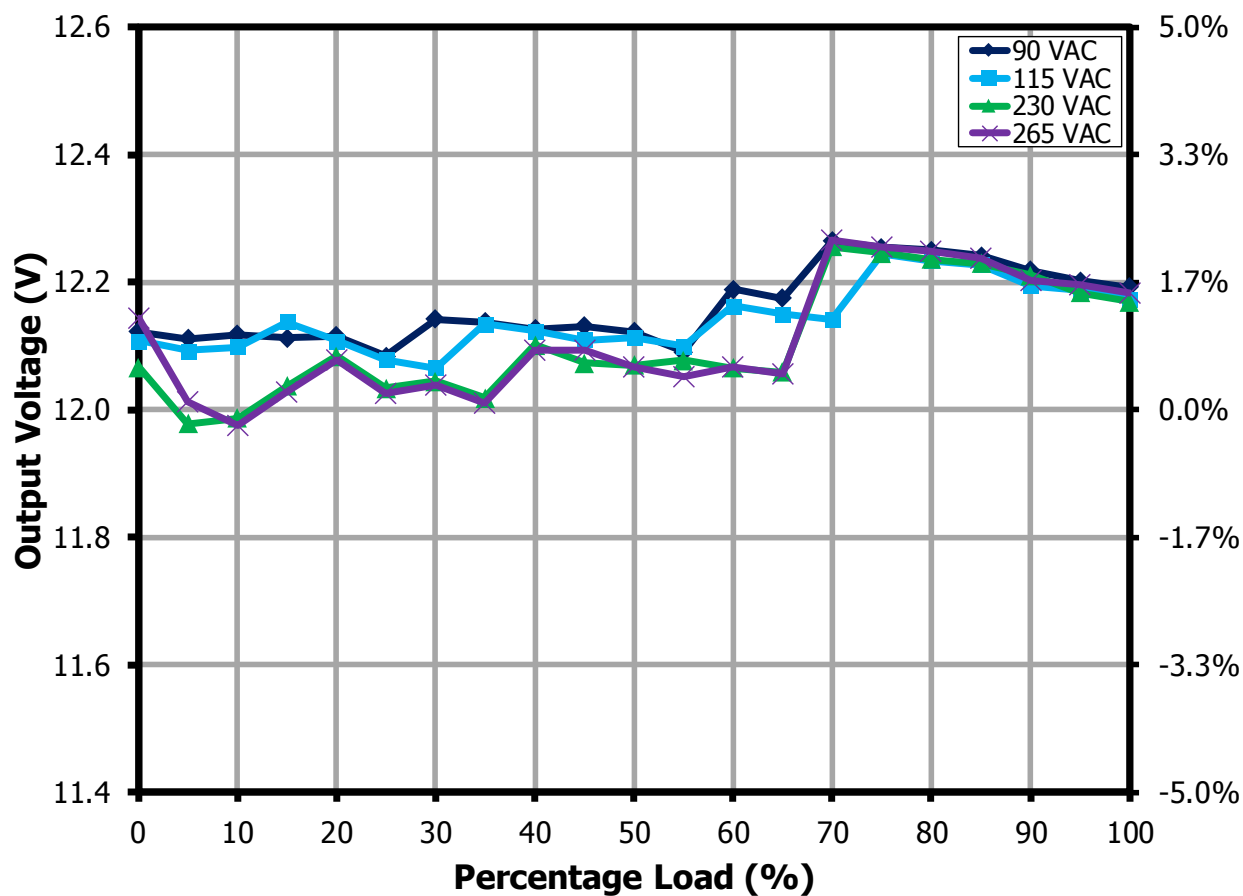
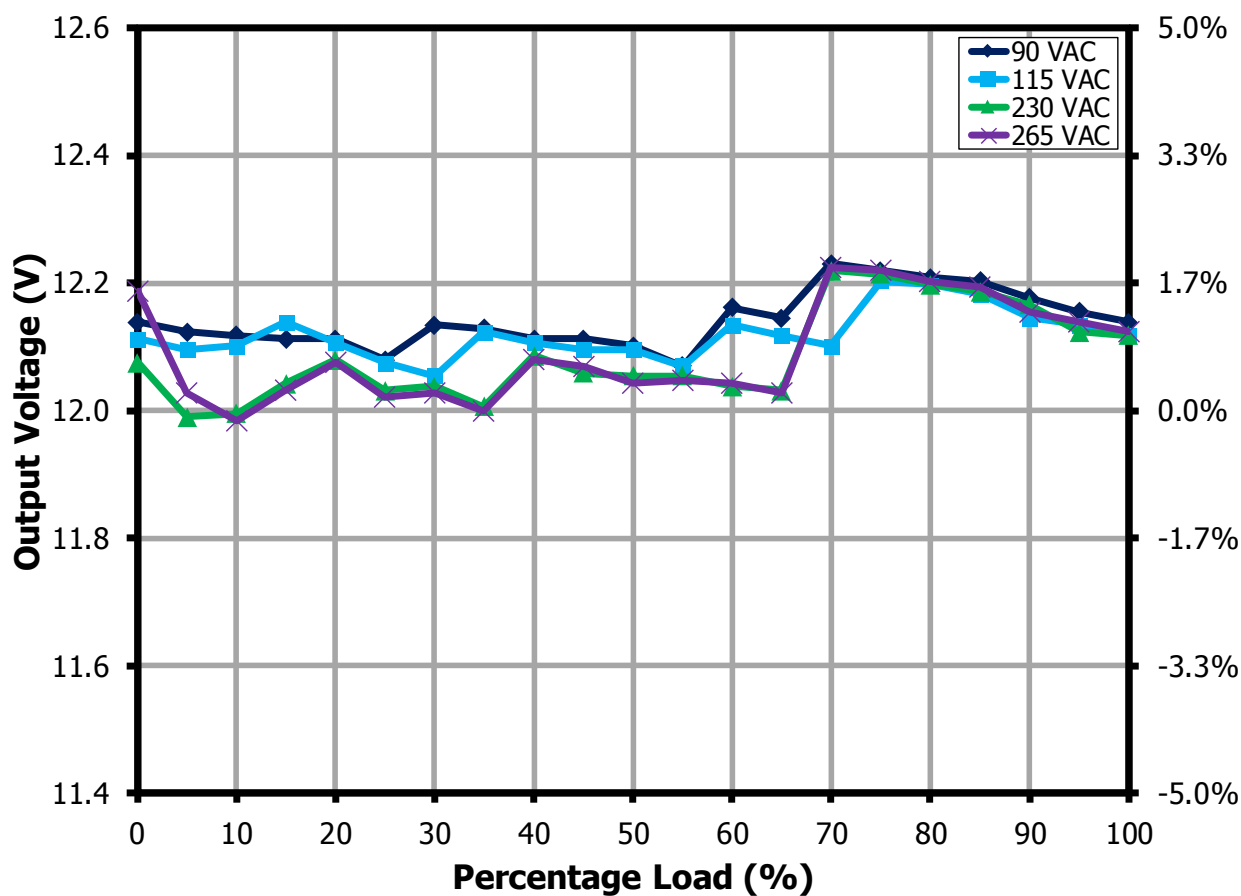


**Figure 20** – Load Regulation (Across PCB Connector).

13.1.2 Measured at the End of 100 m $\Omega$  Cable**Figure 21** – Load Regulation (At End of 100 m $\Omega$  Cable).

## 14 Thermal Performance

### 14.1 *Thermal Scan at Room Temperature*

Open frame unit was placed inside the enclosure to prevent airflow that may affect the thermal measurements. Temperature was measured using Thermal Camera. Soak time at full load is 2 hours.

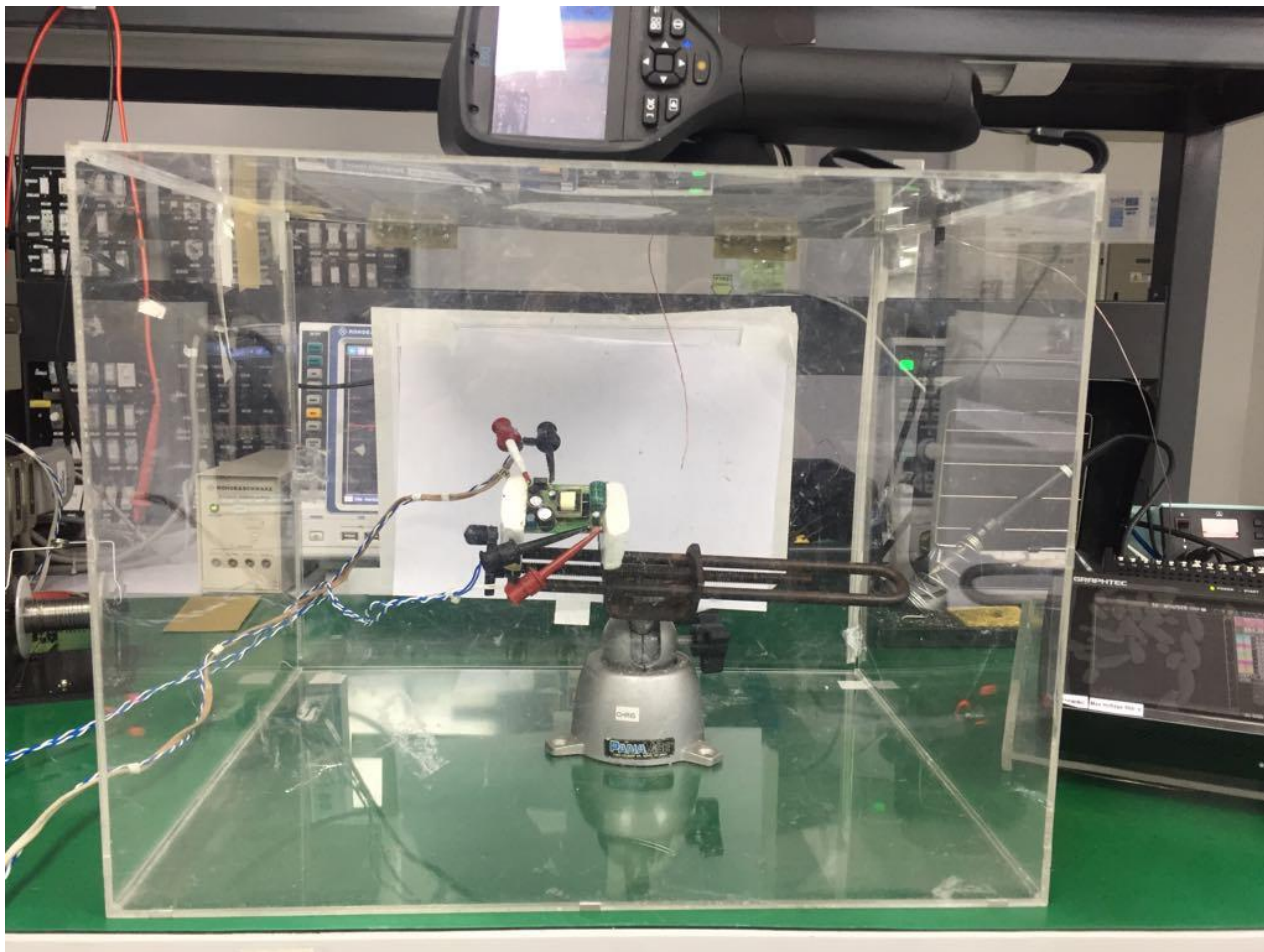


**Figure 22 – Test Set-up.**

## 14.1.1 90 VAC

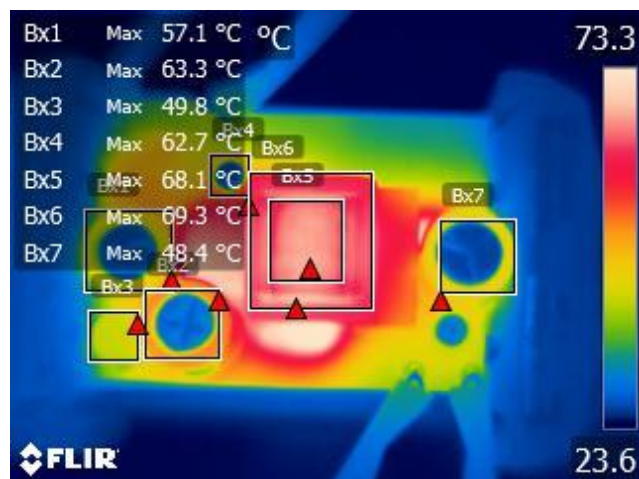


**Figure 23** – 90 VAC, 0.7 A Load. Top Side.  
Ambient = 27.5 °C.

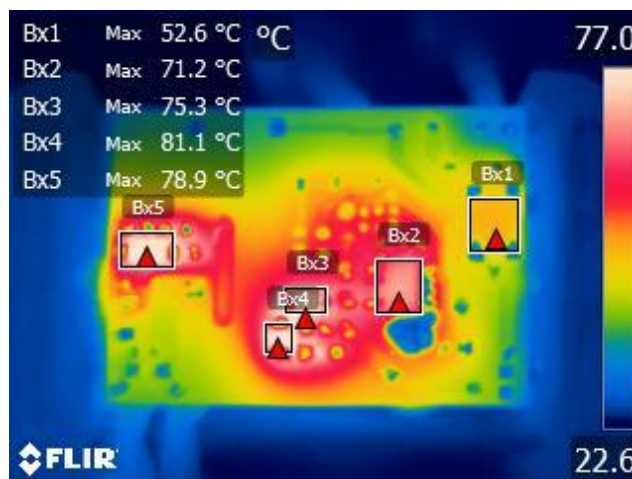


**Figure 24** – 90 VAC, 0.7 A Load. Bottom Side.  
Ambient = 27.5 °C.

| Component                    | Temperature (°C) |
|------------------------------|------------------|
| IC (U1)                      | 71.2             |
| Bridge Rectifier (BR1)       | 52.6             |
| Freewheel Diode (D1)         | 78.9             |
| Snubber Diode (D3)           | 81.1             |
| Input Choke (L1)             | 49.8             |
| Transformer-Core (T1-core)   | 69.3             |
| Transformer-Winding (T1-wdg) | 68.1             |
| Input Capacitor (C1)         | 57.1             |
| Input Capacitor (C2)         | 63.3             |
| Output Capacitor (C3)        | 48.4             |
| Bias Capacitor (C4)          | 62.7             |
| Snubber Resistor (R5)        | 81.1             |

## 14.1.2 115 VAC

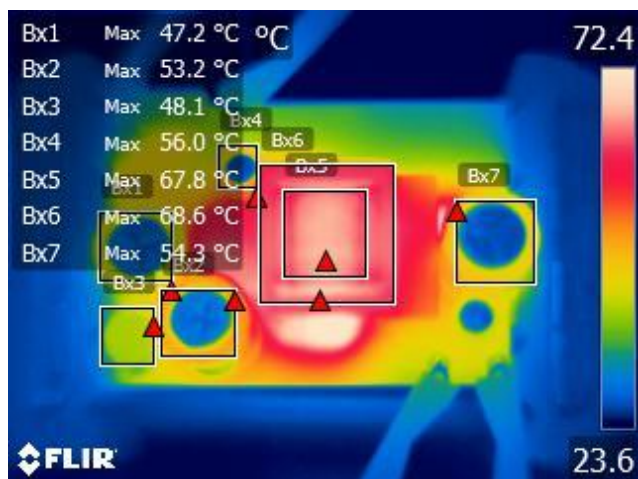


**Figure 25** – 115 VAC, 0.7 A Load. Top Side.  
Ambient = 27.5 °C.

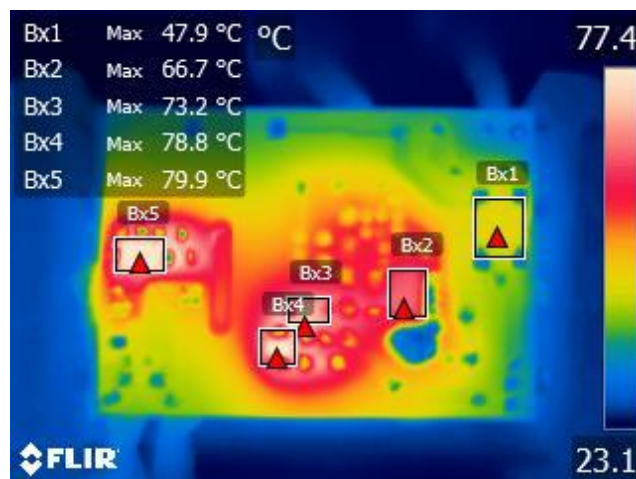


**Figure 26** – 115 VAC, 0.7 A Load. Bottom Side.  
Ambient = 27.5 °C.

| Component                    | Temperature (°C) |
|------------------------------|------------------|
| IC (U1)                      | 66.7             |
| Bridge Rectifier (BR1)       | 47.9             |
| Freewheel Diode (D1)         | 79.9             |
| Snubber Diode (D3)           | 73.2             |
| Input Choke (L1)             | 48.1             |
| Transformer-Core (T1-core)   | 68.6             |
| Transformer-Winding (T1-wdg) | 67.8             |
| Input Capacitor (C1)         | 47.2             |
| Input Capacitor (C2)         | 53.2             |
| Output Capacitor (C3)        | 54.3             |
| Bias Capacitor (C4)          | 56.0             |
| Snubber Resistor (R5)        | 78.8             |

## 14.1.3 230 VAC

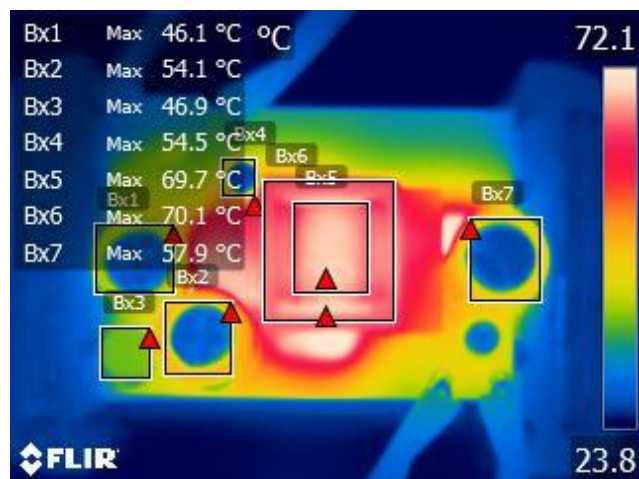


**Figure 27** – 230 VAC, 0.7 A Load. Top Side.  
Ambient = 27.5 °C.

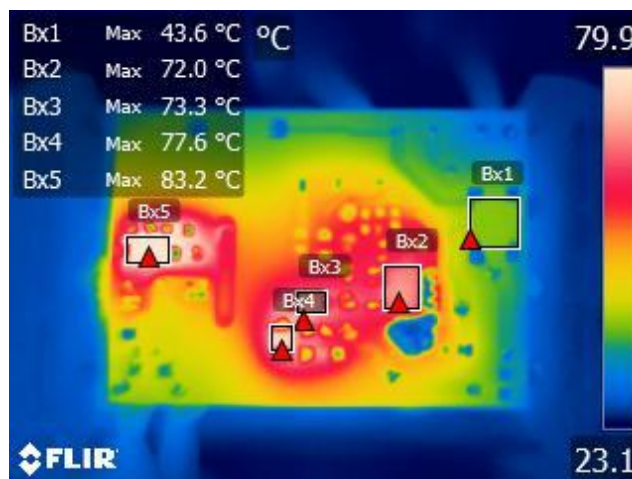


**Figure 28** – 230 VAC, 0.7 A Load. Bottom Side.  
Ambient = 27.5 °C.

| Component                    | Temperature (°C) |
|------------------------------|------------------|
| IC (U1)                      | 72.0             |
| Bridge Rectifier (BR1)       | 43.6             |
| Freewheel Diode (D1)         | 83.2             |
| Snubber Diode (D3)           | 73.3             |
| Input Choke (L1)             | 46.9             |
| Transformer-Core (T1-core)   | 70.1             |
| Transformer-Winding (T1-wdg) | 69.7             |
| Input Capacitor (C1)         | 46.1             |
| Input Capacitor (C2)         | 54.1             |
| Output Capacitor (C3)        | 57.9             |
| Bias Capacitor (C4)          | 54.5             |
| Snubber Resistor (R5)        | 77.6             |

## 14.1.4 265 VAC

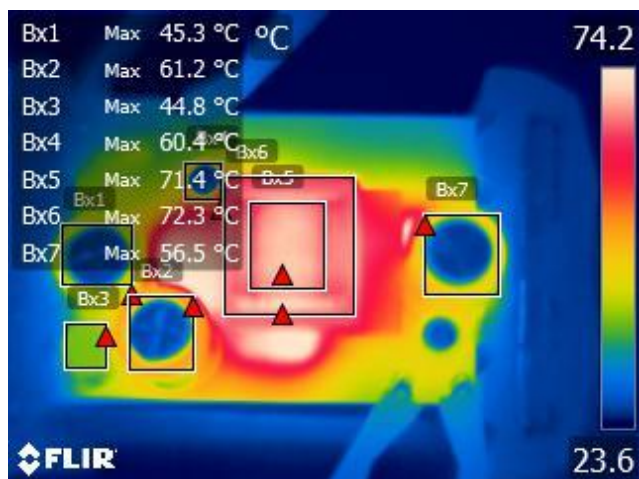


**Figure 29** – 265 VAC, 0.7 A Load. Top Side.  
Ambient = 27.5 °C.

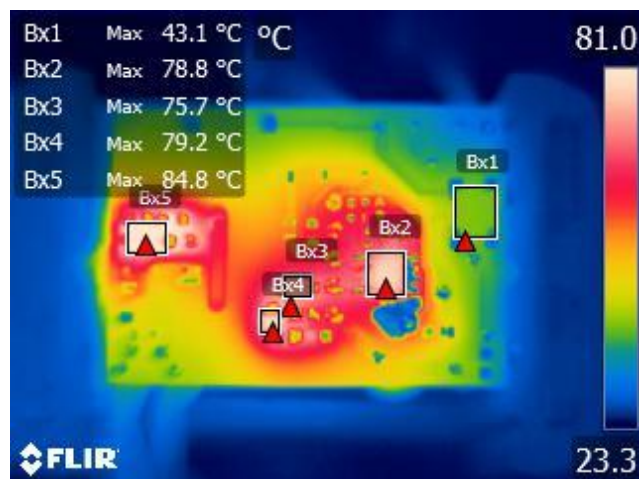


**Figure 30** – 265 VAC, 0.7 A Load.  
Ambient = 27.5 °C.

| Component                    | Temperature (°C) |
|------------------------------|------------------|
| IC (U1)                      | 78.8             |
| Bridge Rectifier (BR1)       | 43.1             |
| Freewheel Diode (D1)         | 84.4             |
| Snubber Diode (D3)           | 75.7             |
| Input Choke (L1)             | 44.8             |
| Transformer-Core (T1-core)   | 72.3             |
| Transformer-Winding (T1-wdg) | 71.4             |
| Input Capacitor (C1)         | 45.3             |
| Input Capacitor (C2)         | 61.2             |
| Output Capacitor (C3)        | 56.5             |
| Bias Capacitor (C4)          | 60.4             |
| Snubber Resistor (R5)        | 79.2             |

## 15 Thermal Performance at 70 °C

Open frame unit was placed inside the enclosure to prevent airflow that may affect the thermal measurements. Ambient temperature inside enclosure is 70 °C. Temperature was measured using type T thermocouple. Soak time at full load is 1 hour.

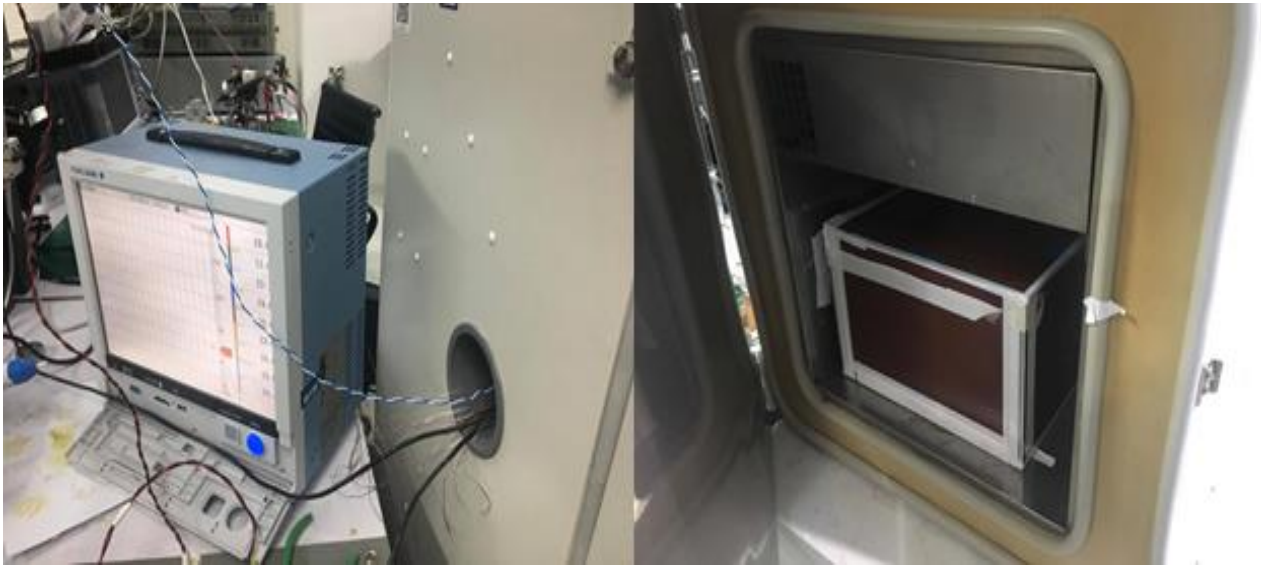
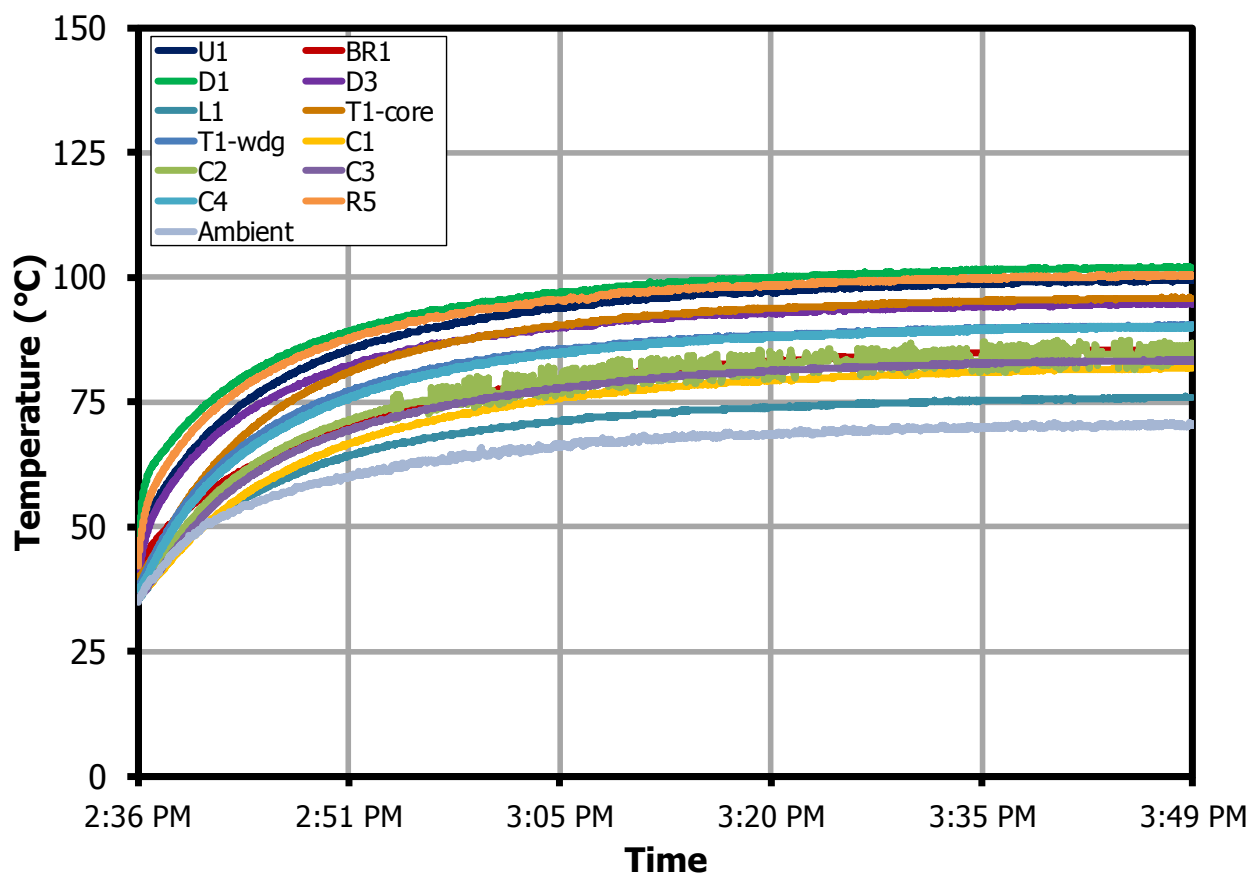
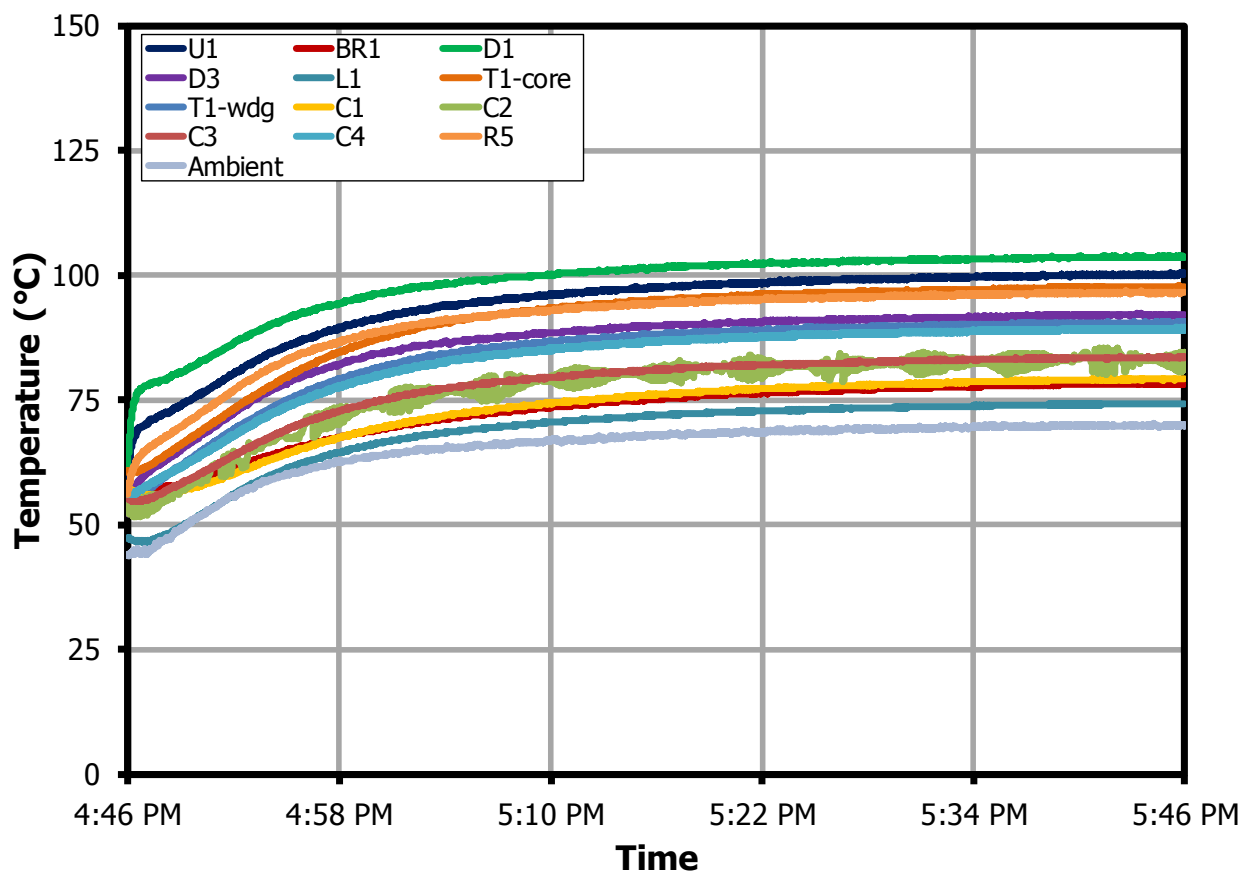


**Figure 31** – Test Set-up.

15.1 **90 VAC****Figure 32** – Thermal Performance at 70 °C (90 VAC).

| Component                    | Temperature (°C) |
|------------------------------|------------------|
| IC (U1)                      | 99.3             |
| Bridge Rectifier (BR1)       | 85.6             |
| Freewheel Diode (D1)         | 101.9            |
| Snubber Diode (D3)           | 94.7             |
| Input Choke (L1)             | 75.9             |
| Transformer-Core (T1-core)   | 95.9             |
| Transformer-Winding (T1-wdg) | 90.3             |
| Input Capacitor (C1)         | 81.9             |
| Input Capacitor (C2)         | 85.6             |
| Output Capacitor (C3)        | 83.3             |
| Bias Capacitor (C4)          | 90.1             |
| Snubber Resistor (R5)        | 100.4            |
| Ambient Temperature          | 70.4             |

15.2 **265 VAC****Figure 33** – Thermal Performance at 70 °C (265 VAC).

| Component                    | Temperature (°C) |
|------------------------------|------------------|
| IC (U1)                      | 100.4            |
| Bridge Rectifier (BR1)       | 78.4             |
| Freewheel Diode (D1)         | 103.7            |
| Snubber Diode (D3)           | 92.2             |
| Input Choke (L1)             | 74.3             |
| Transformer-Core (T1-core)   | 97.8             |
| Transformer-Winding (T1-wdg) | 90.7             |
| Input Capacitor (C1)         | 79.3             |
| Input Capacitor (C2)         | 81.6             |
| Output Capacitor (C3)        | 83.7             |
| Bias Capacitor (C4)          | 89.2             |
| Snubber Resistor (R5)        | 96.6             |
| Ambient Temperature          | 70.0             |

## 16 Over Temperature Protection

### 16.1 90 VAC

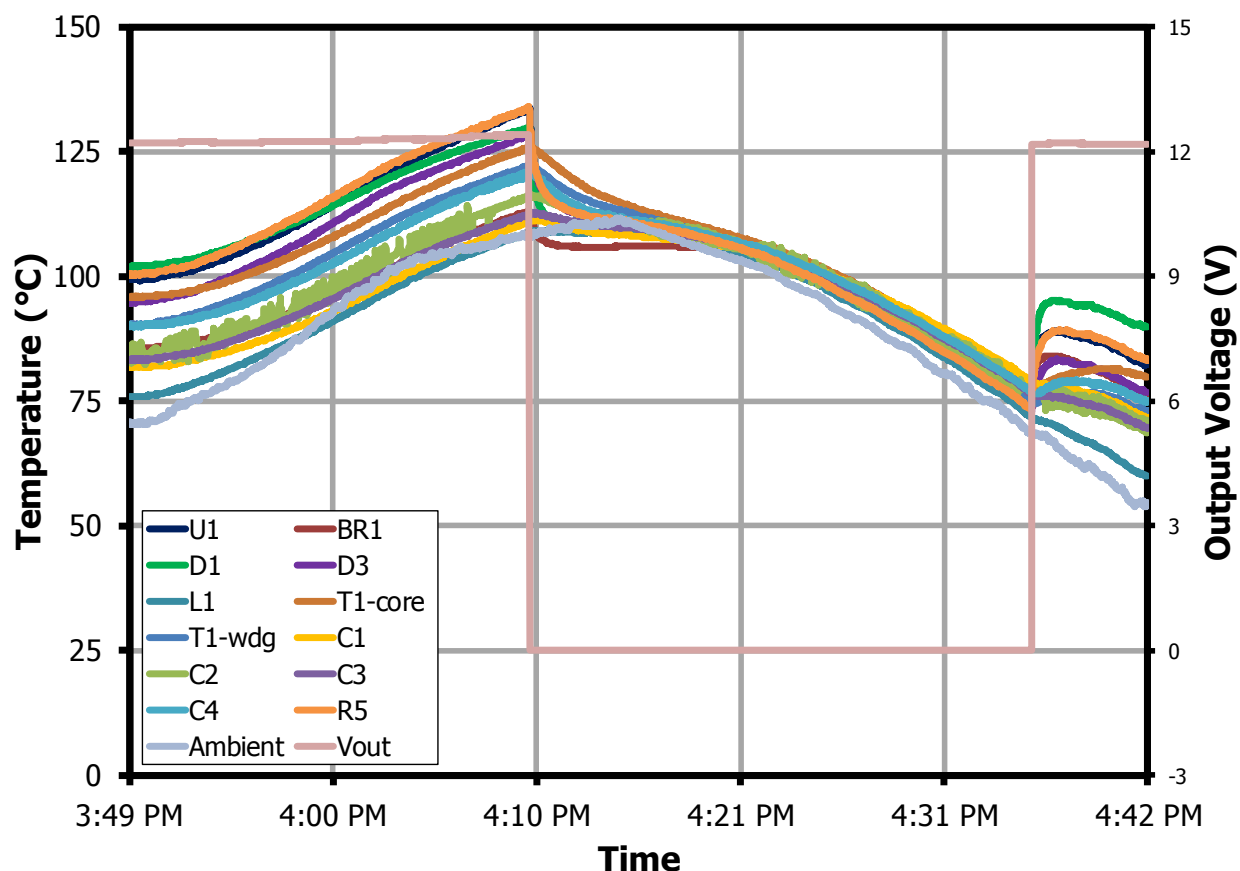
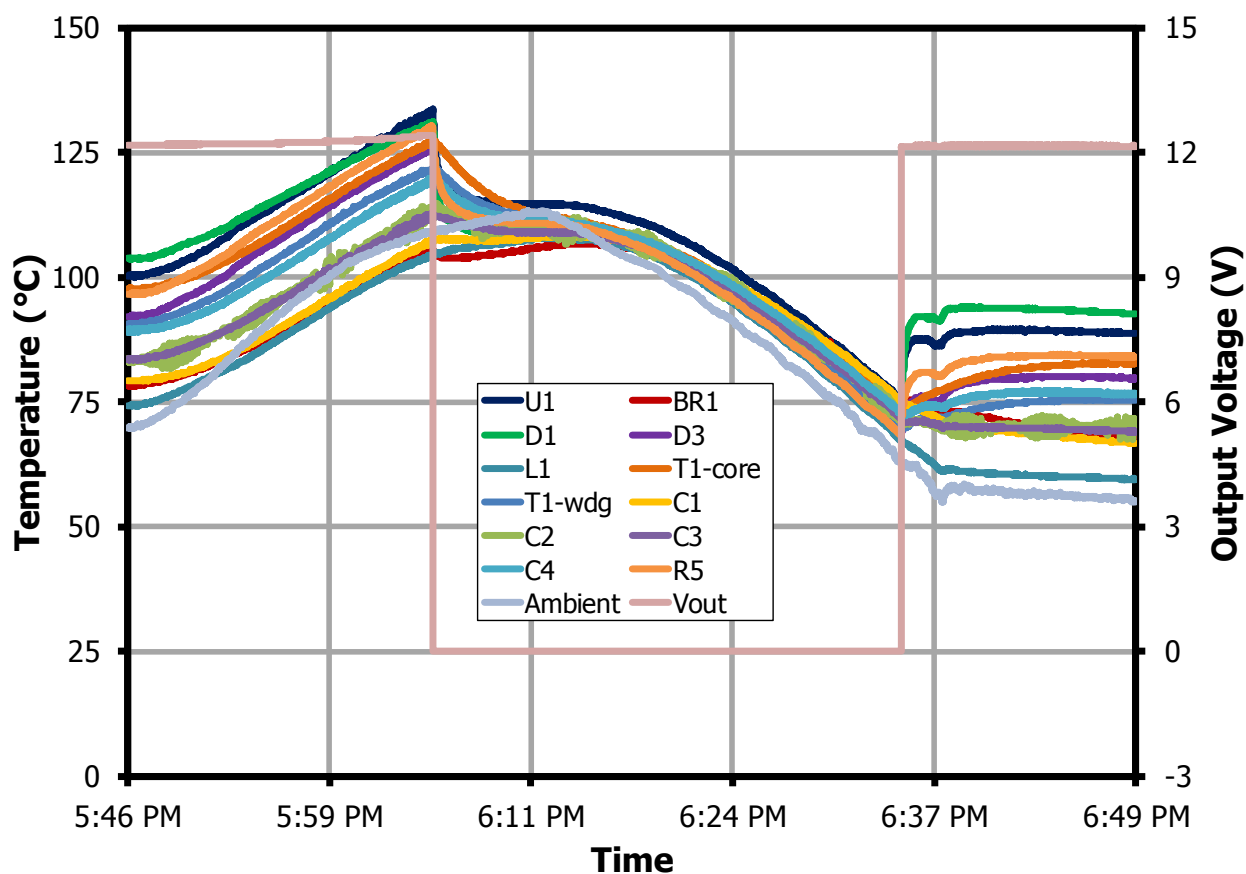


**Figure 34** – 90 VAC Over Temperature Protection.

| Component                    | At OTP Trigger Temperature (°C) | At Recovery Temperature (°C) |
|------------------------------|---------------------------------|------------------------------|
| IC (U1)                      | 133.6                           | 76.6                         |
| Bridge Rectifier (BR1)       | 113.2                           | 78.5                         |
| Freewheel Diode (D1)         | 129.9                           | 76.3                         |
| Snubber Diode (D3)           | 128.5                           | 72.8                         |
| Input Choke (L1)             | 108.8                           | 71.9                         |
| Transformer-Core (T1-core)   | 125.9                           | 78.0                         |
| Transformer-Winding (T1-wdg) | 122.2                           | 74.7                         |
| Input Capacitor (C1)         | 111.0                           | 79.0                         |
| Input Capacitor (C2)         | 115.9                           | 76.3                         |
| Output Capacitor (C3)        | 112.4                           | 76.5                         |
| Bias Capacitor (C4)          | 120.7                           | 76.8                         |
| Snubber Resistor (R5)        | 133.9                           | 73.6                         |
| Ambient Temperature          | 108.5                           | 68.5                         |



16.2 **265 VAC****Figure 35** – 265 VAC Over Temperature Protection.

| Component                    | At OTP Trigger Temperature (°C) | At Recovery Temperature (°C) |
|------------------------------|---------------------------------|------------------------------|
| IC (U1)                      | 133.2                           | 75.5                         |
| Bridge Rectifier (BR1)       | 105.5                           | 74.3                         |
| Freewheel Diode (D1)         | 130.8                           | 71.1                         |
| Snubber Diode (D3)           | 125.8                           | 67.8                         |
| Input Choke (L1)             | 104.5                           | 67.3                         |
| Transformer-Core (T1-core)   | 127.1                           | 73.6                         |
| Transformer-Winding (T1-wdg) | 121.8                           | 70                           |
| Input Capacitor (C1)         | 107.1                           | 75.3                         |
| Input Capacitor (C2)         | 114.1                           | 71.6                         |
| Output Capacitor (C3)        | 112                             | 71.8                         |
| Bias Capacitor (C4)          | 120                             | 72.8                         |
| Snubber Resistor (R5)        | 130.2                           | 68.7                         |
| Ambient Temperature          | 109.1                           | 62.7                         |

## 17 Test Waveforms

### 17.1 Load Transient Response

Measured across PCB connector.

#### 17.1.1 0% - 100% Load Condition

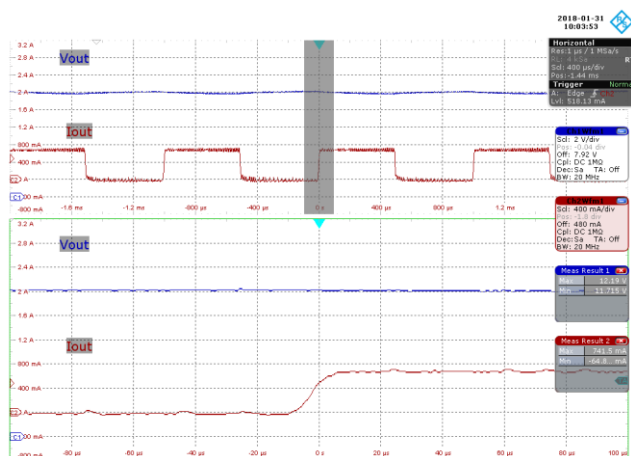


**Figure 36** – 90 VAC 60 Hz, 0% - 100% Load.  
 CH1:  $V_{OUT}$ , 2 V / div., 400  $\mu$ s / div.  
 CH2:  $I_{LOAD}$ , 400 mA / div., 400  $\mu$ s / div.  
 Zoom: 20  $\mu$ s / div.  
 $V_{MAX}$ : 12.19 V,  $V_{MIN}$ : 11.715 V.

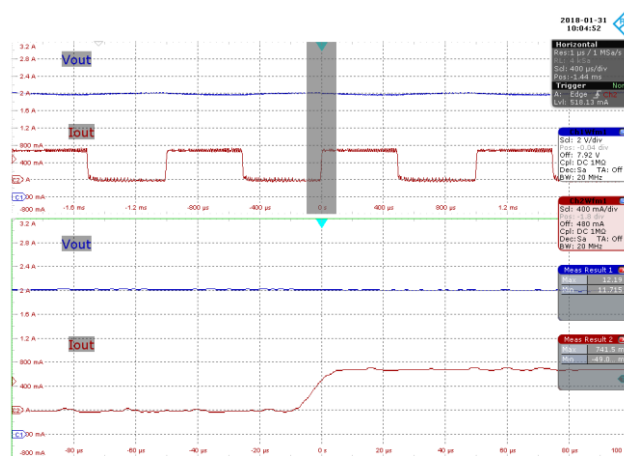


**Figure 37** – 115 VAC 60 Hz, 0% - 100% Load.  
 CH1:  $V_{OUT}$ , 2 V / div., 400  $\mu$ s / div.  
 CH2:  $I_{LOAD}$ , 400 mA / div., 400  $\mu$ s / div.  
 Zoom: 20  $\mu$ s / div.  
 $V_{MAX}$ : 12.19 V,  $V_{MIN}$ : 11.715 V.

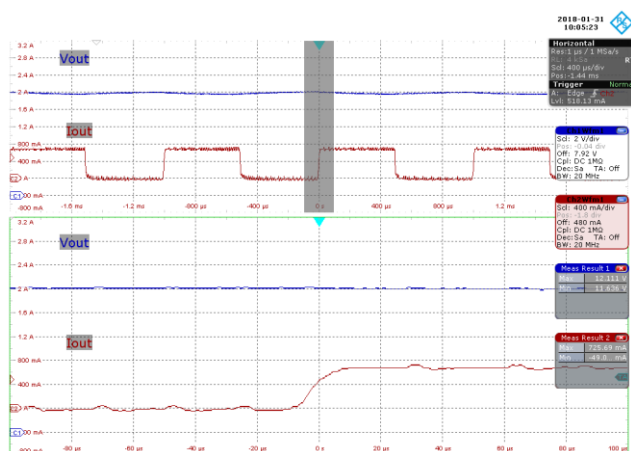


**Figure 38** – 230 VAC 60 Hz, 0% - 100% Load.  
 CH1:  $V_{OUT}$ , 2 V / div., 400  $\mu$ s / div.  
 CH2:  $I_{LOAD}$ , 400 mA / div., 400  $\mu$ s / div.  
 Zoom: 20  $\mu$ s / div.  
 $V_{MAX}$ : 12.111 V,  $V_{MIN}$ : 11.636 V.

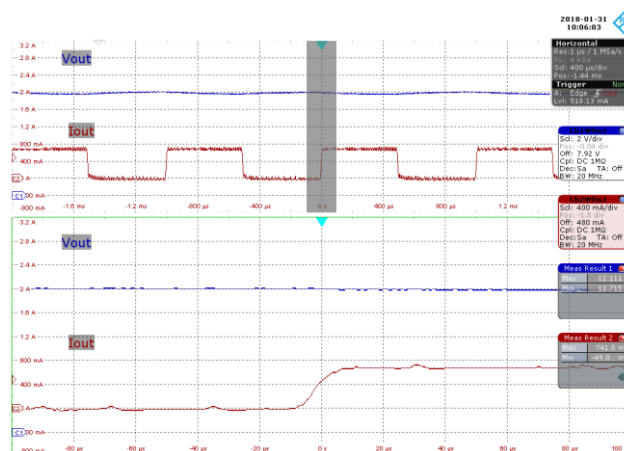


**Figure 39** – 265 VAC 60 Hz, 0% - 100% Load.  
 CH1:  $V_{OUT}$ , 2 V / div., 400  $\mu$ s / div.  
 CH2:  $I_{LOAD}$ , 400 mA / div., 400  $\mu$ s / div.  
 Zoom: 20  $\mu$ s / div.  
 $V_{MAX}$ : 12.111 V,  $V_{MIN}$ : 11.715 V.

## 17.1.2 50% - 100% Load Condition

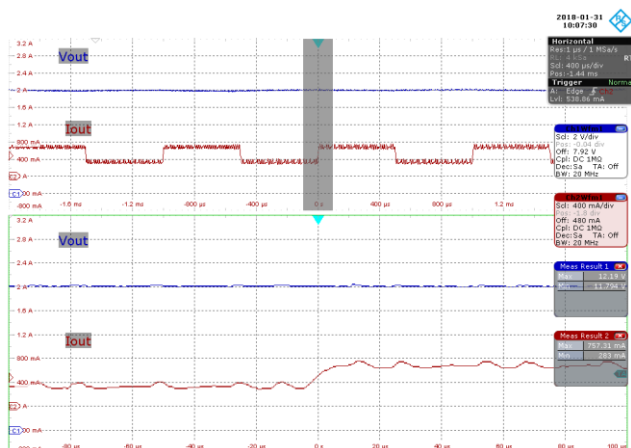


**Figure 40** – 90 VAC 60 Hz, 50% - 100% Load.  
 CH1: V<sub>OUT</sub>, 2 V / div., 400 μs / div.  
 CH2: I<sub>LOAD</sub>, 400m A / div., 400 μs / div.  
 Zoom: 20 μs / div.  
 V<sub>MAX</sub>: 12.19 V, V<sub>MIN</sub>: 11.794 V.

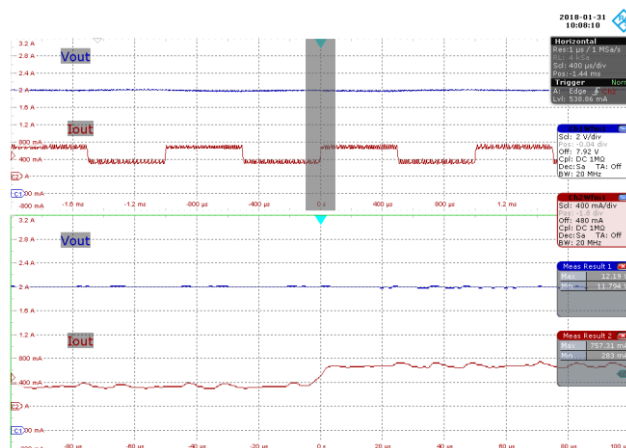


**Figure 41** – 115 VAC 60 Hz, 50% - 100% Load.  
 CH1: V<sub>OUT</sub>, 2 V / div., 400 μs / div.  
 CH2: I<sub>LOAD</sub>, 400m A / div., 400 μs / div.  
 Zoom: 20 μs / div.  
 V<sub>MAX</sub>: 12.19 V, V<sub>MIN</sub>: 11.794 V.

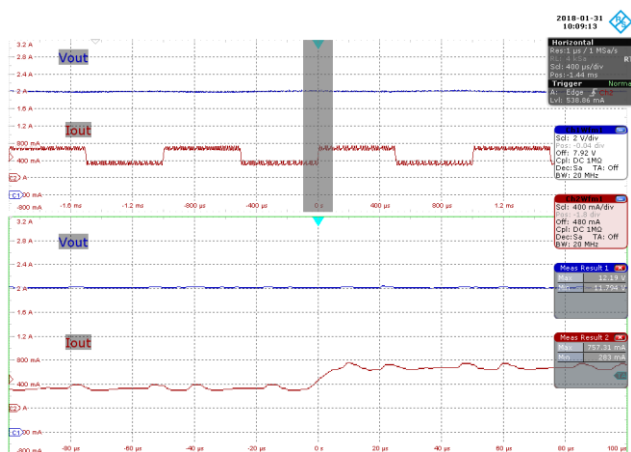


**Figure 42** – 230 VAC 60 Hz, 50% - 100% Load.  
 CH1: V<sub>OUT</sub>, 2 V / div., 400 μs / div.  
 CH2: I<sub>LOAD</sub>, 400m A / div., 400 μs / div.  
 Zoom: 20 μs / div.  
 V<sub>MAX</sub>: 12.19 V, V<sub>MIN</sub>: 11.794 V.

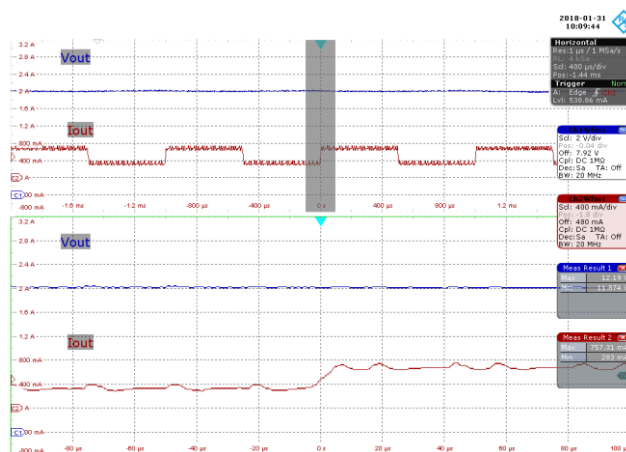


**Figure 43** – 265 VAC 60 Hz, 50% - 100% Load.  
 CH1: V<sub>OUT</sub>, 2 V / div., 400 μs / div.  
 CH2: I<sub>LOAD</sub>, 400m A / div., 400 μs / div.  
 Zoom: 20 μs / div.  
 V<sub>MAX</sub>: 12.19 V, V<sub>MIN</sub>: 11.874 V.

## 17.2 Output Voltage at Start-up

### 17.2.1 Measured at the End of 1.2m #22 Cable

### 17.2.2 CC mode

#### 17.2.2.1 100% Load

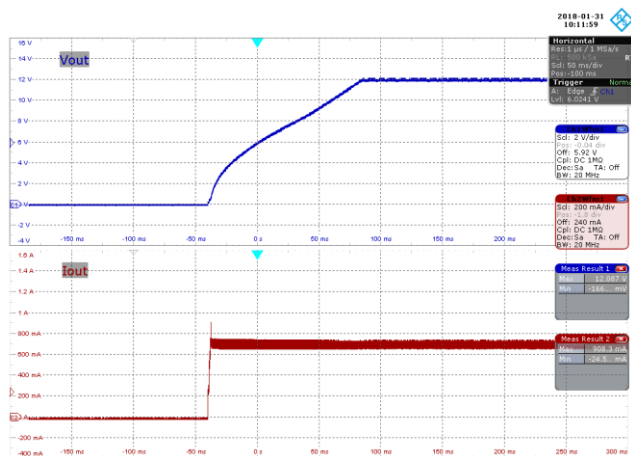


**Figure 44** – 90 VAC 60 Hz, Full Load Start-up.  
Upper:  $V_{out}$ , 2 V / div., 50 ms / div.  
Lower:  $I_{out}$ , 200 mA / div., 50 ms / div.

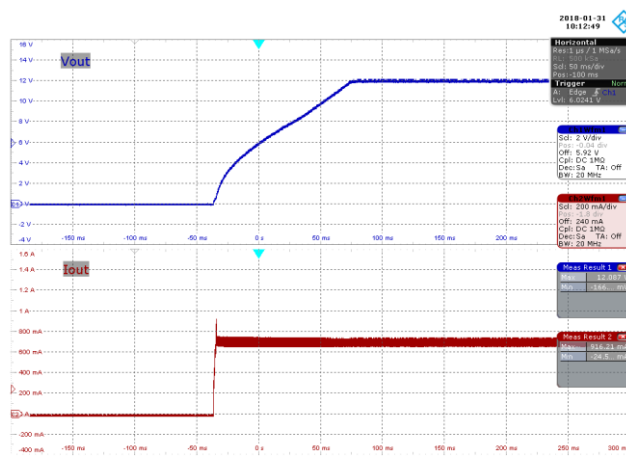


**Figure 45** – 115 VAC 60 Hz, Full Load Start-up.  
Upper:  $V_{out}$ , 2 V / div., 50 ms / div.  
Lower:  $I_{out}$ , 200 mA / div., 50 ms / div.

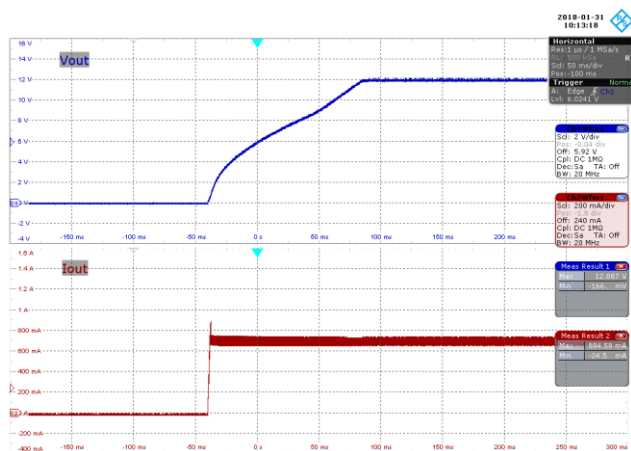


**Figure 46** – 230 VAC 60 Hz, Full Load Start-up.  
Upper:  $V_{out}$ , 2 V / div., 50 ms / div.  
Lower:  $I_{out}$ , 200 mA / div., 50 ms / div.

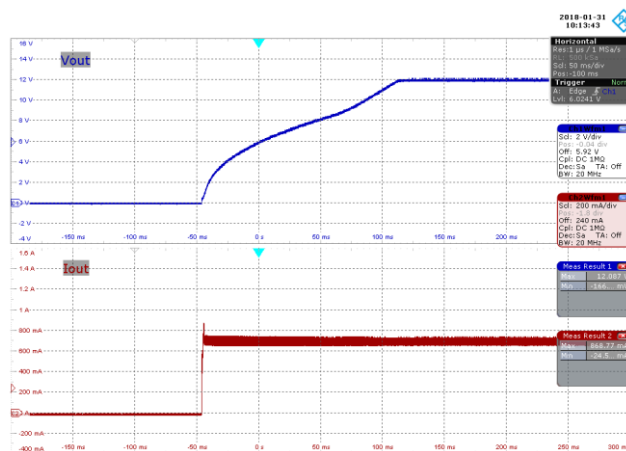
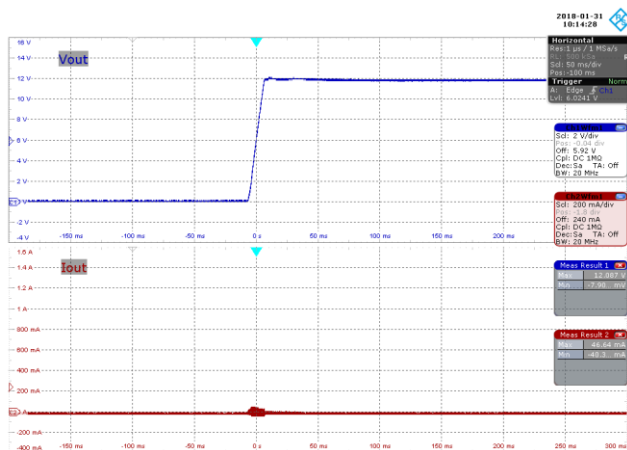
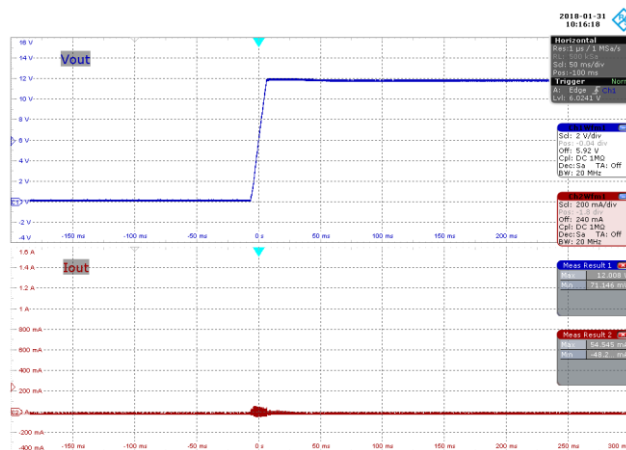
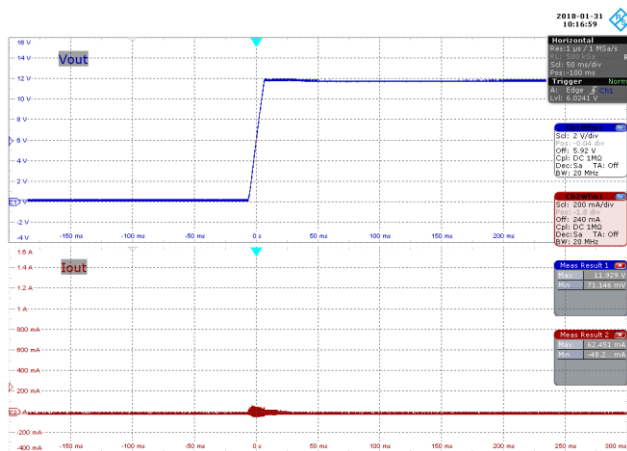
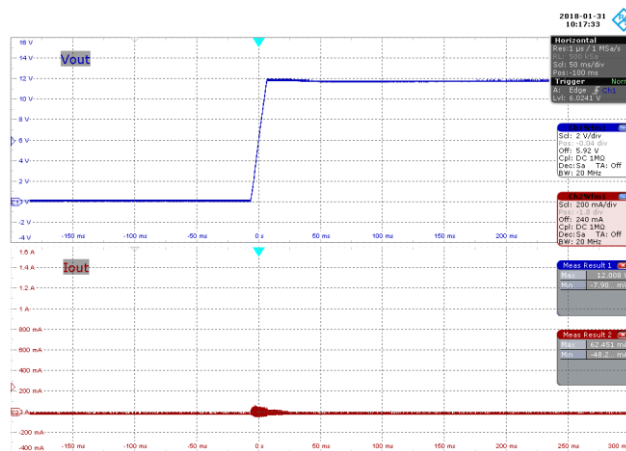


**Figure 47** – 265 VAC 60 Hz, Full Load Start-up.  
Upper:  $V_{out}$ , 2 V / div., 50 ms / div.  
Lower:  $I_{out}$ , 200 mA / div., 50 ms / div.

## 17.2.2.2 0% Load

**Figure 48** – 90 VAC 60 Hz, No-Load Start-up.Upper:  $V_{OUT}$ , 2 V / div., 50 ms / div.Lower:  $I_{OUT}$ , 200 mA / div., 50 ms / div.**Figure 49** – 115 VAC 60 Hz, No-Load Start-up.Upper:  $V_{OUT}$ , 2 V / div., 50 ms / div.Lower:  $I_{OUT}$ , 200 mA / div., 50 ms / div.**Figure 50** – 230 VAC 60 Hz, No-Load Start-up.Upper:  $V_{OUT}$ , 2 V / div., 50 ms / div.Lower:  $I_{OUT}$ , 200 mA / div., 50 ms / div.**Figure 51** – 265 VAC 60 Hz, No-Load Start-up.Upper:  $V_{OUT}$ , 2 V / div., 50 ms / div.Lower:  $I_{OUT}$ , 200 mA / div., 50 ms / div.

## 17.2.3 CR mode

## 17.2.3.1 100% Load

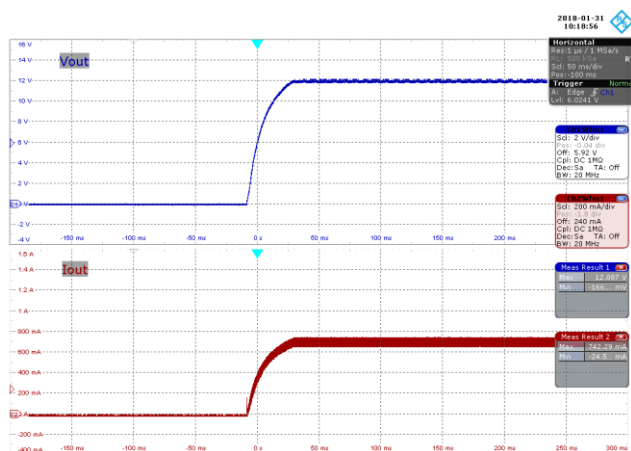


**Figure 52** – 90 VAC 60 Hz, Full Load Start-up.  
 Upper:  $V_{OUT}$ , 2 V / div., 50 ms / div.  
 Lower:  $I_{OUT}$ , 200 mA / div., 50 ms / div.

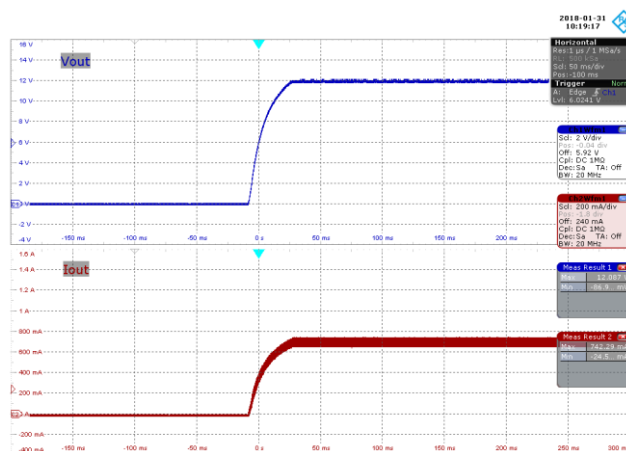


**Figure 53** – 115 VAC 60 Hz, Full Load Start-up.  
 Upper:  $V_{OUT}$ , 2 V / div., 50 ms / div.  
 Lower:  $I_{OUT}$ , 200 mA / div., 50 ms / div.

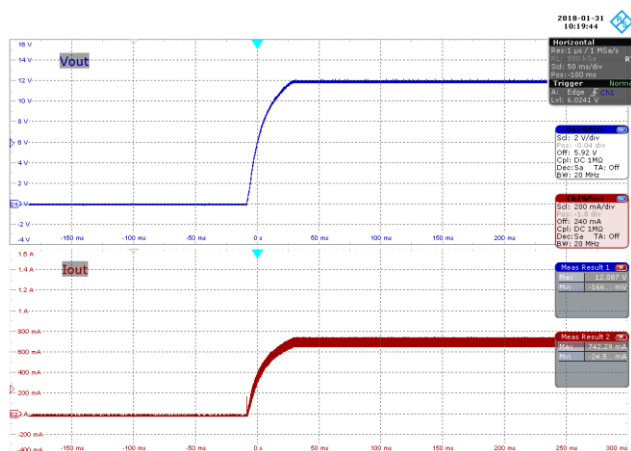


**Figure 54** – 230 VAC 60 Hz, Full Load Start-up.  
 Upper:  $V_{OUT}$ , 2 V / div., 50 ms / div.  
 Lower:  $I_{OUT}$ , 200 mA / div., 50 ms / div.

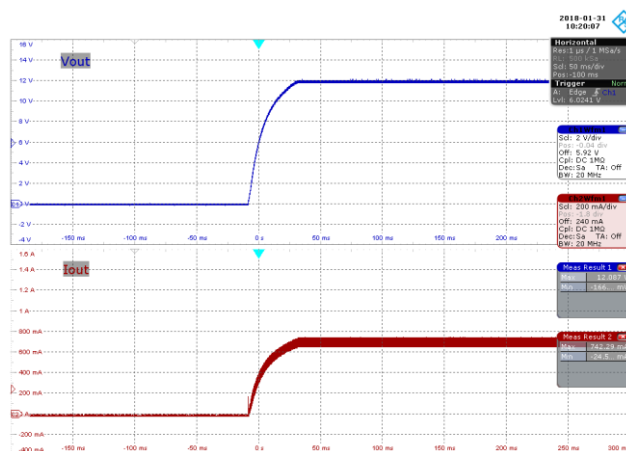


**Figure 55** – 265 VAC 60 Hz, Full Load Start-up.  
 Upper:  $V_{OUT}$ , 2 V / div., 50 ms / div.  
 Lower:  $I_{OUT}$ , 200 mA / div., 50 ms / div.

## 17.2.3.2 0% Load

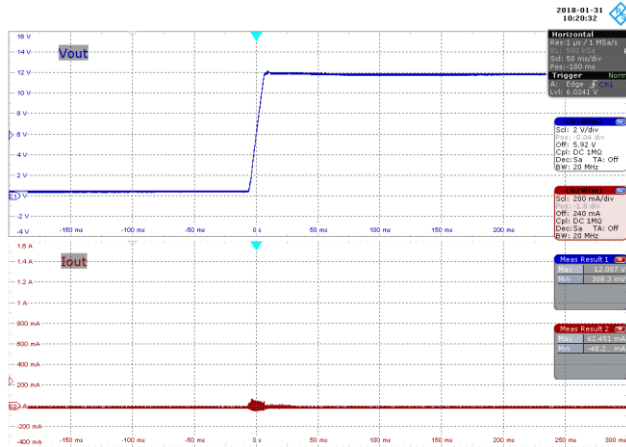


**Figure 56** – 90 VAC 60 Hz, No-Load Start-up.  
 Upper:  $V_{OUT}$ , 2 V / div., 50 ms / div.  
 Lower:  $I_{OUT}$ , 200 mA / div., 50 ms / div.

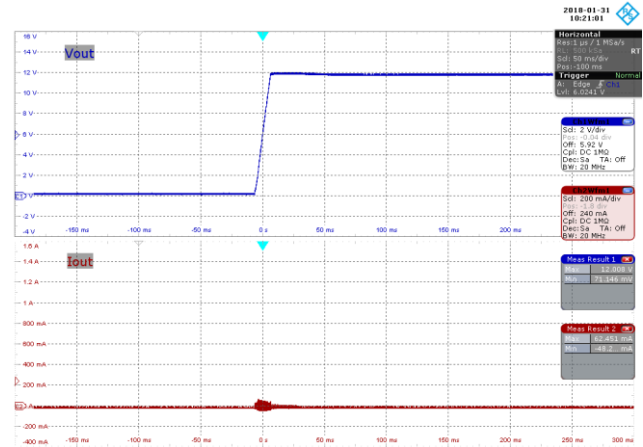


**Figure 57** – 115 VAC 60 Hz, No-Load Start-up.  
 Upper:  $V_{OUT}$ , 2 V / div., 50 ms / div.  
 Lower:  $I_{OUT}$ , 200 mA / div., 50 ms / div.

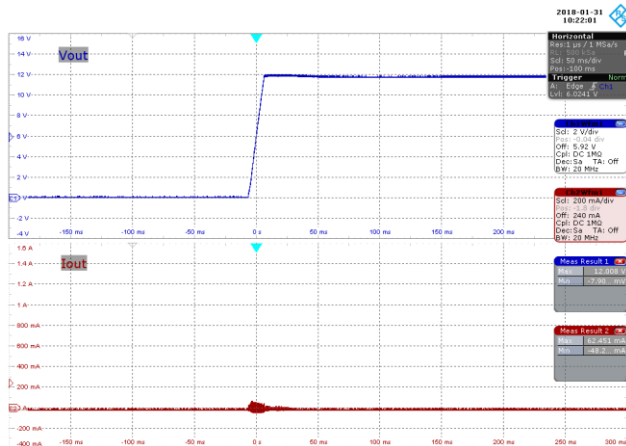


**Figure 58** – 230 VAC 60 Hz, No-Load Start-up.  
 Upper:  $V_{OUT}$ , 2 V / div., 50 ms / div.  
 Lower:  $I_{OUT}$ , 200 mA / div., 50 ms / div.

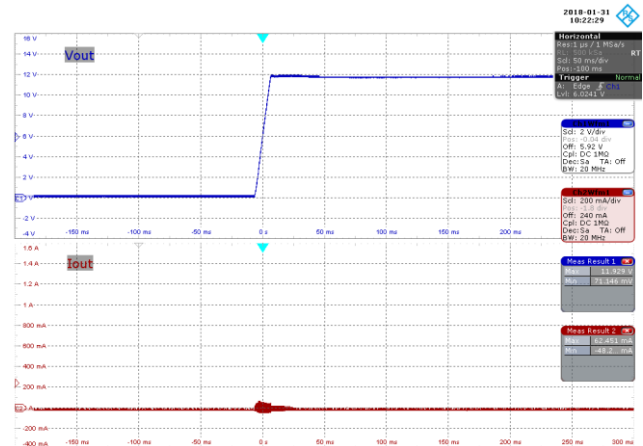


**Figure 59** – 265 VAC 60 Hz, No-Load Start-up.  
 Upper:  $V_{OUT}$ , 2 V / div., 50 ms / div.  
 Lower:  $I_{OUT}$ , 200 mA / div., 50 ms / div.

## 17.3 Switching Waveforms

### 17.3.1 Drain-to-Source Voltage and Current at Normal Operation

#### 17.3.1.1 100% Load

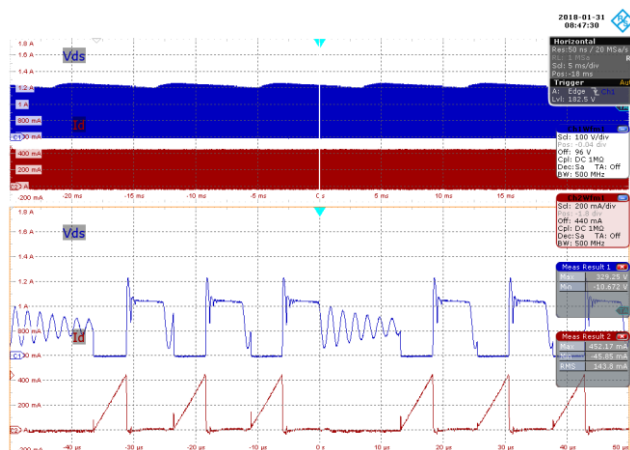


**Figure 60** – 90 VAC 60 Hz, Full Load.

CH1:  $V_{DS}$ , 100 V / div., 5 ms / div.

CH2:  $I_{DS}$ , 200 mA / div., 5 ms / div.

Zoom: 10  $\mu$ s / div.

$V_{DS(MAX)} = 329.25$  V,  $I_{DS(MAX)} = 452.2$  mA.

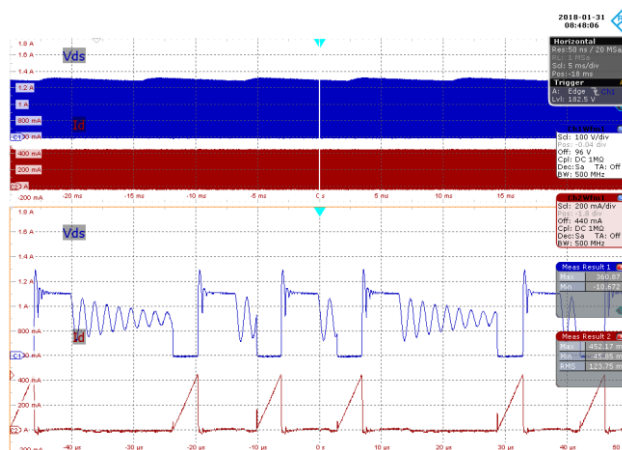


**Figure 61** – 115 VAC 60 Hz, Full Load.

CH1:  $V_{DS}$ , 100 V / div., 5 ms / div.

CH2:  $I_{DS}$ , 200 mA / div., 5 ms / div.

Zoom: 10  $\mu$ s / div.

$V_{DS(MAX)} = 360.87$  V,  $I_{DS(MAX)} = 452.2$  mA.

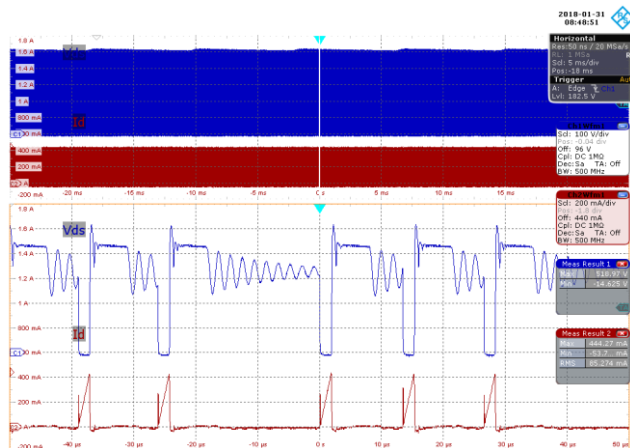


**Figure 62** – 230 VAC 60 Hz, Full Load.

CH1:  $V_{DS}$ , 100 V / div., 5 ms / div.

CH2:  $I_{DS}$ , 200 mA / div., 5 ms / div.

Zoom: 10  $\mu$ s / div.

$V_{DS(MAX)} = 518.97$  V,  $I_{DS(MAX)} = 444.3$  mA.

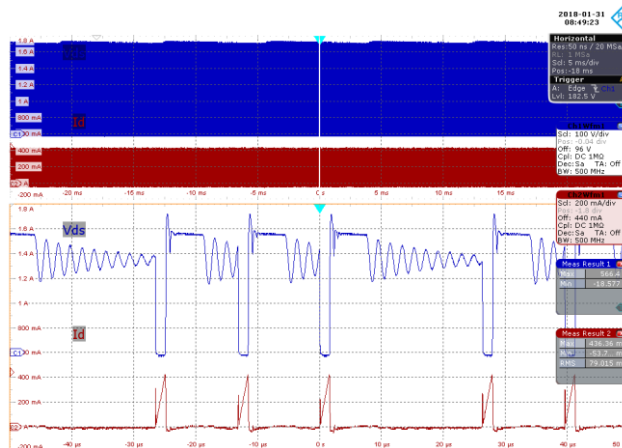


**Figure 63** – 265 VAC 60 Hz, Full Load.

CH1:  $V_{DS}$ , 100 V / div., 5 ms / div.

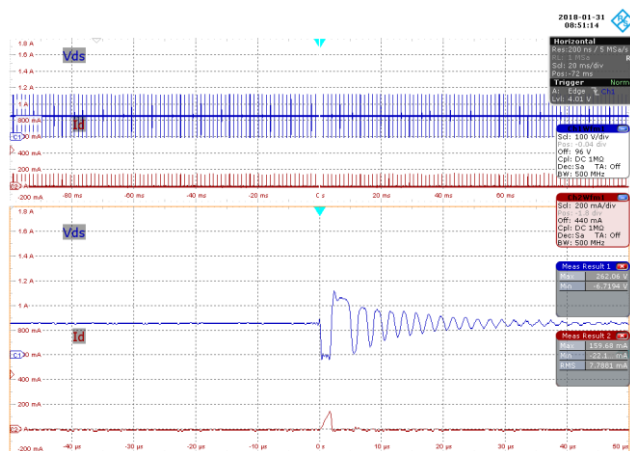
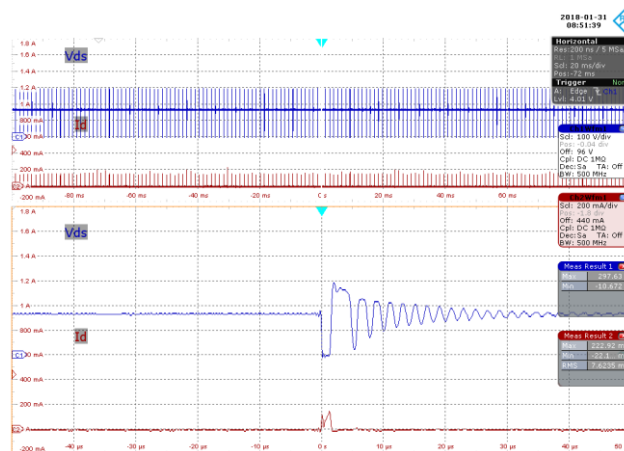
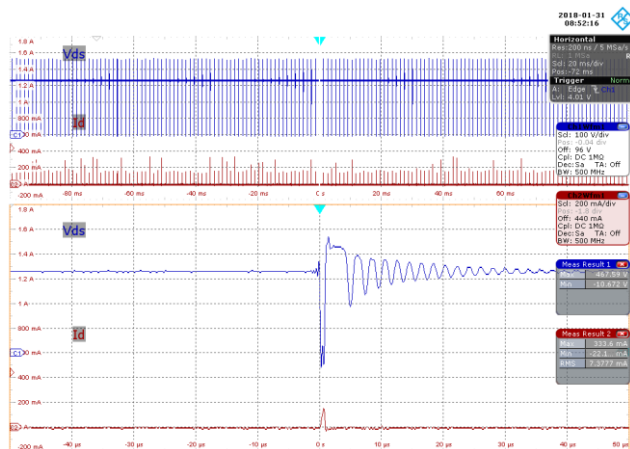
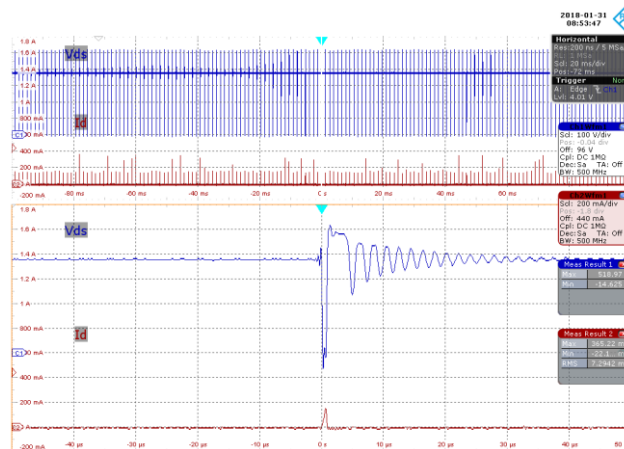
CH2:  $I_{DS}$ , 200 mA / div., 5 ms / div.

Zoom: 10  $\mu$ s / div.

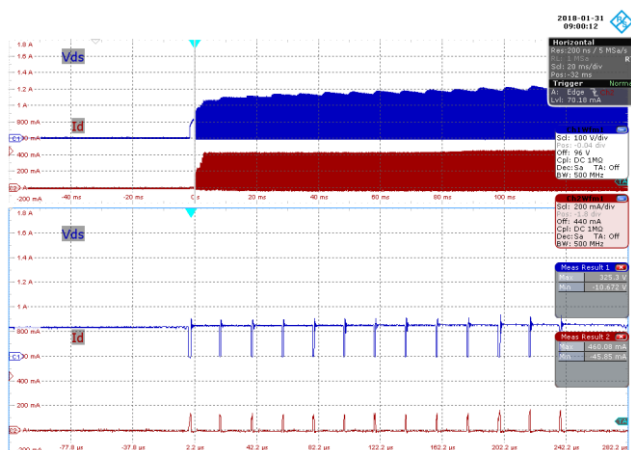
$V_{DS(MAX)} = 566.4$  V,  $I_{DS(MAX)} = 436.4$  mA.



## 17.3.1.2 0% Load

**Figure 64** – 90 VAC 60 Hz, No-Load.CH1:  $V_{DS}$ , 100 V / div., 20 ms / div.CH2:  $I_{DS}$ , 200 mA / div., 20 ms / div.Zoom: 10  $\mu$ s / div. $V_{DS(MAX)} = 262.06$  V,  $I_{DS(MAX)} = 159.7$  mA.**Figure 65** – 115 VAC 60 Hz, No-Load.CH1:  $V_{DS}$ , 100 V / div., 20 ms / div.CH2:  $I_{DS}$ , 200 mA / div., 20 ms / div.Zoom: 10  $\mu$ s / div. $V_{DS(MAX)} = 297.63$  V,  $I_{DS(MAX)} = 222.9$  mA.**Figure 66** – 230 VAC 60 Hz, No-Load.CH1:  $V_{DS}$ , 100 V / div., 20 ms / div.CH2:  $I_{DS}$ , 200 mA / div., 20 ms / div.Zoom: 10  $\mu$ s / div. $V_{DS(MAX)} = 467.59$  V,  $I_{DS(MAX)} = 333.6$  mA**Figure 67** – 265 VAC 60 Hz, No-Load.CH1:  $V_{DS}$ , 100 V / div., 20 ms / div.CH2:  $I_{DS}$ , 200 mA / div., 20 ms / div.Zoom: 10  $\mu$ s / div. $V_{DS(MAX)} = 518.97$  V,  $I_{DS(MAX)} = 365.22$  mA.

### 17.3.2.1 100% Load



2019-01-31 09:08:30

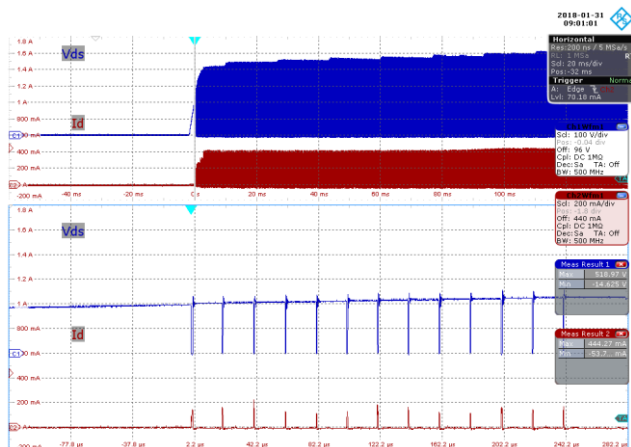
Horizontal  
Pos: 200 ns / 500 mV  
Div: 20 ns  
Pan: 0.0000  
Roll: 0.0000  
Trigger  
Mode: Auto  
Slope: +  
Cou: 75.18 mV

Id: 100 V/div  
Off: 0.6 V  
Ch1 DC: 1MΩ  
Devs: TA: Off  
BW: 500 MHz

Id: 200 mA/div  
Off: 440 mA  
Ch1 DC: 1MΩ  
Devs: TA: Off  
BW: 500 MHz

Meas Result 1  
Val: 500.87  
Ref: 500.00  
Unit: mA

Meas Result 2  
Val: 10.12  
Ref: 10.00  
Unit: V

[illegible]

## 17.3.2.2 0% Load

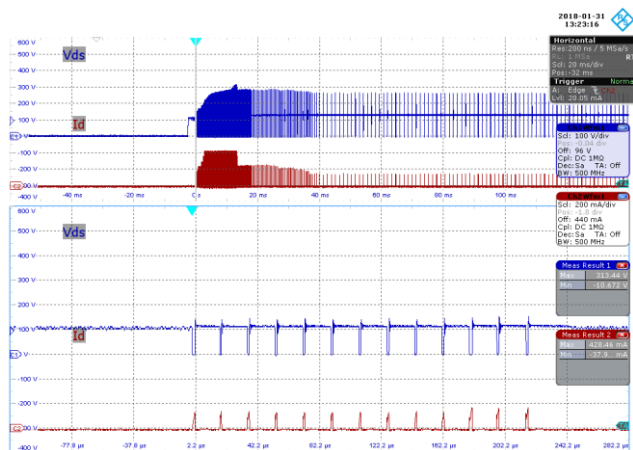


**Figure 72** – 90 VAC 60 Hz, No-Load Start-up.  
 CH1:  $V_{DS}$ , 100 V / div., 20 ms / div.  
 CH2:  $I_{DS}$ , 200 mA / div., 20 ms / div.  
 Zoom: 40  $\mu$ s / div.  
 $V_{DS(MAX)} = 313.44$  V,  $I_{DS(MAX)} = 428.46$  mA.

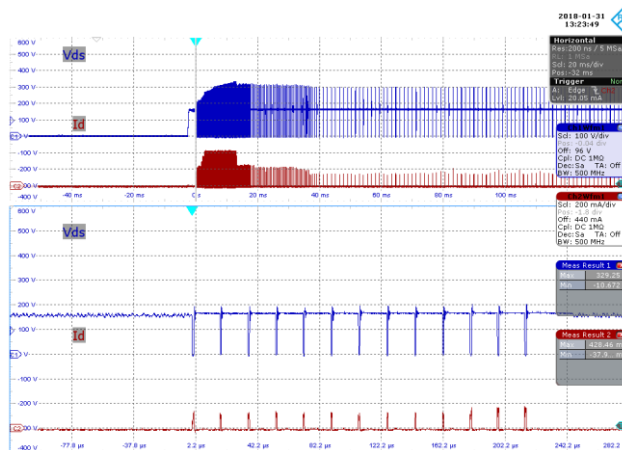


**Figure 73** – 115 VAC 60 Hz, No-Load Start-up.  
 CH1:  $V_{DS}$ , 100 V / div., 20 ms / div.  
 CH2:  $I_{DS}$ , 200 mA / div., 20 ms / div.  
 Zoom: 40  $\mu$ s / div.  
 $V_{DS(MAX)} = 329.25$  V,  $I_{DS(MAX)} = 428.46$  mA.

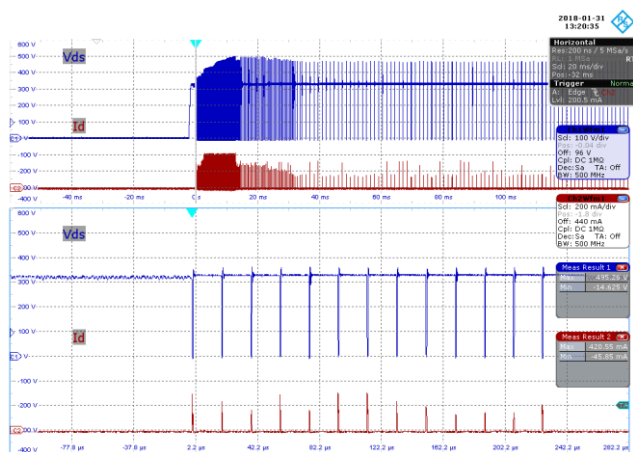


**Figure 74** – 230 VAC 50 Hz, No-Load Start-up.  
 CH1:  $V_{DS}$ , 100 V / div., 40 ms / div.  
 CH2:  $I_{DS}$ , 200 mA / div., 40 ms / div.  
 Zoom: 40  $\mu$ s / div.  
 $V_{DS(MAX)} = 495.26$  V,  $I_{DS(MAX)} = 420.55$  mA.

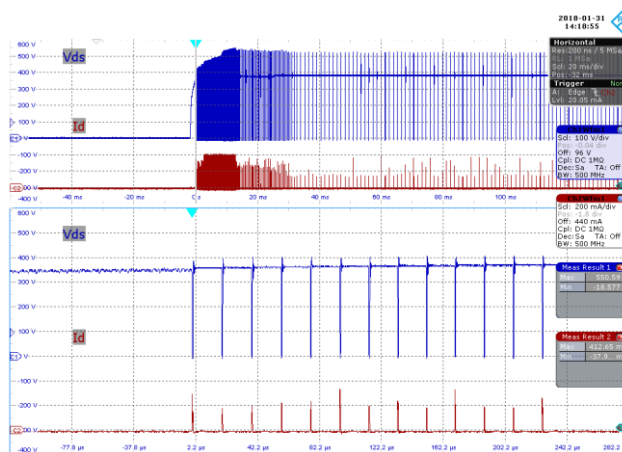
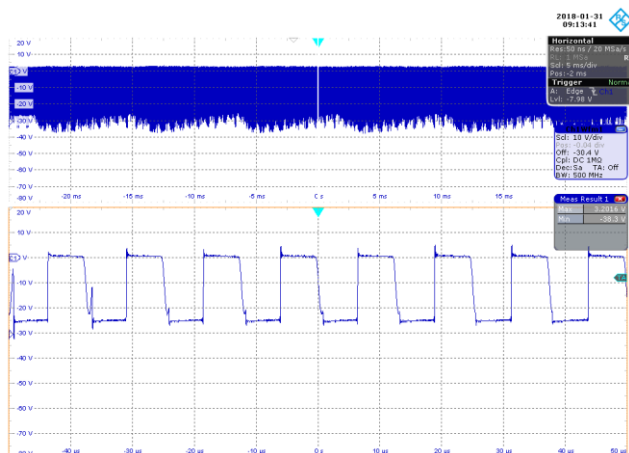
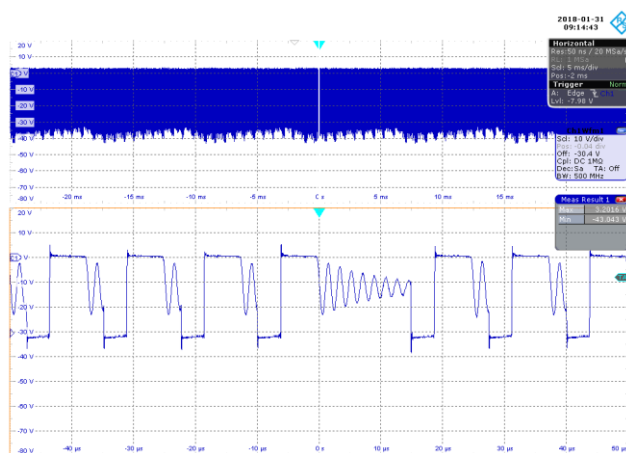
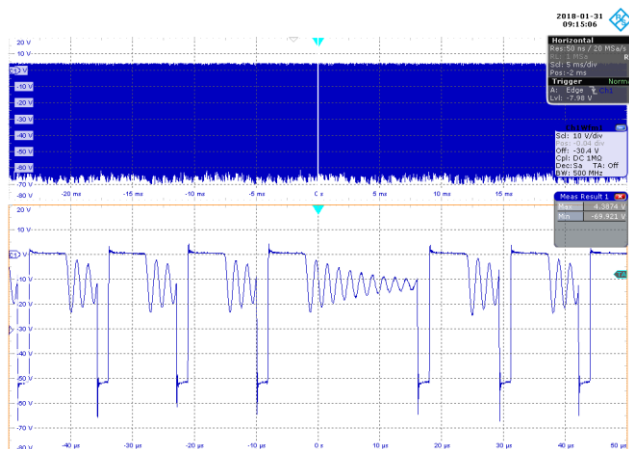
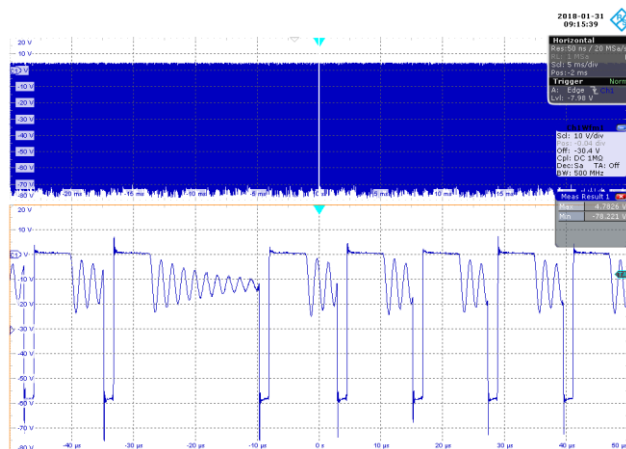


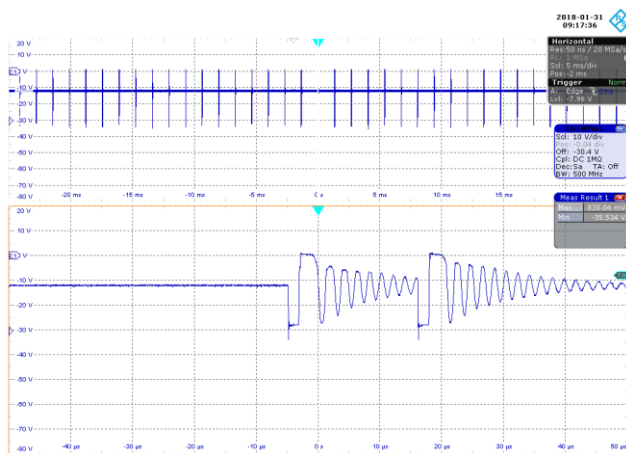
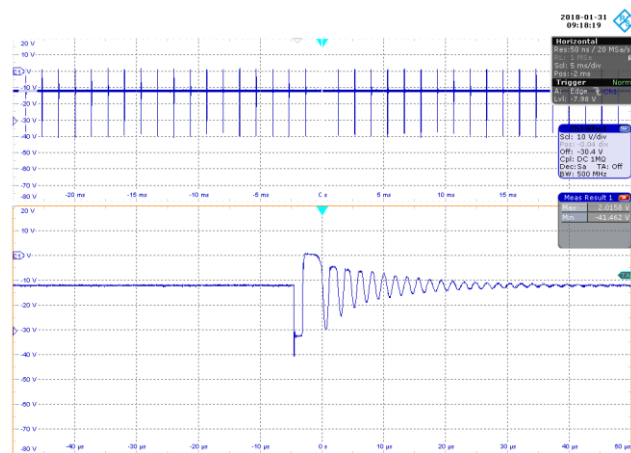
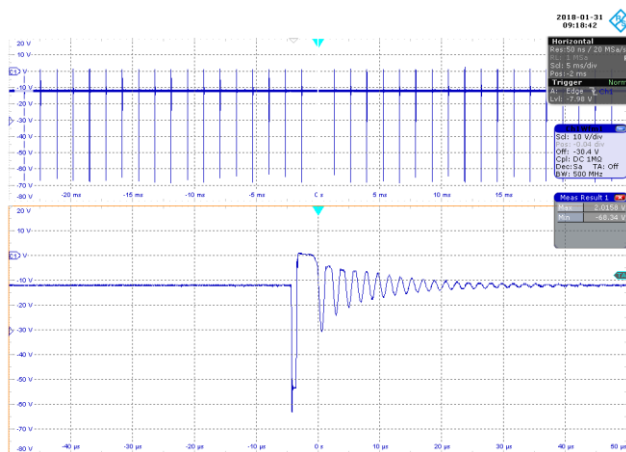
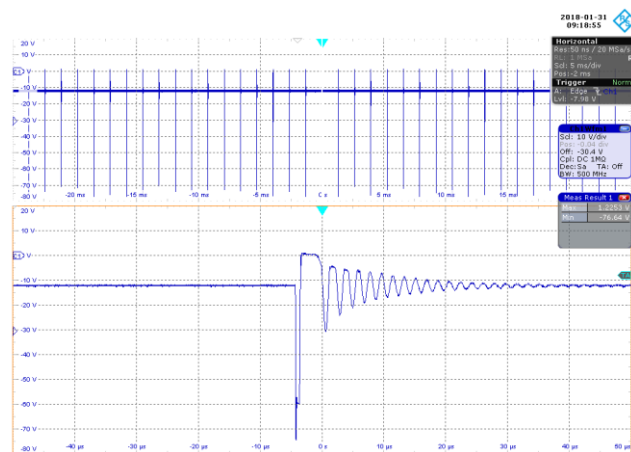
**Figure 75** – 265 VAC 50 Hz, No-Load Start-up.  
 CH1:  $V_{DS}$ , 100 V / div., 40 ms / div.  
 CH2:  $I_{DS}$ , 200 mA / div., 40 ms / div.  
 Zoom: 40  $\mu$ s / div.  
 $V_{DS(MAX)} = 550.59$  V,  $I_{DS(MAX)} = 412.7$  mA.

## 17.3.3 Output Diode Voltage at Normal Operation

## 17.3.3.1 100% Load

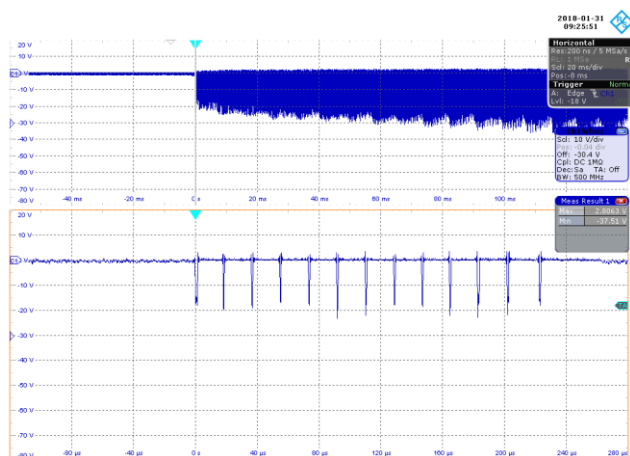
**Figure 76** – 90 VAC 60 Hz, Full Load.CH1:  $V_{FWL\_Diode}$  - 10 V / div., 5 ms / div.Zoom: 10  $\mu$ s / div. $PIV_{MAX} = 38.3$  V.**Figure 77** – 115 VAC 60 Hz, Full Load.CH1:  $V_{FWL\_Diode}$  - 10 V / div., 5 ms / div.Zoom: 10  $\mu$ s / div. $PIV_{MAX} = 43.043$  V.**Figure 78** – 230 VAC 50 Hz, Full Load.CH1:  $V_{FWL\_Diode}$  - 10 V / div., 5 ms / div.Zoom: 10  $\mu$ s / div. $PIV_{MAX} = 69.921$  V.**Figure 79** – 265 VAC 50 Hz, Full Load.CH1:  $V_{FWL\_Diode}$  - 10 V / div., 5 ms / div.Zoom: 10  $\mu$ s / div. $PIV_{MAX} = 78.221$  V.

## 17.3.3.2 0% Load

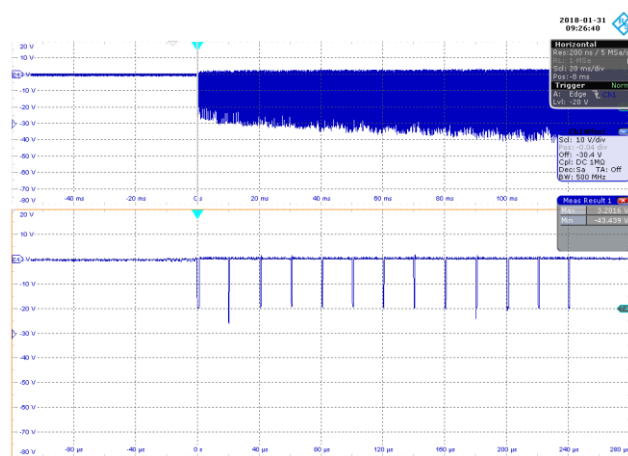
**Figure 80** – 90 VAC 60 Hz, No-Load.CH1:  $V_{FWL\_Diode}$  - 10 V / div., 5 ms / div.Zoom: 10  $\mu$ s / div.PIV<sub>MAX</sub> = 35.534 V.**Figure 81** – 115 VAC 60 Hz, No-Load.CH1:  $V_{FWL\_Diode}$  - 10 V / div., 5 ms / div.Zoom: 10  $\mu$ s / div.PIV<sub>MAX</sub> = 41.462 V.**Figure 82** – 230 VAC 60 Hz, No-Load.CH1:  $V_{FWL\_Diode}$  - 10 V / div., 5 ms / div.Zoom: 10  $\mu$ s / div.PIV<sub>MAX</sub> = 68.34 V.**Figure 83** – 265 VAC 60 Hz, No-Load.CH1:  $V_{FWL\_Diode}$  - 10 V / div., 5 ms / div.Zoom: 10  $\mu$ s / div.PIV<sub>MAX</sub> = 76.64 V.

## 17.3.4 Output Diode Voltage at Startup Operation

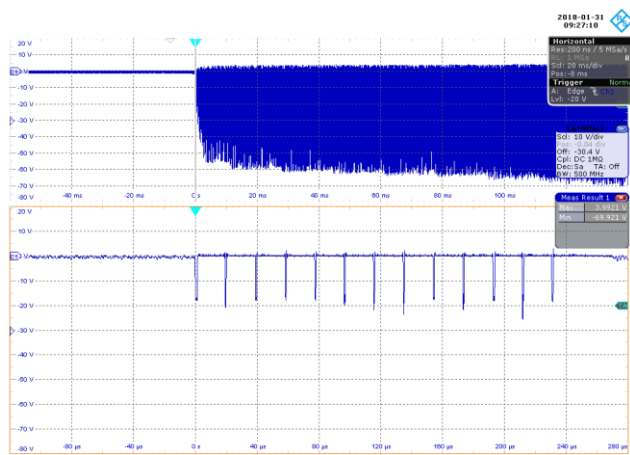
## 17.3.4.1 100% Load

**Figure 84** – 90 VAC 60 Hz, Full Load.

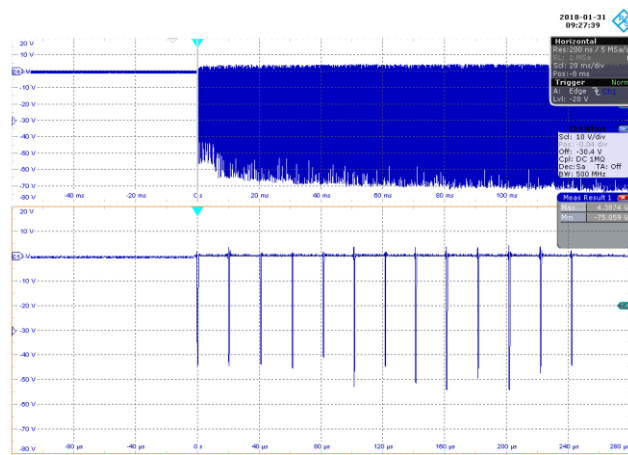
CH1:  $V_{FWL\_Diode}$  - 10 V / div., 20 ms / div.  
 Zoom: 10  $\mu$ s / div.  
 $PIV_{MAX} = 37.51$  V.

**Figure 85** – 115 VAC 60 Hz, Full Load.

CH1:  $V_{FWL\_Diode}$  - 10 V / div., 20 ms / div.  
 Zoom: 10  $\mu$ s / div.  
 $PIV_{MAX} = 43.439$  V.

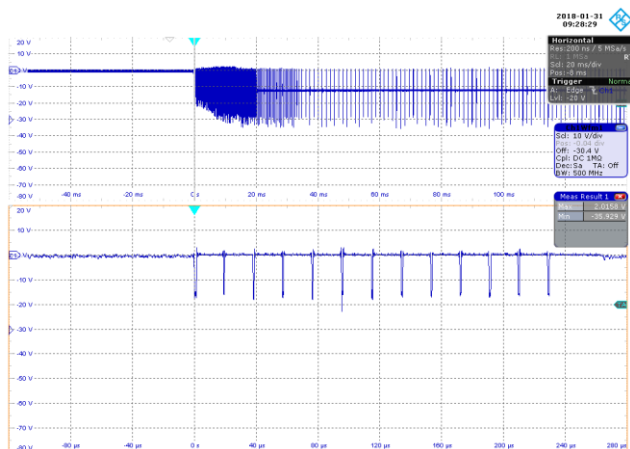
**Figure 86** – 230 VAC 60 Hz, Full Load.

CH1:  $V_{FWL\_Diode}$  - 10 V / div., 5 ms / div.  
 Zoom: 10  $\mu$ s / div.  
 $PIV_{MAX} = 69.921$  V.

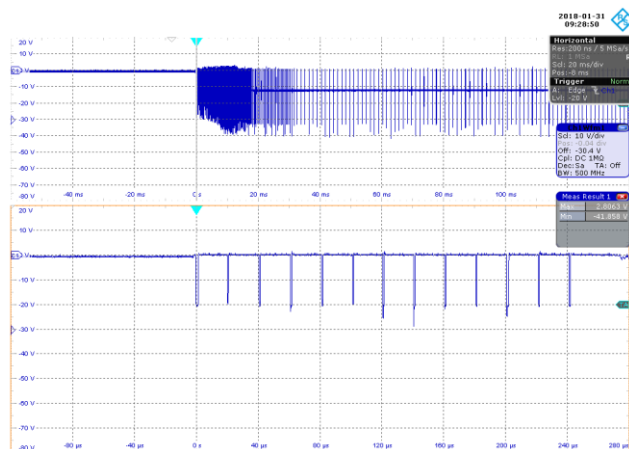
**Figure 87** – 265 VAC 60 Hz, Full Load.

CH1:  $V_{FWL\_Diode}$  - 10 V / div., 5 ms / div.  
 Zoom: 10  $\mu$ s / div.  
 $PIV_{MAX} = 75.059$  V.

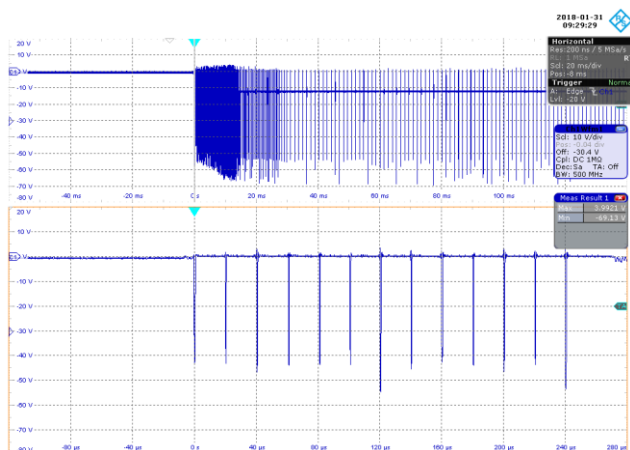
## 17.3.4.2 0% Load

**Figure 88** – 90 VAC 60 Hz, No-Load.

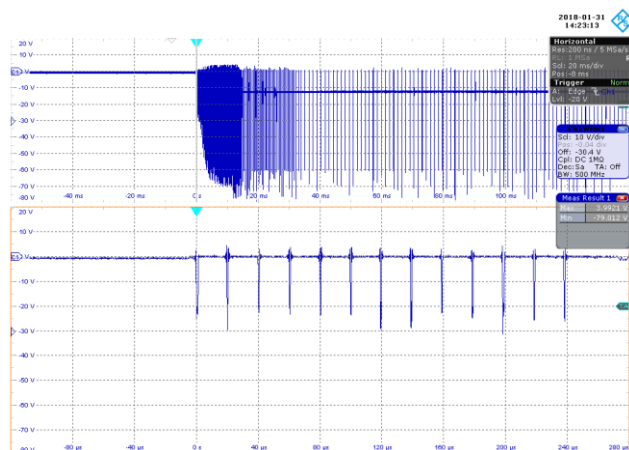
CH1:  $V_{FWL\_Diode}$  - 10 V / div., 20 ms / div.  
 Zoom: 40  $\mu$ s / div.  
 $PIV_{MAX}$  = 36.929 V.

**Figure 89** – 115 VAC 60 Hz, No-Load.

CH1:  $V_{FWL\_Diode}$  - 10 V / div., 20 ms / div.  
 Zoom: 40  $\mu$ s / div.  
 $PIV_{MAX}$  = 41.858 V.

**Figure 90** – 230 VAC 60 Hz, No-Load.

CH1:  $V_{FWL\_Diode}$  - 10 V / div., 20 ms / div.  
 Zoom: 40  $\mu$ s / div.  
 $PIV_{MAX}$  = 69.13 V.

**Figure 91** – 265 VAC 60 Hz, No-Load.

CH1:  $V_{FWL\_Diode}$  - 10 V / div., 20 ms / div.  
 Zoom: 40  $\mu$ s / div.  
 $PIV_{MAX}$  = 79.012 V.

## 17.4 **Brown-in / Brown-out Test**

No abnormal overheating nor voltage overshoot / undershoot was observed during and after 0.1 V / s brown-in and brown-out test.

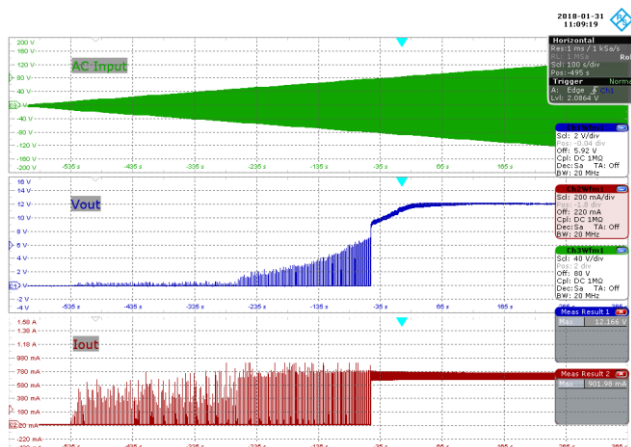


**Figure 92 – Brown-in Test.**  
 0 to 90 VAC 0.1 V / s.  
 CH1:  $V_{OUT}$ , 2 V / div., 100 s / div.  
 CH2:  $I_{OUT}$ , 200 mA / div., 100 s / div.  
 CH3:  $AC_{IN}$ , 40 V / div., 100 s / div.  
 Highest Average Input Power: 10.66 W  
 at 64.6 VAC.

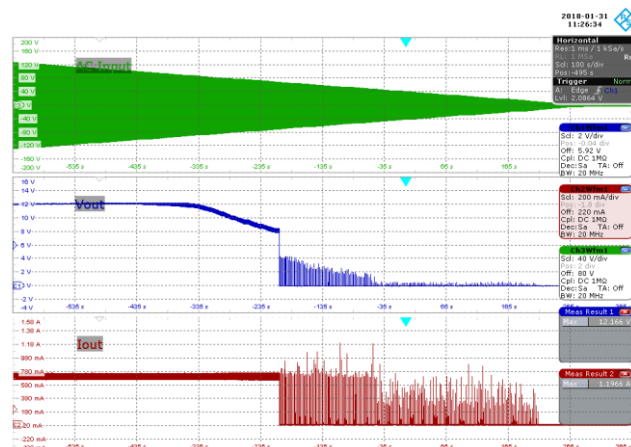


**Figure 93 – Brown-out Test.**  
 90 to 0 VAC at 0.1 V / s.  
 CH1:  $V_{OUT}$ , 2 V / div., 100 s / div.  
 CH2:  $I_{OUT}$ , 200 mA / div., 100 s / div.  
 CH3:  $AC_{IN}$ , 40 V / div., 100 s / div.  
 Highest Average Input Power: 10.575 W  
 at 64.2 VAC.

## 17.5 **Output Short Circuit Auto-restart Test**

Output is shorted at the end of the cable.

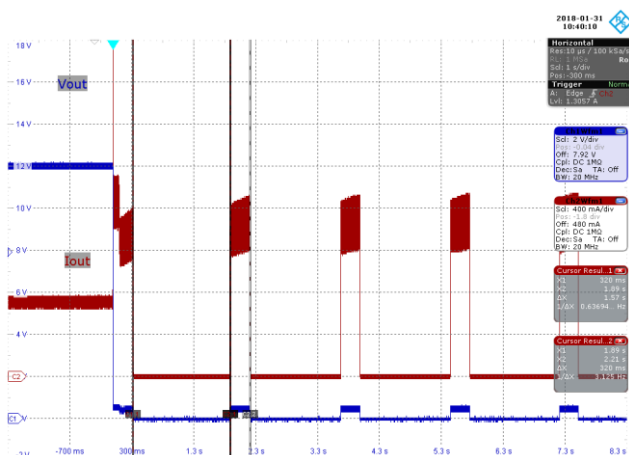


**Figure 94** – 90 VAC, Normal Operation.

CH1:  $V_{OUT}$ , 2 V / div., 1 s / div.

CH2:  $I_{OUT}$ , 400 mA / div., 1 s / div.

$t_{AR(ON)}$ : 320 ms.

$t_{AR(OFF)}$ : 1.57 s.

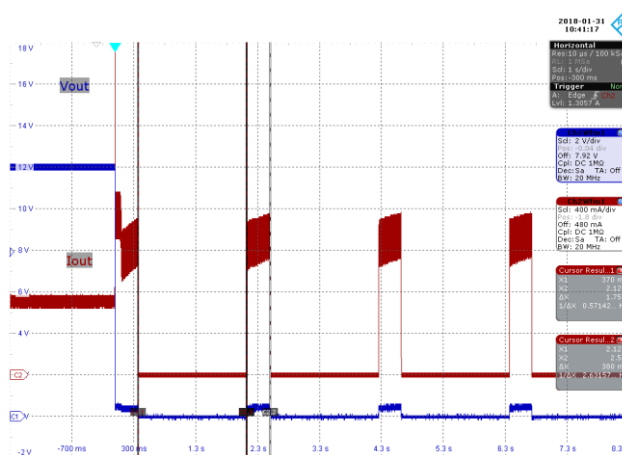


**Figure 95** – 265 VAC, Normal Operation.

CH1:  $V_{OUT}$ , 2 V / div., 1 s / div.

CH2:  $I_{OUT}$ , 400 mA / div., 1 s / div.

$t_{AR(ON)}$ : 380 ms.

$t_{AR(OFF)}$ : 1.75 s.

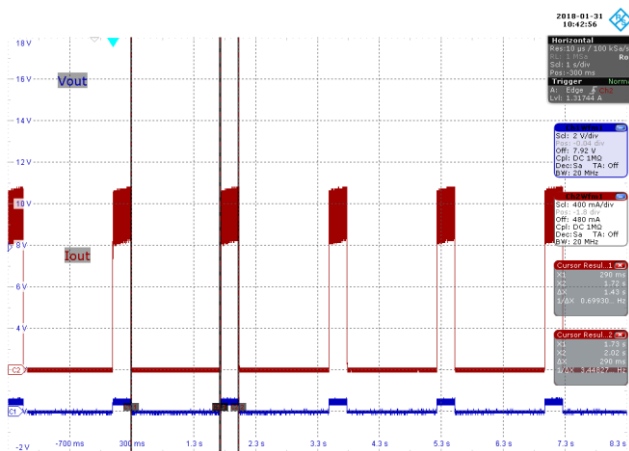


**Figure 96** – 90 VAC, Startup Operation.

CH1:  $V_{OUT}$ , 2 V / div., 1 s / div.

CH2:  $I_{OUT}$ , 400 mA / div., 1 s / div.

$t_{AR(ON)}$ : 290 ms

$t_{AR(OFF)}$ : 1.43 s

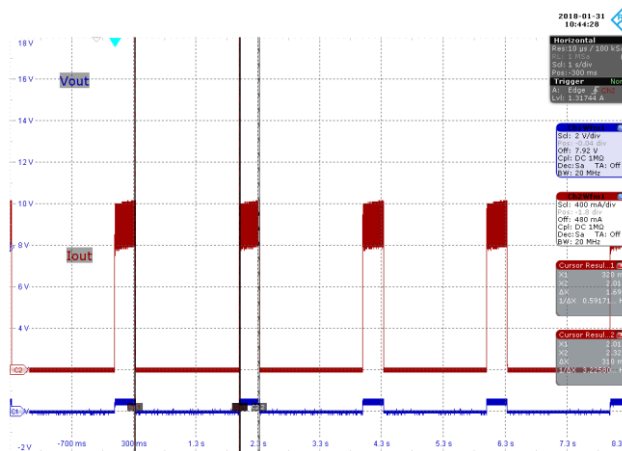


**Figure 97** – 265 VAC, Startup Operation.

CH1:  $V_{OUT}$ , 2 V / div., 1 s / div.

CH2:  $I_{OUT}$ , 400 mA / div., 1 s / div.

$t_{AR(ON)}$ : 301 ms

$t_{AR(OFF)}$ : 1.69 s

## 17.6 ***Output Ripple Measurements***

### 17.6.1 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  $\mu\text{F}$ /50 V ceramic type and one (1) 47  $\mu\text{F}$ /50 V aluminum electrolytic. The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).

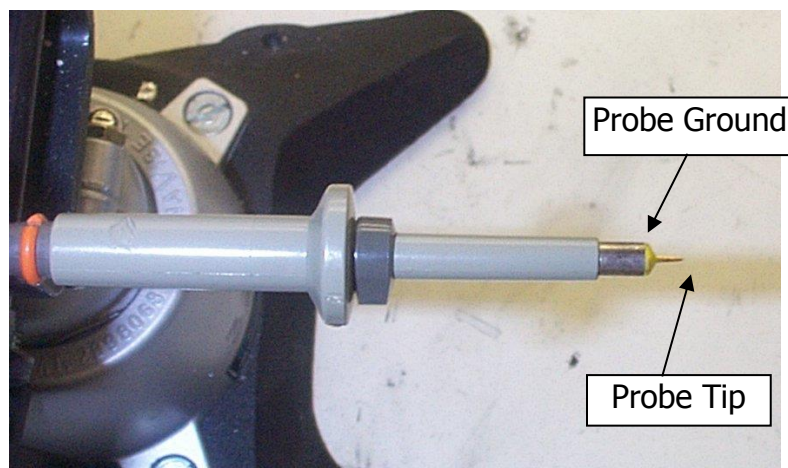


**Figure 98** – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

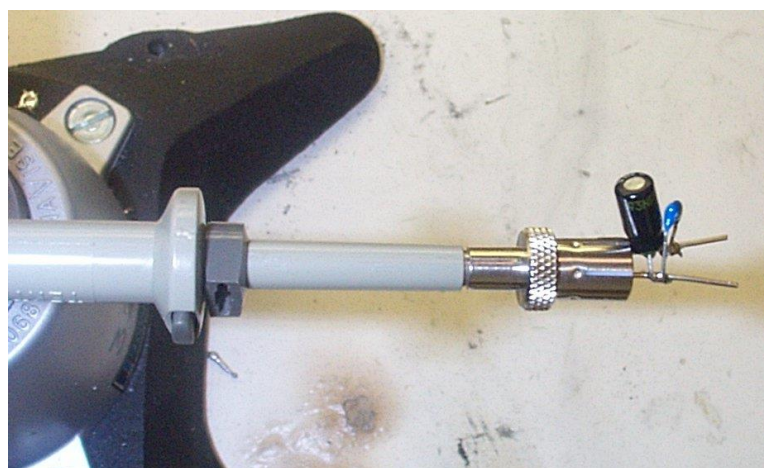


**Figure 99** – Oscilloscope Probe with Probe Master ([www.probemaster.com](http://www.probemaster.com)) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

## 17.6.2 Measurement Results

Measured across the PCB connector

## 17.6.2.1 100% Load Condition

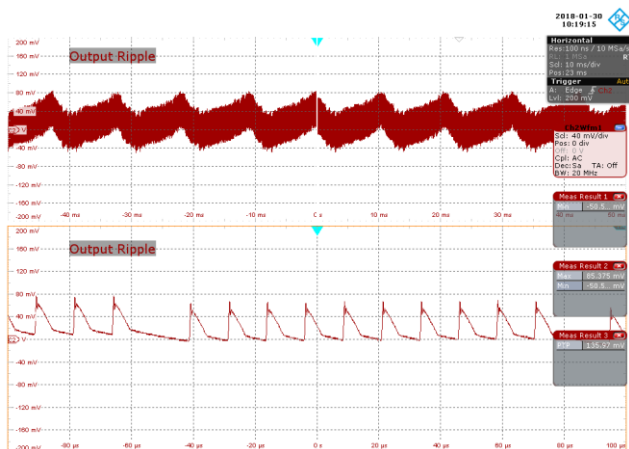


**Figure 100** – 90 VAC 47 Hz, 100% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20  $\mu$ s / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 135.9 mV).

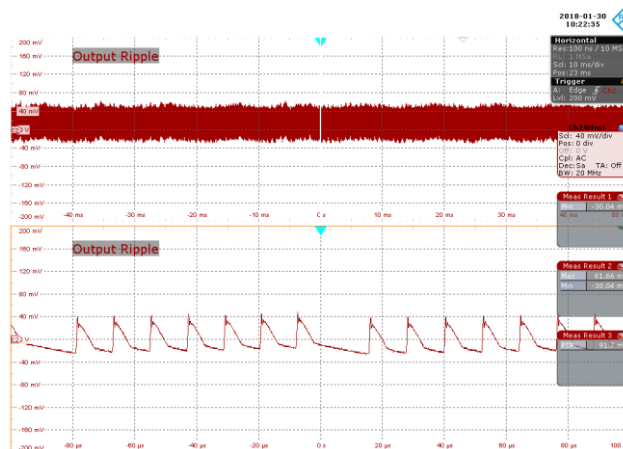


**Figure 101** – 115 VAC 47 Hz, 100% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20  $\mu$ s / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 91.6 mV).

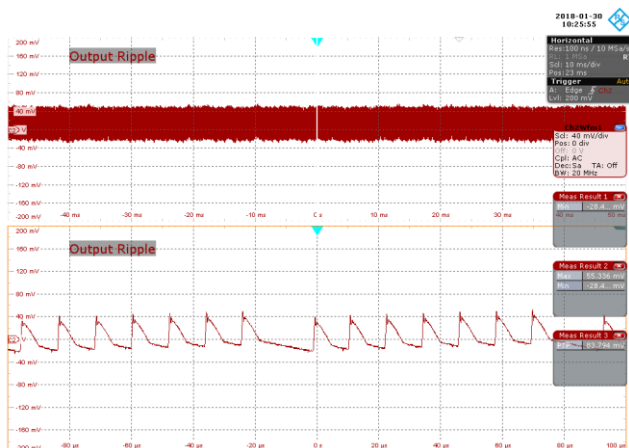


**Figure 102** – 230VAC 47 Hz, 100% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20  $\mu$ s / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 83.7 mV).

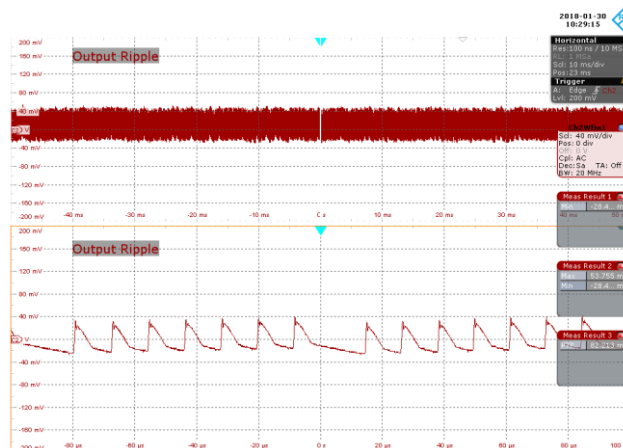


**Figure 103** – 265VAC 47 Hz, 100% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20  $\mu$ s / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 82.2 mV).

## 17.6.2.2 75% Load Condition

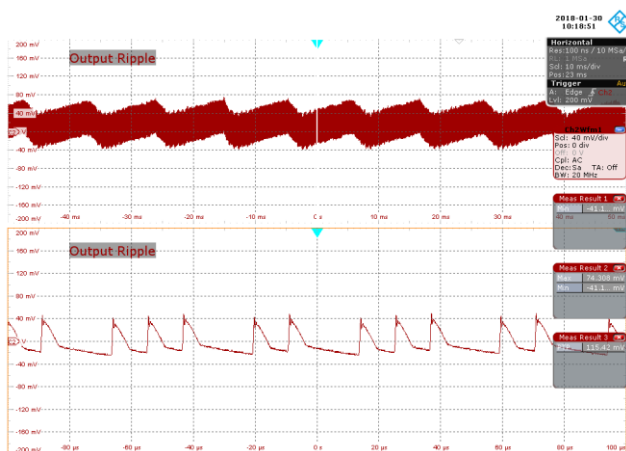


**Figure 104** – 90 VAC 47 Hz, 75% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20 μs / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 85.3 mV).

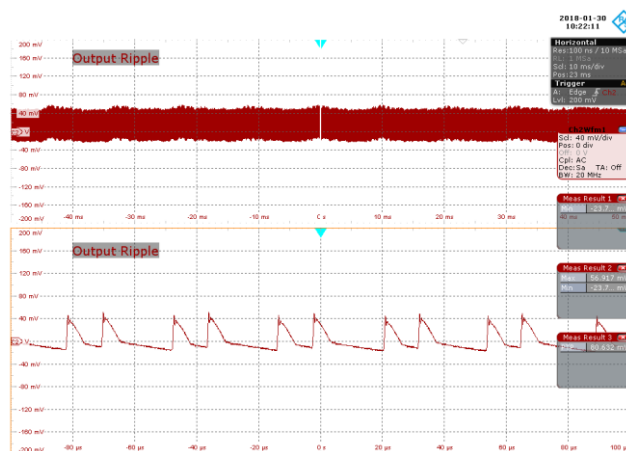


**Figure 105** – 115 VAC 47 Hz, 75% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20 μs / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 80.6 mV).

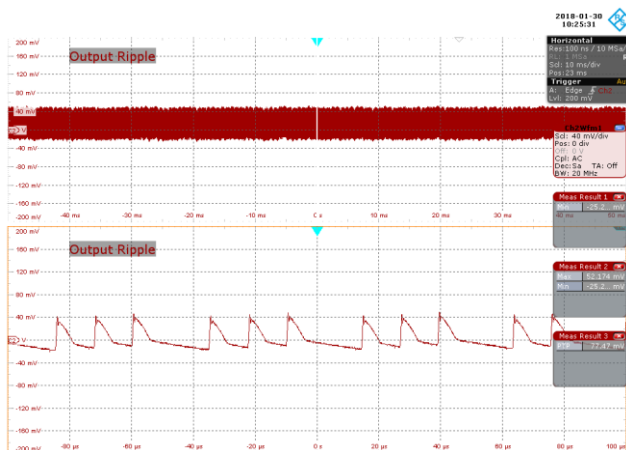


**Figure 106** – 230 VAC 47 Hz, 75% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20 μs / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 64.8 mV).

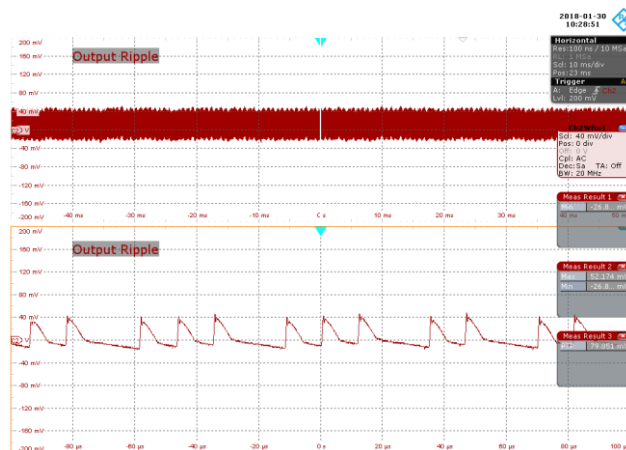


**Figure 107** – 265 VAC 47 Hz, 75% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20 μs / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 63.2 mV).

## 17.6.2.3 50% Load Condition

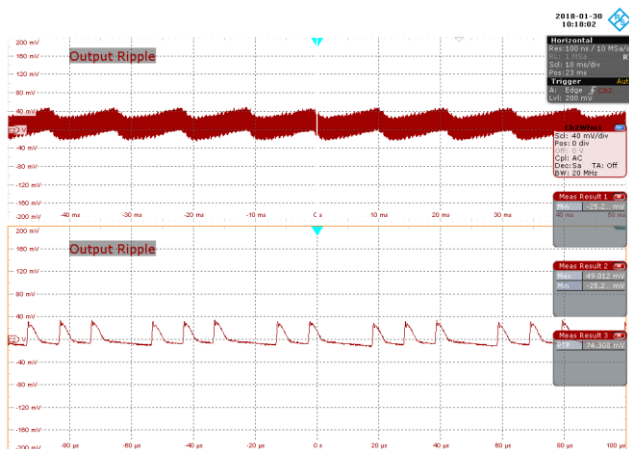


**Figure 108** – 90 VAC 47 Hz, 50% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20 μs / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 74.3 mV).

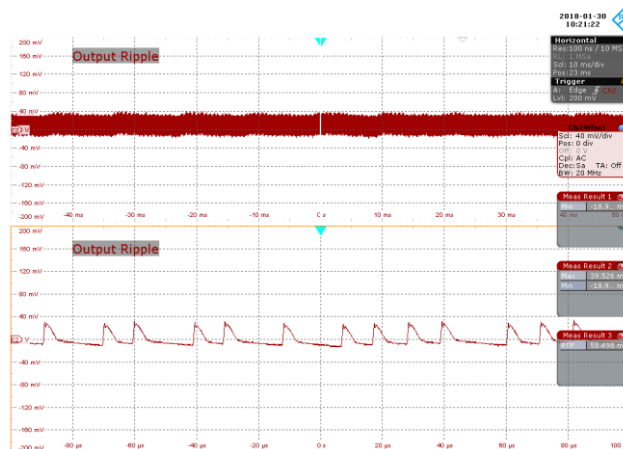


**Figure 109** – 115 VAC 47 Hz, 50% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20 μs / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 58.4 mV).

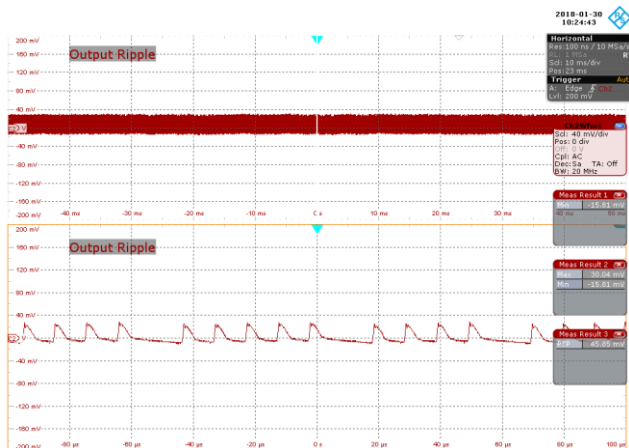


**Figure 110** – 230 VAC 47 Hz, 50% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20 μs / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 45.8 mV).

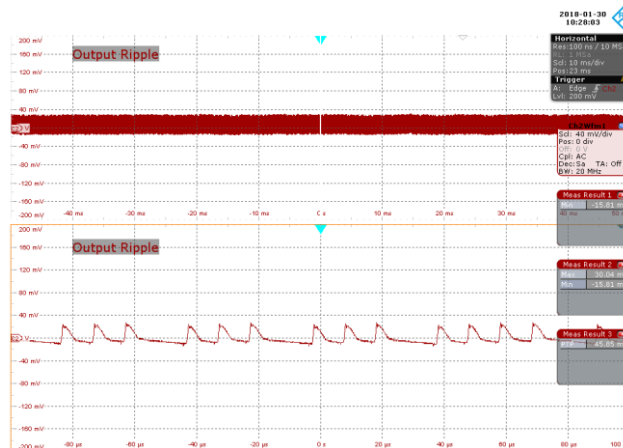


**Figure 111** – 265 VAC 47 Hz, 50% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20 μs / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 45.8 mV).

## 17.6.2.4 25% Load Condition

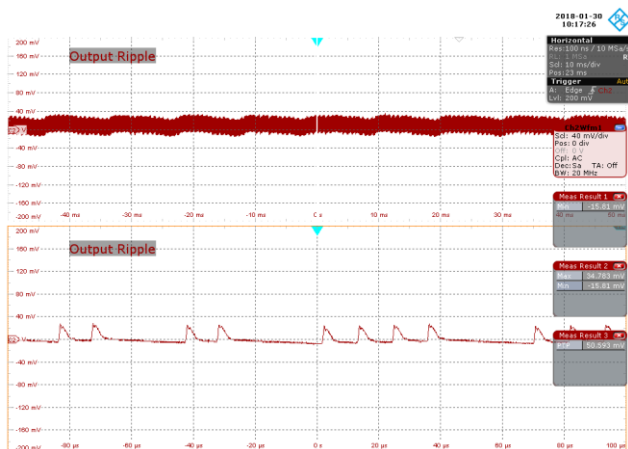


**Figure 112** – 90 VAC 47 Hz, 25% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20 μs / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 50.5 mV).



**Figure 113** – 115 VAC 47 Hz, 25% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20 μs / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 39.5 mV).

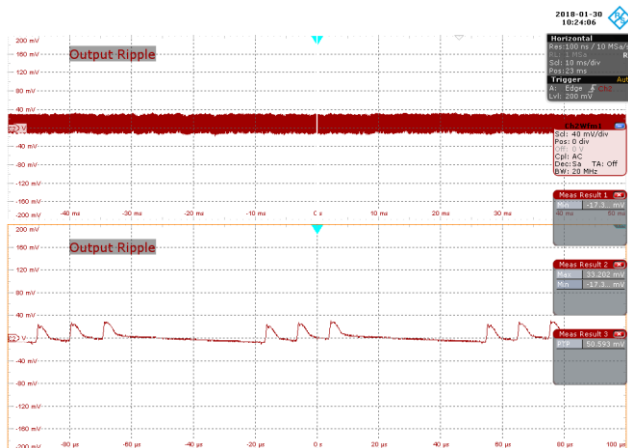


**Figure 114** – 230 VAC 47 Hz, 25% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20 μs / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 50.5 mV).

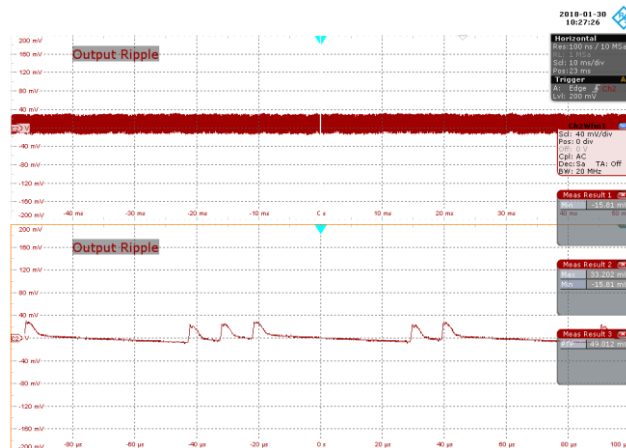


**Figure 115** – 265 VAC 47 Hz, 25% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20 μs / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 49.0 mV).

## 17.6.2.5 0% Load Condition

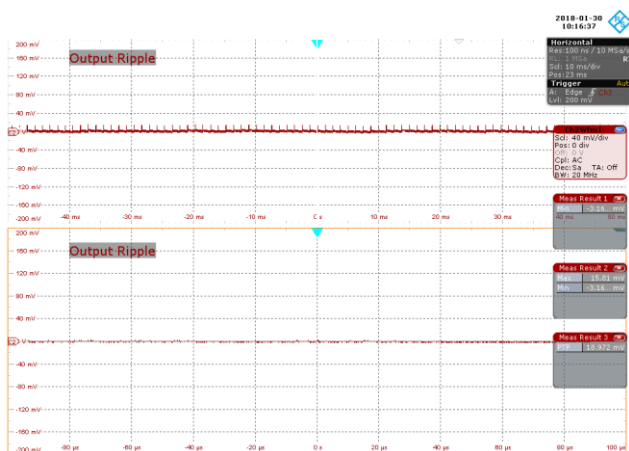


**Figure 116** – 90 VAC 47 Hz, 0% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20  $\mu$ s / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 18.9 mV).

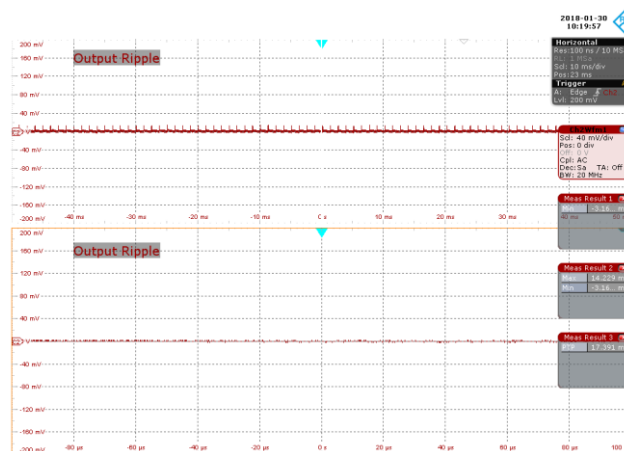


**Figure 117** – 115 VAC 47 Hz, 0% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20  $\mu$ s / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 17.3 mV).

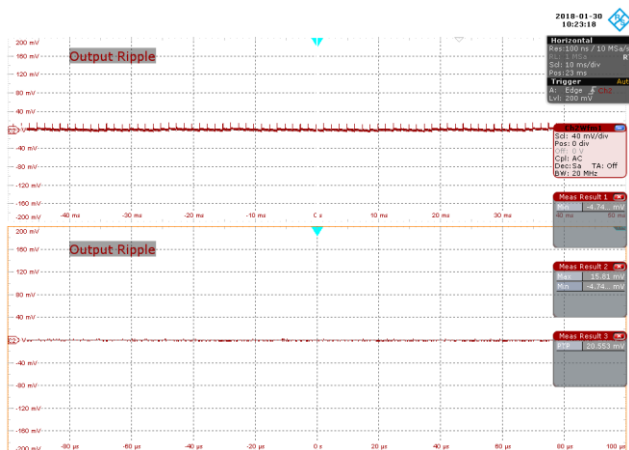


**Figure 118** – 230 VAC 47 Hz, 0% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20  $\mu$ s / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 20.5 mV).

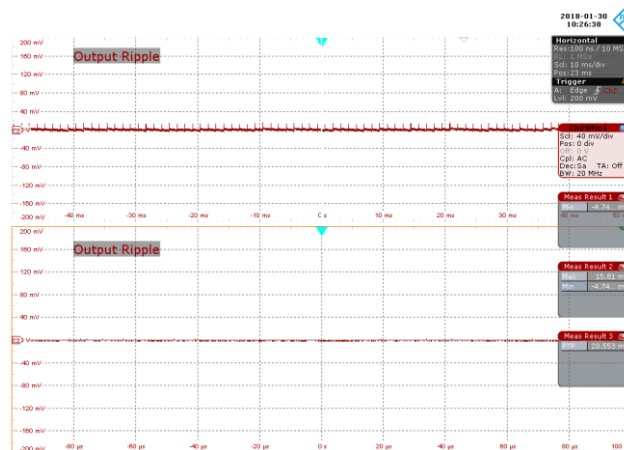


**Figure 119** – 265 VAC 47 Hz, 0% Load.  
 CH1:  $V_{OUT}$ , 40 mV / div., 10 ms / div.  
 Zoom: 20  $\mu$ s / div.  
 Voltage Ripple ( $V_{OUT(PK-PK)}$ ) = 20.5 mV).

## 17.6.3 Ripple at Hot and Cold Temperatures

## 17.6.3.1 90 VAC

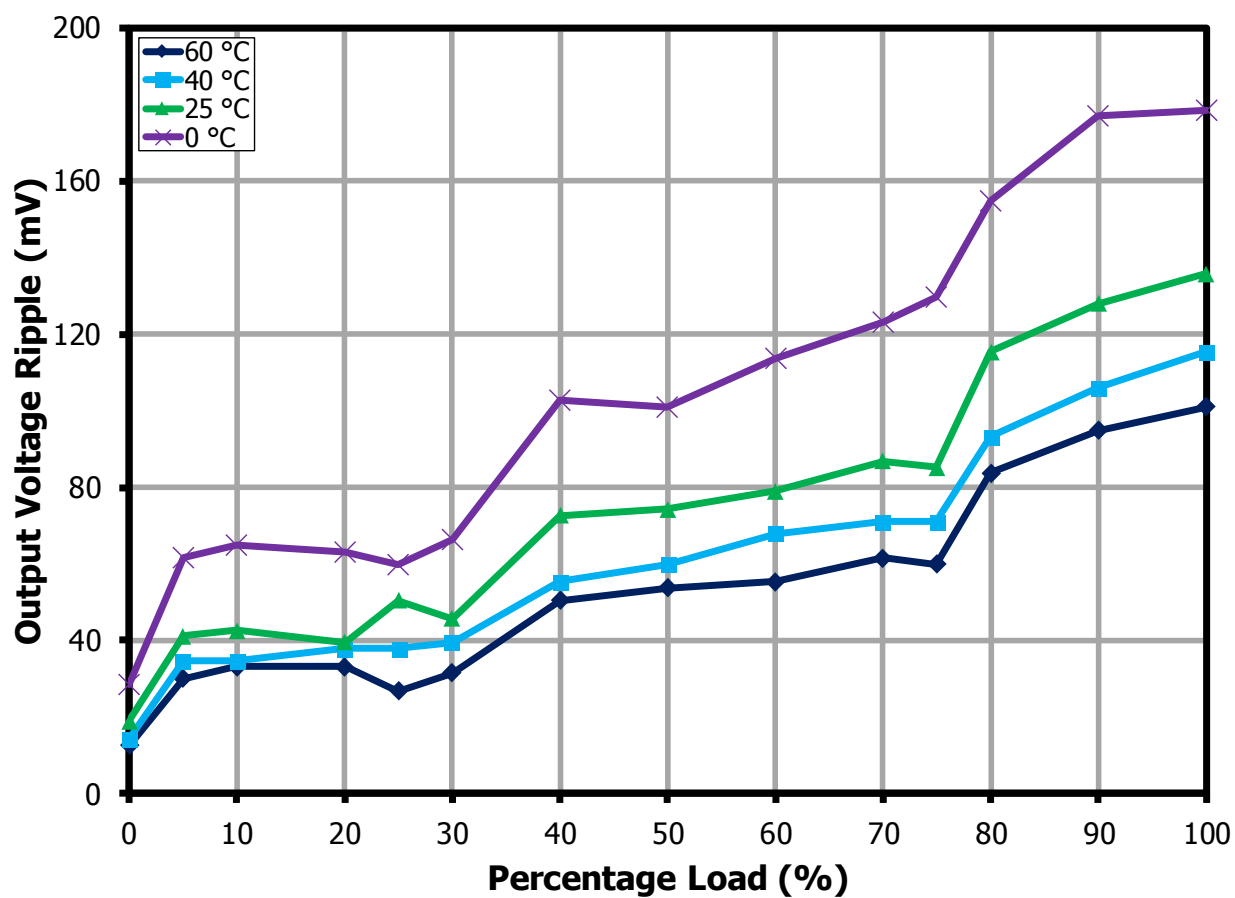
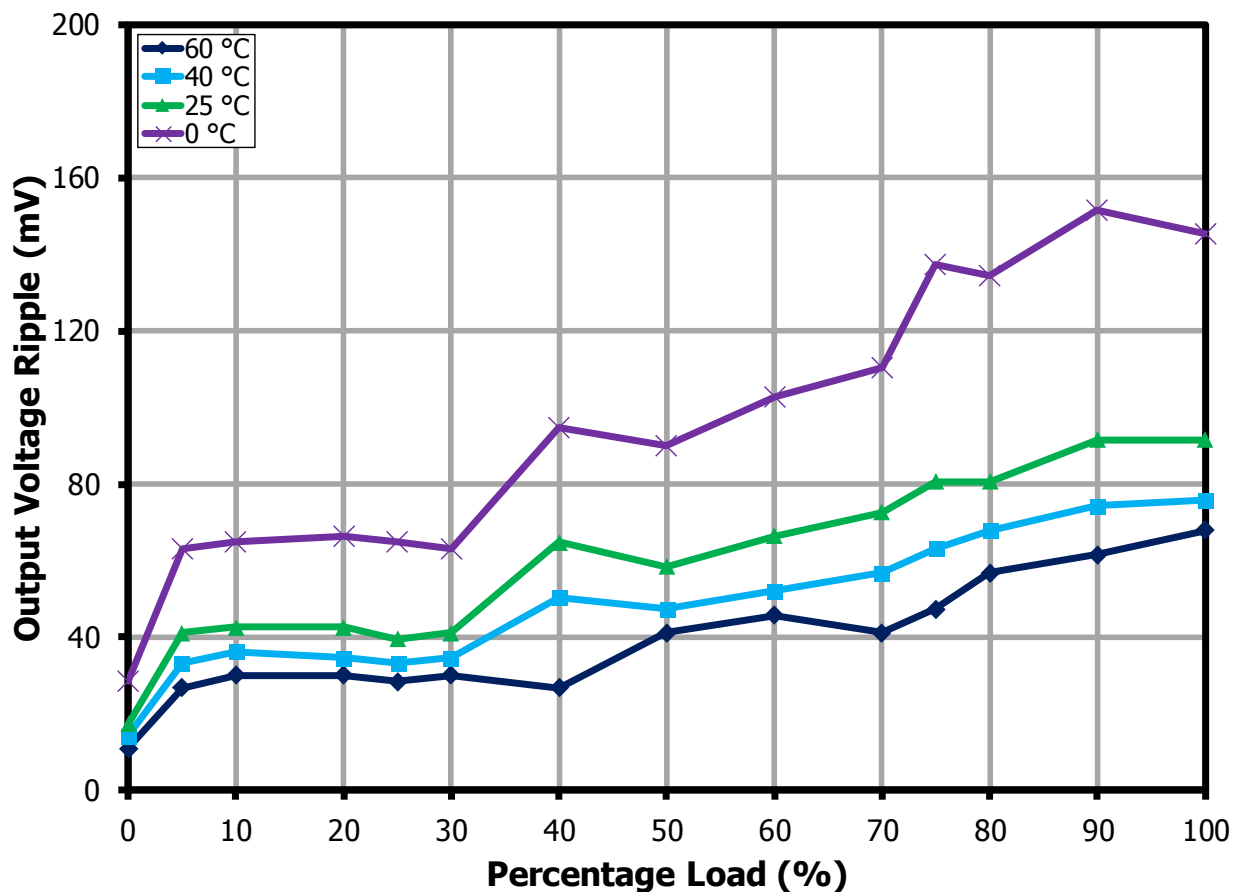


Figure 120 – 90 VAC Voltage Ripple.

## 17.6.3.2 115 VAC

**Figure 121** – 115 VAC Voltage Ripple.

## 17.6.3.3 230 VAC

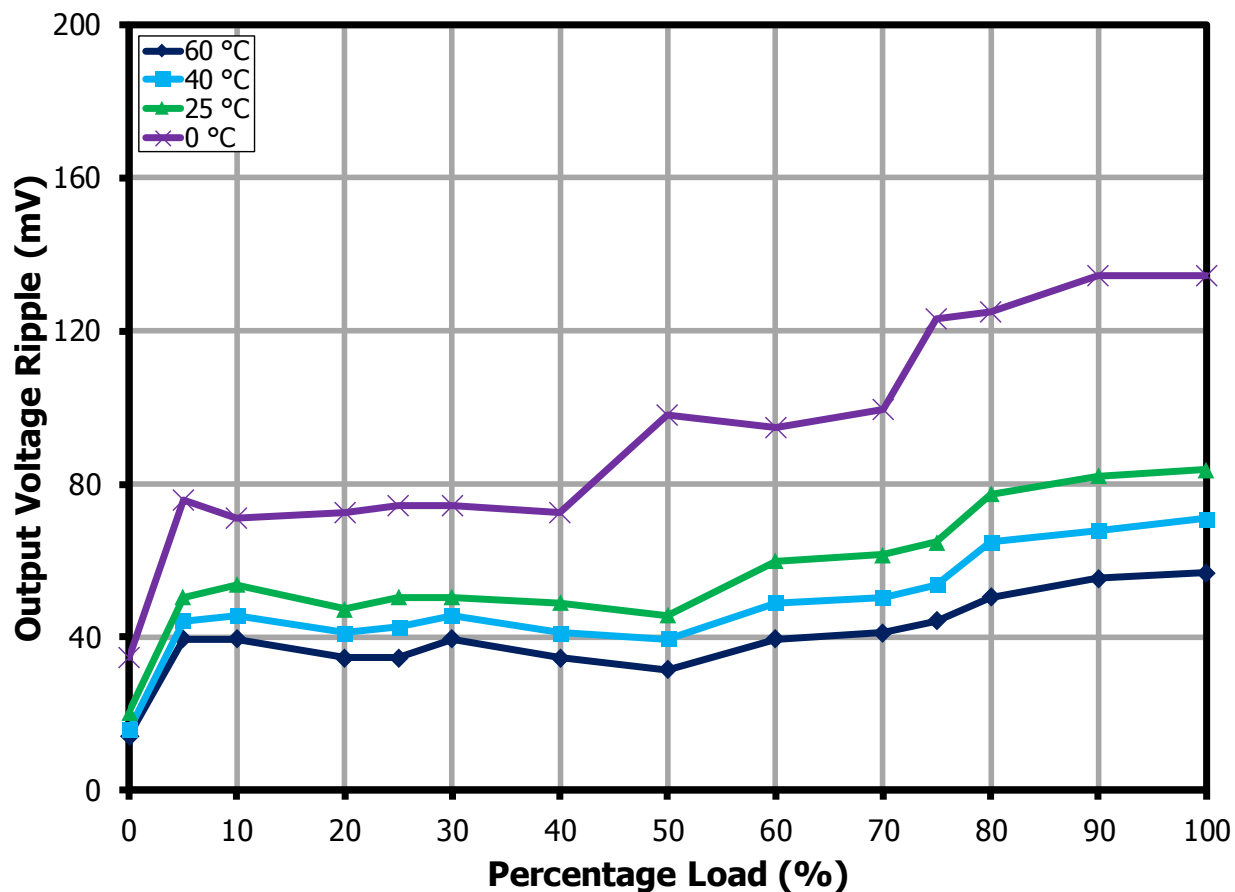
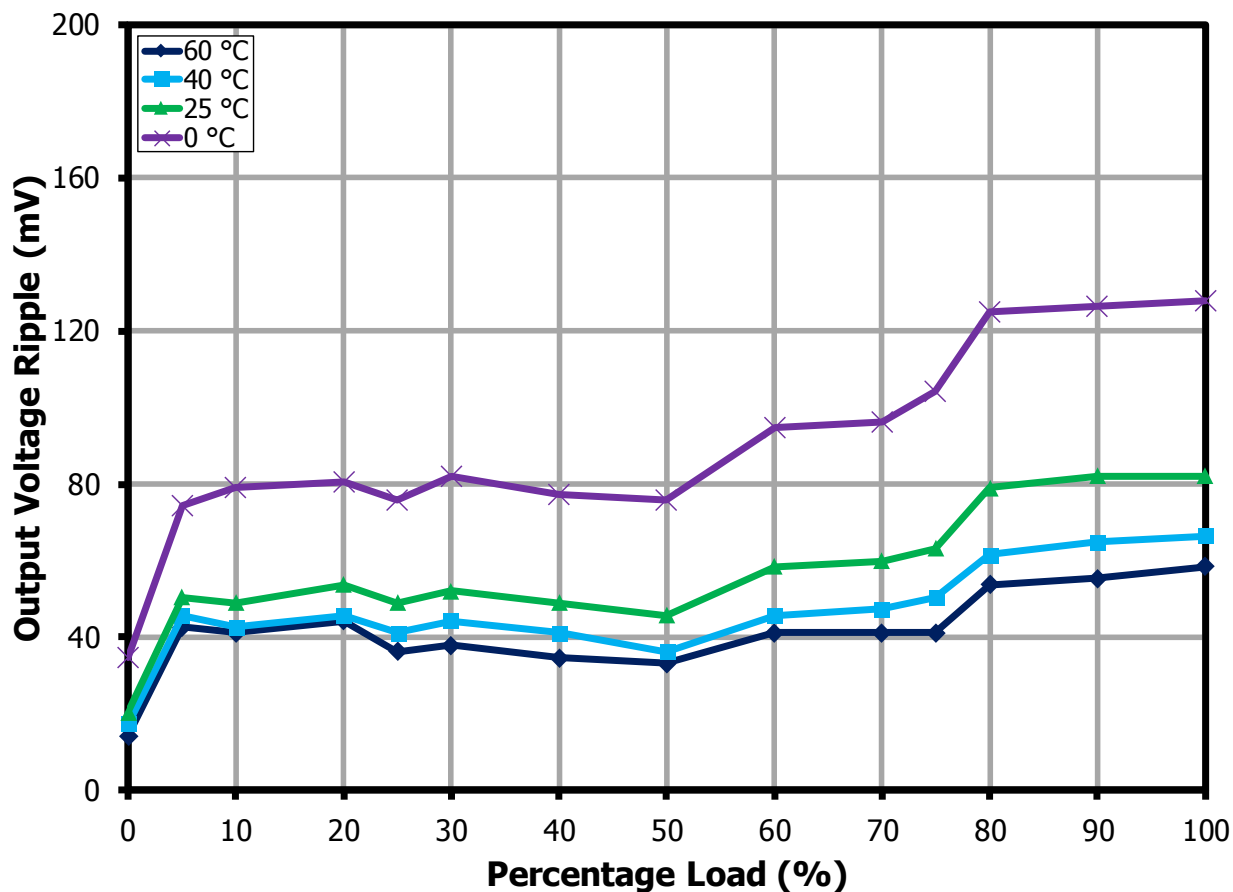


Figure 122 – 230 VAC Voltage Ripple.

## 17.6.3.4 265 VAC

**Figure 123** – 265 VAC Output Voltage Ripple.

## 18 Conducted EMI

### 18.1 *Test Set-up*

#### Equipment and Load Used

1. Rohde and Schwarz ENV216 two line V-network.
2. Rohde and Schwarz ESRP EMI test receiver.
3. Hioki 3322 power hitester.
4. Chroma measurement test fixture.
5. Full Load with input voltage set at 230 VAC and 115 VAC.

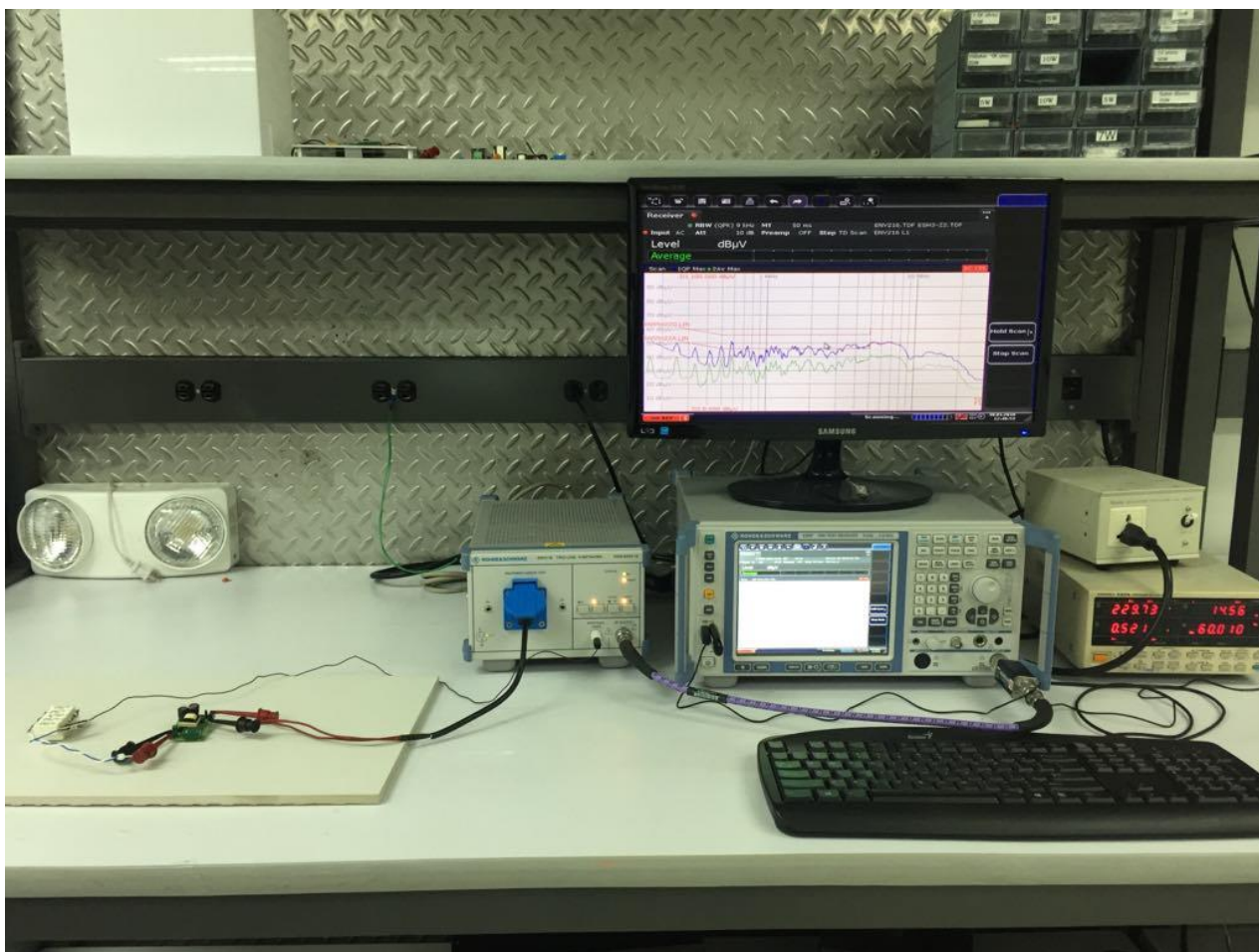
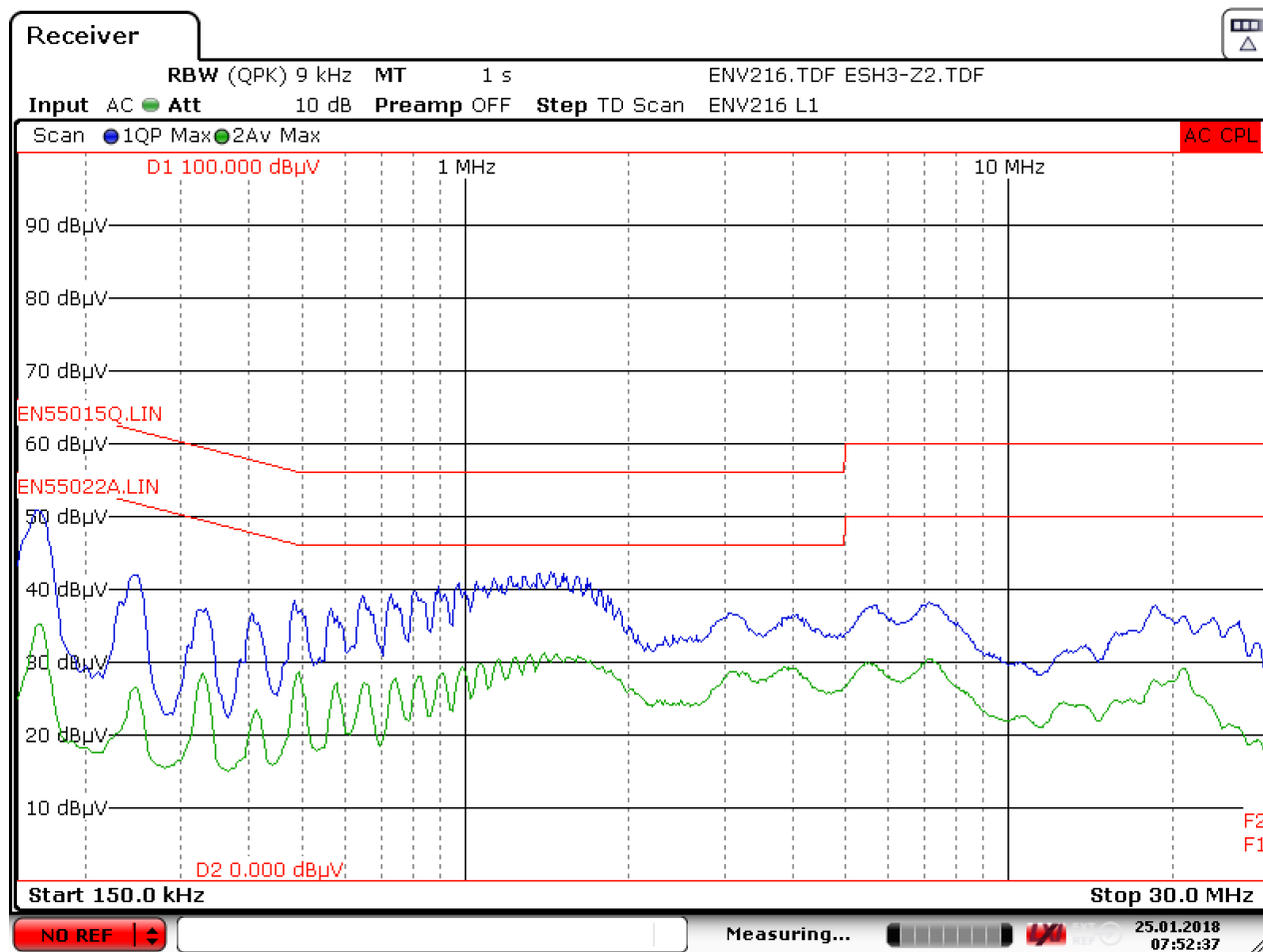


**Figure 124** – Conducted EMI Test Set-up.

## 18.2 8.4 W Resistive Load, Floating Output

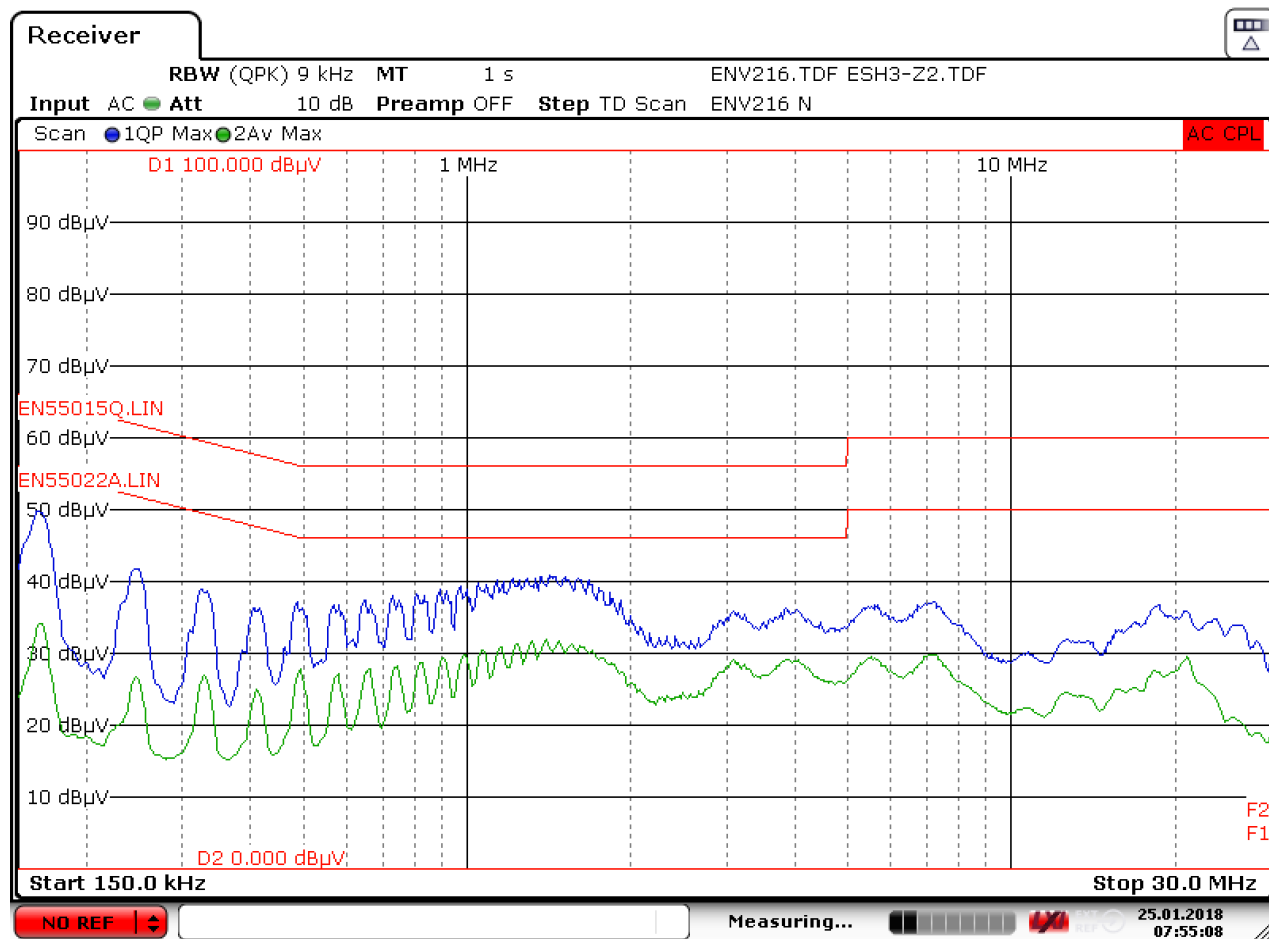
### 18.2.1 115 VAC, Line



Date: 25.JAN.2018 07:52:36

Figure 125 – Floating Ground EMI at 115 VAC, Line.

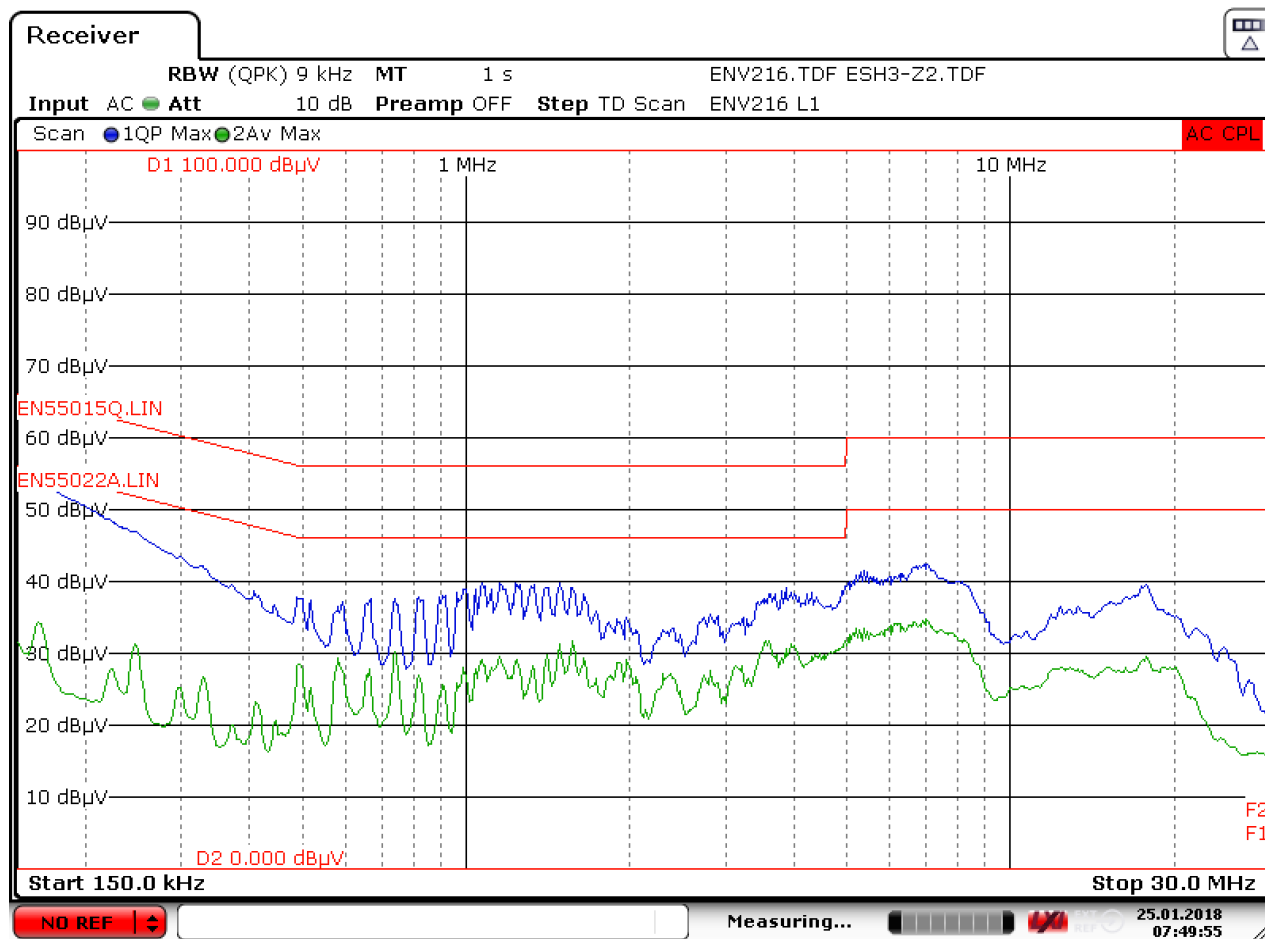
## 18.2.2 115 VAC, Neutral



Date: 25.JAN.2018 07:55:08

Figure 126 – Floating Ground EMI at 115 VAC, Neutral.

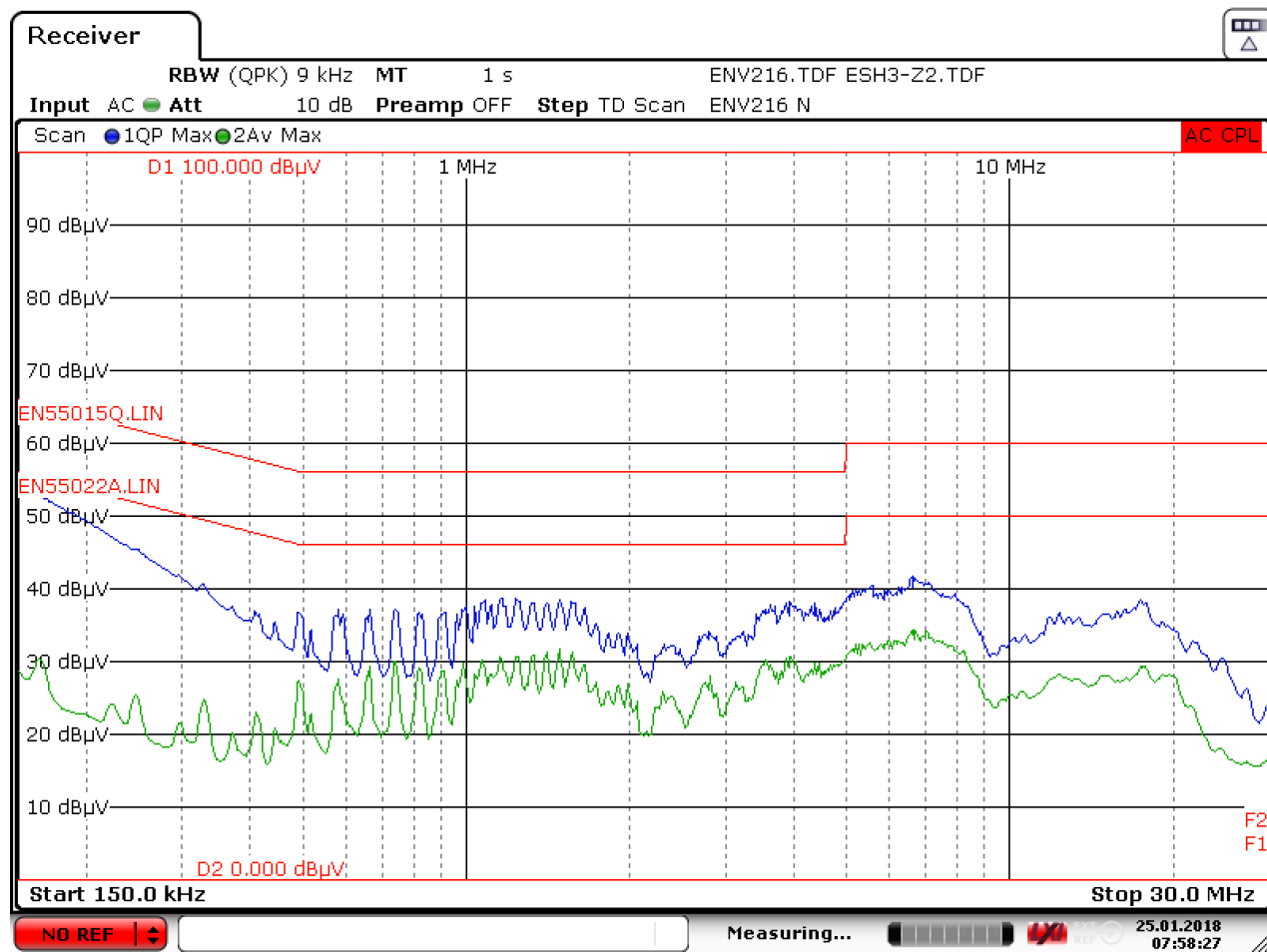
## 18.2.3 230 VAC, Line



Date: 25.JAN.2018 07:49:54

**Figure 127** – Floating Ground EMI at 230 VAC, Line.

## 18.2.4 230 VAC, Neutral

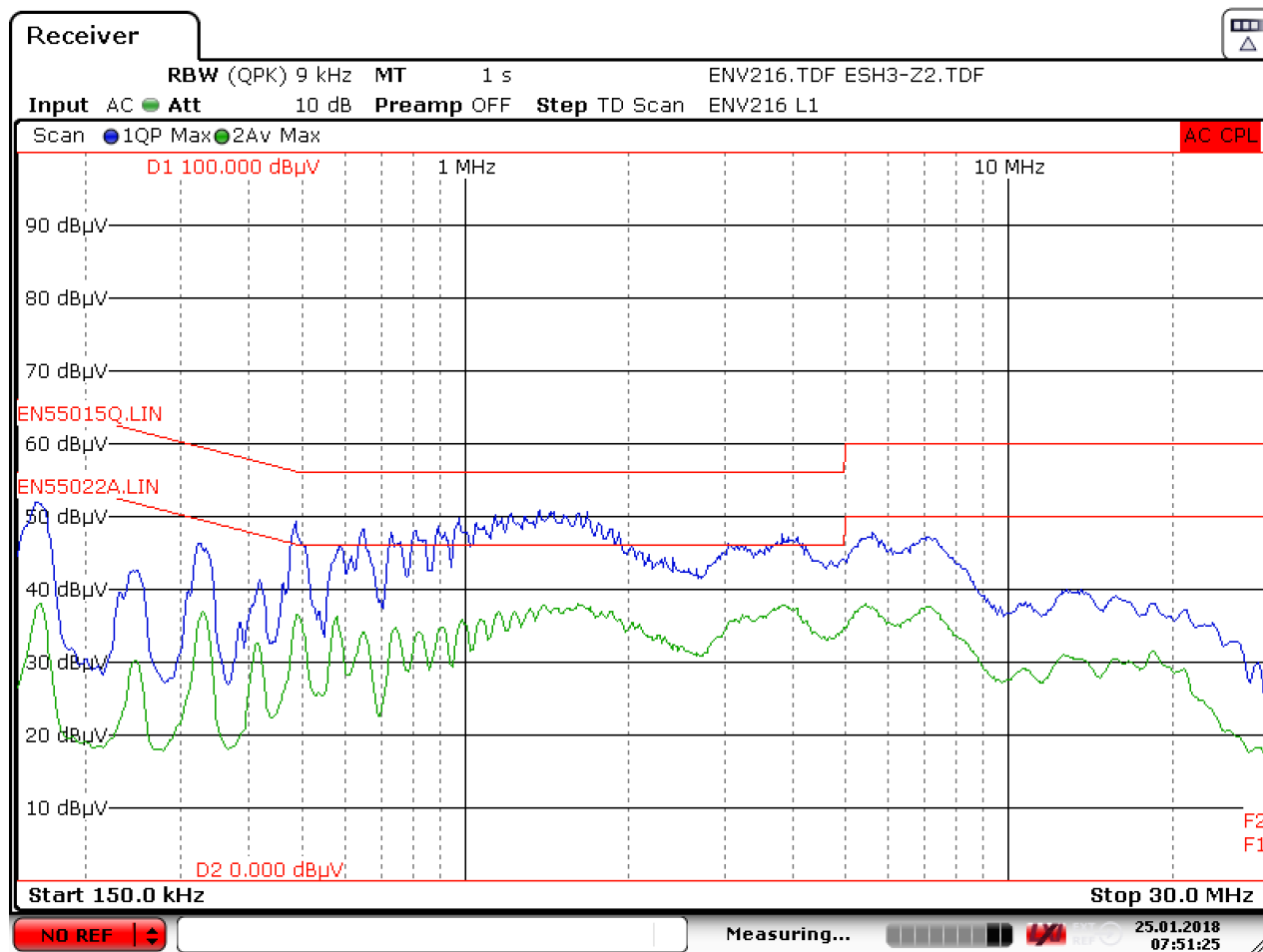


Date: 25.JAN.2018 07:58:27

Figure 128 – Floating Ground EMI at 230 VAC, Neutral.

### 18.3 8.4 W Resistive Load, Artificial Hand

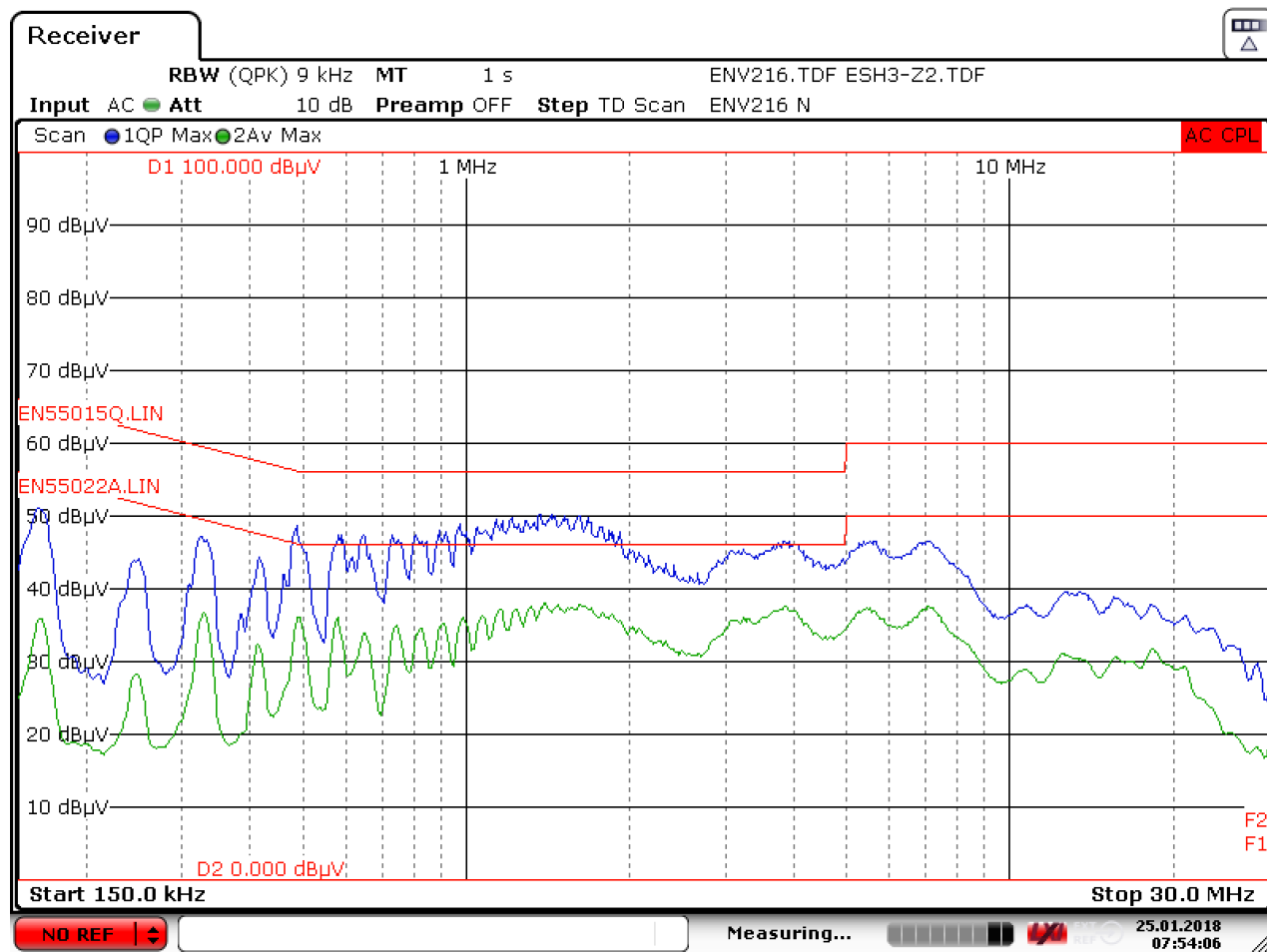
#### 18.3.1 115 VAC, Line



Date: 25.JAN.2018 07:51:24

Figure 129 – Artificial Hand Ground EMI at 115 VAC, Line.

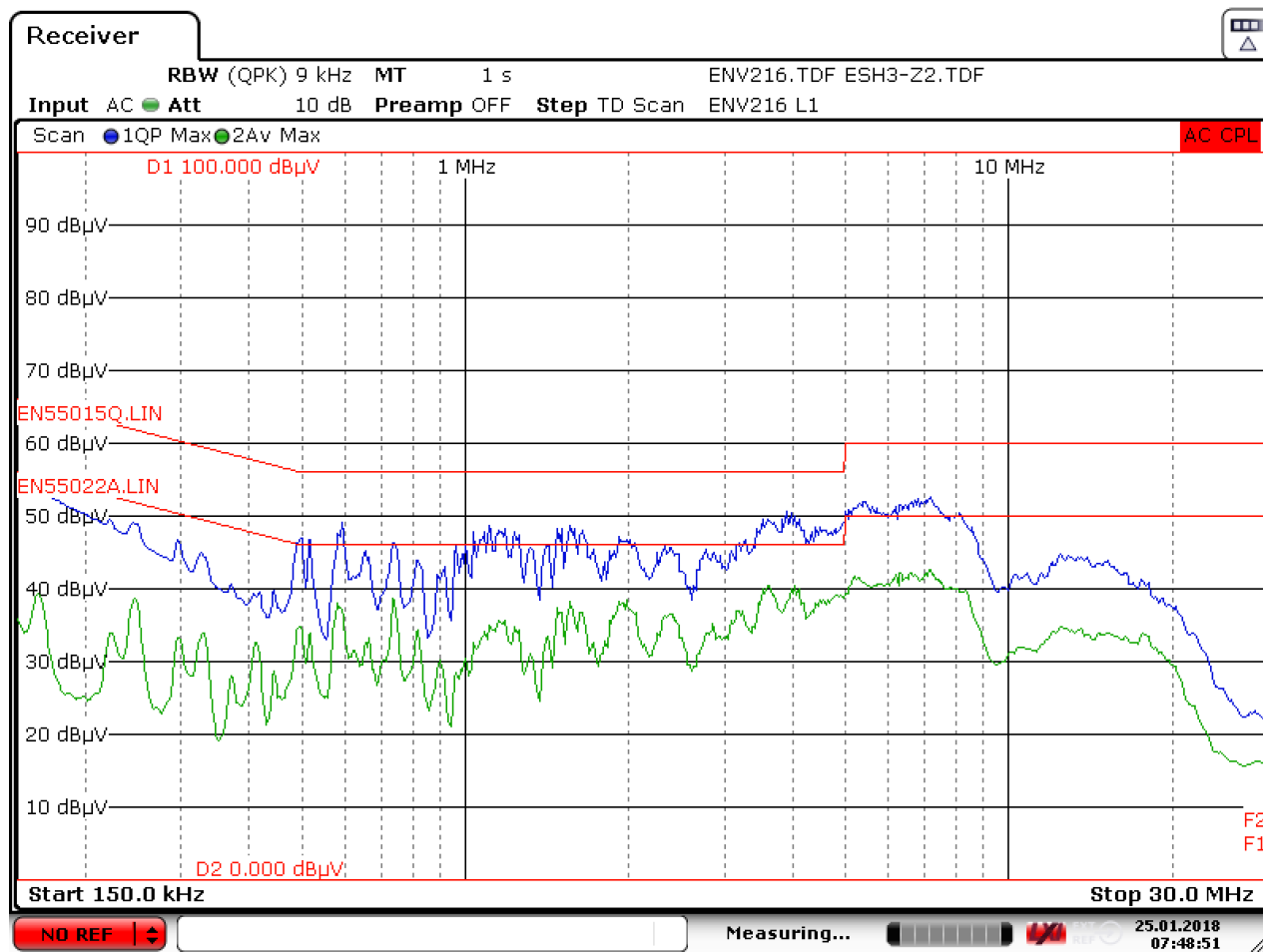
## 18.3.2 115 VAC, Neutral



Date: 25.JAN.2018 07:54:06

**Figure 130** – Artificial Hand Ground EMI at 115 VAC, Neutral.

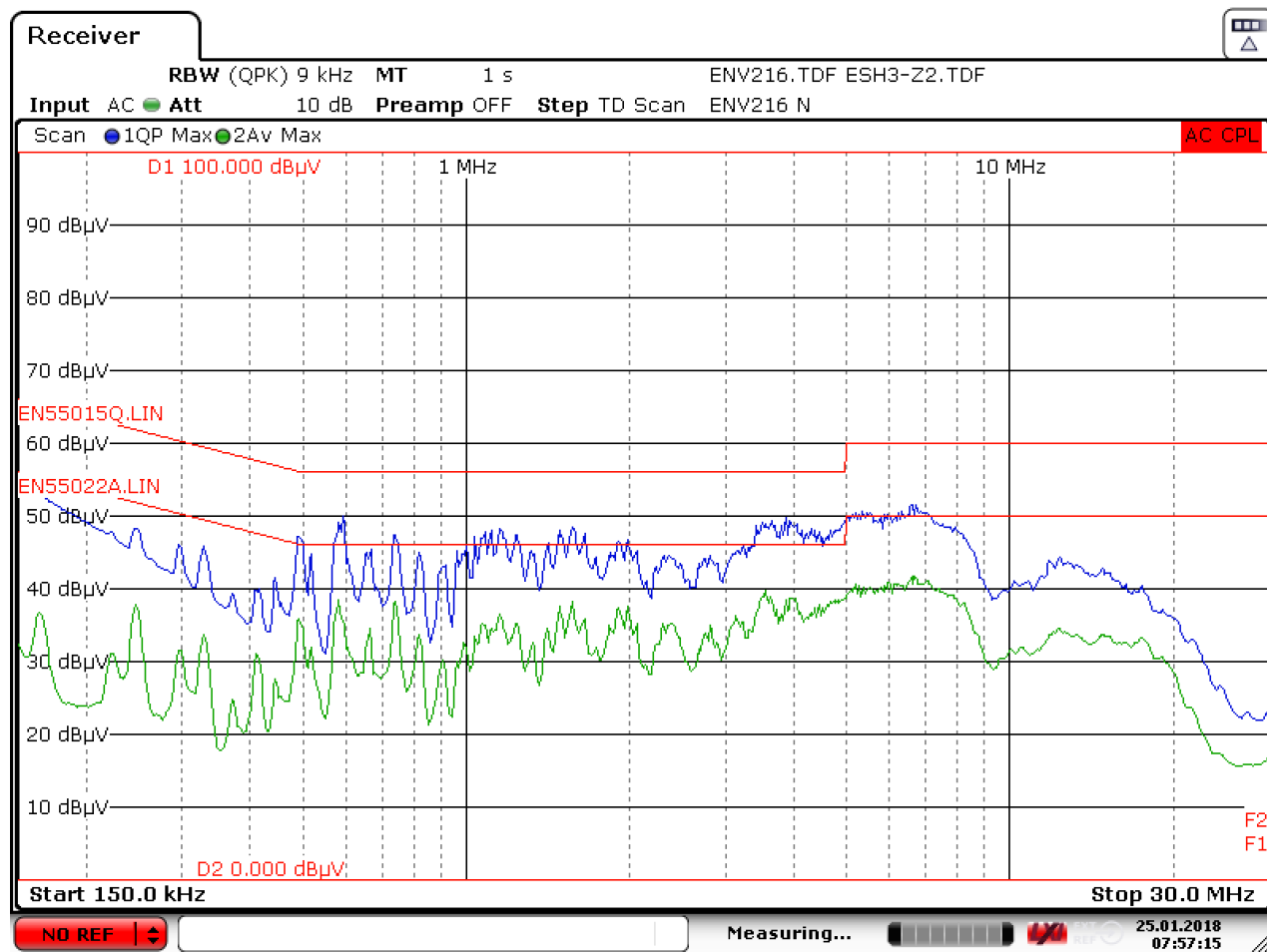
## 18.3.3 230 VAC, Line



Date: 25.JAN.2018 07:48:50

Figure 131 – Artificial Hand Ground EMI at 230 VAC, Line.

## 18.3.4 230 VAC, Neutral



Date: 25.JAN.2018 07:57:14

Figure 132 – Artificial Hand Ground EMI at 230 VAC, Neutral.

## 19 ESD Test

### 19.1 ESD Test

| Level (V) | Input Voltage (VAC) | Discharge | Number of Discharge | Test Result (Pass/Fail) |
|-----------|---------------------|-----------|---------------------|-------------------------|
| +8000     | 115                 | Contact   | 10                  | PASS                    |
| +16000    | 115                 | Air       | 10                  | PASS                    |
| +8000     | 230                 | Contact   | 10                  | PASS                    |
| +16000    | 230                 | Air       | 10                  | PASS                    |

| Level (V) | Input Voltage (VAC) | Discharge | Number of Discharge | Test Result (Pass/Fail) |
|-----------|---------------------|-----------|---------------------|-------------------------|
| -8000     | 115                 | Contact   | 10                  | PASS                    |
| -16000    | 115                 | Air       | 10                  | PASS                    |
| -8000     | 230                 | Contact   | 10                  | PASS                    |
| -16000    | 230                 | Air       | 10                  | PASS                    |

## 20 Revision History

| Date      | Author | Revision | Description & Changes             | Reviewed    |
|-----------|--------|----------|-----------------------------------|-------------|
| 22-May-18 | CE     | 1.0      | Initial Release                   | Apps & Mktg |
| 05-Dec-18 | KM     | 1.1      | Updated Application on First Page |             |
| 31-Jan-19 | KM     | 1.2      | Updated Page 1 Summary Bullets    |             |

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